Grassland classification and ecology in the East Kootenays and Boundary

Prepared for: Deb MacKillop, B.C. Ministry of Forests, Lands and Natural Resource Operations

Prepared by: Kristi Iverson, Iverson & MacKenzie Biological Consulting Ltd.

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Introduction

This project was initiated to provide a grassland classification within B.C.'s Biogeoclimatic Ecosystem Classification (BEC) framework for the grassland group of ecosystems in the East Kootenays and Boundary areas. The grassland group includes sites that are too dry for tree establishment as a result of a semi-arid climate or very dry and warm sites within forested areas.[1]

Within the grassland group, there is the Grassland Class, Shrub-steppe Class, Brushland class, and Alkaline/Saline Meadow class. **Grasslands** are graminoid-dominated ecosystems that are widespread in semi-arid climates and on very dry sites because of very rapid soil drainage, insolation, and/or lack of precipitation. **Shrub-steppe** ecosystems occur only in the relatively hot, semi-arid climates, and are dominated (> 10%) by semi-desert–adapted woody shrubs such as big sagebrush (*Artemisia tridentata*) or antelope-brush (*Purshia tridentata*). Drought-tolerant woody shrubs such as saskatoon (*Amelanchier alnifolia*), junipers (*Juniperus* spp.), cherries (*Prunus* spp.), and snowberry (*Symphoricarpus* spp.) dominate **brushland** ecosystems at climax. **Alkaline/saline meadows** are graminoid- or halophyte-dominated sites that occur in shallow, closed basins of dry climates where water evaporation leads to the accumulation of salts.[2]

Grasslands within the Ponderosa Pine (PP) and Interior Douglas-fir (IDF) biogeoclimatic zones were included in the project area. Separate classifications are presented for the following subzones in the East Kootenays:

- Kootenay Dry Hot Ponderosa Pine Variant (PPdh2),
- Kootenay Dry Mild Interior Douglas-fir Variant (IDFdm2),
- Very dry, Cold Interior Douglas-fir subzone (IDFxk), and
- Columbia Dry, Cool Interior Douglas-fir variant (IDFdk5).

Within the Boundary area, the following subzones are included:

- Boundary Very Dry Hot Ponderosa Pine Variant (PPxh3),
- Boundary Very Dry Hot Interior Douglas-fir Variant (IDFxh4) and
- Kettle Dry Mild Interior Douglas-fir Variant (IDFdm1).

Within the East Kootenays, many formerly forested areas have been cut and burned. Although these sites may resemble brushland ecosystems, they are forested at climax and these areas are not included in this project.

Grassland data from BEC projects, range monitoring, and BEC field sampling in the summer of 2013 by Kristi Iverson, Will MacKenzie, and Mike Ryan were included in the classification.

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[1] MacKenzie 2012; these were previously included in the wetland classification as the Saline Meadow Transition Class
[2] Ibid.

The grassland classification, including seral units, is intended to provide a framework for managing grasslands, mapping grassland ecosystems and plant communities and determining forage production for native ungulates and domestic livestock.

Grassland Distribution

East Kootenays

Grasslands within the East Kootenays total about 43,939 hectares[3]. The majority of grasslands in the East Kootenay Trench are on provincial crown land (63%); almost 90% of these are under a grazing tenure[4]. About 23% are privately owned, including 15.7% owned by The Nature Trust of British Columbia and The Land Conservancy of British Columbia. Approximate grassland areas are shown for the biogeoclimatic units for this project below[5].

Table 1. Approximate area of grasslands for biogeoclimatic units in the East Kootenays.

Geographic area	Biogeoclimatic Unit	Area of Grassland (ha)
East Kootenays	PPdh2	15,881
	IDFdm2	23,111
	IDFxk and IDFdk5	2,249

Within the East Kootenays, approximately 6,720 hectares of grassland have been lost to agricultural conversion, 2,880 ha have been lost to urban and industrial development, and it is unknown what area of grassland was lost to the flooding of the Lake Koocanusa reservoir.[6]

Most of the grasslands in the East Kootenays occur along the river breaks and occupy the benches above the Kootenay, St. Mary's and Columbia rivers in the southern Rocky Mountain Trench. The largest grassland expanses occur on the valley floor, mostly on glaciofluvial deposits, from the Tobacco Plains at the Canada/United States border north to near Radium Hot Springs. In the southern part of the Trench, extensive grasslands follow the lower portions of the Elk, Bull and Wigwam rivers where they enter the Trench.[7]

Extensive tracts of open grassland also extend north from Cranbrook to

[3] Grasslands Conservation Council of B.C. 2004
[4] Ibid.
[5] The boundaries of the biogeoclimatic units have changed since the time of this report, thus the area of grassland is approximate. The IDFxk and IDFdk5 are lumped as they were previously mapped together as 'IDFun'.
[6] Ibid.
[7] Wikeem and Wikeem 2004

Skookumchuck Prairie. Although fragmented by development, St Mary's Prairie is still one of the largest contiguous grasslands in the region. It extends from the north side of St. Mary's River to Skookumchuck Creek on the west side of the Kootenay River.[8]

North of Skookumchuck Prairie, small patches of grassland are often associated with steep, south-facing slopes and silty glaciolacustrine terraces along Columbia Lake and the Columbia River. Small patches are also associated with the bottoms of tributary valleys to the Trench such as Findlay Creek.[9]

In portions of the PPdh2 and IDFdm2, antelope-brush is locally abundant. Although these ecosystems dominated by antelope-brush would normally fall into the shrub-steppe class, it appears that climax non-forested ecosystems generally have <10% cover of antelope-brush, and abundant antelope-brush only occurs on sites disturbed by grazing.

Brushlands occur infrequently as moist shrubby depressions in grassland or grassland/woodland areas of the PPdh2 and IDFdm2. They also occur infrequently on steep colluvial slopes with rocky soils. Although shrubs dominate the vegetation cover in many other areas, these areas appear to be seral forests that have been logged and, often, burned.

Saline/alkaline meadows occur in only a couple of locals: along the Kootenay River between Wasa and Fort Steele and in the Lavington area west of Canal Flats.

Boundary

It is more difficult to estimate the area of grasslands by biogeoclimatic unit in the Boundary portion of the study area because of large changes to biogeoclimatic unit mapping. However, the Southern Okanagan Highland and North Okanagan Highland ecosections cover the majority of the Boundary grasslands and together they include 22,741 ha of grasslands, including higher elevation grasslands in and above the Montane Spruce (MS) biogeoclimatic zone.[10] Most grassland occurs in the Ponderosa Pine and Interior Douglas-fir zones.[11]

Grasslands are predominantly privately owned: 81.2% of grasslands in the Southern Okanagan Highland are privately owned and 41.1% of grasslands in the Northern Okanagan Highland are privately owned. Crown grasslands had grazing licences or permits on more than 90% of them in 2003. Within the Southern Okanagan Highland Ecosection, 61.8% of grasslands are within the Agriculture Land Reserve. Approximately 24% of Southern Okanagan Highland grasslands have been lost to agriculture and 15% to urbanization.[12]

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[8] Ibid.
[9] Ibid.
[10] Grasslands Conservation Council of B.C. 2004
[11] Wikeem and Wikeem 2004
[12] Grasslands Conservation Council of B.C. 2004

In the Boundary area, grasslands primarily occur on the southern portion of the Okanagan Highland from six or eight kilometres west of Bridesville eastward in the main east-west valley to Boundary Falls. Another grassland-dominated area occurs in the valley near Grand Forks[13]. Above the main valleys and the southern portion of the Okanagan Highland, the land rises steeply and grasslands are largely restricted to steep warm aspects.[14] Brushlands occur sporadically on some warm-aspect slopes and steep, rocky colluvial slopes in the PPxh3 and IDFxh4. There are a few seral grasslands with big sagebrush that appear to succeed to grasslands; thus they do not fit into the shrub-steppe class. There are no known occurrences of saline/alkaline meadows in the Boundary area.

Physiography and Climate

East Kootenays

The East Kootenay portion of the Rocky Mountain Trench extends from the United States border in the south to the Windermere Valley in the north. The Trench lies between the Rocky Mountains to the east and the Purcell Mountains to the west. The area was covered by ice during the last glaciation. Melting glacial ice created a temporary lake in the main valley that left behind deep silt deposits. Postglacial rivers and streams also modified the landscape by depositing gravel, sand and silt that created large fans that extended across the valley and created Columbia Lake and Windermere Lake.[15]

The Rocky Mountain Trench has a semi-arid climate. Annual precipitation ranges from 439 to 552 mm (Table 2 below). The Trench lies in a rain shadow created by the Columbia Mountains. Cold continental arctic air masses are common during the winter. In summer, hot, dry air from the Great Basin comes up into the Trench, severely limiting soil moisture available for plant growth. Most precipitation falls as snow between November and January, and as rain in May and June.[16] The IDFxk is drier and cooler than the IDFdm2; the IDFdk5 is cooler than the IDFdm2.

Table 2. Climatic data for selected locations (biogeoclimatic variants) in the Rocky Mountain Trench (from Environment Canada 2014).

Parameter	Grasmere (IDFdm2)	Cranbrook (IDFdm2)	Wasa (PPdh2)
Elevation (m)	869	939	930
Precipitation (mm)	552	383	439
July Temp (°C)	27.5	25.6	25.8

[13] Sprout and Kelley 1964
[14] Pers. obs. 2013
[15] Lacelle 1990
[16] McLean and Holland 1958; Wikeem and Wikeem 2004

Extreme High (°C)	39.4	36.6	37.0
January Temp (°C)	-2.0	-3.2	-2.4
Extreme Low (°C)	-42.8	-40.0	-35.5
Frost Free Days	200	189	184

Boundary

East of the Okanagan Valley, the land rises to the Okanagan Highland. The West Kettle, Granby and Kettle rivers valleys deeply dissect the Okanagan Highland. These valleys are three to five kilometers wide with terraces about 60 m above the valley floors. These valleys were gouged out by glacial ice; glacial debris was left behind when glaciers receded. Some of this debris was melt-water deposits (sandy, gravelly glaciofluvial deposits) and some was glacial till. In the final stages of deglaciation, ice dams formed in the main valley creating temporary lakes. The lake sediments left glaciolacustrine deposits over a large area of the valley floors. Alluvial fans are also common on the toes of valley slopes and often spread over the terraces.[17]

The climate has very hot, very dry summers and mild winters with insignificant snow packs (Table 3 below). Although annual precipitation is higher than in ponderosa pine grasslands in the Okanagan Valley, soil moisture deficits during summer limit plant growth.[18] Based on the BEC system for naming subzones based on their climate, the IDFxh4 should be cooler than the PPxh3; precipitation may be similar or higher, as lower temperatures reduce evaporative losses of moisture. The IDFdm1 in the Boundary likely has a similar climate to the IDFdm1 within the Okanagan Valley (moister and cooler than the IDFxh).

Table 3. Climatic data for selected locations in the Boundary[19] and for the IDFdm1 and IDFxh1[20]

Parameter	Grand Forks (PPxh3)	IDFxh1[21]	IDFdm1
Elevation (m)	516	400-1250	560-1300
Precipitation (mm)	429	304-515	425-625
July Temp (°C)	20.0		
Extreme High (°C)	42.7		
January Temp (°C)	-6.0	-9.5	-10.5

[17] Sprout and Kelley 1964
[18] Wikeem and Wikeem 2004
[19] Environment Canada 2014
[20] Lloyd et al. 1990
[21] The climate of the IDFxh1 is presumed to be very similar to the IDFxh3

Extreme Low (°C)	-38.9		
Frost Free Days	120	131	100

Soils and Parent Materials

Under grassland vegetation, the fine roots of grasses result in the accumulation of organic material in the surface soil creating a darker surface soil horizon (Ah)[22]. Where the organic enriched Ah horizon is greater than 10 cm, grassland soils usually are classified as chernozems, with Ah horizons less than 10 cm (or very light) they are classified as brunisols.[23]

Chernozems are further subdivided into Brown, Dark Brown, Black, and Grey depending on the colour of the surface horizon. Darker colours usual indicate a moister, more productive climate with more organic enrichment, but prolonged overgrazing can also result in lighter coloured soils[24].

East Kootenays

The upland portion of the Trench valley floor is predominantly glacial river (glaciofluvial) deposits with some remnants of silty glacial lake (glaciolacustrine) terraces and areas of glacial till. Both the glacial till and glaciofluvial deposits commonly have a silt and fine sand eolian (wind deposit) capping on them. Deeper eolian deposits occur adjacent to Lake Koocanusa and steep slopes may have rocky colluvial deposits. Silty glacial till materials are common on the lower valley slopes and hills. Silty glaciolacustrine materials are common along Columbia Lake and Lake Windermere. Grasslands within the IDFxk subzone occur primarily on these glaciolacustrine deposits, and some areas of glaciofluvial deposits.[25]

The high calcium carbonate content of parent materials and dry climate has slowed the development of soil horizons. Soil moisture causes the carbonates to leach down in the soils.[26] In many of the grasslands soils, there is a nearly impermeable calcium carbonate layer 25-35 cm deep on glaciofluvial soils (deeper on till and deeper still on glaciolacustrine), indicating the shallow depth that soil moisture typically penetrates.[27] This layer typically occurs were the underlying materials become very sandy and gravelly and there is a hydraulic discontinuity; the finer soils on top must be saturated before water transfers down into the coarser soils below.[28]

[22] Lacelle 1990
[23] Soil Classification Working Group 1998
[24] Johnstone et al. 1971
[25] Lacelle 1990
[26] Ibid.
[27] Ibid.; pers. obs. 2013
[28] pers. obs. 2013

Orthic Dark Brown Chernozems are the dominant grassland soil type in the Trench; Eutric Brunisols are common in areas where grassland and forest mix.[29] Black Chernozems, typical of higher elevation grasslands in the Thompson, Nichola, and Okanagan plateaux[30], are absent in the East Kootenay. This is somewhat surprising given the precipitation levels are comparable to other grassland areas dominated by richer, dark black Chernozemic soils (e.g. other grasslands of the PP and IDF in BC and rough fescue grasslands in Alberta).

Brunisols are more common on drier glaciofluvial materials; grasslands on brunisols may have more depleted soils from historical overgrazing or the droughty soils limit plant productivity. ***It may be important to consider stratifying grassland mapping by parent material as it is likely to have a relationship to forage production.***

Saline/alkaline meadows develop on gleysolic or solonetzic soils that occur in valley bottoms where water from the uplands carries calcium, sodium and magnesium salts in solution to poorly drained depressions on the rolling landscape. As water evaporates in the summer and fall, high concentrations of salts accumulate in the soil profile and on pond beds. The high concentration of salts in these soils often limits vegetation to the most salt tolerant plants, usually grasses and forbs.[31] Common grasses include alkali saltgrass (*Distichlis spicata* var. *stricta*), alkali cordgrass (*Spartina gracilis*), foxtail barley (*Hordeum jubatum*) and Nuttall's alkaligrass (*Puccinellia nuttalliana*) and common forbs include seablite (*Suaeda calceoliformis*) and tufted white prairie aster (*Symphyotrichum ericoides* var. *pansum*)[32].

Boundary

The Boundary area has extensive coarse, sandy glaciofluvial deposits in the valley bottom in the form of both terraces and fans; glacial till and glaciolacustrine deposits are also common above the valley bottom.

Dark brown and black Chernozems are the most prevalent grassland soils in the Kettle Valley.[33] Dark Brown chernozems are also common and occur on the Kettle River valley bottom and adjoining south-facing slopes.[34]

Field data and my own field sampling indicated that soils in the PPxh3 were predominantly dark brown chernozems. The depth of the Ah (the surface horizon enriched primarily by organic matter from grass roots) was quite variable from 10 to 40 cm deep on gentle and moderate slopes and usually only 10 to 25 cm deep on steep warm aspects. Shrubby sites had black chernozem soils with a deep Ah up to 60 cm deep.

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[29] McLean and Holland 1958
[30] Tisdale 1947, van Ryswyk 1966
[31] Valentine and Lavkulisch 1978; Lacelle 1990
[32] MacKenzie and Moran 2004
[33] Wikeem and Wikeem 2004
[34] Sprout and Kelley 1964

Within the IDFxh4, soils were mostly dark brown chernozems on gentle- and moderate-sloping grassland with Ah horizons from 30 to 65 cm deep. Shallow soil sites had very thin Ah (only a few centimeters) and steep warm aspects varied from 0-30 cm deep.

Within the IDFdm1, gentle- and moderate-sloping grasslands had black chernozems and consistently had very deep Ah's of 50-60 cm. Ah's were much thinner and lighter on steep, warm slopes.

Natural Disturbance Regimes

The primary historical disturbance regime within these areas was likely low intensity surface fires. These fires would have killed many small trees encroaching on grassland areas and primarily maintained open, savannah-like forest structure within adjacent ponderosa pine and Douglas-fir stands.[35] Within the IDFdm2, Gray et al. (2002) found a mean fire return interval of 14 years at Isadore Canyon and 19 years at Lewis Ridge. At lower elevations in the Tobacco Plains area (PPdh2), Dorey (1979) found a mean fire return interval of 6 years.

Mean fire return intervals for ponderosa pine forests in the United States vary from 2 years to 15 years.[36] A range of mean fire intervals has been recorded for interior Douglas-fir forests in B.C. including: 22 years in the IDFdk3 (ranging from 5 to 49 years)[37]; 13 years in the IDFdk1[38]; and, 6 to 17 years in the IDFww[39].

In the East Kootenays, numerous large fires occurred between 1914 and 1931 as the litter from logging dried and became extremely flammable; apparently this burning resulted in many crown fires that reduced the forested area and converted them to shrublands.[40]

Most native grassland plants are well adapted to fire because they can re-sprout from buds just at or below the ground surface where fire temperatures typically are lower.[41] Often fire favours perennial forbs for at least a few years after a burn. [42]

Fire suppression, which began in the 1920s, and cessation of traditional burning by First Nations has altered fire regimes, resulting in few fires since 1940.[43] Large areas of open grassland have been lost to tree encroachment, including formerly forested areas cleared by logging and fire associated with settlement and railway construction.[44] In the Rocky Mountain Trench, an assessment of air photos taken 30

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[35] Gray et al. 2002, Dorey 1979
[36] Agee 1993
[37] Iverson et al. 2002
[38] Gray and Riccius 1999
[39] Gray and Riccius 2000
[40] Casselman 1998
[41] Daubenmire 1968
[42] Ibid.
[43] Dorey 1979, Ross and Wikeem 2002
[44] Gayton 1997, Ross 1998

years apart indicates that grasslands are being converted to forest at a rate of about 1% per year.[45]

Grazing and Grassland Succession

Within British Columbia, grasslands likely evolved with few large, hooved mammals. Bison likely were mostly restricted to east of the Rocky Mountains and the dominant ungulates grazing in B.C. grasslands were deer and elk. Bison were likely excluded west of the Rockies because the moisture cycle west of the Rockies resulted in forage production that did not coincide with the timing of calving, when lactation resulted in high nutrient demands on female bison.[46]

Caespitose grasses (bunchgrasses) such as bluebunch wheatgrass (*Pseudoroegneria spicata*) and rough fescue (*Festuca campestris*) dominate Intermountain grasslands. These grasses rely on seed production to maintain themselves, rather than spreading by underground rhizomes, a common strategy of grasses in the prairies. Their bunched form allows them to take advantage of early season warmth to grow and then become dormant during summer drought. They are much more susceptible to trampling and take longer to develop a deep root system.[47] However, bluebunch wheatgrass will sometimes form rhizomes on more mesic sites.

Intermountain grasslands also differ from prairie grasslands in the presence of a well-developed moss, lichen, and blue-green algae layer (sometimes referred to as a cryptogam or microbiotic crust) covering the soil surface between plants. This layer is also susceptible to loss through trampling by large ungulates.[48]

Grazing History

Both the direct effects of logging, and the fires that followed, contributed to opening up large areas of successional grassland and shrub-steppe vegetation throughout the southern part of the Trench.

Grazing by wildlife, domestic livestock, and aboriginal horses have influenced East Kootenay grasslands. The Ktunaxa peoples (Kootenae) have likely had horses since the early- to mid- 1700s.[49]

Large numbers of domestic livestock were brought into the Trench during the gold mining boom and construction of the Canadian Pacific Railroad in the mid to late 1800s. Heavy grazing by domestic livestock and wildlife appears to have been widespread in the Trench up to the 1950s. From the 1960s to 1990s, livestock populations declined, but elk and deer populations have increased dramatically. Range condition on most grassland has continued to deteriorate, or has remained at

[45] Ross and Wikeem 2002
[46] Mack and Thompson 1982
[47] Ibid.
[48] Ibid.
[49] Robbins 1993

an early seral stage. Also, forest encroachment has reduced forage for both livestock and wildlife, and concentrated animals on the smaller remaining areas.[50]

Mining began in the Kettle Valley in the mid 1800's; in the late 1800's agricultural development began with irrigation around Grand Forks; agriculture in the valley continued to expand in the 1900s. Some highland areas west of Grand Forks were also dry farmed for grains. Similar to the Rocky Mountain Trench, many domestic livestock were brought in during the gold rush. By 1892, there were about 20,000 cattle on the Similkameen, Osoyoos, and Boundary areas.[51]

Overgrazing along roadways was recognized as early as 1870 and widespread overgrazing was reported in soil surveys throughout the Okanagan, Similkameen and Boundary areas by the 1960s.[52]

Grazing Effects on Fescue Grasslands

Grazing on rough fescue grasslands creates drier microclimates by reducing litter and vegetation cover, resulting in higher soil temperatures and reduced soil moisture.[53] Reduced soil moisture can reduce the growth of rough fescue[54]; litter can improve the forage production[55]. Soil bulk density increases with grazing and hydraulic conductivity decreases.[56] Soils are also more susceptible to water erosion once about 15% of the surface becomes bare.[57] Additionally, grazing, through soil compaction, can reduce the amount of water absorption and rate of intake.[58]

Moderate and heavy grazing reduces root growth of rough fescue and less organic matter is returned to the soil.[59] In this way, grazing can lighten the colour of the Ah horizon from black to dark brown (thereby changing the soil classification from a Black Chernozem to a Dark Brown Chernozem). It can also reduce the thickness of the Ah horizon.[60] Clipping of rough fescue to 20 cm or clipping only in the fall causes no apparent damage to rough fescue; clipping to 5 cm stubble height causes the greatest injury.[61] Idaho fescue (*Festuca idahoensis*) vigour is little affected by light grazing on richer sedimentary soils but vigour is reduced even by light grazing on poorer, granitic soils.[62] Surprisingly, in southwest Montana, Idaho fescue recovers vigour faster than bluebunch wheatgrass.[63] Low vigour Idaho fescue produces only

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[50] Wikeem and Ross 2002
[51] Sprout and Kelley 1964
[52] Kelley and Spilsbury 1949;
[53] Johnston 1962, Johnston et al. 1971, Willms 1988b, Dormaar et al. 1989
[54] Willms 1988b
[55] Willms 1988a
[56] Dormaar et al. 1989
[57] Johnston et al. 1971
[58] Johnston 1962
[59] Johnson 1961, Dormaar and Willms 1990
[60] Dormaar and Willms 1998
[61] McLean and Wikeem 1985
[62] Pond
[63] Mueggler 1975

2/3 as much herbage and numbers of flower stalks after five years of protection; recovery takes six or more years.[64]

In Alberta grasslands, heavy grazing can reduce the cover of rough fescue and it can be nearly eliminated over time, even with time-controlled grazing.[65] With protection from grazing, rough fescue can dominate to the exclusion of many other plants, but Idaho fescue will increase with increased grazing pressure until it too is eliminated and Kentucky bluegrass and other species become dominant.[66] Light grazing results in a more diverse flora compared to a more pure rough fescue cover in ungrazed Alberta grasslands.[67] In Alberta, some rough fescue grasslands have increased cover of Idaho fescue with grazing.[68] *I speculate that Idaho fescue is likely more drought- and grazing-tolerant than rough fescue.*

Grassland Exclosures

Grassland exclosures provide data about succession patterns in the absence of domestic livestock and/or wildlife grazing. Although many exclosures have not been in place long enough to determine climax plant communities, they still provide information about successional patterns that allow us to infer generally what plant species climax plant communities might be dominated by. Below is a summary of grassland and shrubland exclosures in the study area.

PPdh2

In 1950, the heavily grazed Skookumchuck Prairie area was dominated by Sandberg's bluegrass (*Poa secunda*) and low pussytoes (*Antennaria dimorpha*) with some junegrass (*Koeleria macrantha*) and needle-and-thread grass (*Hesperostipa comata*)[69]. An exclosure was constructed on Skookumchuck prairie in 1951 (Milroy exclosure). Within the exclosure, bluebunch wheatgrass increased and dominated the cover in 1970. Rough fescue also increased while junegrass, needle-and-thread grass, and Sandberg's bluegrass declined substantially. Rough fescue formed the dominant cover in 1982; bluebunch wheatgrass cover was much reduced. In 2009, rough fescue and Idaho fescue co-dominated the site.[70] *Personal observations (2013) suggest that rough fescue plants are becoming decadent and dying back. Perhaps, in the absence of low-intensity surface fires and grazing, rough fescue does not persist as much as it might in a natural disturbance regime*.

A 3-way exclosure was established at Skookumchuck in 1991. Within the exclosures bluebunch wheatgrass cover had declined, rough fescue cover had increased substantially and Idaho fescue had increased slightly in 2009. Outside the exclosures, bluebunch wheatgrass cover declined and rough and Idaho fescue

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[64] Ibid.
[65] Johnston et al. 1971, Willms et al. 1985, Willms et al. 1990
[66] Willoughby 2005
[67] Johnson 1961
[68] Willms et al. 1985, Dormaar and Willms 1990, Willoughby and Alexander 2005
[69] McLean and Tisdale 1972
[70] Wikeem et al. 2012

remained at similarly low levels while spreading needlegrass increased substantially. Antelope-brush cover increased only in the exclosure with wildlife grazing and no cattle grazing.

IDFdm2

The Power Plant exclosure is on a submesic, level site with an eolian cap over a thin morainal deposit. In 1968, when it was established, the exclosure was dominated by Kentucky bluegrass (*Poa pratensis*), common timothy (*Phleum pratense*), cheatgrass (*Bromus tectorum*), antelope-brush, saskatoon (*Amelanchier alnifolia*), and a variety of forbs, many of them non-native.[71] When I sampled the exclosure in 2013[72], it was dominated by spreading needlegrass (*Achnatherum richardsonii*) with some Idaho fescue, rough fescue, and junegrass. Saskatoon and antelope-brush each had 5% cover. Rough fescue plants were decadent and dying back in the centre. There were diverse, scattered forbs, all with low cover, except sulphur cinquefoil (*Potentilla recta*) which has become abundant.

The Wigwam exclosure is on a level, rocky soiled morainal deposit. In 2006, the exclosure was dominated by a high cover of rough fescue with some bluebunch wheatgrass and numerous other grasses and forbs, but none with high cover.[73]

IDFxk

The Columbia Lake East exclosure was established in 1996 and is on a gentle west aspect glaciofluvial deposit with a loamy eolian capping. Inside the exclosure in 2013, the cover of bluebunch wheatgrass, needle-and-thread grass, rough fescue, tufted phlox (*Phlox caespitosa*), and crusts were much higher than outside the exclosure.[74] Outside the exclosure, the vegetation was dominated by junegrass and needle-and-thread grass with some prairie sagewort (*Artemisia frigida*), bluebunch wheatgrass, pussytoes (*Antennaria* spp.), and scattered forbs.[75]

Old Columbia Lake East exclosure, established in 1983, occurs on a submesic lower slope, gentle southwest exposure with very fine sandy eolian soils. Inside it was dominated by needle-and-thread grass and junegrass with low covers of rough fescue and bluebunch wheatgrass in 2013; vegetation was very similar outside the exclosure but lacked rough fescue and bluebunch wheatgrass.[76]

IDFdk5

The Height of Land exclosure is on a gently sloping grassland and data consists only of photos and a few notes (unknown establishment date). Idaho fescue, rough fescue, and Kentucky bluegrass, with some snowberry and Rocky Mountain juniper (*Juniperus scopulorum*), dominate the inside of the exclosure. Outside the exclosure,

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[71] Data from Rick Tucker, 2012
[72] Plot 120093
[73] Plot N06-080
[74] Plot 120076
[75] Plot 120077
[76] Plot 120078

the vegetation is dominated by Sandberg's bluegrass, Columbia needlegrass (*Achnatherum nelsonii*), and pussytoes.[77]

PPxh3

The Overton-Moody exclosure in Gilpin Grasslands Provincial Park was established in 1975, and has burned at least twice since then. The exclosure is submesic and is on a gentle south aspect with eolian material overlying a glaciofluvial deposit. In 2013 invasive annual bromes (*Bromus* spp.[78]), Kentucky bluegrass, Columbia needlegrass, prickly sow-thistle (*Sonchus asper*) and a few forbs dominated the vegetation cover. There was 5% Idaho fescue that was growing in distinct patches, rather than occurring throughout the exclosure. Other than the Idaho fescue, the vegetation was very similar outside the exclosure.[79] The cover of Kentucky bluegrass has dropped substantially from 1983, both in and out of the exclosure. Diffuse knapweed (*Centaurea diffusa*) and common St. John's-wort (*Hypericum perforatum*) were absent in 1983 then abundant in 1998 and had dropped substantially in 2005, outside of the exclosure.[80]

Murray Gulch wildlife exclosure was established in 1995 on a moderate, submesic southwest aspect with deep eolian material overlying a morainal deposit. In 2013 Columbia needlegrass, invasive annual bromes, prickly sow-thistle, and a variety of other grasses and forbs dominated the vegetation inside the exclosure. Lots of pocket gopher activity created areas of exposed mineral soil both inside and outside the exclosure. The outside of the exclosure was similar to the inside, but with less Columbia needlegrass. [81]

The Gilpin Upper wildlife exclosure in Gilpin Grasslands Provincial Park was established in 1995 on a moderate south aspect with deep, black eolian material overlying a morainal deposit. In 2013 the wildlife exclosure was extremely shrubby with roses, snowberry, and some choke cherry (*Prunus virginiana*) and only minor forbs and grasses. There were more invasive alien plants outside the exclosure.[82]

IDFxh4

March Creek cattle exclosure was established in 1980 on a xeric, thin-soiled, gentle upper southwest aspect slope. In 2013 bluebunch wheatgrass, big sagebrush, Idaho fescue, an abundant crust, and a diversity of forbs and other grasses dominated the exclosure. The vegetation was very similar outside the exclosure, but with more abundant Sandberg's bluegrass.[83]

A small exclosure was established east of Johnstone Creek in the early 1960s and then a larger exclosure was built around it in 1995 (Johnstone Creek exclosure). It

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[77] Data from Rick Tucker, 2012
[78] Includes: *Bromus briziformis, B. hordeaceus, B. japonicus, B. squarrosus,* and *B. tectorum*
[79] Plot 12100
[80] Data from Rick Tucker, 2012
[81] Plot 020144
[82] Plot 020143
[83] Plot 020145

was established on a gentle east aspect with a moderately deep eolian deposit overlying morainal materials. In 2013, the inside of the old portion of the exclosure was dominated by bluebunch wheatgrass, Idaho fescue, sticky purple geranium (*Geranium viscosissimum*), and an abundance of other forbs. Outside the exclosure it was dominated by invasive annual bromes, diffuse knapweed, silky lupine (*Lupinus sericeus*), and Columbia needlegrass. The new part of the exclosure was similar to the outside but with some bluebunch wheatgrass and Idaho fescue coming in (2-3% each).[84] *This exclosure was the closest to a climax grassland, on gentle slopes, that I observed in the Boundary area.*

IDFdm1

David Creek exclosure was built in 1997 on a moderate west aspect. By 2005, the cover of bluebunch wheatgrass had increased substantially within the exclosure, but remained low outside. Timber oatgrass (*Danthonia intermedia*) was common both inside and outside the exclosure in 1998, but was not recorded in 2005. No fescues were recorded on this site. Sulphur cinquefoil was the most abundant forb, particularly outside the exclosure. Otherwise a diverse forb and grass community characterize the site without any other notable differences inside and outside the exclosure.[85]

Grassland Classification

Below I present descriptions of grasslands within the study area. I summarize existing descriptions and present the draft classification for each subzone. ***Vegetation tables are presented in a separate excel file***.

PPdh2

Several authors hypothesize that original vegetation on gently sloping grasslands within the PPdh2 resembled the *Agropyron– Festuca* association (dominated by bluebunch wheatgrass and rough fescue) described by Tisdale or the Upper Grasslands described by van Ryswysk in the Thompson Basin[86]. The primary difference seems to be the presence of dark brown chernozems in the PPdh2 rather than the black chernozems present in the upper elevations of the Thompson Basin.[87] *This would generally indicate droughtier conditions, perhaps because of the very coarse-textured soils, differences in precipitation patterns, or more calcareous soils.*

Tucker (2013) describes gently sloping climax grasslands in the PPdh2 as being dominated by a combination of rough fescue, bluebunch wheatgrass, Idaho fescue, mixed forbs, and microbiotic crust with scattered ponderosa pine and antelope-brush on some sites.

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[84] Plot 020146
[85] Data from Rick Tucker, 2012
[86] Spilsbury and Tisdale 1944, Tisdale 1947, and Kelly and Spilsbury 1949
[87] van Ryswyk et al. 1966

Domestic and native ungulate grazing appear to decrease rough fescue, Idaho fescue and bluebunch wheatgrass and increase Sandberg's bluegrass, Columbia needlegrass, Kentucky bluegrass, needle-and-thread grass, antelope-brush and pussytoes.[88]

Table 4 below shows the environment table for the proposed site units for the PPdh2. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

[88] Wikeem and Wikeem 2004, Tucker 2013

Table 4. Environment table for grassland site units in the PPdh2.

Site Units (Temporary names)	***Sand***	***Steep warm & moderate sand***	***Colluvium Shrub***	***Moderate warm***	***Gentle***	***Mesic***	***Shrub***	***Moist $***	***Ga01***
SMR	2	2 (3)	3	2 – 3	2 – 3	4	5	5 – 6	4 – 5
SNR	B – C (A)	C – D	D	C – D	C – D	D	D	D	E (saline)
Slope Position	CR – UP	LW - UP	LW - UP	LW - UP	LW - UP	TO, LW, DP	DP, GU, TO	DP, LV, TO	LV
Typical Slope/Aspect	10 to 30 %, warm (WSW to SSE)	45 to 65%, warm (WSW to SSE)	60 - 70%, variable	20 to 50%, warm (WSW to SSE)	0 - 15% (45), variable (cool)	0 - 15%, variable	0 - 5%, none	0 - 5%, none	0, none
Insolation	Moderate	High	Variable	Moderate	None	None	None	None	None
Parent Materials	E, FG	E, FG, M	C	E, FG, M, (LG)	Exv/FG, FG, (Ev/Mb)	Ev/Mb, Ev/FG	E, or possibly slope wash	L	L
Soil texture	sandy	loamy, sandy	loamy	loamy	loamy at surface, sandy below	fine loamy - coarse loamy	loamy	fine loamy - clayey	loamy
Coarse Fragments	none or low	low – high	high	variable	low at surface, high at depth	low at surface, moderate to high at depth	low	none	none
Important features	Coarse sand with insolation	High insolation slopes, or moderate insolation with sandy soils	Rocky soils on colluvial slopes	Moderate insolation slopes, may have shallow soils on gentler slopes	Often with Ev (10 - 25 cm) over moderately coarse to coarse textured soils, strong calcareous cementation at 40 - 50 cm depth	Mesic morainal sites, or sites that collect more snow and runoff to compensate for coarse soils at depth	Sites collect spring run off	Occurs adjacent to wetlands	Areas with runoff and evaporation resulting in salt accumulation
Soil Classn	EB, MB	**EB, MB**	EB	**EB, MB, DBC**	**DBC, EB,** MB	**DBC, EB**	**DBC**	HG	solonetzic

Site Units

Sand

The “sand” site unit occurs on sandy soils with few to moderate amounts of coarse fragments. This unit is rare and generally only occurs along Lake Koocanusa. Sites may be either eolian or glaciofluvial deposits. Slopes are gentle to moderate (10 – 25%) on warm aspects. Vegetation is dominated by needle-and-thread grass with junegrass, fleabanes and few forbs; sometimes there is scattered antelope-brush. Thyme-leaved sandwort (*Arenaria serpyllifolia*) is common (with low covers) on this site and on other warm aspect sites. Invasive annual bromes are commonly present and increase with disturbance. Shrubs are infrequent but scattered, particularly on sites with some coarse fragments in the soils. The moss and lichen layer is very sparse.

*** Unsure if this might climax to bluebunch wheatgrass. Coarse soils on steeper warm aspects seem to climax to bluebunch.*

Steep Warm and Moderate Sand

The “steep warm and moderate sand” site unit occurs on steep (>50%), warm aspect slopes. This unit is common and widespread. Soils are often ravelling and are usually coarse-loamy with moderate to high amounts of coarse fragments. Slopes may be more moderate on sandy soils sites. Vegetation is dominated by widely spaced bluebunch wheatgrass with some junegrass, prairie sagewort, tufted phlox (*Phlox caespitosa*) and scattered other forbs and antelope-brush. Because of the ravelling soils, the moss and lichen layer is sparse and poorly developed.

$low bunchgrass

On disturbed sites, bluebunch wheatgrass is often replaced by needle-and-thread grass. Invasive annual bromes are more common and the cover of prairie sagewort is higher. The cover of antelope-brush often increases somewhat with grazing.

Colluvium Shrub

The “colluvium shrub” shrubland site unit occurs on steep, rocky, colluvial slopes. This unit is uncommon but widespread at middle and upper elevations of this variant. Coarse fragments dominate soils with loamy soils in between the rocks. Vegetation is shrubby, with saskatoon, antelope-brush, snowberry, choke cherry and some Douglas-fir regeneration. Between the shrubs there is bluebunch wheatgrass, rough fescue, balsamroot, and kinnikinnick (*Arctostaphylos uva-ursi*). Some western cliff ferns (*Woodsia oregana*) grow in rock crevices. The moss and lichen layer is sparse. Data for this unit is limited to a single plot. Warm aspects may have more bluebunch wheatgrass and cool aspects may have more rough fescue at climax.

Moderate Warm

The "moderate warm" site unit occurs on warm aspects with 20 – 45% slopes. This unit is common and widespread. Soils are stable and sites are subxeric to submesic; they are derived from glaciofluvial, morainal, and glaciolacustrine materials. Soils often have an eolian cap on them. Soils are usually loamy or coarse loamy and have moderate levels of coarse fragments. At climax, vegetation is dominated by bluebunch wheatgrass with some rough fescue or Idaho fescue. Abundant balsamroot is commonly present, together with yarrow, Sandberg's bluegrass, junegrass, tufted phlox, and prairie sagewort. Other forbs occur, but diversity is low. Scattered rose, snowberry or antelope-brush may occur. Abundant clad lichens (*Cladonia* spp.) dominate the moss and lichen layer.

$Pseuspi

This late seral unit is lacking fescues and has more abundant needle-and-thread grass, junegrass, and antelope-brush. The moss and lichen layer is generally sparser than at climax.

$Achn

This early seral unit is dominated by abundant Columbia needlegrass and antelope-brush with a very sparse lichen/moss layer. Invasive annual bromes are common with low to moderate cover.

$low bunchgrass

This early seral unit is dominated by low bunchgrasses such as needle-and-thread grass and junegrass; invasive annual bromes are also common and often abundant. The moss/lichen layer is sparse or nearly absent.

Gentle

The "gentle" site unit occurs on level and gently sloping sandy, gravelly glaciofluvial soils, often with a loamy eolian capping (10 to 30 cm deep). It may occur on moderate cool aspects as well. This unit is common and widespread, especially at lower elevations in this subzone. These sites superficially appear mesic, but are usually subxeric or submesic because of the coarse underlying soils. The grassland vegetation largely reflects the loamy-textured soils in the upper horizon[89]. This unit also includes some sites on morainal soils with lots of coarse fragments; these sites tend to be transitional to the "mesic" site unit. Cooler aspects are likely more productive and recover more quickly than level sites.

At climax, the vegetation is dominated by rough fescue, Idaho fescue, and junegrass with scattered forbs. Common forbs, all with low cover, include yarrow, pussytoes, common dandelion, orange arnica (*Arnica fulgens*), mariposa lily (*Calochortus apicularis* or *C. macrocarpus*), fleabanes (*Erigeron* spp.), lemonweed, *Lomatium* spp., meadow death camas (*Toxicoscordion venenosum*), woolly groundsel (*Packera*

[89] Most grassland plants have their roots concentrated in this upper horizon, make the site effectively mesic or submesic from the perspective of the plant, but much drier from the perspective of a tree.

cana), and yellow salisfy (*Tragopogon dubius*). The moss and lichen layer is variable in cover (depending on litter cover) and is dominated by thread mosses, clad lichens and pelt lichens.

At climax, it is differentiated from "mesic" site unit by the general lack or very low cover of silky lupine. Kentucky bluegrass is also more common on "mesic" sites.

Five seral associations were identified. These are described below.

$Festida

This late seral unit is dominated by Idaho fescue, with more abundant bluebunch wheatgrass and junegrass than at climax. Invasive annual bromes are usually present, but with low cover.

$Pseuspi

This mid seral unit is dominated by bluebunch wheatgrass with abundant junegrass and Sandberg's bluegrass. Pussytoes and antelope-brush are often more abundant than at climax. The moss/lichen layer is poorly developed and much lower cover than at climax.

$Achn

This early seral unit is dominated by Columbia needlegrass or spreading needlegrass. Pussytoes, yarrow, antelope-brush, and woolly plantain are more abundant than at climax. The moss/lichen layer is poorly developed and much lower cover than at climax.

$low bunchgrass

This early seral unit is dominated by low bunchgrasses including needle-and-thread grass, junegrass, and Sandberg's bluegrass. Pussytoes are more abundant and the moss/lichen layer is sparser than at climax.

$Poa

Non-native Canada bluegrass and/or Kentucky bluegrass dominate this early seral unit. Low covers of junegrass, Columbia needlegrass, and bluebunch wheatgrass commonly occur. Pussytoes are common and fairly abundant; there are low covers of many other forbs. The moss/lichen layer is very sparse.

Mesic

The "mesic" site unit usually occurs on mesic gently sloping morainal soils, often with an eolian cap. It occasionally occurs on glaciofluvial soils where there are compensating conditions: a gully, or toe slope with additional snow accumulation or runoff. This unit is small and uncommon, but widespread. At climax, the vegetation is dominated by abundant rough fescue and silky lupine. Idaho fescue, bluebunch wheatgrass and Kentucky bluegrass are also common, although they may indicate that the site is late seral rather than climax. Aside from silky lupine, forbs are generally low cover, but very diverse. Abundant litter limits the development of the moss/lichen layer that is dominated by thread-moss (*Bryum* spp.) and clad lichens.

$Festida

This late seral unit is dominated by Idaho fescue, bluebunch wheatgrass and junegrass, with low cover of rough fescue. Silky lupine is abundant; other forbs are diverse but with low cover. The moss/lichen layer is similar to climax sites.

$Achnric

This mid seral unit is dominated by spreading needlegrass, usually with some rough fescue. Forbs are diverse, but none are abundant, although kinnikinnick is sometimes prominent. The moss/lichen layer is similar to at climax.

$Hespcur

This mid seral unit is dominated by short-awned porcupinegrass. Some Idaho fescue is usually present together with junegrass. Forbs are diverse, but none are abundant. The moss/lichen layer is dominated by sidewalk moss (*Tortula ruralis*).

$Poa pra

Non-native Kentucky bluegrass dominates this early seral unit. Low covers of junegrass, Columbia needlegrass, and rough fescue, and needle-and-thread grass commonly occur. Forbs are diverse, but none are abundant. The moss/lichen layer is absent, probably due to the litter build up from Kentucky bluegrass.

Shrub

This site unit occurs in moist depressions where there is some accumulation of moisture. These sites are small and rare; it was observed only in the Tobacco Plains area. Soils are likely an accumulation of slope wash overtop of glaciofluvial or morainal deposits. Snow likely accumulates and is late-lying on these sites. The vegetation is dominated by abundant shrub cover including snowberry, rose, choke cherry together with scattered forbs and grasses. Kentucky bluegrass is common due to some grazing disturbance.

Ga01

This alkali meadow site unit has been described in the *Wetlands of British Columbia* as the alkali saltgrass saline meadow[90]. It occurs on seasonally flooded sites where evaporation accumulates salts and vegetation is limited to salt-tolerant plants. The only plot sampled in this unit was dominated by Alkali saltgrass and invasive annual bromes with some Nevada bluegrass (*Poa secunda* ssp. *juncifolia*), Kentucky bluegrass and a few forbs. This site was drier than is typical for this unit and was probably transitional to upland grasslands.

The plot was located in an alkali area along Highway 95 between Wasa and Fort Steele. There are likely other alkali meadow ecosystems in this area, and some may be similar to those in the IDFdm2. However, these ecosystems are extremely limited in their distribution in this variant.

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[90] MacKenzie and Moran 2004

Other Ecosystems

Moist

The moist site unit has not been observed with climax vegetation. It occurs on toe slopes adjacent to wetlands and may be meadows and may include several ecosystems. Either Kentucky bluegrass or Alaska bentgrass (*Agrostis aequivalvis*) dominated the two sites sampled, both with Baltic rush (*Juncus balticus*). These sites may belong to Ga03 Field Sedge meadow association. At climax, the Ga03 is dominated by field sedge (*Carex praegracilis*) with some Baltic rush. Kentucky bluegrass is often present, even on climax sites, and increases with grazing. Other characteristic species include slender wheatgrass (*Elymus trachycaulus*), and tufted white prairie aster (*Symphyotrichum ericoides* var. *pansum*).[91]

Are there other ecosystems you have observed that haven't been sampled? Are there some true shrublands that weren't previously forested? Any suggestions for locations of wet grassland ecosystems, esp. later seral ones?

IDFdm2

Extensive human-caused fires, logging, and grazing by livestock and wild ungulates have significantly disturbed the IDFdm2. Dominant climax grasses on gently sloping sites include rough fescue, Idaho fescue, and bluebunch wheatgrass. Steep warm aspects are usually dominated by bluebunch wheatgrass. Heavy grazing causes rough fescue, Idaho fescue, and bluebunch wheatgrass to decrease while Sandberg's bluegrass, needle-and-thread grass, junegrass, and pussytoes increase.[92]

Table 5 below shows the environment table for the proposed site units for the IDFdm2. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

[91] Ibid.
[92] Wikeem and Wikeem 2004

Table 5. Environment table for grassland site units in the IDFdm2.

Site Units (Temporary names)	***Steep warm***	***Moderate warm***	***Gentle***	***Mesic***	***Ga01***	***Moist $***
SMR	2 (3)	2 (3)	2 – 3	4	4 – 5	5 – 6
SNR	B – D	C – D	B – D	D	F (saline)	D
Slope Position	MD - UP	MD - UP, CR	level, MD - UP, low crest	DP	LV, DP	DP, LW, TO
Typical Slope/Aspect	55 to 75%, warm (WSW to SSE)	20 to 50%, warm (WSW to SSE), less on crests, steeper on neutral aspects	0 - 15%	0 - 10%, variable	0, none	0 - 5%, none
Insolation	High	Moderate	None	None	None	None
Parent Materials	C, FG, (M)	FG, M, C	Exv/FG, FG, (Exv/Mb)	Ev/Mb, L	L	L
Soil texture	loamy, sandy	loamy	loamy at surface, sandy below	fine loamy - loamy	loamy	loamy - clayey
Coarse Fragments	low – high	variable	low at surface, high at depth	low	none	none
Important features	High insolation slopes, surface soils usually ravelling	Moderate insolation slopes, may have shallow soils on crests and steep slopes on neutral aspects	Often with Ev (10 - 25 cm) over moderately coarse to coarse textured soils, strong calcareous cementation at 30 - 50 cm depth	Small depressions in drier areas	Areas with runoff and evaporation resulting in salt accumulation	Occurs adjacent to wetlands
Soil Classn	**EB**	**EB, MB, BC**	**DBC**, EB, MB	**EB**	MB, solonetzic	HG, DBC

Site Units

Steep Warm

The “steep warm” site unit occurs on steep (>55%), warm aspect slopes. This unit is common, particularly at higher elevation in this subzone. Soils are often ravelling and are usually loamy or sandy with moderate to high amounts of coarse fragments. Vegetation is dominated by widely spaced bluebunch wheatgrass with some junegrass, prairie sagewort, and scattered other forbs and shrubs. Forb diversity is generally low. Because of the ravelling soils, the moss and lichen layer is sparse and poorly developed.

$mid

Mid seral sites are still dominated by bluebunch wheatgrass but its cover is usually lower. Invasive annual bromes are more common and the cover of pussytoes is higher; Kentucky bluegrass is occasionally abundant. Antelope-brush is usually abundant and rose, saskatoon, and snowberry have higher cover than on climax sites.

$early

On very disturbed sites, bluebunch wheatgrass is often replaced by junegrass and rabbit brush may be abundant rather than antelope-brush.

Moderate Warm

The “moderate warm” site unit occurs on warm aspects with 20 – 45% slopes. This unit is common and widespread. It also occurs on gentle crests or steeper neutral aspects. Soils are stable and sites are subxeric to submesic; they are derived from colluvial, glaciofluvial, and morainal, materials. Soils are usually loamy or coarse loamy and have moderate to high levels of coarse fragments. At climax, vegetation is dominated by bluebunch wheatgrass, rough fescue, and balsamroot. Scattered forbs occur, but diversity is low. Antelope-brush and saskatoon are common, but with low cover. Small mosses dominate the moss and lichen layer. (*Limited data are available – uncertain veg characterization*)

$Shrub

This late seral unit is lacking rough fescue and has more abundant invasive annual bromes, junegrass, and shrubs including antelope-brush, saskatoon, and snowberry. Wild bergamot cover is high but the moss and lichen layer is generally absent, perhaps due to disturbance.

$Early

This early seral unit is dominated by antelope-brush and saskatoon with roses, Kentucky bluegrass, and Columbia needlegrass. Scattered forbs are present and black medic is sometimes abundant. The moss/lichen layer is sparse.

$low bunchgrass

This early seral unit is dominated by low bunchgrasses such as needle-and-thread grass and junegrass; invasive annual bromes are also common and often abundant. The moss/lichen layer is sparse or nearly absent.

Gentle

The "gentle" site unit occurs on level and gently sloping sandy, gravelly glaciofluvial soils, often with a loamy eolian capping (10 to 30 cm deep). This unit is common only at lower elevations in this subzone. It may occur on rocky morainal soils as well; these sites tend to be transitional to the "mesic" site unit. The grassland vegetation largely reflects the loamy-textured soils in the upper horizon.

At climax, the vegetation is dominated by rough fescue with fleabanes, roses, bluebunch wheatgrass, junegrass, yarrow, pussytoes and diverse scattered forbs. The moss and lichen layer is well developed and is dominated by sidewalk moss, clad lichens, and pelt lichens.

$AchnHesp

This early seral unit is dominated by short-awned porcupinegrass, Columbia needlegrass or spreading needlegrass, often with Kentucky bluegrass.

$Koelmac

This early seral unit is dominated by junegrass and with spreading needlegrass. The moss/lichen layer is sparser than at climax.

$Poa

Non-native Canada bluegrass and/or Kentucky bluegrass dominate this early seral unit. Low covers of Columbia needlegrass occur. Forb cover and moss/lichen cover is lower than at climax.

$Bromtec

Some early seral sites are dominated by invasive annual bromes and Canada bluegrass. Forb cover and moss/lichen cover is lower than at climax.

$Agrocri

Some sites may have been seeded to crested wheatgrass. Idaho fescue, junegrass, fleabanes, and alfalfa also occur on these sites. There are few or no mosses and lichens.

$Medilup

Some sites are dominated by black medic with some junegrass, Columbia needlegrass, fleabanes, yarrow and a few other forbs. There are few or no mosses and lichens.

Mesic

The "mesic" site unit is rare and is only known to occur in grassland depressions where some snow accumulation or runoff compensates for coarse-textured soils. Most sites with these conditions are forested. At climax, I speculate that the vegetation is dominated by abundant rough fescue with diverse but low cover forbs. Abundant litter would likely limit the development of the moss/lichen layer that is dominated by thread-moss and clad lichens. The only plot in this site unit was dominated by spreading needlegrass with Kentucky bluegrass, roses, a bit of rough fescue, and scattered forbs.

Ga01

This alkali meadow site unit has been described in the Wetlands of British Columbia as the alkali saltgrass saline meadow[93]. This unit is only known from the Lavington area west of Canal Flats. It occurs on seasonally flooded sites where evaporation accumulates salts and vegetation is limited to salt-tolerant plants. The three plots sampled in this unit were each different and may be separated into different units. The driest site was drier than is typical for this unit and was dominated by alkali cordgrass, thickspike wildrye, junegrass, Kentucky bluegrass, and prairie sagewort with abundant clad lichens. One site was more typical with alkali saltgrass, alkali cordgrass, and junegrass with some seablite and pussytoes. The last site was dominated by seablite and Nuttall's alkaligrass with some other grasses.

Other

Moist

The moist site unit has not been observed with climax vegetation. It occurs on toe slopes adjacent to wetlands and may be meadows and may include several ecosystems. Either Kentucky bluegrass or Canada bluegrass with thickspike wildrye, pussytoes, and black medic dominated the two sites sampled.

Are there other ecosystems you have observed that haven't been sampled? Are there some true shrublands that weren't previously forested? Other moist sites with late seral vegetation?

IDFdk5

Little data and few records are available for this subzone. Given that the climate is slightly cooler and moister than other subzones, rough fescue should be abundant at climax, with bluebunch wheatgrass dominating on steeper warm aspects. Seral trends would be similar to other dry IDF subzones.

Table 6 below shows the environment table for the proposed site units for the IDFdk5. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant

[93] MacKenzie and Moran 2004

association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

Table 6. Environment table for grassland site units in the IDFdk5.

Site Unit (Temporary names)	*Steep warm*	*Colluvium*	*Moderate warm*	*Gentle $*	*Moist $*
SMR	(1) 2	2	2 (3)	2 – 3	5 – 6
SNR	B – D	C	C – D	B – D	D
Slope Position	MD - UP	LW - UP	MD - UP, CR	level, MD - UP	DP, LW, TO
Typical Slope/Aspect	50 to 75%, warm (WSW to SSE)	45 - 65%	20 to 50%, warm (WSW to SSE)	0 - 15%	0 - 5%, none
Insolation	High	Variable	Moderate	None	None
Parent Materials	M, C, (FG)	C	M, FG	Exv/FG, FG	L
Soil texture	loamy, fine loamy	coarse loamy	loamy, sandy	loamy at surface, sandy below	loamy - clayey
Coarse Fragments	low – high	high	variable	low at surface, low - high at depth	none
Important features	High insolation slopes, surface soils usually raveling	Rocky colluvial soils	Moderate insolation slopes	Often with Ev (10 - 25 cm) over moderately coarse to coarse textured soils	Occurs adjacent to wetlands
Soil Classn	**EB**	EB	**EB, MB**	**DBC**, EB, MB	HG, DBC

Steep Warm

The "steep warm" site unit occurs on steep (>55%), warm aspect slopes. This unit is widespread and is the most common grassland unit in this variant. Soils are often ravelling and are usually loamy or sandy with moderate to high amounts of coarse fragments. Vegetation is dominated by widely spaced bluebunch wheatgrass with some junegrass, prairie sagewort, and scattered other forbs and shrubs. Forb diversity is generally low. Because of the ravelling soils, the moss and lichen layer is sparse and poorly developed.

Steep warm $

Seral steep warm sites have lower covers of bluebunch wheatgrass and more exposed mineral soils. Seral data is limited to one plot; most steep slopes have limited access for grazing.

Colluvium

The "colluvium" shrubland site unit occurs on steep, rocky, colluvial slopes. This unit is uncommon. Coarse fragments dominate soils with loamy soils in between the rocks. Vegetation is shrubby, with saskatoon, snowberry, choke cherry and tall Oregon-grape (*Mahonia aquifolium*). Between the shrubs there is bluebunch wheatgrass, kinnikinnick, spreading dogbane (*Apocynum androsaemifolium*), and scattered other forbs. The moss and lichen layer is sparse. Data for this unit is limited to a single plot. Warm aspects may have more bluebunch wheatgrass and cool aspects may have more rough fescue at climax.

Moderate Warm

The "moderate warm" site unit occurs on warm aspects with 20 – 50% slopes. This unit is common and widespread. Soils are stable and sites are subxeric to submesic; they are derived from morainal and glaciofluvial materials. Soils are usually loamy or sandy and have moderate to high levels of coarse fragments. There is limited data for this unit. At climax, vegetation is likely dominated by bluebunch wheatgrass, rough fescue, and scattered other forbs and grasses with a well developed crust of mosses and lichens.

$ late

The single late seral plot was dominated by bluebunch wheatgrass with shrubs, needle-and-thread grass, prairie sagewort, tarragon (*Artemisia dracunculus*), Rocky Mountain fescue (*Festuca saximontana*), golden-aster (*Heterotheca villosa*), and a well-developed lichen and moss crust on the soil surface.

$mid

The single early seral plot was dominated by junegrass, Columbia needlegrass, and pussytoes, and fleabanes with a well-developed lichen and moss crust.

Gentle

The "gentle" site unit occurs on level and gently sloping sandy, gravelly glaciofluvial soils with a loamy eolian capping (10 to 30 cm deep). The grassland vegetation largely reflects the loamy-textured soils in the upper horizon. This unit is uncommon and generally only occurs in lower-elevation areas.

Although there is no data, I would expect climax vegetation is dominated by rough fescue with fleabanes, bluebunch wheatgrass, junegrass, yarrow, pussytoes and diverse scattered forbs. The moss and lichen layer would be variable: sparse where litter is thick and well developed elsewhere.

$achn

Columbia needlegrass, spreading needlegrass, junegrass, and Kentucky bluegrass dominated the vegetation in the single plot in this unit. There was also a diverse forb community and a lichen-dominated crust.

Other

Moist

The moist site unit has not been observed with climax vegetation. It occurs on toe slopes adjacent to wetlands and may be meadows and may include several ecosystems. The single sample site was dominated by Canada bluegrass, dandelion, black medic, pussytoes and rose. This plot is likely on the drier end of this unit. There may be sites may belonging to the Ga03 Field Sedge meadow association. At climax, the Ga03 is dominated by field sedge with some Baltic rush. Kentucky bluegrass is often present, even on climax sites, and increases with grazing. Other characteristic species include slender wheatgrass and tufted white prairie aster.[94]

IDFxk

Most of the area has been severely overgrazed by domestic livestock, elk, mule deer, and bighorn sheep. Some of the area was farmed as early as 1882, especially along the benches of Columbia Lake.[95]

At climax, gently sloping grasslands along Columbia Lake were likely dominated by rough fescue, Idaho fescue and bluebunch wheatgrass with scattered Douglas-fir trees. Common shrubs include common rabbit-brush (*Ericameria nauseosa*), Rocky Mountain juniper, common juniper (*Juniperus communis*), and saskatoon. Dominant grasses and forbs include junegrass, Columbia needlegrass, needle-and-thread grass, pinegrass (*Calamagrostis rubescens*), yarrow (*Achillea millefolium*), and prairie sagewort. Junegrass, Columbia needlegrass and needle-and-thread grass commonly increase with grazing. Steep warm aspects are usually dominated by bluebunch wheatgrass at climax, or needle-and-thread grass and junegrass on seral sites. [96]

Table 7 below shows the environment table for the proposed site units for the IDFxk. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

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[94] Ibid.
[95] Wikeem and Wikeem 2004
[96] Ibid.

Table 7. Environment table for grassland site units in the IDFxk.

Site Unit (Temporary names)	*Steep warm*	*Colluvium*	*Moderate warm*	*Gentle*
SMR	1 (2)	1 (2)	3	2 – 3
SNR	B – D	C - D	C – D	B – D
Slope Position	MD - UP, CR	LW - UP	MD - UP	level, MD - UP
Typical Slope/Aspect	50 to 75%, warm (WSW to SSE), less on shallow soils	60 - 70%	15 to 50%, warm (WSW to SSE)	0 - 15%, moderate on neutral aspects, steep on cool aspects
Insolation	High	Variable	Moderate	None
Parent Materials	LG, FG	C	LG	Exv/FG, LG
Soil texture	sandy, loamy, fine loamy	coarse loamy, sandy	coarse loamy	loamy at surface, sandy below or coarse loamy
Coarse Fragments	low – high	high	None	low at surface, low - high at depth or none
Important features	High insolation slopes, surface soils usually raveling	Rocky colluvial soils	Moderate insolation slopes	Often with Ev (10 - 25 cm) over moderately coarse to coarse textured soils; LG tends to be sandy loam texture (silt and very fine sands)
Soil Classn	**EB**	**EB**	**EB, MB**	**DBC**, EB, MB

Steep Warm

The “steep warm” site unit occurs on steep (>50%), warm aspect slopes. This unit is common and widespread. Soils are often ravelling and are usually loamy or sandy with moderate to high amounts of coarse fragments. Vegetation is dominated by widely spaced bluebunch wheatgrass with some junegrass, prairie sagewort, needle-and-thread grass, common rabbit-brush (*Ericameria nauseosa*) and scattered other forbs and grasses. Forb diversity is generally low. The moss and lichen layer is variable and cover depends on how stable the soils are and the amount of disturbance. Lacustrine soils generally have a high diversity of scale and crust lichens. Coarser textured soils tend to be less stable and have more sidewalk moss, less overall cover of mosses and lichens, and lower species diversity.

Colluvium

The “colluvium” shrubland site unit occurs on steep, rocky, colluvial slopes. This unit is uncommon. Coarse fragments dominate soils with loamy soils in between the rocks. Vegetation is shrubby, with Rocky Mountain juniper (*Juniperus scopulorum*), common rabbit-brush, and snowberry. Between the shrubs there is bluebunch wheatgrass, prairie sagewort, and scattered other forbs and grasses. The moss and lichen layer is sparse. Data for this unit is limited to a single plot. Warm aspects may have more bluebunch wheatgrass and cool aspects may have more rough fescue at climax.

Moderate Warm

The “moderate warm” site unit occurs on warm aspects with 15 – 50% slopes. This unit is common and widespread. Soils are stable and sites are submesic; they are derived from glaciolacustrine materials. Soils are usually coarse loamy with no coarse fragments. There is limited data for this unit. At climax, vegetation is likely dominated by bluebunch wheatgrass, rough fescue, and scattered other forbs and grasses with a well developed crust of mosses and lichens. Lacustrine soils generally have a high diversity of scale and crust lichens.

$ Pseu

The single late seral plot was dominated by bluebunch wheatgrass and junegrass with common rabbit-brush, scattered other forbs and grasses, and a moderate cover of lichen and moss crust on the soil surface.

$low bunchgrass

Early to mid seral sites were dominated by junegrass, needle-and-thread grass, and prairie sagewort, with scattered other forbs and grasses and a well-developed and diverse lichen and moss crust.

Gentle & Cool

The “gentle & cool” site unit occurs on level and gently sloping coarse loamy glaciolacustrine soils or sandy, gravelly glaciofluvial soils with a loamy eolian capping (10 to 30 cm deep). This unit also occurs on moderate to steep cool aspects with similar soils. This unit is uncommon and generally occurs at lower elevations in this subzone. The grassland vegetation largely reflects the loamy-textured soils in the upper horizon. Cool aspects are likely more productive with more moisture available due to lower evaporation.

Although there is no data, I would expect climax vegetation is dominated by rough fescue with Idaho fescue, bluebunch wheatgrass and diverse scattered forbs. The moss and lichen layer would be variable: sparse where litter is thick and well developed elsewhere.

$ Pseu

The single late seral plot was dominated by bluebunch wheatgrass and junegrass with common rabbit-brush, needle-and-thread grass, prairie sagewort, pussytoes,

minor rough fescue and a moderate cover of lichen and moss crust on the soil surface.

$low bunchgrass

Early to mid seral sites were dominated by junegrass, needle-and-thread grass, common rabbit-brush, pussytoes , bluebunch wheatgrass and prairie sagewort, with scattered other forbs and grasses and a well-developed and diverse lichen

PPxh3

Grasslands in this subzone are predominantly early seral. Heavy grazing causes junegrass, Sandberg's bluegrass, needle-and-thread grass, cheatgrass, Columbia needlegrass, Kentucky bluegrass, sand dropseed (*Sporobolus cryptandrus*) and pussytoes to increase at the expense of wheatgrass and fescue. Invasive alien species such as cheatgrass (and other alien annual bromes), knapweed, and sulphur cinquefoil are now common on many sites; these non-native species may persist over the long-term.[97]

Gently sloping late seral grasslands are dominated by bluebunch wheatgrass, rough fescue and Idaho fescue; silky lupine, arrowleaf balsamroot (*Balsamorhiza sagittata*), sticky geranium, parsnip-flowered buckwheat (*Eriogonum heracleoides*), and lemonweed (*Lithospermum ruderale*) are common associates.[98] There is little rough fescue recorded in the grassland plot data for this subzone. The climate may be dry and warm enough that Idaho fescue may dominate more than rough fescue at climax on gently sloping sites. Forested sites sometimes have abundant rough fescue[99]; *reduced insolation from shading by trees may allow rough fescue to establish more readily*.

Kentucky bluegrass, bluebunch wheatgrass, Columbia needlegrass, junegrass, black medic (*Medicago lupulina*), rose and snowberry frequently dominate gently sloping early seral sites.[100]

Kentucky bluegrass usually dominated moist grasslands together with creeping bentgrass (*Agrostis stolonifera*), some sedges, and weedy forbs.[101]

Late seral warm aspects are dominated by bluebunch wheatgrass along with silky lupine and arrowleaf balsamroot.[102] Hurlburt and Stanley[103] described seral south-facing grassland dominated by diffuse knapweed, cheatgrass, bluebunch wheatgrass with some rose and snowberry.

Table 8 below shows the environment table for the proposed site units for the PPxh3. Vegetation tables are presented under separate cover in an excel file. Site

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[97] Sprout and Kelly 1964, Wikeem and Wikeem 2004
[98] Sprout and Kelly 1964, Wikeem and Wikeem 2004
[99] Hurlburt and Stanley 1997
[100] Ibid.
[101] Ibid.
[102] Sprout and Kelly 1964, Wikeem and Wikeem 2004
[103] 1997

unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

Table 8. Environment table for grassland site units in the PPxh3.

Site Series (Temporary names)	***Steep Aris***	***Steep warm***	***Moderate warm***	***Gentle***	***Shrub***	***Moist $Leymcin***
SMR	1 – 2	2 (3)	2 – 3	2 – 3	3 – 5	4 - 5
SNR	B	B – D	B – D	C – D	D	D
Slope Position	UP – MD	LW - UP	LW - UP	LW - UP	DP, GU, TO - MD	DP, LV, TO
Typical Slope/Aspect	45 to 70 %, hot (SSW to S)	40 to 65%, warm (W to SE)	20 to 40%, warm (W to SSE), 40 to 50 % on warm-neutral aspects (SE, WNW)	0 - 15%	0 - 20%, variable	0 - 5%, none
Insolation	High	High	Moderate	None	None - Low	None
Parent Materials	FG	FG, Cv, Mv	M, C, FG	Exv/FG, FG, (Ev/Mb)	Ev/M	Fv/M
Soil texture	Sandy	loamy, sandy	loamy (sandy)	loamy or coarse loamy at surface, sandy below	loamy	fine loamy
Coarse Fragments	moderate – high	low – high	low - high	usually low at surface, high at depth	low	none
Important features	Coarse sand with high insolation	High insolation slopes, usually with either sandy soils or shallow soils	Moderate insolation slopes, may be steeper on warm - neutral aspects	Often with Exv (10 - 25 cm) over moderately coarse to coarse textured soils	Sites with some additional moisture inputs	Occurs in depressions or other moisture receiving sites
Soil Classn	**EB, MB**	**DBC, EB, MB**	**DBC**, MB	**DBC**, BLC, MB	**BLC**	**BLC**

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Steep Aris

The “steep Aris” site unit occurs on steep (>45%), hot aspect slopes (SSW to S). Soils are sandy, gravelly derived from glaciofluvial material. This unit is rare. The sandy soils are unstable and actively ravelling, especially where there is any disturbance. The vegetation is dominated by red three-awn (*Aristida purpurea* var*. longiseta*) with needle-and-thread grass, balsamroot, selaginella, thread-leaved phacelia (*Phacelia linearis*) and scattered other forbs and grasses. Because of the coarse, unstable soils, there is no moss/lichen layer. *It is possible that this unit may shift to bluebunch wheatgrass with no disturbance.*

Steep Warm

The “steep warm” site unit occurs on steep (>40%), warm aspect slopes. Soils are often ravelling and are usually loamy or sandy with moderate to high amounts of coarse fragments. This unit is moderately common and widespread. Vegetation is dominated by widely spaced bluebunch wheatgrass with balsamroot, some invasive annual bromes, and scattered other forbs and shrubs. Forb diversity is generally low. Because of the ravelling soils, the moss and lichen layer is sparse and poorly developed.

$mid

Mid seral sites are still dominated by bluebunch wheatgrass but its cover is usually lower than at climax. Invasive annual bromes, needle-and-thread grass, and diffuse knapweed are more common. The moss/lichen layer is even sparser than at climax.

$early

On very disturbed sites, bluebunch wheatgrass cover is often low and invasive annual brome cover is very high. A wide diversity of forbs occurred, including many non-native species. The moss/lichen layer is absent or nearly so.

Moderate Warm

The “moderate warm” site unit occurs on warm aspects with 20 – 50% slopes. On steeper slopes, it is usually on warm-neutral aspects. Soils are stable and sites are subxeric to submesic; they are derived from morainal, colluvial, and glaciofluvial, materials. Soils are usually loamy, coarse loamy or sandy. At climax, vegetation is dominated by bluebunch wheatgrass with rough fescue, balsamroot, selaginella and Idaho fescue. Patches of invasive annual bromes still occur, usually where pocket gopher digging has exposed mineral soil. Scattered forbs occur with moderate diversity but low cover. Small mosses dominate the moss and lichen layer. (*Sparse data – uncertain veg characterization*)

$late

This late seral unit is dominated by bluebunch wheatgrass and has a similar composition to climax sites except that fescues are absent. Lower litter covers shifts the moss/lichen layer to more lichens than mosses.

$early

This early seral unit is dominated by needle-and-thread grass, Columbia needlegrass, invasive annual bromes, and Sandberg's bluegrass are also common and often abundant. Balsamroot has low cover or is absent; forbs are abundant and diverse but non-native species are common. The moss/lichen layer is sparse or absent.

$other

Hurlburt and Stanley[104] also describe seral sites dominated by cheatgrass, diffuse knapweed, and bluebunch wheatgrass. The use of biocontrol agents on knapweed seems to have successfully reduced its abundance substantially; otherwise this mid to early seral community likely occurs in the PPxh3.

Gentle

The "gentle" site unit occurs on level and gently sloping sandy, gravelly glaciofluvial soils, often with a loamy eolian capping (10 to 30 cm deep). It may occur on rocky morainal soils as well. The grassland vegetation largely reflects the loamy-textured soils in the upper horizon. This unit is common and widespread in the valley bottom.

At climax, the vegetation is dominated by Idaho fescue with pussytoes, bluebunch wheatgrass, junegrass, pussytoes and diverse scattered forbs. Invasive annual bromes still occur where pocket gopher diggings have disturbed the soil. The moss and lichen layer is limited by thick litter and is dominated by mosses. *This unit may succeed to a mixture of rough fescue and Idaho fescue.*

$late

This early seral unit is dominated by bluebunch wheatgrass, and junegrass, with some fescue and diverse forbs. The moss/lichen layer is sparse and dominated by mosses.

$mid

Abundant Columbia needlegrass, Kentucky bluegrass, invasive annual bromes and some Idaho fescue characterize this mid to early seral unit. The forb layer is less diverse and is dominated by non-native species such as prickly sow-thistle and yellow salsify (*Tragopogon dubius*). The moss/lichen layer is sparse.

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[104] 1998

$early

This early seral unit is dominated by needle-and-thread grass, Sandberg's bluegrass, Columbia needlegrass, invasive annual bromes and weedy forbs, with low covers of a few native forbs. Forb cover and moss/lichen cover is low.

Shrub

The "shrub" site unit occurs on rich slopes and level areas with deep, loamy soils with few coarse fragments. This unit is uncommon but widespread. These mesic or near mesic sites appear to succeed to shrubs in the absence of cattle grazing. They are dominated by thick shrub cover including snowberry, roses, and choke cherry with scattered forbs and grasses in openings. Weeds such as hairy vetch (*Vicia villosa*) and common St. John's-wort (*Hypericum perforatum*) occur where pocker gophers have been digging. There are no lichens and few or no mosses.

Other

Moist $Leymcin

The moist site unit has not been observed with climax vegetation. Snowberry and non-native grasses and forbs, with some giant wildrye (*Leymus cinereus*), indicating alkaline conditions, dominated the one seral site that was sampled.

Hurlburt and Stanley[105] describe a mesic to moist community dominated by Kentucky bluegrass, black medic, with some rose, snowberry, Columbia needlegrass and junegrass. They observed wetter sites dominated by Kentucky bluegrass and creeping bentgrass. Some of these sites may be seral to the "shrub" site unit, or some of them may be a moist grassland type.

Are there steep colluvial sites dominated by shrubs?

IDFxh4

Climax sites on gentle slopes are very similar to the PPxh3. *However, the slightly cooler climate may allow rough fescue to become more dominant than Idaho fescue at climax.* Hurlburt and Stanley[106] described late seral gently sloping grasslands dominated by rough fescue, Idaho fescue, bluebunch wheatgrass, silky lupine, parsnip-flowered buckwheat, Kentucky bluegrass and junegrass. Junegrass, Columbia needlegrass, needle-and-thread grass, Kentucky bluegrass and Sandberg's bluegrass tend to increase with grazing. Cheatgrass and knapweed and other invasive alien forbs can dominate highly disturbed sites.

Drier sites are dominated by bluebunch wheatgrass along with silky lupine and arrowleaf balsamroot. Hurlburt and Stanley[107] described seral south-facing grassland dominated by diffuse knapweed, cheatgrass, bluebunch wheatgrass with some rose and snowberry.

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[105] 1998
[106] 1997
[107] 1997

Seral mesic grasslands were described as being dominated by Kentucky bluegrass and Columbia needlegrass with a variety of forbs.[108]

Hurlburt and Stanley[109] also described a slightly moist shrubland community dominated by snowberry and rose, or sometimes ninebark (*Physocarpus* sp.) or chokecherry and low cover of grasses and forbs.

Kentucky bluegrass usually dominated moist grasslands together with creeping bentgrass, some sedges, and weedy forbs.[110]

Table 9 below shows the environment table for the proposed site units for the IDFxh4. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

[108] Hurlburt and Stanley 1997
[109] 1997
[110] Hurlburt and Stanley 1997

Table 9. Environment table for grassland site units in the IDFxh4.

Site Unit (Temporary names)	*Steep Aris*	*Colluvium*	*Shallow soil*	*Steep warm*	*Moderate warm*	*Gentle*	*Shrub*
SMR	1	1	1 - 2	2	2	2 – 3	3 – 4
SNR	B	C	B – C	C	B – D	C – D	D
Slope Position	UP - MD	LW - UP	UP, CR	LW - UP	LW - UP	LW - UP	MD
Typical Slope/Aspect	60 to 70 %, hot (SSW to S)	50 -70%, warm	15 - 50%, warm to neutral	40 to 65%, warm (W to SE)	30 to 45%, warm (W to SSE), 40 to 45 % on warm-neutral aspects (SE, WNW)	0 - 15%, up to 60% on cool aspects	40 - 70%, warm
Insolation	High	High	Low to Moderate	High	Moderate	None	Moderate
Parent Materials	FG	Cv	Cxv, Dxv	FG, Cv, Mv	Mv, Cv, Mb	Ev/Mb, Eb/FG, Mv	Ev/M
Soil texture	sandy	loamy	loamy, coarse loamy	loamy, sandy	loamy, coarse loamy	loamy or coarse loamy	loamy
Coarse Fragments	moderate - high	high	low - high	low – high	moderate - high	usually low to moderate at surface, high at depth	low at surface, often high at 50 cm or greater depth
Important features	Coarse sand with high insolation	Rocky colluvial slopes with loamy soils in pockets	Shallow soil sites with 15 - 30 cm deep soils, only minor exposed bedrock	High insolation slopes, usually with either sandy soils or shallow soils	Moderate insolation slopes, may be steeper on warm - neutral aspects	Often with Exv (10 - 25 cm) over moderately coarse and/or rocky soils	Sites with some additional moisture inputs
Soil Classn	**EB**	**EB**	**EB**	**EB, MB**	**DBC**, MB	**DBC**, EB MB	**BLC, DBC, MB**

Steep Aris

The "steep Aris" site unit occurs on steep (>60%), hot aspect slopes (SSW to S). Soils are sandy, gravelly derived from glaciofluvial material. This unit is rare and was observed only in Johnstone Creek Provincial Park. The sandy soils are unstable and actively ravelling, especially where there is any disturbance. The vegetation is dominated by red three-awn (*Aristida purpurea* var. *longiseta*), bluebunch wheatgrass, fleabanes, silverleaf phacelia (*Phacelia hastata*), scarlet gilia (*Ipomopsis aggregata*) and scattered other forbs and grasses. Because of the coarse, unstable

soils, there is minimal moss/lichen layer. *It is possible that this unit may shift to bluebunch wheatgrass with no disturbance.*

Colluvium

The "colluvium" shrubland site unit occurs on steep, rocky, colluvial slopes. This unit is uncommon but widespread. Coarse fragments dominate soils with loamy soils in between the rocks. Vegetation is shrubby, with birch-leaved spirea (*Spirea betulifolia*), various other shrubs and some ponderosa pine and Douglas-fir trees. Between the shrubs there is bluebunch wheatgrass and scattered other forbs and fragile fern (*Cystopteris fragilis*). The moss and lichen layer had clad lichens and minor pelt lichens. Data for this unit is limited to a single plot. Warm aspects may have more bluebunch wheatgrass and cool aspects may have more rough fescue at climax.

Shallow Soil

The "shallow soil" site unit occurs on moderate warm aspects with shallow soils over bedrock (15 – 30 cm deep). This unit is uncommon but widespread. There is minor exposed bedrock. There are often a few shrubs growing in rock crevices (snowberry or mock-orange or sometimes big sagebrush). The vegetation is dominated by widely spaced bluebunch wheatgrass clumps with selaginella, junegrass, and balsamroot. There may be Idaho fescue on more gently sloping sites. The moss/lichen layer is well developed and awned haircap moss (*Polytrichum piliferum*) is a characteristic species of this unit. Other common mosses and lichens include clad lichens and sidewalk moss.

Steep Warm

The "steep warm" site unit occurs on steep (>40%), warm aspect slopes. This unit is common and widespread. Soils are often ravelling, somewhat shallow and are usually loamy or sandy with moderate to high amounts of coarse fragments. Vegetation is dominated by widely spaced bluebunch wheatgrass with some scattered other forbs and grasses. Forb diversity is generally low. The moss and lichen layer is moderately well developed with pelt lichens, awned haircap moss and other species. Data is limited for this unit.

Steep warm $Brom

Seral steep warm sites have lower covers of bluebunch wheatgrass, more invasive annual bromes and more exposed mineral soils with little or no moss/lichen crust. Seral data is limited to one plot; most steep slopes have limited access for grazing.

Moderate Warm

The "moderate warm" site unit occurs on warm aspects with 30 – 45% slopes. This unit is common and widespread. Soils are stable and sites are subxeric; they are derived from shallow, rocky morainal and colluvial materials. Soils are usually loamy or coarse. At climax, vegetation is likely dominated by bluebunch wheatgrass,

Idaho fescue, and scattered other forbs and grasses. Thick litter limits the development of mosses and lichens.

$ PseuBrom

Bluebunch wheatgrass and junegrass with invasive annual bromes, abundant forbs including some non-native forbs dominate this late seral unit. There are no lichens or mosses on the soil surface. Hurlburt and Stanley[111] also described seral sites with the above species and moderate to abundant diffuse knapweed. The use of biocontrol agents on knapweed seems to have successfully reduced its abundance substantially.[112]

Gentle

The "gentle" site unit occurs on level and gently sloping sandy, gravelly glaciofluvial soils with a loamy eolian capping or rocky morainal soils. The grassland vegetation largely reflects the loamy-textured soils in the upper horizon. This unit also occurs on steep cool aspects. This unit is common and widespread at lower elevations in this subzone.

Climax vegetation is dominated by Idaho fescue and bluebunch wheatgrass with diverse scattered forbs. Sticky purple geranium, thin-leaved owl-clover (*Orthocarpus tenuifolius*) and old man's whiskers (*Geum triflorum*) commonly occur in this unit but rarely occur in other units. The moss and lichen layer is variable: sparse where litter is thick and well developed elsewhere. These sites likely do become dominated by rough fescue; Hurlburt and Stanley[113] describe a rough fescue-dominated community on gentle slopes.

$PseuBrom

Bluebunch wheatgrass and junegrass with invasive annual bromes, abundant forbs including some non-native forbs dominate this late seral unit. There are few lichens or mosses on the soil surface.

$Poa sec

Sandberg's bluegrass, thread-leaved sedge (*Carex filifolia*), bluebunch wheatgrass, invasive annual bromes and diverse forbs, including many non-native forbs dominate this unit. There are no mosses or lichens on the soil surface. There is only one plot in this unit.

Shrub

The "shrub" site unit occurs on rich warm aspect slopes with deep, loamy soils with few coarse fragments to about 50 cm depth. This unit is uncommon but widespread. These mesic or near mesic sites appear to succeed to shrubs in the absence of cattle grazing. They are dominated by thick shrub cover including snowberry, roses, choke cherry, and saskatoon with scattered forbs and grasses in openings. Blue wildrye

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[111] 1998
[112] Gayton and Miller 2012
[113] 1998

(*Elymus glaucus*) occurs in this unit but not other grassland or shrubland units. There are no lichens and few or no mosses.

Other

Hurlburt and Stanley[114] describe a mesic community dominated by Kentucky bluegrass, black medic, with some rose, snowberry, Columbia needlegrass and junegrass. These sites may be seral to the "shrub" site unit, or some of them may be a moist grassland type.

IDFdm1

Most of the grasslands in this variant appear to be in early seral stages as a result of grazing and cultivation, and non-native plants are often significant components of plant communities. Rough fescue, Idaho fescue, bluebunch wheatgrass, silky lupine, parsnip-flowered buckwheat, Kentucky bluegrass, and junegrass dominate climax gently sloping grasslands. Junegrass, Columbia needlegrass, needle-and-thread grass, Kentucky bluegrass and Sandberg's bluegrass tend to increase with grazing.

Drier sites are dominated by bluebunch wheatgrass along with silky lupine and arrowleaf balsamroot. Hurlburt and Stanley[115] described seral south-facing grassland dominated by diffuse knapweed, cheatgrass, bluebunch wheatgrass with some rose and snowberry.

Seral mesic grasslands are described as being dominated by Kentucky bluegrass and Columbia needlegrass with a variety of forbs.[116]

Kentucky bluegrass usually dominated moist grasslands together with creeping bentgrass, some sedges, and weedy forbs.[117]

Table 10 below shows the environment table for the proposed site units for the IDFdm1. Vegetation tables are presented under separate cover in an excel file. Site unit descriptions are presented below. Names for site units are temporary, plant association names will be assigned once the classification is correlated with other grassland ecosystems in the province and finalized as site series.

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[114] 1998
[115] 1997
[116] Hurlburt and Stanley 1997
[117] Ibid.

Table 10. Environment table for grassland site units in the IDFdm1.

Site Unit (Temporary names)	*Colluvium*	*Steep warm*	*Moderate warm*	*Gentle & Cool*
SMR	1	1 - 2	2 (3)	(3) 4
SNR	C	(B) C	B – C	(C) D
Slope Position	LW - UP	MD - UP	LW - UP	MD - UP
Typical Slope/Aspect	50 -70%, warm	60 to 65%, warm (WSW to SSE)	25 to 55%, warm (W to SSE)	0 - 15%, up to 60% on cool aspects
Insolation	High	High	Moderate	None
Parent Materials	Cv	Cv (Mb)	Mb	Mb, Mv, likely with eolian mixed in the upper horizon
Soil texture	loamy	loamy, coarse loamy	loamy, coarse loamy	loamy or coarse loamy
Coarse Fragments	high	moderate - high	moderate - high	low to moderate
Important features	Rocky colluvial slopes with loamy soils in pockets	High insolation slopes, usually with rocky soils	Moderate insolation slopes	Rich soils with deep, black Ah
Soil Classification	**MB**	**EB**	**DBC**, MB	**BLC**

Colluvium

The "colluvium" shrubland site unit occurs on steep, rocky, colluvial slopes. This unit is uncommon but widespread. Coarse fragments dominate soils with loamy soils in between the rocks. Vegetation is shrubby, with roses, snowberry, mock-orange, and saskatoon. Between the shrubs there is bluebunch wheatgrass, prairie sagewort, and scattered other forbs and grasses. The moss and lichen layer is sparse. Data for this unit is limited to a single plot. Warm aspects may have more bluebunch wheatgrass and cool aspects may have more rough fescue at climax.

Steep Warm

The "steep warm" site unit occurs on very steep (>60%), warm aspect slopes. This unit is common and widespread. It is the most common grassland unit at higher elevations of this subzone. Soils are often ravelling and are usually loamy or sandy with moderate to high amounts of coarse fragments. Vegetation is dominated by widely spaced bluebunch wheatgrass, abundant balsamroot and junegrass, parsnip-flowered buckwheat, silky lupine and scattered other forbs and grasses. Forb diversity is generally low. The moss and lichen layer is variable and cover depends on how stable the soils are and the amount of disturbance; cover is generally low.

Moderate Warm

The "moderate warm" site unit occurs on warm aspects with 25 – 55% slopes. This unit is common and widespread, particularly at lower elevations of this subzone. Soils are stable and sites are subxeric to submesic. Soils are loamy or coarse loamy with moderate to high levels of coarse fragments. There is limited data for this unit. At climax, vegetation is dominated by bluebunch wheatgrass, Idaho fescue, other grasses and a diverse forb community. Common forbs include yarrow, balsamroot, silky lupine, and fleabanes. Thick litter prevents the development of the mosses and lichen layer.

Seral data is lacking for this unit. Hurlburt and Stanley[118] describe seral sites dominated by cheatgrass, diffuse knapweed, and bluebunch wheatgrass. The use of biocontrol agents on knapweed seems to have successfully reduced its abundance substantially; otherwise this mid to early seral community likely occurs in the IDFdm1.

Gentle & Cool

The "gentle & cool" site unit occurs on level and gently sloping morainal soils. This unit also occurs on moderate to steep cool aspects. This unit is common only at lower elevations of this subzone. The upper horizon often has few coarse fragments; there may be eolian deposits on the top of the till. Cool aspects are likely more productive with more moisture available due to lower evaporation.

Although there is no data, I would expect climax vegetation is dominated by rough fescue with Idaho fescue, bluebunch wheatgrass and diverse scattered forbs. The moss and lichen layer would be variable: sparse where litter is thick and well developed elsewhere. Hurlburt and Stanley[119] describe a rough fescue-dominated community on gentle slopes. Late seral data was dominated by Idaho fescue with abundant silky lupine, and a very high diversity of other forbs and grasses. Thick litter limits the development of the moss/lichen layer.

$ Brom

Early seral sites are dominated by invasive annual bromes with some bluebunch wheatgrass, junegrass, and abundant silky lupine. There are many other forbs on these sites, including many non-native species. Pocket gopher diggings seem to continually disturb soils on these sites.

Other

Hurlburt and Stanley[120] describe a mesic community dominated by Kentucky bluegrass, black medic, with Columbia needlegrass and junegrass, and sometimes minor cover of rose and snowberry. Some sites may be seral to the "shrub" site unit (described in the IDFxh4), or some of them may be a moist grassland type. Rough

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[118] 1998
[119] 1998
[120] 1998

fescue occurred on some of the sites they sampled and may be the dominant climax grass, although non-native grasses dominated the sites they sampled and are likely
Comparison to Other Similar Grasslands in North America

British Columbia

Early descriptions of British Columbia's upper grasslands (those now mapped as occurring in the PP and IDF zones) describe grasslands dominated by bluebunch wheatgrass, rough fescue and junegrass with a diverse forb community on black chernozem soils.[121] These descriptions come primarily from the Thompson-Nicola area and grasslands were likely somewhat seral.

Current drafts of BEClassification for other grasslands within the PP and IDF in the Thompson-Nicola and Okanagan-Similkameen have placed the dominant climax and late seral grasslands into four primary associations[122]:

- Rough fescue – Junegrass association on gently sloping mesic and submesic sites in the IDFxh2
- Rough fescue – Bluebunch wheatgrass association on mesic and submesic sites in the IDFxh1, IDFxh2, and PPxh2
- Idaho fescue – Junegrass on mesic and submesic sites in the IDFxh1
- Idaho fescue – Bluebunch wheatgrass on gentle mesic to submesic sites and moderate warm aspects in the IDFdk1, IDFxh1 and on submesic and mesic gentle slopes and cool aspects in the PPxh1

At this time, I am unclear what ecological features separate these associations. Other minor associations also occur in these grasslands.

In the Cariboo-Chilcotin, upper grasslands within the IDF are dominated by short-awned porcupine grass on level and gently sloping cool aspect sites, with spreading needlegrass on cooler, moister sites, and predominantly bluebunch wheatgrass on warmer, drier sites.[123] Both rough fescue and Idaho fescue are absent from this region, perhaps partly because of a disjunction in the distribution of the upper grasslands.

Alberta

Within Alberta, grasslands of the Foothills Fescue Natural Subregion[124] seem to be floristically the most similar to Kootenay and Boundary grasslands. They are dominated by rough fescue on black chernozem soils that are predominantly glacial till deposits.[125]

Mesic sites are dominated by rough fescue at climax; they shift to Parry oat grass

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[121] Tisdale 1947 and van Ryswyk et al. 1966
[122] Data supplied by Michael Ryan, June 2013
[123] Pers. obs. 1995-2013
[124] The climate here has 397 to 589 mm of precipitation, mean daily temperature of 3.8 to 5.4°C, 88-113 frost-free days, elevations of 850 to 1200 metres, and are affected by Chinook winds in the winter.
[125] Adams et al. 2005

(*Danthonia parryi*), Idaho fescue and short-awned porcupinegrass (*Hesperostipa curtiseta*) with grazing and then Kentucky bluegrass with additional grazing pressure.[126]

Drier sites tend to have more Idaho fescue, short-awned porcupinegrass and Parry oat grass; thickspike wildrye (*Elymus lanceolatus* ssp. *lanceolatus*) and junegrass increase on earlier seral sites. Spreading needlegrass occurs on steeper slopes, and also increases with grazing to replace rough fescue.[127]

The authors consider that winter grazing maintains rough fescue plant communities; grazing at other times of year tends to result in a shift to more drought-tolerant bunchgrasses.[128]

Montanta

Western Montana has many grassland ecosystems similar to British Columbia, particularly those dominated by bluebunch wheatgrass, Idaho fescue and rough fescue. The primary similar associations are briefly described below.

The Rough fescue / Bluebunch wheatgrass association occurs below 1200 m elevation dominated by rough fescue, bluebunch wheatgrass and Idaho fescue. Rough fescue decreases with grazing, but both bluebunch wheatgrass and Idaho fescue can increase or decrease depending on the intensity and duration of grazing.[129]

The Rough fescue / Idaho fescue association occurs on moister sites than the Rough fescue / Bluebunch wheatgrass association on mountain slopes within the 50- to 75-cm precipitation zone. Lightly grazed stands are dominated by rough fescue and heavily overgrazed stands are dominated by Idaho fescue.[130]

The Idaho fescue / Bluebunch wheatgrass association occurs on drier sites than the above two associations with precipitation levels from 35 to 50 cm. At lower elevations with lower precipitation, it occurs on northerly aspects; at higher elevations with higher precipitation, it occurs on southerly aspects. Junegrass, Sandberg's bluegrass, needle-and-thread grass and Columbia needlegrass are other common grass associates. Both Idaho fescue and bluebunch wheatgrass decrease with grazing. Idaho fescue may initially increase with the reduction of bluebunch wheatgrass, but it will also eventually decrease with continued heavy grazing. In years when spring moisture is good and flower stalks are profuse, the authors recommend grazing pastures only lightly until after seeds have ripened on Idaho fescue to hasten recovery.[131]

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[126] Ibid.
[127] Ibid.
[128] Ibid.
[129] Mueggler and Stewart 1978
[130] Ibid.
[131] Ibid.

Antelope-brush ecology

Within the Rocky Mountain Trench, many grasslands have variable densities of antelope-brush. Antelope-brush occurs on dry sites from the Tobacco Plains to about 15 km south of Canal Flats.[132] Apparently, antelope-brush is not a preferred browse species for most ungulates.[133]

Tucker (2013) views antelope-brush as seral and only low covers occur at climax. Wikeen and Ross (2002) also agree that antelope-brush appears to increase on most sites that are heavily grazed. This generally concurs with my observations, however, what factors explain the distribution of antelope-brush?

Antelope-brush appears to be variable in its response to fire. In Idaho, about half of burned shrubs sprouted from the root crown after burning; this seemed to be related to fire intensity. Younger plants may sprout more readily than older plants after burning[134], and shrubs are more likely to re-sprout if fire occurs during a cooler season or when shrubs have higher moisture content[135]. In the south Okanagan, patchy burns can result in the survival of some antelope-brush where fuels are variable, but antelope-brush shrubs with more dead wood are more likely to burn completely in a fire.[136] In the East Kootenays, Wikeem and Ross (2002) observed that antelope-brush appears to increase on burned sites.

After a fire, antelope-brush seeds can remain viable for up to four years, however the rate of shrub recovery depends on seedling establishment in the first two to three years post-fire. Most of the re-sprouting seed is from buried rodent caches.[137] Rodents are the key agents of seed dispersal, which limits the distance that seeds will be dispersed from seed-producing shrubs.[138]

Antelope-brush distribution is likely limited by both climate and soils: it occupies the driest portion of the Rocky Mountain Trench on loamy and sandy soils. More intense fires, or repeated fires over shorter intervals, have likely eliminated antelope-brush from some areas of grasslands. Large areas without antelope-brush are probably able to persist because rodents rather than wind distribute the seeds. Where antelope-brush does occur, grazing disturbance has probably increased its abundance.

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[132] Kelley and Spilsbury 1949
[133] Wikeem and Ross 2002
[134] Blaisdell and Mueggler 1956
[135] Zlatnik 1999
[136] Krannitz and Mottishaw 2003
[137] Ziegenhagen and Miller 2009
[138] Shatford 1997

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