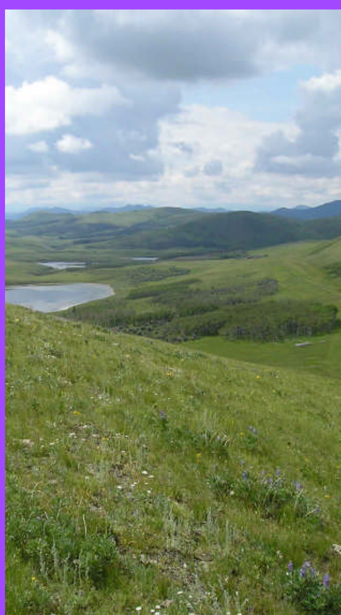
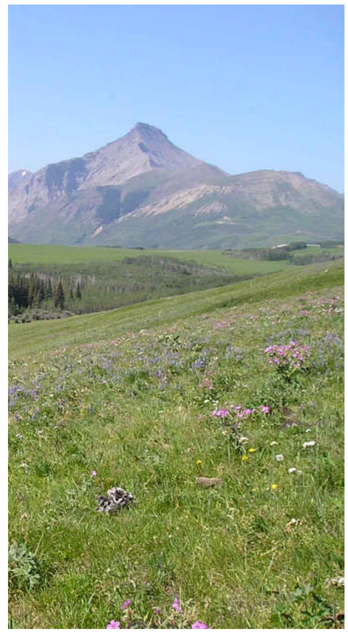
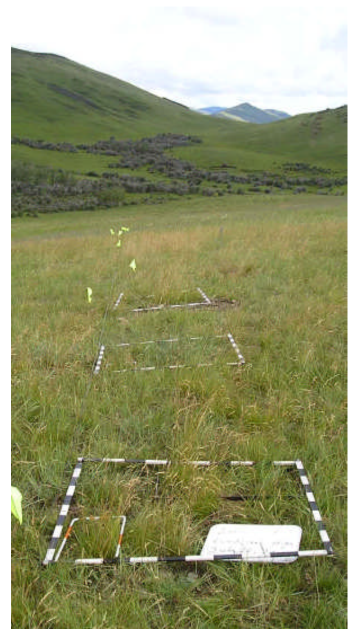
Restoration of Rough fescue (*Festuca campestris*) Grassland

on

Pipelines in Southwestern Alberta



Alberta
SUSTAINABLE RESOURCE DEVELOPMENT
Public Lands & Forests

Publication No. T/121
ISBN: 07785-4829-5 (Printed Version)
ISBN: 07785-4830-9 (Online Version)

A summary of a Master's Project Report as partial fulfillment for a Master of Environmental Design at the University of Calgary prepared under contract for Alberta Sustainable Resource Development, Rangeland Management Branch, Lands Division.

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Citation for this document:

Desserud, P.A. 2006. Restoration of Rough Fescue (*Festuca campsetris*) Grassland on Pipelines in Southwestern Alberta. Rangeland Management Branch, Public Lands Division, Alberta Sustainable Resource Development, Lethbridge, Alberta, Pub. No. T/121. 77 pp.

RESTORATION OF ROUGH FESCUE (*Festuca campestris)* GRASSLAND ON PIPELINES IN SOUTHWESTERN ALBERTA

Pub. No. T/121

June 2006

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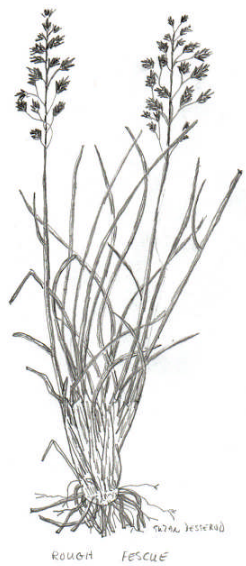

ROUGH FESCUE

Executive Summary

RESTORATION OF ROUGH FESCUE GRASSLAND ON PIPELINES IN SOUTHWESTERN ALBERTA

This research evaluated the effects of pipeline construction and reclamation techniques on the restoration of rough fescue plant communities following pipeline construction in the Foothills Fescue, Foothills Parkland, and Montane natural subregions of southwestern Alberta. The right-of-way (ROW) sites had varying degrees of rough fescue grassland growth and higher proportion of introduced grasses and forbs than the adjacent undisturbed grasslands. The ROW sites also had less topsoil, higher clay content, more bare soil, less plant litter, and reduced range health scores. The factors that most contributed to the recovery of rough fescue grassland were post-growing season pipeline construction, between August and March, and minimum disturbance trench-only stripping. Seeding may not be the best method of *Festuca campestris* revegetation as there was little correlation between the rate it was seeded and the resulting cover. *Festuca ovina*, *Festuca ovina* var. *duriuscala* and *Festuca saximontana* cultivars succeeded in establishment following seeding, persisted over time, infiltrated neighbouring grassland, and may have inhibited natural recovery of native grasses and forbs. The soil heating of large diameter pipe could affect vegetative growth owing to grazing pressure, by attracting grazing ungulates to early greening vegetation in the spring and late senescence in the fall. The passage of time did not necessarily result in better recovery of rough fescue grassland; reclamation techniques appeared more important.

Acknowledgements

Financial support for this project was provided by Alberta Sustainable Resource Development (Public Lands), Alberta Environment, the University of Calgary, the Canadian Land Reclamation Association and the Canadian Gas Association.

Many thanks go to my master's supervisory committee, Rich Revel, Barry, Adams and Cormack Gates. Technical expertise was provided by Dr. Wayne Strong, Marilyn Neville, Varge Craig and Mike Alexander. My field season would not have bene successful without the work provided by my field assistants, and my field assistants, Maarten Dankers and Sarah Gardner, and Janet Main and Darlene Lavender who provided field season housing. Ranchers in my study area provided land management wisdom and access to their land, so thank you to Ed Nelson, Puff and Dan McKim, Francis Gardner, Mac Blades, Brent Barbero and Mac Main and others. Pipeline companies gave me access to their right-of-ways and their reclamation records: TransCanada, Shell Canada Limited and Hunt Oil Company, without which this research could not have been completed.

1.0 Background and Introduction

This report summarizes the master's degree project, "Restoration of rough fescue grassland on pipelines in southwestern Alberta", by Peggy Ann Desserud. The master's degree report addressed the question, "will rough fescue grassland recover following a major disturbance such as pipeline construction, particularly in the Foothills Fescue, Foothills Parkland or Montane natural subregions?"

The objectives of the project were:

- To examine the development of plant communities following pipeline disturbance and assess if revegetation has resulted in the restoration of rough fescue plant communities.
- To evaluate the effects of pipeline construction and reclamation techniques on the restoration of rough fescue plant communities following pipeline construction.
- To develop recommendations for improvements to Alberta provincial minimal disturbance guidelines for the Foothills Fescue, Foothills Parkland, and Montane natural subregions of southwestern Alberta to be provided to Alberta Sustainable Resource Development (SRD), Public Lands and Forests Division, Rangeland Management Branch.

As of 2004, over 330,000 kilometres of buried pipeline underlie the province of Alberta (Alberta Energy 2007) The majority of these pipelines are associated with oil and gas development, long, linear disturbances that usually require revegetation. In the Alberta southwestern foothills, much of the area is rangeland used for cattle grazing and has not been cultivated, owing to the rolling topography, which makes automated cultivation difficult. This has resulted in large tracts of native grassland in the area, considered environmentally significant for plant and animal biodiversity and cattle and ungulate forage value (Dormaar and Willms 1990, Bradley et al. 2002, Alexander 2004, Adams et al. 2005). Fescue grassland bunch grasses contribute to the Foothills watershed through water-trapping capability and soil stabilization, and the large amount of fallen litter adds to carbon sequestration of organic matter (Naeth 1988). Nevertheless, oil and gas development, urban expansion and agriculture have resulted in the loss of native grasslands in southern Alberta. For example, of the 1.1 million hectares in the Foothills Fescue natural subregion, only 250,000 hectares or 16% of native grassland remain (Adams et al. 2005).

Revegetation techniques following surface disturbance have changed over time. Starting in the late 1960s and up to the 1980s, seeding with imported grasses and cultivar such as *Agropyron cristatum* (crested wheat grass) or *Bromus inermis* (smooth brome) was a common reclamation and recovery practice in the oil and gas industry, especially along pipeline routes (Mutrie and Wishart 1989, Lamond et al. 1992, Henderson 2005). Since the 1980s, oil and gas companies have included varying levels of native seed in their reclamation processes, either in compliance with Alberta government seeding requirements or on their own volition.

Re-establishing native plant communities can be difficult and there are few documented examples of successful restoration of rough fescue grassland following surface disturbances or invasion by non-native species (Sinton et al. 1996, Sinton 2001, Bradley et al. 2002, Bradley 2004). Revel (1993) and Petherbridge (2000) indicate some success in transplanted rough fescue grassland sod. Adams et al. (1996) demonstrated success in restoration of Mixed Grass grassland on small diameter pipelines using "no strip" construction. The long establishment time of native perennial grasses like *Festuca campestris* Rybd. (rough fescue), from three to five years, and the little understood ecology of associated forbs and grasses are some of the factors affecting the successful revegetation of disturbed native grasslands to their natural (Johnston and MacDonald 1967, Stout et al. 1981, King et al. 1998, Pahl and Smreciu 1999).

1.1 The Value of Fescue Grasslands

Why is the successful restoration of rough fescue grasslands important and why do ranchers and range managers value rough fescue, and its associated plant communities? Well-managed fescue grasslands are a valuable resource for livestock production, which is a significant economic factor in southwestern Alberta. They are low maintenance and highly productive, especially during the winter, when tame pasture ranchers must provide hay and fescue grassland ranchers can rely on native forage.

In the Black Chernozem soils, forage production is highest from the rough fescue-dominated communities, and declines with species shifts to Parry oatgrass, Kentucky bluegrass and sedge. Forage yields tend to be very stable in rough fescue-dominated communities given the deep rooting characteristics of Festuca campestris. The high curability of rough fescue permits winter grazing, reducing wintering costs, and making grazing options more flexible for the producer. Rough fescue provides quality winter forage for elk and high cover values for a wide variety of wildlife species (Johnston 1961a, Willms and Rode 1998).

Rough fescue canopy cover and deep rooting characteristics result in little exposed soil and soil stability, providing protection from weed invasion. Rough fescue communities produce substantial litter that serves to conserve scarce moisture, enhance moisture infiltration and retention. A healthy rough fescue range will resist change caused by grasshoppers as it provides poor egg laying sites. Rough fescue rangeland benefits from light to moderate, non-growing season grazing, which reduces the build up of litter and results in increased plant species diversity (Stout et al. 1981, Willms et al. 1996).

Festuca campestris is the dominant or climax grass in its native regions where it may grow almost to the exclusion of other plants once established (Moss and Campbell 1947, Looman 1969, Looman 1982). *Festuca campestris* is densely tufted, often forming large tussocks up to 30 cm in diameter, with stiff upright stems from 30 to 140 cm in height and roots up to 120 cm deep (Best et al. 1971, Budd 1987, Aiken and Darbyshire 1990). Its deep root structure makes it resistant to drought and fire (Brown and Smith 2000). In addition, its growth begins early in the spring, completed by June, allowing it to use spring moisture for growth and not requiring much precipitation during the remainder of the growing season (Stout et al. 1981). *Festuca campestris* plants cure on the stem, provide good fall and winter forage and are tolerant of winter grazing of last years 'carry-over' (Johnston 1961b, Willms and Rode 1998, Tannas 2001). The stiff, upright culms of *Festuca campestris* are accessible to foragers such as cattle and elk, even in deep snow.

Understanding the factors that enhance or diminish the restoration of *Festuca campestris* plant communities would contribute to the successful co-existence of oil and gas development and management of native fescue grasslands in the southern foothills of Alberta. To this end, this project's research assessed disturbed areas where attempts were made to restore rough fescue and other native vegetation and analysed the factors that contributed to the success or failure of the restoration. These factors underscored recommendations for improving minimum disturbance guidelines specifically for rough fescue grasslands in the Foothills Fescue, Foothills Parkland and Montane natural sub-regions of Alberta.

2.0 Study Area and Sampling Method

2.1 Study Area

The study area is located in the eastern Foothills of the Rocky Mountains, between Longview and Waterton, Alberta, Canada, in the Foothills Parkland, Foothills Fescue and Montane Natural Subregions. The sites are situated between latitudes 49.317 and 50.55 north and longitudes 114.013 and 114.28 west, within townships 18 and 4 and ranges 1 and 3 west of the fifth meridian.

Table 2.1.1 Climate comparisons for three natural subregions

Natural Subregion	Mean Daily Temperature (°C)	Total Precipitation (mm)
Foothills Fescue	4.0	468
Foothills Parkland	4.5	614
Montane	2.6	682

(Environment Canada 2005)

The common features of the three subregions are native fescue grasslands and, for the most part, the existence of Black Chernozemic soils. Annual precipitation of the study sites varies from approximately 470 mm in the Foothills Fescue natural subregion to over 680 mm in the Montane subregion (Table 2.1.1), versus less than 200 mm found in the Dry Mixed Grass subregion to the east.

The three subregions share the Chinook phenomenon, the winter warming caused by winds off the Rocky Mountains (Strong and Leggat 1992). Summers are cool, with average temperatures of 15 to 18°C in July and August, and winters are cold, with temperatures averaging between -5 and -10°C. Annual snowfall averages approximately 200 mm.

2.1.1 Site Locations and Data Sources

Pipeline sites with a known history of native seeding during reclamation were visited in the spring of 2004 to assess their suitability for further study (Figure 2.1). The criteria for choosing the sites were a pipeline right-of-way (ROW) that exhibited a measure of ecological integrity, as defined by no major equipment or grazing disturbance, alongside native grassland with evidence of rough fescue and associated grasses. Each site consists of one or more pipeline rights-of-way situated in native fescue grasslands (the control). The topography of each site includes a south-facing slope, a level crest, and, if possible, a level bottomland.

GPS location, elevation, aspect, and slope were measurements taken during field research in the summer of 2004. Pipeline location was verified with pipeline alignment sheets provided by the pipeline companies. Soil texture was determined by the hand texturing method, mixing soil with water and assessing the soil plasticity and cohesion (Day 1965, McKeague 1978).

The pipeline companies responsible for the construction and maintenance of the pipeline and rights-of-way provided pipeline construction and reclamation information (Figure 2.2). These were used to locate the location of the pipeline in the ROW and to obtain pre-disturbance soils information. A literature search was the basis for additional data regarding revegetation of disturbance, pipeline construction techniques and the growth characteristics of *Festuca campestris* and associated grasses, forbs and shrubs.

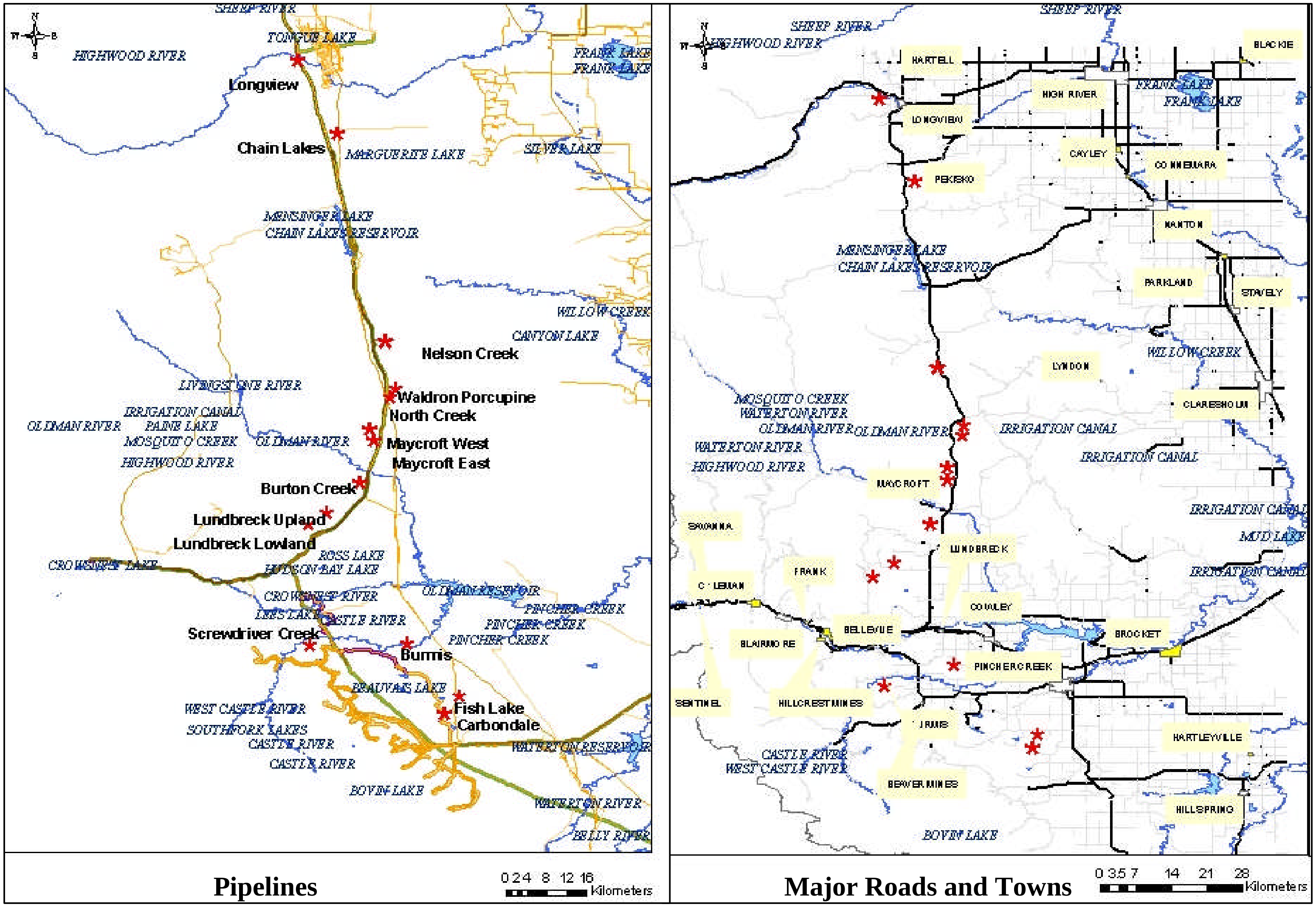


Figure 2.1 Location of sites along pipelines and in relation to roads and towns

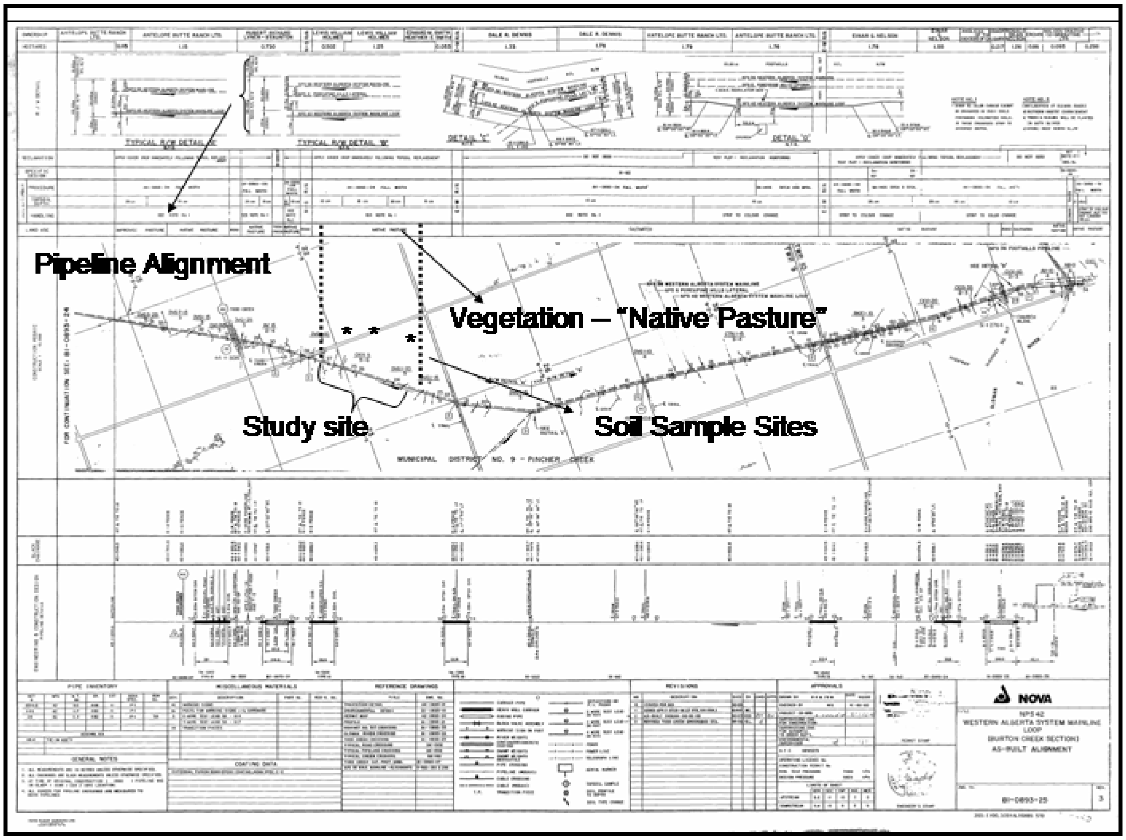


Figure 2.2 Sample Pipeline Alignment Sheet Tilman et al. 1996

Table 2.1.2 Summarized Site Descriptions

Site Name	Legal Description	Latitude Longitude	Elevation (m)	Year Built	Soil Order	Soil Series	Soil Type	Natural Subregion
Burmis	NW24-4-1W5	49.317 N 114.013 W	1570	1998	Chernozemic	Beauvais, Dunvargan	Orthic Black	Foothills Parkland
Burton Creek	NW23-9-2W5	49.75 N 114.178 W	1360	1990	Chernozemic	Dunvargan Ockey	Orthic and Calcerous Black	Foothills Fescue
Carbondale	NW13-6-2W5	49.477 N 114.15 W	1280	1998	Chernozemic	Dunvargan	Orthic Black	Foothills Parkland
Chain Lakes	NW28-16-2W5	50.367 N 114.224 W	1278	1988	Chernozemic	Maycroft	Orthic Black	Foothills Parkland
Fish Lake	SE36-4-1W5	49.338 N 114.006 W	1390	1987	Chernozemic	Dunvargan	Orthic Black	Foothills Parkland
Longview	NW25-18-3W5	50.550 N 114.289 W	1250	1987	Regosolic	Not Classified	Regosolic Black	Foothills Parkland
Lundbreck Lowland	SW13-8-3W5	49.647 N 114.29 W	1481	1993	Chernozemic	Beauvais, Dunvargan	Orthic Black	Foothills Parkland
Lundbreck Upland	SW30-8-2W5	49.675 N 114.267 W	1522	1993	Chernozemic	Beauvais, Dunvargan	Orthic Regosol Orthic Black	Foothills Parkland
Maycroft East	NE12-10-2W5	49.811 N 114.158 W	1315	1961	Chernozemic	Knight	Thin Black	Foothills Fescue
Maycroft West	NE12-10-2W5	49.814 N 114.255 W	1315	1997	Chernozemic	Knight	Thin Black	Foothills Fescue
Nelson Creek	SW7-12-1W5	49.983 N 114.133 W	1472	1992	Chernozemic	Beauvais Hatfield	Orthic Black Dark Gray	Montane
North Creek	NW18-11-1W5	49.941 N 114.127 W	1400	1997	Chernozemic	Beazer	Orthic Black	Foothills Fescue
Screwdriver Creek	SW12-6-3W5	49.455 N 114.283 W	1560	1995	Brunosolic	Bedrock		Montane
Waldron Porcupine	NW18-11-1W5	49.941 N 114.126 W	1400	1987	Chernozemic	Beazer	Orthic Black	Foothills Fescue

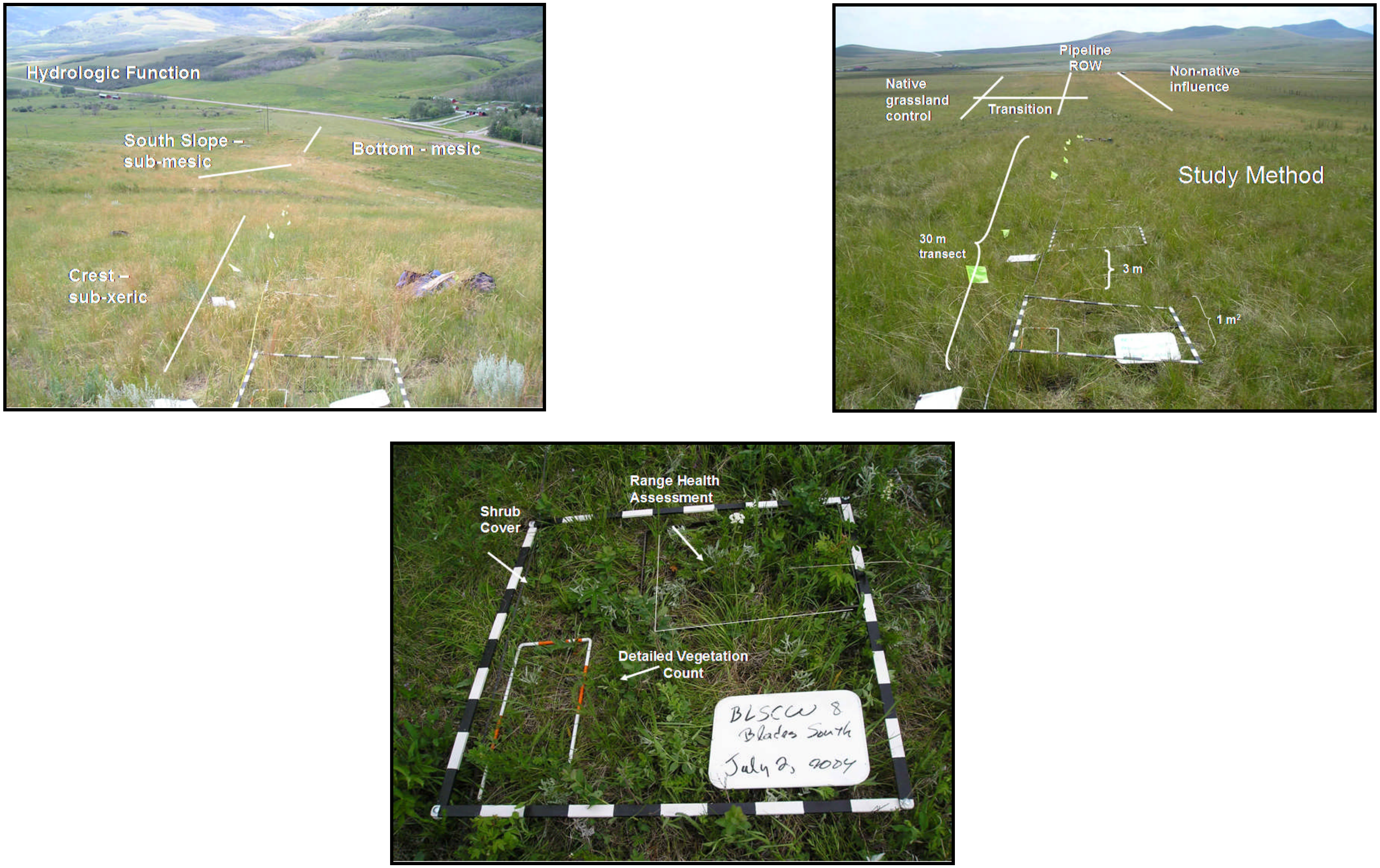


Figure 2.3 Sampling Method

2.2 Sampling

Field sampling occurred between June 15 and August 13, 2004. A stratified random sampling technique targeted ROW sites with three topographic and hydrologic functions: south-facing slopes (sub-mesic or semi-moist), crests (sub-xeric or semi-dry) and bottomland or north-facing slopes (mesic or moist) (Figure 2.3).

The sampling technique consisted of three or four 30 m line transects placed at each location: one over the pipeline in the right-of-way, in the area of the trench and the workside, one as a control in the adjacent native grassland, and one on another pipeline with a different treatment if one was adjacent. Nested subplots (1 m x 1 m) were set up at 3 m intervals, ten subplots per transect. Within each subplot, a Daubenmier frame (20 cm x 50 cm) provided the basis for detailed species cover estimates, a quarter meter frame for range health (the level of litter, bare soil, mosses and lichens, and noxious weeds) and a 1 m x 1 m frame for shrub cover. Appendix A is a table of conversions between Moss scientific names, Moss common names and Alberta Sustainable Resource Development mnemonics.

In addition to plant cover data, environmental data were collected: slope percent, aspect, drainage, soil Ah depth, soil texture and stoniness. The weight of fallen litter was estimated in the field, using Alberta Sustainable Development Range Health Assessment techniques (Adams et al. 2003).

3.0 Control and ROW Comparison

The major grasses normally associated with *Festuca campestris* are included in the evaluation of successful restoration and termed the rough fescue association: *Danthonia parryi*, *Festuca idahoensis*, and *Koeleria macrantha* (Moss and Campbell 1947, Coupland 1961, Moss 1994). In addition to individual analysis, *Festuca campestris* and *Danthonia parryi* were paired as a statistical variable. They normally occur concurrently; however, *Danthonia parryi* may replace *Festuca campestris* as the dominant grass in areas with heavy grazing or where the soils are shallow (Johnston 1961b, Looman 1969, Willms et al. 1985, Willms 1991).

Grazing was not a focus of this study since much research has been done on the effects of grazing on rough fescue plant communities (Smoliak et al. 1985, Willms 1988, Willms and Rode 1998). In addition, although the presence of elk is acknowledged, an estimate of the number of elk and the frequency of their visits was outside the scope of this study. Nevertheless, cattle and elk are known to preferentially select right-of-way sites for grazing, especially in the spring (McKim and McKim, personal communication, March 2005) and this could affect vegetative growth (Lees 1988, Naeth 1988)

3.1 Results and Discussion

All introduced species, including graminoids, occurred in greater percent cover on the right-of-way. Conversely, the controls had more native species including forbs, graminoids and shrubs (Figure 3.1).

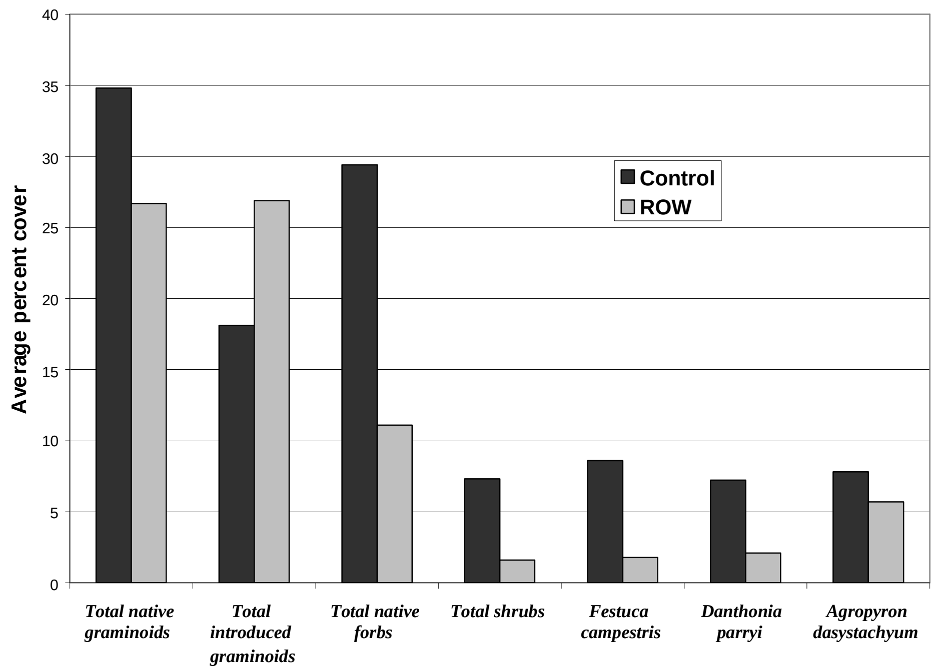


Figure 3.1 Control and Right-of-way comparison showing average percent cover of selected species and groups

3.1.1 Festuca campestris and Danthonia parryi

Festuca campestris and *Danthonia parryi* were present on the right-of-way, occurring on 47% and 43% of the ROWs, respectively, but occurred with 20% to 50% less cover than the control plots. Eleven of the fifty-six ROW sites had greater than 5% cover of *Festuca campestris* and *Danthonia parryi*; and, of those, six showed a statistical similarity to their controls, considered the best recovered sites. Without further disturbance, these ROW sites will probably continue in a successional trend towards rough fescue grassland.

The proximity of undisturbed grassland is one of the factors that probably contributed to the success of four of the best recovered sites, allowing for natural recovery. This is in keeping with findings of Hammermeister (2001) and Van Ham (1998) of natural recovery on pipelines and well sites. The other two sites, both on the Waldron Porcupine pipeline, also showed evidence of natural recovery, with the largest amount of native forbs of any ROW (26 and 42% cover). In this case, the recovery may have occurred with the assistance of four newer pipelines in the same right-of-way, which possibly attracted cattle grazing away from the Waldron Porcupine pipeline (McKim and McKim, personal communication, March 2005), especially in the spring, when new seedlings are most vulnerable (Naeth 1988).

3.1.2 Agropyron dasystachyum **and** *Agropyron smithii*

The abundance of *Agropyron dasystachyum* and *Agropyron smithii*, on the ROW sites, is in line with Osterman's (2001) findings that the pipeline trench zone of a ROW favours rhizomatous grasses. *Agropyron dasystachyum* was evenly distributed between the controls and right-of-way, which, might indicate it neither hinders nor helps the development of *Festuca campestris* and other native grasses. On the other hand, the specific occurrence of *Agropyron smithii* on sites with little *Festuca campestris* and other native grasses could indicate it hampers their growth. In any event, these wheat grasses are mid-seral and could rapidly colonize a disturbed site. This study has insufficient data regarding these wheat grasses to draw definite conclusions.

3.1.3 Introduced grasses and forbs

The pipeline ROW sites had a higher proportion of introduced grasses and forbs than the adjacent undisturbed grasslands, confirming other reports of disturbance recovery (Willms and Quinton 1995, Osterman 2001, Bradley et al. 2002, Vujnovic et al. 2002). *Festuca ovina* was the predominant introduced grass on 40% of the ROW sites, a product of the seed mixes, and showed evidence of strong establishment, with little incursion of native species from the adjacent grasslands, probably prevented by the *Festuca ovina* cover.

All the occurrences of *Bromus inermis* and *Poa pratensis* were on both the ROW and the adjacent control, and neither species was part of the seed mixes. This means they encroached onto the ROW from the control, were exposed from the seed bed during ROW stripping, or may have arrived with straw used for erosion control. Those sites with a dominance of *Bromus inermis* and *Poa pratensis* will probably continue to be so, given the aggressive nature of both of these rhizomatous grasses (Brown 1997).

3.1.4 Weeds

The only noxious weeds found during the sampling were *Cirsium arvense* and *Chrysanthemum leucanthemum* (only at the Screwdriver Creek site). Aside from the Longview site (13% cover of *Cirsium arvense*) neither weed occurred in greater than 5% cover. In some locations, *Cirsium arvense* appeared in isolated clumps on the edge of the ROW, usually in moist depressions. Weed control programs of the pipeline companies may have eliminated *Cirsium arvense* from the ROW; however, with their land access restricted, their programs would not extend into adjacent grassland (Anonymous, personal communication, June 2004). This could account for the presence of *Cirsium arvense* close to, but not on the ROW.

3.1.5 Topsoil Depth

All but three of the study sites were originally black Chernozemic soils; therefore, the topsoil would be expected to average between 10 and 20 cm (Brierley et al. , Dormaar and Willms 1998). In this study topsoil averaged 17.2 cm in the controls, and 7.4 cm in the ROW sites. This difference is consistent with studies on the effects of pipeline construction on soils, mainly due to the mixing of subsoil with topsoil (Culley et al. 1982, Zink et al. 1995, Hanson 1999). For the most part, deeper topsoil occurred on control sites than on ROW sites (Table 3.1.1).

3.1.6 Soil Texture and Stoniness

Most of the sites were loamy, tending to clay loam or clay on the ROW sites. The only sites with silty loam were controls. This is consistent with the findings of Naeth et al. (1987) that pipeline construction causes an increase in clay content of surface material and a decrease in silt, a result of clay from the B and C horizons being incorporated into the A horizon.

Of interest is the stoniness of the controls, which averaged moderately stony, varying from non-stony to exceedingly stony. This might indicate that rough fescue association grasses tolerate rough surface conditions, while more uniform surfaces attract invasive species such as *Poa pratensis.* Personal observations of the recovery of *Festuca campestris* on cut blocks left in rough condition would uphold this supposition (Personal observation, June 2004).

Table 3.1.1 Topographical variables sorted between controls and ROW sites, showing the results tested by Mann-Whitney U-tests (S.D. = standard deviation).

Variable	Controls (n=37)		ROW (n=56)		*p*
	Mean	S.D.	Mean	S.D.	
Ah depth (cm)	17.2	5.6	7.4	8.9	<0.001
Stoniness[1]	1.6	1.2	2.2	0.9	0.066
Bare soil %	10.8	10.0	25.7	17.4	<0.001
Range health score	73.7	16.5	39.8	20.1	<0.001
Litter (kg/ha)	223	169	147.6	151.4	0.012

[1] Stoniness: 0=non-stony, 1=slightly, 2=moderately, 3=very, 4=exceedingly

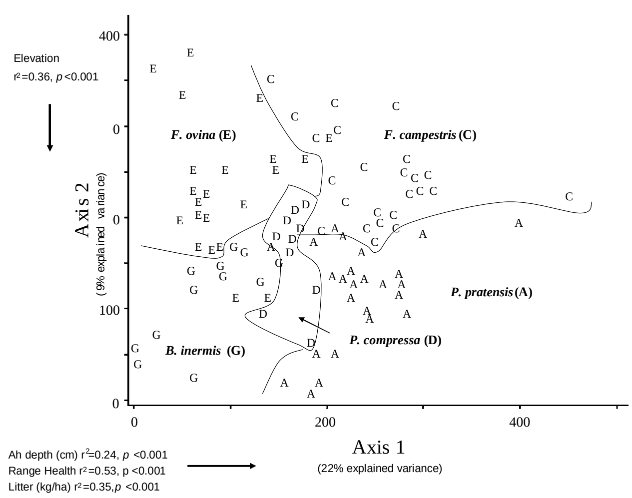
4.0 Plant Communities

4.1 Classification and Ordination

Twinspan and detrended correspondence analysis (DCA) were used to determine the composition of plant communities in the study data. DCA arranges species or plots in three dimensions (along three axes) according to implicit environmental gradients (Figure 4.1). The proximity of plot points indicates similarity in species' composition and the spacing of species' points along the axes indicates associations between species and environmental gradients (McCune and Grace 2002). Five plant communities resulted from the classification and ordination analyses: *Poa pratensis*, *Festuca campestris*, *Poa compressa*, *Festuca ovina*, and *Bromus inermis.* Environmental variables were correlated with the DCA axes to determine which ones might have affected the grouping of the sites into plant communities (Figure 4.1). Ah horizon depth, range health and litter increased along Axis 1, corresponding to the placement of plant communities *P. pratensis, F. campestris,* and *P. compressa*.

The objective of classifying the sample data was to evaluate the study sites in terms of their similarity to rough fescue grassland. The features of rough fescue grassland are:

- a dominance of *Festuca campestris* and/or *Danthonia parryi*
- varying degrees of *Festuca idahoensis, Koeleria macrantha, Agropyron* sp. and *Stipa* sp.
- native forbs, such as *Geum triflorum, Galium boreale, Lupinus sericeus*
- occasional shrubs, e.g. *Symphoricarpos occidentalis, Rosa acicularis, Potentilla fruticosa* (Moss 1944, Moss and Campbell 1947, Coupland 1961)



[1] Moisture regime: 1 = sub-xeric, 2 = sub-mesic, 3 = mesic

Figure 4.1 DCA Diagram with plant communities and environmental variable trends, Axes 1 and 2.

Figure 4.2 Sample *Poa pratensis* community (Carbondale bottomland ROW)

4.2 *Poa pratensis*

The *Poa pratensis* community was a modified grassland community with 40% introduced species. The majority of the sites were in the Foothills Parkland natural subregion, including ten on the same pipeline (built in 1998), in different locations, three (Waldron Porcupine) in the Foothills Fescue natural subregion and two (Screwdriver Creek) in the Montane subregion. *Festuca campestris* and *Danthonia parryi* were present, although in less than 2.5% average cover, and they occurred in only four of the ROW sites. Sixty percent of the sites were bottomlands or north-facing, with clay to sandy clay loam texture, and were moderately drained, which probably accounts for the presence of *P. pratensis* and *B. inermis* and the variety of forb cover. The moisture conditions may also account for the low abundance of *Festuca campestris* and *Danthonia parryi.* The *P. pratensis* community is on a successional trend towards being a modified plant community, the result of pipeline reclamation and possible overgrazing. The ROW sites did not resemble rough fescue grassland, and the adjacent grassland had probably been modified by species from the ROW, e.g. *Agropyron dasystachyum.*

Soil exposure: 13% (0-45) **Moss/Lichen Cover:** 1% (0-10) **Total Vegetation:** 80% (48-123)

Plant Composition	% Cover (Constancy) S.D.	Site Description	Mean (minimum-maximum) n=25
Shrubs	**5.6(7)9**	**Percent ROW:**	**64% (14 ROW, 11 controls)**
Rosa arkansana	**2.0(3)4**	**Percent Native:**	**60%**
Symphoricarpos occidentalis	**1.0(2)3**	**Diversity Index:**	**3.4**
Graminoids	**76(100)14**	**Litter (kg/ha):**	**230 (34-770)**
Poa pratensis	**17.0(9)13**	**Range health:**	**56% (16-83%)**
***Agropyron dasystachyum* ***	**4.0(8)6**		
Bromus inermis	**3.8(6)4**	**Soil texture:**	**Clay Loam**
***Festuca idahoensis* ***	**3.6(6)4**	**Soils:**	**Orthic Black Chernozemic**
Phleum pratense	**2.9(6)5**	**Elevation (m):**	**1497(1267-1570)**
***Festuca campestris* ***	**2.2(6)4**		
Danthonia parryi	**2.0(6)2**	**Moisture regime:**	**Sub-xeric to mesic**
Forbs	**33(100)12**	**Slope:**	**Level to very strong (0-34%)**
Taraxacum officinale	**8.0(7)13**		
Achillea millefolium	**3.1(10)3**	**Aspect:**	**varied**
Galium boreale	**2.8(8)3**		
Geranium viscosissium	**1.4(2)4**		
Potentilla gracilis	**1.5(7)2**		
Artemisia ludoviciana	**1.1(3)3**		

Note: * indicates species were in the pipelines' seed mixes (see Appendix B)

Figure 4.3 Sample *Festuca campestris* community (North Creek crest control)

4.3 *Festuca campestris*

The *Festuca campestris* community was a native grassland community with a graminoids, forb and shrub structure. It was the largest grouping, made up of 24 sites, most of which were controls, with 60% of its sites in the Foothills Fescue, 30% in the Foothills Parkland and 10% in the Montane. The *F. campestris* community was the closest in species composition to the rough fescue grassland. It had the highest species diversity score: 3.6. This community has the second deepest topsoil, with a mean depth of 14 cm. It was comprised predominately of controls (79%), which, would consist of undisturbed grassland with normal topsoil depths of between 10 and 20 cm. This community has the structure of a late-seral rough fescue grassland: native grasses, forbs and shrubs, with a mean health range health score of 75%. The four ROW sites were the closest in recovery to rough fescue grassland, averaging over 5% cover for *Festuca campestris* and *Danthonia parryi*. Without further disturbance, these ROW sites will probably continue in a successional trend towards rough fescue grassland.

Soil exposure: 14% (0-48) **Moss/lichen** 1% (0-4) **Total vegetation:** 90% (68-111)

Plant Composition	% Cover (Constancy) S.D.	Site Description	Mean (minimum-maximum) n=24
Shrubs	**5.6 (79) 8**	**Percent ROW:**	**21% (5 ROW, 19 controls)**
Rosa arkansana	**1.6 (29) 3**	**Percent Native:**	**87%**
Potentilla fruticosa	**1.2 (38) 3**	**Diversity Index:**	**3.6**
Graminoids	**52.0(100)13**	**Litter (kg/ha):**	**206 (70-552)**
Festuca campestris *	**11.0 (92) 1**	**Range Health:**	**75% (35-96%)**
Danthonia parryi	**10.7 (79)12**	**Soil Texture:**	**Silt Loam**
Agropyron dasystachyum *	**8.1 (96) 7**		**Sandy Clay Loam**
Poa pratensis	**4.7 (79) 6**		
Festuca idahoensis	**3.2 (63) 4**	**Soils:**	**Orthic Black Chernozemic**
Stipa richardsonii	**2.3 (29) 5**		
Agropyron spicatum	**2.1 (25) 5**	**Elevation (m):**	**1375(1270-1560)**
Festuca rubra	**1.8 (50) 4**		
Poa compressa	**1.9 (42) 4**	**Moisture regime:**	**Sub-xeric to sub-mesic**
		Slope:	**Level to strong (1-16%)**
Forbs	**32.0 (96)12**	**Aspect**	**varied**
Geum triflorum	**6.1 (54) 9**		
Antennaria umbrinella	**2.9 (58) 4**		
Galium boreale	**2.9 (83) 3**		
Artemisia frigida	**1.7 (67) 3**		

Note: * indicates species were in the pipelines' seed mixes (see Appendix B)

Figure 4.4 Sample *Poa compressa* community (Fish Lake bottom land ROW)

4.4 *Poa compressa*

All the sites in the *P. compressa* community were in the southernmost location of the study area, in the Foothills Parkland natural subregion. Despite the broad occurrence of *Poa compressa*, the community had a diversity of forbs, shrubs and graminoids, and would qualify as a disturbance altered rough fescue grassland. This community's species diversity was average with a score of 3.0. *Festuca campestris* was in evidence on 90% of the sites, 50% of which were rights-of-way. This was a late-seral community which retained much of its native characteristics (65% native cover).

Soil exposure: 13% (0-29) **Moss/lichen** 3.5% (0-12) **Total vegetation:** 85% (56-119)

Plant Composition	% Cover (Constancy) S.D.	Site Description	Mean (minimum-maximum)n=10
Shrubs	**3.0 (80) 5**	**Percent ROW:**	**60% (6 ROW, 4 controls)**
Rosa arkansana	**1.6 (70) 2**	**Percent Native:**	**65%**
Symphoricarpos occidentalis	**1.3 (30) 3**	**Diversity Index:**	**3.0**
Graminoids	**58.0(100)19**	**Soil texture:**	**Sandy Loam**
Poa compressa *	**19.8(100)14**		**Clay Loam**
Agropyron dasystachyum *	**6.5 (90) 6**		**Clay**
Festuca idahoensis	**6.1 (90) 4**	**Litter (kg/ha):**	**127 (10-342)**
Koeleria macrantha *	**5.4 (60) 6**	**Range Health:**	**62% (36-98%)**
Festuca campestris *	**5.2 (90) 3**	**Soils:**	**Orthic Black Chernozemic**
Phleum pratense	**3.4 (80) 4**	**Elevation:**	**1451(1376-1567)**
Danthonia parryi	**2.1 (70) 2**	**Moisture regime:**	**Sub-xeric to mesic**
Forbs	**24.0(100)13**	**Slope:**	**Level to strong (0-20%)**
Lupinus sericeus	**5.1 80) 5**		
Taraxacum officinale	**4.5 (50) 8**	**Aspect**	**15-358°**
Moss	**3.5 (70) 4**		
Geranium viscosissium	**3.4 (50) 4**		
Galium boreale	**2.0 (90) 1**		

Note: * indicates species were in the pipelines' seed mixes (see Appendix B)

Figure 4.5 Sample *Festuca ovina* community (Lundbreck Upland crest ROW)

4.5 *Festuca ovina*

The *Festuca ovina* community sites were divided between the Foothills Fescue and Foothills Parkland natural subregions, in the central part of the study area and all but two of the sites were pipeline rights-of-way. In its native habitat in the United Kingdom, *Festuca ovina* is normally found on less productive, infertile, upland grazing lands (Dawson et al. 2003, Otsus and Zobel 2004). Although the soil texture was clay loam, the Maycroft, Burton Creek and Lundbreck Upland sites were thin breaks and gravely (soil exposure up to 51%) with topsoil depths averaging only 8 cm. Species diversity was moderate with a score of 3.0. The mean range health score (43% - healthy with problems) for this community indicated grazing pressure. *Festuca campestris* was present on six of the pipeline sites, with percent cover ranging from 1 to 10 percent; however, there were no shrubs and almost no forbs, making this a modified community.

Soil exposure: 32% (9-51) **Moss/lichen** 0.4% (0-3) **Total vegetation:** 73% (39-95)

Plant Composition	% Cover (Constancy) S.D.	Site Description	Mean (minimum-maximum) n=22
		Percent ROW:	91% (20 ROW, 2 controls)
Graminoids	**64(100)11**	Percent native:	60%
Festuca ovina *	16.0(9)10	Diversity Index:	3.0
Agropyron dasystachyum *	11.0(10)6		
Agropyron smithii *	5.4(8)6	Soil texture:	Clay loam
Stipa curtiseta *	5.6(6)12	Litter (kg/ha):	105 (46-216)
Poa compressa	4.1(6)8a	Range Health:	43% (8-70%)
Festuca saximontana	3.0(5)4	Soils:	Orthic Black Chernozemic
Festuca idahoensis *	2.7(4)5	Elevation (m):	1400 (1281-1514)
Danthonia parryi	2.1(4)4		
Festuca campestris *	1.7(5)3	Slope:	Level to strong slopes (0 – 12%)
		Moisture regime:	Sub-xeric to sub-mesic
Forbs	**8 (79)9**	Aspect	Varied
Taraxacum officinale	1.0(4)2		

Note: * indicates species were in the pipelines' seed mixes (see Appendix B)

Figure 4.6 Sample *Bromus inermis* community (Lundbreck Lowland bottomland ROW)

4.6 *Bromus inermis*

The *Bromus inermis* community was 92% pipeline rights-of-way, all in the Montane natural subregion. All of the Nelson Creek sites were included in this community, characterized by *Bromus inermis* and *Agropyron smithii*. Two pipelines, one of which had almost 100% cover of *Bromus inermis* and the other 100% cover of *Phleum pratense*, bordered the Nelson Creek right-of-way, resulting in their encroachment into its ROW. The one control, Lundbreck Lowland bottomland, had 27% cover of *Rosa arkansana* but 48% *Poa compressa*, which accounted for its classification with this plant community. The pipelines on these sites were ten years of age or less. The community was a mixture of moisture regimes, and although loamy in texture, the mean Ah depth is a shallow 2.5 cm. This community was highly-modified (range health 32%, unhealthy), with little to no forb or shrub cover, and the least diverse species with a score of 2.8.

Soil exposure: 25% (0-74) **Moss/lichen** 1% (0-6) **Total vegetation:** 63% (20-132)

Plant Composition	**% Cover (Constancy) S.D.**	**Site Description**	**Mean (minimum-maximum) n=12 (13% of the sites)**
		Percent ROW:	**92%, n=12 (11 ROW, 1 control)**
		Percent native:	**43.%**
		Diversity Index:	**2.8**
Graminoids		**Soil exposure:**	**25% (0-74%)**
Bromus inermis	**8.0 (92)8**	**Total vegetation:**	**63%(20-132%)**
Agropyron smithii	**7.4 (75)10**	**Soil texture:**	**Loam**
Poa compressa	**11.0(42)16**	**Litter (kg/ha):**	**188 (0-455)**
Festuca saximontana	**6.9 (50)13**	**Range Health:**	**32% (15-75%)**
Phleum pratense	**4.8 (67)9**	**Soils:**	**Orthic Black Chernozemic**
		Elevation (m):	**1475 (14360-1560)**
		Moisture regime:	**Sub-xeric to mesic**
		Slope:	**Nearly level to strong (2-23%)**
		Aspect	**10-278°**

5.0 Pipeline Reclamation Techniques

5.1 Pipeline construction

Typical pipeline construction requires that both landowner and pipeline company negotiate an easement; this permits the pipeline company to use the land on which the pipeline will be installed. The right-of-way is usually 15 to 40 m in width, sufficient to accommodate the pipeline trench and the construction equipment. The right-of-way may be graded if the terrain is uneven, and the topsoil stripped and stockpiled using conventional equipment such as bulldozers or graders.
The stripping used in the study sites took several forms:

- full right-of-way with no separation of topsoil from subsoil
- double or triple-lift stripping, full right-of-way, with the upper subsoil stripped over the trench width and piled beside the previously stripped topsoil
- trench-only stripping, with the topsoil removed only over the width of the trench, leaving intact much of the topsoil and vegetation on the right-of-way.

Subsoil from the trench is piled on the edge of the right-of-way (Figure 5.1). The pipe is lowered into the trench and backfilled with the spoil, usually to a depth of 0.8 to 2 m, which is then compacted. The right-of-way is ripped and feathered to relieve compaction, if necessary, then the topsoil is spread back over the area that was stripped (Mutrie and Wishart 1989). If the topsoil is to be stored where erosion due to wind or rain may occur, the topsoil may be sprayed with chemical binding agents used to bind or stabilize soil stockpiles, improving the strength of the surface layer by forming a surface crust (Sinton 2001).

Following construction, the right-of-way is seeded according to the type of land requirements. On public land, Alberta Sustainable Resource Development governs the reclamation, while Alberta Environment guidelines apply for all other lands. If private land, the landowners' may specify the type of seeding. The application for construction and reclamation, submitted to Alberta Environment, describes the proposed seed mix. The actual seed mix used may vary depending on the availability of seeds at the time of seeding, and may not be recorded. Pipeline reclamation may involve seeding annual grasses in the first year for site stabilization, then seeding a mixture of short-lived perennials, e.g. *Agropyron trachycaulus* and long-lived perennials, e.g. *Agropyron smithii* or *Festuca campestris*, and no forbs. In addition to the applied seeds, viable seeds could exist in the topsoil and be exposed as the topsoil is removed and replaced.

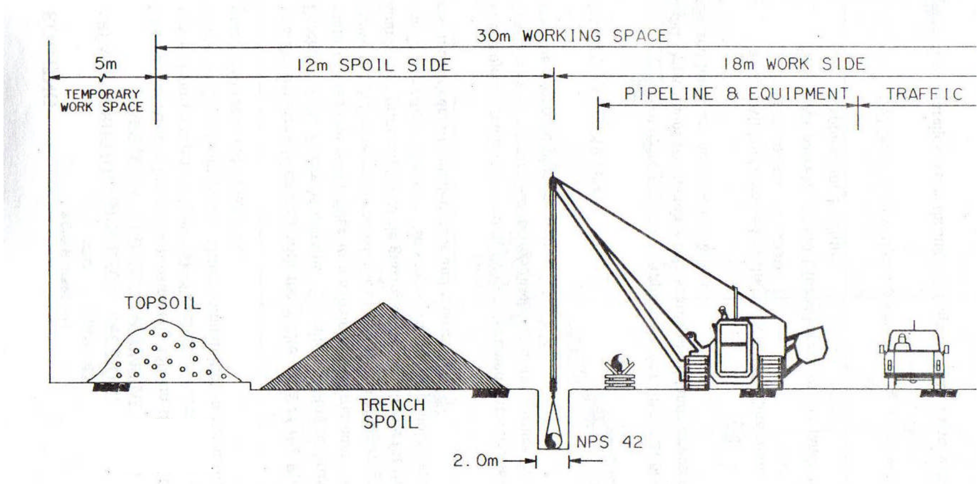


Figure 5.1Typical Pipeline Construction

The movement of natural gas through a pipeline heats up the pipe, especially when the gas is compressed, and may affect the surrounding soil (Yanitsky 1992, Naeth et al. 1993). Ranchers commented that the pipeline right-of-way was the first area to become green in the spring and stayed green longer in the winter, probably due to right-of-way soil temperatures (Anonymous, personal communication, July 2004, McKim and McKim, personal communication, March 2005, and Anonymous, personal communication, March 2005).

Fescue grasslands adjacent to roads and paths are especially vulnerable to invasion by introduced species, either seeded for reclamation, or transported by vehicular, stock or human traffic (Tyser and Worley 1992). A pipeline is a linear disturbance similar to a road or path, although largely un-travelled except by livestock or wild ungulates, and the proximity of the pipeline ROW to undisturbed grassland would suggest that some of the species seeded on the ROW would naturally move into the grassland. This could be termed the shadow effect of the pipeline.

5.2 Variables Selected

The following variables were collected in the field:

- **Drainage (well to moderate)**
- **Slope (%)**
- **Aspect (°)**
- **Elevation (m)**
- **Sand (%)**
- **Clay (%)**
- **Ah depth (cm)**
- **Stoniness (non-stony to exceedingly)**

Alberta Sustainable Resource Development Range Health Assessment techniques were used for the following (Adams et al. 2003). See Chapter 2 for an explanation of the techniques.

- Litter (kg/ha- field estimates)

- Range health rating

Pipeline variables

Pipeline construction and reclamation reports provided the pipeline variables.

- Pipeline age (years)
- Pipeline diameter (cm)
- Seeding rate – kg/ha
- Seeding rate for *Festuca campestris*, *Agropyron trachycaulum*, *Agropyron dasystachyum*, *Festuca ovina*, *Festuca idahoensis* and *Poa compressa*, other native or non-native seed.

Stripping

The weighting of the stripping processes was based on the expectations that trench-only stripping is a minimal disturbance technique, two-lift preserves the topsoil, and the full width is the largest disturbance. Early pipelines with little to no reclamation, e.g. built in the 1960s, were given the highest rating.

- 20 – trench-only stripping
- 50 – two-lift stripping
- 100 – full-width stripping
- 150 – full-width stripping with no reclamation, e.g. pipelines built prior to 1980.

Construction months

The exact date of the construction for each site was not available; therefore, a variable was derived from the range of months given for the construction of the entire pipeline ("construction months"), using two month interval, the smallest date range available for all pipelines.

1 – April and May	**4 – October and November**
2 – June and July	**5 – December and January**
3 – August and September	**6 – February and March**

5.3 Results and Discussion

5.3.1 Site Grouping by Species Dominance

An analysis of the species composition for each site resulted in a separation of the sites into three groupings: *Festuca ovina* (n=21), *Poa pratensis* (n=15), and *Danthonia parryi/Festuca campestris* (n=10) (Table 5.3.1).

Festuca ovina

The twenty-one sites in this group were dominated by *Festuca ovina* and/or *Festuca saximontana*, at 21% cover over 90% of the sites. The next most abundant species was *Agropyron dasystachyum* at 8.6% cover on 93% of the sites, followed by *Agropyron smithii*, 6.0% cover on 71% of the sites, totalling 63% graminoids. There was negligible cover for shrubs, and forbs total only 6.6 %, with *Taraxacum officinale* being the most abundant (1%). Bare soil averaged 33%, litter 108 kg/ha, and range health scores averaged 29, which is unhealthy. Almost all the oldest sites, 44 years, were included in this group: Maycroft West, Burton Creek other ROW, and Lundbreck Upland and Lowland other ROW. These sites were disturbed, with highly-modified vegetative cover.

Poa pratensis

On these fifteen sites, *Poa pratensis* was the most abundant species, at 16.5% cover on 100% of the sites. *Agropyron dasystachyum* followed with 5% cover on 63% of the sites, totalling 43% graminoid cover. No other grasses had greater than 3.6% cover. Twenty percent of these sites had shrub cover, mainly *Rosa arkansana* (1.8% cover), and forb cover totalling 24%, led by *Taraxacum officinale* (3.7% cover, 87% sites). Bare soil averaged 20% cover on 80% of the sites, and range health scores were higher than the *Festuca ovina* sites at 48, although still unhealthy. The average amount of litter was the highest of the three groups, at 202 kg/ha, probably due to the abundance of *Bromus inermis* (3.6% cover, 60% of the sites) and *Phleum pratense* (3.2% cover, 60% of the sites). These sites were disturbed, with modified vegetative cover.

Danthonia parryi/Festuca campestris

Danthonia parryi and *Festuca campestris* had similar cover on these ten sites (5.8 and 5.6% respectively), each on 90 % of the sites. Like the other two groupings, *Agropyron dasystachyum* followed, at 4.7% cover on 90% of the sites, and *Poa compressa* at 14%, although on only 70% of the sites. Other rough fescue association grasses were found: *Festuca idahoensis* (2.7% cover, 70% of the sites) and *Koeleria macrantha* (2.6% cover, 40% of the sites).

The graminoid cover averaged 53%, and shrubs 2.4% on 50% of the sites. Forbs were the most diverse on these sites, including *Geum triflorum* (5% cover, 30% of the sites), *Geranium viscosissium* (2.9% cover, 50% of the sites), and *Lupinus sericeus* (2.3% cover, 60% of the sites). Bare soil averaged 22%, and litter was low, averaging 160 kg/ha. The range health rating for these sites averaged 57, healthy with problems, probably due to the amount of bare soil and the low litter.

Table 5.3.1 ROW sites grouped by dominant species (Only those with percent cover > 1.0 % are shown).

Graminoids	*F. ovina* (n=21)	*P. pratensis* (n=15)	*D. parryi/ F. campestris* (n=10)
Shrubs			
Rosa arkansana	0a	1.8	0.6
S. occidentalis	0.2	0.3	1.1
Total Shrubs	**0.2**	**3.0**	**2.4**
A. dasystachyum	8.6	5.0	4.7
Agropyron pectiniforme	1.6	0	0.1
Agropyron smithii	6.0	1.3	0.7
Agropyron spicatum	2.6	0.2	0.0
Agropyron trachycaulum	1.1	0.1	1.2
Bromus inermis	1.8	3.6	1.3
Carex sp.	0a	2.3	2.2
Danthonia parryi	0.6	1.4	5.8
Festuca campestris	0.8	0.9	5.5
Festuca idahoensis	2.7	3.2	2.7
F. ovina/ F. saximontana	21	2.6	2.1
Koeleria macrantha	1.0	0.1	2.6
Phleum pratense	3.0	3.2	0.5
Poa compressa	3.8	1.1	14
Poa pratensis	0.7	16	1.5
Stipa curtiseta	0a	0	2.2
Stipa richardsonii	2.5	0.1	3.4
Total Graminoids	**63**	**43**	**53**
Forbs			
Achillea millefolium	0.3	1.8	0.7
Antennaria umbrinella	0.1	0	0.8
Artemisia ludoviciana	0	1.2	0
Cirsium arvense	0.3	1.4	0.5
Galium boreale	0.1	2.0	1.6
Geranium viscosissium	0	0.6	2.9
Geum triflorum	0.2	0.3	5.1
Lithospermum incisum	0	0.5	0.5
Lupinus sericeus	0	0.2	2.3
Moss	0.5	0.5	1.5
Potentilla gracilis	0.2	1.1	0.6
Taraxacum officinale	1.0	3.7	2.6
Trifolium hybridum	0.4	1.0	0
Total Forbs	**6.6**	**24**	**22**
Bare soil	33	20.2	22
Range health score (s.d.)	29	48.0	57
Litter (kg/ha)	108	202	160

Nevertheless, these sites approximated rough fescue grassland, dominated by rough fescue association grasses and with a variety of native forbs.

5.3.2 Seeding Rate Correlations

For clarity of presentation in the following diagram, each plant species group was represented by a symbol: '*' = *Festuca ovina*, '+' = *Poa pratensis,* and '#' = *Danthonia parryi/Festuca campestris.*

***Festuca campestris* Seeding Rate**

Axis 1 represented a gradient for *Festuca campestris* seeding with a lower rate in *Festuca ovina* and *Danthonia parryi* groups, and a higher rate in the *Poa pratensis* group. *Festuca campestris* seeding rates had little influence on its resulting percent cover (Figure 5.2).

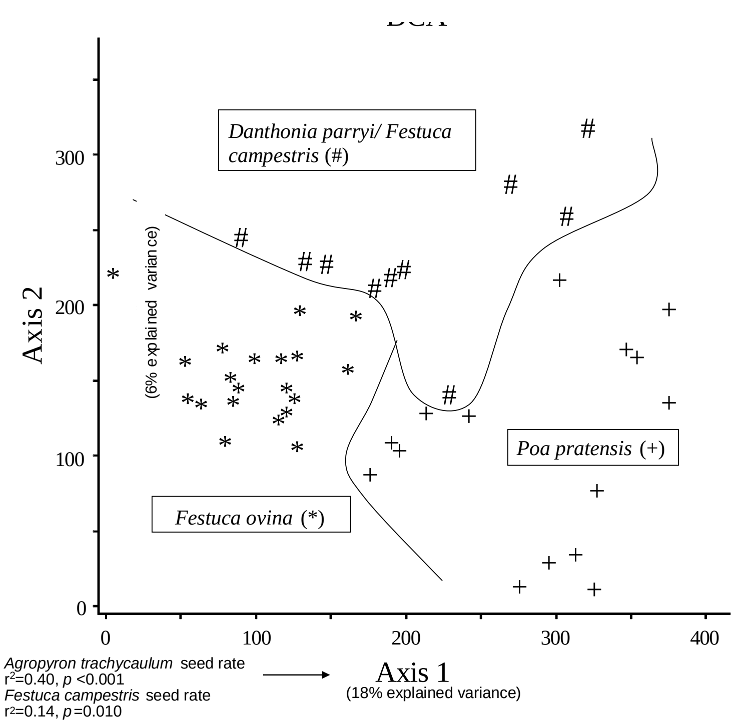


Figure 5.2 Detrended correspondence analysis of pipeline sites, axes 1 and 2, showing species cover with seeding and weed control correlation trends; no seeding variables had significant correlations with axis 3 with *p* < 0001.

Some sites with *Festuca campestris* seeding had no corresponding cover, and conversely, several sites with no *Festuca campestris* seeding, had corresponding cover: Lundbreck Upland other ROW (LHNO, LHSO), Maycroft West (MWS, MWT), and Burton Creek other ROW (BCTO) (Figure 5.3). There appeared to be little correlation between *Festuca campestris* cover and its seeding rate. The seeding rate for *Festuca campestris* varied from 0.4 to 12.5 kg/ha. Some sites with high seeding rates for *Festuca campestris*, e.g. over 6 kg/ha, had no cover of this grass, while others with 2 kg/ha or less had cover of over 10%.

While the source of the seed for each pipeline was not known, at the time of construction, prior to 1998, *Festuca campestris* seed would have been wild-harvested (Pahl and Smreciu 1999). The germination rates of wild-harvested seeds are usually lower than cultivated plants. Some of the contributing factors are the uncertainty of the seed maturity dates, variable field conditions, the location of the seed source being not compatible with the reclamation site (Smreciu et al. 2003), the knowledge of the collector, the hand-collection methods, and the storage methods (Neville, personal communication, June 2005).

Festuca campestris utilizes a form of reproduction called tillering, whereby auxiliary buds are released from dormancy and develop leaves and roots, while remaining attached to the parent plant (Luken 1990). Successful tillering reduces the requirement for seed reproduction, which may account for the variation in seed production found in *F. campestris,* where several years may elapse between seed setting (Johnston and MacDonald 1967). The erratic seed production by *F. campestris* hampers the collection of wild seed and the production of agronomic seed.

Table 5.3.2 Mean seeding rates of each ROW plant grouping

kg/ha	***Festuca ovina*** n=21	***Poa pratensis*** n=15	***D. parryi/ F. campestris*** n=10
Seeding rate	9.5	10.3	14.5
F. campestris	0.7	3.8	2.2
A. trachycaulum	0.1	2.9	1.9
A. dasystachyum	2.2	3.3	5.5
F. ovina	1.1	0.9	1.4
F. idahoensis	0.3	0.4	0.2
P. compressa	0.5	0.6	0.4
Other native	1.5	2.4	2.5
Other non-native	30.0	0.2	0.4

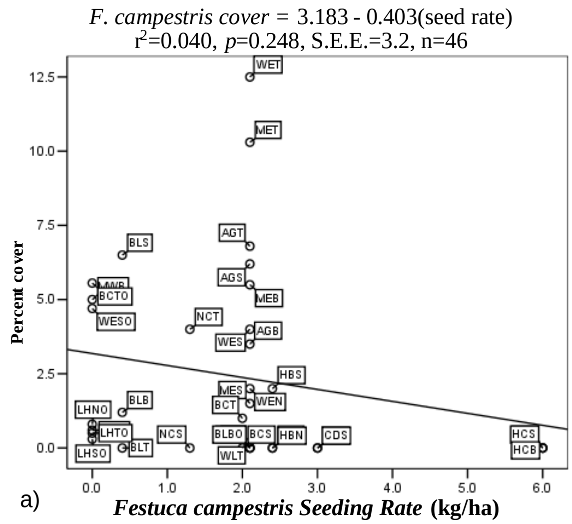


Figure 5.3 Scatter diagram and regression model for *Festuca campestris* seeding rate with *Festuca campestris* cover.

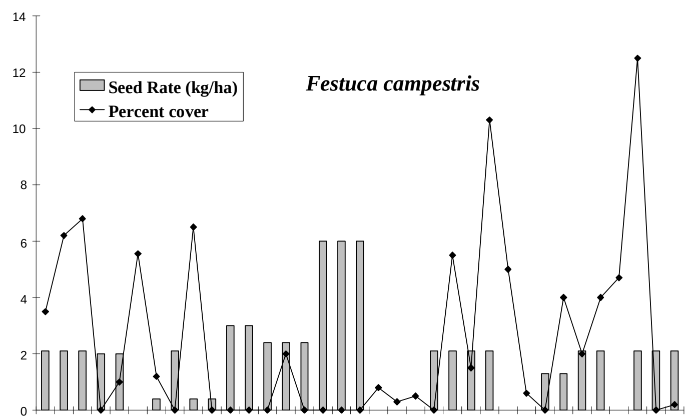


Figure 5.4 Chart of sites showing *Festuca campestris* seeding rate and percent cover, showing only sites seeded with and/or with percent cover of *Festuca campestris*.

Another explanation of the unpredictable success of *Festuca campestris* seeding is substitution of the planned seed mix with another during the final reclamation process. This may have been the case with the Screwdriver Creek pipeline (CDS, CDT). Its seed mix indicates 25% *F. campestris*, at 6 kg/ha, when in fact its cover has no *F. campestris* but instead between 17 and 40% *Festuca saximontana*, which was not listed in the proposed seed mix. The common names for *F. campestris* are Foothills fescue and Mountain fescue. *Festuca saximontana* is a native cultivar known as sheep fescue or Rocky Mountain fescue, readily available from seed companies. Perhaps Rocky Mountain fescue was substituted for Mountain fescue, inadvertently, or because it was a more readily available “native seed”.

Festuca ovina Seeding Rate

Festuca ovina does not occur naturally in the study area; therefore, where found, it must have originated from the seed mixes, making the correlations with its seed mix values probably valid. *Festuca ovina* is a common reclamation species, used widely in Europe, from whence it came, and readily available as a cultivar; therefore, its germination is probably reliable (Otsus and Zobel 2004). This grass appears to benefit from higher seeding rates, and it readily spreads off of its original seeding area, into the adjacent ROW or grassland. Another observation is that there was little incursion of native grasses and forbs from the controls onto the ROW, once *Festuca ovina* is established.

Agropyron dasystachyum and Agropyron smithii Seeding Rates

The apparent persistence of *Agropyron dasystachyum* and *Agropyron smithii* from the seed mixes, is in line with Osterman’s (2001) findings that the trench zone of a ROW favoured rhizomatous grasses. *Agropyron dasystachyum* occurred on over 90% of the ROW sites, and appeared with similar cover in all of the plant communities. *Agropyron dasystachyum* was included in all but two of the pipeline seed mixes: Nelson Creek and Screwdriver Creek, which have little to no *Agropyron dasystachyum* on the ROW (Appendix B). *Agropyron dasystachyum* is a native grass, common in rough fescue grassland; therefore, it was difficult to distinguish between the planted cultivar encroaching off the ROW and the native species encroaching onto the ROW.

Agropyron smithii was also part of many of the seed mixes. *Agropyron smithii* was in the seed mixes of the Burton Creek, Maycroft East and North Creek pipelines, all built in 1997, and appeared well established at 5.9% average cover on 67% of their sites, indicating early establishment and persistence, an observed trait of this rhizomatous grass (Samuel and Hart 1994).

Agropyron trachycaulum Seeding Rate

Agropyron trachycaulum was included in 48% of the seed mixes; nevertheless its percent cover averaged only 1%. *Agropyron trachycaulum* is an early seral grass; therefore, late seral perennials would eventually become more dominant. As well, it grows best in moist conditions and would not persist in subxeric or submesic locations, which make up the majority of the sites (Tannas 2001).

Other Species Seeding Rate

Some of the seed mixes did not correspond to the ecological characteristics of the sites. One example was the Maycroft East pipeline, a dry, wind-swept location with thin soils, and an abundance of *Stipa* spp. *Stipa viridula* was included in the seed mix, a grass suited to moist habitats; however, it was not found during the sampling process, probably because of unsuitable habitat.

Poa pratensis* and *Bromus inermis

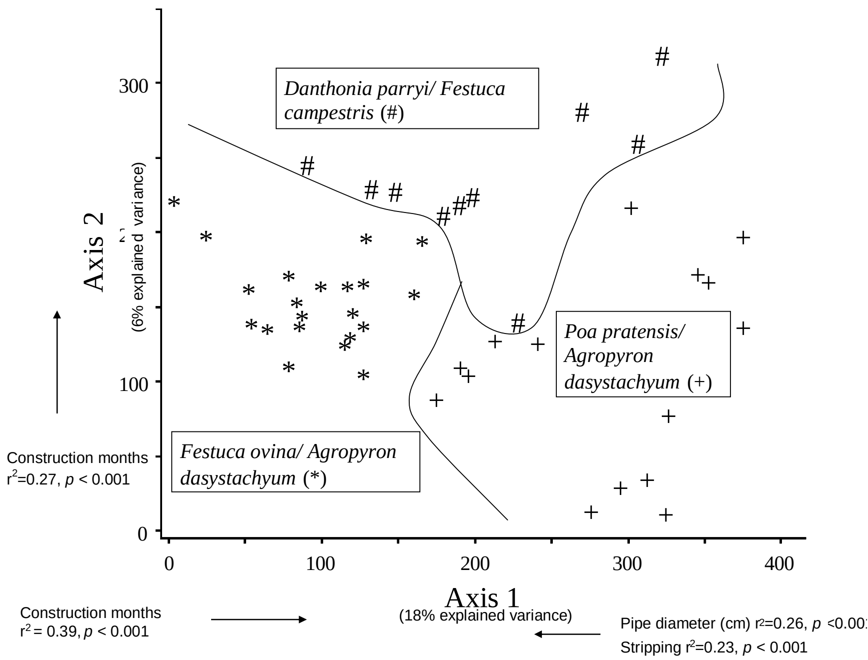
Two grasses that were not seeded, but were well-established, were *Poa pratensis* and *Bromus inermis*, possibly as a result of exposing their seeds, lying dormant in the seed bank, during ROW clearing (Adams et al. 2005). The DCA correlations and regression analysis imply that higher *Festuca campestris* seeding rates favoured *Poa pratensis*-dominated sites, possibly caused by competition among the seeded grasses, causing them to die-off and allowing a grass like *Poa pratensis* to prosper (Sinton et al. 1996, Smreciu et al. 2003). In some cases, *Bromus inermis* occurred in patches on the ROW sites. Since *Bromus inermis* is a common forage crop, its presence may have been a result of hay brought in for grazing. In addition, straw is often used as a stabilizer to prevent erosion during pipeline construction, which could have resulted in the importation of *Bromus inermis* seeds. Both grasses may have a competitive advantage because of fire suppression throughout the region, whereas bunch grasses like *Festuca campestris* would have tolerated fire (Bailey and Anderson 1978, Sinton 1980, Ewing 2002). Willoughby and Alexander (2005) and Adams et al. (Adams et al. 2005) found *Poa pratensis* persisted in sites were it was initially established, eventually reverting to co-dominance with *Festuca campestris.*

***Danthonia parryi* Seeding Rate**

Danthonia parryi appeared on 90% of the *Danthonia parryi* sites, 47% of the *Poa pratensis* sites and 47% of the *Festuca ovina* sites; yet, it was in the seed mix of only one site, Screwdriver Creek. Its presence is probably indicative of encroachment from the native grassland, possibly assisted by grazing (Tannas 2001).

5.4 Pipeline construction months

In the DCA diagram, the further the sites are positioned along each axis, the later the construction months (Figure 5.5). The *Festuca ovina* sites were all built between April and July; whereas, all but two of the *Danthonia parryi* sites were constructed between August and the following March. In the *Poa pratensis* group, the sites the furthest away from the intersection of Axis 1 and 2, Chain Lakes (BLS, BLT and BLB), had *Festuca campestris* and/or *Danthonia parryi* cover and were built in August or September. *Festuca campestris* and *Danthonia parryi* cover had a successful trend following construction in late summer (August or September) or winter (February or March) (Figure 5.5) while *Festuca ovina* had an opposite trend for greater abundance with early construction dates: spring and early summer (April to July). Four of the sites constructed in June or July had cover between 4 and 5.5%; however, the majority of sites constructed before August had 1% cover or less. This is in line with reclamation guidelines that suggest surface disturbance by heavy equipment is reduced when the ground is frozen or after the growing season on dry ground (Wilson 1988, Sinton 2001).



Construction months: 1=Apr/May, 2=Jun/Jul, 3=Aug/Sep, 4=Oct/Nov, 5=Dec/Jan, 6=Feb/Mar
Stripping: 20=trench only, 50=2-lift, 100=full ROW, 150=full ROW with no reclamation

Figure 5.5 Detrended correspondence analysis of pipeline sites, axes 1 and 2, showing species cover with pipeline and topography correlation trends.

During the winter, less topsoil stripping is required, as heavy equipment can operate on undisturbed grassland.

Only one peer-reviewed study was found that examined the effects of heavy equipment on grassland vegetation in relation to season. Wilson (1988) concluded that military tank traffic in the summer, post-growing season, had a less detrimental effect on prairie vegetation than traffic during the spring growing season, finding the effect on vegetation to be similar to that of fire and grazing. His study was in mixed-grass prairie in Manitoba and would be consistent with observations of the resilience of mixed-grass prairie in Alberta (Neville, personal communication, June 2005).

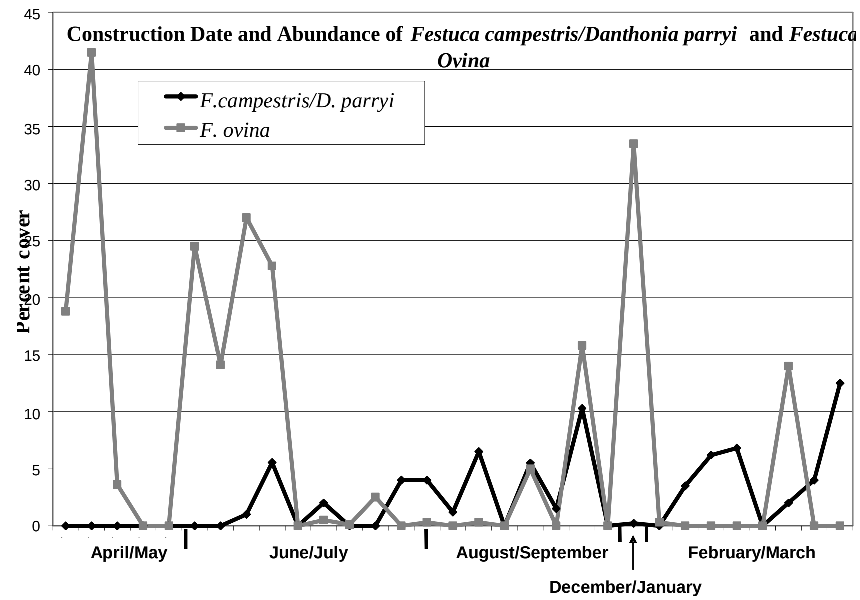


Figure 5.6 Percent cover of *Fesctua campestris* and *Festuca ovina* as sorted by pipeline construction months; only sites seeded with both species are shown.

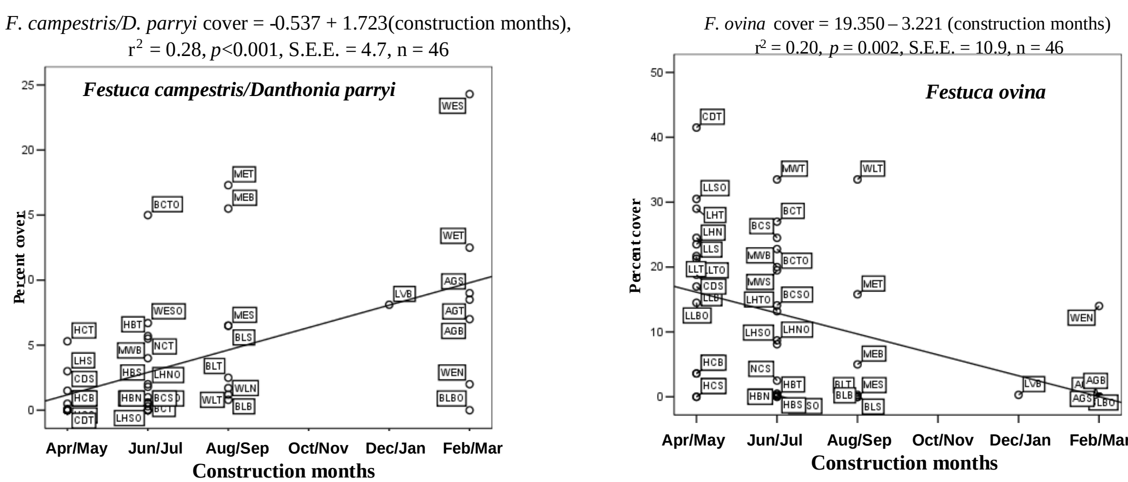


Figure 5.7 Scatter diagrams and regression models for *Festuca campestris /Danthonia parryi* and *Festuca ovina* with pipeline construction months; S.E.E. = standard error of the estimate. Table 4.9.1 gives the site name and acronym translation.

Naeth (1985) concluded that grading and compaction by heavy equipment were less destructive than the trenching operation in Solonetzic soils. Although her studies concentrated on soils, an extrapolation might be made to the impact on vegetation. Black Chernozem soils have a deeper topsoil layer than mixed grass prairie and may be less resistant to heavy equipment disturbance; nevertheless, further study could determine the impact of post-growing season heavy equipment movement in the foothills fescue grasslands.

5.4.1 Stripping technique

Sites with less stripping (e.g. trench-only) are at the right-hand position of the diagram and that those with more stripping (e.g. full right-of-way) are positioned towards the zero value in the DCA diagram (Figure 5.5). The greatest percent cover (>20%) of *Festuca campestris* and *Danthonia parryi* was found on pipelines that employed trench-only stripping.

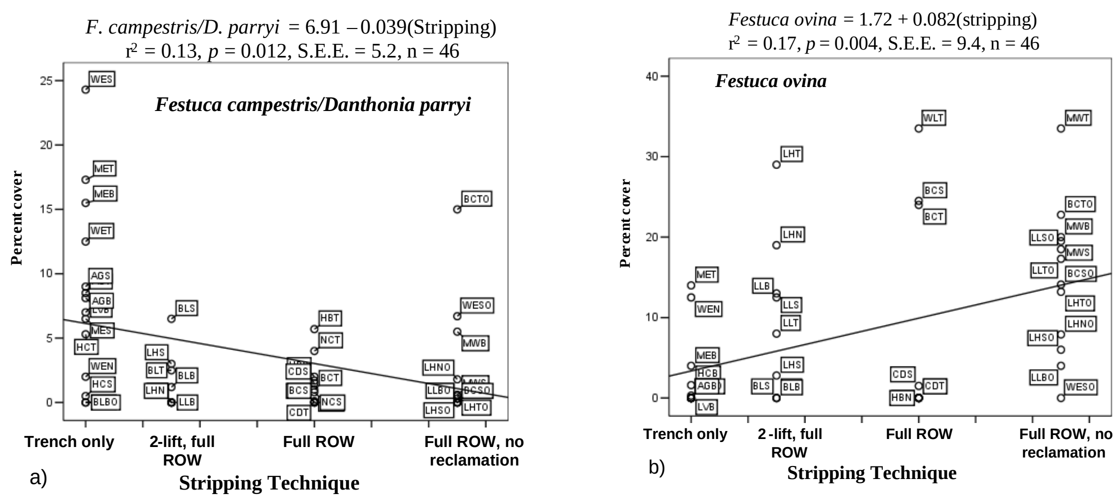


Figure 5.8 Scatter diagrams and regression models for *Festuca campestris /Danthonia parryi* and *Festuca ovina* percent cover as a function of ROW stripping technique. S.E.E. is the standard error of the estimate. Table 4.9.1 gives the site name and acronym translation.

Moderate percent cover (10 to 20%) occurred on several pipelines with full ROW stripping and no reclamation (Figure 5.8a). *Festuca ovina* cover was the most abundant on sites with the largest disturbance, full right-of-way stripping (Figure 5.8b). *Poa pratensis* and *Agropyron dasystachyum* cover showed no relation to stripping techniques.

The lowest impact stripping technique for this study, trench-only, resulted in a correlation with the highest *Festuca campestris/Danthonia* percent cover. Some success in grassland restoration, through natural recovery, has been observed with no-strip and directly ploughed-in techniques for small diameter (< 15 cm) (Adams et al. 1996, Petherbridge 2000).

The majority of the pipelines in this study involved stripping the topsoil from the whole right-of-way. The rationale for full width stripping is that the equipment movement, especially that needed for large diameter pipe (61 cm or greater), might pulverize the topsoil and result in its degradation. In the 1980s, some theories held that removing most of the topsoil aided the reclamation potential. Today, full-width stripping is recommended only when rutting may occur due to wet soils or where the topography requires grading for safety. Otherwise, trench-line stripping is preferred, where the topsoil is removed only over the width of the trench, leaving intact much of the topsoil and vegetation on the right-of-way (Sinton 2001).

Trench-only stripping results in a narrow disturbance with native grassland in close proximity on either side, allowing natural recovery to occur through seed rain, rhizomatous spreading and, in the case of *Festuca campestris,* tillering.
The correlation of greater *Festuca campestris* abundance with later-season construction and trench-only stripping lead to the conclusion that a post-growing season or winter construction date, combined with trench-only or less stripping, will result in better recovery for rough fescue grassland.

5.4.2 Pipe Diameter

Most of the larger diameter pipes had over 5% and up to 35% cover of *Festuca ovina*. Except for a few sites, *Festuca campestris* appeared to have greater cover on the sites where there was no *Festuca ovina* (Figure 5.9).

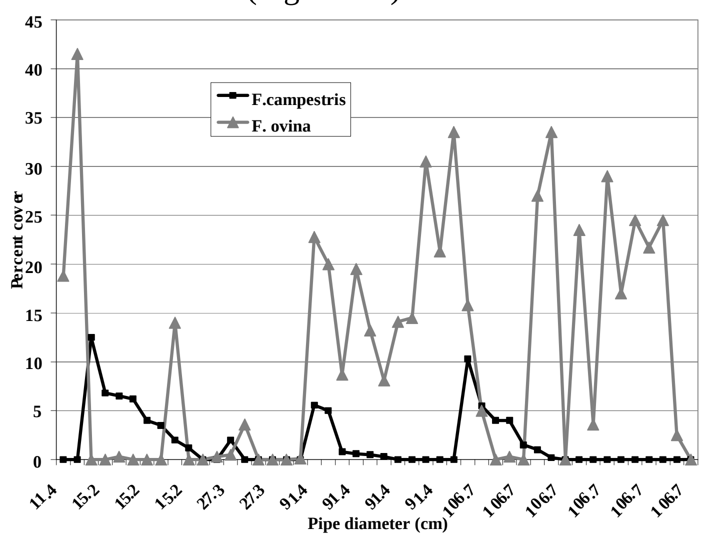


Figure 5.9 Percent cover of *Fesctua campestris* and *Festuca ovina* as sorted by pipe diameter

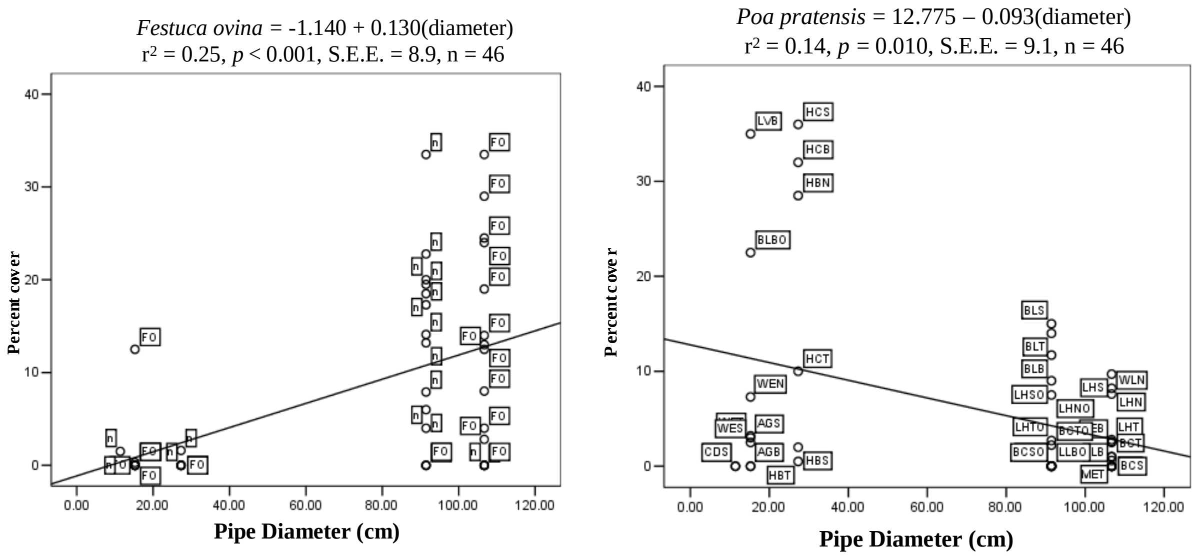


Figure 5.10 Scatter diagrams and regression models for *Festuca ovina* and *Poa pratensis,* as a function of pipe diameter. S.E.E. is the standard error of the estimate

Dividing the pipe diameters into two ranges - small diameter (11.4 to 27.3 cm) and large diameter (91.4 to 107 cm) - showed a distinction between their average values (Table 5.3.3).

Table 5.4.1 Mean values based on pipe diameter ranges.

Pipe Diameter (cm)	Bare soil (%)	Range health (%)	Litter (kg/ha)	Ah depth (cm)
11.4 - 27.3	17.7 (15)	54.5(22)	195(221)	10.2(9.6)
91.4 - 107	32.3(15)	32.9(16)	121(107)	5.1(6.6)

Pipe diameter appeared to have little effect on the success of *Festuca campestris*; however, it may be related to the success of *Festuca ovina*, which had higher abundance on larger diameter pipe. *Poa pratensis*, conversely, increased in abundance on smaller diameter pipe (Figure 5.3.9). The difference could be related to soil temperature, positively affected by the movement of natural gas through a pipeline (Patterson 2000). Naeth et al. (1993) found statistically significant differences in soil temperatures between the right-of-way of a 107 cm pipeline and adjacent undisturbed grassland, attributed to the temperature of the pipe. This is consistent with studies of the effects of pipeline construction on tundra vegetation, which found that pipeline disturbances were warmer than the undisturbed tundra (Yanitsky 1992).

Soil heating by large diameter pipelines would account for the early vegetative growth in the spring, and late vegetative growth and senescence in the autumn on pipeline rights-of-way (Naeth et al. 1993). Cattle and elk are known to preferentially select right-of-way sites, especially in the spring (McKim and McKim, personal communication, March 2005), which could result in increased grazing pressure on the ROW (Lees 1988, Naeth 1988). Heavy grazing could reduce the depth of the topsoil, reduce the amount of litter, and increase the amount of bare soil, thereby negatively affecting the moisture retention capacity of the ROW (Johnston et al. 1971, Willms et al. 1985, Adams et al. 2005). Grazing could also contribute to the success of *Festuca ovina* on large diameter pipe, as it increases with grazing, and thus would flourish with heavy grazing (Tannas 2001, Hartley and Mitchell 2005). On larger diameter pipes in the study sites, grazing may be one of the factors contributing to lower average values for topsoil depth and litter, and greater percent bare soil.

The lower nutrient capacity of a shallower topsoil depth and the reduced moisture retention capacity of the ROW would be conditions that might favour the growth of *Festuca ovina,* which has a shallow root system, transpires little water, is drought tolerant, and grows well on nutrient-deficient, calcareous soils (Brar and Palazzo 1995, Otsus and Zobel 2004). Conversely, the ROW of smaller diameter pipe, with less soil heating effects, would be less heavily grazed, have deeper topsoil with more nutrients, and be better able to retain moisture, thereby allowing competition from other grasses, such as *Poa pratensis,* which prefers moister habitats with higher-nutrient soils (Tannas 2001, Kluse and Allen Diaz 2005). As observed during field sampling, the ROW of small diameter pipe showed evidence of less grazing than adjacent large diameter pipes, as did the controls of larger diameter pipes.

It is possible that seeded *Festuca campestris* was successful in establishing in the first several years on the ROW sites where it was seeded, and that spring grazing by elk and/or cattle resulted in its decrease or extirpation, since it does not tolerate growing season grazing (Willms 1988, Willms et al. 1988). Given that temperature and moisture content of the soil were not recorded during this study, these correlations cannot be validated. Additional research should be conducted into the relationship between the effects of pipeline soil heating and vegetation.

5.4.3 Pipeline Age

The age of the pipelines had no relationship to *Festuca campestris* or any other major grass cover in any of the ordination or statistical analyses, contrary to what might be expected in vegetation succession. This could be explained by the fact that the youngest sites were seven years old, sufficient time for the three to five-year stand establishment time for *Festuca campestris*, or for any of the other grasses (Pahl and Smreciu 1999). Carbondale, one of the seven-year-old sites, was grouped with the *Danthonia parryi/Festuca campestris* group, and showed evidence of natural recovery of native grasses, forbs and shrubs. Conversely, the oldest pipeline sites, constructed in 1961, although showing some evidence of natural recovery, including *Festuca campestris,* were all dominated by either *Festuca ovina* or *Poa pratensis,* and have negligible forb and shrub cover.

6.0 Pipeline Shadow Effect

During the field sampling, a test was conducted to determine the extent of a shadow effect on three ROW sites where an indicator species was evident: *Festuca ovina* and *Festuca saximontana*. They occurred in abundance on the pipeline ROW, as part of the seed mixes, and occurred in one percent or lower cover on the controls, at 15 m from the ROW.

A thirty meter transect was laid where the ROW met the control. At three meter intervals, perpendicular forays were made into the control, measuring where the last occurrence of the indicative species occurred (Figure 6.1). Joining these points indicated the extent of incursion of the indicator species into the adjacent undisturbed control (Figure 6.2).

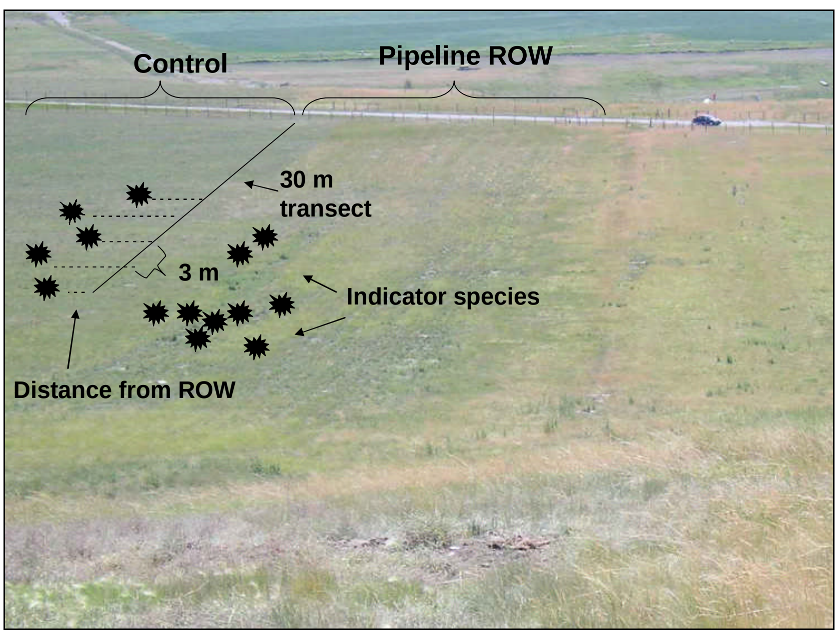


Figure 6.1 Diagram showing shadow effect measurement methodology.

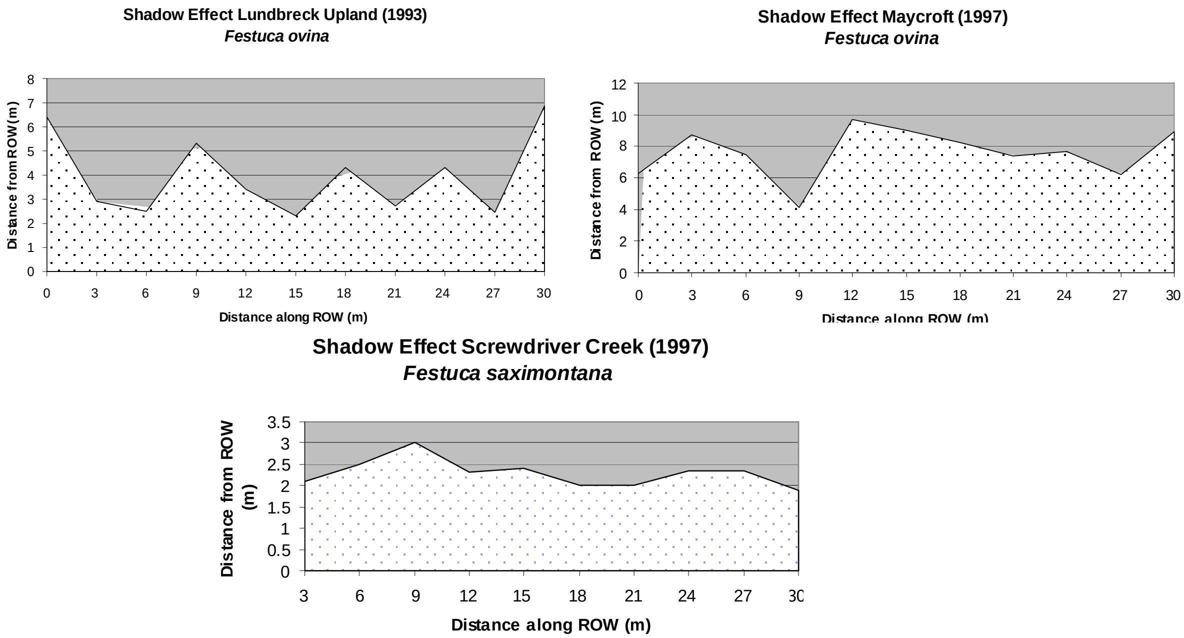


Figure 6.2 Shadow effect of *Festuca ovina* and *Festuca* showing their furthest occurrence in adjacent controls measured at 10 m intervals.

The Lundbreck Upland crest ROW, built in 1993, had 29% cover of *Festuca ovina* (20% of the seed mix) and 0% on the control, 15 m from the ROW. *Festuca ovina* occurred from 2.3 to 6.9 m from the ROW edge, averaging a distance of 4.3 m, or 0.4 m per year. There was no similar incursion of species from the control into the ROW. The Maycroft East ROW crest had 14% cover of *Festuca ovina* (14% of the seed mix) on the ROW and 1% on the control, 15 m from the ROW. *Festuca ovina* extended from 4.1 to 9.7 m into the control, averaging 8.4 m, or 1.2 m per year.

The Screwdriver Creek ROW crest had 41% cover of *Festuca saximontana* with 0% in the control, 15 m from the ROW. *Festuca saximontana* extended off the ROW from 2 to 3 m at an average of 2.3 m, or 0.3 m per year. There was no similar incursion of species from the control into the ROW.

The rate of incursion of a seeded species on two of these pipelines, e.g. 0.4 and 0.3 compares favourably with the conclusions of xxx showing agronomic species encroachment on pipelines varying between 0.3 and 0.6 m per year. The third pipeline, Maycroft East shows a faster rate of 1.2 m per year.

Other Sites

The test of species migration from the ROW into adjacent grassland shows proof of a pipeline shadow-effect. The Burton Creek crest site also had a high percent cover of *Festuca ovina* (24%), 30% of the seed mix, which had migrated over 15 m into the control, where its cover was 14%. The North Creek crest site had 33% cover of *Festuca ovina*, 14% of the original seed mix, which had partially migrated into the adjacent grassland, although its incursion was not measured. The Lundbreck Lowland bottom-land site, with 20% *Festuca ovina* in the seed mix, had 12% cover of it on both the ROW and control.

7.0 ROW Sites Most Similar To Rough Fescue Plant Communities

The Waldron Porcupine south and crest, and the Carbondale crest ROW sites were significantly similar to their controls, as were all the Fish Lake ROW sites. Of the fifty-six ROW sites in total, only these six have statistically significant rough fescue association cover and similarity to their controls, although there were still differences. The ROW sites had fewer rough fescue association grasses, native graminoids and native forbs and lower species diversity. The ROW sites also had lower range health scores (healthy with problems) than the controls (healthy), and lower diversity ratings. *Agropyron dasystachyum* averaged similar cover, although in some cases it was more abundant on the control than the ROW.

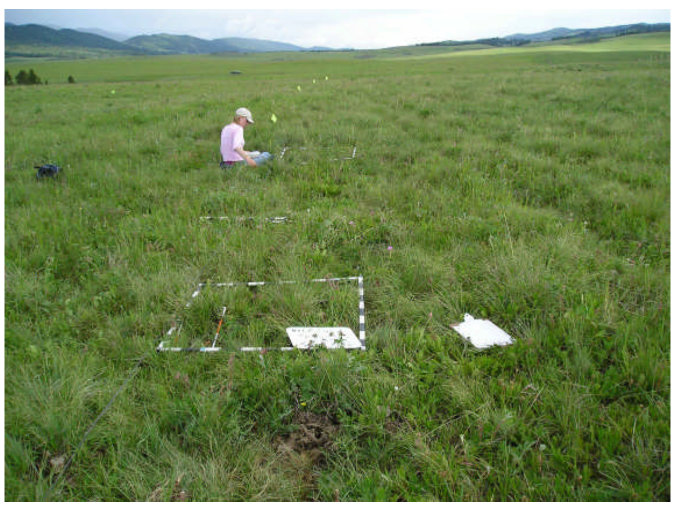


Figure 7.1 Waldron Porcupine South, looking south

All of these pipelines, except the Waldron Porcupine Other ROW, were constructed between August and April, and employed trench-only stripping and varied in age from 7 to 18 years.

The proximity of undisturbed grassland is one of the factors that probably contributed to the success of four of the best recovered sites, allowing for natural recovery. This is in keeping with findings of Hammermeister (2001) and Van Ham (1998) of natural recovery on pipelines and well sites. The other two sites, both on the Waldron

Porcupine pipeline, also showed evidence of natural recovery, with the largest amount of native forbs of any ROW (26 and 42% cover). In this case, the recovery may have occurred with the assistance of four newer pipelines in the same right-of-way, which possibly attracted cattle grazing away from the Waldron Porcupine pipeline, especially in the spring, when new seedlings are most vulnerable.

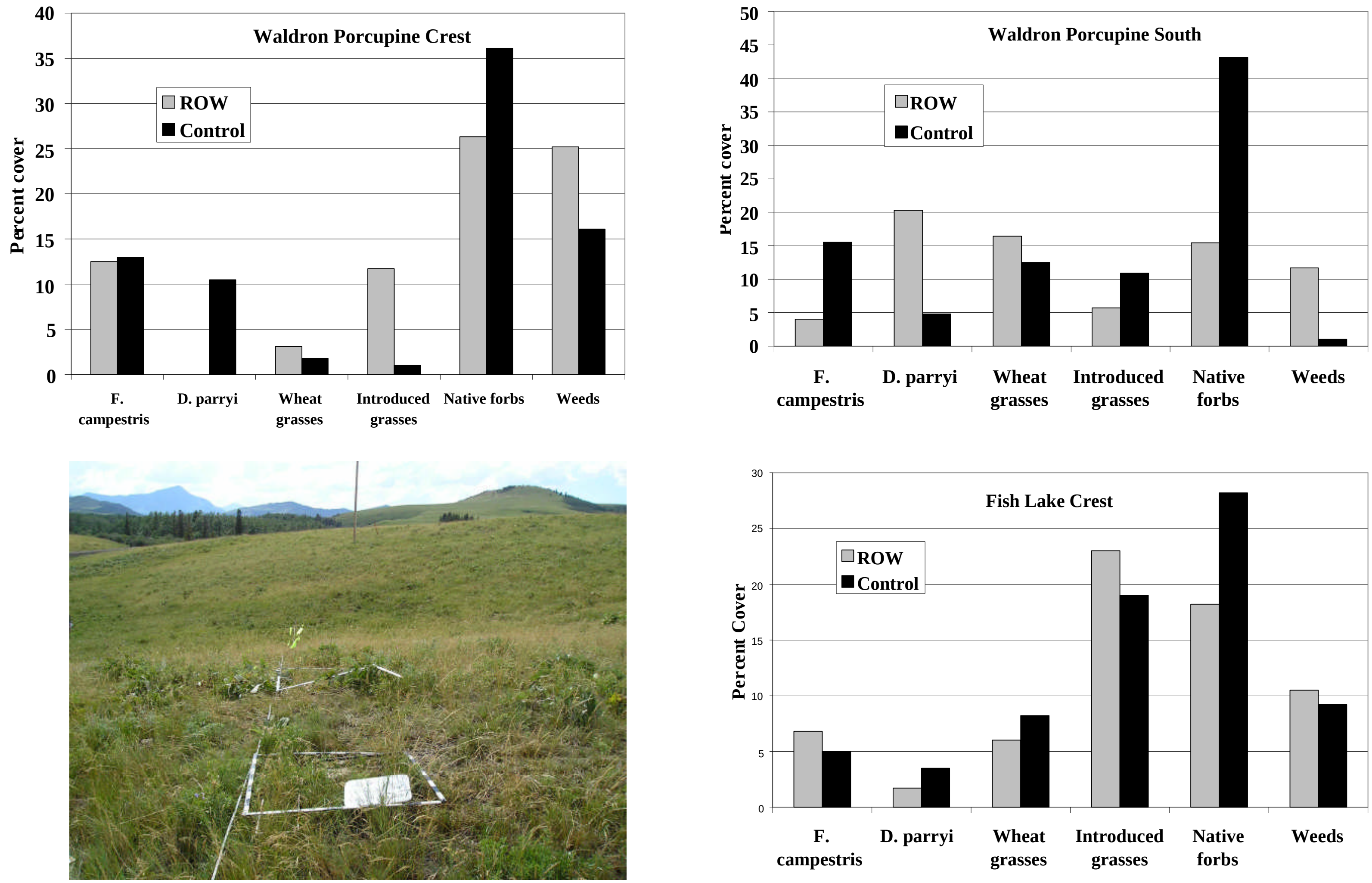


Figure 7.2 ROW and control sites with similar species cover as tested by Wilcoxon signed ranks tests ($p > 0.30$); photo is Fish Creek Bottomland looking north.

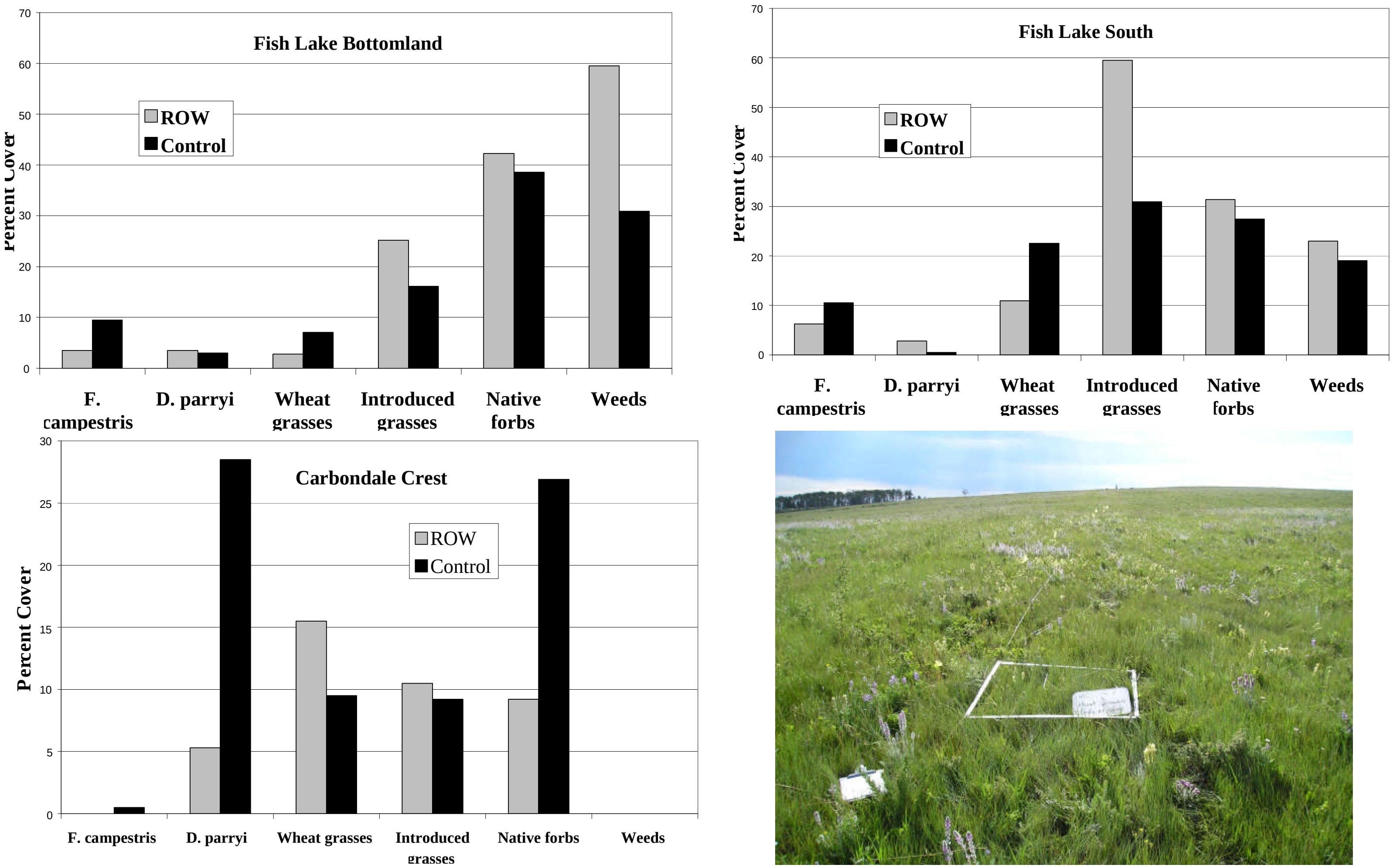


Figure 7.3 ROW and control sites with similar species cover as tested by Wilcoxon signed ranks tests ($p > 0.30$); photo is Carbondale Crest looking east.

8.0 Conclusion

The following conclusions apply to grasslands in the Foothills Fescue, Foothills Parkland, and Montane natural subregions. Study sites were selected because their reclamation practice history was considered favourable to restoration of native rough fescue grassland communities. The site selection criteria were:

- pipelines situated in rough fescue grassland
- native grassland adjacent to the pipeline ROW to serve as a control
- ROW seeded with native seed mixes, including rough fescue, if possible
- crests, south slopes and bottom lands, e.g. areas suitable for fescue grassland growth

While these sites may not represent most pipeline construction, the goal was to reduce the number of factors that could have affected the success of the restoration to those related to construction and reclamation techniques.

Results from 20% of the ROW sites confirmed that although a degree of restoration success was present, based on vegetative cover, these sites had less topsoil, higher clay content, more bare soil, less plant litter, and reduced range health scores than the adjoining control. The construction practices that most contributed to their recovery were post-growing season pipeline construction, between August and March, and minimum disturbance trench-only stripping.

Areas where limited restoration was achieved were hill crests and south facing slopes. Aridity was hypothesized as a factor encouraging reclamation success, fort example, slightly higher levels of rough fescue establishment were observed in the drier Foothills Fescue environment as compared to the Foothills Parkland.

Results from 80% of ROW sites revealed that there is a high risk that reclamation practices may not result in restored rough fescue grassland, thereby affecting the health and function of the disturbed area and future options in terms of values and benefits from the grassland. The factors that detracted from their recovery included growing-season construction and full ROW stripping.

Seeding may not be the best method to achieve *Festuca campestris* revegetation. Wild-harvested seed may be unreliable, seeding rates did not correlate with ensuing cover, and higher seeding rates may be detrimental to stand establishment. *Festuca ovina*, *Festuca ovina* var. *duriuscala* and *Festuca saximontana* cultivars succeeded in establishment following seeding, persisted over time, infiltrated neighbouring grassland, and may inhibit natural recovery of native grasses and forbs. *Agropyron dasystachyum* established well with seeding and it may not inhibit rough fescue association grasses. It was abundant on most ROW sites, including those with *Festuca campestris/Danthonia parryi*.
The soil heating of large diameter pipe could cause concentrated grazing pressure by attracting grazing ungulates to early emergence of vegetation in the spring and late

senescence in the fall. The result could be an increase in *Festuca ovina* and a decrease in *Festuca campestris*, each having an opposite reaction to grazing in the growing season.

Reclamation practices appeared more important than time since disturbance in the restoration of rough fescue grassland. This was demonstrated by 44 year old right-of-way sites that had less rough fescue association grasses than some of the newest right-of-way sites, 7 years old, constructed in the winter with trench-only stripping.

In summary, foothills rough fescue grassland is highly sensitive to timing and extent of disturbance. The reclamation practices used in the majority of the study sites resulted in little to no restoration of rough fescue grassland. On the other hand, some of the sites did show a successional trend towards rough fescue grassland, a result of minimum disturbance techniques and seasonal construction timing.

9.0 Recommendations for Industry and Government

9.1 Pre-construction Planning

Restoration of rough grassland will take many years; therefore, pre-construction consultation processes should include full disclosure to the land owner of the amount of time that their land is likely to look "different." The landowner or leaseholder must be involved in the reclamation process; for example, keeping cattle off the disturbance for the first three to five years, or locating non-sensitive areas to situate oil and gas facilities. Alberta Sustainable Resource Public Lands range managers must be consulted regarding grazing practice recommendations.

Festuca campestris is not a rare plant or a species of special concern; nevertheless, site assessments should be required to draw attention to its presence, and, if found, rough fescue grassland should trigger these guidelines regarding native prairie. The difficulty in restoring rough fescue grassland should qualify inclusion of *Festuca campestris* plant communities in the Foothill Fescue and Foothills Parkland subregions in Alberta Natural Heritage Information Centre Preliminary Plant Community Tracking List (Allen 2008).

Avoidance of sensitive sites and seasons should be the over-riding principle in pre-development assessments to characterize plant communities and ecological sites. This will permit project planning to avoid sensitive cover types in favour more resilient or previously disturbed land cover.

9.2 Construction

The fact that 80% of the study ROW sites showed little resemblance to rough fescue grassland - and those that did, still were appreciably different from undisturbed grassland – suggests that industry should avoid disturbing native fescue grassland, if at all possible.

In rough fescue grassland, industry construction must occur in the post growing season, August or later, and preferably in winter. Construction between April and July, on rough fescue grassland, must be prohibited, as *Festuca campestris* is particularly susceptible to growing season disturbance.

The success of trench-only stripping for pipelines in this study underscores the importance of keeping the disturbance as small as possible and allowing natural recovery from the undisturbed grassland. For example, no-strip techniques should be required for small diameter pipe (<20 cm), trench-only stripping for larger diameter pipe, and well pad-only stripping for well sites, if appropriate.

Feathering and smoothing the topsoil returned to the ROW may not be appropriate in rough fescue grassland. Uniform soils may benefit invasive species such as *Poa pratensis* and *Bromus inermis*, while rough conditions may inhibit their growth, allowing *Festuca campestris* and its associated grasses to flourish.

9.3 Seeding and Reclamation

Provincial guidelines declare, "Disturbances must be reclaimed to an equivalent land capability… (e.g.) native prairie landscape." What constitutes "equivalent land capability" and "native prairie landscape" is open for interpretation. Instead, seed mixes for rough fescue grassland should be prescribed, un-approved changes must be prohibited, and seed mixes used should be recorded. Although seeding rates for *Festuca campestris* require further study, this research reveals several recommendations:

- reduce the overall seeding rate, leaving sufficient bare soil to allow natural recovery from the adjacent grassland, without undue erosion risk
- eliminate *Festuca ovina* and *Festuca ovina* var. *duriuscala* and use *Festuca saximontana* sparingly
- reduce or eliminate the percentage of *Agropyron dasystachyum* and *Agropyron smithii* and other rhizomatous wheat grasses; if they exist in the neighbouring grassland, their rhizomatous reproduction would facilitate natural recovery
- include early successional species, allowing time for *Festuca campestris* and its associated grasses seedlings to become established, without competition from persistent rhizomatous grasses

- include native forbs; while their function in fescue grasslands is not known, they are present in most fescue grasslands and must play a role in grassland development
- ensure the seed mix is compatible with the hydrologic zone of the site; for example, if a pipeline, two or more seed mixes may be required

Rough fescue requires 3 – 5 years to become established from seed; therefore, a monitoring program of a minimum of six years, should be required, not only to validate seeding success, but also to ensure the progression of natural recovery. All stages of monitoring should include recording and reporting of the status of the reclamation results.

Most *Festuca campestris* seed is wild-harvested and may have unreliable germination results. Germination testing, genetic verification and seed certification would improve seeding results. Field-developed ecovars (© Ducks Unlimited) of *Festuca campestris* might result in improved seed germination rates.

The geographic demarcation of rough fescue species may merit a regulation limiting the geographic source of *Festuca campestris* seed, similar to that in place for trees. For example, seed zonation governs wild seed for trees: "Seed zones are geographic subdivisions of natural ecoregions based on general genetic criteria. They limit seed movement to a conservative area where native trees of all species can be moved without risk of maladaptation or erosion of genetic integrity (Alberta Environment 2000)."

9.4 Range Health Assessment

The range health assessment process and reference plant communities, developed by Sustainable Resource Development, was determined to be a valuable tool for assessing reclamation success. Statistical analysis of the main components of the range health protocol, e.g. species composition, litter, noxious weeds and bare soil, resulted in similar findings as the range health scores. Both methods indicated the relative health or reclamation success of the study sites.

The range health assessment is a simplified process and readily learned by those with a basic understanding of range ecological status. It provides a quantified score that could also serve as a company's performance indicator. Assessing range health as a component of the pre-construction site evaluation would provide a baseline, which could be compared to the post-reclamation status. Range health assessment as an element of a long-term monitoring program would provide a tangible measure of the progress of the reclamation.

10.0 Further Research

While avoidance of rough fescue grassland will undoubtedly preserve it, the reality is that increasing oil and gas development in the southwestern foothills will result in disturbances of native grassland. This research shows that recovery may be possible, if not to an identical replacement, then to a successional path towards restoration. Further research in the following areas will aid in ensuring that rough fescue grassland restoration becomes more feasible.

Further research is required into the seeding rates for *Festuca campestris* and the composition of an appropriate seed mix. The seeding rates for *Festuca campestris* in this study ranged from 0.4 to 6.0 kg/ha, with little correlation with the resulting cover. While other factors may have affected germination and stand establishment, e.g. seed viability or grazing, the fact remains that little is known about *Festuca campestris* seeding rates and successful ensuing growth.

All of the pipeline seed mixes lacked native forbs, and only one included any forb (*Medicago sativa*); as result, most of the ROW sites recovered to a grass monoculture. Research into the role of forbs in rough fescue grassland might lead to clues as to the successful restoration of *Festuca campestris.*

While *Festuca campestris* germinates readily, the three to five years of stand establishment exposes the seedlings to a variety of potentially destructive forces prior to maturity. To improve the chance for *Festuca campestris* stand survival, perhaps the best approach is transplanting three-year-old seedlings or already-mature young stands. Successful grassland reclamation results were obtained in Chile, South America, through transplanting *Stipa* sp. and other prairie grasses (Naeth, personal communication, November 2005). Further research could test the viability of rough fescue transplants.

Trench-only stripping, which resulted in better recovery in this study, meant that pipeline equipment travelled directly on undisturbed rough fescue grassland, in both summer and winter. While frozen ground is expected to be durable, thick black Chernozem soil, in the summer and fall, might be less so. Research into the resilience of rough fescue grassland to heavy equipment movement would greatly assist the route selection planning for oil and gas development.

Research has already proven that large diameter pipelines warm the surrounding soil; however, less is available on the resulting effect on vegetation. For example, although one 107 cm diameter pipeline in study area had *Festuca campestris* on the ROW, it is possible that as the plants age, the warmth of the pipe within reach of their lower roots could hamper their growth. This study attributed the persistence of *Festuca ovina* to the surficial soil conditions and grazing results of a large diameter pipe ROW; however, what other factors might soil heating play and to what effect on other species?

Many of the ROW sites in this study showed evidence of natural recovery and further study could reveal the potential of natural recovery by the forbs and grasses found in rough fescue grassland.

Poa pratensis dominated a good portion of the sites. While research is available on the persistence of *Bromus inermis* in rough fescue grassland, little is known about the interactions between *Poa pratensis* and *Festuca campestris.*

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Appendix A: Plant Species Name Conversions

Table A.1 Plant Species Name Conversions

Mnemonic	Moss (1994)	Kartesz (1994)	Common Name
ACHIMIL	*Achillea millefolium* L	*Achillea millefolium* L	Common Yarrow
AGOSGLA	*Agoseris glauca* (Pursh) Raf. var. *glauca*	*Agoseris glauca* (Pursh) Raf. var. *glauca*	False Dandelion
AGRODAS	*Agropyron dasystachyum* (Hook.) Scribn.	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould ssp. *lanceolatus*	Northern Wheat Grass
AGRODAS RIP	*Agropyron dasystachyum var. riparium* (Scribn. & J.G. Sm.) Bowden	*Elymus lanceolatus* (Scribn. & J.G. Sm.) Gould ssp. *lanceolatus*	Streambank Wheat Grass
AGROHIR	*X Agroelymus hirtiflorus (A.S. Hitchc.) Bowden*	*Elyleymus X hirtiflorus (A.S. Hitchc.) Barkworth*	Rye hybrid
AGROINT	*Agropyron intermedium* (Host) Beauv.	*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey.	Intermediate Wheat Grass
AGROPEC	*Agropyron pectiniforme* Roemer & J.A. Schultes	*Agropyron cristatum (L.) Gaertn. ssp. pectinatum (Bieb.) Tzvelev*	Crested Wheat Grass
AGROREP	*Agropyron repens* (L.) Beauv.,	*Elymus repens* (L.) Gould.	Quack Grass
AGROSMI	*Agropyron smithii* Rydb.	*Pascopyrum smithii* (Rydb.) A. Löve	Western Wheat Grass
AGROSPI	*Agropyron spicatum* Pursh	*Pseudoroegneria spicata* (Pursh) A. Löve ssp. *spicata*	Bluebunch Wheat Grass
AGROPYRON SP.	*Agropyron* sp.	*Agropyron spp.*	Undifferentiated Wheat Grass
AGROSUB SUB	*Agropyron trachycaulum* (Link) *Malte* var. *trachycaulum* (Cassidy) Malte	*Elymus trachycaulus* (Link) Gould ex Shinners ssp. *subsecundus* (Link) A.& D. Löve	Awned Wheat Grass (Slender wheatgrass)
AGROTRA TRA	*Agropyron trachycaulum* (Link) Malte var. *trachycaulum* (Cassidy) Malte	*Elymus trachycaulus* (Link) Gould ex Shinners ssp. *subsecundus* (Link) A.& D. Löve	Awned Wheat Grass (Slender wheatgrass)
AGROTRA UNI	*Agropyron trachycaulum* (Link) Malte var. *unilaterale* (Cassidy) Malte	*Elymus trachycaulus* (Link) Gould ex Shinners ssp. *subsecundus* (Link) A.& D. Löve	Awned Wheat Grass
ALLICER	*Allium cernum* Roth	*Allium cernum* Roth	Nodding wild onion
ALLITEX	*Allium textile* A. Nels. & J.F. Macbr.	*Allium textile* A. Nels. & J.F. Macbr.	White wild onion
ALNUS	*Alnus* sp.	*Alnus sp.*	Undifferentiated Alder
AMELALN	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer	Saskatoon berry
ANDRSEP	*Androsace septentrionalis* L.	*Androsace septentriona lis L.*	Fairy candelabra

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
ANELITH	*Anemone lithophila* Rydb.	*Anemone lithophila* Rydb.	Anemone
ANEMCAN	*Anemone canadensis* L	*Anemone canadensis* L	Canada anemone
ANEMMUL	*Anemone multifida* Poir.	*Anemone multifida* Poir.	Cut-leaved anemone
ANEMPAT	*Anemone patens* L.	*Anemone patens L.*	Prairie crocus
ANTEANA	*Antennaria anaphaloides* Rydb.	*Antennaria anaphaloides* Rydb.	Tall Everlasting
ANTEPRI	*Antennaria aprica* Greene	*Antennaria parvifolia* Nutt.	Low Evelasting
ANTEPUL	*Antennaria pulcherrima* (Hook.) Greene	*Antennaria pulcherrima* (Hook.) Greene	Showy Everlasting
ANTERAC	*Antennaria racemosa* Hook.	*Antennaria racemosa* Hook.	Everlasting
ANTEUMB	*Antennaria umbrinella* Rydb.	*Antennaria umbrinella* Rydb.	Pussy-toes
AQUIFLA	*Aquilegia flavescens* S. Wats.	*Aquilegia flavescens* S. Wats.	Yellow columbine
ARCTUVA	*Arctostaphylos uva-ursa* (L.) Spreng.	*Arctostaphylos uva-ursa* (L.) Spreng.	Bearberry
ARNIANG	*Arnica angustifolia* Vahl ssp. *tomentosa* (Macoun) G.W. Douglas & G. Ruyle-Douglas	*Arnica angustifolia* Vahl ssp. *tomentosa* (Macoun) G.W. Douglas & G. Ruyle-Douglas	Narrow-leaved arnica
ARNIFUL	*Arnica fulgens* Pursh.	*Arnica fulgens* Pursh.	Shining arnica
ARNILUN	*Arnica lonchophylla* Greene *ssp. lonchophylla*	*Arnica lonchophylla* Greene *ssp. lonchophylla*	Spear-leaved arnica
ARTEBIE	*Artemisia biennis* Willd.	*Artemisia biennis* Willd.	Biennial sagewort
ARTECAM	*Artemisia campestris* L. spp. *caudata (Michx.) Hall & Clements*	*Artemisia campestris* L spp. *caudata (Michx.) Hall & Clements*	Plains wormwood
ARTEFRIG	*Artemisia frigida* Willd.	*Artemisia frigida* Willd.	Pasture sage
ARTELUD	*Artemisia ludoviciana* Nutt. *ssp. Ludoviciana*	*Artemisia ludoviciana* Nutt. *ssp. Ludoviciana*	Prairie sage
ASTECON	*Aster conspicuus* (Lindl.)	*Eurybia conspicua* (Lindl.) Nesom.	Showy aster
ASTELEA	*Aster laevis*	*Symphyotrichum laeve* (L.) A.& D. Löve. var. *laeve*	Smooth aster
ASTER	*Aster sp.*	*Aster sp.*	Undifferentiated Aster
ASTRALP	*Astragalus alpinus* L.	*Astragalus alpinus* L.	Alpine milk vetch

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
ASTRAME	*Astragalus americanus* (Hook.) M.E. Jones	*Astragalus americanus* (Hook.) M.E. Jones	American milk vetch
ASTRCIC	*Astragalus cicer* L.	*Astragalus cicer* L.	Cicer milk vetch
ASTREYE	*Astragalus eucosmus* B.L. Robins.	*Astragalus eucosmus* B.L. Robins.	Milk vetch
ASTRFLE	*Astragalus flexuosus* (Hook.) Dougl. ex G. Don	*Astragalus flexuosus* (Hook.) Dougl. ex G. Don	Slender milk vetch
ASTRGIL	*Astragalus gilviflorus* Sheldon	*Astragalus gilviflorus* Sheldon	Cushion milk vetch
ASTRSPP	*Astragalus* sp.	*Astragalus sp.*	Undifferentiated Vetch
ASTRDAS	*Astragalus striatus* Nutt.	*Astragalus laxmannii* Jacq. var. *robustior* (Hook.) Barneby & Welsh	Ascending purple milk vetch
BALSSAG	*Balsamorhiza sagittata* (Pursh) Nutt.	*Balsamorhiza sagittata* (Pursh) Nutt.	Balsam-root
BROMANO	*Bromus anomalus* Rupr. ex Fourn	*Bromus anomalus* Rupr. ex Fourn	Nodding brome
BROMCAR	*Bromus carinatus* Hook. & Arn	*Bromus carinatus* Hook. & Arn	Mountain brome
BROMCILI	*Bromus ciliatus* L.	*Bromus ciliatus* L.	Fringed brome
BROMINE	*Bromus inermis* Leyss. ssp. *inermis*	*Bromus inermis* Leyss. ssp. *inermis*	Smooth brome
BROMPUM	*Bromus inermis* spp. *pumpellianus* (Scribn.) Wagnon	*Bromus inermis* spp. *pumpellianus* (Scribn.) Wagnon	Northern awnless brome
CALACAN	*Calamagrostis canadensis* (Michx.) Beauv.	*Calamagrostis canadensis* (Michx.) Beauv.	Marsh reed grass
CALAMON	*Calamagrostis montanensis* Scribn. ex Vasey	*Calamagrostis montanensis* Scribn. ex Vasey	Plains reed grass
CAMPROT	*Campanula rotundifolia* L.	*Campanula rotundifolia* L.	Bluebell
CARDCHA	*Cardaria chalapensis* (L.) Hand.-Maz..	*Cardaria chalapensis* (L.) Hand.-Maz..	Double bladder-pod
CAREX	*Carex* sp.	*Carex sp.*	Sedge
CASTCUS	*Castilleja cusickii* Greenm.	*Castilleja cusickii* Greenm.	Yellow Indian Paintbrush
CERAARV	*Cerastium arvense* L.	*Cerastium arvense* L.	Mouse-eared chickweed
CHRYLEU	*Chrysanthemum leucanthemum* L.	*Leucanthemum vulgare* Lam.	Ox-eye daisy
CIRSARV	*Cirsium arvense* (L.) Scop.	*Cirsium arvense* (L.) Scop.	Canada thistle

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
CIRSFLO	*Cirsium flodmanii* (Rydb.) Arthur	*Cirsium flodmanii (Rydb.) Arthur*	Floodman's thistle
COLLLIN	*Collomia linearis* Nutt.	*Collomia linearis* Nutt.	Collomia
COMAUMB	*Commandra umbellata* (L.) Nutt.	*Commandra umbellata* (L.) Nutt.	Bastard-toadflax
CREPINT	*Crepis intermedia* Gray	*Crepis intermedia* Gray	Goats-beard
DACTGLO	*Dactylis glomerata* L.	*Dactylis glomerata* L.	
DANTINT	*Danthonia intermedia* Vasey	*Danthonia intermedia* Vasey	Intermediate Oat grass
DANTPAR	*Danthonia parryii* Scribn.	*Danthonia parryii* Scribn.	Parry's oat grass
DESCSPP	*Descurainia* sp.	*Descurainia* sp.	Tansy Mustard
DESCURAINIA	*Descurainia* sp.	*Descurainia* sp.	Tansy Mustard
DODECON	*Dodecatheon conjugens* Greene	*Dodecatheon conjugens* Greene	Shooting star
DRABAUR	*Draba aurea* Vahl ex Hornem.	*Draba aurea* Vahl ex Hornem.	Draba
DRABNEM	*Draba nemorosa* L.	*Draba nemorosa* L.	Draba
ELAECOM	*Elaeagnus commutata* Bernh. ex Rydb.	*Elaeagnus commutata* Bernh. ex Rydb.	Wolfwillow
ELYMDAU	*Elymus dauricus*	*Elymus dauricus*	Dahurian wild rye
EPILAUG	*Epilobium angustifolium* L. *ssp. angustifolium L*	*Chamerion angustifolium* (L.) Holub ssp. Angustifolium	Fireweed
ERIGCAE	*Erigeron caespitosus* Nutt.	*Erigeron caespitosus* Nutt.	Tufted fleabane
ERIGGLA	*Erigeron glabellus* var. *pubescens* Hook.	*Erigeron glabellus* var. *pubescens* Hook.	Smooth fleabane
ERIGSPE	*Erigeron speciosus* (Lindl.) DC.	*Erigeron speciosus* (Lindl.) DC.	Showy fleabane
ERIGERON	*Erigeron* sp.	*Erigeron sp.*	Fleabane
EUROLAN	*Eurotia lanata*	*Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit	Winter fat
FESTCAM	*Festuca campestris* Rybd.	*Festuca campestris* Rybd.	Rough fescue
FESTIDA	*Festuca idahoensis* Elmer	*Festuca idahoensis* Elmer	Bluebunch fescue

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
FESTOVI Dur	*Festuca ovina* var. *duriuscala* (L.) Koch.	*Festuca trachyphylla* (Hack.) Krajina	Hard fescue
FESTOVI	*Festuca ovina* L.	*Festuca ovina* L.	Sheep fescue
FESTRUB	*Festuca rubra* L.	*Festuca rubra* L.	Creeping red fescue
FESTSAX	*Festuca saximontana* Rydb.	*Festuca saximontana* Rydb.	Rocky mountain fescue
FRAGVIR	*Fragaria virginiana* Duchesne ssp. *glauca* (S. Wats.) Staudt	*Fragaria virginiana* Duchesne ssp. *glauca* (S. Wats.) Staudt	Strawberry
AGASURT	*Gaillardia aristata* Pursh	*Gaillardia aristata* Pursh	Gaillardia
GAILARI	*Gaillardia aristata* Pursh	*Gaillardia aristata* Pursh	Gaillardia
GALIBOR	*Galium boreale* L.	*Galium boreale L.*	Northern bedstraw
GENTAMA	*Gentianella amarella* (L.) Boerner ssp. *acuta* (Michx.) J. Gillett	*Gentianella amarella* (L.) Boerner ssp. *acuta* (Michx.) J. Gillett	Northern gentian
GERARIC	*Geranium richardsonii* Fisch. & Trautv.	*Geranium richardsonii* Fisch. & Trautv.	Wild white geranium
GERAVIS	*Geranium viscosissium* Fisch. & C.A. Mey. ex C.A. Mey.	*Geranium viscosissium* Fisch. & C.A. Mey. ex C.A. Mey.	Sticky purple geranium
GEUMTRI	*Geum triflorum* Pursh	*Geum triflorum* Pursh	Three-flowered avens
HACKFLO	*Hackelia floribunda* (Lehm.) I.M. Johnston	*Hackelia floribunda* (Lehm.) I.M. Johnston	Stick-seed
Hedysul	*Hedysarum sulphurescens* Rydb.	*Hedysarum sulphurescens* Rydb.	Yellow sweet vetch
HELIHOO	*Helictotrichon hookeri* (Scribn.) Henr.	*Helictotrichon hookeri* (Scribn.) Henr.	Hookers oat grass
HETEVIL	*Heterotheca villosa* (Pursh) Shinners	*Heterotheca villosa* (Pursh) Shinners	Golden Aster
HEUCCYC	*Heuchera cylindrica* Dougl. ex Hook.	*Heuchera cylindrica* Dougl. ex Hook.	Sticky Alum-root
HYMERIC	Hymenoxys richardsonii (Hook.) Cockerell	Hymenoxys richardsonii (Hook.) Cockerell	Colorado rubber-plant
JUNCBAL	*Juncus balticus* Willd.	*Juncus balticus* Willd.	Baltic rush
JUNCDRU	*Juncus drummondii* E. Mey.	*Juncus drummondii* E. Mey.	Rush
JUNICOM	*Juniperus communis* L.	*Juniperus communis* L.	Ground Junpier
JUNIHOR	*Juniperus horizontalis* Moench	*Juniperus horizontalis* Moench	Creeping Juniper

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
KOELMAC	*Koeleria macrantha* (Ledeb.) J.A. Schultes	*Koeleria macrantha* (Ledeb.) J.A. Schultes	Junegrass
LATHOC	*Lathyrus ochroleucus* Hook.	*Lathyrus ochroleucus* Hook.	Cream pea-vine
LESQARE	*Lesquerella arenosa* (Richards.) Rydb. var. *arenosa*	*Lesquerella arenosa* (Richards.) Rydb. var. *arenosa*	Sand bladder-pod
LIATPUN	*Liatris punctata* Hook.	*Liatris punctata* Hook.	Dotted Blazing star
LINULEW	*Linum lewisii* Pursh	*Linum lewisii* Pursh	Wild blue flax
LITHINC	*Lithospermum incisum* Lehm.	*Lithospermum incisum* Lehm.	Narrow leaved Puccoon
LITHRUD	*Lithospermum ruderale* Dougl. ex Lehm.	*Lithospermum ruderale* Dougl. ex Lehm.	Wooley gromwell
LOMAMAC	*Lomatium macrocarpum*	*Lomatium macrocarpum*	Long-fruited Parsley
LUPIARG	*Lupinus argenteus* Pursh	*Lupinus argenteus* Pursh	Perennial Lupine
LUPISER	*Lupinus sericeus* Pursh	*Lupinus sericeus* Pursh	Silky Lupine
MELIOFF	*Melilotus officinalis* (L.) Lam.	*Melilotus officinalis* (L.) Lam.	Yellow sweet clover
MENTARV	*Mentha arvensis* L.	*Mentha arvensis* L.	Wild mint
MONAFIS	*Monarda fistulosa* L.	*Monarda fistulosa* L.	Wild bergamot
MUHLCUS	*Muhlenbergia cuspidata* (Torr. ex Hook.) Rydb.	*Muhlenbergia cuspidata* (Torr. ex Hook.) Rydb.	Plains Muhly
OXYTSER	*Oxytropis sericea* Nutt. var. *spicata* (Hook.) Barneby	*Oxytropis sericea* Nutt. var. *spicata* (Hook.) Barneby	Early Yellow Loco-weed
OXYTSPL	*Oxytropis splendens* Dougl. ex Hook.	*Oxytropis splendens* Dougl. ex Hook.	Showy Loco-weed
OXYTVIS	*Oxytropis viscia* Nutt.	*Oxytropis borealis* DC. var. *viscida* (Nutt.) Welsh	Sticky Loco-weed
PENSALB	*Penstemon albidus* Nutt.	*Penstemon albidus* Nutt.	White Beard-tongue
PENSCON	*Penstemon confertus* Dougl. ex Lindl.	*Penstemon confertus* Dougl. ex Lindl.	Yellow Beard-tongue
PENSNIT	*Penstemon nitidus* Dougl. ex Benth.	*Penstemon nitidus* Dougl. ex Benth.	Smooth Blue Beard-tongue
PETACAN	*Petalostemon candidum* (Willd.) Michx.	*Dalea candida* Willd. var. *candida*	White Prairie Clover
PHLEPRA	*Phleum pratense* L.	*Phleum pratense* L.	Timothy

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
POACOMP	*Poa compressa* L.	*Poa compressa* L.	Canada Bluegrass
POAINT	*Poa interior* Rydb	*Poa nemoralis* L. ssp. *interior* (Rydb.) W.A. Weber	Inland Bluegrass
POAPRAT	*Poa pratensis* L.	*Poa pratensis* L.	Kentucky Bluegrass
POASPP	*Poa sp.*	*Poa sp.*	Undifferentiated Bluegrass
POTEARG	*Potentilla arguta* Pursh	*Potentilla arguta* Pursh	White Cinquefoil
POTEFRU	*Potentilla fruticosa* L.	*Pentaphylloides floribunda* (Pursh) A. Löve	Shrubby cinquefoil
POTEGRA	*Potentilla gracilis* Dougl. ex Hook.	*Potentilla gracilis* Dougl. ex Hook.	Graceful Cinquefoil
POTEPEN	*Potentilla pensylvanica* L.	*Potentilla pensylvanica* L.	Prairie Cinquefoil
PYROSEC	*Pyrola secunda*	*Orthilia secunda* (L.) House	Wintergreen
ROSAACI	*Rosa acicularis* Lindl. ssp. *sayi* (Schwein.) W.H. Lewis	*Rosa acicularis* Lindl. ssp. *sayi* (Schwein.) W.H. Lewis	Prickly Rose
ROSAARK	*Rosa arkansana* Porter	*Rosa arkansana* Porter	Prairie Rose
SALIX	*Salix* sp.	*Salix* sp.	Willow
SEDULAN	*Sedum lanceolatum* Torr.	*Sedum lanceolatum* Torr.	Common Stonecrop
SENECAN	*Senecio canus* Hook.	Packera cana (Hook.) W.A. Weber & A. Löve	Prairie Groundsel
SHEPCAN	*Sheperdia Canadensis* (L.) Nutt.	*Sheperdia canadensis*(L.) Nutt.	Buffalo-berry
SILEDRU	*Silene drummondii* Hook.	*Silene drummondii* Hook.	Drummond's Cockle
SISYMON	*Sisyrinchium montanum* Greene	*Sisyrinchium montanum* Greene	Blue-eyed grass
SMILRAC	*Smilacina racemosa* var. *amplexicaulis* (Nutt.) S. Wats.	*Maianthemum racemosum (L.*) Link *ssp. amplexicaule* (Nutt.) LaFrankie	False Solomon's-seal
SMILSTE	*Smilacina stellata* (L.) Desf.,	*Maianthemum stellatum* (L.) Link	Star-flowered Solomon's-seal
SOLICAN	*Solidago canadensis* L. var. *canadensis*	*Solidago canadensis* L. var. *canadensis*	Canada Godenrod
SOLIMIS	*Solidago missouriensis* Nutt.	*Solidago missouriensis* Nutt.	Low Goldenrod

Table A.1 (continued)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
SOLIMUL	*Solidago multiradiata* Ait.	*Solidago multiradiata* Ait.	Alpine Goldenrod
SOLISIM	*Solidago simplex* Kunth	*Solidago simplex* Kunth	Mountain Goldenrod
SOLISPA	*Solidago spathulata* DC.	*Solidago simplex* Kunth var. *spathulata* (DC.) Cronq.	Mountain Goldenrod
SOLIDAGO	*Solidago* sp.	*Solidago* sp.	Goldenrod
SPHACOC	*Sphaeralcea coccinea* (Pursh) Rydb.	*Sphaeralcea coccinea* (Nutt.) Rydb.	Scarlet Mallow
STELLONG	*Stellaria longifolia* Muhl. ex Willd.	*Stellaria longifolia* Muhl. ex Willd.	Long-leaved Chickweed
STIPCOL	*Stipa columbiana* Macoun	*Achnatherum nelsonii* (Scribn.) Barkworth ssp. *dorei* (Barkworth & Maze) Barkworth	Columbia Needle Grass
STIPCUR	*Stipa curtiseta* (A.S. Hitchc.) Barkworth	*Hesperostipa curtiseta* (A.S. Hitchc.) Barkworth	Western Porcupine Grass
STIPRIC	*Stipa richardsonii* Link	*Achnatherum richardsonii* (Link) Barkworth.	Richardson Needle Grass
STIPA	*Stipa* sp.	*Stipa* sp.	Undifferentiated Needle Grass
STIPVIR	*Stipa viridula* Trin.	*Nassella viridula* (Trin.) Barkworth	Green Needle Grass
SYMPOCC	*Symphoricarpos occidentalis* Hook.	*Symphoricarpos occidentalis* Hook.	Buckbrush
TANAVUL	*Tanacetum vulgare* L.	*Tanacetum vulgare* L.	Common Tansy
TARAOFF	*Taraxacum officinale* G.H. Weber ex Wiggers	*Taraxacum officinale* G.H. Weber ex Wiggers	Dandelion
THALVEN	*Thalictrum venulosum* Trel.	*Thalictrum venulosum* Trel.	Veiny Meadow Rue
THERRHO	*Thermopsis rhombifolia* (Nutt. ex Pursh) Nutt. ex Richards.	*Thermopsis rhombifolia* (Nutt. ex Pursh) Nutt. ex Richards.	Golden Bean
TRAGDUB	*Tragopogon dubius* Scop.	*Tragopogon dubius* Scop.	Goat's-beard
TRIFHYB	*Trifolium hybridum* L.	*Trifolium hybridum* L.	Alsike Clover
TRIFRA	*Trifolium pratense* L.	*Trifolium pratense* L.	Red Clover
TRIFREP	*Trifolium repens L.*	*Trifolium repens* L.	Dutch clover

Table A.1 (concluded)

Mnenomic	Moss (1994)	Kartesz (1994)	Common Name
VICIAME	*Vicia americana* Muhl. ex Willd. ssp. *americana*	*Vicia americana* Muhl. ex Willd. ssp. *americana*	American Vetch
VICISER	*Vicia sparsifolia* Nutt.	*Vicia americana* Muhl. ex Willd. ssp. *minor* (Hook.) C.R. Gunn	Narrow-leaved Vetch
VICISPA	*Vicia sparsifolia* Nutt.	*Vicia americana* Muhl. ex Willd. ssp. *minor* (Hook.) C.R. Gunn	Narrow-leaved Vetch
VIOLADU	*Viola adunca* Sm.	*Viola adunca* Sm.	Early Blue Violet
AGROHIR	X *Agroelymus hirtiflorus* (A.S. Hitchc.) Bowden	*Elyleymus* X *hirtiflorus* (A.S. Hitchc.) Barkworth	Rye hybrid
ZIGAELE	*Zigadenus elegans* Pursh	*Zigadenus elegans* Pursh	White Camas
ZIGAVEN	*Zigadenus venenosus* S. Wats. var. *gramineus* (Rydb.) Walsh ex M.E. Peck	*Zigadenus venenosus* S. Wats. var. *gramineus* (Rydb.) Walsh ex M.E. Peck	Death Camas