Long-term Revegetation Success of Industry Reclamation Techniques for Native Grassland:

Northern Fescue Natural Subregion

Natural Recovery - Rumsey

Rough Fescue Seeding

Narrow-strip Pipeline - Seeded

Prepared For:
PTAC Petroleum Technology Alliance Canada

July 2014

Prepared By:
J. Lancaster, M. Neville, P. Desserud, V. Craig, R. Adams, B. Adams, and J. Woosaree

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- Narrow-strip Pipeline - Seeded, courtesy of Peggy Desserud

Introduction

- Prairie Rose *(Rosa arkansana)*, courtesy of Varge Craig
- Northern Fescue Natural Subregion: Wintering Hills Ecodistrict, courtesy of Peggy Desserud

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1 INTRODUCTION

Industrial development on native grasslands is increasing across the prairies. Healthy range plant communities perform important ecological functions including; net primary productivity, maintenance of soil/site stability, capture and beneficial release of water, nutrient and energy cycling and plant species functional diversity (Adams et al. 2013). Unless we can restore functioning and self-sustaining native plant communities that are resilient to invasive species, we stand to lose our native grasslands. It is clear that our past and some current reclamation practices are not achieving this goal. The goal of this research project is to promote industry stewardship by minimizing the footprint and improving restoration potential on native plant communities.

This study is part of a multi-year, multi-stakeholder initiative to revisit industry revegetation strategies for native prairie in the Grassland Natural Region. Updating the guidelines is a two-step process based on collecting existing learnings, conducting field studies to gather new insight and then using this information to develop practical recovery strategies. The first document from this initiative; *"Recovery Strategies for Industrial Development in Native Prairie: The Dry Mixedgrass Natural Subregion of Alberta – 1st Approximation"*, was published February 2013. Data collection for the Mixedgrass occurred in 2011 and the resulting document, *"Recovery Strategies for Industrial Development in Native Prairie: The Mixedgrass Natural Subregion of Alberta – 1st Approximation"*, was published in March 2014.

This report presents a literature review and summarizes data collection from several sources to assess whether past and present reclamation strategies are achieving restoration of native grasslands in the Northern Fescue NSR.

The purpose of this study is to:

- Assess whether current reclamation methods are achieving the desired long-term goal of restoring native prairie (successes and areas to improve);
- Provide the long-term data to develop best management practices and appropriate revegetation strategies for industrial disturbances on native prairie in the Northern Fescue NSR;
- Link long-term monitoring data to current tools for reclamation planning, including GVI, AGRASID, the Range Plant Community Guides and the Rangeland Health Assessment handbook;
- Use the information collected to develop and update recovery strategies to support the intent of the 2010 Reclamation Criteria for Grasslands and to provide guidance for the oil and gas industry, reclamation practitioners, contractors, landowners and Government of Alberta regulatory authorities.

Prairie Rose (Rosa arkansana)

The following assessment of long-term revegetation success of industry reclamation techniques for native grassland in the Northern Fescue Natural Subregion is a collaborative project with contributions of historic project data, reclamation monitoring data, personal experience and reporting by a number of researchers, industry practitioners and industry sponsors. The compiled information includes:

- A literature review;
- Analysis of existing data from several research programs;
- Results of 2013 field monitoring studies on recovering industry disturbances; and
- Emerging reclamation methods from several current research trials addressing knowledge gaps.

The report synthesizes existing knowledge and the results of 2013 field monitoring surveys and links the results to ecological range sites and plant communities described in the Range Plant Community Guide for the Northern Fescue Natural Subregion (Kupsch et al. 2012).

Northern Fescue Natural Subregion: Wintering Hills Ecodistrict

2 RESTORATION CHALLENGES AND APPROACHES

Restoration of disturbed sites should focus on establishing a pathway or a trajectory consisting of desirable species associated with late seral to reference plant communities In the Northern Fescue NSR. Dominant species vary with ecological conditions. Mesic grasslands in the western regions, with Loamy soils (such as the Rumsey Natural Area), are dominated by plains rough fescue (*Festuca hallii*), western wheat grass (*Agropyron smithii*), western porcupine grass (*Stipa curtiseta*) and sedges. In eastern areas, with drier and sandy soils (such as the Wainwright area), species dominance shifts to sand grass (*Calamovilfa longifolia*), needle-and-thread (*Stipa comata*), and sand dropseed (*Sporobolus cryptandrus*) (Kupsch et al. 2012).

2.1 Climate, Soils and Physiography

The climate of the Northern Fescue NSR is characterized by a continental micro climate with relatively short summers, cold winters and low precipitation. Total annual precipitation in the Northern Fescue is lower than in all Grassland Natural Subregions except the Dry Mixed Grass and effective growing degree-days are lower than most of the surrounding Natural Subregions, (Kupsch et al. 2012). The combination of a short growing season with periods of drought can limit seedling germination, emergence and survival.

Hummocky to rolling hills systems with medium textured glacial till deposits occur to the east, south and western portions of the NSR, including the Neutral Hills, the Hand Hills and the Wintering Hills. The central portion of the NSR is a gently undulating fine textured till and lacustrine plain, and the north encompasses the southern portion of the Rumsey Natural Area (Natural Regions Committee, 2006).

The Northern Fescue NSR is described in the Agricultural Regions of Alberta Soils Information Database (AGRASID) as located in Soil correlation Area 4. Dark Brown Chernozemic soils dominate the NSR, with Solonetzic soils associated with saline and sodic soils common in the central plain (Natural Regions Committee, 2006).

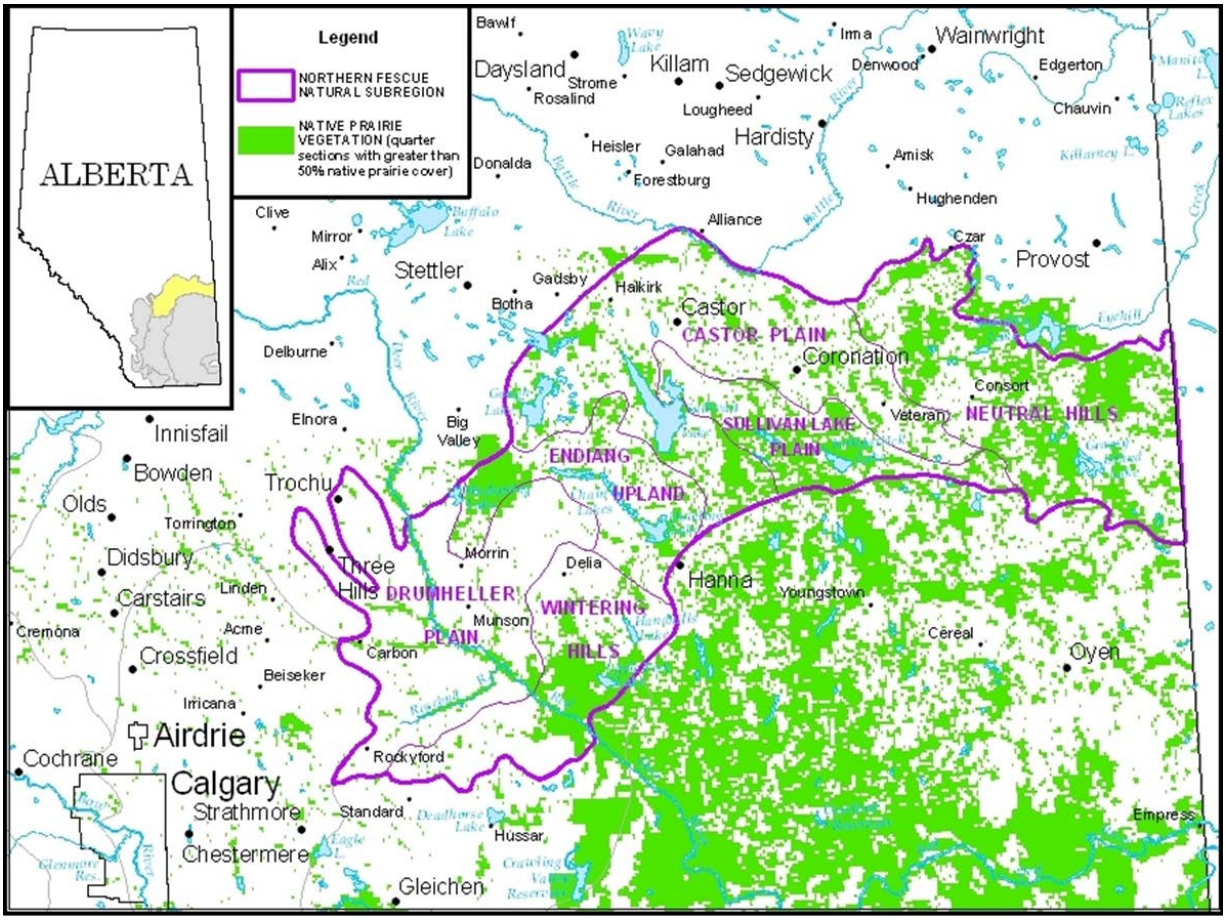
Plains rough fescue (*Festuca hallii*) plant communities dominate sites with average moisture regimes in the remaining upland native grasslands plant communities. Drier than average sites support communities typical of moister sites in the Dry Mixedgrass and Mixedgrass NSRs. Sites with higher than average moisture regimes support shrubland plant communities (Natural Regions Committee, 2006). At higher elevations and in hummocky topography, aspen forests dominate lower slope and north-facing aspects.

2.2 Fragmentation

The Northern Fescue is a mosaic of cultivated fields and remnant native prairie in the plains, with more contiguous native grasslands located in the Neutral and Hand Hills. Approximately 60% of the land base has been cultivated and is in agricultural annual crop production or forage and livestock production. Approximately 40% of the land base is remnant native grassland and shrubland plant communities (Natural Regions Committee, 2006). Figure 2-1 illustrates the mosaic of cultivation (white) and remnant native prairie areas illustrated as green (Kupsch et al. 2012).

Extensive oil and gas exploration and development occurred during the 1990s in native grassland. The construction practices of the day and the infrastructure required to drill and produce petroleum products in the region resulted in a mosaic of surface disturbances associated with wellsites, access roads, flow lines and sales lines. As well, large diameter pipeline corridors for oil, bitumen and natural gas occur within the NSR. Transmission lines, highways and rural road infrastructure contribute to native grassland fragmentation.

Figure 2-1 Ecodistricts and remaining native grassland in the Northern Fescue NSR



2.3 Invasive Non-native Plants

Extensive cultivation and industrial development in the Northern Fescue NSR can increase the risk of non-native plant invasion into native plant communities when surface soils are disturbed. Livestock grazing practices that reduce the vigour and cover of desirable native forage plants can also create an environment for the invasion of non-native plants. This includes Prohibited Noxious and Noxious weeds regulated under the Alberta Weed Control Act (Government of Alberta 2010). The nutrient rich loamy soils that dominate the remnant native grasslands provide an ideal growing matrix for aggressive non-native plants once the native vegetation is removed and the soils exposed. Forage crops, perennial hay land and tame pastures scattered throughout the landscape provide an abundant seed source of invasive agronomic species such as awnless brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*) and sweet clover (*Melilotus officinalis* and *Melilotus alba*). These agronomic species are known to invade exposed soils and encroach into adjacent native plant communities in the Northern Fescue NSR.

The remnant native grasslands of the Northern Fescue are a multiple use landscape. Ranching and farming are vital to local economies. Livestock grazing in native grassland is generally limited to summer months at higher elevations, with spring, fall and winter grazing generally confined to low elevation pastures. Agronomic forage is provided during the winter months. General landscape scale observations made during the 2013 field work for this project indicated invasive agronomic plants such as awnless brome or Kentucky bluegrass readily colonize disturbed soils in moist sites such as riparian areas and water courses or sites such as aspen clones where livestock congregate to seek shelter. Transportation corridors, and stripped and graded wellsites and pipelines built prior to 1993 and seeded to agronomic species provide additional seed source. These pockets and conduits of invasive plants provide a seed source for industrial soil disturbances.

2.4 Past Reclamation and Revegetation Practices

Prior to 1963, there was no requirement in Alberta to reclaim industrial disturbances, although some seeding with tame forages did occur. Alberta legislation requiring the reclamation of land disturbed by industrial activities came into effect in 1963 with the enactment of the Surface Reclamation Act. In 1973 the Land Surface Reclamation Act came into effect and provided for planning industrial development to minimize impact (Sinton 2001). Early reclamation practices were developed, the emphasis was placed on soil conservation and seeding with agronomic grasses such as crested wheat grass (*Agropyron cristatum*), and awnless brome to provide reliable vegetative cover to prevent soil erosion. From 1985 to 1993, reclamation practices focused on improving soil handling procedures, and erosion control. To facilitate precision in soil handling, the area of disturbance required for projects drastically increased. This led to increased disturbance of native plant communities and increased the risk of invasion by aggressive agronomic species invasion. From 1993 to the present, the importance of the native plant communities' role in ecological function has been recognized. The focus of reclaiming industrial disturbances has shifted towards reducing the footprint of industrial disturbance and where that is not possible, revegetating disturbed soils with native plant cultivars (Neville et al. 2013).

Topsoil stripping requires area for storage, resulting in a major soil disturbance. Although topsoil is stripped, stored and replaced, the procedure can result in admixing of soil horizons, and the dilution of the native seed bank (Elsinger, 2009). Wellsite lease construction practices observed during the 2013 field component of this project indicated that a majority of producing wellsites and access roads in native grasslands are full width stripped and graded sites. Many are producing oil facilities, graded and bermed for spill containment.

3 LITERATURE REVIEW

Revegetation practices have evolved over time, starting with little revegetation prior to the 1970s, to planting agronomic species in the 1970s and 1980s, and with attempts to restore pre-disturbance plant communities commencing in the late 1980s and 1990s. This literature review examines current and past research into revegetation of disturbances, focusing on the Northern Fescue NSR of Alberta.

3.1 Seeding

3.1.1 Wild Harvested Seed

One of the greatest obstacles to using native species or changing revegetation practices is the limited range and volume of commercially available native seed (Woosaree 2000). Wilson (2002) identified three major constraints to prairie restoration; lack of seed, among-year variability in establishment, and the persistence of introduced, non-native perennial species. Morgan (1995) outlined several wild seed collection methods: hand harvesting, native seed strippers and combines (if the area is large). Wild harvested seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, seed source genetic locations being incompatible with the reclamation site, knowledge of the collector, hand-collection methods, and storage methods (Morgan et al. 1995; Smreciu et al. 2003). Stewart (2009) and Morgan (1995) noted the importance of selecting the proper collection area and the prime seeding stage, sparing and avoiding rare or endangered species, and obtaining permission or permits as required. Stewart (2009) also cautioned wild seed collection takes time and requires patience. In particular, needle-and-thread and western porcupine grass seed are difficult to harvest due to sharp, hard awns (Barner 2009). Processing is complicated because awns get intertwined, reducing seed flow (Ogle et al. 2006; Bakker 2012).

Plains rough fescue may not produce large volumes of seed every year; however, when it does, plains rough fescue often has a mast-flowering event. Mast-flowering occurs when all occurrences of a species over a large area flower simultaneously. In 2006, plains rough fescue had a mast-flowering event in central Alberta, the first flowering in over 10 years (Desserud 2011). The density of plains rough fescue seeding following the mast flowering event in 2006, allowed Desserud and Naeth (2013a; 2013c) to harvest its seed with an agricultural combine in the Northern Fescue NSR. Nevertheless, occasional rough fescue plants flower every year, and may be harvested by hand (Tannas, S., personal communication. 2010). Desserud (Desserud, P., personal observation, 2010) and Woosaree (Woosaree, J., personal communication, 2013) and Tannas (Tannas S., personal communication, 2013) observed that young plains rough fescue plants flower 3 to 4 years following germination. Wild harvested plains rough fescue germinates readily in greenhouse conditions (Desserud and Naeth 2013c). Desserud and Naeth (2013c) and Sherritt (2012) had success seeding plains rough fescue on reclaimed sites in the Northern Fescue NSR.

Wild harvesting seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, the location of the seed source being not compatible with the reclamation site, the knowledge of the collector, hand-collection methods, and storage methods (Smreciu et al. 2003). In an analysis of germination of wild seed collection of 45 native species from the Central Parkland NSR, Woosaree and James (2004a) found poor germination in the majority of species, possibly due to timing of harvest resulting in collection of un-ripened seeds.

Sometimes germination in controlled environments, e.g. a greenhouse, is not reflected in field conditions. Romo et al. (1991) observed that when moisture is held constant most of the decline in germination of plains roughs fescue was accounted for by seed age. Nevertheless, Desserud (personal communication) and Neville (personal communication) found plains rough fescue germinated on seeded outdoor sites after seven to ten years of storage.

3.1.2 Native Grass hay

A variant of wild seed harvesting is cutting hay from native grassland to use as a mulch and seed source. Straw has long been used as a mulch or erosion control mechanism; however, using hay as a seed source is less well known. Hay was used as a seed source in the Central Great Plains after the drought years of the 1930s, yet few reports of using hay as a seed source have been published after the 1940s.

Factors which affect the viability of native hay include the variability of native seed production from year to year, e.g. some species do not produce seed every year; the timing, which will result in the dominance of whichever species have seeded at that time; and methods, such as tackifying, to keep the hay in place (Romo and Lawrence 1990). Another factor is the viability of seed if the hay is stored for future use. Interestingly, Reis and Hofmann (1983) found hay storage of one year did not decrease the amount of seedlings, and actually increased the establishment of some, those which require a period of dormancy. They also recommend cutting hay several times over the summer, storing it and cutting again the following year, to obtain the most diversity of seeds, e.g. different seeding times and years (Reis and Hofmann 1983).

The state of native grassland in close proximity to a disturbance is crucial in determining if native hay is a suitable seed source. Morgan (1995) cautions the large tractors required for native hay harvest may negatively impact native prairie, and that seed to soil contact may be difficult to achieve. In a plains rough fescue hay experiment in the Northern Fescue NSR in 2006, hay cutting was timed for when rough fescue was setting seed, an event that occurred in 2006, but had not occurred for at least five previous years (Desserud and Naeth 2011). Approximately 2.5 times the disturbed area was cut with a modified harvester. Native hay was sprayed upon a newly disturbed pipeline right-of-way and its growth monitored for three years. Seedling emergence from the hay included plains rough fescue , Kentucky bluegrass, June grass, western porcupine grass, yarrow (*Achillea millefolium*), and other forbs. They concluded native hay is a good seed source for native species in close proximity to a grassland disturbance, if desired species are present (Desserud and Naeth 2011).

3.1.3 Cultivars and Ecovars™

One solution to poor wild seed availability is the cultivation of commercially viable seed from native seed sources to produce a cultivar. A cultivar is a plant variety which has undergone genetic restriction through selection by plant breeders, and which has been registered by a certifying agency (Ferdinandez et al. 2005). However, many cultivars for sale in Canada were developed much further south in the U.S.A. and are structurally different than local plant materials (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Cultivars for several native grasses have been developed in Canada and are widely used in the reclamation industry. For example, Alberta Innovates - Technology Futures researches development of native grass cultivars and is the exclusive licensee for 15 native plant cultivars (Alberta Innovates - Technology Futures 2013).

While cultivation may improve the reliability of seed germination, it often results in a loss of species diversity as a result of genetic shift: the change in the genetic makeup of the line, variety, or hybrid if grown over a long period. For example, Ferdinandez et al. (2005) found an 8% decrease in genetic diversity in a cultivar of awned slender wheat grass (*Agropyron trachycaulum* ssp. *subsecundum* AC Pintail) after only two generations. Reduced diversity depends on how intensively the cultivar has been selected. If seeds of the cultivar are grown for further multiplication, it will lead to less diversity over time as the procedure is repeated. To maintain diversity for further production, one has to go back close to the seed source, even to the F1 generation for further multiplication (Woosaree, personal communication, 2014).

The loss of genetic diversity can also be partially offset by the annual infusion of wild harvested seed into the breeding mix (Burton and Burton 2002).

Cultivated rhizomatous wheat grasses, e.g. western wheat grass in particular, may be particularly persistent and could pose problems in native species restoration. In the Rumsey Natural Area, located in the Central Parkland and Northern Fescue regions, Elsinger (2009) found that approximately half of the wellsites, in plains rough fescue grassland, were dominated by western wheat grass and northern wheat grass (*Agropyron dasystachyum*), persisting for many years following reclamation seeding. As part of commercially available seed mixes, these species most likely were cultivars. Neville and Lancaster (2008) found green needlegrass (*Stipa viridula*) and prairie sand reed grass (*Calamovilfa longifolia*) native plant cultivars were persistent and larger than native species on parts of the Express Pipeline in the Northern Fescue NSR.

An ecovar™ is an ecological variety (coined by Ducks Unlimited) of a native plant species selected to produce a population containing maximum genetic variability (Woosaree 2000). Ecovars™ retain much more genetic variety than do cultivars, and theoretically will be more adaptable to environmental changes as a result. The result of a third type of native plant cultivation is termed “ecotype”. An ecotype is generally defined as a distinct genotype within a species, resulting from adaptation to local environmental conditions, and that can interbreed with other ecotypes of the same species (Hufford and Mazer 2003).

Despite their production in a Subregion which differs from their original source, the genetic uniqueness of native plant cultivars can be maintained by completely renewing the breeder plots every two generations with newly collected wild seed (Woosaree, personal communication, 2007). Following a review of ecovar™ and cultivar literature and information, Downing (2004) cautioned “Native cultivar or ecovar™ suitability in one NSR does not necessarily imply suitability in another.” Some successful native plant cultivars that have been grown by Alberta Innovates - Technology Futures include those suitable for Northern Fescue prairie soils, e.g. Canada wild rye (*Elymus canadensis*), slender wheat grass (*Agropyron subsecundum*), nodding brome (*Bromus anomalous*), Indian rice grass (*Oryzopsis hymenoides*) and blue grama (*Bouteloua gracilis*). Woosaree (2007a) also established plots of plains rough fescue. Due to concerns about original seed sources for rocky mountain fescue (*Festuca saximontana*) and widespread substitutions by the seed industry, seeding rocky mountain fescue is not advised.

3.1.4 Seed Mixes and Seeding Rates

Seed mixes play an important part in native grass revegetation. Emergence success for any seed mix will reflect the combined ability of individual species to emerge under site conditions (soil, climate, and revegetation practices). All else being equal (i.e. site conditions), the major factors affecting emergence will be seed size and seed dormancy (Woosaree and James 2006).

In a Northern Fescue grassland experiment, Woosaree and James (2004b) compared the recovery of plains rough fescue with three seed mixes:

1) plains rough fescue (67%) and awned wheat grass (33%);
2) plains rough fescue (67%) , green needle grass (17%), slender wheat grass (7%), June grass (*Koeleria macrantha*; 5%) and western porcupine grass (4%); and
3) a mix of plains rough fescue (67%) and seven native grasses , including the aforesaid species, Northern wheat grass and western wheat grass, and eleven forbs, including golden prairie aster (*Heterotheca villosa*), American vetch (*Vicia americana*), and others.

After five years, slender wheat grass (*Agropyron trachycaulum*) had started to die-back and be replaced by forbs. Plains rough fescue was present, but not dominant in all treatments, though after eight years, it had started to increase, especially in the mix with only slender wheat grass. They concluded the reduced canopy cover afforded by forbs, from the highly diverse seed mix, as well as slender wheat grass replacement, allowed slow growing rough fescue to increase over time. For plains rough fescue they concluded a time period of five years may be too short to observe plant community changes as they started to see an increase in rough fescue only by year eight and nine.

Desserud and Naeth (2013c) had success seeding plains rough fescue in a seeding experiment in the Northern Fescue NSR. Three years after seeding plots with 99% plains rough fescue, they found incursion of several native grasses, e.g. June grass, blue grama (*Bouteloua gracilis*), and western porcupine grass. They concluded the small stature of slow growing plains rough fescue provided sufficient space for other species to become established. In plots seeded with a native mix including 20% plains rough fescue and only 5% slender and western wheat grasses, wheat grasses dominated after 3 years and almost no rough fescue was found. Five years later, slender wheat grass had died back; however, still no rough fescue was found. They concluded the large stature of the initial slender wheat grass stands outcompeted rough fescue in its early stages and prevented its establishment (Desserud and Naeth 2013c), in contrast to Woosaree and James (2004b) findings.

Desserud and Naeth (2013c) conducted a nearest neighbour analysis of plains rough fescue plants and found larger growth when rough fescue grew close to other rough fescue plants or June grass. It had the shortest growth when growing close to wheat grasses.

Sherritt (2012) had success seeding plains rough fescue in a seeding experiment in the Northern Fescue NSR. He compared three seed mixes: plains rough fescue alone, a native mix including 30% plains rough fescue, and plains rough fescue with Dahurian rye (*Elymus dahuricus*), a common cover crop. He found plains rough fescue grew best when associated with other rough fescue plants or June grass, similar to Desserud and Naeth (2013c) findings. Plains rough fescue did not do well in plots with Dahurian rye, indicating it is not a good cover crop for rough fescue (Sherritt 2012). In a Northern Fescue grassland, a more diverse seed mix resulted in more diverse ground cover (Woosaree and James 2004b).

Hard-coated seeds, for example many *Stipa* species, such as western porcupine grass, may not germinate in the first year unless scarified. Without seed treatment they should be seeded with non-competitive, early establishers such as slender wheat grass, or forbs such as yarrow to give them a competitive edge after germination in the second year (Nurnberg 1994).

Seeding rates for native grass seed used in the reclamation projects of this review are in the order of 10 kg/ha (Table 3-1). Sinton et al. (1996) recommend a rate of 8 – 11 kg/ha for drilled seeds, cautioning that rates will vary depending on the size and weight of the seed. Some researchers consider this rate to be too high and may inhibit the invasion of native plants onto disturbed sites (Hammermeister and Naeth 1996).

Table 3-1 A Selection of Drill Seeding Rates for Projects in this Review

Source	Description and Region	kg/ha
Desserud and Naeth (2013c)	Wellsite reclamation in Northern Fescue	6.6-15.5
Sherritt (2012)	Wellsite reclamation in Northern Fescue	15
Sinton et al. (1996)	Native Plants on Disturbed Sites guide	8-11
Sinton (2001)	Oil and gas reclamation recommendations	10-12
Woosaree et al. (2004b)	Wellsite in Northern Fescue	12-18
Woosaree and James (2006)	Wellsite in Northern Fescue	9.9-16
Woosaree (2007b)	Pipeline in Northern Fescue	10

Small-seeded species must be seeded at a higher rate than larger-seeded species where a comparable emergence and stand density is desired Woosaree and James (2006). Where recruitment of resident native species is desired, the density of seeded species appears to be more important than initial plant cover, at least in the first establishment year. Using a lighter seeding rate or a seed mix with lower expected emergence success will likely favour local recruitment. This will also allow for smaller plants such as June grass and plains rough fescue to find room to grow (Desserud and Naeth 2013c).

3.1.5 Season of Seeding

The best season in which to seed native grasses depends on the species. Generally cool season grasses (C3), e.g. most wheat grasses, plains rough fescue, or June grass benefit from spring or early spring seeding. Nevertheless, Desserud and Naeth (2013c) and Sherritt (2012) had success seeding these species in mid-summer within the Northern fescue NSR. Tannas (2011) successfully planted Foothills rough fescue (*Festuca campestris*) plugs in July within the Foothills Fescue NSR. Warm season grasses (C4), for example blue grama, benefit from warmer soils in late spring and early summer. *Stipa* species, for example western porcupine grass or needle-and-thread, prefer late summer or fall seeding (Pahl and Smreciu 1999). Nurnberg (1994) found hard-coated seeds such as *Stipa* species, may not germinate in the first year unless scarified, which may be the reason for requiring a winter season following seeding. Desserud (personal observation 2011) noted western porcupine grass appeared three years after seeding on a wellsite in the Northern Fescue NSR.

Spring seeding preferences are probably related to higher spring moisture which would favour germination (Grilz 1992). Romo et al. (1991) found plains rough fescue to be particularly sensitive to moisture requirements and that water stress overrides temperature stress and narrows the conditions at which germination will occur. While Tannas (2011) noted Foothills rough fescue responded positively to increased water in greenhouse conditions, he also observed higher soil moisture increased the ability of Kentucky bluegrass to suppress Foothills rough fescue seedlings. Sherritt (2012) had success seeding plains rough fescue in late June and early July and Desserud and Naeth (2013c) had success seeding plains rough fescue in late July and early August in the Northern Fescue NSR.

Soil temperature also plays a role in native seed germination. A higher rate of germination in plains rough fescue can be expected when seedbed temperatures are increasing. Temperatures near 15° C appear to be most favourable for germination (Grilz 1992). Summer dormancy appears to be triggered by moisture stress, since in an experiment, where water was non-limiting, plains rough fescue did not enter dormancy, even at 27°C (King et al. 1998). As a result, in areas with moist summer periods, plains rough fescue may mature the later in the summer, even up to the latter part of July (Pavlick and Looman 1984).

3.1.6 Seed Lot Quality and Viability

Stewart (2009) recommends checking any purchased seed for purity, such as foreign or non-seed material, and germination rates. The seed company may provide this information or the seed may be tested by a laboratory (Stewart 2009).

The Seeds Act and Seeds Regulations of Canada establish standards for grading of crop seeds. Crop seeds include the majority of cultivated crops (including forage crops) grown in Canada but does not cover many native species (or non-crop seeds) used for reclamation of native ecosystems.

Current protocols for testing and reporting have some applicability to native reclamation species including; Pure Seed, Weed Seed Count (individual seeds per sample), Inert Matter, Pure Living Seed, Germination, Tetrazolium Chloride Test (TZ test) and Ergot.

Categories of the analysis and reporting methodology that are not applicable or have limited use are: Other Weed Seeds and Other Crop Seeds.

- The Other Weed Seeds category can include non-crop seeds from native sources such as graminoids, forbs and shrubs that are desirable for reclamation and restoration of native plant communities.
- The Other Crop Seeds can include invasive or non-native species and is too general to evaluate potential contaminants of individual invasive species seed, whose size and weight can vary significantly. A misinterpretation of the amount and effects of a contaminant invasive species in a seed lot could lead to reclamation failure through the establishment of a modified native plant community consisting of undesirable species.

Diligence is required when reviewing certificates for native seed lots to identify all undesirable seed impurities detected. Review of seed lot analyses must keep the above factors in mind when assessing seed lots for purchase. In addition, the testing date for Pure Living Seed, Germination and Tetrazolium should be less than two years old. The presence of noxious weeds, invasive agronomic species, persistent non-native species or plant diseases such as ergot, are reasons to decline reclamation seed lots.

3.2 Transplants, Plugs or Sod

3.2.1 Transplants or Sod

Transplant research for grasslands has focused on bunch grasses, with the goal of giving these slow-growing species a head-start in establishment. Petherbridge (2000) reported good early success with rough fescue grassland sod salvage three years following a pipeline restoration in the Northern Fescue NSR. The result was similar for plains rough fescue density on the sod salvage site and the undisturbed native grassland. He noted that the species composition of the sod salvage areas more closely resembled undisturbed grassland than seeded areas in the short term. From results in a Central Parkland site, Petherbridge (2000) cautioned that if the site initially contained many invasive species they can proliferate through sod salvage. Long-term monitoring after 14 years on the Central Parkland site illustrated that the sod salvage procedure favoured the recovery and increase in shallow rooted, rhizomatous non-native grasses over the deep rooted native bunch grasses. The presence of invasive non-native grasses such as Kentucky bluegrass and awnless brome in the stand prior to disturbance severely limits the success of the sod salvage procedure (Kestrel Research Inc. and Gramineae Services Ltd. 2011).

3.2.2 Plugs

Plugs are transplants of plants grown in greenhouse conditions from seed, normally in root trainer containers. Transplanting established seedlings has advantages over direct seeding, especially for slow-growing species such as plains or Foothills rough fescue. Such seedlings are allowed to develop in an environment protected from competition and environmental effects, thus avoiding the most vulnerable growth periods (Tannas 2011). Tannas (2011) had success with Foothills rough fescue plugs in a wellsite reclamation experiment in southwestern Alberta. Plugs were seeded and grown for four months prior to transplanting. The four month old plugs showed better drought resistance and competition resistance than three month old plugs. He found Foothills rough fescue plugs had better success than seeding, and also found plugs with larger plant size had the best success (Tannas 2011). Greenhouse plugs of plains rough fescue likely require closer to six months growth prior to planting out as this species has a slower establishment rate than Foothills rough fescue (Tannas 2011).

Climate conditions play an important role in plug survival, possibly even more so than seeds, which may survive dry conditions if not already germinated. Tannas (personal communication) found poor survival of plains rough fescue plugs planted into large surface disturbances in extreme dry conditions following a severe drought during reclamation of a pipeline in the Northern Fescue and Mixedgrass NSRs.

3.3 Competition among Native and Invasive Species

Reclamation efforts often must contend with the presence of non-native agronomic grasses, either on the original site, adjacent to it, introduced by grazing cattle or other human activity, including past reclamation practices. Some of these species are well adapted to the black or dark brown soils found in the western and central grasslands, e.g. awnless brome (*Bromus inermis*), crested wheat grass (*Agropyron cristatum*), timothy (*Phleum pratense*) and Kentucky bluegrass.

In an experiment on a wellsite in the Northern Fescue NSR, Desserud and Naeth (2013c) examined competition of plains rough fescue with other native grasses commonly found in reclamation seed mixes. They concluded the large size of slender wheat grass cultivars in the first three years following seeding may have a negative effect on plains rough fescue seedlings. In plots containing slender wheat grass, they found no plains rough fescue. In an analysis of nearest neighbours, they found plains rough fescue does best when in close proximity to other rough fescue plants, June grass or blue grama grass (Desserud and Naeth 2013c).

Sherritt (2012) compared three seed mixes: plains rough fescue alone, a native mix including 30% plains rough fescue, and plains rough fescue with Dahurian rye, a common cover crop. He found plains rough fescue grew best when associated with other rough fescue plants or June grass, similar to Desserud and Naeth (2013c) findings. Plains rough fescue did not do well in plots with Dahurian rye, indicating it is not a good cover crop for rough fescue (Sherritt 2012). Further research is needed to determine if any annual species could provide cover for plains rough fescue establishment.

Invasive species may do more damage than just their presence. In a greenhouse experiment, Jordan et al. (2008) found three invasive plants altered soil properties which negatively affected native species. They assessed soil attribute modifications by awnless brome, crested wheat grass and leafy spurge (*Euphorbia esula*). They found crested wheat grass soil modifications facilitated awnless brome; whereas leafy spurge facilitated both invasive grasses. Crested wheat grass had a negative effect on blue grama, June grass, asters (*Aster spp*.) and prairie coneflower (*Ratibida columnifera*). Awnless brome had negative effects on June grass, prairie coneflower and blue flax (*Linum lewisii*). Leafy spurge had antagonistic effects on all three forbs. On the other hand, needle-and-thread grass, green needle grass (*Stipa viridula*) and plains muhly grass (*Muhlenbergia cuspidata*) were relatively insensitive to altered soil properties (Jordan et al. 2008).

In a similar experiment in Wyoming, Mealor and Hild (2007) transplanted needle-and-thread plants from two areas: one invaded by quackgrass (*Agropyron repens*) and one not invaded. They examined evolutionary traits of needle-and-thread in response to close proximity to quackgrass. Their results showed no difference in needle-and-thread transplants; concluding, needle-and-thread grass is not affected by invasive species.

3.4 Invasive Species

Weed control practices are well described by Alberta government guides and enforced by regulating agencies; therefore, this review will not delve into detail regarding weed control. A few studies are presented that give interesting perspectives.

Colonizing weeds, including annuals, winter annuals and biennial plants, usually appear early in disturbance recovery. They may provide soil stability and microsites for perennial grass establishment. Desserud and Naeth (2013c) observed significant cover of annual weeds in the first two years after seeding a wellsite in the Northern Fescue NSR, e.g. flixweed (*Descurainia sophia*), lamb's quarters (*Chenopodium album*) or shepherd's purse (*Capsella bursa-pastoris*). By the third year, the majority of these weeds had disappeared, being replaced by well established perennial grasses (Desserud and Naeth 2013c). They noted similar results on a pipeline right-of-way seeded with native hay (Desserud and Naeth 2011).

Invasive species, including prohibited noxious and noxious weeds, problem introduced forage species and undesignated weeds of concern in native rangeland are often found on abandoned disturbances and will negatively impact recovery. On a wellsite in the Northern Fescue NSR, Sherritt (2012) concluded the presence of Canada thistle, yellow sweet clover (*Melilotus officinalis*) and awnless brome (*Bromus inermis*) negatively impacted establishment of seeded native species, such as plains rough fescue, June grass and possibly Hookers oat grass (*Helictotrichon hookeri*).

3.5 Soil Management Techniques

A diverse vegetation mix is unlikely to develop rapidly unless strategies to initiate diversity are incorporated in the reclamation planning. Such strategies include seedbed preparation through topsoil handling, enhancing the soil chemical and physical properties and improving the nutrient cycle with irrigation or soil amendments.

3.5.1 Handling Topsoil

Much of the literature on handling topsoil deals with the effects on the chemical, physical and microbial properties of the soil, and only a few were found with relation to resulting plant growth. Topsoil handling and storage can affect the potential success of disturbance recovery. Iverson and Wali (1982) found that seed bank density in four year old stored topsoil was considerably less than that in adjacent undisturbed prairie in North Dakota. The seeds of some species, e.g. pasture sagewort (*Artemesia frigida*) did persist up to four years in stored topsoil; however most others did not.

In a wellsite reclamation experiment in the Northern Fescue NSR, Desserud and Naeth (2013a) found pH levels on a wellsite with soil admixing (topsoil mixed with subsoil) ranged between 8 and 9; whereas, native grassland and wellsites with intact topsoil had pH levels around 7. Kentucky bluegrass (*Poa pratensis*) favoured higher pH levels; while plains rough fescue had a negative reaction to pH above 7.5. They recommend no soil admixing in disturbance reclamation to reduce potential Kentucky bluegrass invasion and improve plains rough fescue recovery (Desserud and Naeth 2013a).

3.5.2 Irrigation

Because grassland species are adapted to relatively dry conditions, irrigation may not be required to establish native seedlings. Plains rough fescue sets seed erratically, sometimes with 5 to 10 years between seeding events. Palit et al. (2012) tested plains rough fescue seedling reactions to nitrogen fertilizer and irrigation. They found seeding density increased with additional water and actually decreased with nitrogen applications (Palit et al. 2012). Despite being known as a drought tolerant species, Tannas (2011) noted Foothills rough fescue responded positively to increased water in greenhouse conditions.

3.5.3 Soil Amendments

Native plant species are generally adapted to nutrient poor conditions. While addition of nutrient and moisture can affect species productivity, it can favor the establishment of non-native invasive species over native species on reclamation sites (Adams, personal communication, 2013).

Blonski et al. (2004) had positive yield results with hog manure application in undisturbed Northern Fescue prairie even in drought years. They applied liquid hog manure once, at rates between 10 and 160 kg/ha, injecting the manure into native fescue grassland in good to excellent ecological condition. In years one and two, all herbage was harvested by clipping, separated into grass, forb or shrub, then dried and analyzed to determine herbage yield and crude protein. They found increased dry matter and crude protein yields for both grasses and forbs in the first year. Despite low rainfall, which should have negatively affected plant growth and primary production, yields continued to increase in the second year following manure application (Blonski et al. 2004). However, this study did not specifically evaluate biodiversity impacts and nutrient additions that are normally discouraged by regulators owing to the potential to shift moisture/nutrient regimes in favor of invasive species.

Larney et al. (2005) examined the effect on soil properties of four topsoil replacement depths and five amendment treatments: compost, manure, straw, alfalfa (*Medicago sativa*) and hay, aimed at reclaiming three wellsites in south central Alberta (Foothills Fescue and Northern Fescue NSRs). The result was increased organic carbon following the organic amendments. They theorized organic amendments play an important role in improving soil properties related to long-term productivity of reclaimed wellsites, especially where topsoil is scarce or absent (Larney et al. 2005). However, soil quality objectives may have potential negative impacts on plant community integrity and with respect to invasive species.

Desserud and Naeth (2013a) had success establishing plains rough fescue in straw amended soil in the Northern Fescue NSR. They applied straw at two rates – 1.0 kg and 0.5 kg/ha to topsoil replaced wellsites. Barley straw was chopped, sprayed onto the wellsite, and rototilled into the soil. Early in the first growing season, the site was mowed to remove volunteer barley plants germinating from the straw. They compared straw-treated responses to un-treated soil. Straw treatments positively affected growth of rough fescue, slender wheat grass, western wheat grass, June grass and blue grama. Weed cover was reduced on the straw treatments. They cautioned straw must be weed free (Desserud and Naeth 2013a).

Awnless brome had a negative response to straw-amended soil on a wellsite in the Northern fescue NSR (Desserud and Naeth 2010). The results were duplicated in a greenhouse experiment. Desserud and Naeth (2010) hypothesized that awnless brome may have a negative reaction to potassium leached from straw as it decomposes.

Soil amendments may also have little effect on some Northern Fescue grass species. June grass and blue grama did not respond to phosphorous or nitrogen fertilizers, nor to an inoculation of a native soil fungus, *Penicittium bilaii*, in a study of Manitoba grasslands (Friesen 2002).

3.5.4 Soil Nutrient Depletion

Even as late as the 1980s, reclamation practices mirrored agricultural methods. For example, Lloyd (1981) recommended crested wheat grass, among native grasses as a preferred species, and suggested fertilizer would probably be required, especially in Mixedgrass Prairie. More recently, the ability of many native species to out compete introduced species in nutrient poor soils has been recognized, with strong intervention by government regulators to eliminate invasive species like crested wheat grass.

Nitrogen is a key element in grassland ecosystems, because of its capacity to limit primary and secondary production. In a Northern Fescue NSR experiment, Desserud and Naeth (2013a) tested reducing soil nitrogen to assist plains rough fescue and other native grass establishment and impede Kentucky bluegrass. They incorporated chopped wheat and barley straw at three rates (1 kg/m^2, 0.5 kg/m^2 and none) into soil as an amendment on reclaimed wellsites. Plains rough fescue responded well to the straw amendment and lowered nitrogen; however, Kentucky bluegrass showed no trends one way or another (Desserud and Naeth 2013a). Desserud (2011) noted June grass, western wheat grass and blue grama also responded well to reduced nitrogen. Slender wheat grass performed well in all treatments.

3.6 Effects of Grazing

Animal herbivory, in particular cattle and wild ungulates, is a factor in grassland reclamation. Cattle are known to congregate on disturbed sites, probably attracted by the young growth, and may adversely affect the establishment of native grasses (Naeth 1985). Adler et al. (2001) examined the literature on the spatial patterns of grazing. Most studies conclude patch grazing, common in cattle grazing, alters plant communities and successional patterns. Fencing requirements will depend on the nature of the grazing operation being impacted by the development, ranging from simple deferral of grazing to one or more years of protection. Recent experience with wellsite reclamation in Alberta grasslands suggest that fences likely need to be removed after the initial season of growth, preventing an excessive build up of litter or residue and encouraging other native species to infill onto the reclaimed area.

In a Saskatchewan Mixedgrass experiment, Pantel et al. (2011) examined responses of northern wheat grass (*Agropyron dasystachyum*) and western porcupine grass following mowing during various months. Northern wheat grass showed no difference in recovery the year following mowing any month between April and October. Western porcupine grass, on the other hand, had poor recovery the year following mowing in August or September, and good recovery if defoliated April to July or October. They recommended western porcupine grass dominated grassland should be rested to at least one year if grazed in August or September.

Pantel et al. (2010) examined recovery of a Saskatchewan Mixedgrass NSR grassland on different slope aspects over 3 years following mowing a single time between April and October. The grassland was dominated by northern wheat grass, plains rough fescue and western porcupine grass. They recommended grazing be deferred for at least one year following mowing, especially if on north-facing slopes, or if grazing was in April, July, or August (Pantel et al. 2010).

Rotational grazing regimes may contribute to the success or failure of reclaimed native grassland. For example, plains rough fescue is suited to late summer, autumn and winter grazing (Horton 1992).

Long-term grazing can alter the species composition of grassland. Slogan (1997) documented the changes in species composition in rough fescue grassland in Riding Mountain National Park, Manitoba, over an twenty-two year period from 1973 to 1995. He discovered a decline in the abundance of plains rough fescue (*Festuca hallii*), a large increase in Kentucky bluegrass, and the presence of awnless brome, which was not present in 1973. Awnless brome was probably a direct result of cattle grazing (Slogan 1997).

3.7 Natural Recovery

The earliest examples of natural recovery in Alberta, whereby a disturbed site is reclaimed with no intervention, are the results of cultivated land abandoned and left to recover naturally. Natural recovery could result in an effective, though potentially slow native prairie recovery, with reduced revegetation and invasive species management costs. Coupland (1961) observed significant natural recovery of Mixedgrass prairie with the rate of recovery being influenced by the size of the disturbance, the time since abandonment and the supply of native seed stock. Conversely, the length of time may delay the issuance of a reclamation certificate and expose the site to erosion and invasive species establishment (Hammermeister and Naeth 1996). A number of factors affect potential success of natural recovery of RoWs from disturbance such as soil type, seed production on the site, range condition, proximity to undesirable vegetation species, length of soil storage, seasonal timing of soil replacement, exposure of the site to wind and water erosion, and pasture management (Lancaster et al. 2012).

Desserud and Naeth (2013b) and Elsinger (2009) monitored natural recovery of three pipelines in the Northern Fescue NSR. Pipelines were constructed with three techniques: plough-in, narrow topsoil strip, and “ditch-witch”. All techniques resulted in cover similar to undisturbed grassland. Plains rough fescue recovered best on plough-in pipelines, with little recovery on “ditch-witch” pipelines, which were dominated by western and northern wheat grasses. They concluded reducing sod disturbance contributed to plains rough fescue recovery, where intact sod would result in intact root structure. Plough-in had the most intact sod and the “ditch-witch” method had the greatest sod break-up (Desserud and Naeth 2013b).

Six natural recovery trials were established on the Express Pipeline in southern Alberta to evaluate the ability of the RoW to naturally revegetate without active re-seeding, relying on the existing seed bank and natural encroachment for seed material (AXYS Environmental Consulting Ltd. 2003). Sites were located in the Northern Fescue grassland, in the Montane on mountain rough fescue grassland and in the Dry Mixedgrass on sandy and on solonetzic soils. Disturbances between 10 m and 30 m wide and 30m long, on sandy soils, Solonetzic soils, wetlands Solonetzic soils and Dark Brown Chernozems in the Montane and Central Parkland were selected for the natural recovery trials. Reclamation techniques employed included straw crimping, straw crimping knolls and imprinting the seeded surface with a patterned roller (Accuroller) to create micro-relief. Six sample sites were established in each of the natural recovery trials representing each of the reclamation techniques. The sites were monitored over five years, during years 1, 2, 3, and 5 of post-construction (AXYS Environmental Consulting Ltd. 2003). Sites were re-monitored again at 14 years of post-construction (Neville and Lancaster 2008).

On the Express pipeline, natural establishment of vegetation on the disturbed, unseeded soils of the RoW varied in different NSRs. Trials on sandy soils were the most successful, with vegetation cover 10 percent greater on the unseeded sites than on seeded sites five years after construction. Native vegetation on sandy soils showed the greatest ability to recover quickly from short-term disturbance. Vegetation recovery from the seed or propagule bank resulted in 71 percent cover after five years while seeded soils resulted in a cover of 61 percent. More species were represented on the natural recovery sites than on the seeded sites (AXYS Environmental Consulting Ltd. 2003).

Fourteen years following construction on the Express Pipeline seeded species such as sheep fescue (*Festuca ovina*) and green needle grass persisted. Plains rough fescue was found on Northern Fescue NSR sites, either from seeding or natural recovery (Appendix A). On one site, invasive non-native species including Kentucky bluegrass and awnless brome were found encroaching from adjacent areas (Neville and Lancaster 2008).

Natural recovery will be influenced by the species composition of adjacent grassland and by the topography of the site. In a seeding and natural recovery experiment on a wellsite in the Northern Fescue region (Neutral Hills, Alberta) a natural recovery site was affected by its position, low on a slope with a mesic moisture regime, and the proximity of non-native species in the adjacent grassland. The resulting cover, ten years following reclamation, was predominately awnless brome with smaller amounts of Kentucky Bluegrass, both favouring moist locations (Fitzpatrick 2005).

Ten years recovery of one seeded block was predominately rough fescue, with other native species such as western porcupine grass, pasture sage (*Artemisia frigida*), and slender wheat grass making up the majority of the remaining cover. A third block also had plains rough fescue and slender wheat grass but also many undesirable forbs, e.g. Canada thistle, a noxious weed (Fitzpatrick 2005).

In natural recovery, early seral species, such as pasture sage, may appear (Woosaree and James 2006). Early seral forbs that are the first to colonize a disturbed site are often species considered to be weeds. Woosaree and James (2006) found annual weeds such as Russian pigweed (*Axyris amaranthoides*) and stinkweed (*Thlaspi arvense*) cover reached up to 31% in the first year following seeding and was even higher in natural recovery areas. They concluded these weeds were not a concern since they were annuals and would soon be replaced by perennial grasses.

On a pipeline in the Bodo Hills in the Northern Fescue NSR, Woosaree (2007b) compared natural recovery to two seed mixes. One seed mix had 50% plains rough fescue with 25% wheat grasses, while the second had 30% plains rough fescue and 5% wheat grasses. An assessment by Desserud and Naeth (2013b) ten years later showed good recovery of plains rough fescue (14% cover) on the natural recovery sites; however, no plains rough fescue on either of the seeded sites. Other species found on the natural recovery sites included Northern and Western wheat grass, June grass, pasture sage and plains muhly (*Muhlenbergia cuspidata*).

4 2013 MONITORING STUDIES

4.1 Monitoring Site Selection

Special Areas was the first jurisdiction in Alberta to recognize the need to use a seed mix composed of native species in reclamation mixes to "protect our dwindling native grasslands from further loss". In the mid-1990s the Land Conservation and Reclamation Council provided a list of "acceptable native and native friendly species to be used in the reclamation of surface disturbances". They recommended four seed mixes for use on Loamy, Sandy, Saline and Solonetzic Clay locations and described methods for establishment and seeding rate.

The oil and gas industry were not required to use native or "native compatible" seed mixes for reclaiming wellsites in native grassland in Alberta until 2001. Several of the non-native compatible species have turned out to be invasive over time, such as hard fescue (*Festuca duriuscula*) and sheep fescue. Others are persistent on the landscape (maintaining themselves indefinitely on a site once established) such as meadow brome (*Bromus biebersteinii*), tall wheat grass (*Agropyron elongatum*) and intermediate wheat grass (Agr*opyron intermedium*). As such, they create permanent changes in plant community composition and structure and create trending-to-modified or modified plant communities over time.

A list of potential wellsites to monitor long-term recovery of sites reclaimed with native seed mixes was developed from Special Areas and ESRD data files. Potential monitoring locations were selected within the Northern Fescue NSR from ESRD and Special Areas databases with the following filters:

- Inactive MSL's (reclaimed wellsites) within the Northern Fescue NSR or current reclamation applications;
- Within areas mapped as native grassland or on grazing leases;
- Reclamation sites older than 5 years with dispositions issued after 1994 at a minimum and post-2001 ideally for requiring seeding with native seed;
- Sites certified after 2003;
- Stripped wellsites, since these have the most consistent reclaimed surface for comparison between sites;
- Pastures with range condition scores of "healthy" or "healthy with problems";
- Sites with better documentation; and
- Sites where land owners or lessees could be contacted to agree to land access.

From this subset, 49 sites were selected for assessment. Information on reclamation details for each site were in most cases sparse or absent for older sites. A lack of documentation of reclamation site history prior to the initiation of the reclamation certification process was a gap identified during the 2013 monitoring study.

Monitoring surveys were conducted July 29th – Aug 2nd, 2013. Twenty-four sites were assessed (Appendix B.2: Table B.2-3). Despite the age of the wellsites between 1994 and 2007, the great majority of reclaimed wellsites turned out not to be native plant communities, although they were located in grazing leases or on Public Land. Some sites were located in tame pasture, others in native grassland were seeded to native compatible species, forages, or invaded by agronomic grasses, particularly awnless brome and sheep fescue. Detailed transects (Appendix B.1) were inventoried at two of the 23 grassland sites, where the surrounding native prairie was in good health. The other was a seeded flow line with trench width disturbance on a Loamy range site (seed mix composition unknown).

Several drilling companies and a pipeline company active in the NSR were also approached directly to participate in the data collection project. Apache Canada, CNRL and TransCanada provided access, historical project information, reclamation information, expertise and sponsorship to the project.

4.2 Data Collection Methods

Monitoring sites were established on existing wellsites and pipelines of various ages in each upland Ecological Range Site type in the Northern Fescue NSR. Sites were sought with available information on site history and reclamation treatments where possible (Appendix B).

For each assessment (disturbance and control), a 30 metre long transect comprised of ten micro-plots were installed to record vegetation species diversity and foliar cover estimates. The controls were an adjacent undisturbed plant community within the same ecological range site to compare vegetation cover, range health and reclamation progress.

Site locations were recorded using hand-held GPS units. Photographs were taken to document each site. A one metre square frame was placed directly over the disturbance and again at the control and photographed from above. A second photo was taken looking along the transect with the frame in the foreground. A third photograph was an oblique view of the Daubenmire frame.

Vegetation inventories were conducted using micro-plot sampling for species composition and canopy cover. A 20 cm x 50 cm Daubenmire frame was used for grassland communities and a 1 m x 1 m for shrubs. Ten frames were inventoried for each transect. Percentage foliar cover estimates of all vascular vegetation species, clubmoss, moss, lichen, litter and bare ground were recorded.

Data was recorded using standard ESRD – Rangelands MF5 range inventory forms and submitted to ESRD for entry into their Ecological Site Information System (ESIS) vegetation database.

A range health assessment was also conducted on disturbed soils and the undisturbed reference, based on the current manual developed by ASRD and LandWise Inc. (2010). Range health assessment provides perspective on the range capability of reclaiming communities. This technique also links current land use to the condition of the reclaiming grassland.

Data was interpreted in the context of tools developed for classifying rangelands including; Grassland Vegetation Inventory (GVI) mapping of ecological range sites (ASRD and LandWise Inc. 2010), AGRASID and the "*Northern Fescue Range Plant Community Guide*" (Kupsch et al. 2012), which links naturally occurring plant communities to ecological range sites. In the event that a plant community did not correlate to a plant community in the guide, then a name was assigned to the community based on what appeared to be key indicator or dominant species. The plant community name included the word "conditional" as an indicator of no known range plant community to date for the subregion.

4.3 Results Summary

4.3.1 Influence of Non-native and Native Compatible Seed Mixes

Older seed mixes from the 1980s and 1990s with high wheat grass concentrations and composed in part of non-native "compatible species" such as hard fescue, sheep fescue, meadow brome, intermediate wheat grass and tall wheat grass, have created permanent changes in plant communities. Compatible seeded species were part of the seed mixes appropriate to the time period (prior to 2010) or as outlined in historical agreements with the Land Manager. These species could be comprised of agronomics that were suitable for grazing purposes and native species but not be native to the subregion. These results are consistent between large surface disturbances from large diameter pipelines (Appendix B.1), full width stripped wellsites and small disturbances of $3m^2$ to 4 m^2 for minimal disturbance wellsites (Appendix B.2).

Wellsites seeded with non-native sheep fescue and hard fescue in a native grass seed mix had lower range health scores. These non-native hard fescues are highly palatable to livestock as they appear lush and green through most of the growing season. However they are quite resilient to grazing pressure, often to the detriment of other seeded native cultivars and native infill species on the recovering disturbance.

Many sites with invasive species establishment from seed mix components or common contaminants, like quackgrass and awnless brome, are now trending-to-modified plant communities. These changes to altered communities are likely to be permanent without significant and costly intervention.

4.3.2 Influence of Adjacent Disturbances on Revegetation of Disturbed Topsoil

To examine the influence of adjacent disturbances on the potential for restoration of disturbed topsoil, a series of sites were examined from parallel large diameter pipeline RoWs in the Northern Fescue NSR (Appendix B.1). Three pipelines of different construction ages, in a common corridor, were assessed. Construction dates were 1956, 1961, 1991 and 2009. Early construction methods with limited soil conservation would have been implemented on the pipelines with 1956 and 1961 construction dates. Where the terrain was challenging, the right of way was graded to allow the passage of equipment required to install the pipe. In level terrain the soil disturbance was mainly confined to the width of the trench. Portions of both pipelines appeared to have been seeded to agronomic species such as awnless brome, likely at the request of the landowners. On many natural recovery sites on the older lines, needle-and-thread and western porcupine grass, desirable infill native grasses and indicators of recovery, were dominant. These lines were built at a time when there was less disturbance on the landscape and natural recovery had some success.

Soil conservation methods were implemented throughout the 1991 pipeline right-of-way. However, this pipeline was one of the first pipelines constructed with an awareness of the need to minimize disturbance to the native grassland soils and vegetation. Detailed soil handling procedures were implemented to reduce the disturbance to the native grassland vegetation and soils. This RoW was seeded to a mix of native grass cultivars and agronomic species suitable for grazing. This type of seed mix was typical of mixes from the 1980s and 1990s, and included awnless brome, non-native sheep and hard fescues and native cultivars such as western and northern wheat grass. These seeded cultivars and agronomics have altered successional trajectories away from restoration of pre-disturbance native grassland communities and created permanent changes in community composition. Many sites with invasive species establishment from seed mix components or common contaminants like quackgrass (*Agropyron repens*) and awnless brome are now trending-to-modified species composition.

If older RoWs successfully revegetate to native cover they pose less risk to newer adjacent disturbances. Adjacent reclaimed vegetation composition can affect infill species composition on more recent large diameter pipeline RoWs. The three year old large diameter pipeline RoW which is immediately adjacent to the older lines, was seeded to several native seed mixes designed for a variety of range sites. On most sites a predictable early successional plant community dominated by seeded species, Green Needle Grass - Slender Wheat Grass – Northern wheat grass is present. Influence from adjacent invasive species is not prominent after three years, but may become more problematic with time. The most invasive species infilling on newer disturbances from older disturbances are awnless brome and Kentucky bluegrass. Three years after seeding, the larger differences in species composition appear to be due to reclamation treatments rather than infill from adjacent older pipeline RoWs.

Data collected from the 2013 field monitoring sites (Appendix B.1) documented four agronomic species that were seeded as non-native compatible species when recommended species were not available prior to 2010: sheep fescue, intermediate wheat grass, meadow brome and hard fescue.

No prohibited noxious weeds were reported from the 2013 monitoring sites. Noxious weeds reported included Canada thistle and perennial sow thistle (*Sonchus arvensis*). Wellsites and pipelines monitored in 2013 all reported herbicide control for broadleaf weeds. These herbicides do not control invasive agronomic grass species such as awnless brome, Kentucky bluegrass or crested wheat grass.

4.3.3 Recovery of Minimal Disturbance Wellsites

Development of minimal disturbance wellsites in native prairie is now standard practice for the majority of the oil and gas industry. This has resulted in much smaller areas of disturbed topsoil on wellsites and clusters of additional types of lesser disturbance including compaction and pulverization of vegetation.

Monitoring on two minimal disturbance wellsites owned by CNRL in the Neutral Hills on Sandy and Loamy range sites identifies much better restoration success on the minimal disturbance portion of the wellsites, where topsoil was not disturbed (Appendix B.2). For both the 56 year old disturbance and the 10 year old disturbance, minimal disturbance practices have resulted in recovery of the plant community composition and health to equivalent to off-site conditions, but not the disturbed topsoil areas. The most common challenge for restoration on disturbed topsoil in the Northern Fescue NSR is preventing the establishment of invasive non-native species.

Mechanisms that introduce non-native species to a site include:

- Non-native and native compatible seed mixes;
- Seed mix contaminants (Appendix A.1 and Appendix B.1);
- Additions of topsoil to a site (Appendix B.2);
- Infill from surrounding modified or trending-to-modified plant communities; and
- Transport by vehicles, animals and people.

Multiple treatments over several years are often required to promote a positive successional pathway towards restoration. For example, a topsoil disturbance on a wellsite on a Sand range site (Appendix B.2, CNRL02) was seeded three times over four years (2000 – 2003), straw crimped for erosion control in 2001, and treated with herbicide to manage broadleaf weeds in 2003. With this intensive adaptive management, the plant community developing on the disturbance is similar to the undisturbed area.

5 MULTIPLE PROJECT MONITORING STUDIES

5.1 Multiple Project Data Collection Methods

Vegetation inventory data from recovering industrial disturbances and associated controls in the Northern Fescue NSR was acquired from several sources in addition to the field data collected in 2013 by the project team. A cluster analysis was conducted to compare disturbed sites and controls (Appendix C).

5.2 Data Analysis and Interpretation

5.2.1 Cluster Analysis and Plant Community Ordination Methods

Detailed descriptions of the methods and results of the cluster analysis and ordination are presented in Appendix C. Several Grassland Vegetation Inventory (GVI) range site types were included in the cluster analysis including; Loamy, Overflow, Sandy and Blowout range sites with better soil development. These range sites were judged to be of similar productivity for comparison. An ordination illustrated fairly tight grouping of undisturbed control sites across these range site types, confirming the validity of combining them in the analysis. Cluster analysis of the control data resulted in eight species groupings, which were correlated with range plant communities described in the *Northern Fescue Range Plant Community Guide* (Kupsch et al. 2012). Control range plant communities and associated seral stage are presented in Table 5-1. Detailed descriptions for control clusters are presented in Appendix C: C.3.

Table 5-1 Control Plant Communities Correlated to the Northern Fescue NSR Range Plant Community Guide

Community Code	Range Plant Community	Seral Stage	Control Cluster
NFA1 high	Plains Rough Fescue – Western Porcupine Grass	Reference (Lo 1)	1
NFA1 low	Plains Rough Fescue – Western Porcupine Grass - grazed	Reference (Lo 1)	2
NFA2	Plains Rough Fescue - Kentucky Bluegrass	Late seral	6
NFC2	Snowberry/Plains Rough Fescue - Kentucky Bluegrass	Mid-seral	7
NFA7	Western Porcupine Grass - Plains Rough Fescue	Reference (Lo 2)	8
NFA10	Plains Rough Fescue - Sedge	Reference (BlO)	8
NFA8	Sedge - Plains Rough Fescue - Western Porcupine	Mid-seral	4
NFA9 Festhal	Blue Grama – Sedge – (Plains Rough Fescue)	Early to mid seral	5
NFA9 Stipcur	Blue Grama – Sedge – (Western Porcupine Grass)	Early to mid seral	3

A total of 179 sites compatible with the Loamy range site were included in the analyses. Disturbance data was collected primarily from areas where topsoil was disturbed and replaced during construction. Several data sets are also from minimal disturbance areas such as access roads and unstripped portions of wellsites. The data set includes data from undisturbed controls, large diameter pipelines, flow lines and wellsites, and encompasses a variety of ages, construction methods and reclamation treatments.

An initial cluster analysis of the entire data set, including undisturbed and disturbed site observations indicated that none of the disturbed sites clustered with the controls; whereas, undisturbed control sites across these range site types were fairly tight clustering, with no obvious outliers on a range site basis.

5.2.2 Assessment of Successional Stage

Succession is a process defined as the gradual replacement of one plant community by another over time. Seral stages are measures of succession used to describe the state and health of a plant community. More mature seral stages have greater range health and greater ability to perform ecological functions, including; net primary production, maintenance of soil/site stability, capture and beneficial release of water, energy and nutrient cycling and plant species functional diversity (Adams et al. 2013).

Assessing the seral stage on disturbance plant community clusters was based on species cover and composition, and an understanding of species persistence (for example annual weeds versus persistent long-lived species versus invasive species). Definitions for plant community seral stages on disturbed topsoil (Table 5-2) have been developed based on long-term reclamation monitoring on the Express Pipeline project (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Invasive non-native species are known to replace native species and establish permanent dominance in grassland communities. Reclaiming grassland sites where invasive non-native species occupy greater than 5% of the total live cover are at risk of succession to non-native modified plant communities.

Table 5-2 Definitions for Plant Community Seral Stages on Disturbed Topsoil

Seral Stage	Description
Bare ground	< 5% cover of live vegetation.
Pioneer	Site dominated by annual weeds, a cover crop or first year seeded colonizing grasses such as slender wheat grass.
Early seral	Site dominated by disturbance forbs such as pasture sagewort and other species such as low sedge. Seeded species and colonizing grasses such as spear grasses also establishing.
Mid-seral	Cover of grasses greater than that of disturbance forbs such as the sageworts; decreaser grasses present as a small component of the cover.
Late mid-seral	Cover of grasses greater than that of disturbance forbs such as the sageworts; decreaser grasses occupy about 50% of the cover; infill species present.
Late Seral - native	Cover of long-lived grass species expanding; native species cover from the seed bank established; slower establishing infill species present; decreaser grasses dominant; no more than one structural layer missing.
Late Seral - cultivars	Cover of long-lived grass species expanding; seeded cultivars clearly still dominant; slower establishing species such as fescues present; decreaser grasses dominant; no more than one structural layer missing.
Reference	Community closely resembles the ecological site potential natural community under light disturbance described in the Range Plant Community Guides.
Trending-to-Modified *	A primarily native plant community where non-native species are increasing over time and occupying > 5% of the total live cover; the succession time scale is as little as 5 and as many as 20 years or more.
Modified	> 70% cover of non-native species.

5.2.3 Influence of Ecodistrict on Range Plant Community

The location of control plant communities was not correlated to Ecodistrict. Similar undisturbed plant communities were found on Loamy, well developed Blowouts, Overflow and Sandy ecological range sites across each of the Ecodistricts sampled, including the Drumheller Plain, Endiang Upland, Neutral Hills, Oyen Upland and Wintering Hills.

5.3 Successional Plant Communities following Disturbance on Loamy Range Sites

Cluster diagrams (Appendix C.5) were produced for undisturbed monitoring sites and recovering disturbances associated with each control plant community (Table 5-1). The diagrams illustrate relationships between species cover and composition on disturbances and undisturbed sites. Across the range of control plant communities, most of the revegetation treatments (including seeded and natural recovery sites) are not clustering closely with the controls, indicating that species composition and cover on the reclaiming disturbance sites are not similar to the undisturbed plant community. However, many of the treatments appear similar to one another.

5.3.1 Time frame for Recovery

None of the disturbance plant communities are equivalent in composition, structure or range health to undisturbed control areas or to native plant communities described in the Northern Fescue Range Plant Community Guide (Kupsch et al. 2012), although some may be trending in this direction (Table 5-3). Only one of the sixteen groupings of disturbance plant communities from the cluster analysis (Plains Rough Fescue - Green Needle Grass - Slender Wheat grass) is categorized as a mid- to late seral plant community (Table 5-3). Succession to later seral stages appears to be slower on Loamy range sites in the Northern Fescue NSR as compared to Mixedgrass seeded sites, where forty percent of all sites where disturbed topsoil was seeded developed into a late seral plant community after 14 years (Kestrel Research Inc. and Gramineae Services Ltd. 2011). However, half of the undisturbed control Northern Fescue range plant community types assessed are also in early to mid-seral or mid-seral successional stages (Table 5-1). Plant communities at an earlier successional stage often have lower range health. Lower range health can affect the diversity and supply of propagules available to naturally revegetate a site. Longer time frames required for native grassland plant communities to recover following industrial disturbance mean that exposed soils are vulnerable for longer periods of time to colonization by invasive species. For example, early seral disturbance cluster 8 (Table 5-4), a Snowberry - Kentucky bluegrass shrubland community, is composed of eight older sites (33-55 years) which appear to have stabilized as an early seral native/non-native community.

5.3.2 Influence of Site Health on Recovery

Disturbance plant communities were more likely to develop native plant communities if range health scores for the comparable control were “healthy” or “healthy with problems”. However, trending-to-modified plant communities and modified plant communities can result whether range sites are healthy or not.

5.3.3 Influence of Invasive Species

About 29% of the observations in the full data set of 179 disturbance monitoring sites are plant communities that have greater than 70% relative cover of non-native vegetation (modified) or greater than 5% cover of persistent or invasive non-native species (Table 5-3). Dominant cover species of primary concern are the seeded non-native bunchgrass sheep fescue and aggressive rhizomatous grasses including awnless brome, Kentucky bluegrass and quackgrass.

5.3.4 Natural Recovery

Of the 36 observations of natural recovery sites in the combined data set, sixteen sites (44%) were trending-to-modified or modified plant communities. This recovery strategy represents a significant risk in the Northern Fescue NSR. Twenty-five sites (9%) were early or early to mid-seral plant communities and eleven sites (31%) had developed into mid-seral or late seral native plant communities. An assessment of the resiliency of sites where natural recovery is proposed, in terms of range health and the potential for invasive species incursion from surrounding areas, is necessary to assess the risk of failure.

Table 5-3 Successional Plant Communities following Disturbance on Loamy Northern Fescue NSR Sites

Seral Stage	Reclaiming Plant Community	# of Observations	Disturbance Cluster
pioneer	Pasture Sagewort - Slender Wheat grass	11	13A
early to mid-seral	Pasture Sagewort - Slender Wheat grass - Foxtail Barley	16	15
early to mid-seral	Pasture Sagewort - Green Needle Grass - Awned Wheat grass	11	14
early to mid-seral	Slender Wheat grass - Green Needle Grass	17	1
early seral	Snowberry - Kentucky Bluegrass	4	8
mid-seral	Slender Wheat grass - Green Needle Grass - Plains Rough Fescue	13	2
mid-seral	Green Needle Grass - Western Wheat grass - Awned Wheat grass	12	6
mid-seral	Western Wheat grass - Northern Wheat grass - Western Porcupine Grass	9	11
mid-seral	Northern Wheat grass - Western Porcupine Grass - Low Sedge	17	12
mid- to late mid-seral	Plains Rough Fescue - Green Needle Grass - Slender Wheat grass	17	5
mid-seral to trending-to-modified	Pasture Sagewort - Slender Wheat grass	11	13B
trending-to-modified	Awnless Brome - Slender Wheat grass - Kentucky Bluegrass	16	4
trending-to-modified	Kentucky Bluegrass - Western Wheat grass	11	9
trending-to-modified	Sheep Fescue - Western Wheat grass	5	7
modified	Quackgrass - Kentucky Bluegrass	4	10
modified	Awnless Brome - Kentucky Bluegrass	5	3

5.3.5 Native Seed Mixes

Dominant seeded species on older sites are green needle grass, northern wheat grass and western wheat grass, which when persisting may express as much taller and more dominant cover than local native seed stock. They are species and cultivars that typically have been most available over the past 20 years. Green needle grass is prominent on both younger and older sites and is represented above natural cover levels (Table 5-4). Similar long-term persistence and cover were observed on the Express Pipeline after 14 years in a variety of range sites (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Northern wheat grass and awned wheat grass are in the top three cover species on several early to mid-seral disturbance plant communities. Western wheat grass is also able to persist with aggressive agronomic grasses on older trending-to-modified sites.

5.3.6 Infill

An important early seral infill (spreading from undisturbed cover to the disturbance or from the seed bank) species in the Northern Fescue NSR is western porcupine grass. It is present in newer seed mixes but has also re-established successfully through infill on large diameter pipelines where topsoil was replaced in the same season after construction. It may take two or three seasons to become established if seeded; however, once established, it will persist on the site, providing diversity and structure and resilience to grazing.

Table 5-4 Descriptions of Reclamation Treatments associated with Successional Plant Communities Following Disturbance on Loamy Northern Fescue NSR Sites

Seral Stage	Reclaiming Plant Community	Description	Comment (treatment & age)	# of Obser-vations	Distur-bance Cluster
pioneer	Pasture Sagewort - Slender Wheat grass	Plant communities with relatively low total vegetation cover (10%); including low cover of native and seeded grasses, annual weeds and infill forbs	1 to 2 years since reclamation (Cluster 13 Subset A; 11 of 22 obs.)	11	13A
early to mid-seral	Pasture Sagewort - Slender Wheat grass - Foxtail Barley	Native plant community dominated pasture sagewort at 15.0% cover, slender wheat grass at 5.6% cover and foxtail barley at 5.8% cover	Native grass seed mixes, two diverse mixes of native grasses and forbs (ARC and collected,) and natural recovery; 9 of 16 sites are 1 or 2 years since reclamation and 7 of 16 sites are 3-5 years since reclamation	16	15
early to mid-seral	Pasture Sagewort - Green Needle Grass - Awned Wheat grass	Pasture sagewort established from infill. Seeded green needle grass and awned wheat grass are the dominant grasses; **Plains rough fescue cover at 4.5% and constancy of 90.9% is associated with seeded treatments**	Native grass seed mixes, two diverse mixes of native grasses and forbs (ARC and collected,) and natural recovery; Observations primarily 2-5 (13) years after reclamation.	11	14

Seral Stage	Reclaiming Plant Community	Description	Comment (treatment & age)	# of Obser-vations	Distur-bance Cluster
early to mid-seral	Slender Wheat grass - Green Needle Grass	Dominated by seeded species and minor cover of pasture and prairie sagewort; 13 of 17 observations appear to be on a positive trajectory to native dominated plant communities while **4 sites are trending-to-modified**	2-5 years since reclamation	17	1
early seral	Snowberry - Kentucky Bluegrass	Shrubland community dominated by buckbrush, common wild rose and **Kentucky bluegrass or quackgrass**	Older sites (33-55 years); appears to have stabilized as an early seral native/non-native community	4	8
mid-seral	Slender Wheat grass - Green Needle Grass - Plains Rough Fescue	Dominated by seeded species including **seeded plains rough fescue**		13	2
mid-seral	Green Needle Grass - Western Wheat grass - Awned Wheat grass	Dominated by seeded green needle grass, western wheat grass and awned wheat grass	Observations reclaimed with native grass seed mixes and agronomic seed mixes (may include native grasses) Observations 3 - 55 years after reclamation	12	6
mid-seral	Western Wheat grass - Northern Wheat grass - Western Porcupine Grass	Dominated by western wheat grass from infill and seed mixes with lesser cover of Northern wheat grass and June grass; Western porcupine grass present as infill	2 of 7 sites trending to a modified plant community; Kentucky bluegrass and sheep fescue are the dominant non-native species associated the trending-to-modified communities	9	11
mid-seral	Northern Wheat grass - Western Porcupine Grass - Low Sedge	Native plant community. Northern wheat grass and western porcupine grass established from infill and /or seed mixes, low sedge from infill; Plains rough fescue averaged 4.5% cover with a constancy of 58.8% and highly variable regarding site treatment and year since reclamation	Native grass seed mixes, agronomic seed mixes (may include native grasses) and as natural recovery; Observations 6 - 55 years following reclamation	17	12

Seral Stage	Reclaiming Plant Community	Description	Comment (treatment & age)	# of Obser-vations	Distur-bance Cluster
mid to late mid-seral	Plains Rough Fescue - Green Needle Grass - Slender Wheat grass	**Native plant community dominated by plains rough fescue** and seeded green needle grass and slender wheat grass, Western porcupine grass was present but at low cover and constancy	Dominance of plains rough fescue in this cluster may be due to minimal disturbance construction and / or superior reclamation practices	17	5
mid-seral to trending-to-modified	Pasture Sagewort - Slender Wheat grass	Includes observations with relatively low total vegetation cover (48%) 3 to 10 years since reclamation. Sites have low cover values for native and seeded grass species and high relative cover of non-natives species (18%)	Other disturbances such as moderate grazing pressure may be a factor in reducing cover and desirable species	11	13B
trending-to-modified	Awnless Brome - Slender Wheat grass - Kentucky Bluegrass	Dominated by invasive species awnless brome, Kentucky bluegrass and to a lesser extent quackgrass, alfalfa and crested wheat grass	Observations on primarily older sites; 3 sites 5 years old or less. 9-55 years old	16	4
trending-to-modified	Kentucky Bluegrass - Western Wheat grass	24% relative cover of non-natives species, including Kentucky bluegrass (19%), awnless brome (3%) and sheep fescue (1%)	Kentucky bluegrass present in 7 controls, absent in 4 controls but present in the adjoining disturbances	11	9
Trending-to-modified	Sheep Fescue - Western Wheat grass	56% relative cover of non-native species, including sheep fescue (32%), meadow brome (7%), intermediate wheat grass (2%) and Kentucky bluegrass (1%)	Older sites (19-51 yrs) reclaimed with a mix of agronomic and native grass species	5	7
modified	Quackgrass - Kentucky Bluegrass	Dominated by quackgrass, Kentucky bluegrass, sweet clover, dandelion, and to a lesser extent, awnless brome	Observations 8-38 years after reclamation, with native and compatible agronomic species mixes, an agronomic mix and a native mix	4	10
modified	Awnless Brome - Kentucky Bluegrass	Dominated by invasive species, seeded or infilled; awnless brome, Kentucky bluegrass, sheep fescue quackgrass, intermediate wheat grass, crested wheat grass and sweet clover	Older sites, surveyed 12 and 18 years since reclamation	5	3

5.4 Beneficial Reclamation Practices - Positive Recovery of Plant Communities on Loamy Range Sites

5.4.1 Diverse Seed Mixes

Recovering plant communities with promising recovering plant community composition are highlighted in the sites and treatments associated with the mid- to late seral recovering plant community cluster, Plains Rough Fescue - Green Needle Grass - Slender Wheat grass (Table 5-3).

This cluster of 17 observations (Appendix C.4 Disturbance Cluster 5) is composed of sites reclaimed with a variety of native grass seed mixes and a diverse mix composed of native grasses and ten forbs (Table 5-5 and Appendix D.1). All the Alberta Research Council (ARC), now known as Alberta Innovates - Technology Futures (AI) sites had 67% plains rough fescue in the seed mixes (Appendix C.1).

Vegetation monitoring transects were completed between 4 and 30 years following reclamation with the majority sampled 12 and 13 years after seeding, when slow growing late seral species like plains rough fescue have become established.

The cluster represents a native plant community dominated by plains rough fescue at 22% cover and seeded grasses green needle grass and slender wheat grass at 11% and 6 % cover, respectively. Western porcupine grass is present at low cover, averaging 3% with a constancy of 47%. The seeded native wheat grasses and green needle grass are present at lower cover than earlier seral clusters.

Dominance of plains rough fescue in this cluster could be due to minimal disturbance construction, high proportions of plains rough fescue in the seed mixes or superior reclamation practices. Desserud and Naeth (2013) observed that seed mixes with no or little wheat grass components may allow rough fescue time to become established by the third year, with reduced competition from fast-growing wheat grasses (Appendix E). The ARC / AI seed mixes that show good establishment of plains rough fescue also had low composition of wheat grasses in mixes M01 and M02 (Appendix D).

Desserud's 2013 rough fescue seeding study (Appendix E) demonstrated that the success of plains rough fescue establishment with little competition underscores the importance of reducing the amount and number of aggressive species in rough fescue grassland reclamation seeding. While monoculture seeding of plains rough fescue is not practical due to low seed availability and high cost, seed mix performance may improve by reducing or eliminating wheat grasses, and instead use other native grasses common in the area.

Prairie and pasture sageworts are the dominant native infill forbs, followed by wild vetch and common yarrow which could have come from native infill or the diverse seed mix treatment, or both. Inclusion of forbs in seed mixes may be beneficial to increase diversity. Long-term monitoring of infill on a BlO range site on the Express pipeline illustrated that infill of perennial forbs other than the disturbance sageworts is lacking after 14 years (1% cover) compared to the undisturbed grassland (14.5% cover) (Appendix A: Figure A.1-4). Forb cover was compared on four revegetation trials established by ARC on three wellsites in mesic plains rough fescue grassland settings (Appendix D:D.2). The trials included a natural recovery site, and three seed mixes including a simple grass mix, a diverse mix including 10 forbs, and a reclamation mix with only two species, plains rough fescue and slender wheat grass (Appendix D:D.1).

Forb cover was greatest and most consistent on the reference site, averaging between 30% and 40% cover. The cover of disturbance forbs may contribute to high forb cover levels on the seeded and natural recovery sites. Forb cover appears to decline on the natural recovery site and the simple mix site. Forb cover increases over time on the reclamation mix site, where only plains rough fescue and slender wheat grass were seeded. The forb cover is more stable with less fluctuation on the diverse mix site. The diverse seed mix included 10 forb species.

In the mid to late seral recovering plant community cluster, Plains Rough Fescue - Green Needle Grass - Slender Wheat grass (Table 5-3), 12 of the observations appear to be on a positive trajectory to native dominated plant communities. Kentucky bluegrass and awnless brome as individual or combined were present in 5 out of 12 sites at 3% to 5% cover. The remaining 4 observations are trending-to-modified with Kentucky bluegrass and awnless brome as individual or combined at 7% to 23% cover. This illustrates that despite best practices, managing invasive species is critical in the Northern Fescue and surface disturbance poses significant restoration challenges.

The risks associated with restoring surface disturbances are mitigated by minimal disturbance construction techniques. Desserud followed recovery of three newly-constructed pipelines in the Rumsey Natural Area which were left to natural recovery (Appendix F). Third year results were combined with Elsinger's (2009) data of natural recovery pipelines constructed between 1983 and 2000. Each of the pipelines was installed in a narrow trench, about 80 cm wide. Five of the pipelines were installed using a plough-in technique. A plough creates a narrow trench the width of the bucket, pipe is fed into the trench, and soil and sod are allowed to fall back into place. Six pipelines were topsoil-stripped, where topsoil was stripped from the trench and replaced following pipe installation. Two pipelines used ditch-witch construction, with a trencher that chops sod, mixing it with trench soil, and the broken sod/soil mix is used to cover the pipe.

Despite differences in specific species, all natural recovery pipelines had something in common with undisturbed grassland. They all have significantly more native species and few non-native species, such as Canada thistle, Canada bluegrass (*Poa compressa*) and awnless brome (Appendix F: Figure F.1).

Table 5-5 Treatments and Site Conditions Associated with a Recovering Mid- to Late Seral Disturbance Community (disturbance cluster 5)

Monitoring Site ID	Disturbance	Treatment	Years Since Reclamation	Control Plant Community	Control Community Seral Stage
AIHH04M01	Wellsite	ARC Simple Seed mix	9	NFA9 Feha	Early to mid seral
AIHH07M01	Wellsite	ARC Simple Seed mix	12	NFA1 high	Reference (Lo 1)
AIHH08M01	Wellsite	ARC Simple Seed mix	13	NFA1 low	Reference (Lo 1)
AINH04M01	Wellsite	ARC Simple Seed mix	9	NFA9 Feha	Early to mid seral
AINH07M01	Wellsite	ARC Simple Seed mix	12	NFA9 Feha	Early to mid seral
AINH08M01	Wellsite	ARC Simple Seed mix	13	NFA9 Feha	Early to mid seral
AIHH07M02	Wellsite	ARC Diverse Seed mix	12	NFA1 high	Reference (Lo 1)
AIHH08M02	Wellsite	ARC Diverse Seed mix	13	NFA1 low	Reference (Lo 1)
AINH04M02	Wellsite	ARC Diverse Seed mix	9	NFA9 Feha	Early to mid seral
AINH07M02	Wellsite	ARC Diverse Seed mix	12	NFA9 Feha	Early to mid seral
AIHH07M03	Wellsite	ARC Reclamation mix	12	NFA1 high	Reference (Lo 1)
AINH08M03	Wellsite	ARC Reclamation mix	13	NFA9 Feha	Early to mid seral
APAC02R	Wellsite	Full width strip; seeded	20	NFA7	Reference (Lo 2)
ELPL09D	Pipeline	Topsoil stripping, likely natural recovery	30	NFA1 high	Reference (Lo 1)
ELWS05D	Wellsite	Minimal disturbance, Natural recovery	4	NFA1 low	Reference (Lo 1)
ELWS21D	Wellsite	??		NFA1 low	Reference (Lo 1)
HUSK732R	Wellsite	Seed Mix	7	NFA7	Reference (Lo 2)

5.4.2 Use of Plains Rough Fescue Seedlings (Plugs)

Use of plugs or seedlings can provide a competitive advantage for slow growing species like rough fescue and can be used to increase diversity on a site, for instance with forb plugs. The data set for the three year old large diameter pipeline includes observations of 28 sites three years after plains rough fescue seedlings (plugs) were planted along with a native seed mix containing plains rough fescue seed (Appendix B.1). Sixty-four percent of the resulting plant communities are on a positive successional pathway and vary from early to mid-seral, and mid-seral successional stages. Plains rough fescue is not dominant on any sites but this is to be expected given the age of the sites and slow growth rates of rough fescue. Several direct observations of plug material during the third year monitoring document their persistence on the seeded RoW. Two sites have stalled at an early seral stage as a community where Kentucky bluegrass is dominant. Twenty-nine percent of the sites are mid-seral to trending-to-modified, or trending-to-modified, indicating a negative trajectory with greater than 5 percent invasive species present on site. These results illustrate that use of seedlings will not outcompete invasive species and emphasize the need for control of invasive species establishment before reclamation and thorough adaptive management after initial reclamation.

6 KEY FINDINGS AND GAP ANALYSIS

From the literature, data analysis and case studies

6.1 Restoration Potential

The monitoring studies support the conclusion from Elsinger 2009, that with few exceptions, disturbed soils support different plant communities than undisturbed soils. The productive soils of the Northern Fescue NSR have resulted in conversion and fragmentation from multiple land uses, principally agriculture. The health of the range before disturbance affects the ability of a disturbed area to respond and can affect the outcome of restoration. However, even healthy rangelands are vulnerable to invasive species establishment in a fragmented landscape. Invasive species are ubiquitous and major barriers to restoration in the Northern Fescue NSR. Re-introducing native plant materials to soil disturbances is needed to compete with invasive species.

6.2 Succession

Succession to later seral stages appears to be slower on Loamy range sites in the Northern Fescue NSR as compared to Mixedgrass seeded sites, where forty percent of all sites where disturbed topsoil was seeded developed into a late seral plant community after 14 years (Kestrel Research Inc. and Gramineae Services Ltd. 2011). However, half of the undisturbed Northern Fescue range plant community types assessed are also in early to mid-seral or mid-seral successional stages. Plant communities at an earlier successional stage often have lower range health. Lower range health in adjoining native prairie can affect the diversity and supply of propagules available to naturally revegetate a site. Longer time frames required for native grassland plant communities to recover following industrial disturbance mean that exposed soils are vulnerable for longer periods of time to colonization by invasive species.

6.3 Seeding

6.3.1 Cultivars

Cultivars for several native grasses are available in Canada and are widely used in the reclamation industry. However, many were developed much further south in the U.S.A and are structurally different than local plant materials. In Alberta successful native plant cultivars have been developed by the Alberta Research Council (now Alberta Innovates - Technology Futures). While cultivars may improve the reliability of seed germination, it often results in a loss of species diversity as a result of genetic shift (Woosaree 2007a). To maintain diversity for further production, one has to go back close to the seed source, even to the F1 generation for further multiplication (Woosaree, personal communication, 2014).

Observation and analysis of the 2013 field monitoring and from the Express Pipeline assessment and 2013 monitoring studies found that seeded non-native species such as sheep fescue and hard fescue will persist. Cultivars, such as green needle grass, may also dominate and persist over time (Kestrel Research Inc. and Gramineae Services Ltd. 2011). Dominant seeded cultivars on older sites are green needle grass, northern wheat grass and western wheat grass. They often persist at higher than natural cover levels due to expansion or high seeding rates. Western wheat grass is also able to persist with aggressive agronomic grasses on older trending-to-modified sites.

6.3.2 Wild harvested seed

Wild harvested seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, location of the seed source being not compatible with the reclamation site, the knowledge of the collector, hand-collection methods, storage methods and unreliable germination.

During a mast-flowering event for plains rough fescue, seed density may be sufficient for mechanical harvesting (Desserud and Naeth 2013c).

Native hay may be a viable technique for ensuring a reliable seed source that is adapted to local site conditions, but its success depends on the variability of native seed production from year to year, e.g. some species do not seed every year; the timing, which will result in the dominance of whichever species have set seed at that time; and methods, such as crimping, to keep the hay in place (Desserud and Naeth 2011).

6.3.3 Plains Rough Fescue

Locally developed plains rough fescue cultivars and wild harvested seed can produce a rough fescue plant community over time. However, seeded wheat grasses can inhibit establishment of seeded rough fescue.

Gaps

- Improved seed mix quality is needed including:
    - Locally developed cultivars/ecotypes; and
    - Wild harvested seed.
- What are the consequences of planting native cultivars from one NSR in a different NSR, or cultivating native cultivars from one natural region in a different natural region?
- Native seed collection could be incorporated into planning for development in an area, for example by harvesting native seed prior to development and storing it for reclamation use. Cutting and storing hay several times over a summer might be a useful technique.
- Plant cultivars should be periodically renewed with wild varieties to prevent establishment of aggressive traits, such as large size or prolific seed production.

6.4 Seed Mixes and Rates

Recommendations for seed mixes include:

- use proportionally less rhizomatous wheat grasses, e.g. western or northern wheat grass;
- use a more diverse seed mix and incorporate native species, and
- use broadcast seeding, which allows the incorporation of small native seeds (Hammermeister et al. 2003).

Slender wheat grass, although dying out within five years, may impede the establishment of slow-growing species such as plains rough fescue (Desserud and Naeth 2013c).

Seeding rate recommendations for native species have traditionally been around 10 – 15 kg/ha depending on seeding methods. Seeding rate should reflect the health of the surrounding community and the opportunity for infill or expression of a viable seedbank in the exposed soils to be seeded.

Gaps

- Little research exists regarding optimal seed mixes or seeding rates for any of the NSRs. What are the habitat requirements for specific native grassland species?
- Recommended seeding rates may be too high to allow infill or too low to create an effective barrier to erosion. What seeding rates are most effective and how do they differ by subregion?
- What effects do tall cultivars, e.g. slender wheat grass, have on rough fescue establishment?
- What native forb seed can be raised or harvested and added to seed mixes to improve diversity?
- How effective is top dressing a seeded site with additional seed or species in the years following to ensure infilling and establishment of native species?

6.5 Season of Seeding

The best season in which to seed native grasses depends on the species. Cool-season grasses (C3), including most wheat grasses, rough fescue and June grass, benefit from spring or early spring seeding, whereas warm-season grasses (C4), such as blue grama benefit from warmer soils in late spring and early summer. Nevertheless, several authors had success with mid-summer seeding of cool-season grasses (Tannas 2011; Sherritt 2012; Desserud and Naeth 2013c).

Gaps

- While the biology of cool and warm season species is well known, the application of seasonality to seeding has been little studied. Include the preferred season for seeding based on the native species in the area.

6.6 Seed Lot Quality and Viability

Prior to purchase or mixing, all reclamation seed lots should be tested by a certified seed testing laboratory for purity, such as foreign or non-seed material, invasive agronomics, plant diseases and germination rates. However, the Seeds Act and Seeds Regulations of Canada (Government of Canada 2014), which establishes standards for grading of crop seeds, does not cover many native species (or non-crop seeds) used for reclamation of native ecosystems. Diligence is required when reviewing certificates for native seed lots to identify all undesirable seed impurities detected. The testing date for Pure Live Seed, Germination and Tetrazolium should less than two years old. The presence of noxious weeds, invasive agronomic species, persistent non-native species or plant diseases such as ergot, are reasons to decline reclamation seed lots.

Gaps

- Presently, there isn't a set of standards for grading and testing native seed. The present procedure for testing native seed is based primarily on the standards established by the Canada Food Inspection Agency for crop seed. Reporting categories of the analysis methodology that are not applicable or have limited use are; Other Weed Seeds and Other Crop Seeds.
    - The Other Weed Seeds category can include non-crop seeds from native sources such as graminoids, forbs and shrubs that are desirable for reclamation and restoration of native plant communities.
    - The Other Crop Seeds can include invasive or non-native species and is too general to evaluate potential contaminants of individual invasive species seed, whose size and weight can vary significantly.

6.7 Transplants and Seedlings

Use of plugs or seedlings can provide a competitive advantage for slow growing species like rough fescue and can be used to increase diversity on a site, for instance with forb plugs. Several research projects have shown that native grass species, especially perennial bunch grasses, can be successfully transplanted or grown as plugs in greenhouses and planted. These projects were all small scale, e.g. Montane transplant project with bluebunch wheat grass and Richardson's needlegrass, plains rough fescue and Foothills rough fescue cuttings from mature plants in the Foothills Fescue NSR (Best and Bork 2003; Tannas 2011). Sod salvage has also had some success in the short term, again on a small scale (Petherbridge 2000). However, sod is vulnerable to invasion by rhizomatous species like brome and Kentucky bluegrass and favors survival of shallow-rooted species rather than deep-rooted species like rough fescue and other bunch grasses.

6.8 Plant Competition

Attempts to reduce or eradicate non-native grasses in native grasslands have met with little success since some non-native species are too aggressive to be completely eliminated once established (Desserud and Naeth 2013b).

Common cover crops, e.g. Dahurian rye, may actually reduce the establishment of some species, such as plains rough fescue (Sherritt 2012).

Gaps

- The difficultly in eliminating several non-native species once they are established (e.g. awnless brome, Kentucky bluegrass) emphasizes the avoidance of those species in revegetation projects.
- Is it possible that some aggressive invasive species may alter soil properties to the detriment of native grasses?
- Education and enforcement will be required to ensure only native species are seeded or transplanted where native grassland/riparian/forested areas are disturbed, or to rehabilitate sites in native grassland that had been improperly reclaimed with invasive species.

6.9 Soil Management Techniques

Topsoil storage may have a negative effect on seedbank viability and recovery (MacKenzie 2013). Most successful recovery appears to be in minimal disturbance conditions, e.g. no-strip or natural recovery (Desserud et al. 2010; Desserud and Naeth 2013b).

Altered pH in admixed soil may adversely affect native species and facilitate establishment of invasive species, such as Kentucky bluegrass (Desserud 2011).

Gaps

- While minimum disturbance is known to result in the best recovery, what other techniques are required and in what conditions? For example, erosion control or stream bank stabilization may require more intensive intervention.
- Further research into the effects of soil properties, e.g. pH on native species establishment.

6.10 Soil Amendments

Nutrient additions to soils are normally discouraged by regulators owing to potential negative impacts on native plant community integrity and the potential to shift moisture/nutrient regimes in favor of invasive species. Native grassland plants are generally adapted to nutrient poor conditions and outcompete introduced species in nutrient-poor soils. While addition of fertilizers and moisture may increase plant productivity, it can favor the establishment of non-native invasive species over native species on reclamation sites.

Straw amendment to reduce soil nitrogen may facilitate native species establishment and hinder some invasive species, such as awnless brome (Desserud and Naeth 2010; Desserud and Naeth 2013a).

Gaps

- Further research into the soil property changes of straw amendment and the effect on awnless brome.

6.11 Effects of Grazing

At least one year of no grazing is recommended following native grass establishment. Season of grazing and slope of disturbance may also affect recovery. Disturbance plant communities can affect grazing response and have long-term effects on pasture management. Palatability and life cycle can affect how grazers utilize a pasture. Species like sheep fescue and hard fescue green up earlier and can attract grazers to the disturbance, creating more pressure on the reclaiming site compared to the surrounding native plant community.

Fencing requirements will depend on the nature of the grazing operation being impacted by the development, ranging from simple deferral of grazing to one or more years of protection. Recent experience with wellsite reclamation in Alberta grasslands indicates that most fences need to be removed after the initial season of growth, preventing an excessive build up of litter or residue and encouraging other native species to infill onto the reclaimed area.

6.12 Natural Recovery

Natural recovery in areas of healthy grassland may result in an effective, though potentially slow native prairie recovery, with reduced revegetation and invasive species management costs. However, monitoring results show that there is a significant risk of invasion by undesirable, persistent or invasive non-native species on natural recovery sites in the Northern Fescue NSR. Of the 36 observations of natural recovery sites in the combined data set, sixteen sites (44%) were trending-to-modified or modified plant communities. This recovery strategy represents a significant risk in the Northern Fescue NSR. An assessment of the resiliency of sites where natural recovery is proposed, in terms of range health and the potential for invasive species incursion from surrounding areas is necessary to assess the risk of failure.

The length of time required for natural recovery of exposed soil may delay the issuance of a reclamation certificate and expose the site to erosion and weeds. The nature of disturbance may also affect the results of natural recovery. If deep-rooted species such as plains rough fescue roots are disturbed by sod chopping, e.g. “ditch-witch”, it may not recover (Desserud and Naeth 2013b).

Gaps

- Natural recovery may be considered the best solution for long-term recovery; however, it is not suitable in all situations. More analysis is required to determine the consequences of allowing a site to recover naturally rather than with assistance.

6.13 Persistent and Invasive Non-native Species

The most common challenge for restoration on disturbed topsoil in the Northern Fescue NSR is preventing the establishment of invasive non-native species. Persistent and invasive non-native species create permanent changes in plant community composition and structure and can transition to modified plant communities over time. Awnless brome and Kentucky bluegrass are problematic regardless of revegetation method. Other common invasive species include sheep fescue, hard fescue, Canada thistle, quackgrass, sweet clover and crested wheat grass. Adaptive management and treatment over several years are often required to promote a positive successional pathway towards restoration.

6.14 Infill

An important early seral infill species is western porcupine grass, which is found in the majority of the late seral to reference plant communities of the Northern Fescue NSR. It is present in newer seed mixes but has also re-established successfully through infill on large diameter pipelines where topsoil was replaced in the same season after construction. It may require two to three seasons to become established from seed; however, once established, it will persist on the site, providing diversity and structure and resilience to grazing.

Recovery of perennial forbs other than the disturbance colonizing sageworts is lacking on sites where grass seed mixes are used. Inclusion of forbs propagules in reclamation mixes can increase diversity on recovering disturbances.

6.15 Time frame for Recovery

Succession to later seral stages appears to be slower on Loamy range sites in the Northern Fescue NSR as compared to Mixedgrass seeded sites, where forty percent of all sites where disturbed topsoil was seeded developed into a late seral plant community after 14 years (Kestrel Research Inc. and Gramineae Services Ltd. 2011). However, half of the undisturbed control Northern Fescue range plant community types assessed are also in early to mid-seral or mid-seral successional stages.

Healthy native grassland communities include tall graminoids and forbs, medium height graminoids and forbs, ground cover of low graminoids, forbs, moss and lichen, and may include low shrubs as structural layers. Diversity in the canopy structure provides resilience to herbivory and climate events. Typically, reclaiming sites on disturbed soils lack a groundcover layer after 14 years or longer. Prairie selaginella, mosses and lichen are the major components of this layer. Bare soils were still more prevalent on the recovering RoWs after many years, which contribute to reduced health scores.

6.16 Reclamation Documentation and Monitoring

Lack of documentation of reclamation prescriptions and activities, particularly for wellsites and smaller pipelines is a gap when assessing successful versus less successful reclamation practices.

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Appendix A Express Pipeline Northern Fescue NSR Field Studies

Express Pipeline – Succession Results for a Native Seed Mix used in the Northern Fescue Natural Subregion

Background

Express Pipeline, owned and operated by Kinder Morgan Canada Inc., is a 24 inch (610 mm) crude oil pipeline that extends from Kinder Morgan's tank farm near Hardisty, Alberta, south 434 kilometres to cross the United States border at Wildhorse, Alberta. The permanent right-of-way (RoW) is 20m wide and an additional 10m of temporary workspace was required for construction.

Portions of the Express RoW cross native prairie in the Central Parkland, Northern Fescue, Mixedgrass and Dry Mixedgrass NSRs. The long-term impact of pipeline construction and reclamation on native prairie ecosystems was an issue identified by stakeholders early in the planning process in 1994. Express Pipeline's regulatory commitment was to reclaim the RoW in native prairie areas with the goal of establishing a positive successional trend towards the native plant community present prior to construction. This was an early opportunity to demonstrate minimum disturbance practices in the Grassland Natural Region. To pursue this goal, native seed mixes were developed, specialized seeding equipment was used, and erosion control procedures were implemented. Revegetation trials such as natural recovery were implemented to test the response of unconventional revegetation techniques.

A five year post-construction monitoring program was conducted between 1997 and 2001. Monitoring sites included; a diversity of soil types and native rangeland plant communities, construction practices, areas where spoil was stored directly on prairie vegetation, areas where construction vehicles were driven on the grass, and areas where disturbed soils were seeded or left to recover naturally. Additional monitoring in 2010, 14 years after construction, built on monitoring results collected in the initial five years.

The Express Pipeline Long-term Revegetation Monitoring Project (Express) provided industry and the Government of Alberta regulatory agencies with much needed data on the long-term revegetation success of reclamation techniques used on native prairie. To obtain a pdf version of the entire document or an abridged edition highlighting the key learnings of the study, visit the Foothills Restoration Forum website at http://www.foothillsrestorationforum.ca.

This section provides a summary of the findings associated with the assessment of reclamation techniques implemented on Express in the Northern Fescue NSR.

Revegetation Treatment – Site 4

One monitoring site was established on the Express Pipeline in the Northern Fescue NSR in the Castor Plain Ecodistrict on SW26-34-9-W4M. The site is a Blowout ecological range site, described as an upland plain with Solonetzic Blowouts and Loamy higher ground. The RoW was blade width stripped, creating a topsoil disturbance about 8m wide. The soils/terrain are HKR(5)/3 Sol (a Dark Brown Solodized Solonetz) and the site was cleaned up and seeded in fall of 1996. The seed mix used for the plains rough fescue site was composed of both native cultivars and wild harvested species. The mix included pioneer and long lived species and species designed to provide cover and structure. Seed mix composition and the rate of application (12 kg/ha) was designed to allow infill and natural succession to occur. Components of the seed mix, "Rough Fescue - Mixedgrass Transition Prairie (Express Seed Mix 2)" are presented in Table A-1.

Table A-1 Rough Fescue - Mixedgrass Transition Prairie (Express Seed Mix 2)

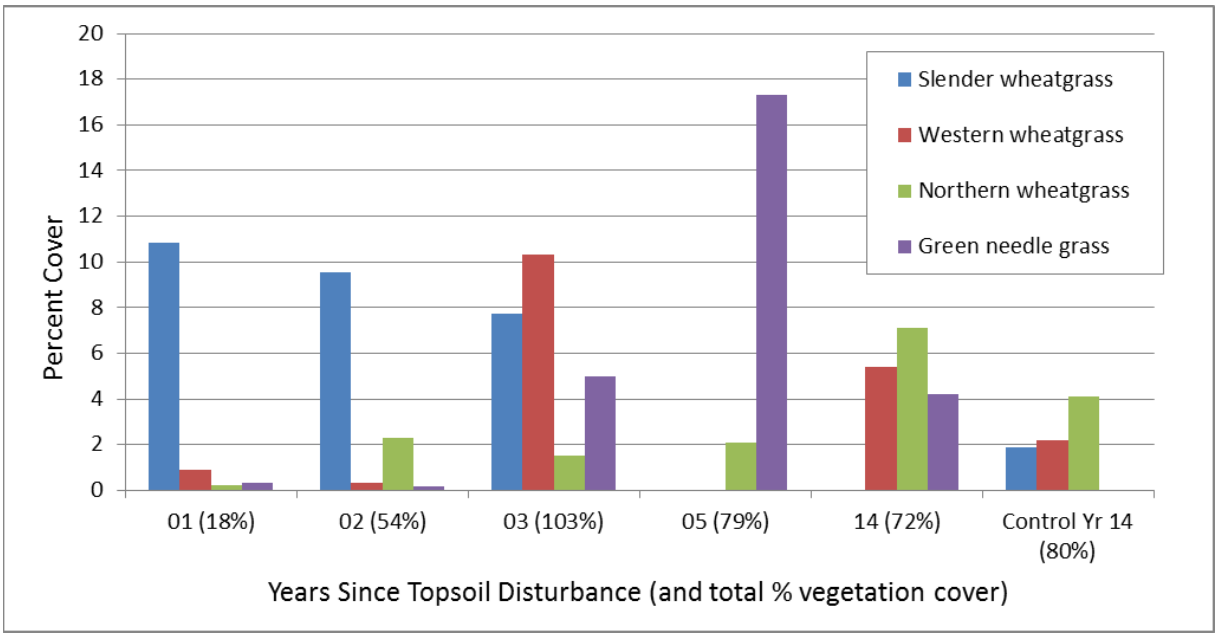
Species	Seeds/g	PLS	Est%	PLS/m2	Plt/m2	kg/ha	%/wt	Total kg
Streambank wheat grass	344	92	25	60	15	1.9	16.3	664
Northern wheat grass	345	92	25	24	6	0.8	6.5	265
Western wheat grass	242	92	25	24	6	1.1	9.3	377
Slender wheat grass *Revenue*	353	83	25	20	5	0.7	5.9	239
Slender wheat grass *Adanac*	353	86	25	28	7	0.9	7.9	323
Green needle grass *Blight*	398	88	10	43	4	1.2	10.4	425
Indian rice grass	518	86	10	50	5	1.1	9.7	393
June grass *Gillespie*	3300	84	10	71	7	0.3	2.2	89
Plains rough fescue *Roes*	386	77	10	25	3	0.8	7.3	296
Rough fescue *Petherbridge*	386	77	10	85	8	2.9	24.6	1000
Totals				**429**	**66**	**12**	**100**	**4,069**

A.1 Native Seed Mix Performance

The performance of each species in the seed mix in terms of cover was tracked over time and compared to undisturbed native plant community on the adjacent control. Figure A-1 illustrates the cover each year of the dominant cultivars in the seed mix (Table A-1). Indian rice grass did not establish on this Blowout range site. No distinction is made between different cultivars of the same species, between streambank and northern wheat grass and between the two wild harvested rough fescue seed lots. It is also not possible to determine what percentage of establishment is from the existing seed or propagule bank in the vicinity.

Breaking up of the hard pan layer on a blowout range site during topsoil stripping and replacement will also affect species response, which can be more vigorous when compared to plant growth on the undisturbed control area.

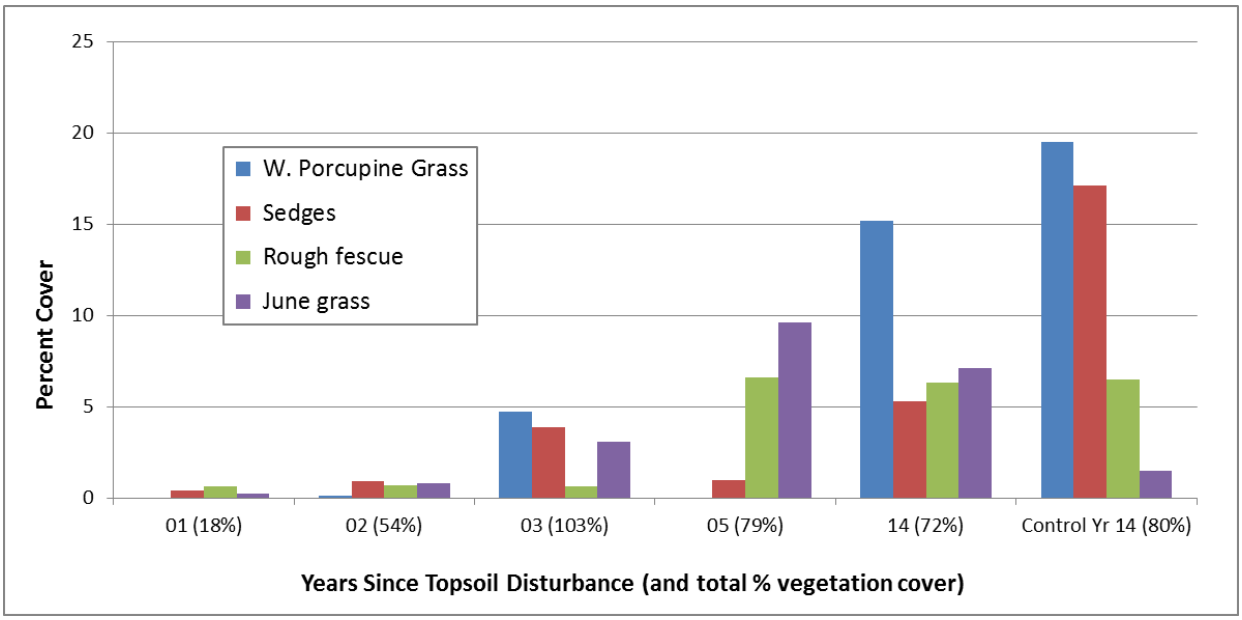
Figure A-1 Expression of Dominant Seeded Grass Cultivars over Time for Express Site 4



Cultivars

- The two slender wheat grass cultivars, *Revenue* and *Adanac*, behaved as transition species, establishing in the early years and providing initial cover to stabilize soils, build litter and shelter other seedlings. Both cultivars have disappeared from the plant community by the fifth year, which was a drought year.
- Northern wheat grass and streambank wheat grass provided consistent cover during the first five years, including the drought year, and at year 14 provided cover values 1.5 times the controls. The seeded cultivars are more robust and taller than their natural counterparts.
- Western wheat grass provided early cover, but not during the drought year. It was present at 2.5 times the natural cover at year 14.
- Green needle grass is not present in the native rangeland control. The seeded cultivar slowly increased cover during the years, and was the dominant species (at 17% cover) on the site during the drought year of 2001, along with pasture sage (at 31% cover). It may out-compete other species for scarce water resources during drought events. It was persisting as an introduction to the plant community at 4% cover after 14 years. This grass cultivar is significantly taller and more robust than the surrounding native vegetation, creating persistent taller structure and differences in composition in the successional plant community.
- After 14 years, persistent cultivars which are still expanding or maintaining relative cover beyond levels on the controls may be influencing the trajectory of plant community succession.

Figure A-2 Expression of Wild Harvested Seed and Infill over Time for Express Site 4



Wild Harvested Seed and Infill of Graminoids

- Establishment of wild harvested rough fescue from two sources (plains rough fescue Roes from the Hand Hills and likely Foothills rough fescue Petherbridge from the Milk River Ridge) was very slow initially, but the average cover has increased. Fourteen years after seeding, average cover values of rough fescue on the seeded RoW are equivalent to cover values on the controls.
- Wild harvested June grass *Gillespie* performed well, reaching average cover values close to those of the controls by the third year. It performed comparatively better than the June grass cultivar used in the Dry Mixedgrass seed mix (Kestrel Research Inc. and Gramineae Services Ltd. 2011). By year 14 it is present at triple the cover on the control site, at 7% cover vs. 3%. This may be an expression of increased soil fertility due to the breaking up of the hard pan layer.
- Western porcupine grass, a characteristic species in the Northern Fescue NSR, has re-established naturally by infill. Cover has increased dramatically over time to near natural cover levels by year 14. Timely replacement of topsoil in the same growing season it was disturbed will benefit the natural re-establishment of this species (Kestrel Research Inc. and Gramineae Services Ltd. 2011).
- Sun-loving sedge, low sedge and blunt sedge are the dominant sedges at this site. They increase in cover as grazing pressure increases and were the dominant species group prior to construction when the pasture was heavily grazed. They can form an important lower structural layer and provide resilience to erosion and climate events. They have re-established naturally through seed or root propagules. They represented about 50% of the cover values found naturally.

A.2 Assessing Plant Community Succession on Disturbed Topsoil

To assess whether succession towards the pre-disturbance native plant community is occurring, a time series of plant community observations were analysed. Figure A-3 illustrates the native and non-native functional groups and species cover present on Site 4 in each monitoring year.

Figure A-3 Species Prominence over Time for Native and Non-native Functional Groups Represented in the Site 4 Seed Mix

Off RoW		On RoW 1997		On RoW 1998		On RoW 1999		On RoW 2001		On RoW 2010		Control 2010	
Total Cover 33.0 (53.4)		18.1 (0)		53.8 (0)		103.1 (0)		79.0 (1.0)		72.1 ( )		80.4 ( )	
Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover
Sun-loving sedge	64.4	Slender wheat grass	69.7	Spear-leaved goosefoot	41.3	Pasture sagewort	27.3	Pasture sagewort	43.5	Pasture sagewort	16.4	Western porcupine grass	19.5
Western porcupine grass	9	Pasture sagewort	12.1	Pasture sagewort	20.7	Spear-leaved goosefoot	17.9	Green needle grass	24	Western porcupine grass	15.2	Blunt sedge	13.0
June grass	5.4	Western wheat grass	4.2	Slender wheat grass	19.5	Flixweed	16.5	Plains rough fescue	7.1	Northern wheat grass	7.1	Buckbrush	7.8
Plains rough fescue	3.4	Plains rough fescue	3.5	Stinkweed	5.5	Western wheat grass	10.5	June grass	11.9	June grass	7.1	Plains rough fescue	6.5
Purple milk vetch	3.3	Dock species	1.9	Northern wheat grass	3.5	Slender wheat grass	6.8	Indian rice grass	8.4	Plains rough fescue	6.3	Prairie sagewort	5.5
Prairie crocus	2.3	Green needle grass	1.8	Summer-cypress	2.1	Streambank wheatgrass	4.1	Crested wheatgrass	1.1	Western wheat grass	5.4	Pasture sagewort	4.2
Blunt sedge	2.3	Northern wheat grass	1.1	Blunt sedge	1.5	Green needle grass	4	Northern wheatgrass	2.4	Low sedge	5.0	Northern wheat grass	4.1
Northern wheat grass	1.2	Sun-loving sedge	1.1	June grass	1.5	Western porcupine grass	3.4	Sun-loving sedge	0.9	Green needle grass	4.2	Low sedge	3.6
Western wheat grass	0.6	Goosefoot species	1.1	Plains rough fescue	1.2	June grass	2.2	unknown forb	0.7	Salt grass	2.5	Golden bean	2.9
Wire rush	0.6	Gumweed	1.1	Common yarrow	1	Sun-loving sedge	2.1			Crested wheatgrass	1.3	Western wheat grass	2.2
Common yarrow	0.5	June grass	1.1	Salt grass	0.7	Crested wheatgrass	1.2			Smooth brome	0.7	Slender wheat grass	1.9
Pasture sagewort	0.3	Snowberry	1.1	Western wheat grass	0.3	Blunt sedge	0.8			Low goldenrod	0.4	Prairie crocus	1.7
Blue grama	0.1	Wild tomato	0.2	Lamb's-quarters	0.3	Northern wheat grass	0.5			Blunt sedge	0.3	June grass	1.5
Northern bedstraw	0.1			Creeping white prairie aster	0.2	Salt grass	0.5			Common yarrow	0.2	Common yarrow	1.0
Alkali bluegrass	0.1			Low goldenrod	0.2	Plains rough fescue	0.5					Owl clover	0.9
Buckbrush	0.1			Needle-and-thread	0.2	Summer-cypress	0.5					ANTEAPR	0.8
Golden bean	0.1			Green needle grass	0.2	Dock species	0.5					Wire rush	0.8
				Flixweed	0.1	Stinkweed	0.2					Mouse-ear chickweed	0.6
				Western porcupine grass	0.1	Smooth brome	0.1					Sun-loving sedge	0.5
				Alfalfa	0.01	Common knotweed	0.1					Northern bedstraw	0.5
				Common knotweed	0.01	Lamb's-quarters	0.01					Northern fairy candelabra	0.3
				Buckbrush	0.01							Purple milk vetch	0.2
												Low goldenrod	0.2
												Annual whitlow-grass	0.1
												Mat Muhly	0.1

	Native Perennial Plant
	Native Annual Plant
	Non-Native Annual Plant
	Non-Native Perennial
	Express PL Native Seed Mix

Pre-Disturbance: The pre-disturbance plant community is composed entirely of perennial native species. Some of these species are represented in the seed mix, represented by the lighter green colour on the chart.

Year 1: Seeded species, a few other native perennials and annual native and non-native species establish in year one for a total of 18% cover. Slender wheat grass is the most prominent species.

Years 2-3: In the following two years the diversity and cover of perennial native species increases, as does the cover and diversity of non-native annual plants and the cover of native annual plants.

Year 5: Annual non-native plants disappear from the stand by year five but two perennial invasive species appear, awnless brome and crested wheat grass.

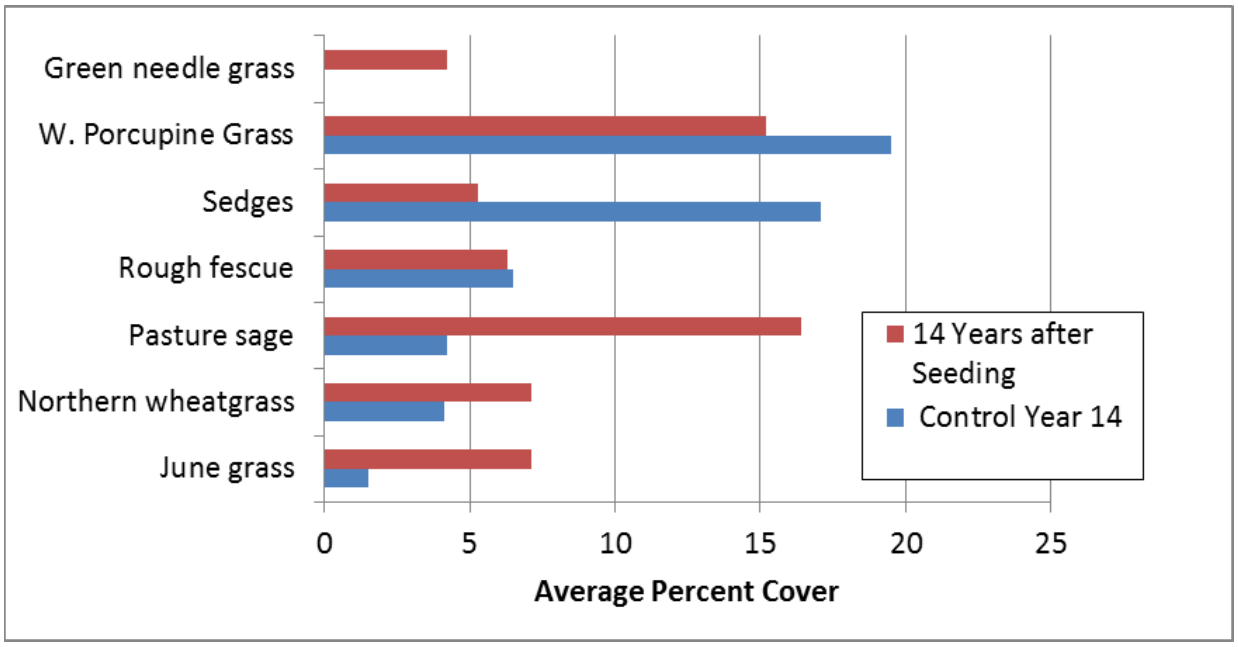
Year 14: The perennial invasive species awnless brome and crested wheat grass persist at low prominence values after 14 years recovery. They were not recorded in the undisturbed control plot although they are present in patches in this pasture. The site is now dominated by native perennial grasses, western porcupine grass, which established by natural infill, as well as three seeded species, Northern wheat grass, June grass and plains rough fescue.

Figure A-4 compares the cover of the dominant species on Site 4 after 14 years recovery. Green needle grass is a new species to the site. Pasture sage, a disturbance forb, has much higher cover, as is typical of recovering topsoil disturbance. The other five graminoid species that characterize Blowout range sites in the Northern Fescue NSR are all present and providing somewhat comparable cover, evidence of positive succession towards the pre-disturbance plant community over time.

Range Health

Management of the pasture has changed over the 14 years and range health has improved considerably. The undisturbed grassland health has changed from unhealthy to healthy over time. After 14 years recovery, the seeded disturbance was described as a mid-seral plant community ranked "Healthy with problems" with a health score of 72%. The surrounding pasture was ungrazed for several years. The cover of plains rough fescue and western porcupine grass is increasing and the dominance of sedges is decreasing. The undisturbed control is described as a mid-seral plant community, NFA11 – Sedge – Plains Rough Fescue, and ranked "Healthy" with a health score of 100%.

Figure A-4 Dominant Species After 14 Years Recovery Compared to the Undisturbed Control



A.3 Recovery of Forbs

The low seeding rate (for the time) was designed to encourage infill from the surrounding area to increase diversity. Annual forbs (including four non-native and one native species) provided increasing cover up to 30% by year three after disturbance (Figures A-5 and A-6). They were not evident after that except in trace quantities on the control. Pasture sage cover increased five-fold by year five and after 14 years it is still present at three times the undisturbed cover values. The cover of perennial forbs has not re-established after 14 years on the disturbance (1% cover) compared to the undisturbed grassland (14.5% cover) (Figure A-5). There were 11 perennial forb species recorded on the control and only two other than pasture sage on the disturbance after 14 years recovery.

Figure A-5 Average Percent Cover of Forbs on the Recovering Disturbance Over Time

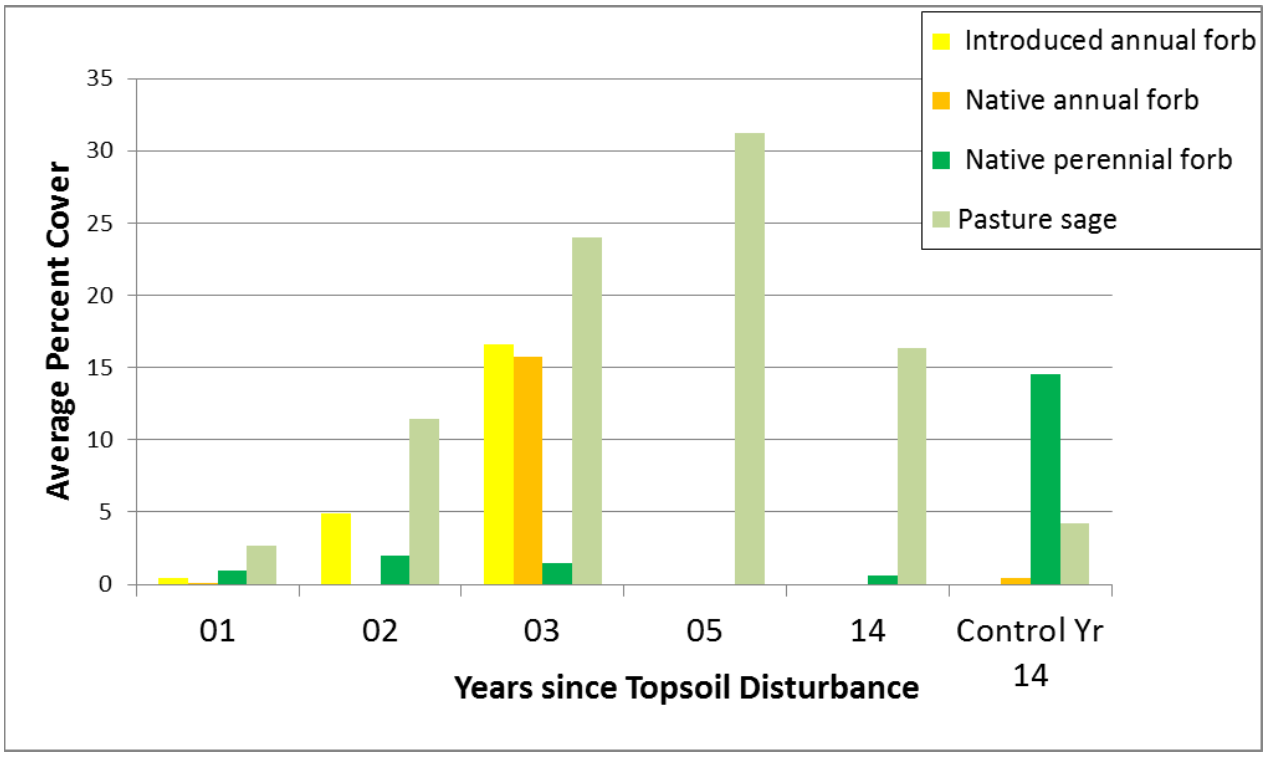
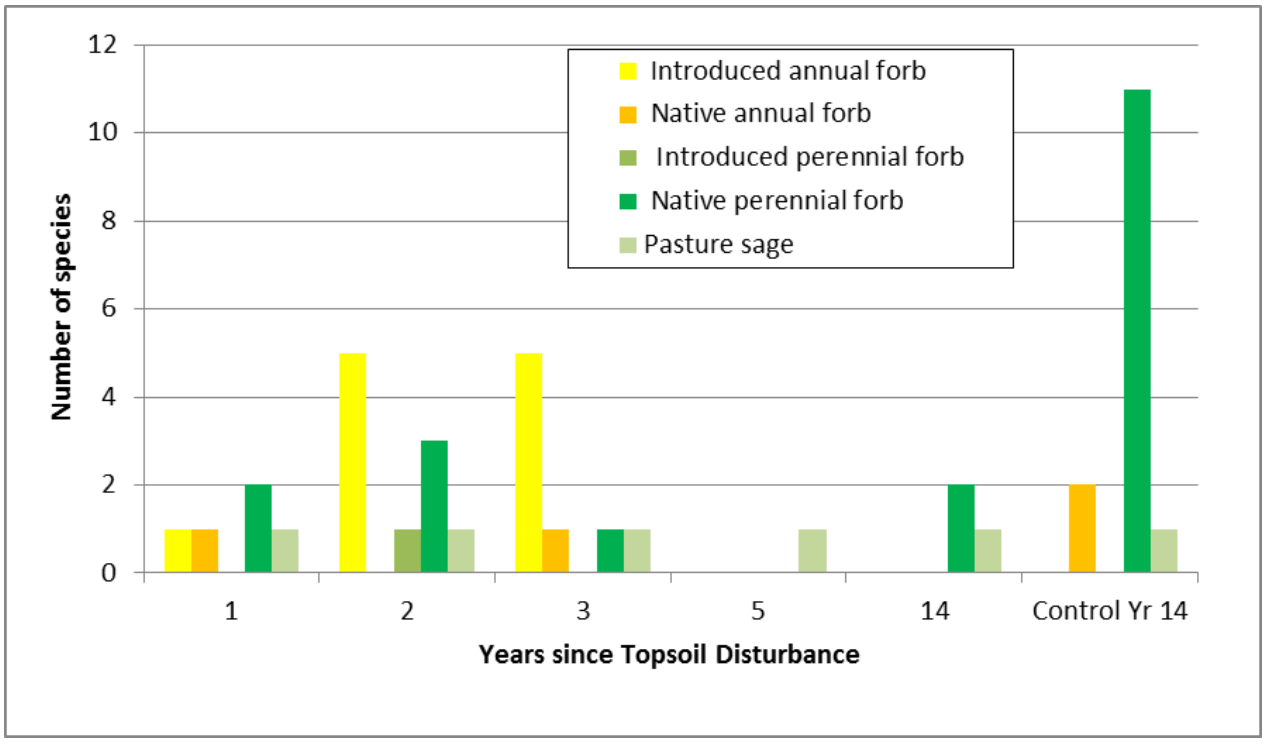


Figure A-6 Number of Forbs on the Recovering Disturbance Over Time



Appendix B Northern Fescue Natural Subregion 2013 Field Studies

B.1 Recovery of Adjacent Large Diameter Pipelines after Topsoil Stripping

Data was collected in the Northern Fescue NSR in 2012 by Alta Rangeland Services Ltd. on a three year old large diameter pipeline right-of-way (RoW) and an adjacent control area of undisturbed native grassland. This pipeline paralleled other older large diamter RoWs. A number of parallel sites on a 22 year old and a 55 year old large diameter pipeline were inventoried in 2013 to assess recovery of adjacent sites. Where necessary to reflect range site conditions, an additional control site was added in 2013 for comparison.

B.1.1 Methods Summary

Revegetation monitoring was conducted using standardized ESRD range monitoring methods summarized in report Sections 4.1 and 4.2. Monitoring sites are ordered by legal land description along the pipeline downstream from north to south. Information on the revegetation strategy and data 2012 monitoring data were provided by the pipeline company. Ecological range site has been correlated with soils mapping, on site observation and the appropriate Range Plant Community Guide.

B.1.2 Monitoring Results

Little information is available on the reclamation treatment of the disturbed topsoil for the 55 year old and 22 year old large diamter pipelines built in 1957 and 1991 respectively. Based on the prominence of long-lived native perennials not readily produced for the reclamation industry on the older sites, it appears that in many areas the disturbance was left to revegetate naturally. Needle-and-thread and western porcupine grass are desirable infill native grasses as indicators of recovery, and the latter is a common component of native plant communities in the Northern Fescue NSR. These lines were built at a time when there was less disturbance on the landscape and natural recovery had some success.

Older seed mixes from the 1980s and 1990s with high wheat grass concentrations and composed in part of non-native “compatible species” such as hard fescue, sheep fescue, meadow brome, intermediate wheat grass and tall wheat grass, have created permanent changes in plant communities. Compatible seeded species were part of seed mixes appropriate to the time period (prior to 2010) or as outlined in historical agreements with the Land Manager. These species could be comprised of agronomics that were suitable for grazing purposes and native species but not be native to the subregion.

Many sites with invasive species establishment from seed mix components or common contaminants like Quackgrass and awnless brome are now trending-to-modified species composition.

If older RoWs successfully revegetate to native cover they pose less risk to newer adjacent disturbances. Adjacent reclaimed vegetation composition can affect infill species composition on more recent large diameter pipeline RoWs. However, larger differences appear to be due to treatments rather than infill. The most invasive species infilling on newer disturbances from older disturbances are awnless brome and Kentucky bluegrass.

The three year old large diameter pipeline RoW has on most sites a predictable early successional plant community dominated by seeded species, Green Needle Grass - Slender Wheat Grass – Northern wheat grass.

Site 13 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
13	SE	8	29	4	4	BEN	Lo	HND

This is a Loamy range site in the Benton Upland, an island of Northern Fescue in the Oyen area surrounded by the Dry Mixedgrass Oyen Plain Ecodistrict. Vegetation on the 3 year old site is an early seral grassland community dominated by seeded grass species and infill grasses and forbs. Western porcupine grass, a desirable infill species, was also present at 6% cover.

One plains rough fescue plug was observed in the frames. It provided 0.1% relative cover while plains rough fescue from seed provided 0.3% cover.

Topsoil is elevated over the trench on the older (55 years old) large diameter pipeline RoW. Species composition includes long-lived native infill perennials. However, native graminoid composition differs from the control and is composed of species adapted to drier conditions. Forbs provide about 5% cover on the 55 year old RoW and 15% cover on the control. Range health is good and the older RoW is likely not negatively influencing recovery of the younger site.

Table B.1-1 Recovery of Adjacent Disturbances at Site 13

Monitoring Site 13 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy w/ Problems (60%)	Early to mid-seral	NFA8: Sedge - Plains rough fescue - Western Porcupine Grass
Seed Mix A1, Rough fescue plugs, site fenced	3	Healthy w/ Problems (52%)	Early to mid-seral	Green Needle Grass - Slender Wheat Grass – Northern wheat grass
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy w/ Problems (58%)	Mid-seral	Western Wheat Grass - Sedge - Needle-and-thread

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 26 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
26	SE	31	32	4	4	NEU	BlO	HKR

This is a Blowout range site in the Neutral Hills. Vegetation on the 3 year old site is a mid-seral grassland community dominated by seeded grass species. Awned wheat grass is a subspecies of slender wheat grass and was recorded in the monitoring as slender wheat grass. The site has a high degree of weed infestation with 6% sow thistle and 4% Canada thistle present, despite the healthy range associated with the undisturbed grassland. Plains rough fescue plants are present at 0.5% cover.

Species composition on the older (55 years old) large diameter pipeline RoW includes long-lived native grasses. Although native, graminoid composition differs from the control and plains rough fescue is absent. Forbs provide about 10% cover on the 55 year old RoW and 8% cover on the control.

Table B.1-2 Recovery of Adjacent Disturbances at Site 26

Monitoring Site 26 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy (75%)	Late seral to reference	NFA10 Plains Rough Fescue - Sedge
Seed Mix A1, Rough fescue plugs, fenced	3	Unhealthy (44%)	Mid-seral	Green Needle Grass - Slender Wheat Grass – Foxtail barley
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy with problems (72%)	Mid-seral	Western Wheat Grass - Plains Reed Grass - Northern Wheat Grass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 27 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
27	NE	31	32	4	4	NEU	Ov/Lo	HND/LFE

This site is an Overflow to Loamy range site in the Neutral Hills. The 3 year old large diameter pipeline control and RoW are situated on a Loamy site. The control is a reference grassland community with a cover of 5% snowberry, 20% plains rough fescue and 13% western porcupine grass. The 3 year old RoW is a mid-seral community dominated by seeded grass species and the native infill pasture sage at 11% cover.

The 55 year old large diameter pipeline and 2013 control are situated on an Overflow site. The 2013 control is a degraded NFC4 Snowberry / Plains rough fescue – Sedge mid-seral community. Plains rough fescue is significantly reduced due to encroachment of shrubs and Kentucky bluegrass. Kentucky bluegrass is present on the 2013 control at 9.5%. On the RoW, approximately 53% of the relative cover is non-native grasses and weedy forbs. The reclaiming plant community on the 55 year old disturbance is trending-to-modified with a cover of shrubs, orchard grass and invasive introduced Quackgrass, a common contaminant of seed mixes in the past.

Table B.1-3 Recovery of Adjacent Disturbances at Site 27

Monitoring Site 27 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diamter Pipeline Control	0	Healthy (75%)	Reference	NFA1 Plains Rough Fescue - Western Porcupine Grass
Seed Mix A1, Rough fescue plugs, site is fenced	3	Unhealthy (47%)	Mid-seral	Green Needle Grass - Slender Wheat Grass – Northern wheat grass
2013 Control	0	Healthy w/ Problems (60%)	Mid-seral	Snowberry – Wild rose/Slender wheat grass – Kentucky bluegrass – Western porcupine grass
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy w/ Problems (56%)	Trending-to-modified	Snowberry / Quackgrass – Orchard grass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 30 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
30	NW	18	33	4	4	NEU	Lo	HND

This is a Loamy range site in the Neutral Hills. Vegetation on the 3 year old site is a mid-seral grassland community dominated by seeded grass species. Plains rough fescue is present at 3.8% cover from both plugs and seed and western porcupine grass is present at 1.2% cover, indicating emergence of desirable long-lived perennial grasses. Forbs are present at 11% cover on both the RoW and the control, with pasture sage representing 5% cover in both instances. There are several perennial invasive species present at trace cover levels on the RoW, including awnless brome, sweet clover and Canada thistle, but no Kentucky bluegrass.

The 55 year old large diameter pipeline RoW is a trending-to-modified shrubland community due to the presence of Kentucky bluegrass at 14% cover. Plains rough fescue is not present and western porcupine grass has a low cover of only 3.3%.

Table B.1-4 Recovery of Adjacent Disturbances at Site 30

Monitoring Site 30 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy w/ Problems (60%)	Early to mid-seral	NFA9: Blue Grama - Sedge
Seed Mix A2 revised, Rough fescue plugs, site is not fenced and has been grazed; mid	3	Healthy with Problems (66%)	Mid-seral	Slender Wheat Grass - Northern Wheat Grass
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy w/ Problems (56%)	Trending-to-modified	Snowberry / Kentucky bluegrass - Green Needle Grass

Seed Mix A2

10.5% Rough Fescue

25% Awned Wheat Grass

30.5% Green Needle Grass

15% Northern Wheat Grass

10.5% Western Wheat Grass

4% Western Porcupine Grass

4.5% June Grass

Site 31 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
31	SW	19	33	4	4	NEU	Sy	DCY

This is a Sandy range site in the Neutral Hills. Vegetation on the 3 year old site is an early to mid-seral grassland community dominated by seeded grass species and infill pasture sagewort. Presence of plains rough fescue at 4% cover was noted from both plugs and seed. The disturbance forb pasture sage is present at 20% cover, but other forbs make up less than 3% cover.

Plains rough fescue is not present on the control site for the 55 year old pipeline RoW. The revegetation on RoW supports a cover of native grasses from infill, including needle-and-thread and blue grama. A 17% cover of forbs (including 9% pasture sage) is present on the 55 year old large diameter pipeline RoW versus 9% cover on the control site.

Table B.1-5 Recovery of Adjacent Disturbances at Site 31

Monitoring Site 31 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diamter Pipeline Control	0	Unhealthy (47%)	Early to mid-seral	Western porcupine grass - Blue Grama Grass – Western wheat grass - Sedge (NFA9)
Seed Mix A2 revised, Rough fescue plugs, site is fenced, gate is open, site has been grazed	3	Healthy w/ Problems (62%)	Early to mid-seral	Slender Wheat Grass - Green Needle Grass – Northern Wheat Grass
2013 Control	0	Healthy w/ Problems (60%)	Early to mid-seral	Blue Grama – Western porcupine grass – Needle-and-thread (NFA9)
55 Year Old Large Diamter Pipeline; likely natural recovery	55	Unhealthy (47%)	Mid-seral	Northern Wheat Grass - Blue Grama - Needle-and-thread

Seed Mix A2

10.5% Rough Fescue

25% Awned Wheat Grass

30.5% Green Needle Grass

15% Northern Wheat Grass

10.5% Western Wheat Grass

4% Western Porcupine Grass

4.5% June Grass

Site 33 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
33	NE	3	35	5	4	NEU	Lo	HND

This is a Loamy range site in the Neutral Hills. Vegetation on the 3 year old site is an early seral grassland community dominated by colonizing and early successional seeded species. Presence of plains rough fescue at 4% cover was noted from both plugs and seed. The disturbance forb pasture sage is present at 5% cover and Canada thistle is present at 3% cover. There is a 4% cover of forbs on the control, including 2% cover of pasture sage.

The prominence of long-lived native perennials not readily produced for the reclamation industry on the 55 year old site suggest that natural recovery was the revegetation strategy. Needle-and-thread and western porcupine grass are desirable infill native grasses as indicators of recovery, and the latter is a common component of native plant communities in the Northern Fescue NSR.

Table B.1-6 Recovery of Adjacent Disturbances at Site 33

Monitoring Site 33 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy w/ Problems (60%)	Early to mid-seral	NFA9 Blue Grama Grass - Sedge
Seed Mix A1, Rough fescue plugs, site is fenced, gate open to grazing	3	Healthy w/ Problems (60%)	Early seral	Slender Wheat Grass - Green Needle Grass
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy w/ Problems (60%)	Mid-seral	Needle-and-thread - Northern Wheat Grass - Western Porcupine Grass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 36 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
36	NW	15	35	5	4	NEU	Sy	MET

This is a Sandy range site in the Neutral Hills. Vegetation on the 3 year old site is an early seral grassland community dominated by seeded grass species and to a lesser extent, Kentucky bluegrass at 3% cover. Kentucky bluegrass is possibly infilling from the adjacent older line, where it was recorded at 16% cover. It is not present on the associated 3 year old large diameter pipeline control site. Forbs include pasture sage, and the invasive species Canada thistle and sow thistle at 3% and 2% cover, respectively.

Natural recovery was likely the reclamation strategy on the 55 year old pipeline RoW. The recovering plant community is a trending-to-modified shrubland type dominated by snowberry and silverberry. Kentucky bluegrass is present at 16% but is only present at 0.2% cover on the 2013 control. Plains rough fescue is present on the RoW at 1.5% cover. Four species of native forbs are present at 13% cover.

Table B.1-7 Recovery of Adjacent Disturbances at Site 36

Monitoring Site 36 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diameter Pipeline Control	0	Healthy w/ Problems (62%)	Early to mid-seral	NFA8 Sedge - Plains Rough Fescue - Western Porcupine Grass
Seed Mix A1, Rough fescue plugs, site is fenced	3	Healthy w/ Problems (60%)	Early seral	Slender Wheat Grass - Green Needle Grass – Northern Wheat Grass
2013 Control	0	Healthy (100%)	Reference	Northern Snowberry - Wolf willow / Plains rough fescue (conditional)
55 Year Old Large Diameter Pipeline; likely natural recovery	55	Healthy w/ Problems (72%)	Trending-to-modified	Snowberry - Wolf willow / Northern wheat grass - Kentucky Bluegrass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 45 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
45	SW	27	36	6	4	NEU	GR	SCD

This monitoring location is on a Gravel range site in the Neutral Hills. Vegetation on the 3 year old RoW site is an early seral grassland community dominated by seeded grass species including plains rough fescue.

The 51 year old large diameter pipeline RoW is possibly a natural recovery site. There are no non-native plants on the RoW and needle-and-thread is dominant at 21% cover. Perennial native forbs make up 8% of the cover, including 5% cover of pasture sage.

Western porcupine grass is present on both the 3 year old large diameter pipeline RoW and 2013 control sites at 8% and 10% cover, respectively. It is present on the 3 year old large diameter pipeline RoW from infill sources at 2.4% cover, but only 0.8% cover on the 51 year old pipeline RoW.

Plains rough fescue is absent from the controls and from the 51 year old RoW but is present on the 3 year old RoW at 4% cover from plugs and seed.

Table B.1-8 Recovery of Adjacent Disturbances at Site 45

Monitoring Site 45 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diameter Pipeline Control	0	Unhealthy (47%)	Early seral	Needle-and-thread - Northern Wheat Grass - Western Porcupine Grass
Seed Mix A1, Rough fescue plugs, site is fenced	3	Unhealthy (39%)	Early seral	Slender Wheat Grass - Northern Wheat Grass – Green Needle Grass
2013 Control	0	Healthy w/ Problems (72%)	Mid-seral	Western Porcupine Grass – Northern Wheat Grass
51 Year Old Large Diameter Pipeline; likely natural recovery	51	Healthy w/ Problems (87%)	Mid-seral	Needle-and-thread – Northern Wheat Grass – Sedge

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

Site 46 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
46	NW	11	37	7	4	NEU	Lo	OVE

This is a Loamy range site in the Neutral Hills. Vegetation on the 3 year old RoW site is an early seral grassland community dominated by seeded grass species and infill forbs dominated by pasture and prairie sagewort.

There is a 3% cover of quackgrass on the 3 year old RoW, but it is not present on the other monitoring locations at site 46. The RoW also supports trace cover of awnless brome, a seed mix contaminant not present on other areas within site 46.

Plains rough fescue is present on the control at 9.6% cover, on the 3 year old RoW at 0.1% cover and on the 51 year old RoW at 1.9% cover. The 51 year old large diameter pipeline is possibly a natural recovery site.

Table B.1-9 Recovery of Adjacent Disturbances at Site 46

Monitoring Site 46 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diameter Pipeline Control	0	Healthy w/ Problems (63%)	Early to mid-seral	NFA8: Sedge - Plains Rough Fescue - Western Porcupine Grass
Seed Mix A2 revised, Rough fescue plugs, fenced	3	Healthy w/ Problems (60%)	Early seral	Slender Wheat Grass - Green Needle Grass – Foxtail Barley
51 Year Old Large Diameter Pipeline; likely natural recovery	51	Healthy w/ Problems (60%)	Mid-seral	Green Needle Grass - Western Wheat Grass - Western Porcupine Grass

Seed Mix A2

10.5% Rough Fescue

25% Awned Wheat Grass

30.5% Green Needle Grass

15% Northern Wheat Grass

10.5% Western Wheat Grass

4% Western Porcupine Grass

4.5% June Grass

Site 49 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
49	NW	21	37	7	4	NEU	Lo	OVE

This monitoring location is on a Loamy range site in the Neutral Hills. The control site is a reference plant community in healthy condition.

Vegetation on the 3 year old RoW site is dominated by seeded native grasses but is a trending-to-modified grassland community due to invasion of awnless brome at 11% cover. Plains rough fescue is present at 1% cover and western porcupine grass is present at 2% cover.

The 22 year old large diameter pipeline RoW has likely been reseeded to tame forages dominated by meadow brome and alfalfa, and to a lesser extent intermediate wheat grass and sheep fescue. The relative cover of the non-native grasses is 92%; therefore it was rated as a tame pasture site.

Table B.1-10 Recovery of Adjacent Disturbances at Site 49

Monitoring Site 49 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy (100%)	Reference	NFA1: Plains Rough Fescue - Western Porcupine Grass
Seed Mix A1 revised, Rough fescue plugs, fenced, but grazed	3	Unhealthy (48%)	Trending-to-modified	Slender Wheat Grass - Green Needle Grass – Awnless Brome
22 Year Old Large Diameter Pipeline; seed mix	22	Healthy Tame (100%)	Modified	Meadow Brome - Alfalfa

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall wheat grass Orbit

Site 51 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
51	SE	31	37	7	4	NEU	Sy	MET

This monitoring location is on a Sandy range site in the Neutral Hills. The 3 year old large diameter pipeline control site is a mid-seral plant community and the 2013 control is a reference community, both in healthy condition.

However, the 3 year old RoW site has an 8% cover of awnless brome, which was not present on any of the other plots so it may be a seed mix contaminant.

The 22 year old seeded pipeline is dominated by non-native seeded species including the invasive sheep fescue, which may have replaced hard fescue in the seed mix or been reseeded along with meadow brome. These non-native species were considered to be compatible species at that time.

Table B.1-11 Recovery of Adjacent Disturbances at Site 51

Monitoring Site 51 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diameter Pipeline Control	0	Healthy (75%)	Mid-seral	NFA8 Sedge - Plains Rough Fescue - Western Porcupine Grass
Seed Mix A1, Rough fescue plugs, site is fenced but has been grazed	3	Unhealthy (48%)	Trending-to-modified	Slender Wheat Grass - Green Needle Grass – Awned wheat grass
2013 Control	0	Healthy (100%)	Reference	NFA7: Western Porcupine Grass - Plains Rough Fescue
22 Year Old Large Diameter Pipeline; seed mix	22	Unhealthy (47%)	Trending-to-modified	Sheep Fescue - Meadow Brome - Intermediate Wheat Grass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall Wheat Grass Orbit

Site 52 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
52	NW	29	37	7	4	NEU	BlO	CUR

This monitoring location is on a Blowout range site on Dark Brown Solodized Solonetz in the Neutral Hills. The 3 year old RoW disturbance is an early to mid-seral grassland community dominated by seeded grasses. Plains rough fescue is present from seed and plugs at 7% cover. Western porcupine grass is prominent on both controls but only present at 1.6% and 1.2% cover on the 3 year old RoW and the 22 year old RoW, respectively.

There is little evidence of the 22 year old large diameter pipeline seed mix on the disturbance with only sheep fescue present at 2.5% cover and contamination and / or invasion of meadow brome present at 0.4% cover. Overall, the site is trending-to-modified due to the invasion of Kentucky bluegrass at 31% cover.

Table B.1-12 Recovery of Adjacent Disturbances at Site 52

Monitoring Site 52 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
3 Year Old Large Diameter Pipeline Control	0	Healthy (87%)	Mid-seral	Sedge - Western Porcupine Grass – Northern Wheat Grass (correlates to NFA11)
Seed Mix A2 revised, Rough fescue plugs, site is fenced, but has been grazed	3	Healthy w/ Problems (62%)	Early to mid-seral	Slender Wheat Grass - Green Needle Grass – Plains Rough Fescue
2013 Control	0	Healthy (84%)	Mid-seral	Western porcupine grass – Sedge – Western wheat grass (correlates to NFA11)
22 Year Old Large Diameter Pipeline; seed mix	22	Unhealthy (47%)	Trending-to-modified	Kentucky Bluegrass - Sedge - Western Wheat Grass

Seed Mix A2

10.5% Rough Fescue

25% Awned Wheat Grass

30.5% Green Needle Grass

15% Northern Wheat Grass

10.5% Western Wheat Grass

4% Western Porcupine Grass

4.5% June Grass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall Wheat Grass Orbit

Site 53 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
53	SE	9	37	7	4	NEU	BlO	CUR

This monitoring location is on a Blowout range site on Dark Brown Solodized Solonetz in the Neutral Hills.

Vegetation on the 3 year old RoW site is dominated by seeded native grasses but is a trending to a modified grassland community due to the presence for quackgrass and Kentucky bluegrass at 8% and 2.2% cover, respectively.

The 22 year old pipeline RoW is trending-to-modified with a 51% cover of hard fescue and an 11% cover of meadow brome. Although meadow brome is persistent, it is not known to be invasive in the Northern Fescue NSR so it may have been seeded included in a re-seeding mix at a later date. Quackgrass and Kentucky bluegrass were not recorded on the older RoW. The four forbs providing the most cover are recorded at 6% on the recovering disturbance and 10% on the control.

Table B.1-13 Recovery of Adjacent Disturbances at Site 53

Monitoring Site 53 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy w/ Problems (62%)	Late seral to reference	NFA10: Plains Rough Fescue - Sedge
Seed Mix A2 revised, Rough fescue plugs, fenced	3	Healthy w/ Problems (60%)	Trending-to-modified	Slender Wheat Grass - Western Wheat Grass - Quackgrass
22 Year Old Large Diameter Pipeline; seed mix	22	Unhealthy (20%)	Trending-to-modified	Hard Fescue – Meadow Brome

Seed Mix A2

10.5% Rough Fescue

25% Awned Wheat Grass

30.5% Green Needle Grass

15% Northern Wheat Grass

10.5% Western Wheat Grass

4% Western Porcupine Grass

4.5% June Grass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall Wheat Grass Orbit

Site 54 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
54	SE	6	38	7	4	NEU	BlO	HKR

This monitoring location is on a Blowout range site on Dark Brown Solodized Solonetz in the Neutral Hills.

Although the control site is a reference Plains Rough Fescue – Sedge plant community, both the 3 year old RoW and the 22 year old RoW disturbances are trending-to-modified plant communities due to the dominance of invasive non-native species.

Plains rough fescue is present at 24% cover on the control, at 0.2% cover on the 3 year old disturbance and at 2% cover on the 22 year old disturbance.

Table B.1-14 Recovery of Adjacent Disturbances at Site 54

Monitoring Site 54 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Healthy (100%)	Late seral to reference	NFA10 Plains Rough Fescue - Sedge
Seed Mix A1, Rough fescue plugs, site is fenced	3	Unhealthy (45%)	Trending-to-modified	Slender Wheat Grass - Awnless Brome – Green Needle Grass
22 Year Old Large Diameter Pipeline; seed mix	22	Unhealthy (32%)	Trending-to-modified	Sheep Fescue - Meadow Brome - Western Wheat Grass

Seed Mix A1

31% Rough Fescue

26% Awned Wheat Grass

27% Green Needle Grass

11% Northern Wheat Grass

5% June Grass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall Wheat Grass Orbit

Site 55 Monitoring

Location and Site Characteristics

Site #	1/4	Sec.	Twp	Rge	Mer.	Eco-district	Ecological Range Site	Soil Series
55	NW	22	38	8	4	NEU	BlO	HKR

This monitoring location is on a Blowout range site on Dark Brown Solodized Solonetz in the Neutral Hills.

Vegetation on the 3 year old RoW site is a mid-seral grassland community dominated by seeded native wetland grass species. The fowl bluegrass and tufted hair grass have a low tolerance to salinity, whereas slough grass has a medium tolerance. It would appear that the topsoil and subsoil replacement improved drainage and / or reduced soil salinity compared to the control which is dominated by species adapted to hard pan and slightly saline soils.

The 22 year old pipeline RoW has recovered to the same plant community as recorded in the control.

Table B.1-15 Recovery of Adjacent Disturbances at Site 55

Monitoring Site 55 Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community
Control	0	Unhealthy (47%)	Early seral	NFA12 Western wheat grass – June Grass
Seed Mix A3	3	Healthy w/ problems (56%)	Mid-seral	Fowl Bluegrass - Slough Grass - Tufted Hair Grass
22 Year Old Large Diameter Pipeline; seed mix	22	Unhealthy (38%)	Early seral	NFA12 Western Wheat Grass - June Grass

Seed Mix A3

20% Western Wheat Grass

20% Slender Wheat Grass

10% Alkali Bluegrass

10% Nuttall's Alkali Grass

10% Tufted Hair Grass

10% Slough Grass

10% Sweet Grass

10% Fowl Bluegrass

22 Year Old Pipeline Seed Mix

15% Northern Wheat Grass Elbee

35% Streambank Wheat Grass Sodar

10% Nuttall's Alkali Grass

5% Indian Rice Grass

20% Hard Fescue Durar

15% Tall Wheat Grass Orbit

B.2 2013 Well Site Revegetation Monitoring Surveys

Sites Seeded to Mixes of Combined Agronomic and Native Plant Cultivars

Older seed mixes from the 1990s with high wheat grass concentrations and composed in part of non-native "compatible species" such as hard fescue, sheep fescue, meadow brome, intermediate wheat grass and tall wheat grass have created permanent changes in plant communities. Compatible seeded species were part of seed mixes appropriate to the time period. Removing these species from a plant community by grazing has not shown good success. Species like sheep fescue and hard fescue green up earlier and can attract grazers to the disturbance, creating more pressure on the reclaiming site compared to the surrounding native plant community.

Table B.2-1 Wellsites Seeded to Mixes of Combined Agronomic and Native Plant Cultivars

Monitoring Site ID	Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community	GVI	Eco-district
APAC01C (11-8-37-7-W4)	Control	0	Healthy (75%)	Reference	Plains rough fescue - Western porcupine grass - Sun-loving sedge	LO	NEU
APAC01R (11-8-37-7-W4)	Full width strip; seeded; unfenced	19	Unhealthy (43%)	Trending-to-modified	Hard fescue - Sheep Fescue - Western Porcupine Grass	LO	NEU
APAC02C (9-29-36-5-W4)	Control	0	Healthy (87%)	Reference	Plains rough fescue - Western porcupine grass - Sun-loving sedge	LO	NEU
APAC02R (9-29-36-5-W4)	Full width strip; seeded; unfenced	20	Healthy w/ problems (60%)	Trending-to-modified	Green Needle Grass - Plains Rough Fescue - Awnless Brome (7%) - Meadow Brome (7%)	LO	NEU

Recovery of Complex Minimal Disturbance Wellsites

Two wellsites owned by CNRL in the Neutral Hills on Sandy and Loamy range sites were inventoried. Monitoring transects were established on an undisturbed control area, a minimal disturbance area where topsoil was not stripped, and stripped, seeded areas (Table B.2-2). Both wellsites (CNRL01 and CNRL02) show much better restoration success on the minimal disturbance portion of the wellsites, where topsoil was not disturbed.

Exposed topsoil has been colonized by invasive sweet clover on site CNRL01R2, possibly through contaminants in introduced topsoil or from infill. Green needle grass and western wheat grass are native species capable of persisting with invasive species and are also dominant species in the plant community. However, the site is trending towards a modified plant community.

On site CNRL03R2, use of an older seed mix with high wheat grass concentrations and composed in part of non-native “compatible species” such as hard fescue and intermediate wheat grass have created permanent changes in plant communities. Compatible seeded species were part of seed mixes appropriate to the time period (prior to 2010). The resulting seeded community is dissimilar to the control and trending-to-modified.

A third well on a Sand range site (CNRL02) was inventoried on the topsoil disturbance, which was seeded three times over four years (2000 – 2003), straw crimped for erosion control in 2001, and treated with herbicide to manage broadleaf weeds in 2003. With this intensive adaptive management, the plant community developing on the disturbance is similar to the undisturbed area.

Table B.2-2 Recovery of Complex Minimal Disturbance Wellsites Requiring Multiple Treatments

Monitoring Site ID	Treatment	Years of Recovery	Range Health	Seral Stage	Plant Community	GVI
CNRL01C (7-1-32-2-W4)	Control	0	Healthy w/ problems (72%)	Early seral	Western porcupine grass - Blunt Sedge - Northern wheat grass	Sy
CNRL01R2 (7-1-32-2-W4)	Stripped, topsoil added early 1990's; seeded to native mix 2005	8	Healthy w/ problems (65%)	Trending-to-modified	Sweet clover - Intermediate wheat grass - Green needle grass - Western wheat grass - Alfalfa	Sy
CNRL01R (7-1-32-2-W4)	Minimal disturbance; Natural recovery	56	Healthy w/ problems (56%)	Mid-seral	Needle & thread - Prairie selaginella - Northern wheat grass - Sedge	Sy
CNRL02C (15-34-31-2-W4)	Control	0	Healthy w/ problems (60%)	Early seral	Sand grass - Sun-loving sedge - Blunt sedge - June grass	Sa
CNRL02R (15-34-31-2-W4)	Constructed Aug 1998; minimal disturbance; 4 disturbed areas seeded Aug 2000, Oct 2002, June 2003; Straw crimp fall 2001; broadleaf herbicide June 2003.	10	Healthy w/ problems (59%)	Early seral	Sand grass - Prairie selaginella - Low sedge - Northern wheat grass	Sa
CNRL03C (1-1-32-2-W4)	Control	0	Healthy w/ problems (72%)	Early seral	Western porcupine grass - Hooker's oat grass	Lo
CNRL03R1 (1-1-32-2-W4)	Minimal disturbance; Natural recovery	11	Healthy w/ problems (52%)	Early seral	Low sedge - June grass - Plains Reed Grass - Northern wheat grass - Western Porcupine Grass – Needle-and-thread	Lo
CNRL03R2 (1-1-32-2-W4)	Disturbed portion from hill cut; seeded native wheat grass cultivars plus hard fescue	10	Healthy w/ problems (55%)	Trending-to-modified	Intermediate wheat grass - Crested wheat grass	Lo

Assessment of Wellsites on Special Areas and Public Lands Grazing Leases

Monitoring surveys were conducted July 29th – Aug 2nd, 2013. Twenty-four sites were assessed (Table B.2-3). The great majority of reclaimed wellsites were not native plant communities. They were seeded to forages, within tame pastures, or invaded by agronomic grasses, particularly awnless brome and sheep fescue. Detailed transects were inventoried at two sites, where the surrounding native prairie was in good health. Information on reclamation details for each site was in most cases sparse or absent for older sites.

Table B.2-3 Assessment of Wellsites on Special Areas and Public Lands Grazing Leases

Site Id	MSL	Legal Land Description	ERS	Disp Yr	Comments	Reclamation / Revegetation Strategy
48	10687	14-14-28-18-4	LO/--	2001	Sold in land sale, therefore private land now	No information
86	10993	6-29-32-12-4	BIO	2002	Reclamatiion not native	No information
130	10967	8-19-33-14-4	BIO	2002	Reclamatiion not native	No information
41	12483	9-25-27-17-4	LO	2004	Minimum disturbance well in dense brome patch in native fescue grassland in Hand Hills; shrubs cut; no tie in or flow line; revegetated to awnless brome	No information
84	11542	13-25-27-17-4	TB/LO	2003	No wellsite was developed here; undisturbed Stipcur-Boutgra native grassland	No information
42	15827	16-31-28-15-4	LO	2006	Seeded to crested wheat grass; significant Melioff invasion; 40% of fenced wellsite is under water in wetland; new PL and access RoW seeded to Bromine in Stipcur native grassland in Hand Hills	No information
119	16284	12-23-33-10-4	--	2007	Tame pasture	No information
91	10053	15-16-10-33-11-4	BIO	2001	Tame hay pasture; active well	No information
100	8243	8-16-34-9-4	Sa	1997	Seeded to bromine	No information
118	14323	12-22-34-9-4	--	2005	Tame pasture; Bromine;	No information
101	7524	6-19-34-9-4	Sa	1995	Wellsite seeded to Bromine; trail natural recovery on Sa and low relief dunes; detailed transect sampling on access trail	No information
103	13119	14-16-28-18-4	LO	2004	Detailed transect sampling along flow line	No information
131	16502	9-31-32-13-4	BIO	2007	Reclamatiion not native	No information
85	10854	4-16-33-12-4	BIO	2001	No sign of disturbance; between 2 active wellsites on native prairie	No information
102		9-20-28-15-4	Lo	2007	Reclamatiion not native	No information
69	9E+05	1-34-28-17-4	--	1994	Farm lease; some native?, some cultivation	No information

Site Id	MSL	Legal Land Description	ERS	Disp Yr	Comments	Reclamation / Revegetation Strategy
47	46017	2-6-29-17-4	LO/--	2004	Very weedy, contaminated seed mix or soil (Agrorep, Phlepra, Melioff, Tragdub); appears seeded to Stipvir-Agropyron mix; Festhal tussocks on site are less prominent, rhizomatous species more prominent	Minimal disturbance wellsite in healthy Stipcur-Festhal grassland in Hand Hills; dry hole; no tie in or flow line; 3x4m disturbance at well head
97	11286	6-32-31-12-4	BlO	2002	Canola	No information
147	16473	9-17-34-9-4	CS/--	after Apr 1994	Access seeded to awnless brome on older portion of access from west; newer access extension natural recovery; natural recovery - good regen of groundcover and shrubs/trees; broadcast seeded w/ native mix	Existing veg on the site was brush-mowed; site then broadcast seeded with a site specific native mix that included 30% Prairie Sandreed, 10% Needle & Thread, 10% Green Needle, 20% Western Wheat grass, 20% fowl bluegrass, and 10% June Grass
P4	9E+05	15-3-34-22-4	NONE	1994	NF NSR Reference community Festhal - Stipcur; wellsite is in a historic awnless brome stand	Seeded to a native wheat grass mix plus Festovi; Brome invasion into wellsite, forming the canopy layer along with Cirsarv, Festovi persistent, forming the mid-layer; native frob infill is primarily Solidago gigantea and Artelud in mid-layer; almost no sign of wheat grasses; both on and offsite ungrazed, bordering unfenced crop; Seed mix 6/26/1995; Agrodas 30%, Festovi 20%, Agrotra 10%, Agrorip 10%, Agrosmi 30%; no till drill; spread 75 straw bales
110	41995	7-25-35-10-4	--	2004	Routine - 20110524; JL Natural recovery; Bromine invasion from pipeline; remediated site – Grassland	No information
P7	1E+06	1-11-37-22-4	NONE	1997	D&A wellsite; recontoured probably; native grassland should have been Stipcur - Festhal or Festhal - Stipcur	Reseeded to tame Festuca and Bromus biebersteinii; invaded by Cirsarv and Poaprat; salted and the whole pasture heavily grazed
140	16504	1-27-32-15-4	None	2007	Hay field	No information
106	10987	16-29-31-13-4	BlO/No	2002	Tame forage; active gas well	No information

Site 101 is an unimproved access trail to an 18 year old wellsite on a Sand range site in the Sullivan Plain Ecodistrict, which was allowed to revegetate naturally. Species composition on the recovering trail is very similar to the control plant community (Table B.2-4). The major differences are in the accumulation of litter and the moss/lichen layer, which are absent from the trail. There is 30% more vegetation growth on the trail compared to the control but this may be a grazing effect. There is also 8.5%more bare soil on the abandoned trail.

Table B.2-4 Natural Recovery of an Access Trail on a Sand Range Site

Sitecode	Percent Cover				Range Health	Plant Community
	Litter	Moss & Lichen	Bare Soil	Total Green Vegetation		
SA101C	98.2	30.6	1.4	58.5	Healthy (100%)	Sun-loving sedge - June grass - Western porcupine grass
SA101R	0	0	9.9	89.5	Healthy w/ problems (51%)	Sun-loving sedge - Western porcupine grass

A visual assessment of a minimal disturbance wellsite in an aspen/shrubland community on a Choppy Sand site showed excellent recovery. The site was not flat and choppy sand hill contours may have been recreated. As part of the reclamation process, existing vegetation on the site was brush-mowed. The site was then broadcast seeded with a site specific native mix that included 30% sand grass, 10% needle-and-thread, 10% green needle grass, 20% western wheat grass, 20% fowl bluegrass, and 10% June grass. Shrub growth has increased to 30% cover and aspen are present on site at 10% cover.

Appendix C Cluster Analysis and Ordination of Plant Communities on Loamy and Blowout Range Sites in the Northern Fescue Natural Subregion

Cluster Analysis, Non-metric Multidimensional Scaling Ordination and Indicator Species Analysis for the Northern Fescue Loamy Ecological Range Site

Ross Adams, Jane Lancaster and Varge Craig

C.1 Introduction

A number of researchers who have conducted reclamation monitoring in the Northern Fescue Natural Subregion generously donated their inventory plot data collected over a number of years to this project. They include data from Mae Elsinger's Master's thesis at the University of Alberta, Peggy Desserud's post-doctoral studies at the University of Calgary, Jay Woosaree's studies with Alberta Innovates and from several oil and gas and pipeline companies' projects. In addition, ESRD provided access to data in their Ecological Site Information System database (ESIS) to assist with describing the control plots data and making linkages to their Northern Fescue Range Plant Community Guide (Kupsch et al. 2012). Data collected during the summer of 2013 by the recovery strategies monitoring crew was also entered into the ESRD ESIS database.

C.2 Methods

Data Selection

Data was acquired from several sources. Data collection methods were similar for all projects, following standard range inventory protocols for assessing vegetation cover and composition (ASRD 2007). All monitoring data originated from the Northern Fescue Natural Subregion. Sites where the undisturbed areas were in unhealthy range condition or trending to modifed non-native species cover were eliminated from the data set. Several range site types were included in the analysis including Loamy, Overflow, Sandy and Blowout sites with better soil development. These sites were judged to be of similar productivity for comparison. A cluster analysis indicated fairly tight clustering of undisturbed control sites across range site types, with no obvious outliers on a range site basis.

Due to the number of observers, slight differences in data collection protocols between projects and differences in taxonomic expertise between observers, the data set contains many single species entries. Single species entries in the combined data set (species scored once in one plot only) were removed from the analysis to reduce the bulk of the data and enhance the detection of relationships between plant communities and environmental factors (McCune and Grace 2002).

Disturbance data was collected primarily from areas where topsoil was disturbed and replaced during construction. Several data sets are also from minimal disturbance areas such as access roads and unstripped portions of wellsites. The entire data set includes data from large and small diameter pipelines, flow lines and wellsites and encompasses a variety of construction and reclamation methods and treatments. A control plot in adjacent undisturbed grassland was established for each plot on a disturbance for comparison purposes.

With a few exceptions, data from vegetation inventory forms (MF5 forms) was entered into the ESRD Ecological Site Information System (ESIS) vegetation database. Averages were calculated for the cover of each individual species, total vegetative cover, cover of litter, soil exposure, and the cover of moss and lichen on each site.

Cluster Analysis and Ordination

Cluster analysis was performed using a distance matrix based on the average species cover for each site (R Core Team 2013). Undisturbed (control) sites (Section C.3) and disturbed sites (Section C.4) clustered separately. Ward's method of hierarchical clustering was used to group sites according to similarity in species composition and cover, and to identify outliers. Outliers were removed from further analyses. The clusters of undisturbed sites were compared to plant communities in ESRD's Northern Fescue Range Plant Community Guide using De-trended Correspondence Analysis (Section C.3). If the first axis eigenvalue was lower than 0.2, the cluster was considered to be a member of the plant community to which it was compared.

The clusters of undisturbed sites formed the basis of the disturbed site ordination (Section C.5). Figures produced using Non-metric Multidimensional Scaling Ordinations were in two or three dimensions, and the number of dimensions was chosen so as to provide a low stress solution. Since the species cover data was measured on the same scale for all sites, data was not relativized prior to ordination. Species cover data was the only data used in the ordination, total vegetative cover, cover of litter, and soil exposure data were excluded due to inconsistencies in data collection between projects.

Data Presentation

For the following groupings, and throughout this report, the top six to eight species are presented to describe the community, based on high constancy, high cover or their value as indicator species in the plant community. The first one to three characteristic species are used to describe the group name according to the Shrub/Grass-Forb format used by Alberta Sustainable Resource Development (e.g. Adams et al. 2013).

C.3 Results – Undisturbed Native Grassland Controls

Clusters of control plots for each monitoring site were assessed to determine which range plant community they represent. With the assistance of ESRD to access their data, the control clusters were compared to the community data used to develop the publication, *Range Plant Communities and Range Health Assessment Guidelines for the Northern Fescue Subregion of Alberta* (Kupsch et al. 2012). This comparison will provide context to the ability of disturbances to recover in these plant communities.

Control Cluster 1 - NFA1. Plains Rough Fescue – Western Porcupine Grass

Cluster 1 consists of 8 observations which correlate to the NFA1 reference grassland plant community on moist Loamy range sites in the Northern Fescue (Table C.3-1). Grazing pressure is light to moderate with plains rough fescue as the dominant species followed by western porcupine grass, and to a lesser extent, other graminoids, forbs and shrub species. The cluster appears to represent the mid to upper range of the NFA1 plant community ecological status. This plant community is at risk to invasion by Kentucky bluegrass and awnless brome under moderate to heavy grazing pressure due to the higher moisture regime associated with this range site. Aspen (*Populus tremuloides*) was recorded at four sites, confirming Kupsch et al. 2012 observations that the range site is at risk of shrub and forest encroachment, particularly on north facing and lower slope positions.

Soils are primarily an Orthic Dark Brown Chernozems and to a lesser extent Orthic Black Chernozems on inclined to hummocky landscapes. Soil exposure is generally less than 2% and moss and lichen will be present as ground cover (Kupsch et al. 2012). Eight reclamation monitoring plots are located in this plant community type (Table C.3-2).

Table C.3-1 Dominant or Indicator Species Associated with Control Cluster 1 (NFA1)

Plant Community NFA1		**Cluster 1**	**8 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	53.6	100.0
Stipa curtiseta	western porcupine grass	6.3	100.0
Danthonia intermedia	intermediate oat grass	2.2	37.5
Geum triflorum	three-flowered avens	2.1	50.0
Achillea millefolium	common yarrow	1.8	100.0
Galium boreale	northern bedstraw	1.7	75.0
Symphoricarpos occidentalis	buckbrush (northern snowberry)	1.3	37.5

Table C.3-2 Site Conditions Associated with Control Cluster 1

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil Series
AIHH00C	WNT	Lo	not available	HATH1/I4h
AIHH07C	WNT	Lo	not available	HATH1/I4h
AIHH99C	WNT	Lo	not available	HATH1/I4h
AIPL07C	NEU	Lo	not available	not available
AIPL08C	NEU	Lo	not available	not available
ELPL03C	END	Lo	Healthy	HND10/H1h
ELPL09C	END	Lo	Healthy	HND10/H1h
PAR1521C	DRU	Lo	Healthy	HND

Control Cluster 2 - NFA1. Plains Rough Fescue – Western Porcupine Grass

Cluster 2 consists of 16 observations which correlate to the NFA1 reference grassland plant community on moist Loamy range sites in the Northern Fescue (Table C.3-3). This cluster is similar to Cluster 1 with plains rough fescue as the dominant species followed by western porcupine grass, but appears to represent the mid to low ecological status for the NFA1 plant community. The difference could be related to a slight increase in grazing pressure for Cluster 2 compared to Cluster 1. The average cover of plains rough fescue is lower while average cover of western porcupine grass is higher compared to Cluster 1. Shrub and aspen forest encroachment will likely occur on lower slope positions. This plant community is at risk to invasion by Kentucky bluegrass and awnless brome under moderate to heavy grazing pressure.

Soils are primarily Orthic Dark Brown Chernozems and to a lesser extent Orthic Black Chernozems on inclined to hummocky landscapes. Soil exposure, and moss and lichen will be similar to the NFA7 reference plant community. Sixteen reclamation monitoring plots are located in this plant community type (Table C.3-4).

Table C.3-3 Dominant or Indicator Species Associated with Control Cluster 2 (NFA1)

Plant Community NFA1		**Cluster 2**	**16 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	37.1	100.0
Stipa curtiseta	western porcupine grass	10.8	100.0
Carex stenophylla	low sedge	4.4	75.0
Artemisia frigida	pasture sagewort	3.9	62.5
Geum triflorum	three-flowered avens	2.3	56.3
Achillea millefolium	common yarrow	2.1	93.8
Symphoricarpos occidentalis	buckbrush (northern snowberry)	4.3	37.5

Table C.3-4 Site Conditions Associated with Control Cluster 2

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
AIHH08C	WNT	Lo	not available	HATH1/I4h
AIHH96C	WNT	Lo	not available	HATH1/I4h
ELPL05C	END	Lo	Healthy with problems	HND10/H1h
ELPL08C	END	Lo	Healthy	HND10/H1h
ELPL12C	END	Lo	Healthy	HND10/H1h
ELPL13C	END	Lo	Healthy	HND10/H1h
ELWS03C	END	Lo	Healthy	HND10/H1h
ELWS05C	END	Lo	Healthy	HNPR1/HP1m
ELWS07C	END	Lo	Healthy with problems	HND10/H1h
ELWS14C	END	Lo	not available	HND10/H1h
ELWS21C	END	Lo	not available	HND10/H1h
ELWS26C	END	Lo	Healthy	HND10/H1h
ELWS28C	END	Lo	Healthy	HND10/H1h
DDDD43C	NEU	Lo	Healthy	HND4/HR2h
DDDD49C	NEU	Lo	Healthy	OVE/H1l
FFFF51C	NEU	SY	Healthy	MET/I3h

Control Cluster 6 - NFA2. Plains Rough Fescue - Kentucky Bluegrass

Cluster 6 consists of 12 observations which correlate to the late seral plant community NFA1 on moist Loamy range sites in the Northern Fescue (Kupsch et al. 2012) (Table C.3-5). Plains rough fescue is still dominant but the cover is reduced while western porcupine grass has increased appreciably due to moderate grazing pressure. The cover of some forbs and graminoids, such as pasture sagewort, prairie crocus, low sedge and June grass, will increase due to their adaptation to moderate grazing pressure. Shrub and aspen forest encroachment will likely occur on lower slope positions. Kentucky bluegrass is present in the NFA2 community which is consistent with Cluster 6 even though the cover and constancy (0.3% and 50%, respectively) were relatively low. Similar to Clusters 1 and 2, it is probable that this plant community is at risk to invasion by Kentucky bluegrass and awnless brome under moderate to heavy grazing pressure. Kupsch (et al. 2012) indicated that recovery back to the NFA1 plant community is possible under a light to moderate grazing regime; however Kentucky bluegrass will most likely be present at low but consistent levels.

Soils associated with this cluster are Orthic Dark Brown Chernozems on hummocky landscapes. Twelve reclamation monitoring plots are located in this plant community type (Table C.3-6).

Table C.3-5 Dominant or Indicator Species Associated with Control Cluster 6 (NFA2)

Plant Community NFA2		Cluster 6	12 obs.
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	22.3	100.0
Stipa curtiseta	western porcupine grass	18.7	100.0
Carex stenophylla	low sedge	7.3	100.0
Artemisia frigida	pasture sagewort	8.5	100.0
Anemone patens	prairie crocus	3.1	100.0
Cerastium arvense	field mouse-ear chickweed	1.5	100.0
Rosa arkansana	prairie rose	3.1	91.7

Table C.3-6 Site Conditions Associated with Control Cluster 6

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
ELPL01C	END	Lo	Healthy with problems	HND10/H1h
ELPL11C	END	Lo	not available	HND10/H1h
ELPL14C	END	Lo	Healthy	HND10/H1h
ELPL16C	END	Lo	Healthy	HND10/H1m
ELWS06C	END	Lo	Healthy with problems	HND10/H1h
ELWS12C	END	Lo	Healthy	HND10/H1h
ELWS17C	END	Lo	Healthy with problems	HND10/H1h
ELWS18C	END	Lo	Healthy with problems	HND10/H1h
ELWS19C	END	Lo	Healthy with problems	HND10/H1h
ELWS23C	END	Lo	Healthy with problems	HND10/H1h
ELWS24C	END	Lo	Healthy with problems	HND10/H1h
ELWS27C	DRU	Lo	Healthy with problems	HND10/H1h

Control Cluster 7 - NFC2. Snowberry/Plains Rough Fescue - Kentucky Bluegrass

Cluster 7 represents 9 observations which correlate to a mid seral shrub plant community for the reference plant community Snowberry/Plains Rough Fescue (NFC1) on lower slope to level moist Loamy range sites (Kupsch et al. 2012) (Table C.3-7). Plains rough fescue and snowberry are the dominant species in the plant community. Snowberry appears to be encroaching onto moist grassland sites due to fire suppression. Kentucky bluegrass is present as a subdominant invasive species as a result of moderate to heavy grazing pressure and a favourable moisture regime. This plant community is at risk to invasion of Kentucky bluegrass where grazing pressure is heavy. Kentucky bluegrass will increase in cover to become co-dominant with plains rough fescue (Kupsch et al. 2012).

Soils are generally Orthic Dark Brown Chernozems on hummocky landscapes. Nine reclamation monitoring plots are located in this plant community type (Table C.3-8).

Table C.3-7 Dominant or Indicator Species Associated with Control Cluster 7 (NFC2)

Plant Community NFC2		**Cluster 7**	**9 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	20.7	100.0
Stipa curtiseta	western porcupine grass	9.5	100.0
Poa pratensis L.	Kentucky bluegrass	7.9	88.9
Artemisia frigida	pasture sagewort	3.6	88.9
Achillea millefolium	common yarrow	2.8	88.9
Artemisia ludoviciana	prairie sagewort	2.2	66.7
Symphoricarpos occidentalis	buckbrush (northern snowberry)	12.3	88.9

Table C.3-8 Site Conditions Associated with Control Cluster 7

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
ELPL04C	END	Lo	Healthy with problems	HND2/HP1h
ELPL15C	END	Lo	Healthy	HND10/H1h
ELWS04C	END	Lo	Healthy with problems	HNPR1/HP1m
ELWS08C	END	Lo	Healthy with problems	HNPR1/HP1m
ELWS09C	END	Lo	Healthy with problems	HNPR1/HP1m
ELWS22C	END	Lo	Healthy with problems	HND10/H1h
ELWS32C	END	Lo	Healthy with problems	HND10/H1m
FFFF27C	NEU	OV	Healthy with problems	HND/H1hd
FFFF36C	NEU	SY	Healthy	MET/H1m

Control Cluster 8 - NFA7 Western Porcupine Grass - Plains Rough Fescue / NFA10 Plains Rough Fescue - Sedge

Cluster 8 consists of 12 observations which appear to represent a reference to late seral grassland community types on late phase Solonetz (Blowout), Rego Dark Brown Chernozem (Limy) and Orthic Dark Brown Chernozem (Loamy - dry) range sites (Table C.3-9). Blowout and Limy range sites have soil features, such as a weak hardpan layer or free lime that limit growth and productivity, respectively. The Loamy - dry range site is usually associated with crest and south aspects on upper slope positions where the moisture regime is lower, which reduces productivity. The NFA7 (Lo-dry) and NFA10 (BlO) appear to correlate to subsets within Cluster 8 based on differentiation by range site. Indicator species are plains rough fescue, sedges, wheat grasses, western porcupine grass, pasture sagewort and prairie crocus (Kupsch et al. 2012). The plant communities have a lower cover of plains rough fescue and greater diversity of other graminoids. This cluster should be less susceptible to invasion by agronomic species due to inherent limitations of the range sites.

Soils are classified as Orthic and Solonetzic Dark Brown Chernozems, and Dark Brown Solodized Solonetz on primarily inclined to hummocky landscapes. Twelve reclamation monitoring plots are located in this plant community type (Table C.3-10).

Table C.3-9 Dominant or Indicator Species Associated with Control Cluster 8 (NFA7/NFA10)

Plant Community NFA7/NFA10		**Cluster 8**	**12 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	16.1	100.0
Stipa curtiseta	western porcupine grass	10.5	100.0
Carex pensylvanica	sun-loving sedge	7.5	83.3
Elymus lanceolatus ssp. lanceolatus	Northern wheat grass	5.7	91.7
Koeleria macrantha	June grass	2.8	91.7
Anemone patens	prairie crocus	2.1	83.3
Artemisia frigida	pasture sagewort	1.9	91.7

Table C.3-10 Site Conditions Associated with Control Cluster 8

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
AIHH97C	WNT	Lo		HATH1/I4h
APAC01C	NEU	Lo	Healthy	HND
APAC02C	NEU	Lo		HND
HUSK732C	WNT	Lo		HND
DDDD24C	NEU	Lo	Healthy with problems	HND6/H1hd
DDDD26C	NEU	BlO	Healthy	HKR/H1hd
DDDD36C	NEU	SY	Healthy with problems	MET/H1h
DDDD46C	NEU	Lo	Healthy with problems	OVE/H1m
DDDD53C	NEU	BlO	Healthy with problems	HNDI3l
DDDD54C	NEU	BlO	Healthy	HRK/I3h
X04C97	CAS	BlO		HKR
X04C99	CAS	BlO		HKR

Control Cluster 4 - NFA8. Sedge - Plains Rough Fescue - Western Porcupine Grass

Cluster 4 consists of 16 observations which appear to represent a mid-seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference plant community on Loamy - dry range sites (Table C.3-11). Increased grazing pressure has reduced the cover of plains rough fescue and western porcupine grass which are replaced by grazing resistant species such as pasture sagewort, upland sedges and June grass. With increased grazing pressure comes the risk of invasion by Kentucky bluegrass and awnless brome (Kupsch et al. 2012). Kentucky bluegrass and awnless brome were recorded in this cluster at 0.9% cover and a constancy of 43.8%, and 0.4 % cover and a constancy of 12.5%, respectively.

Soils associated with this cluster were predominantly Orthic Dark Brown Chernozems on hummocky landscapes. Sixteen reclamation monitoring plots are located in this plant community type (Table C.3-12).

Table C.3-11 Dominant or Indicator Species Associated with Control Cluster 4 (NFA8)

Plant Community NFA8		**Cluster 4**	**16 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Stipa curtiseta	western porcupine grass	15.1	100.0
*Carex species**	undifferentiated sedge	12.0	100.0
Koeleria macrantha	June grass	11.3	100.0
Festuca hallii	plains rough fescue	9.2	100.0
Artemisia frigida	pasture sagewort	13.1	100.0
Erigeron caespitosus	tufted fleabane	3.2	68.8
Anemone patens	prairie crocus	1.8	81.3

**Carex stenophylla (8.5%) & Carex pensylvanica (3.5%)*

Table C.3-12 Site Conditions Associated with Control Cluster 4

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
ELPL06C	END	Lo	Unhealthy	HND10/H1h
ELPL07C	END	Lo	Healthy with problems	HND10/H1h
ELPL10C	END	Lo	Healthy with problems	HND10/H1h
ELPL17C	END	Lo	Healthy with problems	HND10/H1m
ELWS01C	END	Lo	Unhealthy	HND10/H1h
ELWS02C	END	Lo	Unhealthy	HND14/H1m
ELWS10C	END	Lo	Healthy with problems	HND10/H1h
ELWS11C	END	Lo	Unhealthy	HND10/H1h
ELWS13C	END	Lo	Healthy with problems	HND10/H1h
ELWS15C	END	Lo	Unhealthy	HND10/H1h
ELWS16C	END	Lo	Unhealthy	HND10/H1h
ELWS20C	END	Lo	Healthy with problems	HND10/H1h
ELWS25C	END	Lo	Healthy	HND10/H1h
ELWS29C	END	Lo	Healthy with problems	HND10/H1m
ELWS30C	DRU	Lo	Unhealthy	HND10/H1m
ELWS33C	END	Lo		HND10/H1m

Control Cluster 5 - NFA9. Blue Grama – Sedge

Cluster 5 consists of 11 observations which correlate to an early to mid-seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference community on Loamy - dry range sites (Table C.3-13). Moderate to heavy grazing pressure has reduced the cover of plains rough fescue and western porcupine grass which are replaced by grazing resistant species such as upland sedges and blue grama and pasture sagewort. This plant community appears to be associated with drier upper southerly and southwesterly aspects on low to high relief hummocky landscapes (Kupsch et al. 2012). The low moisture regime appears to favour the native low growing graminoids and grazing resistant forbs over agronomic species such as Kentucky bluegrass and awnless brome. This successional process should allow plains rough fescue and western porcupine to recover with a reduction in grazing pressure.

Soils associated with this cluster were predominantly Orthic Dark Brown Chernozems on hummocky landscapes. Eleven reclamation monitoring plots are located in this plant community type (Table C.3-14).

Table C.3-13 Dominant or Indicator Species Associated with Control Cluster 5 (NFA9)

Plant Community NFA9		**Cluster 5**	**11 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Festuca hallii	plains rough fescue	13.4	100.0
Carex species	undifferentiated sedge	10.5	100.0
Bouteloua gracilis	blue grama	4.3	90.9
Artemisia frigida	pasture sagewort	4.6	90.9
Anemone patens	prairie crocus	2.0	81.8
Achillea millefolium	common yarrow	1.4	81.8
Symphoricarpos occidentalis	buckbrush (northern snowberry)	1.8	63.6

Table C.3-14 Site Conditions Associated with Control Cluster 5

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
AIHH04C	WNT	Lo		HATH1/I4h
AINH00C	NEU	Lo		CNHN10/H1l
AINH04C	NEU	Lo		CNHN10/H1l
AINH07C	NEU	Lo		CNHN10/H1l
AINH96C	NEU	Lo		CNHN10/H1l
AINH97C	NEU	Lo		CNHN10/H1l
AINH99C	NEU	Lo		CNHN10/H1l
AIPL05C	NEU	Lo		
AIPL06C	NEU	Lo		
PAR1330C	END	Lo	Healthy	HND
PAR2330C	END	Lo	Healthy	HND

Control Cluster 3 - NFA9. Blue Grama - Sedge

Cluster 3 consists of 15 observations which appear to correlate to an early seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference plant community (Table C.3-15). Heavy grazing pressure has reduced the cover of plains rough fescue to less than 3% cover for this cluster. Western porcupine grass is present but grazing resistant species such as upland sedges, blue grama and pasture sagewort have increased in cover. This plant community is primarily associated with Loamy - dry and late phase Blowout range sites. The aspect and slope are variable for this cluster ranging from northerly and southerly aspects, and crest to mid slope (0 to 18%) positions. Generally, the range sites are drier due to south aspects, and inherent soil limiting characteristics. Successional processes should allow plains rough fescue and western porcupine grass to recover with a reduction in grazing pressure.

Soils are predominantly Orthic Dark Brown Chernozems and Dark Brown Solodized Solonetz on low to high relief inclined and hummocky landscapes. Fifteen reclamation monitoring plots are located in this plant community type (Table C.3-16).

Table C.3-15 Dominant or Indicator Species Associated with Control Cluster 3 (NFA9)

Plant Community NFA9		**Cluster 3**	**15 obs.**
Plant Species	**Common Name**	**Avg.**	**Const.**
Stipa curtiseta	western porcupine grass	21.7	100.0
*Carex species**	undifferentiated sedge	9.0	93.3
Bouteloua gracilis	blue grama	6.4	80.0
Artemisia frigida	pasture sagewort	3.6	100.0
Artemisia ludoviciana	prairie sagewort	1.3	33.3
Anemone patens	prairie crocus	1.2	73.3
Symphoricarpos occidentalis	buckbrush (northern snowberry)	1.4	33.3

*Carex obtusata (3.5%) Carex pensylvanica (3.2%) Carex stenophylla (2.3%)

Table C.3-16 Site Conditions Associated with Control Cluster 3

Monitoring Site ID	Ecodistrict	Ecological Range Site	Range Health	Soil
CNRL01C	NEU	SY	Healthy with problems	HND14/H1m
CNRL03C	NEU	Lo	Healthy with problems	HND14/H1m
ELPL02C	END	Lo	Healthy with problems	HND10/H1h
ELWS31C	DRU	Lo	Unhealthy	HND10/H1h
ELWS34C	END	Lo	Healthy with problems	HND10/H1h
DDDD13C	NEU	Lo	Healthy with problems	HND/H1l
DDDD29C	NEU	Lo	Unhealthy	HND/H1m
DDDD30C	NEU	Lo	Healthy with problems	HND/H1l
DDDD33C	NEU	Lo	Healthy with problems	HND/I3h
DDDD42C	NEU	Lo	Healthy with problems	HND/HR2h
DDDD50C	NEU	BlO	Unhealthy	HKR/I3h
SA103C	DRU	Lo		CNN5/U1h
FFFF31C	NEU	SY	Healthy with problems	DCY/H1l
FFFF52C	NEU	BlO	Healthy	CUR/I3I
X04C10	CAS	BlO	100	HKR/U1h

C.4 Results - Plant Communities on Recovering Disturbance

Cluster 1 - Slender Wheat grass - Green Needle Grass

Cluster 1 (Table C.4-1) consists of 17 observations reclaimed with seed mixes (contractor mix or LDIAPL mixes (Mix A1 or A2)) composed of native grasses (Table C.4-2). The LDIAPL sites (DDDD) also included planted plains rough rescue plugs. Vegetation transects were completed between 2 to 5 years since reclamation with the majority of sites assessed in year three.

The cluster represents early to mid-seral grassland plant communities dominated by seeded species of slender wheat grass at 19.2% cover, green needle grass at 11.8% cover and minor amounts of northern and western wheat grasses (Table C.4-1). Plains rough fescue was in all the seed mixes and was recorded on each site. Western porcupine grass seed was not included in Mix A1, but was recorded in the treatments; therefore it would appear to have established as an infill species. Pasture sagewort is the dominant native infill species at 6.9% followed by prairie sagewort at approximately 1.3% each.

Of the 17 observations, 13 appear to be on a positive trajectory to native dominated plant communities while 4 sites are trending-to-modified due to the higher cover, as individual or combined species, of awnless brome, Kentucky bluegrass, sheep fescue and quack grass. Only one control site adjoining the 4 trending-to-modified sites recorded a non-native species (Kentucky bluegrass at 0.2%).

Reclaimed soils are predominately Orthic Dark Brown Chernozems correlated to the Loamy-dry range site.

Table C.4-1 Dominant or Indicator Species Associated with Disturbance Cluster 1

Plant Species	Common Name	Cluster 1	17 obs.
		Avg.	Const.
Elymus trachycaulus var. trachycaulus	slender wheat grass	19.2	100.0
Stipa viridula	green needle grass	11.8	94.1
Elymus lanceolatus ssp. lanceolatus	northern wheat grass	3.7	88.2
Festuca hallii	plains rough fescue	1.8	100.0
Stipa curtiseta	western porcupine grass	1.6	82.4
Agropyron smithii	western wheat grass	1.3	94.1
Artemisia frigida	pasture sagewort	6.9	94.1
Artemisia ludoviciana	prairie sagewort	1.6	41.2

Table C.4-2 Treatments and Site Conditions Associated with Disturbance Cluster 1

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AIHH97M02	ARC Diverse Seed Mix, Wellsite	2	Lo	WNT	NFA7		
AINH00M02	ARC Diverse Seed Mix, Wellsite	5	Lo	NEU	NFA9 Feha		
AINH97M03	ARC Reclamation Seed Mix, Wellsite	2	Lo	NEU	NFA9 Feha		
AIPL06M02	Contractor's Seed mix, PL	2	Lo	NEU	NFA9 Feha		
AIPL07M02	Contractor's Seed mix, PL	3	Lo	NEU	NFA1 high		
DDDD13R	Disturbed topsoil; Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	Lo	OYE	NFA9 Stcu	Healthy with problems	Healthy with problems
DDDD24R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	Lo	NEU	NFA7	Healthy with problems	Healthy with problems
DDDD26R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	BlO	NEU	NFA7	Unhealthy	Healthy
DDDD29R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	Lo	NEU	NFA9 Stcu	Unhealthy	Unhealthy
DDDD33R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced but gate open to grazing	3	Lo	NEU	NFA9 Stcu	Healthy with problems	Healthy with problems
DDDD36R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	SY	NEU	NFA7	Healthy with problems	Healthy with problems
DDDD42R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced	3	Lo	NEU	NFA9 Stcu	Unhealthy	Healthy with problems
DDDD46R	Disturbed topsoil, Seeded, PL, Seed Mix A2 revised, Rough fescue plugs, Site fenced	3	Lo	NEU	NFA7	Healthy with problems	Healthy with problems
DDDD48R	Disturbed topsoil, Seeded, PL, Seed Mix A1 revised, Rough fescue plugs, Site not fenced	3	Lo	NEU		Healthy with problems	Healthy with problems
DDDD49R	Disturbed topsoil, Seeded, PL, Seed Mix A1 revised, Rough fescue plugs, Site fenced, but grazed	3	Lo	NEU	NFA1 low	Unhealthy	Healthy
DDDD50R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Site fenced but has been grazed	3	BlO	NEU	NFA9 Stcu	Unhealthy	Unhealthy
DDDD53R	Disturbed topsoil, Seeded, PL, Seed Mix A2 revised, Rough fescue plugs, Site fenced	3	BlO	NEU	NFA7	Healthy with problems	Healthy with problems

Cluster 2 - Slender Wheat grass - Green Needle Grass - Plains Rough Fescue

Cluster 2 (Table C.4-3) consists of 13 observations reclaimed with a contractor mix composed of native grasses and a collected mix composed of native grasses and forbs (Table C.4-4). Vegetation transects were completed between 2 to 12 years since reclamation with the majority of sites assessed in year four.

The cluster presents mid-seral plant communities dominated by seeded slender wheat grass at 40.1% and green needle grass at 5.1% (see Table C.4-3). Plains rough fescue has the third highest cover for grasses. The transect completed at year 12 had the highest cover of plains rough fescue at 12.0%, but still had a relatively high cover of slender wheat grass at 31.0%. Pasture sagewort and wild vetch were the dominant native forb species at 8.5% and 2.9%, respectively. Pasture sagewort established as infill whereas the source for wild vetch appears to be from infill. Buckbrush established from infill and was recorded at 2.4% cover and constancy of 46.2%.

The 13 observations appear to be on a positive trajectory to native dominated plant communities. Kentucky bluegrass was recorded at relatively low cover values on 3 sites, ranging from 0.2% to 1.2%.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (7 sites) correlated to the Loamy-dry range site and Orthic Black Chernozems (6 sites) correlated to the Loamy-moist range.

Table C.4-3 Dominant or Indicator Species Associated with Disturbance Cluster 2

Plant Species	Common Name	Cluster 2	13 Obs.
		Avg.	Const.
Elymus trachycaulus var. trachycaulus	Slender wheat grass	40.1	100.0
Stipa viridula	green needle grass	5.1	53.8
Festuca hallii	plains rough fescue	2.4	92.3
Artemisia frigida	pasture sagewort	8.5	69.2
Vicia americana	wild vetch	2.9	84.6
Artemisia ludoviciana	prairie sagewort	1.1	61.5
Symphoricarpos occidentalis	buckbrush (northern snowberry)	2.4	46.2

Table C.4-4 Treatments and Site Conditions Associated with Disturbance Cluster 2

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community
AIHH97M03	ARC Mod. Reclamation Mix	2	Lo	WNT	NFA1 high
AIHH98M03	ARC Mod. Reclamation Mix	3	Lo	WNT	NFA1 high
AIHH99M03	ARC Mod. Reclamation Mix	4	Lo	WNT	NFA7
AIHH00M03	ARC Mod. Reclamation Mix	5	Lo	WNT	
AINH98M03	ARC Mod. Reclamation Mix	3	Lo	NEU	
AINH99M03	ARC Mod. Reclamation Mix	4	Lo	NEU	NFA1 high
AINH00M03	ARC Mod. Reclamation Mix	5	Lo	NEU	NFA1 high
AINH07M03	ARC Mod. Reclamation Mix	12	Lo	NEU	NFA9 Feha
AIHH98M02	ARC Diverse Seed Mix	3	Lo	WNT	NFA9 Feha
AIHH99M02	ARC Diverse Seed Mix	4	Lo	WNT	
AIHH00M02	ARC Diverse Seed Mix	5	Lo	WNT	
AINH98M02	ARC Diverse Seed Mix	3	Lo	NEU	NFA9 Feha
AINH99M02	ARC Diverse Seed Mix	4	Lo	NEU	NFA9 Feha

Note: No range health scores available for the sites in Disturbance Cluster 2

Cluster 3 - Awnless Brome - Kentucky Bluegrass

Cluster 3 (Table C.4-5) consists of 5 observations reclaimed with agronomic species mix, the Rumsey mix composed of native grasses and as natural recovery (Table C.4-6). Vegetation transects were completed between 12 and 18 years since reclamation.

The cluster represents a modified plant community (>70% cover of non-natives species) dominated by awnless brome (44.0%), Kentucky bluegrass (12.2%), sheep fescue (6%) and to a lesser extent quack grass, intermediate wheat grass, crested wheat grass and sweet clover (see Table C.4-5). Western wheat grass is the dominant native infill and seeded grass at 4.7% while plains rough fescue was present at only 0.5% cover on a natural recovery site. Western porcupine grass was not recorded at any of the sites. Native infill forbs were dominated by pasture sagewort and common yarrow at less than 1% each. Common wild rose was recorded at 2.4% cover on 3 sites.

The 5 observations are on a negative trajectory to a modified plant community composed of non-native and native species based on the years since reclamation. Two sites seeded with the agronomic mix 18 years ago would be expected to be modified or near so. Two of the remaining three sites had either no non-natives in the control or a relatively low cover 0.5% and 2.5%, for crested wheat grass and awnless brome, respectively. The control transect data for the fifth site was not available.

Reclaimed soils are representative of Orthic Dark Brown Chernozems correlated to Loamy-dry and moist range sites.

Table C.4-5 Dominant or Indicator Species Associated with Disturbance Cluster 3

Plant Species	Common Name	Cluster 3	5 Obs.
		Avg.	Const.
Bromus inermis	awnless brome	44.0	100.0
Poa pratensis L.	Kentucky bluegrass	12.2	100.0
Festuca ovina	sheep fescue	6.0	40.0
Agropyron smithii	western wheat grass	4.7	60.0
Festuca hallii	plains rough fescue	0.5	20.0
Artemisia frigida	pasture sagewort	0.8	60.0
Achillea millefolium	common yarrow	0.4	60.0
Rosa woodsii	common wild rose	2.4	60.0

Table C.4-6 Treatments and Site Conditions Associated with Disturbance Cluster 3

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AINH07NR	Natural Recovery, WS	12	Lo	NEU	NFA9 Feha		
AINH08NR	Natural Recovery, WS	13	Lo	NEU			
ELWS24D	Topsoil stripping, Agronomic mix, Currently fenced	18	Lo	END	NFA2	Unhealthy	Healthy with problems
ELWS27D	Topsoil stripping, Agronomic mix, Currently fenced	18	Lo	DRU	NFA2	Healthy with problems	Healthy with problems
ELWS34D	Topsoil stripping, Rumsey mix, Currently fenced	13	Lo	END	NFA9 Stcu	Healthy with problems	Healthy with problems

Cluster 4 - Awnless Brome - Slender Wheat grass - Kentucky Bluegrass

Cluster 4 (Table C.4-7) consists of 16 observations reclaimed with variety of native and agronomic seed mixes, planted plains rough fescue plugs and as natural recovery (Table C.4-8). Vegetation transects were completed between 3 and 23 years since reclamation.

The cluster represents a trending-to-modified plant community (40.2% relative cover of non-natives species) dominated by awnless brome (14.0%), Kentucky bluegrass (4.7%) and to a lesser extent quack grass, alfalfa and crested wheat grass (Table C.4-7). Plains rough fescue was recorded in all 4 reclamation type practices, but not in all of the 16 sites. Plains rough fescue ranged in cover from 0 to 8.0%; the highest value was recorded in a collected seed treatment site compared no record in the majority of the natural recovery sites. Slender wheat grass had the highest cover at 6.8% for seeded native grass species; it was also present in most of the natural recovery sites. Prairie sagewort is the dominant native infill forb, followed by common yarrow and wild vetch which could have come from native infill.

The 16 observations appear to be on a negative trajectory toward a modified plant community composed of non-native and native species, based on the medium to long term years since reclamation.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (9 sites) correlated to Loamy-dry and moist range sites, Orthic Black Chernozems (7 sites) correlated to Loamy-moist and a Dark Brown Solodized Solonetz correlated to transition Blowout - Loamy range site.

Table C.4-7 Dominant or Indicator Species Associated with Disturbance Cluster 4

Plant Species	Common Name	Cluster 4	16 Obs.
		Avg.	Const.
Bromus inermis	awnless brome	14.0	75.0
Elymus trachycaulus var. trachycaulus	slender wheat grass	6.8	75.0
Poa pratensis L.	Kentucky bluegrass	4.7	62.5
Artemisia ludoviciana	prairie sagewort	8.1	87.5
Achillea millefolium	common yarrow	3.4	75.0
Vicia americana	wild vetch	2.6	75.0
Festuca hallii	plains rough fescue	1.1	43.8

Table C.4-8 Treatments and Site Conditions Associated with Disturbance Cluster 4

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AIHH04M02	ARC Diverse Seed Mix	9	Lo	WNT	NFA9 Feha		
AIHH04M03	ARC Mod. Reclamation Mix	9	Lo	WNT	NFA9 Feha		
AIHH04NR	Natural Recovery, WS	9	Lo	WNT	NFA9 Feha		
AIHH07NR	Natural Recovery, WS	12	Lo	WNT	NFA1 high		
AIHH08M03	ARC Mod. Reclamation Mix	13	Lo	WNT	NFA1 low		
AIHH08NR	Natural Recovery, WS	13	Lo	WNT	NFA1 low		
AINH00NR	Natural Recovery, WS	5	Lo	NEU	NFA9 Feha		
AINH04NR	Natural Recovery, WS	9	Lo	NEU	NFA9 Feha		
ELWS08D	Topsoil stripping, Agronomic mix, Never fenced	23	Lo	END	NFC2	Unhealthy	Healthy with problems
ELWS10D	Topsoil stripping, Rumsey mix, Never fenced	18	Lo	END	NFA8	Unhealthy	Healthy with problems
ELWS16D	Topsoil stripping, Agronomic mix, Never fenced	23	Lo	END	NFA8	Healthy with problems	Unhealthy
ELWS17D	Topsoil stripping, Rumsey mix, Historically fenced	9	Lo	END	NFA2	Unhealthy	Healthy with problems
ELWS25D	Topsoil stripping, Agronomic mix, Historically fenced	23	Lo	END	NFA8	Healthy with problems	Healthy
DDDD43R	Disturbed topsoil, Seeded, PL, Seed Mix A1 revised, Rough fescue plugs, Not fenced	3	Lo	NEU	NFA1 low	Unhealthy	Healthy
DDDD54R	Disturbed topsoil, Seeded, PL, Seed Mix A1, Rough fescue plugs, Fenced	3	BlO	NEU	NFA7	Unhealthy	Healthy
FFFF49R	Seed Mix A1 revised, Rough fescue plugs, Site is fenced, but grazed	51	Lo	NEU	NFA9 Feha	Healthy (tame pasture)	Healthy

Cluster 5 - Plains Rough Fescue - Green Needle Grass - Slender Wheat grass

Cluster 5 (Table C.4-9) consists of 17 observations reclaimed with a variety of native grass seed mixes and a collected mix composed of native grasses and forbs (Table C.4-10). Vegetation transects were completed between 4 and 30 years following reclamation with the majority occurring between the 12 and 13 year.

The cluster represents a mid to late mid-seral native plant community dominated by plains rough fescue at 22.0% and seeded grasses of green needle grass and slender wheat grass at 10.6% and 5.7 % cover, respectively. Western porcupine grass was present, but at low cover averaging 2.6% and a constancy of 47.1%. It appears that dominance of plains rough fescue in this cluster relative to Cluster 4 could be due to minimal disturbance construction and/or superior reclamation practices.

The seeded native wheat grasses and green needle grass appear to be diminishing in cover. Prairie and pasture sageworts are the dominant native infill forbs, followed by wild vetch and common yarrow which could have come from native infill.

Twelve of the observations appear to be on a positive trajectory to native dominated plant communities. Kentucky bluegrass and awnless brome as individual or combined were present in 5 out of 12 sites at 2.5% to 5% cover. The remaining 4 observations are trending-to-modified with Kentucky bluegrass and awnless brome as individual or combined at 6.9% to 22.8% cover.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (11 sites) correlated to Loamy-dry and moist range sites and Orthic Black Chernozems (6 sites) correlated to Loamy-moist range sites.

Table C.4-9 Dominant or Indicator Species Associated with Disturbance Cluster 5

Plant Species	Common Name	Cluster 5	17 Obs.
		Avg.	Const.
Festuca hallii	plains rough fescue	22.0	100.0
Stipa viridula	green needle grass	10.6	100.0
Elymus trachycaulus var. trachycaulus	slender wheat grass	5.7	52.9
Artemisia ludoviciana	prairie sagewort	4.4	82.4
Artemisia frigida	pasture sagewort	4.2	70.6
Vicia americana	wild vetch	2.7	70.6
Achillea millefolium	common yarrow	2.3	58.8

Table C.4-10 Treatments and Site Conditions Associated with Disturbance Cluster 5

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AIHH04M01	ARC Simple seed mix	9	Lo	WNT	NFA9 Feha		
AIHH07M01	ARC Simple seed mix	12	Lo	WNT	NFA1 high		
AIHH07M02	ARC Diverse Seed Mix	12	Lo	WNT	NFA1 high		
AIHH07M03	ARC Mod. Reclamation Mix	12	Lo	WNT	NFA1 high		
AIHH08M01	ARC Simple seed mix	13	Lo	WNT	NFA1 low		
AIHH08M02	ARC Diverse Seed Mix	13	Lo	WNT	NFA1 low		
AINH04M01	ARC Simple seed mix	9	Lo	NEU	NFA9 Feha		
AINH04M02	ARC Diverse Seed Mix	9	Lo	NEU	NFA9 Feha		
AINH07M01	ARC Simple seed mix	12	Lo	NEU	NFA9 Feha		
AINH07M02	ARC Diverse Seed Mix	12	Lo	NEU	NFA9 Feha		
AINH08M01	ARC Simple seed mix	13	Lo	NEU	NFA9 Feha		
AINH08M03	ARC Mod. Reclamation Mix	13	Lo	NEU	NFA9 Feha		
APAC02R	WS; full width strip, seeded, Unfenced	20	Lo	NEU	NFA7	Healthy with problems	Healthy
ELPL09D	PL, Topsoil stripping, Natural recovery likely based on age	30	Lo	END	NFA1 high	Healthy	Healthy
ELWS05D	Minimal disturbance, Natural recovery, Currently fenced	4	Lo	END	NFA1 low	Healthy with problems	Healthy
ELWS21D	??		Lo	END	NFA1 low		
HUSK732R	WS, Seed Mix	7	Lo	WNT	NFA7	Healthy	Healthy

Cluster 6 - Green Needle Grass - Western Wheat grass - Awned Wheat grass

Cluster 6 (Table C.4-11) consists of 12 observations reclaimed with native grass seed mixes and agronomic seed mixes (may include native grasses) (Table C.4-12). Vegetation transects were completed between 3 and 55 years following reclamation.

The cluster represents a mid-seral native plant community dominated by seeded green needle grass at 26%, western wheat grass at 8.8% and awned wheat grass at 8.7% (Table C.4-12). Awned wheat grass appears as a replacement to slender wheat grass as the dominant short-lived wheat grass bunch-type seeded in over half of the monitoring sites. The presence of Kentucky bluegrass has this cluster at or near trending-to-modified. The near term sites (3 to 5 years since reclamation) did not record Kentucky bluegrass, whereas 5 of the mid to long term sites (9 to 51 years since reclamation) did record Kentucky bluegrass ranging from 5.3 % to 22.5% cover. The ELPL04D site was the only long terms (30 years) that did not record the bluegrass.

Plains rough fescue averaged 2.0% cover and a 50% constancy overall. The four near term sites (3 to 5 since reclamation) had the highest cover (2.3% to 6.9%) but it was absent or at low values (0% to 2.5%) for the remaining sites. Pasture and prairie sageworts are the dominant native infill forbs at 3.8% and 1.5%, respectively. Buckbrush averaged 10.3% cover and a constancy of 50%, with 5 sites having a cover greater than 18%, which could be interpreted as shrubland communities. This interpretation is supported by 2 adjoining control sites categorized as shrubland communities.

Approximately half of the sites are on a positive trajectory toward a native plant community as represented by the near term (3 to 5 years) and two long term (30 and 51 years) since reclamation monitoring sites. The other half of this cluster are on a negative trajectory toward trending-to-modified based on the cover Kentucky bluegrass ranging from 8% to 22.5%. Future monitoring of the positive trajectory sites would be valuable to see if the seeded native grass species (green needle grass and wheat grasses) are replaced by desirable species of plains rough fescue and western porcupine, or the undesirable species of Kentucky bluegrass and other non-native grass species.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (7 sites) correlated to Loamy-dry and moist range sites, Orthic Black Chernozems (3 sites) correlated to Loamy-moist range sites and a Solonetzic Dark Brown Chernozem correlated to a Loamy-dry range site. One site (AIPL08M02) did not have any detailed soils information.

Table C.4.11. Dominant or Indicator Species Associated with Disturbance Cluster 6.

Plant Species	Common Name	Cluster 6	12 Obs.
		Avg.	Const.
Stipa viridula	green needle grass	26.0	100.0
Agropyron smithii	western wheat grass	8.8	75.0
Elymus trachycaulus var. subsecundus	awned wheat grass	8.7	66.7
Poa pratensis L.	Kentucky bluegrass	6.7	58.3
Artemisia frigida	pasture sagewort	3.8	75.0
Artemisia ludoviciana	prairie sagewort	1.5	58.3
Symphoricarpos occidentalis	buckbrush (northern snowberry)	10.3	50.0

Table C.4-12 Treatments and Site Conditions Associated with Disturbance Cluster 6

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AIHH98M01	ARC Simple seed mix	3	Lo	WNT	NFA1 high		
AIHH99M01	ARC Simple seed mix	4	Lo	WNT			
AIHH00M01	ARC Simple seed mix	5	Lo	WNT	NFA1 high		
AIPL08M02	Contractor's Seed mix Pipeline	4	Lo	NEU	NFA1 high		
ELPL04D	Pipeline, Topsoil stripping, Agronomic seed mix	30	Lo	END	NFC2	Healthy with Problems	Healthy with problems
ELPL11D	Pipeline, ?, ?	19	Lo	END	NFA2	?	
ELPL16D	Pipeline, Topsoil stripping, Agronomic seed mix	30	Lo	END	NFA2	Healthy	Healthy
ELWS04D	Topsoil stripping, Agronomic mix, Never fenced	28	Lo	END	NFC2	Healthy with problems	Healthy with problems
ELWS20D	Topsoil stripping, Rumsey mix, Currently fenced	9	Lo	END		Healthy with problems	Healthy with problems
ELWS26D	Topsoil stripping, Rumsey mix, Currently fenced	23	Lo	END		Healthy with problems	Healthy
FFFF30R	Seed Mix A2 revised, Rough fescue plugs, Site not fenced, but has been grazed	55	Lo	NEU		Healthy with problems	Healthy with problems
FFFF46R	Seed Mix A1 revised, Rough fescue plugs, Site is fenced	51	Lo	NEU		Healthy with problems	Healthy with problems

Cluster 7 - Sheep Fescue - Western Wheat grass

Cluster 7 (Table C.4-13) consists of 5 observations reclaimed with a mix of agronomic and native grass species (Table C.4-14). Vegetation transects were completed between 19 and 51years following reclamation.

The cluster represents a trending-to-modified plant community (56.3% relative cover of non-natives species) dominated by sheep fescue at 31.7% cover and to a lesser extent, meadow brome (6.6%), intermediate wheat grass (1.6%) and Kentucky bluegrass (0.8%) (Table C.4-13). Sheep fescue was probably considered a compatible species at the time of reclamation and included in all 5 seed mixes. Meadow brome and intermediate wheat grass were probably considered compatible species at the time as well and included in the FFFF mixes. Sheep fescue appears to be a persistent[1] species and adapted to the area over the long-term recovery from disturbance.

Western wheat grass is the dominant native grass at 4.4% cover followed by northern wheat grass and western porcupine grass at 2.5% and 2.4% cover, respectively. Western porcupine grass appears to be an infill species for the FFFF sites, but its origin in the APAC01R and ELWS22D sites cannot be verified. Plains rough fescue infill was recorded in the FFFF sites ranging from 0.2 to 2.2% cover, but was not recorded in the remaining 2 sites. Prairie and pasture sagewort are the dominant native infill forbs, at 4.0% and 1.3% cover, respectively.

The 5 observations are correlated to a negative seral stage which appears to have stabilized at a trending-to-modified plant community based on the long-term period from the years since reclamation. The long-term species composition for these sites will probably be a non-native / native plant community.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (2 sites) correlated to Loamy-dry and moist range sites, Orthic Dark Brown Chernozems (1 site) correlated to a Sandy range site and Dark Brown Solodized Solonetz (2 sites) correlated to a late phase Blowout range sites.

Table C.4-13 Dominant or Indicator Species Associated with Disturbance Cluster 7

Plant Species	Common Name	Cluster 7	5 Obs.
		Avg.	Const.
Festuca ovina	sheep fescue	31.7	100.0
Agropyron smithii	western wheat grass	4.4	80.0
Elymus lanceolatus ssp. lanceolatus	Northern wheat grass	2.5	80.0
Stipa curtiseta	western porcupine grass	2.4	80.0
Artemisia ludoviciana	prairie sagewort	4.0	80.0
Artemisia frigida	pasture sagewort	1.3	80.0

[1] In restoration or rehabilitation projects, or as natural phenomena, the state where a plant can maintain itself indefinitely once it has become established (Dunster and Dunster 1996).

Table C.4-14 Treatments and Site Conditions Associated with Disturbance Cluster 7

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
APAC01R	WS; full width strip, Seeded, Unfenced	19	Lo	NEU	NFA7	Unhealthy	Healthy
ELWS22D	Topsoil stripping, Rumsey mix, Never fenced	23	Lo	END	NFC2	Unhealthy	Healthy with problems
FFFF51R	Seed Mix A1, Rough fescue plugs, Site is fenced but grazed	51	SY	NEU	NFA1 low	Unhealthy	Healthy
FFFF53R	Seed Mix A2 revised, Rough fescue plugs, Site is fenced	51	BlO	NEU	NFA10	Unhealthy	Healthy with problems
FFFF54R	Seed Mix A1, Rough fescue plugs, Site is fenced but grazed	51	BlO	NEU	NFA7	Unhealthy	Healthy

Cluster 8 - Snowberry - Kentucky Bluegrass

Cluster 8 consists of 4 observations reclaimed with an agronomic mix, a native seed mix and an unknown mix (Table C.4-15). Vegetation transects were completed between 33 and 55 years since reclamation which represents a relatively long-term return interval.

The cluster presents an early seral shrubland community dominated by buckbrush at 47.6% cover, common wild rose at 2.2% cover and Kentucky bluegrass at 13.5% cover (Table C.4-16). Quack grass (24.0% cover) replaced Kentucky bluegrass at one site as the dominant non-native species. Plains rough fescue and western porcupine grass are still at low cover values of 1.7% and 3.2%, respectively, after this significant long period of recovery. Common yarrow and pasture sagewort are the dominant native infill forbs, at 3.5% and 2.8% cover. Upland sedges are re-establishing as a component of ground cover at 3.9% and a constancy of 75%.

Based on the years the since reclamation, the seral stage appears to have stabilized under the present conditions to a native / non-native plant community.

Reclaimed soils are representative of Orthic Dark Brown Chernozems correlated to Loamy-dry (2 sites), Sandy (1 site) and Overflow (1 site) range sites.

Table C.4-15 Dominant or Indicator Species Associated with Disturbance Cluster 8

Plant Species	Common Name	Cluster 8	4 Obs.
		Avg.	Const.
Symphoricarpos occidentalis	buckbrush	47.6	100.0
Rosa woodsii	common wild rose	2.2	100.0
Poa pratensis L.	Kentucky bluegrass	13.5	75.0
Stipa viridula	green needle grass	4.2	100.0
Agropyron smithii	western wheat grass	3.6	75.0
Achillea millefolium	common yarrow	3.5	75.0
Artemisia frigida	pasture sagewort	2.8	50.0
Carex species	sedge species	3.9	75.0

Table C.4-16 Treatments and Site Conditions Associated with Disturbance Cluster 8

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
ELWS02D	Topsoil stripping, Agronomic mix, Never fenced	38	Lo	END	NFA8	Healthy with problems	Unhealthy
ELWS31D	Unknown construction method, Unknown reveg method, Never fenced	33	Lo	DRU	NFA9 Stcu	Healthy	Unhealthy
FFFF27R	Seed Mix A1, Rough fescue plugs, Site is fenced	55	OV	NEU	NFC2	Healthy with problems	Healthy with problems
FFFF36R	Seed Mix A1, Rough fescue plugs, Site is fenced	55	SY	NEU	NFC2	Healthy with problems	Healthy with problems

Cluster 9 - Kentucky Bluegrass - Western Wheat grass

Cluster 9 (Table C.4-17) consists of 11 observations reclaimed with agronomic mixes, native mixes and as natural recovery (Table C.4-18). Vegetation transects were completed between 7 and 51 years following reclamation.

The cluster represents a trending-to-modified plant community (23.8% relative cover of non-natives species) dominated by Kentucky bluegrass at 19.3% cover and to lesser extent, awnless brome (3.3%) and sheep fescue (0.8%) (Table C.4-17). In this cluster, the presence of Kentucky bluegrass in 7 controls (ranging from 0.2% to 20% cover) probably contributed to invasion in the adjoining disturbances (ranging from 11.7% to 34.5% cover). However, 4 controls did not record any Kentucky bluegrass but it was present in the adjoining disturbances (ranging from 7.0% to 23.7% cover).

Western wheat grass and western porcupine grass are the dominant native grass at 8.0% and 5.5% cover, respectively. Western wheat grass appears to be from infill and seed mixes, whereas western porcupine grass is from infill based on a review of the species composition of the various mixes. Plains rough fescue cover was 3.3% and a constancy of 45.5% of which the highest relative cover was in the natural recovery treatments. Prairie and pasture sagewort are the dominant native infill forbs, at 6.0% and 5.1% cover, respectively. Buckbrush infill was recorded at 11.1% cover and constancy of 72.7%.

The 11 observations are either on a negative trajectory toward a trending-to-modified, or a relatively stable negative seral stage plant community. The composition will be a native / non-native plant community.

Reclaimed soils are representative of Orthic Dark Brown Chernozems correlated primarily to Loamy-moist range sites and one Dark Brown Solodized Solonetz correlated to a late phase Blowout range site.

Table C.4-17 Dominant or Indicator Species Associated with Disturbance Cluster 9

Plant Species	Common Name	Cluster 9	11 Obs.
		Avg.	Const.
Poa pratensis L.	Kentucky bluegrass	19.3	100.0
Agropyron smithii	western wheat grass	8.0	90.9
Stipa curtiseta	western porcupine grass	5.5	90.9
Elymus lanceolatus ssp. lanceolatus	Northern wheat grass	3.3	100.0
Artemisia ludoviciana	prairie sagewort	6.0	90.9
Artemisia frigida	pasture sagewort	5.1	81.8
Symphoricarpos occidentalis	buckbrush	11.1	72.7

Table C.4-18 Treatments and Site Conditions Associated with Disturbance Cluster 9

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
ELPL03D	Pipeline, Topsoil stripping, Natural recovery	21	Lo	END	NFA1 high	Unhealthy	Healthy
ELPL05D	Pipeline, PI Natural recovery	7	Lo	END	NFA1 low	Healthy with Problems	Healthy with problems
ELPL12D	Pipeline, Topsoil stripping, Natural recovery	16	Lo	END	NFA1 low	Healthy	Healthy
ELWS06D	Topsoil stripping, Agronomic mix, Never fenced	28	Lo	END	NFA2	Unhealthy	Healthy with problems
ELWS07D	Topsoil stripping, Rumsey mix, Currently fenced	9	Lo	END	NFA1 low	Unhealthy	Healthy with problems
ELWS09D	Topsoil stripping, Agronomic mix, Currently fenced	18	Lo	END	NFC2	Healthy with problems	Healthy with problems
ELWS12D	Topsoil stripping, Rumsey mix, Never fenced	23	Lo	END	NFA2	Unhealthy	Healthy
ELWS15D	Topsoil stripping, Rumsey mix, Never fenced	23	Lo	END	NFA8	Unhealthy	Unhealthy
ELWS18D	Topsoil stripping, Agronomic mix, Never fenced	28	Lo	END	NFA2	Unhealthy	Healthy with problems
ELWS28D	Topsoil stripping, Rumsey mix, Never fenced	18	Lo	END	NFA1 low	Unhealthy	Healthy
FFFF52R	Seed Mix A2 revised, Rough fescue plugs, Site fenced, but grazed	51	BlO	NEU	NFA9 Stcu	Unhealthy	Healthy

Cluster 10 - Quack Grass - Kentucky Bluegrass

Cluster 10 (Table C.4-19) consists of 4 observations reclaimed with a native and compatible agronomic species mix, an agronomic mix and native mix (Table C.4-20). Vegetation transects were completed between 8 and 38 years following reclamation.

The cluster presents a modified plant community (69.8% cover of non-natives species) dominated by quack grass at 22.6% cover, Kentucky bluegrass 9.8% cover, sweet clover at 21.3%, dandelion at 7.6% cover, and to a lesser extent, awnless brome (Table C.4-19). Sheep fescue, intermediate wheat grass and alfalfa were present in low quantities and probably included as compatible agronomic species as a reclamation practice in earlier years. The cover of non-native species in the controls were relatively low (quack grass at 3% on one site and Kentucky bluegrass at 0.2% on another site) compared to the disturbances.

The cover sweet clover was relatively high (33.5% and 50.0%) on two of the 3 sites. Sweet clover is a short-lived biennial but can readily establish on areas of sparse vegetation cover (Tannas 2003) and generally during years of above average precipitation. Therefore, the cover can be quite variable between years and not a good indicator of mid to long term seral plant communities.

Both western porcupine grass (0.5 % cover and a constancy of 25.0%) and plains rough fescue (no record) are relatively non-existent in this cluster. Pasture sagewort and common yarrow are the dominant native infill forbs, at 2.5% and 1.2% cover, respectively.

The 4 observations correlate to a negative seral stage modified plant community. The long-term species composition for these sites will probably be a non-native / native plant community.

Reclaimed soils are representative of Orthic Dark Brown Chernozems correlated to Loamy-moist, and Sandy range sites.

Table C.4-19 Dominant or Indicator Species Associated with Disturbance Cluster 10

Plant Species	Common Name	Cluster 10	4 Obs.
		Avg.	Const.
Elytrigea repens var. repens	quack grass	22.6	75.0
Poa pratensis L.	Kentucky bluegrass	9.8	75.0
Agropyron smithii	western wheat grass	3.9	75.0
Melilotus officinalis	yellow sweet-clover	21.3	75.0
Taraxacum officinale	common dandelion	7.6	50.0
Artemisia frigida	pasture sagewort	2.5	75.0
Achillea millefolium	common yarrow	1.2	50.0

Table C.4-20 Treatments and Site Conditions Associated with Disturbance Cluster 10

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
CNRL01R2	WS, Disturbed, Topsoil added early 1990's, Seeded to native mix 2005	8	SY	NEU	NFA9 Stcu	Healthy with problems	Healthy with problems
ELWS03D	Unknown construction method, Agronomic mix, Never fenced	38	Lo	END	NFA1 low	Unhealthy	Healthy
ELWS19D	Topsoil stripping, Rumsey mix, Historically fenced	23	Lo	END	NFA2	Unhealthy	Healthy with problems
ELWS23D	Topsoil stripping, Rumsey mix, Currently fenced	18	Lo	END	NFA2	Healthy with problems	Healthy with problems

Cluster 11 - Western Wheat grass - Northern Wheat grass - Western Porcupine Grass

Cluster 11 (Table C.4-21) consists of 9 observations reclaimed with native grass seed mixes and as natural recovery (Table C.4-22). Vegetation transects were completed between 6 and 55 years following reclamation.

The cluster represents a mid-seral native plant community dominated by western wheat grass at 26.7% cover which appears to have come from infill and seed mixes (Table C.4-21). Northern wheat grass (6.1% cover) and June grass (5.3% cover) appear to follow similar paths of establishment to that of western wheat grass.

Western porcupine grass was not in the native seed mix (Rumsey mix) and was not available as commercial seed when the FFFF project was completed; therefore it probably established as infill from the adjoining control areas. Plains rough fescue cover is relatively low at 2.4 % and a constancy of 44.4% and was a component of the Rumsey mix. Prairie sagewort and wild vetch are the dominant native infill forbs at 7.2% and 2.6% cover, respectively.

Seven observations are on a positive trajectory towards a native plant community, whereas 2 sites are on a negative trajectory to a trending-to-modified plant community. Kentucky bluegrass and sheep fescue are the dominant non-native species associated the trending-to-modified communities.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (8 sites) correlated to Loamy-dry and moist range sites and one Dark Brown Solodized Solonetz correlated to late phase Blowout range site.

Table C.4-21 Dominant or Indicator Species Associated with Disturbance Cluster 11

Plant Species	Common Name	Cluster 11	9 Obs.
		Avg.	Const.
Agropyron smithii	western wheat grass	26.7	100.0
Elymus lanceolatus ssp. lanceolatus	Northern wheat grass	6.1	88.9
Stipa curtiseta	western porcupine grass	5.4	88.9
Koeleria macrantha	June grass	5.3	77.8
Artemisia frigida	pasture sagewort	7.2	88.9
Vicia americana	wild vetch	2.6	77.8

Table C.4-22 Treatments and Site Conditions Associated with Disturbance Cluster 11

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
ELPL01D	Pipeline, Topsoil stripping, Natural recovery	6	Lo	END	NFA2	Unhealthy	Healthy with problems
ELPL06D	Pipeline, Topsoil stripping, Natural recovery	11	Lo	END	NFA8	Unhealthy	Unhealthy
ELWS01D	Minimal disturbance, Natural recovery, Never fenced	9	Lo	END	NFA8	Unhealthy	Unhealthy
ELWS29D	Topsoil stripping, Rumsey mix, Currently fenced	9	Lo	END	NFA8	Unhealthy	Healthy with problems
ELWS30D	Topsoil stripping, Rumsey mix, Historically fenced	9	Lo	DRU	NFA8	Healthy with problems	Unhealthy
ELWS32D	Topsoil stripping, Rumsey mix, Never fenced	9	Lo	END	NFC2	Unhealthy	Healthy with problems
ELWS33D	Treatment unknown	6	Lo	END	NFA8		
FFFF13R	Seed Mix A1, Rough fescue plugs, Site is fenced	55	Lo	OYE	NFA8	Healthy with problems	Healthy with problems
FFFF26R	Seed Mix A1, Rough fescue plugs, Site is fenced	55	BlO	NEU	NFA2	Healthy with problems	Healthy

Cluster 12 - Northern Wheat grass - Western Porcupine Grass - Low Sedge

Cluster 12 (Table C.4-23) consists of 17 observations reclaimed with native grass seed mixes, agronomic seed mixes (may include native grasses) and as natural recovery (Table C.4-24). Vegetation transects were completed between 6 and 55 years following reclamation.

The cluster represents a mid-seral native plant community dominated by northern wheat grass at 14.4% cover, western porcupine grass at 8.6% cover and low sedge at 8.4% cover (Table C.4-23). Northern wheat grass and western porcupine grass appear to have established from infill and / or seed mixes, whereas low sedge established as an infill species. Plains rough fescue averaged 4.5% cover with a constancy of 58.8% and highly variable regarding site treatment and year since reclamation. Pasture sagewort and small-leaved everlasting were the dominant forbs at 12.9% and 1.4% cover, respectively. Forbs, either as a group or as individual species, have relatively low cover values for this cluster. At least 2 sites in this cluster were categorized as undisturbed (topsoil not disturbed, vegetation and topsoil driven over by vehicles). Recovery will depend on the degree of compaction to topsoil, response of vegetation to no vehicle disturbance and grazing pressure.

Fourteen of the observations appear to be on a positive trajectory to native dominated plant communities. Kentucky bluegrass was present in 5 of the 14 sites at relatively low cover values (ranging from 0.5% to 2.4 %) and sheep fescue and Kentucky bluegrass were present in one of the 14 sites (1.7% and 1.5% cover, respectively). The remaining 3 observations appear to be on a negative trajectory to a trending-to-modified plant community with 2 sites having 7.0% cover each of Kentucky bluegrass, and the one site having 5.3% cover of sheep fescue.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (13 sites) correlated to Loamy-dry and moist range sites, Orthic Dark Brown Chernozems (2 sites) correlated to Sandy range sites, Dark Brown Solodized Solonetz correlated to a late phase Blowout range site. Site DDDD02R is representative of an Orthic Brown Chernozem correlated to a Sandy range site.

Table C.4-23 Dominant or Indicator Species Associated with Disturbance Cluster 12

Plant Species	Common Name	Cluster 12	17 Obs.
		Avg.	Const.
Elymus lanceolatus ssp. lanceolatus	Northern wheat grass	14.4	100.0
Stipa curtiseta	western porcupine grass	8.6	82.4
Carex stenophylla	low sedge	8.4	100.0
Agropyron smithii	western wheat grass	5.5	82.4
Artemisia frigida	pasture sagewort	12.9	100.0
Antennaria parvifolia	small-leaved everlasting	1.4	41.2

Table C.4-24 Treatments and Site Conditions Associated with Disturbance Cluster 12

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
CNRL01R	WS; Minimal disturbance, Natural recovery	56	SY	NEU	NFA9 Stcu	Healthy with Problems	Healthy with problems
CNRL03R1	WS; Minimal disturbance, Natural recovery	11	Lo	NEU	NFA9 Stcu	Healthy with Problems	Healthy with problems
ELPL02D	Pipeline, Topsoil stripping, Natural recovery	19	Lo	END	NFA9 Stcu	Healthy with Problems	Healthy with problems
ELPL07D	Pipeline, Topsoil stripping, Natural recovery	11	Lo	END	NFA8	Healthy with Problems	Healthy with problems
ELPL08D	Pipeline, Ploughed in, Natural recovery	7	Lo	END	NFA1 low	Healthy with Problems	Healthy
ELPL10D	Pipeline, Topsoil stripping, Agronomic seed mix	30	Lo	END	NFA8	Healthy with Problems	Healthy with problems
ELPL13D	Pipeline, Topsoil stripping, Agronomic seed mix	30	Lo	END	NFA1 low	Healthy	Healthy
ELPL14D	Pipeline, Topsoil stripping, Rumsey native mix	19	Lo	END	NFA2	Unhealthy	Healthy
ELPL15D	Pipeline, Topsoil stripping, Rumsey native mix	19	Lo	END	NFC2	Healthy with Problems	Healthy
ELPL17D	Pipeline, Ditch Witch, Natural recovery	16	Lo	END	NFA8	Unhealthy	Healthy with problems
ELWS11D	WS, Minimal disturbance, Natural recovery, Never fenced	9	Lo	END	NFA8	Unhealthy	Unhealthy
ELWS13D	Topsoil stripping, Agronomic mix, Never fenced	23	Lo	END	NFA8	Unhealthy	Healthy with problems
ELWS14D			Lo	END	NFA1 low		
DDDD02R	Disturbed topsoil, Seeded pipeline, Seed Mix A9 revised, Fenced	4	SY	BIN	DMG NSR	Healthy with Problems	Healthy
FFFF31R	Seed Mix A2 revised, Rough fescue plugs, Site is fenced, but grazed	55	SY	NEU	NFA9 Stcu	Unhealthy	Healthy with problems
FFFF33R	Seed Mix A1, Rough fescue plugs, Site is fenced, but grazed	55	Lo	NEU	NFA9	Healthy with Problems	Healthy with Problems
X04D10	Pipeline, disturbed topsoil, native seed mix	14	BlO	CAS	NFA9 Stcu	Healthy with Problems	Healthy

Cluster 13 - Pasture Sagewort - Slender Wheat grass

Cluster 13 (Table C.4-25) consists of 22 observations reclaimed with a variety of native grass seed mixes, a native mix of native grasses and forbs (ARC diverse mix) and natural recovery (Table C.4-26). Plains rough fescue plugs were planted along with a native grass seed mix (DDDD30R), and sheep fescue was included in a native grass seed mix as a compatible agronomic species (CNRL03R2) (Table C.4-25). Vegetation transects were completed between 1 and 10 years following reclamation.

The cluster represents plant communities with relatively low total vegetation cover (average of 26.9% compared to an average of 88.9% cover for the other 14 clusters). The plant communities also have low cover values for native and seeded grass species. The cluster appears to split somewhat between a pioneer to early seral group, 1 to 2 years since reclamation (Subset A), and a mid-seral to trending-to-modified (18.1% relative cover of non-natives species) group, 3 to 10 years since reclamation (Subset B). Subset A is dominated by a low cover of native infill forbs followed by infill and seeded native grass species. Subset A has low cover of annual weeds (lamb's-quarter, stinkweed and oak-leaved goosefoot) which can be expected for early seral plant communities on recently reclaimed topsoil. Approximate total vegetation cover for this subset is 10%.

Subset B is dominated by a low cover of seeded native and agronomic grass species followed by native forbs. Approximate total vegetation cover for this subset is 48%. Other disturbances such as moderate grazing pressure may be a factor in reducing cover and desirable species.

Buckbrush was recorded in the cluster at 1.7% cover and a constancy of 63.6% (0.4 % cover in Subset A and 3.0% cover in Subset B).

Reclaimed soils are representative of Orthic Dark Brown Chernozems (15 sites) correlated to Loamy-dry range sites, Orthic Black Chernozem (6 sites) correlated Loamy-moist range site and one Dark Brown Solodized Solonetz correlated to a late phase Blowout range site.

Table C.4-25 Dominant or Indicator Species Associated with Disturbance Cluster 13

Plant Species	Common Name	Cluster 13	22 Obs.
		Avg.	Const.
Artemisia frigida	pasture sagewort	2.1	72.7
Vicia americana	wild vetch	1.5	77.3
Artemisia ludoviciana	prairie sagewort	1.1	50.0
Elymus trachycaulus var. trachycaulus	slender wheat grass	2.2	45.5
Festuca hallii	plains rough fescue	1.4	68.2
Symphoricarpos occidentalis	buckbrush	1.7	63.6

Table C.4-26 Treatments and Site Conditions Associated with Disturbance Cluster 13

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community	Disturbance Range Health	Control Range Health
AIHH96M01	ARC Simple seed mix	1	Lo	WNT	NFA1 low		
AIHH96M02	ARC Diverse Seed Mix	1	Lo	WNT	NFA1 low		
AIHH96M03	ARC Mod. Reclamation Mix	1	Lo	WNT	NFA1 low		
AIHH96NR	Natural Recovery, WS	1	Lo	WNT	NFA1 low		
AINH96M01	ARC Simple seed mix	1	Lo	NEU	NFA9 Feha		
AINH96M02	ARC Diverse Seed Mix	1	Lo	NEU	NFA9 Feha		
AINH96M03	ARC Mod. Reclamation Mix	1	Lo	NEU	NFA9 Feha		
AINH96NR	Natural Recovery, WS	1	Lo	NEU	NFA9 Feha		
X04D97	PL, disturbed topsoil, native seed mix	1	BlO	CAS	NFA7		
AIHH97M01	ARC Simple seed mix	2	Lo	WNT	NFA7		
AIHH97NR	Natural Recovery, WS	2	Lo	WNT	NFA7		
AIPL07NR	Natural Recovery Pipeline	3	Lo	NEU	NFA1 high		
DDDD30R	Disturbed topsoil, Seeded pipeline, Seed Mix A2 revised, Rough fescue plugs, Site is not fenced and has been grazed	3	Lo	NEU	NFA9 Stcu	Healthy with Problems	Healthy with problems
PAR2330R		6	Lo	END	NFA9 Feha	Healthy	Healthy
PAR1330R	WS, Natural recovery	6	Lo	END	NFA9 Feha	Healthy	Healthy
PAR3330R	WS, Natural recovery	6	Lo	END		Healthy	Healthy
PAR4330R	WS, Natural recovery	6	Lo	END		Healthy	Healthy
PAR5330R	WS, Natural recovery	6	Lo	END		Healthy	Healthy
PAR1521R	WS, Natural recovery	7	Lo	DRU	NFA1 high	Healthy	Healthy
AINH04M03	ARC Modified Reclamation Mix	9	Lo	NEU	NFA9 Feha		
SA103R	Seeded flow line; SA mix, Land purchased through tax recovery December 2007 and now private land	9	Lo	DRU	NFA9 Stcu		
CNRL03R2	Disturbed portion from hill cut, Seeded native wheat grass cultivars plus hard fescue	10	Lo	NEU	NFA9 Stcu	Healthy with Problems	Healthy with problems

Cluster 14 - Pasture Sagewort - Green Needle Grass - Awned Wheat grass

Cluster 14 (Table C.4-27) consists of 11 observations reclaimed with native grass seed mixes, two types of native mixes composed of native grasses and forbs (ARC and collected) and as natural recovery (Table C.4-28). Vegetation transects were completed between 2 and 13 years following reclamation.

The cluster represents an early to mid-seral native plant community dominated by pasture sagewort at 27.4% cover and established from infill (Table C.4-27). All other native forbs are either infill or from seed mixes, at less than 1.0% cover for each species. Seeded native grass species of green needle grass and awned wheat grass were the next dominant graminoids at 8.7% and 5.9%, respectively. Plains rough fescue cover at 4.5% and constancy of 90.9% appears to be primarily associated with seeded treatments, which included plains rough fescue in the mixes. The natural recovery treatments had low cover values for plains rough fescue (ranging from 0 to 0.3% cover) compared to seeded sites (ranging from 2.5% to 3.8% cover) for similar years since reclamation.

Nine observations appear to be on a positive trajectory to native dominated plant communities. Within this group, 6 of the 9 sites have low cover values for non-native grass species (ranging from 0.3% to 2.5%). The remaining 2 observations (AINH99NR & X04D99) appear to be on a negative trajectory of trending-to-modified with non-native species cover at 12.0% and 5.0% cover, respectively.

Reclaimed soils are representative of Orthic Dark Brown Chernozems (9 sites) correlated to Loamy-dry and moist range sites, and Dark Brown Solodized Solonetz (2 sites) correlated to late phase Blowout range sites.

Table C.4-27 Dominant or Indicator Species Associated with Disturbance Cluster 14

Plant Species	Common Name	Cluster 14	11 Obs.
		Avg.	Const.
Artemisia frigida	pasture sagewort	27.8	100.0
Stipa viridula	green needle grass	8.7	72.7
Elymus trachycaulus var. subsecundus	Awned wheat grass	5.9	72.7
Festuca hallii	plains rough fescue	4.5	90.9
Koeleria macrantha	June grass	2.1	72.7
Symphoricarpos occidentalis	buckbrush	5.6	72.7

Table C.4-28 Treatments and Site Conditions Associated with Disturbance Cluster 14

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community
AINH97M01	ARC Simple seed mix	2	Lo	NEU	NFA9 Feha
AINH98M01	ARC Simple seed mix	3	Lo	NEU	
AINH99M01	ARC Simple seed mix	4	Lo	NEU	NFA9 Feha
AINH00M01	ARC Simple seed mix	5	Lo	NEU	NFA9 Feha
AIPL08M03	Collected Seed mix Pipeline	4	Lo	NEU	
AINH08M02	ARC Diverse Seed Mix	13	Lo	NEU	
X04D99	PL, Disturbed topsoil, Native seed mix	3	BlO	CAS	NFA9 Feha
X04D01	PL, Disturbed topsoil, Native seed mix	5	BlO	CAS	NFA9 Feha
AINH97NR	Natural Recovery, WS	2	Lo	NEU	NFA1 high
AINH98NR	Natural Recovery, WS	3	Lo	NEU	
AINH99NR	Natural Recovery, WS	4	Lo	NEU	NFA9 Feha

No range health scores available for the sites in Disturbance Cluster14

Cluster 15 - Pasture Sagewort - Slender Wheat grass - Foxtail Barley

Cluster 15 (Table C.4-29) consists of 16 observations reclaimed with native grass seed mixes, two types of native mixes composed of native grasses and forbs (ARC and collected) and as natural recovery (Table C.4-30). Vegetation transects were completed between 1 and 5 years following reclamation.

The cluster represents an early to mid-seral native plant community dominated pasture sagewort at 15.0% cover, slender wheat grass at 5.6% cover and foxtail barley at 5.8% cover. Both pasture sagewort and foxtail barley are early seral species associated with disturbed soils. The majority of the sites (9 sites) are 1 or 2 years since reclamation and would be considered early seral, but succession to later seral stages appears to be slower on moist loamy Orthic Black and Orthic Dark Brown Chernozemic soils 3 to 5 years since reclamation where the cover of pasture sagewort and foxtail barley remains high, especially on the natural recovery sites. Foxtail barley can be one of the first grasses to establish after disturbance and may become dominant in early seral grassland communities, especially on higher soil moisture sites (Tannas 2003, Tesky 1992).

Slender and awned wheat grass are the dominant seeded native grass species at 5.6% and 2.8% cover, respectively. Plains rough fescue is present at 2.8% and a constancy of 87.5% whereas the cover and constancy of western porcupine grass was relatively low at 0.4% and 31.3%, respectively. All other native forbs are either infill or from seed mixes, at less than 1.4% cover for each species.

Perennial sow-thistle, a noxious weed, was recorded at 1.4% cover and a constancy of 81.3%. This cluster appears to have the highest constancy and second highest cover of noxious weeds, which includes Canada thistle, compared to the other clusters. Only Cluster 11 had a higher cover at 4.1% (perennial sow thistle and Canada thistle combined) but a lower constancy (33%).

Reclaimed soils are representative of Orthic Dark Brown Chernozems (8 sites) correlated to Loamy-dry and moist range sites, Orthic Black Chernozems (7 sites) and one Dark Brown Solodized Solonetz correlated to late phase Blowout range site.

Table C.4-29 Dominant or Indicator Species Associated with Disturbance Cluster 15

Plant Species	Common Name	Cluster 15	16 Obs.
		Avg.	Const.
Artemisia frigida	pasture sagewort	15.0	100.0
Elymus trachycaulus var. trachycaulus	Slender wheat grass	5.6	100.0
Hordeum jubatum	foxtail barley	5.8	75.0
Elymus trachycaulus var. subsecundus	Awned wheat grass	2.8	87.5
Agrostis scabra	rough hair grass	3.0	75.0
Festuca hallii	plains rough fescue	1.8	81.3
Sonchus arvensis	perennial sow-thistle	1.4	81.3

Table C.4-30 Treatments and Site Conditions Associated with Disturbance Cluster 15

Monitoring Site ID	Treatment	Years Since Reclamation	GVI	Eco-district	Control Plant Community
AIHH00NR	Natural Recovery, WS	5	Lo	WNT	NFA1 high
AIHH98NR	Natural Recovery, WS	3	Lo	WNT	NFA1 high
AIHH99NR	Natural Recovery, WS	4	Lo	WNT	NFA1 high
AINH97M02	ARC Diverse Seed Mix	2	Lo	NEU	NFA9 Feha
AIPL05M01	ARC Seed Mix Pipeline	1	Lo	NEU	NFA9 Feha
AIPL05M02	ARC Diverse Seed Mix Pipeline	1	Lo	NEU	NFA9 Feha
AIPL05M03	Collected Seed Mix Pipeline	1	Lo	NEU	NFA9 Feha
AIPL05NR	Natural Recovery Pipeline	1	Lo	NEU	NFA9 Feha
AIPL06M01	ARC Seed Mix Pipeline	2	Lo	NEU	NFA9 Feha
AIPL06M03	Collected Seed Mix Pipeline	2	Lo	NEU	NFA9 Feha
AIPL06NR	Natural Recovery Pipeline	2	Lo	NEU	NFA9 Feha
AIPL07M01	ARC Seed Mix Pipeline	3	Lo	NEU	NFA1 high
AIPL07M03	Collected Seed Mix Pipeline	3	Lo	NEU	NFA1 high
AIPL08M01	ARC Seed Mix Pipeline	4	Lo	NEU	NFA1 high
AIPL08NR	Natural Recovery Pipeline	4	Lo	NEU	NFA1 high
X04D98	PL, Disturbed topsoil, Native seed mix	2	BlO	CAS	NFA7

No range health scores available for the sites in Disturbance Cluster15

C.5 Results – Comparison of Recovery for Seeded and Natural Recovery Reclamation Treatments

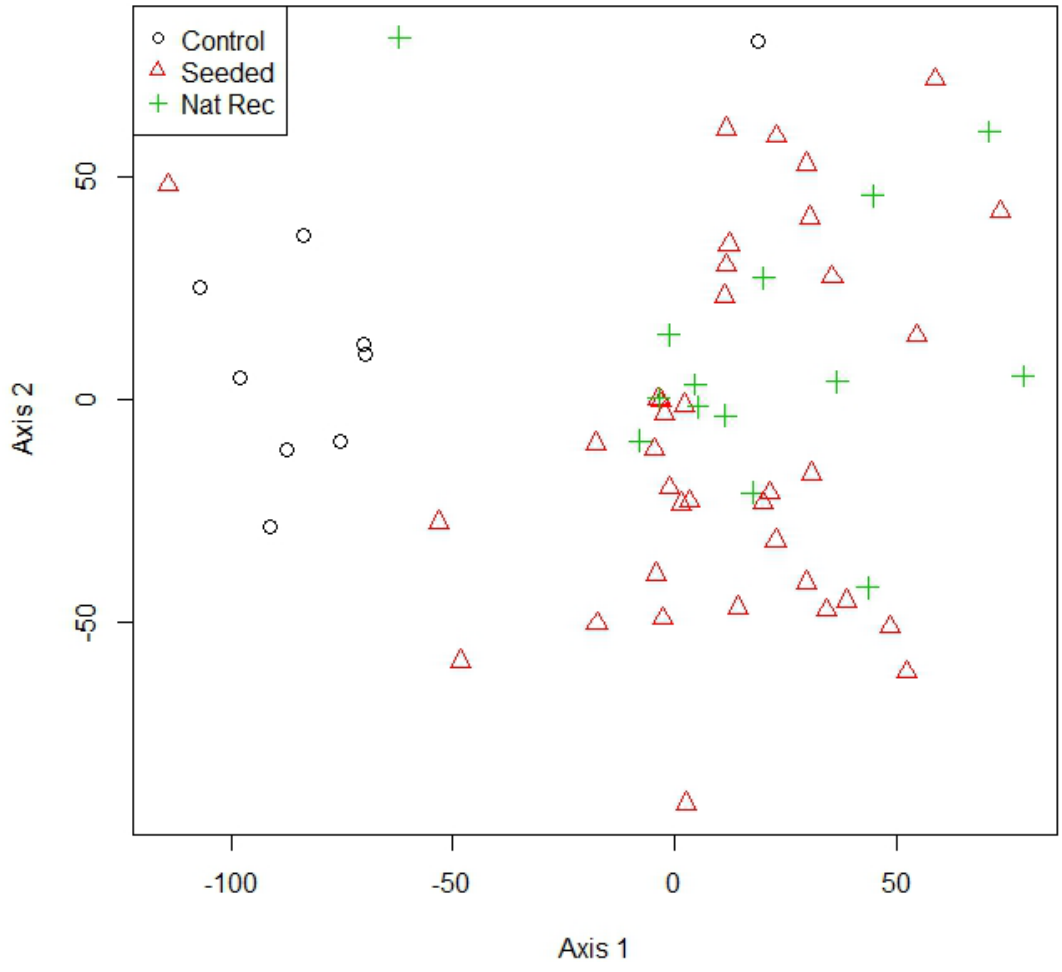
The clusters of undisturbed sites formed the basis of the ordination of associated disturbed sites. Figures were produced using Non-metric Multidimensional Scaling (NMS). The number of dimensions was chosen to provide a low stress solution. Ordination figures for Control Clusters 2 through 8 are in two dimensions. The ordination figure for Control Cluster 1 is in three dimensions. Only vascular species cover data was used in the ordination. Total vegetation cover, litter cover, and soil exposure data were excluded.

Control Cluster 1 - NFA1. Plains Rough Fescue – Western Porcupine Grass

This is a reference grassland plant community on the moister Loamy range sites in the Northern Fescue NSR (Kupsch et al. 2012). Plains rough fescue is the dominant species followed by western porcupine grass. The cluster appears to represent the mid to upper range of the NFA1 plant community ecological status. Range health will be good at these sites with potential for infill from the seed bank or surrounding areas.

The cluster diagram is in three dimensions (Figure C.5-1). None of the seeded or natural recovery sites are clustering closely with the controls, indicating that species composition and cover on the reclaiming disturbance sites is not similar to the undisturbed plant community. However, many of the treatments appear similar to one another.

Figure C.5-1 NMS Ordination of Treatments on Control Cluster 1 Sites (NFA1 Reference)

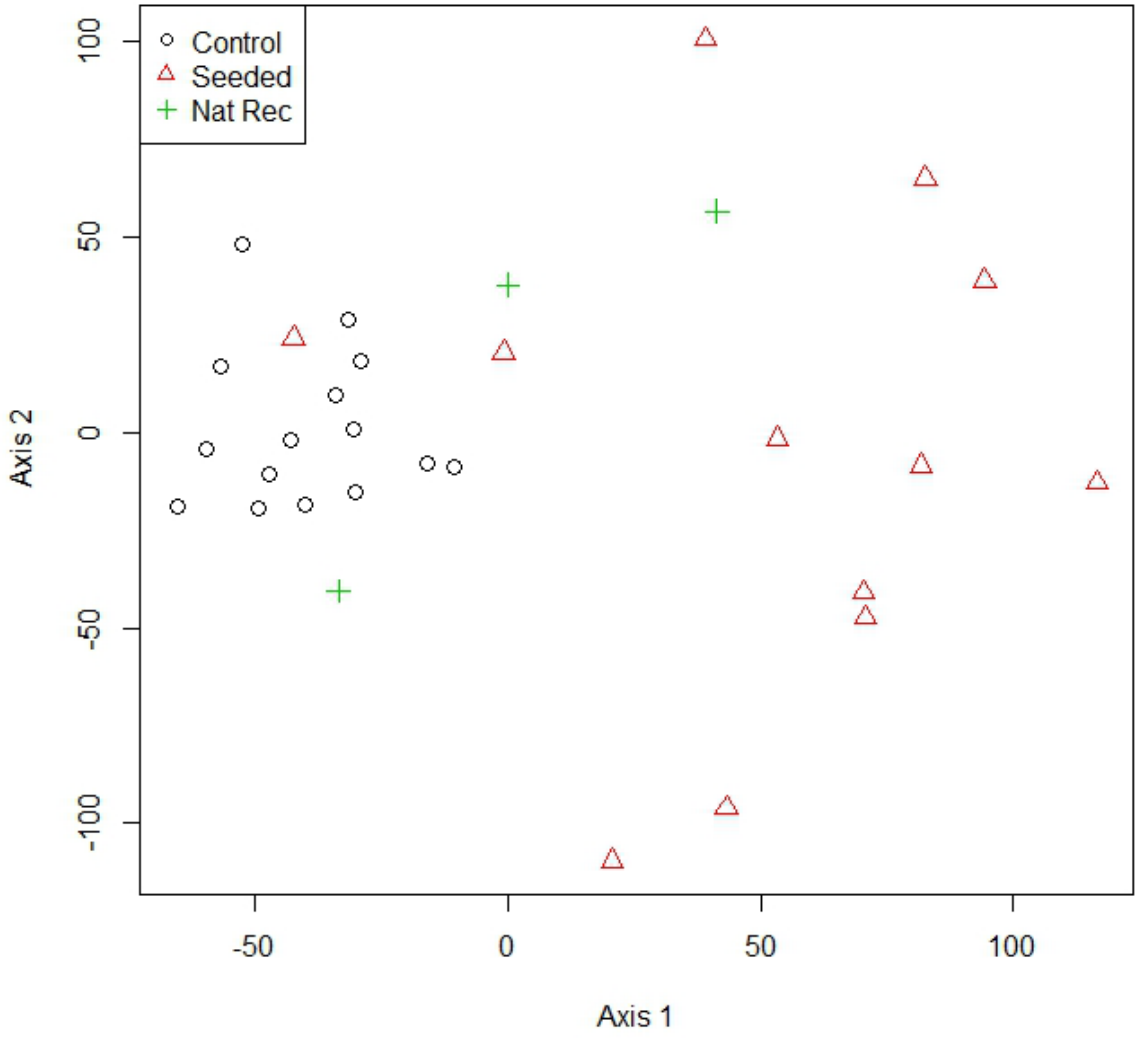


Control Cluster 2 - NFA1. Plains Rough Fescue – Western Porcupine Grass

Control Cluster 2 also correlates to the NFA1 reference grassland plant community on moist Loamy range sites in the Northern Fescue NSR. This cluster is similar to Cluster 1 with plains rough fescue as the dominant species followed by western porcupine grass, but appears to represent the mid to low ecological status for the NFA1 plant community.

The cluster diagram is in two dimensions (Figure C.5-2). A few of the seeded or natural recovery sites are clustering closely with the controls, indicating that at some sites species composition and cover on the reclaiming disturbance sites are similar to the undisturbed plant community. However, this plant community is at risk to invasion by Kentucky bluegrass and awnless brome after disturbance.

Figure C.5-2 NMS Ordination of Treatments on Control Cluster 2 Sites (NFA1 Lower Status)

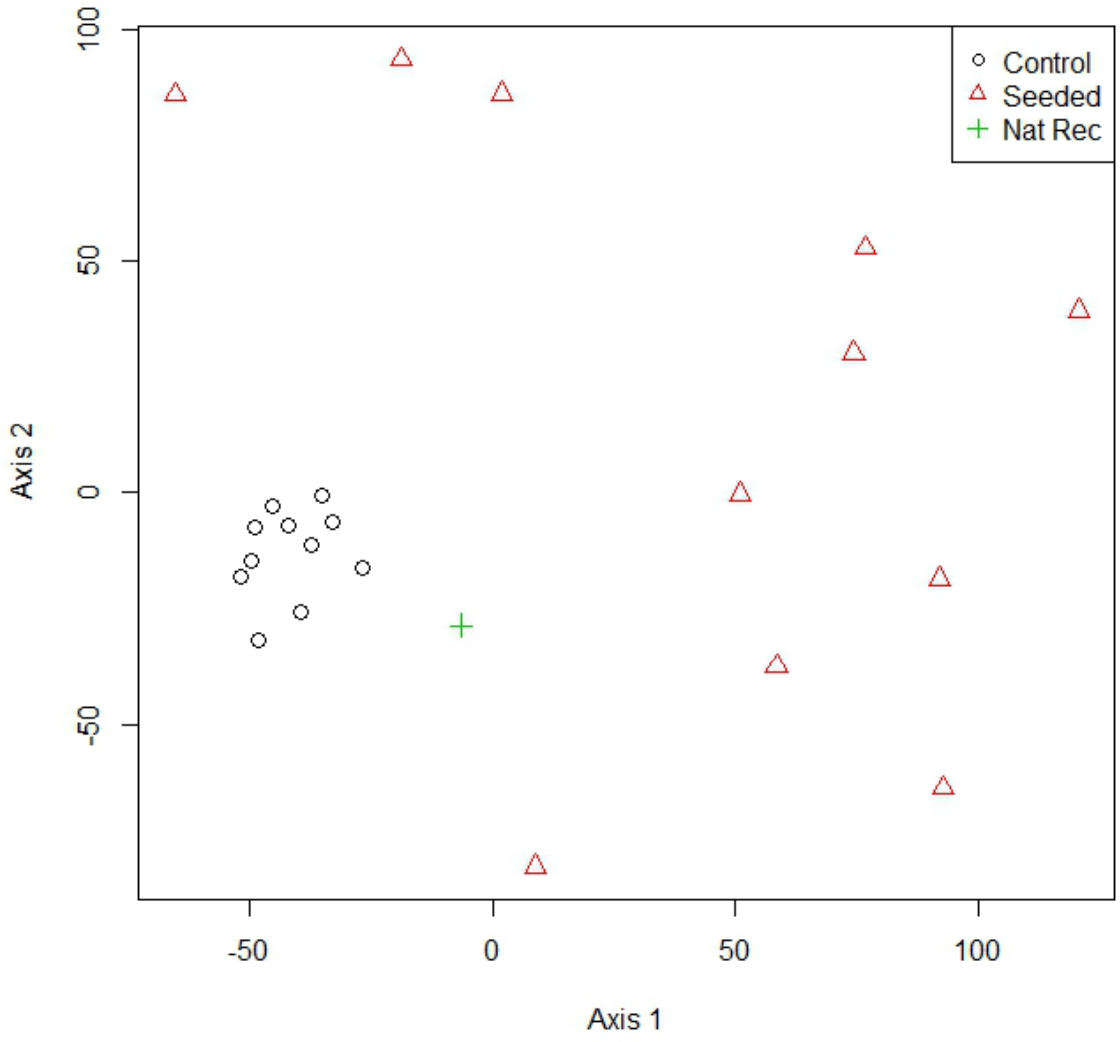


NFA2. Plains Rough Fescue - Kentucky Bluegrass (Control Cluster 6)

Control Cluster 6 correlates to a late seral NFA1 plant community on moist Loamy range sites in the Northern Fescue NSR (Kupsch et al. 2012). Plains rough fescue is still dominant, but the cover is reduced while western porcupine grass has increased appreciably due to moderate grazing pressure. The cover of some forbs and graminoids, such as pasture sagewort, prairie crocus, low sedge and June grass will increase due to their adaptation to moderate grazing pressure. Shrub and aspen forest encroachment will likely occur on lower slope positions. Kentucky bluegrass is present and this plant community is at risk to invasion by Kentucky bluegrass and awnless brome after disturbance.

The cluster diagram is in two dimensions (Figure C.5-3). One natural recovery site is clustering near the controls. All the seeded sites are dissimilar in vascular plant composition and cover.

Figure C.5-3 NMS Ordination of Treatments on Control Cluster 6 Sites (NFA2)

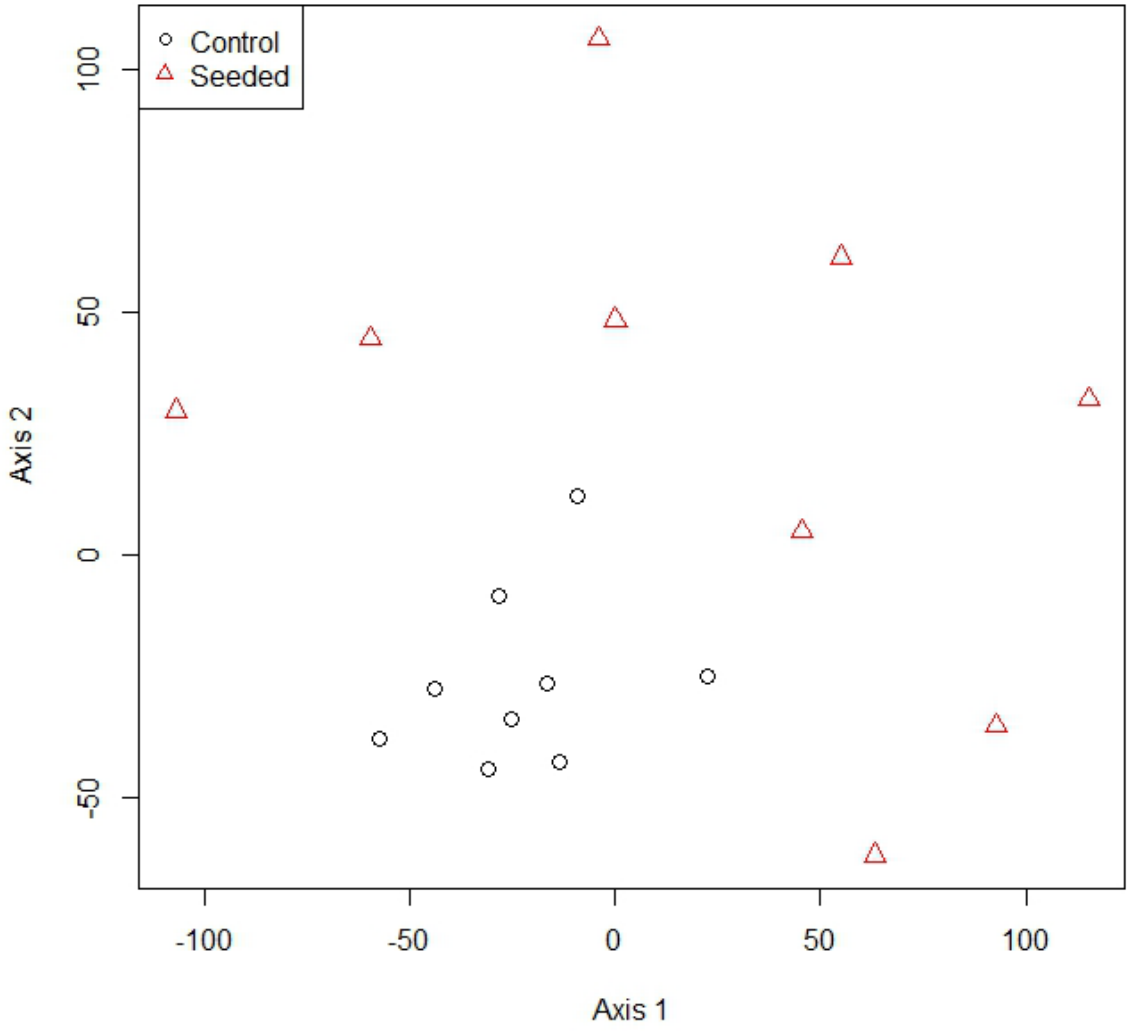


Control Cluster 7 - NFC2. Snowberry/Plains Rough Fescue - Kentucky Bluegrass

Control Cluster 7 represents a mid-seral shrub plant community for the reference plant community Snowberry - Plains Rough Fescue (NFC1) on lower slope to level moist Loamy range sites (Kupsch et al. 2012). Plains rough fescue and snowberry are the dominant species in the plant community. Kentucky bluegrass is present as a subdominant invasive species as a result of moderate to heavy grazing pressure and a favourable moisture regime.

The cluster diagram is in two dimensions (Figure C.5-4). All the disturbances reclaimed by seeding are dissimilar in vascular plant composition and cover and highly variable from one another.

Figure C.5-4 NMS Ordination of Treatments on Control Cluster 7 Sites (NFC2)

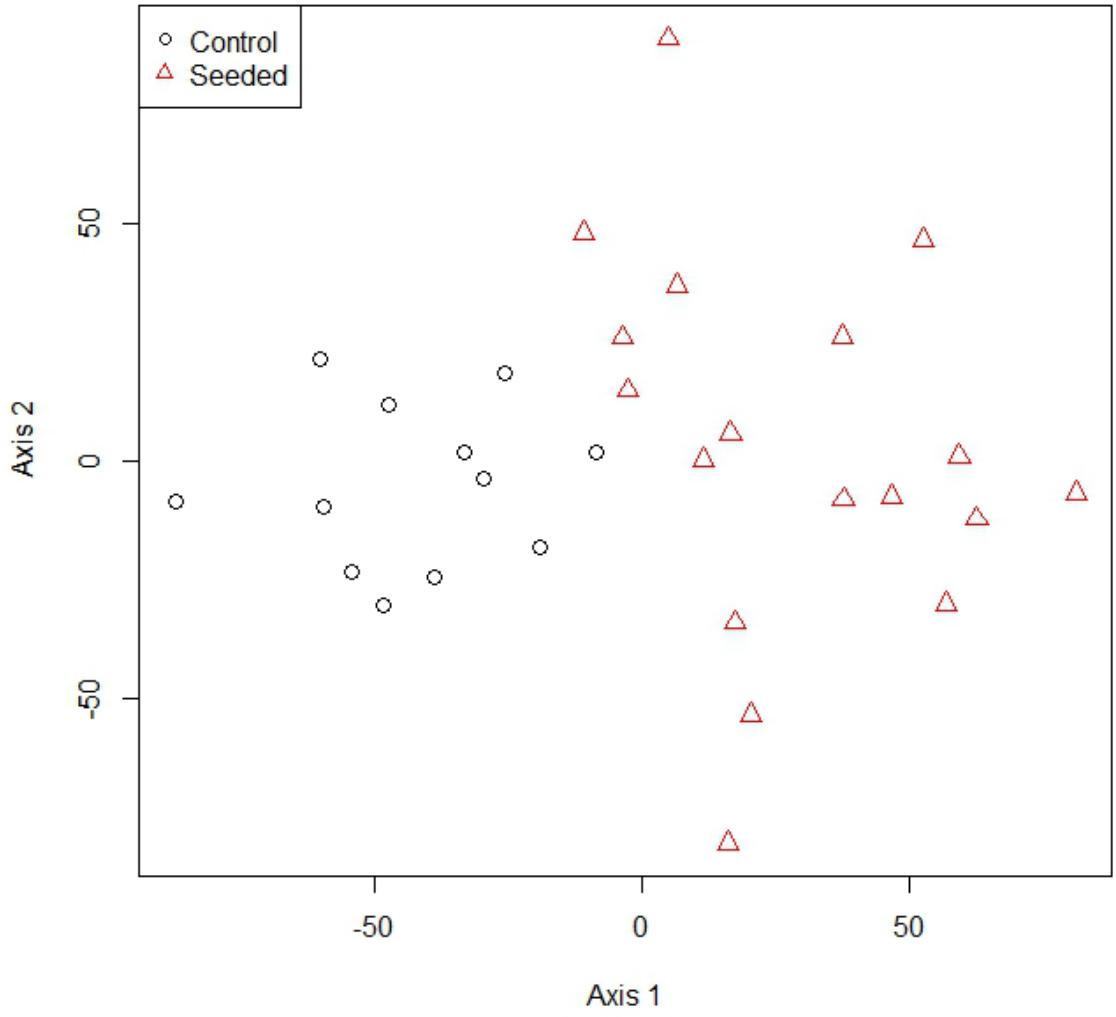


Control Cluster 8 - NFA7 Western Porcupine Grass - Plains Rough Fescue / NFA10 Plains Rough Fescue - Sedge

Control Cluster 8 represents a reference to late seral grassland community types on late phase Solonetz (Blowout), Rego Dark Brown Chernozem (Limy) and Orthic Dark Brown Chernozem (Loamy - dry) range sites (Table C.3-9). Blowout and Limy range sites have soil features, such as a weak hardpan layer or free lime that limit growth and productivity, respectively. The NFA7 (Lo-dry) and NFA10 (BlO) appear to correlate to subsets within Cluster 8 based on differentiation by range site. Sites in this cluster should be less susceptible to invasion by agronomic species due to inherent limitations of the range sites.

The cluster diagram is in two dimensions (Figure C.5-5). Many of the reseeded disturbances are dissimilar in vascular plant composition and cover, although several cluster near the undisturbed grassland. The range of the x and y axes are also smaller than other figures and similar to Figure C.5-1. Growth limitations may favour better reclamation results on these range sites.

Figure C.5-5 NMS Ordination of Treatments on Control Cluster 8 Sites (NFA7/NFA10)



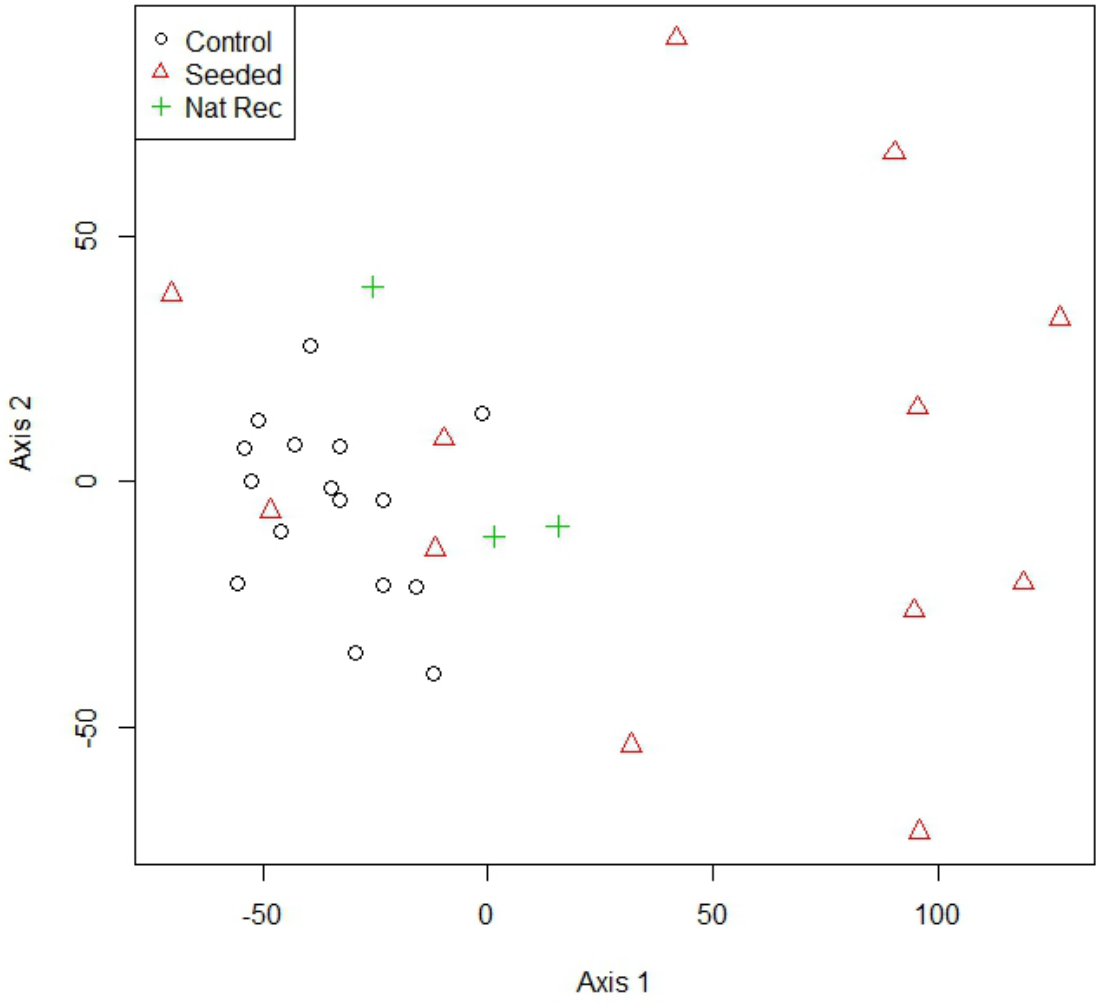
Control Cluster 4 – NFA8 Sedge - Plains Rough Fescue - Western Porcupine Grass

Control Cluster 4 contained a significant outlier which distorted the ordination, so it was run again with the outlier removed. This outlier, site ELWS02D, was seeded to an agronomic mix.

This cluster correlates with a mid-seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference plant community on Loamy - dry range sites. Increased grazing pressure has reduced the cover of plains rough fescue and western porcupine grass which are replaced by grazing resistant species such as pasture sagewort, upland sedges and June grass. There is risk of invasion by Kentucky bluegrass and awnless brome after disturbance.

The cluster diagram is in two dimensions (Figure C.5-6). Seeded sites are highly variable in vascular species composition and cover however, several seeded and natural recovery sites are clustering near the controls.

Figure C.5-6 NMS Ordination of Treatments on Control Cluster 4 Sites (NFA8)

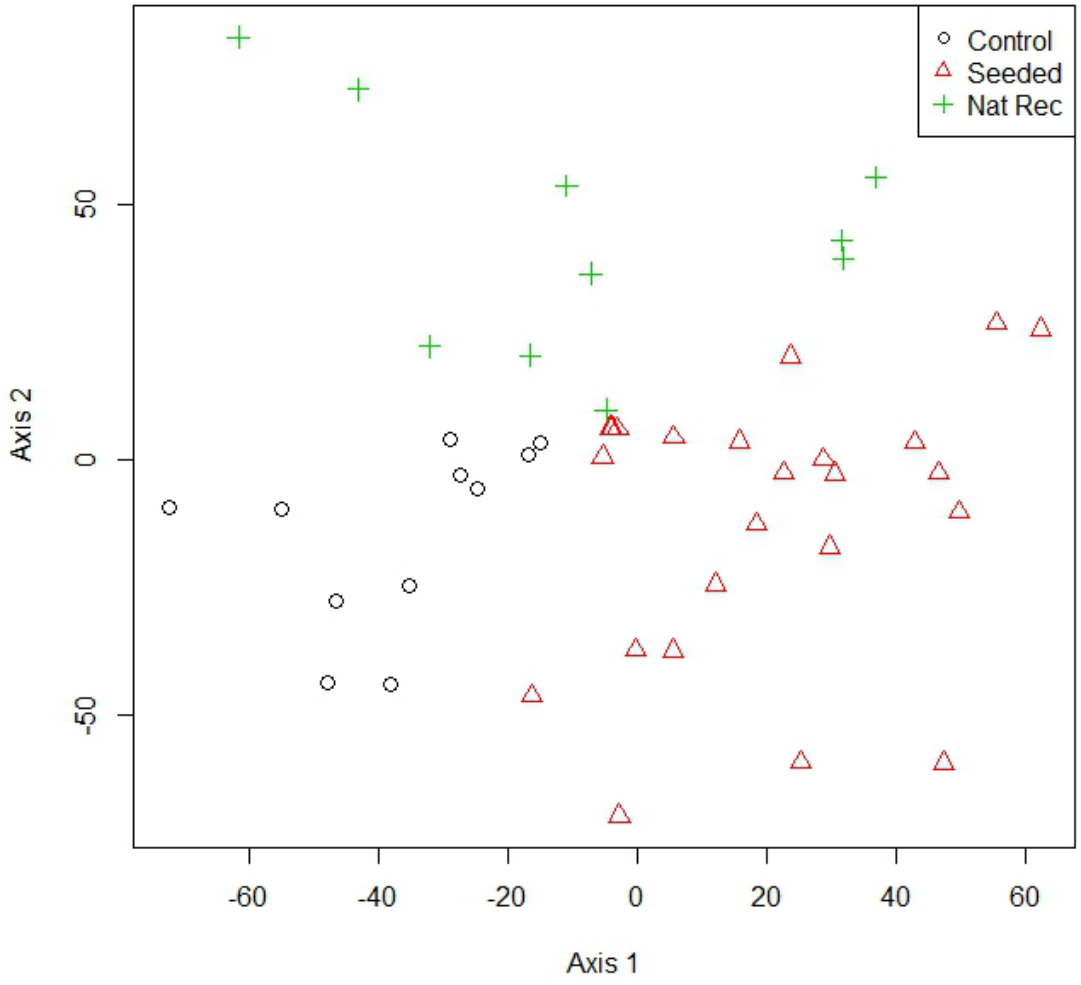


Control Cluster 5 - NFA9. Blue Grama – Sedge

Control Cluster 5 correlates to an early to mid-seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference community on Loamy - dry range sites. Moderate to heavy grazing pressure has reduced the cover of plains rough fescue and western porcupine grass which are replaced by grazing resistant species such as upland sedges and blue grama and pasture sagewort. This plant community appears to be associated with drier upper aspects on hummocky landscapes (Kupsch et al. 2012). The low moisture regime appears to favour the native low growing graminoids and grazing resistant forbs over agronomic species such as Kentucky bluegrass and awnless brome.

The cluster diagram is in two dimensions (Figure C.5-7). Few of the seeded or natural recovery sites are clustering closely with the controls, indicating that species composition and cover on the reclaiming disturbance sites is not similar to the undisturbed plant community. However, the natural recovery treatments appear similar to one another and the seeded treatments appear similar to one another, but represent different species composition and cover.

Figure C.5-7 NMS Ordination of Treatments on Control Cluster 5 Sites (NFA9)

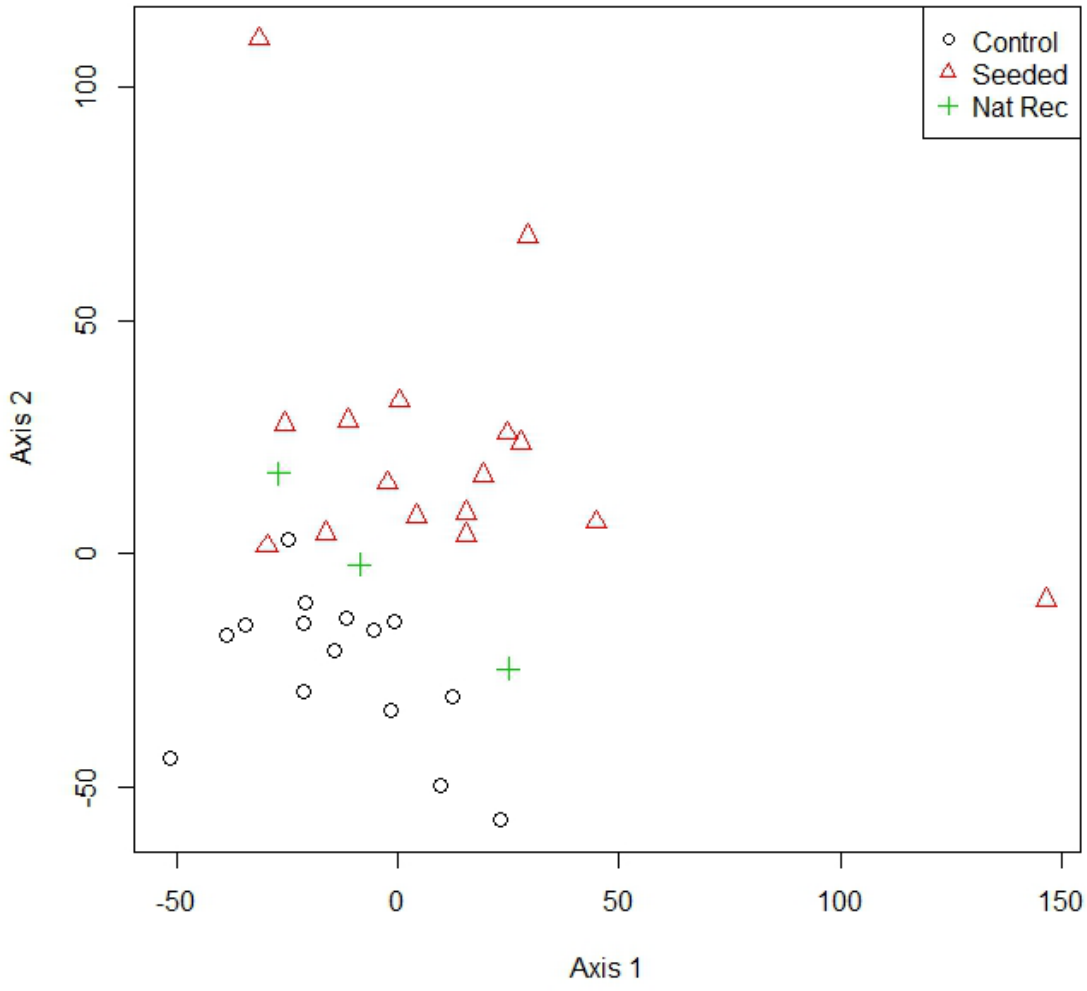


Control Cluster 3 - NFA9. Blue Grama - Sedge

Control Cluster 3 correlates to an early seral grassland community type for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference plant community. Heavy grazing pressure has greatly reduced the cover of plains rough fescue. Western porcupine grass is present, but grazing resistant species such as upland sedges, blue grama and pasture sagewort have increased in cover. This plant community is primarily associated with Loamy - dry and late phase Blowout range sites. Generally, the range sites are drier due to south aspects, and inherent soil limiting characteristics.

The cluster diagram is in two dimensions (Figure C.5-8). Several of the seeded or natural recovery sites are clustering closely with the controls, including the three natural recovery sites. Seeded sites appear to be more dissimilar to undisturbed grassland.

Figure C.5-8 NMS Ordination of Treatments on Control Cluster 3 Sites (NFA9)



Appendix D Alberta Innovates - Technology Futures Native Prairie Revegetation Projects

D.1 Alberta Innovates Seed Mixes used for Revegetation Trials

Table D.1-1 Seeding Mixes Used for Wellsite Revegetation Trials at Hand Hills and Neutral Hills Mesic Grasslands Sites

Site Code	Seed Mix	Species	PLS/m2 (species)	PLS/m2 (total)	Portion of Mix
AIHHM01	**Simple Mix - $451/ha**				
		Festuca hallii	400	600	67.0%
		Stipa viridula	100	600	16.5%
		Agropyron subsecundum Hillcrest	45	600	7.5%
		Koeleria macrantha	30	600	5.0%
		Stipa curtiseta	25	600	4.0%
AIHHM02	**Diverse Mix - $1014/ha**				
		Festuca hallii	400	600	67.0%
		Stipa viridula	50	600	8.3%
		Agropyron trachycaulum Adanac/Revenue/Highlander z	40	600	6.7%
		Stipa curtiseta	25	600	4.2%
		Agropyron dasystachyum Critana/Sodar y	20	600	3.3%
		Koeleria macrantha	15	600	2.5%
		Agropyron smithii Walsh	10	600	1.7%
		Festuca saximontana	6	600	1.0%
		Heterotheca villosa	10	600	1.7%
		Vicia americana	8	600	1.3%
		Achillea millefolium	2	600	0.3%
		Anemone multifida	2	600	0.3%
		Erigeron glabellus	2	600	0.3%
		Gaillardia aristata	2	600	0.3%
		Hedysarum spp.	2	600	0.3%
		Penstemon procerus	2	600	0.3%
		Potentilla gracilis	2	600	0.3%
		Solidago rigida	2	600	0.3%
AIHHM03	**Reclamation Mix - $216/ha***				
		Festuca hallii	400	600	67.0%
		Agropyron trachycaulum Adanac/Revenue/Highlander z	200	600	33.0%

† All numbers based on pure live seed (PLS).
* Actual cost of seed at time of seeding.
y - at proportions of 1:1
z - at proportions of 1:1:1

Table D.1-2 Alberta Innovates Seed Mixes Used on the Neutral Hills Bodo Pipeline Revegetation Trials

Site Code	Seed Mix	Portion of Mix
	Contractor Seed Mix	
AIPL__M02	*Festuca hallii*	50%
	Stipa spartea	10%
	Agropyron dasystachyum/A. subsecundum	10%
	Agropyron smithii	10%
	Agropyron trachycaulum	5%
	Stipa viridula	10%
	Koeleria macrantha / Bouteloua gracilis	5%
AIPL__M01	**ARC Seed Mix**	
	Festuca hallii	30%
	Bouteloua gracilis	20%
	Koeleria macrantha	20%
	Elymus canadensis	10%
	Bromus anomalus	10%
	Agropyron trachycaulum	3%
	Agropyron subsecundum	3%
	Carex sp.	1%
	Ratibida columnifera	1%
	Achillea millefolium	1%
	Solidago missouriensis	1%
	Oenothera biennis	1%
AIPL__03	**Wild Harvested Seed Mix**	
	No analysis done on the wild collected mix, it was harvested using a "seed stripper" (weed whipper with multiple rotating lines and a collection basket) in the adjacent native land (prairie fescue dominant). Based on the control sampling, the collection area is an early to mid-seral grassland community type (NFA9) for the Western Porcupine Grass - Plains Rough Fescue (NFA7) reference community on Loamy - dry range sites. Plains rough fescue cover is present but reduced by grazing pressure.	100%

D.2 Wellsite Revegetation Trials on Mesic Plains Rough Fescue Grassland Sites

Revegetation trials were established on three mesic plains rough fescue grassland sites, two in the Northern Fescue NSR (Hand Hills and Neutral Hills sites) and one in the Central Parkland NSR (Brownfield site). Four trials were established on each wellsite, a natural recovery site, and three seed mix trials including a simple grass mix, a diverse mix including 10 forbs and a reclamation mix with only two species, plains rough fescue and slender wheat grass. The seed mixes are described in Appendix D: Section D.1. The following series of figures illustrate the composition of plant groups on the recovering wellsite disturbances for each of the three seeded and one natural recovery reclamation treatments over 14 years recovery.

Predictably, the cover of moss and lichen is highest on the undisturbed reference site (Figure D.2-1), with fluctuations over time attributed to annual soil moisture and resulting growth, and sampling variability. Moss and lichen is only present at trace cover on all reclamation treatment areas after 14 years (Figures D.2-2 to D.2-5.

Weedy species are present at 1-3% cover on the reference (Figure D.2-1). The natural recovery site had persistent infestations of weeds, occupying on average between 30% and 40% of the vegetation cover, even after 14 years of infill (Figure D.2-2). The seed mixes created much less weedy plant communities, both in the early years and after 14 years (Figures D.2-3 to D.2-5).

The reference area supports about 40% to 60% native grass cover, 25% to 40% forb cover and 2% to 9% shrub cover (Figure D.2-1). Percent shrub cover is similar on seeded sites (Figures D.2-3 to D.2-5) but increases on average in the natural recovery site to between 10% and 15% cover (Figure D.2-2).

Forb cover is greatest and most consistent on the reference site, averaging between 30% and 40% cover. The cover of disturbance forbs may contribute to high forb cover levels on the seeded and natural recovery sites. Forb cover appears to decline on the natural recovery site and the simple mix site. Forb cover increases over time on the reclamation mix site, where only plains rough fescue and slender wheat grass were seeded. The forb cover is more stable with less fluctuations on the diverse mix site. The diverse seed mix included 10 forb species.

Decreases in the exposure of bare soils over the 14 years are similar for all sites including the natural recovery site (Figures D.2-6 to D.2-10). The build-up of litter is also similar, as is the total cover of vegetation. Decreases in litter levels across all trials in years 13 and 14 may reflect grazing pressure across the wellsite.

Plains rough fescue cover is present on the reference site at between 20% and 33% cover in the seven years when monitoring occurred over a 14 year period (Figure D.2-11). Cover of plains rough fescue established slowly on seeded disturbances, reaching cover levels of over 10% by year 8 after seeding. The three seed mixes each included 67% plains rough fescue in the mix. Plains rough fescue is essentially absent on the natural recovery site until year 13, when it was recorded at an average of 10% cover. Levels declined in year 14 to 2% cover, whereas cover levels on the seeded sites were comparable to the reference by year 14, at between 17% and 24% cover.

Figure D.2-1 Relative Cover of Plant Groups Over Time on the Undisturbed Reference Site

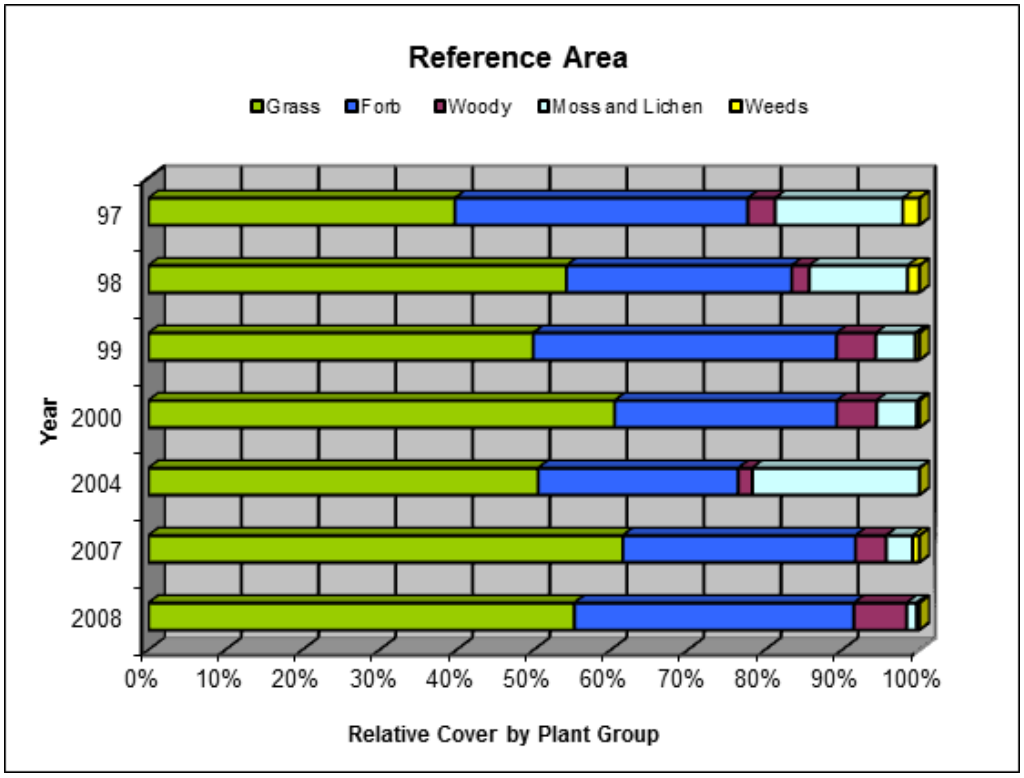


Figure D.2-2 Relative Cover of Plant Groups Over Time on Disturbed Topsoil Allowed to Revegetate Naturally

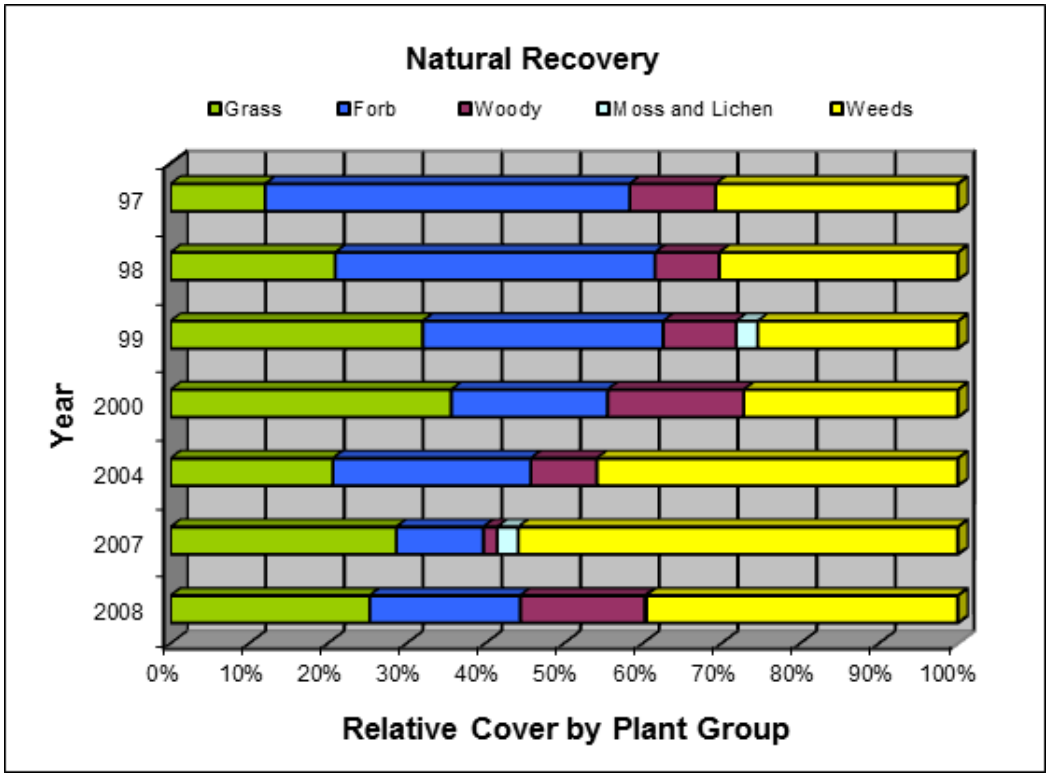


Figure D.2-3 Relative Cover of Plant Groups Over Time on Disturbed Topsoil Seeded to ARC Simple Mix

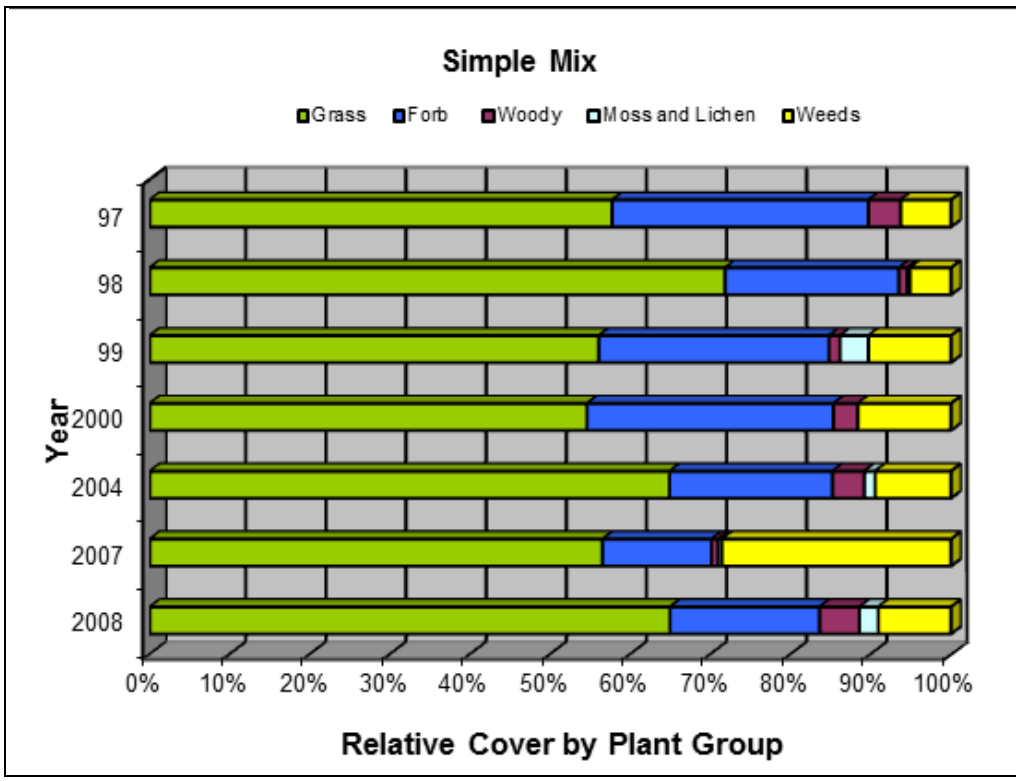


Figure D.2-4 Relative Cover of Plant Groups Over Time on Disturbed Topsoil Seeded to ARC Diverse Mix

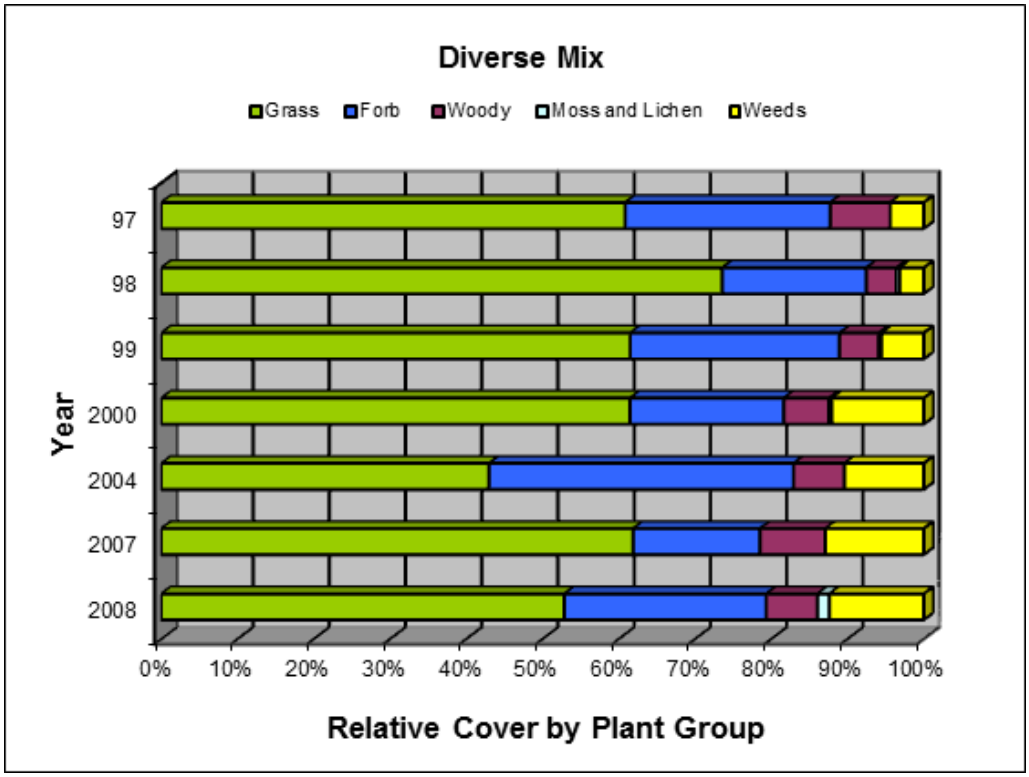


Figure D.2-5 Relative Cover of Plant Groups Over Time on Disturbed Topsoil Seeded to a Reclamation Mix

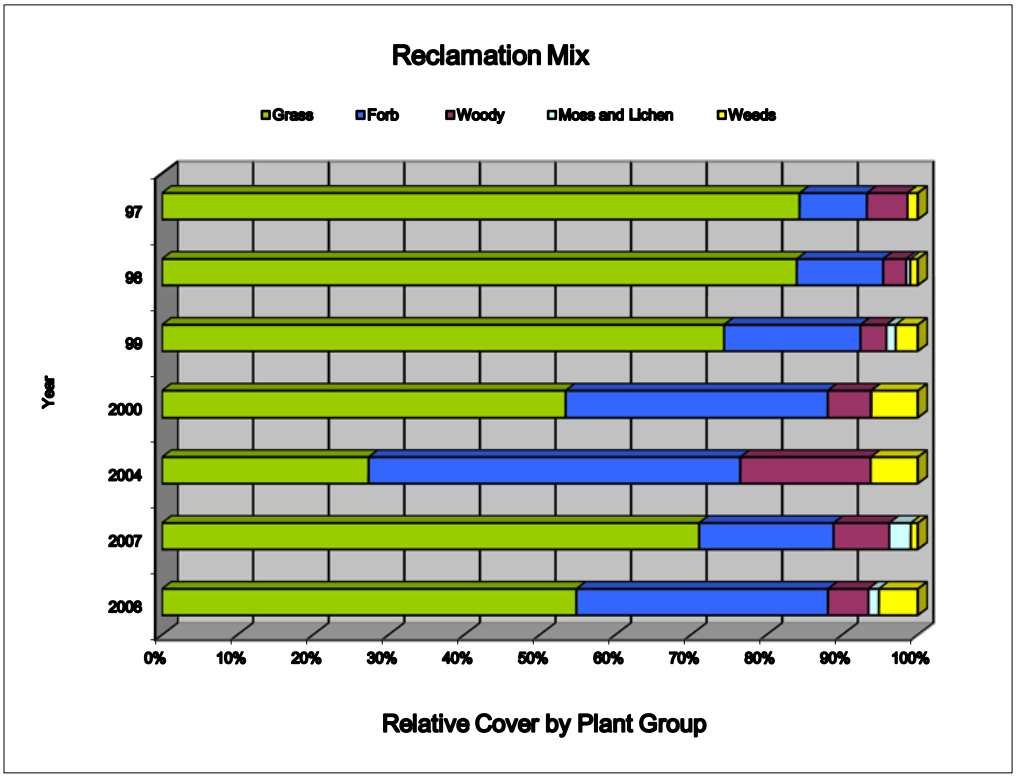


Figure D.2-6 Percent Cover of Bare Ground, Litter and Vegetation Over Time on the Undisturbed Reference Site

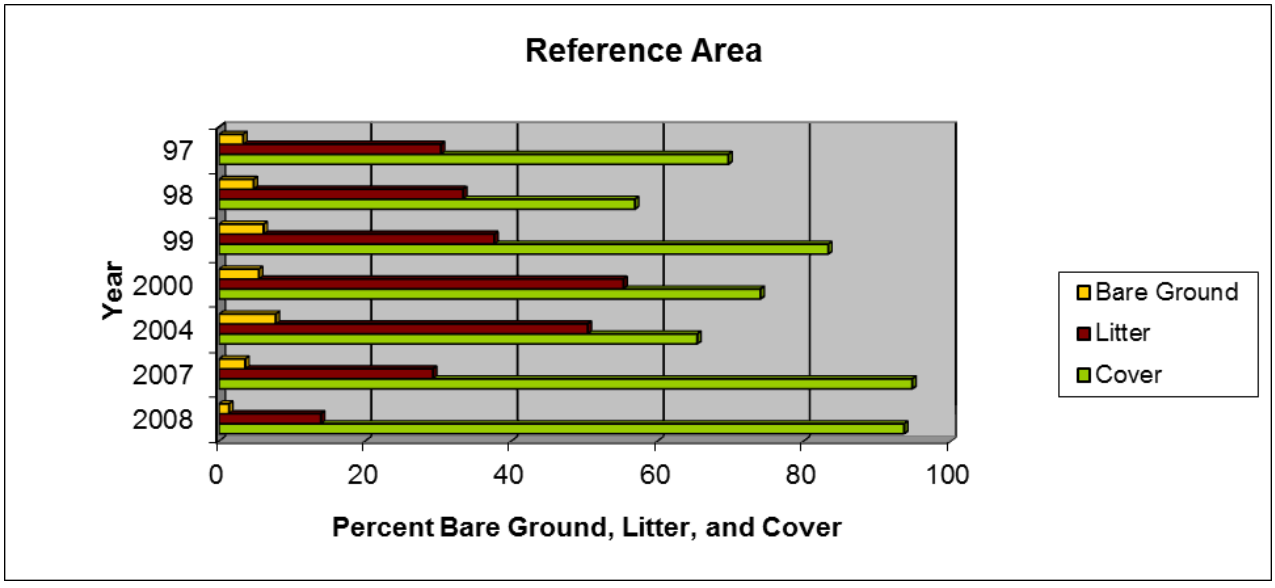


Figure D.2-7 Percent Cover of Bare Ground, Litter and Vegetation Over Time on the Natural Recovery Site

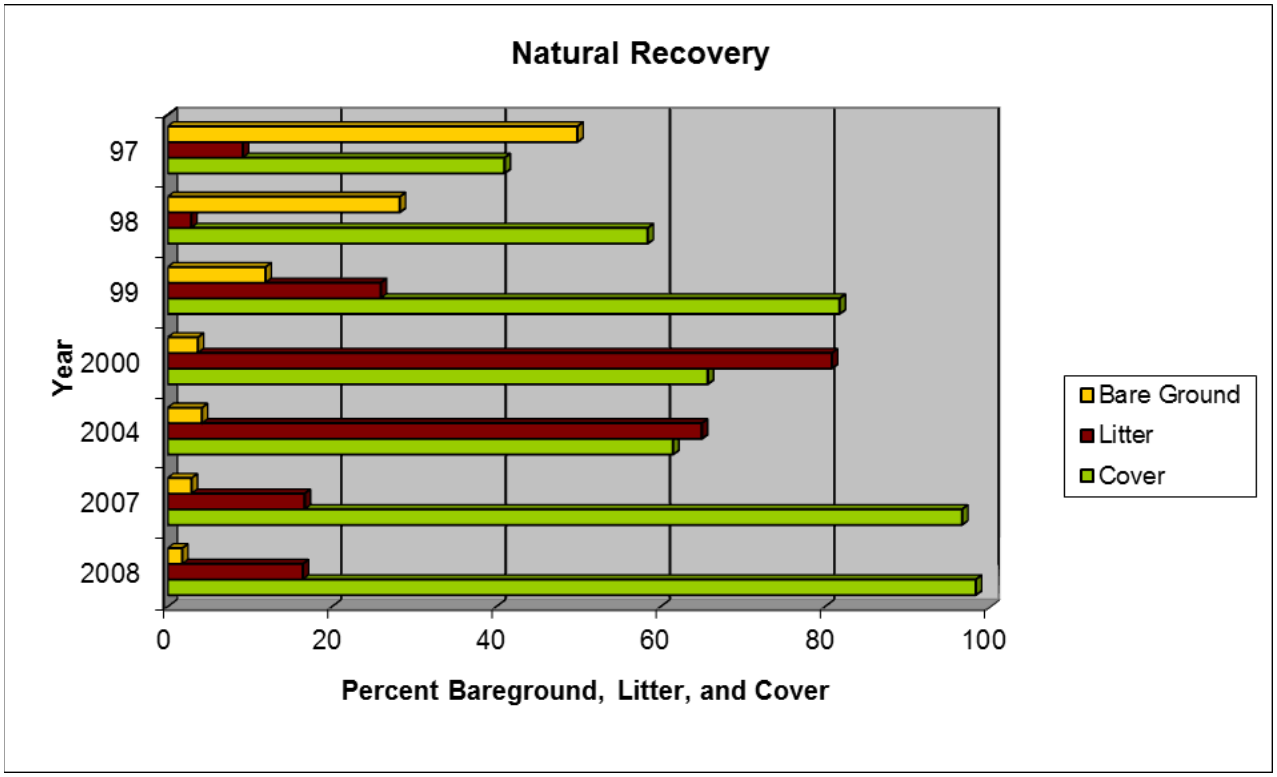


Figure D.2-8 Percent Cover of Bare Ground, Litter and Vegetation Over Time on the Site Seeded to the Simple Mix

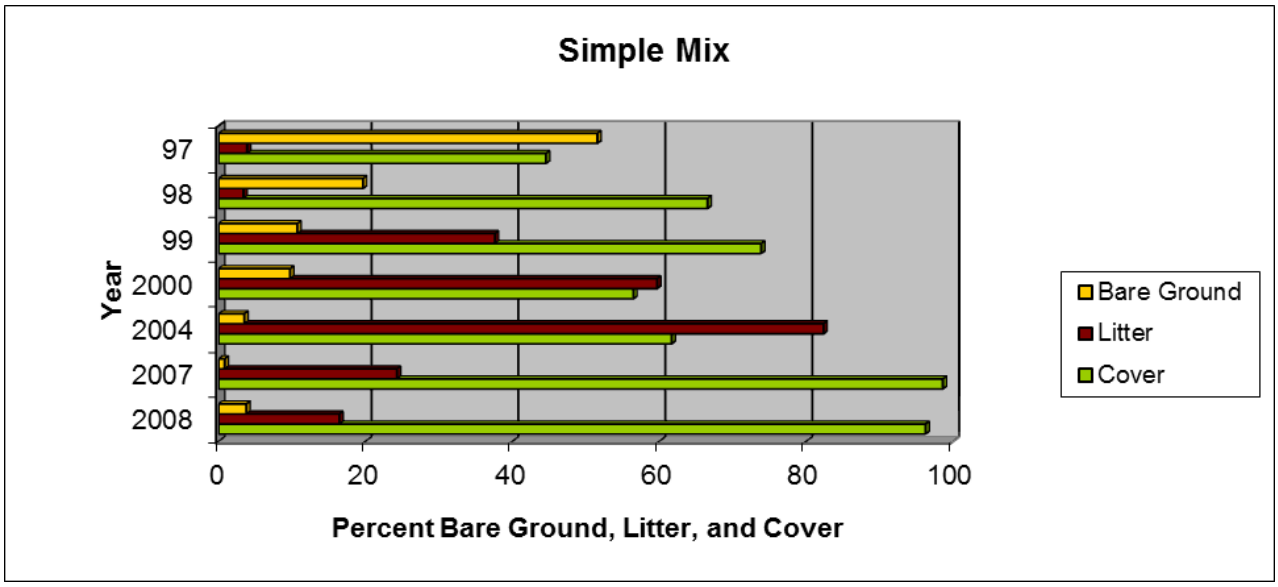


Figure D.2-9 Percent Cover of Bare Ground, Litter and Vegetation Over Time on the Site Seeded to the Diverse Mix

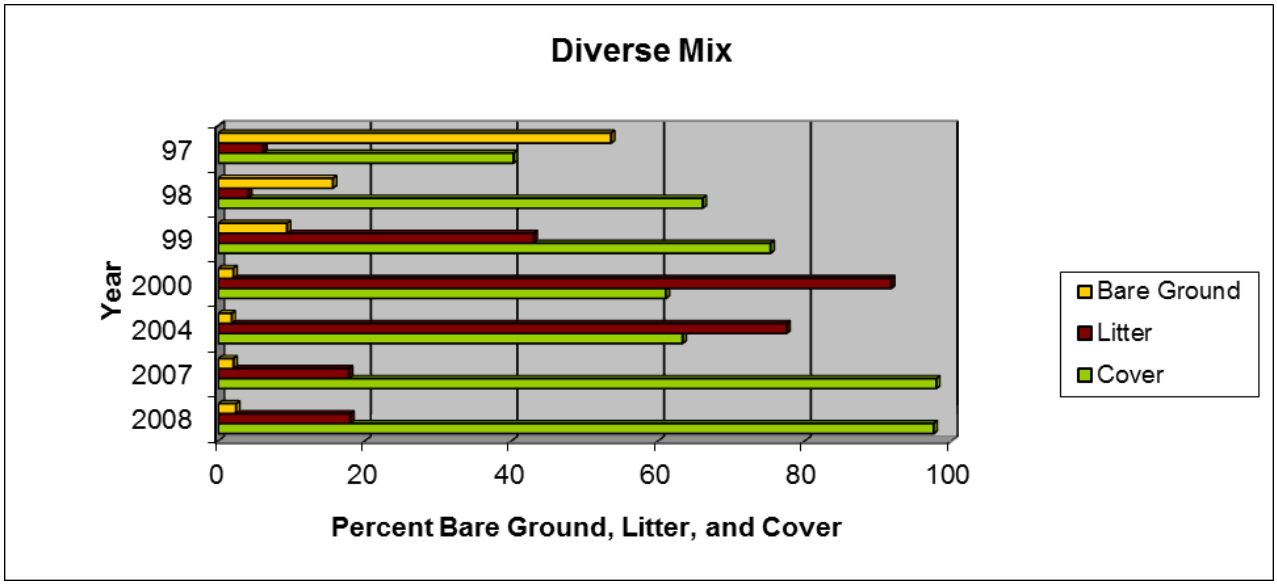


Figure D.2-10 Percent Cover of Bare Ground, Litter and Vegetation Over Time on the Site Seeded to the Reclamation Mix

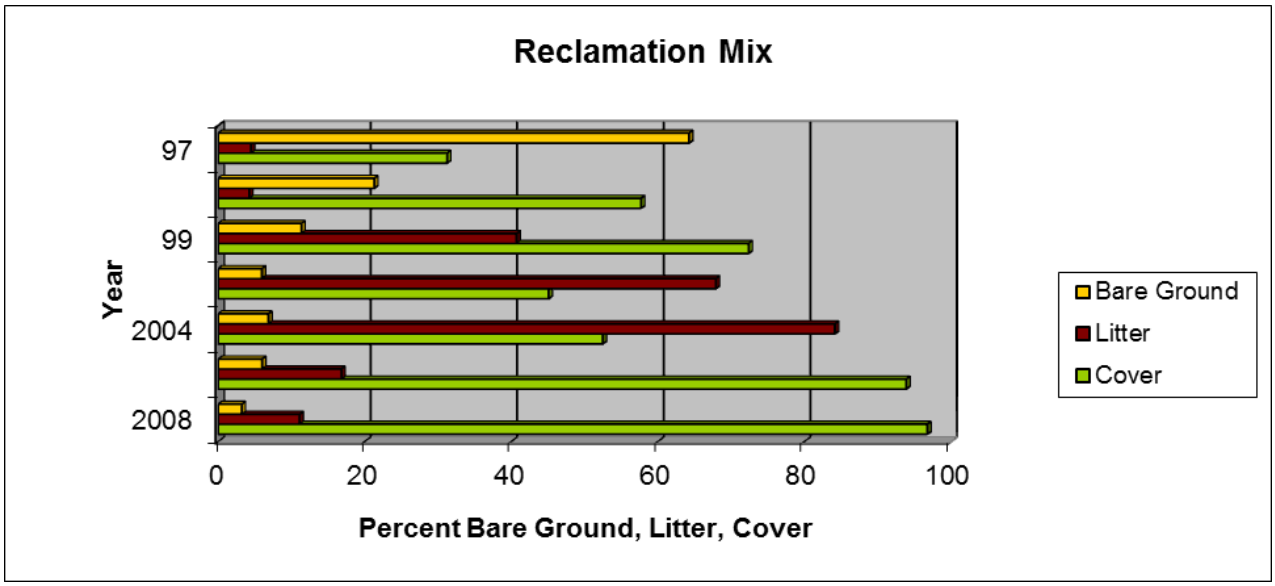


Figure D.2-11 Comparison of Plains Rough Fescue Cover Over Time from All Revegetation Treatments

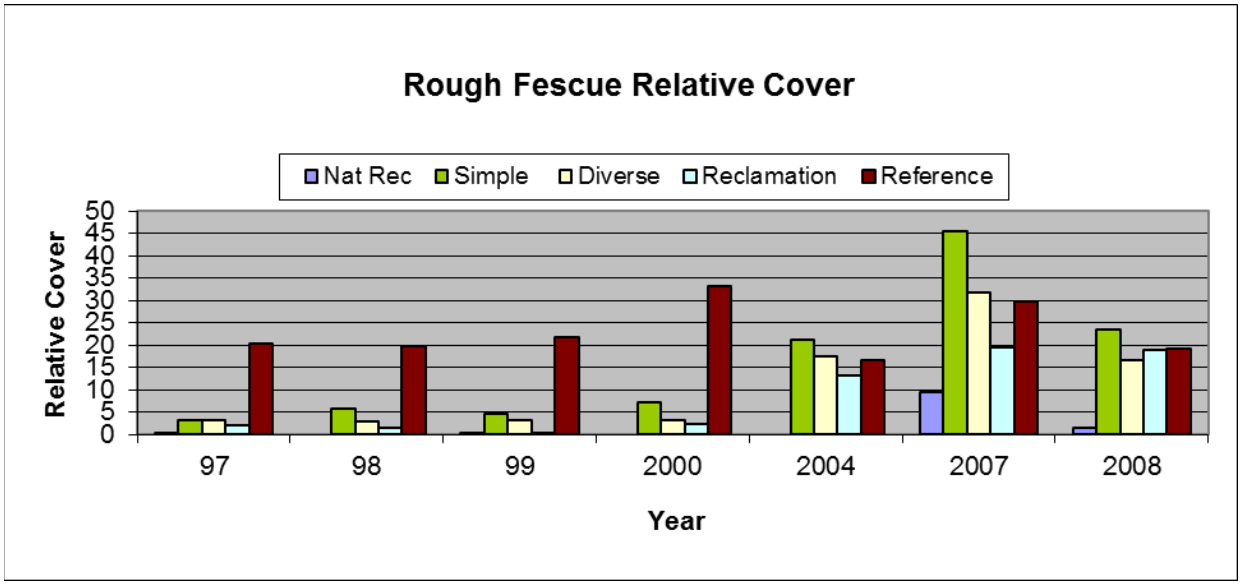


Table D.2-1 Comparison of Revegetation Strategies after 13 Years Recovery (2008) Hand Hills Wellsite (Source: Alberta Innovates)

Undisturbed Control		Simple Seed Mix		Diverse Seed Mix (M2)		Reclamation Mix (M3)		Natural Recovery	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
FESTHAL	35.0	FESTHAL	29.0	FESTHAL	21.7	ARTELUD	54.3	ARTELUD	11.7
STIPCUR	7.8	STIPVIR	20.0	STIPVIR	18.8	AGROTRA	12.2	AGROSCA	10.8
DANTINT	3.8	ARTELUD	7.5	SONCARV	10.0	FESTHAL	8.0	HIERODO	9.3
GEUMTRI	3.3	VICIAME	7.5	AGROSCA	8.3	VICIAME	6.3	BROMINE	9.2
GALIBOR	2.5	ROSAWOO	6.7	STACPAL	6.3	AGROSCA	5.8	KOELMAC	7.5
ACHIMIL	2.0	AGROSCA	5.8	STIPCUR	6.3	TARAOFF	2.8	ARTEFRI	5.7
VICIAME	1.5	ARTEFRI	4.3	ARTELUD	5.3	ASTEFAL	2.5	STACPAL	5.7
AGROSCA	1.2	ACHIMIL	3.0	CAMPROT	5.0	ACHIMIL	2.0	STIPCUR	5.3
ASTESPP	0.8	STIPCUR	2.8	VICIAME	4.7	CERAARV	1.7	ASTEFAL	4.5
STELLON	0.8	KOELMAC	2.7	CERAARV	4.0	GALIBOR	1.7	TARAOFF	4.5
CAMPROT	0.7	ANTENEG	2.0	AGROSMI	2.0	CREPTEC	1.0	AGROTRA	4.2
AGROSMI	0.3	CAMPROT	1.5	AGROTRA	1.7	POAPRA	0.8	AGROSUB	2.3
TARAOFF	0.3	DANTSPP	1.2	SOLISPP	1.7	SISYMON	0.8	ACHIMIL	1.7
ARTELUD	0.2	CERAARV	0.8	TARAOFF	1.5			ASTESPP	1.7
ARNIFUL	0.2	AGRODAS	0.3	ACHIMIL	1.0			FESTHAL	1.7
		BOUTGRA	0.3	ASTEFAL	0.8			VICIAME	1.7
		TARAOFF	0.3	SISYMON	0.3			ASTRFLE	1.0
								FESTSAX	1.0
								BOUTGRA	0.8
								CIRSARV	0.8
								GAILARI	0.8
Total Live Cover	60.5		95.8		99.5		100.0		91.8

Table D.2-2 Comparison of Revegetation Strategies after 13 Years Recovery (2008) Neutral Hills Wellsite (Source: Alberta Innovates)

Control			Simple Seed Mix (M1)		Diverse Seed Mix (M2)		Reclamation Mix (M3)		Natural Recovery	
Species	% Cover	Const	Species	% Cover	Species	% Cover	Species	% Cover	Species	% Cover
CARESPP	11.5	100.0	FESTHAL	27.0	ARTEFRI	17.7	FESTHAL	32.2	BROMINE	50.7
FESTHAL	9.2	100.0	STIPVIR	13.7	FESTHAL	15.0	AGROTRA	18.3	SYMPSPP	15.0
BOUTGRA	6.7	100.0	ARTEFRI	9.5	AGROSMI	8.3	ARTEFRI	11.7	ROSAWOO	7.5
ARTEFRI	6.4	100.0	LYGOJUN	6.7	CAREOBT	8.3	STIPVIR	7.5	POAPRA	6.7
KOELMAC	2.4	100.0	ROSAWOO	6.7	ROSAARK	7.8	POTESPP	3.3	ROSAARK	4.2
THERRHO	1.5	100.0	ARTELUD	6.2	STIPVIR	7.5	SYMPSPP	3.3	EPILSPP	3.3
ARTELUD	1.1	100.0	POASPP	4.2	PSORARG	5.8	ASTELAE	3.2	FESTHAL	2.5
PSORARG	0.8	100.0	FESTSAX	3.8	SYMPSPP	5.3	VICIAME	2.8	HETEVIL	2.5
SYMPOCC	2.7	83.3	HELIHOO	2.5	AGROTRA	4.8	ASTEFAL	2.0	ARTELUD	1.7
ANEMPAT	2.5	83.3	POAPRA	2.5	FESTSAX	4.2	DANTSPP	2.0	ARTEFRI	0.8
GALIBOR	2.1	83.3	PSORARG	2.5	POASPP	3.3	COMAUMB	1.7	FESTSAX	0.8
ACHIMIL	2.0	83.3	KOELMAC	2.3	VICIAME	2.8	HELIHOO	1.7	GALETET	0.8
HETEVIL	1.5	83.3	AGRODAS	1.8	ASTELAE	1.7	CAREOBT	1.5	RUMESPP	0.8
ROSAWOO	1.2	83.3	VICIAME	1.7	HELIHOO	1.7	PSORARG	1.2	THERRHO	0.8
AGROSUB	0.9	83.3	DANTSPP	1.3	ACHIMIL	1.5	AGRODAS	0.8	VICIAME	0.8
AGROSMI	0.6	83.3	AGROSMI	1.2	COMAUMB	0.8	STIPCUR	0.8	POASPP	0.3
COMAUMB	0.6	83.3	CAREOBT	0.8	ARTELUD	0.7	ROSAARK	0.7	ACHIMIL	0.2
STIPCOM	2.3	66.7	TRAGDUB	0.3	ASTRFLE	0.7	ANDROCC	0.3		
SOLIMIS	1.5	66.7			KOELMAC	0.7				
AGRODAS	1.3	66.7			SPHACOC	0.7				
STIPCUR	1.0	66.7			LYGOJUN	0.3				
VICIAME	0.1	66.7								
AGROTRA	0.8	50.0								
POAPRA	0.7	50.0								
SPHACOC	0.5	50.0								
ANEMCAN	0.4	50.0								
SOLIRIG	0.4	50.0								
ASTEERI	0.3	50.0	HELIHOO	0.1	33.3					
CAMPROT	0.2	50.0	LYGOJUN	0.1	33.3					
POTEPEN	0.2	50.0	AGROSCA	0.1	33.3					
MUHLCUS	0.1	50.0	DANTINT	0.1	33.3					
VIOLSPP	0.0	50.0	ANDROCC	0.0	33.3					
SOLISPP	0.4	33.3	PENSSPP	0.0	33.3					
MUHLRIC	0.3	33.3	LITHINC	0.0	33.3					
PHLOHOO	0.3	33.3	CARESTE	1.0	16.7					
ASTELAE	0.2	33.3	ANEMMUL	0.3	16.7					
ERIGSPP	0.1	33.3	POACAN	0.1	16.7					
ASTESPP	0.1	33.3	HELISUB	0.1	16.7					

D.3 Alberta Innovates Plains Rough Fescue Prairie Restoration Trials on a Pipeline Right-Of-Way in Bodo Hills

Table D.3-1 Comparison of Revegetation Strategies after 14 Years Recovery (2008) Neutral Hills Pipeline (Alberta Innovates)

Control			ARC Seed Mix (M1)		Contractor's Seedmix (M2)		Collected Seed Mix (M3)		Natural Recovery	
Species	Cover	Const	Species	Cover	Species	Cover	Species	Cover	Species	Cover
FESTHAL	43.3	100	ARTEFRI	14.7	STIPVIR	31.0	SYMPOCC	17.7	ARTEFRI	10.3
BOUTGRA	3.1	100	ELYMCAN	11.8	POAPAL	17.0	ARTEFRI	17.3	STIPCOM	9.9
ARTEFRI	3.1	100	ACHIMIL	10.0	ARTEFRI	16.9	FESTHAL	8.8	HORDJUB	8.8
KOELMAC	2.4	100	ARTELUD	7.3	AGROTRA	11.9	AGROSUB	7.1	AGROTRA	7.9
ASTELAE	1.4	100	AGROTRA	6.8	SYMPOCC	11.9	STIPVIR	6.5	POTEANS	7.5
ROSAWOO	1.4	100	KOELMAC	6.8	FESTHAL	6.9	STIPCOM	5.8	CIRSARV	4.8
ACHIMIL	1.3	100	SYMPOCC	5.6	ASTRFLE	6.5	KOELMAC	5.4	DISTSTR	4.8
ASTEERI	1.1	100	AGROSUB	5.5	AGROSMI	5.6	POAPAL	4.8	KOELMAC	3.8
POPUTRE	1.0	75	BROMANO	4.5	HETEVIL	4.4	AGROTRA	3.3	ACHIMIL	3.6
SYMPSPP	0.8	75	SOLIMIS	4.1	ARTELUD	4.0	ELYMCAN	2.5	CIRSSPP	3.3
STIPCUR	0.8	75	TARAOFF	4.1	AGROSUB	3.8	BOUTGRA	2.1	ROSAWOO	3.3
POTEPEN	0.5	75	ASTRFLE	2.9	EPILSPP	3.1	AGROSMI	1.9	CARESPP	3.1
AGROSMI	0.2	75	CERAARV	2.7	TARAOFF	3.1	CERAARV	1.7	FESTHAL	2.9
CARESPP	4.6	50	BOUTGRA	2.6	SOLIMOL	2.8	POTEANS	1.7	HETEVIL	2.5
AGRODAS	2.8	50	POAPAL	2.3	BOUTGRA	2.5	ACHIMIL	1.4	SYMPOCC	2.5
STIPCOM	2.5	50	POTEANS	2.1	KOELMAC	2.5	COMAUMB	1.3	ASTRFLE	2.3
GEUMTRI	0.8	50	SONCARV	1.8	RATICOL	2.5	VICIAME	1.3	BOUTGRA	2.1
AGROSUB	0.7	50	CARESPP	1.4	ACHIMIL	2.3	ASTRFLE	1.0	AGROSUB	1.8
DELPBIC	0.6	50	FESTHAL	1.4	CERAARV	2.1	CARESPP	0.9	POAPAL	1.7
GALIBOR	0.1	50	ASTELAE	0.9	POTEANS	1.9	ARTELUD	0.8	THERRHO	1.7
LYGOJUN	0.1	50	STIPCUR	0.9	CARESPP	1.3	ROSAWOO	0.8	SONCARV	1.3
ASTRDAS	1.1	25	SOLIMOL	0.8	COMAUMB	1.3	ASTELAE	0.6	TARAOFF	1.2
SYMPOCC	0.6	25	TRAGDUB	0.8	ROSAWOO	1.3	AGROSCA	0.4	AGROSMI	0.8
THERRHO	0.6	25	THERRHO	0.7	STIPCOM	1.3	DISTSTR	0.4	CERAARV	0.8
DANTINT	0.5	25	AGOSGLA	0.5	ASTELAE	1.0	HETEVIL	0.4	COMAUMB	0.8
SOLIRIG	0.5	25	AGROSCA	0.5	CREPTEC	0.6	SISYMON	0.4	GAURCOC	0.8
ASTRCRA	0.4	25	CAREOBT	0.5	PLANMAJ	0.6	SOLIMOL	0.4	POASPP	0.8
ASTRFLE	0.4	25	COLLLIN	0.5	POTECON	0.6	TRAGDUB	0.4	TRAGDUB	0.8
ANEMPAT	0.3	25	DISTSTR	0.5	HORDJUB	0.3	TARAOFF	0.3	LYGOJUN	0.7
ANEMMUL	0.3	25	RATICOL	0.5	SISYMON	0.3	CAMPROT	0.1	AGROSCA	0.4
ASTRSPP	0.2	25	ROSAWOO	0.5					ASTELAE	0.4
POASPP	0.2	25	CREPTEC	0.2					LINULEW	0.4
SOLIMIS	0.2	25							OXYTSER	0.4
GAURCOC	0.1	25							RANUCYM	0.4
FESTSAX	0.1	25							SOLIMOL	0.4
CAMPROT	0.0	25							AGOSGLA	0.2
AGROSCA	0.0	25							EPILSPP	0.2
COMAUMB	0.0	25							ANDROCC	0.1
ORTHLUT	0.0	25							CREPTEC	0.1

Appendix E Case Study - Plains Rough Fescue Seeding

Peggy Desserud, PhD, MEDes, P.Biol.

Rough Fescue Seeding in the Northern Fescue Subregion - A Case Study

Plains rough fescue (*Festuca hallii*), one of the dominant species in the Northern Fescue NSR, is difficult to restore once disturbed by oil and gas development. Seeding plains rough fescue on oil and gas disturbances has had little success. Rough fescue requires 3 to 5 years to become established, during which time it may be exposed to competition from faster-growing species, such as wheat grasses. Seeding rates for rough fescue are not well established and may vary from 10 to 50% of the seed mix.

In 2007, a seeding experiment was set up on a 0.7 ha wellsite, west of the Hand Hills in the Northern Fescue NSR. The experiment tested the hypothesis that rough fescue could establish more easily if competition from aggressive species was reduced. The site was divided into 6 m wide strips and seeded with two seed mixes in different strips. One seed mix was almost 100% plains rough fescue, and one was a native seed mix containing plains rough fescue, June grass (*Koeleria macrantha*), needle-and-thread (*Stipa comata*), blue grama (*Bouteloua gracilis*), slender wheat grass (*Agropyron trachycaulum*) and Western wheat grass (*Agropyron smithii*) (Table E-1). A mix of Kentucky bluegrass (*Poa pratensis*) and plains rough fescue was also seeded in some of the strips for a different experiment. The well site was fenced to prevent cattle and pronghorn grazing for the first 3 years, after which the fence was removed.

Table E-1 Seed Mixes Used in the Rough Fescue Seeding Experiment

Species in Seed Mixes	Species Scientific Names	Seed Mix %	Seeding Rate kg/ha	PLS %	PLS Seeds/m^2
Rough Fescue Mix			15.5		
Plains rough fescue	*Festuca hallii*	99	15.5	95	1,304
Other native species		1			n/a
Native Mix			6.6		
Plains rough fescue	*Festuca hallii*	20	1.3	95	113
June grass	*Koeleria macrantha*	20	1.3	99	457
Needle and thread	*Stipa comata*	25	1.7	45	19
Blue grama	*Bouteloua gracilis*	30	2.0	70	256
Slender wheat grass	*Elymus trachycaulus var. trachycaulus*	3	0.2	95	5
Western wheat grass	*Agropyron smithii*	2	0.1	67	2

In 2010, three years after seeding, strips seeded with the native mix showed good establishment of all species, except plains rough fescue (Figure E-1). In fact, plains rough fescue was almost non-existent despite having been 20% of the seed mix. On the other hand, slender wheat grass dominated with over 15% of the cover, even though the seed mix contained only 3% of slender wheat grass seed (Figure E-2).

In strips seeded with almost 100% rough fescue, there was good establishment of rough fescue. In fact, its cover was similar to undisturbed rough fescue grassland. Surprisingly many non-seeded species also appeared, including many forbs (Figure E-1). Seed rain from adjacent strips that were seeded with the native mix probably resulted in wheat grass, June grass and blue grama cover. Plains rough fescue seed mix strips had more bare ground than Native mix strips, which probably attracted annual and perennial forbs (Figure E-3). Bare ground and few wheat grasses may have contributed to rough fescue success. With little competition from fast-growing wheat grasses, rough fescue may have had time to become established by the third year (Figure E-4). Interestingly, strips seeded with rough fescue had similar diversity and species richness to native mix strips, even though they were seeded with a monoculture (Figure E-2).

Figure E-1 Comparison of Seed Mix Results with Undisturbed Grassland Showing "Rough fescue" and Native Seed Mixes Species in Year 3

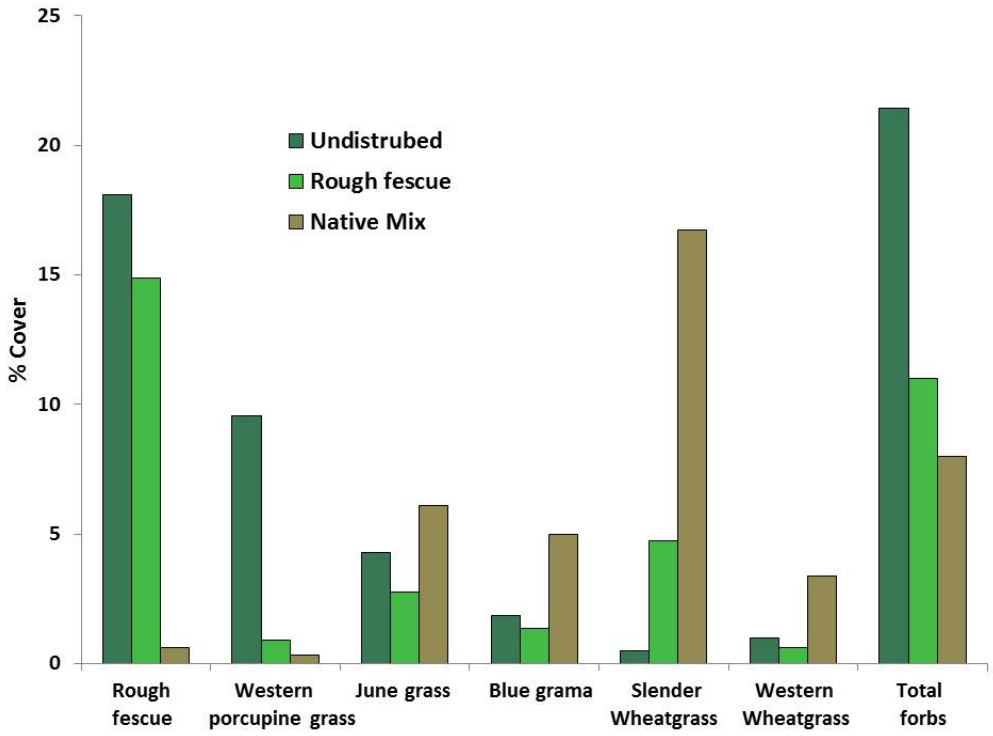


Figure E-2 Sample Plot of Native Mix Seeding in Year 3 Showing Slender Wheat grass, June Grass, Blue Grama, Various Forbs, and No Rough Fescue

Figure E-3 Comparison of Seed Mix Results with Undisturbed Grassland Showing "Rough fescue" and Native Seed Mixes Cover, Non-native Species, Bare ground, Litter and Diversity in Year 3

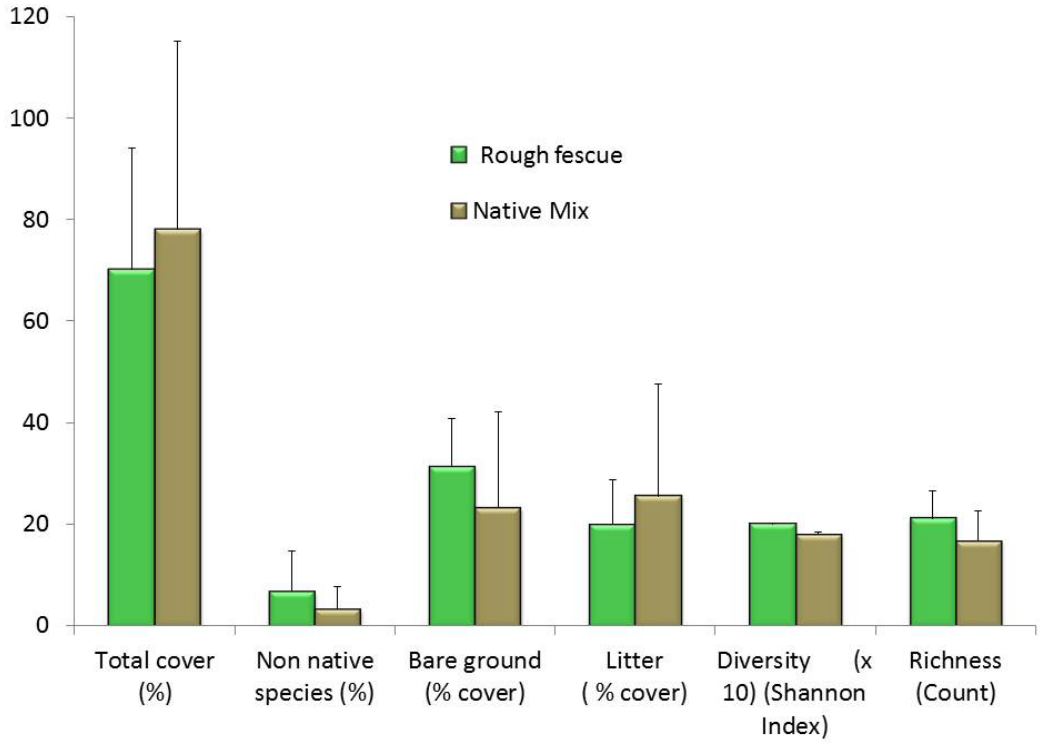


Figure E-4 Sample Plot of "Rough fescue" Seeding in Year 3 Showing Well-established Rough Fescue Plants, One of Which had Flowered

In 2013, seven years after seeding, the site was assessed again and results were compared to overall cover from Year 3 (Table E-2). Green needle grass, which had not been seeded but did occur in the adjacent grassland, was the dominant grass in Year 7. Slender wheat grass, dominant in Year 3, had reduced cover by Year 7. Plains rough fescue persisted into Year 7, being well established. Species which had not been seeded, but appeared in Year 7, included Western porcupine grass, native bluegrasses, Northern wheat grass (*Agropyron dasystachyum*) and tickle grass (*Agrostis scabra*). Prairie rose (*Rosa arkansana*) and buckbrush (*Symphoricarpos occidentalis*) were also found. Species that occurred in Year 3 but disappeared or reduced in cover by Year 7 were foxtail barley (*Hordeum jubatum*) and pasture sagewort (*Artemisia frigida*) (Figure E-5).

Table E-2 Species Found on the Well Site; 3 Years and 7 Years After Initial Seeding

Species Common Name	Species Scientific Name	Age of Recovery	
		Year 3 (% cover)	Year 7 (% cover)
Green needle grass	*Stipa viridula*	8.0	15
Kentucky bluegrass*	*Poa pratensis*	7.1	10
Needle and thread*	*Stipa comata*	1.6	10
Plains rough fescue*	*Festuca hallii*	6.8	10
Western wheat grass*	*Agropyron smithii*	0.9	10
Slender wheat grass*	*Elymus trachycaulus var. trachycaulus*	11.4	5
Awnless brome	*Bromus inermis*	1.0	5
Blue grama*	*Bouteloua gracilis*	7.8	2
June grass*	*Koeleria macrantha*	3.9	2
Western porcupine grass	*Stipa curtiseta*	1.7	2
Tickle grass	*Agrostis scabra*	0.0	1
Crested wheat grass	*Agropyron cristatum*	0.7	0
Foxtail barley	*Hordeum jubatum*	4.6	0
Native bluegrass	*Poa sp.*	1.5	1.0
Northern wheat grass	*Elymus lanceolatus ssp. lanceolatus*	1.6	1.0
Common yarrow	*Achillea millefolium*	0.4	0.5
Pasture sagewort	*Artemisia frigida*	23.0	1.0
Prairie aster	*Aster falcatus*	0.0	1.0
Prairie rose	*Rosa arkansana*	1.0	1.0
Buckbrush	*Symphoricarpos occidentalis*	0.3	1.0

Species found in the seed mixes are indicated with "*"

Figure E-5 Wellsite 7 Years After Seeding Showing Green Needle Grass, Western Porcupine Grass, Northern and Western Wheat Grass, Among Others

On one side of the wellsite was an old oil well, surrounded by awnless brome (*Bromus inermis*) and crested wheat grass (*Agropyron cristatum*). Unfortunately these species invaded the experimental wellsite. For the first three years, these species were spot sprayed, and by Year 7 no crested wheat grass was found. However, awnless brome persisted and in fact increased in cover. Hopefully, the strong presence of needle grasses will keep awnless brome at bay.

In conclusion, this study demonstrated the possibility of restoring plains rough fescue grassland species. The success of plains rough fescue with little competition underscores the importance of reducing the amount and number of aggressive species in rough fescue grassland reclamation seeding. While monoculture seeding of plains rough fescue is not practical due to low seed availability and high cost, seed mixes should include few or no wheat grasses, and instead a mix of other native grasses common in the area.

For more information on the results of this research, please see Desserud and Naeth (2013) or Desserud's PhD dissertation (Desserud 2011) available on the Foothills Restoration Forum web site: http://www.foothillsrestorationforum.ca.

Appendix F Case Study - Natural Recovery in the Rumsey Natural Area

Peggy Desserud, PhD, MEDes, P.Biol.

Natural Recovery of 13 Pipelines in the Rumsey Natural Area - A Case Study

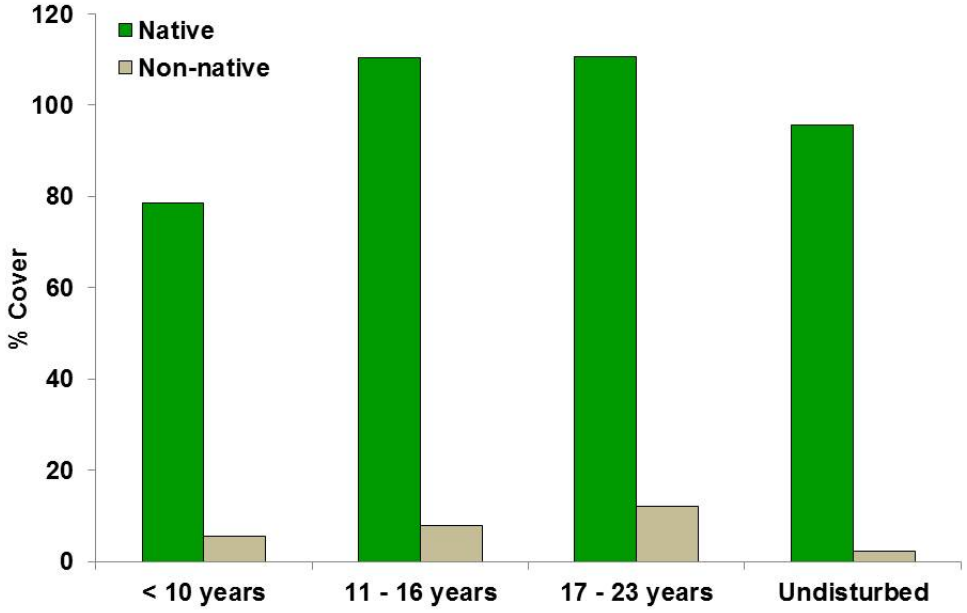
Plains rough fescue (*Festuca hallii*), one of the dominant species in the Northern Fescue NSR, is difficult to restore once disturbed by oil and gas development. Seeding rough fescue on oil and gas disturbances has had little success. Elsinger (2009) assessed vegetation on pipelines and well sites in the Rumsey Natural Area, located in the Northern Fescue NSR. She reported numerous examples of unsuccessful revegetation of rough fescue following seeding. Desserud et al. (2010) studied pipelines in the Foothills Fescue NSR and also found those seeded with Foothills rough fescue (*Festuca campestris*) were unsuccessful. On the other hand, both studies found pipelines left to natural recovery had successful rough fescue establishment.

For three years the recovery of three newly-constructed pipelines in the Rumsey Natural Area which were left to natural recovery was followed. Third year results were combined with Elsinger's (2009) data of natural recovery pipelines constructed between 1983 and 2000. Each of the pipelines were installed in a narrow trench, about 80 cm wide. Five of the pipelines were installed using a plough-in technique. A plough creates a narrow trench the width of the bucket, pipe is fed into the trench, and soil and sod are allowed to fall back into place. Six pipelines were topsoil-stripped, where topsoil was stripped from the trench, and replaced following pipe installation. Two pipelines used ditch-witch construction, with a trencher that chops sod, mixing it with trench soil, and the broken sod/soil mix is used to cover the pipe.

Despite differences in specific species, all natural recovery pipelines had something in common with undisturbed grassland. They all have significantly more native species and few non-native species, such as Canada thistle (*Cirsium arvense*), Canada bluegrass (*Poa compressa*) and awnless brome (*Bromus inermis*) (Figure F-1).

Figure F-1 Comparison of Pipeline ROWs Grouped by Age; Showing Native Versus Non-native Plants

Non-native Species included: Canada thistle (*Cirsium arvense*), Canada bluegrass (*Poa compressa*) and awnless brome (*Bromus inermis*)



Differences were found in vegetation cover based on the age of pipeline construction, although not what was expected (Table F-1). As a slow-growing species, it was expected more rough fescue would occur on older pipelines and less on the youngest. However, pipelines less than 10 years old were dominated by rough fescue and western porcupine grass (Fescue Association), similar to undisturbed grassland. The youngest pipelines had the benefit of low impact construction, such as plough-in pipelines (Figures F-2 and F-3). During plough-in construction, care was taken to retain intact sod, which probably accounted for the recovery of rough fescue. Its deep roots would remain largely intact, allowing it to continue growing once the sod fell back into place.

Table F-1 Selected Species Found on Natural Recovery Pipelines and Their Controls

Species		Pipeline age % Cover			
		<10	11 – 16	17 - 23	Undisturbed
Plains rough fescue	*Festuca hallii*	9.2	1.9	5.1	22.4
Western porcupine grass	*Stipa curtiseta*	8.3	8.1	8.6	13.5
June grass	*Koeleria macrantha*	1.3	5.6	8.5	6.0
Undifferentiated sedge	*Carex spp.*	6.6	7.8	2.7	5.0
Northern wheat grass	*Elymus lanceolatus ssp. lanceolatus*	3.5	13.6	13.0	3.0
Undifferentiated bluegrasses	*Poa spp.*	4.2	6.7	7.7	2.1
Blue grama	*Bouteloua gracilis*	0.0	0.0	2.0	1.7
Western wheat grass	*Agropyron smithii*	5.1	15.7	6.3	1.4
Green needle grass	*Stipa viridula*	0.1	0.9	3.0	0.9
Hooker's oat grass	*Helictotrichon hookeri*	1.3	0.0	0.7	0.8
Slender wheat grass	*Elymus trachycaulus var. trachycaulus*	3.1	4.3	1.5	0.8
Pasture sagewort	*Artemisia frigida*	7.5	16.0	5.9	6.9
Three-flowered avens	*Geum triflorum*	0.2	0.5	2.8	2.9
Tufted fleabane	*Erigeron caespitosus*	0.9	0.9	0.2	2.1
Prairie crocus	*Anemone patens*	0.2	0.0	1.1	1.8
Small-leaved everlasting	*Antennaria parvifolia*	1.1	0.0	5.2	1.7
Golden bean	*Thermopsis rhombifolia*	0.3	3.4	0.5	1.1
American vetch	*Vicia americana*	1.4	1.7	1.9	1.0
Yarrow	*Achillea millefolium*	0.9	1.8	1.9	0.9
Chickweed	*Cerastium arvense*	2.5	0.7	0.0	0.9
Prairie sagewort	*Artemisia ludoviciana*	1.8	0.6	1.9	0.8
Prairie rose	*Rosa arkansana*	1.5	1.8	1.9	1.9
Buckbrush	*Symphoricarpos occidentalis*	4.3	3.8	6.8	1.7
Bare ground		29.7	9.0	17.7	1.5
Litter		20.2	15.3	11.7	25.4
Moss and lichens		0.6	2.4	1.7	9.3

Figure F-2 Paramount Resources First Year Natural Recovery Pipeline

Constructed with a Spider-plow, showing first year recovery on a north-facing slope with dominance of bare ground and initial forbs.

Figure F-3 Paramount Resources Second Year Natural Recovery Pipeline

Constructed with a Spider-plow, showing second year recovery on a north-facing slope with establishment of perennial grasses, e.g. wheat grasses, bluegrasses and rough fescue.

Pipelines 11 to 23 years old were dominated by Western and Northern wheat grass and did not resemble undisturbed rough fescue grassland. These pipelines were constructed with top-soil stripping or ditch-witch, which may have resulted in greater disturbance, attracting wheat grasses. Wheat grasses are aggressive competitors once they become established and can prevent establishment of other perennials, such as slow-growing rough fescue (Figure F-4). These pipelines also had the highest cover of June grass, bluegrasses and pasture sagewort.

Figure F-4 Comparison of Pipeline ROWs By Age of Construction Showing Cover of Fescue Association and Wheat grass Species

Fescue association is composed of rough fescue, Western porcupine grass and June grass. Wheat grasses are Western, Northern and slender wheat grasses.

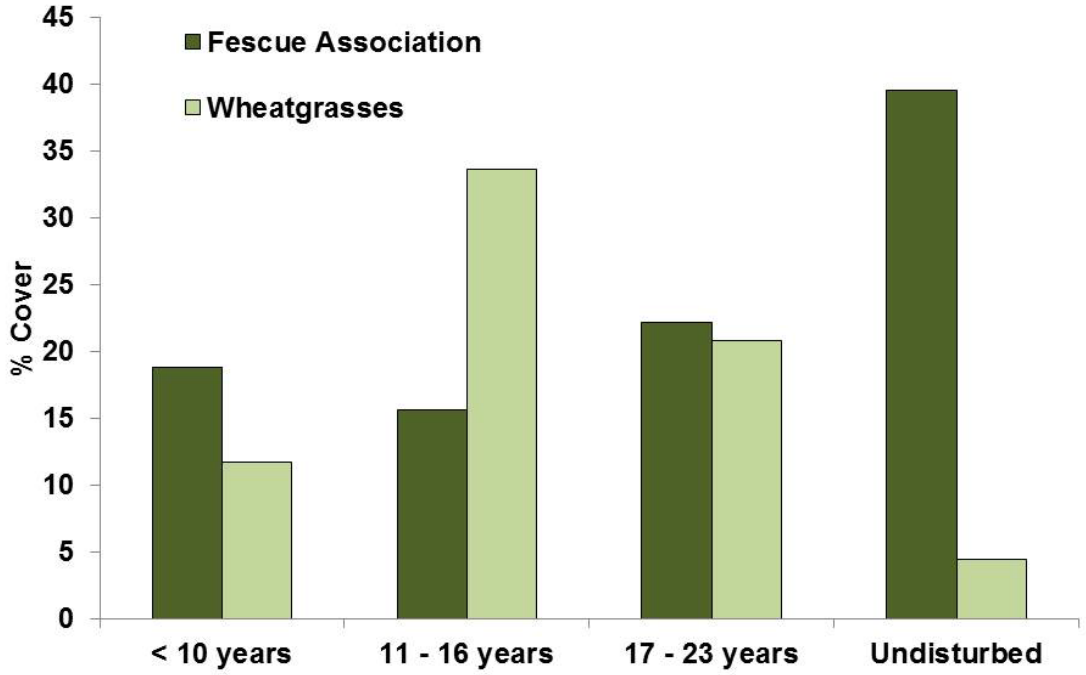
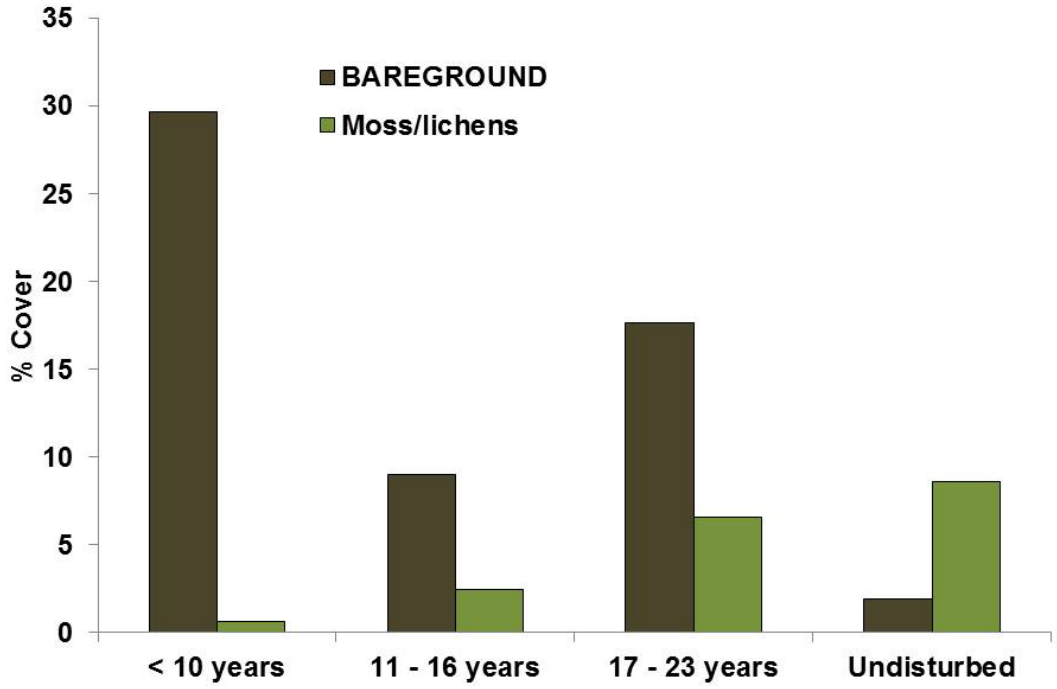


Figure F-5 Comparison of Pipeline ROWs by Age of Construction Showing Bare Ground and Moss / Lichens Cover



An expected trend was found when comparing bare ground and moss/lichens cover between different pipeline ages. Bare ground decreased as pipelines aged, although the oldest pipelines retained more bare ground than younger pipelines, probably due to higher impact construction. None approached undisturbed grassland levels. Moss and lichen cover, on the other hand, followed an expected trend, appearing in greater cover on the oldest pipelines (Figure F-5).

In conclusion, pipelines dominated by wheat grasses were associated with the greatest disturbance in our study, top-soil-strip or ditch-witch construction techniques. Despite being some of the oldest pipelines their covers were dissimilar to undisturbed grassland and were still dominated by wheat grasses, which had probably established in early days. Bare ground was apparent on all pipelines, although bare ground decreased as pipelines aged. Minimal disturbance, such as plough-in pipelines resulted in the best recovery, with trends towards native grassland cover.

For more details about the differences in natural recovery pipeline construction techniques, please refer to Desserud and Naeth (2013) or Desserud's PhD dissertation (Desserud 2011) available on the Foothills Restoration Forum web site: http://www.foothillsrestorationforum.ca.