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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- Rough Fescue Seeding, courtesy of Peggy Desserud
- 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).

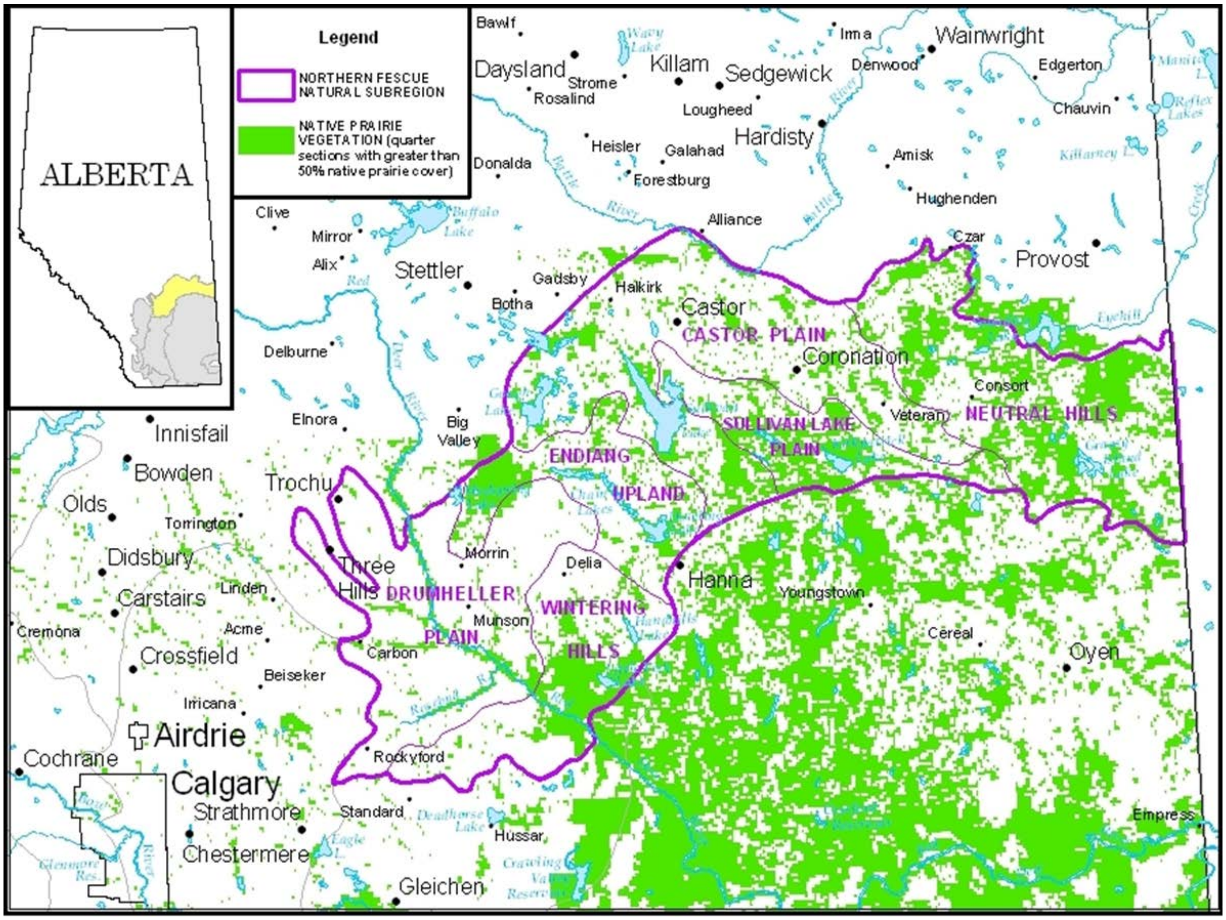
Plains rough fescue (*Festuca hallii*) plant communities dominate sites with average moisture regimes in the remaining upland native grasslands plant communities. Drier than average sites support communities typical of moister sites in the Dry Mixedgrass and Mixedgrass NSRs. Sites with higher than average 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 BIO 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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