IMPACTS OF A SIX YEAR OLD PIPELINE RIGHT OF WAY ON *HALIMOLOBOS VIRGATA* (NUTT.) O.E. SCHULZ (SLENDER MOUSE EAR CRESS), NATIVE DRY MIXEDGRASS PRAIRIE UPLANDS, AND WETLANDS

By

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ABSTRACT

Reclamation of native prairie ecosystems is of growing importance as they continue to be impacted by anthropogenic disturbances. Since European settlement, Alberta grasslands have declined by 61 %. Grasslands are agriculturally important, act as a carbon sink, and many species depend upon them. In Alberta, 77 % of flora and fauna species at risk depend upon or are endemic to native grasslands. Environment Canada recommends a 300 m set back between at risk species, their critical habitat, and pipeline disturbances. Pipeline disturbances can fragment habitat, introduce non native species, impact the soil through admixing and compaction, and alter hydrologic regimes. The impact of pipeline disturbance on at risk plant species and critical habitat is not widely documented or understood.

The objective of this research was to assess the impact of a six year old pipeline right of way on the rare species *Halimolobos virgata* and native dry mixedgrass prairie upland and wetland ecosystems. *Halimolobos virgata* surveys were conducted at two native prairie sites with historic populations. Upland vegetation assessments were conducted at ten locations relative to the pipeline right of way at six native prairie sites. Wetland vegetation assessments were conducted at eight sites on and nine sites off the right of way in native prairie. The research was conducted in southern Alberta, 150 km north of Medicine Hat, over two field seasons in 2014 and 2015.

Halimolobos virgata increased in population size over two field seasons. It appeared to select microhabitat sites with limited competition from other species and a high amount of litter cover. *Halimolobos virgata* was found on the pipeline trench in the last year of the study.

Impacts to the plant community were greatest over highest disturbance zones of the right of way, the trench and work areas. Species richness and diversity were significantly lower in these areas relative to other right of way zones and undisturbed prairie. The trench had greatest bare ground and least live species cover.

Little variability was found in wetlands on and off the right of way. Community composition, species richness, diversity, similarity, and ground cover were consistent across all sites.

After seven growing seasons, the impacts of disturbances caused by pipeline right of ways have begun to lessen on the plant communities of uplands and wetlands. Native species were dominant, and non native species did not appear to be dominating any areas of the right of way. *Halimolobos virgata* does not appear to be negatively impacted by the right of way, thus the 300 m set back is not required, provided similar construction methods are used. The set back of 30 m between *Halimolobos virgata* and pipeline construction that was used by TransCanada is sufficient to protect existing populations and associated habitat.

After the sunset on the prairie,

there are only the stars,

the stars standing alone.

- Carl Sandburg

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I. INTRODUCTION

1. BACKGROUND

Prior to European settlement, North American grasslands spanned across Alberta, Saskatchewan, and Manitoba in Canada and east of the Rocky Mountains, across the Great Plains of the United States (Alberta Environmental Protection 1997). This expanse covered 2.6 million km^2, 14 % of the land mass following glaciation. Some conservation importance of grasslands can be related to their agricultural significance, with grasses tied directly or indirectly to human food sources, their ability to act as a carbon sink, and the many endemic floral and faunal species that depend on them (Sampson and Knopf 1994). A third of all faunal species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) are located on grasslands (Alberta Environmental Protection 1997). There are 324 vascular plants considered rare in Canada; of those 25 % are prairie species, many of which are restricted to specific prairie habitats such as badlands (Alberta Environmental Protection 1997). Within Alberta 77 % of species at risk depend on prairie habitats. Prairie species can be four times more likely than national averages to be listed as at risk.

Since the first settlers arrived on the prairies, Alberta grasslands have declined by approximately 61 % (Sampson and Knopf 1994). Approximately 50 % of dry mixedgrass subregion has been lost over the last century (ASRD and ACA 2009). Current disturbances on grasslands are predominately caused by fragmentation related to linear disturbances, such as pipelines, transportation corridors, and telecommunications lines (Alberta Environmental Protection 1997). Fragmentation results from transportation networks and petroleum and natural gas activities. The grasslands natural region contains approximately 74,629 well sites, each with access roads, accounting for an overall loss of 672 km^2 of prairie habitat. While low intensity disturbances are beneficial to grasslands, maximizing diversity, large scale disturbances can have long term and detrimental effects (Collins and Barber 1985, Sampson and Knopf 1994, Alberta Environmental Protection 1997).

To mitigate some of the risk associated with prairie disturbances, guidelines were developed to protect species at risk and their critical habitat (Environment Canada 2008). The recommended guidelines for construction of pipelines state that no class 3 activity can be conducted within 300 m of endangered or threatened plant species. Class 3 activities are any disturbances that could result in ultimately killing or harming listed plant species or their associated critical habitat. Class

3 activities protect plants from acute and chronic disturbances. Some activities that would qualify as class 3 include the use of moto cross 4 x 4 vehicles, pesticide spraying, fencing, and seeding of non native crops or forage species. Relating to pipelines specifically, the 300 m set back distance means that the entire pipeline right of way (ROW) must be 300 m from the species at risk and their associated critical habitat (Figure 1.1).

The 300 m, class 3, buffer is recommended based on impacts of known detrimental agents (Environment Canada 2008). Impacts from construction, traffic, salinity, nitrogen, hydrologic effects, and non native species can range from immediately adjacent the pipeline disturbance to 1 km away. The 300 m buffer was based on numerous studies, although not directly related to grassland conservation, and was proposed as a reasonable set back distance based on literature interpretation and scientific opinion (Environment Canada 2008, Henderson 2010).

Plants can be vulnerable to anthropogenic activities due to their sedentary nature. Thus humans are responsible for ensuring their activities are not unnecessarily detrimental to plant species and their critical habitats. However, current literature is lacking on how to best protect rare species both globally and at a local level. More research is required to better understand how anthropogenic activities affect rare plant species and their critical habitats.

Like most other jurisdictions, Alberta has limited research on impacts of development on rare plant species. As the oil and gas industry grows across Alberta, current set back guidelines may be challenging to meet due to environmental or economic constraints. This research will focus on effects of construction and reclamation of a six year old pipeline on two prairie plant species at risk and upland and wetland plant communities. This research will address whether the recommended set back distance is appropriate to protect rare plant species, their critical habitat, and wetland plant communities.

2. RARE SPECIES

2.1. *Halimolobos Virgata* (Nutt.) O.E. Schulz (Slender Mouse Ear Cress)

In April 1992, COSEWIC designated *Halimolobos virgata* (Nutt.) O.E. Schulz as endangered; upon re examination of the species, in May 2000, it was designated as threatened (Environment Canada 2012). The Species at Risk Act (SARA) lists *Halimolobos virgata* as threatened as of 2003 and as data deficient in 2005, and the Alberta Natural Heritage Information Centre (ANHIC) ranks it as S1S2 (Gould 2006, Environment Canada 2012). SARA establishes

Schedule 1 (S1) species as the official list of wildlife at risk within Canada. Once listed as S1, species benefit from legal protection and recovery plans as mandated by SARA. S1 listing means there are fewer than five occurrences of the species, with few remaining individuals. ANHIC is a biodiversity data centre with a compilation of species, landforms, and ecological communites found in Alberta (Alberta Environment and Parks 2015). It analyzes trends, location, and conditions of species and ecologocial landforms. Species that are found to be rare or of concern are placed on a provincial tracking list and ranked.

Halimolobos virgata is native to both Canada and the United States (Figure 1.2). Populations in Canada are found in southeastern Alberta and southwestern Saskatchewan (Environment Canada 2012). In Alberta fourteen populations are believed to be extant. Population counts by Alberta Sustainable Resource Development (ASRD) vary slightly with nine extant populations, one extirpated, one historical, and three populations that were reported, but were not found (ASRD and ACA 2009). The historical spread of the subpopulations is 998 km^2, with the extant spread of 530 km^2. The estimated number of productive individuals in the provincial population is 3,000 to 7,000, in years suitable for growth and germination.

In Alberta, *Halimolobos virgata* is found in the dry mixedgrass subregion of the grassland natural region in the South Saskatchewan and Red Deer river basins (Environment Canada 2012). This subregion typically has extreme temperature ranges, warm summers, cold winters, and water deficits. The water deficit stems from surface run off, high evaporation and low precipitation (ASRD and ACA 2009). In the dry mixedgrass subregion, *Halimolobos virgata* is found on seasonally wet uplands to undulating grasslands, and is often found in depressions on the edges of sand dunes. It grows in orthic brown and dark brown chernozems and orthic regosols. One soil property that is consistent across soil types is a coarse texture, with sand and loam (ASRD and ACA 2009, Environment Canada 2012).

Halimolobos virgata requires some moderate disturbance, and is often found in areas with light grazing (Nemirsky 2011, Environment Canada 2012). Light grazing and the resulting disturbance may open areas of the soil, creating depressions which could facilitate germination.

Halimolobos virgata is a member of the mustard family (*Brassicaceae*) and is the only representative of *Halimolobos* in Alberta (ASRD and ACA 2009). It is often considered a biennial, although it can complete a full life cycle in one season as an annual herb and act as a short lived perennial (Looman and Best 1979, ASRD and ACA 2009, Environment Canada 2012). The morphology of *Halimolobos virgata* varies from tall and heavily branched individuals to single stemmed, short and thin (ASRD and ACA 2009). Stem height ranges from 15 to 40 cm for both single and branched forms (Looman and Best 1979, Environment Canada 2012). Distinguishing *Halimolobos virgata* from other similar species in the mustard family, such as *Erysimum inconspicuum S*. Wats. (small wormseed mustard), is that the upper portion of the stem has simple or forked long hairs (trichomes) interspersed with short, branching hairs (ASRD and ACA 2009). Leaves located on the basal rosette are toothed with stalks (petioles) and are up to 6 cm long and 15 mm wide (ASRD and ACA 2009, Environment Canada 2012). The leaves on the stalk decrease in size towards the top of the plant and the uppermost leaves are stalkless and clasp with basal nodes (auricles).

Halimolobos virgata flowers sometime from late May to the beginning of June (Environment Canada 2012). The 4 to 8 mm flowers are whitish, with four petals and four hairy sepals. Fruit pods (siliques) form in June to July, and grow 2 to 4 cm long and 1 mm wide. They are generally hairless in Alberta (ASRD and ACA 2009, Environment Canada 2012). Ripe pods are a reddish brown colour, and split in mid July, releasing tiny seeds (Environment Canada 2012). Each plant averages 100 to 400 seeds (ASRD and ACA 2009).

Halimolobos virgata is threatened by habitat loss and degradation, loss of grazing and fire regimes, changes in hydrological regimes, invasive plant species, sand and gravel extraction, and urban development (ASRD and ACA 2009, Environment Canada 2012). Loss and degradation of habitat are caused by agriculture developments and oil and gas activities.

2.2. *Cryptantha Minima* Rydb. (Tiny Cryptanthe)

In April 1998, COSEWIC designated *Cryptantha minima* Rydb. as endangered; this status was re examined and confirmed in May 2000 (Environment Canada 2006). *Cryptantha minima* qualifies as endangered because the known population at the time of evaluation was less than 250 individuals (ASRD 2004). ANHIC ranked it as S1, due to the five or fewer occurrences of the species reported with limited individuals in each reporting (ASRD 2004).

Cryptantha minima is native to North America (Figure 1.3). In Alberta it is found in association with river systems, such as the South Saskatchewan river valley near the Saskatchewan border. There are 28 known populations of *Cryptantha minima* in Alberta and four in Saskatchewan (Environment Canada 2006). Populations have also been documented near the lower Bow and upper Oldman rivers in Alberta and the Red Deer river in Saskatchewan.

In Alberta, *Cryptantha minima* is found in the grassland natural region of Alberta, mostly in the dry mixedgrass subregion with some occurrences in the mixedgrass subregion (Environment

Canada 2006). This area is characterized by temperature extremes, dry summers and winters, and high evaporation during summer months (ASRD 2004). *Cryptantha minima* is often found in sandy, poorly developed rego brown chernozems, or orthic regosols. They are often coarse and contain fluvial or aeolian materials (ASRD 2004, Environment Canada 2006). Within the dry mixedgrass and mixedgrass subregions, *Cryptantha minima* is located in three broad habitat types: sandy, flat to rolling uplands and sand dunes, valleys with up to a 50 % slope, and sloping terraces in valley bottoms (ASRD 2004).

Cryptantha minima appears to benefit from disturbance. Natural disturbances, such as water movement, gravity, wind, and soil disturbing animals are found with populations (ASRD 2004). Low level disturbance can stimulate germination of existing seedbanks and reduce competition with other species (Environment Canada 2006). While moderate disturbance is desired, areas of active disturbance such as eroding slopes are not associated with populations (Environment Canada 2006). *Cryptantha minima* has not been found in association with compacted areas, such as roads, or where there is alteration of the native plant community, such as in a non native seeded pasture (ASRD 2004).

Cryptantha minima is an annual in the borage (*Boraginaceae*) family (Wei et al. 2009, Environment Canada 2006). It is commonly known as small cryptanthe, little cryptanthe, and little cat`s eye (Environment Canada 2006). Stems have bristly hairs, are branched from the base and can grow 10 to 20 cm in height (ASRD 2004). The leaves are covered in hair, are shaped like spatulas, and are up to 6 cm long and 50 mm wide, getting smaller up the plant.

In Alberta, *Cryptantha minima* flowers in late June to early July (ASRD 2004). While reproduction is sexual, pollination agents and minimum distance for cross pollination are unknown. Flowers are tube shaped, with white petals and yellow centres, located along the top side of branches, with a bract at the base of each flower (Environment Canada 2006). The flowers are small, 2 mm across and 3 mm long. Sepals with whitish midribs are around the flower petals creating a calyx. Four nutlets (seeds) mature in late July and August in the calyx. One of the nutlets is large and smooth, while the other three are bumpy and smaller, all turning brown upon maturation. Under correct conditions there can be large flushes of germination, therefore the number of individuals can vary dramatically from year to year (ASRD 2004).

Cryptantha minima is threatened by habitat degradation linked to decreased grazing, fire control, climate change, and invasive species (Environment Canada 2006). Typically, the sandy soils that *Cryptantha minima* prefers are not ideal for agriculture, however they can be surrounded by areas ideal for agriculture, leading to isolated islands of *Cryptantha minima*. Oil and gas extraction and exploration is threatening existing populations as they have areas of high disturbance and compact the soils (Environment Canada 2006, ASRD 2004).

3. WETLANDS

The wetland region located across the Canadian plains is referred to as the prairie pothole or northern prairie wetland region (van der Kamp and Hayashi 1998, van der Kamp and Hayashi 2009). This region is defined in Canada by a transition zone between the grassland natural region and boreal forest natural region, characterized by equal precipitation and potential evaporation (Winter 1989, van der Kamp and Hayashi 2009) (Figure 1.4). Wetlands in the prairie pothole region are unique due to combinations of a semiarid yet cold climate and deposits left by retreating glaciers.

Approximately 20 % of Alberta is covered by wetlands; 90 % are bogs and fens (peatlands) (ESRD 2013, ESRD 2015). Prairie wetlands cover approximately 1.1 million hectares, or 2 % of the Alberta landscape. Globally, the prairie pothole region is the tenth largest wetland complex (Dodds and Whiles 2010). Alberta wetlands sustain migratory waterfowl, provide flood mitigation, function as natural water filtering systems, and support a variety of flora and fauna. In Alberta approximately 400 species of plants are dependent upon wetlands.

Alberta has historically used several wetland classification methods (ESRD 2015). Until recently, the Canadian Wetland Classification System (CWCS) (NWWG 1997) and the Classification of Natural Ponds and Lakes in the Glaciated Prairie Region (Stewart and Kantrud 1971) were the main systems in use. The Alberta Wetland Classification System (AWCS) was introduced in June 2015 incorporating different classification systems (ESRD 2015). The AWCS identifies five broad classes of wetlands: bogs, fens, swamps, marshes, and shallow open water (ESRD 2015) (Table 1.1), consistent with CWCS and Stewart and Kantrud (1971). Classes are divided into types based on vegetation, and again divided based on water regime. In the dry mixedgrass subregion, wetlands can be further classified as mineral wetlands, including marshes, shallow open water, and swamps. AWCS has developed keys to identify wetland type based on dominant vegetation types, water permanency, and water characteristics.

3.1. Alberta Wetland Policy

Previous Alberta wetland policy, the Wetland Management in the Settled Area of Alberta Interim Policy for Sloughs, stated several objectives for wetland management and conservation (Alberta

Water Resources Commission 1993). Some of the objectives were to conserve slough/marsh wetlands in a natural state, to mitigate degradation or loss of slough/marsh wetland benefits as near to the site of disturbance as possible, and to enhance, restore or create slough/marsh wetlands in areas where wetlands have been depleted or degraded (Alberta Water Resources Commission 1993). This policy only regulated the white area of the province, leaving the green areas to be regulated by wetland sections in other policies such as the Water Act and the Public Lands Act (ESRD 2013). In September 2013, a new wetland policy was released in Alberta, the Alberta Wetland Policy (ESRD 2013). The Alberta Wetland Policy regulates white and green areas of the province, natural wetlands, and wetlands restored or constructed for wetland replacement. Goals of the new policy are to conserve, restore, protect, and manage Alberta's wetlands. To achieve these goals, four outcomes are to be focused on: wetlands of the highest value are protected for the long term; wetlands and their benefits are conserved and restored in areas where losses have been high; wetlands are managed by avoiding, minimizing, and if necessary, replacing lost wetland value; and wetland management considers regional context.

Some of the issues with wetland conservation and/or restoration likely stem from regulatory concerns. Alberta Environment and Sustainable Resource Development list wetland policies with other land based concerns; however, many of the regulations can be tied to water quality acts. This inconsistency of classification as land or water could lead to confusion regarding the appropriate conservation and/or restoration policy. No net loss policies, such as those in the United States and in Alberta from 2007 to 2014, have multiple issues, often stemming from what successful mitigation or replacement actually means (Zedler 1996, Alberta Environment 2007). Often hydrologic regimes are difficult to restore, and that is a main driving factor behind natural wetlands (Zedler 1996).

3.2. Hydrology Of Alberta Wetlands

Prairie potholes may be permanently or ephemerally filled, with years of drought resulting in low to no water levels (Stewart and Kantrud 1971, LaBaugh 1998, van der Kamp and Hayashi 1998, van der Kamp and Hayashi 2009). Precipitation, through rain or snow melt, is the primary factor. The varying seasonality is important with permanent wetlands providing stable habitats, and ephemeral ones showing the highest biological productivity (van der Kamp and Hayashi 2009). Small wetlands lose the majority of their water through groundwater recharge, with high shoreline to area ratios. The high rate of groundwater recharge underneath wetlands forces salts into the surrounding uplands, where evapotranspiration and capillary action remove the water leaving an area of saline soil or subsoil, referred to as a saline ring (Stewart and Kantrud 1971, LaBaugh 1998, van der Kamp and Hayashi 1998, Wentz 2000, van der Kamp and Hayashi 2009). Salinity in wetlands is controlled by dissolved salts and the flux of groundwater recharge and discharge of the wetlands in association with surface water flow.

Groundwater recharge and discharge heavily influence the water table in wetlands (Mitsch and Gosselink 2007). If the wetland is higher in elevation than the surrounding water table there will likely be groundwater recharge. When a wetland is hydrologically below the water table there is often groundwater discharge. Groundwater discharge can result in seep wetlands, located at the base of hills where the groundwater table coincides with the land.

3.3. Geomorphology Of Alberta Wetlands

Soils of the prairie pothole region are clay rich glacial tills, left by a Pleistocene ice sheet (van der Kamp and Hayashi 2009), whose retreat created hummocky landscape with depressions (sloughs, potholes) that are mostly topographically and hydrologically isolated from each other. Glacial soils are rich with nutrients and minerals and no connectivity between sloughs means nutrients are trapped and recycled, not removed by surface runoff. This provides extremely productive habitats, particularly for the several million waterfowl which breed in wetlands.

3.4. Alberta Wetland Plant Communities

Prairie wetlands often have communities dominated by *Typha* (cattail), *Scirpus* (bulrush), *Carex* (sedge), *Poa* (blue grass), and *Calamagrostis* (reed grass) species (ESRD 2015, Kantrud 1986). High levels of productivity and ecological services lead to a number of environmental conservation and/or restoration concerns (van der Kamp and Hayashi 2009). Wetlands supply ecosystem services such as flood management, nutrient cycling, carbon sequestration, and water filtering (Euliss et al. 2006, Bartzen et al. 2010). High productivity in wetlands leads to a disproportionally large number of faunal species relative to land mass that are dependent on wetlands for part of their life cycle (Bartzen et al. 2010).

Differences in wetland species composition are often related to variability in water salinity. Differing levels of salinity and their associated plant communities are classified as fresh, slightly brackish, moderately brackish, brackish, subsaline, and saline (Stewart and Kantrud 1971, ESRD 2015) (Table 1.2). However, measures of specific conductance vary greatly (ESRD 2015). Thus prairie wetlands are hydrologically dynamic, with specific plant communities, not specific conductance, often the better indicator of average salinity. During periods of normal water conditions, fluctuations are in average salinity are lower than in periods of drought.

Throughout the prairie region, seven classes of vegetation may be present. These are distinguished by the vegetational zone occurring in the central or deeper part of the wetland, and occupying 5 % or more of the total wetland area (Stewart and Kantrud 1971). The seven zones are ephemeral ponds, temporary ponds, seasonal ponds and lakes, semi permanent ponds and lakes, permanent ponds and lakes, alkali ponds and lakes, and fen (alkaline bog) ponds (Figure 1.5).

During extended, abnormal water periods, such as drier or wetter seasons, wetlands may change from one class to another (Stewart and Kantrud 1971). Seasonal and semi permanent ponds and lakes cover the most area across the glaciated prairie region. Ephemeral and temporary ponds are present in large numbers, but cover a smaller total area. Permanent and alkali ponds and lakes may be quite large, but are few in number, and fen ponds are often small and highly localized.

The Alberta Conservation Information Management System, an ecological community tracking list, describes communities of plants, often showing affinity for growing proximity, within Alberta that appear to have restricted distributions (Allen 2012). Six rare wetland plant communities are potentially located within southern Alberta and the dry mixedgrass subregion (Table 1.3). The communities are rated from S1 to S3 and have a variety of characteristics, although each of the six communities have an association with a hypersaline type environment. Some of the communities have been characterized, including water properties and community composition, while others are still data deficient.

4. PIPELINE DISTURBANCE

4.1. Pipelines

Pipelines have been used in Canada since 1853, when a 25 km pipe moved natural gas to Trois Rivieres, Quebec (Canadian Energy Pipeline Association 2013). Today pipelines are used to transport liquids such as crude oil, petroleum products, and water or gases such as natural gas, and carbon dioxide. The pipeline network transports approximately three million barrels of petroleum products daily. Without pipelines this amount would require 4,200 rail cars or 15,000 tanker trucks to move crude oil throughout Canada.

There are four main types of pipelines in Canada: gathering lines, feeder lines transmission pipelines, and distribution pipelines. Gathering lines cover short distances to collect products from wells and move them to oil batteries or processing facilities. These lines are typically of 101.6 to 304.8 mm outside diameter. There are more than 250,000 km of gathering lines concentrated in western Canada, primarily Alberta (Canadian Energy Pipeline Association 2013). Feeder lines transport products from storage areas, processing plants, and batteries that are located in the field to the long distance movers, the transmission pipelines. There are more than 25,000 km of feeder lines in western Canada. Transmission pipelines are the long distance haulers of oil and natural gas products across provincial and international boundaries. These lines are 101.6 to 1,212 mm in diameter and there are more than 100,000 km in Canada. Distribution pipelines are used by local companies to move natural gas to homes and businesses. These lines are the smallest, from 12.7 to 152.4 mm diameter, and there are approximately 450,000 km in Canada.

Disturbances caused by pipelines can vary greatly as many factors can affect construction methods and procedures. The timing of the project is one such factor. When topsoil is frozen, there is often less disturbance; other preferable times for construction include during dry periods (Jol and Smith 1995, Sinton 2001). Other factors that can affect pipeline construction and therefore the disturbances are location of the pipeline; this includes soil type and texture, the existing plant community, and topography. The disturbances generally associated with native grassland pipeline construction are removal of native vegetation, invasion of non native plants, changes to soil and landscape structure, fragmentation of undisturbed land, disturbances to wildlife, and potential for spills during and after construction (Sinton 2001). Due to the above factors and disturbances, along with others, native grasslands are now one of the most endangered natural ecosystems (Sinton 2001, Neville 2002).

Several environmental issues were identified by stakeholders and government regulatory authorities related to pipeline development. They include: loss of native vegetation species diversity, scalping of native vegetation and soils, fragmentation of vegetation and habitat, non native species invasion, loss of habitat for wildlife, excessive roach height and width over the trench, altered grazing patterns for livestock, incomplete topsoil and subsoil retrieval from storage areas, topsoil loss due to wind and water erosion, uneven topsoil stripping in rough micro topography, alteration of natural landscape topography and drainage patterns and disruption of normal groundwater flows, diminishing extent of undisturbed native prairie, and improved vehicle access to undisturbed native prairie and sensitive areas (Neville 2002). Fire control is a serious concern to landowners and residents of grasslands. Construction related wildfires can have serious impacts on ranching and farming operations, particularly during periods of extended drought. The ultimate goals of the best management guidelines are to minimize disturbance, avoid sensitive areas, conserve vegetation, soil, wildlife, historical resources, and allow for the eventual restoration of native species in the area.

4.2. Right Of Way Construction

Pipeline ROWs are typically 18 to 36 m wide and allow access to workers for maintenance, construction, emergency, or testing purposes (Enbridge Energy 2013). ROWs are constructed during the pre construction phase of pipeline development. They will be clearly marked, all flora removed, and the top soil removed and stockpiled for future use. The ROW will then be levelled and graded to provide access for construction equipment (Canadian Energy Pipeline Association 2013). Construction can cause major disturbances to the vegetation and soil along pipeline ROWs (Lathrop and Archbold 1980). The ultimate goal of a ROW is to allow company access to a pre determined strip of land in order to survey, construct, maintain, and conduct surveys on the pipeline (Alberta Land Surveyors’ Association 2016).

4.3. TransCanada Pipeline

The TransCanada pipeline is 76.2 cm in diameter and 3,456 km in length, transporting crude oil from Hardisty, Alberta to United States markets of Cushing, Oklahoma, and Wood River and Panoka, Illinois (Nannt 2014, TransCanada 2012). The pipe was buried with minimum cover of 1.2 m depending on land use. Construction and reclamation near research areas occurred February to May 2009.

Pre construction mitigation strategies included marking rare species population sites within 30 m of the pipeline ROW, creating a buffer where there are rare plants within 30 m of the ROW, installing warning signs informing all personnel of rare plant species in the vicinity, fencing known sites, and restricting the location of temporary workspaces to outside of 30 m of a known plant site (Jacques Whitford AXYS Ltd. 2008). Other pre construction mitigation measures included conducting plant surveys of known sites to confirm the presence of the species and their boundaries, including SARA listed plant species location and mitigation as part of environmental inspector and contractor/visitor training, and holding pre construction meetings with construction foremen to review construction plan and mitigation requirements.

Construction mitigation strategies mandated that all equipment brought on site be free of vegetation, soil and other potentially detrimental debris (Jacques Whitford AXYS Ltd. 2008). They include scheduling all construction activities following plant dormancy after flowering and set seed, topsoil stripping limited to ditch lines (approximately 2 m width), no grading within 30 m of a known SARA plant, limiting construction movement to equipment essential for the safe installation of the pipe and one way traffic for equipment passage 2008). During construction, the ROW was 30 m wide, and contained 19 m of temporary work space, 4 m of permanent ROW and 7 m of temporary storage space (TransCanada 2012). During unfrozen conditions a grader was used to strip the topsoil, while during frozen periods a soil mulcher was used (Nemirsky 2011). Seeding and straw crimping occurred May to July 2009 along the ROW.

5. PIPELINE IMPACTS ON VEGETATION

5.1. Wetlands In The Dry Mixedgrass Subregion

Wetlands are being impacted across the prairie pothole region of Alberta, much of the loss and impairment is attributed to agricultural and grazing practices (Galatowitsch and van der Valk 1996b, Bartzen et al. 2010, ESRD 2015). It is difficult to attribute impacts to wetland as being directly related to one disturbance. Many oil and gas developments in the dry mixedgrass subregion, from pump stations to pipelines, occur directly adjacent to, or in the same field as pasture or other agricultural practices. However, research into the impacts of agriculture on wetlands in this region have illustrated that ephemeral wetlands are most susceptible and vulnerable to disturbance (Bartzen et al. 2010). Due to the amount of natural variability observed in natural wetlands, related to the hydrologic cycle, it can be difficult to judge both the impact of disturbances and the success of reclamation on wetlands (Foote and Rice Hornung 2005, Bartzen et al. 2010, Rooney and Bayley 2011). Interestingly, if there is a spring with high precipitation, then the measurable impacts to wetlands are lower and recovery rates are higher (Bartzen et al. 2010). Most of the data related to the status of wetlands in the prairie pothole region are based upon wetland counts done in early May when ephemeral wetlands are still holding water (Conly and van der Kamp 2001).

5.2. Impacts To Plant Communities

While linear effects, such as pipelines, might seem innocuous in nature, they have the potential to result in significant losses and impacts to wetlands (Noble et al. 2011). Some impacts that have been observed in disturbed prairie wetlands are changes in the vegetation community (Bartzen et al. 2010). In Saskatchewan some common species found in undisturbed wetlands are *Myriophyllum spicatum* var. *exalbescens* Fern. (water milfoil), *Ranunculus circinatus* Sibth. (white water crowfoot), *Potamogeton pusillus* L. (pondweed), *Typha latifolia* L. (cattail), *Scolochloa festucacea* (Willd.) Link (common river grass), and *Eleocharis palustris* (L.) R and S (common spike rush) (Conly and van der Kamp 2001). Changes to the vegetation, either through loss of native or addition of non native species can alter both snow trapping potential in winter and evapotranspiration in summer (Conly and van der Kamp 2001, Bartzen et al. 2010). Bartzen et al. 2010 observed significant differences in vegetation community composition between natural and restored wetlands. In areas that have natural grasslands, it is estimated that wetland recovery will be greater compared to heavily farmed areas.

6. THESIS APPROACH

This research has been conducted to study the impact of a six year old pipeline ROW on *Halimolobos virgata* and *Cryptantha minima*, at risk plant species in the dry mixedgrass subregion of Alberta. This research can be used to inform industry about how pipeline construction and operation impacts species at risk and vegetation communities in the dry mixedgrass subregion. The results of this research may be used to influence best management practices for pipelines in prairie environments to ensure to continued persistence of at risk species and native prairie.

This thesis is divided into three main research sections and supplementary material sections. Chapter II addresses the impact of a six year old pipeline ROW on *Halimolobos virgata* and its associated critical habitat. Chapter III addresses the impact of location relative to the ROW on the native dry mixedgrass vegetation community. Chapter IV addresses the impact of the ROW on wetland vegetation communities on and off the ROW. Chapter V summarizes the results of the research, discusses limitations, and suggests future research trajectories.

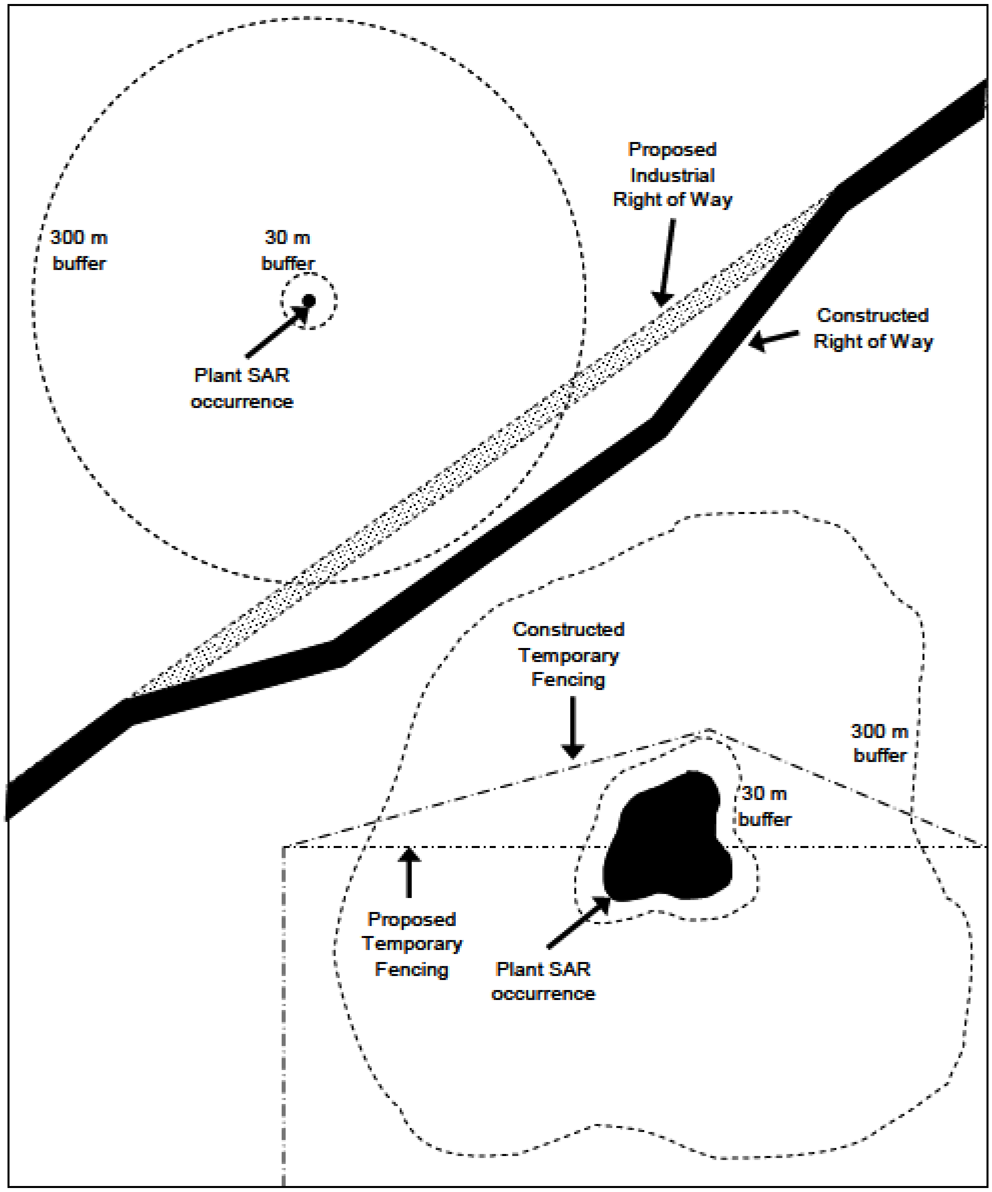

Figure 1.1. Conceptual representation of how set back distance guidelines for 30 and 300 m are used to protect individual plants and habitat by altering construction of new developments on the landscape. Plant occurrences may be points, lines, or polygons, and set backs are created by buffering the boundary of those occurrences (Environment Canada 2008).

Figure 1.2. Known *Halimolobos virgata* range in North America (Environment Canada 2012).

Figure 1.3. Known *Cryptantha minima* range in North America (Environment Canada 2012).

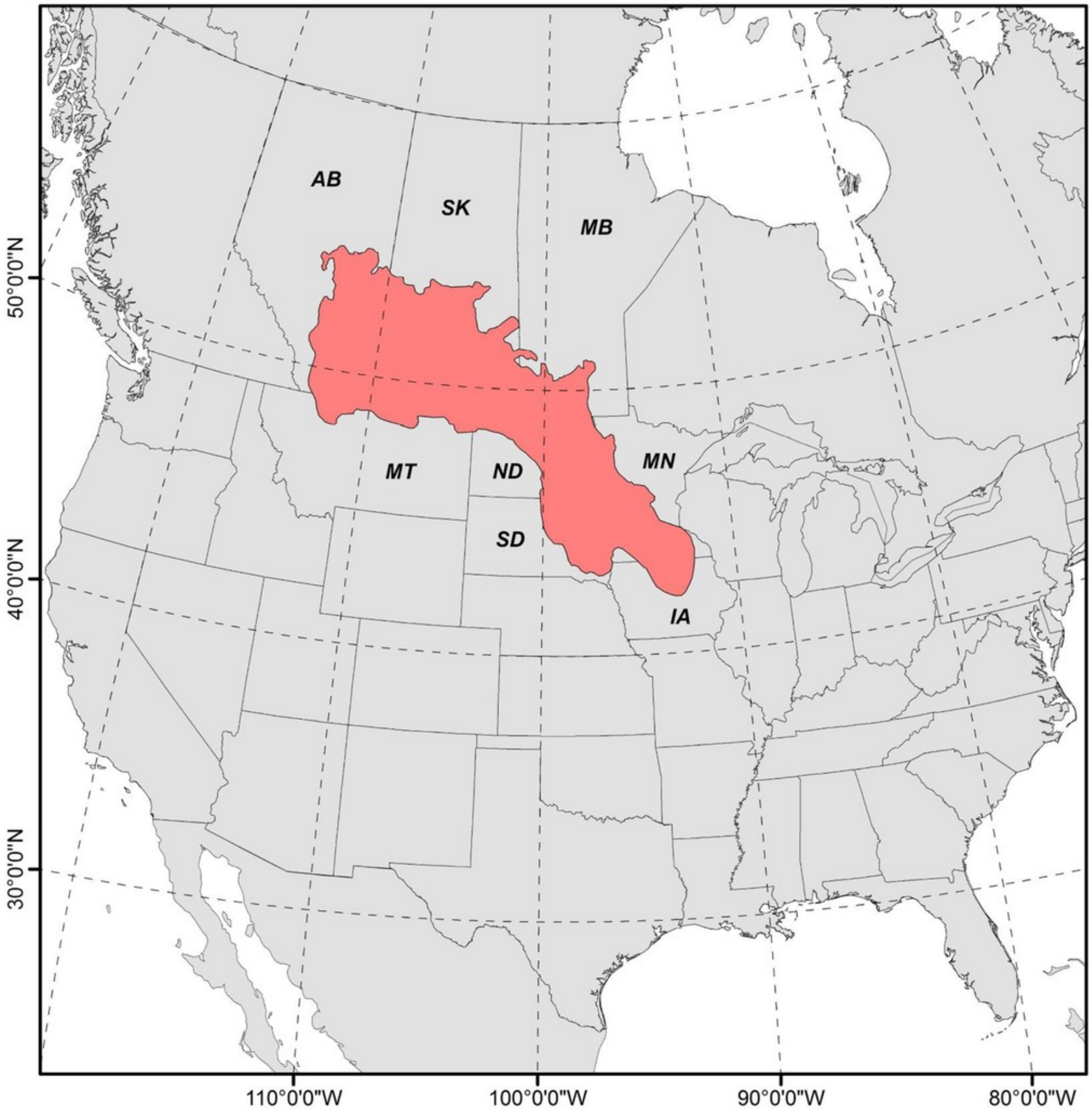

Figure 1.4. Extent (red area) of the northern prairie wetland system across North America (Gong et al. 2015).

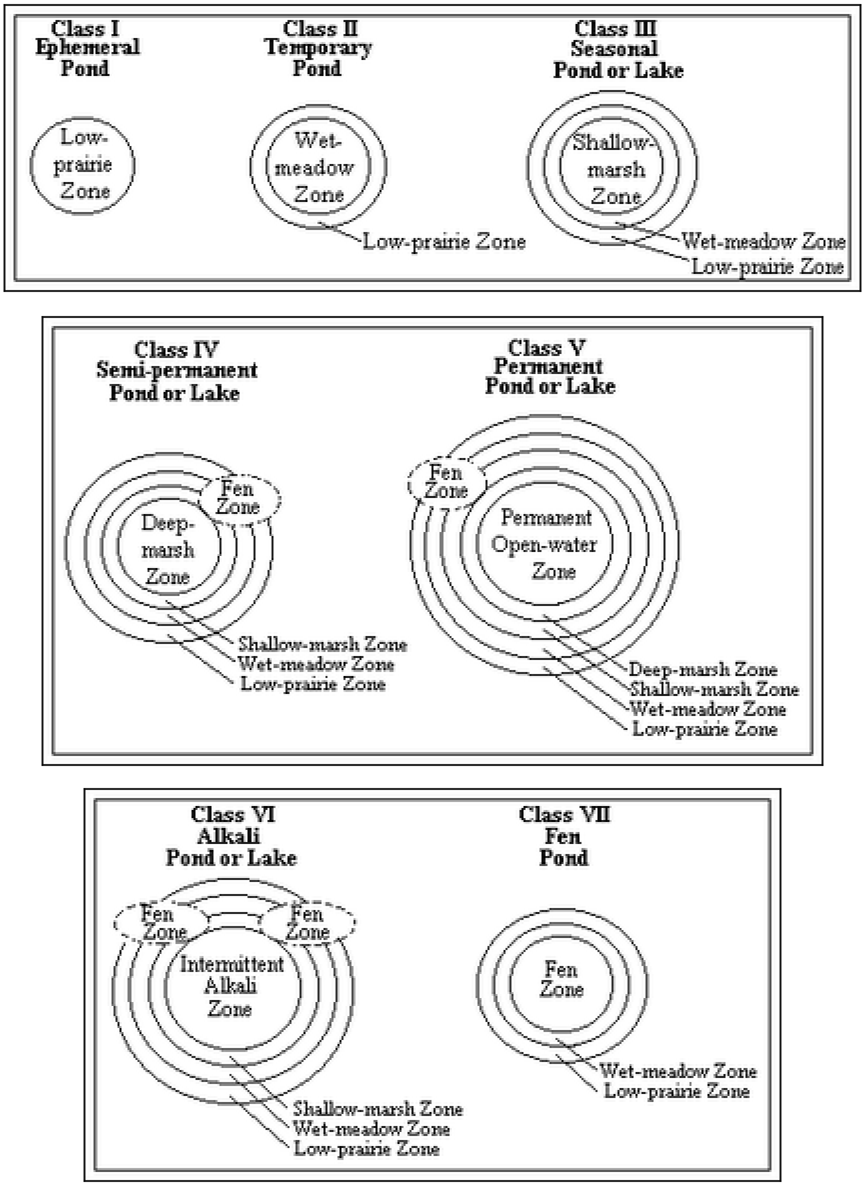

Figure 1.5. Spatial relation of vegetational zones in major classes of natural ponds and lakes (Stewart and Kantrud 1971).

Table 1.1. Description of the Alberta Wetland Classification System.

Class	Form	Types: Salinity	Types: Water Permanence	Types: Acidity Alkalinity
Bog	• Wooded, coniferous • Shrubby • Graminoid	Freshwater	-	Acidic
Fen	• Wooded, coniferous • Shrubby • Graminoid	Freshwater	-	Poor
		Freshwater	-	Moderate rich
		Freshwater to slightly brackish	-	Extreme rich
Marsh	• Graminoid	Freshwater to slightly brackish	Temporary [II]	-
		Freshwater to moderately brackish	Seasonal [III]	-
		Freshwater to brackish	Semi permanent [IV]	-
Shallow Open Water	• Submersed and/or floating aquatic vegetation [A] or bare	Freshwater to moderately brackish	Seasonal [III]	-
		Freshwater to sub saline	Semi permanent [IV]	-
		Slightly brackish to sub saline	Permanent [V]	-
	• [A]	Saline	Intermittent [VI]	-
Swamp	• Wooded, coniferous • Wooded, mixedwood • Wooded, deciduous Shrubby	Freshwater to slightly brackish [2]	Temporary [II] [2]	-
		Freshwater to slightly brackish [2]	Seasonal [III] [2]	-
		Moderately brackish to sub saline [2]	Seasonal [III] [2]	-

Adapted from ESRD 2015

[1] Roman numerals are equivalent to wetland classes by Stewart and Kantrud (1971)

[2] Swamp types are not applicable to wooded swamps due to a lack of available information

Table 1.2. Approximate normal and extreme ranges of specific conductance of surface water in plant communities indicative of differences in mean salinity.

Plant Community	Normal Range (micromhos / cm)	Extreme Range (micromhos / cm)
Fresh	<40 – 500	<40 – 700
Slightly brackish	500 – 2000	300 – 2200
Moderately brackish	2000 – 5000	1000 – 8000
Brackish	5000 – 15000	1600 – 18000
Subsaline	15000 – 45000	3500 – 70000
Saline	45000 – 100000 +	20000 – 100000 +

Adapted from Stewart and Kantrud 1971

Table 1.3. Rare Alberta wetland plant communities in the dry mixedgrass subregion.

Community	Alberta Rank	Characteristics
Ruppia cirrhosa	S1	• Grassland and parkland aquatic community, endemic to the glaciated portion of the great plains • Documented in the mixedgrass and central parkland subregions • Characteristic of hypersaline ponds • These types of ponds usually have an unvegetated shore due to their strongly saline nature
Distichlis stricta - Pascopyrum smithii	S2	• In grassland and parkland natural regions of eastern Alberta • Associated with saline soils, usually at drier edge of saline wetlands • Transition between driest portion of halophytic and adjacent semi halophytic communities • *Distichlis stricta* and *Pascopyrum smithii* dominate community • Numerous associated upland species including *Aster ericoides* and *Grindelia squarrosa*
Salicornia rubra emergent marsh	S2	• Hyper saline marsh of grassland, parkland, and boreal natural regions where minerals accumulate due to evaporative drying • Specific habitat needs; ranked G2G3 • Associated with highly alkali wetlands, semi permanent alkali lakes, exposed mud of alkali flats • Often forms ring or patch near centre of saline depression, typically at nonvegetated mudflat edge • Dependent on hydrological processes; seasonal inundation, evaporative dry down, mineral accumulation, resulting in extreme salinity few species can tolerate • Principle salts are sulphates and chlorides of sodium and magnesium • *Salicornia* is frequent in saline areas of dark brown soils zone; less common in black and brown soil zones of Alberta on silt loam to clay soils • Sparsely vegetated community, typically a pure band of *Salicornia* of 25 % or less basal cover with up to 95 % unvegetated silt loam or clay flats • Associated species may include *Puccinellia nuttalliana, Distichlis stricta, Hordeum jubatum, Triglochin maritima, Chenopodium rubrum* and *Suaeda erecta* • This community often grades into graminoids on the upslope side, commonly *Puccinellia nuttalliana*, *Distichlis stricta* community on coarse textured soils • *Salicornia rubra* community is a small patch community, often forming a ring or patch near the centre of saline depressions

Community	Alberta Rank	Characteristics
Triglochin maritime emergent marsh	S2	• Grassland and parkland saline emergent marsh associated with saline seeps and wetlands • Documented only in the central parkland, but likely occurs grassland subregions including the dry mixedgrass and northern fescue • Typically near centre of saline depressions as a part of vegetation around shallow wetlands • Often subject to extreme fluctuations in water level • Occurs on wetter sites with fine sand to sandy clay soils that are saline and intermittently flooded • Forms a pure band of *Triglochin maritima*, usually with less than 20% cover • Basal cover of *Triglochin* varies from 5 to 15 %, with densest stands associated with coarsest soils • *Puccinellia nuttalliana* is the principle associated species but only occurs in half the stands
Scirpus nevadensis - Triglochin maritime	S2S3	• Saline emergent marsh documented in the central parkland natural subregion, and expected to occur in dry mixedgrass and northern fescue subregions • Associated with wetlands that are often subject to extreme fluctuations in water level • Community appears to be restricted to sandy shores of saline to hypersaline wetlands • *Scirpus nevadensis* usually dominant, with very open growth, often only species in the community • *Triglochin maritima* a frequent associate and may be co dominant in some stands • *Distichlis stricta* may occur on dryer edge of community; or *Puccinellia nuttalliana* on wetter side • May border or occur in patches with a *Suaeda calceoliformis* community on strongly alkali sites, often in a band above an unvegetated alkali shore
Spartina gracilis - Pascopyrum smithii	S2S3	• Saline dry meadow of the central parkland natural subregion • May occur in the dry mixedgrass and northern fescue subregions • Typically found on open sandy sites; may be associated with slightly alkaline seepage springs • Associated with wetlands that are often subject to extreme fluctuations in water level and may become dry basins during drought years • Marks upper zone of the halophytic communities; leading to semi halophytic communities upslope

Adapted from Allen 2012

II. IMPACTS OF A PIPELINE RIGHT OF WAY ON *HALIMOLOBOS VIRGATA* (NUTT.) O.E. SCHULZ AND ASSOCIATED HABITAT IN SOUTHERN ALBERTA

1. INTRODUCTION

Pipeline construction and operation can significantly impact the environment. They can remove native vegetation and soils, often allowing for introduction of non native species (Sousa 1984, Hobbs and Heunneke 1992, Smith and Knapp 1999, Craine et al. 2001, Neville 2002). They can have numerous impacts on soil properties through processes such as topsoil and subsoil mixing (de Jong and Button 1973, Naeth 1985, Shi et al. 2013). This can alter chemical composition, electrical conductivity, pH, salinity, soil water regimes, and light and temperature properties. Compaction is often increased across the right of way (ROW), in turn increasing bulk density and decreasing porosity, and organic carbon decreases in disturbed areas when compared to undisturbed prairie (Naeth et al. 1987, Batey and McKenzie 2006). There are 421,000 km of pipelines within Alberta (Energy Resources Conservation Board 2015) therefore these effects are widespread across the province and can impact floral and faunal species of concern.

Halimolobos virgata (Nutt.) O.E. Schulz (slender mouse ear cress) is a biennial (sometimes annual) in the *Brassicaceae* family, the only *Halimolobos* species in Alberta (ASRD and ACA 2009). In Canada there are 14 known populations in Alberta, and 17 in Saskatchewan (Environment Canada 2012). Most Canadian populations are found in a mixed grassland ecoregion, with some on the edge of moist mixed grassland and the Cypress Uplands. These areas are prone to water deficiencies due to low precipitation, high evaporation, and surface run off. *Halimolobos virgata* inhabits seasonally moist uplands to undulating terrain. It is often found with sand to loam textured soils, on parent material with glaciofluvial, fluvial, or eolian origins (ASRD and ACA 2009, Environment Canada 2012). *Halimolobos virgata* typically grows in areas with small disturbances, such as those from cattle grazing. It can be found in large patches or as individuals sporadically across the landscape. This is potentially due to hydrologic regimes during critical germination times in April and early May (Environment Canada 2012).

Halimolobos virgata was classified by the Committee on the Status of Endangered Wildlife in Canada as threatened in May 2000 (Environment Canada 2012). The Species at Risk Act listed *Halimolobos virgata* as threatened as of 2003, but changed it to data deficient in 2005 and ranks it as S1S2 by the Alberta Natural Heritage Information Centre (Gould 2006, Environment Canada 2012). Threats towards *Halimolobos virgata* include habitat loss, degradation, and fragmentation, crop production, oil and gas activities, changes in natural processes, and introduction of non native species (ASRD and ACA 2009, Environment Canada 2012). These threats can be related to general themes of habitat loss and degradation and changes to the natural ecosystem processes.

In 2008 recommendations were released for Alberta, Saskatchewan, and Manitoba for set back distances and species at risk (Henderson 2010). These guidelines are intended to help avoid harming species at risk and damaging critical habitat. They apply to federal lands, however, provincial practices in Alberta follow the recommended federal set back. Current recommendations suggest a 300 m set back from acute or chronic (Class 3) disturbances and rare species and associated critical habitat. These types of disturbances are likely to kill the plant and destroy its associated critical habitat (Henderson 2010).

2. RESEARCH OBJECTIVES

The general objective of this research was to evaluate the impact of a six year old pipeline ROW on *Halimolobos virgata*. Specific research objectives were as follows:

- To determine whether the historic presence of *Halimolobos virgata* was impacted by the distance from the ROW.
- To determine whether select physical characteristics (height, silique number, flower number) of *Halimolobos virgata* were impacted by the distance from the ROW.
- To determine whether select habitat characteristics (cover type, litter depth, slope, aspect, elevation) of *Halimolobos virgata* were impacted by the distance from the ROW.
- To determine whether *Halimolobos virgata* physical characteristics (height, silique number, flower number) varied with select habitat characteristics (cover type, litter depth, slope, aspect, elevation).
- To determine whether a 300 m set back distance is necessary to eliminate the impact of the ROW on *Halimolobos virgata*.

3. MATERIALS AND METHODS

3.1. Research Area Location And Description

The research area was located in southeastern Alberta in the dry mixedgrass subregion of the grassland natural region (Figure 3.1). It was approximately 20 km west of the Alberta

Saskatchewan border, 150 km north of Medicine Hat, between the Red Deer and South Saskatchewan rivers.

Topography of the research area consists of a few minor uplands, with elevations of 600 to 1,300 m (Alberta Environmental Protection 1997). Low relief moraines are the dominant landforms, with areas of hummocky moraines, eroded plains, glaciolacustrine lake deposits and sand plains, and glaciofluvial outwashes. There are few permanent streams; major waterways are well defined.

The climate is the warmest and driest in Alberta, with cold winters, warm summers, and low precipitation (Alberta Environmental Protection 1997, Adams et al. 2013, Environment Canada 2015). Due to high summer temperatures and wind speeds, there is a high rate of evaporation during summer, resulting in water deficits across the subregion. Mean annual temperature is 4 ^{o}C, 16 ^{o}C during the May to September growing season. The subregion has the highest number of growing degree days (mean temperature > 5 ºC) in Alberta, averaging 1,700 over 30 years. Mean winter temperature is -7 ^{o}C. Total annual precipitation is 260 to 300 mm, with two thirds falling in spring, peaking in June. Summer precipitation in this subregion is the lowest in Alberta. Snowfall accounts for 19 % of annual precipitation. Chinooks are limited to the western edge.

Brown chernozem soils are dominant, with a 10 to 15 cm thick A horizon (Adams et al. 2013). Solonetzic soils are found in areas where sodium rich bedrock is at or near the soil surface, or in areas with saline and sodic ground water discharge. Regosolic soils are found in unstable locations, such as steep slopes, or in areas with young geologic materials. Gleysolic and vertisolic soils are limited. Major soil series in the area are Bingville (orthic brown chernozem), Cavendish (orthic brown chernozem), Purple Springs (orthic brown chernozem), Vendisant (rego brown chernozem), Chin (orthic brown chernozem), and Antelope (orthic regosol) (Adams et al. 2013, Alberta Agriculture and Forestry 2014).

Short and mid height, drought tolerant grasses dominate the vegetation. The most common plant community is *Stipa comata* Trin. and Rupr. (needle and thread grass) – *Bouteloua gracilis* Lag. (blue grama grass) with *Agropyron smithii* Rybd. (western wheat grass) and *Agropyron dasytachyum* (Hook.) Scribn (northern wheat grass) (Alberta Environmental Protection 1997, Natural Regions Committee 2006, Adams et al. 2013). Rare vascular plants in the area include *Cryptantha minima* Rydb. (tiny cryptanthe), *Halimolobos virgata*, *Tripterocalyx micranthus* (Torrey) Hooker (small flowered sand verbena), *Yucca glauca* Nutt. (soap weed), *Iris missouriensis* Nutt. (western blue flag), and *Tradescantia occidentalis* (Britton Smyth) (western spiderwort) (COSEWIC 2015).

3.2. TransCanada Pipeline Description

The TransCanada pipeline is 76.2 cm in diameter and 3,456 km long, transporting crude oil from Hardisty, Alberta to Cushing, Oklahoma, and Wood River and Panoka, Illinois (Nemirsky 2011, McNeely 2012, Nannt 2014). The pipe was buried with minimum cover of 1.2 m depending on land use. Construction and reclamation near research areas occurred February to May 2009.

During construction, 4 m of trench area was stripped with the trench placed in the center 2 m (McNeely 2012, Nannt 2014). The ROW was 30 m (McNeely 2012). At one site this consisted of 20 m of permanent ROW, where work was carried out and the trench was located, and 10 m of temporary soil storage. At another site the area consisted of a 4 m permanent ROW, where the trench was dug, 7 m of temporary storage space, and 19 m of temporary work space. The TransCanada pipeline followed a 28 m wide Alberta Ethane Gathering System (AEGS) ROW. To reduce impact to *Halimolobos virgata* the pipeline ROW overlapped 4 m of the AEGS ROW at one site. Due to topography considerations at the other site, the TransCanada ROW deviates from the AEGS ROW. The pipeline was permitted to use an additional 7 m of AEGS ROW for subsoil and topsoil storage (Jacques Whitford AXYS Ltd. 2008). To prevent invasive plant introduction during construction, a cleaning station was established at site entries.

The TransCanada pipeline passes within 300 m of known *Halimolobos virgata* habitat and was constructed with 30 m buffers from the plant. Mitigation techniques implemented to reduce the impact on *Halimolobos virgata* and its associated critical habitat included: limiting the stripping of topsoil to the permanent ROW, no stripping of topsoil in the temporary workspace, geotextiles placed prior to soil storage or creation of travel lanes, soil and geotextiles being removed before the beginning of the next growing season, and the careful removal of the soil from the geotextile using prairie protectors and sweepers. In addition to mitigation through construction considerations, populations of *Halimolobos virgata* were marked and fenced and warning signs were installed informing workers of their presence (Jacques Whitford AXYS Ltd. 2008).

3.3. Research Site Location And Description

Two sites, Remount Hill and Minor Coulee, were established along the TransCanada pipeline for previous MSc research programs on *Halimolobos virgata* (Figure 2.2) (Nannt 2014, Nemirsky 2011). Both research sites are representative of native dry mixedgrass prairie environment, although specific topography, elevation, and aspect vary, and land management was variable due to individual landowner practices.

Minor Coulee (SW-16-22-3-W4) research site is located on private land, north of Secondary 555, approximately 2,000 m northwest of Remount Highway. The ROW was fenced during construction and is still under that management. Minor Coulee has steep slopes that required extensive grading due to the large pipe. The site has 50 m of *Halimolobos virgata* habitat. The coulee runs in a northeast southwest direction and the pipeline runs northwest southeast.

Remount Hill (NW-2-22-3-W4) research site is located south of Secondary 555 in the Remount community pasture, approximately 1,650 m south east of Secondary 555. It is along the permanent TransCanada pipeline ROW within the AEGS ROW. Land management includes cattle grazing and no fencing of the ROW. Remount Hill site has *Halimolobos virgata* habitat over 100 m and was located at a toe of a slope near an intermittent water course at the edge of a saline drainage way (Nemirsky 2014, Nannt 2011, Jaques Whitford AXYS Ltd. 2008).

3.4. *Halimolobos Virgata* Surveys

Halimolobos virgata surveys were conducted May 22 to 23, 2014 and May 19 to 28, 2015, corresponding with blooming and maturation times of *Halimolobos virgata* for simpler identification among grasses and the time during which Nannt (2014) and Nemirsky (2011) conducted surveys. GPS coordinates of known *Halimolobos virgata* locations at both sites were collected from Alberta Conservation Information Management System, Nemirsky, and Nannt. A Garmin Dakota 20 GPS was used to locate previous coordinates of *Halimolobos virgata* at Remount Hill and Minor Coulee. At each GPS location a ground survey was carried out in a 100 x 100 m grid with the GPS point as the central marker. From a north to south direction surveyors searched at 5 m intervals from each other scanning the ground, allowing for a slight overlap of scanned area. Any *Halimolobos virgata* located during the grid surveys were flagged and assessed. Due to the large number of GPS points at many locations, to maximize searcher efficiency, larger grids up to 200 x 200 m were created.

Halimolobos virgata was identified according to Kershaw et al. (2001) and Alberta Sustainable Resource Development and Alberta Conservation Association (2009). Each individual plant was assessed in a 20 x 20 cm quadrat, with the plant at its centre. GPS location and elevation was recorded using a Garmin Dakota 20 GPS and slope and aspect were determined using a Brunton Type 15 compass. Distance to pipeline trench from each individual plant was measured with a 100 m measuring tape. Habitat characteristics of cover type percentages and litter depth were recorded. Cover types visually assessed were live, litter, bare ground, moss, scat, fungi, lichen, and rock. To measure litter depth, 5 random measurements were taken within the 20 x

20 cm quadrat using a ruler. Health was recorded on a five point scale with 1 being > 90 % live, 2 > 75 % live, 3 > 50 % live, 4 < 25 % live, and 5 < 10 % live. Plant characteristics of flower and silique number were counted and height of each plant was measured with a ruler. Photos were taken of each plant, at a height of 1 m, and general observations were recorded.

In 2015 at Remount Hill site, due to the population size, detailed analyses were conducted to 65 m of the pipeline trench. Outside of that distance, groups of *Halimolobos virgata* were surveyed together. For each grouping of plants, GPS points were placed, and general health, population count, slope, elevation, and aspect were recorded according to the methods above. Full analyses were conducted at Minor Coulee.

3.5. Statistical Analyses

All statistical analyses were conducted using R version 3.2.2 (R Core Team 2015). Mean, standard deviation, standard error, and 95 % confidence intervals were calculated for habitat characteristics and plant physical characteristics. Normality was checked using the Kolmogorov Smirnov normality test for sample sizes greater than 30 for 2014 data and the data from Remount Hill in 2015 (Lilliefors 1967, Logan 2010). Normality was checked using the Shapiro Wilk normality test for sample sizes less than 30 for the Minor Coulee 2015 data (Logan 2010, Shapiro and Wilks 1965). Data were not normally distributed.

Impacts of distance to pipeline were calculated using correlation analyses. Kendall's tau (τ) was used to determine correlation between distance to pipeline trench; and height, silique number, live, litter, and bare ground cover; and litter depth for Remount Hill data with sample size greater than 30 (Logan 2010). Spearman's rank correlation coefficient (ρ) was used to determine the relationship between distance to pipeline trench; and height, silique number, live, litter, and bare ground cover; and litter depth for Minor Coulee with a sample size less than 30 (Logon 2010).

Correlation analyses were conducted to determine relationships between site characteristics and plant characteristics, Kendall's tau (τ) was used to determine correlation between height, flower number, silique number, ground cover type, slope, aspect and elevation for Remount Hill data with a sample size greater than 30 (Logan 2010). Spearman's rank correlation coefficient (ρ) was used to determine correlation between height, flower number, silique number, ground cover type, slope, aspect and elevation for Minor Coulee data as sample size was less than 30 (Logon 2010). Differences in cover type, height, silique, and flower number between years was calculated using the Mann Whitney Wilcoxon non parametric test (Logon 2010).

4. RESULTS

4.1. Plant Number And Physical Characteristics

In May 2014, 85 *Halimolobos virgata* plants were found at Remount Hill (Figure 2.3; Table 2.1). No plants were found at Minor Coulee. Plant development varied from not in bloom to having fully developed siliques. Mean height was 17.6 cm (Table 2.1). Siliques were present on 42 of the 85 plants. Mean silique number was 3.2. Mean flower number on individual plants was 2.6 open flowers.

In May 2015, 1,705 *Halimolobos virgata* plants were found at Remount Hill and 23 plants were found at Minor Coulee (Figures 2.4, 2.5; Tables 2.1, 2.2). Plants varied from having no opened buds to having fully developed siliques. Mean plant height was 25.9 cm at Remount Hill and 18.9 cm at Minor Coulee (Tables 2.1, 2.2). Siliques were present on 569 of 595 plants at Remount Hill and on all plants at Minor Coulee. Mean silique number was 21.9 and 13.5 at Remount Hill and Minor Coulee, respectively. Mean flower number was 8.8 at Remount Hill and 12.8 at Minor Coulee.

At Remount Hill, height increased with increasing flower number (τ 0.21, $P \leq 0.001$) and silique number (τ 0.57, $P \leq 0.001$) (Figures 2.6, 2.7; Table 2.3). At Minor Coulee, height increased with increasing flower number (ρ 0.42, P 0.04) and silique number (ρ 0.58, P 0.004) (Table 2.3). At Remount Hill site, height (W 12786, $P \leq 0.001$), flower number (W 12554, $P \leq 0.001$), and silique number (W 4830, $P \leq 0.001$) increased from 2014 to 2015 (Table 2.4).

4.2. Plant Location Relative To The Pipeline Trench

At Remount Hill in May 2014, *Halimolobos virgata* was found 3.4 to 129.8 m from the pipeline trench (Table 2.1). There were 16 plants on the 30 m pipeline ROW and 69 plants off the ROW. At Remount Hill, in May 2015, *Halimolobos virgata* was found 0.0 to 256.8 m from the pipeline trench. There were 216 plants on the 30 m ROW, with 2 occurrences directly over the trench, and 1,489 occurrences off the ROW. From 2014 to 2015 the distance from the pipeline trench in which *Halimolobos virgata* plants were located increased (W 40153, $P \leq 0.001$) (Table 2.4). At Minor Coulee all plants were off the 30 m ROW, 121.6 to 169.5 m from the pipeline trench (Table 2.2). There were no significant correlations between distance to pipeline trench, flower number, silique number, and live, litter, and bare ground cover types at Remount Hill or Minor Coulee (Table 2.5).

4.3. Cover Type

At Remount Hill live, litter, and bare ground cover varied across the study area. Mean live cover was 13.3 %, litter 71.9 %, and bare ground 13.6 % (Table 2.6). Height (τ -0.10, $P \leq 0.001$) and silique number (τ -0.12, $P \leq 0.001$) decreased with increasing live cover (Figures 2.8, 2.9). Height (τ 0.14, $P \leq 0.001$) and silique number (τ 0.11, $P \leq 0.001$) increased with increasing litter cover (Figures 2.10, 2.11). Height (τ -0.14, $P \leq 0.001$) and silique (τ -0.09, $P \leq 0.001$) number decreased with increasing bare ground cover (Figures 2.12, 2.13). Mean litter depth was 21.5 mm (Table 2.7). Height (τ 0.21, $P \leq 0.001$) and silique number (τ 0.15, $P \leq 0.001$) increased with increasing litter depth (Figures 2.14, 2.15).

At Minor Coulee live cover, litter cover, bare ground cover, and litter depth varied considerably across the study area (Tables 2.7, 2.8). Mean live cover was 15.5 %, litter cover 73.4 %, and bare ground cover 11.1 % (Table 2.8). Mean litter depth was 14.0 mm (Table 2.7). There were no significant correlations between height or silique number and either live, litter, or bare ground cover types (Table 2.9).

At Remount Hill litter depth increased from 2014 to 2015 (W 19108, $P \leq 0.001$) (Table 2.4). Live cover (W 37560, $P \leq 0.001$), litter cover (W 16400, $P \leq 0.001$) and bare ground cover (W 31315, P 0.003) increased from 2014 to 2015 (Table 2.4).

4.4. Plant Location Relative To Slope, Elevation, And Aspect

At *Halimolobos virgata* sites mean slope was 4.3 % at Remount Hill and 1.3 % at Minor Coulee (Table 2.10). There was no significant correlation between height and slope at Remount Hill or Minor Coulee (Table 2.11). There was a weakly significant correlation between number of siliques on individual *Halimolobos virgata* plants and slope (τ -0.08, P 0.004) at Remount Hill but no correlation at Minor Coulee site (Table 2.11).

Mean elevation was 615.9 m at Remount Hill and 622.3 m at Minor Coulee (Table 2.12). There was no significant correlation between height or silique number and elevation at Remount Hill or Minor Coulee (Table 2.11).

At Remount Hill *Halimolobos virgata* was found 50.4 % and 40.1 % of the time on north west and west facing exposures (Table 2.13). At Minor Coulee *Halimolobos virgata* was located on flat ground 87 % of the time and on south facing exposures 8.7 % of the time (Table 2.13). There was no correlation between aspect and height or silique number at Remount Hill or Minor Coulee (Table 2.11).

5. DISCUSSION

5.1. *Halimolobos Virgata* Population

The large increase in population at Remount Hill between 2014 and 2015 is difficult to explain due to lack of data on life history of *Halimolobos virgata*. The critical time for germination is approximately April and May, with precipitation a major factor (Environment Canada 2012). Many arid adapted species are susceptible to climatic variation and demonstrate plasticity for germination and potential for dormancy (Koornneef et al. 2002, Clauss and Venable 2000). Plants in mesic environment show less plasticity relative to xeric environments. Precipitation effects on growth can be observed in *Halimolobos virgata* (Environment Canada 2012, ASRD and ACA 2009). Years with high precipitation often result in large patches of *Halimolobos virgata* and less precipitation results in sporadic individual plants. This was not the trend for 2014 and 2015 field seasons. Combined precipitation in March, April, and May in 2014 was 48.9 mm and in 2015 it was 22.1 mm (Alberta Agriculture and Forestry 2016). The year with least precipitation resulted in the largest population of *Halimolobos virgata* at Remount Hill. However, being primarily a biennial means that seeds were developed in the year prior to germination, therefore conditions of that year play a role in population size. Precipitation in March, April, and May 2013 was 43.9 mm, similar to 2014. This suggests that the amount of precipitation during seed development and emergence to the basal rosette stage are very important to the growth of the reproductive stage in the third year.

Halimolobos virgata produces small seeds in high quantities, which could mean they are more susceptible to temporal variability in climate, relative to larger seeds with greater reservoirs (Pake and Venable 1996). Drought conditions during critical times might keep seeds dormant or desiccate them upon germination and emergence. Though seeds contain the necessary resources to sustain them to germination (Bewley 1997) small seeds could be dependent upon environmental resources and conditions shortly after germination. Desiccation was observed in many individual plants, with stems, siliques, and flowers crumbling upon contact and overall health declining over the survey period. Many *Halimolobos virgata* across both research sites likely succumbed to drought conditions prior to maturing and releasing seeds.

Based upon photo documentation and field notes, many tall *Halimolobos virgata* plants were multibranched, rather than single stalked, as found with shorter plants. This observation could account for the correlation between increasing height of the individual plant and corresponding increase in both silique and flower number.

5.2. Plant Location Relative To Distance To The Pipeline Trench

Halimolobos virgata height, number of flowers and siliques was not impacted by the distance from the trench. This suggests individual plants are not negatively affected by pipeline construction or ongoing operation of the pipeline. *Halimolobos virgata* appeared to be occupying areas with similar ground cover across the population. No differences were observed in live, litter, or bare ground cover around individual plants at increasing distances from the pipeline.

At Remount Hill and Minor Coulee all *Halimolobos virgata* occurrences were within 300 m of the pipeline trench. Due to the presence of *Halimolobos virgata* directly over the trench and many within the temporary ROW at Remount Hill (n = 2, n = 216) a 300 m set back seems unnecessary for *Halimolobos virgata* for pipelines consistent with the TransCanada pipeline construction methodology.

5.3. Ground Cover

Higher mean live cover in 2014 than 2015 could be attributed to increased precipitation resulting in greater early season growth. Increased litter in 2015 at Remount Hill is likely a result of increased live cover the previous year, resulting in larger litter accumulation. Decreasing bare ground from 2014 to 2015 could be a result of site recovery over time, as less was observed as litter cover increased between years. Litter cover, consisting of dead and decaying forbs, graminoids, and woody material, was dominant at both sites. Litter cover can decrease seed emergence due to decreased light, mechanical impedance, fungal infection, or allelopathic effects (Goldberg and Warner 1983, Olson and Wallander 2002, Ruprecht et al. 2002, Jensen and Gutekunst 2003). Large seeds are thought to increase germination success under deep litter due to their increased energy reservoir, with small seeds having greater light requirements (Jensen and Gutekunst 2003).

These results were not consistent with *Halimolobos virgata* presence, height, or silique number. Both height and number of siliques increased with increasing litter depth at Remount Hill. Benefits to litter cover include stability in surface temperature and decreased evapotranspiration due to decreased solar exposure (Willms et al. 1993, Donath and Eckstein 2010). The increase in height and silique number of *Halimolobos virgata* could be attributed to increased soil water availability during the critical period of April and May. Mesic and xeric adapted species may have increased positive effects to litter cover, due to regular seasonal water shortages. Moderate litter application can increase seedling viability, through moderating drought conditions, while heavy litter application can hinder seedling viability (Eckstein and Donath 2005). However, more studies are needed to examine the relationship of litter depth and cover to *Halimolobos virgata* germination and emergence.

Halimolobos virgata is often found in association with low disturbance, such as those caused by hooves of ungulates (ASRD and ACA 2009, Environment Canada 2012). Native vegetation can increase in response to low grazing intensity, however intense grazing can result in native vegetation decline or collapse (Milchunas et al. 1989, Yates et al. 2000). Much of the bare ground around individual plants could be attributed to animal burrows and ant colonies based upon photo documentation. Nemirsky (2011) suggested disturbances from modern grazing regimes could be compared to those caused by historic migratory bison herds. *Halimolobos virgata* is not a strong competitor with other species and it may be opportunistically colonizing the increased bare ground created by cattle grazing and pipeline construction.

The correlation between decreasing height and silique number and increasing live vegetation could be attributed to shading of the seedling upon emergence. From photo documentation, much of the live vegetation was *Artemesia cana* Pursh (sagebush) and *Opuntia polyacantha* Haw. (prickly pear cactus), both which would hang over or cover emerging *Halimolobos virgata*.

5.4. Plant Location Relative To Slope, Elevation, And Aspect

Prior to the study by Nannt (2014), *Halimolobos virgata* was found on slopes 3 to 8 %, typically less than 5 % (ASRD 2005, Nannt 2014). Previous research on the same sites found greater than 90 % of the population on southerly aspects on > 8 % slopes (Nannt 2014). Combined data from the 2014 and 2015 field seasons at Remount Hill varied from this trend. *Halimolobos virgata* was found 10.3 % of the time on slopes > 8 %. Of those plants on slopes, 74.3 % were on west aspects, followed by 21.6 % on north west aspects.

This trend could be attributed to increased water availability on slopes with lower gradients and north aspects. Wang et al. (2011) found greater water recharge on north facing than south facing slopes in the Loess Plateau region of China. Similar results were found in North America, with north facing slopes having as much at 20 % more water availability than south facing or east facing slopes (Hanna et al. 1982). More water was available on lowest points of the slope relative to the summit and shoulders (Hanna et al. 1982, Gong et al. 2008).

In mesic environments, such as the habitat of *Halimolobos virgata*, increased water holding capacity could be beneficial as water deficit is a challenge to germination of *Halimolobos virgata*

(ASRD and ACA 2009, Environment Canada 2012). Northern aspects, with decreased solar radiation, have lower rates of evapotranspiration, thereby increasing soil water (Stoeckeler and Curtis 1960). The observed correlation between decreasing number of siliques with increasing slope could possibly be attributed to increased water availability on less extreme slopes. Since the field sites are located near the northern extent of the range of *Halimolobos virgata* (ASRD and ACA 2009, Environment Canada 2012), the impact of slope and aspect could become increasingly important in microclimates that they provide (Bennie et al. 2008).

This trend was not observed at Minor Coulee, where 87 % of the population was found on a large *Bouteloua gracilis*, *Artemesia cana,* and *Opuntia polyacantha* dominated flat. The rest of the population was on either side of a minor gully on southern and western aspects. The entire population was surrounded by large hills. This could mean there was increased water availability throughout the area due to the high rate of run off observed in the subregion and increased soil water of the base of slopes (Hanna et al. 1982, Bennie et al. 2008, ASRD and ACA 2009, Environment Canada 2012).

6. CONCLUSIONS

Halimolobos virgata was found in increasing numbers over two field seasons, with a new population found at a site in 2015. Flower and silique number increased with increasing height. Height, silique number, flower number, and distance to pipeline trench increased from 2014 to 2015. It was found with varying levels of ground cover types and litter depth. It appears to utilize areas with deep litter and low live cover. While it seems to grow in areas with low levels of disturbance, increasing bare ground cover, can negatively affect height and silique number. No correlations between distance to pipeline trench and *Halimolobos virgata* height, silique number, flower number, and live, litter, and bare ground cover types was observed. No correlation was observed between height or silique number of *Halimolobos virgata* and elevation or aspect. The number of siliques on individual plants decreased slightly with increasing slope. *Halimolobos virgata* does not appear to be impacted by the pipeline ROW and the population has moved onto the pipeline trench within six years of pipeline completion. A 300 m set back distance is not required for *Halimolobos virgata* and pipeline construction and operation under similar methods to that used for the TransCanada pipeline.

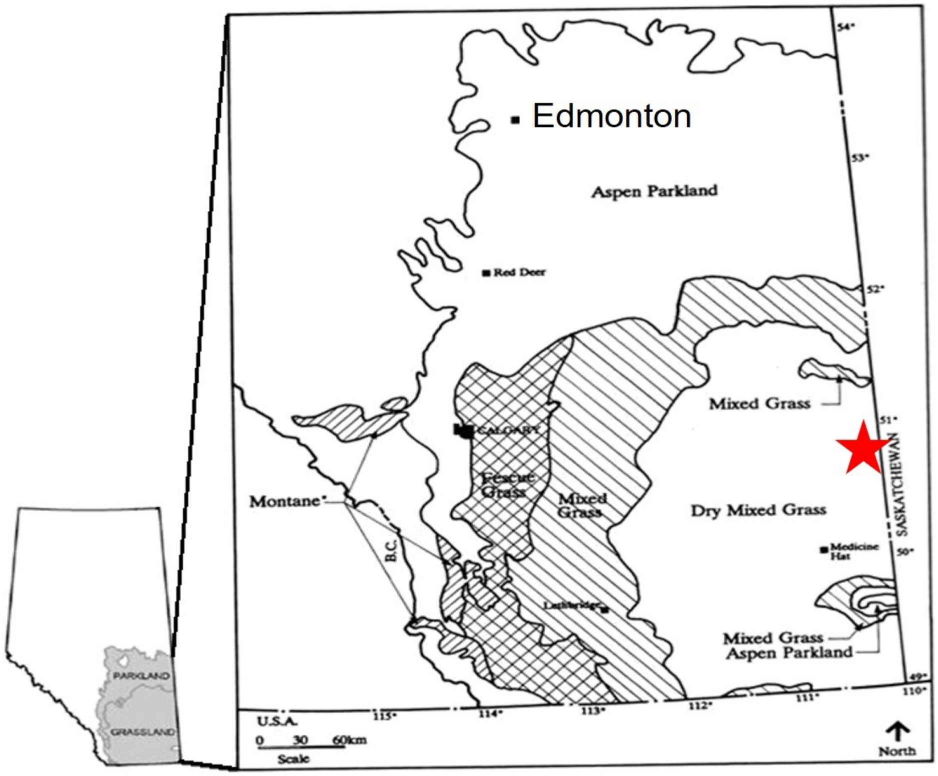

Figure 2.1. General location of study sites in southern Alberta denoted by the red star. Adapted from Kerr et al. 1993.

Figure 2.2. Location of *Halimolobos virgata* survey sites. Locations marked by red stars (Google Earth 2016).

Figure 2.3. Location of *Halimolobos virgata* at Remount Hill 2014. Locations marked by blue points, pipeline trench marked by black line (Google Earth 2016).

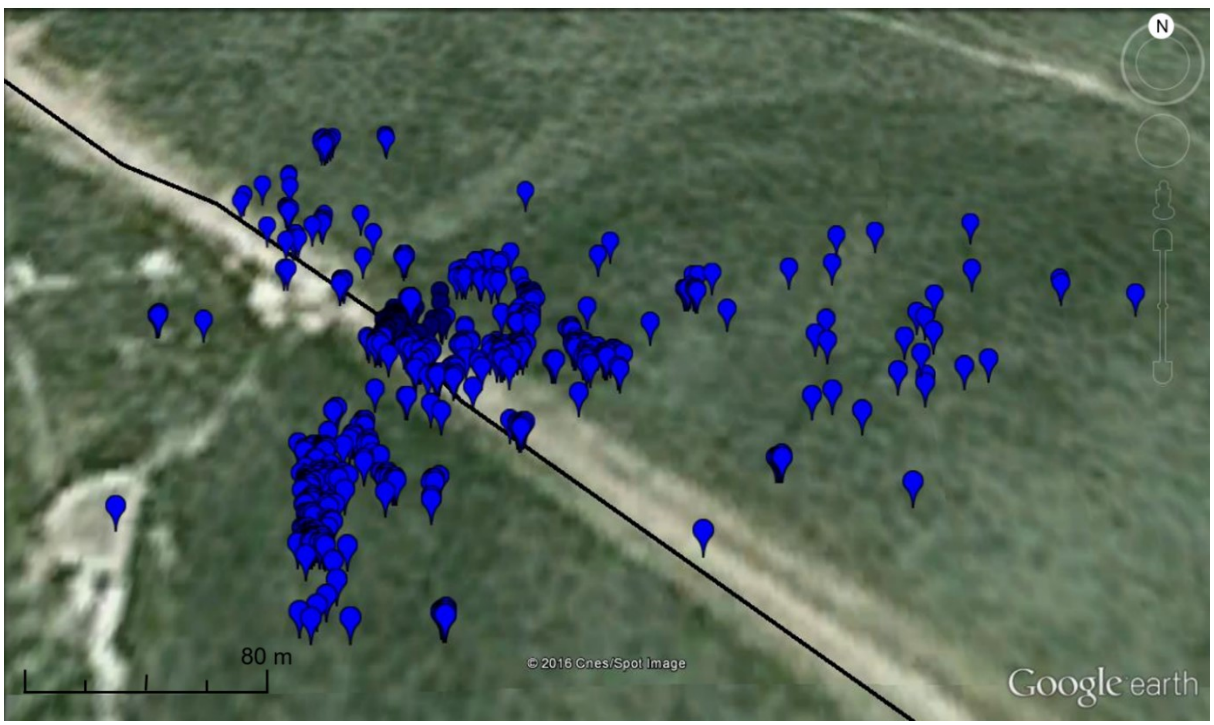

Figure 2.4. Location of *Halimolobos virgata* at Remount Hill 2015. Locations marked by blue points, pipeline trench marked by black line (Google Earth 2016).

Figure 2.5. Location of *Halimolobos virgata* at Minor Coulee 2015. Locations marked by pink points, pipeline trench marked by black line (Google Earth 2016).

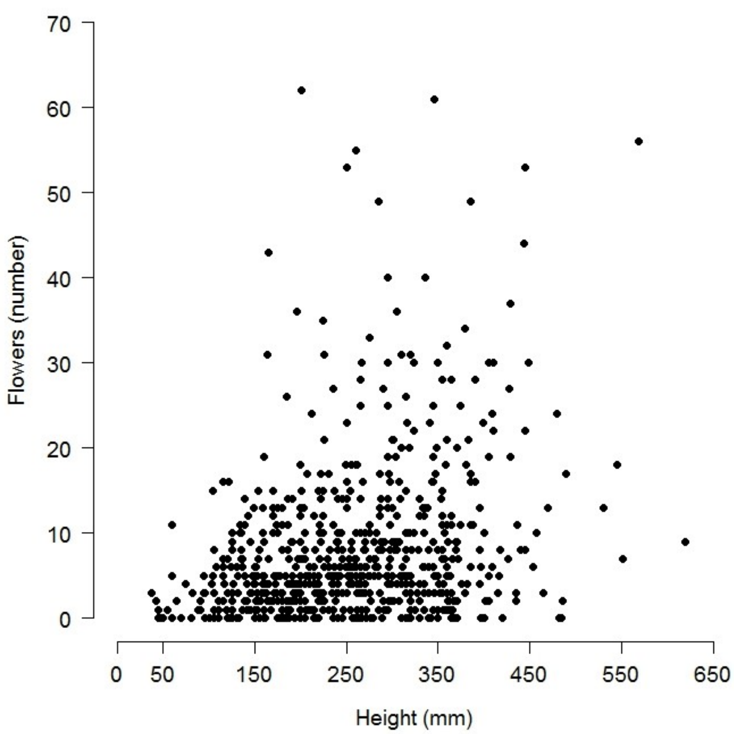

Figure 2.6. Relationship between flower number of *Halimolobos virgata* and height at Remount Hill using Kendall's tau ($\tau = 0.21$, $P = \leq 0.001$, $n = 680$).

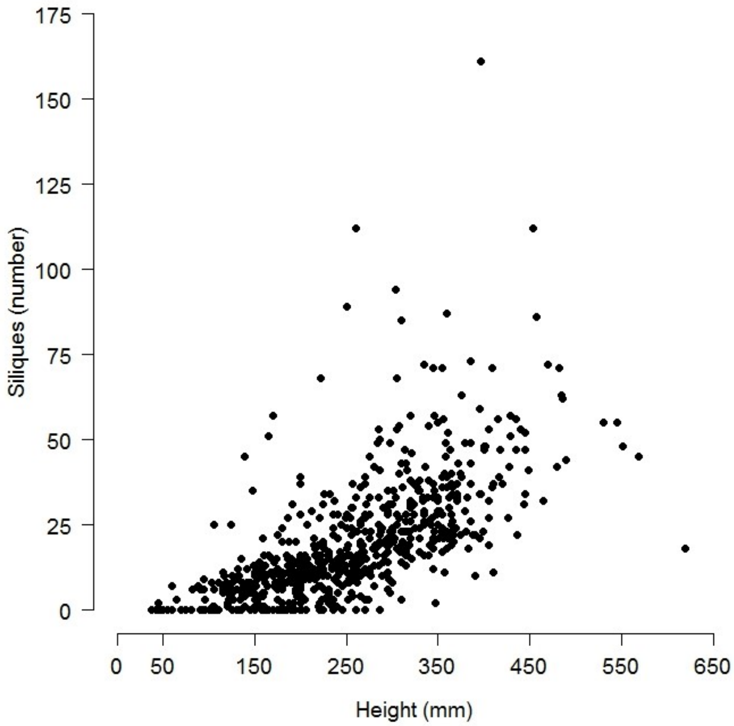

Figure 2.7. Relationship between silique number of *Halimolobos virgata* and height at Remount Hill using Kendall's tau (τ = 0.57, P = ≤0.001, n = 679).

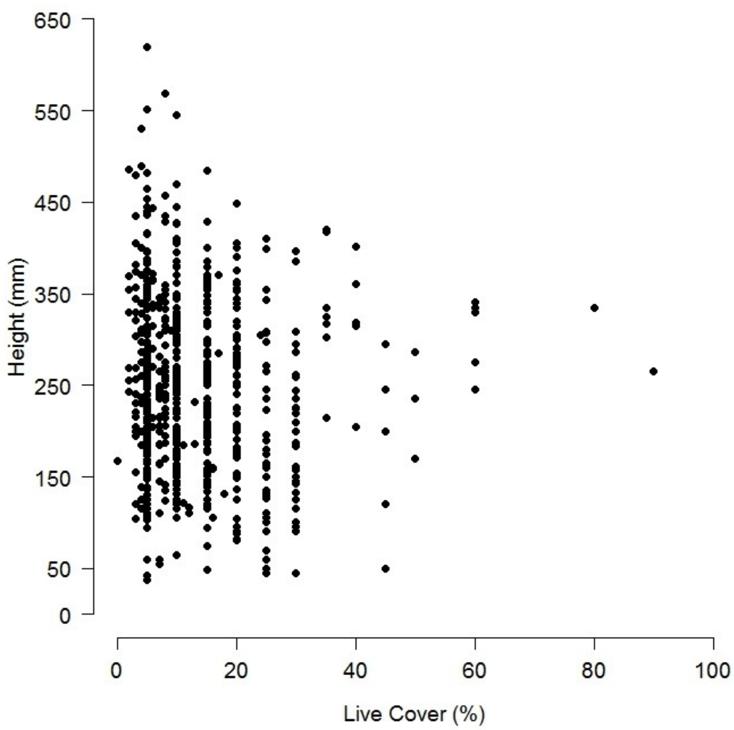

Figure 2.8. Relationship between height of *Halimolobos virgata* and live cover at Remount Hill using Kendall's tau (τ = -0.10, P = ≤0.001, n = 696).

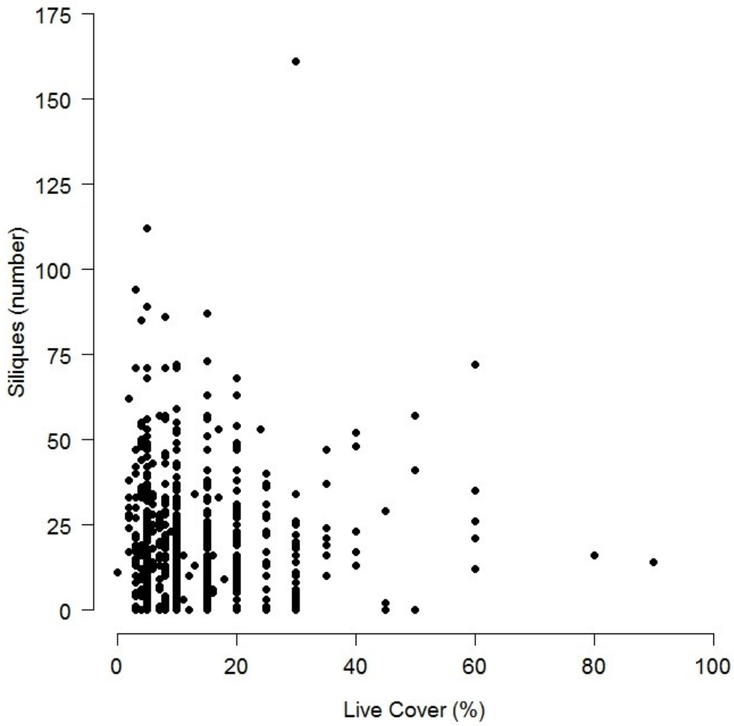

Figure 2.9. Relationship between number of siliques of *Halimolobos virgata* and live cover at Remount Hill using Kendall's tau (τ = -0.12, P = ≤0.001, n = 680).

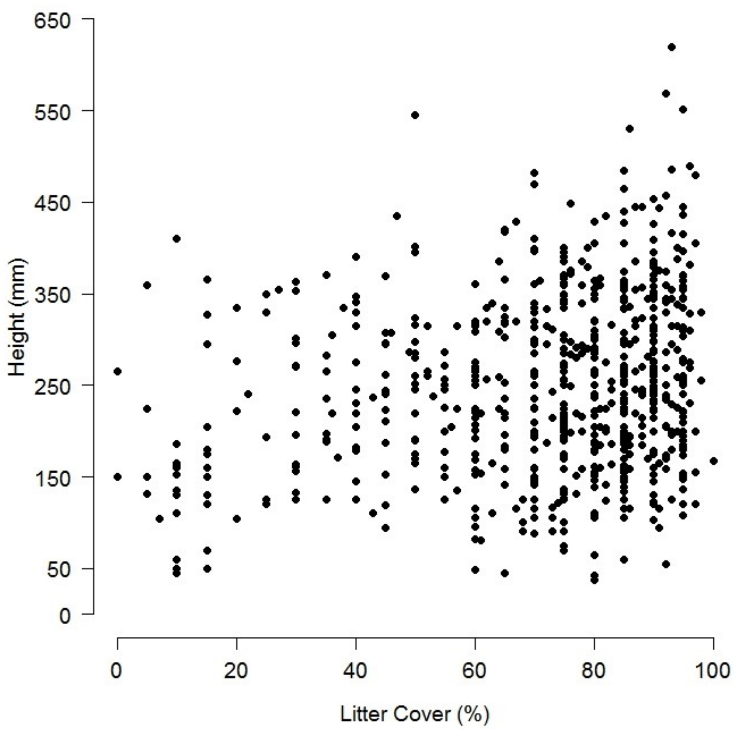

Figure 2.10. Relationship between height of *Halimolobos virgata* and litter cover at Remount Hill using Kendall's tau (τ = 0.14, P = ≤0.001, n = 696).

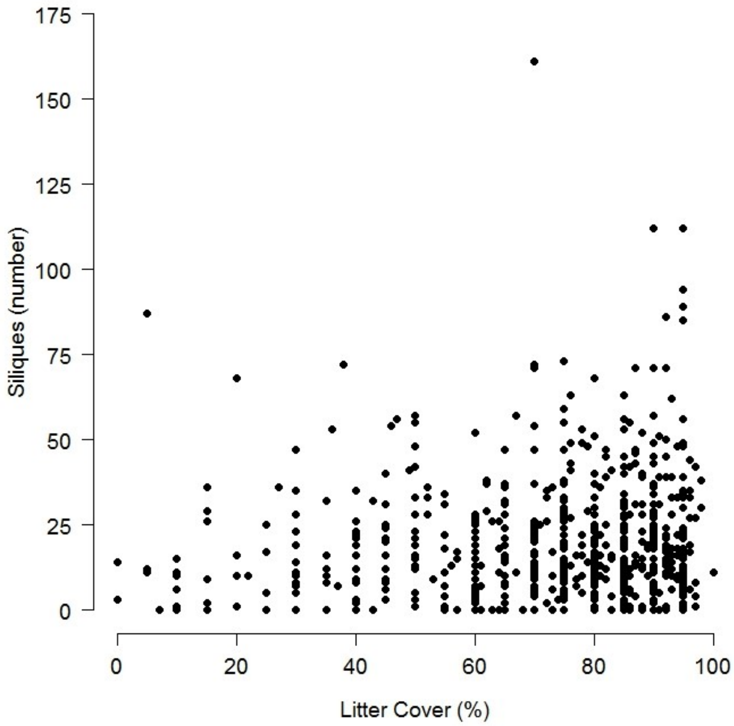

Figure 2.11. Relationship between number of siliques of *Halimolobos virgata* and litter cover at Remount Hill using Kendall's tau (τ = 0.11, P = ≤0.001, n = 680).

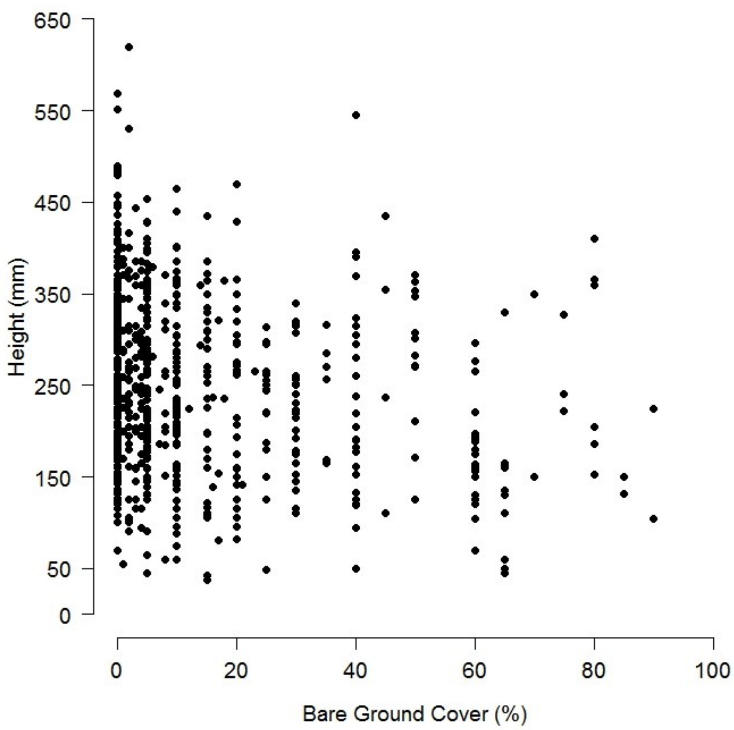

Figure 2.12. Relationship between height of *Halimolobos virgata* and bare ground cover at Remount Hill using Kendall's tau (τ = -0.14, P = ≤0.001, n = 696).

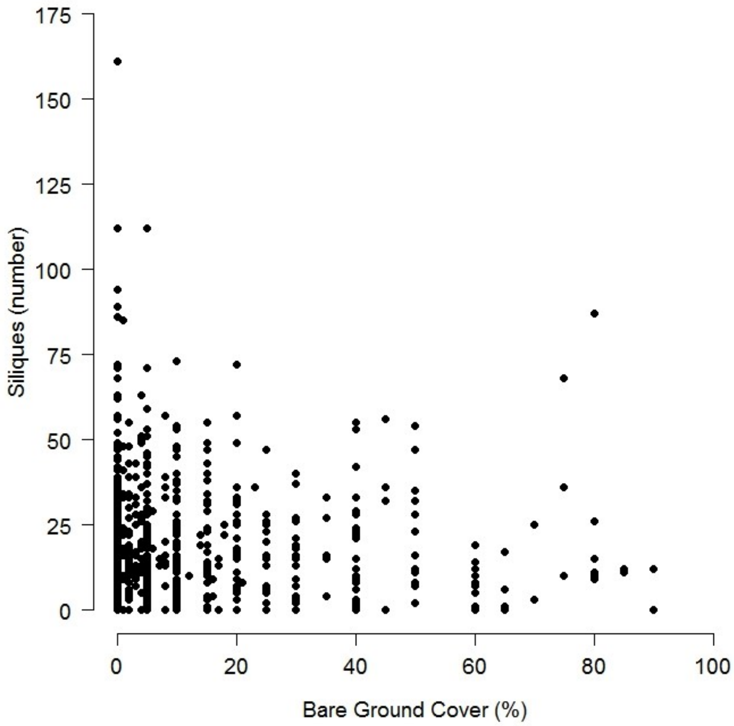

Figure 2.13. Relationship between number of siliques of *Halimolobos virgata* and bare ground cover at Remount Hill using Kendall's tau (τ = -0.09, P = ≤0.001, n = 680).

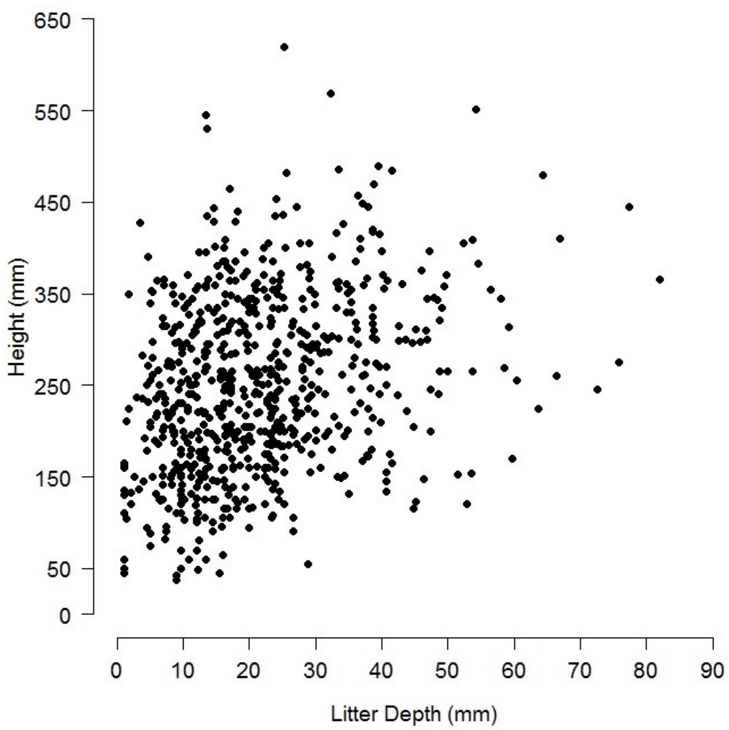

Figure 2.14. Relationship between height of *Halimolobos virgata* and litter depth at Remount Hill site using Kendall's tau (τ = 0.21, P = ≤0.001, n = 696).

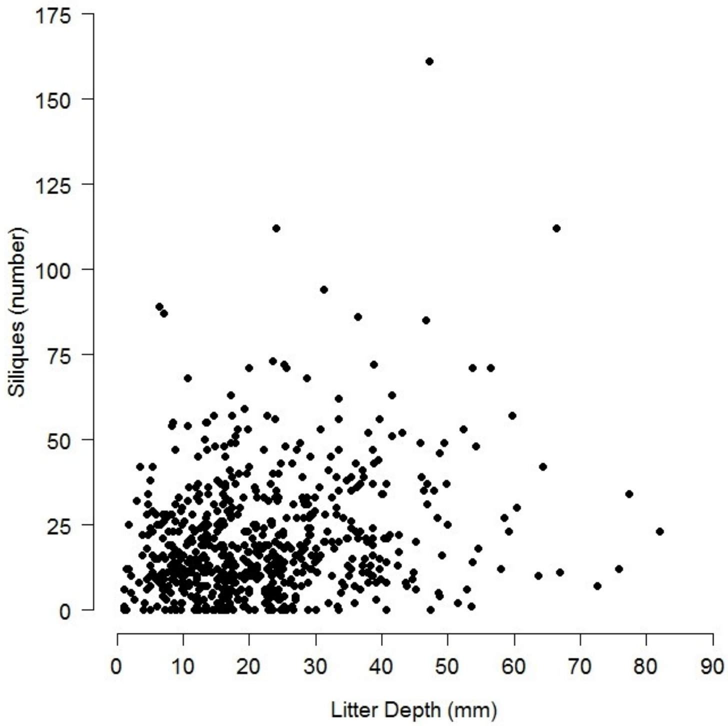

Figure 2.15. Relationship between the number of siliques of *Halimolobos virgata* and litter depth at Remount Hill site using Kendall's tau (τ = 0.15, P = ≤0.001, n = 680).

Table 2.1. Descriptive statistics of *Halimolobos virgata* physical characteristics at Remount Hill 2014, 2015.

	Year	n	Mean	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Height (mm)	2014	85	176.3	68.15	7.39	14.70	45	369
	2015	611	259.6	95.38	3.86	7.58	37	620
	Average	696	249.4	96.39	3.65	7.17	37	620
Siliques (number)	2014	85	3.2	4.85	0.53	1.05	0	24
	2015	595	21.9	18.15	0.74	1.46	0	161
	Average	680	19.6	18.15	0.70	1.37	0	161
Flowers (number)	2014	85	2.6	2.48	0.27	0.53	0	10
	2015	594	8.8	9.63	0.40	0.78	0	62
	Average	679	8.0	9.28	0.36	0.70	0	62
Distance To Pipeline Trench (m)	2014	85	66.09	34.76	3.77	7.50	3.4	129.8
	2015	1705	95.38	62.11	1.50	2.95	0.0	256.8
	Average	1790	93.99	61.40	1.45	2.85	0.0	256.8

Table 2.2. Descriptive statistics of *Halimolobos virgata* physical characteristics at Minor Coulee 2015.

	n	Mean	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Height (mm)	23	189.8	61.49	12.82	26.59	90	291
Siliques (number)	23	13.5	9.86	2.06	4.26	2	43
Flowers (number)	23	12.8	8.82	1.84	3.82	0	36
Distance To Pipeline Trench (m)	23	131.06	14.89	3.10	6.44	121.6	169.5

Table 2.3. Relationships between *Halimolobos virgata* physical characteristics at Remount Hill and Minor Coulee using Kendall's tau (τ) and Spearman's rank correlation coefficient (ρ).

		n	ρ	τ	P value
Remount Hill	Height (mm):Flowers (number)	680	-	0.21	≤0.001 *
	Height (mm):Siliques (number)	679	-	0.57	≤0.001 *
Minor Coulee	Height (mm):Flowers (number)	23	0.42	-	0.04 *
	Height (mm):Siliques (number)	23	0.58	-	0.004 *

* denotes significance
\- = test not conducted

Table 2.4. Relationship between 2014 and 2015 *Halimolobos virgata* physical characteristics, distance to pipeline trench, cover types, and litter depth.

	n			
	2014	2015	W	P value
Height (mm)	85	611	12786	≤0.001 *
Flowers (number)	85	679	12554	≤0.001 *
Siliques (number)	85	680	4830	≤0.001 *
Distance To Pipeline Trench (m)	85	1705	40153	≤0.001 *
Live Cover (%)	85	614	37560	≤0.001 *
Litter Cover (%)	85	614	16400	≤0.001 *
Bare Ground Cover (%)	85	614	31315	0.003 *
Litter Depth (mm)	85	613	19108	≤0.001 *

* denotes significance

Table 2.5. Relationship between distance to pipeline trench and physical characteristics or cover types of *Halimolobos virgata* sites at Remount Hill and Minor Coulee using Kendall's tau (τ) and Spearman's rank correlation coefficient (ρ).

		Physical Characteristics	n	ρ	τ	P value
Distance To Pipeline Trench (m)	Remount Hill	Height (mm)	696	-	-0.04	0.09
		Silique (number)	680	-	-0.03	0.28
		Live Cover (%)	726	-	-0.02	0.41
		Litter Cover (%)	726	-	-0.02	0.39
		Bare Ground Cover (%)	726	-	-0.01	0.63
	Minor Coulee	Height (mm)	23	0.15	-	0.50
		Silique (number)	23	-0.19	-	0.39
		Live Cover (%)	23	-0.26	-	0.24
		Litter Cover (%)	23	0.01	-	0.97
		Bare Ground Cover (%)	23	-0.15	-	0.48

\- = test not conducted

Table 2.6. Percent ocular ground cover at Remount Hill 2014, 2015.

Cover (%)	Year	n	Mean (%)	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum (%)	Maximum (%)
Live	2014	85	18.7	9.46	1.03	2.04	4	50
	2015	614	12.5	10.44	0.42	0.83	T	90
	Mean	699	13.3	10.51	0.40	0.78	T	90
Litter	2014	85	57.1	28.93	3.14	6.24	0	95
	2015	614	74.0	20.44	0.82	1.62	0	100
	Mean	699	71.9	22.32	0.84	1.66	0	100
Bare Ground	2014	85	23.8	25.68	2.79	5.54	0	70
	2015	614	12.2	17.65	0.71	1.40	0	90
	Mean	699	13.6	19.16	0.73	1.42	0	90
Lichen	2014	85	-	-	-	-	-	-
	2015	614	1.2	3.77	0.15	0.30	0	40
	Mean	699	1.1	3.56	0.13	0.26	0	40
Moss	2014	85	0.1	0.76	0.08	0.16	0	5
	2015	614	0.0	0.04	0.00	0.00	0	1
	Mean	699	0.0	0.27	0.01	0.02	0	5
Scat	2014	85	0.3	2.21	0.24	0.48	0	20
	2015	614	0.1	1.33	0.05	0.11	0	30
	Mean	699	0.1	1.46	0.06	0.11	0	30
Rock	2014	85	-	-	-	-	-	-
	2015	614	0.0	0.16	0.01	0.01	0	4
	Mean	699	0.0	0.15	0.01	0.01	0	4

T = trace (< 1 % cover)
- = not found

Table 2.7. Litter depth at Remount Hill and Minor Coulee 2014, 2015.

	Year	n	Mean (mm)	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum (mm)	Maximum (mm)
Remount Hill	2014	85	16.2	11.04	1.20	2.38	1.0	47.4
	2015	613	22.2	13.36	0.54	1.06	1.0	82.0
	Mean	698	21.5	13.21	0.50	0.98	1.0	82.0
Minor Coulee	2015	23	14.0	6.00	1.25	2.59	2.0	32.2

Table 2.8. Percent ocular ground cover at Minor Coulee 2015.

Cover (%)	n	Mean (%)	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum (%)	Maximum (%)
Live	23	15.5	8.26	1.72	3.57	5	40
Litter	23	73.4	14.00	2.92	6.06	0	94
Bare Ground	23	11.1	12.28	2.56	5.31	0	60
Lichen	23	0.0	0.00	0.00	0.00	0	T
Moss	23	-	-	-	-	-	-
Scat	23	0.0	0.00	0.00	0.00	0	T
Rock	23	-	-	-	-	-	-

T = trace (< 1 % cover)
- = not found

Table 2.9. Relationship between different cover types and physical characteristics of *Halimolobos virgata* at Minor Coulee using Spearman's rank correlation coefficient (ρ).

	Physical Characteristic	n	ρ	P value
Live	Height (mm)	23	0.01	0.96
	Silique (number)	23	0.32	0.13
Litter	Height (mm)	23	-0.27	0.21
	Silique (number)	23	-0.19	0.38
Bare Ground	Height (mm)	23	0.38	0.07
	Silique (number)	23	0.26	0.23
Litter Depth	Height (mm)	23	-0.01	0.98
	Silique (number)	23	-0.26	0.23

Table 2.10. Slope at Remount Hill and Minor Coulee.

	Year	n	Mean (%)	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum (%)	Maximum (%)
Remount Hill	2014	85	6.9	5.02	0.54	1.08	0	17
	2015	1705	4.2	2.97	0.07	0.14	0	15
	Mean	1790	4.3	3.15	0.07	0.15	0	17
Minor Coulee	2015	23	1.3	3.44	0.72	1.49	0	10

Table 2.11. Relationship between slope, elevation, and aspect, and height and silique number at Remount Hill and Minor Coulee using Kendall's tau and Spearman's rank correlation coefficient.

	Site Characteristic	Physical Characteristic	n	ρ	τ	P value
Remount Hill	Slope (%)	Height (mm)	696	-	-0.03	0.20
		Silique (number)	680	-	-0.08	0.00 *
	Elevation (m)	Height (mm)	696	-	-0.02	0.43
		Silique (number)	680	-	0.04	0.17
	Aspect	Height (mm)	696	-	-0.00	0.96
		Silique (number)	680	-	-0.00	0.98
Minor Coulee	Slope (%)	Height (mm)	23	0.29	-	0.18
		Silique (number)	23	-0.11	-	0.62
	Elevation (m)	Height (mm)	23	-0.02	-	0.92
		Silique (number)	23	-0.05	-	0.84
	Aspect	Height (mm)	23	0.27	-	0.21
		Silique (number)	23	-0.09	-	0.68

* denotes significance
\- = test not conducted

Table 2.12. Elevation at Remount Hill and Minor Coulee.

	Year	n	Mean (m)	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Remount Hill	2014	85	613.2	6.78	0.74	1.46	594	625
	2015	1705	616.1	4.16	0.10	0.20	588	630
	Mean	1790	615.9	4.36	0.10	0.20	588	630
Minor Coulee	2015	23	622.3	0.81	0.17	0.35	621	623

Table 2.13. Aspect at Remount Hill and Minor Coulee.

	Year	n	North	East	South East	South	South West	West	North West	Flat
Remount Hill	2014	85	0	0	0	10.6 (9)	12.9 (11)	42.4 (36)	18.8 (16)	15.3 (13)
	2015	1705	0.59 (10)	0.53 (9)	0.35 (6)	0.76 (13)	2.1 (36)	40.1 (683)	50.4 (859)	5.2 (89)
	Mean	1790	0.56 (10)	0.50 (9)	0.34 (6)	1.2 (22)	2.6 (47)	40.2 (719)	48.9 (875)	5.7 (102)
Minor Coulee	2015	23	0	0	0	8.7 (2)	0	4.3 (1)	0	87.0 (20)

Numbers are percentages with counts in brackets

III. IMPACTS OF A PIPELINE RIGHT OF WAY ON NATIVE DRY MIXEDGRASS PRAIRIE

1. INTRODUCTION

Native grasslands are of conservation concern due to the variety of functions that they perform (Sampson and Knopf 1994, Sinton 2001, Neville 2002). From an ecological perspective they act as a carbon sink, form soil, maintain water quality, protect watersheds, and many endemic flora and fauna are dependent upon them (Sampson and Knopf 1994, Sinton 2001). Grasslands can be tied directly and indirectly to an anthropogenic food source (Sampson and Knopf 1994) as the forage value is high on native grasslands for wildlife and livestock (Bailey et al. 2010). Prior to European settlement, aboriginal groups, such as the Cree, Blackfoot, and Sioux managed the land through extensive burns, thought to improve forage quality for bison and other ungulates (Alberta Environmental Protection 1997). This anthropogenic impact was small relative to the larger natural processes of flooding, fires, and grazing. With the advent of the fur trade in the 1700s and 1800s large mammals and birds were hunted extensively, resulting in the near extinction of bison and severe decreases in other prairie fauna. With European settlement in the late nineteenth century, native prairie was degraded with the introduction of livestock, and large tracts of land were cleared for farming. This resulted in a nearly 61 % decrease of Alberta grasslands (Sampson and Knopf 1994).

While prairies cover only 14.5 % of Alberta, they are home to 77 % of the provinces species at risk (24 of 31) (Alberta Environmental Protection 1997). The dry mixedgrass subregion is the largest prairie subregion in Alberta, encompassing 7.1 % of the area of the province (Alberta Environmental Protection 1997, Adams et al. 2013). Approximately 50 % of native dry mixedgrass prairie has been lost over the last century (ASRD and ACA 2009).

Current disturbances on grasslands are predominately from linear fragmentation by pipelines, transportation networks, telecommunication lines, and petroleum activities (Alberta Environmental Protection 1997). The grasslands natural region contains approximately 74,629 well sites, each with access roads, accounting for an overall loss of 672 km^2 of prairie habitat. Other disturbances include roads and highways, urbanization, and agriculture (Alberta Environmental Protection 1997, Bailey et al. 2010). While low intensity disturbances can be beneficial to grasslands by maximizing diversity, large scale disturbances can have long term, detrimental effects (Collins and Barber 1985, Sampson and Knopf 1994, Alberta Environmental Protection 1997).

Pipelines have a number of benefits over other methods of transporting natural resources such as movement of high volumes of product, high security, and low energy costs (Xiao et al. 2014, Xiao et al. 2016). However, pipeline development significantly impacts native prairie ecosystems. During construction native vegetation and topsoil are removed, often allowing for introduction of non native species, which can fragment the landscape and disturb wildlife (Sousa 1984, Hobbs and Heunneke 1992, Smith and Knapp 1999, Craine et al. 2001, Sinton 2001, Neville 2002, Olsen and Doherty 2012, Xiao et al. 2014, Xiao et al. 2016). Pipelines can impact soil properties through processes such as topsoil and subsoil mixing (de Jong and Button 1973, Naeth 1985, Olsen and Doherty 2012, Shi et al. 2013, Xiao et al. 2014, Xiao et al. 2016). This can alter chemical composition, electrical conductivity, pH, salinity, soil water, texture, and light and temperature properties along the pipeline right of way (ROW) (de Jong and Button 1973, Naeth 1985, Ivey and McBride 1999, Shi et al. 2013). Through soil compaction bulk density is often increased across the ROW, in turn decreasing porosity and organic carbon relative to undisturbed prairie (Naeth et al. 1987, Batey and McKenzie 2006, Olsen and Doherty 2012).

There are 421,000 km of pipelines in Alberta (Energy Resources Conservation Board 2015), therefore impacts are widespread across the province potentially affecting flora and fauna species of concern. Research needs to be continued on long term effects of pipeline disturbances on native dry mixedgrass prairie to preserve the remaining resource.

2. RESEARCH OBJECTIVES

The objective of this research was to evaluate the impact of a six year old pipeline ROW on native dry mixedgrass prairie. Specific research objectives were as follows:

- To determine whether plant community species composition was impacted by location relative to a pipeline ROW.
- To determine whether ground cover (live, litter, bare ground, lichen, moss, fungi, scat, and rock) was impacted by location relative to a pipeline ROW.

3. MATERIALS AND METHODS

3.1. Research Area Location And Description

The research area was located in southeastern Alberta in the dry mixedgrass subregion of the grassland natural region (Figure 3.1). It was approximately 20 km south of the Alberta

Saskatchewan border, 150 km north of Medicine Hat, between the Red Deer and South Saskatchewan rivers.

Topography of the research area consists of a few minor uplands, with elevations of 600 to 1,300 m (Alberta Environmental Protection 1997). Low relief moraines are the dominant landforms, with areas of hummocky moraines, eroded plains, glaciolacustrine lake deposits and sand plains, and glaciofluvial outwashes. There are few permanent streams; major waterways are well defined.

The climate is the warmest and driest in Alberta, with cold winters, warm summers, and low precipitation (Alberta Environmental Protection 1997, Adams et al. 2013, Environment Canada 2015). Due to high summer temperatures and wind speeds, there is a high rate of evaporation during summer, resulting in water deficits across the subregion. Mean annual temperature is 4 ^{o}C, 16 ^{o}C during the May to September growing season. The subregion has the highest number of growing degree days (mean temperature > 5 ºC) in Alberta, averaging 1,700 over 30 years. Mean winter temperature is -7 ^{o}C. Total annual precipitation is 260 to 300 mm, with two thirds falling in spring, peaking in June. Summer precipitation in this subregion is the lowest in Alberta. Snowfall accounts for 19 % of annual precipitation. Chinooks are limited to the western edge.

Brown chernozem soils are dominant, with a 10 to 15 cm thick A horizon (Adams et al. 2013). Solonetzic soils are found in areas where sodium rich bedrock is at or near the soil surface, or in areas with saline and sodic ground water discharge. Regosolic soils are found in unstable locations, such as steep slopes, or in areas with young geologic materials. Gleysolic and vertisolic soils are limited. Major soil series in the area are Bingville (orthic brown chernozem), Cavendish (orthic brown chernozem), Purple Springs (orthic brown chernozem), Vendisant (rego brown chernozem), Chin (orthic brown chernozem), and Antelope (orthic regosol) (Adams et al. 2013, Alberta Agriculture and Forestry 2014).

Short and mid height, drought tolerant grasses dominate the vegetation. The most common plant community is *Stipa comata* Trin. and Rupr. (needle and thread grass) – *Bouteloua gracilis* Lag. (blue grama grass) with *Agropyron smithii* Rybd. (western wheat grass) and *Agropyron dasytachyum* (Hook.) Scribn (northern wheat grass) (Alberta Environmental Protection 1997, Natural Regions Committee 2006, Adams et al. 2013). Rare vascular plants in the area include *Cryptantha minima* Rydb. (tiny cryptanthe), *Halimolobos virgata* (Nutt.) O.E. Schulz (slender mouse ear cress), *Tripterocalyx micranthus* (Torrey) Hooker (small flowered sand verbena), *Yucca glauca* Nutt. (soap weed), *Iris missouriensis* Nutt. (western blue flag), and *Tradescantia occidentalis* (Britton Smyth) (western spiderwort) (COSEWIC 2015).

3.2. TransCanada Pipeline Description

The TransCanada pipeline is 76.2 cm in diameter and 3,456 km long, transporting crude oil from Hardisty, Alberta to Cushing, Oklahoma, and Wood River and Panoka, Illinois (Nemirsky 2011, McNeely 2012, Nannt 2014). The pipe was buried with minimum cover of 1.2 m depending on land use. Construction and reclamation near research areas occurred February to May 2009.

The ROW was 30 m at all research sites (McNeely 2012). The TransCanada pipeline followed a 28 m wide Alberta Ethane Gathering System (AEGS) ROW. To reduce impact to rare species the pipeline ROW overlaps 4 m of the AEGS ROW at most sites. Due to topography the TransCanada ROW deviates from the AEGS ROW at one research site. The pipeline was permitted to use an additional 7 m of AEGS ROW for subsoil and topsoil storage (Jacques Whitford AXYS Ltd. 2008). To prevent invasive plant introduction during construction, a cleaning station was established at site entries.

At three research sites TransCanada pipeline passes within 300 m of known rare species habitat and was constructed with 30 m buffers between any construction activities and rare species habitat. Mitigation techniques implemented to reduce the impact on rare species and its associated critical habitat include: limiting the stripping of topsoil to the permanent ROW, no stripping of topsoil in the temporary workspace, geotextiles placed prior to soil storage or creation of travel lanes, soil and geotextiles being removed before the beginning of the next growing season, and careful removal of the soil from the geotextile using prairie protectors and sweepers. Populations of rare species were marked and fenced, and warning signs were installed informing workers of their presence (Jacques Whitford AXYS Ltd. 2008).

3.3. Research Site Location And Description

Six research sites were established along the TransCanada pipeline for previous MSc research programs (Nemirsky 2011, Nannt 2014). All sites are representative of the native dry mixedgrass prairie environment, although specific topography, elevation, and aspect vary, and land management was variable due to individual landowner practices.

Remount Hill (NW-2-22-3-W4), Remount Highway (SW-10-22-3-W4), and Remount Lowland (SE-10-22-3-W4) sites are located south of Secondary 555 in the Remount Community pasture (Jaques Whitford AXYS Ltd. 2008, Nemirsky 2011, McNeely 2012, Nannt 2014). Remount Hill is approximately 1000 m south east of Remount Lowland, which is 500 m south east of Highway, which is 150 m south east of Secondary 555. All three sites are along the TransCanada pipeline

ROW within the AEGS ROW, and subject to the same land management including cattle grazing and no fencing of the ROW. Remount Highway has a dry water course running east to west. Remount Hill is located at a slope toe near an intermittent water course at the edge of a saline drainage way. Remount Lowland has flat topography. All three sites had similar pipeline construction, with the 30 m ROW consisting of a stripped 4 m trench area with the pipeline laid in the middle 2 m, 19 m of work area north of the trench, and 7 m of storage area to the south.

Minor Coulee (SW-16-22-3-W4) and Minor Coulee Upland (NE-9-22-3-W4) sites are located on private land, north of Secondary 555 (Nemirsky 2011, McNeely 2012, Nannt 2014). Minor Coulee Upland is located approximately 1200 m north west of Remount Highway and Minor Coulee is located 800 m north west of Minor Coulee Upland. The ROW was fenced during pipeline construction and remains fenced. Minor Coulee has steep slopes that required extensive grading due to the large diameter pipe. The coulee runs north east to south west and the pipeline runs north west to south east. Coulee Upland is along 20 m of the AEGS ROW on flat terrain. Both sites had a 30 m ROW, with 4 m of trench area stripped and the pipe placed in the centre 2 m. At Minor Coulee, the entire ROW was stripped and consisted of a 10 m storage area south of the trench, 14 m work area south of the trench, 2 m trench, and 4 m of work area north of the trench. At Minor Coulee Upland the 30 m ROW consisted of 10 m of temporary storage to the south, 16 m of work space to the north, and 4 of trench and pipeline.

McNeil (SE-22-21-1-W4) site is located on private land on the opposite side of the South Saskatchewan river, 21 km south east of Hill site and 15 km north of Secondary 545 along the Alberta Saskatchewan border. The site has flat terrain and borders a high relief coulee. The ROW was 30 m and consisted of a 2 m trench, 10 m of storage area south of the trench, 11 m of work area on the south side, and 7 m of work area to the north.

3.4. Treatment Descriptions And Sampling Strategy

Ten treatments were located on and adjacent to the pipeline ROW to determine impacts of the different pipeline construction activity zones and distance from the pipeline ROW (Figure 3.2). The trench treatment is directly over the pipe. The work treatment is where construction equipment was used during pipeline construction. The storage treatment is where soil was stored following stripping from the ROW and before replacement over the trench. Off the edge of the storage and work ROW treatments, distance treatments of 5, 10, and 20 m were established on each side of the pipeline ROW. An undisturbed treatment was located 100 m from the trench on one side of the ROW. The exact treatment locations varied slightly at each site due to pipeline construction differences (Table 3.1). Minor Coulee and McNeil had three less treatments as the 5, 10, and 20 m were only located off one side of the pipeline ROW. Based on previous research (Nemirsky 2011, Nannt 2014) the 300 m distance treatment was not assessed, as impacts of the pipeline were no longer significant at 30 m from the trench, and not observed or statistically significant at 50 m from the trench.

At each site a 100 m transect was staked along the trench in the same locations as for previous research sampling and assessments (Nemirsky 2011, Nannt 2014). Within this 100 m transect, at each site, seven distances were randomly selected, 9, 17, 37, 68, 78, 90, and 100 m, for location of sampling replicates. At each of these distances on the trench, with the starting point on the pipe centre, the transect depicted in Figure 3.2 was staked for sampling. Thus there were (4 sites x 10 treatments x 7 replicates = 280) + (2 sites x 7 treatments x 7 replicates = 98) for a total of 378 vegetation assessment locations.

3.5. Vegetation Assessments

Vegetation was assessed July 16 to 20, 2014, similar to previous assessment times (Nemirsky 2011, Nannt 2014). These dates represent general maturation time for many prairie species, making identification considerably easier and more accurate. Species were identified and classified as native or non native according to Moss (1994), Tannas (2003), and Tannas (2004). At each of the 378 assessment locations identified in section 3.4, a 20 x 50 cm (0.1 m^2) quadrat was placed with the long side along the north side of the transect and the bottom right corner on the sampling transect. Individual species canopy cover and ground cover of litter, live vegetation, bare ground, lichen, fungi, manure or scat, and rocks were visually estimated. Species richness was determined from the cover data as frequencies in the quadrats.

3.6. Statistical Analyses

All statistical analyses were conducted using R version 3.2.2 (R Core Team 2015). Mean, standard deviation, standard error, and 95 % confidence intervals were calculated for species richness, the Shannon Wiener diversity index (H), and cover type. Normality was checked using the Kolmogorov-Smirnov test (Logan 2010, Lilliefors 1967). Data were only normally distributed for H. Thus cover type and species richness were analyzed with Kruskal Wallace rank sum test, a non parametric ANOVA alternative. When significance was determined, post hoc comparisons were completed using the Kruskal test with a Bonferroni correction. Differences in H were tested using ANOVA and post hoc comparisons were conducted with the Tukey test (Tukey 1953).

4. RESULTS

4.1. Species Richness

Species composition varied among treatments (Tables 3.2, 3.3, 3.4, 3.5, 3.6, 3.7). *Cirsium arvense* (L.) Scop (Canada thistle) was the only listed noxious weed on the research sites. Most common non native species were *Taraxacum officinale* Weber (dandelion) and *Tragopogon dubius* Scop. (goat's beard), at all treatments except undisturbed for *Taraxacum officinale* and storage 20 m for *Tragopogon dubius* (Table 3.2). *Agropyron dasystachyum* (Hook.) Scribn. (northern wheat grass), *Agropyron smithii*, *Bouteloua gracilis*, *Carex stenophylla* Wahl. (sedge), *Stipa comata*, and *Artemisia frigida* Willd. (pasture sage) were in all treatments (Tables 3.4, 3.5). Two rare species, as listed by the Alberta Natural Heritage Information Centre, were found. *Arabis holboellii* Hornem. (reflexed rock cress), rated S1, was found three times in trace amounts at work 5, 10, and 20 m at Remount Hill. *Schedonnardus panniculatus* (Nutt.) Trel. (tumble grass), rated S2, and was found once at storage 10 m at Minor Coulee Upland.

Overall species richness varied across treatments (Table 3.6), with a total of 69 species. Highest mean species richness was 5.1 at storage 10 m; lowest was 3.2 at the trench. Species richness on the trench was significantly lowest, except for work, and work 20 m.

Species richness varied with native and non native categories (Table 3.7). Highest mean native species richness was 4.6 at storage 20 m; highest non native was 0.5 at storage and storage 5 m. Lowest native species richness was 2.9 at trench; lowest non native was 0.1 at storage 20 m and undisturbed. Significant differences were not found with treatments for non native species. The trench had significantly lower native species richness than other treatments except work.

4.3. Shannon Wiener Diversity Index

Overall (native and non native species combined) diversity varied across all treatments, being highest at the storage 10 m, 1.2, and lowest at trench 0.8 (Table 3.8). The trench treatment had significantly lowest diversity, except for storage 10 m and undisturbed.

Diversity varied greatly between native and non native species (Table 3.9). Highest diversty of native species was 1.2 (SD 0.32) at storage 10 m; highest non native was 0.09 (SD 0.24) at storage 5 m. Lowest mean diversity of native species was 0.7 (SD 0.44) at trench; lowest of non native species was 0 at storage 20 m, work 10 m, work 20 m, and undisturbed. The trench was significantly lower in native species mean diversity than storage 10 m and undisturbed.

4.4. Ground Cover

Ground cover varied across treatments (Table 3.10). Highest mean live cover was 24.3 % at storage and lowest was 12.0 % at the trench. Highest mean litter cover was 77.5 % at work 5 m and lowest was 61.0 % at the trench. Highest mean bare ground cover was 26.5 % at the trench and lowest was 2.9 % at work 10 m. Lichen, fungi, scat, and rock cover was mostly in very low or trace amounts.

Significant overall relationships were found for live (H 66.8 P ≤0.001), litter (H 25.3 P 0.003), bare ground (H 40.3 P ≤0.001), and lichen (H 39.7 P ≤0.001) covers (Table 3.11). The trench was significantly lower in live cover than all other treatments, except work and work 5 m (Table 3.10). Live cover was not significantly different among the four storage treatments, or the four work treatments. The undisturbed native prairie was not significantly different from any treatments except higher than the trench and work in live cover. While a significant relationship was found in litter cover across treatments, individual treatments were not significantly different.

Undisturbed bare ground cover was not significantly different from all other treatments (Table 3.10). The trench was significantly higher than storage, storage 20 m, and work 5, 10, and 20 m.

Lichen cover was highly variable across treatments (Table 3.10). Trench, storage, work, and undisturbed were lowest but not significantly different from each other. Lichen cover was highest across work 10 m which was not significantly different from work 5 and 20 m, all four storage, and undisturbed treatments.

Of the four cover types with treatment specific differences, species richness increased with increasing live (τ 0.45 P 0.002) cover at work 5 m and decreased with increasing lichen (τ -0.32 P 0.01) cover at undisturbed (Table 3.12). Diversty increased with increasing litter cover at the storage (τ 0.33 P 0.002) treatment. Diversity decreased with increasing bare ground cover at the storage (τ -0.42 P ≤0.001) and storage 5 m (τ -0.26 P 0.02) treatments Diversity decreased with increasing lichen cover at storage 5 m (τ -0.31 P 0.01) and work 5 m (τ -0.34 P 0.02).

5. DISCUSSION

5.1. Plant Community Species Composition

Typical plant communities in the dry mixedgrass subregion are *Stipa-Agropyron*, *Stipa-Bouteloua-Agropyron*, and *Agropyron-Bouteloua* (Adams et al. 2013). The community at the research sites was *Stipa-Bouteloua-Agropyron* with *Stipa comata*, *Stipa viridula* Trin. (green needle grass), *Bouteloua gracilis*, *Agropyron dasystachyum*, and *Agropyron smithii* on almost every treatment. The abundant *Bouteloua gracilis* at all sites is indicative of past continuous grazing. The desired native plant community across the ROW, including areas with highest disturbance, indicates that reclamation techniques were successful. While native species are present over all treatments, lower species richness over the trench suggests the full range of species that would be expected in an undisturbed prairie environment are not yet present. This was not observed in either of the two rare species, *Arabis holboelli* and *Schedonnardus paniculatus*, both being present over the work and trench areas. Naeth (1985) found that it took 15 years for vegetation over the trench to return to pre disturbance levels. The recovery of the TransCanada pipeline ROW is still within this time frame. The trench and work treatments were similar in native species richness, again suggesting that increased disturbance from topsoil stripping was more detrimental than soil storage. Following six growing seasons the trench and work areas of the ROW have not recovered in species richness and diversity. Impacts of the ROW are no longer observed 20 m off the work and storage areas, and species richness and diversity are consistent with undisturbed prairie.

Artemisia cana Pursh. (silver sagebrush) is an important species for plant community structure. The landscape is almost devoid of trees and *Artemisia cana* fills that niche for many species, such as breeding habitat for birds (Adams et al. 2013). *Artemisia cana* was present on all but the most heavily disturbed treatments of trench and work. Pipeline construction techniques involving soil removal negatively impacted *Artemisia cana*. However, the less destructive techniques used with soil stockpiling and geotextile placement facilitated its persistence on the landscape. Nemirsky (2011) did not find any *Artemisia cana*, *Opuntia polyacantha* Haw. (prickly pear cactus), or *Selaginella densa* Rybd. (little club moss), which are considered climax species (Ostermann 2001) on the ROW. Nannt (2014) observed little encroachment of these species onto non trench areas of the ROW, although they continued to increase by 2014. This suggests that recovery is not yet complete, and the climax community has not been reached.

In dry mixedgrass prairie environments, large numbers of non native species are typically found in nitrogen rich areas, with high water content and protection from grazing (Blumenthal et al. 2010). This is not descriptive of the research sites, which are all grazed and occur on uplands. A study on tallgrass prairie found an increase in species richness and diversity as a result of grazing (Hickman et al. 2004). Grazing can aid in non native species establishment in many ecosystems, but this not apparent in mixedgrass environments (Hickman et al. 2004, Blumenthal et al. 2010). The resilience of mixedgrass ecosystems to grazing may be associated with the long historical exposure of grazing by large mammals (Blumenthal et al. 2010). All research sites have cattle grazing, suggesting that allowing grazing over ROWs is potentially beneficial to species richness and diversity.

With the exception of *Taraxacum officinale* and *Tragopogon dubius* which were present on all but one treatment, the limited number of non native species and cover, richness, and diversity being similar across treatments, suggests limited negative impact of the ROW on native plant communities. A species of concern in prairie regions, *Agropyron cristatum* (L.) Gaertn. (crested wheatgrass), was present as a result of its occurrence along the AEGS running adjacent to the TransCanada pipeline. While there is concern about the invasion of *Agropyron cristatum* in prairie environments (Henderson and Naeth 2005, Willms et al. 2005, Adams et al. 2013) it appears as though along the linear disturbance of pipelines, it is not currently spreading invasively from the original planted area. Henderson and Naeth (2005) found overall diversity decreased as a result of invasion of *Agropyron cristatum*, mainly as a result of lower forb richness. This does not appear to be the case on the study sites. *Agropyron cristatum* is present on four of the treatment areas at very low cover, with low variability; no large patches were observed on the ROW. Only one listed noxious weed was present at all sites, *Cirsium arvense*. It was present over the pipeline trench as a singular occurrence. An individual plant many not be considered an invasion; however, it is important for pipeline operators and managers to control any occurrence before the weed spreads.

5.2. Ground Cover

Results of this study were consistent with those of previous research on the sites that found greater impacts to live and bare ground cover types over the trench (Nemirsky 2011, Nannt 2014), although not for litter cover. The high variability of live and bare ground over the trench, suggests that patchy recovery of native species may be occurring along the trench, reducing bare ground and increasing live vegetation. This trend was also observed for the work treatment, with similar construction techniques to that of the trench. Both areas had topsoil removed and then later replaced (McNeely 2012). This resulted in the highest impact to ground cover. High occurrences of bare ground are of concern due to the increased potential for water and wind erosion in exposed prairie environments (Kerr et al. 1993). Increased bare ground can decrease the height of some common prairie species (Willms et al. 1993), which could negatively impact their survival and reduce forage productivity of the grassland. Bare ground did not appear to negatively impact species richness and only moderately impacted diversity across two storage treatments. This suggests that while bare ground is present across all treatments, and in high cover on the trench, it is not negatively impacting the plant community.

Litter maintains soil water content through protection from solar radiation and helps retain water following rainfall in temperate grasslands (Ayyad and Dix 1964, Willms et al. 1993, Deutsch et al. 2010a, Deutsch et al. 2010b). Litter enhances water infiltration and reduces surface runoff. Species present at the research sites such as *Bouteloua gracilis* and *Agropyron smithii* can decrease in height with removal of litter cover (Willms et al. 1993). Litter cover across the ROW ensures that all areas are retaining water in the same way, thus promoting growth of live vegetation in areas with low live cover, such as the trench and work treatments. The potential for litter cover to reduce weed infestation (Facelli and Pickett 1991) may reduce invasive species along the ROW. This was observed through low overall presence of non native species, and one noxious species at the research sites. The presence of litter across all areas of the ROW serve to reduce soil temperature through shading, thereby reducing evapotranspiration (Deutsch et al. 2010a), which will likely become increasingly important as the trajectory for climate change in these areas is expected to raise temperatures and decrease precipitation.

In grassland environments, decreased species richness and diversity have been associated with increased litter cover (Foster and Gross 1998, Lamb 2008). This was not the case at the study sites. Litter can have detrimental effects on emerging vegetation through decreased light and temperature, mechanical impedance, fungal infection, or allelopathic effects (Goldberg and Warner 1983, Facelli and Pickett 1991, Foster and Gross 1998, Olson and Wallander 2002, Ruprecht et al. 2002, Jensen and Gutekunst 2003, Deutsch et al. 2010a). However, the combination of bare ground and litter cover will likely allow plants to successfully germinate. The potential of litter to hold water appears to have little impact in semi arid environments, since there was no decrease in species richness across treatments. Overall, litter does not appear to have any negative effects on the plant community and may serve in stabilizing the emerging vegetation in the areas with greatest disturbance from the pipeline ROW.

Lichen cover, while low overall, displayed interesting trends. It was lowest on treatments with highest disturbance, trench, work, and storage, suggesting there is a slow recovery for lichen on soils disturbed by pipeline construction. However, outward from those treatments lichen cover increased markedly. Lichens are often a pioneer species following disturbances (Rydgren et al. 2004, Ketner-Oostra and Sýkora 2004, Jandt et al. 2008), consistent with the lower cover of lichen over the trench and the increase outwards from the maximum disturbance.

Lichens aid in soil aggregation on disturbed sandy sites, create microhabitats for other vascular and non vascular species, and add organic matter and nitrogen to developing soils (Looman 1964, Schulten 1985, Ketner-Oostra and Sýkora 2004, Rydgren et al. 2004, Jandt et al. 2008). High nutrient soils, such as those in grasslands (Hobbie 1992) would likely benefit from nitrogen fixing pioneer species on disturbed sites prior to vascular plant establishment. Prairie lichen species were patchy on the landscape; from field notes and raw data, lichen were absent or present in large patches. This variability was notable in the undisturbed treatment, which was not different in lichen cover relative to other treatments. Decreases in species richness and diversity with increasing lichen cover could be attributed to the specific microsite. Lichens often adapt to difficult environments relative to vascular species (Schulten 1985). This results in lichen species occupying areas which are not hospitable to vascular plants, attributed to increased compaction of the substrate, low soil organic matter, and low soil stability (Schulten 1985, Ketner-Oostra and Sýkora 2004). After six growing seasons the lichen cover has not returned to native prairie levels across areas of the ROW with highest disturbance. This suggests that prairie lichens are slow to recover from pipeline disturbance regardless of their role as early pioneer species and can be outcompeted by more dominant vascular species (Ketner-Oostra and Sýkora 2004).

Fungi, rock, and scat cover were seldom observed. When present, they were often in high quantities, such as a large rock, cow scat, or *Calvatia* species (puffball) of mushroom. While present at all research sites, they were randomly distributed across the landscape. This appears to be consistent with visual observations made of other native prairie areas, suggesting the pipeline ROWs do not negatively impact these cover types.

6. CONCLUSIONS

After six growing seasons the pipeline right of way is still having some significant impact on plant community composition, species richness, and diversity. Climax community species, such as *Opuntia polyacantha* and *Artemisia cana* were not observed over the trench and work areas at the same cover level as undisturbed prairie. Species richness and diversity index decreased over the work and trench areas. Non native species richness and diversity were not significantly different across treatment areas, native species richness and diversity were lower over the trench and work areas. Native species were dominant across all treatments, and non native species were not increasing or comprising a significant portion of the plant community. The greatest impacts to the plant community were over the most disturbed areas of the right of way, the trench and work area, where bare ground cover was greatest, and live vegetation was least. Lichen, fungi, scat, and rock cover were present in low or trace amounts across all treatments. At some treatments, species richness increased with increasing live cover and decreased with increasing lichen cover. Diversty increased with increasing litter cover and decreased with increasing bare ground and lichen cover at some treatments. Species richness and diversity were no longer significantly different from undisturbed prairie after 5 m from storage and work treatments. Ground cover was still impacted on trench, storage, and work areas, but not 5 m from the storage and work treatments.

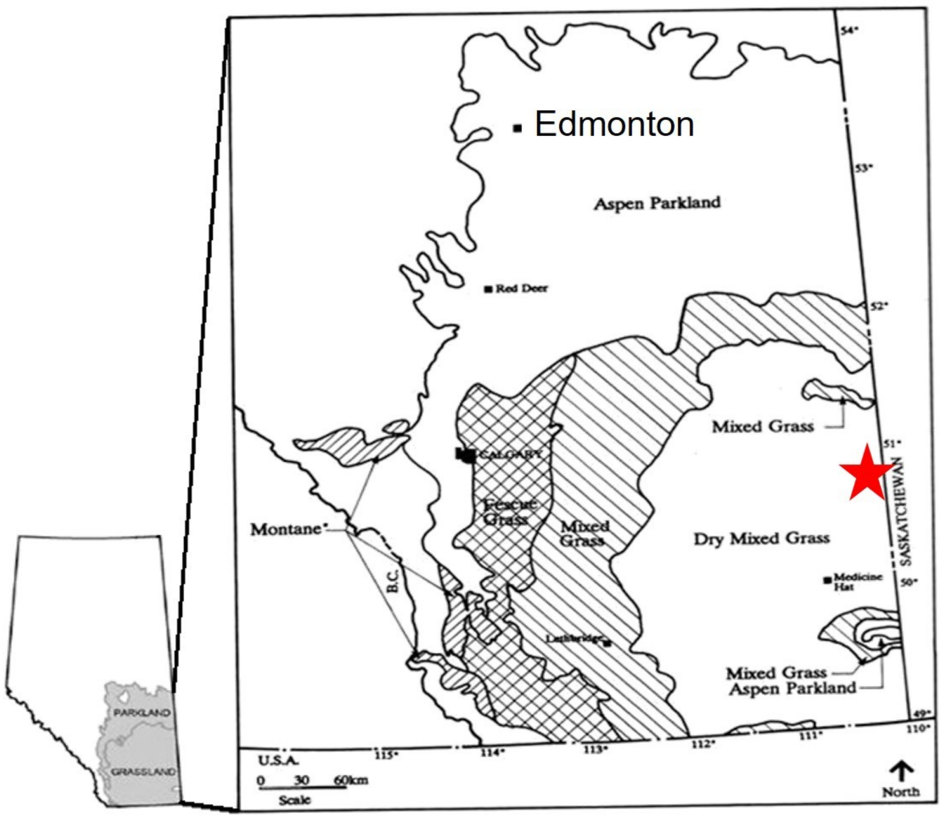

Figure 3.1. General location of study sites in southern Alberta denoted by the red star. Adapted from Kerr et al. 1993.

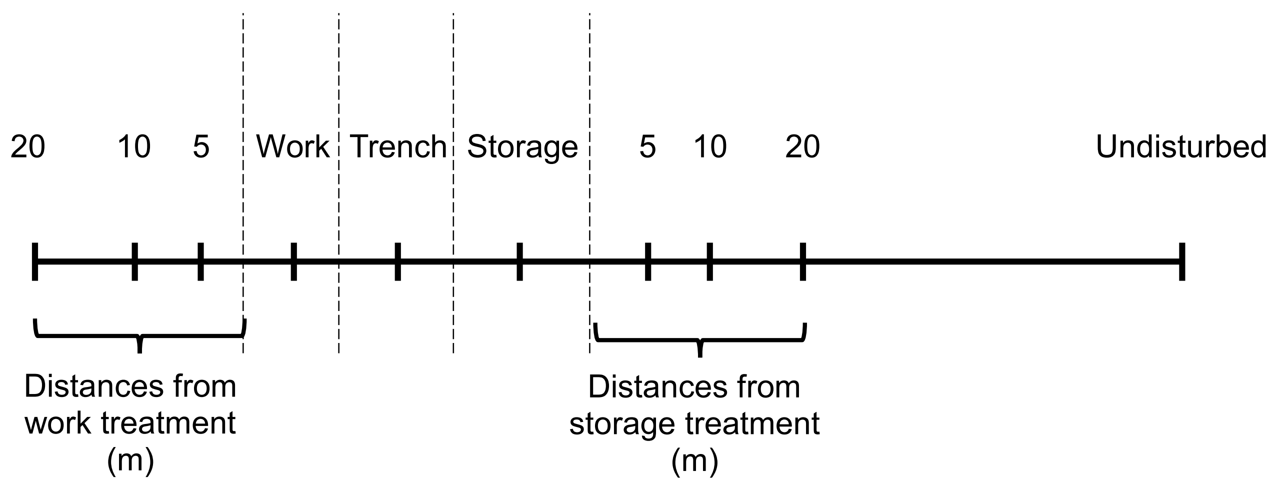

Figure 3.2. Generalized schematic of treatment locations on and adjacent to the pipeline right of way.

Table 3.1. Location of sample points on treatments at the research sites in July 2014.

Treatment	Remount Highway, Hill, Lowland	Minor Coulee	Minor Coulee Upland	McNeil
Trench	0 m	0 m	0 m	0 m
Storage	5.5 m S	20 m S	8 m S	17 m S
Work	11.5 m N	8 m S	8.5 m N	6.5 m S
Storage 5 m	14 m S	30 m S	18 m S	27 m S
Storage 10 m	19 m S	35 m S	23 m S	32 m S
Storage 20 m	29 m S	45 m S	33 m S	42 m S
Work 5 m	26 m N	-	22 m N	-
Work 10 m	31 m N	-	27 m N	-
Work 20 m	41 m N	-	37 m N	-
Undisturbed	100 m S	100 m S	100 m S	100 m S

- = No treatment on one side of the pipeline right of way due to construction techniques

Table 3.2. Non native forb species on pipeline treatments in 2014.

	Trench	Storage	Storage 5 m	Storage 10 m	Storage 20 m	Work	Work 5 m	Work 10 m	Work 20 m	Undisturbed
Cirsium arvense **	3.0 *	-	-	-	-	-	-	-	-	-
Crepis tectorum	-	-	-	-	-	-	-	1.0 *	-	-
Descurainia sophia	-	-	T (0.0)	2.0 *	-	-	T	-	-	1.0 *
Kochia scoparia	1.0 *	-	-	-	-	-	-	-	-	-
Linaria species	-	-	-	1.0 *	-	-	-	-	-	-
Taraxacum officinale	0.7 (0.6)	1.2 (0.83)	0.8 (0.5)	0.5 (0.7)	1.0 *	1.0 *	1.0 (1.0)	1.0 *	1.0 *	-
Tragopogon dubius	0.8 (0.5)	1.0 (0.0)	0.8 (0.5)	0.8 (1.5)	-	1.0 *	2.2 (0.4)	1.1 (0.9)	T *	0.5 (0.7)

Numbers are mean cover (%) with standard deviations in brackets
T = trace (< 1 % cover), - = not found
* n = 1, ** noxious weed

Table 3.3. Non native graminoid species on pipeline treatments in 2014.

	Trench	Storage	Storage 5 m	Storage 10 m	Storage 20 m	Work	Work 5 m	Work 10 m	Work 20 m	Undisturbed
Agropyron cristatum	-	T *	2.5 (0.7)	3.3 (2.1)	-	2.3 (2.2)	-	-	-	-
Agropyron repens	T *	-	-	-	-	-	-	-	-	-
Bromus biebersteinii	1.0 *	-	-	-	-	1.0 *	-	-	-	-
Hordeum jubatum	5.0 *	-	-	-	-	-	-	-	-	-

Numbers are mean cover (%) with standard deviations in brackets
T = trace (< 1 % cover), - = not found
* n = 1

Table 3.4. Native graminoid species on pipeline treatments in 2014.

	Trench	Storage	Storage 5 m	Storage 10 m	Storage 20 m	Work	Work 5 m	Work 10 m	Work 20 m	Undisturbed
Agropyron dasystachyum	4.3 (3.1)	3.5 (2.2)	2.3 (1.8)	3.4 (2.4)	3.4 (3.3)	3.3 (3.0)	1.6 (1.3)	0.8 (1.0)	0.4 (0.5)	1.8 (1.2)
Agropyron smithii	3.8 (4.7)	3.7 (2.6)	2.5 (2.5)	2.8 (2.6)	2.0 (1.7)	3.0 (2.1)	3.5 (2.2)	3.3 (2.6)	3.3 (3.2)	3.6 (3.8)
Agropyron species	-	T *	-	1.0 *	-	T *	-	-	-	-
Agropyron trachycaulum	1.0 (0.0)	-	-	-	-	2.0 (0.0)	-	-	-	-
Bouteloua gracilis	3.5 (3.2)	12.9 (14.6)	8.3 (7.9)	6.2 (4.5)	8.8 (13.0)	4.3 (4.9)	5.6 (4.0)	7.7 (5.9)	4.6 (3.5)	6.8 (5.0)
Calamovilfa longifolia	16.8 (13.5)	2.0 *	-	1.0 *	T *	3.0 (2.0)	-	-	-	5.0 (6.9)
Carex filifolia	-	3.0 (2.6)	7.0 (1.4)	5.5 (0.7)	10.0 (2.8)	-	-	-	-	12.0 (4.6)
Carex lanuginose	-	-	-	-	-	-	0.0 *	-	-	-
Carex phaeocephala	-	-	12.0 *	-	-	-	-	-	-	-
Carex species	-	-	-	-	1.0 *	-	0.7 (0.6)	1.0 (0.0)	1.3 (0.6)	-
Carex stenophylla	0.0 *	3.4 (1.9)	4.3 (6.8)	3.6 (2.4)	5.4 (5.3)	5.1 (6.3)	3.9 (2.5)	6.8 (5.3)	9.5 (8.7)	6.9 (6.7)
Distichlis stricta	9.5 (6.4)	8.5 (9.2)	14.0 (0.0)	5.0 (2.8)	2.0 (0.0)	7.3 (4.6)	5.5 (3.5)	5.5 (2.1)	13.5 (12.0)	-
Koeleria macrantha	-	1.0 (0.0)	1.0 *	1.8 (1.0)	1.0 *	-	-	-	-	2.7 (1.2)
Muhlenbergia cuspidate	-	23.0 *	T *	-	6.0 *	-	-	-	-	-
Poa palustris	3.0 *	-	-	-	-	-	-	-	-	-
Poa sandbergii	-	-	-	6	-	-	-	-	-	-
Poa species	-	1.0 *	-	0.5 (0.7)	1.0 *	-	-	-	-	-
Schedonnardus paniculatus	-	-	-	1.0 *	-	-	-	-	-	-
Stipa comata	1.0 (1.0)	3.8 (3.5)	4.9 (4.2)	6.5 (5.5)	6.4 (5.3)	3.3 (2.0)	5.3 (4.0)	4.6 (3.5)	4.1 (1.7)	5.4 (4.5)
Stipa viridula	4.3 (3.2)	5.0 (4.2)	5.0 (3.6)	4.2 (2.7)	0.0 *	2.9 (3.4)	6.0 *	-	30.0 *	8.0 (1.0)

Numbers are mean cover (%) with standard deviations in brackets
T = trace (< 1 % cover), - = not found
* n = 1

Table 3.5. Native forb, shrub, and bryophyte species on pipeline treatments in 2014.

	Trench	Storage	Storage 5 m	Storage 10 m	Storage 20 m	Work	Work 5 m	Work 10 m	Work 20 m	Undisturbed
Achillea milefolium	-	-	-	T *	-	-	-	-	-	3.0 (2.8)
Androsace septentrionalis	-	-	-	T *	(T) (0.0)	-	-	1.0 *	T *	-
Antennaria parvifolia	-	-	-	-	T (0.0)	-	-	-	-	2.0 *
Antennaria species	-	-	-	-	-	-	-	-	-	3.0 *
Arabis holboellii	-	-	-	-	-	-	T *	-	T (0.0)	-
Arabis species	-	-	-	T (0.0)	T *	-	-	-	-	T *
Artemisia cana	-	3.0 *	8.0 (9.9)	1.0 *	9.0 (4.2)	-	7.0 (4.2)	6.0 (5.7)	1.0 *	2.0 (1.7)
Artemisia frigida	2.1 (2.9)	3.0 (4.1)	2.7 (3.9)	2.3 (2.1)	2.0 (1.6)	6.8 (8.1)	1.8 (1.9)	0.8 (1.0)	1.5 (1.0)	3.0 (4.1)
Artemisia ludoviciana	-	3.8 (0.96)	4.4 (1.9)	5.0 *	2.5 (0.7)	-	-	6.0 *	-	9.0 (5.7)
Aster species	-	0.5 (0.7)	T (0.0)	T (0.0)	T *	-	0.5 (0.7)	T *	1.2 (1.6)	0.3 (0.5)
Bryophyta species	2.5 (2.4)	6.0 *	T *	10.0 *	5.0 *	4.0 (7.3)	-	-	-	1.3 (0.6)
Chenopodium leptophyllum	-	-	-	T *	-	-	-	-	-	-
Chenopodium pratericola	T *	-	T *	-	T *	T *	T *	T *	-	T *
Chenopodium species	-	-	-	-	-	T *	-	-	-	-
Cirsium undulatum	-	-	-	2.0 *	-	-	-	-	-	-
Coryphantha vivipara	-	-	-	T *	-	-	-	T *	-	-
Erigeron canadensis	-	T *	T *	T *	T *	-	0.7 (1.1)	0.3 (0.6)	2.0 (1.4)	1.5 (1.9)
Eurotia lanata	-	-	-	6.0 *	-	-	-	-	-	5.5 (6.4)
Gaura coccinea	-	-	1.0 *	1.0 (1.4)	1.0 (1.4)	-	-	1.0 *	1.0 *	-
Hedeoma hispidum	-	1.0 (1.0)	T (0.0)	1.0 (0.0)	T (0.0)	-	T (0.0)	1.0 (0.0)	T (0.0)	-
Heterotheca villosa	-	3.0 *	-	2.0 *	-	-	-	-	-	-
Lepidium densiflorum	T *	-	-	-	-	-	T *	T *	-	-
Marchantiophyta species	-	-	1.0 (0.0)	-	-	-	-	-	-	-
Linum rigidum	-	-	-	T *	-	-	1.0 *	-	-	-
Lygodesmia juncea	1.0 *	0.6 (0.9)	1.0 *	0.3 (0.6)	T *	T *	-	-	1.0 *	0.5 (0.7)
Opuntia fragilis	T *	0.5 (0.7)	1.0 (1.4)	1.0 *	-	T *	-	-	-	T *
Opuntia polyacantha	-	-	1.0 *	2.8 (2.2)	6.7 (4.5)	1.0 *	4.0 (0.0)	3.3 (2.5)	4.5 (4.9)	2.0 *
Paronychia sessiliflora	-	2.0 *	-	-	2.5 (2.1)	-	-	-	-	-
Phlox hoodii	-	3.3 (3.2)	3.0 (4.4)	2.0 (1.9)	T (0.0)	6.5 (7.8)	-	-	-	-
Pinus banksiana	-	-	-	-	-	T *	-	-	-	-
Plantago patagonica	2.5 (3.5)	-	2.0 *	-	-	-	1.0 (1.0)	T *	T *	1.0 *

	Trench	Storage	Storage 5 m	Storage 10 m	Storage 20 m	Work	Work 5 m	Work 10 m	Work 20 m	Undisturbed
Psoralea argophylla	2.0 *	1.0 *	-	2.0 (1.4)	0.5 (0.7)	10.0 *	-	-	T *	2.0 (1.0)
Ratibida columnifera	-	-	-	1.0 *	-	-	-	-	-	-
Rosa acicularis	-	-	-	-	-	-	-	-	-	1.0 *
Rosa woodsia	3.0 *	1.0 *	-	-	-	-	-	-	-	-
Selaginella densa	-	10.0 (10.3)	7.2 (8.3)	18.7 (9.9)	12.5 (3.5)	T *	4.0 *	16.0 (12.7)	10.0 (2.0)	4.0 (4.4)
Sphaeralcea coccinea	-	0.9 (0.8)	1.3 (1.3)	1.9 (1.6)	1.2 (0.9)	0.7 (0.9)	0.8 (0.9)	1.3 (0.9)	2.3 (1.5)	1.0 (0.7)

Mean cover (%) with standard deviations in brackets
T = trace (< 1 % cover), - = not found
* n = 1

Table 3.6 Descriptive statistics and significance of species richness Kruskal Wallace evaluations.

Treatment	N	Mean Species Richness	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Number	Maximum Species Number
Trench	42	3.2	b	1.47	0.23	0.46	1	7
Storage	42	4.9	a	1.55	0.24	0.48	2	8
Storage, 5 m	42	4.9	a	1.83	0.28	0.57	1	8
Storage, 10 m	42	5.1	a	1.97	0.30	0.61	2	12
Storage, 20 m	42	4.3	a	1.37	0.21	0.43	2	7
Work	42	4.1	ab	1.28	0.20	0.40	2	7
Work, 5 m	28	4.7	a	1.72	0.33	0.67	2	8
Work, 10 m	28	4.5	a	1.48	0.28	0.57	2	8
Work, 20 m	28	4.4	ab	1.64	0.31	0.64	2	8
Undisturbed	42	4.5	a	1.25	0.19	0.39	2	7

Treatments with the same letter are not significantly different for mean species richness

Table 3.7. Descriptive statistics and significance of native and non native species richness using Kruskal Wallace evaluations.

	Treatment	N	Mean Species Richness	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Number	Maximum Species Number
Native	Trench	42	2.9	b	1.32	0.20	0.41	1	7
	Storage	42	4.5	a	1.31	0.20	0.41	2	7
	Storage 5 m	42	4.5	a	1.67	0.26	0.52	1	8
	Storage 10 m	42	4.6	a	1.45	0.22	0.45	2	9
	Storage 20 m	42	4.2	a	1.34	0.21	0.42	2	7
	Work	42	3.8	ab	1.38	0.21	0.43	1	7
	Work 5 m	28	4.3	a	1.63	0.31	0.63	2	8
	Work 10 m	28	4.1	a	1.51	0.29	0.58	2	8
	Work 20 m	28	4.2	a	1.55	0.29	0.60	2	8
	Undisturbed	42	4.4	a	1.23	0.19	0.38	2	7
Non Native	Trench	42	0.3	a	0.72	0.11	0.22	0	4
	Storage	42	0.5	a	0.77	0.12	0.24	0	3
	Storage 5 m	42	0.5	a	0.92	0.14	0.29	0	3
	Storage 10 m	42	0.4	a	0.99	0.15	0.31	0	5
	Storage 20 m	42	0.1	a	0.33	0.05	0.10	0	1
	Work	42	0.3	a	0.55	0.09	0.17	0	2
	Work 5 m	28	0.4	a	0.63	0.12	0.24	0	2
	Work 10 m	28	0.4	a	0.49	0.09	0.19	0	1
	Work 20 m	28	0.2	a	0.39	0.07	0.15	0	1
	Undisturbed	42	0.1	a	0.35	0.05	0.11	0	1

Treatments with the same letter are not significantly different for mean species richness

Table 3.8. Descriptive statistics and significance of the Shannon Wiener diversity index using Tukey test evaluations.

Treatment	N	Mean Species Diversity	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Diversity	Maximum Species Diversity
Trench	42	0.8	b	0.41	0.06	0.13	0.00	1.85
Storage	42	1.1	ab	0.44	0.07	0.14	0.00	1.94
Storage 5 m	42	1.0	ab	0.49	0.07	0.15	0.00	1.87
Storage 10 m	42	1.2	a	0.37	0.06	0.11	0.38	2.05
Storage 20 m	42	1.0	ab	0.36	0.06	0.11	0.01	1.71
Work	42	1.0	ab	0.31	0.05	0.10	0.01	1.59
Work 5 m	28	1.1	ab	0.44	0.08	0.17	0.01	1.88
Work 10 m	28	1.0	ab	0.39	0.07	0.15	0.33	1.78
Work 20 m	28	1.0	ab	0.32	0.06	0.12	0.44	1.84
Undisturbed	42	1.1	a	0.36	0.06	0.11	0.01	1.77

Treatments with the same letter are not significantly different for mean species diversity

Table 3.9. Descriptive statistics and significance of native and non native Shannon Wiener diversity index using Tukey test evaluations.

	Treatment	N	Mean Species Diversity	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Diversity	Maximum Species Diversity
Native	Trench	42	0.7	b	0.44	0.07	0.14	0.00	1.85
	Storage	42	1.0	ab	0.41	0.06	0.13	0.00	1.66
	Storage 5 m	42	1.0	ab	0.44	0.07	0.14	0.00	1.75
	Storage 10 m	42	1.2	a	0.32	0.05	0.10	0.38	1.77
	Storage 20 m	42	1.0	ab	0.36	0.06	0.11	0.01	1.71
	Work	42	1.0	ab	0.37	0.06	0.12	0.00	1.59
	Work 5 m	28	1.0	ab	0.41	0.08	0.16	0.01	1.74
	Work 10 m	28	0.9	ab	0.41	0.08	0.16	0.23	1.78
	Work 20 m	28	1.0	ab	0.32	0.06	0.13	0.44	1.84
	Undisturbed	42	1.1	a	0.36	0.06	0.11	0.01	1.77
Non Native	Trench	42	0.0	a	0.15	0.02	0.05	0.00	0.95
	Storage	42	0.1	a	0.20	0.03	0.06	0.00	1.01
	Storage 5 m	42	0.1	a	0.24	0.04	0.08	0.00	1.00
	Storage 10 m	42	0.1	a	0.23	0.04	0.07	0.00	1.39
	Storage 20 m	42	-	a	-	-	-	-	-
	Work	42	0.0	a	0.01	0.00	0.00	0.00	0.06
	Work 5 m	28	0.0	a	0.13	0.02	0.05	0.00	0.69
	Work 10 m	28	-	a	-	-	-	-	-
	Work 20 m	28	-	a	-	-	-	-	-
	Undisturbed	42	-	a	-	-	-	-	-

Treatments with the same letter are not significantly different for mean species diversity
- = not found

Table 3.10. Descriptive statistics and significance of cover types and treatments using Kruskal Wallace evaluations.

Cover	Treatment	N	Mean	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Live	Trench	42	12.0	d	6.60	1.02	2.06	4	35
	Storage	42	24.3	a	12.16	1.88	3.79	11	68
	Storage 5 m	42	20.7	ab	8.40	1.30	2.62	10	45
	Storage 10 m	42	20.3	ab	8.27	1.28	2.58	6	52
	Storage 20 m	42	19.7	abc	10.90	1.68	3.40	10	76
	Work	42	14.2	cd	8.03	1.24	2.50	3	33
	Work 5 m	28	15.8	bcd	4.58	0.87	1.78	5	28
	Work 10 m	28	18.8	abc	6.96	1.31	2.70	5	38
	Work 20 m	28	19.8	abc	9.74	1.84	3.78	4	40
	Undisturbed	42	20.3	ab	9.06	1.40	2.82	5	55
Litter	Trench	42	61.0	a	25.89	3.99	8.07	12	96
	Storage	42	66.7	a	17.48	2.70	5.45	9	89
	Storage 5 m	42	68.1	a	16.25	2.51	5.06	10	90
	Storage 10 m	42	68.2	a	17.31	2.67	5.39	10	89
	Storage 20 m	42	75.3	a	12.44	1.92	3.88	20	89
	Work	42	72.6	a	19.60	3.02	6.11	8	97
	Work 5 m	28	77.5	a	9.18	1.73	3.56	52	89
	Work 10 m	28	74.3	a	12.29	2.32	4.77	25	88
	Work 20 m	28	73.5	a	11.33	2.14	4.40	40	88
	Undisturbed	42	66.4	a	18.36	2.83	5.72	6	89
Bare Ground	Trench	42	26.5	a	25.29	3.90	7.88	0	75
	Storage	42	7.3	b	10.36	1.60	3.23	0	40
	Storage 5 m	42	8.9	ab	14.07	2.17	4.39	0	75
	Storage 10 m	42	8.0	ab	16.39	2.53	5.11	0	83
	Storage 20 m	42	3.0	b	4.10	0.63	1.28	0	21
	Work	42	9.8	ab	14.58	2.25	4.54	0	70
	Work 5 m	28	4.2	b	7.24	1.37	2.81	0	30
	Work 10 m	28	2.9	b	5.38	1.02	2.09	0	25
	Work 20 m	28	4.3	b	9.05	1.71	3.51	0	47
	Undisturbed	42	8.7	ab	15.80	2.44	4.92	0	87

Cover	Treatment	N	Mean	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Lichen	Trench	42	0.2	c	0.98	0.15	0.30	0	6
	Storage	42	0.5	abc	1.21	0.19	0.38	0	6
	Storage 5 m	42	1.0	ab	1.99	0.31	0.62	0	10
	Storage 10 m	42	1.5	ab	3.35	0.52	1.04	0	15
	Storage 20 m	42	1.1	ab	2.29	0.35	0.71	0	10
	Work	42	0.2	bc	0.89	0.14	0.28	0	5
	Work 5 m	28	2.5	a	4.64	0.88	1.80	0	21
	Work 10 m	28	3.4	a	12.38	2.34	4.80	0	66
	Work 20 m	28	1.8	ab	3.33	0.63	1.29	0	16
	Undisturbed	42	1.1	abc	2.72	0.42	0.85	0	12
Fungi	Trench	42	0.0	a	0.00	0.00	0.00	0	T
	Storage	42	0.0	a	0.31	0.05	0.10	0	2
	Storage 5 m	42	0.0	a	0.00	0.00	0.00	0	T
	Storage 10 m	42	0.0	a	0.00	0.00	0.00	0	T
	Storage 20 m	42	0.0	a	0.00	0.00	0.00	0	T
	Work	42	-	-	-	-	-	-	-
	Work 5 m	28	0.0	a	0.00	0.00	0.00	0	T
	Work 10 m	28	-	-	-	-	-	-	-
	Work 20 m	28	0.1	a	0.26	0.05	0.10	0	1
	Undisturbed	42	0.0	a	0.00	0.00	0.00	0	T
Scat	Trench	42	0.3	a	1.75	0.27	0.54	0	11
	Storage	42	1.1	a	3.84	0.59	1.20	0	20
	Storage 5 m	42	1.1	a	4.91	0.76	1.53	0	30
	Storage 10 m	42	2.0	a	8.64	1.33	2.69	0	55
	Storage 20 m	42	0.7	a	2.51	0.39	0.78	0	15
	Work	42	3.2	a	13.64	2.11	4.25	0	80
	Work 5 m	28	0.0	a	0.19	0.04	0.07	0	1
	Work 10 m	28	0.8	a	2.90	0.55	1.12	0	15
	Work 20 m	28	0.6	a	1.70	0.32	0.66	0	8
	Undisturbed	42	3.5	a	11.25	1.74	3.51	0	60

Cover	Treatment	N	Mean	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Rock	Trench	42	0.0	a	0.00	0.00	0.00	0	T
	Storage	42	0.1	a	0.46	0.07	0.14	0	3
	Storage 5 m	42	0.2	a	0.86	0.13	0.27	0	4
	Storage 10 m	42	0.0	a	0.15	0.02	0.05	0	1
	Storage 20 m	42	0.2	a	1.23	0.19	0.38	0	8
	Work	42	0.0	a	0.15	0.02	0.05	0	1
	Work 5 m	28	-	-	-	-	-	-	-
	Work 10 m	28	0.0	a	0.00	0.00	0.00	0	T
	Work 20 m	28	0.0	a	0.00	0.00	0.00	0	T
	Undisturbed	42	0.0	a	0.00	0.00	0.00	0	T

Treatments within a cover type with the same letter are not significantly different, T = trace (< 1 % cover), - = not found

Table 3.11. Significance of Kruskal Wallace rank sum test of different cover types.

Cover (%)	N	H	P value
Live	378	66.8	≤0.001 *
Litter	378	25.3	0.00 *
Bare Ground	378	40.3	≤0.001 *
Lichen	378	39.7	≤0.001 *
Fungi	378	11.5	0.24
Scat	378	5.3	0.81
Rock	378	4.8	0.85

* Denotes significance of cover types across all sites and treatments

Table 3.12. Relationship between cover types, species richness, and the Shannon Wiener diversity index using Kendall's Tau (τ).

			Species Richness		Shannon Wiener Diversity Index	
Cover (%)	Treatment	N	τ	P value	τ	P value
Live	Trench	42	-0.08	0.51	-0.13	0.23
	Storage	42	0.06	0.60	-0.22	0.05
	Storage 5 m	42	0.11	0.34	0.07	0.50
	Storage 10 m	42	0.03	0.79	-0.02	0.84
	Storage 20 m	42	-0.04	0.76	-0.16	0.14
	Work	42	0.11	0.33	-0.05	0.63
	Work 5 m	28	0.45	0.00 *	0.27	0.05
	Work 10 m	28	0.13	0.37	0.13	0.33
	Work 20 m	28	0.05	0.73	-0.16	0.24
	Undisturbed	42	-0.05	0.69	-0.09	0.42
	Average	378	0.15	≤0.001 *	0.01	0.69
Litter	Trench	42	-0.11	0.33	-0.08	0.45
	Storage	42	0.12	0.29	0.33	0.002 *
	Storage 5 m	42	0.10	0.37	0.19	0.08
	Storage 10 m	42	-0.003	0.98	-0.001	0.99
	Storage 20 m	42	0.22	0.06	0.30	0.01 *
	Work	42	0.001	0.99	0.14	0.19
	Work 5 m	28	-0.12	0.41	0.02	0.87
	Work 10 m	28	0.07	0.64	0.09	0.53
	Work 20 m	28	-0.24	0.11	0.07	0.61
	Undisturbed	42	0.11	0.36	0.11	0.32
	Average	378	0.02	0.56	0.09	0.01 *
Bare Ground	Trench	42	0.19	0.11	0.16	0.13
	Storage	42	-0.24	0.05	-0.42	≤0.001 *
	Storage 5 m	42	-0.18	0.14	-0.26	0.02 *
	Storage 10 m	42	0.03	0.80	0.03	0.77
	Storage 20 m	42	-0.08	0.51	-0.20	0.08
	Work	42	0.16	0.18	0.12	0.30
	Work 5 m	28	-0.14	0.36	-0.25	0.07
	Work 10 m	28	0.06	0.68	-0.14	0.35
	Work 20 m	28	0.25	0.11	0.27	0.07
	Undisturbed	42	0.04	0.76	-0.06	0.60
	Average	378	-0.04	0.28	-0.08	0.02 *
Lichen	Trench	42	0.09	0.51	0.08	0.56
	Storage	42	-0.21	0.10	-0.17	0.17
	Storage 5 m	42	-0.25	0.05	-0.31	0.01 *
	Storage 10 m	42	-0.16	0.23	-0.17	0.16
	Storage 20 m	42	-0.12	0.36	-0.20	0.09
	Work	42	-0.14	0.31	-0.03	0.79
	Work 5 m	28	-0.20	0.19	-0.34	0.02 *
	Work 10 m	28	-0.06	0.68	-0.20	0.17
	Work 20 m	28	-0.06	0.70	-0.01	0.97
	Undisturbed	42	-0.32	0.01 *	-0.20	0.10
	Average	378	-0.09	0.04 *	-0.14	≤0.001 *

* denotes significance within category

IV. IMPACTS OF A PIPELINE RIGHT OF WAY ON NATIVE DRY MIXEDGRASS PRAIRIE WETLANDS

1. INTRODUCTION

The wetland region across the Canadian prairies is referred to as the prairie pothole or the northern prairie wetland region (van der Kamp and Hayashi 1998, van der Kamp and Hayashi 2008). Wetlands in this area are unique due to combinations of a semiarid yet cold climate and deposits left by retreating glaciers. Prairie potholes range from permanent to ephemeral, with years of drought resulting in low to no water levels (Stewart and Kantrud 1971, LaBaugh 1998, van der Kamp and Hayashi 1998, van der Kamp and Hayashi 2009).

Prairie wetlands cover approximately 1.1 million hectares, or 2 % of the Alberta landscape and perform a variety of functions (ESRD 2013, ESRD 2015). They improve water quality, store carbon, recharge ground water tables, mitigate the impacts of flooding, and support many flora and fauna (Euliss et al. 2006, ESRD 2013, ESRD 2015). The high productivity in wetlands leads to a disproportionally large number of faunal species relative to land mass that are dependent on wetlands for part of their life cycle (Bartzen et al. 2010). In Alberta approximately 400 species of plants are dependent upon wetlands (ESRD 2013).

Current disturbances on grasslands are predominately from linear fragmentation by pipelines, transportation networks, telecommunication lines, and petroleum activities (Alberta Environmental Protection 1997). The grasslands natural region contains approximately 74,629 well sites, each with access roads, accounting for an overall loss of 672 km^2 of prairie habitat. Other disturbances include roads and highways, urbanization, and agriculture (Alberta Environmental Protection 1997, Bailey et al. 2010). While low intensity disturbances can be beneficial to grasslands by maximizing diversity, large scale disturbances can have long term, detrimental effects (Collins and Barber 1985, Sampson and Knopf 1994, Alberta Environmental Protection 1997).

Pipelines have a number of benefits over other methods of transporting natural resources such as movement of high volumes of product, high security, and low energy costs (Xiao et al. 2014, Xiao et al. 2016). However, pipeline development significantly impacts native prairie ecosystems. During construction native vegetation and topsoil are removed, often facilitating introduction of non native species, which can fragment the landscape and disturb wildlife (Sousa 1984, Hobbs and Heunneke 1992, Smith and Knapp 1999, Craine et al. 2001, Sinton 2001, Neville 2002, Olsen and Doherty 2012, Xiao et al. 2014, Xiao et al. 2016). Pipelines can impact soil properties through processes such as topsoil and subsoil mixing (de Jong and Button 1973, Naeth 1985, Olsen and Doherty 2012, Shi et al. 2013, Xiao et al. 2014, Xiao et al. 2016). This can alter chemical composition, electrical conductivity, pH, salinity, soil water, texture, and light and temperature along the pipeline right of way (ROW) (de Jong and Button 1973, Naeth 1985, Ivey and McBride 1999, Shi et al. 2013). Through soil compaction bulk density is often increased across the ROW, in turn decreasing porosity and organic carbon relative to undisturbed prairie (Naeth et al. 1987, Batey and McKenzie 2006, Olsen and Doherty 2012).

Pipelines have potential to result in significant losses and impacts to wetlands (Noble et al. 2011). Some impacts that observed in disturbed prairie wetlands are changes in the plant community (Bartzen et al. 2010). Changes to vegetation, either through loss of native or addition of non native species can alter snow trapping potential in winter and evapotranspiration in summer (Conly and van der Kamp 2001, Bartzen et al. 2010). There are 421,000 km of pipelines within Alberta (Energy Resources Conservation Board 2015) therefore these effects are widespread across the province and can impact floral and faunal species of concern.

On a global scale, continental fresh water sources, such as wetlands, are often ignored when discussing the ecological functions of water, regardless of the growing evidence that highlights their importance (Downing et al. 2006). Prairie wetland research has increased due to historical loss and climate change projections (Conly and van der Kamp 2001, Foote and Rice Hornung 2005). Further research is required to preserve and better understand the role of wetlands on local and international landscapes as they relate to disturbances, such as pipelines.

2. RESEARCH OBJECTIVES

The objective of this research was to evaluate the impact of a six year old pipeline ROW on native dry mixedgrass prairie wetlands. Specific research objectives were as follows:

- To identify the wetland types on and off the ROW.
- To determine whether plant species richness, community composition, and diversity were impacted by location relative to a pipeline ROW .
- To determine whether ground cover (live, litter, bare ground, lichen, moss, fungi, scat, and rock) was impacted by location relative to a pipeline ROW.
- To determine whether water chemical properties were impacted by location relative to a pipeline ROW.

3. MATERIALS AND METHODS

3.1. Research Area Location And Description

The research area was located in southeastern Alberta in the dry mixedgrass subregion of the grassland natural region (Figure 3.1). It was approximately 20 km west of the Alberta Saskatchewan border, 150 km north of Medicine Hat, between the Red Deer and South Saskatchewan Rivers.

Topography of the research area consists of a few minor uplands, with elevations of 600 to 1,300 m (Alberta Environmental Protection 1997). Low relief moraines are the dominant landforms, with areas of hummocky moraines, eroded plains, glaciolacustrine lake deposits and sand plains, and glaciofluvial outwashes. There are few permanent streams; major waterways are well defined.

The climate is the warmest and driest in Alberta, with cold winters, warm summers, and low precipitation (Alberta Environmental Protection 1997, Adams et al. 2013, Environment Canada 2015). Due to high summer temperatures and wind speeds, there is a high rate of evaporation during summer, resulting in water deficits across the subregion. Mean annual temperature is 4 ^{o}C, 16 ^{o}C during the May to September growing season. The subregion has the highest number of growing degree days (mean temperature > 5 ^{o}C) in Alberta, averaging 1,700 over 30 years. Mean winter temperature is -7 ^{o}C. Total annual precipitation is 260 to 300 mm, with two thirds falling in spring, peaking in June. Summer precipitation in this subregion is the lowest in Alberta. Snowfall accounts for 19 % of annual precipitation. Chinooks are limited to the western edge.

Brown chernozem soils are dominant, with a 10 to 15 cm thick A horizon (Adams et al. 2013). Solonetzic soils are found in areas where sodium rich bedrock is at or near the soil surface, or in areas with saline and sodic ground water discharge. Regosolic soils are found in unstable locations, such as steep slopes, or in areas with young geologic materials. Gleysolic and vertisolic soils are limited. Major soil series in the area are Bingville (orthic brown chernozem), Cavendish (orthic brown chernozem), Purple Springs (orthic brown chernozem), Vendisant (rego brown chernozem), Chin (orthic brown chernozem), and Antelope (orthic regosol) (Adams et al. 2013, Alberta Agriculture and Forestry 2014).

Prairie wetlands often have communities dominated by *Typha* (cattail), *Scirpus* (bulrush), *Carex* (sedge), *Poa* (blue grass), and *Calamagrostis* (reed grass) species (ESRD 2015, Kantrud 1986). Rare vascular plants in this area include *Cryptantha minima* Rydb. (tiny cryptanthe), *Halimolobos virgata* (Nutt.) O.E. Schulz (slender mouse ear cress), *Tripterocalyx micranthus* (Torrey) Hooker (small flowered sand verbena), *Yucca glauca* Nutt. (soap weed), *Iris missouriensis* Nutt. (western blue flag), and *Tradescantia occidentalis* (Britton Smyth) (western spiderwort) (COSEWIC 2015).

3.2. TransCanada Pipeline Description

The TransCanada pipeline is 76.2 cm in diameter and 3,456 km long, transporting crude oil from Hardisty, Alberta to Cushing, Oklahoma, and Wood River and Panoka, Illinois (Nemirsky 2011, McNeely 2012, Nannt 2014). The pipe was buried with minimum cover of 1.2 m depending on land use. Construction and reclamation near research areas occurred February to May 2009.

The ROW at the research sites was 12 to 40 m at the time of construction (McNeely 2016). The TransCanada pipeline followed a 28 m wide Alberta Ethane Gathering System (AEGS) ROW. To reduce impact to rare species the pipeline ROW overlaps 4 m of the AEGS ROW at most sites. The pipeline was permitted to use an additional 7 m of AEGS ROW for subsoil and topsoil storage (Jacques Whitford AXYS Ltd. 2008). To prevent invasive plant introduction during construction, a cleaning station was established at site entries.

3.3. Site Selection

Prior to field exploration Google Earth imagery was used to select 153 wetland sites on and off ROW sites for potential study. On ROW sites were classified as within 50 m off the pipeline trench and off ROW sites were outside of this distance. This distance was based on previous research in which the impacts of pipeline construction and operation were not observed beyond 50 m (Nemirsky 2011, Nannt 2014). At the field site and upon consultation with TransCanada pipeline inspectors, a number of sites were removed from the list due to factors such as site access or incorrect initial selection. Wetland assessment sites were finalized after in situ examination and accessibility and distance to pipeline. Distance to pipeline was measured from the leading edge of the wetland closest to the ROW. From the initial list, eight on ROW wetlands were suitable for assessment. Thus nine off ROW were selected for comparison.

All selected wetland sites were mineral wetlands, of the marsh form. The innermost zone is comprised of > 25 % graminoid species. The water level is at, or near the ground surface for the majority of the growing season. There was very little shrub cover at any site (< 25 %) although some sites had an outer shrub ring consisting of predominately *Symphoricarpos occidentalis*

Hook (buckbrush) and *Rosa* (rose) species. Wetland classes included temporary freshwater marshes (7), temporary slightly brackish marshes (2), seasonal freshwater marshes (4), and seasonal slightly brackish marshes (4).

3.3. Research Site Location And Description

Research sites were established along the TransCanada pipeline ROW between Oyen and Bindloss, Alberta (Table 4.1). All sites were located on native prairie on rolling topography and all of the research sites had evidence of cattle grazing. ROW footprints contained topsoil storage and seeded areas.

3.4. Wetland Assessments

Wetland assessments were conducted July 11 to 17, 2015 at all 17 sites. This corresponded with the maturation of many prairie species, facilitating accurate identification. Species were identified and classified as native or non native according to Moss (1994), Tannas (2003), and Tannas (2004). Maximum time spent at each site was 2 hours. Vegetation was assessed using a time bounded floristic habitat sampling method (Locky and Bayley 2006). This involved ranking plant cover on a 4 point scale, where 1 is rare (< 1 % cover), 2 is few (~ 2-10 % cover), 3 is common (~ 11-74 % cover), and 4 is abundant (~ 75-100 % cover).

At each wetland site, vegetation zones were classified by assessing dominant vegetation type cover and assigning them a category based on Stewart and Kantrud (1971) and the Alberta Wetland Classification System (ESRD 2015). All species in that zone were recorded and assigned a plant cover code; total species composition was therefore recorded with the plant cover code for each site. Wetlands were further classified by assessing dominant plant species cover present in each vegetation zone and a wetland class was assigned to each site according to Stewart and Kantrud (1971) and the Alberta Wetland Classification System (ESRD 2015). All ecological communities and species found on site were checked for their commonness rarity rating. All of the wetland communities were assessed for rarity (Allen 2012) (Table 4.2) and all of the plant species were checked for provincial rarity status, S1-S5 according to Alberta Environment and Parks (2015).

Ocular percentage cover of live vegetation, litter, bare ground, rocks, manure, lichen, fungi, and moss were determined. The distance to pipeline trench was measured from the leading edge of the wetland closest to the pipeline using a 100 m measuring tape.

3.5. Ground Water Sampling

Ground water sampling was not possible due to the drought in southern Alberta during the 2015 assessment period. At two wetland sites, water wells were dug to approximately 1 m and left for 4 to 6 hours to fill from the water table. No water was observed in either well following that time period, therefore wells were not dug and water sampling was not conducted at the other sites.

3.6. Statistical Analyses

Statistical analyses were conducted using R version 3.2.2 (R Core Team 2015) and Microsoft Excel. Mean, standard deviation, standard error, and 95 % confidence intervals were calculated for species richness, the Shannon Wiener diversity index (H), cover type, and distance to pipeline trench. Normality was checked using Shapiro-Wilks normality test (Logan 2010, Shapiro and Wilks 1965). Data were not normally distributed except for species diversity.

To determine site specific (on ROW, off ROW) differences, the non parametric Kruskal Wallace rank sum test was used to compare species richness and H with wetland class and individual sites (Logan 2010). To determine degree of similarity of total species, native species, non native species, class II, and class III wetlands between on and off ROW sites, Sørenson's coefficients of community similarity were calculated. Cover type and species richness differences were tested using Kruskal Wallace rank sum test. When significant post hoc comparisons were done using Kruskal Wallace test with a Bonferroni correction.

To calculate H, plant cover codes were converted to percentages from code mid ranges. Conversions were 1 to 0.01 %, 1.5 to 3 %, 2 to 6 %, 2.5 to 25 %, 3 to 43 %, 3.5 to 66 %, and 4 to 88 %. Differences in H were tested using ANOVA and post hoc comparisons were conducted with the Tukey test (Tukey 1953). Spearman's rank correlation coefficient (ρ) was used to compare the distance to pipeline trench with species richness and H (Logan 2010).

4. RESULTS

4.1. Wetland Types

Selected wetland sites were mineral wetlands, of the marsh form. The innermost zone was > 25 % graminoids. Six temporary freshwater marshes (II A), one seasonal freshwater marsh (III A), and two seasonal slightly brackish marshes (III B) were off ROW (Table 4.3). One temporary freshwater marsh (II A), two temporary slightly brackish marshes (II B), three seasonal freshwater marshes (III A), and two seasonal slightly brackish marshes (III B) were on ROW. No rare wetland ecological communities or S2 or lower ranked species were on or off ROW.

4.1.1. Temporary freshwater marsh II A

Temporary freshwater marshes II A were characterized by a wet meadow plant zone in the deepest part of the basin and a low prairie plant zone around the periphery. Some characteristic species of this wetland type included *Carex lanuginosa* Michx (wooly sedge), *Carex praegracilis* W. Bott (graceful sedge), *Poa palustris* L. (fowl bluegrass), *Galium trifidum* L. (small bedstraw), *Mentha arvensis* L. (wild mint), and *Hordeum jubatum* L. (foxtail barley).

4.1.2. Seasonal freshwater marsh III A

Seasonal freshwater marshes III A were characterized by a shallow wetland plant zone in the deepest part of the basin, an adjacent wet meadow zone, and a low prairie plant zone around the periphery. Some characteristic species were *Carex atherodes* Spreng. (awned sedge), *Carex aquatilis* (Rydb.) Hult. (water sedge), *Beckmannia syzigachne* (Steud.) Fern (slough grass), *Polygonum coccineum* Muhl. (water smartweed), and *Hordeum jubatum*.

4.1.3. Temporary slightly brackish marsh II B

Temporary slightly brackish marshes II B were characterized by a wet meadow plant zone in the deepest part of the basin and a low prairie plant zone around the periphery. Some characteristic species of this wetland type included *Hordeum jubatum*, *Juncus balticus* Willd. (wire rush), *Mentha arvensis*, *Carex lanuginosa*, and *Carex praegracilis*.

4.1.4. Seasonal slightly brackish marsh III B

Seasonal slightly brackish marshes III B had a shallow wetland plant zone in the deepest part of the basin, a wet meadow plant zone adjacent to the wetland plant zone, and a low prairie plant zone around the periphery. Some characteristic species of this wetland type were *Beckmannia syzigachne*, *Eleocharis palustris* (L.) R. & S. (creeping spike rush), *Carex atherodes*, *Polygonum coccineum*, *Polygonum amphibium* L. (water smartweed), and *Hordeum jubatum.*

4.2. Species Richness

A total of 109 species were found across the sites, 94 off ROW, and 99 on ROW. Species richness of wetland types varied on and off the pipeline ROW (Table 4.4) Highest species richness was found at seasonal freshwater wetlands on the pipeline ROW (90 species); lowest species richness was found at temporary fresh water wetlands on the pipeline ROW (32 species). Species richness varied little on and off the pipeline ROW (Table 4.5), with no site or wetland class specific relationships. Off ROW mean species richness was 22.5 and on ROW mean species richness was 25.2. Off ROW mean native species richness was 16.7 and on ROW mean native species richness was 18.5 (Table 4.6). Off ROW mean non native species richness was 5.8 and on ROW mean non native species richness was 6.7. There were no significant differences in species richness on and off the pipeline ROW for native, non native, and all species combined (Tables 4.5, 4.6).

4.3. Shannon Wiener Diversity Index

The Shannon Wiener diversity index varied little on and off the pipeline ROW (Table 4.7). No site or wetland class specific relationships were found for diversity. Off ROW mean diversity was 2.6 and on ROW mean diversity was 2.7. Off ROW mean native diversity was 2.3 and on ROW mean native diversity was 2.4 (Table 4.8). Off ROW mean non native diversity was 1.2 and on ROW mean non native diversity was 1.5. There were no significant differences in diversity on and off ROW for native, non native, and all species combined (Tables 4.7, 4.8).

4.4. Species Composition

Two listed noxious weed species were found on the sites, *Cirsium arvense* (L.) Scop. (Canada thistle) and *Sonchus arvensis* L. (perennial sow thistle). The most widely found non native species present on the sites were *Hordeum jubatum* L. (foxtail barley), *Chenopodium album* L. (lamb's quarters), *Crepis tectorum* L. (annual hawksbearb), and *Rumex crispus* L. (curled dock) (Tables 4.9, 4.10).

Agropyron dasystachyum (Hook.) Scribn. (northern wheat grass), *Agrostis scabra* Willd. (tickle grass), *Agropyron smithii* Rydb. (western wheat grass), *Calamagrostis montanensis* Scribn. ex. Vasey (plains reed grass), *Carex brevior* (Dewey) Mack. (brevior sedge), and *Eleocharis palustris* (L.) R. & S. (creeping spike rush) were the most common graminoid species found across all wetland types on and off the pipeline ROW (Table 4.11). *Achillea milefolium* L. (common yarrow), *Artemisia ludoviciana* Nutt. (prairie sagewort), *Mentha arvensis* L. (wild mint), *Potentilla arguta* Pursh (white cinquefoil), and *Potentilla hippiana* Lehm. (wooly cinquefoil) were the most common native forb species found across all wetland types on and off the pipeline ROW (Table 4.12).

The Sørenson coefficients of similarity provided an indication that there was greater variation between broad wetland classes (class II and class III) than there was between the total native and non native species composition (Table 4.13). Plant communities were similar overall on and off the pipeline ROW.

4.5. Ground Cover

Ground cover was consistent on and off ROW (Table 4.14). Live vegetation was dominant at all sites and on and off ROW, followed by litter, bare ground, and scat. Fungi, moss, and rock cover were found in trace amounts. No significant differences were found in cover type on and off ROW (Table 4.15). There was no relationship between either species richness or diversity and live, litter, and bare ground cover (Table 4.16).

4.6. Distance From Pipeline

Mean distance of off ROW sites was 134.39 m and on ROW sites was 11.70 m (Table 4.17). Four study sites were located over the pipeline trench. There was no relationship between the distance to pipeline trench and either species richness or diversity (Table 4.18).

5. DISCUSSION

5.1. Species Richness, Diversity, Similarity, Ground Cover, And Distance To Pipeline Trench

The lack of significant results within and between species richness, diversity, similarity, ground cover, and distance to pipeline trench on and off ROW is representative of the overall community and consistency of wetland communities in the area. High ecosystem diversity, number of plant species and relative abundance, have been connected to shorter recovery times following various disturbances (Tillman and Downing 1994). Wetland recovery following drought is a function of increasing plant species richness. This relationship could be extended to other disturbances that would affect the plant community, such as pipeline ROWs. Sites with higher overall richness might show a shorter recovery time from pipeline construction. The similarity between species richness and diversity on and off ROW may be indicative of this.

Following seven growing seasons, wetlands on ROW no longer showed impacts of disturbance. All sites had high species numbers and diversity indicative of diverse plant communities. The lack of relationship between distance to the pipeline trench and species richness and diversity further supports this idea. Increasing stress of linear disturbances on wetlands (Noble et al. 2011) appears to decrease if the plant community diversity is high enough and they have sufficient time to recover. Following seven growing seasons, the impacts of a pipeline ROW are not longer observed on wetland sites on and off the ROW at the scale that was assessed.

5.2. Plant Community Species Composition

Prairie mineral wetlands have communities dominated by *Typha* (cattail), Scirpus (bulrush), *Carex* (sedge), Poa (bluegrass), and *Calamagrostis* (reedgrass) species (Kantrud 1986, ESRD 2015). Many characteristic *Carex* species were found on and off ROW such as *Carex lanuginosa* Michx (wooly sedge) and *Carex praegracilis* W. Bott (graceful sedge). Due to the classification of all wetlands as temporary or seasonal, more aquatic dependent species such as *Typha* and *Scirpus* were not widely observed, if at all. This is likely more representative of the specific wetland type rather than a vegetation community altered by the pipeline ROW. No rare wetland types were found. However, since it is not known if rare wetland types were present prior to pipeline construction, it cannot be determined if the pipeline negatively impacted them. No rare species were found across wetland types; the wetlands were composed of secure native and non native species overall. The consistency between similarity on and off ROW suggest there is limited variation between the plant communities.

5.3. Field Observations And Interpretations

Temporary and seasonal wetlands experience a high degree of water fluctuation, which can result in slow recovery from disturbances (ESRD 2015, ESRD 2013, Adams et al. 2013, Bartzen et al. 2010, Conly and van der Kamp 2001, Shay and Shay 1986). Changes in water levels, such as observed during a natural drawdown phase affect the plant community of wetlands (Lieffers 1983). This fluctuation was observed at all wetland sites. There was no water at any wetland sites even after water pits were dug and left for four to six hours. A drought occurred during the 2015 growing season. Mean ten year accumulated precipitation from April 1 to July 31 is 176 mm (Alberta Agriculture and Forestry 2016). During the 2015 growing season, precipitation during the same period was 87 mm. The lower precipitation was likely the reason for the lack of accessible ground water. Drought conditions were observed on the landscape, with much of the upland vegetation desiccated, and wetland areas, regardless of the lack of standing water, the only green spots on the landscape. The ability of wetlands to hold water for longer periods relative to upland sites ((ESRD 2015, ESRD 2013) may have facilitated vegetation in those areas to persist in drought conditions.

Water fluctuation in temporary and seasonal wetlands can strongly affect the plant community and productivity, making those types of wetlands more susceptible to anthropogenic disturbance (Johnson et al. 2004, Bartzen et al. 2010). Recovery of wetlands after disturbance can be attributed to various factors including land use, climate impacts, wetland characteristics, and landscape structure. Observed impacts at all sites, besides the pipeline, such as grazing, may hinder recovery of the desired native plant community. Dry mixedgrass ecosystems are typically resistant to the impacts of grazing, however, non native species are often found in areas with high water content and protection from grazing (Blumenthal et al. 2010). High impacts of grazing were noted in areas with no exclusion. At fenced ROW areas, grazing reduced vegetation nearly down to the ground level off ROW, with fenced on ROW vegetation larger and fully matured. Effects of grazing on prairie wetlands is not well understood (Foote and Rice Hornung 2005). Cattle selectively eat emergent wetland vegetation such as *Typha latifolia* L. (common cattail).*Typha latifolia* was present at one site located on ROW. Field observations noted a large amount of grazing on *Typha latifolia*, and across the wetland. Grazing was so extensive that no seed heads were observed.

Restored wetlands in the southern prairie pothole region had fewer floral and faunal species relative to natural ones (Galatsowitch and van der Valk 1996a). Prior to the mid to late 1990s, techniques for restoring wetlands in the United States involved little planning, as it was assumed hydrologic functions were easily recreated through simple construction methods, hydrophytic plants would rapidly colonize the new wetland, and faunal species would immediately begin to utilize the environment (Galatowitsch and van der Valk 1996a, Galatowitsch and van der Valk 1996b). However, many restored sites fail hydrologically and fail to provide habitat for faunal species. Natural wetlands can have higher species diversity than reflooded, restored wetlands (Galatowitsch and van der Valk 1996c). Low diversity in disturbed wetlands has been attributed to propagules failing to reach the disturbance or inappropriate conditions that do not allow for vegetation reestablishment. The approach for recovery of disturbed wetlands work towards restored biodiversity and ecological functions (Zedler 2000). In this regard the disturbed study sites on the pipeline ROW appear to have returned to a native biodiversity level with similar species composition across sites on and off the ROW. The trajectory that the disturbed wetlands were placed on following pipeline ROW creation has been sufficient in restoring the plant community to native levels.

6. CONCLUSIONS

Wetland vegetation communities on and off a pipeline ROW were not affected by the pipeline ROW six years after construction. All wetland sites were marshes, and four types, II A, II B, III A, and III B, were sampled. Species composition, richness, similarity, diversity, and ground cover types were consistent across sites individually, in separate wetland classes, and on and off the pipeline ROW. Live cover was dominant at all sites, followed by litter, bare ground and scat. Fungi, moss, and rock cover were found in trace amounts. Native species were more dominant than non native species at all sites. *Cirsium arvense* and *Sonchus arvensis* were the only noxious species found on site. No rare species or rare wetland ecosystems were found. There were no relationships between either species richness or diversity and distance to pipeline trench. Impacts of grazing and drought were observed across the research area, and may have impacted the plant community more directly than the pipeline ROW.

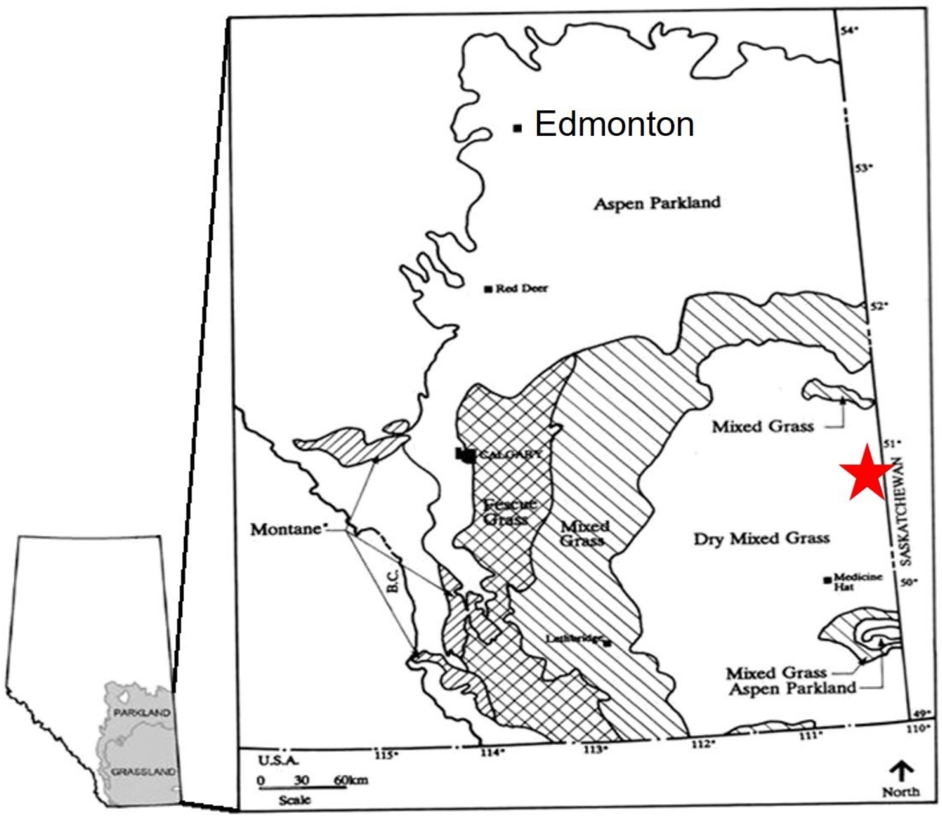

Figure 4.1. General location of study sites in southern Alberta denoted by the red star. Adapted from Kerr et al. 1993.

Table 4.1. Wetland research site descriptions.

Site	Location	Public / Private Land	Reclamation Technique	Fenced ROW	ROW Footprint (m)	Distance To Pipeline Trench (m)
Off ROW 1	• SE 29-27-4-W4 • east of highway 45 • north of seconday 274	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	n/a	40	107.4
Off ROW 2	• SE 29-27-4-W4 • east of highway 45 • north of seconday 274	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	n/a	40	74.8
Off ROW 3	• NE 8-27-4-W4 • west of highway 44 • south of secondary 272	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	n/a	40	119.8
Off ROW 4	• NE 8-27-4-W4 • west of highway 44 • south of secondary 272	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	n/a	40	175.2
Off ROW 5	• SE 29-25-4-W4 • east of highway 45 • north of secondary 254	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	n/a	40	99.9
Off ROW 6	• NW 34-22-4-W4 • west of township road 23-2A	Public	• native seed mix • straw soil stabilization	n/a	12	215.7
Off ROW 7	• NW 34-22-4-W4 • west of township road 23-2A	Private	• native seed mix • straw soil stabilization	n/a	12	107.4
Off ROW 8	• SW 34-22-4-W4 • east of township road 23-2A	Private	• native seed mix • straw soil stabilization	n/a	40	132.5
Off ROW 9	• SW 34-22-4-W4 • east of township road 23-2A	Public	• native seed mix • straw soil stabilization	n/a	40	176.8

Site	Location	Public / Private Land	Reclamation Technique	Fenced ROW	ROW Footprint (m)	Distance To Pipeline Trench (m)
On ROW 1	• SE 29-25-4-W4 • east of highway 45 • north of secondary 254	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	No	40	32.8
On ROW 2	• SE 29-25-4-W4 • east of highway 45 • north of secondary 254	Public	• native seed mix • oat cover crop • wetlands, 5 m topsoil striped • remaining area, 27 m topsoil stripped	No	40	0
On ROW 3	• SW 15-23-4-W4 • west of Highway 41 • south of secondary 232	Public	• native seed mix • straw soil stabilization	Yes	12	17.4
On ROW 4	• NW 10-23-4-W4 • west of Highway 41 • south of secondary 232	Public	• native seed mix • straw soil stabilization	Yes	12	0
On ROW 5	• NW 10-23-4-W4 • west of Highway 41 • south of secondary 232	Public	• native seed mix • straw soil stabilization	No	12	15.7
On ROW 6	• SW 3-23-4-W4 • west of township road 23-2A	Public	• native seed mix • straw soil stabilization	No	12	27.7
On ROW 7	• NW 34-22-4-W4 • west of township road 23-2A	Public	• native seed mix • straw soil stabilization	Yes	12	0
On ROW 8	• SW 34-22-4-W4 • east of township road 23-2A	Private	• native seed mix • straw soil stabilization	Yes	40	0

Table 4.2. Rare Alberta wetland plant communities in the dry mixedgrass subregion.

Community	Alberta Rank	Characteristics
Ruppia cirrhosa	S1	• Grassland and parkland aquatic community, endemic to the glaciated portion of the great plains • Documented in the mixedgrass and central parkland subregions • Characteristic of hypersaline ponds • These types of ponds usually have an unvegetated shore due to their strongly saline nature
Distichlis stricta - Pascopyrum smithii	S2	• In grassland and parkland natural regions of eastern Alberta • Associated with saline soils, usually at drier edge of saline wetlands • Transition between driest portion of halophytic and adjacent semi halophytic communities • *Distichlis stricta* and *Pascopyrum smithii* dominate community • Numerous associated upland species including *Aster ericoides* and *Grindelia squarrosa*
Salicornia rubra emergent marsh	S2	• Hyper saline marsh of grassland, parkland, and boreal natural regions where minerals accumulate due to evaporative drying • Specific habitat needs; ranked G2G3 • Associated with highly alkali wetlands, semi permanent alkali lakes, exposed mud of alkali flats • Often forms ring or patch near centre of saline depression, typically at nonvegetated mudflat edge • Dependent on hydrological processes; seasonal inundation, evaporative dry down, mineral accumulation, resulting in extreme salinity few species can tolerate • Principle salts are sulphates and chlorides of sodium and magnesium • *Salicornia* is frequent in saline areas of dark brown soils zone; less common in black and brown soil zones of Alberta on silt loam to clay soils • Sparsely vegetated community, typically a pure band of *Salicornia* of 25 % or less basal cover with up to 95 % unvegetated silt loam or clay flats • Associated species may include *Puccinellia nuttalliana, Distichlis stricta, Hordeum jubatum, Triglochin maritima, Chenopodium rubrum* and *Suaeda erecta* • This community often grades into graminoids on the upslope side, commonly *Puccinellia nuttalliana*, *Distichlis stricta* community on coarse textured soils • *Salicornia rubra* community is a small patch community, often forming a ring or patch near the centre of saline depressions

Community	Alberta Rank	Characteristics
Triglochin maritime emergent marsh	S2	• Grassland and parkland saline emergent marsh associated with saline seeps and wetlands • Documented only in the central parkland, but likely occurs grassland subregions including the dry mixedgrass and northern fescue • Typically near centre of saline depressions as a part of vegetation around shallow wetlands • Often subject to extreme fluctuations in water level • Occurs on wetter sites with fine sand to sandy clay soils that are saline and intermittently flooded • Forms a pure band of *Triglochin maritima*, usually with less than 20% cover • Basal cover of *Triglochin* varies from 5 to 15 %, with densest stands associated with coarsest soils • *Puccinellia nuttalliana* is the principle associated species but only occurs in half the stands
Scirpus nevadensis - Triglochin maritime	S2S3	• Saline emergent marsh documented in the central parkland natural subregion, and expected to occur in dry mixedgrass and northern fescue subregions • Associated with wetlands that are often subject to extreme fluctuations in water level • Community appears to be restricted to sandy shores of saline to hypersaline wetlands • *Scirpus nevadensis* usually dominant, with very open growth, often only species in the community • *Triglochin maritima* a frequent associate and may be co dominant in some stands • *Distichlis stricta* may occur on dryer edge of community; or *Puccinellia nuttalliana* on wetter side • May border or occur in patches with a *Suaeda calceoliformis* community on strongly alkali sites, often in a band above an unvegetated alkali shore
Spartina gracilis - Pascopyrum smithii	S2S3	• Saline dry meadow of the central parkland natural subregion • May occur in the dry mixedgrass and northern fescue subregions • Typically found on open sandy sites; may be associated with slightly alkaline seepage springs • Associated with wetlands that are often subject to extreme fluctuations in water level and may become dry basins during drought years • Marks upper zone of the halophytic communities; leading to semi halophytic communities upslope

Adapted from Allen 2012

Table 4.3. Wetland types on and off the ROW.

Marsh Wetland Types	Sites
Temporary Freshwater II A	Off ROW 1 Off ROW 2 Off ROW 4 Off ROW 5 Off ROW 8 Off ROW 9 On ROW 8
Temporary Slightly Brackish II B	On ROW 5 On ROW 6
Seasonal Freshwater III A	Off ROW 3 On ROW 2 On ROW 3 On ROW 7
Seasonal Slightly Brackish III B	Off ROW 6 Off ROW 7 On ROW 1 On ROW 4

Table 4.4. Total species richness on and off a pipeline right of way by wetland class.

	Marsh Wetland Class			
	II A	II B	III A	III B
Off ROW	80 (6)	-	51 (1)	55 (2)
On ROW	32 (1)	40 (2)	90 (3)	64 (2)

n is in brackets

Table 4.5. Descriptive statistics and significance of species richness using Kruskal Wallace evaluations.

	N	Mean Species Richness	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Number	Maximum Species Number
Off ROW	21	22.5	a	9.54	2.08	4.34	10	39
On ROW	22	25.2	a	12.20	2.60	5.41	7	43

Treatments with the same letter are not significantly different

Table 4.6. Descriptive statistics and significance of native and non native species richness using Kruskal Wallace evaluations.

		N	Mean Species Richness	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Number	Maximum Species Number
Native	Off ROW	21	16.7	a	7.80	1.70	3.55	5	29
	On ROW	22	18.5	a	9.38	2.00	4.16	5	32
Non Native	Off ROW	21	5.8	a	2.71	0.59	1.24	0	10
	On ROW	22	6.7	a	3.11	0.66	1.38	2	12

Treatments with the same letter are not significantly different

Table 4.7. Descriptive statistics and significance of the Shannon Wiener diversity index using Tukey test evaluations.

	N	Mean Species Diversity	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Diversity	Maximum Species Diversity
Off ROW	21	2.6	a	0.47	0.10	0.21	1.66	3.34
On ROW	22	2.7	a	0.67	0.14	0.30	1.24	3.54

Treatments with the same letter are not significantly different

Table 4.8. Descriptive statistics and significance of native and non native Shannon Wiener diversity index using Tukey test evaluations.

		N	Mean Species Diversity	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum Species Diversity	Maximum Species Diversity
Native	Off ROW	21	2.3	a	0.51	0.11	0.23	1.25	3.04
	On ROW	22	2.4	a	0.73	0.16	0.32	0.76	3.26
Non Native	Off ROW	21	1.2	a	0.48	0.10	0.22	0.00	1.99
	On ROW	22	1.5	a	0.63	0.13	0.28	0.01	2.34

Treatments with the same letter are not significantly different

Table 4.9. Non native graminoid species on and off a pipeline right of way by wetland class in 2014.

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Agropyron cristatum	-	-	-	-	-	2.0 *	-
Bromus inermis	2.0 *	3.0 (0.0)	3.0 *	-	2.0 *	3.2 (0.3)	3.2 (0.3)
Hordeum jubatum	2.9 (0.5)	2.7 (0.6)	2.6 (1.1)	2.5 *	2.6 (0.6)	2.9 (0.6)	3.0 (0.6)
Lolium persicum	2.0 *	2.0 *	-	-	-	2.0 *	2.0 *
Phleum pratense	2.5 (0.7)	2.0 *	1.5 (0.7)	3.0 *	-	1.5 (07)	2.0 *
Poa pratensis	3.0 *	3.0 *	-	-	-	-	-

Numbers are mean plant cover code with standard deviations in brackets
II A = temporary freshwater marsh, II B = temporary slightly brackish marsh, III A = seasonal freshwater marsh, III B = seasonal slightly brackish marsh
- = no presence detected
* n = 1

Table 4.10. Non native forb species on and off a pipeline right of way by wetland class in 2014.

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Capsella bursa-pastoris	-	-	-	3.5 (0.7)	-	-	-
Chenopodium album	2.2 (0.4)	1.0 *	2.5 (0.5)	3.5 (0.7)	2.7 (0.6)	2.4 (0.7)	2.0 (0.0)
Cichorium intybus	2.0 *	-	2.0 *	-	-	3.0 (0.0)	2.5 (0.7)
Cirsium arvense **	1.5 (0.7)	2.0 *	1.0 *	3.0 *	-	2.0 (0.8)	3.0 (0.0)
Conium maculatum	-	-	-	-	-	1.0 *	2.5 (0.7)
Crepis tectorum	2.3 (0.6)	3.0 *	2.3 (1.2)	2.5 (0.7)	3.0 (0.0)	2.8 (0.9)	3.2 (0.3)
Descurainia sophia	2.0 (0.0)	-	2.0 (0.8)	3.5 *	3.0 *	3.2 (0.3)	2.0 *
Erysimum cheiranthoides	2.2 (0.4)	1.7 (0.6)	-	3.0 (0.0)	-	2.5 (0.7)	2.3 (0.6)
Kochia scoparia	1.0 *	-	-	-	-	-	-
Medicago sativa	1.0 *	-	1.0 *	-	-	1.0 *	2.0 *
Melilotus albus	-	-	-	-	-	2.0 (0.0)	1.0 *
Polygonum persicaria	2.0 *	1.0 *	-	-	-	-	-
Rumex crispus	2.2 (0.6)	2.0 (0.0)	2.7 (0.5)	3.0 (0.0)	2.0 (1.0)	2.8 (0.4)	2.5 (0.8)
Sonchus arvensis **	2.7 (0.6)	-	2.4 (0.5)	3.5 (0.7)	3.0 (0.0)	3.0 (0.0)	3.3 (0.4)
Sonchus uliginosus	-	-	2.0 *	-	-	2.7 (0.6)	-
Taraxacum officinale	2.0 (0.7)	-	2.0 *	3.0 (0.0)	3.0 *	2.5 (0.5)	3.2 (0.3)
Thlaspi arvense	3.0 *	-	2.5 (0.7)	3.3 (0.4)	-	-	-
Tragopogon dubius	2.0 (0.7)	2.0 (0.0)	2.0 *	3.0 (0.0)	-	2.0 (0.0)	1.9 (1.2)

Numbers are mean plant cover code with standard deviations in brackets
II A = temporary freshwater marsh, II B = temporary slightly brackish marsh, III A = seasonal freshwater marsh, III B = seasonal slightly brackish marsh
- = no presence detected
* n = 1, ** noxious weed

Table 4.11. Native graminoid species on and off a pipeline right of way by wetland class in 2014.

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Agropyron dasystachyum	3.0 (0.0)	2.0 *	3.0 (0.0)	3.0 *	3.0 *	2.7 (0.6)	3.0 (0.0)
Agrostis scabra	2.4 (0.5)	3.0 (0.0)	2.8 (0.8)	3.0 (0.0)	2.7 (0.6)	2.7 (0.9)	2.7 (0.5)
Agropyron smithii	3.0 (0.0)	2.5 (0.7)	3.0 (0.0)	2.5 (0.7)	3.0 (0.0)	3.0 (0.0)	2.7 (0.6)
Agropyron species	3.0 *	-	-	-	-	2.0 (0.0)	3.0 (0.0)
Agropyron trachycaulum	2.7 (0.6)	3.0 *	-	3.0 *	-	3.0 *	3.0 *
Beckmannia syzigachne	2.8 (0.5)	-	-	-	2.0 (0.0)	2.2 (0.8)	2.0 (1.4)
Bouteloua gracilis	-	3.0 *	-	-	-	2.0 *	-
Calamagrostis montanensis	2.4 (0.5)	2.5 (0.7)	1.0 *	3.0 (0.0)	2.0 *	3.0 (0.0)	2.9 (0.6)
Carex aquatilis	-	3.0 *	-	2.0 *	-	-	-
Carex atherodes	2.5 (0.7)	2.0 *	3.0 *	2.0 *	-	3.0 *	3.0 *
Carex aurea	2.0 (0.0)	-	2.5 (0.9)	3.3 (0.4)	-	2.7 (0.6)	2.5 (0.7)
Carex brevior	2.7 (0.7)	2.5 (0.7)	2.7 (0.6)	3.0 (0.0)	3.0 *	2.5 (1.2)	3.3 (0.4)
Carex lanuginosa	2.8 (0.8)	3.0 (1.4)	2.0 *	2.3 (1.8)	-	3.0 (0.8)	3.3 (0.3)
Carex praegracilis	3.0 (0.0)	-	-	3.0 *	-	3.0 (0.0)	-
Carex species	-	-	-	-	2.0 *	-	-
Eleocharis palustris	2.9 (0.7)	-	2.8 (1.6)	3.0 *	3.2 (1.0)	3.1 (0.7)	3.5 (0.7)
Festuca hallii	3.3 (0.4)	3.0 *	-	-	-	3.5 *	3.5 (0.7)
Juncus balticu	3.0 *	-	-	-	2.0 *	-	-
Oryzopsis hymenoides	2.8 (0.5)	2.5 (0.7)	-	-	2.7 (0.6)	2.8 (0.8)	2.7 (0.6)
Poa palustris	2.0 (0.0)	-	-	-	-	3.0 *	-
Stipa comata	2.8 (0.5)	3.0 *	-	-	3.0 *	2.3 (0.5)	3.0 (0.0)
Stipa viridula	2.0 *	3.0 *	-	-	-	-	2.0 *
Typha latifolia	-	-	-	-	-	2.5 (0.7)	-

Numbers are mean plant cover code with standard deviations in brackets
II A = temporary freshwater marsh, II B = temporary slightly brackish marsh, III A = seasonal freshwater marsh, III B = seasonal slightly brackish marsh
- = no presence detected
* n = 1

Table 4.12. Native forb, shrub, and non vascular species on and off a pipeline right of way by wetland class in 2014.

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Achillea milefolium	2.8 (0.4)	3.0 (0.0)	2.5 (0.6)	2.5 (0.7)	2.5 (0.7)	2.6 (0.5)	2.8 (0.4)
Agoseris glauca	3.0 (0.0)	-	3.0 (0.0)	2.5 (0.7)	2.5 (0.7)	2.7 (0.6)	3.0 *
Amelanchier alnifolia	1.0 *	-	-	-	-	-	-
Ambrosia artemisiifolia	2.8 (0.5)	-	3.0 (0.0)	3.5 (0.7)	2.9 (0.6)	2.8 (0.5)	3.0 (0.0)
Antennaria parvifolia	-	-	-	-	-	1.0 *	-
Arabis glabra	1.8 (0.5)	2.0 *	1.8 (0.5)	2.0 *	-	2.0 *	2.5 (0.7)
Arabis species	-	-	-	-	-	-	2.0 *
Arnica chamissonis	1.5 (0.7)	-	-	-	3.0 *	2.0 *	-
Arnica species	-	-	-	-	-	-	2.0 *
Artemisia cana	-	2.0 *	-	-	-	2.0 *	2.0 (0.0)
Artemisia frigida	2.0 (1.4)	3.0 *	-	2.0 *	2.0 *	2.0 (1.4)	-
Artemisia ludoviciana	2.8 (0.7)	3.0 (0.0)	3.0 (0.0)	3.0 (0.0)	3.0 (0.0)	2.7 (0.7)	3.0 (0.0)
Aster species	-	-	-	-	-	1.0 *	-
Astragalus canadensis	-	-	-	-	-	-	2.8 (0.8)
Atriplex argentea	2.5 (0.7)	-	2.3 (0.5)	-	-	-	-
Campanula rotundifolia	2.3 (1.0)	-	2.0 (1.0)	3.0 (0.0)	2.0 (0.0)	3.0 (0.0)	2.0 (0.0)
Cirsium undulatum	1.0 *	-	1.0 *	2.0 *	-	2.0 *	3.0 *
Collomia linearis	3.0 (0.0)	-	2.0 (0.0)	-	-	3.0 *	-
Elaeagnus commutata	1.0 *	-	-	-	-	-	-
Epilobium angustifolium	-	2.0 *	-	-	-	-	-
Epilobium paniculatum	2.7 (0.6)	-	2.0 (0.0)	-	2.0 *	2.8 (0.5)	3.0 *
Erigeron caespitosus	2.2 (0.4)	-	1.3 (0.6)	2.5 (0.7)	2.5 (0.7)	2.5 (0.6)	2.5 (0.7)
Erysimum inconspicuum	-	2.0 *	-	2.0 *	-	-	3.0 *
Forb species	1.5 (0.7)	-	-	-	-	1.5 (0.7)	2.0 *
Gaillardia aristata	1.5 (0.7)	1.0 *	2.0 *	2.0 *	2.0 *	2.0 *	2.5 (0.7)

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Galium trifidum	2.3 (0.6)	2.0 *	-	1.0 *	-	2.0 *	3.0 *
Geum triflorum	1.0 *	-	-	-	-	-	-
Grindelia squarrosa	3.0 (0.0)	-	2.8 (0.5)	3.0 *	3.0 (0.0)	3.2 (0.3)	3.2 (0.3)
Gaura coccinea	1.7 (0.6)	2.0 *	1.0 *	-	-	1.7 (0.6)	2.3 (0.6)
Heterotheca villosa	-	-	-	-	-	-	2.0 *
Heuchera parvifolia	-	2.0 *	1.0 *	1.5 *	-	-	-
Heuchera richardsonii	1.0 (0.0)	-	-	-	-	-	2.0 *
Hieracium umbellatum	-	-	-	-	-	-	2.0 (0.0)
Juniperus horizontalis	-	-	2.0 *	-	-	-	-
Linum rigidum	-	-	-	-	-	1.0 *	-
Mentha arvensis	2.5 (0.8)	2.5 (0.7)	2.0 *	2.0 *	2.7 (0.6)	2.8 (0.5)	2.5 (1.0)
Bryophyta species	-	-	-	-	-	-	1.0 *
Orthocarpus luteus	2.0 (0.0)	-	2.0 (0.8)	1.0 *	-	2.3 (0.5)	2.0 *
Paronychia sessiliflora	2.0 *	-	-	-	-	-	-
Penstemon procerus	1.8 (0.5)	-	1.0 *	2.0 *	2.0 *	2.0 (0.0)	2.0 *
Plantago patagonica	-	-	-	-	2.0 *	-	-
Polygonum amphibium	3.0 (0.0)	3.0 *	2.5 (1.0)	-	3.0 (1.4)	3.1 (0.3)	3.3 (0.4)
Polygonum coccineum	2.0 *	3.0 *	-	-	-	3.0 (0.0)	2.0 *
Populus tremuloides	2.0 (1.4)	2.0 *	-	-	-	-	2.5 (0.7)
Potentilla arguta	2.3 (0.5)	2.0 (1.0)	2.5 (0.7)	2.5 (0.7)	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)
Potentilla gracilis	3.3 (0.4)	2.0 *	2.5 (0.7)	3.0 *	-	2.0 (0.0)	2.0 *
Potentilla hippiana	2.0 (0.0)	2.0 *	2.0 (0.0)	2.0 *	2.0 (0.0)	2.0 (0.0)	2.0 *
Potentilla norvegica	2.3 (0.5)	-	2.0 *	2.0 (0.0)	-	2.0 (0.0)	2.0 (0.0)
Potentilla pensylvanica	2.0 *	2.0 (0.0)	2.0 *	-	2.0 *	2.0 *	2.0 (0.0)
Psoralea argophylla	2.0 *	3.0 *	-	2.0 *	-	-	-
Ranunculus pensylvanicus	2.0 (0.0)	-	-	-	-	-	3.0 *
Ratibida columnifera	-	-	-	2.0 *	2.0 (0.0)	1.8 (0.8)	2.0 (1.4)

	Off ROW			On ROW			
	II A	III A	III B	II A	II B	III A	III B
Rosa acicularis	2.5 (0.7)	2.0 *	-	-	-	-	2.5 (0.7)
Rosa arkansana	2.5 (0.8)	3.0 *	2.8 (0.8)	2.5 (0.7)	3.0 (0.0)	2.5 (0.6)	2.3 (1.8)
Salix exigua	-	1.0 *	-	-	-	1.0 *	2.0 *
Sisyrinchium montanum	1.0 (0.0)	-	-	3.0 *	-	-	-
Solidago canadensis	2.0 (0.0)	-	2.0 *	3.0 (0.0)	-	-	3.0 *
Stachys palustris	2.7 (0.5)	3.0 *	2.0 *	2.5 (0.7)	-	2.3 (0.6)	3.0 (0.0)
Stellaria crassifolia	-	-	-	-	-	-	-
Symphoricarpos occidentalis	2.7 (0.8)	2.5 (0.7)	2.7 (1.4)	3.5 *	2.5 (0.7)	2.9 (0.5)	2.8 (0.8)
Vicia americana	1.5 (0.7)	-	-	2.0 *	-	2.0 (0.0)	-
Zizia aptera	2.0 (0.0)	-	-	-	-	-	1.0 *

Numbers are mean plant cover code with standard deviations in brackets
II A = temporary freshwater marsh, II B = temporary slightly brackish marsh, III A = seasonal freshwater marsh, III B = seasonal slightly brackish marsh
- = no presence detected, * n = 1

Table 4.13. Sørenson coefficients of similarity on and off the pipeline right of way.

	Sørenson Coefficients Of Similarity	Shared Species
Total Species	0.85	81
Native Species	0.86	64
Non Native Species	0.83	17
Class II Wetlands	0.79	58
Class III Wetlands	0.79	65

Table 4.14. Descriptive statistics and significance of all cover types and treatments using Kruskal Wallace evaluations.

Cover (%)		N	Mean	Significance	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum	Maximum
Live	Off ROW	9	76.1	a	4.17	1.39	3.20	70	80
	On ROW	8	76.3	a	2.31	0.82	1.94	75	80
Litter	Off ROW	9	8.9	a	3.33	1.11	2.56	5	15
	On ROW	8	10.3	a	3.45	1.22	2.89	5	15
Bare Ground	Off ROW	9	8.9	a	3.33	1.11	2.56	5	15
	On ROW	8	6.0	a	3.46	1.22	2.90	2	10
Fungi	Off ROW	9	0.0	a	0.00	0.00	0.00	0	T
	On ROW	8	0.0	a	0.01	0.00	0.00	0	T
Moss	Off ROW	9	0.0	a	0.00	0.00	0.00	0	T
	On ROW	8	-	a	-	-	-	-	-
Scat	Off ROW	9	5.6	a	3.91	1.30	3.00	T	15
	On ROW	8	6.8	a	3.01	1.06	2.52	2	10
Rock	Off ROW	9	0.6	a	1.67	0.56	1.28	0	5
	On ROW	8	1.4	a	1.51	0.53	1.26	0	3

Treatments with the same letter are not significantly different
T = trace (< 1 % cover), - = not found

Table 4.15. Significance of Kruskal Wallace rank sum test of different cover types.

Cover (%)	N	H	P value
Live	17	0.01	0.91
Litter	17	0.62	0.43
Bare Ground	17	2.89	0.09
Fungi	17	1.34	0.25
Moss	17	3.05	0.08
Scat	17	1.29	0.26
Rock	17	2.07	0.15

Table 4.16. Relationship between cover types, species richness, and the Shannon Wiener diversity index using Spearman's rank correlation coefficient.

			Species Richness		Shannon Wiener Diversity Index	
Cover (%)	Treatment	N	ρ	P value	ρ	P value
Live	Off ROW	9	0.36	0.35	0.33	0.39
	On ROW	8	0.38	0.36	0.38	0.36
	Combined	17	0.31	0.23	0.34	0.18
Litter	Off ROW	9	0.15	0.70	0.06	0.89
	On ROW	8	-0.01	0.98	-0.03	0.95
	Combined	17	0.16	0.54	0.02	0.95
Bare Ground	Off ROW	9	-0.11	0.77	-0.19	0.63
	On ROW	8	0.19	0.66	0.37	0.37
	Combined	17	-0.06	0.82	-0.04	0.89

Table 4.17. Descriptive statistics of distance to pipeline trench of all sites.

	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval	Minimum (m)	Maximum (m)
Off ROW	9	134.39	45.40	15.13	34.90	74.8	215.7
On ROW	8	11.70	13.61	4.81	11.38	0.0	32.8
Combined	17	76.65	71.39	17.31	36.70	0.0	215.7

Table 4.18. Relationship between distance to pipeline trench and species richness and Shannon Wiener diversity index of native species, non native species, and combined species.

		Species Richness		Shannon Wiener Diversity Index	
	N	ρ	P value	ρ	P value
DTP : Native	9	-0.14	0.58	-0.20	0.44
DTP : Non Native	8	-0.25	0.34	-0.35	0.17
DTP : Combined	17	-0.25	0.3.4	-0.30	0.24

DTP = distance to pipeline trench (m)

V. SUMMARY AND FUTURE RESEARCH

1. RESEARCH SUMMARY

Research was conducted in the dry mixedgrass subregion of southern Alberta on impacts of a six year old pipeline right of way (ROW) on native prairie uplands and wetlands, *Halimolobos virgata* (Nutt.) O.E. Schulz (slender mouse ear cress), and its associated critical habitat. Environment Canada has recommended a 300 m set back between rare species and pipeline disturbance on federally owned land. This recommendation is not species specific and is based on literature reviews of the extent of impact from pipeline disturbances. Research objectives were to assess the presence, physical characteristics and habitat properties of *Halimolobos virgata*, to assess native prairie vegetation and ground cover at locations relative to the ROW, and to assess wetland vegetation communities and water properties on and off the ROW. Research was conducted along the TransCanada pipeline at two sites for *Halimolobos virgata* surveys, six sites for vegetation assessment, and 17 sites for wetland assessments.

Halimolobos virgata was found in increasing numbers across the two field seasons. Populations were at one site the first assessment year and at two sites in the second year. No relationships were found between height, silique, or flower number and distance to pipeline trench. This suggests that proximity to the pipeline trench did not negatively impact physical characteristics of *Halimolobos virgata*. It appeared that *Halimolobos virgata* physical characteristics were more likely to be impacted by ground cover. Height and silique number decreased with increasing live and bare ground and increased with increasing litter cover. *Halimolobos virgata* appeared to be growing in habitat niches with limited competition from other plant species, the benefits that increased litter cover provide, such as increased water availability. While distance to the pipeline trench did not negatively impact *Halimolobos virgata*, fewer plants were found directly over the trench and across the ROW than on areas outside of the ROW.

Impacts of the ROW on ground cover types and plant communities were greatest over trench and work areas. Species richness and diversity were lowest on trench and work areas. Storage areas had recovered species richness and diversity relative to undisturbed prairie. The trench area had lowest richness of native species, while non native species richness was highest in storage areas and in low abundance relative to native species. The trench had less live cover and more bare ground than all other ROW. There was high variability in all assessment parameters suggesting that dry mixedgrass ecosystems have high inherent variability. The areas of most intense disturbance over the ROW have not returned to native prairie ground cover, species richness, or diversity.

Floristic habitat sampling methods were used to assess wetland vegetation on and off the ROW. No differences in any assessment parameters were detected on and off the ROW. Native species were dominant in both species richness and diversity and cover types and percentages were consistent across all areas. This suggests that recovery of wetlands on the ROW have reached near native levels within seven growing seasons.

Pipeline ROWs continue have an impact on plant communities seven growing seasons after construction. Desired climax species such as *Artemisia ludoviciana* Nutt. (prairie sagewort) and *Opuntia polyacantha* Haw. (prickly pear cactus) are beginning to return to the trench area of the ROW, although have not reached native prairie levels. While recovery is noted, particularly over the storage areas, the areas of greatest disturbance over the trench and work areas have not reached the climax community. A 300 m set back is not required for *Halimolobos virgata* provided similar construction methods are used as for the TransCanada pipeline in this study. The 30 m set back that was used during construction of the TransCanada pipeline is adequate to protect *Halimolobos virgata* and its associated critical habitat.

2. PIPELINE CONSTRUCTION AND RECLAMATION IMPLICATIONS

Pipeline construction should be avoided during critical times for *Halimolobos virgata* and construction techniques that mitigate the impact on the rare species and critical habitat should be employed. These critical periods for *Halimolobos virgata*, include germination and seedling emergence times in April and May, and reproductive maturation times from mid May to early June. Construction should occur under frozen or dry soil conditions to reduce compaction on ROW. Other mitigative measures could include use of geotextiles to protect native prairie vegetation, clear marking and signage around rare species, erosion matting in unstable areas along the ROW, limits on movement of vehicles and machinery (one lane traffic), and weed cleaning stations to reduce introduction of non native species.

Reducing non native species on site, either through use of weed cleaning stations, or manual control, will enable *Halimolobos virgata* to opportunistically move onto areas of moderate disturbance without being outcompeted by non native species. If non native species establish on site, it is possible that *Halimolobos virgata* populations and the critical habitat would decrease in size, or disappear entirely.

If these construction techniques are not used, it is unclear as to the impact of pipeline ROWs on *Halimolobos virgata*. However, with appropriate measures *Halimolobos virgata* may move onto the ROW in a few years (Nannt 2014) and specifically on the trench area of a pipeline ROW within seven growing seasons following construction. Using construction techniques that are not detrimental towards *Halimolobos virgata* and associated critical habitat will aid in preservation of native prairie around the ROW. Through protecting rare species and native dry mixedgrass ecosystems as a whole, reclamation following construction will be more successful and the trajectory of recovery after disturbance will likely result in the desired plant community across the pipeline ROW.

3. RESEARCH LIMITATIONS

Remount Hill site had robust *Halimolobos virgata* populations over both growing seasons, resulting in a robust data set. Minor Coulee only had a small population over one growing season. Remount Hill and Minor Coulee were different topographically and in pipeline ROW layout. A larger population at the second site would have provided a more detailed understanding of microhabitat requirements of *Halimolobos virgata*.

Due to the very large number of *Halimolobos virgata* plants at Remount Hill in 2015, detailed analyses could only be conducted to 65 m on either side of the ROW. Outside of that distance, only general counts, overall health, and observations were recorded. No detailed assessments were possible at this distance due to time constraints within the small blossoming period for the species. It would have been ideal to conduct the full analyses at that site, as with increasing distance to the pipeline trench, it appeared as though the microhabitats around *Halimolobos virgata* changed. The plants were often found in association with large *Artemesia cana* Pursh (sagebush), *Opuntia polyacantha* Haw. (prickly pear), and *Bouteloua gracilis* (HBK) Lag. (blue grama). Conducting the full analysis at the site may have resulted in stronger correlations and more significant results.

Due to the short time frame of MSc research programs, the environmental conditions over two field seasons likely played a large role. The 2014 field season had normal precipitation over the growing season, while 2015 had below normal precipitation. This may have resulted in differences in the plant community and properties of *Halimolobos virgata*. *Halimolobos virgata* populations appear to fluctuate with extended periods of abnormal environmental conditions. Longer term studies are required to see if this is occurring at the study sites.

Due to the below normal precipitation in 2015 it was not possible to collect water samples as planned at wetland sites. Therefore, wetland data were based on plant community assessments. Water sampling may have found some differences among wetland sites on and off ROW and may have made wetland classification more accurate. A number of sites had characteristics of freshwater and slightly saline sites; water testing would have aided in differentiating them. A larger data set may have increased statistical power of the analyses.

The broad general scale of ground cover that was taken during wetland assessments was not sufficient in highlighting differences between on and off ROW. All sites had similar ground cover, and the assessment protocol may not have been detailed enough to detect any variation.

Surveys were conducted over the 2014 and 2015 field seasons for *Cryptantha minima* Rybd. (tiny cryptanthe) at Remount Highway and Minor Coulee sites. No plants were located at either site over both years.

4. FUTURE RESEARCH

To increase our understanding of the interactions between pipelines and rare species, further long term studies are needed. High variability in population sizes of *Halimolobos virgata* over the past seven growing seasons suggests there are underlying environmental factors that may impact the populations in addition to pipeline construction. Increasing our understanding of the relationships between *Halimolobos virgata* and the environment may assist in better understanding the impacts of disturbance. Long term studies would provide important information about the success of dry mixedgrass prairie reclamation techniques and provide a timeline to measure the return of disturbed areas to native dry mixedgrass prairies.

Monitoring should continue for *Halimolobos virgata* at Remount Hill and Minor Coulee site. It will be interesting to see if the fluctuations in population size and expansion of the range continue, or if the populations stabilize in both size and spread. More data need to be collected on the population at Minor Coulee. It is not yet possible to evaluate yearly trends at that site, due to one year of data. Due to observed differences in topography and associate plants between Remount Hill and Minor Coulee, it might be beneficial to conduct soil analyses to determine if they are utilizing the same microhabitats or if there is variation between sites.

Due to observations in 2015 of *Halimolobos virgata* appearing to utilize specific microhabitats it would be interesting to understand them. Detailed vegetation analyses including species cover surrounding *Halimolobos virgata* may highlight some specific habitat requirements. Many individual plants in 2015 were found in large clusters, therefore larger assessment quadrats of 1 x 1 m may be appropriate to evaluate habitat requirements on a slightly larger scale.

The observed correlation between increased height and silique number and litter depth would be interesting to explore further. Little is known about the impact of litter on *Halimolobos virgata*, although many studies suggest that litter cover is detrimental to plant growth. This was not observed with *Halimolobos virgata*. Litter depth measurements should continue to be taken, analyses of any possible allelopathic effects of litter in the area might be beneficial, and measurements should be taken for the impact of water content and light availability on the surface beneath litter cover.

Continued studies on ground cover should be conducted at various locations relative to the pipeline ROW. While there appears to be some recovery along the ROW in the storage areas, there is still recovery required over the trench, and in the work areas. Bare ground across the trench and work areas may persist on site and continue to impact recovery of native vegetation.

The movement of climax native species, such as *Artemesia cana* Pursh (sagebush), *Opuntia polyacantha* Haw. (prickly pear cactus), and *Selaginella densa* Rybd. (little club moss), onto the trench area of the ROW should be further explored. These species are important components of a native dry mixedgrass prairie community and when they are found in high quantities over the trench it may be an indicator of reclamation success, in association with low quantities of non native species.

The monitoring of non native species, especially listed noxious weeds, and species that have known detrimental effects on plant and soil complexes such as *Agropyron cristatum* (L.) Gaertn. (crested wheatgrass) is important. If non native species appear in high quantities across the ROW, research should be conducted to determine what conditions changed to allow them to establish.

If environmental conditions return to normal, water samples at the wetland sites should be collected. This may illustrate differences between sites on and off the ROW. Finer scale analyses may be beneficial at wetland sites. More detailed descriptions of cover, for example randomly over 10, 1 x 1 m quadrats, at each site, may highlight differences on and off the ROW. The effects of grazing on wetland communities on the ROW could be researched. Some wetland sites were partially on and off the fenced ROW and there were noticeable differences in plant structure. Some studies suggest that exclusion of grazing in wetland environments increase non native species cover. While the size and health of non native species with grazing exclusion are were observed to be greater than areas with grazing, further analysis at a finer scale could be beneficial.

Monitoring for *Cryptantha minima* should continue at Remount Highway and Minor Coulee sites. The species is known for sporadic population sizes and locations, therefore populations could appear at either site.

REFERENCES

Adams, B.W., J. Richman, L. Poulin-Klein, K. France, D. Moisey, and R.L. McNeil. 2013. Rangeland plant communities for the Dry Mixedgrass Natural Subregion of Alberta. Second Approximation. Rangeland Management Branch, Policy Division. Alberta Environment and Sustainable Resource Development. Lethbridge, AB. 135 pp.

Alberta Agriculture and Forestry. 2016. Current and historical Alberta weather station data viewer. Online at http://agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp. Accessed February 15, 2016.

Alberta Agriculture and Forestry. 2014. Soil survey map for Alberta. Online at http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag11111. Accessed February 4, 2016.

Alberta Environment. 2007. Provincial wetland restoration/compensation guide. Environmental Partnerships and Education Branch. Edmonton, AB. 21 pp.

Alberta Environment and Parks. 2015. Management and Land-use. Online at http://www.albertaparks.ca/albertaparksca/management-land-use/alberta-conservation-information-management-system-acims/download-data.aspx#trackedWatch. Accessed March 5, 2016.

Alberta Environment and Sustainable Resource Development (ESRD). 2015. Alberta Wetland Classification System. Water Policy Branch, Policy and Planning Division, Edmonton, AB. 66 pp.

Alberta Environment and Sustainable Resource Development (ESRD) 2013. Alberta wetland policy. Government of Alberta, Edmonton, AB. 27 pp.

Alberta Environmental Protection. 1997. The grassland natural region of Alberta. Natural Resources Service, Recreation and Protected Areas Division, Natural Heritage Protection and Education Branch. Edmonton, AB. 229 pp.

Alberta Land Surveyors' Association. 2016. Easements and right-of-ways. Online at http://www.alsa.ab.ca/publicinformation/easementsandrightsofway.aspx#Whatisaneasementorright-of-way. Accessed February 2, 2016.

Alberta Water Resources Commission. 1993. Wetland management in the settled area of Alberta: an interim policy. Alberta Water Resources Commission, Edmonton, AB. 18 pp.

Allen, L. 2012. Alberta conservation information management system. Ecological community tracking list. Alberta Tourism Parks and Recreation. Edmonton, AB. 127 pp.

Alberta Environment and Parks. 2015. Management and land use overview. Online at http://www.albertaparks.ca/albertaparksca/management-land-use/alberta-conservation-information-management-system-acims/overview/#ACIMS. Accessed March 30, 2016.

Alberta Sustainable Resource Development (ASRD). 2004. Status of the tiny cryptanthe (*Cryptantha minima*) in Alberta. Wildlife Status Report No. 54. Fish and Wildlife Division, Alberta Sustainable Resource Development and Alberta Conservation Association. Edmonton, AB. 39 pp.

Alberta Sustainable Resource Development (ASRD). 2005. Status of the slender mouse-ear-cress (*Halimolobos virgata*) in Alberta. Alberta Sustainable Resources Development, Fish and Wildlife Division, and Alberta Conservation Association. Wildlife Status Report No. 55. Edmonton, AB. 27 pp.

Alberta Sustainable Resource Development and Alberta Conservation Association (ASRD and ACA). 2009. Status of the slender mouse-ear-cress (*Halimolobos virgata* or *Transberingia bursifolia* subsp*. virgata*) in Alberta: Update 2009. Alberta Sustainable Resource Development. Wildlife Status Report No 55. Edmonton, AB. 28 pp.

Allen, L. 2012. Alberta Conservation Information Management System Ecological Community Tracking List. Alberta Tourism, Parks and Recreation, Edmonton, AB. 127 pp.

Ayyad, M.A. and R. Dix. 1964. An analysis of a vegetation microenvironmental complex on prairie slopes in Saskatchewan. Ecological Monographs 34:421-442.

Bailey, A.W., D. McCartney, and M.P. Schellenberg. 2010. Management of Canadian prairie rangeland. Agriculture and Agri-Food Canada. Swift Current, Saskatchewan. 58 pp.

Bartzen, B.A., K.W, Dufour, R.G. Clark, and F.D. Caswell. 2010. Trends in agricultural impact and recovery of wetlands in prairie Canada. Ecological Applications 20:525-538.

Batey, T. and D.C. McKenzie. 2006. Soil compaction: identification directly in the field. Soil Use and Management 22:123-131.

Bennie, J., B. Huntley, A. Wiltshire, M.O. Hill, and R. Baxter. 2008. Slope, aspect and climate: spatially explicit and implicit models of topographic microclimate in chalk grassland. Ecological Modelling 216:47-59.

Bewley, J.D. 1997. Seed germination and dormancy. The Plant Cell 9(7):1055-1066.

Blumenthal, D.M., A.P. Norton, S.E. Cox, E.M. Hardy, G.E. Liston, L. Kennaway, D.T. Booth, and J.D. Derner. 2012. *Linaria dalmatica* invades south-facing slopes and less grazed areas in grazing-tolerant mixed-grass prairie. Biological Invasions 14:395-404.

Canadian Energy Pipeline Association. 2013. Welcome to pipelines 101. Online at http://www.cepa.com/about-pipelines. Accessed February 1, 2016.

Canada Committee on Ecological (Biophysical) Land Classification. National Wetlands Working Group (NWWG). 1997. The Canadian wetland classification system. Warner BG, Rubec CD, editors. Wetlands Research Branch, University of Waterloo. 76 pp.

Clauss, M.J. and D.L. Venable. 2000. Seed germination in desert annuals: an empirical test of adaptive hedge betting. The American Naturalist 155:168-186.

Collins, S.L. and S.C. Barber. 1985. Effects of disturbance on diversity in mixed-grass prairie. Vegetation 64:87-94.

Conly, F.M. and G. van der Kamp. 2001. Monitoring the hydrology of Canadian prairie wetlands to detect the effects of climate change and land use changes. Environmental Monitoring and Assessment 67:95-215.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2015. Wildlife species search. Online at http://www.cosewic.gc.ca/eng/sct1/index_e.cfm. Accessed October 10, 2015.

Craine, J.M., J. Froehle, D.G. Tilman, D.A. Wedin, and F.S. Chapin Iii. 2001. The relationships among root and leaf traits of 76 grassland species and relative abundance along fertility and disturbance gradients. Oikos 93:274-285.

de Jong, E. and R.G. Button. 1973. Effects of pipeline installation on soil properties and productivity. Canadian Journal of Soil Science 53:37-47.

Deutsch, E., E. Bork and W. Willms. 2010a. Soil moisture and plant growth responses to litter and defoliation impacts in parkland grasslands. Agriculture, Ecosystems and Environment 135:1-9.

Deutsch, E.S., E.W. Bork and W.D. Willms. 2010b. Separation of grassland litter and ecosite influences on seasonal soil moisture and plant growth dynamics. Plant Ecology 209:135-145.

Dodds, W. and M. Whiles. 2010. Freshwater ecology. Concepts and environmental applications of limnlogy. Second edition. Academic Press. Burlington, MA. 811 pp.

Donath, T.W. and R.L. Eckstein. 2010. Effects of bryophytes and grass litter on seedling emergence vary by vertical seed position and seed size. Plant Ecology 207:257-268.

Downing, J.A., Y.T. Prairie, J.J. Cole, C.M. Duarte, L.J. Tranvik, R.G. Striegl, W.H. McDowell, P. Kortelainen, N.F. Caraco, J.M. Melack, and J.J. Middelburg. 2006. The global abundance and size distribution of lakes, ponds, and impoundments. Limnology and Oceanography 51:2388-2397.

Eckstein, R.L. and T.W. Donath. 2005. Interactions between litter and water availability affect seedling emergence in four familiar pairs of floodplain species. Journal of Ecology 93:807-816.

Enbridge Energy. 2013. Understanding the Pipeline Right-of-Way. Online at http://www.enbridge.com/InYourCommunity/PipelinesInYourCommunity/UnderstandingthePipelineRightOfWay.aspx. Accessed December 12, 2013.

Energy Resources Conservation Board. 2015. What we do. http://www.aer.ca/about-aer/what-we-do. Accessed November 27, 2015.

Environment Canada. 2015. Canadian climate normal 1981-2010 Oyen Station Data. Online at http://climate.weather.gc.ca/climate_normals/index_e.html. Accessed February 4, 2016.

Environment Canada. 2012. Recovery strategy for the sender mouse-ear-cress (*Halimolobos virgata*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, ON. 45 pp.

Environment Canada. 2008. Activity set back distance guidelines for prairie plant species at risk. Ottawa, ON. 14 pp.

Environment Canada. 2006. Recovery strategy for the tiny cryptanthe (*Cryptantha minima*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, ON. 24 pp.

Euliss Jr, N.H., R.A. Gleason, A. Olness, R.L. McDougal, H.R. Murkin, R.D. Robarts, R.A. Bourbonniere, and B.G. Warner. 2006. North American prairie wetlands are important nonforested land-based carbon storage sites. Science of the Total Environment 361:179-188.

Facelli, J.M. and S.T. Pickett. 1991. Plant litter: its dynamics and effects on plant community structure. The Botanical Review 57:1-32.

Foote, A.L. and C.L.Rice Hornung. 2005. Odanates as biological indicators of grazing effects on Canadian prairies. Ecological Entomology 30:273-283.

Foster, B.L. and K.L. Gross. 1998. Species richness in a successional grassland: effects of nitrogen enrichment and plant litter. Ecology 79:2593-2602.

Galaowitsch, S.M. and A.G. van der Valk. 1996a. Characteristics of recently restored wetlands in the prairie pothole region. Wetlands 16:75-83.

Galaowitsch, S.M. and A.G. van der Valk. 1996b. The vegetation of restored and natural prairie wetlands. Ecological Applications 6:102-112.

Galatwitsch, S.M. and A.G. van der Valk. 1996c. Vegetation and environmental conditions in recently restored wetlands in the prairie pothole region of the USA. Vegetation 126:89-99.

Goldberg, D.E. and P.A. Werner. 1983. The effects of size of opening in vegetation and litter cover on seedling establishment of goldenrods (*Solidago* spp). Oecologica 60:149-155.

Gong, W., H. Brueck, K.M. Giese, L. Zhang, B. Sattelmacher, and S. Lin. 2008. Slope aspect has effects on productivity and species composition of hilly grassland in the Xilin River Basin, Inner Mongolia, China. Journal of Arid Environments 72:483-493.

Gong, Y., G. Liu, and F.W. Schwartz. 2015. Quantifying the Response Time of a Lake–Groundwater Interacting System to Climatic Perturbation. Water 7:6598-6615.

Google Earth. 2016. Google earth software version 7.1.2.2041. Bindloss, AB, imagery date 09/20/2011. Online at http://www.google.com/earth/ index.html. Accessed February 24, 2016.

Gould, J. 2006. Alberta Natural Heritage Information Centre tracking and watch lists: vascular plants, mosses, liverworts and hornworts. Alberta Community Development, Parks and Protected Areas Division, Edmonton, AB. 30 pp.

Hanna, A.Y., P.W. Harlan, and D.T. Lewis. 1982. Soil available water as influenced by landscape position and aspect. Agronomy Journal 74:999-1004.

Henderson, D.C. 2010. Activity set back distance guidelines for prairie plant species at risk. Canadian Wildlife Service. Environment Canada, Saskatoon, SK. 22 pp.

Henderson, D.C. and M.A. Naeth. 2005. Multi-scale impacts of crested wheatgrass invasion in mixed-grass prairie. Biological Invasions, 7:639-650.

Hickman, K.R., D.C. Hartnett, R.C. Cochran, and C.E. Owensby. 2004. Grazing management effects on plant species diversity in tallgrass prairie. Rangeland Ecology & Management, 57:58-65.

Hobbie, S.E. 1992. Effects of plant species on nutrient cycling. Trends in ecology and Evolution 7:336-339.

Hobbs, R.J. and L.F. Huenneke. 1992. Disturbance, diversity and invasion: implications for conservation. Conservation Biology 6:324-337.

Ivey, J. and R. McBride. 1999. Delineating the zone of topsoil disturbance around buried utilities on agricultural land. Land Degradation & Development 10:531-544.

Jacques Whitford AXYS Ltd. 2008. Mitigation for plant species at risk on the Alberta portion of the Keystone pipeline project. Prepared for TransCanada Keystone Pipeline GP Ltd. Calgary, AB. 15 pp.

Jandt, R., K. Joly, C. Randy Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter range in Alaska tundra: potential influences of climate warming and other disturbance factors. Arctic, Antarctic, and Alpine Research, 40:89-95.

Jensen, K. and K. Gutekunst. 2003. Effects of litter on establishment of grassland plant species: the role of seed size and successional status. Basic and Applied Ecology 4:579-587.

Jol, H.M. and D.G. Smith. 1995. Ground penetrating radar surveys of peatlands for oilfield pipelines in Canada. Journal of Applied Geophysics 34:109-123.

Johnson, W.C., S.E. Boettcher, K.A. Poiani, and G. Guntenspergen. 2004. Influence of weather extremes on the water levels of glaciated prairie wetlands. Wetlands 24:85-398.

Kantrud, H.A. 1986. Effects of vegetation manipulation on breeding waterfowl in prairie wetlands – a literature review. United States Department of the Interior Fish and Wildlife Service, Fish and Wildlife Technical Report 3. Washington, DC. 22 pp.

Kerr, D.S., L.J. Morrison and K.E. Wilkinson. 1993. Reclamation of native grasslands in Alberta: a review of the literature. Alberta Land Conservation and Reclamation Council. Calgary, Alberta.

Kershaw, L., J. Gould, D. Johnson and J. Lancaster. 2001. Rare vascular plants of Alberta. The University of Alberta Press and the Canadian Forest Service. Edmonton, AB. 484 pp.

Ketner-Oostra, R. and K.V Sýkora. 2004. Decline of lichen-diversity in calcium-poor coastal dune vegetation since the 1970s, related to grass and moss encroachment. Phytocoenologia, 34:521-549.

Koornneef, M., L. Bentsink, and H. Hilhorst. 2002. Seed dormancy and germination. Current Opinion in Plant Biology 5:33-36.

LaBaugh, J. W., T.C. Winter, and D.O. Rosenberry. 1998. Hydrologic functions of prairie wetlands. Great Plains Research 8:17-37.

Lamb, E.G. 2008. Direct and indirect control of grassland community structure by litter, resources, and biomass. Ecology 89:216-225.

Lathrop, E.W. and E.F. Archbold. 1980. Plant response to utility right of way construction in the Mojave Desert. Environmental Management 4:215-226.

Lilliefors, H.W. 1967. On the Kolmogorov-Smirnov test for normality with mean and variance unknown. Journal of the American Statistical Association 62:399-402.

Lieffers, V.J. 1983. Emergent plant communities of oxbow lakes in Northeastern Alberta: salinity, water-level fluctuation, and succession. Canadian Journal of Botany 62:310-316.

Logan, M. 2010. Biostatistical design and analysis using R: a practical guide. First Edition. Wiley Blackwell. West Sussex, UK. 546 pp.

Looman, J. 1964. The distribution of some lichen communities in the Prairie Provinces and adjacent parts of the Great Plains. Bryologist 67:209-224.

Looman, J. and K.F. Best. 1979. Budd's flora of the Canadian prairie provinces. Research Branch, Agriculture Canada, Publication 1662. Ottawa, ON. 872 pp.

McNeely, D. 2016. Environmental Coordinator (Keystone Pipeline Projects), TransCanada Pipelines. Personal Communication. February 2016.

McNeely, D. 2012. Environmental Coordinator (Keystone Pipeline Projects), TransCanada Pipelines. Personal Communication. July 2012.

Milchunas, D.G., W.K. Lauenroth, P.L. Chapman, and M.K. Kazempour. 1989. Effects of grazing, topography, and precipitation on the structure of a semiarid grassland. Vegetation 80:11-23.

Mitsch, W.J. and J.G. Gosselink. 2007. Wetlands. Forth Edition. John Wiley & Sons, Inc. Hoboken, N.J. 582 pp.

Moss, E.H. 1994. Flora of Alberta. 2nd Edition (revised by J.G.Packer). University of Toronto Press. Toronto, Ontario. 687 pp.

Naeth, M.A., W.B. McGill, and A.W. Bailey. 1987. Persistence of changes in selected soil chemical and physical properties after pipeline installation in solonetzic native rangeland. Canadian Journal of Soil Science 67:747-763.

Naeth, M.A. 1985. Ecosystem reconstruction and stabilization following pipeline construction through Solonetzic native rangeland in southern Alberta. M.Sc. Thesis. University of Alberta, Departments of Soil Science and Plant Science. Edmonton, AB. 213 pp.

Nannt, M.R. 2014. Impacts of distance to pipeline disturbance on mixed grass prairie and *Halimolobos virgata* (Nutt.) O.E. Schulz (slender mouse ear cress). University of Alberta. Edmonton, AB.

Natural Regions Committee. 2006. Natural regions and subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. 264 pp.

Nemirsky, C.L. 2011. Prairie plant species at risk in Southern Alberta: identification of critical habitat at the microsite level for *Halimolobos virgata (*Nutt.) O.E. Schulz and determination of set back distance between pipeline disturbance and *Halimolobos virgata* and *Cryptantha minima* Rydb. University of Alberta. Edmonton, AB.

Neville, M. 2002. Best management practices for pipeline construction in native prairie environments. Alberta Environment and Alberta Sustainable Resource Development. Edmonton, AB. 133 pp.

Noble, B., M. Hill, and J. Nielsen. 2011. Environmental assessment framework for identifying and mitigation the effects of linear development to wetlands. Landscape and Urban Planning 99:133-140.

Olson, B.E. and R.T. Wallander. 2002. Effects of invasive forb litter on seed germination, seedling growth and survival. Basic and Applied Ecology 3:309-317.

Osko, T. 2010. Gap analysis of wetland reclamation knowledge and practices in northern Alberta. Prepared by Circle T Consulting, Inc. Vegreville, AB. 43 pp.

Pake, C.E and D.L. Venable. 1996. Seed banks in desert annuals: implications for persistence and coexistence in variable environments. Ecology 77:1427-1435.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Online at https://www.R-project.org/. Accessed October 5, 2015.

Rooney, R.C. and S.E. Bayley. 2011. Setting reclamation targets and evaluating progress: submersed aquatic vegetation in natural and post-oil sands mining wetlands in Alberta, Canada. Ecological Engineering 37:569-579.

Ruprecht, E., M.Z. Enyedi, R.L. Eckstein, and T.W. Donath. 2002. Restorative removal of plant litter and vegetation 40 years after abandonment enhances re-emergence of steppe grassland vegetation. Biological Conservation 143:449-456.

Rydgren, K., R.H. Økland, and G. Hestmark. 2004. Disturbance severity and community resilience in a boreal forest. Ecology, 85:1906-1915.

Sampson, F. and F. Knopf. 1994. Prairie conservation in North America. BioScience 44:418-421.

Schulten, J.A. 1985. Soil aggregation by cryptogams of a sand prairie. American Journal of Botany 72:1657-1661.

Shapiro, S.S. and M.B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591-611.

Shay, J.M. and C.T. Shay. 1986. Prairie marshes in western Canada, with specific reference to the ecology of five emergent macrophytes. Canadian Journal of Botany 64:443-454.

Shi, P., J. Xiao, Y.-F. Wang, and L.-D. Chen. 2013. The effects of pipeline construction disturbance on soil properties and restoration cycle. Environmental Monitoring and Assessment:186:1825-1835.

Sinton, H. 2001. Prairie oil and gas: a lighter footprint. Alberta Environment. Edmonton, AB. 67 pp.

Smith, M.D. and A.K. Knapp. 1999. Exotic plant species in a C4-dominated grassland: invasibility, disturbance, and community structure. Oecologia 120:605-612.

Sousa, W.P. 1984. The role of disturbance in natural communities. Annual Review of Ecology and Systematics 15:353-391.

Stewart, R. E. and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. Resource Publication 92, Bureau of Sport Fisheries and Wildlife, U.S. Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center. Online at http://www.npwrc.usgs.gov/resource/wetlands/ pondlake/index.htm. Accessed July 5, 2014.

Stoeckeler, J.H. and W.R. Curtis. 1960. Soil moisture regime in southwestern Wisconsin as affected by aspect and forest type. Journal of Forestry, 58:892-6.

Tannas, K. 2003. Common plants of the western rangelands. Volume 1 grasses and grass-like species. Alberta Agriculture and Rural Development. Edmonton, AB. 356 pp.

Tannas, K. 2004. Common plants of the western rangelands. Volume 3 forbs. Alberta Agriculture and Rural Development. Edmonton, AB. 505 pp.

Tillman, D. and J.A. Downing. Biodiversity and stability in grasslands. Nature 367:363-365.

TransCanada. 2012. Keystone XL Pipeline project. On line at http/www.transcanada.com/ keystone.html. Accessed December 8, 2013.

Tukey, J.W. 1953. The problem of multiple comparisons. Mimeographs Princeton University, Princeton, N.J. As cited in Steel et al. 1997.

van der Kamp, G. and M. Hayashi. 2009. Groundwater-wetland ecosystem interaction in the semiarid glaciated plains of North America. Hydrogeology Journal 17:203-214.

van der Kamp, G. and M. Hayashi. 1998. The groundwater recharge function of small wetlands in the semi-arid northern prairies. Great Plains Research 8:39-56.

Wang, L., S. Wei, R. Horton, and M.A. Shao. 2011. Effects of vegetation and slope aspect on water budget in the hill and gully region of the Loess Plateau of China. Catena 87:90-100.

Wei, Y., Y. Bai, and D.C. Henderson. 2009. Critical conditions for successful regeneration of an endangered annual plant, *Cryptantha minima*: a modeling approach. Journal of Arid Environments 73:872-875.

Wentz, D. 2000. Dryland saline seeps: types and causes. Conservation and Development Branch of Alberta Agriculture, Food and Rural Policy Division. Lethbridge, AB. 4 pp.

Willms, W.D., B.H. Ellert, H.H. Janzen, and H. Douwes. 2005. Evaluation of native and introduced grasses for reclamation and production. Rangeland Ecology and Management 58:177-183.

Willms, W.D., S.M. McGinn, and J.F. Dormaar. 1993. Influence of litter on herbage production in the mixed prairie. Journal of Range Management 46:320-324.

Winter, T.C. 1989. Hydrologic studies of potholes in the northern prairies. In: van der Valk A (ed) Northern prairie wetlands. Iowa State University Press, Ames, IA. Pp 17–54.

Xiao, J., P. Shi, Y. Wang, and L. Yang. 2016. The vegetation recovery pattern and affecting factors after pipeline disturbance in northwest China. Journal for Nature Conservation 29:114-122.

Xiao, J., Y.F. Wang, P. Shi, L. Yang, and L.D. Chen. 2014. Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions. Environmental Monitoring and Assessment 186:8037-8048.

Yates, C.J., D.A. Norton, and R.J. Hobbs. 2000. Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia: implications for restoration. Austral Ecology 25:36-47.

Zedler, J.B. 2000. Progress in wetland restoration ecology. Tree 15:402-407.

Zedler, J.B. 1996. Ecological issues in wetland mitigation: an introduction to the forum. Ecological Adaptations 6:33-37.

Zedler, J.B. and J.C. Calloway. 1999. Tracking wetland restoration: do mitigation sites follow desired trajectories? Restoration Ecology 7:69-73.

APPENDIX

Table A1. Off ROW 1 species cover by wetland zone. Wetland class II, type A.

Species	Zone: Wet Meadow	Zone: Low Prairie
Oryzopsis hymenoides	3	3
Stachys palustris	3	3
Mentha arvensis	3	2
Beckmannia syzigachne	3	-
Calamagrostis montanensis	3	-
Carex lanuginosa	3	-
Carex praegracilis	3	-
Eleocharis palustris	3	-
Hordeum jubatum	2	3
Rosa acicularis	2	3
Rumex crispus	2	2
Agrostis scabra	2	-
Symphoricarpos occidentalis	1	3
Achillea millefolium	-	3
Agropyron smithii	-	3
Artemisia ludoviciana	-	3
Poa pratensis	-	3
Stipa comata	-	3
Arnica chamissonis	-	2
Cirsium arvense	-	2
Erigeron caespitosus	-	2
Galium trifidum	-	2
Gaura coccinea	-	2
Lolium persicum	-	2
Paronychia sessiliflora	-	2
Potentilla arguta	-	2
Potentilla norvegica	-	2
Ranunculus pensylvanicus	-	2
Stipa viridula	-	2
Tragopogon dubius	-	2
Zizia aptera	-	2
Artemisia frigida	-	1
Campanula rotundifolia	-	1
Geum triflorum	-	1
Populus tremuloides	-	1
Sisyrinchium montanum	-	1
Taraxacum officinale	-	1

- = not found

Table A2. Off ROW 2 species cover by wetland zone. Wetland class II, type A.

Species	Zone	
	Wet Meadow	Low Prairie
Carex lanuginosa	4	-
Mentha arvensis	3	2
Beckmannia syzigachne	3	-
Carex atherodes	3	-
Carex praegracilis	3	-
Eleocharis palustris	3	-
Calamagrostis montanensis	2	3
Oryzopsis hymenoides	2	3
Poa palustris	2	2
Rumex crispus	2	2
Phleum pratense	2	-
Polygonum coccineum	2	-
Achillea millefolium	-	3
Agropyron smithii	-	3
Artemisia ludoviciana	-	3
Festuca hallii	-	3
Galium trifidum	-	3
Hordeum jubatum	-	3
Populus tremuloides	-	3
Rosa arkansana	-	3
Stipa comata	-	3
Symphoricarpos occidentalis	-	3
Agropyron trachycaulum	-	2
Bromus inermis	-	2
Erigeron caespitosus	-	2
Erysimum cheiranthoides	-	2
Gaura coccinea	-	2
Ranunculus pensylvanicus	-	2
Stachys palustris	-	2
Taraxacum officinale	-	2
Arnica chamissonis	-	1
Cirsium undulatum	-	1
Elaeagnus commutata	-	1

- = not found

Table A3. Off ROW 3 species cover by wetland zone. Wetland class III, type A.

Species	Zone: Shallow Marsh	Wet Meadow	Low Prairie
Carex lanuginosa	4	2	-
Agrostis scabra	3	3	-
Carex aquatilis	3	-	-
Polygonum coccineum	3	-	-
Hordeum jubatum	2	3	3
Carex brevior	2	3	-
Oryzopsis hymenoides	2	3	-
Rumex crispus	2	2	-
Potentilla arguta	1	3	2
Erysimum cheiranthoides	1	2	2
Chenopodium album	1	-	-
Achillea millefolium	-	3	3
Artemisia ludoviciana	-	3	3
Bromus inermis	-	3	3
Calamagrostis montanensis	-	3	2
Mentha arvensis	-	3	2
Crepis tectorum	-	3	-
Poa pratensis	-	3	-
Polygonum amphibium	-	3	-
Stachys palustris	-	3	-
Agropyron smithii	-	2	3
Symphoricarpos occidentalis	-	2	3
Potentilla pensylvanica	-	2	2
Tragopogon dubius	-	2	2
Carex atherodes	-	2	-
Cirsium arvense	-	2	-
Epilobium angustifolium	-	2	-
Lolium persicum	-	2	-
Potentilla gracilis	-	2	-
Rosa acicularis	-	2	-
Gaillardia aristata	-	1	-
Agropyron trachycaulum	-	-	3
Artemisia frigida	-	-	3
Bouteloua gracilis	-	-	3
Festuca hallii	-	-	3
Psoralea argophylla	-	-	3
Rosa arkansana	-	-	3
Stipa comata	-	-	3
Stipa viridula	-	-	3
Agropyron dasystachyum	-	-	2
Arabis glabra	-	-	2
Artemisia cana	-	-	2
Erysimum inconspicuum	-	-	2
Galium trifidum	-	-	2
Gaura coccinea	-	-	2
Heuchera parvifolia	-	-	2
Phleum pratense	-	-	2
Populus tremuloides	-	-	2
Potentilla hippiana	-	-	2
Polygonum persicaria	-	-	1
Salix exigua	-	-	1

- = not found

Table A4. Off ROW 4 species cover by wetland zone. Wetland class II, type A.

Species	Zone: Wet Meadow	Zone: Low Prairie
Eleocharis palustris	4	-
Agrostis scabra	3	2
Beckmannia syzigachne	3	-
Carex lanuginosa	3	-
Hordeum jubatum	3	-
Mentha arvensis	3	-
Phleum pratense	3	-
Polygonum amphibium	3	-
Symphoricarpos occidentalis	2	3
Chenopodium album	2	-
Polygonum persicaria	2	-
Potentilla arguta	2	-
Rosa arkansana	1	3
Penstemon procerus	1	2
Rumex crispus	1	-
Agropyron dasystachyum	-	3
Agropyron smithii	-	3
Artemisia ludoviciana	-	3
Stipa comata	-	3
Achillea millefolium	-	2
Calamagrostis montanensis	-	2
Epilobium paniculatum	-	2
Erigeron caespitosus	-	2
Forb species	-	2
Orthocarpus luteus	-	2
Potentilla hippiana	-	2
Potentilla norvegica	-	2
Potentilla pensylvanica	-	2
Psoralea argophylla	-	2
Solidago canadensis	-	2
Zizia aptera	-	2
Heuchera richardsonii	-	1

- = not found

Table A5. Off ROW 5 species cover by wetland zone. Wetland class II, type A.

Species	Zone	
	Wet Meadow	Low Prairie
Carex lanuginosa	3-4	2
Mentha arvensis	3	3
Potentilla arguta	3	2
Rumex crispus	3	2
Carex praegracilis	3	-
Hordeum jubatum	3	-
Calamagrostis montanensis	2	3
Carex atherodes	2	-
Chenopodium album	2	-
Eleocharis palustris	2	-
Festuca hallii	-	3-4
Potentilla gracilis	-	3-4
Achillea millefolium	-	3
Agropyron dasystachyum	-	3
Agropyron smithii	-	3
Agropyron species	-	3
Artemisia frigida	-	3
Artemisia ludoviciana	-	3
Carex brevior	-	3
Potentilla norvegica	-	3
Rosa arkansana	-	3
Stachys palustris	-	3
Symphoricarpos occidentalis	-	3
Agrostis scabra	-	2
Carex aurea	-	2
Crepis tectorum	-	2
Erysimum cheiranthoides	-	2
Gaillardia aristata	-	2
Galium trifidum	-	2
Solidago canadensis	-	2
Stipa comata	-	2
Taraxacum officinale	-	2
Tragopogon dubius	-	2
Arabis glabra	-	1
Gaura coccinea	-	1
Medicago sativa	-	1
Sisyrinchium montanum	-	1
Vicia americana	-	1

- = not found

Table A6. Off ROW 6 species cover by wetland zone. Wetland class III, types B.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Agrostis scabra	3-4	3-4	-
Hordeum jubatum	3-4	2	1
Carex aurea	3-4	-	2
Eleocharis palustris	3-4	-	-
Rumex crispus	3	3	3
Polygonum amphibium	3	3	1
Ambrosia artemisiifolia	3	3	-
Chenopodium album	3	2	3
Carex atherodes	3	-	-
Sonchus arvensis	2	2	-
Atriplex argentea	2	-	2
Carex lanuginosa	2	-	-
Crepis tectorum	1	3	2
Phleum pratense	1	-	-
Achillea millefolium	-	3	3
Artemisia ludoviciana	-	3	3
Grindelia squarrosa	-	3	3
Orthocarpus luteus	-	3	2
Arabis glabra	-	2	1
Sonchus uliginosus	-	2	-
Stachys palustris	-	2	-
Erigeron caespitosus	-	1	1
Calamagrostis montanensis	-	1	-
Rosa arkansana	-	-	3-4
Symphoricarpos occidentalis	-	-	3-4
Agoseris glauca	-	-	3
Agropyron dasystachyum	-	-	3
Agropyron smithii	-	-	3
Campanula rotundifolia	-	-	3
Carex brevior	-	-	2
Cichorium intybus	-	-	2
Collomia linearis	-	-	2
Descurainia sophia	-	-	2
Gaillardia aristata	-	-	2
Juniperus horizontalis	-	-	2
Potentilla gracilis	-	-	2
Potentilla hippiana	-	-	2
Potentilla norvegica	-	-	2
Solidago canadensis	-	-	2
Thlaspi arvense	-	-	2
Tragopogon dubius	-	-	2
Cirsium arvense	-	-	1
Cirsium undulatum	-	-	1
Gaura coccinea	-	-	1
Penstemon procerus	-	-	1

- = not found

Table A7. Off ROW 7 species cover by wetland zone. Wetland class III, type B.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Hordeum jubatum	4	3	2
Eleocharis palustris	4	1	-
Ambrosia artemisiifolia	3	3	-
Chenopodium album	3	2	2
Polygonum amphibium	3	-	-
Sonchus arvensis	2	3	3
Agrostis scabra	2	3	2
Rumex crispus	2	3	2
Collomia linearis	2	-	2
Phleum pratense	2	-	-
Crepis tectorum	1	4	3
Descurainia sophia	1	3	2
Medicago sativa	1	-	-
Agoseris glauca	-	3	3
Artemisia ludoviciana	-	3	3
Carex brevior	-	3	3
Grindelia squarrosa	-	3	2
Potentilla gracilis	-	3	-
Thlaspi arvense	-	3	-
Atriplex argentea	-	2	3
Potentilla arguta	-	2	3
Rosa arkansana	-	2	3
Achillea millefolium	-	2	2
Arabis glabra	-	2	2
Epilobium paniculatum	-	2	2
Orthocarpus luteus	-	2	1
Symphoricarpos occidentalis	-	1	3-4
Campanula rotundifolia	-	1	2
Agropyron dasystachyum	-	-	3
Agropyron smithii	-	-	3
Bromus inermis	-	-	3
Carex aurea	-	-	2
Erigeron caespitosus	-	-	2
Mentha arvensis	-	-	2
Potentilla hippiana	-	-	2
Potentilla pensylvanica	-	-	2
Taraxacum officinale	-	-	2
Heuchera parvifolia	-	-	1

- = not found

Table A8. Off ROW 8 species cover by wetland zone. Wetland class II, type A.

Species	Zone	
	Wet Meadow	Low Prairie
Eleocharis palustris	4	3
Hordeum jubatum	3-4	-
Ambrosia artemisiifolia	3	3
Grindelia squarrosa	3	3
Rumex crispus	3	3
Carex brevior	3	2
Polygonum amphibium	3	-
Agrostis scabra	2	3
Chenopodium album	2	3
Erysimum cheiranthoides	2	3
Rosa arkansana	2	3
Sonchus arvensis	2	3
Beckmannia syzigachne	2	-
Artemisia ludoviciana	1	3
Forb species	1	-
Symphoricarpos occidentalis	-	3-4
Achillea millefolium	-	3
Agoseris glauca	-	3
Agropyron dasystachyum	-	3
Agropyron smithii	-	3
Agropyron trachycaulum	-	3
Campanula rotundifolia	-	3
Erigeron caespitosus	-	3
Juncus balticus	-	3
Potentilla arguta	-	3
Potentilla gracilis	-	3
Stachys palustris	-	3
Taraxacum officinale	-	3
Tragopogon dubius	-	3
Arabis glabra	-	2
Carex aurea	-	2
Carex lanuginosa	-	2
Cichorium intybus	-	2
Crepis tectorum	-	2
Descurainia sophia	-	2
Penstemon procerus	-	2
Potentilla norvegica	-	2
Solidago canadensis	-	2
Amelanchier alnifolia	-	1
Cirsium arvense	-	1
Gaillardia aristata	-	1
Heuchera richardsonii	-	1
Mentha arvensis	-	1

- = not found

Table A9. Off ROW 9 species cover by wetland zone. Wetland class II, type A.

	Zone	
Species	Wet Meadow	Low Prairie
Carex brevior	3-4	2
Artemisia ludoviciana	3	3
Collomia linearis	3	3
Epilobium paniculatum	3	3
Carex lanuginosa	3	2
Ambrosia artemisiifolia	2	3
Atriplex argentea	2	3
Campanula rotundifolia	2	3
Rosa arkansana	2	3
Arabis glabra	2	2
Chenopodium album	2	2
Descurainia sophia	2	2
Potentilla arguta	2	2
Potentilla hippiana	2	2
Rumex crispus	2	2
Eleocharis palustris	2	-
Orthocarpus luteus	2	-
Tragopogon dubius	1	2
Achillea millefolium	-	3
Agoseris glauca	-	3
Agropyron dasystachyum	-	3
Agrostis scabra	-	3
Agropyron smithii	-	3
Agropyron trachycaulum	-	3
Crepis tectorum	-	3
Grindelia squarrosa	-	3
Sonchus arvensis	-	3
Symphoricarpos occidentalis	-	3
Thlaspi arvense	-	3
Calamagrostis montanensis	-	2
Erigeron caespitosus	-	2
Erysimum cheiranthoides	-	2
Penstemon procerus	-	2
Potentilla norvegica	-	2
Stachys palustris	-	2
Taraxacum officinale	-	2
Vicia americana	-	2
Kochia scoparia	-	1

- = not found

Table A10. On ROW 1 species cover by wetland zone. Wetland class III, type B.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Hordeum jubatum	3-4	3	2
Carex lanuginosa	3-4	3	-
Agrostis scabra	3	3	2
Mentha arvensis	3	3	1
Beckmannia syzigachne	3	3	-
Conium maculatum	3	2	-
Astragalus canadensis	2	3-4	3
Calamagrostis montanensis	2	3	3
Erysimum cheiranthoides	2	3	2
Rumex crispus	2	3	1
Carex atherodes	2	3	-
Potentilla arguta	2	2	2
Heterotheca villosa	2	2	-
Polygonum coccineum	2	2	-
Chenopodium album	2	-	-
Eleocharis palustris	2	-	-
Potentilla hippiana	2	-	-
Stellaria crassifolia	2	-	-
Rosa acicularis	1	2	3
Festuca hallii	-	4	3
Artemisia ludoviciana	-	3	3
Bromus inermis	-	3	3
Cirsium arvense	-	3	3
Stachys palustris	-	3	3
Gaillardia aristata	-	3	2
Erysimum inconspicuum	-	3	-
Galium trifidum	-	3	-
Symphoricarpos occidentalis	-	2	3-4
Achillea millefolium	-	2	3
Cichorium intybus	-	2	3
Gaura coccinea	-	2	3
Populus tremuloides	-	2	3
Hieracium umbellatum	-	2	2
Arabis species	-	2	-
Carex aurea	-	2	-
Erigeron caespitosus	-	2	-
Potentilla norvegica	-	2	-
Potentilla pensylvanica	-	2	-
Tragopogon dubius	-	1	1
Agropyron dasystachyum	-	-	3
Agropyron species	-	-	3
Stipa comata	-	-	3
Agropyron smithii	-	-	2
Arnica species	-	-	2
Artemisia cana	-	-	2
Campanula rotundifolia	-	-	2
Forb species	-	-	2
Potentilla gracilis	-	-	2
Salix exigua	-	-	2
Stipa viridula	-	-	2
Melilotus albus	-	-	1

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Ratibida columnifera	-	-	1
Zizia aptera	-	-	1

- = not found

Table A11. On ROW 2 species cover by wetland zone. Wetland class III, type A.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Carex lanuginosa	4	2	3
Hordeum jubatum	3	3	3
Rumex crispus	3	3	2
Polygonum coccineum	3	3	-
Calamagrostis montanensis	3	-	3
Carex atherodes	3	-	-
Carex praegracilis	3	-	-
Agrostis scabra	2	3	3
Mentha arvensis	2	3	3
Eleocharis palustris	2	3	-
Beckmannia syzigachne	2	2	-
Chenopodium album	1	3	-
Cirsium arvense	-	3	2
Stachys palustris	-	3	2
Typha latifolia	-	3	-
Stipa comata	-	2	2
Phleum pratense	-	2	1
Arnica chamissonis	-	2	-
Conium maculatum	-	1	-
Agropyron smithii	-	-	3
Bromus inermis	-	-	3
Descurainia sophia	-	-	3
Oryzopsis hymenoides	-	-	3
Rosa arkansana	-	-	3
Symphoricarpos occidentalis	-	-	3
Achillea millefolium	-	-	2
Agropyron dasystachyum	-	-	2
Agropyron species	-	-	2
Erysimum cheiranthoides	-	-	2
Forb species	-	-	2
Galium trifidum	-	-	2
Gaura coccinea	-	-	2
Lolium persicum	-	-	2
Potentilla arguta	-	-	2
Potentilla hippiana	-	-	2
Potentilla pensylvanica	-	-	2
Antennaria parvifolia	-	-	1
Carex brevior	-	-	1
Ratibida columnifera	-	-	1

- = not found

Table A12. On ROW 3 species cover by wetland zone. Wetland class III, type A.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Eleocharis palustris	3-4	3	-
Rumex crispus	3	3	2
Sonchus arvensis	3	-	3
Crepis tectorum	2	3-4	3-4
Hordeum jubatum	2	3-4	2
Oryzopsis hymenoides	2	3-4	-
Ambrosia artemisiifolia	2	3	-
Taraxacum officinale	2	2	3
Chenopodium album	2	-	2-3
Typha latifolia	2	-	-
Agrostis scabra	1	3-4	3
Beckmannia syzigachne	1	3	-
Medicago sativa	1	-	-
Grindelia squarrosa	-	3-4	3-4
Carex brevior	-	3-4	-
Epilobium paniculatum	-	3	3
Erigeron caespitosus	-	3	3
Mentha arvensis	-	3	2
Polygonum amphibium	-	3	-
Artemisia ludoviciana	-	2	3-4
Achillea millefolium	-	2	3
Orthocarpus luteus	-	2	3
Stipa comata	-	2	3
Symphoricarpos occidentalis	-	2	3
Penstemon procerus	-	2	2
Bouteloua gracilis	-	2	-
Stachys palustris	-	2	-
Artemisia frigida	-	1	3
Festuca hallii	-	-	3-4
Agropyron smithii	-	-	3
Agropyron trachycaulum	-	-	3
Campanula rotundifolia	-	-	3
Cichorium intybus	-	-	3
Erysimum cheiranthoides	-	-	3
Ratibida columnifera	-	-	2-3
Agoseris glauca	-	-	2
Agropyron cristatum	-	-	2
Agropyron species	-	-	2
Arabis glabra	-	-	2
Artemisia cana	-	-	2
Carex aurea	-	-	2
Cirsium arvense	-	-	2
Cirsium undulatum	-	-	2
Gaura coccinea	-	-	2
Melilotus albus	-	-	2
Potentilla arguta	-	-	2
Potentilla gracilis	-	-	2
Potentilla norvegica	-	-	2
Rosa arkansana	-	-	2
Tragopogon dubius	-	-	2
Aster species	-	-	1

- = not found

Table A13. On ROW 4 species cover by wetland zone. Wetland class III, type B.

Species	Zone			
	Shallow Marsh	Wet Meadow	Low Prairie	Upland in Centre
Eleocharis palustris	4	3	-	-
Polygonum amphibium	3-4	3	-	-
Ambrosia artemisiifolia	3	3	3	-
Rumex crispus	3	3	3	-
Taraxacum officinale	3	-	3-4	3
Agrostis scabra	2	3	3	3
Oryzopsis hymenoides	2	3	3	-
Phleum pratense	2	-	-	-
Beckmannia syzigachne	1	-	-	-
Carex brevior	-	3-4	3	-
Sonchus arvensis	-	3-4	3	-
Carex lanuginosa	-	3-4	-	-
Crepis tectorum	-	3	3-4	3
Grindelia squarrosa	-	3	3-4	3
Hordeum jubatum	-	3	3-4	-
Achillea millefolium	-	3	3	3
Mentha arvensis	-	3	3	-
Symphoricarpos occidentalis	-	2	3	3-4
Potentilla pensylvanica	-	2	2	-
Chenopodium album	-	2	-	-
Heuchera richardsonii	-	2	-	-
Medicago sativa	-	2	-	-
Potentilla hippiana	-	2	-	-
Rosa arkansana	-	1	-	3-4
Bryophyta species	-	1	-	-
Calamagrostis montanensis	-	-	3-4	2
Tragopogon dubius	-	-	3-4	2
Bromus inermis	-	-	3-4	-
Agropyron dasystachyum	-	-	3	3
Agropyron smithii	-	-	3	3
Artemisia ludoviciana	-	-	3	3
Arabis glabra	-	-	3	2
Agoseris glauca	-	-	3	-
Agropyron species	-	-	3	-
Agropyron trachycaulum	-	-	3	-
Carex aurea	-	-	3	-
Cirsium arvense	-	-	3	-
Cirsium undulatum	-	-	3	-
Epilobium paniculatum	-	-	3	-
Erigeron caespitosus	-	-	3	-
Ranunculus pensylvanicus	-	-	3	-
Ratibida columnifera	-	-	3	-
Solidago canadensis	-	-	3	-
Campanula rotundifolia	-	-	2	2
Artemisia cana	-	-	2	-
Descurainia sophia	-	-	2	-
Gaura coccinea	-	-	2	-
Lolium persicum	-	-	2	-
Orthocarpus luteus	-	-	2	-
Penstemon procerus	-	-	2	-
Potentilla arguta	-	-	2	-

Species	Zone			
	Shallow Marsh	Wet Meadow	Low Prairie	Upland in Centre
Potentilla norvegica	-	-	2	-
Stipa comata	-	-	-	3

- = not found

Table A14. On ROW 5 species cover by wetland zone. Wetland class II, type B.

Species	Zone	
	Wet Meadow	Low Prairie
Eleocharis palustris	4	2
Polygonum amphibium	4	2
Agrostis scabra	2	3
Ambrosia artemisiifolia	2	3
Hordeum jubatum	2	3
Beckmannia syzigachne	2	2
Carex species	2	-
Rumex crispus	1	3
Agropyron dasystachyum	-	3
Agropyron smithii	-	3
Arnica chamissonis	-	3
Artemisia ludoviciana	-	3
Crepis tectorum	-	3
Descurainia sophia	-	3
Erigeron caespitosus	-	3
Grindelia squarrosa	-	3
Mentha arvensis	-	3
Oryzopsis hymenoides	-	3
Rosa arkansana	-	3
Sonchus arvensis	-	3
Stipa comata	-	3
Taraxacum officinale	-	3
Achillea millefolium	-	2
Agoseris glauca	-	2
Bromus inermis	-	2
Calamagrostis montanensis	-	2
Campanula rotundifolia	-	2
Chenopodium album	-	2
Epilobium paniculatum	-	2
Penstemon procerus	-	2
Plantago patagonica	-	2
Potentilla arguta	-	2
Potentilla hippiana	-	2
Ratibida columnifera	-	2
Symphoricarpos occidentalis	-	2

- = not found

Table A15. On ROW 6 species cover by wetland zone. Wetland class II, type B.

Species	Zone	
	Wet Meadow	Low Prairie
Eleocharis palustris	3-4	-
Ambrosia artemisiifolia	3	3-4
Chenopodium album	3	3
Hordeum jubatum	2	3
Mentha arvensis	2	3
Oryzopsis hymenoides	2	3
Beckmannia syzigachne	2	2
Achillea millefolium	-	3
Agoseris glauca	-	3
Agrostis scabra	-	3
Agropyron smithii	-	3
Artemisia ludoviciana	-	3
Carex brevior	-	3
Crepis tectorum	-	3
Grindelia squarrosa	-	3
Rosa arkansana	-	3
Sonchus arvensis	-	3
Symphoricarpos occidentalis	-	3
Artemisia frigida	-	2
Campanula rotundifolia	-	2
Erigeron caespitosus	-	2
Gaillardia aristata	-	2
Juncus balticus	-	2
Potentilla arguta	-	2
Potentilla hippiana	-	2
Potentilla pensylvanica	-	2
Ratibida columnifera	-	2
Rumex crispus	-	2

- = not found

Table A16. On ROW 7 species cover by wetland zone. Wetland class III, type A.

Species	Zone		
	Shallow Marsh	Wet Meadow	Low Prairie
Eleocharis palustris	4	-	-
Agrostis scabra	3-4	3-4	2
Hordeum jubatum	3-4	3-4	-
Polygonum amphibium	3-4	3	3
Grindelia squarrosa	3	3	3
Mentha arvensis	3	3	3
Rumex crispus	3	3	3
Taraxacum officinale	3	3	2
Ambrosia artemisiifolia	3	3	-
Beckmannia syzigachne	3	-	-
Carex brevior	2	3-4	-
Artemisia ludoviciana	2	3	3
Chenopodium album	2	3	3
Sonchus uliginosus	2	3	3
Crepis tectorum	2	-	-
Bromus inermis	-	3	3-4
Descurainia sophia	-	3	3-4
Symphoricarpos occidentalis	-	3	3-4
Achillea millefolium	-	3	3
Agoseris glauca	-	3	3
Agropyron dasystachyum	-	3	3
Agropyron smithii	-	3	3
Carex aurea	-	3	3
Sonchus arvensis	-	3	3
Epilobium paniculatum	-	3	2
Carex lanuginosa	-	3	-
Rosa arkansana	-	2	3
Erigeron caespitosus	-	2	2
Orthocarpus luteus	-	2	2
Potentilla arguta	-	2	2
Potentilla gracilis	-	2	2
Vicia americana	-	2	2
Campanula rotundifolia	-	-	3
Carex praegracilis	-	-	3
Cichorium intybus	-	-	3
Collomia linearis	-	-	3
Poa palustris	-	-	3
Gaillardia aristata	-	-	2
Melilotus albus	-	-	2
Penstemon procerus	-	-	2
Potentilla hippiana	-	-	2
Potentilla norvegica	-	-	2
Ratibida columnifera	-	-	2
Tragopogon dubius	-	-	2
Cirsium arvense	-	-	1
Forb species	-	-	1
Gaura coccinea	-	-	1
Linum rigidum	-	-	1
Salix exigua	-	-	1

- = not found

Table A17. On ROW 8 species cover by wetland zone. Wetland class II, type A.

	Zone	
Species	Wet Meadow	Low Prairie
Ambrosia artemisiifolia	4	3
Capsella bursa-pastoris	4	3
Chenopodium album	4	3
Sonchus arvensis	4	3
Carex aurea	3-4	3
Thlaspi arvense	3-4	3
Carex lanuginosa	3-4	1
Descurainia sophia	3-4	-
Agrostis scabra	3	3
Artemisia ludoviciana	3	3
Calamagrostis montanensis	3	3
Campanula rotundifolia	3	3
Carex brevior	3	3
Erysimum cheiranthoides	3	3
Rumex crispus	3	3
Solidago canadensis	3	3
Taraxacum officinale	3	3
Tragopogon dubius	3	3
Achillea millefolium	3	2
Crepis tectorum	3	2
Potentilla arguta	3	2
Stachys palustris	3	2
Carex praegracilis	3	-
Eleocharis palustris	3	-
Grindelia squarrosa	3	-
Hordeum jubatum	2-3	-
Agoseris glauca	2	3
Agropyron smithii	2	3
Erigeron caespitosus	2	3
Rosa arkansana	2	3
Potentilla norvegica	2	2
Arabis glabra	2	-
Carex aquatilis	2	-
Carex atherodes	2	-
Mentha arvensis	2	-
Potentilla hippiana	2	-
Orthocarpus luteus	1	-
Symphoricarpos occidentalis	-	3-4
Agropyron dasystachyum	-	3
Agropyron trachycaulum	-	3
Cirsium arvense	-	3
Phleum pratense	-	3
Potentilla gracilis	-	3
Sisyrinchium montanum	-	3
Artemisia frigida	-	2
Cirsium undulatum	-	2
Erysimum inconspicuum	-	2
Gaillardia aristata	-	2
Penstemon procerus	-	2
Psoralea argophylla	-	2
Ratibida columnifera	-	2

	Zone	
Species	Wet Meadow	Low Prairie
Vicia americana	-	2
Heuchera parvifolia	-	1-2
Galium trifidum	-	1

- = not found

Table A18. Complete species list over 2014 and 2015 field season.

Species	Origin	2015 General Status	Location
Achillea millefolium	Native	S5	V, W
Agoseris glauca	Native	S5	W
Agropyron cristatum	Exotic	SNA	V, W
Agropyron dasystachyum	Native	S5	V, W
Agropyron repens	Exotic	SNA	V
Agropyron smithii	Native	S5	V, W
Agropyron trachycaulum	Native	S5	V, W
Agrostis scabra	Native	S5	W
Ambrosia artemisiifolia	Native	S3	W
Amelanchier alnifolia	Native	S5	W
Androsace septentrionalis	Native	S5	V
Antennaria parvifolia	Native	S5	V, W
Arabis glabra	Native	S4	W
Arabis holboellii	Native	S1	V
Arnica chamissonis	Native	S5	W
Artemisia cana	Native	S5	V, W
Artemisia frigida	Native	S5	V, W
Artemisia ludoviciana	Native	S5	V, W
Astragalus canadensis	Native	S4	W
Atriplex argentea	Native	S3	W
Beckmannia syzigachne	Native	S5	W
Bouteloua gracilis	Native	S5	V, W
Bromus biebersteinii	Exotic	SNA	V
Bromus inermis	Exotic	SNA	W
Calamagrostis montanensis	Native	S5	W
Calamovilfa longifolia	Native	S5	V
Campanula rotundifolia	Native	S5	W
Capsella bursa-pastoris	Exotic	SNA	W
Carex aquatilis	Native	S5	W
Carex atherodes	Native	S5	W
Carex aurea	Native	S5	W
Carex brevior	Native	S3	W
Carex filifolia	Native	S5	V
Carex lanuginosa	Native	S5	V, W
Carex phaeocephala	Native	S4	V
Carex praegracilis	Native	S5	W
Carex stenophylla	Native	S5	V
Chenopodium album	Exotic	SNA	W
Chenopodium leptophyllum	Native	S3	V
Chenopodium pratericola	Native	S3	V
Cichorium intybus	Exotic	SNA	W
Cirsium arvense	Exotic	SNA	V, W
Cirsium undulatum	Native	S3	V, W
Collomia linearis	Native	S5	W
Conium maculatum	Exotic	SNA	W
Coryphantha vivipara	Native	S3	V
Crepis tectorum	Exotic	SNA	V, W
Descurainia sophia	Exotic	SNA	V, W
Distichlis stricta	Native	S4	V
Elaeagnus commutata	Native	S5	W
Eleocharis palustris	Native	S5	W
Epilobium angustifolium	Native	S5	W

Species	Origin	2015 General Status	Location
Epilobium paniculatum	Native	S3	W
Erigeron caespitosus	Native	S5	W
Erigeron canadensis	Native	S4	V
Erysimum cheiranthoides	Exotic	SNA	W
Erysimum inconspicuum	Native	S5	W
Eurotia lanata	Native	S5	V
Festuca hallii	Native	S5	W
Gaillardia aristata	Native	S5	W
Galium trifidum	Native	S5	W
Gaura coccinea	Native	S4	V, W
Geum triflorum	Native	S5	W
Grindelia squarrosa	Native	S4S5	W
Halimolobos virgata	Native	S2	V
Hedeoma hispidum	Native	S3	V
Heterotheca villosa	Native	S5	V, W
Heuchera parvifolia	Native	S3	W
Heuchera richardsonii	Native	S5	W
Hieracium umbellatum	Native	S5	W
Hordeum jubatum	Exotic	SNA	V, W
Juncus balticus	Native	S5	W
Juniperus horizontalis	Native	S5	W
Kochia scoparia	Exotic	SNA	V, W
Koeleria macrantha	Native	S5	V
Lepidium densiflorum	Native	S5	V
Linum rigidum	Native	S4	V, W
Lolium persicum	Exotic	SNA	W
Lygodesmia juncea	Native	S5	V
Medicago sativa	Exotic	SNA	W
Melilotus albus	Exotic	SNA	W
Mentha arvensis	Native	S5	W
Muhlenbergia cuspidata	Native	S4	V
Opuntia fragilis	Native	S4	V
Opuntia polyacantha	Native	S5	V
Orthocarpus luteus	Native	S5	W
Oryzopsis hymenoides	Native	S3	W
Paronychia sessiliflora	Native	S3	V, W
Penstemon procerus	Native	S5	W
Phleum pratense	Exotic	SNA	W
Phlox hoodii	Native	S5	V
Pinus banksiana	Native	S5	V
Plantago patagonica	Native	S5	V, W
Poa palustris	Native	S5	V, W
Poa pratensis	Exotic	SNA	W
Poa sandbergii	Native	S5	V
Polygonum amphibium	Native	S5	W
Polygonum coccineum	Native	S4	W
Polygonum persicaria	Exotic	SNA	W
Populus tremuloides	Native	S5	W
Potentilla arguta	Native	S4	W
Potentilla gracilis	Native	S5	W
Potentilla hippiana	Native	S5	W
Potentilla norvegica	Native	S5	W
Potentilla pensylvanica	Native	S5	W
Psoralea argophylla	Native	S3	V, W

Species	Origin	2015 General Status	Location
Ranunculus pensylvanicus	Native	S3	W
Ratibida columnifera	Native	S4	V, W
Rosa acicularis	Native	S5	V, W
Rosa arkansana	Native	S5	W
Rosa woodsii	Native	S5	V
Rumex crispus	Exotic	SNA	W
Salix exigua	Native	S3S4	W
Schedonnardus paniculatus	Native	S2	V
Selaginella densa	Native	S5	V
Sisyrinchium montanum	Native	S5	W
Solidago canadensis	Native	SNA	W
Sonchus arvensis	Exotic	SNA	W
Sonchus uliginosus	Exotic	SNA	W
Sphaeralcea coccinea	Native	S5	V
Stachys palustris	Native	S5	W
Stellaria crassifolia	Native	S5	W
Stipa comata	Native	S5	V, W
Stipa viridula	Native	S5	V, W
Symphoricarpos occidentalis	Native	S5	W
Taraxacum officinale	Exotic	SNA	V, W
Thlaspi arvense	Exotic	SNA	W
Tragopogon dubius	Exotic	SNA	V, W
Typha latifolia	Secure	S5	W
Vicia americana	Secure	S5	W
Zizia aptera	Secure	S5	W

V = native dry mixedgrass prairie upland assessment species (2014)

W = native dry mixedgrass prairie wetlands assessment species (2015)

S1 = five or fewer occurences or very few remaining hectars

S2 = six to 20 occurences or few remaining hectares

S3 = 21 to 80 occurences. May be rare and local throughout its range or found locally, even abundantly, in a restricted range

S4 = apparently secure globally province wide, though it may be quite rare in parts of its range, especially at the periphery

S5 = demonstrably secure globally province wide, though it may be quite rare in parts of its range, especially at the periphery

SNA = not applicable. A conservation status rank is not applicable because the community is not a suitable target for conservation activities

S#S# = range rank*. A numeric range rank is used to indicate any range of uncertainty about the status of the species or community