EVALUATION AND MANAGEMENT OF GRASSLANDS IN THE CITY OF CALGARY, ALBERTA

Submitted by: Sukhvinder Kaur Dhol

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of the requirements for the degree,
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"EVALUATION AND MANAGEMENT OF GRASSLANDS IN THE CITY OF CALGARY, ALBERTA

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfilment of the requirements of the degree of Master of Natural Resources Management.

By

Ms. Sukhvinder K. Dhol

1994

ABSTRACT

Introduced species have become a limiting factor in the maintenance of native grasslands in Calgary, Alberta. Currently, there are no formal techniques being used to manage Calgary's grasslands. The primary purpose of this study was to determine the pattern of species distribution along an environmental gradient in order to recommend appropriate management prescriptions.

The study site for this project was Nose Hill Park located in northwest Calgary. A Canonical Correspondence Analysis was performed on species frequency data, environmental factors, and disturbance factors which revealed that moisture regime had the largest influence on plant community composition on Nose Hill Park.

Four main grassland associations were found to occur on Nose Hill. **Needlegrass/western wheatgrass** was found on steep south facing slopes with rapid drainage and high levels of insolation. The main disturbance was light to moderate grazing in the past. If prescribed burns are to be used as a management technique, fire intensity must be tightly controlled since further moisture loss from the site may favour a community type dominated by more xeric species such as blue grama grass. The **rough fescue/Parry oatgrass** association occurred on well drained Black Chernozemic soils, with ample moisture. Rough fescue is susceptible to heavy grazing pressure, and may be eliminated in favour of Kentucky bluegrass under intense disturbance. **Smooth brome** and **smooth brome/Kentucky bluegrass** associations represent areas on Nose Hill that were planted, intensely grazed, or developed as a result of agricultural activity. Cattle grazing can be used to help eliminate swards of smooth brome, but Kentucky bluegrass may increase in abundance with grazing.

Based on the research findings, a number of management options were recommended to deal with each of these four vegetation associations. It was concluded that these techniques should be implemented in the form of small experimental plots accessible to the public, before any large scale manipulations are attempted.

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GLOSSARY OF TERMS

Cultivar: For "cultivated variety," is a named and released assemblage of plants, which are mainly selected ecotypes that exhibit superior performance in defined areas (Thornberg 1982).

Disturbance: Defined as forces that alter an existing ecosystem; can result from grazing, fertilizers, herbicides, mechanical treatment and prescribed burning (Saskatchewan Agriculture 1991).

Grassland: Includes any herb-dominated vegetation, steppe to tundra to marsh, as well as herb-dominated layers of savanna or open forest (Daubenmire 1968).

Native vegetation: Any species that was naturally occurring in the area prior to settlement (Dangerfield 1993).

Plant community: A combination of plants that are dependant on their environment and influence one another and modify their own environment (Mueller-Dombois and Ellenberg 1974).

Restoration: Replacement of an authentic plant community on a site where that particular community no longer exists. Restoring rather than revegetating ecosystems may involve providing habitat for the preservation of species and ecological phenomena, restoring sound ecological function to badly damaged landscapes, or re-establishing biological diversity (Collicut and Morgan 1991).

Revegetation: Defined as the replacing of vegetation on a formerly vegetated site or the establishment of a vegetative cover not representative of an authentic plant community on a non-vegetated site (Collicut and Morgan 1991).

Vegetation Management: The area and science of manipulation of the composition, structure, and function of vegetation over a landscape to achieve some predetermined goal (Romo and Lawrence 1990).

Weeds: Undesirable species that occupy an area. These include all introduced species, as well as native species that aggressively dominate a stand (Dangerfield 1993).

CHAPTER 1: INTRODUCTION

1.1 Background

Coupland (1979) defines grassland as being any region where herbaceous plants are natural community dominants, and woody vegetation is absent or marginal. The biotic composition of grasslands in a particular geographical area is a product of characteristic climate, fire frequency and soil type (Peterson and Adler 1982). In addition to inherent ecosystem properties, the grasslands have been greatly influenced by land-use conversions to agriculture and livestock grazing (Peterson and Adler 1982). Urbanization impacts the interaction of natural ecological units, and has provoked major alterations in the grassland biome (Curtis 1971). The removal of vegetation for housing and industrial development fragments large habitats into smaller isolated ones (Sharpe et al. 1986). Processes such as river channelling, wetland drainage, levelling of rough ground, slope terracing, and agricultural practices contribute toward modifying the natural environment, and intensifying disturbance of remnant native vegetation (Gill and Bonnett 1973).

The rapid growth experienced in recent years by the city of Calgary, Alberta has placed pressure on the natural environment (City of Calgary 1979). To protect remaining elements of the natural environment in an urban form, the city is undertaking a more active role in natural area conservation and management. Many areas in and around the city that are valuable from the ecological perspective have been identified as being "Environmentally Sensitive Areas" (ESAs) (City of Calgary 1979). The City of Calgary defines an Environmentally Sensitive Area as;

> "an area of land and/or water that may contain distinctive or unusual features, important biotic communities, or performs significant ecological functions. It may include escarpments or drainage courses, but can also include relatively flat lands generally considered suitable for development (City of Calgary 1979)."

The purpose of an ESA designation is not to prevent all development in the identified regions, but rather, to provide some degree of protection of these areas from irreversible damage until the city has assessed the proposed development and its potential impact on the ESA (Geisbrecht 1993).

The 1991 Calgary Urban Parks Survey, **"Pulse on Parks"** indicated that the Citizens of Calgary have a strong interest in protecting the open spaces and natural habitats found throughout the City (Calgary Parks & Recreation 1991). In response to the desire of Calgarians to manage their natural areas and resources, Calgary Parks and Recreation is in the process of producing a **Natural Areas Management Plan** which will reflect the vision of "an extensive, connected, representative, and healthy natural parkland system" throughout Calgary (Elphinstone 1993). The City's aim is to:

> "use resource management techniques to protect, administer and/or reclaim significant plant and animal communities, landforms, and ecological processes (Elphinstone 1993)."

Calgary Parks & Recreation will ensure the long term viability of the prairie landscape by maintaining diversity and representivity of native and natural habitats throughout the City (Elphinstone 1993).

1.2 Problem Statement

Introduced weed species have become a limiting factor in the maintenance of native grasslands in Calgary by lowering species biodiversity (Elphinstone 1993). Cultivated and escaped material are replacing native species in areas of general stress, to the extent that some areas are now dominated by invader species (Elphinstone 1993). Smooth brome (*Bromus inermis*) and Canada thistle (*Cirsium arvense*) are becoming regular understorey species in many natural areas (Elphinstone 1993). There is also an expansion of shrubs into native Fescue and Mixed grasslands (Elphinstone 1993).

There is increasing concern over the City's traditional methods for controlling weed and other pest species, as well as with the overall management of native plant communities. Generally, control of encroaching weeds is handled by spraying, but chemicals will be a problem in the future as the public pushes for a ban of their use in natural environments (Elphinstone 1993). Loss of the natural ecological state of grasslands increases management costs (eg. weed control, fire control) as well as potential conflicts (eg. users, neighbouring uses and wildlife).

At the present time, there are no formal techniques being used to manage native grasslands in the City of Calgary. The intent of "managing" grassland ecosystems involves:

1) the protection of Calgary's existing native grasslands considering the propagation of introduced species,

2) the restoration of disturbed grasslands to a near native state if practical, and,

3) adjusting to the loss of natural controls such as grazing and fire (Elphinstone personal communication 1993).

The knowledge of how to maintain a continuous and regenerating system, and how to influence habitats that normally have natural controls, is lacking within Calgary Parks & Recreation (Elphinstone 1993).

It must be noted that full restoration of highly disturbed grasslands, that is restoration of a site to its pre-damaged condition, may be unfeasible within the bounds of the predictive capability of ecology (Cairns 1988). Full restoration is difficult, costly, and uncertain for the following reasons:

"1) Information about the original system may be inadequate in terms of detailed species inventories as well as detailed descriptions of the spatial relationships, trophic dynamics, and functional attributes of the system.

2) An adequate source of species for recolonization may not be available because of the uniqueness of the damaged community or because the remaining communities of this type would be damaged by removing organisms for recolonization elsewhere.

3) It may be impossible to put a halt to some of the factors causing damage.

4) The original ecosystem may have developed as a result of a sequence of meterological events that are unlikely to be repeated and may be difficult or impossible to reproduce.

5) The sheer complexity of duplicating the sequencing of species introductions is overwhelming. To re-create the original community, it is not only necessary that species colonize at the appropriate time, but also that some disappear at the appropriate time (Cairns 1988)".

Alternatives to full restoration include partial restoration (restoration of selected ecological attributes of the site), and creation of an alternative ecosystem type.

1.3 Objectives

The principle objective of this study was to determine the pattern of species distribution along an environmental gradient in order to formulate appropriate management prescriptions. Secondary objectives included:

1) A description of each selected site on the basis of existing species composition, land uses within the site, soil characteristics, and site conditions;

2) A comparative analysis of the species composition of the various sites in relation to disturbance factors as well as intrinsic environmental differences;

3) Presentation of potential management strategies and recommendations to the City of Calgary based on the findings of the study.

CHAPTER 2: METHODS

2.1 Site Identification

In general, information regarding the various types and locations of grassland communities in the Calgary region is limited. In 1993, however, the City contracted Sentar Consultants Ltd., to conduct a detailed biophysical inventory of Nose Hill Park. Because relatively detailed information on grassland communities was available for the Nose Hill area, and data pertaining to grasslands in other regions of Calgary is not as descriptive, site selection was limited to Nose Hill. Restricting the study area to this region saved a considerable amount of time and mileage. A sizeable patch of the blue grama community type could not be found on Nose Hill, and was thus sampled on Briar Hill where a larger area was known to exist.

For purposes of the biophysical inventory, grassland habitats were mapped on a scale of 1:2500 (Kansas and Strong 1993). This level allowed slope and aspect conditions, which have a large influence on the distribution of grassland species to be mapped. The intent of the large scale was to map individual community types rather than assemblages of community types (Kansas and Strong 1993).

The format of the inventory was an **Integrated Ecological Land Classification**, which is a hierarchial system developed by the Lands fundamental unit of classification was the ecosite. An ecosite is defined as "an area with a unique recurring combination of vegetation soil, landform and environmental components (Kansas and Strong 1993)."

The method used to derive ecological units was air-photo interpretation through the use of a stereoscope. Land surface was stratified according to parent material and then segmented by interpreting relationships among environmental factors and vegetation (Kansas and Strong 1993). After initial interpretation, ground truthing was done to verify the accuracy of the outlined map polygons, as well as to compile vegetation data.

Field sampling took place between June 17-29, 1993. Transects were taken in each of the outlined map polygons, on sites considered representative of the community being sampled (Kansas and Strong 1993). Five 0.2 m X 0.5 m plots were sampled along each 15 m transect. An area was identified as being a grassland if the total grass cover was greater than that of shrubs, and no aspen was present in the area (Lewis and Johnson 1980). Data from individual plant communities were grouped into preliminary community types based on similar physiognomy, species dominants by strata, species composition, percent cover, constancy values and abundance (Kansas and Strong 1993). Following field collection, data were re-evaluated and a final classification was developed. The community types were named based on two species that dominated by stratum. Plant community ecosite mapping was transferred to mylar overlay and these sheets registered to CalSIM (City of Calgary Spatial Information Management; Computer maps of city infrastructure and natural features) planimetric base maps which provided a geometrically corrected base (Kansas and Strong 1993).

This biophysical inventory produced a "large scale ecological land classification of Nose Hill (Kansas personal communication, 1993)." For purposes of this study, however, additional plots of a smaller size (0.25 m X 0.25 m) along each transect were required to observe the behaviour of individual species along an environmental gradient. The inventory consisted of fifty-six grassland community types on Nose Hill. For this project, the data were reviewed and heavily disturbed sites, repetitive brome sites, and shrub dominated sites, were eliminated. Thirty-five community types remained. These thirty-five communities, depicted by polygons on the mylar map, were physically located in the field with an aerial photograph and re-sampled to obtain small scale changes in vegetation.

2.2 Site Assessment

In each of the thirty-five sites, a 20 m straight line transect was placed in a spot that was representative of the surrounding homogenous area. At every 0.8 m interval a sample was taken using a 0.25 m X 0.25 m quadrat, until a total of twenty plots on the transect had been sampled. A sample of every plant species present in each plot was taken and tagged according to the site number and plot number in which it was found. These samples were later identified, and presence in each plot was recorded (Johnson and Lewis 1980). Species nomenclature was based on Moss (1959). Species frequency data were collected between July 23, 1993-August 3, 1993.

The physical parameters recorded for each map polygon were collected between June 17, 1993 and June 27, 1993 as part of the Nose Hill biophysical inventory. A soil pit was dug at each inventory site in order to identify surficial material, and to classify the soils to the subgroup level according to the Canadian System of Soil Classification (Kansas and Strong 1993). Drainage, moisture conditions and surface texture were also noted for each site. It was necessary to have a specific measure for percent slope and aspect at each of the sites from which actual species data were collected. Percent slope was measured using a clinometer, and aspect was obtained through the use of a compass.

Past land use of the area, such as grazing, cultivation or burning, was determined primarily though interviews, The Glenbow Museum archives, and the aerial photograph collection at the University of Calgary.

2.3 Site Analysis

2.3.1 General

For each site a frequency value was calculated for all species identified within the stand. The data were entered as a matrix with species as columns and sites as rows into Microsoft Excel Version 4.00. In total, sixty-four species were identified, but the data were condensed to twenty-two dominant species in order to facilitate the analysis, and decipher actual patterns of distribution. A Canonical Correspondence Analysis (CCA) was performed on the data using Canoco version 3.11. Variables were entered either as continuous data or discrete data (Table 1).

Table 1: Form of data entry for CCA

VARIABLE	*FORM IN WHICH DATA WAS ENTERED*
Aspect 1 (north/south)	Coded as continuous data
Aspect 2 (west/east)	Coded as continuous data
Grazing	low (1); moderate (2); heavy (3)
Burning	none (0) occurred (1)
Cultivation	none (0); cultiv. ceased before 1974 (1) cultiv. ceased in 1974 (2)
Drainage	low (1); moderate (2); well (3)
Slope	Actual percent slope entered (continuous)

Like any algorithm, the CCA produced two sets of site (species) scores, and although ter Braak (1988, 1990) suggests using the linear combination of variables to plot ordination diagrams, this created distortions in the data. Site scores (species scores) determined by weighted averaging were used in the ordination diagrams instead. Cluster Analysis (Syntax Version 3.0) was also performed on site data in order to group sites on the basis of similarity of species composition, environmental factors and disturbance factors. Species abundances were then averaged for all sites belonging to a particular cluster.

2.3.2 Description of Canonical Correspondence Analysis

Numerical methodologies that achieve a representation of data structure in a lower dimensional space, while retaining as much of the trended variation in the data as possible, are known collectively as "ordination" or "scaling" methods (Orloci 1978). Correspondence analysis (CA; Hill 1974) is one such ordination method. In CA, the squared canonical correlation r^2 between the rows and columns of the data set is maximized along successive ordination axes (Kenkel 1994). This can be accomplished through an eigen analysis, where the eigenvalues equal r^2 (range 0 to 1). The corresponding eigenvector elements are used to obtain component scores for the row elements, and a simple transformation yields scores for the column elements as well (Kenkel 1994).

In ecological application, an ordination is interpreted under the assumption that it is an "optimal" representation of species-environmental relationships (Kenkel 1994). In practice, however, the interpretation of environmental relationships can be difficult. To overcome this problem, ter Braak (1986) proposed a method named canonical correspondence analysis (CCA) "because it is a correspondence analysis technique in which the axes are chosen in the light of the environmental variables." The method is somewhat analogous to producing a CA ordination of a data set, and then obtaining an "estimate" of the site scores from a multiple regression of the environmental variables. Palmer (1993) provides a complete description of the method and gives examples of its use.

The results of CCA are generally displayed as a "biplot" of species and site scores, together with environmental variable vectors originating from the centroid of the ordination diagram. Vector direction indicates the direction of increasing values of the variable, while the relative length of the vector indicates the "strength" of the trend. Environmental variables that are highly correlated with species composition will therefore have the largest vector lengths (Kenkel 1994).

CHAPTER 3: STUDY SITE DESCRIPTION

3.1 Location

As of 1990, 1127.5 ha (2786 acres) constitute Nose Hill Park. The area is located within Section 32, Township 24, Range 1, West of the Fifth Meridian; and Sections 4, 5, 6, 7, 8, and 9, Township 25, Range 1, West of the Fifth Meridian (Bird 1972). The park is located within the city of Calgary's northwest quadrant, approximately five kilometres from the city centre (Calgary Parks & Recreation 1992). Nose Hill is bordered by 14th Street N.W. on the east, John Laurie Boulevard on the south and Shaganappi Trail on the west. MacEwan Glen residential subdivision bounds the Park to the north (Calgary Parks & Recreation 1992) (Figure 1). The plateau on top of the hill has an average elevation of 1,200 m above sea level but the average relief above the surrounding land and urban development of approximately 90 m (Calgary Parks & Recreation 1992).

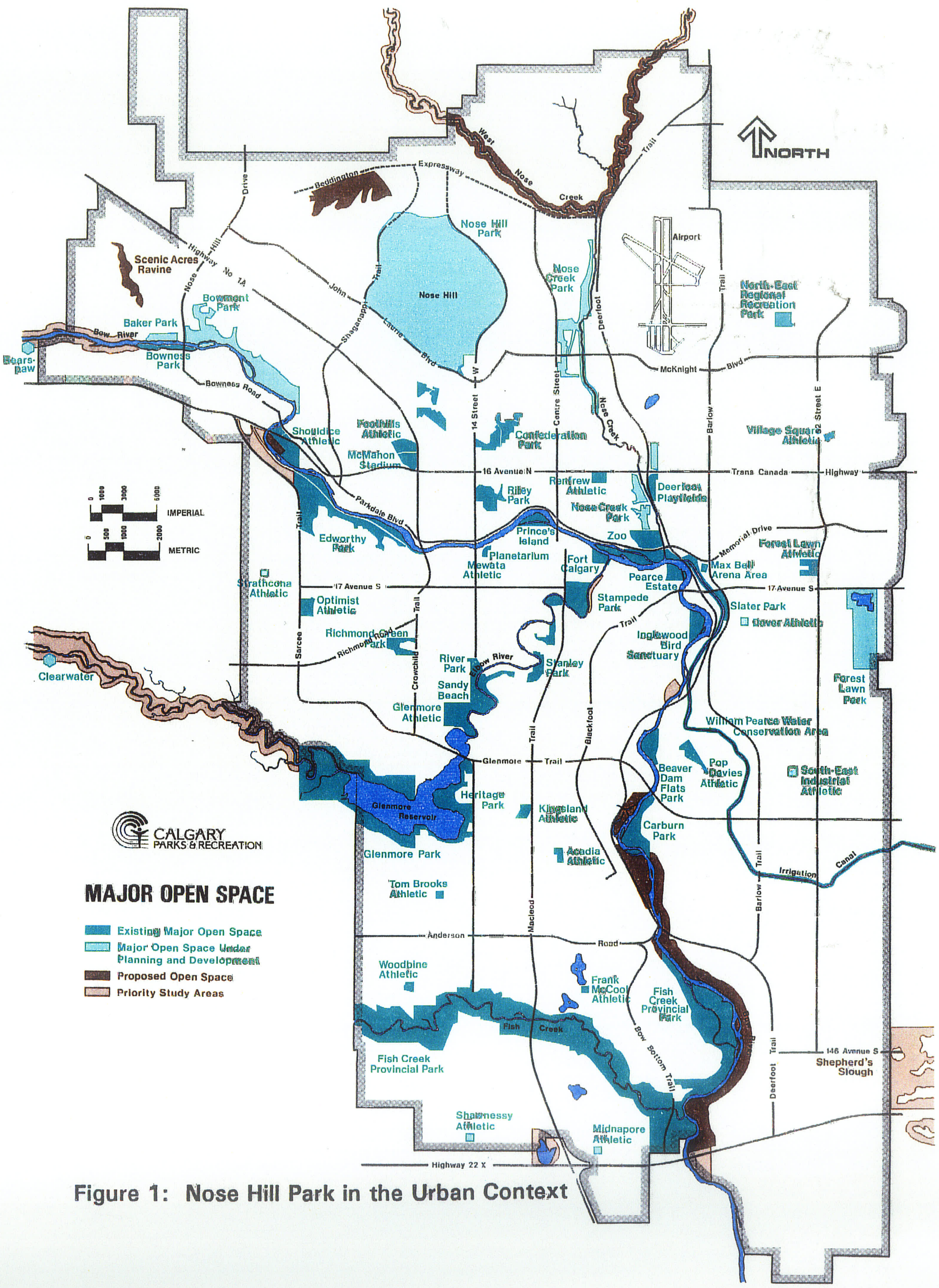


Figure 1: Nose Hill Park in the Urban Context

3.2 Climate

Calgary's climate has been classed as being "cold temperate" or "continental" (Wilson 1981). The annual temperature range in the Calgary region is greater than in any other climatic zone in Canada. The average amount of sunshine in Calgary is 6 hours per day (Wilson 1981). Southern Alberta receives more hours of sunshine per year than any other area in Canada (Fletcher 1972). The summers are short and warm with maximum temperatures frequently reaching above 30 degrees Celsius. On a typical day in July, dry air and moderately strong winds can moderate the effect of high temperatures, but very dry conditions are produced on the ground (Calgary Parks & Recreation 1992). Summer temperatures may be experienced as late as September or October. Spring is short and the transition from winter to summer can occur within a month (Wilson 1981). Winters are long, and extremes of -45 degrees Celsius have been recorded, although there is generally a moderation of temperature by periodic chinook winds (Wilson 1981). Chinook winds are surges of warm relatively dry air which sweep over the Rockies to the western plains. Chinooks occur 25 to 30 days a year, and have been known to raise sub-zero temperatures 17 degrees Celsius within only a few hours (Wilson 1981). The highest wind speeds in Calgary are experienced in April or May. The average wind speed is 12 km/hr during this time, with the mean wind speed throughout the rest of the year being 10.5 km/hr (Wilson 1981).

Temperatures also fluctuate over a wide range within a 24 hour period. This range is due to the continental location and relatively high elevation of the Calgary area (over 1100 m above sea level) (Wilson 1981). On Nose Hill, the effects of rapid changes in temperature are aggravated by low relative humidities and the absence of dense vegetation (Calgary Parks & Recreation 1992). The severe temperature changes experienced in Southern Alberta represent a major stress factor to which plants must adapt.

The spring and summer months receive the most rain. During the growing season, which lasts about 108 days between the months of May through August, average rainfall exceeds 260 mm of the 438 mm yearly total. Rainfall distribution is often highly variable over these months. Part of the imbalance is due to the heavy rainfall from the many thunderstorms which occur in this area. Calgary experiences low winter precipitation, and has a median snow depth of 10 cm (Wilson 1981). On Nose Hill specifically, snow begins to collect in coulees and on north facing slopes by October. A total of 155 cm of snow can be expected to fall but depths on the ground vary according to location. It is not unusual for south and west facing slopes and the plateau to be free from snow for most of the winter. Strong westerly winds quickly remove snow from exposed sites and deposit it in sheltered coulees. Since monthly snowfalls increase over the winter to a maximum in April, substantial snow cover may be present on Nose Hill until late spring. Much of the local meltwater infiltrates directly into the soil

(Wilson 1981). Rivers draining the mountain front have run-off peaks in early summer from snow melt at higher altitudes (Wilson 1981). Precipitation reaches a peak early in the growing season to enhance moisture conditions for plants. This is critical since winter chinooks may leave little snow for spring melt and can cause an early spring shortfall in soil moisture (Wilson 1981).

3.3 Geology

Calgary lies on the western fringe of the Great Interior Plains Physiographic Province (Wilson 1981). The plains are flat to gently rolling and elevations range from 150 m above sea level east of Alberta, to 1200 m above sea level on the Western Margin (Wilson 1981). This geological province of Western Canada consists of a wedge of Phanerozoic sedimentary rock which lies upon older rocks of the Precambrian igneous and metamorphic shield (Carrigy 1970). The eastern edge of this wedge thins to expose precambrian rocks in Manitoba and Northern Saskatchewan, and from the west it begins to thicken until the rocks are folded, faulted and uplifted to form the Rocky Mountains (Carrigy 1970).

Beneath the City of Calgary, the sedimentary rocks are approximately 2100 m thick (Wilson 1981). The Precambrian rocks on which the sedimentary rocks were deposited consist of granites and other igneous rocks and are more than 600 million years old. The lower 450 m of the sedimentary rock succession consists almost entirely of limestones and dolomites (Gaia Consultants et al. 1993). These rocks represent the time interval from 600 million years to 300 million years ago and include rock of the Cambrian, Devonian and Mississippian periods (Gaia Consultants et al. 1993) The upper part of the wedge (1650 m) contains shales and sandstones that range from 180 million to 55 million years in age and are formed from Jurassic and Cretaceous period rocks, and the earliest rocks of the Tertiary period (Gaia Consultants et al. 1993). The shales and sandstones of the Porcupine Hills Formation, formed approximately 55 million years ago during the Tertiary period, are exposed in the Calgary region (Gaia Consultants et al. 1993). These rocks have their origin in material derived from the southwest near the Porcupine Hills and were deposited along the northern margin of a large delta complex (Gaia Consultants et al. 1993).

Geological deposits in the Calgary areas are resolved into four mappable packages: Palaeocene bedrock, Tertiary (preglacial) gravels, glacial deposits, and postglacial deposits (Gaia Consultants et al. 1993) The Palaeocene bedrock in the Calgary area has been referred to by Carrigy (1970) as the Porcupine Hills Formation of Late Palaeocene age (Gaia Consultants et al. 1993). The Paskapoo Formation supports the Porcupine Hills Formation and is first met along the Bow Valley in outcrop near the mouth of the Highwood River. Tertiary and Quaternary preglacial gravels can be combined into a single map unit. They range in geomorphic position from the top of Nose Hill to the walls of the inner Bow Valley (Gaia Consultants et al. 1993) Considering the history of downcutting, deposits at different elevations are likely of different ages. Quaternary glacial deposits can be stratigraphically subdivided into six glacial formations, each of which (except for the Calgary Formation which is a unit of glaciolacustrine silts and sands) includes glacial till and associated glaciolacustrine and glaciofluvial deposits ("stratified drift") (Gaia Consultants et al. 1993). The six, from oldest to youngest are:

1) the Lower Spy Hill Formation
2) the Upper Spy Hill Formation
3) the Lochend Formation
4) the Balzac Formation
5) the Crossfield Formation
6) the Calgary Formation

3.4 Localized Surficial Geology and Topography

Nose Hill is a partially isolated topographic remnant of the upland plain that flanks the Bow Valley (Kansas et al. 1993). Erosion in the valley created relatively steep valley wall slopes along the south side of Nose Hill and the development of Nose Creek Valley to the northwest isolated the area from the surrounding uplands, except in the northwest area. Ravine development in the northwest portion of the area, however, has severed the connection of the outlier with the upland plain, resulting in what is referred to as Nose Hill (Kansas et al. 1993).

The topography of Nose Hill Park can be divided into three distinctive components: (1) the upland plain; (2) the side-slopes; and (3) the ravines that cut into the upland plain. Approximately 80 m of relief occurs between the upland plain surface and the lowest elevations in the Nose Hill Park. In contrast, overall natural relief on the upland plain is generally less than 5 m. The upland plain tends to have a gently undulating (2-5 percent) to moderately sloping (5-9 percent) surface, while the side-slopes are steeply inclined (15-30 percent). Ravines have very steeply sloping sides (30-45 percent) with more gently lower slopes and bottoms. Three major ravine systems and approximately twenty smaller ravines occur along the side-slopes of Nose Hill. All major ravines are incised into the east side of the upland plain (Kansas et al. 1993).

Quaternary tills dominate the surficial materials of the Nose Hill area (Moran 1986). Along the side-slopes, moraine overlies sandstones, siltstones, and shales of the Porcupine Hills Geologic Formation. Tertiary gravels ranging up to 10 m in thickness occurs between the surface till and the underlying bedrock beneath the upland plain (Shetsen 1981). Up to 3 m of till cover the Tertiary gravels. In the boundary between the upland plain and the side-slopes, both bedrock and Tertiary gravels are commonly exposed. The thickness or the unconsolidated till and associated materials is greatest in the lower portions of the side-slopes (Kansas et al. 1993).

3.5 Soil

The majority of Nose Hill is covered with shallow Black Chernozem soils. These soils have developed under grassland vegetation, about 440 mm of annual rainfall and generally good drainage conditions (Calgary Parks & Recreation 1992). The parent material is primarily glacial till consisting of sorted or unsorted silty clays and coarse gravels. A 1 to 4 cm thick soil profile ranges in colour from black to dark brown. Since the organic layer is occasionally very thin on exposed hillsides, there is a danger of exposing the inorganic soils beneath and hindering the growth of plant cover (Calgary Parks & Recreation 1992).

The Canada Land Inventory agricultural rating for the Nose Hill plateau falls between Class 3C and Class 6. The soil's capability for agriculture is described as having "... moderately severe.. to very severe.. limitations that restrict the range of crops or require special conservation practices (adverse climate)" (Calgary Parks & Recreation 1992).

Soils of the Podzolic Order have developed where the microclimate is wetter. Parent material for this type of soil ranges from glacial till composed of silty clays and gravels to valley alluvium and slope wash deposits from weathered tills. Soils in this zone are usually not as rich as those of the

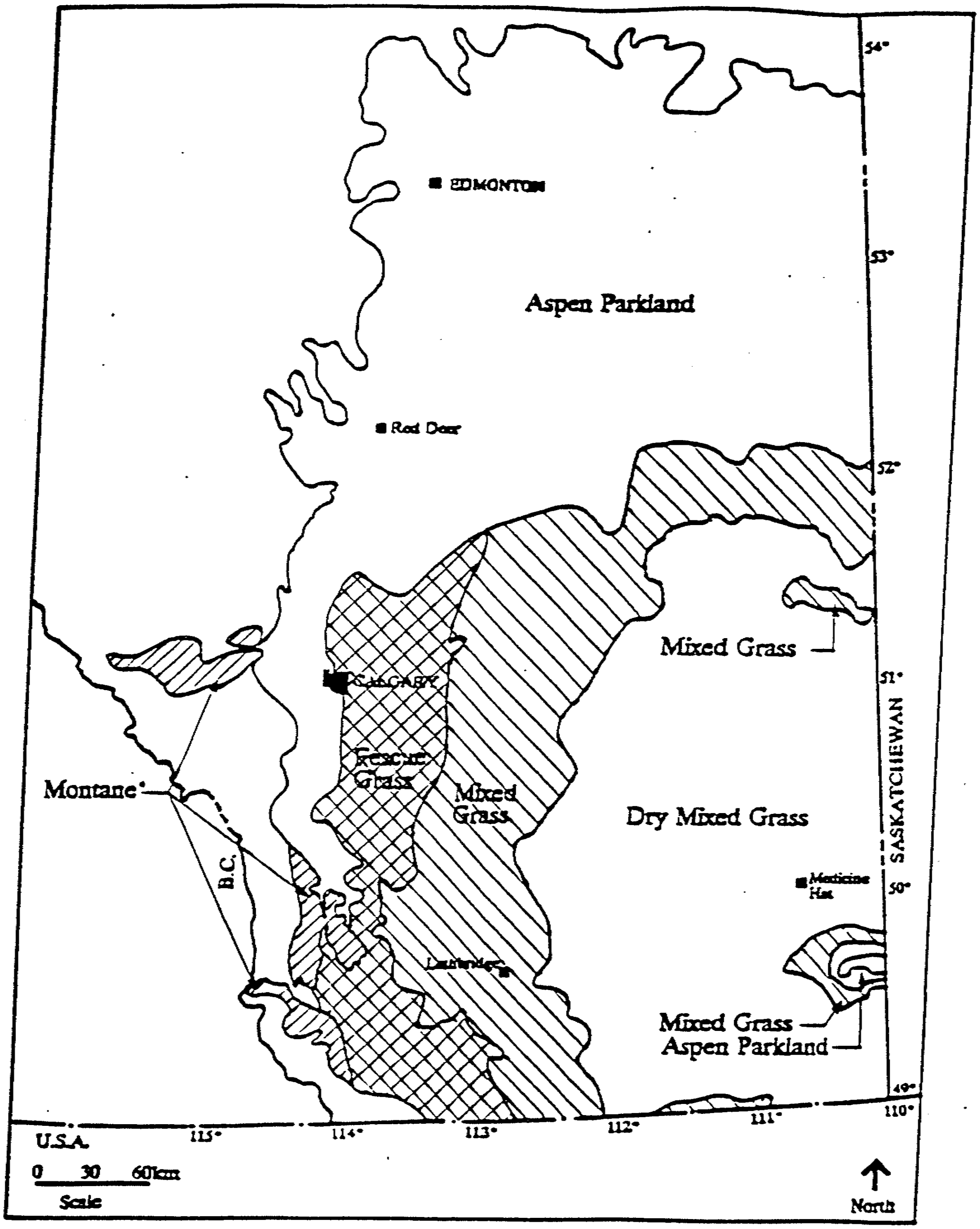
Black zone (Calgary Parks & Recreation 1992).

3.6 Hydrology

Surface water features are limited in Nose Hill Park with the exception of two man-made ponds and weak seepage areas associated with major ravine systems, such as Porcupine Valley (Kansas et al. 1993). Most of surface of Nose Hill is covered by glacial till that is high in clay content (Calgary Parks & Recreation 1992). Air and water infiltration and percolation capacity of the glacial till are rated fair to poor. As a result, most of the surface water (from precipitation or snow melt) enters the ponds or runs off as slope wash via the ravines and coulees (Calgary Parks & Recreation 1992).

3.7 Ecoregion Classification

Calgary lies within an area of transition between the Fescue Grass Ecoregion on the east and the Aspen Parkland Ecoregion on the west (Kerr et al. 1993) (Figure 2). The Aspen Parkland Ecoregion is characterized by the co-occurrence of rough fescue grassland and stands of aspen on medium textured, moderately well drained sites without topographic extremes (Kansas et al. 1993). The grasslands generally occupy drier situations within this vegetation mosaic relative to aspen. Associated with the rough fescue grassland-aspen complex are a variety of shrub communities that occupy transitional positions between these two physiognomically different types of vegetation. Among the common shrub communities are saskatoon (*Amelanchier alnifolia*), rose (*Rosa acicularis*), and snowberry (*Symphoricarpos albus*) (Kansas et al. 1993). Black Chernozemic soils are typically found in association with Aspen Parkland vegetation, however, on steep north facing slopes Eutric and Melanic Brunisolic soils are more common (Kansas et al. 1993).



*Montane Ecoregion is in the Cordilleran Ecoprovince

Figure 2: Ecoregions of the Prairie Ecoprovince in Alberta
(Source: Strong and Leggat, 1981; Strong 1991)

The Fescue Grass Ecoregion is characterized by the occurrence of rough fescue (*Festuca scabrella*) vegetation on medium textured moderately well drained sites without topographic extremes. The main environmental determinant of this ecoregion appears to the Cordilleran-based climate that results from the presence of the elevated Rocky Mountains to the west (Kerr et al. 1993). Tree and shrub communities are limited to the north aspect of steep slopes, seepage sites, the bottoms of draws, and valley bottoms where moisture is more abundant (Kansas et al. 1993). Trees are very limited in their abundance, but can occur in ravine and coulee bottoms. The Fescue Grassland Ecoregion occurs primarily in the eastern half of Calgary (Kansas et al. 1993). Although there are not fixed or precise boundaries between ecoregions, and urban development has destroyed most of the native vegetation needed to identify ecoregions, and ecological break appears to occur immediately west of Crowchild trail. As a result, Nose Hill Park occurs within the **Fescue Grass Ecoregion** (Kansas et al. 1993)

The synecology of this ecoregion is that of a "boreal community on dry-mesic to moist soils of low fertility in cold-temperate sub-humid regions with a short growing season (Looman 1944)." Fescue Prairie occurs in the Black "Chernozemic" Soil zone in the Foothills of the Rocky Mountains, Western and Central Saskatchewan as well as in the benchlands and upper slopes of the Cypress Hills (Saskatchewan Agriculture 1991). The annual precipitation ranges from 450 to 550 mm, and the ratio of precipitation to evaporation is about 1.0 (Smoliak et al. 1990). Soil textures vary from fine sandy loam to clay loams. Some areas are underlain by gravel and flat, water-washed stones up to 25 cm in diameter (Looman 1944). This grassland climate has a greater moisture effectiveness than the adjacent mixed prairie (Saskatchewan Agriculture 1991). The yield of Fescue grassland is higher than that of any other grassland community in western Canada except the Tall Grass Prairie in Manitoba, which today only exists as a remnant (Saskatchewan Agriculture 1991).

Fescue Grassland is characterized by rough fescue which may range from completely dominant along the northern fringe, to codominant with northern porcupine grass (*Stipa Spartea*) along the southern edge (Smoliak et al. 1990). In the lower southern foothills of the Rocky Mountains, the combination of rough fescue and Parry oatgrass (*Danthonia parryi*) are dominant. This is the warmest and driest part of this region. At somewhat higher altitudes this combination becomes restricted to warm slopes or stony soils (Smoliak et al. 1990). In northern locations, rough fescue grows with aspen groves. Shrubby cinquefoil is the characteristic shrub, but rose, western snowberry and wolf willow are also common.

3.7.1 Grassland Community Types

All ecosites on Nose Hill are representative of the Fescue Grassland Ecoregion. In addition to tree and shrub communities, five native and five disturbance grassland/forb plant communities were identified in the Nose Hill biophysical inventory. These communities include rough fescue-golden bean (*Thermopsis rhombifolia*); rough fescue-Parry oat grass; needlegrass (*Stipa comata*)-Parry oat grass; western wheatgrass (*Agropyron smithii*); alfalfa (*Medicago sativa*)-wheatgrass; western wheatgrass-bluegrass (*Poa pratensis*); smooth brome; smooth brome-quack grass (*Agropyron repens*); bluegrass (Kansas et al. 1993).

Rough fescue vegetation was the most common native plant community and represented approximately 37 percent of the total vegetation cover. Rough fescue plant communities represent the zonal vegetation for the Fescue Grassland Ecoregion and the study area, since it occurs on moderately well to well drained sites without extreme conditions. The **rough fescue-golden bean** community type most commonly occurs on the upland plain where the topography is relatively subdued. This plant community represented 13.8 percent of the park. Among the living foliage also occurred a significant amount of litter. Between the tussocks occurred species such as northern bedstraw (*Galium boreale*), cut-leaved anemone (*Anemone multifida*), and golden bean. Soils were moderately well-drained to well-drained Black Chernozems. Many of the rough fescue-golden bean stands in Nose Hill Park could be considered good examples of climax vegetation. This community type is similar to the vegetation described by Moss and Campbell (1947) for the Fescue Grassland formation of Alberta, although golden bean tends to be more abundant in the study area.

The **rough fescue-Parry oatgrass** community was most commonly found on the slopes around the upland plain. Rough fescue in this vegetation was less dominant and was mixed with other grasses such as Parry and Hooker's (*Helictrotichon hookeri*) oatgrass, western wheatgrass, and june grass. It did not form distinctive tussocks and contained a greater proportion and higher diversity of forbs than did the rough fescue-golden bean community type. This community is similar to the Festuca-Danthonia Association recognized by Moss (1944) in southwestern Alberta. Well drained Black Chernozemic soils on moderately steep slopes (10-20 percent) are commonly associated with this community type. This vegetation type represents approximately 24 percent of the study area, which makes the most common community in Nose Hill Park.

Needlegrass-Parry oatgrass community type occurs on less than 1 ha, but it is a relatively distinctive association that occurs on steep south facing slopes (<45 percent) where conditions are very dry due to rapid run off and high levels of solar insolation. This association is dominated by a 40 percent cover of graminoid species such as needlegrass, Parry oatgrass, rough fescue, wheatgrasses, june grass, Kentucky bluegrass (*Poa pratensis*), and sedges (*Carex filifolia*) that occur on dry sites.

Western wheatgrass communities are dominated by western wheatgrass with approximately a 30 percent cover of forbs. This vegetation is most commonly associated with steep south facing slopes where conditions are xeric due to rapid drainage and high levels of insolation. The wheatgrass phase most commonly occurs on ravine slopes, while the golden bean phase tends to occur on the south facing side-slopes of the upland plain. Dark Brown Chernozemic soils most commonly occur in association with this vegetation. Approximately 32 ha of the study area is vegetated by this community type.

The **alfalfa-wheatgrass**, western wheatgrass, smooth brome, smooth brome-quack grass, and bluegrass community types represent vegetation that has been planted or has developed as a result of agricultural activities. These communities primarily occur on the upland plain where cultivation has occurred, but can also occur where other intensive land use has destroyed the native plants. Approximately 47 percent of the study area is composed of these plant communities (Kansas et al. 1993).

Although there are two climatic zones in the Calgary area: Fescue Grass Ecoregion and Aspen Parkland Ecoregion, the vegetation inventory for the grassland communities found on Nose Hill generally coincided with the inventory that was conducted for the larger Bow Valley area as part of the Calgary Urban Parks Project (Table 2). As such, the results for this study based upon data collected on Nose Hill, may be applicable to the entire Calgary area, but the possibility that limitations such as localized soil moisture differences may exist must be noted.

Table 2: Correlation of plant community-types (CT) for Nose Hill Park and the Calgary Urban Parks Project (Kansas et al. 1994)

Nose Hill Park Area	Calgary Urban Parks Project Area
Aspen/Rose CT	Similar to the Aspen/Saskatoon-Dogwood CT but lacks the dogwood component and has a reduced saskatoon content.
Balsam Poplar/Rose CT	-
Aspen/Snowberry CT	-
Aspen/Smooth Brome CT	Similar to the Balsam Poplar/Smooth Brome CT but has aspen as an overstory rather than balsam poplar.
Willow/Snowberry CT	-
Choke Cherry/Snowberry CT	Similar to the Choke Cherry CT but has a much a more dominant snowberry stratum.
Saskatoon/Snowberry CT	Saskatoon/Snowberry CT
Wolfwillow/Bluegrass CT	-
Rose/Snowberry CT	Rose/Snowberry CT
Snowberry CT	Snowberry CT
Poplar/Dandelion CT	-
Alfalfa-Wheatgrass CT	-
Rough Fescue-Golden Bean CT	-
Rough Fescue-Parry Oatgrass CT	Similar to the Rough Fescue CT
Needle Grass-Parry Oatgrass CT	Similar to the Needle-Wheatgrass CT but with a much greater abundance of Parry oatgrass
Western Wheatgrass CT	-
Smooth Brome CT	Occurs within the Smooth Brome-Thistle CT complex, but with a reduced thistle component.
Smooth Brome-Quack Grass CT	A component within the overall disturbance community complex described as Smooth Brome-Thistle but with a reduced thistle and enhanced wheatgrass component.
Bluegrass CT	

CHAPTER 4: VEGETATION MANAGEMENT TOOLS

Prairie grasslands can be managed by a variety of options including fire, grazing, mowing, fertilization, and herbicides (Higgins et al. 1989). This chapter will present a general overview of these various options as a part of management strategies in order to attain a specific goal.

4.1 Prescribed Burning

Burning is considered by some prairie restorationists to be "the single most important tool available to establish and maintain a quality prairie" (Prairie Restorations, Inc. 1992). This technique has obvious limitations in many restoration and reclamation projects such as restrictions on use, the large labour force required, potential for damage to adjacent vegetation types, and possible increased erosion (Kerr et al. 1993). The increased human impact of prescribed burning must also be realized, especially in a large urban setting. Vegetation or stubble burning often elicits an emotional response from the public. Health factors such as lung ailments (in particular asthma) may be aggravated by smoke inhalation resulting from prescribed fires, especially in closely spaced residential areas. When burning sections within residential areas, the increased potential for property damage must be considered, and extra precaution must be taken to ensure that the fire is tightly controlled.

Unlike grazing, prescribed burns can be done in a single day, so in the long run fire is less costly in terms of time and finances than the ongoing use of cattle (Clark, personal communication, 1993). In addition, grazing requires a full complement of animals, since different species forage on different plant material at different times of the year (Clark, personal communication, 1993).

Burning of grasslands as a management option is often done with the specific objectives of reducing vegetative litter, controlling noxious weeds, and to improve the height and density of plant cover (Higgins et al. 1989). Fire can remove litter (consisting of dead grass, leaves, and inflorescence stalks) which is broken down slowly by micro-organisms, and tends to accumulate and smother many low-growing species. Smothering may eventually result in a species poor sward which contains only coarse grasses and few herbs (Duffy 1974).

In general, burning of grasslands may bring about a reduction in microbial competition at the soil surface, thereby permitting successful development of postfire fungal colonists (Risser et al. 1981). Although combustion of living, dead and humic plant materials results in the volatization of nitrogen and sulphur, most nutrients are added to the soil as soluble salts which are readily available to the plants. Both total and available nitrogen in the soil have been observed to increase after burning (Young 1983). This is primarily due to the stimulation of nitrogen fixing bacteria and increased rates of organic matter decomposition. Burning removes plant cover and exposes the soil surface to increased water and wind erosion, but overall, erosion following fires is not likely to be a serious problem unless the slopes are steeper than 20 percent (Wright et al. 1976). Immediately after burning there may be an increase in soil water loss when there is no mulch cover and the soil surface temperature is higher (Risser et al. 1981). Later in the growing season, when a large biomass has been stimulated by burning, water loss by transpiration may also reduce soil water (Anderson 1964).

4.1.1 Fire Effects on Wildlife

Depending on the size of the area, wildlife found in fescue grasslands may include large mammals such as whitetail deer (*Odocoileus virginianus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and mule deer (*Odocoileus hemionus*). The possible effects on existing fauna in smaller reserves may be limited to small mammals, bird and insect populations (Clark and Johnson 1993). Direct effects of fire on wildlife include higher mortality from direct burning, heat stress, asphyxiation, physiological stress from overexertion while escaping, and increased predation due to loss of cover (Clark and Johnson 1993). Indirect effects may include changes in the patterns of mortality, reproduction, and movement due to a change in quality and quantity of food, the availability of nesting sites, predation pressure, competition and social interactions (Clark and Johnson 1993). Animals may be forced to escape the fire and not return to the site following the burn (Clark and Johnson 1993). Abortion of litters or the abandonment of dependent young may reduce reproductive output (Clark and Johnson 1993).

Small Mammals

In ungrazed grasslands, fires generally have a negative impact on folivorous rodents that usually use litter to nest on the surface (eg. microtine rodents and harvest mice), and who forage for invertebrates in the litter layer. Species that forage for seeds and/or invertebrates in habitats which generally lack litter cover may be positively affected by fire (eg. ground squirrels (*Spermophilus spp.*) (Kaufman et al. 1990). Disturbed populations generally return to normal levels within two to three years following a major fire (Kaufman et al. 1990).

Invertebrates

Mortality of invertebrate species will occur unless they are able to escape either below the soil or into the air. The soil layer provides an effective barrier to the heat of the fire front, and therefore species which are below the soil surface (ie. soil arthropods) should be relatively unaffected (Clark and Johnson 1993). Invertebrates may also suffer indirect effects due to changes in food quality and quantity, increased predation, etc. The presence of refugia for both invertebrates and small mammals in adjacent unburnt areas can provide a source for recolonizing areas that were burned (Clark and Johnson 1993).

Birds

Ground nesting birds may be negatively effected by prescribed burns, but the effects are primarily dependent on the time of treatment. Spring fires may burn birds' nests and destroy the young. If this occurs early enough in the breeding season, the parents will usually emigrate elsewhere and lay a second clutch of eggs. Fall burns usually have little impact on birds (Clark and Johnson 1993). Moving nests or protecting the area immediately around them should protect these nests from effects of fire such as smoke and heat, and help reduce the chances of mortality (Clark and Johnson 1993).

4.1.2 Fire Effects on Vegetation Composition

While general predictions can be made about how different groups such as grasses, forbs, and woody species will be affected by fire there is still little known about individual species within groups or how grassland communities as a whole will react (Clark and Johnson 1993). It should be noted that species react differently to fire depending on the geographical location, and that the available literature pertaining to fescue grassland species is limited. As such, this section provides general species reactions to fire which may or may not be specific to fescue grasslands of the Calgary area. The work conducted by Kruse and Higgins in South Dakota is applicable to mixed grass and fescue prairie, but does not include aspen parklands (Higgins et al. 1989a,).

The following are general observations that have been noted in field studies in northern mixed prairie and have not been based on quantitative data (Wright and Bailey 1980; Higgins et al. 1989a);

Repeated burning on the first of March can result in a sharp decrease in the number of Kentucky bluegrass plants (Kruse and Higgins 1988). Kentucky bluegrass and quackgrass apparently decline in abundance after several consecutive spring fires (May-June). Fires at the time of seedhead emergence appear most effective (Higgins et al. 1989b). Thus, warm-season native grasses have higher yields because of decreased competition from cool-season invaders such as Kentucky bluegrass.

Kruse and Higgins (1988) found that summer fires are usually detrimental to warm-season plants such as blue grama, but that spring burning increases production. Steuter (1987) however, found that production of blue grama was increased when burned in the late summer, but decreased if burned early in the growing season. Use of fire alone to increase the herbage of warm-season species on upland sites was not effective since warm-season species were less well adapted to fire disturbance on these dry sites (Steuter 1987).

Steuter (1987) saw that cool season plants such as needle grasses, sedges (*Carex spp.*) and western wheatgrass which dominate upland silty sites increased under all burn treatments. Cool season dominance on upland sites is attributed to long-term adaptation rather than short-term adjustments to fire or weather effects (Steuter 1987). Western wheatgrass was found to increase in abundance after spring, summer or early fall burns, but considerably more after late summer or early fall fires Higgins et al. (1989b).

Contrary to the above, however, Clarke et al. (1943) found that prescribed burning in spring reduced yield of associated grasses in the wheatgrass consociation by 15 percent in the second year after burning in southeastern Alberta. This site had fully recovered by the third year. Fall burning decreased the yield 30 percent on the site in the first year with no significant reduction in the following years (Clarke et al. 1943). Coupland (1973) states that western wheatgrass communities are more detrimentally affected by burning than the needlegrass/blue grama communities. Wright and Bailey (1982) did not find any benefit from burning herbaceous species in the arid Mixed Prairie where wheatgrass predominates.

Composition and coverage of green needlegrass (*S. viridula*), needlegrass, and porcupine grass (*S. spartea*) generally increase during the first few sequential (May-June) burns, but often decline rapidly after a sequence of five or more spring fires on the same area. Spring burning to reduce Kentucky bluegrass will commonly reduce *Stipa spp.* at the same time (Higgins et al. 1989b).

Slight to no decrease occurs after periodic spring fires for prairie and pasture sage, common yarrow, northern bedstraw, and leafy spurge (*Euphorbia esula*). Pasque flower (*Aster falcatus*), lady slipper (*Cyprpedium spp.*), wild lily (*Lilium philadelphicum*), purple prairie clover (*Dalea purpurea*), and harebell (*Campanula rotundifolia*) increased in abundance following spring burns. Alfalfa was favored by early spring burns, but substantial declines follow late summer or fall burns.

Dramatic increases in sprouts of western snowberry often occur after a first fire, particularly on areas that have been idle for several years. A sequence of spring fires on the same area will eventually reduce abundance. Significant reduction requires five or more fires in 10 years or less. One or two fires followed by a series of rest years will result in an increase of aerial coverage. Hot burns in late summer to early fall have caused severe root burns on western snowberry plants. *Rosa spp.* and willows (*Salix spp.*) apparently survive frequent fires fairly well even though there appears to be a small reduction in plant abundance after repeated fires (Higgins et al. 1989b). Stems of older plants of choke cherry (*Amelanchier alnifolia*) are often killed by hot spring fires, but they can survive cool or incomplete burns. Sprouting of new shoots occurs after spring or fall burns but is less pronounced after late summer or fall burns. Resprouting has been seen in areas with histories of five or six fires over a period of about 15 years. Aspen (*Populus tremuloides*) in the northern grassland prairie will be either enhanced or inhibited by fire, depending on the frequency of burns. Fire often kills the tops of aspen, but regeneration from root suckers takes place quickly after burning. Frequently, post-burn aspen abundance will exceed that of pre-burn (Anderson and Bailey 1980).

4.2 Effects of Grazing

The Beneficial effects of grazing on plants include:

"1) removal of older tissue, which is less efficient in photosynthesis than younger tissue;

2) increased light availability to lower, younger tissue;

3) increased stomatal resistance, which promotes water conservation;

4) increased forage production due to compensatory growth;

5) recycling of nutrients contained in animal waste;

6) speeding senescent forage breakdown by trampling; and

7) creation of favourable microsites in hoof prints for seedling establishment, especially on hard packed, well drained soil (Saskatchewan Agriculture, 1991)"

4.2.1 Individual Species Response to Grazing

When an area is overgrazed there is a decrease in plant root volume and depth decrease since reduced leaf area is unable to produce food reserves for root growth (Kerr et al 1993). Roots of heavily grazed plants tend to be shorter, sparser, and more concentrated in the top part of the soil profile (Vallentine 1990). This reduces the competitive ability of the plant and it becomes more prone to environmental stresses such as temperature extremes and lack of moisture (Trottier 1992).

The ability of any plant to recover from grazing involves both the re-establishment of photosynthetic tissue and the ability to retain competitive position in the plant community (Caldwell 1984). The response of an individual plant to grazing is related to site and climatic conditions, palatability, morphology, phenological stage, competition from other plants, intensity of grazing and grazing history (Saskatchewan Agriculture Development Fund 1991).

Range plants are characterized in relation to their response to grazing and are classified as being "decreasers", "increasers", or "invaders" (Coupland 1979). Range condition is determined by estimating the composition of each of these types of species (Willms et al. 1992). Only increaser and decreaser species contribute directly to range condition (Willms et al. 1992). Invader species contribute indirectly in that they make up part of the total composition, but their contribution is not added to the estimate (range condition is based on native species, not those introduced) (Willms et al. 1992).

Decreasers are plant species of the original or climax vegetation that will decrease in relative amount with continued overuse. They are dominant on rangeland whose condition is excellent or good. They tend to be deep-rooted species, and are also the largest and most productive. Decreasers are likely to be overused by grazing animals because they are palatable and have a high forage value (Willms et al. 1992).

Increasers are plant species of the existing vegetation that will increase initially in relative amount with increased grazing pressure. They are dominant on rangeland that is in fair condition (Willms et al. 1992). These species tend to be shallow rooted and resistant to grazing because of their short stature and their efficient reproduction. They initially increase with grazing pressure but eventually decline with very heavy grazing. In general, as grazing pressure increases species in the community which are less productive and less palatable to livestock increase and species composition shifts as soil conditions change (Kerr et al. 1993).

Invaders are normally non-native plants that encroach as decreaser and increaser plants are weakened by heavy grazing (Adams et al. 1986). Invader species are opportunists that are not native to the climax plant community. Because prolonged heavy grazing pressure is required for their invasion, their presence indicates a decline in range condition (Kerr et al. 1993). A list of probable increasers, decreasers, and invaders are given in Appendix A.

4.2.2 Plant Community Responses to Grazing

Heavy grazing causes a shift in the composition of vegetative cover towards a more xeric type of community (Coupland 1961). This process includes an increase in the percent composition of short grasses and unpalatable forbs such as pasture sage (Epp 1989). Changes due to overgrazing are exacerbated by conditions such as low rainfall, high evapotranspiration potential and low water yields (Antevs 1953; Branson 1975).

Heavy grazing of wheatgrass dominated communities will cause an increase in the relative abundance of blue grama grass in relation to mid grasses, and of needlegrass in relation to western porcupine grass (Coupland 1960). A high cover of needlegrass relative to blue grama suggests that grazing has not had a significant impact on most upland grasslands in the area (Blood and Ledingham 1986). A slightly greater cover of blue grama than western wheatgrass may be more of a reflection of drought than grazing, since the latter is usually more abundant under wet conditions. Pasture sage (*Artemisia frigida*) increases with grazing, but this species is adversely affected by drought. If drought is high, then pasture sage will not be abundant even if grazing is severe (Blood and Ledingham 1986).

With increased levels of grazing in Alberta's fescue prairie, Moss and Campbell (1947) noted an increase in the abundance of Idaho or bluebunch fescue and Parry oat grass in relation to rough fescue. Rough fescue became quite patchy, tending to persist on moister land and where it was shielded from grazing by the presence of shrubs (Moss and Campbell 1947). Although Looman (1969) reported a decrease in rough fescue and initial increase in oatgrasses with grazing, as grazing pressure intensified, oatgrasses also decrease. There was a corresponding increase in sedges on drier sites, and Kentucky bluegrass on wetter sites. Floristic composition becomes poor with moderate grazing. Common invaders on overgrazed fescue prairie were timothy (*Phleum pratense*) and smooth brome (Looman 1969). Willms et al. (1985, 1988) produced similar results more recently. In fields where rough fescue is the dominant species, it may be nearly eliminated after 5 years of high grazing pressure (Willms 1988).

Though shrubs seldom cover more than 10 percent of the total area in undisturbed sites, the density of shrub cover often can increase five or six fold under the influence of grazing. This is a result of changes in the moisture regime which favours shrubs (Looman 1944). Common species of shrubs in Fescue Grassland, however, are not thorny and overgrazing and browsing eventually may lead to the destruction of the entire vegetative cover.

4.2.3 Grazing as a form of weed control

Grazing may be limited technique for weed control because of toxic compounds in the weeds (Lawrence et al. 1988). Short periods of grazing may be used to control weeds and decrease shading, increase available space, and make more water available for seeded plants (Heady 1975). Grazing as a form of weed control often involves a combination of animal species with different dietary preferences (Saskatchewan Agriculture Development Fund, 1991).

Sheep grazing is currently being considered for leafy spurge control (it can also be used for snowberry and dandelion) by City of Calgary Weed Control Division (Hergert, personal communication, 1993). Sheep grazing does not eradicate leafy spurge, but reduces the density and limits its spread. After sheep are removed the leafy spurge tends to return (Stevenson and Laing 1987). Advocates who strongly support sheep grazing as a means of biological control against leafy spurge, particularly in Fish Creek Provincial Park, state the following reasons:

"1) Total kill of desirable plant material, erosion and other environmental concerns associated with pesticides would be reduced or eliminated in areas where grazing is possible. We could then reclaim areas where non-selective herbicides have been utilized.

2) Rotational grazing would allow for grasses and other plant material to continue to grow and provide competition to leafy spurge and other noxious and nuisance weeds. Grazing may also assist in maintaining native grass species.

3) Introduction of sheep into Fish Creek Park could be an exciting addition to the current interpretive educational programs. It is compatible with the historic ranching operation in the park.

4) Sheep grazing could be effective in reducing the fire hazard in many areas of the park.

5) Using sheep as an alternative to pesticide application would allow regional spray crews to be available for other projects, and in the long term, sheep grazing could be less costly than chemical control (Stevenson and Laing 1987)."

Disadvantages include;

"1) Sheep require a 1 to 3 week adjustment period. If sheep have eaten something else first, it will take them about 2 weeks to adjust to leafy spurge. Since sheep prefer young plants, grazing of leafy spurge should start early in the growing season.

2) Predator control, night pens and herding are required.

3) A good shepherd is needed.

4) Sheep will forage on forbs and shrubs important for wildlife cover.

5) Herding is needed to keep the sheep on spurge infested areas.

6) Night pens need to be moved frequently (twice a week).

7) Money saved on chemical control is spent on herding (Stevenson and Laing 1987)."

In any case, livestock grazing should not be allowed on a revegetated native grassland until the plants are suitably established or self-sustaining (Kerr et al. 1993). Holzworth and Lacey (1991) recommend that grazing be deferred in re-seeded pastures until the first seed crop has matured, and it may be advisable to extend the non-use period during dry years. In some cases, fencing may be desirable to prevent the use of the area by ungulates as well as livestock (Special Areas Board et al. 1992).

4.2.4 Systems of Grazing

Heavy grazing pressure in winter is a proven method for reducing rank cover (accumulation of old growth) (Willms et al. 1992). In winter the forage quality is more uniform and livestock are less selective in their feeding habits. They can be attracted to under-used areas with supplements or contained by cross fences. This procedure can be repeated for several years until the desired reduction in old litter is achieved (Willms et al. 1992). During winter, many dicotyledons are dormant with no growth above ground, and are not directly affected by winter grazing (Duffy 1974). Insects are also below ground and are not harmed by grazing (Duffy 1974). Winter grazing lowers competitive ability of many grasses and favours low growing species the following spring. However, hard winter grazing which removes all plant litter destroys the habitat of many invertebrate animals living in or on dead organic material (Duffy 1974).

Grazing should be delayed in the spring to allow new leaves to develop sufficiently so that new growth is not dependent on stored reserves, but can continue from the energy captured only by the leaves (Willms et al. 1992). A plant's greatest energy need is in the spring before new leaves appear, and when seeds are developing. Many grasses are therefore particularly susceptible to heavy grazing in spring and again during summer flowering (Willms et al. 1992).

One of the primary objectives of management on grassland reserves is the maintenance of floristic diversity (Duffy 1974). Often this can only be achieved by controlling the growth, development and spread of aggressive dominants which may be best achieved by grazing (or cutting) during late spring to early summer. Grazing at time when the dominant grass is making its maximum growth is an effective way of controlling competitive ability (Duffy 1974). Highly unpalatable species are eaten in the April-May period but hardly at all at other times of the year. Although this may prevent flowering in many species, some are able to produce a second crop of flowers late in the year following cessation of grazing (Duffy 1974).

Rotational grazing, which is the system of grazing where parts of an area are grazed, while others are not, is probably the best way of managing grasslands for diversity unless they are species with specialized requirements. This system allows parts of the grassland to develop to different pre-determined stages. By grazing different parts of the area in succession, different structural formations are established. By regulating stocking rates and time of grazing, more aggressive and dominant grasses may be kept in check and prevented from overwhelming the lower-growing species (Duffy 1974). Longer rotational systems of 5 or 10 years, are probably only suitable for grassland overlying shallow soils where nutrient factors prevent excessive development of grasses and litter accumulation. In addition it will almost certainly be necessary to remove scrub during a long rotation, because grazing cannot be used to control bushes once they reach more than 25 cm in height (Duffy 1974). Two or three short rotations are the most effective way of managing grasslands on deeper, more fertile soils (Duffy 1974).

It is important not to graze everything but to leave a carryover, or dead plant material into the next year. This can be achieved by using species of animals that only graze on the surface, such as cattle, or by lowering the grazing pressure for species that chew to the bottom of forage (eg. horses and sheep) (Smith, personal communication, 1994). Carryover consists of litter that protects the soil surface from extreme temperatures, conserves water by reducing evaporation, and provides emergency feed in years when production is low. Leaving behind a portion of grass leaf and stem also ensures uninterrupted growth as the plant continues to capture energy and fix carbon during the growing season, thereby providing stored energy in the plant stems to help keep the plant healthy during the dormant season (Willms et al. 1992).

4.2.5 Domestic Grazer Preferences

Where both flat ground and slopes are present, cattle tend to spend less time on the slopes than on flatter area (Mueggler 1965). Plant communities on area slopes, therefore, should be less modified by grazing than those on uplands or valley bottoms (Mueggler 1965). Grazing animals eat certain plants while rejecting others. Selection occurs with factors such as hairiness, amount of fibre and stage of growth (Duffy 1974). The maximum intake of a species is at the time of year when the plant is most palatable, with secondary maxima occurring at other times when the animals are confronted with little or no choice (Duffy 1974). Physiologically young material may be preferred because it is generally short or because it differs in chemical composition from old material. The presence of dead plant material also has an effect on food selection. As the proportion of dry or dead material in a pasture increases, the grazing animal is unable to eat an entirely green diet and eventually there may be a complete suppression of preferences (Duffy 1974).

Sheep and cattle move in a horizontal plane but select in a vertical plane as they graze (Arnold 1960). Sheep usually eat the uppermost parts first, moving downwards, but rarely reduce a sward from 15 to 2 cm in one grazing (Arnold 1960). They prefer to move across the sward, gradually reducing the height, although the pattern of grazing is heavily influenced by the size of the area and the numbers of livestock (Arnold 1960). On short, green pastures, sheep bite a number of leaves and part of the leaf is consumed. Sheep select leaf in preference to stem, and green (or young) material in preference to dry (or old) material (Arnold 1960). Cattle, on the other hand, curl the tongue around a tuft of vegetation, tearing the plant tissue (Duffy 1974). This makes cattle less selective than sheep. Cattle grazed pastures generally result in a mosaic of taller tufts interspersed with shorter vegetation. Horses are highly selective and obtain their food by close grazing (Duffy 1974). They select the most palatable and nutritive species, often reducing them in quantity by over-grazing, while other areas of the pasture remain ungrazed and become course and rank (Duffy 1974).

4.3 Mowing

Cutting or mowing is most often used for weed control, or to defoliate swards of overgrown grass. Time of cutting is under the direct control of the land manager, and may be related to growth of important species in the sward, whether this be to control dominant and aggressive grass species at the peak of growth or to allow a rare plant or insect to complete its life cycle (Duffy 1974). Height of the cutting may be controlled within certain limits, enabling the operator to cut certain species and to avoid others (Duffy 1974).

Mowing for weed control is usually most effective on taller-growing species (Kerr et al. 1993). Caution must be practised when mowing stands with bunch-grasses (eg. fescue) as these can be killed by low mowing which takes out the crown and kills the plant (Kerr et al. 1993). In newly seeded sites, Ode (1972) has suggested mowing to a 15 cm height several times during the first growing season since native prairie species will not be tall enough yet to be harmed by this procedure (Kerr et al. 1993). Another recommendation is to mow when weeds shade 70 percent of the ground or before seed heads form (Wilson 1971). Mowing may also be necessary in the second year. Ode (1972) recommends a rotary mower as opposed to a sicklebar type mower. The ability of rotary mowers to remove weeds and provide mulch is an advantage. Rotary mowers are considered unsuitable for rough, stony terrain, however, as they scatter plant debris thereby smothering new growth (Saskatchewan Agriculture Development Fund, no date). Once native vegetation is established, the need for mowing should be reduced as the perennial roots spread and prevent the establishment of annual weeds (Kerr et al. 1993). In roadside plantings in Iowa, weeds were reduced dramatically by the third year after seeding, strictly due to competition from native prairie species. No mowing or spraying was required (Landers 1972).

One of the major disadvantages of mowing is that, if conditions are wet in the spring, it may be impossible to mow early to control weeds. Another problem is that too early or too frequent mowing may stimulate shorter weed growth with rapid seed head formation (Leskiw 1978). Additionally, many prairie forbs have been shown to decrease in vigour when mowed (Hesse 1973).

4.4 Fertilizers

Fertilizers are used on grasslands for two purposes. First, to increase productivity in terms of fresh weight or dry weight yield per unit area, and secondly to manipulate the floristic composition so that the proportion of the more productive and palatable species is increased and that of so called "weeds" decrease (Heddle 1967). In general, studies have indicated that (Kerr et al. 1993):

"1) Little effect of fertilization is seen in reclaimed lands during the first year after fertilization but significant effects may be noted several years later, suggesting that the effects of fertilization sometimes require time for full ecological expression;

3) Under conditions of excessive fertilization the production of plant biomass exceeds the ability of some reclaimed soils to decompose it, resulting in massive litter accumulations on the soil surface, altered microclimatic conditions, immobilized nutrients, a disrupted nutrient cycle, and ultimately, reduced plant vigour over time; and

4) The application of nitrogen and phosphorus fertilizer increases the initial total vegetation productivity but over time, with repeated fertilizer applications, community diversity is reduced, particularly at the expense of native grasses, forbs and shrubs which are less able to compete with invasive, non-native species (Depuit and Redente 1988)." Broad leaved herbs may be completely eliminated after 2 or 3 years of heavy nitrogen applications. Of particular importance to the conservationist is the inability of many herbs to reestablish in the thick grass sward which is produced, so that the process is irreversible in contrast to grazing or cutting treatments (Duffy 1974).

Many native species of semi-arid and arid ecoregions are adapted to conditions of relatively low soil fertility (Depuit and Redente 1988). This characteristic, coupled by the typically slow establishment rate of native grasses, would make semi-arid or arid areas seeded with native species less responsive to short-term fertilization or irrigation practices (Depuit and Redente 1988). Fertilizers should only be added where appropriate for the soil conditions and the needs of the revegetation program (Depruit and Redente 1988). Improper fertilization practices are often as detrimental to vegetation as is a lack of soil fertility. If fertilizers are not necessary they may also add an unnecessary cost to the reclamation program.

A study by DePuit and Redente (1988) supports the theory that areas reclaimed with native grasses may not require fertilization. They found that fertilization often reduced species diversity in reclaimed areas because:

> "1) The application of nitrogen (N) rich fertilizer may reduce the N-fixing advantage held by legumes while increasing the growth rates of vigourous, N responsive grasses allowing the latter to rapidly dominate the community;
>
> 2) There is some evidence that fertilization favours earlier growing species at the expense of later growing species. Also fertilizers may also retard development of certain components of the microbial community (Depuit and Redent 1988)."

The problem with adding fertilizer at seeding time is that it often benefits the weeds more that the native species (Kerr et al. 1993). Not only were these species found to be undesirable, but they are often non-mycorrhizal and, as such, tend to retard mycorrhizal (microbial) colonization of reclaimed soils (DePuit and Redente 1988). On heavy, fertile soils that present the most weed problems, attempts are sometimes made to de-fertilize the soil to increase the chances of success of native plant establishment. To de-fertilize the soil, a mixture of sugar and sawdust may be broadcast onto a plot (Kerr et al. 1993). The sugar enhances the growth of soil microbes which take up considerable N, thus making it unavailable for the plants (Morgan, personal communication 1992 in Kerr et al. 1993). Effects on soil organic matter and overall soil quality of such a technique have not been examined in detail (Kerr et al. 1993).

4.5 Herbicides

Spraying with chemicals seems to be one of the most widely used techniques for weed control in native grasslands (Kerr et al. 1993). Herbicides can be used to alter species composition of a site by selectively harming susceptible species (McMurphy et al 1976).

The effect of the herbicide will depend on:

"1) type of herbicide used;

2) amount of herbicide used;

3) season of use and phenological stage of plants;

4) current and subsequent environmental conditions such as climate (Romo and Lawrence 1990)."

The advantages of herbicide use for weed control are that they require minimum labour, cost is generally less than for mechanical control, spraying may be done on steep slopes or stony terrain where mechanized equipment cannot operate, herbicides can produce a rapid plant response over a large area, and they do not cause soil erosion, as tillage does (Romo and Lawrence 1990; Vallentine 1989b).

Disadvantages include:

"1) In native mixed grass and forb stands use of chemicals may not be possible except prior to seeding;

2) Species response differs depending on time of application;

3) Some undesirable plants cannot be controlled by herbicides while other desirable ones are eliminated by herbicide use;

4) Cost of control may be higher than the expected forage increase on some rangeland;

5) A poor seedbed may result for subsequent seeding;

6) Careless use can damage untargeted species and contaminate the environment;

7) Plants poisonous to livestock may be grazed more readily after chemical treatments (Romo and Lawrence 1990; Saskatchewan Agriculture 1991; Vallentine 1989b)."

In order to minimize dispersion of herbicide from the application source, it should be applied when temperatures are mild, relative humidity is high, and when wind speeds are less than 8 to 10 kmph (Saskatchewan Agriculture 1991). Herbicide application treatments are presented in Appendix B.

It must be stressed that any vegetation management strategy, or combination of strategies that the city may chose to adopt ultimately depends on public acceptance. Techniques such as prescribed burning, herbicide use and grazing may be highly contentious issues with the public. An understanding of the purpose of these practices, will require extensive public outreach efforts on the part of Calgary Parks & Recreation.

CHAPTER 5: RESULTS

5.1 Description of Sites

Sites were chosen within the study area in order to represent as large a diversity of grassland community types as possible. Location of individual sites are mapped in Figure 3. The entire list of species identified within the study area is presented in Appendix C. Table 3 shows the condensed data set that was used to facilitate the analysis. A description of each of the thirty-five plots that were used for the Canonical Correspondence Analysis is shown in Table 4. The name of each community type was based upon dominant composition that was observed during sampling for the biophysical inventory.

Site history, determined by interpretation of aerial photographs taken between 1960 and 1991, and through personal communication, is documented in Appendix D. The scale of the photographs made interpretation somewhat subjective, and eventually was based upon personal judgement. An attempt was made to trace land use through aerials taken on 5 year intervals. In some cases the time interval is either greater or less than 5 years, due to the fact that aerials for the desired year could not be located, or that land use was not decipherable on aerials that were obtained.

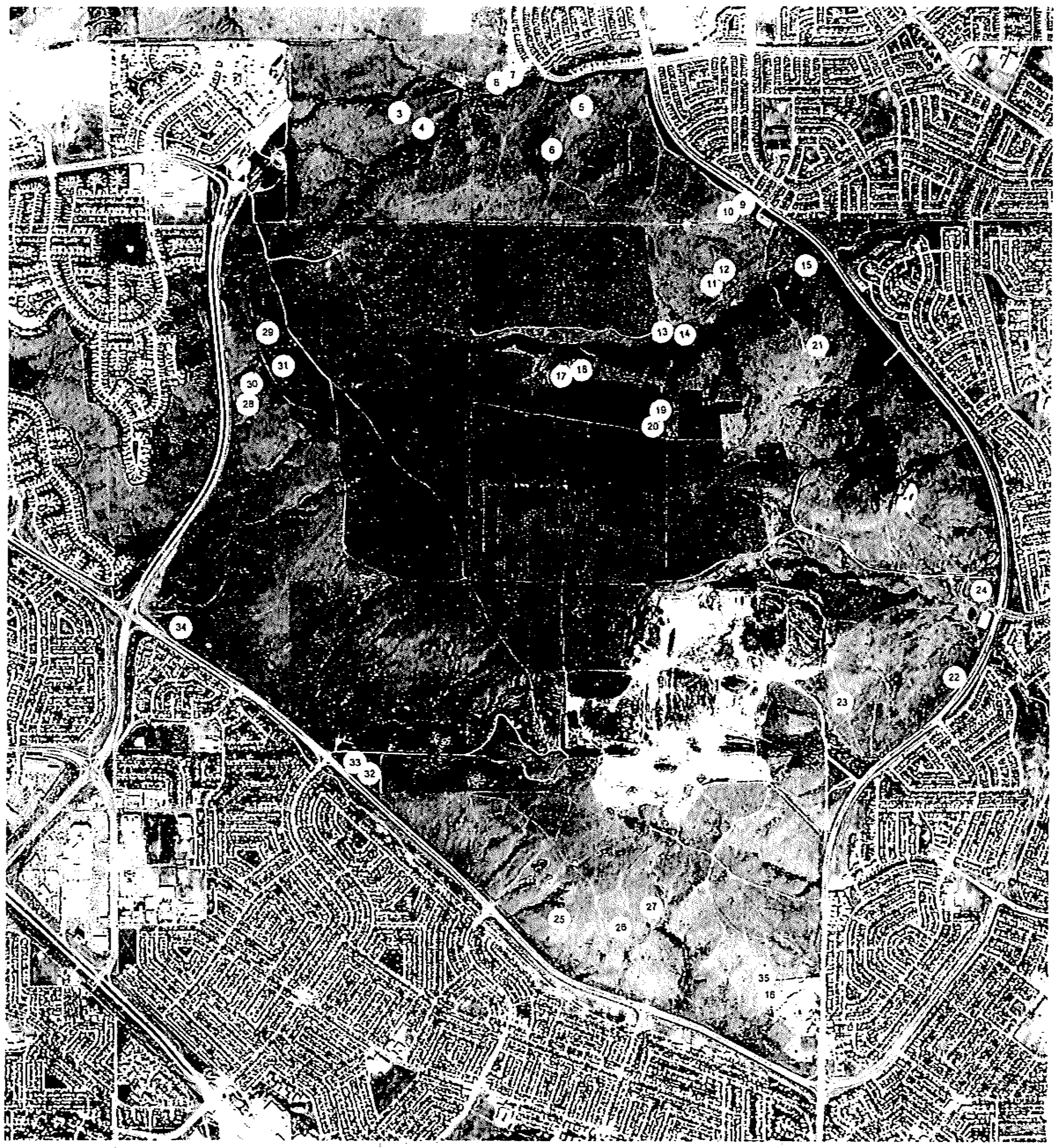


Figure 3: Location of Study Sites on Nose Hill Park, Calgary

SCIENTIFIC NAME	ABBREVIATION	COMMON NAME
Agropyron smithii	AGSM	Western Wheat Grass
Agropyron subsecundum	AGSU	Awned Wheat Grass
Agropyron trachycaulum	AGTR	Slender Wheat Grass
Anenome multifida	ANMU	Cut-leaved Anenome
Artemisia frigida	ARFR	Pasture Sagewort
Artemisia ludoviciana	ARLU	Prairie Sagewort
Aster species	ASTER SPP.	Aster
Aster pansus	ASPA	Tufted White Prairie Aster
Bromus inermis	BRIN	Smooth Brome
Danthonia parrii	DAPA	Parry's Oat Grass
Festuca scabrella	FESC	Rough Fescue
Galium boreale	GABO	Northern Bedstraw
Koleria cristata	KOCR	June Grass
Muhlenbergia cuspidata	MUCU	Prairie Muhly
Poa species	PO SPP.	Bluegrass spp.
Poa pratensis	POPR	Kentucky Blue Grass
Rosa Acicularis	ROAC	Prickly Rose
Solidago species	SO. SPP.	Goldenrod spp.
Stipa comata	STCO	Needle and Thread Grass
Symphorcarpus occidentalis	SYOC	Buckbrush
Thermopsis rhombifolia	THRH	Golden Bean
Vicia Americana	VIAM	Wild Vetch

Table 3: Species used in the analysis

SITE	DOMINANT VEGETATION TYPE	LANDFORM	SURF. TEXT	DRAINAGE	% SLOPE	SOIL GREAT GROUP	ASPECT
1	Blue grama-Western Wheat	lacustrine	silty loam	well	10	orthic black chernozem	S
2	Stipa comata	lacustrine	silty clay loam	well	40	orthic black chernozem	S-SW
3	Rough fescue	\	\	\	5	orthic black chernozem	S-SE
4	MIxed Stipa	\	\	\	60	orthic black chernozem	S
5	Rough fescue	morainal slope		well	30	orthic black chernozem	N-NW
6	Rough fescue	ravine slope	sandy loam	well	40	orthic black chernozem	NW
7	Wheat grass-June grass	south facing ravine slope	sandy loam	well	40	orthic black chernozem	S
8	50% Smooth brome-20% Rose- 30% Blue grass	ravine bottoms and slopes	sandy loam	moderate	1	orthic black chernozem	NE
9	Smooth brome	cuts and fills	\	well	5	orthic black chernozem	NE
10	40% Rough fescue 40% Smooth Brome 20% Blue grass-10% Rose	moraine	\	moderate	15	orthic black chernozem	NE
11	70% Smooth brome- 30% Blue grass	moraine	loam	moderate	5	orthic black chernozem	NE
12	Rough fescue	morainal slope	loam	mod. to wel	10	orthic black chernozem	NE
13	60% Wheat grass-June grass 20% Saskatoon	morainal slope	sandy loam	well	45	orthic black chernozem	S-SE
14	70% Smooth brome 30% Blue grass	ravine slope	sandy loam	moderate	10	orthic black chernozem	S-SE
15	Smooth brome	ravine slopes and bottoms	sandy loam	moderate	30	orthic black chernozem	E
16	50% Blue grass- 50% Snowberry	morainal slope	\	mod. to wel	30	orthic black chernozem	S-SE
17	Rough fescue	moraine	\	moderate	5	orthic black chernozem	N-NE
18	Rough fescue	morainal slope	\	well	15	orthic black chernozem	E
19	40% Rough fescue-20% Snowberry	ravine	sandy loam	moderate	5	orthic black chernozem	NW
20	60% Wheat Grass-40% Blue grass	morainal plain	loam	moderate	5	orthic black chernozem	NW
21	Rough fescue	moraine	\	moderate	15	orthic black chernozem	NE
22	Wheat grass-June grass	south facing moraine	\	moderate	5	orthic black chernozem	S-SE
23	Wheat grass-June grass	south facing moraine slop	\	moderate	30	orthic black chernozem	SE
24	Rough fescue-Needle grass	south facing moraine	\	mod. to wel	10	orthic black chernozem	SE
25	Rough fescue-Needle grass	south facing morainal slop	\	well	30	orthic black chernozem	SW
26	50% Blue grass-25% Smooth brome 15% Rose-10% Snowberry	ravine slopes and bottoms	sandy loam	well to mod	5	orthic black and dark brown chernozem	S-SE

Table 4: Sample site descriptions

SITE	DOMINANT VEGETATION TYPE	LANDFORM	SURF. TEXT	DRAINAGE	% SLOPE	SOIL GREAT GROUP	ASPECT
27	50% Rough fescue 50% Blue grass	moraine	\	well to mod.	15	orthic black chernozem	SE
28	50% Blue grass-30% Smooth brome 10% Snowberry-10% Rose	ravine bottoms	sandy loam	well	45	orthic black chernozem	SW
29	50% Smooth brome -20% Rose 30% Blue grass	ravine slopes and bottoms	sandy loam	moderate	10	orthic black chernozem	S-SW
30	80% Blue grass-20% Wolf willow	morainal plain	loam	moderate	5	orthic black chernozem	SW
31	Alfalfa	undulating morainal plain	loam	moderate	5	orthic black chernozem	SW
32	Rough Fescue	hummocky moraine	sandy loam	well	20	orthic black chernozem	W-NW
33	40% Blue grass-20% Snowberry 30% Smooth Brome	morainal draw	\	moderate	5	orthic black chernozem	W-NW
34	80% Blue grass-20% Snowberry	morainal plain	loam	moderate	2	orthic black chernozem	W
35	Wheat grass-June grass	moraine	\	moderate	30	orthic black chernozem	S

5.2 Environmental Factors

Figures 4 and 5 represent the distribution of sites and species respectively while considering environmental factors. The first axis consists of the ordering of species and sites that produces the maximum possible correlation between site and species scores. The second axis also has maximal site-site-species correlation subject to the constraint that the second axis is orthogonal to the first (Palmer 1993). It should be noted, that mean values from the CCA represent rank orders, and should not be interpreted as quantitative data.

The environmental factors under question were grazing, recent burns (in the last 2 years), cultivation, drainage, slope and aspect (which was entered as code comprised of two variables; one representing the north-south direction, and the other representing east-west direction). In general, floral composition was largely influenced by the north/south component of aspect, as well as by slope and drainage. The largest disturbance factor that appeared to affect vegetation was grazing. The relatively small influence of burning and cultivation may be attributable to the fact that these disturbances were only encountered on three of the thirty-five sites. Grazing tended to occur on steeper slopes (grazing-aspect correlation $r^2=0.19$), since flatter, well drained surfaces were used for cultivation in the past (cultivation-slope $r^2=-0.27$). Recent burns appear to be located on land that was previously used for cultivation ($r^2 = .42$).

5.3 Distribution of Sites/(Species)

A cluster analysis (Syntax 3.0) was performed on site data in order to obtain more definitive clusters of sites based on species similarity. Figure 6 illustrates the grouping scheme that was derived from the analysis, and table 5 shows the percent composition of the species within each of the four associations. Sites were broken down into 2 major groups; group A/B and group C/D. These were further sub-divided into groups A, B, C, and D.

Group A had less than 1 percent smooth brome and Kentucky bluegrass. Rough fescue and Parry oatgrass were present in low percentages. This group was primarily dominated by western wheatgrass, needlegrass and to some degree, tufted white prairie aster *(Aster pansus)* and june grass. **Group B** had an even lower percentage of the non-native species and was primarily dominated by rough fescue and Parry oatgrass.

Sites comprising **Group C** were dominated almost exclusively by smooth brome. Native grasses such as rough fescue, Parry oatgrass, needlegrass and western wheatgrass were excluded from sites of Group C. This cluster also had a high abundance of Kentucky bluegrass and buckbrush. Excluding Group C, all clusters had a high percentage of golden bean and northern bedstraw. **Group D** sites were dominated of smooth brome and Kentucky bluegrass in almost equal proportions. Site 13 was placed in Group D, but was an anomaly since the species composition was dominated by june grass.

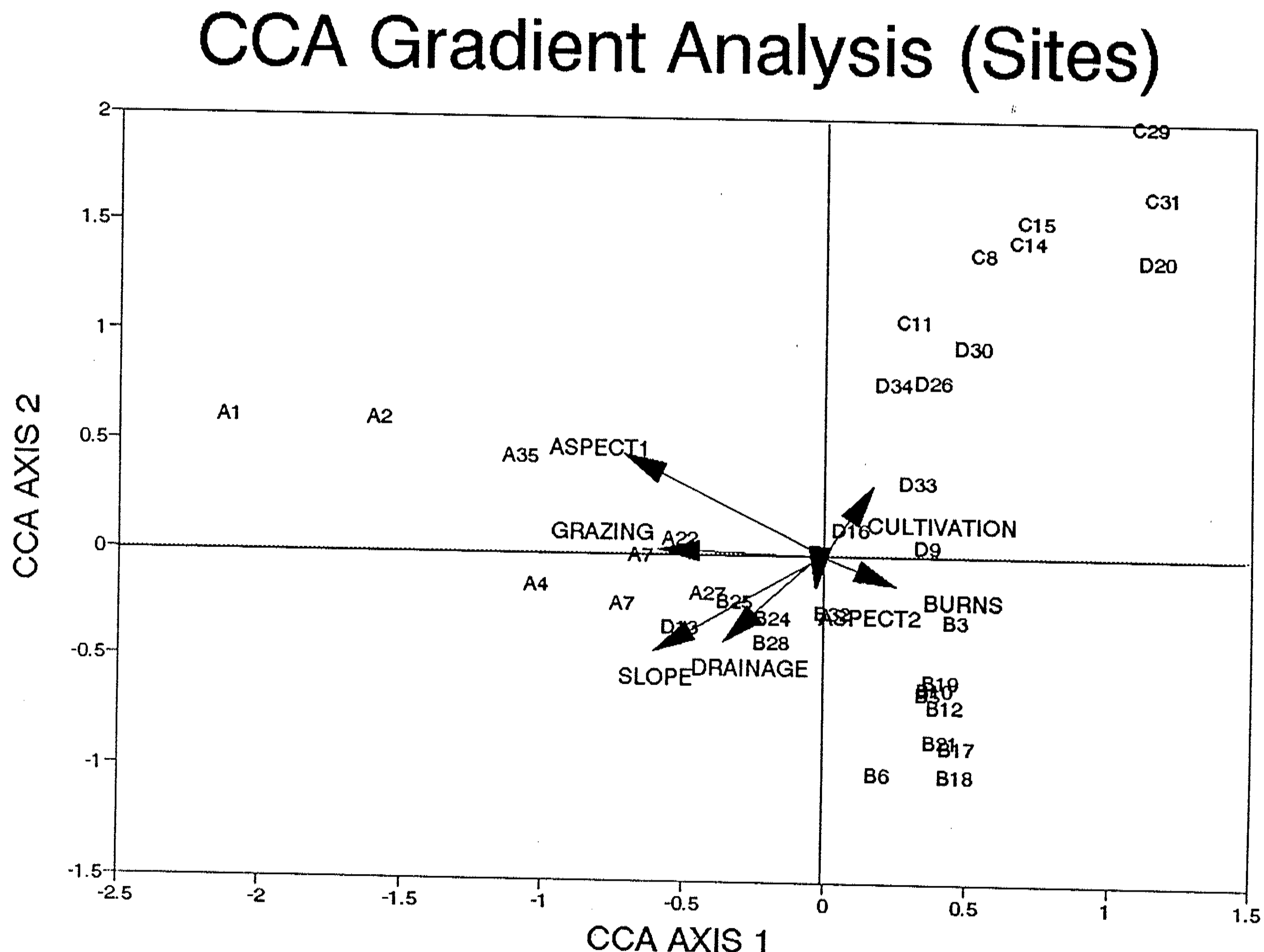


Figure 4: CCA Gradient Analysis (Site Distribution)

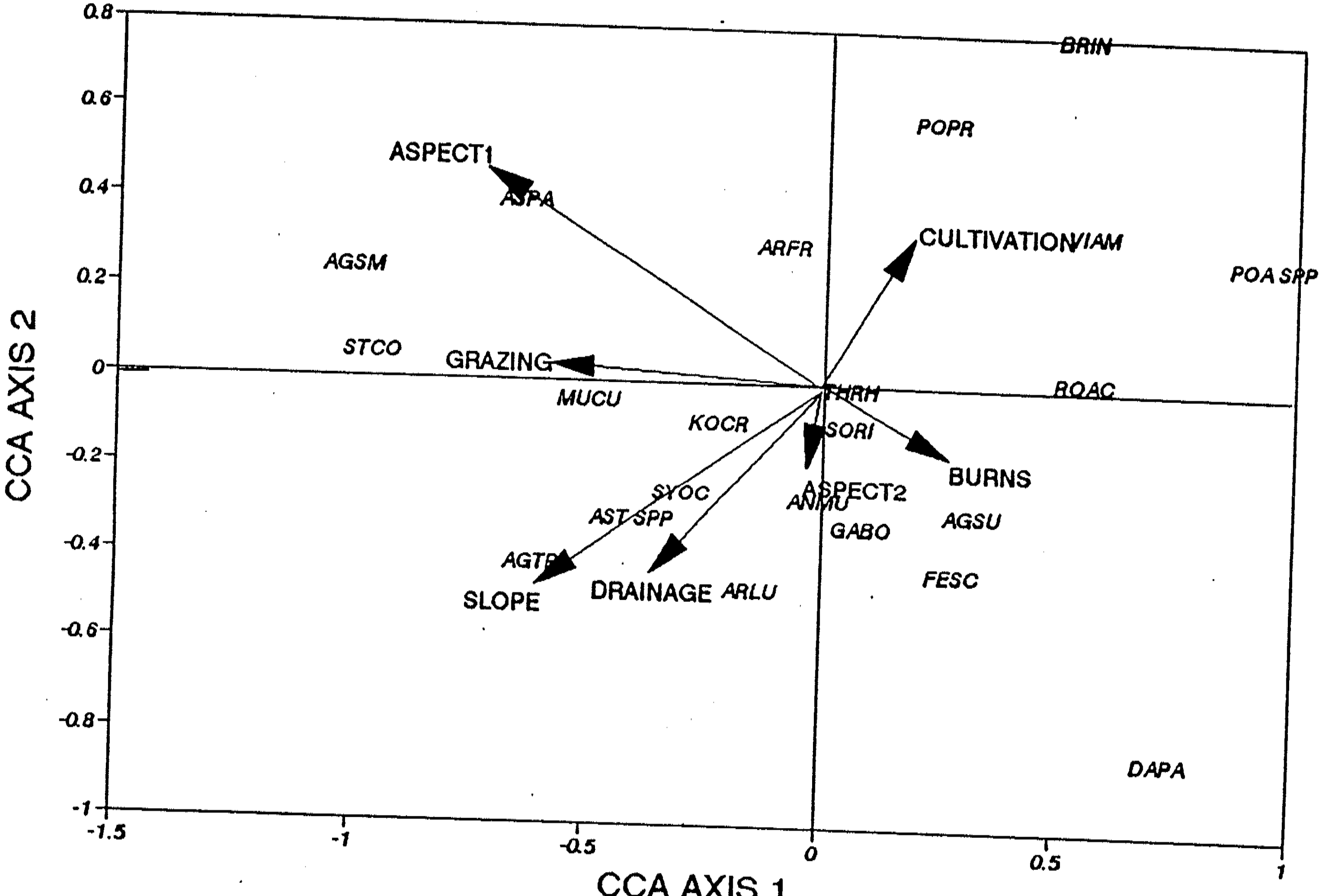


Figure 5: CCA Gradient Analysis (Species Distribution)

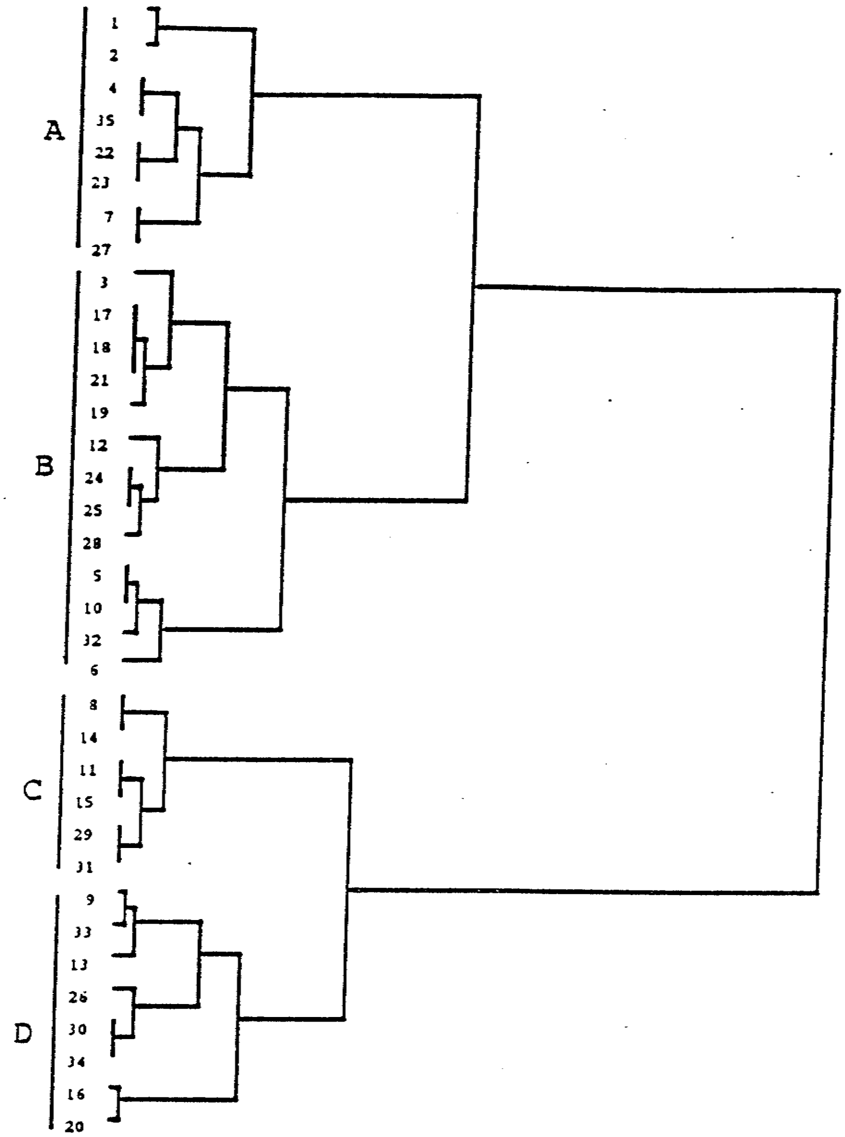


Figure 6: Cluster Analysis of sites based on species distributions and environmental factors

SPECIES	Group A (Needlegrass/Western Wheatgrass)	Group B (Rough Fescue/Parry Oatgrass)	Group C (Smooth Brome)	Group D (Smooth Brome/Kentucky Bluegrass)
BRIN	0.02	0.01	0.98	0.47
FESC	0.13	0.72	0	0.03
DAPA	0.02	0.36	0	0.01
THRH	0.46	0.7	0.03	0.39
GABO	0.24	0.47	0.01	0.19
STCO	0.69	0.13	0	0.02
ARFR	0.16	0.23	0.02	0.09
POPR	0.07	0.02	0.1	0.54
ROAC	0.01	0.03	0.01	0.15
SORI	0.07	0.09	0.02	0.01
AGSU	0	0.1	0	0.06
VIAM	0.03	0.07	0.1	0.06
SYOC	0.1	0.07	0.09	0.36
MUCU	0.05	0.04	0.03	0
KOCR	0.23	0.01	0	0.03
ARLU	0.08	0.01	0.03	0.14
ANMU	0.13	0.08	0	0.03
AGSM	0.53	0.07	0	0.03
AS SPP.	0.14	0.03	0.13	0.06
AGTR	0.07	0.04	0.02	0.08
ASPA	0.26	0.09	0	0.06
PO SPP.	0.03	0.06	0.06	0.12

Table 5: Species Frequencies (mean scores) for Each Cluster

In general, Groups A and B were both dominated by native species. Group A was comprised of species such as needlegrass, western wheatgrass, and june grass which are found in more xeric regimes of the Fescue prairie. The needlegrass/western wheatgrass association was found in areas with a steep south facing slope, where the only disturbance was grazing.

Group B was dominated by rough fescue and Parry oatgrass which is a common association of the Southern Alberta Fescue Prairie. The main environmental characteristic of the rough fescue/Parry oatgrass association is that these community types appear to be found on moderately drained north-facing slopes, which may have been burned recently. It appears as though these areas were lightly grazed in the past, but cultivation was absent. The native vegetation associations had a higher species diversity as compared to the non-native stands.

Groups C and D had high abundances of non-native species. Group C sites were almost complete monocultures of smooth brome. Both the smooth brome and smooth brome/Kentucky bluegrass sites appear to be have been influenced by past cultivation, and are found on flatter land with poor drainage. Sites of Group D appear to have been overgrazed, or subject to vehicular traffic in the past.

It should also be noted that although blue grama was excluded from the analysis because of its very low rate of presence in the majority of stands, site 1 was sampled specifically because was it was the dominant species. This site was situated along an anthropogenic dirt path on a slope surrounded by a residential area. Blue grama was able to grow and survive in a heavily trampled environment.

Figure 7: Group A: Needlegrass/Western wheatgrass association

Figure 8: Group B: Rough Fescue/Parry oatgrass association

Figure 9: Rough fescue/Parry oatgrass at a distance

Figure 10: Blue grama site

Figure 11: Group C: Smooth brome association

Figure 12: Smooth brome/Kentucky bluegrass association

CHAPTER 6: DISCUSSION

6.1 Influences on Site Species Composition

The over-riding influence on vegetation composition in the study area appears to be the moisture regime. Slope and aspect influence physical factors such as soil type, drainage, solar irradiance, and temperature, which affect botanical characteristics of any geographical region. Plants native to a given climatic region have growth and reproductive characteristics suitable for those specific conditions (Coupland 1979). As such, disturbances such as grazing, burns or cultivation which alter physical characteristics of the land, change the species composition of the affected area. Only a few species of grasses are sufficiently well adapted to function as dominants in any particular grassland habitat (Coupland 1979). Therefore, as the habitat changes due to disturbance, the composition of grasses and forbs also changes.

According the results of the CCA, grazing was found to have a greater effect on community type than cultivation and burning. This may be due to the fact that almost all of the sites sampled were at one time grazed (to different degrees), but cultivation was identified to have occurred on only 4 sites. Effects of past burning are indeterminable from this study. Bluegrass and wheatgrass are dominant in a site that was thought to have been burned in April, 1993. This is contrary to literature which states that

Kentucky bluegrass and western wheatgrass, which are both cool season species, are detrimentally affected by spring burning (Clarke et al. 1943, Kruse and Higgins 1988, Wright and Bailey 1992). Parameters of controlled burns on Nose Hill have not been recorded in the past, and thus it is difficult to speculate upon what the comparative intensity of the April 1993 fires were. Past land uses of some sites may not be accurately described due to personal judgement of position of sample sites. It may be possible that for some sites (particularly sites 19, 20 and 21) the spot at which they were located on the map may not coincide exactly with the actual physical location where the samples were taken. Thus a site that was said to have been burned, may actually have been missed by the fire.

Using cluster analysis, the sampled sites were divided into four groups based on similarity of species composition and environmental characteristics. Group A is dominated by needle grass/western wheatgrass; Group B by rough fescue/Parry oatgrass; Group C by smooth brome; and Group D by smooth brome/Kentucky bluegrass.

6.2 Group A

Needle grass/western wheatgrass community type was found on steep south-facing slopes where the main disturbance was light to moderate grazing in the past. Tufted white prairie aster and june grass were also abundant. Needlegrass and western wheatgrass are often found at the xeric end of the moisture gradient of Fescue Grassland where there is rapid drainage and high levels of insolation. It often occurs in association with Dark Brown Chernozemic soils (Kansas et al. 1993).

Although cover of needlegrass decreases with grazing, it can survive moderate grazing intensity by rapid regrowth after defoliation (Lewis and Johnson, 1980). Similarly, rhizomatous growth may ensure survival of western wheatgrass under moderate grazing, but early internodal elongation makes its apical meristem vulnerable to heavy grazing (Branson 1953). A high cover of needlegrass relative to blue grama suggests that grazing has not had a significant impact on most of these sites in the study area. Characteristics of plants which make them adapted to xeric sites, such as slow growth rates, rhizome production, rapid production of lateral shoots, short heights and acaulesent growth forms, late seed germination, spring growth, and late elevation of fertile stems, also confer resistance to grazing (Lewis and Johnson 1980). Site 1, which was dominated by blue grama, showed signs of intense trampling. The surrounding vegetation on Briar Hill close to site 1 showed much less human disturbance. Site 2, which was upslope of site 1, for example, was dominated by needlegrass.

6.3 Group B

Cluster B species are representative of rough fescue/Parry oatgrass grassland which is native to the Calgary region. Rough fescue dominates these sites, and associated species appear to be Parry oatgrass and northern bedstraw. It occurs on well drained Black Chernozemic soils on moderately steep slopes around the upland plain (Kansas et al. 1993). Fescue Grassland is best adapted to well-drained sites with ample moisture and deep soils, but Rough Fescue has a deep-root system that enables it to maintain good production during short-term water deficits (Willms et al. 1992).

The only land disturbance in areas occupied by this association was light grazing. Parry oatgrass increases in abundance in drier regions, or in regions where light grazing has occurred. Rough fescue is very sensitive to overgrazing (Saskatchewan Agriculture 1991). Continued heavy use can almost eliminate rough fescue from the community, encouraging an increase in Parry oatgrass, followed by replacement with needlegrass, june grass, blue grama, and pasture sage.

6.4 Groups C and D

Smooth brome and Kentucky bluegrass associations represent areas that were planted, intensely grazed, or developed as a result of agricultural activity (Group D). Clusters C and D were present under mesic conditions generally in flat ravine bottoms, or on the top of Nose Hill. Both species are known to be highly tolerant of trampling, and increase at the expense of mesic species under heavy grazing regimes. Kentucky bluegrass can withstand grazing due to extensive reproduction by rhizomes (USDA 1937). Cultivation reduces soil stability to the point where a large proportion of the annually produced organic material turns over rapidly, and the organic content of the soil is only a small fraction of that in native grasslands (Coupland 1979). This makes it conducive to swards of smooth brome outcompeting native species (Group C sites). Smooth brome is believed to release toxic exudates through its roots which inhibit the growth of surrounding species (Strong 1993 personal communication).

There was no clearly evident factor which accounted for the difference in species composition between Groups C and D, although smooth brome unlike Kentucky bluegrass, can tolerate high salinity levels in cultivated soils (Hardy BBT 1989). Both species survive well in the Festuca microhabitat (Looman 1944). The presence of species such as rosa, buckbrush and golden bean in Group C sites are also indicative of intense grazing. These plants increase in response to grazing, since they have a low palatability and overgrazing speeds up root spread (Saskatchewan Agriculture 1991). In the long-run, Kentucky bluegrass is unable to compete with smooth brome, and may eventually be competitively excluded from the sites which comprise Group D.

CHAPTER 7: SUMMARY AND CONCLUSIONS; VEGETATION MANAGEMENT STRATEGIES

7.1 Summary

Before any manipulations are made to existing vegetation, desired vegetation types must be defined specifically. A strict definition of the end use is required whether it be for maintenance of a natural environment essentially unaltered by human activities, aesthetics, wildlife habitat, watershed protection, suppression of weeds, or some combination of these elements. Vague notions of a desired outcome present serious consequences when there is a need for accountability of activities, or fine tuning and prescribing procedures for present and future vegetation management (Romo and Lawrence 1990). The Calgary Parks & Recreation Department does not presently have a detailed strategy, the only outcome that is defined is preservation of whatever native grasses still exist and to keep undesirables out (Hergert, personal communication, 1993).

The first step to formulating a vegetation management plan is to obtain an inventory of the topography, soils, existing and potential plant communities, and past land use. This is essential since each landscape unit and vegetation type requires unique management prescriptions because each responds in its own way (Romo and Lawrence 1990). It is critical to identify a site as being devoid of vegetation, dominated by indigenous or exotic plants, or characterized by mixture of native or invader species. A catalog of ecological information and expertise in management is also required in addition to the biological and physical resource inventory. If the composition and structure of the desired vegetation is defined then at this point all possible alternatives to vegetation management must be evaluated (Romo and Lawrence 1990). The critical information in this analysis includes how the specific plants will respond to management and the logistics of meeting a specific goal. The alternative that has the highest probability of enabling the manager to meet the landscape goal is then selected (Romo and Lawrence 1990).

The results of this study identified four primary groups of grassland associations on Nose Hill Park which is part of the overall Fescue Ecoregion of Calgary, Alberta. These groups included; 1) needlegrass/western wheatgrass association, 2) rough fescue/Parry oatgrass association, 3) smooth brome association and 4) smooth brome/Kentucky bluegrass association. The management strategies presented in this chapter will focus on the maintenance of the two native associations, and potential for restoring the non-native associations into near native stands.

7.2 Conclusions

7.2.1 Stands Supporting Native Vegetation

The primary criteria which was found to influence species composition on a particular site was moisture regime (aspect, slope, and drainage). The needlegrass/western wheatgrass association occurred on the xeric end of the moisture gradient of the Fescue Prairie. It appeared mostly on steep south-facing slopes. The rough fescue/Parry oatgrass association was found to exist in slightly more mesic environments, where past grazing intensity was minimal.

Native Fescue grasslands evolved in Alberta under natural cycles of wildfire, drought and grazing. With the suppression of natural forces, management techniques which simulate the effects of these disturbances is necessary in order to maintain the species composition and diversity of stands of native grasslands in Calgary. It is recommended that native stands of grasses be managed by a combination of fire, mowing, and grazing established as a system.

A decadent stand should initially be treated with 3 to 4 reclamation burns. The first burn should occur in the spring before green-up of native plants in order to control Kentucky bluegrass which is a drought avoider. After the first fire, a dramatic increase in Canada thistle should be fully anticipated, followed by smooth brome and quackgrass (Smith, personal communication, 1994). Decadent stands are shaded by litter which shades out dead spots (Wark, personal communication, 1994). Once litter is removed, the dead spots provide open areas for C3 invasives, especially with nutrient release (Wark, personal communication, 1994). Weed seed propagules do exist in decadent stands, but are not fully expressed until a niche is provided. Much of the Canada thistle resulting from burning of a decadent site is killed by a second burn. After 3-4 burns, occurring every second year, an expansion of wheatgrass and fescue is expected. At this point, there should be a healthy re-establishment of native grasses, and a rest period of 1-2 years is needed before a transition to grazing.

Cattle grazing can be used to decrease smooth brome and quackgrass (Smith, personal communication, 1994). A rotational system of grazing should be employed through 4-5 sites for 14 days (at the recommended Alberta stocking rate), for three to four grazes. (Smith, personal communication, 1994). The sites should be grazed at different times each year (Smith, personal communication, 1994). Since short duration grazing is becoming an important management alternative in Alberta, and it is important to consider increasing compaction of moist soil from grazing (Naeth et al 1990a). Under wet or very moist conditions such as springmelt or during intense rains, the duration of grazing will have to be reduced in order to minimize compaction (Naeth et al. 1990b). Cattle are the preferred species of grazers since they will graze the surface of the cover (thereby leaving a carryover for the next year), and selectively chose brome. Horses and sheep tend to graze to the bottom of the sward. If horses and/or sheep are used, then grazing pressure will be increased, and thus the rotation time of 14 days should be decreased. As seen in the results, over-grazing may initially result in an increase of Parry oatgrass at the expense of rough fescue, until a point where the rough fescue/Parry oatgrass association is totally replaced with a more grazing tolerant needlegrass/western wheatgrass community. Over-grazing of the needlegrass/western wheatgrass association may result in an increase of blue grama, as well as an increase in Kentucky bluegrass in both communities which will defeat the purpose of the burning-grazing system. Care must be taken to establish the proper grazing regime, and to carefully monitor grassland for the above changes in species composition which may indicate excessive grazing pressure.

After the renovation burns and grazing have been completed, maintenance burns or mowing should be carried out every 5-6 years (Wark, personal communication, 1994). Since the needlegrass/western wheatgrass association appears to exist on the xeric end of Fescue grasslands, caution must be taken to ensure that burns are not too hot. Excessive moisture loss from the soil may reduce the percentage of needlegrass, and favour species more common in Mixed-grass community types such as blue grama or june grass. When there is accumulation of duff, mowing may be more preferable than burning (Wark, personal communication, 1994).

At present, the city of Calgary does not have a specific prescription for burning local grasslands. Controlled burns that have taken place on Nose Hill recently have been undertaken with the primary objective of reducing the thick sward of grass which could be a natural fire hazard, and to burn off the dead stalks of goatsbeard (Logue, personal communication, 1993). The Parks Department performs "slash and dice burning" without using a prescription for fire, or monitoring the regrowth in order to make future modifications (Logue personal communication, 1993).

If the intention of prescribed burns is to reduce natural fire hazard, it should be understood that these burns do not provide a guarantee that wildfire will be completely eliminated. A fall burn will reduce the chances of wildfire occurrence the following spring, but maintenance burns will not be done every year. Additionally, in grassland ecosystems, although the amount of fuel may be small, the high rate of fire spread results in a high intensity fire. Therefore, once a fire is ignited a low amount of standing litter may still result in an intense fire.

Without a proper prescription which clearly links fire behaviour to fire effects it is impossible to speculate if a burn will be effective at meeting the desired management goals of the fire program (Clark and Johnson 1993). In the end, a fire may end up doing more harm than good, therefore wasting valuable time and money. If it turns out that the fire was effective, without a proper prescription there is no way to know exactly how to duplicate the effects (Clark and Johnson 1993).

Clark and Johnson provide a recommended sequence of fire treatments as part of a fire management plan that was developed for the University of Calgary Rough Fescue Prairie Reserve. A description of fire behaviour, the fire behaviour model, treatment prescriptions, and techniques for monitoring have been adapted directly from Clark and Johnson et al. 1993, and are provided in Appendix E.

7.2.2 Sites Supporting Exotic Vegetation

The two non-native grassland associations were smooth brome, and smooth brome/Kentucky bluegrass. Both associations were found in mesic environments such as ravine bottoms that had been subject to intense disturbances for example over-grazing or vehicular traffic. It appeared as though monocultures of smooth brome appeared in locations where past cultivation occurred, although there is no discrete variable which distinguishes the two community types.

If a stand is comprised almost completely of exotic species, a decision has to be made about whether to allow the existing vegetation to persist, or to eradicate the existing cover, and re-seed with the intension of establishing a native stand. In general, if a stand is comprised of more than 50 percent exotics, an attempt is made to eliminate all vegetation and create a situation where the site can be artificially re-seeded (Romo and Lawrence 1990). This section will deal with the situation in which it has been decided that the non-native stands of vegetation will be eliminated and native species will be replanted.

Vegetation Eradication

Wark (personal communication, 1993 recommends mechanical weed control with chemicals to eliminate Canada Thistle and smooth brome and Kentucky bluegrass when revegetating a site which is not susceptible to erosion (Figure 13). The land should be tilled three times. The first tillage should occur when weeds are about 7-10 cm high, in late May. After 2 weeks the soil should be turned over, and after another 2 weeks, the third tillage should occur. The last tillage should occur prior to July 21. Tillage can be accomplished using a single row seeder tied to a cultivator which ploughs 1 row at a time. The site should be left for 6 weeks during the thistle rosette stage when the plant pumps all of its energy into the roots. On the first of September, a mix of Roundup (1 L/acre) should be sprayed to eliminate brome, thistle and quack grass. If other broadleaved plants are present, then 0.7 L of roundup and 0.4 L of Banvel should be sprayed instead. A final tillage should take place 2 weeks after herbicide application (Wark, personal communication, 1993). In a smooth brome field infested with Canada thistle 0.6 L per acre lontrel + 0.4-0.6 L/acre 2,4D Amine 500, should be applied when the thistle is at the prebud to rosette stage and grass is at the two to three leaf stage. An alternative is to mow the smooth brome field twice a year for 2-3 years in order to weaken the roots of Canada thistle (Wark, personal communication, 1994).

In the few areas where equipment can not be used, such as on a steep slope, a prescribed burn may be used to remove undesirable vegetation but the potential for erosion should be considered (Dangerfield, 1993). Smooth brome may be reduced by 2 or 3 consecutive late spring burns, but can be enhanced by an early spring burn (Dangerfield, 1993). The best method to eradicate a full field of smooth brome would be though an initial application of Round-up, followed by the mechanical weed control system (Figure 14) (Wark, personal communication, 1994). The method for removing persistently invasive plants such as Kentucky bluegrass and smooth brome is outlined in Figure 15.

In-crop weed control should be done if there are problems of erosion and salinity (Figure 16) (Wark 1990). Barley is advised as it is both highly competitive with weed species and is tolerant of the herbicide suggested for the weed control strategy and saline soil. In year one, barley should be planted in the spring to act as a cover crop for protection against water and wind erosion. Once the barley has been established, a chemical fallow system should be implemented to control weeds (Figure 14). In year two, the crop should remain only as standing stubble, which should be burned off and the soil can then be re-seeded with a native mixture. If the soil is extremely susceptible to erosion, trash ploughs to remove stubble should be used instead of burning. Chemical fallow is much less effective than the mechanical weed control with chemicals system. With mechanical weed control, only a 15 percent carryover of Canada thistle is expected, unlike chemical fallow where Canada thistle can carryover up to 50 percent (Wark, personal communication, 1993).

Whether using the summer fallow system or the chemical fallow system planting can take place in year two, provided there is less than 5 percent perennial weeds present (Figure 17) (Wark 1990). If problem species make up more than 5 percent of the composition, another year of cropping or tillage is necessary. In the planting year an application of 1 litre of Round-up herbicide in 8 gallons of water per acre is required before planting or within 7 days after planting, prior to grass emergence (Wark 1990).

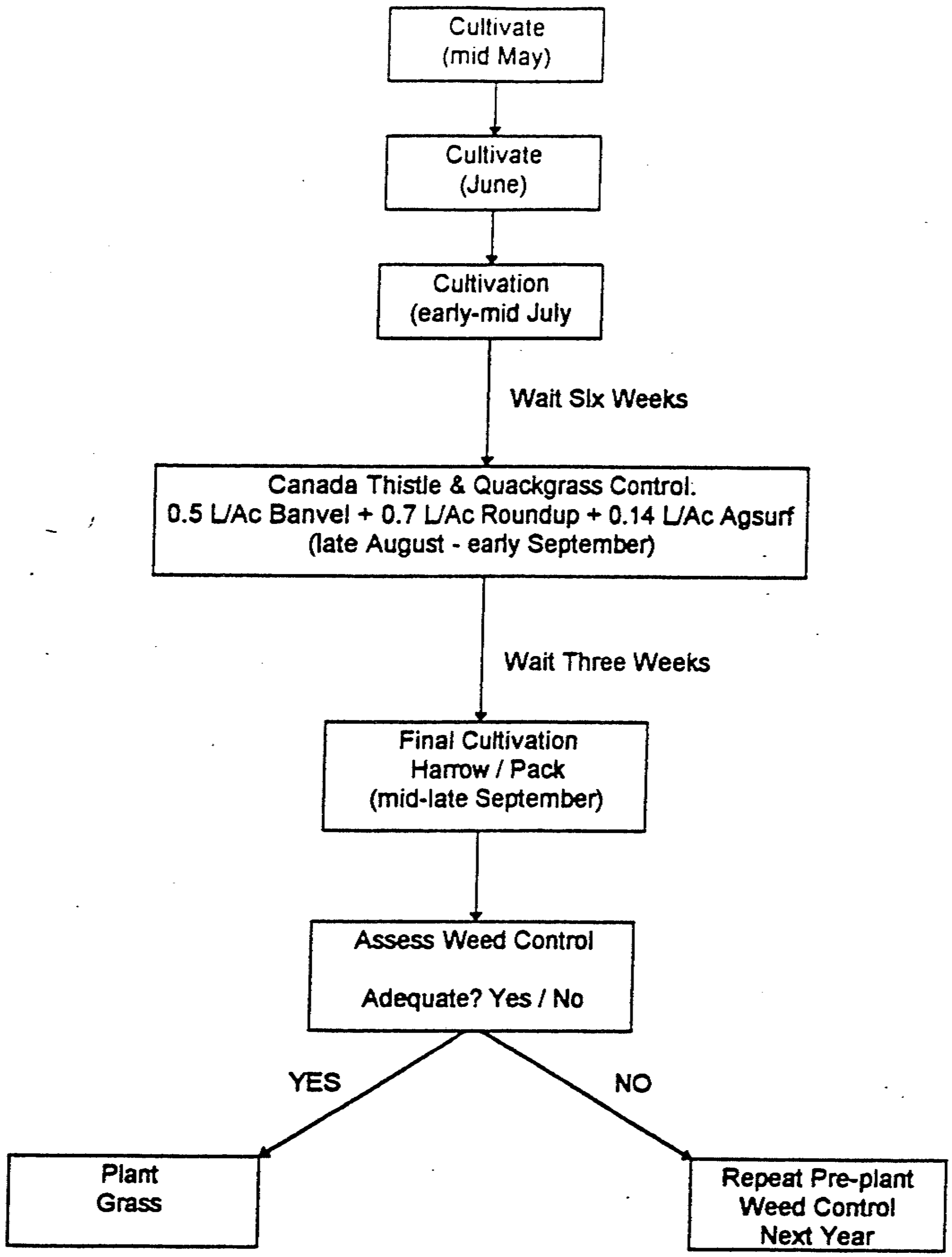


Figure 13: Mechanical Weed Control Flowchart (Wark 1994)

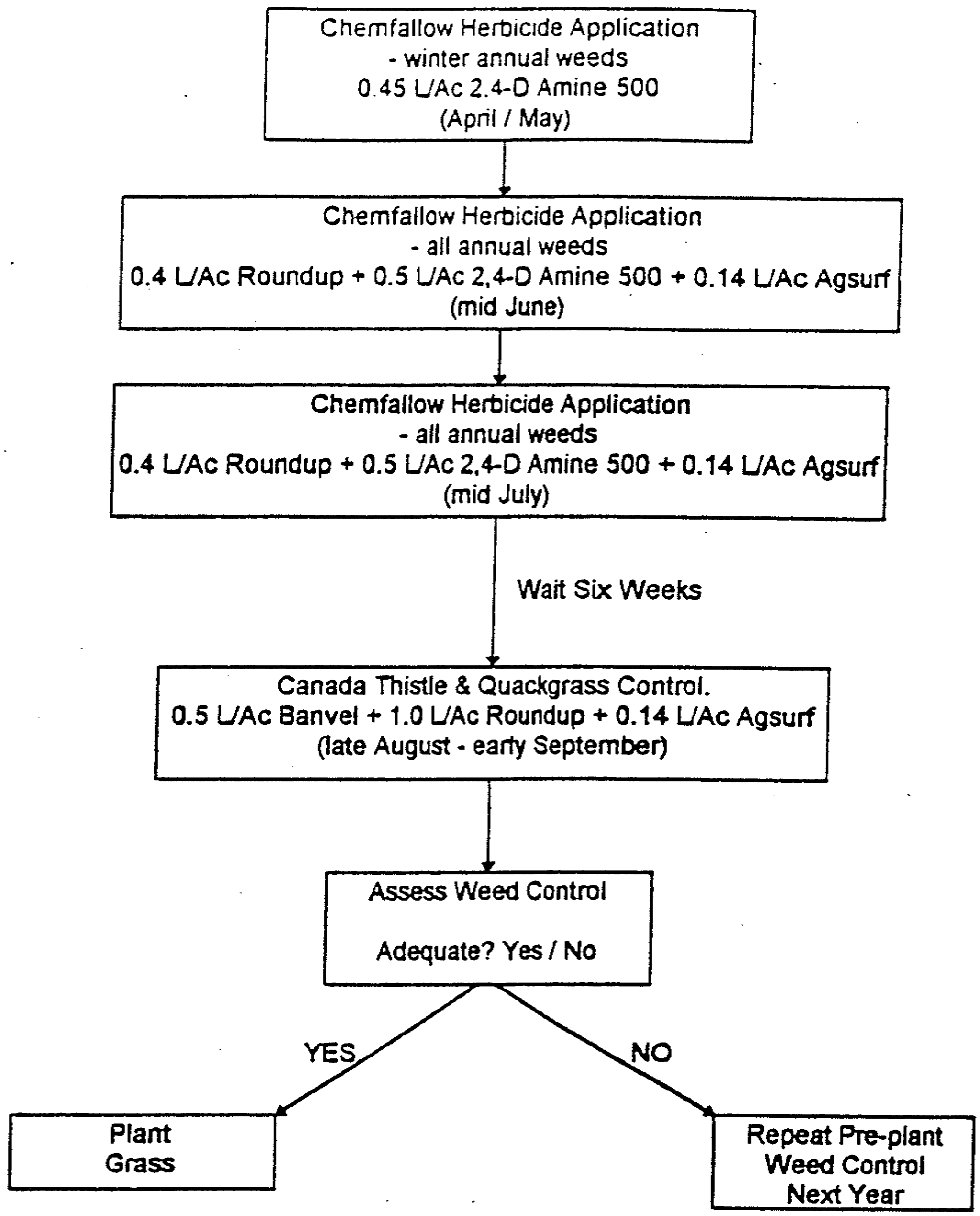


Figure 14: Chemical and Mechanical Weed Control Flowchart (Wark 1994)

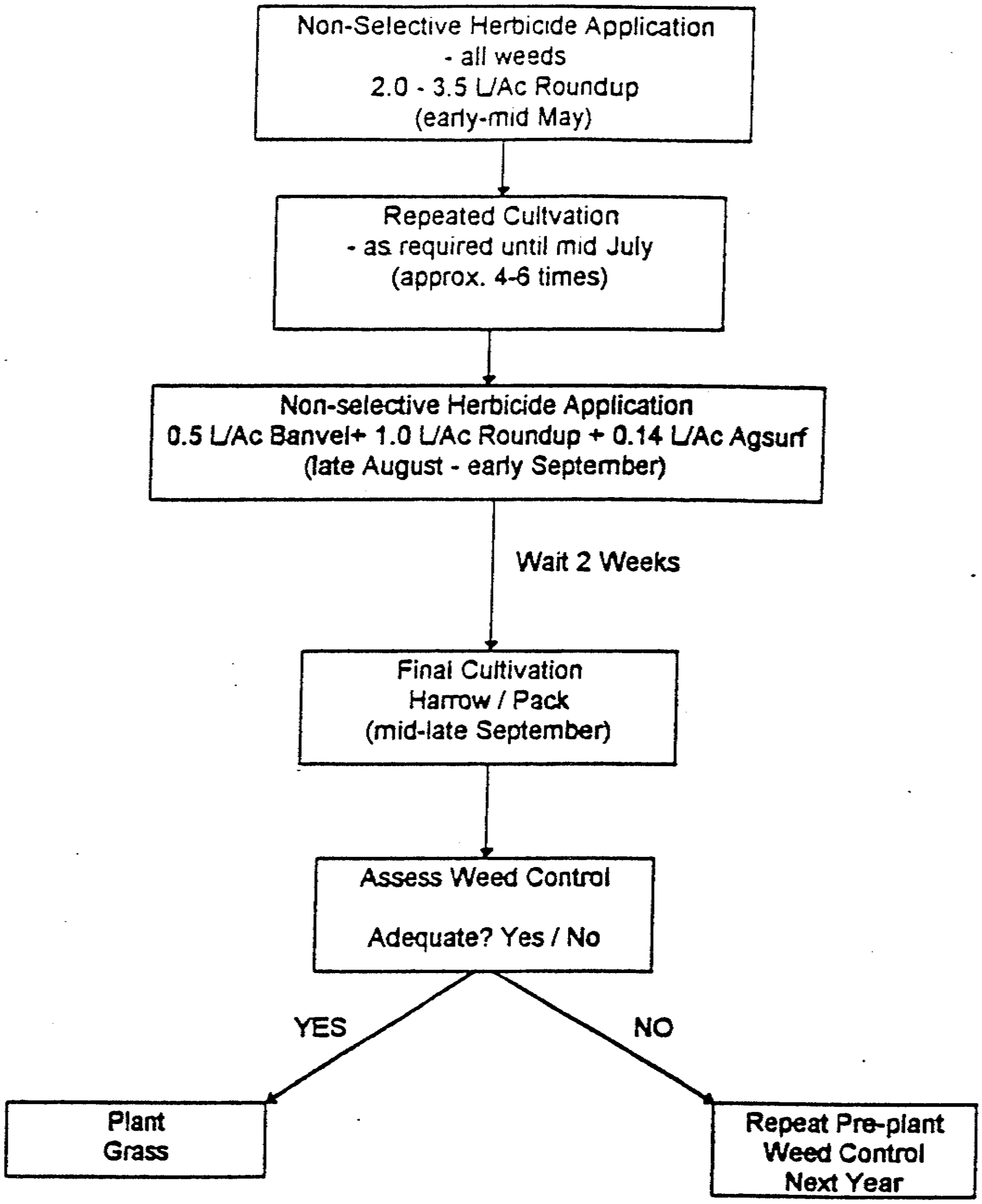


Figure 15: Removal of Invasive Plants Weed Control Flowchart (Wark 1994)

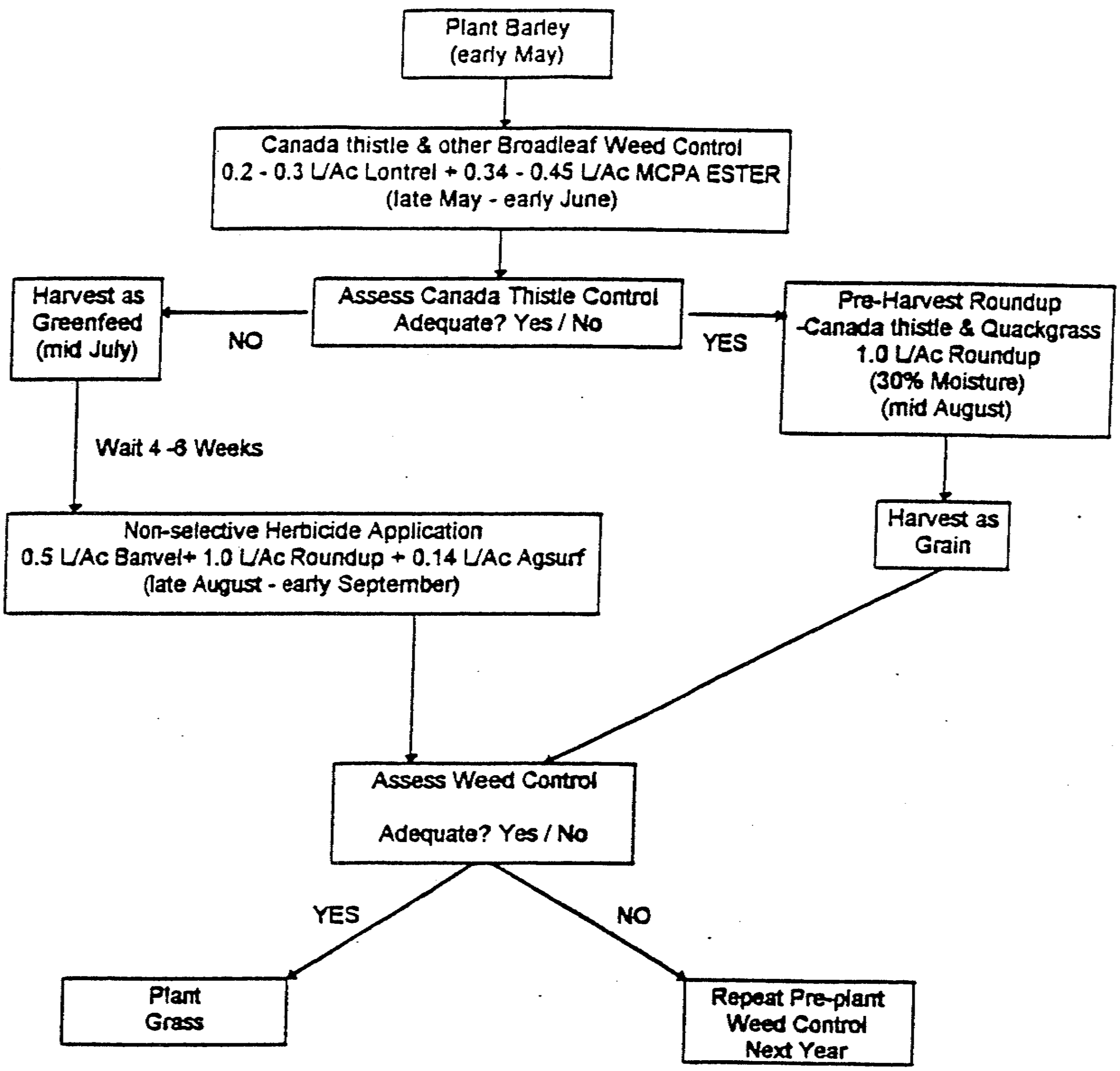


Figure 16: In-Crop Weed Control Flowchart (Wark 1994)

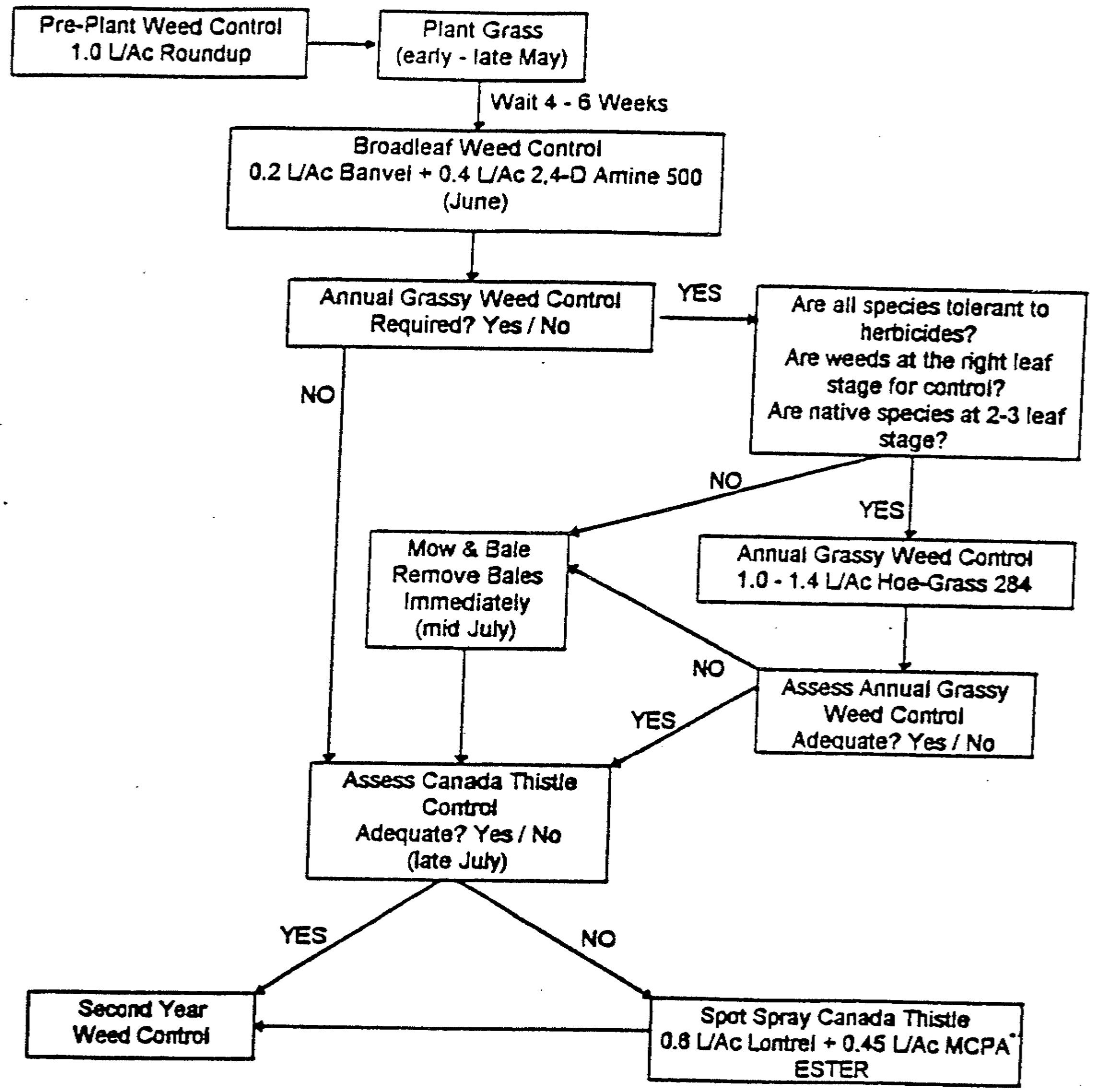


Figure 17: Planting Year Weed Control Flowchart (Wark 1994)

Seedbed Preparation

The most important factor in planting of native prairie species is proper site preparation (Morgan and Morgan 1992). Inadequate weed suppression is the single most common cause of grass seeding failures (Duebbert et al 1981). After sufficient control measures have been taken to reduce or eliminate undesirable vegetation, the adequacy of the humidity and soil moisture for seedling germination must be determined (Winkel et al. 1991). This becomes of particular importance in arid or semi-arid native grassland areas where seeds sown deep or under litter have a higher success rate than those distributed at or near the soil surface (Schuman et al. 1987).

The ideal seedbed is one where the seed is surrounded by soil particles that are firmly packed around the seed to ensure conductivity of water from soil to seed (Winkel et al. 1991). Seeding into stubble is usually recommended for areas that are frequented by wind and water erosion, because it is inexpensive and provides a better microclimate for seedling establishment (Romo and Lawrence 1990). The seedbed should be firmly packed but not compacted, through the use of a spike-tooth harrow or corrugated roller after tillage (Kerr et al. 1993). A good rule of thumb to follow is that the soil should be firm enough so that the footprint of a 81 kg person barely registers on it (Wark, personal communication, 1993). The tillage and compaction process should not occur when soils are wet (Kerr et al. 1993). Seeding should occur just prior to the high rainfall period to maximize soil moisture as seeds germinate (Kerr et al. 1993). This will also promote adequate plant growth prior to the onset of late summer drought conditions in many native grassland areas (Duebbert et al 1981).

Species Selection

The selection of plant species is critical to the ultimate success of reclamation (Collicut and Morgan 1991). In choosing plant species to reclaim a disturbed site factors outlined in Appendix F should be taken into consideration.

In Calgary seeding mixtures have traditionally been determined by Parks' Planners based upon land uses such as irrigation, decorative purposes and tolerances to drought (crested wheat grass) (Hergert, personal communication, 1993). In the past, no consideration was given to natural areas, so the planting of native species as opposed to domestic species was never considered (Logue, personal communication, 1993). Since native grass was thought to provide less forage than domestic species on farm land, native species were never produced commercially (Kaufman 1993).

Seeds of native species can be manually collected or purchased from commercial seed dealers (Romo and Lawrence 1990). There may be several cultivars of each species available when ordering (Dangerfield 1993). The locality and site characteristics from where the seed was collected must be known to ensure revegetation success (Romo and Lawrence 1990). Plants exist in genetically differentiated ecotypes which develop in response to elevation, precipitation, temperature, growing season, and soil site conditions of a particular habitat (Romo and Lawrence 1990). If the plants associated with one ecotype are moved to another site interactions and competitive strategies change in response to the varied resources. Thus, species that may be compatible on one site may not be at another site (Romo and Lawrence 1990). A guideline used for cultivar selection is not to move the cultivar more than 400 to 480 km north or 160 to 240 km south of the point of origin to areas of comparable soils and moisture (Thornburg 1982). Movement east or west is dependent on elevation and precipitation. Generally, an increase of 305 m in elevation is equal to a move 280 km north (Dangerfield 1993). Usually, southern plants moved to a new northern location will be greener and leafier because of the higher availability of moisture, but they often produce few if any viable seeds (Romo and Lawrence 1990). Northern plants moved south do not take advantage of the extended growing season, therefore, moving plants greater distances than described above weakens the competitiveness of the plant species and alters the interaction of the plant community thus producing unpredictable and sometimes undesirable results (Romo and Lawrence 1990).

Purity and quality of seed should be carefully analyzed before widespread seeding occurs. Special attention should be made to ensure that no exotic species are contained in the seeds (Wark 1990). When ordering seed, a seed analysis report from the distributor should be requested (Dangerfield 1993). The report will provide information on percent pure seed, inert matter, germination and dormant seed, as well as the amount and type of weed species present. Class A of pure live seed represents 76 percent germination (Wark, personal communication, 1993). Presence of weed species should be analyzed and reported to 0.01 percent. If a dominating or problem weed species is present, then the seed should not be purchased. All seeds purchased should be certified and have a certification tag. Mixtures cannot carry a certified tag, so seeds will have to be mixed after delivery (Dangerfield 1993). Ducks Unlimited Canada is currently working on production of ecovars (ecological variety) in the Prairie Provinces in conjunction with Agriculture Canada and Prairie Province Universities (Wark, personal communication, 1993). An ecovar is a source identified plant material, with a narrower range of adaptability than a cultivar, and thus it maintains a broader gene pool than a cultivar (Jacobson et al. work in progress). Ducks Unlimited expects to have 8 ecovars of Canadian source available commercially in approximately 5 years (Wark 1993).

Mixtures rather than single species should be used for planting because they are better suited to the varying terrain and climatic conditions produced when site characteristics change rapidly within a short distance (Romo and Lawrence 1990). Mixtures should include rapidly developing short-lived species for immediate ground cover, as well as slower growing perennial to reduce invasion of undesirable species as the early seral species decline (Romo and Lawrence 1990).

Less than 1 percent of seed actually germinates in the prairie landscape (Morgan, personal communication, 1993). In Alberta this problem is exacerbated due to lack of moisture, and therefore irrigation and planting more seed per square metre should be considered (Morgan, personal communication, 1993). Rough fescue is especially difficult to establish in dry land, but may be possible with sprigging (plants are cut out by a machine and respread elsewhere) or mulch for vegetative propagation (Willms, personal communication, 1993).

Revegetation

Four main methods of revegetation are currently being used to reclaim native grasslands including seeding (eg. drill seeding, imprinting, broadcast seeding and hydroseeding); spreading harvested seed/straw; sprigging; and salvage of existing materials (sodding). A description of the methods are provided in Appendix G.

In general, it is recommended that a Truax grass drill be used for native planting. A Truax grass drill can plant the entire range of grass species including warm season seeds which are fluffy and lightweight (Wark 1990). The drill must be calibrated for each seed mix. Planting perennial grasses requires uniform distribution of seed at the proper rate per hectare, placing the seed at the proper depth, and firming the soil around the seed

(Duebbert et al. 1981). The sculptured seeding concept (Jacobson et al., work in progress) is recommended when seeding fields of variable topography to ensure correct seed mix placement on high, mid and low prairie. Duebbert et al. (1981) recommends that the xeric and mesic prairie boundary be delineated by driving the boundary with a 1/2 tonne truck so the operator can use the tire marks as a guide before seeding takes place. High prairie knoll areas should be seeded first (Dangerfield 1993). The operator must check the seed boxes to ensure the seed is distributed evenly when seeding a steep slope (Dangerfield 1993).

Time of Seeding

Time is critical to revegetation success. In general, seeding should be timed just prior to the greatest probability of precipitation (Cook et al. 1974; Ries et al. 1987a; Vallentine 1989a). In Alberta, most seeding (and revegetation by other means) takes place in the early spring or late fall to take advantage of peak rainfall levels in late May and June (Adams, personal communication, 1992 in Kerr 1993).

Cool season grasses are best seeded in late summer for fall establishment, or late fall for spring establishment to minimize winter damage, increase growth, and initiate growth earlier next season (Romo and Lawrence 1990). Warm-season grasses are best seeded in mid to late spring as the seedlings are sensitive to late fall and early spring frost (Romo and Lawrence 1990).

Post Planting Management

Post planting weed control will have to be done during the first year of planting (Dangerfield 1993). Wark (1990) recommends a field inspection, then a general herbicide (0.4 L 2,4-D per 45.5 L of water/acre) and if warranted and leaching is not a concern, an additional 0.2 L of Banvel application 6 to 8 weeks after seeding. A spot weed control treatment with Lontrel is also recommended to combat Canada thistle in mid to late August (Wark 1990). Dangerfield (1993) recommends Refine extra, a herbicide for broadleaf plants, in place of Banvel and 2,4-D. Refine Extra is comparable in price and is more compatible because in breaks down much quicker than Banvel and 2,4-D. A surfactant or wetter should be used with Refine Extra. It should be noted that Lontrel, used for spot spraying of Canada thistle, has a higher residual than Banvel and 2,4-D (Dangerfield 1993).

It may be necessary for spot seeding and/or weed control in the second year (Dangerfield 1993). Use of Refine Extra will make the second year weed control more likely than if Banvel were used (Dangerfield 1993). The site should be inspected in early May. Spot replanting should occur in large patches of unvegetated area (Dangerfield 1993). Weed control can consist of either spot spraying or spot mowing by rotary mower with guards removed, which scatters the moved matter (otherwise swaths must be removed immediately) (Wark 1990). The site should be inspected again in year 3 using the same procedure for year 2 (Dangerfield 1993). Since forbs are very susceptible to herbicides, planting of forbs needs to wait for establishment of grasses, and the control of problem species (Dangerfield 1993).

The first management treatment after seeding should be a burn to expand the rhizomes of the plant. The site should be first burned 3-5 years after planting. Two weeks after the burn, forb seed can be planted using a sod seeding drill, or by hand planting by scuffing a hole with a boot and dropping the seed in (Dangerfield 1993). Due to the cost of seed, limited planting of forbs should take place and then be evaluated before large scale planting occurs (Dangerfield 1993). Subsequent management, can be a mixture of techniques (Wark, personal communication, 1993). The same strategy, however, should not be applied back to back or else the vegetation of the region adapts accordingly and treatment becomes ineffective (Wark, personal communication, 1993).

In semiarid areas where precipitation is usually less than adequate, site moisture conservation is an important consideration (Shaller and Sutton 1978). Contour terracing, contour furrowing, contour trenching, constructing small basins, pitting, surface manipulating, mulching, topsoiling and tillage are commonly used for retention and conservation of water (Romo and Lawrence 1990).

Costs for preparation and planting can vary according to donated equipment and volunteered labour. Ducks Unlimited estimates that their costs for revegetation range from $100 to $200 an acre. Pre-planting weed control costs include tillage operations and herbicides, estimated at $38/acre, and herbicide application estimated at $20/acre (based on 1990 cost estimates)(Wark 1990).

7.2.3 Sites with Native and Exotic Vegetation

Natural succession of stands with mixed native and exotic species to a point where native species regain dominance is not possible within our lifespan (Romo and Lawrence 1990). It may be possible, however, to convert plant communities that are a mix of exotics and native species to a native dominated plant community by applying the correct management treatments (Romo and Lawrence 1990). Appropriate selective control is required in order to treat unwanted species during susceptible periods, while minimizing damage to native foliage (Romo and Lawrence 1990).

It must be understood that conversion of non-native, or non-native/native stands that have suffered years of neglect, is a process which requires a great deal of patience. Ten to 20 years is needed for satisfactory manipulation of the although improvements can be observed in 6-8 years (Smith, personal communication, 1994).

Smooth Brome Infestation

Excellent control of Smooth Brome has been achieved using the combined application of prescribed burning and wick application of Roundup

(Romo, unpublished data). Burning is used to remove dead plant material, stimulate the growth of exotics, and depress growth of native species thereby increasing the height differential between the exotics and natives (Romo and Lawrence 1990). Smooth brome in native stands should be burned when it is at the 3-5 leaf stage, prior to the emergence of needlegrass (Smith, personal communication, 1994). A controlled burn every 2-3 years at this stage of growth will help eliminate smooth brome. Burning will also reduce the amount of Kentucky bluegrass in the stand.

Livestock grazing of smooth brome at the 3-4 leaf stage when vulnerable and into flowering will also help eradicate brome (Smith, personal communication, 1994). As stated in the previous section, rotation times should be no longer than 14 days, and the rest period should be at least 28 days (Smith, personal communication, 1994). Cattle will only forage on the top half of the cover, whereas horses or sheep eat down to the ground and will eliminate more native forbs than brome (Smith, personal communication, 1994). The best grazing regime would be sheep in combination with horses and cows, and adjusted rotation times for increased grazing pressure. Because cattle are brome selective, after 3-4 rotations, there should be a reduction in exotic grasses (Smith, personal communication, 1994). If sheep grazing is occurring to control leafy spurge, it should be realized that once they the sheep are removed from the site, unless natives are planted to take over the niche, leafy spurge will increase again (Smith, personal communication, 1994).

It should be noted that in fields where Kentucky bluegrass exists with smooth brome, as in the sites of Group D, grazing cannot be used, since it will result in an increase of the bluegrass (Smith, personal communication, 1994). In this situation, burns should be used as a control method. Kentucky bluegrass should be burned in the late spring, before any native grass green up. A fall burn will dry the soil sufficiently through the winter, and reduce Kentucky bluegrass emergence in the spring (Smith, personal communication, 1994).

Smooth brome is harder to get rid of than Canada thistle. A C3 herbicide cannot be used to kill invasives (Canada thistle, Kentucky bluegrass, quack grass or smooth brome) since it will also kill needlegrass, native wheatgrasses, and fescue (Wark, personal communication, 1994). If the site is has C4 natives, then a spot application of C3 herbicide can be used (Wark, personal communication, 1994).

In a smooth brome field which has minimal Canada thistle infestation, after the first burn, new ground opens up and there will be a large increase in Canada thistle. A spring burn should be timed so as to encourage growth of native C3 grasses, such as western wheatgrass. If burned at the 2 to 3 leaf stage, western wheatgrass will tiller, and growth of rhizomes will put increased pressure on Canada thistle growth. The field should then be mowed in order to remove the photosynthetic portion of the thistle. The plant is weakened in the following year since it is living solely off of its root reserves. If enough moisture is received (if precipitation is 10 cm below the average annual level, then a site should not be burned), then the field can be hit back to back for 2-3 years with a system of burning and mowing (Wark, personal communication, 1994). Mowing of Canada thistle twice a year (June and August) for 2 years in a row, should sufficiently reduce the number of plants, since this species cannot endure clipping twice in a year (Smith, personal communication, 1994).

Canada Thistle Infestation

On sites where there is a mix of both native vegetation and Canada thistle, burns to control Canada thistle should occur in late spring (usually May or June), when the stems have begun to emerge (Clark and Johnson 1993). Early spring burns should be avoided since they will increase sprouting and reproduction of this species (Hutchinson 1990; Wisconsin Department of Natural Resources 1992). For chronic infestations repeated burns are usually necessary in conjunction with other control measures (eg spot-spraying with herbicide, mowing, tillage and replanting) provided they are done properly (Clark and Johnson 1993). Foliar application of a 1-2 percent solution of Roundup in the spring when stems are 15-25 cm high may be effective in controlling light infestations, or in conjunction with prescribed burning in more problem areas (Hutchison 1990; Wisconsin Department of Natural Resources 1992). Since Roundup is a nonselective herbicide caution must be used to avoid contact with non-target plants (Clark and Johnson 1993). This can be accomplished by spot treating selected plants using a wick applicator (Clark and Johnson 1993). The herbicide should not be dripping off the plant and it should be applied while backing away from the plant to avoid walking through wet herbicide (Clark and Johnson 1993). If applied properly, Roundup will kill the entire plant including the roots and is therefore recommended to be used in conjunction with fire (Clark and Johnson 1993). Once under control, prescribed fire should be effective at preventing a recurrence (Clark and Johnson 1993).

CHAPTER 8: BROAD RECOMMENDATIONS

The City of Calgary is faced with increasing problems in the maintenance of native grassland species. Weed species and brush continue to encroach on these areas, and public pressure for the city to re-evaluate its past management methods is increasing. The purpose of this study was to examine differences in plant species composition in response to environmental gradients and disturbance. in order to suggest appropriate management techniques. This chapter presents broad recommendations that have been developed after consideration of the conclusions presented in the preceding chapters.

1. Encourage public acceptance of the importance of native prairie, and vegetation management techniques

Many people in the general public still view native grasslands as being "wasted land", or "just an empty field". An educational program should be developed which outlines the value of natural areas in general, but which also specifically focuses on the benefits of preserving the native prairie as a part of Alberta's natural history. The program may be developed on various levels to target different audiences: elementary schools, junior high schools, senior high schools and adult audiences (community groups), and staff of relevant city departments (eg. Parks & Recreation, Planning, Weed and Pest Control, Engineering and Environmental Services). The program may include; native vegetation of the Calgary area and conditions under which they evolved, existing vegetation types and ecological conditions under which they occur, the importance of maintaining or restoring natural checks and balances, effects of urbanization and other disturbances, landscape ecology and patch dynamics, and an overview of management techniques.

In regards to grasslands, there should be an emphasis on the role of fire and grazing in maintaining these ecosystems. The public should be made aware of the need to restore the natural disturbance regime under which Alberta's Fescue Prairie evolved. Left untended, native grasslands may become stagnant, susceptible to disease, and invasion by exotic species. Burning will create a great deal of public attention (especially on Nose Hill) due to the close proximity of surrounding residential areas. Notable efforts will have to be made to change residents' misconceptions concerning the safety and effectiveness of prescribed fire. When grazing or fire are being considered as management alternatives, public information sessions should be available for residents in the surrounding areas. Signage should be posted in managed areas which presents information explaining the technicalities of the specific management tool, as well as the overall benefits of grazing or prescribed fire.

2. Develop Native Grassland Conservation Partnerships

Calgarians take pride in the natural environment of their communities.

This has been demonstrated in the past by local volunteer efforts to restore natural areas such as Tom Campbell's Hill, McHugh Bluff, and the Heritage Escarpment. There has also been a significant amount of volunteer effort in patrolling parks, and in the planning of projects involving the natural environment.

Natural resource co-management agreements between Parks & Recreation and the citizens of Calgary should be encouraged in order to compensate for the financial limitations of keeping the necessary number of expert personnel on staff, as well to foster a sense of local stewardship for remaining native grasslands Calgary. Public consultation and encouragement of participation should be an intrinsic part of natural area project planning, implementation and monitoring. Partnerships may be established between the city and the Calgary Field Naturalists Society, interested community groups, or with various departments from the University of Calgary.

3. Complete detailed biophysical inventories for potential management areas.

There is a classification of natural areas in Calgary based upon broad ecotypes, but in general, information regarding specific vegetation associations in a particular area is limited. Recent detailed biophysical inventories have been conducted for the Bow River Valley System and for Nose Hill Park. Although it may be financially unfeasible to obtain such detailed information for all of Calgary's grasslands, it must be understood that manipulations to existing vegetation cannot be made without access to the relevant baseline biophysical data. This should include a detailed survey of soils and vegetation, the present state of vegetation, the desired state of vegetation, and where possible, past land use activity.

Calgary Parks & Recreation should use its existing inventories completed as part of the "environmentally sensitive area" survey, to identify which areas deserve closer attention for management. If a particular region requires some form of management, then a detailed survey of that area must be made before any management techniques are put into place.

In order to decrease the financial expenses involved in hiring consultants, specific information can be collected on an ecosite basis through resource management partnerships between Calgary Parks & Recreation and parties that have the knowledge required to conduct an inventory. Such groups may include members of the local naturalist's society and students working in co-operative programs, or summer students in disciplines such as geology, geography, ecology, or biology at the University of Calgary.

4. Development of specific management goals.

This study was conducted to explore various factors that influence species composition, and strategies that may be implemented to manipulate this composition. This is only a starting point, however, and grassland management cannot take place until the city has defined what its long-term objectives for natural area management are.

After a complete inventory of the biophysical resources of grassland sites of interest has been completed, very specific goals can then be formulated based upon the desired vegetation complex. This will require a series of logical decisions, and exhaustion of all possible alternatives, that are specific to each plant community, rather than employing blanket or generalized prescriptions. Haphazard management activities can create more harm than good and will be costly in time and money.

Grassland Management priorities that may be considered are;

1) Preserving and propagating existing native grasslands.

2) Controlling exotic species in stands where a mixture of natives and exotics exist.

3) Reseeding unvegetated sites.

4) Attempt to convert stands supporting exotic vegetation into native dominants. This is the most difficult option, and presently may not be feasible in soils that have been broken and have subsequently lost the surrounding rhizosphere (Bullion, 1994, personal communication).

Despite wishes of the public, it may not be feasible to bring disturbed areas entirely back to fescue grassland, and an attempt should be made first to suppress growth of obnoxious weeds such as thistle and dandelion. Unless dealing with very short grasses such as blue grama, both Mixed Grass Prairie and Fescue Prairie require some type of intervention in order to mimic the natural disturbances of bison grazing and wildfire. Without disturbance, a site tends toward a monoculture, or deteriorates from high amounts of accumulated old growth. If Nose Hill, for example, were left entirely to the process of natural succession, it is expected that smooth brome would eventually outcompete all remaining native communities. The effects of surrounding urbanization, such as the spread of exotic seed, or heavy anthropogenic use, on natural areas requires some form of human interference for long term maintenance of the site.

A fire management plan should be developed to provide detail describing a program of prescribed burns which links fire behaviour to fire effects; and to outline a program to monitor and evaluate the long term effects of different burning treatments on species diversity (Clark and Johnson 1993). Because many of the natural areas are close to residential areas, extra precaution must be taken to minimize the amount of smoke produced from the burn. Accurate records of all burns should be kept, and fires should be prescribed; not ad hoc.

Various treatments should be attempted though the use of small scale experimental plots prior to any large scale initiation, in order to examine specific localized effects of the treatment. These experimental plots should be located in regions where they are publicly visible, so that changes in vegetation composition can be witnessed directly, and used as an educational tool. The old adage "Seeing is believing" may in fact be the best way to gain public confidence in the City's efforts toward vegetation management.

5. Long-term monitoring encouraged

Vegetation management demands constant action and a long-term commitment. A monitoring schedule should be developed before a management plan is put into action. If monitoring is initiated after management activities have been implemented, then baseline information needed to compare the impacts of the manipulations may not be available.

Species inventories, and habitat mapping should be regularly updated using a Geographic Information System to determine if current techniques are working toward achieving the desired goal. If the desired result is not being realized, the manager must re-evaluate the alternatives and implement additional activities (Romo and Lawrence 1990). After a plan is implemented and impacts are evaluated, this information can then be used to make adjustments accordingly in both present and future management decisions.

6. Ecologically based training for personnel in the area of grassland management.

Currently, the effectiveness of Calgary Park's staff to manage natural areas is lacking. The Calgary Parks Department should create specialized staff for natural area management within its current staff allocation. These specialists need a thorough understanding of ecological principals and their relevance in vegetation management. This factor becomes of special importance in the area of prescribed burning. Burns should only be carried out with the proper staff in order to mitigate the chances of serious damage, and also to reduce the liability of negligence.

A training session should be provided for all City of Calgary staff concerned with natural area management techniques. Staff specialized in natural area management can help in the training of community groups involved in natural area reclamation or parks planning. Staff and community training may include site specific planting standards, basic ecological principles, and basics in resource inventory using the ecosite approach (Elphinstone 1993). Vegetation maintenance managers and landscape architects should be encouraged to consider species suitability to a particular site, and not just revegetate areas haphazardly with the sole intention of producing an aesthetically pleasing landscape.

7. Increased research focused on native grasslands conservation

Most of the available literature pertaining to native grasslands is focused toward range management or production agriculture. This research is targeted toward the maintenance of native prairie for the purpose of providing high forage yield. Except for displaying general trends, much of this information is of limited value in formulating management strategies for conserving native prairie for its ecological purposes, and to preserve biodiversity.

There are many areas of grassland management and reclamation that may provide high research possibilities for local graduate students. Local graduate students should be encouraged to undertake research projects in the areas of successful reclamation techniques, the possibility of regenerating stands of native prairie, and the effectiveness of management techniques such as grazing and fire in the Calgary area.

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APPENDIX A:
RESPONSE OF MAIN SASKATCHEWAN RANGE PLANTS TO CONTINUED HEAVY GRAZING
(Source: Saskatchewan Agriculture, 1991)

	BROWN	DARK BROWN	BLACK-GRAY
1) GRASSES			
Alkali cord grass	INCREASER	INCREASER	INCREASER
Bearded wheatgrass	DECREASER	DECREASER	DECREASER
Big bluestem	-	DECREASER	DECREASER
Blue grama	INCREASER	INCREASER	INCREASER
Canada reed grass	INCREASER	INCREASER	INCREASER
Canada wildrye	DECREASER	DECREASER	DECREASER
Fowl blue grass	DECREASER	DECREASER	DECREASER
Fowl manna grass	DECREASER	DECREASER	DECREASER
Fringed brome grass	DECREASER	DECREASER	DECREASER
Green needlegrass	DECREASER	DECREASER	DECREASER
Hair grass	INVADER	INVADER	INVADER
Hairy wildrye	-	-	INCREASER
Hooker's oatgrass	DECREASER	DECREASER	DECREASER
Indian rice grass	DECREASER	DECREASER	DECREASER
Intermediate oatgrass	-	INCREASER	INCREASER
June grass	INCREASER	INCREASER	INCREASER
Kentucky bluegrass	INVADER	INVADER	INVADER
Little bluestem	INCREASER	INCREASER	INCREASER
Mat muhly	INCREASER	INCREASER	INCREASER
Narrow reed grass	DECREASER	DECREASER	DECREASER
Needle-and-thread	DECREASER	INCREASER	INCREASER
Northern awnless brome	-	DECREASER	DECREASER
Northern reed grass	DECREASER	DECREASER	DECREASER
Northern wheatgrass	DECREASER	DECREASER	INCREASER
Nuttall Alkali grass	DECREASER	DECREASER	DECREASER
Plains muhly	INCREASER	INCREASER	INCREASER
Plains reed grass	INCREASER	INCREASER	INCREASER
Porcupine grass	-	DECREASER	DECREASER
Prairie dropseed	DECREASER	DECREASER	DECREASER
Purple oat grass	-	DECREASER	DECREASER
Rough fescue	DECREASER	DECREASER	DECREASER
Salt grass	INCREASER	INCREASER	INCREASER
Sand dropseed	DECREASER	DECREASER	DECREASER
Sand grass	INCREASER	INCREASER	INCREASER
Sandberg's bluegrass	INCREASER	INCREASER	INCREASER
Sheep fescue	INCREASER	INCREASER	INCREASER
Side-oats grama	-	DECREASER	DECREASER
Slender wheatgrass	DECREASER	DECREASER	INCREASER
Slough grass	INCREASER	INCREASER	INCREASER
Spangle top	DECREASER	DECREASER	DECREASER
Sweet grass	-	INCREASER	INCREASER
Switch grass	DECREASER	DECREASER	DECREASER
Tall manna grass	DECREASER	DECREASER	DECREASER
Western porcupine grass	DECREASER	DECREASER	INCREASER
Western wheatgrass*	DECR/INCR	DECR/INCR	INCREASER
White-grained rice grass	-	DECREASER	DECREASER
Wild barley	INVADER	INVADER	INVADER
2) GRASSLIKE PLANTS			
Awned sedge	DECREASER	DECREASER	DECREASER
Baltic rush	INCREASER	INCREASER	INCREASER
Beaked sedge	-	DECREASER	DECREASER
Graceful sedge	DECREASER	DECREASER	DECREASER
Low sedge	INCREASERI	NCREASER	INCREASER
Pen or sun-loving sedge	INCREASER	INCREASER	INCREASER
Thread-leaved sedge	INCREASER	INCREASER	INCREASER

Appendix C continued...

	BROWN	DARK BROWN	BLACK-GRAY
3) FORBS			
Beard tongue	INCREASER	INCREASER	INCREASER
Bedstraw	INCREASER	INCREASER	INCREASER
Blazing aster	DECREASER	DECREASER	DECREASER
Broomweed	INVADER	INVADER	INVADER
Cactus	INCREASER	INCREASER	-
Canada thistle	INVADER	INVADER	INVADER
Club moss	INCREASER	INCREASER	INCREASER
Common peppergrass	INVADER	INVADER	INVADER
Cream-colored vetchling	-	DECREASER	DECREASER
Crocus	INCREASER	INCREASER	INCREASER
Dandelion	INVADER	INVADER	INVADER
Death camas	INCREASER	INCREASER	INCREASER
Everlasting	INVADER	INVADER	INVADER
Gaillardia	INCREASER	INCREASER	INCREASER
Goatsbeard	INVADER	INVADER	INVADER
Golden aster	INCREASER	INCREASER	INCREASER
Golden bean	INCREASER	INCREASER	INCREASER
Graceful goldenrod	INCREASER	INCREASER	INCREASER
Gumweed	INVAD/INCR	INVADER	INVADER
Lamb's quarters	INVADER	INVADER	INVADER
Leafy spurge	INVADER	INVADER	INVADER
Locoweeds	INCREASER	INCREASER	INCREASER
Long-headed coneflower	INCREASER	INCREASER	INCREASER
Low goldenrod	INCREASER	INCREASER	INCREASER
Meadow rue	INCREASER	INCREASER	INCREASER
Milkvetches	INCREASER	INCREASER	INCREASER
Moss phlox	INCREASER	INCREASER	INCREASER
Prairie sage	INCREASER	INCREASER	INCREASER
Purple prairie clover	DECREASER	DECREASER	DECREASER
Scarlet mallow	INCREASER	INCREASER	INCREASER
Silky or silvery lupine	INCREASER	INCREASER	INCREASER
Skeleton weed	INCREASER	INCREASER	INCREASER
Smooth aster	INCREASER	INCREASER	INCREASER
Solomon's seal	INCREASER	INCREASER	INCREASER
Sweet-broom	INCREASER	INCREASER	INCREASER
Three-flowered avens	INCREASER	INCREASER	INCREASER
Vetches	DECREASER	DECREASER	DECREASER
White prairie aster	INCREASER	INCREASER	INCREASER
Wild licorice	INCREASER	*INCREASER	INCREASER
Wild peavine	-	DECREASER	DECREASER
Woolly yarrow	INCREASER	INCREASER	INCREASER
Yellow avens	INCREASER	INCREASER	INCREASER
4) SHRUBS AND TREES			
Aspen poplar	-	INVAD/INCREAS	INVAD/INCREAS
Chokecherry	DECREASER	DECREASER	DECREASER
Currant	-	-	INCREASER
Fringed sage	INCREASER	INCREASER	INCREASER
Greasewood	INCREASER	INCREASER	-
Green alder	-	-	INCREASER
Low bush-cranberry	-	DECREASER	DECREASER
Nuttall's saltbush	DECREASER	DECREASER	DECREASER
Pin cherry	-	DECREASER	DECREASER
Prairie rose	INCREASER	INCREASER	INCREASER
Prickly rose	INCREASER	INCREASER	INCREASER
Red-osier dogwood	-	DECREASER	DECREASER
Saskatoon	DECREASER	DECREASER	DECREASER
Shrubby cinquefoil	INCREASER	INCREASER	INCREASER
Silver sage	INCREASER	INCREASER	INCREASER
Western snowberry	INCREASER	INCREASER	INCREASER
Willow	INCREASER	INCREASER	INCREASER
Winterfat	DECREASER	DECREASER	DECREASER
Wolfwillow	INCREASER	INCREASER	INCREASER
Wood's rose	INCREASER	INCREASER	INCREASER

* Status varies with range sites

APPENDIX B

Herbicide application treatments include the following;

Broadcast Foliage Treatment: This is the most commonly used herbicide control method for herbaceous perennial and brush. It involves the application of a herbicide in a 110 to 220 L water per hectare (45 to 90 L per acre) solution using a ground sprayer, or in at least 35 L of water or oil per hectare (15 L per acre) using an aircraft sprayer (Saskatchewan Agriculture 1991).

Aerial applications: This type of application covers large acreages quickly and is suitable for rough stony terrain. Ground application equipment permits the use of higher water volumes for better coverage and is less prone to herbicide drift (Saskatchewan Agriculture 1991).

Individual Stem Foliage Treatment: involves the addition of a herbicide to about 1000 L of water, and applying the solution to brush foliage and stems until it runs off. The volume of spray mixture applied per hectare varies with brush height and density. Treatments are made using a sprayer fitted with a hose assembly and a hand held spray gun, or with a backpack sprayer and extended wands. The spray is directed at the target species and away from non-target susceptible species. Treatments should be limited to species less than 2.5 m in height, and only enough pressure should be used to penetrate the target species. Although labour intensive this provides excellent foliage coverage (Saskatchewan Agriculture 1991).

Individual Stem Treatment: is a selective application method useful for sparse tree strands, small areas and controlling undesirable plants near crops. Applications are possible any time of the year. They often require less herbicide per hectare but are labour intensive. There are several ways to apply herbicide to an individual stem;

1) Conventional basal bark involves spraying the lower 50 cm of a stem to the point of run-off at the ground line.

2) Thin line requires spraying a 15 cm wide strip around the stem 15 cm above the ground line.

3) Frill uses special injection equipment or an axe to make 5 cm intervals around the stem. The cut should penetrate the inner wood in a downward stroke to allow herbicide application into the frill.

4) Dormant stem involves spraying a herbicide in oil to the lower 50 cm of the stem to ground line when vegetation is dormant.

5) Cut stump requires felling the tree and completely spraying the stump surface. Dormant stem and cut stump treatments can be used throughout the year. Cut stump is environmentally safe, requires small amounts of herbicide per hectare, prevents burnout and eliminates drift to nearby susceptible crops (Saskatchewan Agriculture 1991).

Wiper Applicator Treatment: is effective when there is a visible difference in height between taller undesirable plants and shorter desirable plants. It should be possible to wipe sufficient herbicide on the undesirable plants to kill them without affecting herbaceous plants. This is usually the case with tree species such as aspen, but not with small shrubs like western snowberry. Herbicide is only applied to the target plants, which allows the use of a non-selective chemical, a bigger dose of a suitable selective chemical or a more expensive chemical. Less herbicide is required because it is not wasted on non-targeted plants, resulting in a smaller or no effect on the surrounding environment (Saskatchewan Agriculture 1991).

APPENDIX C: LIST OF ALL SPECIES IDENTIFIED

SCIENTIFIC NAME	ABBREVIATION	COMMON NAME
Achillea millefolium	ACMI	Common Yarrow
Agropyron smithii	AGSM	Western Wheat Grass
Agropyron subsecundum	AGSU	Awned wheatgrass
Agropyron trachycaulum	AGTR	Slender Wheat Grass
Amelanchier alnifolia	AMAL	Saskatoon
Anenome canadensis	ANCA	Canada Anenome
Anenome multifida	ANMU	Cut-leaved anenome
Anenome patens	ANPA	Prairie Crocus
Apocynum spp.	AP Spp.	Dogbane spp.
Artemisia frigida	ARFR	Pasture Sagewort
Artemisia ludoviciana	ARLU	Prairie Sagewort
Aster pansus	ASPA	Tufted White Prairie Aster
Aster species	AS SPP.	Aster spp.
Astragalus dasyglottis	ASDA	Purple Milk Vetch
Bergamont monarda	BEMO	Bergamont
Bouteloua gracilis	BOGR	Blue Grama
Bromus inermis	BRIN	Smooth Brome
Campanula rotundifolia	CARO	Harebell
Cirsium arvense	CIAR	Canada Thistle
Commandra pallida	COPA	Pale Commandra
Danthonia parrii	DAPA	Parry's Oat Grass
Elaegnus commutata	ELCO	Silverberry
Elymuss species	El spp.	Rye spp.
Erigeron species	ER SPP.	Fleabane spp.
Festuca scabrella	FESC	Rough Fescue
Fragaria glauca	FRGL	Wild Strawberry
Galium Boreale	GABO	Northern Bedstraw
Gallardia aristata	GAAR	Galardia
Geranium viscosissimum	GEVI	Sticky Purple Geranium
Geum triflorum	GETR	Three-flowered Avens
Hedysarum species	HE SPP.	Hedysarum
Hordeum jubatum	HOJA	Foxtail Barley
Koeleria cristata	KOCR	June Grass
Lupinus argeteus	LUAR	Silvery Lupine
Medicago sativa	MESA	Alfalfa
Muhlenbergia cuspidata	MUCU	Prairie Muhly
Petalostemon puppureum	PEPU	Purple Prairie Clover
Phleum pratense	PHPR	Timothy
Phlox species	PH SPP.	Moss
Plantago major	PLMA	Common Plantain
Poa pratensis	POPR	Kentucky Blue Grass
Potentilla species	PO SPP.	Cinguefoil spp.
Rosa acicularis	ROAC	Prickly Rose
Rosa Woodsii	ROWO	Common Wild Rose
Solidago species	SORI	Goldenrod spp.
Stipa comata	STCO	Needle and Thread Grass
Stipa viridula	STVI	Green Needle Grass
Symphoricarpos occidentalis	SYOC	Buckbrush
Symphoricarpos albus	SYAL	Snowberry
Thermopsis rhombifolia	THRH	Golden Bean
Tragopogon dubius	TRDU	Yellow Goat's -beard
Vicia americana	VIAM	Wild Vetch

APPENDIX D:
PAST LAND USE ON NOSE HILL

SITE	LAND USE BY YEAR 1960	1969	1971	1975	1976	1978	1982	1986	1991	1993
1	\	\	\	\	\		\	\	\	
2	\	\	\	\	\		\	\	\	
3	G	\	G	\	G	G	G	G	G	
4	G	\	G	\	G	G	G	G	G	
5	G	\	G	\	G	G	BURN	G	G	
6	G	\	G	\	G	G	BURN	G	G	
7	G	\	G	\	G	G	G	G	G	
8	G	\	G	\	G	G	G	G	G	
9	G	\	G	\	G	G	BURN	G	G	
10	G	\	G	\	G	G	BURN	G	G	
11	G	\	G	\	G	G	BURN	G	G	
12	G	\	G	\	G	G	BURN	G	G	
13	G	\	G	\	G	G	G	G	G	
14	G	\	G	\	G	G	G	G	G	
15	G	\	G	\	G	G	BURN	G	G	
16	VEHIC	VEHIC	G	\	HG	OVERG*	HG	G	G	
17	LG	\	LG	LG	LG	LG	LG	LG	LG	
18	LG	\	LG	LG	LG	LG	LG	LG	LG	
19	ACULT	ACULT	ACULT	CULT67-74	OCROP	OCROP	G	G	Controlled burn\sp ?	Controlled burn (April 21)
20	ACULT	ACULT	ACULT	CULT67-74	OCROP	OCROP	G	G	Contolled burn\sp ?	Controlled burn (April 21)
21	FCROP	\	FCROP	\	G	G	DIST ?	G	BURN BET. 91-93	Wildfire (April 14) ?
22	FCROP\G	FCROP\G	FCROP\G	\	HG	OVERG	HG	G	G	
23	FCROP\G	FCROP\G	FCROP\G	\	HG	OVERG	HG	G	G	
24	FCROP\G	FCROP\G	FCROP\G	\	HG	OVERG	HG	G	G	
25	VEHIC	VEHIC	HG	\	HG	OVERG	HG	G	G	
26	VEHIC	VEHIC	HG	\	HG	OVERG	HG	G	G	
27	VEHIC	VEHIC	HG	\	HG	OVERG	HG	G	G	
28	G	\	G	\	G	PRAIRIE	G	G	G	
29	ACULT	\	OCROP	OCROP	OCROP	ACULT	G	G	G	
30	G	\	G	\	G	PRAIRIE	G	G	G	
31	ACULT	\	OCROP	OCROP	OCROP	ACULT	G	G	G	
32	VEHIC	VEHIC	G	\	G	OVERG	BURN\HG	G	G	
33	VEHIC	VEHIC	G	\	G	OVERG	BURN\HG	G	G	
34	G	\	G	\	G	OVERG	BURN\HG	G	G	
35	VEHIC	VEHIC	G	\	G	OVERG	HG	G	G	

\ = SITE INFORMATION NOT AVAILABLE FOR THAT YEAR
G = GRAZE
ACULT = ACTIVE CULTIVATION
LG = LOW GRAZING OR UNTOUCHED
FCROP = FILLED IN CROP; NOW GRAZING
OCROP = OLDER CROP; NOT COMPLETELY FILLED
OGRAV\G = OLD GRAVEL PIT, NOW GRAZED
BURN\G = BURNED THEN GRAZED
BURN\SP = BURNED AND SPRAYED (spray for toadflax, probably 2-4D)
OVERG = LOCAL OVERGRAZING
VEHIC = VEHICULAR TRAFFIC
DIST ? = UN-IDENTIFIED DISTURBANCE

There have been no "land uses" on Nose Hill since 1989, except for contolled and natural fires. There are still visible marks of past useage, however (eg. cultivation and grazing).

In 1959, there were no real "uses" of the Hill except for the presence of the occasional berrypicker

From old newsletters it appears that the last year of cultivation was 1978.

Sites 19 and 20 were cultivated from 1967-1974

Sites 1 and 2 were taken on Brier Hill, and both were under heavy human trampling (especially the blue grama site)

Sites 3,4,5,and 6 may have been grazed by cattle, but in 78 it looks as though cattle grazing is localized to the most NW corner of the park.
In 1987, NoseHill became a park and in 1989 horse grazing ceased

*The horse stables were located in this area, and some regions were locally overgrazed. Approxiamately 60 horses used this area for pasture, and 9 were used for rental

APPENDIX E

Adapted from Clark and Johnson, 1993

FIRE BEHAVIOUR

Fuels (their amount, moisture, and distribution), weather (particularly temperature, humidity, and wind), and the ignition pattern form the operational elements of the burning prescription (McArthur 1966). These elements link the burning prescription with the fire objectives (McArthur 1966). Ignition pattern largely dictates how the available energy will be released and, therefore, the observable fire behaviour (McArthur 1966).

Fire behaviour consists primarily of fire intensity, rate of spread, and fuel consumption. Fire intensity is the most important descriptor since it is a measure of the heat flux produced by fire (Johnson 1992). Heat flux is what affects biological systems, and can be described using the equation $I=HwR$ (Byram 1959).
Where:
I=fire intensity (kW/m) of the flaming front;
H=low heat of combustion of the fuels (kJ/kg);
w=the weight of fuel consumed per unit area (kg/m2); and
R=the fire's rate of spread (m/s).

Environmental factors which affect rate of spread and fuel consumption are fuel type, weather, and topography (Daubenmire 1968).

1. Weather:

Weather determines the dryness of the fuel, moistness of soil (as this provides a heat sink and at the same time facilitates heat conduction), current temperature of the combustible material (determines the additional heat required for expelling and igniting gases), and wind velocity. Winds tend to have cooling effect on an open fire (Masson, 1949), but this may be more than offset by its bringing in fresh supplies of oxygen which speeds up the rate of combustion and so increases temperatures (Morton 1964). Warm dry summers, low humidity, frequent thunder storms and wind, supply the conditions necessary both to initiate and to sustain fires (Vogl 1974). Wind, temperature, and humidity are especially important to fire intensity and are incorporated into models that predict fire behaviour (Forestry Canada 1987). Presence of wind during a fire can significantly increase the fire's rate of spread, thus increasing fire intensity.

Owing to increases in oxygen supply, backfires, those spreading against the wind, move somewhat faster into a strong wind than into a light wind, but the effect of wind increasing the rate of spread is much greater in a head fire, i.e. one spreading with the wind (Bryam, 1958). Trollope (1984) found that fireline and rate of spread were greater in headfires because they consume fuel more rapidly and spread more rapidly than backfires. Other time-temperature parameters did not differ between fire type because time-temperature profiles reflect both the intensity (heat release rate) and heat transfer for the entire combustion period (Bidwell and Engle 1990).

2) Kind and disposition of fuel accumulated since last fire.

Fuel Type: In the prairies, fuels which consist mostly of grasses are known as fine fuels (Daubenmire 1968). Fine fuels are characterized by a high surface to volume ratio and low bulk density, which means less heat energy is required for them to reach ignition than would be needed for woody aerial stems (Forestry Canada 1992a) (Rothermel 1972, Brown 1970B, 1981, 1982). Also the former fuel type burns more rapidly and completely as the fire front passes (McArthur, 1966). Grass fires are characterized by a rather narrow zone of flames advancing across a finely divided and rather homogeneously dispersed fuel (Daubenmire 1968). The Canadian Fire Behaviour Prediction System (Forestry Canada 1992) classifies grassland fuels into the open (O-1) fuel type group since it has continues grass cover with only occasional tree or shrub clumps which do not significantly alter fire behaviour. The O-1 can by subdivided based on differences in fuel structure which influence fire behaviour, specifically rate of spread. O-1a applies to the matted grass condition normally found in the spring following snow melt or after cutting; and O-1b describes standing dead grass of late summer and early fall.

Fuel Consumption: The fine fuels are assumed to have a standard load of 0.3 kg/m2 unless otherwise measured. McArthur (1963) states that with each doubling of fuel quantity per unit area the rate of fire spread, flame height, and fire intensity are doubled. In event of a fire, complete combustion of these fuels by the advancing flame front is assumed. However, if these fine fuels are allowed to accumulate beyond the standard fuel load, they form a second layer of fuels, equivalent to the duff layer in the Canadian Fire Weather Index system (Forestry Canada 1987) with different fuel moisture properties. The duff layer has a larger capacity to hold moisture and requires more time to dry following precipitation than the surface fine fuels. While the surface fine fuels usually dry to a moisture content able to sustain a flame within hours of precipitation, the underlying duff fuels may require several days. Fuel consumption can no longer be assumed a constant, but rather is dependent on the availability of dry fuels within this duff layer as the flame front passes. Therefore fuel consumption becomes a function of the fuel moisture content.

Fuel Moisture Content: The moisture content of fuels is important in determining fuel consumption and helps to determine the fire's rate of spread. The drier the soil, the higher is its surface temperature when grass burns, but at same time the low moisture content reduces the downward conduction of heat (Daubenmire 1968). Heyward (1938) states that as moisture content increases, heat conduction through a soil increases up to a point, then remains constant. Texture itself is of little importance (Heyward 1938). Higher ambient temperatures and low relative humidity mean less heat is required for ignition since the fuels contain less moisture. Excess moisture must be removed from the fuels requiring energy and time. The greater the amount of heat available to dry the fuels, the less time is required to ignite the fuels and the faster the fire's rate of spread. The drier the fuel layer when the flame front passes, the more fuel that is available for consumption. However, if the fuels contain too much moisture (generally greater than fifty percent) too much energy is lost evaporating off the water for the fire to sustain itself. Grass fuels commonly dry sufficiently to carry fire within a few hours after a shower, although the intensity of burning under such circumstances is minimal. Fires start more rapidly at the time of maximum intensity of solar radiation (approximately 11.00 h) rather than at the time of minimum moisture content of the grass (Daubenmire 1968).

Towards the end of their growing season grass stems gradually lose their moisture, a process known as curing. The degree of curing of the grass stems has an important influence on fire behaviour. If the degree of curing is less than fifty percent a fire is unlikely to spread (Wright and Beall 1938 as cited by Forestry Canada 1992a). It is thought that the rate of spread for a grassland fire increases proportionally to the percentage (above fifty percent) of cured or dead material (Van Wagner 1975). for every ten percent decrease in the degree of curing of the fuels, there is a twenty percent decrease in the predicted rate of spread.

3) Topography:

Topography affects the character of grass fires since fires move faster upslope than on level ground, advancing still more slowly when moving downslope. Fire spreads up a 10 degree slope twice as fast as on the level, and progresses four times as fast up a 20 degree slope. Where the slope is very steep, the rate of spread may exceed 65 km/h (McArthur, 1963). The direction that a slope faces is important through its control over microclimate factors which determine the initial temperature of combustible material and moisture conditions (McArthur 1963).

FIRE BEHAVIOUR MODEL

Prescriptions can be based upon two subsystems of the Canadian Forest Fire Danger Rating System (Forestry Canada 1992b), the Canadian Forest Fire Weather Index (FWI) system (Forestry Canada 1987) and the Canadian Forest Fire Behaviour Prediction (FBP) system (Forestry Canada 1992a). The FWI system calculates a series of indexes based on weather, which are later used in the FBP system to predict fire behaviour in different fuel types. The FWI system is dependent on weather, and provides a series of three codes of fuel moisture (Fine Fuel Moisture Code, the Duff Moisture Code and the Drought Code) and three indexes which describe fire behaviour (the Initial Spread Index, the Build up Index, and the Fire Weather Index). For a grassland fire the Fine Fuel Moisture Code (FFMC) rates the moisture content of the fine fuels from the surface depth of about 1.5 cm (ie surface litter) with a standard load of 0.25 kg/m2. The FFMC is an indicator of the flammability of the fire fuels and the ease with which they will ignite (Forestry Canada 1984). The FBP system describes the moisture conditions of all the fuels in the grassland fuel types (O-1a and O-1b).

Monitoring for the above parameters should begin in the spring once the snow cover has disappeared. Standard practice is to use the daily noon (standard time) weather reading for temperature, relative humidity, wind speed and precipitation (24 hour). With easier access to weather information it is now possible to update the FFMC on an hourly basis providing a more accurate estimate of a fire's potential behaviour (Van Wagner 1977). The FFMC is combined with wind speed to calculate Initial Spread Index (ISI), which is a numerical indicator of the initial rate of spread under various fuel moisture and wind conditions (Forestry Canada 1984). The ISI approximately doubles with every 14 km/h increase in wind speed so sudden changes in wind speed (i.e. gusts) or direction can seriously alter fire behaviour. ISI is used to estimate a fire's potential rate of spread when calc the FWI.

A special case appears in grasslands when sufficient fuels have accumulated (eg. due to fire suppression) so that the amount of fuel exceeds the standard fuel load assumed for grassland fuel types (0.3 kg/m2). The moisture content of these additional fuels must be considered separately form the FFMC because of the different water holding capacity and slower rates of moisture loss associated with deeper and more compacted fuels.

The Duff Moisture Code (DMC) is an indicator of the average moisture content of the loosely compacted organic (duff) layers to a depth of about 7.0 cm. Like FFMC, the DMC is monitored daily beginning in the spring and code values similarly increase with decreasing moisture content. DMC is used to calculate the Build-up Index (BUI). The BUI represents the total fuel available to the spreading fire and is therefore a component used in calculating fuel consumption for the FWI. The FWI is essentially an index of fire intensity bases on Byram's (1959) equation. It uses the constant low heat of combustion (18 000 kJ/kg), the ISI value to estimate the rate of spread and the BUI value to estimate fuel consumption. The index values are combined in a series of equations to give an estimate of the fire behaviour potential for that day. Daily monitoring of the weather and fuel moisture codes is necessary for the model to work. Predicting fire behaviour cannot be done on the basis of a single day's weather data; nor can fire behaviour be predicted more than a day in advance.

TREATMENT PRESCRIPTIONS

The purpose of each prescription is to describe the conditions under which a burn can be conducted safely and with the desired behaviour. The same fire behaviour must be applied to all treatments. Therefore, the prescriptions are based on the calculated indexed used in the Canadian forest fire Danger Rating System (Forestry Canada 1992b).

The desired behaviour for all the treatments is a consistent range of about 800 to 1200 kW/m (Forestry Canada 1987). Given that a fire's rate of spread must remain within safe limits of control, the ISI value should not exceed 10.0 and winds should be steady averaging less than 12 km/h. at the time of the burn. The DMC value should be greater than 60 (about 100% duff moisture content) to ensure complete fuel combustion. Obviously fire intensity will vary with the amount of fuel consumed. This will be especially true in the first season of treatments due to the greater fuel loads. The amount of fuel consumed during the initial burns will have to be measured using fuel plots. Future prescribed burns should be able to assume a standard fuel load (eg 0.3 kg/m2), but this value should be verified and the prescription adjusted to compensate for changes in fuel consumption.

The presence of nearby residential neighbourhoods means we must be concerned with atmospheric conditions and not burn when smoke will remain close to the ground (i.e. temperature inversions) affecting the air quality.

Based on the above, Clark and Johnson recommend the following prescription for fescue grassland in the Calgary region;

Treatment 1: Early Spring Burn should be conducted as soon as the ISI and DMC values are met after the snow pack has disappeared. It is important that none of the spring growth has started yet.

Treatment 2: Late Spring Burn should be conducted only after the herbaceous vegetation has begun to green, but while the proportion of cured grass to new shouts remains greater than 90%. ISI and DMC values are the same as above.

Treatment 3: Fall Burn should be done since the structure of the fuels change (O-1b fuel type) characterized by more standing fuels. Air is better able to mix with the fuels resulting in higher rates of spread then in the O-1a fuel type given the same ISI value. A higher rate of spread means greater fire intensity. Since there is an increased danger of losing control in this type of fuel, burns should be conducted at slightly lower ISI values than in the spring, but the DMC should remain the same as above. The degree of curing in the grass fuels should be greater than 90 percent.

Treatment 4: Early Spring Burn and Fall Reburn conducted at same time as the other treatments (1 and 3). Thus the prescriptions for this treatment combination are the same as what was described above. In the fall reburn, however, there may be differences in fuel consumption because the spring burn should reduce the accumulated fuel load. Less fuel consumption will result in a lower fire intensity during the fall reburn as compared to treatment 3 which is the fall only burn.

Note: For all treatments, maintaining the proper prescription is essential in order to link fire behaviour to fire effects.
Therefore, if the DMC and ISI values are not reached for a particular treatment then burning should not be conducted for that treatment period that year.

In the case of reserves where the area of the burn treatments is small the impact on wildlife populations will be minimal. The impact will be further mitigated because of the presence of refugia created by the adjacent unburnt treatment plots. This means that species will not be without suitable habitat in which to escape the direct and indirect effects of the fire. These adjacent unburned areas will also serve as sources for recolonizing burnt areas once the vegetation has begun to return.

RATIONALE FOR PRESCRIPTION

First Year

The early spring burn treatment is aimed primarily at woody species and removing accumulated litter; herbaceous species should be unaffected since their meristems are still protected beneath the soil. Those plants not killed outright will be forced to expend stored energy reserves to resprout. Repeated early spring burns should eventually deter woody vegetation while having either no, or a positive effect on the herbaceous vegetation. Late spring burn are to examine the effects of burn once the herbaceous vegetation has begun to emerge. Grass species should be mostly unaffected by these burns since their meristems lay below the soil surface where they are protected from the heat of the fire. Thus grasses should recover quickly. However, broad-leaved plants (forbs), with above ground growing tips, will likely respond negatively to this treatment (i.e. Canada Thistle) and suffer increased mortality. Repeated late spring burns should eventually control "weedy" forb species such as Canada thistle and permit their eradication. The Fall prescription is to determine the effects of fire in the later part of the growing season when many of the spring grasses, like rough fescue, will have completed their seasons' growth. A fall burn will affect woody species and later emerging herbaceous species and serve to remove the year's accumulated plant litter. The purpose of spring and fall reburn treatment is to determine how well the vegetation is affected under a more intense disturbance regime. It is aimed towards those woody species which may resprout or sucker following a spring burn. The fall reburn should kill new shoots thus further depleting plant energy reserves. This treatment combination may not be possible in consecutive years because of insufficient fuel loads.

Second Year

Following the first year of treatments, the results should be analyzed so the treatment program can be assessed. Beginning second year, treatment plots are to be split into a second level of treatment. The purpose of this second treatment program is to determine what effect the FIRE RETURN INTERVAL has on vegetation (Ojima et al. 1990). Treated plots should be subdivided into three plots each with the same number of vegetation monitoring plots (about ten) according to different fire return interval treatments of every year, every two years, and every five years. All treatments are then to be compared to the unburnt control plot to determine treatment effects. The outcomes are not predictable, and the purpose of the program is to monitor the effects (positive and negative) of burning at different seasons and with various return intervals.

MONITORING

Vegetation must be monitored before and after the prescribed burn treatments to determine the effect of the burning prescription. This requires that permanent monitoring plots be established that can easily be relocated following a fire. Vegetation should be sampled twice in a growing season; in the late spring and again in the late summer to ensure a thorough sampling of the vegetation. Monitoring should be conducted every year around the same time and continue even if prescribed burns are discontinued, in order to determine long term effects. Additional notes should also be made in the field for individual species, i.e. How do individuals establish following fire (e.g. seed, tillers)?

Calibrating the Fire Behaviour Model;

While the model generally predicts fire behaviour under the prescribed conditions it relies on certain assumptions. To test the accuracy of the model at prescribing fire behaviour, measurements of actual fire behaviour must be taken. Fuel consumption is the first factor that must be determined to calculate fire intensity. Therefore, prior to burning, a number of fuel plots will be established within the treatment plots and the amount of fuel measured. Following fire plots should be remeasured to determine the amount of fuel consumed (kg/m2 dry weight). Plots should be established in a variety of different fuel types. The second factor that should be calculated the prescribed fire's actual intensity is the rate of spread (m/s) of the flame front. Several techniques can be used to monitored of spread such as a stop watch and video camera. Simply measure the distance the flame front travels in a give period of time. Flame height is also a good indicator of fire intensity (Johnson 1992) and is the third factor that should be measured. Often flame heights are recorded on a video camera with an appropriate scale so flame height can be determined.

APPENDIX F

FACTORS FOR CONSIDERATION WHEN SELECTING SPECIES FOR RESEEDING;

"1) The end land use of the site to be reclaimed must be clearly understood in order to establish the goals and objectives of the revegetation program. This will entail an assessment of the size of the area to be reclaimed, and understanding of local site conditions, a description of adjacent land uses and a cost estimate to complete the reclamation program.

2) The cost of reclamation using native species is usually higher compared to using conventional agronomic species. This is primarily due to the shortage of seed supply combined with the difficulties of seed collection and cleaning.

3) Species, whether native or agronomic, should be adapted to the local climate and physical environments (Ries et al. 1987b). Most authors that recommend species compositions for reclamation specify different arrays for xeric, mesic and wet conditions (Bowen 1990). Grass species in particular exhibit a wide degree of ecological tolerance to flooding, drought, salinity, acidity, alkalinity, heat and cold.

4) If native species are to be used, an initial list of candidate native species should be compiled from a site inventory or a review of species lists from similar sites and discussion with native seed suppliers and/or local prairie restoration companies, where these exist. Species should be representative of the original community. In some cases, recommended species compositions for certain geographic regions are available (Hardy BBT 1989; Harper-Lore 1990) 5) The availability of native species may be limited. While sources are increasing each year, agronomic species are still widely available.

5) A mixture of forbs, grasses and possibly shrubs rather than a few, highly competitive species will provide food and cover for a diversity of animal species. A diverse plant community generally also has more aesthetic appeal.

6) The use of species which are long-lived, competitive and/or invasive such as crested wheat-grass, smooth brome grass, timothy, and red fescue should be avoided if native plant succession is desired (Walker 1989).

7) Competitive relationships, mutualism, and predator-prey relations in the community should be taken into account when compiling seed mixes (Call and Roundy 1991).

8) Overstory shrub plantings may increase the establishment of understorey species. For example, shrubs can catch windblown soil, seeds and mycorhizal spores, and provide resting sited for animals to bring in seeds. Decreased irradiation and re-radiation resulting from shrub planting may affect understorey temperatures which may, in turn decrease evapotranspiration and increase nutrient cycling. Shrubs may also decrease insect herbivory of associated plants by providing habitat for insect predators (West 1989). The presence of shrubs or trees has been shown to increase productivity compared to associations shrub-free grass stands (Frost and McDougald 1989)."

APPENDIX G

REVEGETATION TECHNIQUES

Seeding

The following recommendations were developed for seeding agronomic species, but they are however thought to be generally applicable to seeding native grasslands;

"1) Appropriate species selection.

2) Adequate seedbed preparation.

3) Proper timing of seeding operations.

4) Use of suitable equipment and seeding rates based on our current level of knowledge.

5) Proper depth of seeding and covering the seed to avoid losses due to desiccation, predation etc.

6) Suitable maintenance-although experimental trial data are limited, in some cases irrigation, use of mulches, fertilizer application, mowing or burning may enhance stand establishment.

7) It may be necessary to destroy competing vegetation prior to seeding.

Seeding rates vary with location, technique and species seeded (Romo and lawrence 1990). Sparser seedings can result in more robust plants in some instances and can allow for some invasion of adjacent native species. Seeding rates should consider how much natural diversification of the vegetative community is desired. If none is desired, a heavy seeding may be preferred, with strong fertilization programs to promote the rapid establishment of a relatively closed grass community. If some natural diversification is desired, the seed density and fertilizer programs should be less intensive, allowing some species for natural revegetation to intermix with planned revegetation species (Wathern and Gilbert 1979).

Drill Seeding and Interseeding

Drill seeding and interseeding is the preferred method of revegetation on native rangelands primarily because of the degree of control which is affected in seeding rates and seed placement beneath the soil surface (Ries et al 1987b; Vallentine 1989a; Walker, personal communication. 1992). In recent years seed drills have been developed specifically for native species (Kerr et al. 1993). The preferred characteristics of drills used for native seeding include the following (Kerr et al. 1993);

"1) ability to withstand adverse terrain, rocks and brush with minimum maintenance;

2) separate boxes for large, small and fluffy seeds;

3) agitator in seedbox to prevent seed and trash bridging over the seeder openings;

4) precise metering of seed (force feed usually better than gravity feed except for fluffy seed);

5) baffles to maintain distribution of seed in seedboxes on steep slopes;

6) side openers equipped with band-type regulators;

7) flexible equipment to allow individual planters to adjust to irregular seed;

8) mechanism for rapid and accurate setting of seeding rates; and,

9) wide packer wheels to decrease sinking, especially on sandy soils.

When seeding small seeded grasses, it is beneficial to mix in autoclaved (sterilized by high heat) wheat seeds for bulk to prevent bridging (Smreciu, pers. comm. 1992 in Kerr et al. 1993). Sand or other coarse material will ensure even distribution, and help carry light, fluffy grass seeds through the drill (Trottier 1992). This carrier material should be added a approximately half the bulk grass seeding weight (Ducks Unlimited, no date). Similarly, partially dried vermiculite has been mixed with forb seeds to facilitate their movement through the seed drill (Schramm 1972).

The rates at which seeds are sown for restoration seems to have evolved largely on a trial and error basis (Collicut and Morgan 1990). Rate of seeding is dependent on seed type, size and germination percentage. For planting, the quantity of viable seed is generally expressed as kilograms/hectare (or pounds/acre). This value represents the actual number of seeds per unit area of the soil surface and thus, when planting a small-seeded species, fewer kilograms are required for large-seeded species (Cook et al. 1974; Duebbert et al 1981). In order to account for seed quality the grass seeding rates should be expressed as pure live seed (PLS) in kilograms/hectare (Kerr et al. 1993). The percentage of pure live seed delivered to the soil medium is expressed by the formula;

> Pure Live Seed = % germination X % purity
> EG. a 23 kg bag of seed marked 90% germination and 90% purity contains:
> 90% X 90% = 81% pls, and
> 81% pls X 23 kg = approximately 18.6 kg pls (Heady 1975).

Drills should be calibrated to deliver the desired amount of pure live seed per square meter and place it at the proper depth. They should also be calibrated for every mixture type to ensure proper seeding rates (Kerr et al. 1993). Calibration can be performed by jacking up the drill and turning the drive wheel for a set number of revolutions, catching the seed flowing out, and weighing it (Vallentine 1971).

It is generally recommended that native grasses are seeded from 1.0 to 2.5 cm deep for maximum seedling establishment (Vallentine 1989b). The kind and size of seed, soil texture, and moisture conditions are the principal factors that influence seeding depth. Grass seed should be planted a depth of 1.25 to 2.5 cm in coarse textured sandy soils (Duebbert et al. 1981). Small seeded grasses, such as blue grama grass should be seeded at shallower depths (1.0 cm or less) than larger seeded species such as wheat grasses and green needle grass which can tolerate depths of 1.0 to 2.5 cm (Ries et al. 1987b). Seeding too deep delays emergence and reduces total emergence of new plants, while seeding too shallow results in loss of seed due to desiccation, removal by wildlife and erosion (Cook et al. 1974). As moisture decreases, seeding depth should increase, however seed should never be placed deeper than five times its diameter (Alberta Agriculture 1990b).

Packing or rolling the soil after seeding is necessary to ensure the soil is in firm contact with the seed, permitting water uptake by capillary action (Alberta Agriculture 1990b). Drill seeding, followed by cultipacking, is a preferred method of seeding because it provides proper placement and covering of the seed in a single operation (Ries et al. 1987; Vallentine 1989a).

Romo and Lawrence (1990) suggest that drill spacing can vary from 15 to 30 cm using the wider spacing where moisture is limited. Proper row spacing is important to eliminate inter- and intra- specific competition for water and nutrients Correct row width allows faster stand establishment and the highest production under dryland conditions (Holzworth and Lacey 1991). When seeding a field, seeding should overlap two drill widths past the boundary. This precludes chances of a drill miss (Wark, personal communication 1993). Missed drill holes generally end up being filled with weeds (Wark, personal communication, 1993). Twenty-five to thirty seed species should be planted for biodiversity (Wark, personal communication 1993).

Advantages of drill seeding include (Sims et al. 1984);

"1) improved soil moisture availability;

2) more uniform stands;

3) more wind protection for seeds compared to broadcasting;

4) rapid production;

5) less seed required per unit areas than broadcast seeding;

6) controlled seeding rate;

7) controlled depth of sowing;

8) the ability to spread fertilizer and other amendments at the same time (Sims et al. 1984)."

Disadvantages of drill seeding are;

"1) Machinery is mainly restricted to uniform near-level sites.

2) Cost and time are often increased over such methods as broadcasting,
although broadcasting may require up to twice as much seed.

3) In native grassland restoration projects, a plant community in visible rows in undesirable. Schramm (1972) has suggested making more than one pass over a field, in different directions, to alleviate this problem (Sims et al 1984)."

Interseeding is a method used to introduce desirable plant species to a grassland by preparing only strips of the area for seeding (Vallentine 1989a). It relies on the eventual spread of the newly seeded species and is generally slow because of competition between the seedlings and the existing vegetation. It may be preferred over seedbed preparation and seeding, however, where soil erosion is a problem, preparing a seedbed is impractical, or the aim is to modify not replace the existing vegetation (Vallentine 1989a). It also has advantage of being cheaper than trying to reseed an entire area (Vallentine 1989a). Drills can be borrowed or leased from Agriculture Canada PFRA offices, forage associations and some conservation districts (Trottier 1992).

Imprinting

Imprinting is a relatively new technique for tilling and planting which has been developed for arid and semi-arid regions of the world (Kerr et al. 1993). It involves the use of a machine which imitates the action of animal's hooves on soil (Kerr et al. 1993). Most imprinting machines are constructed to resemble "large rolling pins with a waffled surface (Dixon 1988)" and are pulled by a tractor (Kerr et al. 1993). Seeds are scattered, often from a broadcast seeder mounted just ahead of the roller, and are pressed into the imprinted surface. The Depressions formed increase the percolation of water into the soil, decrease runoff and funnel water to sites where seed and mulch are likely to accumulate (Dixon 1988). According to Anderson (1981) rainfall is concentrated and in effect, doubled and a minium of rainfall is utilized to a maximum extent. Imprinting differs from conventional tillage in that the soil is not turned over and therefore disruption of the surface litter is minimized (Kerr et al. 1993). Imprinting results in a firm seedbed, and reduces soil erosion by keeping rainwater where it falls (Anderson 1981). The imprinting machine is of simple construction, it is relatively inexpensive, durable and maintenance free (Kerr et al. 1993). (Dixon 1988) suggests that imprinting would be effective in revegetating dry prairies and dunes as well as non-prairie sites where adequate water supply is a problem.

Broadcast Seeding

Broadcast seeding is any method of seeding that scatters the seed directly on the soil surface (Kerr et al. 1993). It is designed to simulate natural dissemination by wind and may be done by hand, rotary or box-type seeders, or by airplanes or helicopters. The seed should be broadcast onto a roughened seedbed and then covered by soil using rakes, harrows, discs, or by pulling a small sheepsfoot roller over the seeded area (Kerr et al. 1993). Running a small tracked vehicle over the area may also cover the seed and compact loose or freshly tilled soil. The pressure should not be applied when soils are fine-textured and prone to compaction (Cook et al. 1974). When forbs are added to a revegetation program, about three to five seeds per 0.5 square meter should be allowed (Cook et al. 1974). Much of this seed is small and should be spread thinly to achieve best results. Seeding should be followed with a light raking for best results (Prairie Restorations Inc. 1992).

The advantages of broadcast seeding are that it is;

"1) easier to use on rough terrain, and steep slopes;

2) relatively inexpensive;

3) fertilizer can be spread simultaneously; and

4) it is often an effective way of establishing a diverse community (Depuit and Coenenberg 1979)."

The disadvantages include;

"1) larger amounts of seed are required than for drill seeding (usually about twice the amount). Poor sites such as those which have low quality soil conditions or rough terrain, require an even higher amount of seed;

2) uneven dispersal (this could be alleviated by applying at low wind speeds);

3) unless the seed is covered, it is exposed to erosion, predation and desiccation which can result in lower establishment rates (Sims et al. 1984)."

In general, broadcast seeding is not recommended due to limited seedling establishment due to desiccation, predation of seed, and wind and water erosion (Romo and Lawrence 1990). However, this method may be the only way to seed steep and rough slopes that are inaccessible to conventional farming equipment (Romo and Lawrence 1990).

Hydoseeding

Hydroseeding involves the application of a slurry of seed and water to soil (Kerr et al. 1993). It is primarily used as an erosion control technique on steep slopes or thin soils. Hydroseeding does not appear to have been widely used in native grassland reclamation and is not recommended by some prairie restorationists primarily because of the problem of poor seed/soil contact (Bowen, pers. comm. 1992 in Kerr et al. 1993).

Spreading Harvested Seed/Straw

Hay is harvested when the majority of the seeds of the desired species are ripe and the resultant mulch is spread over a smooth and weed-free seedbed or over stubble (Kerr et al. 1993). Mulching is reported to increase the success of establishing native species through enhanced germination (Fraser and Wolfe 1982). An ideal mulch should hold the seed

in place, should not inhibit the emergence of the seeding, should prevent erosion, should promote infiltration, insulate the seed from extreme temperature variation, and retain soil moisture (adapted from Fraser and Wolfe 1982).
Mulching is useful for preventing erosion, conserving soil moisture and providing a suitable seed bed for germination on difficult reclamation sites. Were annual precipitation is higher, mulches are generally not required (Fraser and Wolfe 1982).

Mulch is anchored by packing with a subsurface packer, covered with a disk-drill set to a shallow depth, or tacked sown in some manner (Romo and Lawrence 1990). Hay or straw material application rates range rom 1500 kg/ha to 2000 kg/ha and may be effective in soil stabilization for a period of 12 to 18 months after application (Lees pers. comm. 1992). The mulch should be spread as uniformly as possible, prior to the season of greatest precipitation. Factors that should be taken into account are (Romo and Lawrence 1990);

> "1) Native species seed production is variable from year to year and site to site and therefore optimal harvest time is also variable;
>
> 2) Generally one or a few species will be dominant in the mix;
>
> 3) Exotic species may be present in the mulch, and cultivars of native species seeded in the plot to be revegetated, will likely be more competitive than native species persistent in the mulch; and
>
> 4) Tackifers or crimping will likely be necessary to hold the mulch in place where there is a potential for wind erosion (Romo and Lawrence 1990)."

To obtain hay with the highest number of desired species , one should harvest in a year when conditions are favourable for seed production of that species (Kerr et al. 1993). It is therefore important to know how long hay can be stored without a loss of viability. Advantages of using spread harvested material as a seed source are;

"1) Species diversity may be increased over conventional seeding;

2) Seeds are supplied that are not commercially available;

3) Mulch can provide a supplemental seed source of locally adapted native seed;

4) If properly anchored, the hay mulch decreases erosion;

5) Mulch creates favourable microsites for seedling establishment by conserving soil moisture, increasing water infiltration, and decreasing soil crusting;

6) No specially designed equipment is necessary;

7) Adapted to a wide range of site conditions and purposes such as landscaping, rangelands rejuvenation, and reclamation of parks, natural areas and surface-mined lands;

8) Relatively inexpensive;

9) Process can accelerate natural succession;

10) Using hay mulch as a revegetation method has a high success rate (Ries et al. 1980; Romo and Lawrence 1990; Wenger 1941)."

Disadvantages are that the process is labour intensive, and depending on climatic conditions, time of harvest and species composition of the stand harvested, one species (not necessarily a desired species) may predominate in the mulch (Kerr et al. 1993).

Sprigging

In some environments, if seed production is sparse and erratic, using vegetation plugs to revegetate is a feasible option. These plugs may also be valuable in supplying soil with micro-organisms as well as accelerating invasion of native species (Bell and Meidinger 1977). It is not used much in reclamation of native grasslands, because of the high cost and the fact that may prairie species are not highly rhizomatous (Vallentine 1989b) Seeding seems to be a more effective, less costly method of establishing native prairie vegetation (DePuit, pers. comm. 1992)

Sodding

Sodding involves the removal and subsequent replacement of existing sod from an area to be disturbed (Kerr et al. 1993). In some cases, sod may be taken from a similar plant community within the vicinity and placed on the areas to be revegetated (Kerr et al. 1993). Although it does not appear to be a widely practised as a reclamation technique in native grasslands in Alberta it may be considered in black soil zones with native plant cover (Kerr et al. 1993). Possible benefits of sodding as a restoration technique are that the species composition of the site can be maintained, no seed must be purchased, and besides the actively growing plants, the sod also supplies soil micro-organisms, mycorrhiza and a latent seed source (Kerr et al. 1993).

Cutting sod decreases effective water storage which the previously extensive root system had tapped (Kerr et al.). Bunin et al (1982) suggest irrigating the sod before cutting and after laying (Kerr et al. 1993. Late winter (but not frozen soil) or early spring sod transplanting is recommended so that the spring precipitation will help establish roots and bind the sod to the subsoil (Kerr et al. 1993). Native grassland sodding is workable where there is sufficient soil-binding by vegetation (especially rhizomatous grasses) and is particularly suited to cooler locations because there is larger root biomass under these conditions (Sims et al. 1984). The vegetation characteristics required for successful native grassland sodding are sufficiently high plant cover, and enough with shallow roots or horizontal stems in the surface soil (Sims et al 1984). Sod-forming plants such as bluestems, blue grama grass, western wheat grass and sedges have numerous rhizomes or stolons and are capable of good vegetative spread (Kerr et al. 1993). Good surface soil binders include bluebunch wheat grass, blue grama grass, fringed sage, threadleaf sedge, and western wheat grass. Poor surface binders include; blue-bunch wheat grass, green needlegrass, needle-and-thread, june grass, Sandberg bluegrass and sagebrush (Kerr et al. 1993). It should be noted that there is a very high rate of seedling mortality associated with sodding (Johnson, 1994, personal communication)