

ESTABLISHING NATIVE PLANT COMMUNITIES



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Ann Smreciu, Heather Sinton, David Walker and Jeanie Bietz

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Foreword

There was a time when we thought our landscapes would go on forever, that we could clear, break and develop land indefinitely, and still there would be no limit. Now, we have awakened from this extended dream to find many of our unique prairie, forest and mountain landscapes degraded and at risk.

Instead of standing by and wringing hands, authors Smreciu, Sinton, Walker and Bietz take a proactive approach to the crisis. They have produced a handbook that says to us, “If you care enough about the loss of these landscapes, we can show you how to get some back.”

After all the restoration and reclamation debates are over, we all must make that first tentative step on the land to effect physical changes in a positive direction. This is where this handbook comes in, providing thoughtful advice to guide us through those first crucial steps.

It is not surprising that this handbook, the first of its kind in Canada, comes from Alberta. The Alberta chemistry brings passionate environmentalists together with ingenious and pragmatic farmers, ranchers, nurserymen, seedgrowers, industry and government to produce a vibrant native plant movement that is the envy of the rest of the country.

I am always intrigued at how ecosystem restoration engages the loftiest of ideals together with the minutest of the practical — how we can talk of Aldo Leopold’s philosophies in one breath and Pure Live Seed calculations in the next. The practical is where this handbook shines. But don’t for a minute think that practicality limits creativity. Think of *Establishing Native Plant Communities* as a springboard for the imagination.

Don Gayton

Ecologist and author of *The Wheatgrass Mechanism*



About the Authors

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INTRODUCTION



About this book

Over time, Alberta's native landscapes have been changed by agricultural, industrial, commercial, recreational and residential/urban development. Threats to remaining native landscapes include further fragmentation into increasingly smaller areas and the introduction and expansion of weeds and problem agronomic species. The past use of non-native plants on revegetated sites has sometimes resulted in the exclusion of native species (i.e., plant species that are indigenous to a particular Natural Region; they were in that region prior to the time of Euro-American settlement). Non-native plants have the potential to alter native communities if they invade undisturbed areas. The loss of native plant species may be detrimental to the way an ecosystem functions.

Interest in the use of native plant materials for revegetation projects in Alberta has increased dramatically. Native plants are used for revegetating industrial disturbances throughout Alberta, where the end land use has been identified as re-establishment of a diverse native plant community. The use of native plants in urban landscapes and along highway rights-of-way is gaining acceptance as information about the benefits of using native plants spreads. Also, cultivation of native plants for medicinal, aesthetic and traditional cultural uses continues to gain popularity. The supply of native plants is increasing steadily as more producers learn how to grow them.

In 1996, *A Guide to Using Native Plants on Disturbed Lands* was produced by Alberta Agriculture, Food and Rural Development (Gerling et al.). It includes details about native plants and their communities in Alberta, and provides fundamental information regarding native plant revegetation. It was followed by *Growing Native Plants of Western Canada* (Pahl and Smreciu 1999). It provides specific information about producing seeds of individual native species.

The Native Plant Working Group (NPWG) was formed in 1998. Its representatives come from a number of government jurisdictions, various industries and

non-government organizations (Appendix 1). The NPWG recommended provincial guidelines for the use of native plants for revegetation. The Native Plant Revegetation Guidelines were used on a trial basis in 1999 and were released by several government departments in 2001. During the development of these guidelines, the NPWG recognized the need for a companion document to address the specifics of native revegetation that are not adequately covered in a guideline document.

This book was written to fulfil that need. It assists anyone in Alberta who has to plan native plant revegetation projects or carry out the revegetation. This publication provides more specific information regarding native revegetation considerations and methodologies. It includes sections on planning, planting, management, monitoring and assessing revegetation projects. It also contains both general information that can be applied to all native plant revegetation projects as well as specific methodologies for specific types of sites.

The information in this book has been drawn from a number of sources, including the experience of the authors and other practitioners and published and unpublished reports of native plant revegetation projects. There are still many gaps in the information about establishing native plant communities. The authors encourage all individuals and agencies involved in native plant revegetation to continue to monitor their projects and share their results with other practitioners and agencies.

Plants in this book are identified according to the scientific nomenclature of Moss (revised by Packer 1983), a widely used taxonomic authority in Alberta. Plant taxonomy has changed rapidly in recent years with several international movements actively working on standardizing the nomenclature of plant species, especially those with ranges that extend across political boundaries. To minimize possible confusion over species identity and extend the usefulness of this book, synonyms (from the Germplasm Resources Information Network) for some of the common native grass species are provided in Appendix 5.

Objectives of reclamation in Alberta

Reclamation is the return of disturbed land to its original use or the conversion to another productive use. The main objective of reclamation in Alberta is to achieve equivalent capability. This is defined in the Environmental Protection and Enhancement Act (EPEA) (Appendix 2) as: “The ability of the land to support various land uses is similar to the ability that existed prior to any activity being conducted on the land, but the ability to support individual land uses will not necessarily be equal after reclamation.” In Alberta today, reclamation is a proactive process that considers the entire life of a project or activity through the planning, operation and abandonment phases. Revegetation is typically one of the last activities of the reclamation process, but careful planning can greatly enhance the outcome. This is particularly true when native landscapes are involved.

Goals for revegetation on native landscapes

The goals of revegetation on native landscapes vary depending on the end land use. There is increasing acknowledgement that it is desirable to use native plants to revegetate native landscapes. It is also recognized that plant communities are more than a mere assemblage of plants. Each species has an intrinsic role in maintaining the stability and integrity of the whole native plant community. The goal for native revegetation is not necessarily to replicate the original native vegetation, but to promote the re-establishment of sound ecological function and eventually restore a full range of variability in biological structure and diversity. The re-establishment of sound ecological function must take a holistic approach that includes knowledge and understanding of the site soil characteristics (physical, chemical and biological), the site history (its current and past uses), the hydrology of the site, the requirements of the native plants (i.e., plants indigenous to the region and adapted over time in association with the local landscape and climate) and the interactions among all of these.

The establishment of sound ecological function provides benefits and allows multiple uses. These uses and

benefits include the provision of sustainable grazing for domestic livestock, food and cover for wildlife, the conservation of soil and watersheds, the protection of habitat and diversity of plant communities, and the maintenance of aesthetically pleasing landscapes. While revegetation efforts can go a long way toward re-establishing a complex ecosystem, the difficulty in erasing the footprint of human activity has to be recognized. The established native vegetation community must also meet the approved end land use regulatory objectives and the requirements of the landowner.

Many native landscapes have already been significantly altered. There also needs to be a recognition that native revegetation may not be the best choice in these cases. The cost and effort to restore native landscapes where non-native populations have already taken over can be huge and the results may be disappointing. It is important to be realistic when evaluating sites. There may be opportunities to integrate the use of native and non-native species in some revegetation projects to best meet the needs of land use in an area.



Partially vegetated sand hills near Edgerton, Alberta.



Cattle grazing in the Wainwright, Alberta area.

Factors influencing successful revegetation

There are native landscapes in Alberta that are particularly sensitive due to climate, rough topography, presence of rare or threatened plants and animals, paleontological or archaeological significance, or other unique features. The revegetation process can be enhanced by keeping these fundamental principles in mind:

- Wherever possible, disturbance on such lands should be avoided. For example, rerouting a pipeline around threatened plant communities, such as rough fescue prairie, protects remaining areas and makes revegetation planning for the project easier.
- Minimize the disturbance. Revegetation is simpler, faster and less costly when efforts are made to disturb the smallest possible area.
- The salvage and replacement of topsoil helps to ensure successful revegetation. Separate salvage of the top few centimetres (seedbank salvage) of soil that contains valuable seeds and rhizomes is another way to enhance regeneration efforts.
- When the activity is completed it is important to restore the original landscape features and drainage patterns, and relieve any soil restrictions. The surface must be adequately stabilized and revegetation techniques employed that initiate, enhance or accelerate the establishment of the plant community.
- The site has to be protected from further stress while the plant community is being re-established. The site must also be managed to ensure long-term sustainability.

PLANNING



Goals for pre-development revegetation planning

The goals of pre-development and revegetation planning are:

- to identify the composition, relative abundance and extent of native plant communities
- to identify, salvage and conserve resources such as topsoil and native plant material
- to ensure that existing plant communities are minimally disturbed
- to identify and conserve rare and sensitive plants and plant communities
- to identify and address concerns with existing problem plant species such as weeds
- to have sufficient and appropriate plant materials available for revegetation
- to investigate revegetation techniques that re-establish appropriate, functioning plant communities that also encourage soil building

The goals of the reclamation project must be clearly understood when deciding what type of plant materials to use for revegetation, and how and where to use them. Project goals might include one or several of the following: erosion control, sustainable wildlife or livestock foraging, maintenance or development of wildlife habitat, re-establishment of tree cover, control of problem plant species invasion, maintenance of biodiversity and aesthetics.

Native plant species, which may differ in Alberta's Natural Regions, are generally preferred for reclamation purposes on native landscapes. Where rare or sensitive native plant species and communities are present, or where there is important wildlife habitat, the conservation and use of local native plant materials is extremely important.

Disturbance types

The development of a revegetation strategy for a site depends largely on the size, nature and age of the disturbance. Some small disturbances, after topsoil

replacement and surface preparation, can be left to revegetate naturally without supplemental planting. This strategy is inappropriate for large disturbances. Sites where the topsoils and subsoils are severely disturbed require more preparation and different plant species (e.g., more early seral species) than those where the topsoil and subsoil are intact. Revegetation choices for new disturbances are often not possible on older sites because options, such as use of stored topsoil, may be limited.

Mines



Coal mine in the Rocky Mountains.

Mines, including coal mines in mountain, grassland and parkland areas, as well as oil sands extraction sites in northern Alberta, affect large tracts of land. Some existing mines pre-date the concern over native plant communities and the large scale availability of quality native plant materials. Topsoil and/or existing vegetation were previously not conserved for use later. The salvage of native topsoils is now the accepted practice. Native vegetation is often non-existent on the disturbance and existing adjacent native vegetation is often a considerable distance from portions requiring revegetation. Thus, natural re-colonization by native plants is extremely slow and not acceptable as the only revegetation strategy. Contamination (e.g., boron, salts)

may be a problem on some mine sites and can be detrimental to native plant establishment. As some mines are located in the midst of previously undisturbed native plant communities, reclamation planning to integrate the site into the surrounding native landscape is critical. Post disturbance mine sites are frequently very different from the pre-disturbance site, with varying soil textures, topography (e.g., steep slopes) and drainage patterns. Revegetation of these large sites must include a variety of seed/plant mixes and revegetation strategies suitable for different conditions and end land uses.

Sand and gravel pits



Gravel pit.

Sand and gravel pit disturbances are small to medium sized areas (ranging from less than a hectare to more than 65 ha). Sites disturbed prior to 1977 often have little topsoil or subsoil. Newer sites have salvaged soils. Sites are generally not contaminated, but may have small spills from machinery. Often, no native vegetation is present on these sites and the potential for weed problems is high due to seeds being transported through traffic movement. Sand and gravel pits often offer opportunities to create new wetlands and water bodies.

Transportation and utility corridors

Transportation and utility corridors include highways and roads, railroad rights-of-way, powerline rights-of-way, access routes to other types of disturbances such as mines, forest harvest sites and agricultural land. These disturbances are mostly linear, are of varying widths and affect small or large areas. Topsoils were rarely saved on older projects, but they can be saved on new projects.



Transportation corridor.

Surrounding or adjacent native vegetation is often disturbed and patchy. Weeds can be a persistent problem on these sites due to traffic carrying in weed seeds. Contaminating spills, salt contamination and vehicle emissions are also concerns along roads, highways and railway accesses. A concern unique to these disturbances is that vegetation must be low and not attract wildlife. Care must be taken on rights-of-way to limit access for safety reasons and to discourage poaching. Roadway and railway disturbances are generally high profile sites and therefore aesthetics must be considered. Most highways and roadsides have been revegetated with non-native grasses, many of which (e.g., *Bromus inermis* - smooth brome, *Phleum pratense* - timothy, and *Agropyron pectiniforme* - crested wheat grass) are invading adjacent native landscapes. Recently, Alberta Transportation has started to use native plant mixes along the primary highways in Alberta.

Forestry cut blocks



Forestry cut block near Hinton, Alberta.

Timber harvest areas may be medium to large in size and most are non-linear. Some may be associated with linear disturbances along access corridors. The topsoil is usually not disturbed, although it can be severely compacted. This can restrict plant establishment and growth, especially of conifers (Lane 1998). Soil scarification is a common practice on deforested sites. It turns up mineral soils, but this also buries the existing seedbank. Adjacent vegetation is often undisturbed and can provide seed rain. On some sites, large quantities of native vegetation (particularly understory native plants) remain after harvest and a viable seedbank and soil micro-organisms can persist. However, other harvested sites will not recover naturally and require replanting. Weeds and persistent agronomics can be a concern on cut blocks, especially if local populations exist or they are transported to the site with machinery.

Peat extraction sites



Peat extraction.

Areas where peat has been extracted or harvested vary in size. They range from approximately one to 1,200 ha. Drainage ditches are common and other than ensuring large drainage patterns are restored, little is done to reclaim these areas. Old sites were often revegetated with non-native species. Today, harvested areas are left to revegetate naturally. If weeds are a problem, they should be controlled.

Large construction projects

Construction projects can include dams, plant sites and other infrastructure projects such as landfills. These sites are generally small to medium-sized disturbances. Construction projects can change the nature of the



Oldman River Dam.

entire site (e.g., dams increase the amount of moisture in the surrounding area and landfills change the topography and drainage of a site). Topsoil and subsoils may be present on recent projects, but are often lacking on older sites. Various contaminants are common on landfill sites and spills of various kinds may be a concern on other construction projects. Little or no native vegetation remains on these sites and there is a great potential for weed seeds being transported into the area through traffic movement.

Pipelines



A pipeline in the Parkland Region of Alberta.

Pipelines are typically long, narrow disturbances, ranging in width from one to 40 m. Although topsoil and subsoil were not salvaged on older pipelines (pre-1983), these resources have been salvaged and replaced on newer projects. A “no-strip” construction method has sometimes been used on small diameter pipelines (up to 30 cm or 12 in.) to conserve native vegetation in prairie grasslands.

Most old pipelines were not seeded and many have reverted to native vegetation. Those reclaimed between the 1940s and the 1990s were seeded to non-native, invasive forages such as *Agropyron pectiniforme* (crested wheat grass), *Bromus inermis* (smooth brome) and *Phleum pratense* (timothy). Beginning in the 1990s, pipelines on publicly-owned prairie areas had to be seeded to native species. Narrow pipeline disturbances in prairie, one to two metres in width, are an exception and can be left to revegetate naturally. Contamination may be a concern on some pipelines (e.g., salt water spills from salt water disposal lines). Weeds can be a problem if there are adjacent populations or if seeds are transported to the site during construction.

Wellsites and batteries



Wellsite in the Rocky Mountains.

Wellsites and batteries are small sites (0.8 to 1.7 ha or one to three acres). Efforts are being made to reduce the size of wellsite disturbances within native landscapes. Topsoil salvage has been required by legislation since 1983. Generally, topsoil and subsoils are stripped separately. Although water-based drilling waste is usually mixed with clay and spread over the lease prior to soil replacement, a reduction in lease size and soil stripping means water-based waste is sometimes sprayed over adjacent native vegetation or trucked to cultivated land and spread. Prior to 1940, wellsites were generally left to revegetate on their own. Wellsites created between 1940 and 1990 are likely to have a cover of tame forage. Today, wellsites on publicly-owned native landscapes are seeded to native species or left to recover naturally without seeding. Producing wellsites have the potential for contamination (e.g., salts, hydrocarbons and sulphur). This must be addressed prior to revegetation. On old

wellsites and batteries, chemical contamination and inappropriate soil pH may be a problem for native plant community establishment. If contamination is found, the entire lease may have to be disturbed again, remediated and then revegetated. Weeds can be a concern on these sites due to the movement of machinery.

Agricultural land

Disturbances on agricultural lands include cultivated fields, hayland and pastures, and abandoned livestock feedlots. Most of these disturbances are medium-sized, non-linear areas. Topsoil is usually present, although it may have few native propagules in it. Depending on how long an area has been cultivated, the topsoil is likely quite different from the topsoil there prior to cultivation. Often there is little or no subsoil disturbance, although subsoil compaction can be a problem. The soil can also be contaminated with various pesticides and other agricultural chemicals. Usually, there is little or no native vegetation remaining on the sites and adjacent vegetation may be only partially native. Depending on the crops previously grown on the site, there may be pests that are a concern for some native plants. Large weed populations are common and problem tame forages are also frequently found on these sites.

Overgrazed native rangeland is also an agricultural disturbance type. These sites can be extensive, but there is generally a layer of topsoil and an undisturbed subsoil. There is usually some native vegetation remaining and a source of native propagules, such as seed. Depending on the level of overgrazing, there may also be erosion and large weed populations that must be controlled prior to successful revegetation.



Agricultural land.



Alpine vegetation in the Rocky Mountains.

Site location

Climate, moisture, soil and topographical differences affect the composition of a native plant community. These differences are used to divide Alberta into Natural Regions and Subregions (Alberta Environmental Protection 1992). Each of the six Natural Regions is divided into several Subregions. Each Subregion is characterized by specific vegetation community types with dominant and subdominant native plant species. Full descriptions of these areas are provided by Alberta Environment's Alberta Natural Heritage Information Centre (ANHIC) (Appendix 2). Descriptions are updated periodically as new information becomes available. Identifying the Natural Region in which a disturbed or soon-to-be disturbed site is located is the first step in the pre-disturbance inventory and evaluation. This location is a primary consideration when planning native plant revegetation.

Site conditions

Pre-disturbance site assessments and resource inventories are essential for successful revegetation planning. The quality of pre-disturbance assessments varies depending on the size and type of the project. They range from full environmental impact assessments

to quick surveys according to specific regulations for the disturbance type.

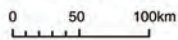
After a site has been located in a Natural Subregion, it can be surveyed to determine the soil type(s), moisture regime(s), topographical feature(s) and vegetation type(s). General climate information, including snowfall and precipitation amounts, summer and winter temperature averages, and wind directions and speeds, should be noted. Soils should be classified based on the amount and balance of sand, silt, clay particles and organic materials. The types and amount of rock and gravel should also be noted. Moisture availability (wet, moist, mesic, dry or arid) should be recorded and should include differences



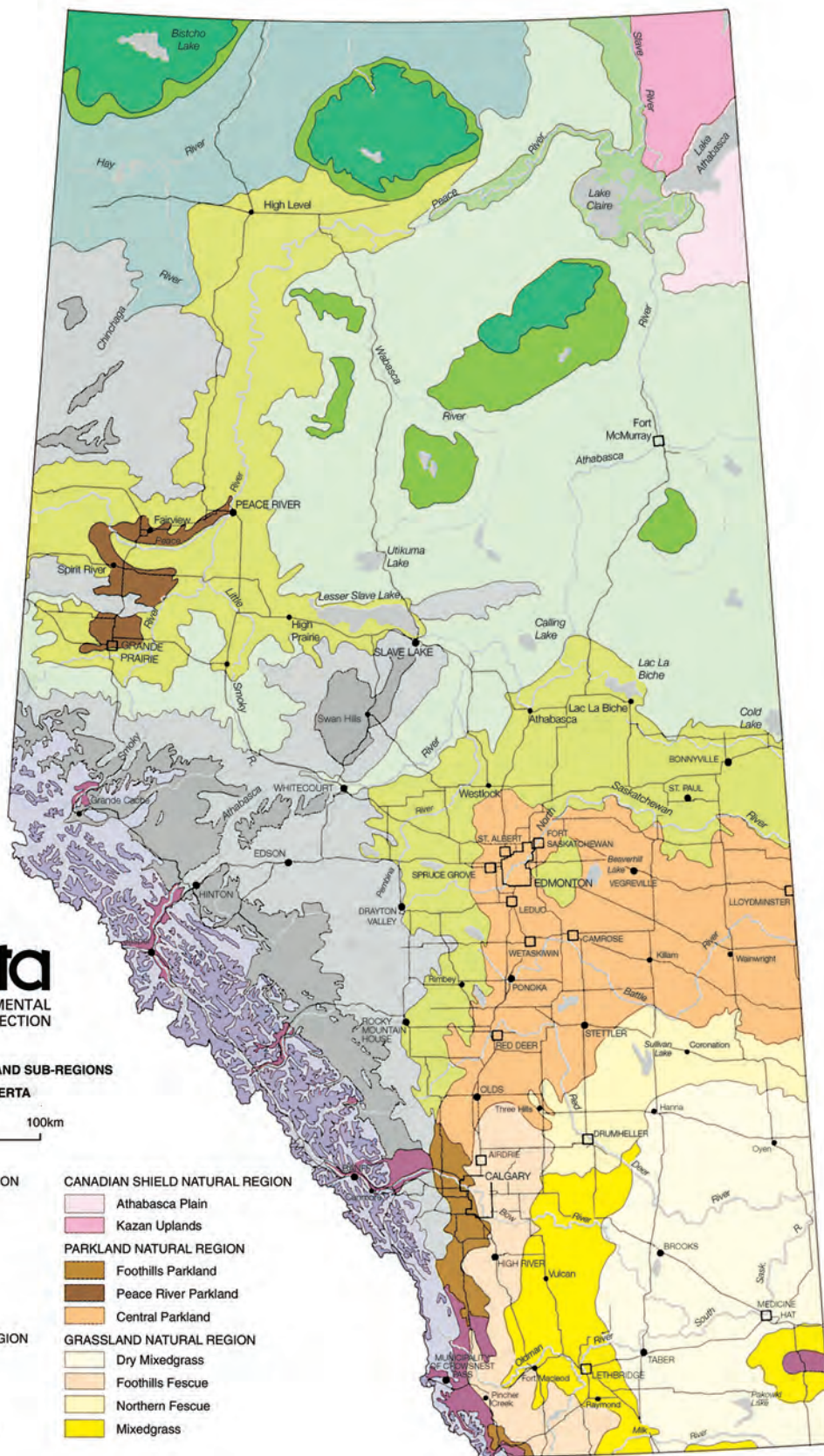
Soil sterilant damage.

Alberta
ENVIRONMENTAL
PROTECTION

**NATURAL REGIONS AND SUB-REGIONS
OF ALBERTA**



- | | |
|--------------------------------------|---------------------------------------|
| BOREAL FOREST NATURAL REGION | CANADIAN SHIELD NATURAL REGION |
| Central Mixedwood | Athabasca Plain |
| Dry Mixedwood | Kazan Uplands |
| Wetland Mixedwood | PARKLAND NATURAL REGION |
| Sub-Arctic | Foothills Parkland |
| Peace River Lowlands | Peace River Parkland |
| Boreal Highlands | Central Parkland |
| ROCKY MOUNTAIN NATURAL REGION | GRASSLAND NATURAL REGION |
| Alpine | Dry Mixedgrass |
| Sub-Alpine | Foothills Fescue |
| Montane | Northern Fescue |
| FOOTHILLS NATURAL REGION | Mixedgrass |
| Upper Foothills | |
| Lower Foothills | |



Produced by Alberta Parks Services, Management Support Division. 1994

within a site. Gross topography, including slopes and aspects, should also be noted. This survey information can be used to determine what types of vegetation are best suited to the site (Gerling et al. 1996). A series of guides to Alberta ecosites (Beckingham and Archibald 1996, Beckingham, Corns, and Archibald 1996, and Archibald, Klappstein, and Corns 1996) can be used to classify native plant communities and assist with planning revegetation in forested regions of the province.

Site history

Every effort should be made to compile as much information as possible about the history of the site to be revegetated. Information about construction and operations can provide valuable insights into possible problem areas. For example, with wellsites it is useful to have a construction diagram and air photos indicating where hot spots like the well centre, sump (for disposal of drilling waste) and flare pit were located. These spots are more likely to have hydrocarbon contamination than other areas of the lease.

Other useful information includes: a history of sterilant, herbicide and fertilizer use on the area; the type of vegetation growing there and for how long; the types of weeds found on the site; the location of topsoil storage piles; and, whether soil amendments such as manure or straw were used. These types of records are hard to locate for older sites (pre-1980s). If the site is on public land, there may be information on the lease files that can be accessed through contacting the local Public Lands office.



Crude oil spill.

Current and future use

The current land use can affect the final site revegetation plan. For example, converting a field of forage, such as *Bromus inermis* (smooth brome), to native prairie is going to take more time, effort and money than converting a field currently growing annual crops with few weeds. If the site is in an urban area, the acceptability of native plants in the landscape must be considered.

Contamination

If contamination is suspected due to a hydrocarbon smell in the soil or bare patches in an otherwise vegetated area, soil samples should be taken to determine the nature and extent of the problem. Once this is known, a remediation plan can be developed.

A fairly new area of research and interest in reclamation is phytoremediation. This is the use of plants to remove, contain or render harmless environmental contaminants. Certain plants are more tolerant of contaminants such as salt. Some plants are able to draw contaminants out of the soil or water, without ill effect to themselves. This poses a new problem; the disposal of the now contaminated plants. Other plants are able to metabolize the contaminants and convert them into less harmful compounds.

There is a great deal of interest in North America in the potential for various native plants to be useful for phytoremediation. At the University of Alberta, studies are underway to evaluate numerous native grasses and forbs for remediation of hydrocarbon contaminated soils and to dewater various oil sand tailings materials (A. Naeth, pers. comm.). The University of Saskatchewan will soon have a database for native plants on a new phytoremediation website (J. Germida, pers. comm.). Trials are currently underway in various locations using native *Populus* and *Salix* species (poplars and willows) to draw up hydrocarbons from contaminated groundwater.

Landscape

The best way to determine how topography and aspect will affect the revegetation plan is to visit nearby sites in the same Natural Region with the same or similar landscapes. Notes should be taken on the differences in species composition that are seen. There are native plants that are adapted to every specific landscape condition. For example, plant species that grow well on



Steep slopes of various aspects along a river valley.

north-facing slopes are likely to be different from plant species found on south-facing slopes. The specific adaptations for many of Alberta’s native plants can be determined by consulting the Native Plant Species Characteristics section of *A Guide to Using Native Plants on Disturbed Lands* (Gerling et al. 1996). It is critical to the survival of aquatic plants that they be placed in the appropriate zone or water depth (e.g., that emergent plants such as *Typha latifolia* (cattail) be grown in standing water, but that the water not be so deep that they can’t emerge).

Soils

The soil type and condition is an important consideration in a revegetation project. It is important to test soil throughout the site (i.e., chemical constituents, texture, organic content and pH). There are native plants adapted to all kinds of soils. It is important to match the plants to the soil type. Sometimes industrial development, such as oil sands mining, can change the soil environment completely. For example, the post-mining substrate can consist of sand tailings that are different from the original forested soil. It is necessary to look at sandy soils elsewhere in the Natural Region to determine what native plants would be best suited for revegetating these tailings.



A soil pit provides valuable information.

Soil examination also determines if there are any soil restrictions, such as compaction, that might be on the site as a result of construction or operations. It can also

determine the drainage characteristics of the soil and identify rare soil types that should be conserved. Locally rare soils often support rare or unique plant and animal communities (L. Fuller, pers. comm.) that impact the diversity in specific areas.



Testing soil at a grassland site.

Topsoil is an integral part of a functioning ecosystem and takes a long time to form. Usually, topsoil should be conserved and spread on reclamation and revegetation sites. Exceptions may occur where weed populations in the topsoil will jeopardize the success of the native revegetation project. In extreme cases, the topsoil and its seedbank of weeds or non-native vegetation cover (e.g., lawn) is removed and the native vegetation is planted on the subsoil. This technique is only used in small, usually urban restoration projects where the weed problem is severe. Some native plants can grow quite well on soils that have little organic material or nutrients. Manure or fertilizer should not be added to these sites as they tend to promote weed growth.

Vegetation

The existing vegetation is an important consideration in a revegetation project. A complete vegetation survey should be done prior to revegetating any site. Preferably, this is done before the disturbance occurs. A vegetation survey should include inventories of native vegetation, rare plants and plant communities, and existing weeds and problem species. These inventories should be extensive and should include adjacent areas, as well as the construction site. The successional stage of the plant



Parkland vegetation along the North Saskatchewan River.

community should be identified as early successional species may be more suited for revegetation of the altered site than existing species.

Native vegetation

The presence of native plant communities on or adjacent to a site is an important component of a vegetation survey. If present, these communities can provide a source of native propagules (seeds or various cuttings). These propagules should be salvaged onsite prior to disturbance, or from surrounding areas to provide a parent population for seed multiplication fields. Sites located in otherwise undisturbed native settings may require little supplemental planting after the site is prepared.



Wildflowers in the Cypress Hills.

Rare plants and plant communities

A rare plant species is any native species that due to its biological characteristics, its occurrence at the fringe of its range or other reasons, exists in low numbers or in restricted areas. Rare plant species or rare plant communities in Alberta include those listed on the current Alberta Natural Heritage Information Centre (ANHIC) tracking list (Allen 2002) and by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Conservation Data Centres (CDCs) in other provinces have developed tracking lists for rare species within their borders. Lists of rare species change as new information becomes available and as the status of populations change.



The presence of rare plants on site should be ascertained prior to disturbance and plans made for their preservation (*Cypripedium acaule* - stemless lady's slipper).



Rare plants are often found in sandy areas and dunes.

Plant surveys are undertaken to determine the presence and location of all rare plant species and botanically significant plant assemblages on a survey site. A rare plant survey can confirm the presence of a rare species on a site, but it cannot rule out the existence of rare species on a site. The Alberta Native Plant Council (ANPC) has published *Guidelines for Rare Plant Surveys* (Lancaster 2000). It is available on their website (Appendix 2).

Although rare plants or plant communities can be found anywhere, there are particular environments where they are more likely to be found. Microhabitats, ephemeral habitats, unusual landscape features and transition zones between habitats are important sites for rare plants. These fine scale biotic patterns occur within and between larger, mappable vegetation units. They are often closely linked to substrate, seasonal water patterns, small scale landscape features and particular plant associations. For instance, in grassland areas, rare plants are often found associated with sandy areas and dunes, depressional areas or coulees, saline or gravelly areas, and sites affected by fire. Rare plants tend to have small discrete populations or are thinly scattered on a landscape.

Once a rare plant or rare plant community has been identified within a project area, there are four types of mitigation that can be considered:

- avoidance
- minimizing impacts
- salvaging plants or propagules
- propagation and replacement



Salvaging sod during pipeline construction in the parkland area of Alberta.

The primary consideration is whether the disturbance can be avoided. In the case of pipelines, for example, it is often possible to reroute around or drill under the rare plant population. If disturbance is unavoidable, the use of winter construction or specialized matting may minimize disturbance to the rare plant community. Salvaging seeds or other propagules requires some knowledge of the rare plant's autecology. This can be gained from searching the literature or consulting with botanists and native plant propagation specialists. Some rare plants are best propagated by seed. In other cases, it may be more effective to salvage the topsoil seedbank (top few centimetres) and store it separately from the remainder of the topsoil. Sometimes it is necessary to salvage whole plants. It is very important to sample the soils that the plants are growing in and to reproduce those conditions during storage or propagation. When putting rare plants or seed back on disturbed sites, it may be necessary to alter the revegetation mix on the site by lowering seeding rates or by changing or eliminating other revegetation species completely to minimize competition. Companion planting is also effective in some cases. For example, *Parietaria pennsylvanica* - a small prairie forb, grows best if planted in the disturbed soil under *Crataegus rotundifolia* - hawthorn. These species are often placed together (M. Neville, pers. comm.). If propagation is proposed, it is important to consider whether the rare species is early or late seral and the conditions under which it will be re-introduced. Is the species a colonizer or a climax species? Is it dependent on a specialized plant association or habitat? It may be better to relocate the plants into an intact plant community (out of the project area) rather than to replace them in site conditions that have changed completely.

Back-up mitigation measures should be in place in case changes in operating conditions make the planned mitigation impractical. For instance, collecting seeds from plants that are to be avoided by narrowing down the pipeline right-of-way is good insurance. If primary mitigation is successful, the seeds can be replaced after construction with no net damage to the site.

Weeds and problem species

Weeds and invasive plants are a primary source of problems in revegetation projects. The presence of perennial weeds (e.g., *Cirsium arvense* - Canada thistle, *Linaria vulgaris* - toadflax, *Lythrum salicornia* - purple loosestrife) or problem species (e.g., *Bromus inermis* - smooth brome, *Trifolium* spp. - clovers,

Phleum pratense - timothy) can discourage or inhibit the establishment of native plants. In large quantities, annual weeds (e.g., *Kochia scoparia* - summer cypress, *Descurainia sophia* - flixweed, *Thlaspi arvense* - stinkweed) can also hinder the establishment of native plant communities. Control measures must be considered at the planning stage as it may require years to control large volumes of seeds in the soil.



Uncontrolled weeds can be a primary source of problems in a revegetation project (*Ranunculus acris* - tall buttercup).

Land use planning

Public lands

Public land in Alberta, administered under the Public Lands Act, covers approximately 56.5 per cent of the land base, or over 37 million hectares. The land is managed for multiple uses by Alberta Sustainable Resource Development's Public Lands Division. Although public land is scattered throughout Alberta, most is concentrated in the northernmost and southernmost thirds of the province.

Public land in northern Alberta (formerly the Green Area - unsettled forest lands) is managed primarily for forest production, watershed protection, and fish and wildlife concerns although other uses such as oil and gas development, recreation, livestock grazing and sand and gravel extraction occur.

The majority of the public land in the southern part of Alberta (former White Area - settled areas) is under some form of agricultural disposition such as grazing leases. There is also significant surface access for development of mineral resources by the oil and gas industry. Other resource uses that are accommodated in the agricultural landscape include sand and gravel extraction and recreation.

Ownership

Ownership of land in Alberta can be verified by the Alberta Resource Development, Crown Resource Data and Services, Land Status Automated System (LSAS) or by searching at the Land Titles Office (LTO). The best option is to check LSAS first to determine whether the land is occupied, vacant, public land (owned by the government) or freehold (privately owned). A land status report can be requested from LSAS that provides valuable information about the disposition of the lands in question. For public land, this report also provides information about surface restrictions that may occur on the lands. For example, key wildlife areas and serious soil problems are noted and sensitive areas or features may be identified. LSAS information may be obtained by contacting the Calgary Information Centre at Alberta Energy (Appendix 2). Information regarding land in Special Areas is available through the Special Areas Management System (SAMS) (Appendix 2).

Wildlife



Elk in Jasper National Park.

The use of a specific area by wildlife should be considered prior to disturbing a site and again before revegetation. It is important to consult with local wildlife specialists, including those knowledgeable about and responsible for various animal groups including fish, ungulates, predators and insects. Particular emphasis should be placed on rare or

endangered species and those with narrow environmental tolerances. The assessment period varies among animal species. Fisheries, for example, require a longer assessment period than do ungulates. Timing restrictions during construction can minimize effects on wildlife. Construction during the spring (April to June) can be extremely disruptive to nesting songbirds. Raptor nesting can be disrupted unless construction is delayed until after mid July.

Regional planning



Sand dunes in the Richardson River Dunes Wildland Provincial Park in northeastern Alberta.

It is essential that all possible sources of information be utilized to plan a revegetation project. There are often numerous activities in a particular area and sometimes revegetation prescriptions only address one or a few of the many possible land uses. Conflicts can arise between the various users or uses. For example, the best time to plant for the successful establishment of a native plant community may conflict with breeding birds. Thus, consultation with many different people and agencies is important.

Direction on land and resource use in Alberta is found in a variety of planning documents that cover the majority of public land. These plans provide guidance about permitted end land uses in an area which affect the revegetation strategies that can be used. Examples of the regional planning information available include:

- Integrated Resource Plans (IRP) - These are available for regional, sub-regional and local areas. These can be obtained from the Alberta Environment Information Centre.
- Municipal Land Use Zoning - Consult the appropriate Municipal District.
- Lake Management Plans - Copies can be obtained from Public Lands offices in the area in which the lakes exist.
- Forest Land Use Zones - Contact Public Lands offices.

- Forest Management Agreement Areas - Contact Public Lands offices.
- Access Management Plans (AMP) - Copies can be obtained from Public Lands offices.
- Protected Areas: Special Places, Ecological Reserves, Wilderness Areas and Natural Areas - Information on these areas can be obtained from Community Development, Parks and Protected Areas (Appendix 2).
- Ecologically Sensitive Areas (ESA) - Information about these can be obtained from the Alberta Natural Heritage Information Centre (ANHIC), Alberta Community Development (Appendix 2).
- Special Wildlife Considerations (crown surface land or mineral searches - with or without restrictions, e.g., habitat) - use LSAS, through Alberta Energy Information Centre (Calgary), or SAMS through Special Areas (Appendix 2).
- Native land claims.
- Historical resources - Alberta Community Development's Cultural Facilities and Historical Resources Division administers historical and cultural resources under Alberta's *Historical Resources Act* (Appendix 2).

Other specific sources of information for planning revegetation

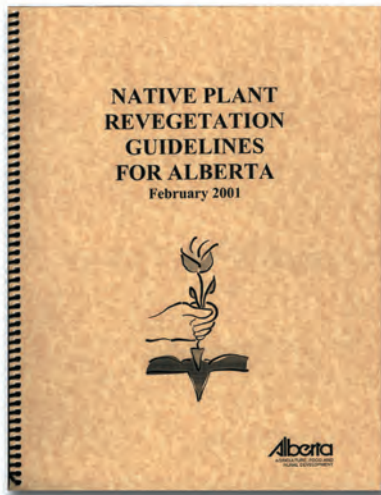
There are a number of other sources of information that can be consulted when planning revegetation projects that affect native landscapes.

Alberta Natural Heritage Information Centre (ANHIC)

ANHIC is a joint project of the Nature Conservancy, Canadian Heritage (Alberta Region) and Alberta Community Development. The University of Alberta, Devonian Botanic Garden is also an affiliate. The centre's purpose is to collect, evaluate and make available information on the elements of natural biodiversity in Alberta. The information encompasses plants, animals, native plant communities and landscapes. ANHIC also develops tracking lists of

elements that are considered high priority because they are rare or special in some way (Allen 2002). Project managers should consult this database to determine if their project has the potential to affect any of these high priority elements (for contact information see Appendix 2). Planning can then take these elements into account and special avoidance, salvage and revegetation strategies can be employed.

Native Plant Revegetation Guidelines for Alberta



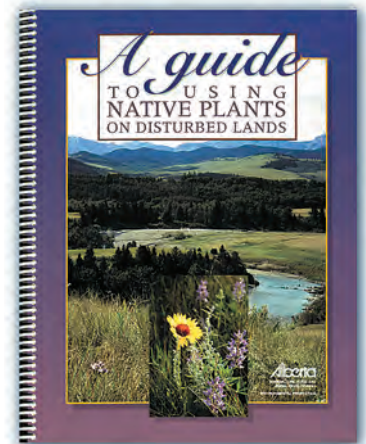
These guidelines were developed by a government, industry and non-governmental agency working group. They provide clear, consistent and integrated information about using native plant materials where the revegetation goal is to re-establish a native plant community. The guidelines are not prescriptive. Rather, they recognize that

site specific circumstances have to be considered when planning revegetation projects. The guidelines have a number of useful appendices. These include a list of weeds from the Alberta *Weed Control Act* (for website see Appendix 2), information about how to interpret seed analysis certificates, lists of commercially available native plant material and guidelines on wild harvesting of native plants. The Native Plant Revegetation Guidelines are available from Sustainable Resource Development's Public Lands Division and from the Alberta Environment Information Centre (Appendix 2).

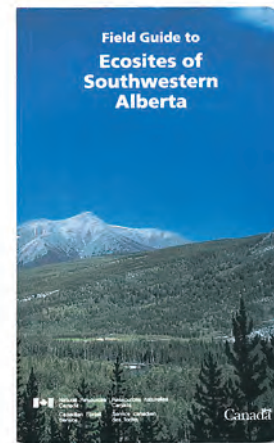
A Guide to Using Native Plants on Disturbed Lands

This publication (Gerling et al. 1996) provides a list of native trees, shrubs, forbs and grasses that are found on various site types in the different Natural Regions of Alberta. The average plant cover values in climax communities are provided to assist practitioners in deciding how much of various species they should plant on any given site. Information about each species is also

included in a separate section. This information is for practitioners who need to know soil or grazing tolerances of various plants, whether they are poisonous and who supplies them. This book does not eliminate the need for on-site evaluation, but it does provide a starting point for planning revegetation projects. This priced publication is available from Alberta Agriculture, Food and Rural Development's Information Packaging Centre (Appendix 2).



Field Guides to Ecosites of Alberta



These publications (Beckingham and Archibald 1996, Beckingham, Corns, and Archibald 1996, and Archibald, Klappstein and Corns 1996) provide a well-recognized classification for forested regions of Alberta. They are used extensively to design silvicultural prescriptions and can be used for revegetation planning and developing revegetation prescriptions. These publications can be obtained through UBC Press (Appendix 2).

Native Plant Source List and Collection and Use Guidelines

The Alberta Native Plant Council (ANPC) publishes a source list to support and promote the use of native Alberta plants for environmental restoration, landscapes and gardens. It gives revegetation practitioners up-to-date information about the availability of native plant materials, including trees, shrubs, forbs and grasses. Plant materials include seeds and plants of various sizes and maturity. Supplier contact information is also provided. This list can be downloaded from the ANPC website or ordered by mail (Appendix 2).

Guidelines for Rare Plant Surveys

The ANPC published these guidelines (Lancaster 2000) to help to standardize approaches to the assessment of lands for the presence of rare plants. The guidelines address topics including qualifications of surveyors, pre-field work, how to conduct field work, documenting and reporting results. These guidelines are available from the ANPC (Appendix 2).

Guidelines for Wetland Establishment on Reclaimed Oil Sand Leases

This information letter (Alberta Environment 2000a) provides an introduction to the guidelines and includes background information, objectives and a wetland development approach. It also includes sections on performance assessment and reclamation certification for these areas.

Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region

This document (Oil Sands Vegetation Reclamation Committee 1998) provides information on terrestrial forest ecosystems that can be established to support commercial forests and wildlife habitat. It also presents practical information on reclamation and monitoring based on past experience.

Consultation with landowners and land managers

It is important to talk to private landowners, land managers and disposition holders to determine if there are any specific features or management concerns that should be addressed in a revegetation plan. For example, a significant proportion of public land is under grazing disposition. It is helpful to consult with the grazing disposition holder or land manager to determine grazing patterns and how they can be managed to assure revegetation success.

End land-use

To some extent the eventual use of the land determines how the site is revegetated. For example, if recreation is the proposed end land use, then chosen species and communities should have some tolerance to human use. If grazing is the proposed land use, species should be chosen to enhance this application. Some of the other factors to consider include succession and time frames for revegetation, biodiversity, erosion and watershed concerns, wildlife and aesthetics.

Succession and time frames

Succession refers to the changes that take place in a plant community over time as it moves from a pioneer community to mature, a self-sustaining system. Because changes are slow and each depends upon the previous stage, the development of a stable native plant community takes longer and involves more than merely planting a vegetation cover. Time is required. Consideration must also be given to what successional stage a site should be replanted to. This decision can be made based on a understanding of the present site conditions, the time frame required to reach the desired plant community and what plant materials are available. The seed and plant mix should reflect the early and late successional stages in the development of a plant community. Multiple seedlings/plantings may be planned to accomplish the goal of establishing a functional native plant community.



Opuntia polyacantha (prickly pear cactus).

Biodiversity

One of the primary reasons for using native plants in revegetation is to maintain the diversity that exists in nature. Plant diversity leads to a diversity of other life forms such as animals, insects, etc. (Walker 1996). It also maximizes ecological stability (Munshower 1994). Biodiversity increases the resilience of a community to minor or major fluctuations in the non-biotic environment. This could be higher than usual rainfall, hotter weather than normal, drier summers, poor snow cover over a number of years, fire or global warming. Diversity exists at four major levels: within and among plant species and at the community and landscape level. All of these should be considered when planning a native plant revegetation project.

Planning for a diverse native plant community involves consideration of a number of factors:

Diversity of macrosites and microsites

In the past, there has been a tendency to use the same site preparation methods for both native revegetation and agriculture projects. Entire areas were prepared uniformly. However, if the goal is to create a diverse plant community, providing a variety of niches for various plant species assists the process. Native plants have many different characteristics and needs. The best way to accommodate these is to simulate offsite variability and roughness. Many people assume that topsoil is of even depth across the landscape. Even on level landscapes this is not the case. Replacing topsoil at varying depths is more likely to stimulate diversity. Surface roughness is also important. A series of ridges and hollows provides ideal microsites for the establishment of native seedlings. The hollows collect moisture that assists germination. The ridges provide initial protection for emerging plants.

Plant species selection

Although diversity can be encouraged by providing a variety of sites, planting a number of plant species is also necessary. Several different species should be combined in the seeding or planting mix. If cultivars are to be seeded, a variety of cultivars of the same species can be used to introduce genetic diversity (within species) onto the site. Creating a diverse community means using a range of species that have varying life cycles (i.e., annuals, biennials and perennials), longevity (i.e., long-lived and short-lived), growth forms (i.e., trees, shrubs, forbs, grasses or non-vascular plants) and reproductive

strategies (e.g., seeds vs. rhizomes). Plants representing various successional stages should be considered. Early seral plants are useful for erosion control. Late seral plants can accelerate the development of a functioning ecosystem, provided they are carefully chosen to survive existing site conditions. Careful consideration of the growth patterns below the ground is important. Planting native species that root in a similar manner and to the same depth does not result in a diverse plant community. In dry areas this makes the revegetated area susceptible to drought as all the plants are getting their moisture from the same soil zone.

Fertility

High levels of nutrients favour aggressive plant species. Recently disturbed sites and agricultural areas have a relatively high proportion of available nitrogen as compared to undisturbed native plant communities. This condition influences the species composition on a revegetated site. Early successional species, including weeds, flourish in an environment where nitrogen is readily available. They tend to dominate the stand in the first few years until the nutrient levels decline.



Natural recovery on a pipeline right-of-way in the northern fescue prairie.

Competition and dependency

Establishing native plants compete for space, light and nutrients. Some competition is direct (e.g., allelopathy) while competition for things like nutrients is indirect. The more intense the competition among plants, the lower the diversity is in the resulting plant community.



Geum triflorum (three-flowered avens).

This is why heavy rates of seeding are not recommended. High levels of competition also prevent desirable native plants from moving onto revegetated areas from offsite.

Certain native plant species can be directly or indirectly dependent on other plant species. If hemi-parasitic plants are to be established, it is important to establish host plants first (e.g., *Castilleja* spp. - Indian paintbrushes are hemi-parasitic on grasses; *Corallorhiza* spp. - coralroot orchids require certain soil fungi). In other cases, certain plants just grow better in the vicinity of other plants (e.g., *Parietaria pennsylvanica* - a small prairie forb, grows best if planted in under *Crataegus rotundifolia* - hawthorn). Other considerations include the need of some species for shade that is provided by larger established plants.

Seedbank

The seedbank is composed of buried seeds or seeds on the soil surface. Most seeds are viable for a number of years. In both urban and agricultural areas where native revegetation is being established, the main concern is the number of weed seeds and problem species in the seedbank. Preparation usually means several years of allowing seeds from the seedbank to germinate and the elimination of the unwanted plants. In remote areas, where disturbances are often surrounded by native vegetation, it is important to conserve and replace the top few centimetres of soil that contain a tremendous source of genetic variability. The contribution of this seedbank to subsequent revegetation is usually overlooked in reclamation. Where populations of native seed in the seedbank are high, adding seed or plants is unnecessary. The relative health of the seedbank can be inferred by the condition of surrounding vegetation and the soil salvage strategies on the site. Often, seedlings emerge from the seedbank first, providing the needed erosion control. Seeded native species may not establish until much later.



Natural recovery on a wellsite in southeastern Alberta. *Stipa comata* (needle and thread grass) effectively colonized the sandy site after two years.

Seed rain

The contribution of offsite plant propagules, through seed rain, is an overlooked source of potential diversity, particularly on smaller disturbances within native plant communities. In some cases, where the surrounding vegetation is in good condition (e.g., not overgrazed) and there are few weeds, using additional seeds or plants may be an unnecessary expense.

Arrival sequence

The timing of the introduction of native species is influential in determining community structure. Often, early colonizers on a site use up a particular resource and prevent other native plants from becoming established. In other cases, the first colonizers enhance the site and make it more suitable for subsequent native plants to grow. Our understanding of these relationships is rudimentary. Many revegetation practitioners use the “shot-gun” approach; using a single mix or planting. This may work in some situations, but on large disturbances such as mines it is often more effective to use staged plantings. In a staged approach, early successional species are planted first and late successional species are added later.

Management for diversity

Maximum diversity tends to occur in medium-aged, rather than in very early or very late, successional communities. Managing a planted native stand is vital to achieving any of these states. Judicious use of grazing, mowing or burning after the initial establishment period helps reduce the competitiveness of early successional plants and move the plant community further down the successional pathway. Removing unwanted species is also critical to creating a sustainable native plant community.

Erosion control and watershed concerns



Erosion control is a primary concern on steep slopes.

In past decades, erosion control was considered the primary, and often the only, objective of revegetation. Although it is not necessarily the only goal of native plant revegetation, erosion control is generally accepted as one of the most important considerations. Erosion, at its worst, is the loss of plant and soil resources to wind, water and/or gravity. Erosion can occur on any site, but is most prevalent on:

- steep slopes
- sites where sub-soils are compacted and little vegetation exists to hold the topsoil in place
- sites where wind is constant or prevalent
- sites where water flows occur continuously or temporarily

The primary concerns are the loss of topsoil and seedbank, and the silting or loading of local waterways such as rivers and streams.

Watershed considerations

Revegetation strategy planning must take into consideration watershed concerns, such as:

- **site location in relation to the regional/local watershed**
- **whether the site is in a recharge or discharge area**
- **the site's erosion potential based on its position in the watershed**
- **the rainfall characteristics, especially storm events, at the site**
- **the expected infiltration potential at the site**

Critical wildlife habitat

A healthy, functioning ecosystem is managed holistically rather than for a single or few animal species. Revegetation strategies need to be as holistic as possible because wildlife populations in native landscapes are diverse. Managing for one species can negatively affect others. Some areas are critical to the health of specific wildlife populations such as raptors, songbirds or ducks,



Burrowing owl.

large and small mammals, fish or insects. This should be determined prior to disturbance or at least prior to revegetation. It is essential to select plant materials that fulfil life-cycle requirements of the target wildlife (Green and Salter 1987, Eccles et al. 1988, Green et al. 1985, 1986, 1992). Plants should be selected and placed for use as food, thermal cover, shelter and protection from predators, movement corridors and escape routes. Native plants that discourage a particular species of concern in the area should be avoided. Knowledge of the local wildlife and their requirements is fundamental.

Aesthetics

If a disturbance is completely surrounded by native vegetation, it is important that the post disturbance site should fit aesthetically with the surrounding vegetation. Aesthetics are also important in areas where people are using the site for outdoor pursuits. The choice of native



This replanted shrub thicket integrates well into the surrounding vegetation.

species in the revegetation mix should reflect the existing vegetation. For example, dense plantings of grasses should not be used in high alpine areas where the surrounding vegetation is sparse. The use of trees and shrubs is preferable to grasses in boreal areas. The creation of native landscapes within urban environments may be vulnerable to criticism, but they provide wonderful opportunities to educate the urban public about an important environmental issues. Education programs about urban revegetation projects can be critical to their success. It is important to involve managers, users and neighbours around the project site.

Cultural considerations



Local native peoples should be consulted to conserve locally significant areas such as this vision quest site.

Some areas are utilized for hunting and gathering by native peoples. This should be considered when selecting species for revegetation during the planning process. Local native peoples need to be consulted so that culturally significant areas are avoided and

significant native plant materials conserved. Native species should also be included in both the planning and long-term management of revegetation projects. Native plant species that produce important foodstuffs, medicines and other necessary cultural materials should be included in the revegetated landscape. If hunting is an activity, the area should be treated as wildlife habitat.

Recreation



Fishing in the Cypress Hills.

Revegetated sites that are to be used for recreation (e.g., hiking, horseback riding, wildlife watching, hunting and fishing) require some level of maintenance. One of the ways to reduce maintenance is to use appropriate, locally adapted species that require less replanting over time. Because recreation areas are continually disturbed, it is important to maximize diversity. This provides the site some measure of resiliency. It is also important to develop protective measures and access management plans. Weeds and other problem plants pose a difficulty on sites used for recreation. An ongoing maintenance program, including weed and invader control, should be part of a revegetation plan. On public lands, the recreational lease holder is responsible for continuing maintenance. On unleased public lands (e.g., Natural Areas), the government is responsible for ongoing maintenance.



Bird watching.

Grazing

The creation or rehabilitation of grazing areas is one of many possible end land uses. This includes sustainable pastures in grassland regions or sustainable grazing in the forested region of the province. If the end land use is grazing, the suitability of plant materials for livestock grazing must be considered. The nutritional value and toxicity of the plants are important considerations (Jorgensen 1996, Majak 2000a,b). A long-term grazing plan must be prepared and implemented for grazing vegetation. Fencing and short-term grazing management should be considered as part of initial protection strategies. The use of native plant cultivars can also be considered. It is important to consult local landowners and land managers when developing a revegetation plan for sustainable pastures.



Livestock grazing on native grassland.

Revegetation methods

Careful assessment of the site construction methods and the time of construction are required before deciding how to revegetate. There are three primary means by which to revegetate a site to a desired plant community. These include:

- active revegetation; various methods are used to replant the site to native plants
- natural recovery (no addition of plant materials); after site preparation, little input from the proponent is required
- a combination of the two methods; site is planted sparsely and re-colonization by plants from the seedbank and from surrounding or adjacent plant communities is encouraged

Establishing native vegetation

Sites where native vegetation should be established by active revegetation include:

- large mine sites located in previously undisturbed areas
- previously cultivated sites
- urban sites

Sites where native vegetation may be established by natural recovery include:

- small diameter pipelines and small wellsites in excellent quality native grasslands and boreal forest areas
- small alpine areas that lack topsoil and where problem species are not a concern
- wetlands dominated by sedges, rushes, cattails, willows or sphagnum mosses where the hydrology of the area has not been significantly altered
- small sandy areas in grasslands that are dominated by early successional species such as *Stipa comata* (needle and thread grass)

Sites where native vegetation can be established by combined methods include:

- large mines and pits
- previously cultivated land adjacent to undisturbed native vegetation
- newly created wetlands
- pipelines in areas where erosion may be a concern

Active revegetation

If appropriate plants and/or seeds are available and the time frame for revegetation can be reduced by their use, active revegetation should be the first choice. Active revegetation with native plants can be accomplished in numerous ways. These include salvaging plant and soil resources from the existing site or from similar sites slated

for future disturbance, or by replanting with seeds or other commercially obtained native plant material. Planting can occur in stages. Depending on the revegetation objectives and the plant community being established, there can be one or more seedings or plantings. Active revegetation is recommended for the following:

- large disturbances
- areas where the physical landscape is highly altered from its pre-disturbance condition
- sites where there is no topsoil or the topsoil has been stored for long periods of time (more than two years)
- areas with a high water or wind erosion potential
- sites where there is a high potential for invasion by problem species
- disturbances where the surrounding native plant community is non-existent or in poor condition (e.g., native grasslands where the surrounding or adjacent lands have been heavily grazed by livestock)
- sites that were previously seeded to non-native crops and forages



Large disturbances, such as this oil sand site in northern Alberta, must be actively revegetated.

Natural recovery (no supplemental planting)

Natural recovery, leaving a disturbed area in a native landscape to regenerate native vegetation without supplemental planting, is a suitable revegetation strategy for some disturbances. Native vegetation often re-establishes itself from the seedbank or from roots, rhizomes and other propagules in the soil. It must be understood that the time frame for native plant community establishment may be longer when using this option, particularly in dry areas of the province.



Narrow pipelines in good quality grassland can be left to recover naturally.

The timing of topsoil stripping can have a dramatic effect on the success of this technique. In Alberta, practitioners have noted that stripping soils in the fall after the seed set of most species is more successful than construction at other times of the year. It is also extremely important not to re-disturb an area left to recover naturally. Re-disturbance sets the recovery process back significantly. For example, final cleanup on pipelines must be done immediately following construction, not a year later when native plants may already be prolific on the site (M. Neville, pers. comm.).

Slash or rollback are terms used to describe the woody debris remaining after an area has been logged or disturbed. Slash is replaced on disturbed sites during reclamation to discourage the use of an area for another activity such as recreation or grazing. When slash is replaced, it should be walked in with a tracked vehicle (e.g., cat, dozer) to ensure good soil contact. Slash replacement has several advantages. Slash can be a valuable source of native plant propagules and it



Natural regrowth of trees in a forested landscape.

provides microsites for plant regeneration and wildlife. It also returns nutrients to soil for the developing native plant community.

Natural recovery is often considered because it is easier and less expensive. However, there are costs associated with maintenance and monitoring that should be considered. This method should only be the treatment of choice after careful consideration. It might be used if all or most of the following criteria are met:

- the disturbance is a small area surrounded by a thriving, stable, native plant community (e.g., narrow pipeline rights-of-way, seismic lines or wellsites in otherwise undisturbed areas)
- appropriate native species or preferred seeds and mixes are unavailable for revegetation
- there are no concerns about persistent weeds and aggressive agronomic species
- there has been little disturbance to the topsoil
- the topsoil seedbank can be or was carefully salvaged and replaced
- there is a low potential for wind or water erosion
- soils are suitable (e.g., not crust-forming clays)
- rotational grazing pressure is light and the pasture is in excellent grazing condition



Slash is replaced on disturbed sites during reclamation to discourage incompatible activities such as recreation or grazing.

Wetlands dominated by *Carex* spp. (sedges), *Juncus* spp. (rushes), *Typha latifolia* (cattails), *Salix* spp. (willows) or *Sphagnum* spp. (sphagnum mosses) should be left to recover naturally, provided the hydrology of the area has not been significantly altered.



Natural recovery along a pipeline in northern Alberta, one year after installation.

Combined methods

A combination of active revegetation and natural recovery techniques can be used successfully on a variety of disturbances, including large diameter pipelines. The time needed for natural revegetation can be shortened with the addition of duff, sod pieces or slash over the surface. Sites where an active revegetation plan is proposed can sometimes benefit from sparse seeding. This allows for some natural recovery by native plants. Sometimes, annual cover crops (e.g., *Linum usitatissimum* - flax, x *Triticosecale* Wittmack - winter triticale, *Triticum durum* - durum wheat) are used on natural recovery

areas if erosion is a concern, but other conditions allowing successful natural recovery are met. When colonization by off-site native species is desired, use a higher proportion of short-lived species in the seed mix. Use of combined methods assumes that the majority of conditions for natural recovery are met.

With some planning prior to disturbance, small or large islands of native vegetation can be left undisturbed. This method is particularly effective for mining operations. These vegetation islands can act as sources of propagules, especially seeds, for the surrounding disturbed area. The island method allows faster recolonization by some species. This method also increases diversity more rapidly than seeding a limited mix of species.

Native plant species composition

It is important to know what native plant species composition best meets the needs of each project. Species lists for revegetation for Natural Regions and Subregions in Alberta are published in Gerling et al. (1996). These should be used as a guide. This reference also presents typical or average cover figures that can assist in determining proportions of species in revegetation mixtures. However, these are only a guide and are not meant to replace the need for a pre-disturbance inventory to determine species composition and relative abundances that exist on and adjacent to the proposed disturbance. Pre-disturbance evaluations should also take into consideration previous and ongoing disturbances, and their effect on the existing vegetation.

Although many of the dominant species in a given community are currently unavailable in commercial quantities, efforts should be made to include as many as possible in the planting/seeding mixtures. Their presence can be critical to sustaining soils and functioning plant communities. Regeneration of these integral species can often be encouraged by preserving and replacing the seedbank and by using low seeding rates.

Site specific conditions and end land use need to be considered. For example, landfills may require shallow-rooted vegetation to ensure that the final vegetation cover on the landfill does not breach the landfill cap.

Salvaging native plant materials

With some pre-construction planning, numerous plant and soil resources can be salvaged from a site prior to disturbance. The primary source of plants is the seedbank. The seedbank can be harvested using several methods. Timing is important. The moisture content of the soil must be such that handling soils won't cause compaction or loss of structure.

Native plant materials that can be salvaged include:

- topsoil
- seeds
- plants
- plant cuttings
- sprigs
- seedbank
- hay
- sod

Topsoil

Salvaging topsoil conserves native plant propagules. In addition to housing a seedbank and other propagules, topsoil also contains microbial flora and fauna that are instrumental in the decay of organic material, essential for nutrient and water uptake by plants (e.g., mycorrhizal fungi and rhizobial bacteria) and helpful in preventing



Topsoil salvage prior to construction.

plant diseases. The microbial flora and fauna also become a food source for larger organisms and are a vital part of the food chain. Topsoils also house macro-fauna such as earthworms and beneficial insects.

It is important to limit the manipulation of the topsoil. Generally, there is no need to screen, sieve or disturb the native soil structure and the plant propagules it contains. Direct placement of topsoil from the disturbance onto a prepared site is the best way to ensure the retention of the many resources it contains. Early success with this method has been recorded on oilsands tailing sites in northern Alberta (C. Qualizza, pers. com.). Two years of field data from this study suggest that direct placement of salvaged surface material, to approximately 10 centimetres deep, increased vegetation cover and diversity compared to standard soil replacement practices. If direct placement is not possible, topsoil can be stockpiled and stored for a short period of time. The longer the storage period, the greater the potential for compaction, a reduction in the micro- and macro-faunas and floras, a reduction in seed and propagule viability, and detrimental changes to the physical and chemical qualities of the soil (Thurber et al. 1990). Seeding topsoils that are to be stored for long periods (greater than one year) improves the viability of the topsoil.

Seeds

For large projects, plans should include a provision for the collection of native plant seeds from the site prior to disturbance. Seeds can be sent to commercial seed producers to be increased under controlled conditions. It is important to plan sufficient lead time if seed quantities need to be increased. Depending on the plant species, one to three years is required to produce appropriate quantities for use in revegetation. Seeds collected from small projects sites prior to disturbance can often be used directly for revegetation. However, it should be remembered that wild collected seed can have variable germination, and should be tested before seeding.

The initial seed quality is probably the most important factor for seed viability. Seeds should be ripe and collected just prior to natural dispersal. If they are collected too early, the moisture content can be too high. Seeds should be collected in such a way as to limit damage. Also, seeds of different groups of plants have varying longevity periods. Although some native plant seeds remain viable as long as 20 years, other seeds (e.g., *Populus* and *Salix* spp.- poplars and willows) have a short viability period and must be sown immediately.



Handpicking *Populus balsamifera* (balsam poplar) tree seeds.

These are often seeded directly on prepared sites as they are harvested. They can also be sown immediately in nurseries to produce plants to be transplanted to the revegetation site. Although many seeds can be stored for periods of several years at ambient room temperatures, low temperatures (2 to 6°C) are recommended to preserve viability and reduce insect damage. Storage conditions should be dry to avoid moulds and bacterial damage. It is critical that seeds be stored in rodent and insect-proof containers.



A seed stripper, pulled behind a tractor, is suitable for large, relatively uniform sites.



Hand-held seed strippers work well for small grass or forb areas.

Plants

Entire plants can be removed from a site prior to construction. Plants can either be removed in groups or individually. The limitation with the salvage of entire plants or plant groupings is that they must be planted immediately, or at least heeled-in carefully in a nursery until they can be used. Groups of plants can be used to create islands of native vegetation on a newly disturbed site. Individual plants can be transplanted to a revegetation site or placed in field nurseries where they can be used to harvest seeds and/or produce cuttings. Many aquatic plants used in revegetation are salvaged from comparable, nearby wetlands and sloughs. Aquatic plants such as *Typha latifolia* (cattails), *Nuphar variegatum* (yellow water lily), and *Carex* and *Juncus* spp. (sedges and rushes) can be established successfully by transplanting entire plants or portions of the rhizome with sufficient roots and buds. With both terrestrial and aquatic plants it is essential that the site where the plants are to be placed is similar to those where the plants were collected. Aspect, soil, moisture regime and water depth are examples of characteristics to consider.



Many aquatic plants can be salvaged from local sloughs and wetlands without damage to the existing community.

Cuttings

Many different kinds of cuttings can be used in establishing native plant communities. The different methods for taking cuttings are described in detail in many horticultural texts (e.g., Hartmann and Kester 1997). Because cuttings are exact genetic replicas of their parents, it is important to maintain diversity by taking cuttings from a variety of individuals. Many woody plants can be propagated by stem cuttings; either by hardwood cuttings of dormant wood or softwood, or semi-hardwood cuttings taken during the growing season (Smreciu and Barron 1997). Rooted stem cuttings or rooted rhizomes and stolons of herbaceous plants can also be successful, but this is generally a slow process compared to using seeds of herbaceous perennials.



Rooting cuttings of native plants in a greenhouse.

Salix (willow) stems are often harvested for use in rebuilding and revegetation of river and stream banks (Schiechtel 1980). Stems are cut (approximately 1.5 to 2 m lengths) and stored in water until they are placed



Harvested willow whips for placement on revegetation sites.

between layers of soil and coir (jute) fabric. With the correct moisture conditions, these cuttings will create a “living bank.” Similar techniques are used in ditches or on slopes where seasonal or occasional water flow can create rills and washouts. *Salix* (willow) cuttings are bundled and planted at intervals along the slope to retard the flow and spread the water movement over wider areas.

Sprigs



Sprigs are cut from existing sod using a sprigging machine.

Sprigging is a technique that has been tried with limited success in Alberta. It is a process used for grasses and herbaceous plants with robust rhizomes. Sprigging requires special machinery for both the harvest and placement of sprigs. Small sprigs (roots and shoots) are removed from an existing field (cultivated or native), usually after the field has been mowed. Sprigs are then planted with a special planter on a prepared site as soon as possible after the harvest. If sprigs need to be transported any distance, they should be protected from drying. Sprigs can be mixed with moist peat moss. The planting area can be rolled to ensure good contact between the plant material and the soil. Good moisture is essential and sometimes watering may be necessary for plants to establish. There are several inherent problems associated with this method. If sprigs are harvested from a site that is to be disturbed, there is little concern about damaging the harvest site. However, if sprigs are removed from a natural area, it leaves disturbed strips. These are areas where weeds and other aggressive problem species can invade. Nursery sites, grown specifically for the harvest of sprigs, are useful for native plant species that have very robust rhizomes (e.g., *Hierochloe odorata* - sweet grass). It is important that the harvesting sites are weed free. Rhizomatous weeds, such as *Cirsium arvensis* (Canada thistle) and *Euphorbia esula* (leafy spurge) can be spread quickly by using this method.



An individual sprig of *Festuca hallii* (rough fescue).

Seedbank

Seedbank salvage is carried out in one of two ways, either lifting the top three to five centimetres of soil without the rest of the topsoil or by vacuuming seeds from the ground surface. A seedbank topsoil lift is kept separate from the remaining topsoil lift, thus limiting dilution of the seedbank. This method works best with a reasonable depth of topsoil and a limited number of rocks. Topsoil should only be stored for short time periods (up to 48 hours). Vacuuming seeds involves using a specialized vacuum to obtain seeds from the soil surface. This method is particularly effective in grasslands, but can also be used in other native plant



Small, hand-held seed vacuum.

communities. Street sweepers have been considered (but not yet used to our knowledge) on sandy unconsolidated soils to take up the top few centimetres of soil containing seeds and rhizomes. Seedbank harvest should occur late in the season when a large number of seeds are ripe or have been released from plants.

In a recent Quebec peat reclamation, a live peat donor site was rotovated in winter. This surface material was spread over the barren peat with a manure spreader and the entire area was covered with straw (using a bail buster). Sphagnum and a few other species established on the site (W. Tedder pers. comm.).

Hay

In grassland communities, spreading native hay over sites where native plant establishment is desired is another method of introducing a variety of native plant species. This method may be less effective than other methods outlined in this publication, but may be used in combination with them. Hay can be harvested from areas prior to disturbance, then baled and stored. Then the bales are broken up and spread evenly on the intended area and crimped into place. Crimping ensures more contact with soil and holds the hay in place against wind and water movement. Alternately, grasslands can be cut using a forage harvester (Cerney 2000). The cut material is either spread when fresh, or dried and stored under dry and cool conditions. It is then placed on a prepared site. Plant material can be cut either when a wide variety of plant species are in seed (generally mid to late summer) or at particular times to select a species when its seeds are ripe (e.g., *Festuca hallii* - rough fescue in early to mid summer). Fields with persistent perennial weeds or agronomic plants should not be used as sources for native hay.



Bales of local native hay are split and spread over an area to be revegetated.

If hay is harvested from an undisturbed site (not from the area to be disturbed), it is important that fields are not harmed in the process. Harvesting should only occur once every two to three years from any one area so that original plant communities have sufficient plant propagules to be sustainable. Only a small portion of the site should be harvested in any one year. It is also important to use harvesting machinery that has a minimal impact on the soil and plant community.



Forage harvesters can be used to salvage the hay as a seed source.

Sod

Sod or vegetation islands are often used in large areas where they are placed at intervals in the disturbance. The remaining areas are sparsely seeded or planted to promote the expansion of the vegetation from the sods or islands. These methods allow a wide diversity of plant species to be obtained and much of the micro-flora and fauna can be taken with the plants. It is also effective for rescue of some significant plant species. Sod stripping and replacement is also used to quickly establish native plant communities where erosion is a problem (e.g., run-off channels, lakeshores and stream banks). Sod transplants work particularly well where the vegetation is low growing, such as grasslands. However, this method does not necessarily maintain all native plant species. Deep, tap-rooted species are often lost or severely set back. Sod can be stripped (with the top 15 to 30 cm of soil) and placed immediately or rolled or stacked, covered and stored for short periods before replacement after construction. Blading vegetation aside can also be effective, provided it is transplanted within



A concrete cutting blade is mounted on the front blade to cut sod.

48 hours. Transplanting can be as rough as sweeping the sod back into place with a prairie protector blade. Conventional sod stripping machinery is inadequate as it strips very thin layers of sod. Native sod can also be contract grown and transplanted (Macquarie et al. 2002).

Case study

A large scale native sod transplant was conducted on behalf of Alberta Transportation in the summer of 2000 (Western Rangeland Consultants Inc. 2000). A total of 4.1 ha (9 ac.) of a rare Peace River region natural grassland ecosystem was moved from a newly expanded highway right-of-way to other locations on a privately owned farm. This rare, remnant prairie area was dominated by intermediate oatgrass, probably due to extensive summer grazing by horses and bison. Soils were Black Solodized Solonetz. Prior to salvage, grazing was prevented for a year. In areas where litter accumulation was heavy, a rotary mower was used. Shrubs were mowed to a height of 10-15 cm.

The sod was cut with a 2.15 m (7 ft.) wide, deep sod cutter pulled by a Caterpillar 14G grader. A pavement cutter mounted on a skid steer was used for cross-cutting the sod into 2.15 m by 2.15 m pieces. A front-end loader was used to push steel pallets under the sod, lift, stack and load them on to semi-trailer trucks. The depth of the soil on the pallet was about 40 cm, rather than the prescribed 20 cm.

The receiving site and adjacent land was prepared by killing persistent perennial weeds and invasive agronomic species using tillage and herbicides for at least two years prior to sod transplantation. A grader levelled the receiving site prior to sod placement and provided a windrow of topsoil for crack-filling purposes. A John Deere 410E equipped with a front-end forklift and a rear mounted backhoe was used to pick up pallets from the semi-trailer and transport them to the placement site. Four labourers assisted with sod placement and crack filling.

Subsequent site inspections show that the sod transplants are regrowing successfully at the receiving site. Many forbs have flowered and native species are growing in the cracks of soil between the sod pieces.

Islands of vegetation from other types of plant communities can be excavated and placed in an area that is being revegetated. This works well with herbaceous communities. It also works with shrub and tree communities, provided that trees are not too large. It is important to ensure that large woody shrubs are pruned back to encourage establishment and growth. Island transplanting has some limitations. Large chunks of plants cannot be stored and in most cases this method is best suited to areas where the plant material can be placed on the establishment site immediately. Also, large pieces of tree and shrub communities are difficult to remove and the size of the island is limited by the type of machinery. Backhoes, front-end loaders and tree spades can be used.

It is important that sod or island plantings are placed in areas with similar soils, moisture availability, aspect, slope and winds. Poor placement is the most common reason for failure with this method. Sufficient moisture is important and these areas may need supplemental water. Moving plant material when it is dormant is most successful, particularly if storage is necessary.

Commercially available native plant material

Seeds



Seed production field of *Trisetum spicatum* (spike trisetum) during cultivar development at Alberta Research Council (Vegreville).

Seeds are the plant material of choice for most revegetation projects. They are also the least expensive method for introducing plant material to a site. Seeds used in revegetation projects should be free of weeds, invasive agronomics or other problem species. All suppliers of seeds should provide a Certificate of Seed

Bidding on seeds

Before going to bid for seeds (R. Dunne, pers. comm.):

- **know the acreage or kilograms required and method of seeding**
- **determine if species, varieties and quantities will be available when required**
- **ask if superior species or varieties are available**
- **determine alternative species if necessary**
- **outline your tolerance to weeds and other crops if ordering seed**
- **allow enough time for delivery and testing before materials are planted**
- **determine if a filler or carrier is necessary**
- **ask if there are any other constraints that may jeopardize goals**

Clearly defined specifications for ordering plant material (R. Dunne, pers. comm.) include:

- **ordering by scientific or botanical name**
- **specifying acceptable alternatives**
- **specifying acceptable genetic origin (same Natural Region)**
- **specifying tolerance for undesirable weed or crop species**
- **including minimum acceptable purity and germination**
- **determining acceptable seed test dates and whether a seed certificate is required**
- **determining seed testing procedures**
- **specifying whether seed should be mixed or unmixed**
- **asking for bag weight**
- **asking if the price includes delivery**
- **asking about any extra costs (e.g., mixing fee, inoculation charge, bag charge)**



Common seed production plot of the native forb, *Monarda fistulosa* (bee balm).

Analysis for each seed lot. This certificate indicates the type and number of seeds from problem species. It also provides information about the amount of inert material such as chaff. Although it is nearly impossible to obtain a seed mix that is absolutely contaminant-free, it is important to determine the types and amounts of contaminating species in each seed lot prior to preparing the final seed mix. Native seed lots should be free of prohibited, primary and secondary noxious weeds as defined by the *Canada Seeds Act* (Government of Canada 1996). Native seed lots should also be free of restricted and noxious weeds as designated by the *Alberta Weed Control Act* or by the local municipality. Seeds should be analysed for purity and germination. This can be done for a fee at official seed labs.

Seeds should originate from the same Natural Region in Alberta or a comparable region in Canada or the United States (Native Plant Working Group 2000). Alberta Sustainable Resource Development has more specific rules regarding seed provenance of reforestation species. Native tree seeds should come from the same ecodistrict, and in many cases from the same altitude (Alberta Environment 2001).

A native plant source list is published by the Alberta Native Plant Council (ANPC). This list can be ordered from ANPC (for website see Appendix 2). A market survey of the native plant industry (Woosaree 2000) contains information about recent availability of native plant material in Western Canada.

Cultivars

A cultivar, or named variety, is selected or developed from plant materials for improved agronomic traits such as ease of establishment, increased yield or disease resistance. Cultivars have documented performance records and their genetic distinctness is maintained by plant breeders. Their performance is more predictable than seed from wild harvest. Cultivars maintain their species name with a cultivar name attached (e.g., *Agropyron trachycaulum* 'AEC Highlander') and their origin is often quoted as the place where the breeding and selection was done (e.g., Vegreville, Alberta for Highlander). The source of the original material is usually a different geographical location (e.g., Crowsnest Pass, Alberta for Highlander). When selecting a specific cultivar for use in revegetation of a disturbed site, it is important to know the original genetic source of the material and where the testing and performance records were taken. Many of the cultivars used widely in Alberta were developed and tested in other parts of Canada or in the United States. Cultivars originating from similar Alberta Natural Regions (or their equivalent in adjacent jurisdictions) are most appropriate.



Seed production field of *Poa alpina* 'AEC Blueridge' (alpine bluegrass).

Common seed

Much of the native plant seed available at this point is common seed. There are three sources of common seed: seed of native species cultivars that has been downgraded to common status because it does not satisfy the rigid standards of germination, purity or genetic integrity required for pedigree status; seed propagated from native collected material in a cultivated setting; and, seed harvested from wild native plants.

In all cases it is important to know the source and origin of the material. Material should come from the same Natural Region. Often, common seed of a particular species comes from a distant geographic location, sometimes as far away as Europe. Seed from distant sources is unlikely to perform well.

Plants

Although seeds are the primary method for introducing native plant material to a revegetation site, plants can also be used. Young trees are planted for reforestation. Planting trees and shrubs is a technique used on small sites or in specific, smaller areas of larger sites. Herbaceous perennials or grass plants can be used for very specific sites, especially in grassland areas or at higher elevations such as in alpine areas.

Plants are available in two forms: containerized or bare root stock. Containerized native plants are generally more expensive, but often have higher survival rates because roots are not disturbed during planting. Poor survival can often be attributed to poor root formation due to inappropriate container size (Crofts and Carlson 1982). Containerized plants are cumbersome to handle and transport to revegetation sites, but can successfully be planted most times during the growing season (although are best planted early or late in the season when dormant). Bare root stock of native plants costs less than containerized material. They must be lifted and planted when dormant, and the roots are susceptible to drying during transportation and planting. They are not as bulky as containerized plants and therefore are simpler to handle. Trees and shrubs for revegetation use should be two years old (or have been forced over a single year in a greenhouse or controlled environment). Herbaceous perennial and grass plants should be at least three to four months old and have robust root systems.



Tree seedlings grown for reforestation.

The first step in obtaining the correct native plant material is to ask for it by species (using the scientific or botanical name) from a reputable grower. Mistakes, ranging from confusing two closely related species to the substitution of totally different species, happen because common, rather than scientific, names are used.

Purchasing native plant material



Growing trees for reforestation.

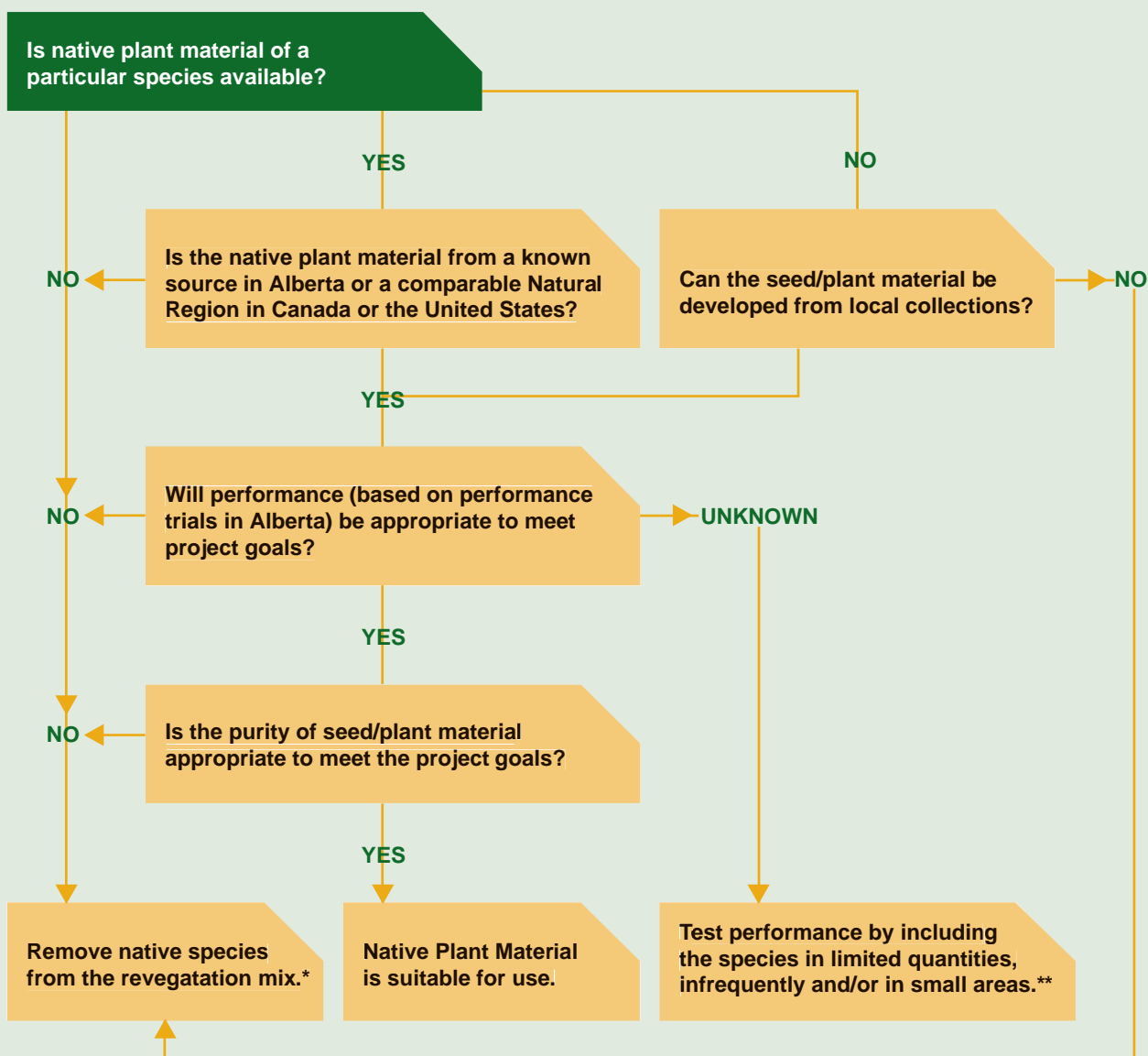
It is important to ask your native plant material supplier where the plant material is grown and what is the original genetic source. There are some native species that have wide ranges (e.g., *Koeleria macrantha* - June grass which is circumpolar). Native plant materials whose genetic origin is offshore (e.g., Europe, Asia or Australia) should not be used. Try to use materials with a genetic source from close to the project area, preferably from within the same Natural Region. Species moved too far north from their original genetic source may not be winter hardy and may not produce seed. Movement east or west can also cause problems due to changes in elevation or precipitation. Since different species can be successfully moved different distances, it is wise to consult with someone who has previously used the species in your area. If there is some question about ability of plant material to perform in a given area, it is prudent to use the material in small quantities at first.

It is a good idea to consult with the vendor about problems with species mixes (R. Dunne, pers. comm.). Problems can include:

- using seeds that only germinate at shallow depth with those that only germinate at greater depths
- mixes which may not flow through available seeders
- mixing aggressive species with non-competitive species
- using poorly adapted species or varieties
- mixing species that can separate in transit or in seed drills

Ask suppliers about hardiness, susceptibility to diseases or pests, appropriate spacing, the best containers to use, the best planting techniques, protection requirements from rodents, cattle and deer, the appropriate mulches or fabrics to use and maintenance requirements. When ordering native forb plugs, shrubs or trees, it is best to use contractors who grow and install their own materials or have a partnership with a nursery. During preliminary planning of a project, consultant fees should be considered for the people who produce the materials as they may have to look at the sites and analyse the soils. Consider adding a one, two or three-year maintenance clause into the contract, along with the installation.

Decision-making chart: sourcing native plant material (Native Plant Working Group 2000)



Notes: * prior to removing species from the revegetation mix, multiple attempts to secure alternative sources is recommended
 ** records of procedures and results should be maintained and made generally available

The next step in getting the right materials at the right time is to give the supplier as much lead time as possible. Larger projects, such as mines or dams, should have five-year budgets and provide three to five years of lead time. Other industries or municipal governments may only have one or two years of lead time. In general, the more scarce that the required plant material is, the longer the lead time needed. Sometimes, nature does not co-operate as a species may not set seed in a particular year. Seeds of some scarce species are only available for a short time following harvest. The best plant materials can be purchased at the lowest prices during slow seasons (e.g., January and February). Orders can be timed to coincide with the entry of new materials onto the market.

Seeds



Linum lewisii (wild blue flax) seeds.

In Canada, companies sell seed on a bulk basis and the customer receives the exact bulk amount of seed expected. If 1,000 kg is ordered then 1,000 kg is delivered. What is unknown in this system is the Pure Live Seed (PLS) of the seed lot. Unless the seed test results are with the seed, the reclamation contractor doesn't know how much bulk seed to spread (K. Lowen, pers. comm.).

In the United States, seed is bought and sold on a PLS basis. What is unknown in this system is the weight of the seed itself. If the customer asks for 1,000 kg PLS, the bulk delivery can be anywhere from 1,100 to 1,500 kg. The extra 100 to 500 kg is inert material, weeds and other crop seeds. The problem is not knowing how much bulk seed to spread on the ground until the seed is delivered.

Land managers of public land resources in Alberta have a responsibility to ensure that the integrity of native landscapes is not jeopardized by the introduction of

weeds and invasive agronomic plant species. Government agencies require a complete certificate of seed analysis (on an 100g sample) for each native seed lot used for reclamation purposes (AFRD and AENV, 2000).

Obviously, neither system is perfect. There are some regulations in both systems that help the buyer.

- In Canada, bulk seed must meet a minimum purity and germination. This is done through the *Canada Seeds Act* (Government of Canada 1996) which includes a seed grading system, grade tables and seed grade. By defining the seed grade to the grower, the seed company knows the seed lot has a minimum purity, germination and PLS. Unfortunately, most native seed is not certified under this Act. More information on grade standards is available from the Canadian Food Inspection Agency website (Appendix 2).
- In the United States, the regulations are not as stringent as in Canada. There are no seed grades, only certified or uncertified classes. There are no grades of certified or common #1 or #2. For some species, there are minimum PLS levels with certified and common seed. Seed regulations are set by the individual states and restrictions vary from state to state. The undesirable weeds change from state to state, as does the number of weed seeds allowed. Except for the prohibited and restricted weed categories, the tolerance for other weeds (e.g., an allowance for up to two per cent weed seeds) is much higher than in Canada. Native seed often carries a source identification tag that indicates the genetic source.

In both systems, the finite seed quality of a particular lot can only be determined by the Seed Analysis Certificate. Under the American PLS system, the seed certificate



Seed harvested from field plots prior to cleaning and processing.

determines how much bulk seed has to be seeded. Under the Canadian Bulk Seed system, the seed certificate allows calculation of PLS. With both systems, the information about weeds and other crops on the certificate allows the buyer to eliminate or select the particular seed lot (K. Lowen, pers. comm.) .

Many important seed sources in the native plant industry do not currently have a place in the pedigreed seed certification system because they do not fit the legal definition of a variety. Several U.S. states now have native grass seed certification programs, known as Pre-variety Germplasm Certification. The Canadian Seed Growers' Association (CSGA) has been asked to develop a similar program (R. Preater, pers. comm.).

Two certification classes are proposed: source identified and selected. Source identified class seed will be produced from a parental population where no selection or testing has been done. The seed will be certified for a specific geographic location. Seed production fields that are planted for seed increase and wild harvested material will be included in this class. Selected class seed will be produced from selected plants of untested parents that have promise, but not proof of genetic superiority or distinctive, identifiable characteristics.

The new native seed certification classes and CSGA tags will only provide assurance of genetic identity or purity. As in most American programs, a second tag will provide the assurance of germination, the date tested, the pure live seed (PLS) and a mechanical purity statement (of other crop, weed seeds or inert material) as required by federal seed legislation. The new CSGA standards and procedures will be posted with other regulations on Canadian Food Inspection Agency website (Appendix 2).

Plants

When purchasing plants, it is recommended that the origin of the plants be determined. They should be grown from seed from known sources within the same Natural Region. Plants should not be from wild

collections unless taken from areas slated for disturbance. A visit to the nursery or greenhouse prior to purchase is advised to ensure that all plants are of appropriate age and size and that all plants are robust and healthy. All plants should be appropriately hardened-off prior to placement at their final sites. Particular care must be taken in transporting plants from nurseries to the revegetation site. Plants that are in excellent condition in the nursery can arrive on-site in poor condition or dead due to poor transport conditions. Plants should be protected from drying by providing sufficient cover. This also avoids breakage due to wind. It is recommended that buyers include a monitoring component in contracts with suppliers.



Containerized native shrubs salvaged from local sites slated for disturbance.

FIELD OPERATIONS



Site preparation

Contouring

Contouring can occur at two levels. First, a site is contoured to match the surrounding landscape. For example, if the adjacent area is sloped, then the subsoil or mine spoil is graded to fit into the same slope. Micro-contouring or mounding occurs with the replacement of topsoils or reclamation materials at mine and oil sands sites. Mounding on such areas can result in more native plant diversity and better establishment of planted materials on the site. Care should be taken to re-establish drainage patterns across the site. This is particularly important where roads or pipelines are built through wetland areas. It is impossible to re-establish wetland vegetation in upland conditions.

Alleviating compaction

Compaction is a problem on industrial sites where heavy traffic makes a number of passes over the soil, especially if the soil has an appreciable clay content. If it is not alleviated, plant re-establishment and growth will be affected. If soil examination determines that there is a compacted soil layer, it is necessary to deep rip or paratill the site prior to final site preparation. Paratillers are used to relieve compaction with little mixing of the soil layers. Areas should be rolled after paratilling to ensure that the seedbed is not too loose.



Paratillers are used to relieve compaction with little mixing of soil layers.

Surface preparation



Imprinters, such as this Dixon land imprinter, leave a waffle-like impression as they pack soil.

Available topsoil is spread over the subsoil. Avoid bringing in topsoil from other sites, particularly from cultivated areas. This just adds weed seeds and unwanted nutrients to the site. A firm seedbed is important. On urban sites, the topsoil should be packed if the area is to be drill-seeded (Morgan et al. 1995).

In the dry prairie areas of southern Alberta, imprinters, like the Dixon land imprinter, have been used to prepare reclamation sites for drill seeding. Imprinters



The Hodder gouger can be used to create hollows.

leave a waffle-like impression behind as they pack the soil. They create microsites that retain more moisture and result in better germination and establishment of native seed. Other equipment, including Hodder gougers and tracked vehicles, is used in various areas of the province to imprint soil.

Sites that are broadcast seeded can be packed after seeding to ensure better soil to seed contact. Although also a seeder, the Kinsella acuroller packs and indents the soil and rolls the seeds into contact with the soil. This is a good solution on many sites.

Placing sod on a revegetation site requires some preparation. It is essential that there be good contact between the existing soil or substrate and the sod pieces. If this contact is poor, the sod will dry out and die. The roots must be able to grow directly into the existing substrate. Generally, a well-packed (not compacted) substrate is required. This can be achieved by rolling or packing the soil.

Existing vegetation

Weeds and problem non-native agronomic plants are the main consideration when preparing a site for native revegetation. If these are not controlled, revegetation efforts will fail. The control of weeds like the perennial *Cirsium arvense* (Canada thistle) and *Bromus tectorum* (annual downy brome) or problem agronomics such as *Bromus inermis* (smooth brome) and *Phleum pratense* (timothy) requires persistent attention. The preparation of an area with a high density of species like these may take several years. The cultivation of weedy areas should be avoided as it cuts and spreads rhizomes and stimulates the germination of more seeds in the soil. Mowing or burning does not control these plants either, although these methods can be used to remove dead vegetation and to set the plants back to a younger stage. Applications of a herbicide such as glyphosate, several times throughout the growing season, is usually effective. A combination of treatments, including a glyphosate application early in the growing season followed by grazing, also works well. This may have to



Weeds, such as *Cirsium arvense* (Canada thistle), must be controlled on the site and in adjacent areas prior to planting.



Plants, such as *Agropyron pectiniforme* (crested wheat grass), can prevent the establishment of native plant communities and need to be controlled on site prior to planting.

be repeated for several years until the seedbank and rhizomes in the soil are depleted. Other herbicides may be required to treat problem areas. Properly trained and licenced personnel must be employed to apply the herbicides.

Another approach can be used for small urban sites like schoolyards. In these cases, non-native lawns need to be killed or removed prior to planting native species. Black plastic can be placed over the vegetation and left until the grass below dies. Native plants can be placed into holes in the dead sod, or the area can be prepared for seeding.

Microbial symbionts

Almost all native plants form root associations with various soil fungi. The composite root-fungus structures are termed mycorrhizas. These associations provide native plants with greater access to water and nutrients (e.g., phosphorus and nitrogen) and in some cases they provide some measure of protection from diseases. There are five

distinct types of mycorrhizas based on the type of fungi involved in the association and the type of association formed (R. Currah, pers. comm.). These include:

- Vesicular-arbuscular mycorrhizas (VAMs) are formed by various fungi and are endophytes (grow within the cortical cells of the roots). These are associated with many of the forbs and some tree species (Currah and Van Dyk 1986).
- Ectotrophic mycorrhizas are formed by many of the mushroom forming fungal species in Alberta. These form an external mantle or sheath on the small roots of mostly tree species such as conifers.
- Ericaceous mycorrhizas are formed particularly with plants in the heath or heather family (e.g., *Ledum groenlandicum* - Labrador tea or *Vaccinium myrtilloides* - blueberry).
- Orchidaceous mycorrhizas are a particular type that form with plants in the orchid family.
- Dark septate endophytes are a particularly poorly studied group that form associations with numerous native plants in a variety of habitat types.



Ectotrophic mycorrhiza form an external mantle or sheath on the small roots of tree species.

Although little work has been carried out with the large number of fungal species that form mycorrhizas, these organisms are extremely important to the establishment and survival of most native plants. They are especially important in severe habitats. It is becoming clear that these organisms form an integral part of natural ecosystems and are essential for revegetation success. The fungi are not yet available commercially due to the lack of knowledge and basic research. Increased funding for research is needed before native mycorrhiza fungi can become available for use in revegetation. Mycorrhizal fungi exist in native soils. The salvage and proper

handling of topsoils can preserve the fungi and be a source for these organisms on some revegetation sites.

Rhizobial bacteria form specific symbiotic relationships with the roots of native legumes. As with mycorrhizal fungi, rhizobial bacteria help individual plants survive, grow and compete in harsh environments. They also fix atmospheric nitrogen, making it available to plants in low nitrogen habitats. Numerous strains of *Rhizobia* are commercially available for use with non-native legume species. Although some commercially available strains may function (most have not been tested) to some extent with some native legume species by forming nodules, these commercial strains are likely not the most effective strains. Some native strains of *Rhizobia* have been isolated and preliminary tests show some promise in enhancing establishment and growth of some of the native legumes (Smreciu 1993). Further evaluation of



Rhizobia nodules on the roots of young *Hedysarum boreale* (northern sweetbroom).

native rhizobial bacteria strains is required before making these available through commercial sources. As with mycorrhizal fungi, the preservation of topsoil is the best method available to ensure that the native rhizobial bacteria is available for native legumes planted at revegetation sites.

Seeding

Seeding rates



The number of desired plants per unit area can be extrapolated from similar, existing, native plant communities.

Due to the tremendous variability from species to species in seed size, performance, interactions with other species and differences in seeding and growing conditions, determining seeding rates (the number of seeds to plant per unit area) is more of an art than a science. However, some of the guesswork can be eliminated by gathering information about the species being used. In addition, understanding the short and long-term goals of the revegetation project is vitally important.

The optimal stand density to achieve these goals needs to be considered. As a general rule, the minimum stand density (to prevent erosion) for many grassland communities is 10 plants per square metre (Walker 2000). In semi-arid areas and in areas where weed competition is a concern, the optimal stand density should be increased to 25 plants/m². Where the long-term revegetation goal is to allow ingress of surrounding native species, the optimal stand density can be decreased (e.g., 5 plants/m²). It is often useful to examine similar, existing native plant communities to determine the number of desired plants per unit area of any one species. Once the optimum stand density has



Seeding rates are best determined from field research such as these grassland plots.

been determined, the practitioner has to determine the approximate number of seeds that have to be planted to achieve the desired outcome. There are two benchmarks in plant community development to consider. They are:

- Initial establishment is usually measured at the end of the first growing season. The factors that affect first year establishment are climatic conditions following seeding, the ability of a species to germinate and seedling vigour. Cultivars typically have a higher initial establishment than wild-collected seed.

Determining seeding rates

These general principles should be used to determine seeding rates for revegetation:

- **avoid high seeding rates that can result in early, dense stands that can choke themselves out and/or discourage the encroachment of native plants from adjacent and surrounding native stands**
- **use higher seeding rates on highly erodible sites**
- **use higher seeding rates, two to three times higher than recommended, if seeds are broadcast instead of drilled**
- **increase seeding rates if seed lots have high dormancy levels, and/or germination below 70 per cent**

- The second benchmark is plant maturity. This is the point at which the species are able to sustain themselves within the community. Typically, for grasses and forbs, this is measured three years after seeding. The factors that affect survival to maturity are climatic conditions, disturbance to the community (e.g., grazing pressure), competition among plants and rate of spread. Typically, 20 to 40 per cent of native grass/forb first year seedlings will reach maturity. Species with strong competitive seedlings after the first year of establishment will have an increased chance of reaching maturity.

It is wise to discuss proposed seeding rates with those who have experience with a particular species or mix in the local area. It is also important to keep good records of what was done and why. Results should be monitored. A spreadsheet program, based on pure live seed, has been developed by David Walker to calculate seeding and planting rates. It takes into account relevant factors (see Appendix 3). As a rough guide, drill seeding rates for grasslands should not exceed 10 to 12 kg PLS/ha. Below 10 kg/ha fillers may be required to enable the seeds to flow through the seeder. Forbs are usually seeded at two to five kg PLS/ha (Morgan et al. 1995). Useful information regarding calculating seeding rates for establishing pastures with native grasses is provided in Abouguendia (1995).



Undisturbed native plant communities can be used as models for revegetation.

There is no single rate that can be recommended for each species, for all sites. A general seeding formula has to be modified to adjust for the following factors:

- seed size
- germinability (viability and dormancy)
- mechanical purity
- seed and seedling vigour
- rate of spread
- seeding methods
- soil and site characteristics
- project goals

Seed size



Seed size varies with plant species and must be considered when determining seeding rates. Pictured above are *Gaillardia aristata* – blanket flower seeds.

Seed size is described by the number of seeds per unit, most often per pound (lb) or per gram. Seed weight charts can be found in different references, but few give a range of number of seeds per unit (Appendix 4) for approximate seed sizes of common species. For example, *Agropyron dasystachyum* - northern wheat grass, seed can vary from 352 to 550 seeds/gram. The seed size of any species changes depending on the growing conditions. Plump seed is produced under good conditions and thin seed under poor conditions. The exact weight per unit varies with the seed lot. A seed chart which lists seed as PLS/gram is specific to only that one particular seed lot. Seed weight charts only provide the general size of seed.

Dormancy

Some species (e.g., *Agropyron smithii* - western wheat grass) have a high percentage of dormant seed. The per cent of dormant seed decreases with the age of the seed. Dormant seed germinates over time, but it may take three weeks to three years. If other seed in the mix has established and filled in during that time, the late germinating seed will likely not survive.

Seed and seedling vigour



How well seeds germinate and emerge influence seeding rates. Pictured above is a *Lonicera involucrata* (bracted honeysuckle) seedling one year after seeding.

Some species are aggressive starters in that they germinate quickly and have strong, aggressive seedlings. Other species have a slow germination and may germinate over several months to years. The seedlings may be strong or weak, independent of the germination of the species. Seed vigour refers to how the seeds germinate. Seedling vigour refers to how aggressive the seedlings are after germination or emergence. There are few rules to follow, but some generalizations can be made with seed size and vigour. In general, larger seeded species germinate quickly and produce strong seedlings. This is true for natives as well as agronomics. For example, some of the *Agropyron* spp. (wheat grasses) have large seed and start well. Usually, small seeded species germinate more slowly and produce weaker seedlings initially. It is interesting that small seed is produced on a plant in high numbers, but it lacks the vigour to germinate and establish quickly. Essentially, what they lack in vigour they make up for in numbers. Seed size varies within the species as well. Seed lots with larger seed are more vigorous than those lots with small seed.

Rate of spread

Some species (e.g., *Agropyron dasystachyum* and *A. smithii* - northern and western wheat grasses) spread vegetatively by rhizome following establishment. Consideration should be given to lowering the initial per cent of such species in a seed mix.

Seeding methods

Seeds can be drilled into the soil or broadcast over the surface dry or in a slurry with water (hydroseeding). In each case it is extremely important not to place the seeds too deep and to ensure good soil/seed contact. Some native plant species (e.g., *Koeleria macrantha* - June grass) have specific light requirements for germination. Those that require light should not be drilled. Alternatively, seeds that require dark conditions should be covered when seeded.

Drill seeding

The advantages of drill seeding are: less seed is required than with broadcasting, seed is in direct contact with the soil, seeding can be done on slightly frozen soils or in slightly windy conditions, and seeding is usually completed in one pass.

There are various seed drills available that have been either adapted from agricultural use or designed specifically for native seed. All the drills work well if the project site has been evaluated properly for equipment needs and the operator is competent. Some examples of



Truax seed drill.

these seed drills are the Truax, Tye, Nesbit and Great Plains. A rangeland seed drill (e.g., John Deere Rangeland drill or John Deere power drill) can also be effective. Power air seeders can also be used, but it is difficult to ensure shallow seed depths for small seeds with these devices. Although drill seeders work more efficiently with large amounts of seed in the boxes and larger seeds, seed carriers such as roasted grains, vermiculite, sand or chick starter can be used with small or chaffy seeds to improve flow and bulk up seed volumes. Drills also require cleaner seed than do most broadcasters. The resulting row effect can be limited by cross seeding at right angles to the first pass (after adjusting the seeding rates). All seeders must be calibrated for each mix to get the most effective use of native seed. This should be done according to the equipment's instructions, based on the seeding rate.

Broadcast seeding



A chain harrow can be used following broadcast seeding to rake in seeds.

One advantage to broadcast seeding is a more random seeding that results in a more aesthetically pleasing plant establishment pattern in the short-term. In remote areas, with little or no ground access, aerial broadcasting is often the only way to revegetate disturbances. As a general rule, small seeded species (greater than 2,000 seeds/gram) should be broadcast rather than drilled as drills place the seeds too deep (B. Pelech, pers. comm). The biggest disadvantage to broadcast seeding is that more seed is required per unit area as the seed is placed on the surface with less soil/seed contact. Sites that are broadcast seeded should be packed after seeding. This ensures better soil to seed contact. If rolling is not possible, seed should be either raked in by hand or by using a chain, tire or diamond harrow to promote good seed to soil contact. Cultivators should not be used because they set the seed too deep in the soil.



Nodwell mounted power seeder.

Seeds can be broadcast by hand, hand-held seeders, a powered seeder mounted on an all-terrain vehicle, or by helicopter or fixed-wing aircraft. Helicopter broadcast seeding is best suited to projects with a reasonable staging distance. The ferrying distance from the project to the staging area should not be much more than 15 km or this technique may not be cost effective. Fixed-wing aircraft are best for broadcast seeding bigger projects that are close to an airstrip. Seeding from the air can be rather imprecise. It is best to seed in calm conditions because seeds, particularly small seeds, are often blown off-course.

The Kinsella acuroller is a broadcast seeder that was discussed previously (see Surface Preparation under Site Preparation). This machinery is designed to pack the seedbed, broadcast seed close to ground level and roll the seed into the soil. Truax broadcast seeders perform similar functions. They have been used successfully on many sites, but cannot be used on sites with large rocks or steep sites.

Coated seed

Seed coating can improve the flow characteristics of seed through broadcast and drill seeders. The flow characteristics of small seeds, or seeds with hairs, awns or bristles, may be improved with the addition of a smooth coating. The increased diameter added to small seeds by coating them can improve their ballistics if aurally seeded. Coating also provides a method to introduce seed inoculants, if called for. An alternative to coating seed is to add a carrier to the seed drills (discussed previously). Coated seed must be kept dry or it will clog the dispersal mechanism of the broadcast seeder. Be very careful when using coated seed in a seeder with an active agitator as the coating may be

knocked off the seed and gum up the seeder. Limiting the amount of coated seed in a mix or using a seeder with a less active agitator may help to alleviate seeder clogging. If coated seed is to be incorporated into seed mixes, it is important to remember that the coating adds weight. This must be considered when calculating amounts required and ordering seed (Appendix 3).

Seeding time



Warm-season grass *Bouteloua gracilis* (blue grama).

Seeding is best done when there is sufficient soil moisture and sufficient warmth for germination. It is suggested that cool soil temperatures can favour the establishment of native plants over other non-natives (Walker 1996), so there may be advantages to sowing in early spring or late fall. Seeding during the hottest, driest periods should be avoided for most species in most areas because the potential for drought is high.

Cool-season native herbaceous species (e.g., *Agropyron* spp. - wheat grasses, *Bromus ciliatus* - fringed brome and *Geum triflorum* - three-flowered avens) are best seeded

in early spring. If seed dormancy is a concern, late fall seeding of cool-season plants allows them to take advantage of cold temperatures or the freeze-thaw cycles to break dormancy (e.g., *Stipa* spp. - needle grasses). Seeding too early in the fall can result in seedling emergence in the same season and high seedling mortality due to cold temperatures and drought. In particular, native legumes have winter-killed due to fall seeding. However, if seeded late enough they will not germinate until spring. This is especially important if seeds have been scarified prior to seeding.

Warm-season native herbaceous perennials (e.g., *Bouteloua gracilis* - blue grama, *Petalostemon purpureum* - purple prairie clover and *Liatris punctata* - dotted blazing-star) should be seeded after the soil has warmed up (greater than 10°C) in late spring. Native annuals (e.g., *Cleome serrulata* - bee plant) can be seeded in early spring. Those with stratification requirements (e.g., *Helianthus annuus* - annual sunflower) can be planted in the fall. Winter annuals or biennials (e.g., *Oenothera biennis* - yellow evening primrose) can be sown in late spring or late summer. They will likely complete their life cycle and set seeds the following season.

Woody, native plants (trees and shrubs) should be seeded in late summer or early fall. This should be late enough that they will not emerge prior to freeze-up. Much of the dormancy in seed lots of woody plants will be overcome by the exposure of the seeds to winter conditions. Some species (e.g., *Symphoricarpos* spp.- buckbrush and snowberry and *Viburnum* spp.- bush cranberries) require exposure to at least two winters prior to emergence. Early spring seeding of pre-treated seeds can also be effective, but is somewhat more difficult and costly.



Amelanchier alnifolia (Saskatoon berry) can be seeded in the fall at most sites.

Planting

Planting rates

Planting rates for plugs, cuttings and containerized plants vary according to species and the type of plant community being targeted. Reforestation guidelines recommend a stems per hectare measurement as a guide to how many plants to place in a specific area (Alberta Environment 2001). For other revegetation projects, the following native plant densities are recommended (D. Everts, pers. comm; J. Morgan, pers. comm.):

- grasses – 10 to 15 plants/m²
- forbs – five to nine plants/m²
- shrubs – one to two plants/m²
- trees – a distance of approximately two metres apart

Large competitive plants should be planted less densely than those that remain small. The number of plants placed in the ground depends on a number of factors: the eventual desired density, other plant species seeded or planted on the site, the type of plant stock being used (containerized or bare root stock, or unrooted cuttings), the age of the material, the health of the plants and the site conditions. Expected mortality due to site conditions should be estimated and accounted for in the quantity of plants placed at a site.

Determining planting density

The following principles can guide decisions regarding planting densities:

- **smaller plant forms (herbaceous perennials) are planted more densely than larger forms (trees)**
- **bare root stock and cuttings are planted more densely than potted plant material**
- **younger, smaller or weaker plant materials are planted more densely than older, larger and hardier, healthier plant material**



Transplanting trees for reforestation.

Planting methods

As mentioned previously, it is important that plants be well cared for during transportation. Although placement of transplants and cuttings is well documented in basic horticultural texts, there are a few points that need to be mentioned. Plants should be positioned such that they are level with the surrounding ground surface. A small trough should be left around each plant. This allows rain and moisture to collect. At high elevations or in colder regions, frost heaving pushes transplants upward and out of the ground. This not only dries the exposed roots, but allows moisture to be wicked upward from lower soil regions. Complete drying of the plant occurs. In these areas, plants should be placed lower than the surrounding ground level and the depressions around each plant should be deeper. It is also important that a small area around each plant be free of other vegetation. This prevents unnecessary competition and discourages small mammals from seeking shelter around the base of the plant and



A tree spade can be used to transplant large material.

browsing on them. All transplants should be watered-in at planting time. Mulches can be used in small areas around each plant to reduce competition.

A number of tools are available for planting. Most of these are hand tools that push aside the soil as the tool is pressed into the ground. The plant is dropped into the opening and the soil is released and tamped slightly around the plant. These types of tools are used extensively for tree planting and work well in forest soils. At high elevations and in grasslands (especially on hard soils) a soil auger (ship auger) method is recommended. A hole (larger than the diameter of the plant plug) is augered into the soil at an angle to the surface, the transplant is placed upright in the hole and soil is filled in around the roots. This allows the plant some room to establish quickly into a robust individual that can then penetrate the adjacent heavy or compacted soils.



Dryland plug transplanter.

Several mechanized seedling transplanters are available. These include the modified Whitfield transplanter, the Forestland transplanter and the Dryland plug planter. They are used on mine sites in areas of North America. Other equipment used in transplanting includes tree-spades of various types, bobcats, backhoes and front-end loaders. These are used for larger material and for transplanting large plugs of native plant material that has been salvaged from other sites. Regardless of the equipment used in placing transplants, equipment operators must be well trained and have a basic understanding of the various practices being used.

Aquatic plants are often lifted from native settings and placed directly into wetlands using a backhoe or an excavator. When planting most aquatic plants (e.g., *Typha*, *Carex* and *Juncus* spp. - cattails, sedges and rushes), it is important to ensure that the roots or rhizomes are anchored in the mud in water of a suitable depth.



Backhoes are used to lift large plugs of native plant material. They are often used for aquatic plants.

Planting time

As with seeding, sufficient moisture is necessary for successful transplanting. Generally, plants of both herbaceous and woody native plant material have the best chance of survival if transplanted when they are still dormant in spring. This ensures that the root systems have time to grow and establish during the growing season. Alternatively, transplants of woody material can be placed in late summer or early fall. Deciduous material is best placed after the leaves have dropped, whereas evergreen material can be transplanted after the onset of dormancy. This allows the plants time to establish roots prior to freeze up, but reduces water loss. In areas where there is little time between the onset of dormancy and freeze-up, it is recommended that transplants be placed in spring, preferably prior to

flushing. All transplants should be hardened-off prior to planting at revegetation sites. The direct placement of woody cuttings (e.g., *Salix* spp. - willows, *Populus* spp. - poplars), generally taken in winter and maintained in a frozen state, should occur as soon as possible after snow melt. Rooted softwood and semi-softwood cuttings are best placed at the site in late summer, or early fall after leaf drop.

At high elevations the timing of planting is particularly tricky. Plants placed in spring are often already growing and can suffer heavily from transplant shock. Plants must have robust root systems and must be hardened-off (kept cold and relatively dry) for at least two weeks prior to planting in such harsh environments. An alternative is to plant them cold. The plants are frozen (dormant) and planted in the late fall in a frozen state. Aquatic plants are generally adaptable and can be transplanted at any time during the growing season. It is best to complete transplanting several weeks prior to freeze-up so plants are well established before winter.

Ensuring establishment success

Erosion control

Cover crops

The decision to use a cover crop should be based on an evaluation of the site type, available moisture, potential competition or other effects on, native seedlings and potential grazers. Cover crops are generally only used where erosion is a concern (i.e., due to steep slopes or on sand dune areas). Cover crops should not be used in drought conditions where the crop will compete with native plants for moisture. Any crop that is used should be non-persistent, non-invasive and should not have any allelopathic effects. A Certificate of Seed Analysis should be obtained for cover crop seed. If a cover crop is used, it should be seeded at no more than half the normal seeding rate. Annuals should be seeded separately from the native mix in the fall. If the cover crop seems to be competing with the native plants for moisture and light, it can be mowed. The timing of construction must also be considered when deciding to use a cover crop. For example, if a disturbance is seeded in November, a cover crop would not achieve the goal of protecting the soil from erosion over winter.



A cover crop mixture that is being used on sensitive natural recovery sites in southern Alberta is certified fall rye and flax, seeded at half a bushel per acre.

Seeding of annuals is not recommended for pastures that are grazed early in the spring in southern Alberta. Either *Triticum durum* (durum wheat) or *Triticum aestivum* (winter wheat) is favoured in southern Alberta because they do not attract grazers as much as barley or oats. The use of barley and oats has led to overgrazing by cattle and wildlife in some forested areas of the province. A mixture that is being used on a trial basis on erosion prone natural recovery sites in southern Alberta is certified fall rye and flax, seeded at less than half a bushel per acre each. The flax is relatively unpalatable and protects the soil in the first growing season and winter. Cattle graze the fall rye heavily the first year and firm up the ground with their hooves. The rye is relatively unpalatable the second year and provides soil protection and snow trap. Some shelling occurs on both the rye and flax. This helps retain ground cover as the native species establish themselves (B. Cairns, pers. comm.).

Regreen is a relatively new product that is a cross between *Triticum aestivum* (wheat) and *Agropyron elongatum* (tall wheat grass). It has sterile heads, gets as tall as grain and has some palatability. There is minor survival of plants to the second and third years after seeding. Regreen has not undergone extensive field testing under Alberta.

Straw/hay crimping

Planting into stubble from previous year's crops is a common agricultural practice in areas where winds are prevalent and erosion potential is high. Although this is rarely an option on revegetation sites, artificial stubble has been used on numerous projects (Walker 1987, Smreciu and Hobden 1992). It has been used extensively in southern Alberta to prevent soil erosion on wellsites and

pipelines. Crimping is a soil stabilization technique that presses straw (or native hay) into the soil in a wave-like pattern. Crimping is used where:

- soils after disturbance are loose and friable
- germination of seed will be delayed, possibly until the next season
- poor snow cover and/or high winds are an issue
- snow/moisture catchment is desired
- animal grazing is difficult to control
- soils are coarse textured and sandy

Straw is spread over the site at a rate of approximately 2,000 kg/ha, providing a cover up to 2.5 cm (1 in). Somewhat greater cover can be used on sandy soils. A straw crimper is used to press one end of the straw into the soil, pushing the other end upright. The vertical wheel blades on a crimper bend the straw fibres and push the straw into the soil with little disturbance or churning. An additional pass at right angles can be done if prevailing winds come from more than one direction.



Finn straw crimper.

Crimping helps provide protection for emerging seedlings, traps snow and allows water to infiltrate the soil. Wheat straw is the most popular material for straw crimping. It usually provides erosion protection for a single growing season. Flax straw is used on sites that are susceptible to erosion. It provides some protection for up to two years.

Concerns about the quality of straw being used for crimping have arisen in recent years. Often, the source of straw has not been adequately checked and the use of weedy material has caused the spread of persistent weeds such as downy brome. On public land in southern Alberta, the use of straw for crimping has to be cleared

by the local public land manager. The source of the straw must be known and an inspection of source fields for weeds must be done. Samples of bales should also be analysed by a laboratory for seeds of weeds and other problem species.

Mulches



Close up of the discs of a straw crimper.

Wood chips, bark and cones have been used extensively in horticultural situations. They are used to reduce weeds and other persistent invaders, maintain soil moisture and modify soil temperature fluctuations (Smreciu and Barron 1997). Wood chips can be used successfully where trees and shrubs are planted or seeded. Although this method is extremely effective, it is generally only used in small areas. It is particularly useful where trees and shrubs are planted into a thick understorey. If forbs are seeded, a wood chip mulch can act as a barrier to emergence or can lead to weak seedlings.

Wood chips



Spreading clean aspen chips on a revegetation site.

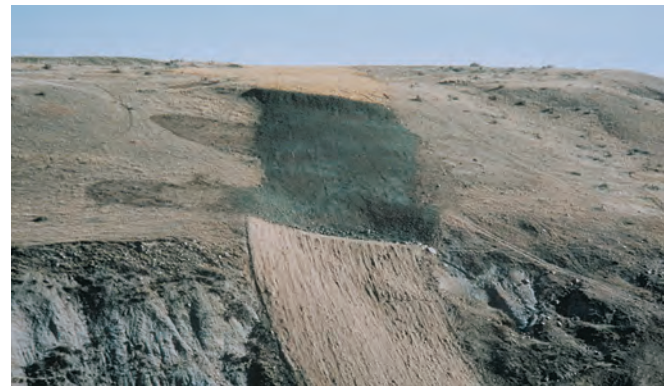
Wood chips are placed around the plant to discourage competition from the understorey growth. Wood chip mulch maintains a buffer zone between the young trees and shrubs until they can establish and compete on their own. It is important that chips are disease-free to avoid transmitting diseases throughout a revegetation site. It is advisable to use clean winter chips (i.e., without leaf litter) to avoid disease problems. Chips from softwoods (e.g., *Pinus* spp. - pine, *Picea* spp. - spruce) can acidify soils. They also contain tannins that can potentially affect establishment and growth of some plants. Generally, poplar chips are used.



Picea glauca (white spruce) seedling growing through a wood chip mulch.

Erosion control products

Organic erosion control products of various types have been used to hold soil in place on revegetation sites in all parts of Alberta. Only natural fibre netting (e.g., jute or coir fabric) should be used. It comes in various weights and sizes. Netting is generally used on small areas, especially on slopes that are highly susceptible to water and wind erosion. Heavier weights should be used in more erosion prone areas. To avoid trapping animals in the material, the use of netting is discouraged in high density wildlife areas. Tackifiers are non-toxic mixes of wood fibre and “glue” that are combined with water and sprayed on topsoil piles during construction. Tackifiers can prevent wind erosion for a few days through several weeks, depending on the product.



Various erosion control methods (straw crimping, tackifier and coir matting) on a steep slope.

Other erosion control methods

A variety of other erosion control methods have been used on individual sites to address unique erosion concerns. Water movement has been effectively controlled by the placement of rock. Straw bales can also be placed on sandy sites to form cells to decrease wind velocity and decrease soil movement. In forested areas, logs or brush are often rolled back onto disturbed sites and flattened by construction equipment.



Straw bales are laid out in cell patterns to reduce wind erosion on sandy soils.

Berms created from brush or the construction of waterbars (a combination of angled ditch and downslope berms) also slow or direct water movement down slopes. Live willow whips, fastened into bundles (facines) can be planted into slopes or along banks of water courses to slow or reduce the effects of water movement, or to stabilize sharp banks (Gray and Sotir 1996). The establishment and survival of live willow cuttings is variable and moisture dependent. Better results may be obtained with willow seedlings that are nursery grown from stock collected on-site.



Bundles of willow whips are placed along banks – as they grow they will stabilize the bank.

Fertilizers

Fertilizing native species is not presently recommended for most native revegetation or reclamation work. In particular, nitrogen seems to promote weed growth which competes with the native plants. Adding fertilizer may actually slow down natural processes by favouring early successional species on the reclaimed area. It can also cause grasses to become dominant on a site, lowering species diversity. The use of a native nitrogen fixer, such as legumes (e.g., *Vicia americana* - American peavine or *Astragalus* spp. - milkvetches), may be a reasonable alternative. The addition of phosphorous may be beneficial to assist the establishment of native seedlings, especially on sandy soils. More research is required to understand the relationships between fertility and native plant establishment, competition and succession.

In-planting

In-planting, the placement of additional plant material after initial vegetation has been established, is a way of increasing species diversity and of accelerating the natural successional processes. Either seeds or transplants can be used for in-planting. Seeds of late seral native species can be broadcast following the initial establishment of vegetation on site. Unopened cones of coniferous trees (e.g., *Picea glauca* - white spruce or *Pinus* spp. - pine) or berries of shrubs (e.g., *Cornus stolonifera* - dogwood, *Prunus virginiana* - chokecherry, *Elaeagnus commutata* - wolf willow) have been used successfully to increase cover and diversity on revegetated sites (Smreciu and Barron 1997). More frequently, in-planting involves the transplanting of trees, shrubs and herbaceous perennials into an established matrix of low growing cover. The existing cover can provide the required shade or protection for the newly placed plants. However, if the cover is too dense, transplants are not able to compete for space, water and nutrients. Dense stands of grasses and forbs can also house large populations of small rodents (e.g., mice) that cause excessive damage to transplants.



Placement of additional plant material after initial vegetation has been established can increase species diversity and accelerate natural succession.

MANAGEMENT



Managing an established plant community

Site management is an important part of ensuring the establishment of native plant communities. Management is an important component of assisting rare plant mitigation sites to become sustainable. The objectives of site management are to:

- control weeds and agronomic species
- enhance seed production
- enhance wildlife habitat
- provide grazing productivity
- improve ecosystem health
- improve aesthetic appeal
- promote biodiversity

Numerous management methods are used to maintain and improve a site following planting. These include:

- weed control
- burning
- mowing
- grazing
- protection
- in-planting through the placement of additional seeds or plants

These treatments can be used alone or in combination.

Although management is generally considered for the short-term, limited management may be required over a longer period. Native grasslands are well adapted to grazing and need light to moderate grazing in order to remain productive and healthy. Grassland restorationists have found that introducing grazing, mowing or burning beyond the establishment phase of the revegetated area is an effective means of promoting successional development of the plant community.

Weed control

Annual weeds are generally a transient problem. They can prevent soil erosion and protect emerging native seedlings from extreme environmental conditions.

Annual weeds should be controlled if they compromise the establishment and growth of the native plants. Once native perennials are established, annual weeds can generally not compete. Mowing is often used to control annuals. Mowing and baling should occur just as plants are coming in to flower, when the plants are the most vulnerable. This practice also reduces the number of viable seeds produced, alleviating problems later.



Annual weeds should be controlled if they compromise establishment and growth of native plants.

Perennial weeds and problem agronomic species are a much greater concern. These plants compete with the native species for nutrients, water and space. They are generally more aggressive than the native plant species and if left uncontrolled, eventually take over entire sites. Although manual control, which involves digging and removal of the offending species, is the most effective method of control, this is rarely possible except on extremely small sites. Careful application of herbicides or combination treatments that include herbicides, grazing and/or burning are recommended to control troublesome perennial species. Local agricultural or forestry field personnel should be consulted as to the types of herbicides that can be used for specific perennials. Chemicals can only be applied by a trained and licenced applicator.



Perennial weeds, such as *Cirsium arvense* (Canada thistle), compete with native vegetation for nutrients and water.

Although numerous species of weeds can create problems on particular sites, a specific mention of *Bromus tectorum* (downy brome) must be made. This introduced species has become a major problem in the Great Plains of North America and is becoming a problem in the southern parts of British Columbia, Alberta and Saskatchewan. *Bromus tectorum* thrives on medium to coarse textured soil types (sandy or gravelly soils) and in low to medium



Bromus tectorum (downy brome) can be a problem on coarse-textured sites in southern Alberta.

precipitation zones. It is currently listed as a nuisance weed in the *Alberta Weed Control Act*, but has been elevated to noxious weed status by several municipalities in Alberta. It can displace native grasses that are much more nutritious for cattle and its sharp awns can cause lump jaw in cattle. It is difficult to get rid of once it is established. It can also spread quickly and enhance the increase of other weeds. It is important that this weed species not be introduced into revegetation project sites. Therefore, it should not be tolerated as a contaminant in any seed lot. All steps should be taken to eradicate this weed if it appears on a reclamation site (Gerling 2000).

Burning



Prescribed burning can remove excess litter, stimulate flowering and seed production, and reduce disease and insect damage.

Prescribed burning on a site can remove excess litter, stimulate blooming and seed production, and reduce disease and insect damage. Although fire management is usually relatively inexpensive, there are some concerns about the use of fire in vegetation control. These include a public fear of fire, the possibility of a fire getting out of control and problems with smoke. Good communication between land managers, land users and local populations is important. Burning must only be done by trained, experienced personnel. The timing of burns is extremely important for both vegetation management and safety.

Mowing or haying

This refers to the removal of most of the above-ground biomass. It is an alternative to grazing, herbicide use or burning. It can be used in combination with other techniques to manage revegetated areas. Mowing removes

excessive litter, promotes species diversity, increases seed production and helps control undesirable plants. The timing of mowing can be used to accomplish different results. Mowing early is helpful with the management of weeds and problem species. Mowing should occur prior to seed dispersal by these species. Late mowing, following seed ripening, stimulates seed dispersal. Late mowing, following seed dispersal can also stimulate flowering and seed production in subsequent years.

Grazing

Properly managed grazing on mature revegetated sites can remove excess litter, control undesirable plants, increase seed production and enhance wildlife habitat. Livestock grazing requires extensive monitoring and usually requires the placement of fences so grazing can be deferred until plants are well established. The erosion potential on the site, the grazing pressure expected and the condition of the surrounding vegetation should be the major factors in determining the type of fencing used. Once the vegetation is established, the fences should be removed to prevent the accumulation of excess litter. If there is a concern about erosion or overgrazing, fences can be left in place longer.



Grazing revegetation sites can remove excess litter and control undesirable plants, increase seed production and enhance wildlife habitat. Sensitive sites should be protected from overgrazing.

Site protection

Revegetated sites often require protection during the establishment period. This can be accomplished by using traditional or temporary electric fencing. Whether to fence or not is a decision that should be reached after consultation with landowners and land managers. Where cattle will be in the vicinity of the revegetated area, grazing patterns and the pressure and timing of grazing

have to be considered. The condition of the adjacent pasture must also be taken into consideration, particularly in drought prone areas. Sometimes grazing can be delayed until later in the season. Where grazing pressure is likely to be high, the use of electric fencing can effectively prevent damage to seedlings during the establishment year.

The attractiveness of the revegetated areas for grazing or browsing animals is also a consideration. Cover crops like barley or oats are often too attractive to both domestic animals and wildlife. This results in damage to the project area. The use of annual cover crops that grow quickly and are unpalatable when mature, like *Triticum durum* (durum wheat), is effective as long as the area is not grazed in spring when the crop is still young and tender.

Where fences are erected to reduce human access, signs explaining the project and the sensitive nature of the revegetated area are effective if placed at common access points. Community education and involvement are crucial to the general acceptance of native revegetation projects, particularly in urban areas.

In open areas or in areas prone to high winds, snow fencing can be used during the establishment period. Fences trap snow (moisture) during the winter and break drying winds during the summer. Snow fences are particularly helpful on small, urban sites to maintain snow cover.



Snow fences protect revegetation sites from drying winds and trap snow to maintain moisture.

Woody plants are often browsed by wildlife including deer, moose, rabbits and mice. They can also be removed completely by beaver. Some woody species, such as *Rosa* spp. (rose) and *Elaeagnus commutata* (wolf willow), respond to browsing by putting up suckers and increasing the number of stems per unit area. This can be beneficial to revegetation success (Smreciu and Barron 1997).



Animal repellants can be applied to plants for the establishment period to discourage browsing.

Other plants do not respond in this way. They must be protected. There are two ways to avoid revegetation failure due to animal foraging damage. The first is to plant in much larger quantities than are required in the end. This can be more expensive initially, but more economical in the end, especially on large sites. The other method is to apply commercial animal repellents for a period of up to three years (Walker 1996, Smreciu and Barron 1997). Animal repellents can be painted or sprayed on small trees and shrubs. Although time consuming, this can be effective on smaller sites against rabbits and deer (D. Everts, pers. comm.). Wire cages can also be used to protect trees from beaver on small scale projects, especially urban sites. These are rarely feasible with large scale plantings. In rare cases, areas are fenced to eliminate natural browsing pressures for a period of one to two years.

MONITORING & ASSESSMENT



Record keeping

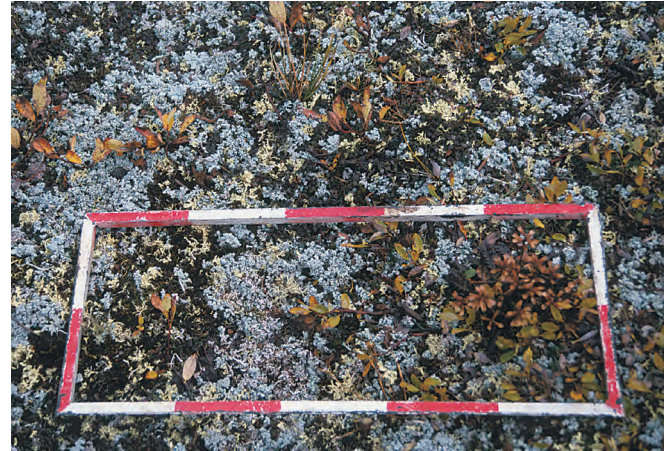
Keeping records of every step in any revegetation program helps manage the specific site and assists with the planning and preparation of future disturbances. Data should include information concerning (adapted from Strong 1999):

- topsoils - type, where they came from, storage times, stockpiling methods (including whether they were planted in storage and with what) and placement depths
- site preparation - what was done, what equipment was used and when each task was carried out
- plants and seeds - type of plant material, suppliers, genetic sources, seed analysis certificates, seeding rates and planting densities, and species composition
- other techniques used - ripping, paratilling, mulching, fertilizing and fencing
- management and mitigation activities
- dates when each activity was done
- maps indicating where each activity was carried out



Evaluating the success of revegetation on a prairie site.

Rare plant mitigation monitoring



Using standard methods, revegetation projects should be monitored to determine success or failure of plant establishment.

Monitoring to determine the success or failure of rare plant mitigation efforts is a critical part of any revegetation assessment program. Monitoring should occur at each rare plant mitigation site on a project. As a minimum, information should be collected on presence, absence, number and size of plants. Whether or not plants are propagating and how they are propagating is also important to determine the sustainability of rare plants. Information on survey and monitoring techniques is available in the *ANPC Rare Plant Survey Guidelines* (Lancaster 2000) and in the U.S. Bureau of Land Management publication, *Measuring and Monitoring Plant Populations* (Elzinga et al. 1998).

Appropriate mitigative procedures are not well known for most rare plants. Frequently, the causes of plant rarity are not well understood and there is no empirical evidence on suitable mitigative procedures for a wide variety of rare plant species in Alberta. Mitigation options for rare plants are species and site specific and cannot be generalized (Bush 2001). The lack of information for specific plants means that mitigation choices are often made based on botanical and horticultural information from more common, related species or other plants in the same plant family. However, it cannot be assumed that the mitigative measures used will be successful. If rare plants are preserved or replaced on a revegetation site, monitoring program results can be used to ensure that the rare plants establish and thrive or to plan further mitigative strategies.



Although avoiding rare plants during disturbance is preferable, rare plant salvage can be used.

Time frames for monitoring depends somewhat on species and types of mitigation used. Generally a one to 10 year period of monitoring is recommended. One or two year monitoring may be all that is necessary to confirm that avoidance was successful but a longer period (five to 10 years) is required to confirm re-establishment.

It is important that the results of rare plant mitigation monitoring be communicated to at least two agencies:

- The regulatory agency involved should be informed to ensure that developers continue to follow through with rare plant mitigation monitoring.
- The Alberta Natural Heritage Information Centre (ANHIC) (Appendix 2), that manages and maintains data on rare plant locations in the province, should be informed of the success and failure to conserve rare species and the methods used. This information can then be used to inform future mitigative efforts and help ANHIC track rare species populations in the province. This information is also used to determine the degree of rarity and the type of mitigation that should be used for rare plant species.

Evaluating the success of revegetation on other sites

The interpretation of successful revegetation is closely tied to the specific revegetation goal(s) for the site. The current or planned land use for the reclaimed area must be sustainable.

Timing of the evaluation will vary according to the type of disturbance, type of soil salvage procedures and precipitation. A wellsite or pipeline in a moist forest environment may be ready for final assessment by the second growing season. However, revegetation of a similar site in a droughty prairie environment may require a number of years before a final assessment would be appropriate.

Criteria for evaluating natural recovery sites are outlined in Alberta Environment (2002).

Sustainable plant growth

The reclaimed site must be able to sustain plant growth that is equivalent to pre-disturbance growth, to similar nearby controls or to a target agreed upon (in writing) with the landowner and regulator.



Revegetation must be sustainable and capable of meeting end land use goals.

Revegetation is successful if:

- there is healthy, vigorous above-ground growth with no more evidence of plant disease or stress than is found on suitable controls
- plants have healthy root systems with no evidence of disease or limiting obstruction (e.g., horizontal layering that is compressing roots) than is found on suitable controls
- perennial plants are mature enough to survive locally normal grazing/browsing pressure or locally normal ATV use through at least one growing season (with all fences removed)
- nutrient cycling has been re-established as verified by evidence of litter decomposition

Erosion prevention

The revegetated area must be able to prevent wind and water erosion, unless it is an integral part of the landscape (e.g., sand dunes, badlands). The minimum level of acceptable ground cover is site specific and varies according to offsite cover levels, safety requirements, soil type/texture, plant community, wind, precipitation and slope.

Revegetation is successful when:

- the stability of the landform/landscape is assured
- there is no evidence of progressive erosion (e.g., erosion rills, fans or gullies, raised pebbles, pedestalling of plants, increased topsoil depth along fence lines or ditches) compared to appropriate controls
- there is sufficient litter to ensure protection from future erosion

Compatibility

Revegetation success depends on the establishment of native plant species that are compatible with the surrounding landscape and/or the desired end land use. The integrity of native plant communities must be maintained.

Sites left to recover naturally often get a flush of non-persistent annual weeds (such as *Descurainia* sp. flixweed) in the first few years. This is not usually a concern since they provide early erosion control.

Revegetation is successful if:

- the species growing on the site demonstrate that the existing or proposed end land use/s can be sustained (e.g., grazing, wildlife habitat, timber production)
- the reclaimed area can be utilized in the same manner and in conjunction with the adjacent lands
- restricted or noxious weeds as designated in the *Weed Control Act* (or by the local municipality) are no more abundant than in controls
- invasive non-native plants (e.g., *Bromus inermis* - smooth brome, *Agropyron pectiniforme* - crested wheatgrass, *Phleum pratense* - timothy) are absent unless they are established in the adjacent control
- vegetation on the site is developing along expected successional trends (e.g., annual weeds are not significantly inhibiting native perennial establishment or growth)

Choosing appropriate controls

Often in natural ecosystems, direct comparisons with controls are not possible. Usually the vegetation type or land use in the adjacent undisturbed land differs significantly from that on the reclaimed area or is at a different successional stage.

In forested natural recovery areas, for example, some early succession understory species can recover quite quickly (e.g., *Epilobium angustifolium* - fireweed). Plant composition, however, won't look like offsite for a number of years (unless the surrounding area was recently burned or harvested).

It is sometimes possible to use appropriate adjacent areas or surrogate controls (similar sites at a distance) to draw inferences about expected performance on revegetated areas. For example, if a particularly sandy site has very little grass cover offsite, then it is unrealistic and likely undesirable to expect a lot of grass cover onsite.

Surrogate controls should be as close to and as similar to the disturbed area as possible (e.g., same Natural Subregion, same end land use, soils, vegetation type, successional stage, slope and aspect).

The number of controls used is dependent on the variability and the size of the disturbed area.

Evaluation of prairie and natural recovery areas



On natural recovery sites such as this pipeline, sufficient plant cover must be present to prevent erosion.

Assessment of disturbed areas on native landscapes (e.g., prairie) show that many years may go by following either seeding to native species or natural recovery (no seeding) before species composition, cover and density begin to approximate offsite conditions. For example, *Selaginella densa* (little club moss), a major constituent of many mixed grass prairie sites, can take more than 50 years to re-establish. In these situations, it is not reasonable to compare the disturbed area to offsite controls. The following criteria should be used on these site types:

- Native species must be seeded on publicly owned prairie areas disturbed after January 1, 1993 (AENV, 2001). Native species must also be seeded where required by public land disposition conditions or by the *Environmental Protection and Enhancement Act* (EPEA) approval on large pipelines and mines.
 - In forested areas, native species must be seeded on public land if required in the disposition conditions or in the EPEA approval.
 - Sufficient plant cover must be present to provide acceptable levels of erosion control. Generally, a minimum of 50 to 60 per cent live cover (absolute) and 10 to 20 per cent naturally produced litter is sufficient. More cover (75 per cent live/10 to 20 per cent naturally produced litter) is required to control erosion on slopes.
- On older mixed grass prairie sites where comparisons are being made to offsite, *Selaginella densa* (little club moss) should be discounted from the control estimates of per cent cover, unless it has also re-established on-site.
 - On areas that were not seeded, the presence of minor amounts of transient, nuisance weeds, such as *Descurania* sp. (flixweed), is not a problem. These weeds can appear quickly following disturbance, but usually disappear within three to five years as the disturbed area fills in with native species.
 - The presence of noxious or restricted weeds or persistent annual weeds (e.g., *Bromus tectorum* - downy brome) is unacceptable on the disturbed area if they are not found on adjacent land.

Reclamation criteria

Under *Alberta's Environmental Protection and Enhancement Act* (EPEA) (Appendix 2) coal mines, oil sands mines, quarries, sand and gravel pits, pipelines, wellsites, railways, roadways, peat operations and transmission lines currently require reclamation certification. To date, reclamation criteria have been developed for wellsites, pipelines and abandoned railways in Alberta. Criteria are being developed for borrow excavations and other activities. The criteria measure the success of industry's efforts to return disturbed land to equivalent land capability. On large sites, such as mines, companies must meet conditions set out in the Conservation and Reclamation approval.

Reasons for failure

Revegetation is an imprecise science because there are so many factors that have an effect on the outcome. However, there are a number of common reasons for the failure to establish native plant communities. These include:

- species composition and varieties not being considered carefully and the choice of inappropriate varieties
- compacted soil being left untreated
- seed being planted too deeply (often using an inappropriate equipment such as a grain drill)
- seed being broadcast in a heavy wind
- an improperly prepared seedbed (not firm enough)
- broadcast seeds not being raked in or covered

- the lack of a plan to reseed or replant failed areas
- little or no weed control
- lack of control of vehicular traffic on the site
- cattle not excluded for an appropriate time period
- the use of poor quality seeds or plants (often not obtained from a reputable dealer)



Soil erosion due to water movement.

The future

The increased use of native plants for revegetation over the last decade has led to a vast increase in the knowledge of how to use these plants to mitigate disturbed sites in Alberta. This book is a beginning. It describes the state of the knowledge in the province at the time of publication. Although it will assist practitioners in making decisions about establishing native plants on disturbed sites, there are still large gaps in our knowledge. The art and science of establishing native plant communities can only grow if new information continues to be generated by research, trials and the monitoring of existing and future projects. This information will only be valuable if the individuals, companies and agencies involved in revegetation continue to innovate and share their results with others.

Glossary

Absolute vegetation cover: An estimation of the percentage of the ground within a given area that is covered by live vegetation (stems and leaves) or naturally occurring litter (dead fallen vegetation).

Agronomic: Introduced annual cereals, forage and turf species.

Allelopathy: Derived from two Greek words meaning mutual harm, this is the direct or indirect harmful effect of one plant on another through the release of chemical retardants. The action of micro-organisms is also included in this context.

Annual: A plant that completes its life cycle in a single year.

Biodiversity: The diversity of life in all its forms and all levels of organization.

Certified seed: A classification of pedigreed seed; usually produced from foundation or registered seed.

Contamination: The condition or state of soil, water or air as caused by a substance release or escape that results in an impairment of or damage to the environment, human health, safety or property.

Cool-season plant: A plant, mostly of temperate origins, that completes the major proportion of its growth during the spring and early summer months.

Cover (vegetation): See absolute vegetation cover above.

Cultivars/named variety: A plant variety that has undergone genetic selection by plant breeders, has been registered by a certifying agency and is propagated under specific guidelines to maintain its genetic integrity. Generally, it is less variable genetically and phenotypically than native or natural populations.

Drastic disturbance: Native vegetation and animal communities have been removed and most of the topsoil is lost, altered or buried (e.g., transportation systems, shopping centres, housing developments and eroded farmlands).

Early seral: Of a plant species; one that is commonly found in plant communities following disturbance; characteristic of an early succession stage.

Early successional species: A plant species that appears soon after disturbance in the natural sequence of plant communities and often disappears once late successional species establish.

Ecodistrict: A subdivision of Natural Subregions within the land classification system used by the Alberta Government for the province. Ecodistricts are defined by broad physiographic features.

Ecological Reserves: Designated under the *Wilderness Areas, Ecological Reserves and Natural Areas Act* (Appendix 2). These are lands selected as representative of special native landscapes and features of the Province of Alberta. They are protected as examples of functioning ecosystems, gene pools for research and education and heritage appreciation sites. They are managed to permit natural ecological resources to operate with a minimum of external influence.

Ecosystem: A system of living organisms that interact with each other and their environment. They are linked together by energy flows and material cycling.

Ecosystem structure/function: An area (or volume) where species interact with the physical environment. A community is the assemblage of interacting species in an ecosystem. The structure of an ecosystem/community refers to the distribution of energy, materials and species. Functioning refers to the flows of energy and materials in food chains and cycles (Forman 1995).

Equivalent land capability: The ability of the land to support various land uses after reclamation is similar to the ability that existed prior to any activity being conducted on the land. The ability to support individual land uses will not necessarily be equal after reclamation (Powter 2001).

Ericaceous: Pertaining to members of the heath plant family.

Forb(s): Broad-leaf, herbaceous or non-woody plant.

Harden-off: To acclimatize plants to local environmental conditions. This is usually accomplished by exposing plants to lower temperatures and/or drier conditions.

Introduced species: A species that is not native to a particular area.

Late successional species: A plant species that appears later in the natural sequence of plant communities, preferring an undisturbed environment.

Native landscapes: Landscapes that contain assemblages of plants and plant communities that are native, and have not been substantially altered by man.

Native plant material: Seeds, rootstocks and other propagative materials from plants that are indigenous to a particular region.

Native plant species: Plant species that are indigenous to a particular Natural Region. They were in Alberta prior to the time of Euro-American settlement.

Natural Areas: These are designated under the Alberta *Public Lands Act* or the *Wilderness Areas, Ecological Reserves and Natural Areas Act* (Appendix 2). They are established to represent special or sensitive natural landscapes and features. These areas allow low intensity recreation and opportunities for nature appreciation and education. They may also allow other uses on a site specific basis.

Natural recovery strategy: A revegetation option that involves no addition of native plant material to the site. This type of revegetation depends on the plant materials in the replaced soil and those that re-colonize from surrounding areas.

Natural Regions: The land classification system currently used by the Alberta Government that divides the province into units that reflect natural features. The Natural Regions system accounts for the entire range of natural landscape or ecosystem diversity, emphasizes overall landscape pattern and best represents the ecosystem and biodiversity elements of importance to conservation. There are six Natural Regions in Alberta.

Natural Subregion: The six Natural Regions of Alberta are sub-divided into 20 Subregions, based on recurring landscape patterns relative to other parts of the Natural Region.

Noxious weed: Designated by the Alberta *Weed Control Act*. The control of their spread, growth, ripening or scattering of seed is required.

Orchidaceous: Of or relating to members of the orchid plant family.

Organic material: Plant or animal residues or derivatives.

Perennial: A plant that persists for more than two seasons.

Phytoremediation: The use of plants for the in-situ treatment of contaminated soils or water by sequestering and/or destroying pollutants.

Population: A community of individual plants of a single species which share a common gene pool.

Problem species: Agronomic or designated weed species that disrupt the functioning and structure of native plant communities. They are invasive or persistent.

Provenance: The original geographic source of plant material.

Pure living seed (PLS): Calculated by multiplying the per cent purity times the per cent germination.

Purity (for seeds): The percentage of actual seed of the species requested in the seed lot. It is expressed as a per cent pure seed. The weeds, crops seed and inert plant material are accounted for and expressed as a per cent of the seed lot that is not pure seed.

Rare plant: Any native vascular or non-vascular (mosses and liverworts) plant, lichen or fungi species that exists in low numbers or in a restricted area (Lancaster 2000). Rare plants tracked by the ANHIC typically have populations of 20 or fewer occurrences in the province.

Reclamation: The process of reconverting disturbed land to its former or other productive uses (Powter 2001).

Registered seed: A classification of pedigreed seed; produced from foundation seed.

Release site: For a cultivar, the location of the organization that developed and released the cultivar.

Restoration: The process of restoring disturbed lands to conditions existing prior to disturbance.

Revegetation: The establishment of vegetation that replaces original ground cover following land disturbance (Powter 2001).

Rhizomatous: Having rhizomes; in grasses: sod-forming.

Rhizome: A creeping, underground stem that can give rise to new plants.

Riparian: Of, on or relating to the banks of a natural course of water (Hansen et al. 1995).

Scarification: To scratch, scrape or disturb the surface. To break down the outer seed coat by mechanical, physical or chemical means. Also, to aerate soil or bring mineral soil to the surface using special equipment.

Seed rain: Naturally produced seed that arrives on a site through seed fall from plants on or adjacent to the area. Also, seed that is carried to the site by wind, water or animals.

Seedbank: Viable seed and other plant propagules that are found in the soil/thatch layer.

Self-sustaining: The ability of an ecosystem/community to maintain its ecological integrity over the long-term without human intervention or inputs.

Slash: Debris left as a result of forest and other vegetation being altered by forestry practices or other land-use activities (e.g., timber harvesting, thinning and pruning, road construction and seismic line clearing). Slash includes materials such as logs, splinters or chips, tree branches and tops, uprooted stumps, and broken or uprooted trees and shrubs (Dunster and Dunster 1996).

Soil: The naturally occurring unconsolidated material on the surface of the earth that has been influenced by parent material, climate (including the effects of moisture and temperature), macro- and micro-organisms, and relief, all acting over a period of time to produce soil that may differ from the material from which it was derived in many physical, chemical, mineralogical, biological, and morphological properties (Powter 2001).

Special Places (designated): An Alberta Government initiative to provide a strategic plan to complete a comprehensive system of protected areas. This system represents the environmental diversity of Alberta's six Natural Regions and 20 Subregions. Designated Special Places are protected areas that are explicitly legislated and managed to preserve significant elements of Alberta's natural heritage.

Spoil: The overburden or non-ore material removed in gaining access to the ore or mineral material in surface mining, or debris or waste material from a mine (Powter 2001).

Sprigging: A procedure where rhizomatous plants are uprooted in small clumps and the clumps are replanted into the soil of a new site with the expectation that they will establish.

Stratification: Exposing seed to cool, moist conditions to break seed dormancy.

Succession: The natural sequence or evolution of plant communities where each stage is dependent on the preceding one, and on environmental and management factors (Powter 2001).

Successional species (early): A plant species that appears soon after disturbance in the natural sequence of plant communities and makes way for late successional species.

Successional species (late): A plant species that appears later in the natural sequence of plant communities, preferring an undisturbed environment.

Topsoil: The uppermost part of the soil. It is ordinarily moved in tillage or its equivalent in uncultivated soils. Normally ranges in depth from five cm to 45 cm (Powter 2001).

Warm-season plants: Plants, mostly of tropical origins, that complete the major proportion of their growth during the mid to late summer months. They require full sunlight and warm temperatures.

Weed: A plant so designated by the Alberta *Weed Control Act* (Appendix 2) or Canada *Seeds Act* (Government of Canada 1996).

Wild harvest seed: Seed that is collected directly from native species populations in the wild.

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Appendices

Appendix 1. Native Plant Working Group

In 1997, Alberta Agriculture, Food and Rural Development and Alberta Environmental Protection, together responsible for the management of public land in Alberta, decided that it was important to develop a consistent approach to the use of native plant material for revegetation. A number of industry groups were invited to participate in the development of guidelines. Those that accepted became part of the Native Plant Working Group. The current active members of this group (in alphabetical order) are:

Terry Andersen*	Canadian Seed Trade Association
Andy Etmanski	Coal Association of Canada
Heather Sinton (Chairperson)	Alberta Environment
Elgar Grinde	Alberta Cattle Commission
Rob Kessler	Sustainable Resource Development
Cam Lane	Sustainable Resource Development
Jim Lindquist	Public Lands, St. Paul
Kerby Lowen	Canadian Seed Trade Association
Ann Smreciu	Alberta Native Plant Council
Dan Smith*	Public Lands Division, Barrhead
Don Watson	Alberta Environment
Jay Woosaree	Alberta Research Council

* alternate members

The following people had previous involvement with the process or provided substantial review of the document:

Jeanie Bietz	formerly representing the Canadian Energy Pipeline Association
Lorne Cole	Special Areas Board
Rick Ferster	formerly representing the Coal Association of Canada
Bernd Martens	formerly representing the Coal Association of Canada
Ian Proctor	representing the Canadian Association of Petroleum Producers
Rob Staniland	alternate representative of CAPP
Laura Morrison	formerly representing the Alberta Energy and Utilities Board
Michelle Pahl	formerly representing Alberta Research Council

The following people provided academic review of the guideline document:

Tom Jones	Research Geneticist, USDA, University of Utah
Mark Majerus	Agronomist/Botanist, Plant Materials Centre, Bridger, Montana
Anne Naeth	Professor, University of Alberta, Edmonton, AB
Chris Powter	Team Leader, Environmental Sciences Division, Alberta Environment
David Walker	Revegetation Specialist, David Walker and Associates, Calgary, AB
Walter Willms	Range Ecologist, Agriculture and Agri-food Canada, Lethbridge, AB

Appendix 2.

Websites and contact numbers

Alberta Agriculture, Food and Rural Development, Information Packaging Centre, Publications Office. Phone: 1-800-292-5697 (in Canada) or (780) 427-0391. Website: <http://www.agric.gov.ab.ca>

Alberta Community Development, Cultural Facilities and Historical Resources Division. Phone: (780) 431-2300. Website: <http://www.gov.ab.ca/mcd>

Alberta Environment. Website: <http://www.gov.ab.ca/env>

Alberta Environment Information Centre. Main Floor, 9920-108 St. Edmonton, AB. T5K 2M4. Phone: (780) 944-0313 Fax: (780) 427-4407. Website: <http://www3.gov.ab.ca/env/info/infocentre/index.html>

Alberta Environment, Land Reclamation. Website: <http://www.gov.ab.ca/env/protenf/landrec/index.html>

Alberta Environment, Natural Resources Service, Parks and Protected Areas. Phone: (780) 427-7009 or 1-866-427-3582. Websites: www.cd.gov.ab.ca/gateway
www.cd.gov.ab.ca/parks

Alberta Natural Heritage Information Centre (ANHIC). Phone: (780) 427 5209 Fax: (780) 427-5980. Website: <http://www.gov.ab.ca/env/parks/anhic/anhic.html>

Alberta Native Plant Council (ANPC). Alberta Native Plant Council, Garneau P.O. Box 52099, Edmonton, Alberta. T6G 2T5. Website: <http://www.anpc.ab.ca>.

Alberta Sustainable Resource Development, Land and Forest Service. Website: <http://www3.gov.ab.ca/srd/> Phone: (780) 427-8474.

Alberta Sustainable Resource Development, Public Lands. Website: <http://www3.gov.ab.ca/srd/> Phone: (780) 427-6597.

Alberta Statutes and Acts. Available through Queen's Printers or at the following website(s) Website: <http://www.gov.ab.ca/qp/acts.html>

Canadian Acts:
Seeds Act.
Website: <http://www.cfia-acia.agr.ca/english/actsregs/seeds/seedae.html>

Canadian Food Inspection Agency.
Website: <http://www.cfia-acia.agr.ca>

Committee on the Status of Endangered Wildlife in Canada (COSEWIC).
Website: <http://www.cosewic.gc.ca>

Department of Energy Information Centre (Calgary) 3rd Floor, Monenco Place, 801 - 6 Avenue SW, Calgary, Alberta, T2P 3W4
Phone: (403)297-6324 Fax: (480) 297-2576
Website: <http://www.energy.gov.ab.ca/com/Room/default.htm>

Environmental Protection Act.
Website: <http://www.gov.ab.ca/qp/ascii/acts/E13P3.TXT>

Historical Resources Act.
Website: <http://www.gov.ab.ca/qp/ascii/H08.TXT>

National Resource Conservation Service of the United States Department of Agriculture.
Website: <http://www.mt.nrcs.usda.gov/pas/techmt.html>

Native Plant Revegetation Guidelines for Alberta
Website: <http://www.agric.gov.ab.ca/publiclands/nprg/>

Public Lands Act
Website: <http://www.gov.ab.ca/qp/ascii/acts/P30.TXT>

Special Areas. Address: Box 820, Hanna, Alberta. T0J 1P0. Phone: (403) 854-5600. Fax: (403) 854-5527. Website: www.specialareas.ab.ca

UBC Press (c/o Raincoast Fulfillment Services). Address: 8680 Cambie Street, Vancouver, B.C. V6P 6M9. Phone: 1-800-663-5714. Fax: 1-800-565-3770. E-mail: custserv@raincoast.com

Weed Control Act.
Website: <http://www.gov.ab.ca/qp/ascii/acts/W06.TXT>

Wilderness Areas, Ecological Reserves and Natural Areas Act.
Website: <http://www.gov.ab.ca/qp/ascii/acts/W08.TXT>

Wilderness Areas, Ecological Reserves and Natural Areas Act. Amendments
Website: <http://www.gov.ab.ca/qp/ascii/acts/00/CH18.TXT>

Appendix 3.

Calculating seeding rates

Given the current knowledge about individual species and their performance, alone or in a mix, calculating seeding rates for native species is still more of an art than a science. Planning seeding rates based on a weight per unit area basis (i.e., kg/ha or lbs/ac) is unreliable as seed weight varies tremendously among species. This can produce problems such as unexpected dominance by some species or a plant density that is higher or lower than anticipated (Hammermeister 1998). An alternative to a weight-based seeding rate calculation is the pure live seed per unit area calculation (i.e., pure live seeds/m² or PLS/m²). This emphasizes potential plant density. Seeding rate information for native plantings can be obtained from Abouguendia (1995) and from the National Resource Conservation Service of the United States Department of Agriculture website (Appendix 2).

The following information must be gathered before seeding rates can be calculated:

Number of plants/m² for each species being planted

This number is the desired density following plant establishment, usually by the end of the first growing season. The desired density reflects the relative dominance of the plant in the plant community being restored or reclaimed, as well as the project goals. The number of plants/m² reflects that only 20 to 40 per cent of most seedlings reach maturity in three years. For example, if a final density of four plants/m² of a particular species is desired at maturity, then 10 to 20 plants is the target to use in the planning formula. The exception to this is those species that spread rapidly (particularly by rhizome) following establishment. These species should be planted more sparingly.

Number of seeds per gram

The number of seeds per gram varies widely by species. Information for commonly used native species is found in Appendix 4.

Pure live seed (PLS) of seed lot

Pure live seed (PLS) is the amount of live or healthy seed found in a seed lot, excluding weed seeds and chaff. It is calculated by multiplying the per cent germination by the per cent purity. Per cent germination is usually determined by the tetrazolium chloride (TZ) test, a chemical that stains living seed. This TZ test does not indicate anything about seed dormancy.

However, if dormancy is suspected, a germination test can be done in addition to the TZ test. A certificate of seed analysis provides the PLS. When the PLS is known, it can be put into the formula. When it is unknown, the minimum acceptable PLS for the project is entered. As a guide (and in the examples that follow), 80 per cent germination is used in estimating amounts of seed required. If the exact PLS of a seed lot is known, that figure should be used in the calculations.

Estimated per cent establishment (first growing season)

The relationship between seeding rate in the field and density of established plants is not precise because of the great variability of stresses that cause seedling deaths during the stages of germination, emergence and seedling development. Seedling development occurs in several stages that vary considerably with the differing strategies for survival that are characteristic of each species. In the following example (calculating seed mix proportions), the seedlings have reached the "established stage" (the target density), when they are no longer reliant on food reserves in the seed. Root development is also sufficient to supply adequate water (if available) to the leaves so that enough food reserves are stored for growth the following spring. Depending on environmental conditions, this can take from several weeks to several months for native species in Alberta. While potential establishment from laboratory testing may be above 90 per cent, maximum field establishment may average only 20 per cent and typically less for most native species, even under excellent environmental conditions. Of the many factors that affect establishment, the weight of the seed, or amount of food reserves, stands out as a major influence. Larger seeds benefit seedling establishment.

Another major influence on seedling establishment is seeding rate, the effect on inter- and intra-specific competition. Some species are very tolerant of high plant densities (density independent, early seral species). Others are very intolerant of crowding, especially at the seedling stage (mid to late seral species). Still others manage to compete successfully by growing very slowly and outlasting species with a fast lifestyle. Despite the uncertainties, seed mixtures can be designed to produce stands of plants with a composition that is reasonably close to that predicted. It is not possible to control all the factors that affect seedling establishment, so the same mix never produces the identical composition of a previous seeding. Nor would this be desirable. Diversity of species and composition is the goal so seed mixtures should be changed in both species composition and proportions within a range that still results in reasonably predictable results.

A seedling establishment factor can be developed by field experience and by field research (as is done for agricultural crop species). The following table contains estimates of typical rates of establishment of species categorized by seed weight. Readers are urged to monitor seedlings and adjust rates to reflect local environmental and cultural practices.

Typical estimates of seedling establishment (% seedlings per pure live seed after one season)

25 - 50% Establishment	15 - 25% Establishment	5 - 15% Establishment	0.1 - 5.0% Establishment
crested wheatgrass smooth brome grass timothy perennial ryegrass cereal grains	western wheatgrasses northern wheatgrass slender wheatgrass Canada wild rye green needlegrass	native alpine fescues red fescue cultivars sheep, hard fescues alfalfa, clovers	tufted hairgrass June grass Canada bluegrass many wild harvested seeds

Formula

Approximate seeding rates per species can be calculated using the following formula.

Note: This information is provided by David Walker. He has an Excel spreadsheet that does this calculation automatically. This allows users to make changes to the various components and see how the outcome is affected without going through numerous manual calculations. You can contact David Walker by e-mail: david.walker@shaw.ca for a copy of the MS Excel spreadsheet.

Target Plant Density	No. Seeds in a Gram	Pure Live Seed %	Establishment %	Conversion g/m ² to kg/ha
$\frac{\text{plants}}{\text{m}^2} \times$	$\frac{1 \text{ gram}}{\text{no. seeds}} \times$	$\frac{1}{\text{PLS \%}} \times$	$\frac{1}{\text{est \%}} \times$	$\frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10,000 \text{ m}^2}{1 \text{ ha}}$

Key to Symbols:

- seeds/g - number of seeds per gram for each species
- PLS - pure live seed (per cent purity times per cent germination)
- est % - establishment; estimated per cent seedlings per number PLS after one season based on expected germination and seedling vigour (see Appendix 4)
- PLS/m² - pure live seeds planted per square metre
- plants/m² - number of seedlings expected per square metre after one season
- kg/ha - weight of seed (in total) per hectare; the seeding rate
- % by wt - seed mixture calculated in proportion by weight
- total kg - total seed weight of each species, and overall seed weight used to seed indicated area

Example: Seeding rate for plains rough fescue

Target chosen = 30 plants/m²
 Seeds/gram = 890
 PLS % = 80%
 Est. % = 20%

$$\frac{30 \text{ plants}}{\text{m}^2} \times \frac{1 \text{ g}}{890} \times \frac{1}{.80} \times \frac{1}{.20} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10,000 \text{ m}^2}{1 \text{ ha}} = 2.1 \text{ kg/ha}$$

Sample Calculation: Northern Fescue Mix

Species (and cultivar or source identification)	plt/m ²	seeds/g	PLS	est%	PLS/m ²	Drill Rate kg/ha	%/wt	Brdcast Rate kg/ha
plains rough fescue (wild harvest A.Roes)	30	890	77	20	150	2.2	32	4.4
streambank wheatgrass Sodar	3	350	92	25	12	0.4	5	0.7
northern wheatgrass Elbee	3	345	97	25	12	0.4	5	0.7
western wheatgrass Walsh	4	242	92	25	16	0.7	10	1.4
slender wheatgrass Revenue	3	353	83	25	12	0.4	6	0.8
slender wheatgrass Adanac	2	353	86	25	8	0.3	4	0.5
green needlegrass Lodorm	10	398	95	25	40	1.1	15	2.1
June grass (wild harvest) Gillespie	15	4500	90	5	300	0.7	11	1.5
Rocky Mtn. fescue (field grown Prairie Seeds)	15	1500	88	15	100	0.8	11	1.5
Totals	85				650	6.9	100	13.7

References for seeding rates (Appendix 3)

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Appendix 4.

Species characteristics

Grass Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Agropyron dasystachyum</i> (northern/thickspike wheat grass)	Elbee Critana	290-400	excellent/excellent/ rhizomes
<i>Agropyron smithii</i> (western wheat grass)	Walsh Rosanna	240-275	excellent/excellent/rhizomes
<i>Agropyron subsecundum</i> (bearded wheat grass)	AEC Hillcrest	345	excellent/excellent/ unknown
<i>Agropyron riparium</i> (streambank wheat grass)	Sodar	345	excellent/excellent/rhizomes moderate competitor (low growing)
<i>Agropyron trachycaulum</i> (slender wheat grass)	AEC Highlander Revenue Adanac	290-370	excellent/excellent/ very competitive in first few years
<i>Agropyron violaceum</i> (broadglumed wheat grass)	AEC Mountaineer	225-350	moderate/good/unknown
<i>Agrostis scabra</i> (hairgrass)	none/common seed only	11,000	good/good/unknown
<i>Bouteloua gracilis</i> (blue grama grass)	common, source identified	1,820-1,900	sporadic/weak/
<i>Bromus anomalus</i> (nodding brome)	common, source identified	255	moderate/good/good
<i>Bromus carinatus</i> (mountain brome)	common, source identified	150-200	good/good/competitive
<i>Bromus ciliatus</i> (fringed brome)	common, source identified	300	good/good/competitive
<i>Bromus pumpellianus</i> (northern awnless brome)	common, source identified	280	
<i>Calamovilfa longifolia</i> (prairie sandreed)	Goshen; common source identified	600	poor/good/excellent
<i>Danthonia parryi</i> (Parry's oatgrass)	common, source identified	220	
<i>Deschampsia cespitosa</i> (tufted hairgrass)	common, source identified	3,500-5,500	good/moderate/excellent
<i>Distichlis stricta</i> (saltgrass)	common, source identified	1,150	
<i>Elymus canadensis</i> (Canada wild rye)	common, source identified	200-250	good/good/competitive in first few years
<i>Elymus innovatus</i> (hairy wild rye)	common, source identified	390	
<i>Festuca altaica</i> (northern rough fescue)	common, source identified	655	

Grass Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Festuca brachyphylla</i> (alpine fescue)	ARC Vista	1,250-1,670	excellent/good/slow
<i>Festuca campestris</i> (mountain rough fescue)	common, source identified	600	good/moderate/slow growth
<i>Festuca hallii</i> (plains rough fescue)	common, source identified	890	good/moderate/slow growth
<i>Festuca idahoensis</i> (Idaho fescue)	common, source identified	950	poor/depends on seed lot/ unknown
<i>Festuca saximontana</i> (Rocky Mtn. fescue)	ARC Plateau	1,250-1,670	excellent/weak/not competitive
<i>Hierochloe odorata</i> (sweet grass)	common, source identified	1,670	poor/moderate/spreads readily by rhizome
<i>Koeleria macrantha</i> (June grass)	ARC Mountain View	3,500-5,000	moderate/variable/unknown
<i>Oryzopsis hymenoides</i> (Indian ricegrass)	Nezpar, common, source identified	300-400	80%+dormancy; good/ moderate-good/unknown
<i>Poa alpina</i> (alpine bluegrass)	AEC Blueridge AEC Glacier	2,100-2,200	good/excellent/slow
<i>Poa canbyi</i> (Canby bluegrass)	Canbar; common, source identified	2,050	
<i>Poa cusickii</i> (early bluegrass)	common, source identified	2,000	
<i>Poa juncifolia</i> (alkali bluegrass)	Sherman; common, source identified	2,022	
<i>Poa palustris</i> (fowl bluegrass)	common, source identified	2,000-2,300	good/good/unknown
<i>Puccinellia nuttalliana</i> (Nuttall's alkaligrass)	common, source identified	4,648	good/good/unknown
<i>Sporobolus cryptandrus</i> (sand dropseed)	common, source identified	11,700	may be dormant/good/moderate
<i>Stipa comata</i> (needle and thread grass)	common, source identified	250	50-80% dormant; poor/ good/unknown
<i>Stipa curtiseta</i> (western porcupine grass)	common, source identified	180	
<i>Stipa viridula</i> (green needlegrass)	Lodorm; common,source identified	360-400	50-80% dormant; poor/good/ competitive in first few years
<i>Trisetum spicatum</i> (spike trisetum)	ARC Sentinel	2,800-4,000	variable/unknown/unknown

Forb Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Achillea millefolium</i> (yarrow)	common	580	good/good/good
<i>Anemone multifida</i> (cut-leaved anemone)	common	600	poor/unknown/unknown
<i>Aster ericoides</i> (tufted white prairie aster)	common	1,590	good if stratified/good/ unknown
<i>Astragalus alpinus</i> (alpine milk vetch)	common	590	moderate if scarified/good/ good for years; rhizomes
<i>Astragalus americanum</i> (American milk vetch)	common	240	poor (even if scarified)/poor/poor
<i>Astragalus flexuosus</i> (slender milk vetch)	common	500	moderate if scarified/moderate/unknown; rhizomes
<i>Astragalus pectinatus</i> (narrow-leaved milk vetch)	common	230	moderate if scarified/weak/ moderate
<i>Astragalus striatus</i> (ascending purple milk vetch)	common	700	moderate if scarified/good/ unknown
<i>Campanula rotundifolia</i> (harebell)	common	1,570	good/weak/excellent; rhizomes
<i>Gaillardia aristata</i> (blanket flower)	common	400	good/good/good
<i>Geum triflorum</i> (three flowered avens)	common	1,700	moderate/moderate/good
<i>Glycyrrhiza lepidota</i> (wild licorice)	common	140	moderate if scarified/moderate/good; rhizomes
<i>Hedysarum alpinum</i> (American sweetbroom)	common	230	moderate if scarified/moderate/good
<i>Hedysarum boreale</i> (boreal sweetbroom)	common	200	moderate-good if scarified/ excellent/good
<i>Hedysarum sulphurescens</i> (yellow sweetbroom)	common	165	moderate if scarified/ poor/poor
<i>Heterotheca villosa</i> (golden aster)	common	2,500	moderate/moderate/good
<i>Lathyrus ochroleucus</i> (white peavine)	common	70	moderate if scarified/poor/ moderate
<i>Liatris punctata</i> (dotted blazing star)	common	300	good/good/moderate
<i>Linum lewisii</i> (wild blue flax)	Lewis (U.S.)	620	good/good/good
<i>Oenothera biennis</i> (common evening primrose)	common	3,300	good/good/good; biennial

Forb Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Oxytropis cusickii</i> (alpine loco-weed)	common	350	good if scarified/moderate/ unknown
<i>Oxytropis deflexa</i> (reflexed loco-weed)	common	1,100	moderate if scarified/moderate/good; good spread by seeds
<i>Oxytropis monticola</i> (late yellow locoweed)	common	800	good if scarified/good/good
<i>Oxytropis sericea</i> var. <i>spicata</i> (early yellow locoweed)	common	550	good if scarified/good/good
<i>Oxytropis splendens</i> (showy locoweed)	common	770	moderate-poor if scarified/ good/good; good spread by seeds
<i>Penstemon nitidus</i> (smooth blue beard tongue)	common	750	poor/moderate/slow
<i>Petalostemon purpureum</i> (purple prairie clover)	common	420	moderate/moderate/good
<i>Ratibida columnifera</i> (prairie coneflower)	common	3,000	good/good/moderate
<i>Solidago canadensis</i> (Canada goldenrod)	common	2,000	poor due to dormancy/ good/excellent; rhizomes
<i>Thermopsis rhombifolia</i> (golden bean)	common	70	moderate if scarified/good/ good; rhizomes
<i>Vicia americana</i> (American vetch)	common	75	good if scarified/moderate/ weak

Tree and Shrub Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Alnus crispa</i> (green alder)	common	5,000	
<i>Alnus tenuifolia</i> (river alder)	common	1,600-2,000	
<i>Amelanchier alnifolia</i> (Saskatoon)	common	370-385	good/good/slow
<i>Arctostaphylos uva-ursi</i> (bearberry)	common	130-182	poor/unknown/unknown
<i>Betula papyrifera</i> (paper birch)	common	3,000-10,000	moderate/good/good
<i>Cornus stolonifera</i> (red-osier dogwood)	common	35-39	good/good/excellent
<i>Prunus pensylvanica</i> (pincherry)	common	22-35	poor in 1 st year better in 2 nd year/good/excellent

Tree and Shrub Species	Variety	Seeds/g	Emergence/ Seedling Vigour/ Growth
<i>Prunus virginiana</i> (chokecherry)	common	14-17	excellent/excellent/ excellent
<i>Rosa acicularis</i> (prickly rose)	common	93-100	better in 2 nd year/good/excellent
<i>Ribes triste</i> (wild red currant)	common	275-350	
<i>Symphoricarpos albus</i> (snowberry)	common	175-204	dormant- needs two cold periods/good/good
<i>Viburnum edule</i> (mooseberry)	common	40-51	dormant - needs two cold periods/moderate/excellent

References for species characteristics (Appendix 4)

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Appendix 5.

Scientific nomenclature

Plants in this book are identified according to the scientific nomenclature of Moss (revised by Packer 1983), a widely used taxonomic authority in Alberta. Plant taxonomy has changed rapidly in recent years with several international movements actively working on standardizing the nomenclature of plant species, especially those with ranges that extend across political boundaries. Canada is an active participant in these efforts and some of the names referenced in this book could become outdated with respect to how plant names are reported when seed is sent to a lab for analysis. Under the *Canada Seeds Act*, all seed sold in Canada must be tested and graded by an accredited seed laboratory that issues the results in a Certificate of Seed Analysis. Certified seed labs test seed following protocols established by the Association of Official Seed Analysts (AOSA), an organization with representatives from countries that regularly trade seed products, including Canada and United States. AOSA has adopted the system of nomenclature used by the United States Department of Agriculture (USDA), Agriculture Research Service (ARS), National Genetic Resources Program. The current list of accepted plant names and their synonyms is maintained in an online database -- The Germplasm Resources Information Network (GRIN), available on the web (AOSA Nomenclature Committee 2000).

When the Canadian Food Inspection Agency is finished reviewing and revising Canadian seed standards, seed test results may begin appearing with plant names according to the GRIN system of scientific nomenclature (CFIA 1999). Seed certificates for native seed imported from the US may already carry names according to the new nomenclature, depending on the seed certifying agency. To minimize possible confusion over species identity and to extend the usefulness of this book, synonyms are listed in the following table. Only those species with name changes that have been accepted by the international botanical community and now differ from the name in Moss (1983) are listed. The table does not include names that have not yet been verified or if an accepted synonym is listed in Moss. The reader is advised to consult the GRIN database if a new or unfamiliar name is encountered in the book or on a certificate of seed analysis.

Scientific nomenclature for plants and animals has been under constant change since the beginning. However, over the past two decades, new techniques for studying phylogenetic relationships between plant species have broadened our understanding of their origins and relationships. These studies have also changed, sometimes radically, the definition of species. For example, two common species on the Canadian Prairies, northern wheat grass (*Agropyron dasystachyum*) and western wheat grass (*Agropyron smithii*) are morphologically very similar and sometimes difficult to separate in the field. But because of differences in genetic structure, the new nomenclature places western wheat grass in a different genus (*Pascopyrum*) than northern wheat grass (*Elymus*). In contrast, because of similarities in genetic structure, streambank wheat grass (*Agropyron riparium*) and northern wheat grass (*Agropyron dasystachyum*) are placed by the new system in the same genus and species (*Elymus lanceolatus*) with no distinction at the sub-species or variety level, despite the fact that the two can be readily distinguished in the field. Canby bluegrass (*Poa canbyi*) and alkali bluegrass, (*Poa juncifolia = ampla*), are classed together under the new nomenclature as *Poa secunda*. Very few name changes are actually new names but rather a return to a name previously described and documented in published journals according to a previous taxonomic system.

The name changes may leave the reader wondering if plants with the same name at the species or sub-species level can be used interchangeably when selecting plants for restoration. The answer is that equivalency in scientific name never has been a guarantee of performance. For example, Gruening alpine bluegrass (*Poa alpina*), a cultivar released by the USDA Plant Material Center in Palmer Alaska, is not native because the plant material originated from Switzerland. Barkoel crested hairgrass, a cultivar from The Netherlands, is indistinguishable from the North American native June grass (*Koeleria macrantha*) except that drought and cold tolerance do not appear to be even approximately similar. Neither the scientific nor the common name is a good basis for selecting seed. Selection of plant material for restoration should be based on performance. This means knowing the source; using seed of a cultivar or seed with an identified source and proven track record. This could be seed harvested from a production field grown from native seed acquired from a known source or seed harvested from a native stand that has previously provided good performance. Other seed sources should be used cautiously and with good monitoring and record keeping.

Species listed by old and new scientific name and common name.

Moss 1983 Nomenclature	AOSA (GRIN) Nomenclature	Local Common Name
<i>Agropyron dasystachyum</i>	<i>Elymus lanceolatus</i> (Scribn. & Smith) Gould	northern wheatgrass (Can) thick-spike wheatgrass (USA)
<i>Agropyron riparium</i>	<i>Elymus lanceolatus</i> (Scribn. & Smith) Gould	streambank wheatgrass
<i>Agropyron smithii</i>	<i>Pascopyrum smithii</i> (Rydb.) A. Love	western wheatgrass
<i>Agropyron subsecundum</i>	<i>Elymus trachycaulus</i> subsp. <i>subsecundus</i> (Link) Gould	bearded wheatgrass awned wheatgrass
<i>Agropyron trachycaulum</i>	<i>Elymus trachycaulus</i> subsp. <i>trachycaulus</i> (Link) Gould	slender wheatgrass
<i>Agropyron violaceum</i>	<i>Elymus trachycaulus</i> subsp. <i>violaceus</i> (Hornem.) Love	broad-glumed wheatgrass violet wheatgrass
<i>Elymus innovatus</i>	<i>Lymus innovatus</i> (Beal) Pilger	hairy wildrye
<i>Oryzopsis hymenoides</i>	<i>Achnatherum hymenoides</i> (Roem. & Schult.) Barkworth	Indian ricegrass
<i>Poa canbyi</i>	<i>Poa secunda</i> J.Presl	Canby bluegrass
<i>Poa juncifolia</i>	<i>Poa secunda</i> J.Presl	alkali bluegrass
<i>Stipa comata</i>	<i>Hesperostipa comata</i> (Trin. & Rupr.) Barkworth	spear grass needle and thread
<i>Stipa curtisetata</i>	not verified in GRIN but accepted elsewhere as <i>Hesperostipa curtisetata</i> (A.S.Hitchc.) Barkworth	western porcupine grass
<i>Stipa viridula</i>	<i>Nassella viridula</i> (Trin.) Barkworth	green needlegrass

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