Plant Material Selection and Seed Mix Design for Native Grassland Restoration Projects

Year End Data Summary

Preliminary Assessment

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1.0 Introduction

With the increasing concern over the damage caused to natural ecosystems, restoration ecology is a growing science worldwide. When designing seed mixes with the goal of restoration, it is critical that we understand that every project is different and requires a unique plan. True restoration requires a wide variety of native species, of which, many have differing reproduction strategies, life cycles, environmental requirements, and fit within different successional stages. Due to the inherent complexity of restoration of natural systems, it is necessary that a controlled scientific approach is taken in design, implementation, and monitoring phases of a restoration plan.

The need to improve seed mix design and plant material selection techniques is driven by increased regulation (i.e. Alberta: 2010 Reclamation Criteria(AEP, 2010), evidence from past success and failures outlined in the recovery strategies projects (Neville, 2013), and the need to update existing publications (i.e. Andrew Hammermeister's, Seeding Rate Conversion Charts for Using Native Species in Reclamation Projects (Neville 2013)). There are currently many seed mix calculators being used that vary in complexity and purpose. The goal of this update is to provide guidance based on recent findings and in light of more stringent criteria to create native seed mixes for the purpose of plant community restoration. However the techniques provided here will allow for users to create calculators to work for their specific.

To understand the need for a seed mix calculator consider the following:

> It is not uncommon to see seeding rate specifications set at approximately 25kg/ha (drill seeding) regardless of the seed mix composition. Such actions have resulted in seeding rates of anywhere between ~827 seeds/m^2 (western porcupine grass) and ~27,500 seeds/m^2 (tickle grass). This vast difference in the number of seeds being planted on a given area of ground can have drastically different results on trajectories. Mixing these two species together can further complicate matters. Say we add 12.5kg of each species to the mix for simplicity (50%) this will result in 3% of the seeds in the mix being western porcupine grass and 97% of the seeds being tickle grass. At this seedling density only a fraction of 1% of the seedlings will be able to survive to maturity as the seedling density is much too high. The area possibly could support 10 western porcupine plants and maybe 25 tickle grass plants. If only a fraction of 1% of the seedlings survive, it is possible not even one western porcupine seedling will survive the intense competition even though tickle grass is an extremely poor competitor.
>
> Now imagine adding 10 different species together in such a manner. The plant community composition will not look at all like the composition of each species in the mix. Rather, seed size and the aggressiveness of each seedling will determine

the composition. In a case where an aggressive species has small seeds, it is highly likely a monoculture of one species will be the ultimate result. This type of result can easily occur with wheat grasses (competitive ability) and bluegrass (size of seed) species.

In other situations where conditions are dry or topography dictates that erosion is a high risk, increases in the seeding rate are common. Say we increase seeding rate from 25k/ha to 50kg/ha to increase establishment density and prevent erosion. Using our initial two species seed mix, our percent of each species in ratio will remain the same (3% vs 97%), but only a fraction of the species will be able to survive (20 - 50 plants), as we have packed many more seedlings into the same amount of ground.

Due to these mistakes many restoration projects have resulted in plant communities vastly different than the ones that were targeted. In some cases, long term restoration trajectories can correct themselves, but in many cases, those species once established are extremely difficult to replace and a new trajectory may be set that changes the micro-climate and soils in such a way that the target trajectory will never be achieved.

The following techniques are meant to guide restoration ecologists in setting appropriate trajectories, designing restoration plans, and monitoring programs that maximize the chances of successfully restoring a desired plant community to a disturbed or degraded ecosystem.

2.0 Field Assessments and Information Quality

With regard to seed mix design, it is important that each restoration project start with a comprehensive assessment of the environmental characteristics that make up the specific site in question. Assessments will be conducted in two ways (Literature review and Field Survey). The first is a literature review. The literature review may include a number of different sources of information depending on your site and its history. Some of the great resources out there include: the Grassland Vegetation Inventory (GVI), Alberta Vegetation Inventory (AVI), recovery strategies documents (i.e (Neville, 2013)), plant community guide (Adams, 2013), historical assessments (vegetation assessments, soils, reports, land use…), and government publications (i.e. Enhancing Oil and Gas Reclamation on Native Grasslands in Alberta: A detailed Curriculum to complement the 2010 Criteria).

Field assessments should be completed to fill in any information not available during the literature review. Information required for a strong reclamation plan will require detailed information on the: vegetation composition, soils, macro climatic conditions, micro-climate, and disturbance regimes. This information will directly influence factors such as seeding rates, seed mix composition, planting designs, season of planting, and maintenance required. The quality of data used is directly related to the success or failure of each project. The complexity of natural ecosystems tends to magnify our mistakes, not minimize them, as a poor quality initial result will result in a much worse end product. Resources for collecting field information include the range health manuals (Adams, 2009), and the techniques within the range inventory manuals (Willoughby, 2014).

2.1 Setting the Target Community

In different restoration projects there are different targets and requirements. In general, we can have two distinct starting situations. The first is that we have a local target plant community that we are trying to match. The second is that we have no local target community to match. These two situations call for unique strategies in forming your target plant community and as such, call for completely different initial strategies.

2.1.1 Strategy 1 (Adjacent Community Exists)

When your project is adjacent to the target plant community that you desire to replicate, then it is possible to build your entire seed mix and planting design off of the adjacent community. The best method to achieve this is to assess the plant community composition using a detailed vegetation transect. The more detailed the information and the more species you include, the more accurately you can replicate the community. When assessing the adjacent target community, ensure that the site is similar in soils, aspect, topography, and microclimate to your site. Transects should be run in each unique plant community with a minimum of ten $1/10^{th}$ m^2 frames in grasslands. Shrubs can be assessed using ocular estimates or larger plots (1 m^2). Use of the MF5 form produced by the Alberta Government or a similar form will allow the collection of all relevant information for creation of your seed mix.

Once this data is collected it can be analyzed. Associating structural layer and grazing response to each species allows you to assess the successional status of your community and each species you may potentially use in your reclamation project. It also helps determine suitable substitution species that will aid you in setting the appropriate trajectory and avoiding species that will hinder this process. The data set can then be associated to the appropriate plant community from the range plant community guides produced by the Alberta Government. This will be a resource to suggest suitable substitution species for your site.

2.1.2 Strategy 2 (Adjacent Community Does Not Exist)

When you do not have access to a similar plant community to the one you are trying to create (i.e. in large disturbances or conversion of large fields to native species), it is not possible to utilize an adjacent plant community to create your seed mix. Resources such as GVI, and Plant Community Guides become very useful when no reference plant community is found adjacent to your site. These tools can be used to help classify your site and find comparable ones to model your target plant community off of.

Once a comparable location is found a range health assessment may be utilized as a guide to select the appropriate plant community out of a plant community guide. While your plant community may not exist, it is still necessary to assess the soil type, topography, and environment so that when you select your appropriate plant community. You can also run a simple range health assessment to help guide you through the plant community guides and confirm your desired target. However, you should create your seed mix off the plant community in the guide and not your range health assessment, as the plant communities within the guides are created off of robust assessments (detailed transects) on multiple similar plant communities within the natural subregion in question.

Similar to the first strategy, you should determine the grazing response and structural layer of each species prior to creating your seed mix. This will allow you to choose appropriate substitutions for any species that is not available.

3.0 Plant Material Selection

When determining what species are available, in what form (i.e. wild harvest seed, ecovars, common seed, live plants, root cuttings, live stakes, etc.), and in what quality (i.e. germination, invasive species, acclimatization, etc.), it must be understood that each material available has its advantages and disadvantages. Wild harvested seed may have trace amounts of other desired native species, but it may also have a lot of weedy species and straw in it. On the other hand, carefully bred varieties may be clean and establish well, but become too aggressive on your site. For each species each option should be weighed carefully and appropriate substitutions used where necessary.

Prior to selecting each species it is critical to research the availability of the species in question. With thousands of native species, it is likely that the majority of the species you find in any given location are not commercially available. Prior to making a seed mix; consider the availability, timeline until you need the seed. In addition, research both the common and scientific name of the species to ensure it is actually the species you are asking for. Finally consider the source location of the seed lot and whether the seed is adapted to your site. If a species has been commercially bred for generations it may be much more aggressive than you expect. If it is a circumpolar species you may be getting seed originating from Asia, Europe or South America. Each of these factors will affect the results of your restoration project.

3.1 General Guidelines for Seed Testing

The purity test is an analysis that determines the composition of a seed lot. It is a test required by the Canada Seeds Act to determine whether or not a lot makes a Canadian seed grade. It is also useful information to the producer planting the seeds. It can tell you if other crop species, fungal bodies, or weeds exist in a seed lot that you do not have or want in your area. It will also tell you the number of these contaminants so that you can keep from planting large quantities of them with your crop. Many weed species can be extremely invasive and expensive to control once established.

There are two main areas used in physical purity testing. One is the percentage test. The other is the numbers by count or search of a particular weight of seed.

- **The Percentage Test –** This test breaks the quantity analysed down into these main components: pure seed, other crops, weed seeds, inert matter, and ergot or sclerotia bodies. The results are expressed as a percentage by weight. Different weights are examined for different crop kinds with a goal of looking at approximately 2,500 seed units. This test is especially important when planting really chaffy species or kinds that are prone to be high in contaminating species. The percentage pure seed in combination with the germination test helps determine seeding rates.

- **Examination by Count (Purity) –** This test is an examination of known quantity of a seed lot for contaminants. Different weights are examined for different crop species with a goal of looking at approximately 25,000 seed units. Contaminants are retrieved and classified into different categories including: prohibited noxious weeds, primary noxious weeds, secondary noxious weeds, other weed seeds, other crop kinds, ergot, and sclerotia bodies and others as required.

Other tests offered include weed checks and seed or plant identifications.

It is often preferred to test the components of a mixture for purity, percentage tests, and pure live seed before the components are blended into the mixture. This is beneficial because undesirable contaminants and seed lots with low viability can be removed prior to mixing.

It may be desired to do a component breakdown on the mixture after blending to show that the desired components and percentages were calculated correctly. When it comes to mixtures carried over from one season to the next or more: new germination or Tetrazolium tests should be performed on the mixture from a new sample representing the way the seed lot has been stored. Seed tests on mixtures are more costly due to the time it takes to properly identify and separate species. A test on the mixture taken at random instead of separated out is considered unreliable information.

3.1.1 Quality and Expectations of Purity Tests

The first and most important thing to consider is that the quality of the professional completing the analysis will result in the quality of the weed analysis you get. A properly completed weed analysis will include random samples being taken from different parts of a single seed lot and then being combined and submitted for analysis. This subsample may only be a few hundred grams of thousands of kilograms of seed. As such it is only a very rough estimate of the weeds that are in the seed lot and should be treated as such. Expect many rare weeds not to show up in a weed analysis and some very rare weeds to be overestimated.

3.1.2 When to get a Weed Analysis?

For virtually every seed lot you purchase, a weed analysis and a germination analysis should be supplied prior to the purchase of the seed. The only time this may not be possible is in the case of small hand harvested seed lots where sending out an analysis is either cost prohibitive or will result in the majority of your seed being used up.

3.1.3 Certificates of Authenticity and Credentials of the Seed Collection Specialist

It is worth checking out the validity of the seed you are sourcing. This is especially important if a weed analysis cannot be completed, but is also important for species that have easily misidentified seed such as fescue species. The first step is to determine the validity of the material. This can be done in a number of ways:

1) Obtain a Certificate of Authenticity for the seed lot – this is only supplied by a qualified plant taxonomist who inspects the field or wild harvest location to ensure the species is legitimately what it claims to be. The experience and qualifications of the certification agent is critical in this process.

2) Obtain a sample plant from the field or wild harvest location – this sample can be submitted to a qualified plant taxonomist for verification.
3) Obtaining a registered variety – this can give some confidence, but again the qualifications of the specialist who collected the variety is still important as there are a number of species that have been mislabeled in the past. An example is sheep's fescue (*Festuca ovina*), which has been sold as rocky mountain fescue (*Festuca saximontana*) even though it is not native. Compounding this problem is the fact that in a weed analysis, both species have identical seeds that cannot be differentiated.

3.2 Germination Analysis

Testing for the viability of any given seed lot is critical in the process of creating a seed mix. If the viability of a given species is only 10%, then you will need significantly more seed of that species in the mix than if the viability is 95%. As such, no seed lot should be used unless a germination/ Tetrazolium Tz analysis has been completed. Depending on the species in question, a combination of the two tests may be beneficial. Additionally, seed deteriorates with age. As such, it is recommended that germination tests should as close as possible to seeding. Within this it must be understood that germination can drop within 3 months or it could remain the same for months or years depending on the species, storage and other factors.

3.2.1 Native Seed Testing:

Native seed has an array of special issues when it comes to seed use, sales, and testing in Canada. There are only six native species that fall on the grade tables in the Seeds Act and are therefore well addressed by the Seeds Act and Regulations and seed testing rules. These are: northern wheatgrass/ Thickspike (*Elymus lanceolatus* ssp. *lanceolatus* var. *lanceolatus*), western wheatgrass (*Pascopyrum smithii*), slender wheatgrass (*Elymus trachycaulum*), streambank wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus* var. *riparius*), fowl bluegrass (*Poa palustris*), and creeping bentgrass (*Agrostis stolonifera*). All other native species are treated as follows:

Purity Testing

- Any seed or mixture of seeds for land reclamation, soil conservation, green cover, wildlife grazing or habitat, wetland restoration, or similar purposes must meet the minimum standards for weeds and other crops on Table 13 of the Seeds Regulations.
- Percentage tests for other crop and ergot bodies are requirements, but not percentage pure seed. However, most people require this as a condition for sales.
- The classification of other crops requires that a species falls on one of the grade tables leaving many desirable species in the lot, to be listed as other weeds unless it is labelled a mixture.
- Everything that is not listed on the Grade tables or in the weed seeds order (noxious weeds) is labelled "Other Weed"

Germination Testing:

- There is no minimum required standard for germination.
- There are often no prescribed germination methods even in American or international rules.

- The seeds of native species are more often than not perennial species with the built in survival mechanism of extreme dormancy. This means that lab germination could take 6 months to a year. For some species, lab germination may never be complete due to unknown requirements for dormancy breaking.
- Modern thinking in the industry has led to a shortened test at neutral temperatures for 2 to 3 weeks. This is followed by a Tetrazolium (TZ) test to determine the number of viable seeds left in the ungerminated ones. At the end of that period, the client knows the number of seedlings which will establish rapidly. The TZ provides the client with an estimate of the number of seedlings which have the potential to develop over time as natural mechanical, chemical, and temperature mechanisms induce dormancy breaking.

It is of key importance that the seed technologist is familiar with the species and methods they are using.

3.2.2 What Is a Germination Analysis

The object of germination testing is to determine the maximum germination potential of the seed. Testing under field conditions cannot normally be repeatable. Laboratory methods have evolved in which controlled conditions are used to give rapid and complete germination for the majority of samples of a particular species. The conditions have been standardized within limits as near a possible to those determined by random sample variation.

Seed Germination in seed laboratory practice is defined as "the emergence and development from the seed embryo those essential structures which, for the kind under test, are indicative of the ability to produce a useful, mature plant under favourable field conditions".

The competent seed analyst plants pure seed under prescribed conditions for the species being tested. The seeds are the incubated for the prescribed period of time and the seed analyst evaluates the test. Seeds are normal sorted into six categories:

- **Normal Seedlings**: Seedlings possessing the essential structures that are indicative of their ability to produce useful mature plants under favourable field conditions.
- **Abnormal Seedlings**: A seedling that does not have all essential structures or is damaged, deformed, or decayed that prevents normal development.
- **Dead Seeds**: Seeds, which are neither hard nor dormant or have produced any part of a seedling.
- **Dormant Seeds**: Viable seeds, other than hard seed which fail to germinate when provided prescribed germination conditions.
- **Fresh Seeds**: Seeds which have imbibed moisture, but have failed to germinate and may be dormant
- **Hard Seeds**: Seed which remain hard at the end of the test period because their impermeable seed coats prevent the absorption of water.

Causes of Seedling Abnormalities:

1. Mineral deficiencies in the soil
2. Frost damage
3. Heating
4. Mechanical damage
5. Insect damage

6. Chemical injury
7. Declining vigour
8. Pathogenic infections

3.2.3 Tetrazolium Testing

The Tetrazolium or TZ Test: The Tetrazolium test originated in the early 1940's in Germany. It provides a quick estimate of seed viability.

The AOSA (Association of Official Seed Analysts) definition: Tetrazolium: Indicates a class of chemicals that have the ability to accept hydrogen atoms (and undergo reduction) from dehydrogenase enzymes during the respiration process in viable seeds. This is a basis of the Tetrazolium test during which the Tetrazolium chemical undergoes a colour change, usually from colorless to red.

In theory, Tetrazolium tests are the highest potential of a seed lot, with the germination being lower. Lots with really high or really low viability vary little from the germination test.

The Canadian Methods and Procedures for Testing Seed:

- Western wheatgrass: used at the beginning or end of the test as an estimate of dormancy. It can be used for grading purposes when combined with the germination test.
- Can be used for grading fall planted cereals when confirmed by a standard germination test.

The United States:

- Tetrazolium Hand book contribution no. 29 referenced in the AOSA rules.
- Up to five states allowing seed for sale using limited use of the Tetrazolium test.

Practical Use:

- Rapid result for use in buying, selling, making storage decisions, vigour testing, dormant seed lots, and verifying germination results.

The Process:

1. **Sample Preparation**
   It is of key importance that the sample is properly mixed, especially with chaffy and super chaffy seeds. Random selection of **200 or more** pure seed units must be taken from the pure seed portion of the purity analysis. If there is no Percentage test required: a qualified purity analyst should select pure seed randomly by analyzing one quarter of a pure seed portion.
2. **Preconditioning**
   Seeds are hydrated by placing them in water or between wet blotters at temperatures favorable for germination.
3. **Seed Preparation**
   Seed is prepared to facilitate the entry of Tetrazolium into the embryo. This may include cutting, piercing, removing structures, or no preparation at all.
4. **Staining**
   Seed is place in Tetrazolium solution and incubated at a specific temperature and appropriate concentration as prescribed by the rules. The higher the concentration and temperature, the faster the staining time. Over staining will make evaluation difficult or impossible.

5. **Evaluation**

   Requires and experienced technician using AOSA or ISTA rules.

   Limitations of the TZ Test:

   - Specialized training and experience required
   - Sometimes fungal and bacterial issues cannot be detected.
   - Minor seed damage may not be detected
   - Chemical damage may not be detected
   - Time and labor are required, therefore costs are higher
   - Destroys the seed

   Advantages and Capabilities of the TZ Test:

   - Turnaround time rapid
   - We can determine the viability of most dormant seeds, which is better than a germination in many native species
   - Can show when a seed lot is starting to drop in vigour
   - Back up of a germination result or remaining seeds at the end of a test.

3.3 Calculating Pure Live Seed (PLS)

To calculate pure live seed, multiply the germination rate (%) by the amount of the seed mix that is seed (100% - % Inert Material) for each species. For species known to have a strong seed dormancy it may be worth using the TZ value for a more accurate calculation of the amount of live seed.

Formula 1: Calculating Pure Live Seed (PLS)

$$\%\,Germination \times \%\,Purity\,(100\% - \%\,Inert\ Material) = \%\,Pure\ Live\ Seeds\,(PLS)$$

This step is commonly ignored in seed mix creation, but can result in significant problems. Some people have mandated that all seed must have over a 90% germination rate instead of calculating PLS. While this can reduce the impacts of low germination, it is a poor practice with native species that can have on average low germination rates and as such, seed with over 90% germination can be very difficult to procure. Additionally, this is a simplified technique that reduces accuracy and due to the inherent complexity and variability of natural systems anything that reduces the chance of success is a significant problem.

4.0 Selecting the Appropriate Seeding Rates

The seeding rate you choose should always be on a seeds$^{(PLS)}$/m^2 basis. This rate is the most accurate way to ensure that you achieve the desired composition of your plant community once it is established. Your chosen seeding rate will vary greatly by the requirements of your individual project. Table 1 below highlights some general guidelines for seeding rates that can be chosen based on some specific criteria. It is expected that almost no project will fit perfectly into one of the categories below, but that for each project an appropriate trained and experienced person will be required to modify the seeding rate based on the criteria in table 1.

Table 1: Seeding Rate Guide Lines For the Dry Mixed Grass and Mixed Grass Natural Subregions. Seeding rates are set for use of a Brillion seed drill or similar drill. Use of other seeding methods will require modifications to the seeding rate

	Rate (seeds$^{(PLS)}$/m^2)						
Erosion Risk	**Dry Site**	**Moist Site**	**Wet Site**	**Presence of Invasive Species**	**Soil Conditions and Seed Bed**	**Desire for Infill of surrounding Species**	**Cover Establishment**
Very Low	150*	300	400	No Risk	Excellent	Lots of Infill Desired	Slow
Low	250	400	1000	No Risk	Good	Lots of Infill Desired	Slow to Moderate
Low to Moderate	300	1000	1500	Low to Moderate Risk	Moderate	Moderate Infill Desired	Moderate
Moderate	400	1500	2000	Moderate Risk	Poor	Low Infill Desired	Fast
High	1000	2000	5000	High Risk (competition Required)	Poor	No Infill Desired	Very Fast

4.1 Other Factors that Affect the Seeding Rate

Once you have selected your seeding rate based on the environment, a number of additional modifications can be made through a management factor and an establishment factor. Each modification is critical to the final outcomes in your plant community as they will modify the selected seeding rate based on a number of additional factors.

4.1.1 Management Factors

The management factor is the impact management decisions will have on establishment success. These decisions can vary in form (i.e. seed placement, timing of seeding, availability of watering…). This factor can be applied at the time when you select the seeding rate (i.e. increase or decrease the overall rate) or later to specific species within the seed mix. It is important that any seed mix wide modification occur prior to calculating the percentage of each species within the seed mix. This will allow species specific modifications that are required due to the overall seeding rate to be calculated.

Factors to consider within the seed mix wide modifications include: seeding equipment to be used and the time of year seeding is occurring.

Seeding Equipment and Techniques

Seeding techniques are a critical component of the potential for a successful seed establishment. The use of a Brillion seed drill or similar device is typically the most effective for small grass seeds. This is because it places seed at the soil surface and packs the seed into the soil ensuring strong soil seed contact. Other methods such as drill seeding and no-till drill seeding tend to place seed much deeper in the soil profile and while this is very effective for larger native seeds, it can cause high mortality for small seeded native species requiring much higher seeding rates to compensate. In contrast, broadcast seeding leaves seed on the soil surface and when combined with rolling may be very similar to a Brillion drill. However, when harrowed or left without any treatment, the seed may be buried too deep or end up blowing away. Therefore increased seeding rates are recommended when broadcast seeding. Finally hydro-seeding is known to create very poor soil seed contact, and although moisture retention allows germination, poor soil contact can cause seedling mortality. Higher seeding rates are generally recommended for hydro-seeding applications due to this issue as shown in Table 2

Table 2: Examples of using a management factor for a site selected to have a seeding rate of ~400 seeds/m^2 in Table 1. This is only an example of one situation. Seeding rates found below are to be used only as guides for a theoretical site.

Seeding Rate (seeds/m^2)	Seeding Method
~400	Brillion Seed Drill
~500	Drill Seeding
~600	No-till Drill Seeding
~800	Broadcast Seeding
>1200	Hydro Seeding

Season of Seeding

The season of seeding can have a significant impact on the survival of your seed. If you are seeding in early spring, the plants are able to take advantage of the conditions and germinate quickly, growing during the moist cool part of the year. Because the majority of the species growing in Alberta are cool season species, this is likely the time when you will get the best establishment. As you seed later into spring and early summer there is a much higher risk of seedling mortality due to moisture deficits that occur during July and August in Alberta. This can also vary due to micro-climate and as such, careful consideration should be made as to whether this impact will occur for your specific site. In late summer you may be able to get a strong germination of your seed allowing it to grow to a size where it can over winter effectively. However late fall planting or dormant planting may result in loss of seed over winter and as such, it may be necessary to increase your seeding rates to compensate. These modifications as noted are relatively minor, but may be important to consider in your design.

Table 3: Examples of how Season of Seeding May affect seeding rates (400 seeds/m^2 in Table 1, Brillion Drill Table 2).

Seeding Rate (seeds/m^2)	Season
~350	**April** – Ideal time to Seed
~400	**Mid May** – Ideal time to seed to take advantage of moisture
~600	**Mid June** – Only appropriate in moist regions or environments
>800	**July** (Failure is almost guaranteed without irrigation)
~400	**Late August or Early September** – ideal timing for many projects
~600	**October (Dormant)** – may lose seed over the winter.

4.1.2 Establishment Factors

For each selected species that is available to you for use in your seed mix, the following assessment should take place with full consideration of each of the following factors:

Species Specific Requirements and Life Cycles

For each species it is important to understand its unique biology and how it will influence establishment success and the final density of plants required to achieve your goals. Factors such as successional stage, life cycle, reproductive cycle, seedling recruitment rates, mature plant size, response to disturbance, grazing response, and rooting habits must be carefully considered. For more aggressive species, less seed is required while more seed may be required for bunch grasses and small plants as compared to creeping species and large plants.

Environmental Concerns

Each species has a specific environmental adaptation and these adaptations can be completely different for each species at a seedling stage. For example, rough fescue species (plains and foothills) are drought tolerant as adults, but immature seedlings are susceptible to drought conditions. Many species have very narrow tolerances during establishment and so increased volumes of seed may be required for successful establishment in harsh environmental conditions. Some conditions may be so harsh for a given species that seedling establishment is virtually impossible. In this case it is recommended that another establishment technique is used.

Other Species in the Mix

For uncompetitive or slow growing species, they may be outcompeted by other species in the mix during the initial establishment. This can be true for climax grassland species which establish very slowly. Reducing the density of competitive species, while increasing uncompetitive species, is recommended in most situations where a specific community is desired. The higher the seeding rate, the more drastic this modification must be to maintain your desired target composition, as discussed in seeding techniques.

Seeding Technique

Each seeding technique will have an impact on the potential for each species to establish. For small seeded species, drill seeding may require that their percentage is increased within the mix. In the case where heavy seeding rates are utilized for erosion control purposes, it may be necessary for significant increases to the percentage of uncompetitive species while significant reductions to competitive species are required.

For each of these categories you will modify the establishment factor accordingly. For species with no concerns, the establishment factor will be set to 1.0 (i.e. 100% of the calculated percent of the mix). You can set species that are going to be too aggressive with a number below 1.0 (less than 100%) to decrease their presence in the mix. In contrast, species that have establishment issues or are not as adapted to your specific site are assigned a number higher than 1.0 (higher than 100%). Within this factor, the lowest numbers (i.e. 0.1 = 10% of the calculated amount of the mix) will be only used for the most aggressive species, while the highest numbers (i.e. 1.6 and up = 160% and higher of the calculated amount in the mix) will only be used for species with significant establishment challenges. For species with the most severe establishment challenges, it is recommended that vegetative establishment is utilized instead of seed in order to guarantee some level of success.

4.2 Calculating your Seeding Rate

Once you have determined the management factor, modified your target seeding rate (seeds/m^2), and set your establishment factor for each species in your mix, you are ready to calculate the percentage of each species in your seed mix and then calculate your seeding rate (kg/ha). Carefully follow each step in this process. Creating a spreadsheet to complete this task is sometimes the most effective method of creating a seed mix. Using the information in Table 4 (seeds/kg for each species) you can set your seeding rates and final seed mix (%).

Formula 2: Calculate Required Seeding Rate (kg/ha PLS)

F2.1 For each species in the weed mix calculate seeds required

$$Seeding\ Rate\ \left(\frac{PLS}{m2}\right) \times \%Target\ Cover \times EF\ \times \frac{1}{\frac{Seeds}{kg}} = Seeds(kg/m^2)$$

*EF= Establishment Factor

*Establishment Factor (EF) will vary from 0.1 for extremely aggressive and fast germinating species to 2 for species that have extremely poor germination and establishment rates. Site conditions, other species, seeding rate, and the goals of the project

F2.2: Calculate the percentage of each species required in the mix on a PLS basis to obtain the target community composition

$$\frac{Seeds(kg/m^2)}{\sum\ all(Seeds(kg/m^2)} = \%\ of\ Mix\ \text{(PLS)}^{(Species\ Specific)}$$

F2.3 Calculate the seeding rate for each species assuming 100% PLS

$$\left(Seeds(kg/m^2)\right) \times 10{,}000\ m^2/ha = kg/ha^{(Species\ Specific)}$$

F2.4 Calculate seeding rate (PLS)

$$(\sum all\ \left(Seeds(kg/m^2)\right) \times 10{,}000 = kg/ha^{(Whole\ Mix)}$$

Formula 3: Calculating the Amount of Seed Required

F3.1 Calculate the actual % of mix of each individual species using result of F2.2

$$\frac{\dfrac{kg/ha^{(Species\ Specific)}}{\%Germination \times \%\ Purity}}{\sum all\left(\dfrac{kg/ha^{(Species\ Specific)}}{\%Germination \times \%\ Purity}\right)} = \%\ of\ Mix^{(Species\ Specific)}$$

F3.2 Calculate the Actual Seeding Rate of Each Species (kg/ha)

$$\frac{kg/ha^{(Species\ Specific)}}{\%Germination \times \%\ Purity} = Seeding\ Rate^{\ (Species\ Specific)}$$

F3.3 Calculate the Actual Seeding Rate of the Mix

$$\sum all\left(\frac{Seeding\ Rate^{\ (Species\ Specific)}}{\%Germination \times \%\ Purity}\right) = Seeding\ rate^{(Whole\ Mix)}$$

4.3 Example Seed Mix Calculation

The following is an example of a seed mix being designed for the Northern Fescue Natural Subregion.

Northern fescue community (hypothetical example) using 800 PLS/m^2 broadcast seeded.

Species	Target % Cover	% of seed mix	% Germination	% Purity	PLS	Seeds/kg	Establishment Factor
Festuca hallii	30	30	85	90	77	886,600	1.3[1]
Stipa curtiseta	40	40	70	100	70	331,000	1.2[2]
Koeleria macrantha	30	30	90	90	81	3,300,000	1[3]

1- *Festuca hallii* is a slow establishing low competitive species
2- *Stipa curtiseta* is a slow establishing, but moderately competitive species
3- *Koeleria macrantha* is a moderately fast establishing species that is moderately competitive at high densities

Formula 2.1

Rough Fescue

(800 PLS/m^2 x 30%) x 1.3 x (1/886 600 seeds/kg) = 0.00035 kg/m^2

Western Porcupine Grass

(800 PLS/m^2 x 40%) x 1.2 x (1/331 000 seeds/kg) = 0.001 kg/m^2

June Grass

(800 PLS/m^2 x 30%) x 1 x (1/3 300 000 seeds/kg) = 0.00007 kg/m^2

Formula 2.2

Rough fescue

(0.00035 kg/m^2/ 0.00142) x 100 = 25%

Western Porcupine Grass

(0.001 kg/m^2 / 0.00142) x 100 = 70%

June Grass

(0.00007 kg/m^2 / 0.00142) x 100 = 5%

Formula 2.3

Rough Fescue

0.00035 kg/m^2 x 10 000 m^2/ha = 3.5 kg/ha

Western Porcupine Grass

0.001 kg/m^2 x 10 000 m^2/ha = 11.6 kg/ha

June Grass

0.00007 kg/m^2 x 10 000 m^2/ha = 0.7 kg/ha

Formula 2.4

(0.00035 kg/m^2 + 0.001 kg/m^2 + 0.00007 kg/m^2) x 10 000 m^2/ha = 14.2 kg/ha

Formula 3.1

Rough Fescue

(3.5 kg/ha /(85 %*90 %)) / ((3.5 kg/ha /(85 %*90 %)) + (11.6kg/ha / (70 %*100%)) + (0.7 kg/ha / (90% * 90%))) = 23%

Western Porcupine Grass

(11.6 kg/ha /(70 %*100 %)) / ((3.5 kg/ha /(85 %*90 %)) + (11.6kg/ha / (70 %*100%)) + (0.7 kg/ha / (90% * 90%))) = 73%

June Grass

(0.7 kg/ha /(90 %*90 %)) / ((3.5 kg/ha /(85 %*90 %)) + (11.6kg/ha / (70 %*100%)) + (0.7 kg/ha / (90% * 90%))) = 4%

Formula 3.2

Rough Gescue

3.5 kg of PLS/ha / 77% PLS/kg = 4.55 kg/ha

Western Porcupine Grass

11.6 kg of PLS/ha / 70%PLS/kg = 16.6 kg/ha

June Grass

0.7 kg PLS/ha / 81%PLS/kg = 0.86 kg/ha

Formula 3.3

Sum of species

4.55 + 16.6 + 0.86 = 22.01 kg/ha of seed

Table 4: Seed weight of selected native species found across the Canadian Prairies. Scientific Names are based on that found in Tannas (2001).

Latin Genus	Latin Species	7 Letter Code	Common Name	Seeds/kg
Agropyron	*dasystachyum*	*Agrodas*	Northern Wheatgrass	345,000
Agropyron	*smithii*	*Agrosmi*	Western Wheatgrass	242,000
Agropyron	*spicatum*	*Agrospi*	Bluebunch Wheatgrass	310,000
Agropyron	*trachycaulum*	*Agrotra*	Slender Wheatgrass	353,000
Agropyron	*violaceum*	*Agrovio*	Violet Wheatgrass	352,000
Agrostis	*scabra*	*Agrosca*	Rough Hairgrass	11,000,000
Andropogon	*gerardii*	*Andrger*	Big Bluestem	318,000
Arctagrostis	*latifloia*	*Arctlat*	Polargrass	3,968,000
Astragalus	*canadensis*	*Astrcan*	Canada Milkvetch	497,200
Beckmannia	*syzigachne*	*Becksyz*	Sloughgrass	1,603,000
Bouteloua	*curtipendula*	*Boutcur*	Sideoats Grama	351,000
Bouteloua	*gracilis*	*Boutgra*	Blue Grama	2,866,000
Bouteloua	*curtipendula*	*Boutcur*	Side-Oats Grama	na
Bromus	*anomalus*	*Bromano*	Nodding Brome	255,000
Bromus	*carinatus*	*Bromcar*	Mountain Brome	198,000
Bromus	*ciliatus*	*Bromcil*	Fringed Bromegrass	520,000
Bromus	*pumpellianus*	*Brompum*	Northern Awnless Brome	280,000
Bucloe	*dactyloides*	*Bucldac*	Buffalo Grass	220,000
Buchloe	*dactyloides*	*Buchdac*	Buffalograss	739,000
Calamagrostis	*canadensis*	*Calacan*	Bluejoint	8,460,000
Calamagrostis	*stricta/inexpansia*	*Calastr*	Narrow Leaved Reedgrass	11,684,000
Calamovilfa	*longifolia*	*Calalon*	Prairie Sandreed	603,000
Carex	*bebbii*	*Carebeb*	Bebb's Sedge	na
Dalea	*purpureum*	*Dalepur*	Purple Prairie Clover	462,000
Danthonia	*parryii*	*Dantpar*	Parry's Oat Grass	222,000
Deschampsia	*caespitosa*	*Desccae*	Tufted Hairgrass	5,510,000
Distichlis	*stricta*	*Diststr*	Inland Saltgrass	1,144,000
Elymus	*canadensis*	*Elymcan*	Canada Wildrye	254,000
Elymus	*glaucus*	*Elymgla*	Smooth Wildrye	240,000
Elymus	*innovatus*	*Elyminn*	Hairy Wildrye	392,000
Elymus	*piperi*	*Elympip*	Giant Wildrye	290,000
Festuca	*brachyphylla*	*Festbra*	Alpine Fescue	1,111,000
Festuca	*altaica*	*Festalt*	Northern Rough Fescue	654,000
Festuca	*campestris*	*Festcam*	Foothills Rough Fescue	664,000
Festuca	*hallii*	*Festhal*	Plains Rough Fescue	886,600
Festuca	*idahoensis*	*Festida*	Idaho Fescue	992,000
Festuca	*saximontana*	*Festsax*	Rocky Mountain Fescue	1,498,000

Latin Genus	Latin Species	7 Letter Code	Common Name	Seeds/kg
Koeleria	*macrantha*	*Koelmac*	Junegrass	3,300,000
Oryzopsis	*hymenoides*	*Oryzhym*	Indian Ricegrass	518,000
Panicum	*virgatum*	*Panivir*	Switchgrass	571,000
Phleum	*alpinum*	*Phlealp*	Alpine Timothy	2,200,000
Poa	*alpina*	*Poaalpi*	Alpine Bluegrass	2,200,000
Poa	*ampla*	*Poaampl*	Alpine Bluegrass	3,300,000
Poa	*glauca*	*Poaglau*	Glaucous Bluegrass	2,910,000
Poa	*juncifolia*	*Poajunc*	Alkali Bluegrass	3,300,000
Poa	*palustris*	*Poapalu*	Fowl Bluegrass	6,957,000
Poa	*sandbergii*	*Poasand*	Sandberg Bluegrass	2,308,000
Schizachyrium	*scoparium*	*Schisco*	Little Bluestem	530,000
Scholocholaa	*festuceacea*	*Schofes*	Whitetop	386,000
Sorghastrum	*nutans*	*Sorgnut*	Indiangrass	385,000
Spartina	*gracilis*	*Spargra*	Alkali Cordgrass	231,000
Spartina	*pectinata*	*Sparpec*	Giant Cord Grass	140,000
Sporobolus	*cryptandrus*	*Sporcry*	Sand Dropseed	12,346,000
Stipa	*comata*	*Stipcom*	Needle and Thread	555,000
Stipa	*curtiseta*	*Stipcur*	Western Porcupine Grass	331,000
Stipa	*viridula*	*Stipvir*	Green Needlegrass	398,000
Trisetum	*spicatum*	*Trisspi*	Spike Trisetum	5,511,000
Vicia	*americana*	*Viciame*	American Vetch	72,600
Puccinellia	*nuttalliana*	*Puccnut*	Alkali Grass	4,647,000

Example 1: Creating a Seed Mix based on a Neighoring Community

Step 1 Assessing the Coummunity:
Using a detailed vegetation transect, run a minimum of ten $10^{th}/m^2$ Frames across each unique habitat on your site. Create a separate mix for each unique habitat. For shrubs use the back of the form on the next page.

Tannas Conservation Services Ltd

Company	Field	Site	Polygon	Date: Y/M/D
LSD	Slope (%)	Aspect	Elevation	Examiner

Site Diagram	Direction	Forms Completed	Site Description (circle one in each column)		
			Regional Landform	Local Landform	Landform Element
	✧	Range health ☐	Mountains	Steep slopes	Crest
		Rare Plant ☐	Hills	Hilly	Upper Slope
		Rare Plant Com ☐	Uplands	Rolling	Mid-Slope
		Wetland ☐	Midlands	Hummocky	Lower-Slope
		Invasive Species ☐	Lowlands	Undulating	Terrace
		Woody Species ☐	Valleys	Ridged	Level
		Veg survey ☐		Plain	Depression

Start:	Photo's	Bearing:	Est. Production	________ kg/ha lbs/ac
End:		Soils/ERS:	Est. Litter	________ kg/ha lbs/ac

Plot Number

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Notes
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
	Total Vegetation																
	Lichen																
	Litter																
	Exposed Soil																
	Rock																
	Sela den																

		Major Risks to Ecological Integrity	
Plant Community Type ________	Utilization ________	Grazing ☐	No Grazing ☐
Range Health Form Type ________	Trend ________		
Estimated Range Health ________	Land Use Type ________	Weeds ☐	Woody Invasion ☐
Healthy ☐	Land Type ________	Cultivation ☐	Fragmentation ☐
Healthy with Problems ☐	Owner ________	Oil/Gas ☐	Subdivision ☐
Unhealthy ☐	Contact ________	Other ☐ ____________	

Tannas Conservation Services Ltd

Range Use Category	grazing Intensity (Est. long term)	Current Utilization	Vigour
☐ Primary ☐ Secondary ☐ Non Use	☐U ☐L ☐M ☐H	Est. %	☐E ☐G ☐F ☐P

	Woody Species	Density Dist	Median Height	Height Range (m)	% Cover	Basal Diamet
1				--		
2				--		
3				--		
4				--		
5				--		
6				--		
7				--		
8				--		
9						
10				--		
11				--		

Density Distribution

ss	Description of abondance	Distribution
0	None	
1	Rare	
2	A few sporadically occurring individual plants	
3	A single patch	
4	A single patch plus a few sporadically occurring plants	
5	Several sporadically occurring plants	
6	A single patch plus several sporadically occurring plants	
7	A few patches	
8	A few patches plus several sporadically occurring plants	
9	Several well spaced patches	
10	Continuous uniform occurences of well spaced plants	
11	Continuous occurrences of plants with a few gaps in the distribution	
12	Continuous dense occurrence of plants	
13	Continuous occurrences of plants with a distinct linear edge in the polygon	

	Invasive Species	Density Dist Class	% Cover	GPS Location
1				
2				
3				
4				
5				
6				

Water Source Photo:____________________

☐ Creek ☐ dugout ☐ trough ☐ slough

☐ lake/pond ☐ other (specify) ________________

GPS Location: ______________________________

Water Quality/ Access (Specify) __________________

	Poisonous Plants	Density Dist Class	% Cover	GPS Location
1				
2				
3				
4				
5				
6				

Salt Source Photo:____________________

☐ Natural ☐ Block ☐ Bag

☐ Other Specify ____________________________

GPS Location: ______________________________

Access (Cattle)

☐ G ☐ F ☐ P ☐ truck trail ☐ road

☐ seismic ☐ game trail ☐ valley bottom

☐ Other (specify) ____________________________

Comments and Management Conerns

Step 2 Calculate Average Percent Cover and Percent Prominence:

Using the data collected in your transect, calculate the average percentage cover and ideally the percent prominence value (weighted average taking frequency into account). You can use either of these numbers to calculate your seed mix, but the percent prominence value is more robust when less micro-plots are used (frames).

Site:	Transect 1		Easting	Northing		Number of Microplots:	10
Bearing		Start				Number of Species:	0
Soil / ERS		End				Date of Inventory:	August 20,
Plot Photo		Plant Community Type:		Range Use Category:		Regional Landform	
LSD	11-23-12-28 W4M	Health Form Type:		Grazing Intensity:		Local Landform	
Slope		Utilization:			Vigour:	Landform Element	
Aspect		Trend:				Elevation	

		% Canopy Cover																		
No.:	Species:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	% Cover	% Comp.	Dom. Val.	% P.V.
1	BOUTGRA	35	30			20	10										9.5	11.5	32.3	14.6
2	MUHLCUS	2									8						1.0	1.2	1.1	0.5
3	ASTEFAL	3		5		5	1	3	4								2.1	2.6	3.4	1.5
4	SOLISPA	10	3				25				8						4.6	5.6	10.9	4.9
5	STIPCOM	15	2	20		35	10	8									9.0	10.9	29.8	13.5
6	ARTEFRI	1		2	2	2				3							1.0	1.2	1.1	0.5
7	ANDRSEP	1	2														0.3	0.4	0.2	0.1
8	ARTECAM	1	T	3		3	3										1.0	1.2	1.1	0.5
9	SISYMON		1														0.1	0.1	0.0	0.0
10	GEUTSAR		5	2			6										1.3	1.6	1.6	0.7
11	KOELMAC		5														0.5	0.6	0.4	0.2
13	GRINSAR		3			2											0.5	0.6	0.4	0.2
14	RHINMIN			2													0.2	0.2	0.1	0.0
15	LIATPUN			2		5	2	4	7	15	15						5.0	6.1	12.3	5.6
16	CIRSFLO			3							5						0.8	1.0	0.8	0.4
17	POAPRAT			3				70	50	20							14.3	17.4	59.6	27.0
19	STIPCUR				65						10						7.5	9.1	22.6	10.2
20	GALIBOR				8	2											1.0	1.2	1.1	0.5
21	FESTSAX				3												0.3	0.4	0.2	0.1
22	HETEVIL				3		3	2	4	3							1.5	1.8	2.0	0.9
23	AGROPEC					12				50							6.2	7.5	17.0	7.7
24	SENECON					3					1						0.4	0.5	0.3	0.1
25	CAREPEN						8	8		10	10						3.6	4.4	7.5	3.4
26	HELIHOO						2	12	20								3.4	4.1	6.9	3.1
27	ANEMMUL						3										0.3	0.4	0.2	0.1
28	COMAUMB						1	2									0.3	0.4	0.2	0.1
29	PHLOHOO						8			15							2.3	2.8	3.8	1.7
30	ERIGCAE						2										0.2	0.2	0.1	0.0
31	LINURIG						1										0.1	0.1	0.0	0.0
32	THERRHO							15									1.5	1.8	2.0	0.9
33	ANEMPAT							4									0.4	0.5	0.3	0.1
34	ROSAARK							3									0.3	0.4	0.2	0.1
35	VICIAME								2								0.2	0.2	0.1	0.0
36	ACHIMIL								8								0.8	1.0	0.8	0.4
37	ROSAACI									5							0.5	0.6	0.4	0.2
38	LYGOJUN									3							0.3	0.4	0.2	0.1
39	ANTEPAR									1	3						0.4	0.5	0.3	0.1
Total Species																	82.3	100.0	221.0	100.0
Total Vegetation		75	50	80	95	90	95	##	##	##	##						88.5			
Lichen		2			4						40						4.6			
Litter																	0.0			
Exp. Soil		15	12	8		20	3										5.8			
Rock																	0.0			
Sela den																	0.0			

Step 3 Asses the Structural Layer and Grazing Response:

For each species the structural layer and grazing response should be assessed to determine the successional information. This information will give you a grasp of the ecosystem function of your final community and what will be required in order to successfully restore it.

Name	Average Cover (%)	% Prom. Value	Grazing Response	Structural Layer
POAPRAT	14.30	26.97	Invader	not applicable
BOUTGRA	9.50	14.61	Increaser - Type 2	Ground cover (prostrate shrubs, graminoids, forbs, moss/lichen)
STIPCOM	9.00	13.47	Increaser - Type 1	Medium Graminoids & Forbs
STIPCUR	7.50	10.25	Increaser - Type 1	Medium Graminoids & Forbs
AGROPEC	6.20	7.70	Invader	not applicable
LIATPUN	5.00	5.58	Increaser - Type 1	Medium Graminoids & Forbs
SOLISPA	4.60	4.92	Increaser - Type 1	Medium Graminoids & Forbs
CAREPEN	3.60	3.41	Increaser - Type 1	Medium Graminoids & Forbs
HELIHOO	3.40	3.13	Decreaser	Medium Graminoids & Forbs
PHLOHOO	2.30	1.74	Increaser - Type 1	Ground cover (prostrate shrubs, graminoids, forbs, moss/lichen)
ASTEFAL	2.10	1.52	Increaser - Type 1	Medium Graminoids & Forbs
HETEVIL	1.50	0.92	Increaser - Type 1	Medium Graminoids & Forbs
THERRHO	1.50	0.92	Increaser - Type 2	Medium Graminoids & Forbs
GUTISAR	1.30	0.74	Increaser - Type 1	Medium Graminoids & Forbs
MUHLCUS	1.00	0.50	Increaser - Type 1	Medium Graminoids & Forbs
ARTEFRI	1.00	0.50	Increaser - Type 2	Medium Graminoids & Forbs
ARTECAM	1.00	0.50	Increaser - Type 2	Medium Graminoids & Forbs
GALIBOR	1.00	0.50	Increaser - Type 1	Medium Graminoids & Forbs
CIRSFLO	0.80	0.36	Increaser - Type 1	Tall Graminoids & Forbs
ACHIMIL	0.80	0.36	Increaser - Type 2	Medium Graminoids & Forbs
KOELMAC	0.50	0.18	Increaser - Type 1	Medium Graminoids & Forbs
ROSAACI	0.50	0.18	Increaser - Type 1	Low Shrubs
SENECAN	0.40	0.13	Increaser - Type 1	Medium Graminoids & Forbs
ANEMPAT	0.40	0.13	Increaser - Type 1	Medium Graminoids & Forbs
ANTEPAR	0.40	0.13	Increaser - Type 2	Ground cover (prostrate shrubs, graminoids, forbs, moss/lichen)
FESTSAX	0.30	0.08	Increaser - Type 1	Medium Graminoids & Forbs
ANEMMUL	0.30	0.08	Increaser - Type 1	Medium Graminoids & Forbs
COMAUMB	0.30	0.08	Increaser - Type 1	Medium Graminoids & Forbs
ROSAARK	0.30	0.08	Increaser - Type 1	Low Shrubs
LYGOJUN	0.30	0.08	Increaser - Type 1	Medium Graminoids & Forbs
ORTHLUT	0.20	0.04	Increaser - Type 1	Medium Graminoids & Forbs
ERIGCAE	0.20	0.04	Increaser - Type 1	Medium Graminoids & Forbs
VICIAME	0.20	0.04	Decreaser	Medium Graminoids & Forbs
SISYMON	0.10	0.02	Increaser - Type 1	Medium Graminoids & Forbs
LINURIG	0.10	0.02	Increaser - Type 1	Medium Graminoids & Forbs

Step 4 Summarize your information:

Once you have summarized the information you will be able to determine how much of the community will have to be comprised of species from each of the three successional stages and how much of the community must be replaced with native species (replace invasive species with native species).

Grazing Response Code (GR)		Average Cover (%)	% Prom. Value
1	Decreaser	3.60	3.17
2	Increaser - Type 1	43.60	45.02
3	Invader	20.50	34.67
4	Increaser - Type 2	14.20	17.00
	Litter	88.50	0.00
	Exposed soil	5.80	0.00
	Sela den	4.60	0.00

Step 5 Seeding Rate Calculations:

Select Equipment: Brillion Drill

Select Rate Based on Environment: Moist Site with invasive species (Target 1,500 seeds/m2)

Step 6 Calculate Real Seeding Rates Using Supplied Formulas:

Target seeds/m2	hectars of land to seed	actual seeds/m2	Actual kg/ha (PLS)	Amount to Purchase (Kg/ha)	Amount to Purchase	Estimated Cost
1500	1.00	1147.84	18.64	23.68	23.68	$5,309

As visible in the table below, the % Prom Value (% Prominence Value) is significantly different than the % of mix (PLS) column. This means that seed size and establishment factors have resulted in significant increases to some species and reductions in others. Specifically, western porcupine grass (Stipcur) is increased from 20.2% to 71.5% of the mix. This is because of the large seed size of this species. In contrast Blue grama grass (Boutgra) has a small seed and high establishment rates and as such, is decreased from 14.6% prominence to 3.1% of the mix. In addition it is important to note that only 66.57% cover is represented in the prominence value. This is because other species should be present, but no seed is available. Those species will have been replaced with suitable substitutes in the mix and hopefully infilling will bring those species back into the community.

7 Letter code	% Prom Value	Grazing Response	% of mix (PLS)	Kg/ha (PLS)	Estimated Price/kg	Kg required	Estimated Cost
BOUTGRA	14.6	I2	3.1%	0.7	$ 26.00	0.7	$ 19.32
STIPCOM	13.5	I1	19.3%	4.6	$ 228.00	4.6	$ 1,040.87
KOELMAC	10.2	I1	3.3%	0.8	$ 142.00	0.8	$ 54.74
STIPCUR	20.2	I1	71.5%	16.7	$ 250.00	16.7	$ 4,176.24
FESTSAX	8.1	I1	3.3%	0.8	$ 46.00	0.8	$ 17.81
	66.57		100%			23.6	$ 5,308.98

Step 7 Modify Community As Required:

Where seed is not available, live plants, sprigs, and other materials may be required to achieve your final results. Also make use of wild harvested seed, hand collected flower seed, native hay, and other materials to enhance the restoration process. Considering the above mix it is very easily apparent that only a few species have been established based on commonly available seed. Other species will be required. Creative establishment of additional species will be necessary for restoration success.

5.0 Bibliography

Adams, B., G. Ehlert, C. Stone et.al. 2009. Rangeland Health Assessment for Grassland, Forest, and Tame Pasture. Alberta Sustainable Resource Development: Lands Division, Rangeland Management Branch. http://esrd.alberta.ca/lands-forests/grazing-range-management/documents/RangelandHealthAssessment-Revised-2009.pdf.

Adams, B.W., J. Richman, L. Poulin-Klein, K. France, D. Moisey , R.L. McNeil. 2013. *Range plant communities and range health assessment guidelines for the Dry Mixedgrass natural Subregion of Alberta*. Lethbridge, Alberta: Rangeland Management Branch, Policy Division, Alberta Environment and Sustainable Resource Development, Pub. No. T/040 135pp.;

Alberta Environment and Parks. (AEP). 2010. 2010 Reclamation criteria for wellsites and associated facilities for native grasslands, (2010). http://esrd.alberta.ca/lands-forests/land-industrial/programs-and-services/reclamation-and-remediation/upstream-oil-and-gas-reclamation-and-remediation-program/wellsite-reclamation-certificate-application-process.aspx.

Neville, M. 2013. Recovery Strategies for Industrial Development in Native Prairie for the Dry Mixedgrass Natural Subregion. http://www.foothillsrestorationforum.ca/recovery-strategies-for-dry-mixedgrass.

Willoughby, M. 2014. Range inventory manual for forest reserve allotments and grazing leases within Rocky Mountain, Foothills, Parkland and Grassland Natural Regions.