Yukon Revegetation Manual

PRACTICAL APPROACHES AND METHODS

Paul Matheus and Toos Omtzigt

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Preface

This *Manual* describes methods for planning and implementing revegetation projects in Yukon. It takes a practical approach based on experience with various methodologies and plant species that have proven to be successful in the territory over the past three decades. The *Manual* was designed to address a range of revegetation sites and applications, from borrow pits and mine sites, to highway rights-of-way, transmission lines and pipeline corridors, even parks.

Land managers in Yukon need to wear many different hats, and this *Manual* was written to be useful to professionals who do not necessarily come from a background in revegetation but who in the course of their work need to develop or implement revegetation plans. Professionals with more experience, including those outside the territory, should find this document to be a useful summary of the current approaches to revegetation work in Yukon and elsewhere in the north.

Revegetation projects in Yukon face a number of fundamental climatic and environmental challenges, usually simultaneously: a short growing season; little and poorly-timed precipitation; and weakly-developed, shallow soils with a variety of nutrient deficiencies and little organic content. Adding to these challenges are a lack of specialized equipment in the territory for seeding and fertilizing, and limited commercial availability of appropriate seeds, fertilizers and other supplies. Usually, these need to be special-ordered and trucked long distances, which adds to project costs and complicates logistics. The methods and strategies recommended in this *Manual* were developed specifically to increase the chances of revegetation success in light of these challenges.

Yukon Revegetation Manual was written to update *Guidelines for Reclamation/Revegetation in the Yukon,* produced by the Government of Yukon in 1993 (Vol. 1) and 1996 (Vol. 2). Those *Guidelines* represented the first large-scale attempt to compile a set of seed mixes and practices for revegetation projects in Canada's north. It primarily used a framework of regional ecological data, patterns in native vegetation-soil associations, and field trials for individual revegetation species to recommend regionally-specific seed mixes. With this approach, the old *Guidelines* focused principally on the biology of the vegetation, but less on the practical aspects of site preparation and implementation. At the time the old *Guidelines* were written, the Yukon revegetation industry was still in its infancy. Since then, a number of species or cultivars it recommended have turned out to be commercially unavailable, while others were ineffective in Yukon conditions and a few have turned out to be invasive. There also have been subsequent advancements and refinements in revegetation methodologies.

The current *Manual* uses the lessons learned over the past two decades to winnow out those practices and plant species that have proven to be impractical or unsuccessful. It takes a less regional approach because experience has shown that the geographic location of a revegetation project in Yukon is less critical than other aspects of the site, such as slope, elevation, soil fertility, soil moisture, soil organic content and level of disturbance. Consequently, the current *Manual* uses a more site-specific approach; it presents revegetation as a more integral component of overall project design; and it recognizes that a more aggressive approach to revegetation often is necessary because many sites in Yukon will consist of bare mineral soil and/or have steep slopes. Because of those challenges, this *Manual* takes a decidedly more "how-to" approach by explaining methods and equipment in greater detail.

None of this implies that the learning process is over – far from it. Revegetation planners are encouraged to continue experimenting with plant species, soil amendments, equipment and other aspects of the revegetation process. Despite best efforts, some revegetation projects will still fail. But practitioners can take heart knowing that the success of a Yukon revegetation project sometimes hinges as much on the vagaries of extreme weather events (*i.e.*, "luck"), as on good planning and good project execution.

Finally, this *Manual* was written in collaboration with practitioners, planners and managers in industry and the Government of Yukon. However, it is not to be taken as a guide to regulatory requirements for revegetating disturbed sites. Regulators and the various departments within the Government of Yukon differ in their revegetation policies and the obligations that they place on permit-holders to revegetate disturbed ground. Thus, this Manual is not a guide for *when* to develop a revegetation plan or what it must include; rather, it provides practical methods and advice to achieve good results *once the decision already has been made to revegetate disturbed ground in Yukon.*

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1 Key Messages

Successful revegetation projects in Yukon depend on the application of several principle stratagems ("key messages") that run as threads throughout this *Manual*. They are presented in this chapter to underscore their importance and to serve as a preview of the detailed information that will be found in subsequent chapters.

Key Message 1: Revegetation Projects Succeed Because of Good Follow Through on all Stages of the Work

Growing conditions in Yukon are challenging, and the main reason why revegetation projects fail here is because critical steps in the revegetation work are neglected or not properly implemented. The most important ones are:

- Minimizing ground disturbance and compaction during development activities, well before revegetation work occurs (this step is not always possible or within the control of revegetation planners)
- Collecting baseline information about site conditions, including soil testing
- Preserving or stockpiling and then reapplying soil organic materials
- Properly preparing the ground prior to seeding, with particular attention paid to decompacting soils
- Fertilizing when necessary with the appropriate blend and at the appropriate rate
- Prescribing and properly sowing a seed mix with the right species and appropriate diversity for the site conditions
- Properly timing each activity

Each one of these steps adds incrementally to the quality and outcome of the project. Whenever one step is skipped, or corners are cut, the results will suffer proportionately. Shortcutting too many steps, or even one critical step, can result in complete site failure – the conditions in Yukon are just too unforgiving.

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FIG 1.1
Too often in the past, a revegetation project in Yukon has meant simply broadcasting a generic grass mix on sterile, compacted ground with few organics and little surface preparation other than dragging a harrow behind the broadcaster. Most sites prepared in this manner will yield poor results, or fail completely.

Successful revegetation projects in Yukon are the result of proper ground preparation, preserving organic materials, applying fertilizer when necessary, and selecting the proper species for seed mixes. Each activity must be properly timed, and good site information, including results from soil testing, is key to developing a successful revegetation plan.

Key Message 2: Define the Objective

Clearly defining the objectives of a revegetation project is fundamental to planning and evaluating its success. But it is important to emphasize that objectives and desired outcomes can vary dramatically between projects, which is why there is no single criterion for judging project success.

In many cases, the primary goal will be to stabilize ground surfaces in order to prevent runoff and erosion on sites that are highly disturbed and have significant amounts of exposed mineral soil. In these projects, planners will want to establish a functional ground cover in a short period of time, usually one season, through a single cost-effective treatment. The second most common goal in Yukon projects is to facilitate the recovery of natural vegetative communities, with less emphasis placed on rapid re-establishment of ground cover and more emphasis placed on reestablishing a specific community structure and the site's biological functionality.

Other goals and objectives include: maintaining the ground's thermal stability (permafrost sites), excluding invasive species, maintaining or re-establishing the genetic integrity of the native vegetation, mitigating impacts to wildlife, inhibiting the regrowth of woody species (*e.g.*, along roadways), enhancing aesthetics, or simply achieving the most ground cover for the least cost. These are discussed in more detail in Chapter 2.

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FIG 1.2
Good site preparation is critical for revegetation success in Yukon, including the addition of organic materials and measures to control for runoff and erosion.

Key Message 3: Minimize the Initial Disturbance Whenever Possible

In Yukon, it can be extremely challenging to establish new vegetation on stripped sites consisting of bare mineral soil, especially when it has been compacted by machinery. A site with intact soils and organic materials will recover much more quickly and will require far less effort and cost. Not only does it provide good soil conditions for plant growth, it leaves intact a seed bank of native plants to recolonize the site. To realize these benefits, developers must make considerations for a site's revegetation needs early on in the planning process, so that workers can be instructed to avoid unnecessary stripping and ground compaction. This approach goes hand-in-hand with *Key Message 5: Saving and Applying Surface Organic Materials*.

The reality, however, is that most sites calling for revegetation work in Yukon will have been moderately to highly disturbed, due to the nature of the development activity, and these sites will become recolonized by native vegetation very slowly. With that in mind, the techniques presented in this *Manual* are mostly meant to help managers develop prescriptions for active revegetation plans when processes of natural revegetation alone will be inadequate to achieve project goals.

Key Message 4: Know Your Site

There is no single, one-size-fits-all approach to revegetation. Every site will be truly unique. Therefore, in order to develop an effective revegetation plan, it is imperative that practitioners become familiar with each site's specific conditions and challenges. Minimally, this involves a site visit, developing a site narrative, and collecting baseline information about site conditions that affect plant growth.

T. OMTZIGT

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FIG 1.3
Know your site. These three photos illustrate the effect that aspect and slope have on revegetation. All were taken at the same site in southern Yukon, within 100 m of each other. The first photo (a) is a north-facing slope, the second (b) is a south-facing slope and the third (c) is a flat spot above the slopes. All have the same gravely, organic-poor substrate and all were seeded with a generic grass mix 25 years ago. Essentially none of the planted grass became established; plants in the photos revegetated naturally. Notice how much the vegetation differs on each surface due mostly to the way that the different slopes and aspects affect moisture retention.

T. OMTZIGT

Typically, this information includes a description of the site's elevation, slope, aspect, sediment properties, drainage patterns, precipitation regime, and a survey of the surrounding vegetation. Soil samples should also be collected to analyze the nutrient status and pH of the soil. All of these data will be critical for making informed decisions regarding issues such as which species to include in a seed mix, seeding rate, fertilizer application, surface treatments, and setting realistic goals. Knowledge of the surrounding native vegetation will provide insight into general soil conditions and limitations to plant growth, as well as natural colonizing species that are in the vicinity. It also provides a preview of what the disturbed site may look like after it has been revegetated, and thus may serve as a criterion for gauging the project's success.

Chapter 2 provides a more thorough review of the planning process, including guidance on the type of baseline information required for proper planning and methods of data collection.

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FIG 1.4
Stockpiling and reapplying organic materials is one of the most effective ways to increase the success of revegetation projects in the territory.

Key Message 5: Saving and Applying Surface Organic Materials

The difference in germination and growth between seeds sown in organic-rich soil versus bare mineral soil is remarkable. However, many projects call for revegetation work on sites where the surface has been graded or stripped, or on fill material, with little or no organic content. Consequently, one of the best steps that can be taken to enhance revegetation is to preserve (stockpile) any surface organic materials that are stripped during development activities and reapply them prior to seeding. This is by far the best way to improve the soil's nutrient status, structure and moisture-retaining qualities. Organic material that is stockpiled and stored for years still retains its value. In addition, seeding rates can be cut in half or more when organic materials have been re-applied, because they contain a natural seed supply that will germinate when the organics are spread and exposed to air and water. Not only is this practice the common-sense approach, it often costs less money and effort in the long run and offers the best chance for establishing natural vegetative cover that retains local plant genetics.

Being able to preserve soil organics for later use requires careful project planning. It takes a deliberate effort to separate the different ground materials (soils, organics, sediments) into stockpiles, and it means identifying good stockpile locations as part of the overall site development plan. This may be as simple as pushing the material to just outside of the work area. Methods and practices of preserving and applying soil organics are described in Chapter 3.

Keep in mind that many of the tools and techniques presented in this *Manual* are only necessary because it is assumed that soil organic content will be poor. In other words, they mostly apply when the goal is to establish vegetation on barren ground. Throughout the planning process and during deliberations over how much ground preparation is necessary and how much seed and fertilizer to apply, planners should ask themselves how much trouble and money could have been saved if the original organic material on-site had been stockpiled and re-spread.

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P. MATHEUS

FIG 1.5
Decompaction is one of the most important aspects of site preparation because it provides for aeration, water absorption and root penetration. Here, a five-shank subsoiler ("ripper") is used to decompact a site. Large disk harrows and other tilling implements can also be used. The application of properly-formulated fertilizer also is a key to successful revegetation in Yukon.

Key Message 6: Ground Conditioning and Fertilizing

As part of a successful revegetation strategy in Yukon, it is almost always necessary to take actions that will improve poor soils and poor growing conditions. Increasing soil organic levels and providing tillage (*i.e.,* decompacting the soil) are the main methods used to develop good soil structure. In addition, fertilizing nutrient-poor soil will provide an important short-term influx of nutrients that will enhance initial plant growth, though the effect will only last one to three seasons. Once the plants are established, soil-building processes will continue naturally due to the turnover and breakdown of plant matter, and generally no further soil amendments will be needed.

The surface preparation techniques used to create suitable and stable soil conditions depend on the site's topography and erosion potential. Flat surfaces can simply be decompacted using tilling techniques, while slopes with erosion-prone surfaces or very steep sites may require the application of ground cover materials, such as mulches, or bioengineered approaches (*e.g.*, the creation of terraces and willow staking).

Chapter 3 discusses the requirements for plant growth in the context of revegetation. It also summarizes data on nutrient deficiencies and other limitations to plant growth encountered in Yukon soils and describes the use of ground preparation techniques and fertilizers to improve growing conditions.

T. OMTZIGT

FIG 1.6
Choose the right species for the site. The species recommended for use in Yukon are listed in Chapter 5 and described in Chapter 6. They have been selected for their proven performance in Yukon's challenging conditions. Still, each species has a unique set of adaptations and it is important to match the right species for site conditions. For example, slender wheatgrass (*Elymus trachycaulus*) is a good colonizing plant on dry to moist sites with alkaline soil. It is a good species to seed on slopes because of its moderately fast growth and roots that hold the soil well.

Key Message 7: Choose the Right Species for the Seed Mix

The previous *Guidelines for Reclamation/Revegetation in the Yukon* presented about four dozen species to consider for revegetation seed mixes. Many of those species are not available commercially, some have turned out to be unsuitable for Yukon conditions, and a few are now known to be invasive. This *Manual* has reduced the list of recommended plants to 23 commercially available species, and has removed the invasive species (this number does not include the numerous local species which are recommended for seed collecting and transplanting).

These 23 species have broad application in the territory and are proven performers, but each species still exhibits strengths and weakness and will grow best in a given set of conditions (for instance wetter versus drier sites or alkaline versus acidic soils). Thus, one of the best hedges for success is to understand the characteristics of these 23 species in order to create a seed mix that is matched to the site conditions and the project objectives. Chapter 5 presents options for species to consider in seed mixes based on site conditions, while Chapter 6 presents individual summaries each of the 23 species and their adaptive traits.

Key Message 8: Native versus Non-Native Species Selection

Currently in Yukon and elsewhere, the major trend in the revegetation industry is to seed or transplant species that are native to a region. The main rationale behind this trend is twofold. First, native species are arguably the best-adapted plants for site conditions, and generally they require less maintenance and persist longer than non-local species (though this is certainly not always the case). When properly established, they form plant communities with the potential to be self-sustaining. Second, some practitioners argue from a biogeographical as well as a bioethical standpoint that it is inappropriate to introduce non-native species to a region because of the potential that they will alter natural ecosystems.

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FIG 1.7
The use of non-native plants, such as annual ryegrass, is still an option for certain applications, especially on difficult terrain where it is critical to establish stabilizing ground cover rapidly. While the industry trend is to plant only native species, currently that is extremely difficult to implement in Yukon because commercial seeds of "native" species are propagated outside Yukon (in Alberta and Alaska), and therefore will have foreign genotypes that can contaminate native populations through cross-breeding. When it is a project priority to protect native genotypes, one strategy is to plant non-native species that cannot hybridize with local plants, as long as these non-native species are not invasive, will not cause ecological harm, and will gradually yield ground to native plants. The non-native species recommended in this *Manual* have been selected for those criteria.

However, there is another approach that is gaining support in this debate. It argues that most varieties of "native" plants used in revegetation are actually developed and cultivated far from the locale where they will be planted. Through cultivation and selection by growers, these cultivars develop unique genomes that are no longer "native." Thus, when seeds from those cultivars are planted, they have the potential to introduce new, non-native genetics into the system (sometimes referred to as "genetic contamination") as they hybridize with native conspecific plants. Using this rationale, planting non-native plants may actually introduce less genetic contamination because they are less likely to breed with native plants, though interspecies hybridization can occur, especially among grasses. Proponents of this unconventional approach advocate for the intentional planting of non-native species, but carefully choosing species that will only persist for a few years and then give way to native species. On the other hand, the evidence is still equivocal regarding the long-term effects or harm done by the hybridization of native plants with non-native cultivars of the same species. And it should be pointed out that the practice of planting non-native cultivars and non-native species has been occurring for over 50 years in Yukon, with no apparent harm to local genetics.

Clearly, there is much debate and even confusion in the native versus non-native plant discussion, even to the level of defining what constitutes a native plant. Because this is one of the more important decisions to be made by revegetation planners, the native versus non-native discussion will be taken up in more detail in Chapter 4, where it will be shown that the issue is complicated in Yukon because there is no commercial production of native plant cultivars in the territory. Essentially all commercial seed is cultivated outside Yukon, so the only way to plant true native plants is for practitioners to collect and sow local seeds themselves. Often that is not practical, especially for large sites. Thus, it is inevitable that the vast majority of revegetation projects in Yukon will necessarily utilize non-native cultivars, and that fact alone renders moot much of the native versus non-native debate. It is emphasized throughout this *Manual* that commercial seed must be sourced from suppliers in western Canada (excluding southern/coastal B.C.) or Interior Alaska because those cultivars will be adapted to Yukon conditions.

In some circumstances, this *Manual* will suggest the use of non-native species (two annual grasses, seven perennial grasses, and one legume) as an option to achieve a specific goal. This practice can be justified because the recommended species do not spread or persist and are not known to form a threat to native systems.

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FIG 1.8
Good timing for each step of the revegetation process is critical in Yukon because of the short working season. The jute/straw matting at this site was placed the first week of October, just before the first snow. By then, local willow shrubs had gone dormant, meaning willow cuttings could be harvested and immediately staked in ground that was not yet frozen.

Key Message 9: Timing

Timing is an important consideration for any revegetation work done in Yukon. Due to the short growing season, work on the ground is typically limited to the period from late May to the end of September. Moreover, seeding is not recommended between early July to the end of August because seedlings will emerge but will not have enough time to mature and build the reserves necessary to survive winter. Normally, seeding is done in spring or early summer. Alternatively, frost seeding may be done when the ground is beginning to freeze, usually in October for most areas of Yukon. Chapter 4 elaborates on these options.

The short work season in Yukon means that planning ahead is critical. Revegetation often represents the last stage of a larger development project, but revegetation work should be included in the early stages of overall project planning. There are two main reasons why this is so important. First, contractors may need to be instructed how to prepare the site in a manner that is conducive to subsequent revegetation efforts. For instance, they may be required to scrape and stockpile organic materials when the project begins, or to contour and condition the site surface after construction (while equipment is still on site). Second, the process of soil testing and then ordering appropriate fertilizer and seed takes time. Waiting until construction is completed in September is much too late to begin thinking about the revegetation plan, if planting still needs to occur that season.

Key Message 10: Follow-up Monitoring

Finally, it is important to remember that the outcome of a revegetation project, even one that is carefully planned, can go awry for no fault of the planner or implementation team. Yukon has a challenging climate for young plant growth and the weather in any given season can be a complete wild card. In a wet year, the chance of success is much higher, but a dry year or a year in which it does not rain during critical periods can spell failure. Poorly-timed rainfalls seem to be the norm in Yukon. If the revegetation effort has failed, or new growth is very sparse, a second or even third seeding may be required. Therefore, for a revegetation project to have a good chance of success, it is essential to make periodic site visits to monitor the progress of plant growth and other developments, such as erosion.

Revegetation, restoration, rehabilitation, and reclamation – what's the difference?

Revegetation The goal of a revegetation program is simply to re-establish plant growth on a disturbed site. Revegetation programs do not necessarily have an implied intent to achieve a natural ecological condition or specific successional (seral) stage. Their goals often have more to do with stabilizing surfaces, increasing soil fertility, promoting native plant growth, or promoting the growth of certain plant types or species over others. As such, revegetation work is only one aspect of restoration, rehabilitation or reclamation projects, and this *Manual* primarily provides guidance for revegetation, not the broader fields of restoration, rehabilitation or reclamation.

Ecological Restoration Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is an intentional activity that initiates or accelerates whole ecosystem recovery with respect to species composition, community structure and ecological function. A restored ecosystem will be self-organized, and self-sustaining. Not all revegetation projects have the goal of restoring a natural ecosystem. However, when ecological restoration is the larger project goal, it will greatly affect revegetation strategies.

Rehabilitation This term is often used synonymously with ecological restoration. However, it implies an effort to intentionally improve ecological conditions on a site without an original, pre-disturbance ecosystem available for reference. Usually this means that humans have lived in the area for such a long period and have altered the landscape to the extent that there is no surrounding original ecosystem towards which the site can be driven. Given this definition, there is little true rehabilitation work that occurs in Yukon.

Reclamation As the terms "restoration" and "rehabilitation" come into more common usage, the term "reclamation" is used less, though it is still commonly applied in the mining industry. In part, this is because there is a perception that "reclamation" implies that only some former attributes or uses of the site will be recovered – *i.e.*, that the site is not capable of being fully "restored" or "rehabilitated" because some vital aspect has been removed or irreparably altered during development. These points are debatable, and a more neutral use of "reclamation" would be in reference to the shaping and reconstructing of features on a site such that it is habitable for the same or similar plant and animal species that existed prior to the disturbance. Thus, the goal of a reclamation projects usually is not to achieve exactly the same community structure, ecosystem function, or diversity as the pre-existing ecosystem. Rather, the intent is to establish some stability and semblance of healthy biological function on the site; it is understood that site may have less diversity and biological complexity than a natural ecosystem, especially in the early stages. Actively revegetating the site is usually fundamental to the reclamation process, but reclamation also addresses larger issues such as the cleanup of contaminated materials, surface recontouring, landscape engineering and public safety.

Definitions modified from: Clewel and Aronson (2007), SER (2002), and FHWA (2007).

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2 Planning Steps

Although revegetation work generally is the last step in a development project, planning for it should be an integral part of the overall project design from the beginning. This allows for better decisions to be made regarding site logistics (*e.g.*, locations to stockpile organic material), site preparation (*e.g.*, slopes, grades), and areas to avoid disturbing because they may be very difficult or costly to revegetate. This chapter outlines the range of issues and questions that practitioners should consider when developing a revegetation plan.

2.1 Defining the Revegetation Objectives and Goals

Even without intervention, essentially all disturbed sites in Yukon will eventually become revegetated on their own over time, due to natural processes of plant colonization and succession. Planners intervene to actively revegetate a disturbed site for a number of reasons. In most cases, it is because the level of disturbance is so extensive that recolonization by native plants will take many years or decades, during which time the risks posed by erosion and surface degradation are great – risks to waterways, structures, earthen works, and permafrost, for example. Leaving the site untreated may also undermine other goals and site values, such as managing human-wildlife interactions, aesthetic concerns, and preventing the spread of invasive plants. The challenge is to develop a revegetation plan that mitigates these issues in a realistic and cost-effective way. The process starts by identifying the project objectives and goals.

2.1.1 Short-Term and Long-Term Erosion Control

Erosion can cause costly or irreparable damage to landscapes, waterways and infrastructure. Ongoing erosion also impedes recolonization by natural vegetation on a site. For these reasons, the prevention or reduction of erosion on barren sites (those scraped to bare mineral soil or infilled) is often the most important and immediate objective of a revegetation project. It is worth reiterating that sites on which the original soils and organic detritus are left intact will be far less prone to erosion than sites that are scraped or infilled.

When designing a revegetation plan to prevent immanent erosion on barren sites, it is important to choose seed mixes and soil amendments that will establish ground cover quickly. This can be accomplished by seeding a mix of fast-growing perennial grasses and annual grasses to

FIG 2.1
Properly assess the challenge. A common mistake is to rely solely on revegetation for erosion control. Simply seeding this fill slope will not stabilize it quickly enough to prevent gullying and sedimentation of the adjacent creek. If stockpiled organics are available, they should be spread on the slope, followed by seeding and covering with jute matting. If large rock rubble is available, rocks could be placed at the base of the slope. Alternatively, willow cuttings should be staked where the slope meets the water (see Chapter 4). Vulnerable sites like this require good follow-up monitoring as well.

provide good ground cover in the first season. But the seed mix should also include slower growing perennial species for long-term stability of the site. Not all sites require such aggressive seeding, and Chapter 4 discusses strategies for formulating seed mixes in more detail. Fertilizing is another key to the rapid establishment of vegetation on barren (organic-poor) sediments.

A common mistake is to rely too heavily on revegetation to fix serious and immediate erosion problems, such as imminent slope failures (Fig. 2.1). Seeding slopes is a major theme running throughout this *Manual*, but seeding efforts can be wasted on a steep slope with unconsolidated fill because the new vegetation may not create sufficient ground stability to help prevent mass slope failure. Measures such as erosion control blankets or mulching may help provide additional slope stability, but more likely engineered solutions may need to be developed. In those situations, revegetation should be part of the solution, but cannot be used alone. Section 3.4 describes advanced erosion protection methods (Fig. 2.2).

FIG 2.2
Erosion control will be a challenge on this site. The project engineers had no choice but to construct such a steep slope and narrow ditch. But as a consequence, a variety of techniques will have to be used to control erosion, and revegetation costs will be higher. Jute/straw matting could be placed over seed or some bioengineering and willow staking could be prescribed. However, both of these solutions will be expensive because the site is very large. A more cost-effective solution would be to place rocks and check dams in the ditch and hydroseed the slopes (both sides of the ditch). It would still be advised to place jute matting on the most vulnerable sections of slope.

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FIG 2.3
a: Melting permafrost. Ice-rich ground was encountered unexpectedly during slope work at this road reconstruction site. The disturbance and removal of insulating ground cover caused thermal destabilization of the ice and initiated melting. The debris flow in the foreground is sediment saturated with water from the melting ice. Once initiated, such melting is difficult to halt. If ice bodies in permafrost ground are disturbed, the situation should be remediated as quickly as possible with the application of granular fill, organic materials and a dense seeding of grasses adapted for cold, wet soils (it is important to measure the pH of these sites and match the grass species accordingly).

b: Same site as photo a after soil and organics were placed over the melting permafrost. This provided insulation and halted the melting process.

2.1.2 Maintaining or Restoring Thermal Regimes on Permafrost Sites

The prevention or minimization of permafrost melting can be an important objective of revegetation planning in Yukon, and the successful re-establishment of a vegetative cover can minimize thermal degradation (Fig. 2.3).

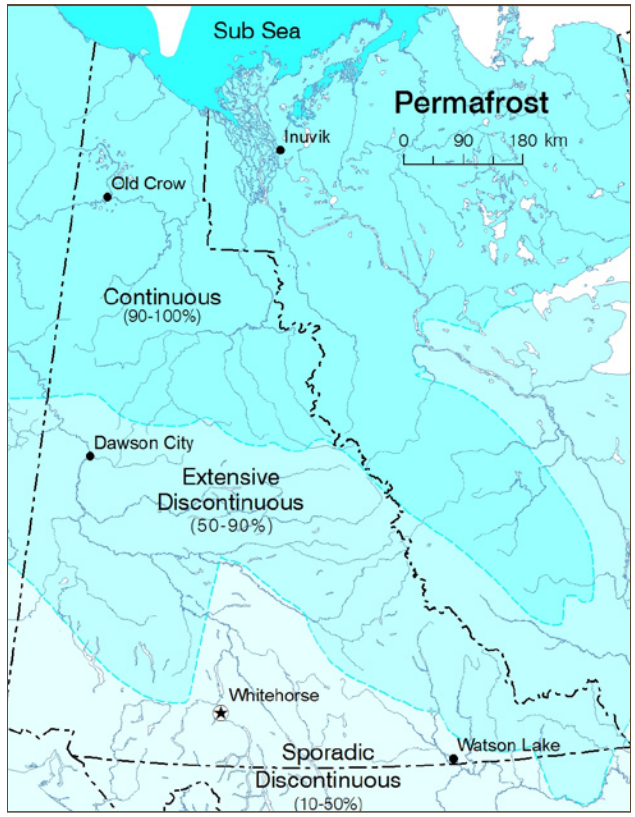
Except in the high arctic, permafrost requires an insulating surface cover in order to remain stable. Without cover to keep it cool, permafrost will melt in a short period (often during first summer it is exposed), and will usually result in thermokarsting – melting and ground saturation, followed by slumping and erosion. Thermokarsting can lead to the formation of depressions, potholed ground, shallow ponds/lakes, and mass wasting (landslides). Accumulated organic matter on the ground surface as well as live plants form the insulative cover that protects permafrost from melting. When a development project removes the insulative cover, especially in summer, permafrost degradation and thermokarsting can occur quite rapidly and there is a very short window of opportunity to complete the work and remediate the site (Fig. 2.3).

If a development project occurs in a permafrost area (Fig. 2.4), revegetation planners will need to work closely with project engineers and work crews to recreate the insulative layer that once protected the permafrost as quickly as possible. Experience has shown that it is difficult to halt, and nearly impossible to reverse, the melting and thermokarsting process once it has begun. Every effort should be made to stockpile organic layers that will be stripped from the site and reapply them as soon as possible. In addition, seeding densities should be increased and seed mixes should include 10% annual grasses (for rapid cover), with a balance of perennial grasses adapted to cold, low-nutrient environments. Species that are planted on permafrost sites usually do not need to be as drought-tolerant as at non-permafrost sites, but careful attention should be paid to the site's pH, with appropriate plant species chosen to match (permafrost sites in Yukon vary widely in pH). Strategies for permafrost sites are discussed in more detail in Scenarios 5, 6 and 7 of Chapter 5.

2.1.3 Mitigating for Wildlife Impacts

When designing elements of a revegetation plan, practitioners need to consider the potential impacts on wildlife and human-wildlife interactions. The most common problem is seeding with species that are attractants to grazing ungulates along roadways, which presents a traffic hazard to drivers and well as wildlife (Fig. 2.5). Consequently, a common goal in Yukon revegetation projects (especially in highway rights of way) is to minimize the site's attractiveness to wildlife. Planners should be cognizant of which plant species used in revegetation are palatable to wildlife and when to minimize or eliminate them from a mix. Information to make those decisions is provided in Chapters 5 and 6.

Likewise, it is usually considered desirable to inhibit the regrowth of woody species in road rights-of-way because trees and shrubs make wildlife less visible to drivers, which also is a safety concern. Young woody plants, particularly willows, are also a forage attractant to some wildlife, especially moose. For those reasons, road rights-of-way are often seeded with aggressive, fast-growing grass species and at high densities with the intent of inhibiting woody regrowth (collecting and sowing seeds of local plants is usually unrealistic in road rights-of-way because the site acreage is too great). This also reduces future maintenance costs because the



YG ENVIRONMENT

FIG 2.4
Distribution of permafrost in Yukon.
Also see Bonnaventure and Lewkowicz (2012)

YG HIGHWAYS & PUBLIC WORKS

FIG 2.5
Elk foraging on brome grass that was seeded along the Alaska Highway. Brome is no longer recommended for inclusion in Yukon revegetation seed mixes, partly because it is a strong attractant to wildlife.

YG HIGHWAYS & PUBLIC WORKS

FIG 2.6
The fillslope of this road was left to revegetate naturally, with no seeding. Soon, the woody species growing up to the roadbed will impede driver visibility and will need to be cleared. If the site had been seeded with grasses, the growth of woody species could have been slowed, resulting in reduced maintenance costs.

frequency of clearing and grubbing is reduced (Fig. 2.6).

The challenge is to seed rights-of-way with grasses that are aggressive and prolific at high enough densities to inhibit woody species without creating a salad bar for wildlife. Chapter 6 provides information on the growth characteristics and palatability of the recommended revegetation species, and Scenario 4 in Chapter 5 lists species specifically recommended for use in highway rights-of-way. Fertilizing these sites can be important for establishing ground cover, but over-fertilizing will increase the nutrition and palatability of grasses, and thus increase their attractiveness to wildlife. See fertilizer recommendations in Chapters 3 and 4.

It should be noted that the goal of some projects might be to provide favorable habitat for wildlife, rather than excluding wildlife. In these cases, planners do not need to avoid high-palatability species listed in Chapter 6, and seeding densities will not need to be so high as to exclude woody species.

2.1.4 Controlling for Invasive Plants

Revegetation work plays a vital role in territory-wide efforts to control for the introduction and spread of invasive species. Sweetclover currently is the most problematic invasive species (Fig. 2.7). In the southern half of Yukon it grows thickly along many roadsides and has become a major management problem in some areas. Not only is it invasive and tenacious, it is an attractive forage to wildlife and can grow tall enough to obscure a driver's view. Brome grass used to be a recommended species for application in revegetation projects, but no longer is because it also is a wildlife attractant and has invasive tendencies. Section 4.2.4 provides more information about the status of invasive and noxious species in the territory.

Perhaps the best step planners can take to prevent the spread of invasive species is to actively seed exposed surfaces in order to establish good ground cover. Invasive plants tend to be colonizing species and usually get a

T. OMTZIGT

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FIG 2.7
Stands of sweetclover (*Melilotus alba*), an invasive plant, have become a nuisance in parts of southern and central Yukon, particularly along roadsides where stands can become so thick that they block visibility. It also is an attractive forage species for wildlife, which creates an additional road hazard. The spread of invasive species can be managed during revegetation by seeding with competitive species, increasing seeding density and fertilizing.

foothold on disturbed, nutrient-poor surfaces. Most are readily excluded when pre-existing vegetation is in place. Fertilizing often helps preferred species to outcompete invasive species.

Seeding during revegetation work can be a major vector for the introduction of invasive plants. Nowadays this mostly occurs when seeds of invasive species arrive as contaminants in commercial seed lots. But in the past, some non-native species that were intentionally seeded and have since proven to be invasive. Sweetclover most likely was introduced to Yukon as an agricultural crop. Once invasive species are introduced and have a foothold, they can be extremely difficult to eradicate. Thus, an objective in all revegetation plans should be to avoid the introduction of any seeds of invasive species. Planners can accomplish this by ordering certified invasive-free seed and by planting other aggressive species that will out-compete invasive plants. Section 4.2.4 discusses details of seed purity and quality.

The revegetation planner can take other steps to reduce the spread of invasive species as well. Ensure that all equipment (*e.g.*, tractors, harrows, seeders) used for revegetation work is clean and does not function as a carrier of weed seed. If the work is contracted, include language in the contract requiring workers to clean equipment before transporting it to the site.

Many new stands of invasive species in Yukon become established simply from the use and transport of contaminated fill-dirt and aggregates. The most common case is the use of gravel from borrow pits where sweetclover is growing. Whenever a project involves infill or the transport of aggregates, the revegetation planner should specify that they not come from sources where invasive species are growing. Furthermore, revegetation plans for decommissioned borrow pits should be designed with the specific intent of excluding sweetclover and other invasive plants.

YG HIGHWAYS & PUBLIC WORKS

FIG 2.8
Most grasses planted for revegetation are bunch grasses, but native forbs will grow between the grass tufts, either on their own or by planting seeds that were collected locally. This relationship can be put to use when planning for site aesthetics. The purple flowers are beautiful Jacob's Ladder (*Polemonium pulcherrimum*).

2.1.5 Visual and Aesthetic Considerations

In many Yukon revegetation projects, scenic and aesthetic effects are important considerations. In these cases, planners need to think beyond the functional aspects of plant species chosen for seeding, and should ask themselves whether the species will produce an aesthetically-pleasing vegetative cover in an acceptable period of time.

In the revegetation world, much emphasis is placed on seeding grasses, but consider adding forbs and translocating shrubs to enhance the site's appearance. Sometimes visual enhancement simply means using taller vegetation to create a visual barrier, to block the view of a borrow pit for instance. In such cases, the best strategy can be to translocate some local shrubs or trees *en masse*. Most grass species chosen for revegetation mixes tend to be bunchgrasses. The bare spaces between tufts of bunchgrasses may be unattractive to some people; consider planting companion plants to fill-in the spaces, including locally-collected forbs (Fig. 2.8) (see Section 4.2.2 – *Gauging the Appropriate Level of Species Diversity*).

Aesthetic sensibilities can also influence how quickly the new vegetation should become established. Even with a good revegetation plan, it could take years, which might be acceptable for a remote or wildland site, but it is often desirable to establish vegetation more quickly on sites with a high public profile and where beautification is a high priority. This can mean allocating more funds in the revegetation budget for a higher seeding density, seeding with more rare and often expensive seeds, using more fertilizer, and translocating woody species. When these projects fall more in the realm of landscaping than revegetating, then they are beyond the scope of this *Manual*.

2.1.6 Managing Project Costs

It is easy for revegetation project costs to balloon out of control, because more can always be done – more seed, more fertilizer, more erosion control materials. Consequently, prudent cost control is important, and the revegetation budget has to be kept in-line with overall project costs. Often, there will be pressure to aim for the least amount of seed and fertilizer necessary to accomplish the project goals, and that is not a bad exercise. Beware however, that one reason revegetation projects go over budget (and fail) is because corners are cut to save money and the site has to be seeded a second time. Too often, the revegetation plan consists of simply spreading and harrowing a generic seed mix on a site, with inadequate attention paid to decompacting and preparing the soil, or the application of fertilizer. Money spent on site preparation, fertilizer and the right seed is usually money well spent.

FIG 2.9
Minimizing per hectare costs can be an important objective on long, linear projects; for instance when decommissioning trails or temporary roads. The same principles of good ground preparation and implementation apply, but they need not be complicated. Decompacting this roadbed with a ripper or large disker, followed by fertilizing and seeding with a basic seed mix (3 – 4 appropriate species) will suffice. The vast majority of work and expense on these projects occurs where the road or trail intersects a slope or water body. In those locations, more extensive erosion control measures may be required.

Cost control is particularly important on large projects such as rights-of-way for highways, pipelines and power lines, or mine reclamation, where the per-acre cost gets multiplied many fold (Fig. 2.9). In these situations, managing the initial costs may not be as important as planning for long-term maintenance costs. In rights-of-way, the growth of trees and shrubs is often considered undesirable because they impede visibility (sight distances) or interfere with structures such as power lines (Fig. 2.9). In these situations, grasses should be seeded at higher densities. This will result in higher upfront costs, but should result in lower long-term maintenance costs.

2.2 Facilitated Natural Revegetation

It only makes sense to prescribe the minimum amount of seeding, fertilizing and ground preparation necessary to meet project goals, and smart planners will utilize natural processes of colonization and succession as much as possible to revegetate a site. In fact, a common management objective is to work the site in ways that facilitate the return of natural vegetation as soon as possible. This is referred to as "facilitated natural revegetation". Note that

FIG 2.10
Sites that are only cleared or grubbed, and where the organic soil layer is left intact, usually will revegetate quickly on their own – with results that are as good or better than seeding. Even if the organic layer was disturbed, a light seeding may be all that is required if enough organics soil remains in place and there is low risk for erosion.

it does not preclude actions such as seeding, fertilizing or tilling, but uses them judiciously to help rather than hinder native species.

In order to decide on the appropriate level of intervention, planners will need to assess the site's capacity for natural revegetation. The three most important factors to assess are as follows:

1) There should be some semblance of the original soil components remaining on the surface. This is important because the soil contains mineralized nutrients that are available in forms that can be assimilated by plants. Organic detritus alone does not, as its nutrients are tied up mostly as complex organic molecules. The less original soil that is intact, the more that fertilizating should be considered.

2) There must be natural seed sources in place. This will include the natural seedbank found in organic soils and organic detritus on-site, as well as sources in nearby vegetation. Large, non-linear sites can be problematic because the distance from the center of the site to the seed sources can reduce the rate of colonization.

3) The presence of coarse organic matter/detritus on the surface is an important asset. In addition to housing a natural seedbank, it is the source of organic material and nutrients for future soil-building processes and it functions much like a mulch to provide erosion protection.

When managing for facilitated natural revegetation, minimize disturbances to the ground surface during development, and leave as much as possible of the original soil and organic materials in place (Fig. 2.10). Consider for example whether all areas of the site need to be stripped and graded during the development, or whether some areas can just be grubbed (Section 3.2.1). When the ground must be scraped, graded, or infilled, try to stockpile and then reapply surface organic materials and soil components. They will contain nutrients for plant growth, a natural seedbank, and will add valuable structure to the new surface (Section 3.2.2). It can be extremely difficult to achieve acceptable rates of natural regrowth on sites comprised of bare mineral soil and graded infill. So when preparing this type of ground, make sure it is thoroughly decompacted and left with a moderately rough surface (Section 3.2).

It is often wrongly assumed that fertilizer does not need to be applied to a site being managed under a regime of facilitated natural revegetation. In fact, fertilizer is very beneficial to most native plants and fertilizing the site is a good way to accelerate recolonization and succession. Fertilizer can play a particularly important role on sites where coarse organic material has been reapplied to surfaces that were stripped and graded down to mineral soil. There are no true organic soils left on these sites, and while the organic material will contain a rich natural seedbank, there will be a lack of mineralized nutrients available for uptake by young plants (see Chapter 3 for a discussion of soil dynamics). Fertilizing makes nutrients available for new plants until soil-building processes begin to mineralize nutrients in the coarse organic matter. Rates of fertilization for various treatment strategies are discussed in Section 3.3.1.

Another misnomer is that seeding with a commercial seed mix will necessarily inhibit the growth of natural vegetation. While collecting and sowing seeds of local plants is the preferred method of facilitating natural revegetation (discussed in detail in Section 4.6), it is often impractical or cost-prohibitive. In lieu of local seeds, a light to moderate seeding with a commercial grass mix can be a good strategy. The seeded grasses will stabilize the ground surface, serve as nursery plants for native colonizers, and the turnover of their biomass will add organic matter to the soil. The challenge is to prescribe a seeding rate that is high enough to achieve these goals, without choking out native colonizers. Section 4.2.3 provides advice for gauging seeding rates. For similar reasons, it is advised to prescribe a mix with high diversity so that no species is likely to become dominant, and avoid species in the mix that are overly aggressive and long-lived (Chapter 6). A light seeding of annual grasses can be very effective, too (Section 4.2.1).

Planners should exercise caution when prescribing light seeding because it is a common mistake to under-seed (and under-fertilize) a site when it is assumed that natural succession will finish the job. On sites with challenging conditions, the result will most likely be poor regrowth of both native and cultivated plants. There must be good evidence from the site visit and site data (Section 2.3) to justify the seeding rate, and the rate should be chosen with all site objectives in mind. Chapter 4 provides more specific guidance for making these decisions.

One approach to facilitated natural revegetation that planners will sometimes encounter in Yukon is referred to as the "rough and loose" technique, whereby the ground is simply recontoured after a disturbance (if contouring is even necessary), decompacted and left in a "rough and loose" condition. This leaves a surface microtopography that creates catchments for water and naturally-dispersed seeds. In a general sense, the term "rough and loose" can be viewed simply as a term for good ground preparation and decompaction, which are important steps in revegetation work. But when used by industry, "rough and loose" normally implies that there will be no follow-up seeding or fertilizing. Consequently, the problem with "rough and loose" (*sensu stricto*) as a stand-alone prescription is that it does not directly address the question of where seeds and soil nutrients will come from in order

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FIG 2.11
Natural revegetation can be a slow process, particularly in alpine environments and on slopes. The photo above shows an abandoned gravel pit in a subalpine region on the Haines Road, B.C. The photo to the left shows the same site four years later. No seeding was done at this site. Note how there has been very little change during that amount of time; natural revegetation on the disturbed ground is developing very slowly.

to initiate and support new plant growth. Thus it is an incomplete prescription. Furthermore, preparing the ground in a rough and loose manner does not necessarily preclude the application of commercial seed or fertilizer. Seeding and fertilizing decisions should be made based on good data that quantify the soil nutrients, organic matter and natural seed sources present on-site (Fig. 2.11).

The following is a summary of situations where it is **not** recommended to rely solely on processes of natural revegetation; some degree of intervention and facilitation should occur, including ground decompaction/scarification, seeding and fertilizing:

- When the site has little or no organic content; *i.e.*, the surface is essentially comprised of bare mineral soil.
- When there is an imminent threat of significant harmful erosion and runoff at the site; this includes most sites with a slope over 15% grade. The exception is sites that have only been cleared or grubbed.
- When it is desirable to exclude certain species or types of plants, such as shrubs and trees; this is the case for instance along many roadways. In those situations, aggressive seeding with grasses at high densities helps to delay the return of woody species.
- When populations of invasive plants are known to inhabit the area, because they will tend to outcompete native colonizers (this applies mostly to barren sites).
- When a site is so large or shaped such that central areas will be too far from seed sources and colonizing plant populations (a "donut-hole effect").
- When a site has a high public profile and it would be aesthetically unpleasing or bad public relations to leave the site with an unkempt appearance for many years.

Generally, there are only two situations where it is advisable to forgo seeding and rely solely on processes of natural revegetation alone:

- When the organic soil horizons are essentially undisturbed and a substantial layer of organic material remains on the surface or can be spread on the site, such as when the ground has been grubbed but not scraped (this assumes that natural revegetation will satisfy all other project goals).
- When it is critical to avoid all risk of introducing foreign genetics to the area, including cultivars of native species (see Section 4.1). Collecting and sowing local plants in these situations can supplement natural colonization. However, these sites may be at risk to invasion by invasive plant species.

2.3
Assessing the Site and Gathering Baseline Information

Successful revegetation depends largely on making informed planning decisions based on sound data regarding soil and site conditions – soil fertility, pH, soil structure, sediment type, precipitation regime, drainage, slope, aspect, elevation, *etc*. Some of this information can be obtained from extrapolation of regional data, or it can be ascertained fairly quickly from a site visit or even photographs. A valuable resource with summaries of regional data ranging from soil types and geology to climate and vegetation patterns is *Ecoregions of the Yukon Territory: Biophysical Properties of Yukon Landscapes* (Smith *et. al*, 2004).

It is worth the time and effort to research whether other revegetation projects have been undertaken in the area in order to learn, for example, which species in a seed mix succeeded or failed. Past experience can also be used to make predictions about soil conditions likely to be encountered, such as nutrient deficiencies or the presence of permafrost.

Information extrapolated from regional data, photos and nearby sites is extremely useful, but ultimately it will be necessary to collect site-specific baseline data. This will include site visits to measure and record attributes such as slope, aspect, moisture conditions, indicators of permafrost, extent of surface disturbance, sediment structure, drainage features and spatial complexity. It also will be important to survey the surrounding vegetation and plant communities, which will provide information about soil conditions (*e.g.*, pH) and natural seed sources. Perhaps most important, soil samples should be collected for nutrient testing and pH. The following subsections include more specific instructions for developing a good site description and conducting soil testing.

2.3.1 Site Description

Unless the site is very large and/or spatially-complex, it is fairly straight forward to record general site information in a short amount of time. However, planners will find themselves in two very distinct situations: 1) describing the site before the disturbance has occurred, or 2) describing the site when work is finished and the site is already in a disturbed state (maybe even ready for revegetation work). Most of the procedures that follow assume the latter, but the general procedure applies to both cases.

Begin by providing a general site narrative. For instance, is the site within a lowland riparian area, or is it on a gently-sloping, mid-elevation hillside? In general, is the surface smooth or rough? Rocky or covered in fine sediments? Was fill material brought in? Is there a creek, ditch, seep or other waterbody on-site? Describe the overall native vegetation surrounding the site (*e.g.*, "mature, white spruce – pine boreal forest"). Then measure and record specific features as follows:

- Record the site's elevation, because it influences the species chosen to include in seed mixes.
- Record the predominant slope aspect. On large or complex sites, there may be more than one aspect. Aspect data will help in assessing how much solar radiation and warming the site receives and how dry it is. North-facing sites will have colder soils and shorter growing seasons, but may be more moist; south-facing sites will have warmer and deeper soil profiles, and a longer growing season, but may be prone to long periods of extreme dryness in summer.
- Record the percent slope at various locations using a clinometer or measured from a topographic map. In some cases, it is adequate to simply estimate the slope. At a minimum, use descriptors like, "mostly flat," "gently sloping," "steeply sloped," "has rock outcropping and boulders that will be problematic," "cannot use tractors, will need to use quads for seeding because of rough terrain," *etc.*
- Dig a few shallow test holes with a shovel and make a qualitative description of the sediments, such as, "Sediment is not native soil, but is fill that was brought in during construction. Structure is a mix of course gravel, sand and clay." Then provide an estimation of its moisture-carrying capacity and drainage characteristics. Does water percolate through the sediments? Are there clay-rich areas or depressions where water pools?
- It is important to record the type and amount of organic materials on the site, and whether there is an intact soil layer, versus bare mineral soil. This will greatly affect the type and amount of fertilizer that will be required, and the revegetation species that are chosen. If organics are present, describe them (*e.g.*, "forest duff layer," "fine sticks and debris," "slash and stumps in push piles," "scraped organics nicely stockpiled during construction," *etc.*), and make a note as to how they could be used during the revegetation process.
- Make observations for the presence or absence of features that indicate permafrost is in the area. Generally, south-facing slopes in central and southern Yukon will be permafrost-free. However, even in southern Yukon, low-lying, flat, poorly drained ground may contain isolated permafrost pockets and ice bodies. On tundra sites, assume that permafrost is

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FIG 2.12
Some sites are a challenge, and the cost of revegetation has to be considered relative to the return. This small mine site has been inactive for over 30 years and little natural revegetation has occurred. There was no attempt to actively revegetate the site. If tasked to develop a revegetation plan for this site, planners should first recognize that the site has at least three distinct surfaces, or "sub-sites," each of which should receive quite different treatment. In the foreground, there is a coarse soil with some native grasses and trees that are establishing voluntarily. This area probably could be overseeded by hand, with little or no soil disturbance or machinery traffic – in other words, do not destroy the vegetation that has taken hold. The flat area in the pit bottom (centre of photo) also has fine to coarse sediments but is showing little sign of natural revegetation because it was so heavily compacted by equipment traffic when the mine was operating. It should be thoroughly decompacted followed by fertilizing and seeding. The rocky scree slopes in the background present a real challenge. Unless massive amounts of fine materials are trucked in, it will be pointless to actively revegetate these areas. The exception may be the few small benches that support pockets of thin vegetation. The best approach may be to simply contour the steepest areas of scree so they blend in with the rest of the site. Scree slopes do occur naturally and in this case should be used as a positive aesthetic feature in the overall reclamation plan.

present (see Chapter 6 for differences in dealing with alpine versus lowland permafrost). In boreal forest sites, indicators of permafrost include: stands of stunted black spruce, thick mossy duff layers, tussocks, shallow ponds or pools of standing water and spongy ground. Common vegetation found growing on permafrost includes tussocky sedges, Labrador tea, blueberries and salmonberries. Be sure to look well beyond the immediate project site for evidence of permafrost.

- A final stage in the site description is to survey the undisturbed plant communities that surround a site (Fig. 2.13). The natural vegetation cover is a good indicator of specific underlying soil properties, including texture, drainage, thermal regime, pH, salinity, and nutrient status. Information about surrounding plant communities is very useful as a supplement to soil testing data (see below), and to create a more complete picture of the site conditions. Appendix A contains information from

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FIG 2.13
Even for the smallest site, recording baseline information about site conditions is an essential first step when preparing a revegetation plan.

the 1993 *Guidelines* that correlates natural vegetation communities with soil conditions in most regions of Yukon.

- Assessing the surrounding vegetation will also help planners decide on the best revegetation strategy to employ, specifically the extent to which a natural recolonization can be relied on and the intensity of active revegetation efforts that will be required. For instance, surveying the surrounding vegetation will indicate the presence and abundance of natural colonizing species, which may be harvested for seed (Section 4.6). Facilitating natural processes of colonization and revegetation are discussed below in Section 2.3.

2.3.2 Soil Testing

Soil testing involves the systematic collection of soil samples that are sent to a laboratory for analyses of nutrient levels and other soil properties relevant to plant growth (Fig. 2.14). This information is invaluable for making accurate assessments regarding the type and amount of fertilizer to apply and the appropriate species to include in seed mixes. It is the only way, for instance, to determine whether the site is phosphorous-deficient (a common but unpredictable condition of many Yukon soils), which is easily rectified with the appropriate fertilizer mix. Table 2.1 summarizes criteria for evaluating the status of the most important soil properties and nutrients based on soil testing data.

Despite its high value and relatively low cost, soil testing is one of the most neglected aspects of revegetation work in Yukon. The usual reason is a failure to plan ahead for soil testing, and as a result, many prescriptions for fertilizer and seed are based only on generalizations and assumptions about soil nutrients. For instance, the following scenario is not uncommon: It's late August, seeding still needs to occur but there is no time to wait for test results; it is just assumed that nitrogen and phosphorous will be deficient, so a fertilizer with high percentages of both nutrients is applied. While this is not the recommended approach, it is recognized as a reality of revegetation work in Yukon and guidelines are provided in Chapter 3 for gauging the application of fertilizer in the absence of soil-testing data.

Another situation where planners forgo soil testing is for small sites, based on the rationalization that a small site is less critical and that it makes more sense to spend project funds on fertilizer than on soil testing. However, the decision to conduct soil testing or not should be based on how important it is for the revegetation plot to succeed, not how large it is.

Collecting samples for soil testing is not complicated and does not require specialized equipment. Step-by-step instructions are given at the end of this chapter. However, it is important to remember that soil testing requires planning ahead. It can take two weeks or more for test results to be returned from the lab, and another two to four weeks for fertilizer to arrive. Consequently, sampling should occur at least one month prior to the targeted seeding date, but realistically more like six to eight weeks.

It can be important to develop a good working relationship with a testing lab and a fertilizer manufacturer, for a number of reasons. The interpretation of soil data and formulation of fertilizers can be technical and benefits from applied experience. Planners will depend on testing labs for good interpretations of test results and recommendations for fertilizers. Furthermore, the more samples that testing labs see from a given region, the more insight they gain into its soil chemistry, so it is good to have continuity with a given lab. Over time, the lab will also learn to spot samples that are aberrant or non-representative, in which case they may advise to resample.

Despite these recommendations and the specialized knowledge provided by testing labs, it is valuable if planners develop some of their own discretionary skills

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FIG 2.14
The surrounding vegetation can provide a good starting point for predicting site soil conditions, and knowledge of regional trends is useful as well. However, soil sampling should be considered standard procedure for assessing basic soil parameters such as nutrient status and pH. Without this information, prescriptions for seeding and fertilizing are often little more than best guesses.

regarding soil data and fertilizers. This is because experience has shown that testing labs are: 1) usually oriented towards agricultural applications and crop production, and 2) unfamiliar with Yukon conditions and the goals of revegetation planners this far north. When analyzing samples of bare mineral soils from Yukon, for instance, some labs may express shock at the wholesale deficiency of the soil and make overly aggressive (and expensive) recommendations for fertilization – in part as well because they are accustomed to dealing with samples from agricultural fields in southern Canada. Chapter 3 discusses in detail how to use soil testing data to develop fertilizer mixes and application rates, and provides additional practical guidelines for dealing with soil deficiencies in Yukon.

Table 2.1
Criteria for evaluating soil properties and nutrient status based on data from soil testing.

Soil Properties	Range	Classification
pH Values	< 4.5	extremely acid
	4.6 – 5.0	very strongly acid
	5.1 – 5.5	strongly acid
	5.6 – 6.0	medium acid
	6.1 – 6.5	slightly acid
	6.6 – 7.3	neutral
	7.4 –7.8	mildly alkaline
	7.9 – 8.4	moderately alkaline
	> 8.5	strongly alkaline
Calcium carbonate ($CaCO_3$)	1 – 5 %	low
	6 –15 %	moderate
	> 16%	high
Electrical Conductivity	< 1 mmho/cm	low salinity
	1 – 5 mmho/cm	moderate salinity
	> 5 mmho/cm	high salinity
Nitrogen (N)	0 – 3 ppm	low
	3.1 – 5 ppm	moderate
	> 5.0 ppm	high
Phosphorus (P)	0 –10 ppm	low
	10.1 – 25 ppm	moderate
	> 25 ppm	high
Potassium (K)	< 75 ppm	low
	76 – 150 ppm	moderate
	> 150 ppm	high
Sulfur (S)	0 – 7.5 ppm	low
	7.6 – 15 ppm	moderate
	> 15 ppm	high
Organic Matter	0 – 4%	low
	4.1 – 14%	moderate
	14.1 – 29%	high
	> 29%	very high

2.4 Implementation and Monitoring

Even the best-planned revegetation projects can fail if not properly implemented. Examples of improper implementation include: insufficient ground decompaction (or not deep enough), spreading seeds unevenly, not adequately incorporating seeds into the ground, purchasing poor quality seed, or last-minute seed substitutions. Consequently, planners should work closely with crews to ensure that each part of the work plan is properly executed. This means being on site and inspecting the work as it is being performed. Waiting until the following spring to find out that the stockpiled organic material was never re-applied or was applied after the seed and fertilizer is too late.

Even with proper implementation, it is important to continue monitoring the site for at least two growing seasons. In a significant number of Yukon revegetation projects, there is a need for touch-up seeding, and it is not unheard of for an entire site to fail and require a second seeding. As often as not, the reason is an extreme weather event – an unusually heavy rain causing an unforeseen washout, or maybe it was a bad year for winter seed survival or spring germination. Sometimes, subsequent construction activity and destructive traffic occurs on the site without crews being aware that the ground had just been seeded. Follow-up monitoring is a way to ensure that the investment made in site planning and implementation actually pays off.

In the early stages of revegetation, the most useful performance indicator to monitor is "percent ground cover" (also referred to as "percent soil cover") – *i.e.*, how much of the surface is covered by vegetation (see side bar on next page and Fig. 2.15). There are no hard and fast rules regarding the percent cover that is acceptable versus unacceptable, other than "more is usually better." On an erosion-prone slope, a good target is 50 – 60% ground cover by the end of the first growing season; otherwise it may not be effective at preventing erosion. And it is recommended to spot seed any patches that appear on these slopes because that is where erosion is likely to occur.

On flat or gently-sloping sites with a stable surface, a ground cover of 20 – 30% after the first season is usually adequate. Anything lower than 20% warrants enough concern to continue monitoring; a round of spot seeding or overseeding should be considered as well. The decision to reseed or not will depend on whether the level of growth is meeting project objectives and the assessed likelihood that natural revegetation will infill. Note that ground cover in the 25% range with a good showing of native regrowth after one year may actually be an excellent outcome if the site is flat and the goal was simply to facilitate the natural revegetation processes.

If the site was seeded but the cover is less than 10% after the first year, then something went wrong. Most likely, the site will require reseeding, and it is worth reviewing the project to find out what caused the failure. Was there an error in calculating the prescribed seeding density, or was it a poorly-chosen seed mix? Was it decided to forgo fertilizing? Were all of the prescriptions for site preparation followed? Were site preparation, fertilizing and seeding done with good workmanship? Just as important, review the weather records for the past year. Was it an unusually cold winter with little insulating snow cover? If so, perhaps winter kill of dormant seeds is to blame. These types of forensic analyses will be valuable learning exercises for planning better projects in the future.

Another informative performance indicator is relative species survival and stand diversity. If only one out of five species in a seed mix is growing, this should be a red flag. It could indicate that a poor seed mix was chosen, or that inadequate fertilizer was applied. Either case would suggest that poor information was collected on site conditions, or that this information was not heeded in the seed and fertilizer prescriptions. Alternatively, the survival of one out of five species could simply mean that winter conditions were so severe that only one species was hardy enough to survive. Indeed, that is one of the reasons for including multiple species in a seed mix. And depending on the project goals, having one species survive and stabilize the site may be deemed an acceptable project outcome.

How is percent ground cover measured?

Percent ground cover is important because it measures the amount of soil being held in-place by plants and debris and therefore helps to gauge risks of erosion. There are many methods available to measure the percent ground cover, some simple and some more complex. For the revegetation planner, the measurement generally does not require high precision. But just what is meant by the terms "ground cover" or "good ground cover?"

Ground cover refers to both living and dead plant materials lying on and within 2 cm of the ground surface. Basically, this means only the part of the plant sticking into the ground and excludes all of the leaves and stems higher than 2 cm off the ground. That is why a measured value for percent ground cover often seems lower than the perceived value – because most of the visible plant that is obscuring the view of the ground does not count in the calculation.

Most methods for measuring ground cover involve dropping an open ring (usually 30 – 100 cm in diameter or width) on the ground, clipping or brushing aside stems and leaves taller than 2 cm, and then visually estimating the percentage of bare versus covered

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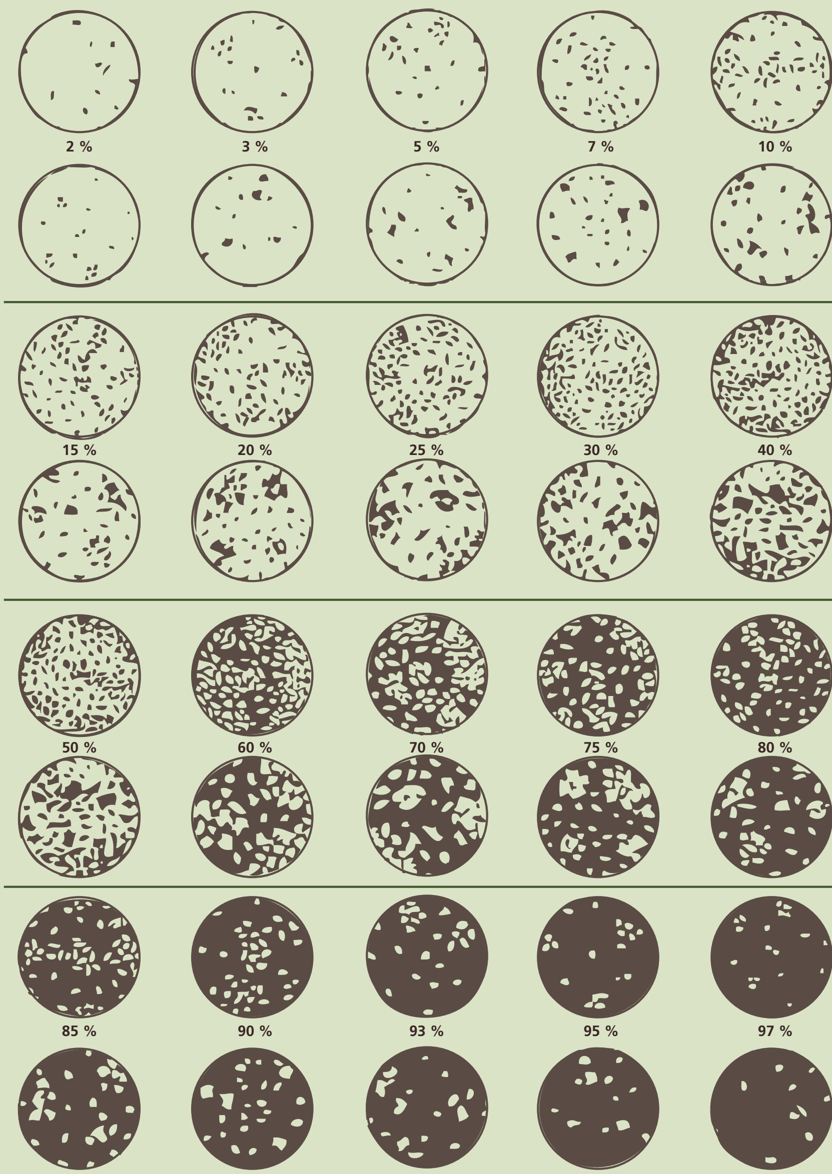
2.15
Ground cover on this site was measured to be 15 – 20% after one year. Because the site is relatively flat, this coverage would be adequate if the site objectives were to stabilize the ground and facilitate natural regrowth. If the goal was to exclude the natural re-establishment of woody species (a common objective along roadways), then the coverage should be at least twice this level.



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ground using guides such as the one above. Multiple ring drops and measurements are made in either a systematic (*i.e.*, following a grid pattern) or a random (*i.e.*, randomly determined points) pattern.

Keep in mind that even mature stands of native bunch grasses will have inherently less ground cover than turf-forming grasses. Fifty percent ground cover is lush for bunch grasses, but would be low for a turf grass. Consequently, the goal is never 100% ground cover, but more like 20 – 60%, depending on the growth characteristics of the species planted and how many years have transpired since planting.

As mentioned, the revegetation planner usually does not need a high degree of precision when assessing percent ground cover at recently-planted site, with one important exception: when contract specifications require that a stated ground cover be achieved within a specified period of time. For example, 60% ground cover after one year. When testing for contract compliance, the planner may need to use a more formal measuring protocol and sampling design. Recommended methods can be found in *Roadside Revegetation: An Integrated Approach to Establishing Native Plants* (FHWA 2007).

Procedures for soil sampling and testing

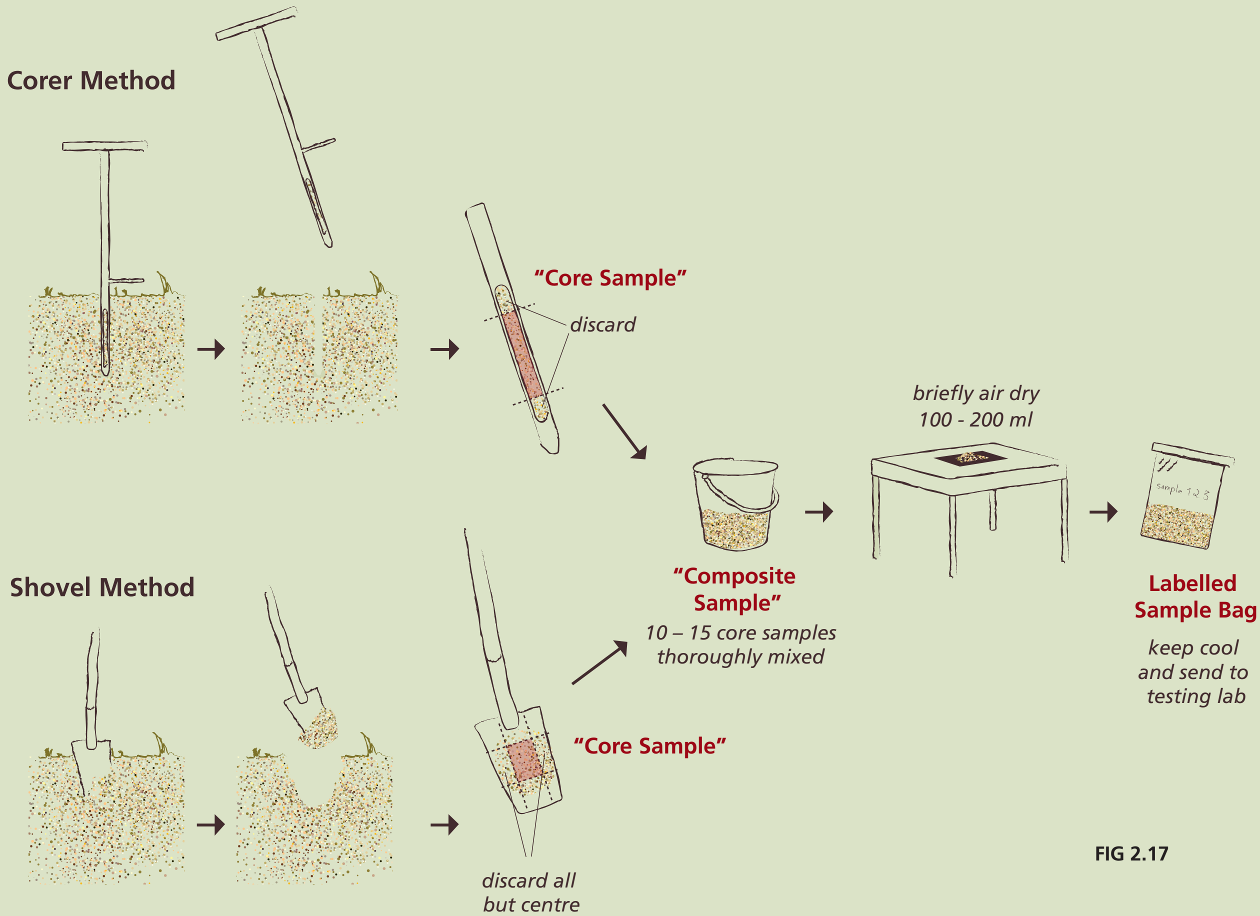


FIG 2.17

In revegetation projects, the goal of soil sampling and testing is to characterize the general soil properties of a site, particularly its nutrient status and pH, with the aim of developing effective prescriptions for fertilizers and seed mixes. The revegetation planner needs a very general assessment of these conditions and deficiencies, not a detailed profile. That is the main way that soil sampling techniques for revegetation work differ from those in agriculture, contaminants testing and other soil-based industries. In those industries, two major goals of soil testing are to characterize a site's heterogeneity and to identify "hot-spots" – aberrant areas where nutrients or contaminants exist in particularly high or low concentrations. In contrast, soil sampling protocols for revegetation work should be designed to minimize the "noise" from site heterogeneity and hot-spots in favour of a composite snapshot of the site's overall soil nutrient status.

With those goals in mind, the following protocol has been developed as a straightforward and cost-effective approach to soil sampling for revegetation projects in Yukon.

1. General Synopsis of Soil Sampling

Soil samples are collected systematically as a series of shallow "cores" (also called "core samples" or "sub-samples") using a coring tool (tube sampler) or shovel (Fig. 2.17). Each core is placed in a bucket and mixed with other cores to constitute a "sample" (also called a "composite sample"). Generally, a composite sample consists of 10 – 15 core samples and multiple composite samples will be collected systematically (see below). After thorough mixing, the composite samples are air-dried and only small sub-samples (~100ml) are sent to a testing laboratory for analysis. Results are usually returned in two to four weeks.

Sampling can be done any time of year (nutrient levels do not vary significantly by season), but for practical reasons sampling should not occur when the soil is frozen or wet. The best time to sample is in summer when the soil is dry or slightly moist, but other aspects of site development usually will dictate the timing. Conduct sampling after the final grading and fill material is in place but before organic materials have been spread.

2. Determining Sample Numbers and Locations

A good goal for sampling intensity is two composite samples (10 – 15 cores each) per hectare on sites less than 10 hectares total and one composite sample (10 –15 cores) per hectare on sites greater than 10 hectares total. When in doubt or when the site is heterogeneous, take more cores and/or pool fewer cores per composite sample.

Sampling (coring) locations should be determined using judgemental and systematic sampling protocols, rather than a strictly random sampling protocol. For instance, use a map to lay out sampling locations that are broadly but evenly spaced (*i.e.*, systematic, not random) and will fall on ground that typifies the site (Figs. 2.18 and 2.19).

On non-linear sites, plot a grid pattern on a site map (Fig. 2.18) and use a compass and engineer's tape measure to locate sampling locations on the ground (*e.g.*, follow a course of 27° and sample every 20 m). It is not critical to sample exactly where the tape measure stops. If a sample location lands in an obviously aberrant spot, like a large rock or stump, it is acceptable to reject or move that location by choosing the most representative spot in the surrounding 10 m^2. If the location lands near a tree, sample outside of the tree's dripline and away from large lateral roots.

For linear sites, simply follow a transect down the middle of the right-of-way and collect a core every 30 metres. Consider adding a systematic left-right zig-zag to the transect to average-out site variation (Fig. 2.19). If the site is greater than 30 m wide, sample along two or more parallel transects. Use the same guidelines in the previous paragraph for rejecting aberrant sampling locations.

On sites with two or more distinct soil types, conditions or surface treatments, design the sampling protocol to test these units separately, and ensure that cores from the different areas are not combined when creating composite samples. For instance, a site with a flat area that received fill from off-site and a prominent cut slope may warrant separate sampling transects for each. Sampling these areas separately will give the planner information to determine individual treatment parameters such as where to fertilize more heavily.

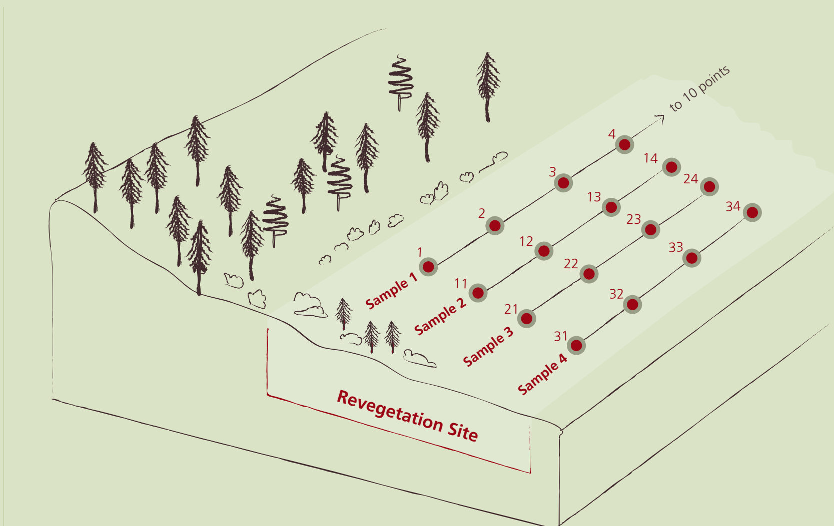


FIG 2.18
A systematic sampling pattern for non-linear sites.

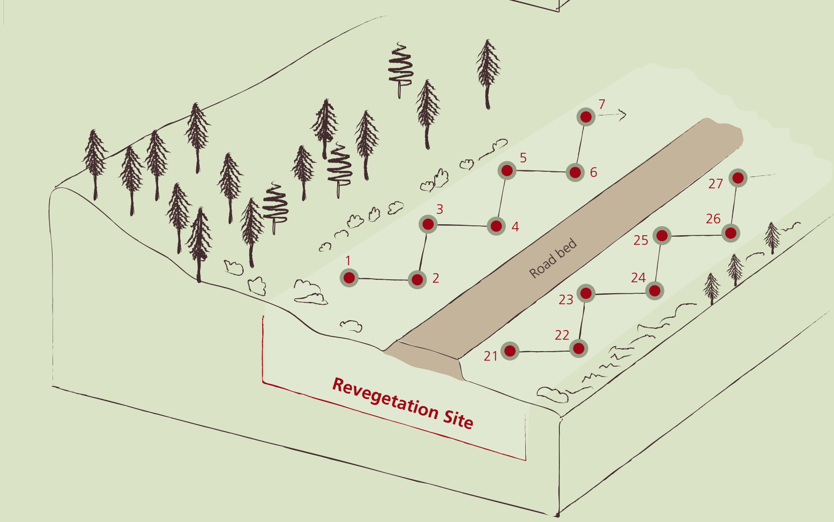


FIG 2.19
A systematic sampling pattern for linear sites.

3. Sampling Depth
Most soil sampling protocols in agricultural and other industries call for sampling at two depths, often 0 – 15 cm and 15 – 30 cm. This is a form of stratified sampling and is usually unnecessary when collecting samples for revegetation.

A single sampling depth is adequate because the goal is to sample at a depth where roots of one to two year-old plants will be growing and utilizing applied fertilizer. For most northern grasses, this depth is 10 – 20 cm. Rooting depth for most forbs is a little less (5 – 10 cm). Consequently, if the revegetation species will be all grasses, a sampling depth of 10 – 20 cm is recommended. If species will be a mix of grasses and forbs, then a depth of 5 – 15 cm is recommended.

An important principle is to ensure that all cores are collected at a consistent depth, and from the mineral soil zone (see Figs. 3.3 – 3.4 in Chapter 3). Also note that the depths are not target ranges or averages; all the soil in the core from the prescribed depth is collected. In other words, a sampling depth of 10 – 20 cm means that all of the soil in the core from the 10 to 20 cm range is included in the subsample.

On rough surfaces, the depth should be measured from halfway down a furrow (*i.e.*, halfway between the highest and lowest point of an undulation).

If coarse organic materials have been applied to the surface, begin measuring the depth from below the organic layer. In other words, do not include the organic layer when measuring the depth). Do not collect samples directly from the organic layer either, as they will yield misleading test results.

4. Collecting the Samples
Sub-samples can be collected with either a coring tool (tube sampler) or a shovel (Figs. 2.14, 2.17). A tube sampler is inexpensive and will pay for itself in time-savings very quickly. In both cases, avoid contamination by surface materials, and clean all tools between samples.

<u>a) Coring Method</u>

After navigating to the predetermined sampling location, the tube corer is simply pushed into the ground and pulled out to extract a cylindrical soil sample. Most corers are designed to penetrate the ground 20 – 50 cm and produce a core that is 2 – 4 cm in diameter.

If the desired sampling depth is 10 – 20 cm, use a knife or spatula to remove the top 10 cm of the core and any material below 20 cm. Pre-marking the desired sampling interval on the barrel of the tube corer or the spatula will obviate the need to measure each sample with a ruler. Remember: do not include organic materials at the top of the core in the depth measurement.

Once the ends of the core have been cut and discarded, place the core in a plastic bucket. Do not use metal buckets (especially galvanized) because they can contaminate samples with cations (positively charged metals). It is also important to wipe clean the corer and spatula after each sub-sample is collected.

After the predetermined number of cores (usually 10 – 15) has been collected in the bucket, the soil in this composite sample should be thoroughly mixed. Next, remove 100 – 200 ml (about ½ cup) and spread it on a flat surface to air-dry for a brief period. This is the sample that will be sent to the lab. Do not over-dry the sample or dry it in an oven, as this can change the chemistry and volatilize certain nutrients. Some practitioners prefer to dry the entire composite sample first, before final mixing and sub-sampling because a dry sample can be homogenized more completely than a wet sample.

After drying, remove all visible pebbles, sticks, leaves and other large items and place the sub-sample in a plastic bag. Often, testing labs will provide sample bags. Otherwise, a sturdy plastic freezer bag or zip-tie bag can be used. Be sure to label the bag with your name, project name, sample number, grid location and date.

If possible, store the samples at a cool temperature, preferably around 4° C. Cooling is not critical, unless there will be significant delay (days to weeks) between the time the samples are collected and sent to the testing lab. It also is acceptable to freeze the samples. If sampling in a remote location where samples can not be placed in a refrigerator the same day as they are collected, consider bringing a cooler with ice for storage and transport. At a minimum, keep samples out of the sun and in the coolest location possible.

<u>b) Shovel Method</u> (a trowel can also be used)

The method for shovel sampling is essentially the same as for coring, except for the way the soil is extracted. A shovel with a long and narrow, straight blade works best (Fig. 2.17).

The sampling depth usually will fall within the depth reached by a single scoop from a shovel. However, sometimes it is necessary to first remove the top 5-10 cm of material in order to collect a sample from the entire depth range in a single shovel-full. Either way, a v-shaped hole is cut into the ground and then a continuous slice is cut with the shovel from one sidewall of the hole (Fig. 2.17). With the slice of soil still on the shovel blade, use a knife or spatula to remove the top, bottom and sides, leaving behind a central core from the prescribed depth (*e.g.*, from the 10 - 20 cm zone). This core constitutes the sub-sample and is added to the sample bucket. Subsequent treatment is identical for samples collected using a tube corer.

5. Working with a Testing Laboratory and Test Results

Ideally, testing labs should be contacted before soil samples are collected because they may have specific instructions regarding sample size, sample preparation or shipping (and they may want to supply their own sample bags). It is also the best time to discuss the soil testing goals, as the lab may have useful suggestions regarding sampling protocols. At the same time, the lab will indicate the current turn-around time for sample results, which may affect project planning.

Be sure to indicate that the soil testing is for revegetation work on non-cultivated land and not for crop production, gardening, or landscaping, because this will affect the type of feedback and recommendations that lab provides.

Generally, revegetation work only requires the most basic soil analysis, which provides the following data:

- Nitrogen content (ppm)
- Phosphorous content (ppm)
- Potassium content (ppm)
- Sulfur content (ppm)
- Percent organic matter
- pH
- Electro-Conductivity (an indicator of salinity)

The test results may include data for other soil parameters, such as micronutrients, or these can be requested for an additional fee. Some practitioners may find this additional data to be useful.

Carbonate content is often included in basic test results because agronomists use it in conjunction with soil pH to calculate liming rates (application of calcium carbonate) for agricultural fields. However, carbonate content is generally not a concern in Yukon revegetation projects for two reasons. First, most Yukon soils already have high carbonate levels (there are exceptions). Second, adding lime to soils is expensive in Yukon because commercial sources are distant, making shipping costs prohibitively high. If soil testing indicates the site is acidic, it is usually best to compensate by planting species adapted to acidic conditions, not by liming. The exception is that liming may be appropriate for a small, aberrant pocket of acidic soil on a site with otherwise normal pH (see Section 3.3.3).

The data obtained from soil testing are used to determine the fertilizer formula and application rate following guidelines and tables in Section 3.3.4, and to choose appropriate plant species for seed mixes following guidelines in Chapters 5 and 6.

P. MATHEUS

3

Improving Conditions for Plant Growth

This chapter provides information and methods to improve conditions for plant growth. After a brief introduction to Yukon soils, it discusses procedures for improving soil structure, particularly through decompaction; the application of organic materials; and it explains how to deal with nutrient deficiencies through the proper formulation of fertilizers. Advanced methods of erosion control are briefly outlined.

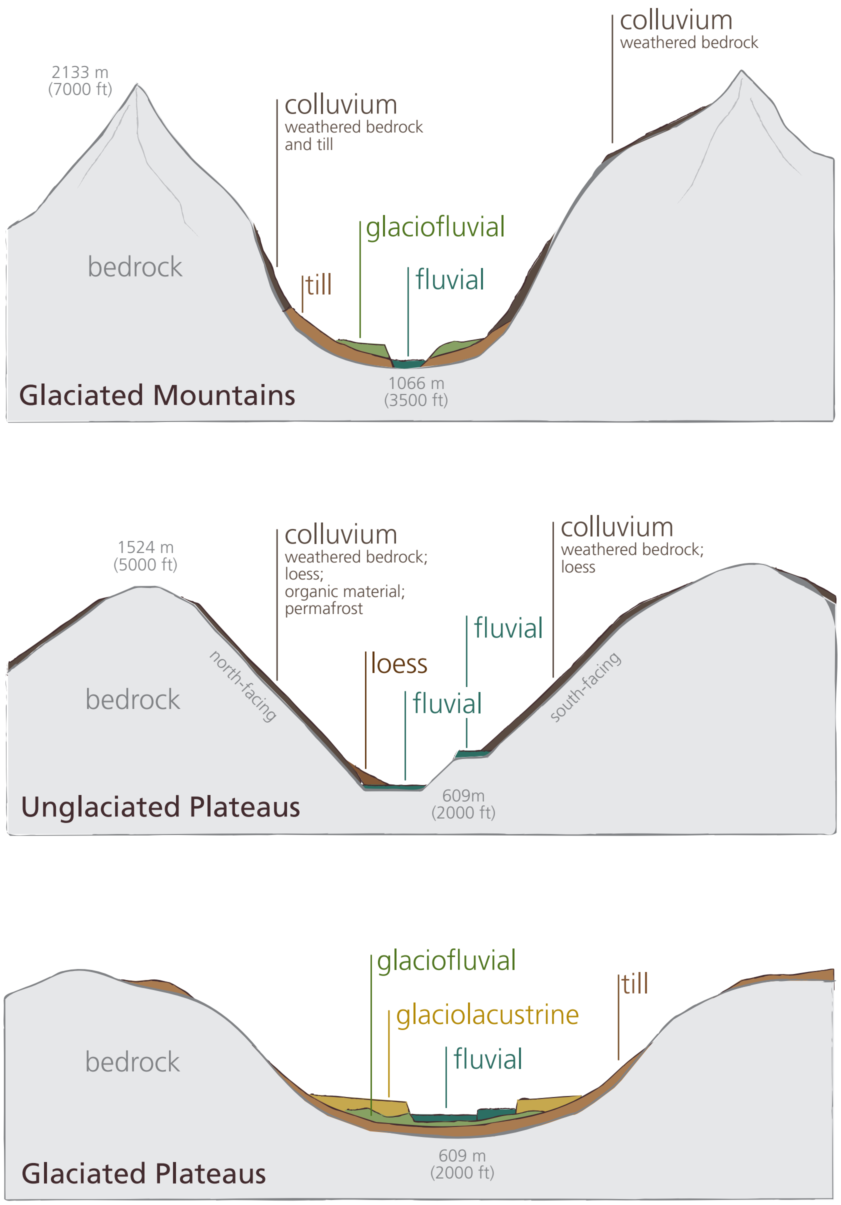
3.1 Background to Yukon Soil Development and Status

Yukon soils have formed under cold, semi-arid to moist subarctic climates on a range of geologic materials (Yukon's bedrock geology is one of the most complex in North America). While mineralogically diverse, most Yukon soils are shallow, have cold temperature profiles, exhibit weak to mild chemical weathering and contain very little organic material. Over a third of the ground in Yukon contains near-surface permafrost. Add to this the fact that Yukon has a very short growing season and low precipitation levels and it all spells a very challenging environment to promote plant establishment and growth.

The nutrient status and productivity of Yukon soils is largely influenced by soil temperature. Cold conditions decrease the rate of chemical reactions and microbial metabolism within soils, thereby slowing processes such as mineral weathering and organic matter decomposition. In cold climates, the immobile nature of nutrients in permafrost further impedes nutrient cycling, as nutrients in frozen soil are essentially locked-up. Cold conditions are one of the main reasons why Yukon soils are so deficient in available nitrogen.

Over two thirds of Yukon was glaciated until ~10,000 years ago. As a consequence, many ground surfaces have been scraped of pre-existing soils or covered by barren glacial deposits. After deglaciation, soils formed in a variety of sediment types, from glacial outwash and till to glacial lakebeds. But since they have been ice-free for only a short period of time, the soils are immature and weakly developed, with shallow profiles (Figs. 3.1 – 3.4). Soils in non-glaciated areas, while older, are not much better developed because they occur in areas of Yukon that have been mostly cold and dry and/or underlain by permafrost.

FIG 3.1
The relationship between landforms and soil formation in Yukon



ADAPTED FROM *A GUIDE TO SOIL SAMPLING IN YUKON* (2007), YUKON GEOLOGICAL SURVEY

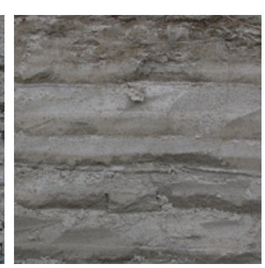
Parent Material	Genesis
weathered bedrock	in situ weathering
fluvial	stream/river
loess	wind
lacustine	lake
moraine/till	directly by glacier
glaciofluvial	glacial meltwater
glaciolacustrine	glacial lake
colluvium	slope/gravity

Parent Material Textures

weathered bedrock
- sand and angular rock fragments

loess
- silt with minor organics and roots
- oxidation common
- no bedding, cohesive

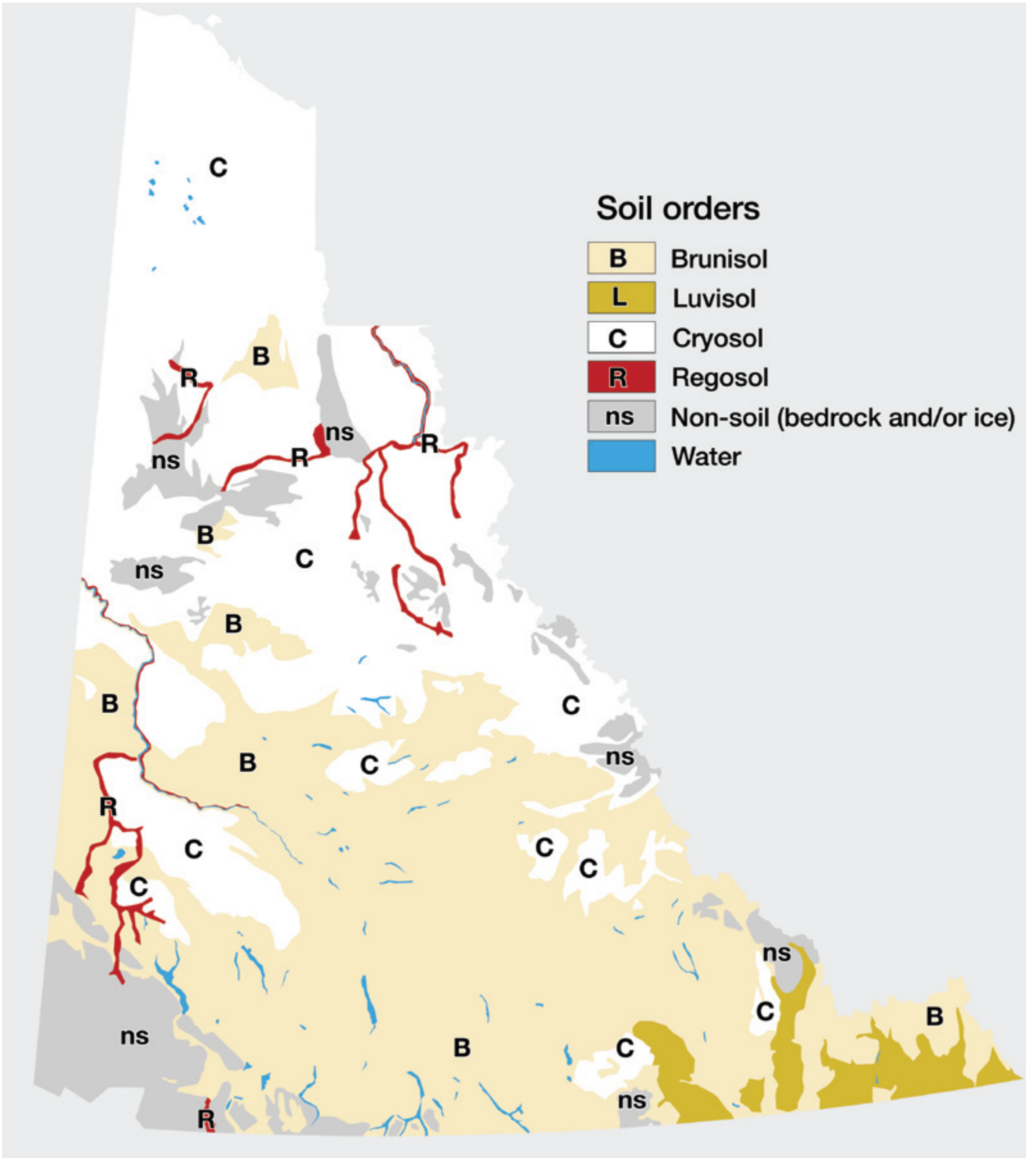
till
- mixed clay, silt, sand and gravel
- no bedding (massive)
- polished stones, compact



glaciolacustrine
- clay, silt, and sand
- few stones
- laminae (banded), bedding

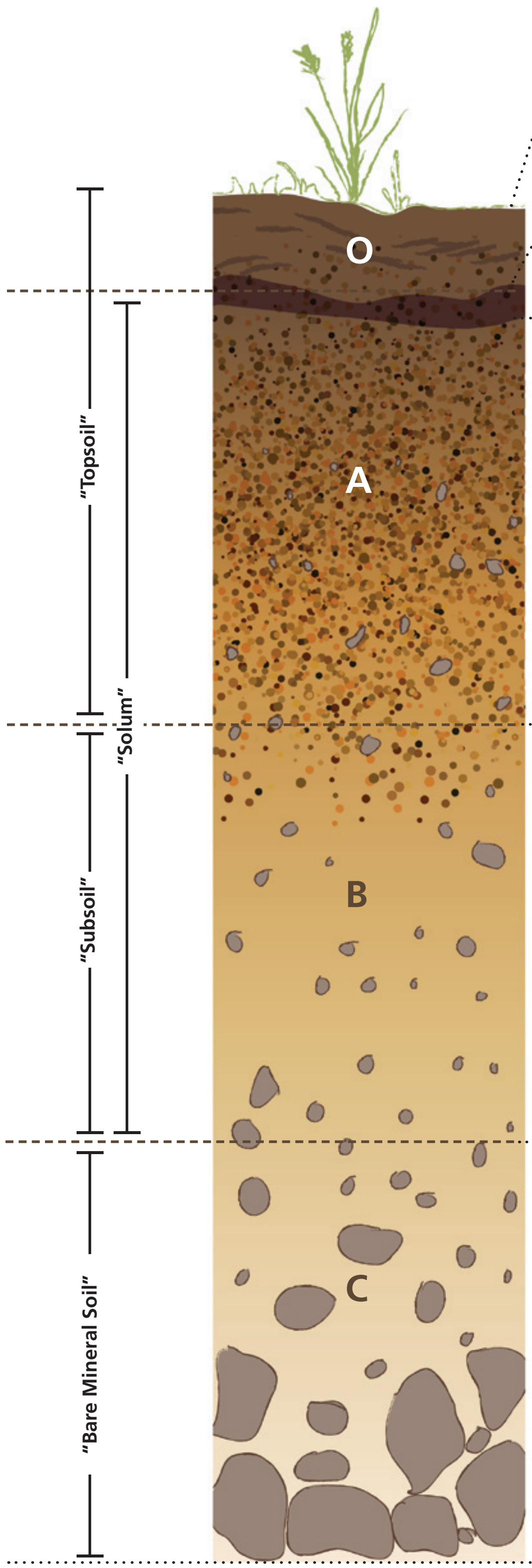
fluvial or glaciofluvial
- sand and gravel
- non-cohesive
- laminae, bedding, cross-bedding

FIG 3.2
Distribution of soil types in Yukon



Soil order	Occurrence	Description
Brunisol	Very common in Boreal Cordilleran Ecozone	Mildly weathered mineral soil, commonly forms under forest cover and grasslands in southwest and central Yukon. The most common subgroup of Brunisol in the Yukon is the Eutric Brunisol, which has a pH in the surface soil of >5.5. Dystric Brunisols are less common acidic subalpine and alpine soils with pH <5.5.
Cryosol	Very common in all northern ecozones	Permafrost-affected soils, may be associated with wetlands, tundra, or taiga forest conditions. Turbic Cryosols are mineral soils strongly affected by frost churning, which generates various forms of patterned ground. Static Cryosols lack this frost-churning process. Organic Cryosols are the soils of peatlands underlain by permafrost.
Regosol	Scattered throughout all ecozones	Regosols are soils that have not been weathered and are associated with active landforms such as floodplains, colluvial slopes, dunes, thaw slumps and debris flows. The soils do not exhibit horizon formation typical of other soils.
Luvisol	Restricted to ecoregions in southeastern Yukon	Luvisols are the soils associated with fine-textured soils under boreal and temperate forests throughout Canada. In the Yukon, they only develop at lower elevations on clay-rich glacial deposits under relatively mild and wet conditions such as are found in the Liard Basin, Hyland Highland and Muskwa Plateau ecoregions.
Organic	Scattered wetland soils of Boreal Cordilleran Ecozone	In soil taxonomic terms, Organic refers to soils that are formed of decomposed vegetation (peat) rather than sand, silt and clay. Organics are associated with fen wetlands that are not underlain by permafrost.
Podzol	Rare	Podzols are associated with temperate, high rainfall forested areas. In the Yukon, they are occasionally found in Selwyn Mountains and Yukon Stikine Highlands ecoregions. All Podzols identified in the Yukon have been classified as Humo-Ferric Podzols (*i.e.* those with enriched iron concentrations in the subsoil).

FIG 3.3
Schematic profile showing major soil horizons in a generalized soil.
In Yukon, soil horizons are often not this well developed or clearly discernible.



Organic Horizon

- accumulated organic matter in various stages of decomposition
- also referred to as the Ao horizon
- contains very little parent material (mineral soil)

A1 Horizon

- thin zone of humic matter (decomposed organic matter)
- contains more organic material than parent materials (mineral soil)
- sometimes visible as a thin dark brown or black layer

A2 Horizon

- altered parent sediment rich in humic (organic) matter weathered from A1 (this subsequently leaches to the B Horizon, but minimally so in Yukon soils)
- many nutrients are in mineralized forms that can be taken up by plants (see Fig. 3.5)
- often has a reddish brown or black coloration that distinguishes it from the parent sediment and B Horizon
- referred to as the "zone of leaching" because nutrients and minerals leach from the A Horizon to the B Horizon
- little clay content, as most leaches to the B Horizon
- the A and O Horizons are collectively called "organic soil" or "topsoil"

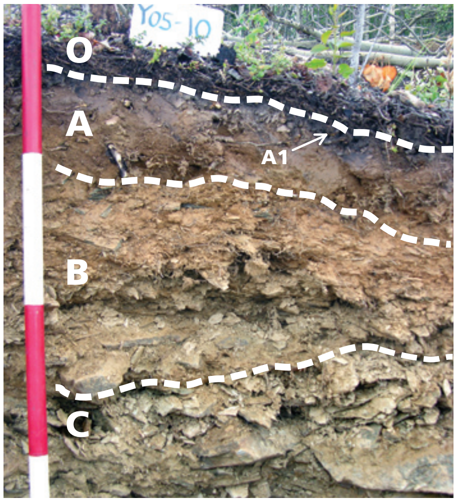
B Horizon

- receives leached minerals, nutrients and organic molecules from the A Horizon and thus called the "zone of accumulation"
- has fewer nutrients than the A horizon, but plant roots will penetrate the B Horizon for nutrients and water
- discolouration and streaking distinguish it from sterile parent material comprising the C Horizon
- in Yukon, usually will be lighter colour than A Horizon
- higher clay content than A Horizon
- The B Horizon is also referred to as the "subsoil"

C Horizon

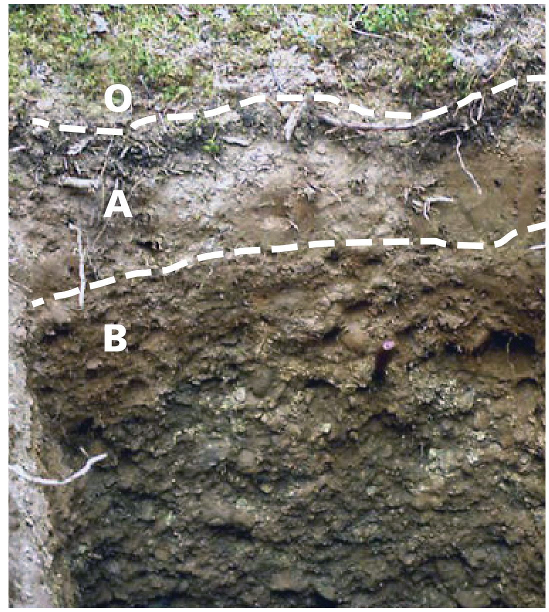
- weakly-altered parent material with no leached organic content
- may be discoloured at top from minerals leaching from B Horizon
- otherwise little affected by weathering and soil-forming processes
- sometimes referred to as "bare mineral soil"

FIG 3.4
Five typical soils found in Yukon. Divisions between horizons are weakly developed in Yukon soils and do not always follow visual demarcations because they are defined by their mineral and organic content as well as degree of weathering and leaching. Many Yukon soils have subhorizontal and uneven profiles due to cryoturbation.



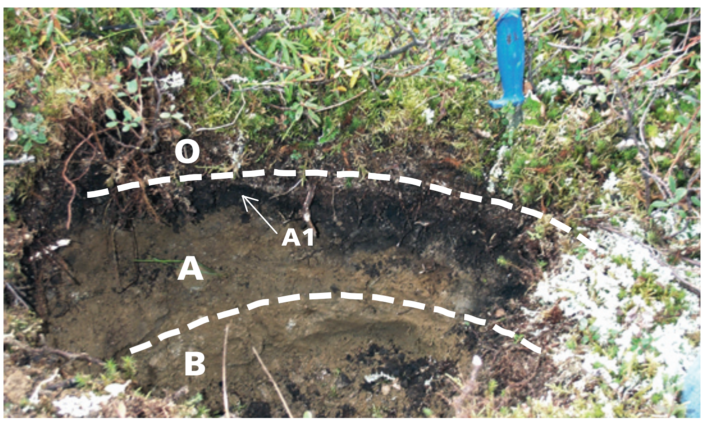
YUKON GEOLOGICAL SURVEY

Typical brunisol found in unglaciated upland areas of the Klondike region. Differentiation between the soil horizons is very weekly developed. Note the shallowness of the weathering profile, the thinness of the A Horizon, and the loess (wind-blown silt) layer in the upper B Horizon.



AGRICULTURE AND AGRI-FOOD CANADA

A luvisol from a valley bottom in the Liard basin. Note the deep weathering profile and deep B Horizon. The light-coloured A Horizon is a result of significant leaching of minerals and nutrients to the B Horizon. Luvisols form under lowland boreal forests in relatively warm, wet areas and are mostly limited to southeastern Yukon (see map in Fig. 3.2).



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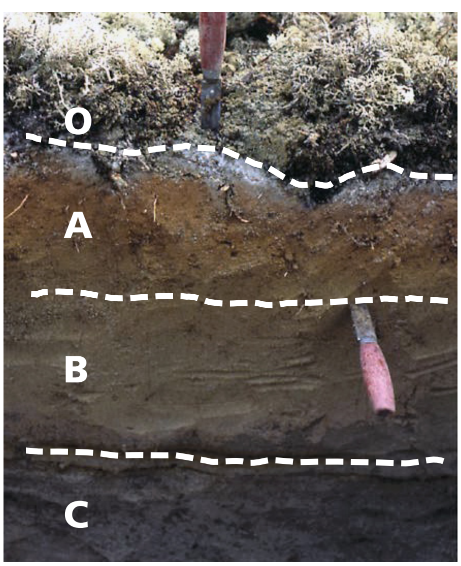
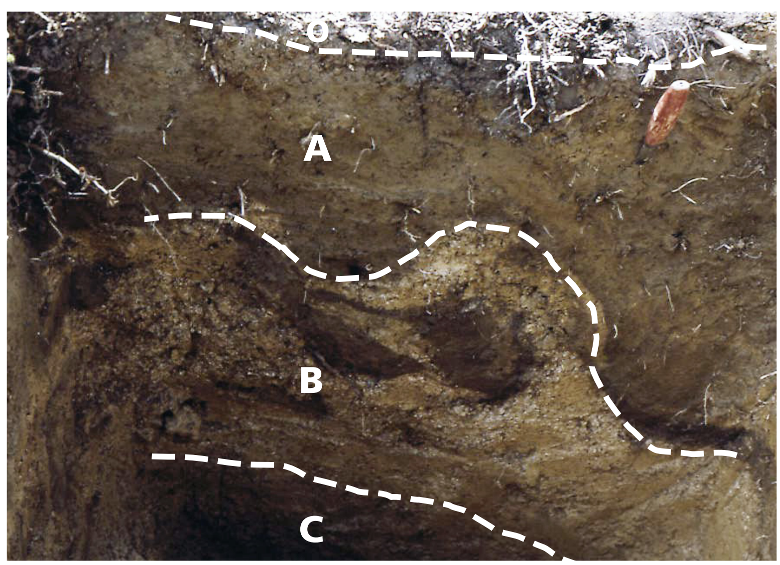
A brunisol on an unglaciated lowland surface in the Klondike region. Note the deeper layer of fine sediments and slightly deeper weathering profile.



AGRICULTURE AND AGRI-FOOD CANADA

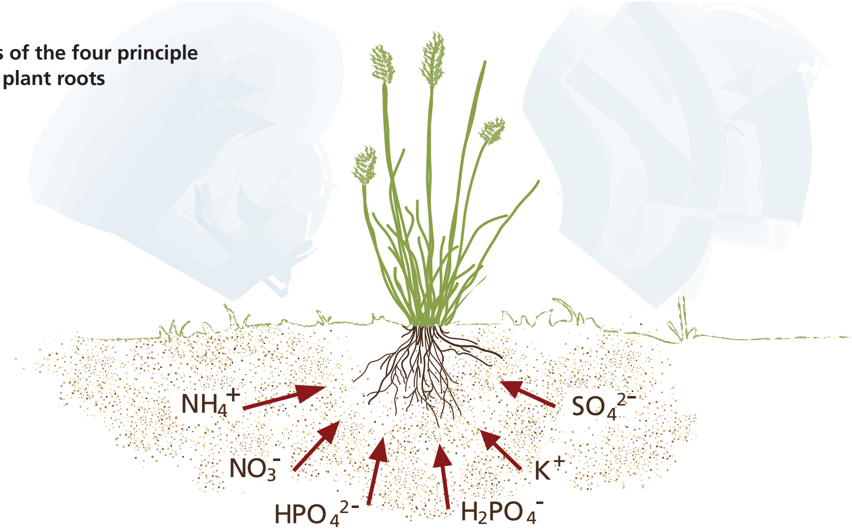
Profile of a brunisol from south central Yukon. White material in upper A Horizon is volcanic ash.



AGRICULTURE AND AGRI-FOOD CANADA

A turbated cryosol under taiga forest in northern Yukon. Note the mixing of horizons and parent material due to cryoturbation.

FIG 3.5
Organic and inorganic forms of the four principle macronutrients taken up by plant roots



	Nitrogen (N)	Phosphorous (P)	Potassium (K)	Sulfur (S)
Form taken up by plants	NH_4^+ NO_3^-	HPO_4^{2-} $H_2PO_4^-$	K^+	SO_4^{2-}
Typical forms in soil	NH_4^+ (ammonium) NH_3 (ammonia) NO_3^- (nitrate) NO_2^- (nitrite) plus complex organic compounds from decomposed biological material	$CaPO_4$ $AlPO_4$ $FePO_4$ $MgPO_4$ (inorganic phosphates) plus complex organic compounds from decomposed biological material	major component in crystalline structures of many rocks and minerals, including feldspars, micas and clays K^+ either free (dissolved in soil water) or loosely bound to clays	$CaSO_4$ (gypsum) K_2SO_4 (potassium sulfate) elemental sulfur plus complex organic compounds from decomposed biological material
Typical form in solid (dry) fertilizers	$(NH_2)_2CO$ (urea) NH_4NO_3 (ammonium nitrate)	H_3PO_4 (phosphoric acid) Listed by convention as "P_2O_5"	KCl, K_2SO_4, K_2CO_3 (all found in potash) listed by convention as "K_2O"	$(NH_4)_2SO_4$ (ammonium sulfate) sometimes as elemental S

What about micronutrients?

In the plant propagation world, nitrogen, phosphorous, potassium and sulfur are referred to as macronutrients. They are usually the most limiting nutrients for growth and are required in large quantities by growing plants. Other nutrients required for growth and metabolic functioning, but in lower quantities, are called micronutrients. The main micronutrients are: manganese, boron, copper, iron, zinc, molybdenum and chlorine. Micronutrient deficiencies are sometimes limiting to plant growth as well, and it is common in agricultural applications to specify the addition of micronutrients to fertilizer mixes. Yukon farmers now routinely have boron added to fertilizer mixes because boron has been shown to be deficient in some agricultural fields.

However, micronutrients tend to be limiting only when plants are growing at very high rates, and currently there is no evidence to suggest that micronutrient deficiencies are a limiting factor for revegetation in Yukon, or that testing for micronutrients and adding them to fertilizers is a cost-effective way to increase the success of revegetation plots. This underscores again the need to exercise caution when making comparisons between agricultural and revegetation practices: the goal in agriculture is to maximize productivity, year after year, whereas the goal in revegetation is to establish ground cover in a one-time effort.


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FIG 3.6
This surface has been very well tilled and decompacted. However, it consists of bare mineral soil and will not support vegetation without the addition of organic material or fertilizer. When no organic material is available to spread and incorporate into bare mineral soil, these sites should be fertilized.

While nitrogen is the main nutrient limiting plant growth in Yukon, phosphorous levels also tend to be low in most regions of the territory and can be growth-limiting. Phosphorous exists in a variety of organic and inorganic forms in soils, and much is locked up in mineral forms that cannot be utilized by plants (Fig 3.5). While local geology is a determinant of overall phosphorous levels, biological activity and the decomposition of plant matter over many millennia are required to create a substantive pool of phosphorous in forms that can be taken up by plants. Thus, as with nitrogen, the lack of available phosphorous can be attributed in large part to Yukon's young, cold soils. As a result, fertilizers applied to revegetation plots in Yukon often require high amounts of both nutrients.

Adding to these challenges, many Yukon revegetation sites will have had their surface organics and meager organic soils removed during development activities, leaving behind only bare mineral soil (Fig. 3.6). In other cases, inorganic fill may have been spread on the surface when the site was graded. Furthermore, surface materials often become compacted from equipment operation and other traffic. Compacted ground impedes plant emergence and root growth, as well as good water absorption.

For all of these reasons, the key to successful revegetation in Yukon often hinges on proper soil conditioning (especially decompaction), stabilizing ground surfaces, and the addition of properly formulated fertilizer, with particular attention paid to nitrogen and phosphorous.

3.2
Improving Soil Structure

Increasing soil organic levels and providing tillage (*i.e.* decompacting the soil) are the main actions to be taken to improve soil structure. In addition, fertilizing nutrient-poor soil will provide a short-term influx of nutrients that will enhance initial plant growth. Once the plants are established, soil-building processes will continue as a result of plant decomposition and turnover.

3.2.1 Improving Soil Organic Content

When a site has been heavily disturbed and stripped to bare mineral soil, the most efficient way to improve soil structure and tilth is by adding organic material and mixing it with the surface sediments (Fig. 3.7). Sources of organic material include stripped topsoil, wood chips, forest duff, peat moss, manure, straw, *etc*. Keep in mind that organic materials with high C:N ratios, such as wood chips and straw, will initially tie-up soil nitrogen as they decompose. The value of these high-carbon soil amendments is that they add structure and increase aeration, but the fact that they tie-up nitrogen often calls for a slightly higher rate of fertilizer (N) application. Some mine sites process sewage and other organic waste that can be used as a source of organics. Larger quantities of compost may be available from landfills for projects located near urban centers, such as Whitehorse. However, in many cases it is too costly and impractical to use off-site sources of organic materials in Yukon.

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FIG 3.7
Saving organics. Surface organic material is being hauled and stockpiled at this site for reapplication after construction is completed. This effort, which required planning ahead and good communication between the site manager and contractor, will pay huge dividends in the revegetation results and significantly reduce fertilizer and seed cost.

The most practical source of organic material for Yukon sites is the topsoil and duff layer that likely existed on the site prior to development. With proper project planning this material can be saved and stockpiled for reapplication. Even the smallest amount of re-applied organic material will help with the revegetation effort. This can include stumps and woody debris, which will decompose over time. The practice of stockpiling and re-applying soil organics is becoming common-place for many industries because it is so effective.

Note that the organic material to be saved for reapplication refers to the living plant cover, all sticks and organic debris in the duff layer and the top 10 – 20 cm of the soil profile (referred to as the "solum" – see Fig. 3.3). Trees usually are not stockpiled with saved organic materials, but woody slash from harvested trees is. The solum is distinguishable from the lower mineral soil layer by its staining, usually orange, brown or occasionally black. While all of it may not look "organic", the solum is important because it contains weathered (mineralized) nutrients in forms that can be used directly by plants and micro-organisms.

Before re-applying organic materials, the top 25 – 40 cm of the treated surface often will need to be decompacted/tilled using a plough, disk harrow, ripping teeth on a tracked vehicle, or even hand tools (small sites) (Fig. 3.8). If this is not done, the organic materials cannot be

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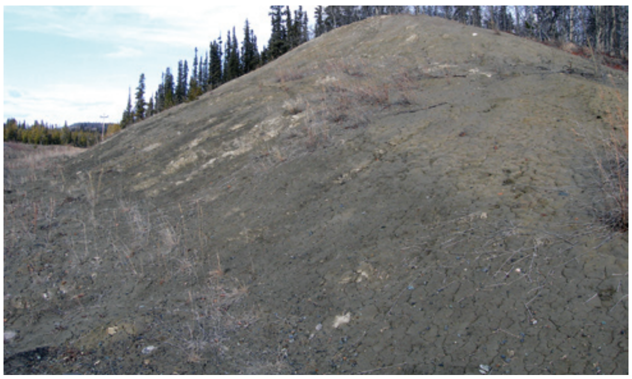
FIG 3.8
Ground should be decompacted before organic materials are spread.

incorporated into the surface and surface water will run off the site rather than seaping into the ground. In other words, the ground will not develop good structure or tilth for plant growth. This assumes that the site has been disturbed down to bare mineral soil. If the original soil surface is not heavily disturbed, then it is unlikely that there is a need to re-apply organic material and tilling will not be required (see Section 2.3).

When spreading organic materials, try to achieve a minimum thickness of 5 to 10 cm, though more is better. Incorporate this material with a harrow into the top 10 – 30 cm layer of tilled surface sediments so they become one integrated layer. Sometimes, the same equipment used for decompacting and tilling can be used for soil mixing, but a disk harrow works best. It is not important to smooth-out the surface but do not leave large furrows; the microtopography on a rough and loose surface is actually beneficial because small pockets and undulations provide germination sites and facilitate water retention.

FIG 3.9
Preparing the surface of steep slopes.



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(a) Ground preparation on slopes is one of the biggest challenges faced in Yukon revegetation projects. Slopes tend to be dry, extremely poor in organic content (most have no true soil), and are prone to erosion. The main challenge is to decompact the surface of slopes and provide microsites to retain seed, fertilizer and surface moisture. But often, slopes are too steep to be worked with ATVs and wheeled tractors, such as this slope, which is approaching 20 degrees. It also is hindered by fine, clay-rich sediments that are crusting over. Often, the best solution is to track-walk the slope (see photo f).

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(b) A common mistake when contouring slopes is to glaze the surface, which usually occurs when the slope is contoured with the bucket of an excavator. Glazed surfaces are difficult to revegetate because they are smooth and compacted; as a result there are no microsites for germination. Glazing also promotes runoff of surface water, rather than water absorption. The solution is to rip, till or track-walk these surfaces prior to fertilizing and seeding.

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(c) This photo illustrates the use of a modified bucket to create germination pockets (microsites) on a slope without causing glazing.

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(d) The rills forming from runoff on this slope will become gullies in one or two seasons. The slope should be track-walked and seeded as soon as possible, or treated by hydroseeding (the site was hydroseeded; results can be seen in photo i).

(e) An excavator and dozer being used to grade and prepare a slope for seeding. Note the scour marks from the excavator bucket running up and down the slope, a situation that could quickly lead to rill and gully formation from runoff. However the dozer was track-walked up and down the hill to remove the scours and provide micro-topography.

(f) This slope has been properly track-walked. Notice how the tractor was driven up-slope, rather than cross-slope. The result is that cleat tracks run perpendicular to the slope and serve as catchments for seed, fertilizer and surface water.

(g) This slope has not been properly track-walked. The tractor was driven across the slope leaving cleat tracks running parallel to the slope. Surface water will run down these tracks causing rill formation and loss of seed and fertilizer due to runoff.

(h) This slope was successfully track-walked and seeded. A few rills formed but erosion was effectively halted as the grass became established.

(i) Instead of track-walking and conventional seeding, this slope was hydroseeded (same slope depicted in photo d). Note how seeding was correctly extended all the way to the edge of the roadbed (*i.e.*, seeded on both sides of the ditch). This will help stabilize the roadbed and prevent the spread of invasive plants. Also note the installation of temporary check dams in the ditch to slow the velocity of flowing water until vegetation is established.

(j) Revegetation cannot be used to solve every slope issue, at least not alone. This slope is slumping for two reasons. First, the slope was cut at a steep angle into unconsolidated fill (glacial till) that is difficult to stabilize. Second, the situation is aggravated by the presence of a small drainage that runs off onto the newly exposed surface. Solution: control (divert or channel) drainage, decrease the slope angle and consider bioengineering solutions (see Chapter 4). Only then will the surface be stable enough for seeding.

3.2.2 Surface Preparation Techniques When No Organic Cover Materials Are Available

If no organic materials are available for surface application on highly disturbed sites, it is even more important that the ground is decompacted and treated to improve the structure of the bare mineral soil. The surface preparation techniques used to create suitable soil conditions depend on the topography and the subsequent erosion potential of the site.

Flat surfaces can simply be decompacted/tilled using roughening techniques described in the previous section, but the till depth should be at least 30 cm. Again, it is not important to smooth the surface, as surface conditioning will occur after fertilizing when the ground is harrowed. It is important, however, to avoid subsequent traffic on these roughened sites so they do not become re-compacted. Even when seeding and fertilizing, minimize equipment use that can cause compaction. Bulldozers and other tracked vehicles compact the ground less than wheeled tractors, but the compaction of wheeled tractors can be reduced substantially by using dual wheels. ATVs generally impart little compaction because of their balloon tires.

Erosion-prone sites and slopes (generally, those >1V:5H, or 20%) require special treatment, since loosening the ground surface via decompaction/roughening techniques may actually increase the erosion potential (Fig. 3.9). In these cases, "track-walking" methods should be used to prepare the surface. Track-walking is a compromise between compaction and roughening. A large tracked vehicle is driven over the surface, perpendicular to the slope (*i.e.*, up and down the slope, not side-hilling). The trail left by the cleats of the tracks imparts numerous small pockets on the surface parallel to the slope, forming catchments for seeds and water.

If sloped ground is also highly compacted, consider decompacting the surface with rippers mounted on the back of a tracked vehicle prior to track-walking. Do not use a wheeled tractor for these operations, as they are very prone to rollover. Teeth mounted on the bucket of an excavator with a long reach can also be used to decompact and roughen a steep slope. When slopes are very steep (>1V:2.5H, or 44%), other erosion control measures are required. These are addressed at the end of this chapter, in Section 3.4 *Advanced Erosion Protection*.

3.3 Assessing and Improving Soil Nutrients: the Strategic Use of Fertilizer

3.3.1 Fertilizer Basics and Limitations

Because Yukon soils are so consistently infertile, fertilizer is a very powerful tool when trying to establish new vegetation, especially on sites with no solum or organic horizon. Except for the application of organic materials, there is no better hedge for success on barren sites than the addition of fertilizer. In fact, revegetation success can often depend on it. Even applying organic materials to raw ground cannot compensate for the absence of true organic soil horizons containing mineralized nutrients in forms readily assimilated by plants. That is why the application of organic materials alone does not always obviate the need for fertilizing. Organic matter provides soil structure and the parent materials for future soil nutrients, but fertilizers provide nutrients that are immediately accessible to plants.

The benefit of fertilizing is magnified on sites where ground cover needs to be established rapidly, for instance to prevent erosion or to exclude invasive species. Both native and cultivated plants benefit from fertilizing but the effect is more pronounced for cultivars. Thus, applying fertilizer when seeding with commercial cultivars will tend to confer a competitive advantage to the cultivars over native colonizers. But even when no seeding is prescribed, a light application of fertilizer will promote more vigorous and rapid colonization by native plants.

Despite the benefits of fertilizer, its use should be weighed judiciously. For one, fertilizer can be expensive, though the cost is often minor in relation to overall projects costs, and relative to the returns. As stated earlier, fertilizer is often unnecessary on sites that have received minimal disturbance and with original soils still in place. On sites where concerns for erosion and invasive species are minimal, and there is no need to establish ground cover rapidly, then fertilizing is less critical as well. If it is a project goal to re-establish the site's native vegetation without the use of cultivated seedstock, then fertilizing will still be beneficial, but it is less critical because most native Yukon plants are adapted to nutrient-poor (but not sterile) soil conditions.

No fertilizer should be added to saline sites, such as those occasionally encountered northwest of Whitehorse along the Alaska Highway and in the Takhini Valley. Saline soils develop from the accumulation of salts, specifically the ions (Na^{+}, K^{+}, Mg^{2+}, Ca^{2+} and Cl^{-}) released by the dissociation of accumulated salts. Many components of fertilizers are essentially salts, especially the potassium component. Consequently, the addition of most fertilizers to saline soils will usually have the effect of increasing salinity. Few plants grow well in saline soils, but some are adapted to them, for instance slender wheatgrass (*Elymus trachycaulus*), tufted hairgrass (*Deschampsia caespitosa*), and barley (*Hordeum vulgare*). Chapters 5 and 6 discuss species and seed mixes that can be sown on saline sites.

Fertilizer use should be avoided in areas where it could pollute water bodies through surface runoff. Generally, this means that fertilizer should not be applied within 30 m of a water body. If the project requires licensing, it is likely that regulators will stipulate this condition in the license. Most contamination issues arise when fertilizer is applied to steep slopes and cutbanks immediately adjacent to water bodies. It is important to ensure such slopes are prepared with a rough and loose surface textures so that fertilizer (and seed) is retained.

Plants often do not respond very well to fertilizer under extremely dry conditions because water becomes the factor limiting plant growth more so than nutrient availability. A balance of water and nutrient supplies is important for healthy plant development, and an over-application of fertilizer in dry conditions will be counter-productive. But since it is impractical to irrigate most sites in Yukon, the focus is placed on managing fertilizer, not water. For these reasons, in extremely arid rangelands of the western United States, for instance, fertilizer is generally not applied when seeding a site. That rationale has not been applied in Yukon, even in its driest regions, because most sites in the territory still experience at least one period of ground saturation each year, and rates of evapotranspiration in Yukon are not desert-like.

In summary, fertilizer is an invaluable tool in Yukon revegetation projects, but fertilizer use can be reduced or eliminated when:

- The ground surface retains significant amounts of original soil (solum) and organic materials
- There is little or no need to establish ground cover rapidly, for instance in order to mitigate against immanent erosion
- There is little or no threat that invasive species will colonize the site (fertilizing helps other plants to outcompete invasive species)
- The ground has high salinity
- There is a potential to pollute water bodies (*e.g.*, do not apply fertilizer within 30 m of a water body)

Section 3.3.4 discusses methods for calculating fertilizer rates while taking such factors into consideration.

3.3.2 Soil Assessments

Clearly, it is critical to assess and understand soil conditions at the site in order to make the best decisions about fertilizer use, application rates, and formulas. This assessment should include soil testing to profile the site's nutrient status and other soil conditions including acidity, electrical conductivity (a measure for salinity), and percent organic matter (see Chapter 2, Section 2.3.2 – *Soil Testing*). With results from soil testing, it is fairly straightforward to calculate fertilizer formulas and application rates, which is discussed in the next section.

In the absence of data from soil testing, planners will need to estimate the nutrient status of a site based on regional soil trends and using native vegetation as guide. In these situations, planners can only develop a best-guess prescription for fertilizer formulas and application rates.

Even when regional trends are considered, it is almost axiomatic that essentially all soils in Yukon have very low nitrogen content, and most are deficient in phosphorus. Potassium and sulfur abundances vary considerably and are dependent in large part on local geology. Table 3.1 provides a regional summary of trends in soil condition and nutrient levels across Yukon. It will help planners predict soil deficiencies they may encounter based on the site location, and develop regionally-appropriate fertilizer prescriptions when data from soil testing is unavailable.

The type of native vegetation growing near a site can be used as a secondary indicator of local soil conditions, but the utility of local analogs diminishes on highly disturbed sites where little native soil remains, or when fill material has been brought to the site. Such sites really do require soil testing to make informed decisions about fertilizing. The tables in Appendix 1 describe the most common vegetation communities found in each region of Yukon and the associated soil conditions in which they grow. The information in those tables is taken directly from *Guidelines for Reclamation/Revegetation in the Yukon* (1993). Native vegetation can also be used to red-flag sites that may have special soil issues such as high salinity, acidity or alkalinity.

3.3.3 Special Cases: Soil Amendments for Saline, Acid and Alkaline Soils

If soil testing or other indicators show that the soil is saline, acid or alkaline, planners should confirm that this is typical for the area (see tables in Appendix 1). If so, it is not practical to attempt changing these conditions through soil amendments. Instead, select revegetation species for planting that are adapted to those conditions.

If testing shows the soils to be saline, acid, or alkaline when the surrounding native soils are not, this should be a red flag. Most likely, the site has been highly disturbed, such as at an abandoned mine site (old tailings), or the native soil was removed. This can also be the result when fill material was brought in. In these situations, it may be realistic to amend the soils.

For acidic soils, apply agricultural lime (ground limestone) at a rate of 2 – 4 tonnes per hectare for each rise in pH unit required (*e.g.*, a rise in pH from 4 to 5).

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FIG 3.10
When ordering fertilizer from a supplier, nearly any NPK(S) formula can be specified to match the nutrient needs of the site. Yukon Government programs have helped purchase fertilizer storage bins that are located at farms around the territory (farmers still buy and arrange trucking for the fertilizer that gets stored in the bins). While intended for agricultural use, small amounts of fertilizer (<2 tonnes) can sometimes be purchased directly from one of the farms. If planners know well in advance when they will need fertilizer, they may be able to put in their request with a farmer when fertilizer is being ordered for the following season.

On alkaline soils, add additional organic materials to lower the pH, particularly sphagnum or peat moss if it is available. For small pockets of saline soil, try deep tilling and a period of intense irrigation. Saline soils can be treated with elemental sulfur at a rate of 0.5 – 1 tonnes per hectare, which can be specified in the fertilizer mix. Adding elemental sulfur will also lower pH.

Custom fertilizer mixes can be used to amend soil conditions in other ways, too. For instance, fertilizers that supply nitrogen in the form of ammonium sulfate will help acidify alkaline soils.

Perhaps more important, do not to apply fertilizers with formulas that exacerbate an existing problem (*e.g.*, applying ammonium sulfate on acidic soils), and inform the fertilizer supplier if the site has any special conditions, such as saline, acidic, or alkaline soils. Finally, when treating soils for these conditions, follow-up monitoring is important to determine if the amendments are working.

3.3.4 Calculating Fertilizer Formulas and Application Rates

Fertilizer Formulas

All commercial fertilizers will indicate their formulation as a weight percentage of the nutrients they contain, the principal ones being N, P, K and S (nitrogen, phosphorous, potassium and sulfur) (Fig. 3.10). Fertilizer with a formula 16-20-10 (14) contains (by weight) 16% N (usually in the form of urea), 20% P (measured as P_2O_5 equivalent), 10% K (measured as K_2O equivalent) and 14% S (usually in the form of NH_4SO_4). S is not always included in a mix.

While the weights listed in a fertilizer formula are percentages, they do not add up to 100% for two reasons. First, there are other materials in the mix, mostly carriers and binders. These are added to control (dilute) the concentration of nutrients and to make stable pellets. But the main reason why the percentages do not add up to 100% is because the nutrients are not in their elemental forms; they are compounds and some of the fertilizer weight is accounted for by other elements in these compounds (mostly oxygen).

To complicate matters further, the weight percentages for phosphorous and potassium are actually lower than reported on the label because formulae do not indicate the elemental weight percentages for those two nutrients, but rather the total weight percentage of the compounds P_2O_5 and K_2O, respectively. P_2O_5 contains 43% phosphorous and K_2O contains 83% potassium. Fortunately, application rates for P and K are always discussed as application rates for P_2O_5 and K_2O, so no further calculations are necessary. Nitrogen and sulfur are reported as actual elemental weight percentages of the fertilizer – what you see is what you get.

Fertilizer manufacturers can readily create mixes to suit the customer's request. In the past, it was costly to mix small batches of custom blends, so most fertilizer was sold in a number of standard formulations, *e.g.*, 20-24-15 (0) or 13-16-10 (0). This has changed in recent years and some suppliers now only mix according to customer specifications, regardless of the batch size. And for big projects, where large fertilizer purchases will be made, there is no reason not to specify the formula. In the provinces, custom blends are now the norm and ensure that each nutrient is applied at the appropriate rate, and the same now applies if fertilizer is ordered for shipment to Yukon. The exception will be for small revegetation projects where an off-the-shelf fertilizer from a local supplier or farmer will be purchased (there are no fertilizer batch plants in Yukon).

In many agricultural and garden applications, nutrient concentrations must be kept low so they do not "burn" plant tissues and to control the rate of release. However, in revegetation projects, where fertilizer often is applied to bare soil and will be incorporated before plants develop, this is generally not a concern. In fact, fertilizer is sometimes applied to revegetation sites on bare mineral soil at concentrations that would be considered excessive on agricultural fields.

Calculating the Application Rate for Seeded Sites

To begin calculating a fertilizer mix and application rate for sites that are to be seeded, first determine the site's nutrient status either by soil testing or using regional soil data (see Section 3.3.2). When soil test data is available, use Table 3.2 to calculate the amount of nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) and sulfur (S) to include in a fertilizer mix. For instance, if testing shows that nitrogen levels are 3.2 ppm (moderate), the recommended amount of nitrogen fertilizer is 60 kg/ha. In the absence of soil test data, first use the guidelines provided in Table 3.1 and Appendix A to make a qualitative estimate of nutrient levels and then calculate the amount of each nutrient to include in the fertilizer mix using Table 3.2.

Note that applying 60 kg of nitrogen is not the same as applying 60 kg of fertilizer. To calculate the total amount of fertilizer that will deliver a particular amount of each nutrient, multiply the desired amount of nutrient by 100 and divide by the percent of the nutrient present in the fertilizer.

Example:

desired amount of nitrogen: 60 kg/ha (from Table 3.2)

fertilizer blend being used: 20-24-15

rate of fertilizer application: $\frac{60 \times 100}{20} = 300$ kg/ha

300 kg/ha of 20-24-15 would also supply: $\frac{24 \times 300}{100} = 72$ kg/ha of P_2O_5

and: $\frac{15 \times 300}{100} = 45$ kg/ha of K_2O

Table 3.1
Regional trends in soil conditions and nutrient status across Yukon. Use these estimates and Table 3.2 when calculating fertilizer needs in the absence of soil test data. For maps of the regions, see Appendix A

Region	N	P	K	S	Organic matter	pH	Notes
South-Central Yukon	Low to very low	Low to very low	Usually moderate	Usually moderate	Low to moderate	6.5 – 7.5 Most soils are slightly alkaline	Lowland sites occasionally have moderate nitrogen levels; saline areas occur in Takhini Valley and elsewhere around Whitehorse; water limits plant growth in most areas
South-East Yukon	Low to very low	Highly variable, but usually low	Often high	Usually moderate	Variable from low to very high	4.0 – 8.1 Acidic soils predominate (usually support pine stands); some flood-plain soils neutral to alkaline	Soils are so variable in this region that soil testing is highly recommended
South-West Yukon	Consistently low	Consistently low	Moderate to high	Moderate to high	Soil organics content low; surface organics can be high, especially over permafrost	5.4 – 8.0 But majority are neutral (6.1 – 7.3); grassland sites slightly alkaline	Permafrost is widespread; grassland areas near Kluane Lake require only moderate fertilization with N and P
Pelly-Cassiar Mountains	Very low to low	Very low to low	Low to moderate	Low to moderate	Very low on slopes; moderate to high on benches, over permafrost and in valley bottoms	4.0 – 7.0 Usually acidic	Soil textures often course; heavy fertilization with N and K usually required
West-Central Yukon	Consistently low	Consistently low	Moderate to high	Moderate to high	Moderate; sometimes high; organic accumulation can be high in permafrost areas and valley bottoms	5.3 – 8.4 Majority are neutral (6.1 – 7.3); grassland and white spruce regions are alkaline (8.0); pine regions are acidic (5.3 – 6.0)	Permafrost is common; moderate to heavy fertilization with N and K usually required
Ogilvie-Wernecke-Peel Region	Consistently low	Consistently low	Moderate to high	Moderate to high	Low to moderate in valley bottoms; low on slopes	3.5 – 7.6 organic soils as low as 3.0; majority of soils only slightly acidic (4.8 – 6.0); boggy	Permafrost is common; unglaciated regions have fine silt soils; glaciated regions have coarse soils; mid elevation benches typically tundra

SOIL DATA FROM *GUIDELINES FOR REVEGETATION/RECLAMATION IN THE YUKON* (1993)

Table 3.2
Typical data provided by soil testing and how it is used to classify nutrient levels and determine fertilizer application rates

Nutrient	Range	Classification	Fertilizer Application Rate	
Nitrogen (N)	0 – 3 ppm 3.1 – 5 ppm > 5 ppm	Low Low – Moderate Moderate – High	90 – 60 kg/ha 60 – 40 kg/ha 40 – 0 kg/ha	**N**
Phosphorus (P)	0 – 10 ppm 10.1 – 25 ppm > 25 ppm	Low Low – Moderate Moderate – High	70 – 50 kg/ha 50 – 30 kg/ha 30 – 0 kg/ha	**P_2O_5**
Potassium (K)	<75 ppm 76 – 150 ppm > 150 ppm	Low Low – Moderate Moderate – High	60 – 40 kg/ha 40 – 30 kg/ha 30 – 0 kg/ha	**K_2O**
Sulfur (S)	0 – 7.5 ppm 7.6 – 15 ppm > 15 ppm	Low Low – Moderate Moderate – High	17 kg/ha 0 kg/ha 0 kg/ha	**S**
Organic Matter	0 – 4% 4.1 – 14% 14.1 – 29% > 29%	Low Moderate High Very High	For every 1% increase in soil organic matter over 4%, decrease the above rates by 2 kg/ha (*e.g.* with 9% organic matter, decrease N-P-K-S each by 10 kg/ha)	

DATA ADAPTED FROM *GUIDELINES FOR REVEGETATION/RECLAMATION IN YUKON* (1993); RECOMMENDATIONS DEVELOPED IN CONJUNCTION WITH THE AGRICULTURE BRANCH, GOVERNMENT OF YUKON DEPARTMENT OF ENERGY, MINES & RESOURCES

When using a standard fertilizer mix, rather than a custom mix, it will not be possible to supply precisely the desired amount of each nutrient. In that case, choose a standard mix that provides the best compromise and apply it at a rate that delivers at least the minimum required amount for each nutrient (especially nitrogen). This means two or more of the nutrients may be supplied in excess, but that is preferable to applying one or more nutrient at an inadequate level.

3.3.5 Modifying Calculated Fertilizer Rates for non-Seeded Sites and Specific Site Goals

The fertilizer application rates calculated above are recommended for sites that will be seeded and when the project goal is to establish substantial ground cover in the first season of growth. Usually, this applies to sites that have been stripped or graded, have no solum, and it is important to establish good ground cover for erosion control (*e.g.*, Fig. 3.6). The density of emerging plants on seeded sites will be high, and all of the applied fertilizer will be utilized.

Section 3.3.1 discussed situations where these might not be the project goals. As well, some sites will not be seeded because it has been decided to let the site revegetate from the native seedbank. When no seeding is to be done, planners have a tendency to forgo fertilizer as well. But fertilizing is quite beneficial for unseeded sites, too, as it increases the rate and success of colonization and natural succession. It also helps native colonizers outcompete invasive species. However, fertilizer rates on unseeded sites should be reduced by one half to one quarter the rate calculated for seeded sites, for two reasons. First, native colonizing species are adapted to low-fertility soils and have a limited capacity to respond to fertilizer. Second, plant densities will be low in the first two years, meaning the fertilizer is feeding fewer plants relative to a seeded site.

The benefits of fertilizers generally only last one to two years and there is no reason to apply fertilizer that cannot be utilized by the colonizing plants. Sites with reapplied organic materials require less fertilizer than barren sites. Reapplied organics function mostly to provide soil structure and raw materials from which future soil nutrients will be mineralized, but coarse organics provide few nutrients that are immediately available for plant uptake. When organic materials are reapplied to a surface that will be seeded, but the solum is otherwise removed (*i.e.*, organics are simply being worked into bare mineral soil), then the calculated rates can be cut in half (one quarter if the site is not to be seeded). In these situations, the organic materials should be spread, followed by the fertilizer, and then the two should be mechanically incorporated into the upper 10-40 cm of the ground

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FIG 3.11
While this grubbed slope may look unkempt to some, the debris could be left in-place as an effective measure to protect against erosion. It also will keep the organic content of the site higher than if it is bladed and graded. Consequently, only a light seeding would be needed, and no fertilizer. If leaving large woody debris in place will present a hazard to future mowing and maintenance, it could be chipped and spread as a mulch on the site.

surface at the same time by harrowing or even track-walking (see Section 4.4 for more details). If the fertilizer is applied to bare mineral soils and then covered by organics, it is possible that the fertilizer will end up being too deep for young plant roots to reach. Incorporating fertilizer into the organic material also increases the rate that nutrients in the organic material become mineralized (because the fertilizer feeds microbes that mineralize organic nutrients).

If a site will not be seeded, and its solum and organic horizon are still more or less in-place, then there usually is no reason to fertilize. Fertilizing a site covered with coarse organic debris will accelerate the breakdown of the debris, but the cost usually is not justified.

3.4 Advanced Erosion Protection

Often, it is not adequate to use revegetation methods alone to stabilize sites with high risk for erosion. When erosion is already occurring or is an immanent threat, the revegetation process will take too long before it can effectively stabilize the surface. Just as important, seeds that are planted on an unstable site will be lost due to runoff and erosion.

In extreme cases, the site may require engineering solutions to provide the necessary stability (*e.g.*, unstable rock slopes and slopes that are steeper than 1V:2H, or 50%). Engineering approaches to erosion control are beyond the scope of this guide. However, a number of detailed manuals are available to assist in developing and implementing erosion protection measures (see *References and Sources for Further Information* for full references):

- Alberta Ministry of Transportation (2011). *Field Guide for Erosion and Sediment Control*.
- Transportation Association of Canada (2005). *National Guide to Erosion and Sediment Control on Roadway Projects*.
- Government of Yukon, Department of Environment, Water Resources Branch (2011). *Best Management Practices for Works Affecting Water in Yukon*.
- Gillies, C. (2007). *Erosion and Sediment Control Practices for Forest Roads and Stream Crossings*.

FIG 3.12a
This stretch of lake shore was unintentionally disturbed during a road widening project. Without immediate erosion control and/or revegetation efforts, this roadbed will be undercut by wave action.

FIG 3.12b
The same site (opposite angle) showing riprap rock and jute/straw matting placed to control for erosion. Flat areas were seeded prior to placing the matting, and willow cuttings were staked through the matting to provide long-term vegetative protection.

The following methods are commonly employed in conjunction with revegetation techniques to control and prevent erosion on less extreme slopes.

Mulching

Mulching is the application of fibrous plant material, such as straw, to the soil surface. Mulching can be an effective means of controlling runoff and erosion on flat to moderately sloped ground and is often applied as a component of revegetation (seeding) programs because it helps retain soil moisture, promote germination, and protect seedlings. By design, mulching is a temporary measure that protects the ground surface while seeds germinate and develop into significant ground cover. Loose mulches should not be placed on steep slopes without staking or netting because they easily erode off slopes and accumulate in ditches and other waterbodies.

Besides straw, other examples of commonly used mulches are wood fibre cellulose (used in hydroseeding) and wood chips. In Yukon, the most practical option for mulching is to chip wood debris that was cleared from the site. Straw tends to be less available and expensive in Yukon. Hay can be used as well, but it is less effective than straw. Straw breaks up and spreads more easily, and its coarseness imparts a loose structure that water and germinating seedlings can penetrate. Hay has a tendency to form a dense mat, especially if care is not taken to break it up and spread it well. Hay can also contains weed seeds that may be undesirable.

Spreading coarse organics

A low-tech, low-cost approach similar to mulching is the spreading of tree stumps, logs or slash material on the surface to provide structural elements that will retain soil (Fig. 3.11). These materials also provide micro-shading and wind protection; direct sunlight and wind can quickly dry-out a site. Coarse materials should only be spread on sites where it is not deemed an eyesore (a subjective decision) or where the materials might interfere with mower blades and other equipment during maintenance work.

Rolled erosion control products (RECPs)

One of the most common and effective approaches to erosion protection is to spread and stake a rolled erosion control product (often called a "blanket") on unvegetated

FIG 3.12c
Grass and willow cuttings growing through the blanket the following spring.

surfaces. These products come in large rolls and range from simple matting (*e.g.*, jute mesh) to multi-layered blankets. They are used where seeding and mulching alone are inadequate or where mulch must be anchored and other methods such as crimping or tackifying are unfeasible, such as directly adjacent to streams (Fig. 3.12).

Most RECPs are designed to decompose in a few years, after which the seeded or staked vegetation takes over the job of ground stabilization and erosion protection. However, other products, including geotextile fabrics, are made from UV-stable synthetics, usually polypropylene, and are intended for long-term slope protection. While seeds will not germinate, nor will seedlings develop, through geotextile fabrics, a common strategy is to stake willow cuttings through geotextile fabric that is installed on stream banks.

For decades, simple jute mesh and comparable biodegradable matting products have been effective products when used in conjunction with seeding. Their use is still recommended. In recent years, advanced multi-layered blankets have been developed that contain a central layer of permeable fibres (often straw) sandwiched between two layers of coarse mesh.

These products essentially function as both a mulch and an erosion control devise. Often the outer mesh is jute, which will decompose in 5 – 10 years; others have polypropylene mesh that is designed to break-down after a longer period. Consequently, the type of blanket chosen largely depends on the desired longevity of the product on the site.

Bioengineering

Bioengineering is a term used to describe methods of slope and bank stabilization that incorporate live stakes, usually from willow, as structural elements in retaining walls, streambanks, terraces and similar earth works (though woody species other than willow can be used as well). As a bound network of wooden structural components, the stakes provide a fabric that anchors the ground and entraps new sediments, which in turn provides stabile ground for other vegetation to grow. Bioengineering solutions are covered in more detail at the end of Chapter 4, after a discussion of the general use of willow cuttings in revegetation work.

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4 Plant Materials

The previous chapters discussed key principles of soil and site preparation. This chapter provides specific guidance about plant materials that will be planted on the site – how to choose the right species for the site and how to promote their growth. It addresses the use of native versus non-native plants in more detail, discusses commercial seed mixes, including methods to calculate seeding rates, and concludes with sections on collecting local seeds and woody plants.

4.1 The Use of Native Plants, Non-Native Plants and Cultivars: Definitions, Theories and Practical Considerations

In Chapter 1, the use of native plants was introduced because the major trend in the revegetation industry is to plant species that are mostly or solely native to a region. That discussion is expanded more fully in this section, first by defining important terms (*e.g.*, what exactly is a native plant?), then by exploring the theory versus the practical limitations of planting native seedstock in Yukon.

In the simplest terms, "native Yukon plant" refers to a species that is indigenous to Yukon. It may be endemic to Yukon, or have a wider distribution. In the former case, the concept of "native" is straightforward. But consider a plant species that is native to Yukon, but also naturally occurs in other areas of Canada, such as ticklegrass (*Agrostis scabra*). Is it appropriate to plant seeds of ticklegrass in Yukon that were propagated from genetic stock (propagules) in southern Ontario, and still call it a "native plant?" If not, are seeds from northern Alberta acceptable? What about southern Alberta?

For the past decade or more, the standard answer to these questions in the revegetation industry has been this: plant native *species* using *cultivars* that have traits suited for (adapted to) the site conditions *and* propagated at farms that are as nearby as possible. For instance, on sites that are cold and dry, it is advised to plant a regionally-propagated cultivar that is frost-hardy and drought-resistant. In some cases these may be registered cultivars; in other cases they may not be registered but are recognized as the best "common" native species option for a given region (see Section 4.2.4 for definitions of "registered cultivars" and "common" seed). The opinion of most revegetation professionals would be that it is perfectly acceptable in Yukon to plant seeds of native species that were cultivated in northern Alberta, and even southern Alberta, if they have been bred for traits adaptive for Yukon conditions. A number of excellent cultivars adapted for Yukon conditions have also been developed in Alaska and are included in seed mixes recommended in Chapter 5.

However, for some practitioners, there is a larger issue in the native versus non-native discussion: Is it appropriate to introduce seed stock containing *any* non-native germplasm? In other words, in addition to being a native species, must the seed stock also be a local genotype, whereby the seed stock was collected directly from local plants or was cultivated from local propagules? To confound the matter, even seed stock from Yukon propagules can become genetically altered if it is cultivated for generations at a seed farm or nursery outside of Yukon, either because it adapts to its new local conditions or through hybridization with local conspecifics.

Elsewhere in North America, some jurisdictions are employing a strategy of "seed transfer zones." A plant germplasm is deemed "native" if it is derived from and cultivated within a given radius (seed transfer zone) of the site. A seed transfer zones can range in size from 50 – 500 km and is species-specific because it reflects individual patterns of genetic diversity. This means there is a significant requirement for baseline data on genetics and taxonomy before a seed transfer zone can be established for any given species.

Species-specific genetic data are just beginning to be generated for Yukon plants. Consequently, Yukon is a long way away from establishing seed transfer zones. Lacking this information, the best advise for practitioners wanting to plant commercial seed of nominally native plants in Yukon is to use cultivars that were developed and propagated from northern Alberta and Alaska.

For projects where it is deemed critical to avoid the introduction any non-native germplasm (*e.g.*, a national park), there are only two options for selecting seedstock, which at first glance may seem to be contradictory. The first option is to collect and plant local seeds or cuttings. This still is the gold-standard for native plant revegetation, but it is costly, labour-intensive, takes much time and planning and generally is not practical for large projects. The second option is to plant totally non-native species (though they should never be invasive or noxious – see Section 4.2.4). The rationale behind this option is two-fold. First, there is less chance that non-native species will introduce genetic contamination to native species (*i.e.*, native genotypes) because no native conspecifics will be present to hybridize with. There is a small possibility of cross-species hybridization between a non-native species and a closely related native species, but there is no evidence that this has occurred or is a problem in Yukon. Second, if the site is fertilized, it is often the case that


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FIG 4.1
Even if a commercial revegetation seed mix contains only species that are native to Yukon, in almost all cases the seeds will have been propagated outside the territory and will contain non-native genotypes. Therefore, it is essentially impossible to plant a seed mix that is free from non-native genetic material, unless the seed is collected directly from local plants. This will be an unrealistic expectation for large projects, but for small projects in certain areas it can be the right decision.

The plants seen in this photo (yellow locoweed, *Hedysarum* and sage) are good sources of seed and have naturally revegetated this exposed ground near Kluane National Park. A third option is to plant non-native species (but only those that are not invasive), because there is little chance they will introduce foreign genetics to populations of native plants. Various options for planting native and non-native plants are discussed throughout this chapter.

seeds of non-native species grow well in the first few years but then fade as the fertilizer is exhausted and native plants begin to outcompete them. The non-native plants serve their function of stabilizing the site and facilitating subsequent native plant growth and then senesce – *i.e.*, they function as nurse plants. Another benefit of this approach is that seeds of good-performing, non-native species are readily available from seed suppliers on short notice.

The revegetation planner in Yukon must weigh the issue of native versus non-native species, and even native versus non-native genetics, against all the other project goals and priorities. There is also a role to be played by personal convictions and the policies of the government department, institution or contractor that is responsible for the revegetation project. For over forty years, non-native grasses have been successfully planted along many Yukon highways, and there are reasons to continue this practice in some cases and with some species – there is little evidence either supporting or contesting the hypothesis that it has introduced genetic contamination to native populations. In contrast, different considerations come into play when a revegetation site occurs in or adjacent to a national or territorial park being managed for its natural biological integrity. In that case, planners should consider developing a seed mix comprised solely of locally-collected seed stock so no exotic germplasm is introduced.

Chapter 5 provides planning tips and seed recommendation for specific revegetation scenarios likely to be encountered in Yukon. Within each scenario, species are recommended for inclusion in seed mixes based on traits that are adaptive for conditions likely to be encountered in each scenario. But the recommended species are divided into four categories (Tables) so that planners can develop a seed mix that is appropriate to meet their goals for genetic integrity:

- Native species that are effective colonizers (recognizing that they will be non-native cultivars)
- Non-native species (several of which are short-lived) known to be effective in Yukon, but which are not invasive.
- Species of local colonizing plants for which it is practical to collect seeds.
- Species of local shrubs for which it may be practical to collect and cuttings or seeds.
- A combination of all four approaches is possible, and even recommended at times, but the tables in Chapter 5 have been designed so that it is possible for planners to derive a mix that uses only native species or native germplasm and still constitutes a complete, balanced mix.

Yukon seed producers

At this time, the seed producing industry in Yukon is still in its infancy. In the last two decades, a few agricultural producers have made efforts to propagate native seed from seed stock collected in Yukon, and to grow seeds of cultivars developed outside the territory. But currently, there is no significant amount of commercial seed produced here. There is hope that the industry will grow in coming years, but the current market demand for seed is being satisfied from producers outside the territory. However, if a revegetation planner desires to collect native grass seed and have it propagated in Yukon, there is some capacity in the Yukon agricultural industry to cultivate the seed for special projects (contact the Government of Yukon Agriculture Branch for a list of possible producers).

4.2 Designing and Applying Mixes from Commercial Seed Stock

Broadcast seeding of commercial seed stock is the most common approach used to create general site cover because it is quick, effective and relatively inexpensive.

Other revegetation methods, such as collecting and sowing seeds of local plants, or planting nursery stock, tend to be more labour-intensive and therefore costly. These methods are more commonly employed for specific purposes such as accelerating natural succession, increasing species diversity, or preserving local genotypes, rather than creating general site cover. The use of transplants, cuttings and locally-collected seed stock is discussed in Section 4.6.

The following key decisions and calculations need to be made when designing seed mixes from commercial seed stock:

- Selecting the right species for the site conditions
- Gauging the appropriate level of species diversity
- Seeding rate (density)
- Sourcing seed stock and selecting seed of appropriate quality (avoiding the introduction of unwanted species)

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FIG 4.2
Grass species that are adapted to dry, nutrient-poor soils are the workhorse of revegetation projects in Yukon. Violet wheatgrass (*Elymus alaskanus*) is a native plant that has been successfully cultivated from seed collected in Yukon and is available commercially. It does well in a variety of Yukon conditions, including dry, nutrient-poor, alkaline and moderately saline soils.

A. CESKA

FIG 4.3
Revegetating lowland tundra sites in northern Yukon will require species selected for their ability to grown on cold, shallow soils that may be saturated or moist for most of the summer. Special attention should be paid to the site pH, as lowland tundra sites can vary from highly acidic to moderately alkaline (usually based on the site's glacial history). It is important that revegetation species are selected to match the pH. Polargrass (*Arctagrostis latifolia*) is one of the best choices for revegetation on wet tundra sites, but it only grows well on acidic soils (see Chapter 6 for individual species information).

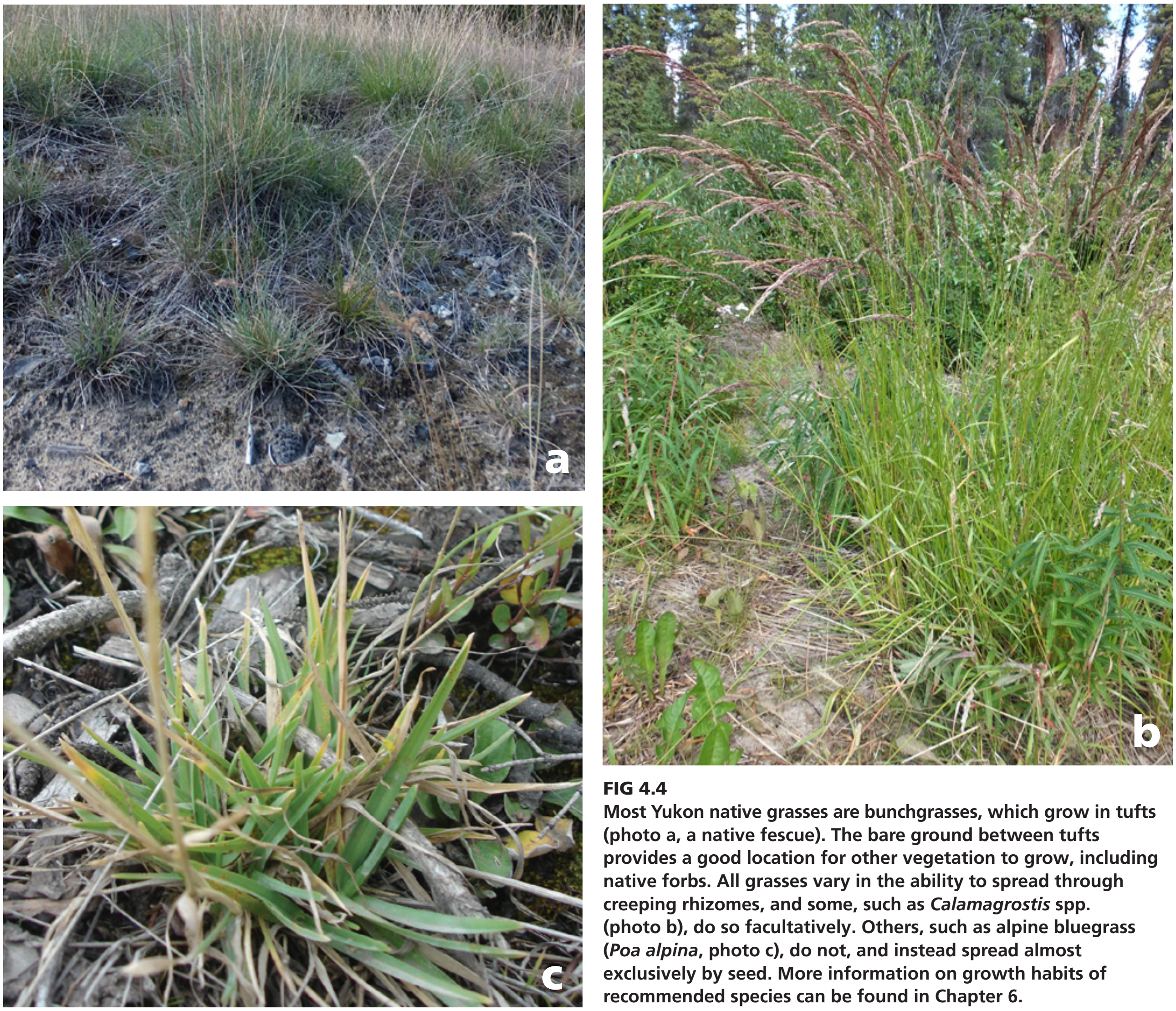
4.2.1 Selecting the Right Species for the Site

Essentially all commercial seed used in Yukon revegetation projects will be from grass species (alfalfa is the only exception, and it will be used only rarely). Grasses are natural colonizers in Yukon ecosystems and their seeds are readily available commercially. They are also the best plant type to accomplish most revegetation goals, such as establishing rapid site cover and stabilizing ground surfaces. Seeds from non-grass species generally are: 1) not available in appropriate quantities, 2) from species that are not suitable to Yukon conditions, 3) are not effective at meeting project goals, and 4) can be very expresive.

Seed mixes should be composed of species selected for traits that are adaptive to the site conditions. In general, all recommended species in Yukon should be tolerant of summer frost down to –4˚C and extended periods of drought. They should also be fast growers with short maturation times, due to the short growing season. If planted in fall, seeds must be from species that have good resistance to winterkill. The species recommended in this *Manual* for use in revegetation have been selected for these traits, but there is variation among them as noted in species descriptions found in Chapter 6.

It is very important to determine the approximate pH of the site and choose species for the seed mix accordingly. Yukon soils range from strongly acid (pH down to 5.0) to strongly alkaline (pH up to 8.5), though most have a pH between 6.2 (mildly acidic) and 7.8 (mildly alkaline). Even if a species is well adapted to all other site conditions, such as dryness and nutrient-poor soils, it will grow poorly if the site is acidic but the species is adapted to alkaline soils. Planners will occasionally encounter sites that have high salinity in central and southwestern Yukon, especially in localities northwest of Whitehorse. Soil testing and surrounding vegetation will indicate the presence of saline soils, and it is critical to choose species for the seed mix that are adapted to saline conditions (see species description in Chapter 6).

Planners will need to give consideration to other geographic factors as well. For instance, species recommended for northern Yukon are especially adapted to soils that are cold, shallow, and nutrient poor (*i.e.*, underlain by permafrost), though these conditions could exist anywhere in Yukon. This underscores the fact that there is not a generic seed mix that will be applicable to a specific geographic region. Sites in northern Yukon will vary from lowland, acidic sites on permafrost with



T. OMTZIGT

A. NERING, WILD ABOUT FLOWERS, AB

T. OMTZIGT

FIG 4.4
Most Yukon native grasses are bunchgrasses, which grow in tufts (photo a, a native fescue). The bare ground between tufts provides a good location for other vegetation to grow, including native forbs. All grasses vary in the ability to spread through creeping rhizomes, and some, such as *Calamagrostis* spp. (photo b), do so facultatively. Others, such as alpine bluegrass (*Poa alpina*, photo c), do not, and instead spread almost exclusively by seed. More information on growth habits of recommended species can be found in Chapter 6.

poorly drained and saturated soils, to upland, gravely slopes that are well-drained and alkaline, with a deep active layer. Species that are selected for the revegetation mix must take those specific factors into account even more so than the site's northern latitude. Again, Chapters 5 and 6 provide guidance for selecting the appropriate species.

Grass species vary in their ability to grow in nutrient-poor soils, so it is important to match species selection to the prescribed fertilizer regime. If it has been decided to use a minimal amount of fertilizer, or even no fertilizer, then it is imperative to choose species that grow well in extremely nutrient-stressed conditions. There are trade-off to such decisions. Species adapted to low-nutrient environments usually deal poorly with competition from other plants, and they may be slow growing.

Grasses also vary widely in morphology and growth strategies, which influences their applicability in revegetation projects. Bunch grasses grow in clumps called "tufts", leaving space between individual plants, and they spread principally by seed, rather than by rhizomes. Most native grasses in Yukon are bunch grasses (Fig. 4.4). In contrast, sod-forming grasses spread laterally by rhizomatous growth and tend to form a more continuous ground cover (a "turf"). The majority of grasses recommended for use in Yukon happen to be bunch grasses, but they are not specifically recommended for this fact – they simply happen to be adapted to Yukon conditions.

Both bunch grasses and rhizomatous grasses are integral to successful seed mixes. Bunch grasses are good nurse plants for other species, including native forbs, because these other plants can grow between tufts; this makes them good species to use when a primary goal is to promote natural vegetation. Conversely, it is a good strategy to plant a higher proportion (>50%) of rhizominous grasses when ground stabilization and erosion protection are the main site objectives because their spreading rhizomes hold onto more ground than bunch grasses. Recommended native grasses that spread partially or mostly by rhizomatous growth include bluejoint

B. BENNETT

FIG 4.5
Tufted hairgrass (*Deschampsia caespitosa*) is a native grass with broad applications in revegetation. It will grow well in any moist, low-nutrient site from southern Yukon to the arctic coast, including high elevations. It performs well in highly acidic conditions and tolerates heavy metals; thus it is a good choice for revegetating mine sites.

reedgrass (*Calamagrostis canadensis*) and polargrass (*Arctagrostis latifolia*); recommended non-native grasses that spread rhizomatously are creeping red fescue (*Festuca rubra*), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), streambank wheatgrass (*Elymus lanceolatus*) and red top (*Agrostis gigantea*).

Another strategy to consider when planting for immediate ground cover and stabilization is the use of annual grasses. They are fast-growing, inexpensive, and senesce after one year. During that first year, they stabilize the site, help retain surface water, and serve as nurse plants for other species. After they senesce, they add structure and organic matter to the soil. The two commercially-available annuals that are recommended for revegetation projects in Yukon are barley (*Hordeum vulgare*) and annual rye (*Lolium multiflorum*). Both are non-native (Fig. 4.6).

There are potential drawbacks to the use of annuals, so they must be prescribed with caution. Both barley and rye, but particularly rye, compete strongly with other plants for nutrients and can develop very thick ground cover. This can choke-out seedlings of other desired species. When annuals are planted too thickly, sites will be green and lush in year one, but brown and lifeless in year two. In such cases, the organic residue from the dead annual will need to be tilled under and the site replanted. A heavy cover of annual grasses is also an attractant to wild herbivores, which may not be desirable if the site borders a roadway. In addition, annual rye is allelopathic, meaning it secretes substances into the ground that keep other plants from growing. These are not reasons to avoid annual grasses; they simply must be seeded at an appropriate density. A basic rule is that annuals should not constitute more than 10% of any seed mix for revegetation projects. At that rate, the site will experience the benefits bestowed by annual grasses without the drawbacks.

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T. OMTZIGT

FIG 4.6
Two non-native annual grasses, barley (*Hordeum vulgare*) (photo a) and annual rye (*Lolium multiflorum*) (photo b), are recommended for use in special circumstances, principally when rapid ground cover is required. These species senesce after a season, but their ground-stabilizing effect can last multiple seasons. Annuals also serve as good nurse plants for slower-growing permanent species that are in the seed mix. But to avoid choking-out preferred species, annuals should only be planted as 10% of the seed mix.

4.2.2 Gauging the Appropriate Level of Species Diversity

There are four considerations to keep in mind when deciding on the level of species diversity to include in a commercial seed mix:

- Ecological considerations: how much vegetative diversity is needed to achieve adequate biological functionality at the site?
- Hedging for success: planting multiple species means that if one or two species fail to germinate or establish stands, other species may still grow.
- Visual considerations: are site aesthetics important?
- Whether it is desired to facilitate or retard the growth of natural vegetation.

In most cases, the industry practice is to include three to five complementary species in the seed mix (each constituting 10 - 40% of the mix), with additional species sometimes included to increase overall diversity or serve other functions discussed below (10 - 20% each). This strategy of using multiple species in the mix stems from practical experience and research of natural ecosystems, where it has been shown that increased diversity and complexity often confer greater resilience

FIG 4.7
Planners will need to make decisions on the appropriate species diversity to include in a seed mix. Generally, a mix with four to five species is recommended because a heterogeneous stand will confer more resilience to the site. It also is a hedge for success if one or more species fails to become established. There are situations, however, where it is appropriate to target a lower or higher diversity. For instance, on sites with very unusual or extreme conditions, such as highly saline soil, only two or three species may be tolerant to those conditions. Seed mixes applied along roadways typically are comprised of three or four species, usually a wheatgrass (*Elymus* spp.), a fescue (*Festuca* spp.), and a bluegrass (*Poa* spp.).

and adaptability to an ecosystem. Thus, planting multiple species is likely to increase the chances that a revegetation project will be successful at stabilizing the site and facilitating growth of a healthy stand in the future.

It is also not uncommon that one or more species in the seed mix will fail to germinate or mature due to winterkill or unusual weather conditions. By planting multiple species, the chances are good that one or more of them will become established, even if others fail.

Planting a high number of species (>4) can be a good idea for sites that have public exposure, as it may be more visually appealing if the site is not a monoculture of one or two grasses. Some grass species are considered more aesthetically pleasing than others, too. Most of the species recommended for seeding in this *Manual* are bunchgrasses, so there will be open ground between individual tufts of a dominant grass. Other species in the seed mix will fill in the space between the tufts creating a more complete and diverse vegetative cover. When visual characteristics are a priority, consider collecting seeds of native forbs and planting them for visual appeal. Not only will they fill in between bunch grasses, their flowers add colour (see Fig. 2.8).

When it is a goal to facilitate natural regrowth by local vegetation, the key is to avoid creating a stand with thick cover or a dominant species. A good approach is to plant only two to three bunchgrass species in equal proportions at a moderate density, which will stabilize the surface but still leave space for native vegetation to colonize. Alternatively, if the goal is to retard the establishment of local plants, then the mix can be reduced to as little as two species, and planted at higher density (see Section 4.2.3 for specific information on gauging seeding density).

There are a few other situations where the best strategy will be to seed only two to three species. One situation is when there is an unusual soil condition, such as a highly saline site. Often, there are only a couple of species suitable for these conditions and it would be a waste of effort and resources to plant others (see information in Chapters 5 and 6). Another situation is when spot seeding small repetitive areas, such as the disturbed ground around newly installed towers along transmission lines. Usually, only a few square meters of disturbed soil will need to be seeded at each tower, and a very basic mix will suffice.

Nitrogen Fixers: In the past, it was common practice to include a nitrogen-fixing legume species in Yukon seed mixes (*e.g.*, clover, alfalfa). The rationale was that the legume would help increase nitrogen levels in nitrogen-poor soils that typify Yukon sites. The theory was sound, however experience has shown that planting legumes seems to have little effect on the long-term success of revegetation sites. Most likely, legumes are not fixing nitrogen to levels that contribute significantly to the

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FIG 4.8
Alfalfa is the only legume still recommended for use in Yukon revegetation projects. It should be used only in special circumstances, namely on slopes where other plants have difficulty becoming established.

overall growth of the stand, especially relative to other measures that can be taken to improve growth of the targeted species. The application of nitrogen fertilizer, for instance, is much more effective because it provides an immediate boost to emerging plants.

Other factors have led to the delisting of commercial legumes in seed mixes. Many exhibit high rates of winterkill when planted in Yukon. The only ones that have demonstrated good overwintering abilities are alsike clover, lucerne, and alfalfa (all are non-native). Non-native legumes also carry a risk of becoming invasive or persistent. Decades ago, lucerne was planted in agricultural test plots around Haines Junction and it is now a persistent weed that dominates fallow fields there. Finally, legumes can be very strong wildlife attractants because they are excellent forage species (undesirable in most situations).

Currently, the only commercial legume recommended for use in Yukon is alfalfa, but only in special applications (Fig. 4.8). One situation where alfalfa can be very effective is on problematic slopes that are difficult to revegetate with other species. Alfalfa has the ability to take hold on these sites when other plants cannot. In the past, it was common to use legumes at 10 – 25% of the seed mix, but on these problematic slopes alfalfa can be increased to 50% of the mix.

While expressing caution about the use of commercial legumes, it should be pointed out that a large percentage of naturally-occurring, colonizing forbs in Yukon are legumes. Examples are yellow locoweed (*Oxytropis campestris*), showy locoweed (*Oxytropis splendens*), bear root (*Hedysarum alpinum*), Mackenzie's hedysarum (*Hedysarum mackenzii*) and lupine (*Lupinus arcticus*). A wide-spread nitrogen-fixing shrub is soapberry (*Shepherdia canadensis*). These species thrive in Yukon's nitrogen-poor soils where there is little competition from other plants. On highly disturbed sites with nutrient-poor soils, or even bare mineral soil, native legumes are often the first colonizing plants to take hold in Yukon (see Fig. 4.1), and their seeds are some of the easiest to collect of all Yukon wild plants (methods of collecting and planting seeds are discussed in Section 4.6). Unfortunately, there is little evidence that native legumes in Yukon actually provide much immediate nitrogen for use by other plants, so it is not advised to plant them with that intention.

4.2.3 Seeding Rate and Density

Strategic decisions about seeding application rates should be made in concert with decisions about species diversity discussed in the previous section. A good starting point for seeding density (all species combined) on a relatively flat, well-prepared site is 1,500 PLS/m^2 (Pure Live Seed/m^2 – see Table 4.1) when seed is broadcast as a dry seed mix. Seeds vary tremendously in their size and weight, but generally, this density equates to a rate of 20 – 50 kg/ha. For comparison, this is about one fifth of the rate used for planting lawns. However, throughout this *Manual*, seeding rates will always be discussed as numbers of seeds per unit area, not weight for reasons explained in the sidebar on page 64.

It is important to emphasize that the seeding rates recommended in this *Manual* only apply when seed is spread with a broadcast (cyclone) seeder and incorporated into the surface with a harrow or similar means, unless stated otherwise.

A broadcast-harrow system is practical and cost effective, but it is a coarse-grained seeding method, and not all seed ends up covered or covered to the optimal depth. Seeds that are left lying on the surface or with poor seed-soil contact usually will not germinate. Seed drills are implements that place seeds at the desired depth much more consistently than broadcast/harrow methods, and thus produce higher germination rates. Consequently, if a seed drill is used, the seed quantities can be reduced by about one half. However, it is a rare situation where a seed drill will be a practical option in Yukon. The two seeding methods are described in depth in Section 4.5.

The default seeding rate of 1,500 PLS/m^2 is a starting point that applies to sites that are flat to moderately sloped and have little or no organic content. That rate should be adjusted to suit specific sites conditions and goals (Table 4.1). On flat to moderately sloped sites where the solum is still intact, and/or substantial organic materials have been reapplied, the seeding rate can be reduced by as much as

Plant Materials 4

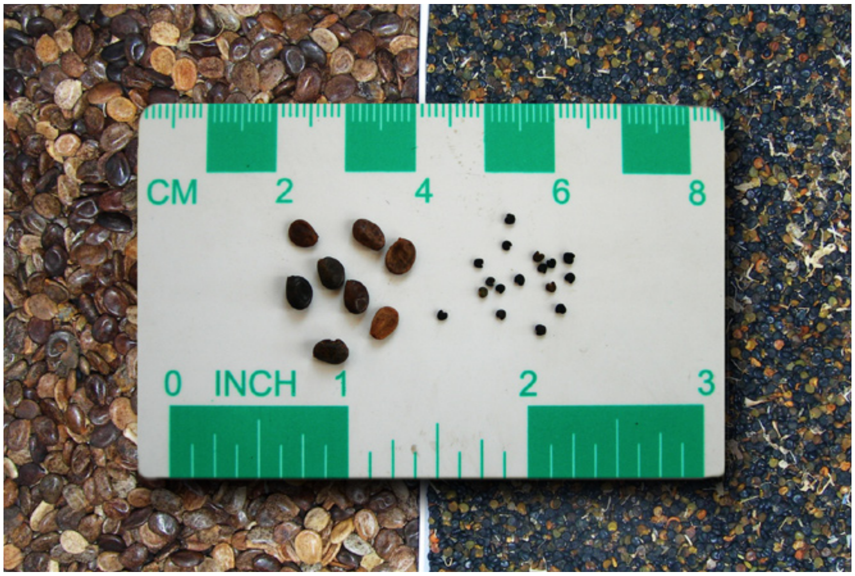

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FIG 4.9
Calculating the amount of seed from each species to include in a seed mix is complicated by the fact that seed sizes and weights can vary dramatically. Seeding densities are prescribed as the actual number of seeds desired per m² of ground. However, because application rates in the field are calculated in kg/ha, planners need to know the number of seeds that go into making up one kilogram for each species. Species-specific seed sizes and densities are listed in Chapters 5 and 6, and methods for calculating seeding rates are found in section 4.2.3 (arctic lupine (*Lupinus arcticus*) on left, showy locowed (*Oxytropis splendens*) on right).

Seed density and "Pure Live Seed" (PLS)

Seed is sold by weight, and seeders are calibrated to plant seeds by weight. But seeding densities are prescribed and calculated by the actual number of seeds sowed per m^2, not by weight. To convert seeds/m^2 to seeds/kg, it is important to know the number of seeds per kilogram for each species in the mix. Here are some examples:

Ticklegrass (*Agrostis scabra*)	11,000,000 seeds/kg
Polargrass (*Arctagrostis latifolia*)	3,960,000 seeds/kg
Sheep fescue (*Festuca ovina*)	1,100,000 seeds/kg
Violet wheatgrass (*Elymus alaskanus*)	330,000 seeds/kg

Seed densities for all species recommended for use in Yukon are listed in Chapters 5 and 6.

Furthermore, not all seeds in a seed lot will be viable, and seeds of other species (including weeds) may contaminate the mix. Therefore, it is important to know the viability and purity of seeds seed being sown in order to convert seeds/m^2 to seeds/kg (otherwise too little seed will be applied). This assessment of viability and purity is expressed as percent "Pure Live Seed" (PLS), and is certified by an independent testing lab. Normal values for PLS range from 70 – 95%. All commercial seed purchased for a project should come with a certificate indicating the percent PLS.

Why are seed prescriptions listed in seeds/m² rather than seeds/ha or kg/ha?

Revegetation sites are usually large, and measured in hectares, not square meters. So why are seeding rates discussed in seeds per m^2? Moreover, no one counts out seeds when planting, so why not prescribe seeding densities in kilograms per hectare?

First, consider that each seed will develop into an individual plant, regardless or seed size, but that seed size (seeds/kg) varies widely between species. Seed size is also not well correlated with the size of adult plants or how much space they occupy on the ground. Ultimately, it's the density of adult plants on the site that matters, so it only makes sense to plan in terms of the density of seeds to sow, not the weight of seeds to sow – that comes later, during implementation.

But why not prescribe the seeding rate in seeds per hectare? Because the numbers tossed around would be so large as to be meaningless. Which one of the following makes more sense and is easier to manipulate when developing a seed mix:

1,500 seeds per m^2
or
15,000,000 seeds per hectare?

Table 4.1
Recommended seeding rates (see text and scenarios in Chapter 5 for more information).

Broadcast Method	(PLS/m^2)
Default rate, no/few surface organics in place	1,500
Good surface organics in place	750
Steep slopes with high erosion potential	2,250 – 3,000
Disturbed permafrost sites	at least 1,500
Wet sites	do not exceed 1,500
Arctic tundra sites	500 – 1,000
Alpine and subalpine sites	750 – 1,000
Goal to exclude woody species	2,500 minimum
Nursery crop for facilitated natural revegetation	500 – 1,000
Seed Drill Method	
Generally reduce above rates by 50%, but never below 500 PLS/m^2	
Hydroseeding	
All sites (generally sites will be sloped)	2,250 – 3,000

How to calculate a seed mix application rate

1. Determine the area that will be seeded in m^2 (1 ha = 10,000m^2), because even though actual seed application rates will be calculated in kg/ha, recommended seed densities are prescribed in seeds/m^2.
2. Decide on the species to be planted using recommendations from Chapters 5 and 6.
3. Check seed availability with a seed supplier and obtain values for percent pure seed and percent viable seed for each species and each lot of seeds (values vary between lots).
4. Determine the desired density for each species (seeds/m^2) to suite the site conditions and project goals. If the total density for the seed mix will be 1500 PLS/ m^2, then each species will probably range from 150 to 600 PLS/m^2 (10% – 30%). The species-specific densities will be tailored to address site conditions, but also may take into account factors such as seed cost and availability.
5. Note the number of seeds per kilogram for each species, which is listed in Chapters 5 and 6. This information will be required to calculate the total weight of seed to apply.
6. Next, calculate the application rate for the each species using the following formula (note that this calculation will have to be made for each species in the mix):

$$\textbf{Amount (kg) of seed (per species)} = \frac{\text{area to be seeded } (m^2) \times \text{desired seed density } (PLS/m^2)}{\text{\# of seeds/kg} \times \text{percent seed purity} \times \text{percent seed viability}}$$

Table 4.2
Example of a seed mix and application rate with a desired seed density of 1,500 PLS/m^2 for a 1.2 ha site (see box above for formula used to calculate the mix).

Plant Species	Seeds/kg	Purity (% of weight)	Viability (% germination)	Desired PLS/m^2	Total in Mix (Kg)
violet wheatgrass	330,000	93%	90%	300	**13.0**
tufted hairgrass	3,300,000	84%	80%	400	**2.2**
glaucous bluegrass	2,904,000	71%	91%	400	**1.6**
fowl bluegrass	4,840,000	95%	85%	400	**1.2**
				Total for 1.2 ha	**18.0 kg**

half (750 PLS/m^2). This rate should be adequate to establish stabilizing ground cover and still facilitate colonization by native plants. If the goal is to exclude regrowth of native plants (*e.g.*, woody species), the rate should be left at 1,500 PLS/m^2 for sites that retain soils and organics, and increased to 2,000 PLS/m^2 or more on sites comprised of bare mineral soil.

Steep slopes are likely to experience significant seed loss due to runoff, and it is important to establish a thicker stand more quickly when erosion is a threat. Therefore, it is advisable to increase the seeding rate by 50 – 100% on steep slopes (2,250 – 3,000 PLS/m^2). If a slope is hydroseeded, then the seed quantities should be increased by 50 -100% as well, to account for increased seed loss and damage during hydroseeding.

Creating a balanced seed mix with the proper number of seeds per species can get complicated because the number of seeds per kilogram varies greatly between species. For example, one kilogram of ticklegrass (*Agrostis scabra*) contains 11 million seeds, while the same mass of violet wheatgrass (*Elymus alaskanus*) contains only 330,000 seeds. Most fescue species contain around one million seeds per kilogram. A seeding density of 1,500 PLS/m^2 would equate to 0.0001 kg/m^2 of ticklegrass, or 0.0045 kg/m^2 of violet wheatgrass, or 0.0015 kg/m^2 of fescue, assuming 100% PLS. Converting these values to a typical field application rate (kg/ha) equates to 1.4 kg/ha of ticklegrass, or 45 kg/ha of violet wheatgrass, or 15 kg/ha of fescue (see below for details on calculating seed mixes).

But it is important to remember that seeding rates are prescribed in terms of PLS, and no lot of seed can be expected to be 100% pure or have 100% viability. Seed purity can be reduced by the presence of weed seed and other materials (*e.g.*, organic detritus, stones). Seed viability (*i.e.*, germination) will also vary by species and by seed lot; the highest viability rates are around 95%.

Seed that is more than two or three years old or has not been stored properly will lose viability. To account for this, seed is sold with a certification of the *percent seed purity* and *percent viable seed* (germination rate). The analysis of seed purity and viability are performed and certified by an independent third-party lab (Fig. 4.12), and are available upon request from seed suppliers; sometimes they are specified on the tag attached to seed bags. The percent PLS is calculated by multiplying the percent seed purity by the percent viable seed. A reasonable expectation for PLS is 70% to 90%.

In summary, be sure to base the actual seeding rate in the field on the calculated weight of pure live seed, not the gross weight. The box on page 65 shows a step-by-step procedure for calculating the actual composition and weight of a seed mix as it would be applied in the field.

4.2.4 Seed Nomenclature, Quality and Sourcing

Seed Nomenclature

Seed classification and nomenclature can be confusing (Fig. 4.10). A "cultivar" of a given species is the product of selective breeding for uniform and predictable traits in the population when planted in an environment to which it has become adapted. Once a true-breeding genetic line (population) has been established, it can be registered with a certifying agency (*e.g.*, the Canadian Seed Growers' Association). "Breeder seed" is the seed stock produced by the institution that developed the cultivar and is only sold to a limited number of licensed producers as seed stock to grow "foundation seed" under controlled conditions and extensive testing for purity and consistency. This first-generation progeny of the breeder seed is then sold to secondary producers to grow second generation progeny called "registered seed." This seed must be grown and handled using protocols established by the certifying agency to preserve genetic purity and identity.

Registered seed is the seed stock used to grow "certified seed," which is also referred to as "pedigreed seed" (occasionally, certified seed is the direct progeny of foundation seed). Usually it is the first, and purest, generation of a cultivar that is available commercially to the revegetation and agriculture industries for general use. However, certified seed is also used to produce further generations of commercial seed stock, in which case it can be sold only as "common seed." Common seed can state that it is a registered cultivar (*i.e.*, the cultivar name will be listed), but it cannot be sold as Certified Seed.

"Common seed" is also the appropriate classification for seed that was propagated from wild plant sources, but for which no selective breeding or specific cultivar has been developed. Violet wheatgrass (*Elymus alaskanus*), for instance, is only available as common seed.

Seed Quality and Sourcing

Many of the commercial revegetation species recommended in this *Manual* will be available only as common seed. When purchasing common seed, it is important to buy seed that was propagated in Yukon, Alberta, or Alaska. For species that are available as registered cultivars, the *Manual* will indicate which cultivars are recommended for use in Yukon, because not all cultivars of a species are successful in Yukon conditions. All seed species and cultivars recommended in this *Manual* are registered with the Canadian Seed Growers Association (CSGA) and/or the Alaska Seed Growers Association.

Whether seed stock is certified or common, the quality of seed that is planted is the most important determinant of germination success. According to the *Canada Seeds Act* (2005), any certified or common seed that has been advertised for sale in Canada must be tested and graded.

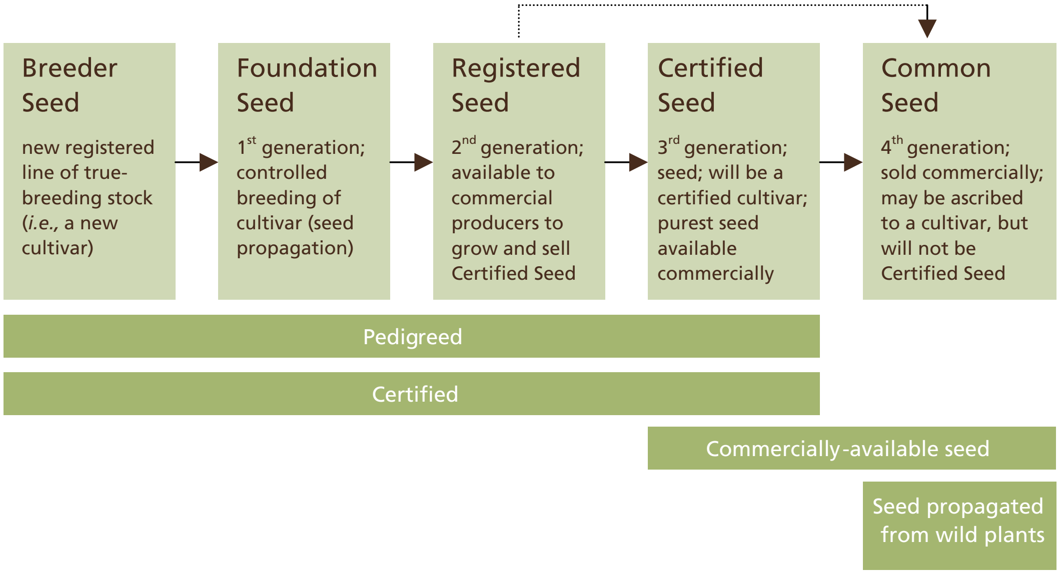

FIG 4.10
Seed classification and nomenclature

In addition, under Canada's *Weed Seeds Order* (2005), all seed must be tested for noxious and prohibited plants. All graded seed (certified and common) will be traceable to a lot number and a seed testing certificate containing the following information:

- Lot number
- Species and cultivar name
- Presence and amount of prohibited, invasive, and noxious seeds, as well as other weed seeds (see section on *Invasive and Noxious Species* below)
- Percent pure seed
- Germination rate (from testing)
- Percent Pure Live Seed (percent pure seed x germination rate)
- Place and date of analysis
- Seed grade (see below)

Currently, there is no Yukon legislation addressing seeds or seed purity. However, all seed sold as Certified in Canada will have an official Canada Certified tag on the seed bag and will have been produced by a CSGA-registered seed grower. The tag will state the species, cultivar name, grade, lot number and crop certificate number. A similar certification system is used in the U.S., including Alaska. Canada has over 4,000 registered farms involved in seed production and each seed grower is required to follow stringent production requirements to ensure that quality standards are met. A CSGA crop certificate and tag are only issued when a pedigreed seed crop has successfully passed crop inspection by a third party inspector.

The *Canada Seeds Act* specifies criteria for certified labs to assign an overall grade to a seed lot, which includes measures of purity, germination rate, and weed content. The only grades relevant to revegetation work will be

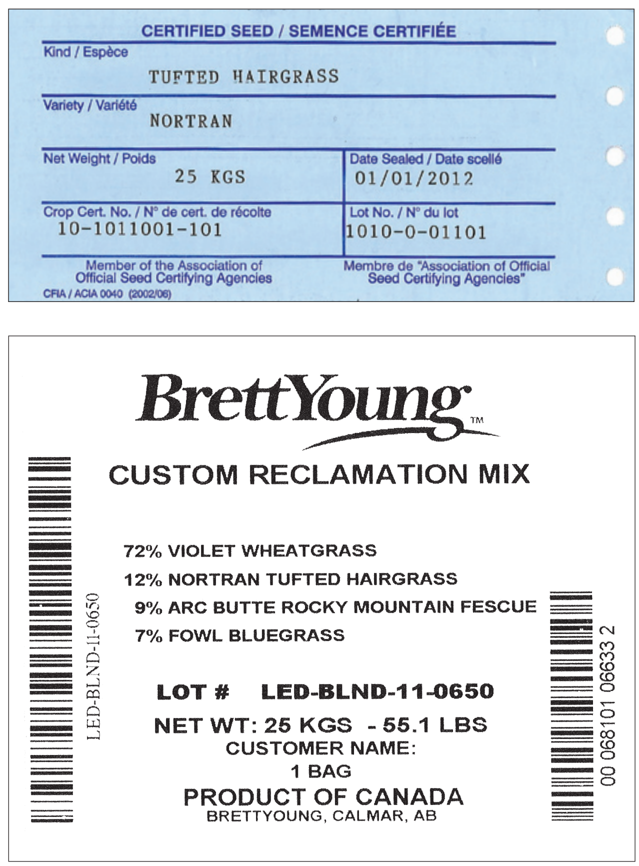

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FIG 4.11
According to the Canada Seeds Act, any certified or common seed sold in Canada must be tested and graded. Bags of graded seed will have an official blue "Canada Certified" tag (top) and will have been produced by a grower registered with the Canada Seed Growers Association. On the bottom is a producer's label indicating the lot number and species content by weight percentages.

Certified #1, Certified #2, Common #1 and Common #2. Because most of the difference between grades #1 and #2 regards weed content, planners should only use grade #1 seed (it has fewer weeds than #2).

If requested by the purchaser, a seed supplier is required under the *Canada Seeds Act* to provide a testing certificate within 30 days. Revegetation planners should request this certificate and keep it in the project files in case there is a problem with seed germination on the site (this way the quality of the seed can be verified). A high number of weed seeds, the presence of prohibited seeds or low germination rates are reasons to reject the seed from a given lot. It is also important to know the age of the seed lot because some seed species maintain their ability to germinate for many years, while others lose their viability quickly, after only a year or two. Figure 4.12 shows a report of seed analysis for a lot of slender wheatgrass.

Customer: Big Bob's Seeds PO Box 1500 Fescue Fields Forever, Saskatchewan		Seed Type: Slender Wheatgrass Cultivar: Common Lot#: 310228 Analyzed According to Canadian Methods & Procedures for testing Seeds	
Tests: Germination, Canadian Purity			
Total Grams Analyzed: 50	Per 25	Date Received: Jun 12, 2009 Purity Date: Jun 12, 2009	Per 25
Prohibited Noxious:	0	Other Crop Seeds:	
		(Bromus spp.) Bromegrass	0
		(Poa pratensis) Kentucky Bluegrass	0
		(Agropyron cristatum/desertorum) Crested	
Primary Noxious:		Wheatgrass	0
Total Primary	0		
Secondary Noxious:		Total Other Crop Seeds	<1%
		Sweet Clover	0
		Brassica spp.	0
Total Primary & Secondary Noxious	0	Ergot Bodies	<1%
Other Weed Seeds: (per customer request)		Percentage Test:	2.0511g
		Pure seed %	97.3
Brassicaceae: (Persicaria spp.) Smartweed	2	Other crop %	0.0
		Weed Seed %	0.0
Sweet Clover:	0	Inert matter%	2.7
Ergot	0	Jun 26, 2009 Germina	92%
		% Abnormal Seedlings	3
		% Dead Seed	5
		% Pure Living Seed	89
Total Noxious & Other Weed Seeds	2		

FIG 4.12

Example of a seed analysis report generated for a specified lot of slender wheatgrass (*Elymus trachycaulus*). Even though such reports are provided by the seed supplier, the testing is performed by an independent accredited laboratory. The results are important because they show the percentage of Pure Live Seed as well as the incidence of prohibited noxious weeds, primary noxious weeds and secondary noxious weed seeds. Typically these reports include occurrences of "Other Weed Seeds" not classified as noxious or crop seeds. In this particular case, the customer also requested testing for the presence of sweet clover, *Brassica* species and ergot (a fungal plant pathogen).

Invasive, Noxious and Persistent Species

Contaminated seed mixes are a common vector for the introduction of invasive and noxious plants to Yukon. Invasive plants are non-native species that grow rapidly, spread aggressively, and displace native plants in the process, often to the detriment of naturally-occurring plant communities. By no means are all non-native plants invasive, but all invasive species are non-native. In large part, they become invasive because there are few natural checks on their growth. "Noxious" plants are defined more generally as plants that grow aggressively and competitively and have harmful or undesirable traits. Furthermore, "noxious species" is the legal term found in weed legislation and regulations to describe undesirable or problematic species. Invasive species often are categorized as a type of noxious plants.

Another category of potentially problematic plants to be aware of are those categorized as "persistent species." Unlike invasive species, they do not spread aggressively. Rather, they are tenacious and become difficult to replace once established. Species can become persistent for a number of reasons. Often, it is because they were seeded too thickly or in a monoculture, such as in old farm fields. Red, white and Alsike clover are examples of plants that have become persistent and difficult to displace in fields where they were planted in Yukon.

In this *Manual*, all invasive plants have been removed from the list of recommended species. Red, white and Alsike clover are no longer recommended because they can be overly-persistent, but also because they confer no significant advantage in a revegetation mix. Alfalfa and Kentucky bluegrass are the only two species recommended for Yukon revegetation mixes that could be classified as slightly persistent, but they are only recommended for special applications as discussed in Chapters 5 and 6 (alfalfa can be used on difficult to revegetate slopes and the Kentucky bluegrass cultivar called "Nugget" excells on cold, wet tundra). When considering the use of any non-native plant, the main question should be: what is the potential harm it could cause relative to the advantage it confers when trying to meet site objectives.

As mentioned in the previous section, revegetation planners need to ensure they are not inadvertently introducing invasive and noxious species by purchasing contaminated seed. A limited amount of legislation exists to regulate the importations and spread of noxious species through contaminated seed. The *Canada Seeds Act* (2005) and *Weed Seeds Order* (2005) specify a list of prohibited species ("zero tolerance") and the maximum number of "other" weed seeds permitted as contaminants in any seed that is imported to or sold in Canada. Paradoxically, noxious weed problems are regionally-defined, whereas the *Canada Seeds Act* is national in scope and does not address regional weed issues. Currently only 21 species

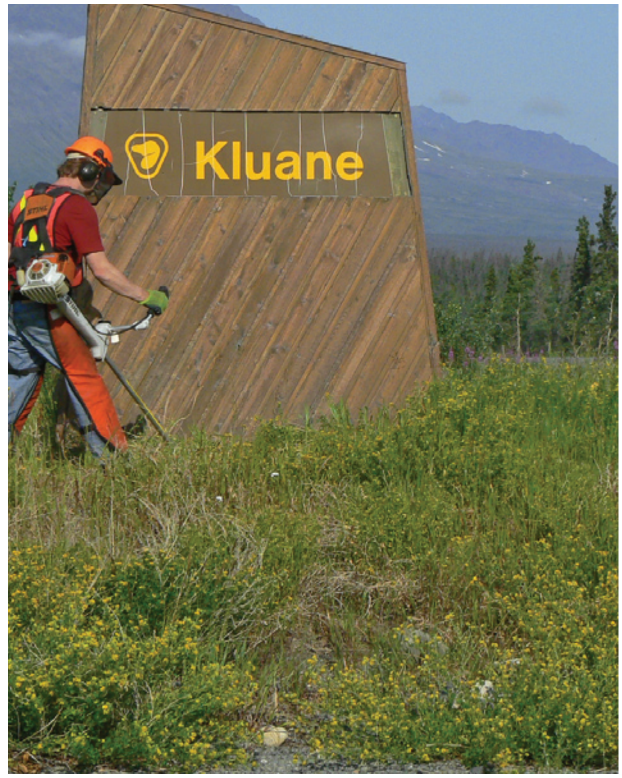

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FIG 4.13
Good intentions gone awry. Soil with high organic content was transported to this site near Kathleen Lake to improve soil conditions for revegetation. Unfortunately, the soil was contaminated with seeds of yellow lucerne (*Medicago falcata*), an invasive and persistent species found in the Haines Junction area. Now it is a management issue.

are listed as prohibited in Canada by the *Seeds Act*, but several species that are invasive in Yukon are not on that list. In fact, they are grown agriculturally in southern Canada (*e.g.* sweetclover).

Consequently, there is significant responsibility on the part of revegetation planners to proactively manage unwanted species by:

- Purchasing seed graded as Certified #1 or Common #1 whenever possible.
- Giving seed suppliers a list of Yukon-defined invasive species that cannot be permitted to contaminate the seed mix (not a single seed). This list is constantly updated and can be obtained from the Yukon Invasive Species Council or the Government of Yukon (Department of Environment or the Agriculture Branch).
- Requesting seed analysis certificates and carefully screening them for the presence of invasive and noxious species.
- Clearly stating the above criteria in the purchase contract. Planners should reject mixes that do not comply with contract specifications.

4.3
Timing and Conditions for Fertilizing and Seeding

Timing of the work is a very important consideration for any revegetation project in Yukon. Work on the ground is typically limited to the period from mid May through late September. Due to the short growing season, crews should be out preparing the soil for fertilizing and seeding as soon as the ground is workable. The reality, however, is that revegetation work often must occur late in the season because it cannot commence until other development work on the site is completed.

4.3.1 Spring/Summer Seeding and Fertilizing

Most seeding on revegetation sites in Yukon is completed in late May and June. If seed is in the ground before the end of June, generally there is sufficient time for the plants to emerge and grow into seedlings that will be mature enough to survive winter. Seeding should not occur in July (sometimes the first week of July is acceptable) or August because emergent seedlings will not have enough time to build the reserves necessary to overwinter.

Once the ground has been prepared, the site should be fertilized and then seeded, in that order. The reason is because dry fertilizer pellets should be incorporated deeper into the soil than seeds, and because fertilizer benefits from a second pass with a harrow and equipment traffic whereas seeds usually do not.

It is also recommended that seeding occur as quickly as possible after fertilizing, preferably immediately after, but no more than two weeks later. This will minimize the amount of fertilizer loss due to volatilization, and it will prevent invasive weeds from using the fertilizer to get a head-start on the seeded species. Also, losing more than two weeks in the growing season will diminish the growth potential of the seeded plants, as well as their over-wintering success.

Work should be planned and timed to occur when ground conditions are favorable. First and foremost, avoid working ground that is wet. Second, do not start a process that cannot be finished before bad (wet) weather arrives. Always consult the weather forecast.

Grading, decompacting and any tillage should not occur when the ground is wet because it can create clods that will harden when dried. Dried clods will need to be broken up, necessitating another pass with equipment. Decompacting should also be timed to occur when other work on the site has been completed, lest the ground become recompacted by equipment traffic. If no further ground-compacting traffic is anticipated, it is acceptable to allow significant time (weeks) to lapse between decompacting and fertilizing/seeding.

Fertilizing, seeding and harrowing must also be done when the ground is dry, but ideally will be completed just before a good soaking rain. Fertilizing/seeding should be timed so that, once started, the whole process can be completed without interruption. For instance, do not rush to complete the fertilizing before a rainstorm, only to find that the ground is then too wet to seed until three weeks later.

4.3.2 Fall/Frost Seeding and Fertilizing

Fall seeding (also called "frost seeding") can be a successful strategy in Yukon. The idea behind frost seeding is that seeds are sown in late fall, as the ground starts to freeze, but remain dormant until the following spring. The advantage is that the seeds start germinating early in spring when the ground has good moisture, long before it would be possible to operate seeding equipment on the land (due to saturated ground). This can lengthen the effective growing season by up to a month, which is significant in Yukon.

There are certain gambles with frost seeding. To survive winter, it is critical that the seeds remain dormant and not initiate the germination process until spring. If temperatures are persistently above freezing after fall seeding, and the seeds are in contact with water, they may break their dormancy. Therefore, timing is critical and must be fine-tuned to the weather each fall. This means that equipment and personnel must be ready to deploy on short notice. Generally, frost seeding is done in October in Yukon, but the window of opportunity can be from late September until the first week of November.

A common approach to frost seeding is to spread seed and fertilizer when the ground has a surface crust of frost, but is not completely frozen. Usually, this is when temperatures are freezing hard at night but may still rise above freezing during the day. Seed and fertilizer will get worked into the ground mechanically by daily freeze-thaw cycles. It is important that the seed and fertilizer receive a covering of snow fairly quickly after it is applied (within a week or two). This keeps the seeds dormant and reduces fertilizer loss due to volatilization and runoff.

Some farmers who frost-seed their crops like to wait until there is already a thin skiff of snow on the ground, especially if daytime temperatures still occasionally reach above freezing. The snow helps to protect the seed and prevent if from breaking dormancy. The risk to this approach is that seed and fertilizer can be lost to spring runoff the following year if it does not get incorporated into the ground by freeze-thaw action. On flat sites with a gentle melt, this risk is minimal because the seeds will settle into the ground and become incorporated during freeze-thaw cycles in April and May.

4.4
Methods of Fertilizing

4.4.1 Start with Surface Preparation

Prior to fertilizing and seeding, the ground surface should be graded and decompacted with subsoiling equipment to a depth of at least 20 cm, but preferably closer to 40 cm (see Chapter 3). Often, the final grading will already be in place, and in some cases decompaction may not be necessary either – for instance, if loose fill material was trucked in and spread without being compacted by subsequent traffic. Either way, a loose subsoil is important because it allows for water absorption/retention and aeration and helps roots to penetrate more deeply. Failure to decompact the soil is a major reason why some revegetation sites exhibit poor stand development.

Decompaction and other earthwork often leave the surface with large undulations, or large clods may be present if the surface was wet when worked. In those situations, the surface should be harrowed with a tine harrow, chain harrow or disk harrow prior to fertilizing (information on harrowing below). If the slope is too steep for harrowing, it should be track-walked (Chapter 3).

4.4.2 Applying Fertilizer

Chapter 3 described methods for calculating fertilizer needs and application rates. This section describes the actual methods of applying fertilizer.

Broadcast Spreaders

In almost all cases, except hydroseeding, fertilizer will be applied in dry (pellet) form with a broadcast spreader, also called a "cyclone spreader" or just "broadcaster" (Fig. 4.14). Broadcast spreaders are multi-purpose implements that are pulled by a tractor, ATV, or truck, though smaller units exist that are human-propelled or hand-held. They can be used to spread seed, fertilizer, or other dry, granular materials (*e.g.*, lime).

Broadcast spreaders have a central hopper to hold a large quantity of fertilizer or seed that is gravity fed to metering and spreading devices at the bottom. The spreading devise is either a rotating disk (cyclone spreader) or a swinging pendulum arm (pendulum spreader). In either case, the fertilizer or seed is aerially propelled in a dispersal pattern behind the spreader before falling to the ground.

Broadcast spreaders are imprecise delivery systems and need to be calibrated to apply fertilizer at the prescribed rate. It also takes experience to gauge the proper combination of meter settings and travel speed to achieve the desired application rate.

More precise implements do exist for fertilizing. For instance, fertilizer can be drilled into the ground to a precise depth using a seed/fertilizer drill, or liquid fertilizer can be injected. Unfortunately, for the most part these methods are impractical for revegetation work in Yukon either because the equipment is not available or the site conditions are too rough to allow for their use. On large sites with well-tilled soil, their use should be considered.

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P. MATHEUS

FIG 4.14
Fertilizer and seed are usually applied to the ground surface using a broadcast spreader, after which they are worked into the soil with a harrow. The broadcaster on top is a cyclone type spreader and the one on the bottom is a pendulum spreader.

Plant Materials 4

Harrowing

Harrowing is the process of lightly tilling and turning the ground surface and should be done after broadcast fertilizing and seeding to incorporate fertilizer and seed into the soil.

When fertilizer is broadcasted onto the surface, nitrogen components are prone to volatilizing or dissolving in surface water and being lost through runoff. The nitrogen in modern fertilizers normally will be in the form of urea. When exposed to moisture and air, urea quickly converts to ammonium, which is highly volatile. However, if buried it is less volatile and is available for plant uptake directly, or it becomes mineralized into nitrate, which also is stable and able to be used directly by plants (Fig. 3.5).

T. OMTZIGT

Harrowing is the usual method used to cover and incorporate fertilizer into the soil. Harrows come in a variety of forms. The three types most often used in revegetation work are tine harrows, disk harrows and chain harrows (Fig. 4.15). Often, they are used in combination – *e.g.*, a chain harrow is pulled behind a disk or tine harrow. Disk harrows are the most aggressive and can work soil to a greater depth (up to 25 cm). Consequently, they require the most horsepower from the towing vehicle. Tine and chain harrows are effective at burying seed (see below), but less effective at incorporating fertilizer, especially chain harrows, because they only work the upper few centimetres of soil.

A good depth to target for harrowing after fertilizing is the upper 5 – 15 cm of soil. This will place fertilizer at a depth that can be utilized by emerging plants, and it creates a fine-textured surface to receive seed.

Often, equipment can be configured to pull a harrow immediately behind the broadcast spreader so that fertilizing and harrowing are accomplished in one pass. A common configuration is to mount a broadcaster on the back of an ATV or tractor and tow a tine harrow behind. However, if the broadcaster throws fertilizer in a wide arc, then an equally wide harrow should be pulled, and the harrow has to be far enough behind the broadcaster so that fertilizer is thrown in front of the harrow, not over it. And while this is a common configuration because it is easy and efficient, it is better to use a disk harrow than a tine harrow to incorporate fertilizer. Chain harrows are the least effective at incorporating fertilizer.

YG HIGHWAYS & PUBLIC WORKS

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FIG 4.15

Three types of small harrows used to work the upper soil surface, prepare a seedbed, or incorporate seed and fertilizer into the soil. Disk harrow (a), tine harrow (b), chain harrow (c). The harrows shown are relatively easy to transport and can be drawn by a low horsepower tractor or ATV, but they are inefficient for sites larger than ~10 ha. Larger equipment is shown in Fig. 4.16.

FIG 4.16
Large sites will call for large equipment, such as this tandem disk harrow, to prepare soil. Harrows of this size require large tractors (over 100 horsepower) as draft machines.

Plant Materials 4

Are ATVs replacing tractors?

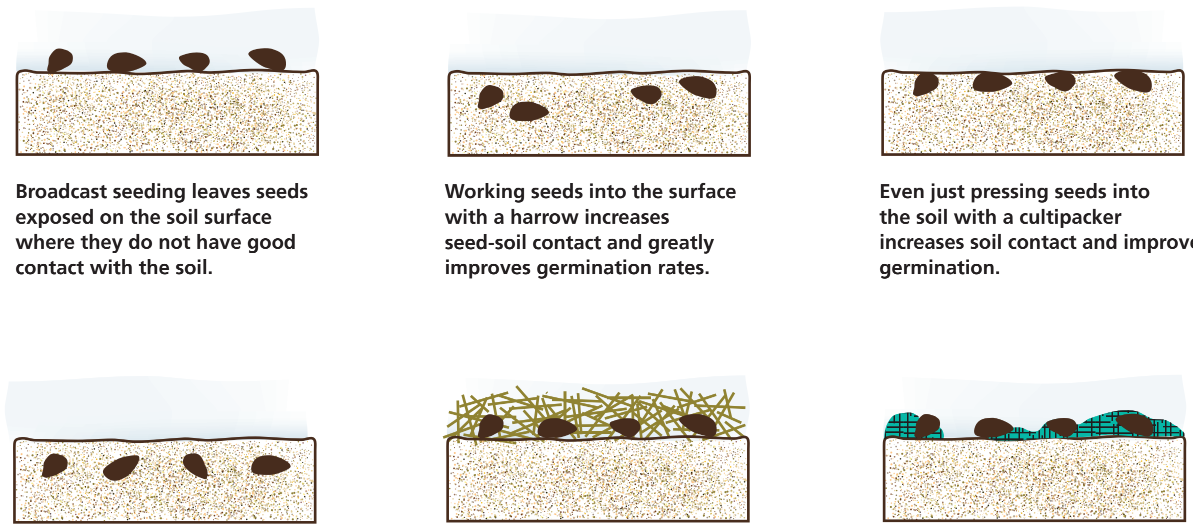
Revegetation work invites creative use of equipment combinations. Tractors (both wheeled and tracked) have been rigged to pull a variety of implements for tilling, harrowing, seeding and fertilizing – often simultaneously.

In recent years, the revegetation industry has benefited from the development of numerous small implements that can be pulled by ATVs, including broadcast spreaders and harrows – even mini hydroseeders. ATVs are more readily available than tractors, and are safer to operate on sloped or rough terrain. ATVs also are cheaper to operate, the implements can be rented at low rates, and the whole package is relatively easy to transport.

The main disadvantage of an ATV-based operation is that ATVs have very little draft strength, so the implements they pull cannot work the soil very deeply. And naturally, the small size of the equipment means that more passes are required to cover a given area, compared to a tractor operation. But for small sites, ATVs can be ideal, and they work well as finishing tools when larger equipment is used for the heavy work.

When harrowing with an ATV, tine and chain harrows tend to be more commonly used than disk harrows because they are lighter and flex a little over rough terrain (disk harrows do not). However, tine and chain harrows are not as effective as disk harrows for working soil or incorporating fertilizer because they do not reach deep enough into the ground. Consequently, it is not uncommon to use a combination of vehicles: a tractor with a disk harrow or other tillage implement for heavy draft work and an ATV with a tine or chain harrow for finish work.

FIG 4.17
Seed being covered using the small tine harrow pictured in Fig. 4.15. Note the limited penetration of the tines on this gravely surface. In this case, the ground was harrowed twice to increase the amount of seed-soil contact.



Broadcast seeding leaves seeds exposed on the soil surface where they do not have good contact with the soil.

Working seeds into the surface with a harrow increases seed-soil contact and greatly improves germination rates.

Even just pressing seeds into the soil with a cultipacker increases soil contact and improves germination.

Seed drills place seeds at a more consistent depth with more even spacing. Drilled seeds have the highest germination rates.

Covering broadcasted seeds with long-fibered mulch is very effective in conserving moisture around the seeds, but does not increase soil contact.

Applying seeds in a hydromulch places a portion of seeds on the soil surface but leaves most of the seed suspended in the hydroseeding matrix above the surface.

ADAPTED FROM *ROADSIDE REVEGETATION: AN INTEGRATED APPROACH TO ESTABLISHING NATIVE PLANTS* (2007), US FEDERAL HIGHWAYS ADMINISTARTION

FIG 4.18
Good seed-to-soil contact is critical for achieving adequate germination rates and is greatly affected by the method of seeding.

4.5 Methods of Seeding

The method used to sow seed will depend on terrain features, the amount of ground to be seeded, and the type of equipment that is available. In most cases, seed will be sown using the same broadcast spreader that was used to apply fertilizer. Occasionally, it will be possible to use a seed drill, though they are impractical for use on rough terrain and they are rarely available in Yukon. If conditions allow for the use of drills, they will usually pay for themselves in reduced seed costs and they are much more effective at sowing seed to the proper depth. The following sections describe and evaluate the various seeding methods that are available, including broadcasting, drilling, hydroseeding and handseeding.

4.5.1 Broadcast Seeding and Harrowing

Broadcast spreaders are by far the most frequently used seeding devises for revegetation projects in Yukon. They were described above, in the section on fertilizing. Because broadcasters are attached to the back of a tractor or ATV, they can be used on any terrain that can be driven on with those vehicles. Broadcasters also are inexpensive, transport well, have few moving parts, are easy to maintain and do not require sophisticated calibrating, relative to drill seeders. Broadcast seeders are commonly available for rent or purchase in Yukon or by special order from an outside supplier.

There are shortcomings, however, to using a broadcast spreader for seeding. As mentioned in the fertilizer section, broadcast spreaders are relatively imprecise delivery systems and it can be a challenge to achieve even seed coverage. Just like when fertilizing, it is important to calibrate the metering devise, and the rate of application is dependent on the speed of travel. Broadcast seeding requires vigilance on the part of the operator to avoid under-seeding when speeding up and over-seeding when slowing down or turning.

Broadcast spreaders only deliver seed to the surface, and seed that remains lying on the surface will have a very low germination rate (Fig. 4.18). Consequently, seed that is broadcasted must be harrowed in order to increase seed-to-soil contact (seed drills do not require harrowing). Harrows are imprecise devises, too, and do not result in uniform or precise depths of seed burial. They should be configured to work the upper 2 – 5 cm of ground, which will position seeds with an average soil coverage of 0.5 – 2 cm. Disk harrows often cannot be set to harrow this shallow and still be effective at covering seed.

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FIG 4.19
This no-till seed drill has aggressive coulters and a heavy cultipacker and is designed to seed through ground without ploughing. These drills are mainly intended for agricultural and landscaping applications but they are very effective for revegetation sites that have fairly even ground, few rocks and little coarse debris.

Therefore, most harrowing after seeding is performed with a tine or chain harrow. Of the two, tine harrows are much more effective, but the best set-up can be a combination tine-chain harrow.

Most grass seed benefits from slight compaction (rolling) of the soil surface after sowing because it increases the contact between seed and soil. An excellent implement to accomplish this is a cultipacker, which is a heavy roller with short, blunt teeth that is pulled behind a harrow as a type of surface finisher (most seed drills will have a built-in cultipacker) (Fig. 4.19). A cultipacker only compacts the top few millimetres of soil and the teeth leave behind holes that improve water absorption. If a cultipacker is not available, an alternative, albeit less effective solution, is to attach a heavy metal pipe to the back of the harrow.

Because broadcast seeding is so imprecise, germination success is often only ~50%, which is the reason why seeding rates for broadcast spreaders are twice the rate as those for drills and drop seeders. Despite these shortcomings, broadcast seeding in conjunction with harrowing is the main seeding method used for revegetation work in Yukon because the equipment is readily available, adaptable, and relatively uncomplicated to operate.

A final note on the use of broadcast spreaders: Seed and fertilizer should never be mixed together in the spreader for simultaneous application. The two materials will dissociate in the hopper when agitated, due to differences in weight and density, usually with fertilizer on the bottom. The result will be a very non-uniform distribution of both seed and fertilizer. For the same reason, it can be problematic to spread seeds of very different size, texture (*e.g.*, fuzzy versus smooth) or density simultaneously. If a prescription calls for the application of seeds that vary tremendously in these characteristics, then it may be necessary to perform a separate application for each class of seed. In those cases wait to harrow until the last seed is spread.

4.5.2 Seed Drills

Seed drills are implements that sow seed directly into the ground without the need to harrow. They provide much better control over seeding depth and evenness of coverage (Fig. 4.19 – 4.21). Some drills can also be used to apply fertilizer. In the standard design, seeds are stored in a hopper and metered down multiple delivery tubes either mechanically or using air pressure. In front of each tube opening there is a coulter that cuts a furrow (called a "drill") in which the seed is dropped, and behind each tube is a chain, tine, wheel, cultipacker or other devise that functions as a rake to fill the channel and cover the seed. Seed drills can be large and heavy, so usually must be pulled by a tractor, and they generally only work on fairly flat, even ground. However, a growing number of smaller models are becoming available that can be pulled by an ATV and are designed for use on uneven ground (Fig. 4.20).

LAND PRIDE, SALINA, KS

FIG 4.20
This small, handy seeder is called a food plot seeder (which refers to its normal application planting feed crops for wildlife). A set of coulters in front breaks the ground surface and creates furrows. The seed is broadcast from the hopper and then covered and rolled by the trailing cultipacker. Food plot seeders are small enough to be pulled by a small tractor, ATV, or truck, and are either ground-driven or operate by 12V current from the draft vehicle. Seeders of the size pictured here are only appropriate for small sites.

U.S. FOREST SERVICE, BOISE, ID

FIG 4.21
This large rangeland seed drill has been designed by the U.S. Forest Service to re-establish grasses on rangeland. It has been designed for rugged simplicity: seed tubes open directly into furrows as they are cut by coulters. This model covers the seed with chains, while other models use wheels or cultipackers. Note that even this heavy-duty type of drill still will not perform well on very uneven ground because it cannot flex, and the coulters are vulnerable to rocks and debris. Large pieces of wood and organic debris on the surface can also quickly clog the coulter and tube array.

Seed drills are far more precise than broadcast spreader-harrow systems in regard to placing and covering seed, leading to less seed waste and more uniform plant spacing. Germination rates of drilled seed are at least twice that of broadcast seed, allowing seeding rates to be cut in half.

There are a number of practical drawbacks to seed drills that limit their use in Yukon revegetation work. First and foremost, most models are designed for use on tilled agricultural land or fields with light crop residue. These agricultural models are not suitable for use on rough terrain, and they are especially prone to malfunction or damage caused by rocks and woody debris. Even the so-called "no-till" drills tend to be inadequate for use in revegetation work, for similar reasons; no-till drills are meant to seed through crop residue and pasture, not woody debris and gravely soil.

There are specialized drills for use on untilled land called "hard-land" or "rangeland" drills. They have extra heavy-duty frames, coulters and packers, but the delivery tubes are still somewhat vulnerable to rocks and heavy debris and the rigid structure of the implement means they do not perform well on uneven ground. Still other designs, such as food plot seeders and some rangeland drills, do not use tubes for seed delivery at all; instead, seed is simply metered/dropped onto the ground surface through slots and buried by a cultipacker. These are also called seeder-cultipackers. If a revegetation contracter were to pursue seed drilling in Yukon, a seeder-cultipacker or very large rangeland drill probably would be the best type to consider.

So when is it appropriate to use seed drills and other specialized seeders in Yukon revegetation work? The first consideration should be terrain. If the site is relatively flat

P. MATHEUS

FIG 4.22
Hand-held seeders are useful on small and remote sites. They also are valuable for spot seeding on any type of site.

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FIG 4.23
Nearly all sites will require some hand-work to cover seed and fertilizer in places where equipment cannot operate.

and free of rocks and sticks, then a drill will work well. But to be cost-effective, the site will need to be quite large (over 100 ha). Not only will that justify the cost of renting or purchasing and transporting the drill, but it will also yield a 50% savings in seed costs. So there is an economy of scale to consider.

When using seed drills, traverse slopes parallel to the contour so that the small furrows formed by the drill run across the slope. These will form catchments for water and reduce runoff and erosion. Note that this is the opposite direction of travel compared to track-walking.

4.5.3 Hand Seeding

Hand seeding is integral to nearly every revegetation project. On small projects (< 0.5 ha), or those that are not road accessible, the entire site may need to be seeded by hand, as it may not be cost-effective to mobilize equipment. But even on larger projects, hand seeding will be required for sections where machinery cannot operate and for touch-up or spot-seeding.

The basic tools for hand seeding are shovels, rakes, and human-powered seeders. Hand-held seeders have straps that allow the seeder to be hung from the shoulders and rest on the operator's chest (Fig. 4.22). They have a fabric hopper that holds up to 4 kg of seed and a slotted disk at the bottom that spins to distribute seeds when a hand crank is turned. Essentially, they are hand-held cyclonic broadcast seeders. A variety of wheeled seeders are available that can be either pushed or pulled. They also function as cyclonic seeders, relying on a ground-driven spinning disk to broadcast seed. Most human-powered seeders can also be used to spread fertilizer. Otherwise, fertilizer will need to be broadcast with a bucket or a shovel and wheelbarrow operation.

As with mechanical methods, the ground surface must be properly prepared prior to hand fertilizing and seeding. Use shovels and rakes to decompact and roughen the surface (Fig. 4.23). After fertilizing and seeding, it is important to rake the ground to incorporate the fertilizer and cover seed with an appropriate depth of soil (usually 0.5 – 2 cm).

Aerial seeding

Aerial seeding has not been tried in Yukon. However, for lengthy, linear revegetation projects, such as a pipeline or transmission line, aerial seeding should be explored, especially when access is a problem. Either helicopters or fixed wing aircraft can be used if proper landing and loading sites are available. There are no experienced aerial seeders in Yukon, so an outside contractor would need to be arranged.

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FIG 4.24
A hydroseeder being used to seed sloped ground along the Campbell Highway. Inset: closeup of dried slurry and mulch after being hydroseeded.

4.5.4 Hydroseeding

For slopes where machinery cannot be driven safely, or hand-seeding is not practical, hydroseeding is the next viable option. In hydroseeding, the seed and fertilizer, along with a tackifier and a mulch (usually cellulose), are mixed with water to form a slurry in a large tank mounted on a truck or trailer. The slurry is applied to the slope using a pressurized hose and can be sprayed up to a distance of 60 m (Fig. 4.24).

Hydroseeding has the potential to be quite effective because the slurry adheres well to ground surfaces. Because the slurry is highly visible it is easy to monitor the coverage, and hydroseeding can be much faster than conventional seeding.To account for seed loss and the need for slope stabilizations, seed application rates are increased by 50 – 100% when hydroseeding.

In southern Canada, hydroseeding is a cost-effective option because equipment and materials are readily available. Given that, and the fact that hydroseeding is fast and less labour-intensive than other seeding methods, there is a cost savings from hydroseeding on large routine revegetation projects down south because there is an economy of scale. In Yukon, hydroseeding is usually reserved for steep slopes and other problematic sites that are prone to erosion and do not retain seeds well.

To date, the results of hydroseeding in Yukon have been mixed. Poor results are often attributable to overly-dry site conditions, which cause the slurry to crust over and simply encapsulate (trap) the seeds, leading to very low germination rates. The wetter the site, the better hydroseeding works; unfortunately, many slopes in Yukon – where hydroseeding has the potential to be the most useful – are quite dry.

The size and weight of hydroseeding trucks and trailers usually limit their use to sites along roadways or wide trails. Also, with a maximum reach of only 60 m, hydroseeding is a practical option only on sites that are long and narrow. Finally, hydroseeding requires large quantities of water to make the slurry, so there must be a nearby source of relatively clean water.

Recently, small hydroseeding units on trailers have been developed to be pulled by an ATV. These units expand the range of ground that can be treated with hydroseeding, but they are extremely limited in their slurry volume and spraying distance. These small hydroseeders are relatively inexpensive and can be operated with minimal training, so they may prove to be quite useful in the future for small jobs.

Operating hydroseeding equipment requires specialized training and the work will almost always be contracted out. Therefore, detailed methods of hydroseeding are not covered in this *Manual*.

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FIG 4.25
Lupine *(Lupinus arcticus*), Mackenzi's Hedysarum (*Hedysarum mackenzii*) and showy locoweed (*Oxytropis splendens*) are three legumes that are conspicuous and widespread in most of Yukon. Seeds from these plants are relatively easy to collect and plant, but they require stratification or scarification. (Note both colour morphs of *Hedysarum*, white and pink).

4.6 Locally-Sourced Plant Materials

The best course of action for some revegetation projects will be to collect and plant seeds and wood cuttings from the local vegetation. Local seed stock can be prescribed as the only material to be seeded, or can be used to compliment a commercial seed mix. Either way, the main motivator is usually a desire to promote or accelerate site recovery by native vegetation. Likewise, management plans may dictate the avoidance of introducing any foreign genetics from non-local plants. From a practical standpoint, collecting seeds from local plants is often the only way to include forbs (non-grasses) in an otherwise grass-dominated revegetation mix, because forb seeds can be expensive or not available in volumes required for revegetation work. Likewise, cutting and planting stakes from local willows is more effective and less expensive than planting nursery stock to revegetate and stabilize streambanks and other wet slopes.

Collecting and planting local plant materials can be labour-intensive and time-consuming, as it mostly involves handwork. It requires staff to be trained in methods of collecting, processing, storing and planting local seed stock and wood stock. It also requires significant planning, sometimes as much as a year or more ahead of planting. Nonetheless, the practice is strongly encouraged, as the payoffs are usually worth the effort, and planners should consider how they can include at least some locally-sourced plant material in every project.

It is beyond the scope of this *Manual* to provide complete methodologies for collecting, cleaning, storing, propagating and sowing native seeds and wood cuttings. Basic principles and some examples are presented here to give practitioners enough information to make decisions on the appropriateness of using local plant sources, with additional technical references provided as needed. The discussion focuses on hand-collecting methods, rather than implements for commercial harvesting, because it is assumed that most applications will be small-scale.

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FIG 4.26
Grass seed can be collected by beating seed heads with a badminton racket and collecting seeds in a hopper.

4.6.1 Locally-Sourced Seed Stock

Collecting Seed

Seed collecting methods will vary depending on the species. Grass seed is harvested by stripping or shaking it off the stem, or by clipping the stem with scissors just below the spikelet (seedhead). Often, the stripped seed is simply collected in buckets, but a more efficient method is to use a racket (such as a badminton racket) to beat the seed head while catching the seeds in a wide funnel-shaped hopper slung from the shoulder (Fig. 4.26). Handheld power strippers – essentially modified weed trimmers – also are available (Fig. 4.27).

Native grasses to target for seed collection in Yukon include various species of fescue (*Festuca* spp.), bluegrass

PRAIRIE HABITATS INC., ARGYLE, MB

FIG 4.27
Specialized equipment, such as this harvester fabricated from a weed-trimmer, has been developed for collecting wild seed.

(*Poa* spp.), tufted hairgrass (*Deschampsia caespitosa*) wheatgrass (*Elymus* spp.), sweetgrass (*Hierochloë* spp.), bentgrass/ticklegrass (*Agrostis* spp.) and reedgrass (*Calamagrostis* spp.). It is not necessary to collect pure lots of each grass; essentially any grass seed collected while stripping stems can be saved for sowing, with the possible exception of foxtail barely (*Hordeum jubatum*) – see sidebar.

Seeds of many legume species in Yukon are easy to collect and process. Colourful and locally-abundant species include arctic lupine (*Lupinus arcticus*), yellow locoweed (*Oxytropis campestris*), showy locoweed (*Oxytropis splendens*), bear root (*Hedysarum alpinum*) and Mackenzie's hedysarum (*Hedysarum mackenzii*). Being colonizing plants and nitrogen-fixers, they are excellent for use in revegetation. Many native legumes grow in clusters, and along roadways, which makes them efficient to collect. The pods are picked by hand just before they would naturally dehisce and allowed to dry for a few weeks. Those that dehisce explosively (*e.g.*, lupine) should be dried in mesh or paper bags to catch the seeds. Others will need to have the seeds stripped from the pods.

Non-legume forbs that have abundant seeds and are not too difficult to collect include yarrow (*Achillea millefolium*), a number of sage species (*Artemisia* spp.), mountain avens (*Dryas* spp.), and cinquefoil (*Potentilla* spp.). The seeds of these plants tend to be very small, however, so it is best to clip seed heads just before maturity and let them mature and dehisce in a paper bag or box. To separate seeds from seed heads, shake the containers and screen the material. For some species, it may be necessary to remove pubescence (see below).

Seeds of shrubs and trees are not usually collected for direct planting, but rather for the purpose of developing nursery stock when the species cannot be propagated from cuttings. This includes birch, spruce and pine (see more below in Section 4.6.2 *Locally-Collected Woody Species*).

It is easy to collect a large amount of birch seed in a short time because each catkin contains hundreds of seeds. Catkins should be cut from the plant in mid summer just before they mature (if cut when mature, most of the seeds probably will have dropped out already). Put the catkins in a paper bag and allow a few weeks for them to mature and dry. Then shake the bag to release the seeds from the catkin structure. At mine sites in the Northwest Territories, seeds have been collected from native shrub birch (*Betula glandulosa*), propagated to the seedling stage in nurseries (in Alberta), and successfully planted at the mine site the following year (for more information see Martens 2003 in *References and Further Reading*).

Cones of conifer species should also be collected in summer, just before the bracts open; only collect fresh cones of the year. They should be stored in a warm, dry place so the cones will mature and open. At that point, the seeds are easily separated from the cones by shaking.

Whether collecting seeds from grasses, forbs or woody plants, it is standard practice to leave at least 50% of the seed crop in the area undisturbed to allow for natural recruitment in the collecting area. It is preferable to collect from multiple stands, rather than a single stand, to increase genetic diversity. From a genetic integrity standpoint, the closer the collection site is to the revegetation site, the better, but collecting within 100 km is still considered to be "local."

Seed Processing and Storage

Often, native seeds will not be planted until the year after they were collected, so they must be stored properly to remain viable. Cool, dry conditions are best. Ideal storage temperatures are between 0° to +5° C, but room temperature is acceptable if humidity levels are kept low. A general rule of thumb is that the temperature (in Fahrenheit) plus the percent humidity should always equal less than 100. Store seeds in unsealed paper bags or cardboard boxes that can breathe, rather than plastic containers. It is also best to store them in the dark, to avoid UV exposure. Label all seed containers with the species name, collection location, collection date, and name of the collector.

Another simple option is to store seeds in a freezer, though it is not ideal. All native seeds collected in Yukon are adapted to overwinter in freezing conditions. In fact, some seeds require exposure to cold (stratification) before they will germinate (see sidebar next page). However, even in natural conditions, the seeds will be covered with snow and plant litter and thus insulated from severe low temperatures. Furthermore, many northern seeds have evolved to undergo an initial phase of growth and maturation in their first summer and fall prior to freezing and germination the next spring. If seeds are collected from the plant in summer and then immediately stored in a freezer, this development process will be interrupted. Just as important,

T. OMTZIGT

Foxtail barley – good or bad?

Foxtail barley (*Hordeum jubatum*) is a native Yukon bunch grass and a very effective colonizer on calcareous, alkaline, and even saline sites. As a prolific and aggressive grass that tolerates nutrient poor soils and is very drought resistant, foxtail barely would seem to be ideally suited for revegetation applications in the territory. And indeed it is, especially on mining reclamation sites. However, mature foxtail barley is one of the most problematic weeds for Yukon farmers and a bane to livestock and pet owners because the long awns from its seeds have barbs that catch on the skin, mouth and throat of animals that eat it, leading to irritation and even serious infection. Therefore, all effort should be made to avoid the spread of foxtail barley near any agricultural area, as well as urban and suburban areas. In these areas, it is advised to plant bare sites quickly with other species to prevent foxtail barley from gaining a foothold.

prolonged exposure to severe cold can reduce seed viability, principally because the seeds will desiccate. Consequently it is recommended that freezers used for seed storage be set to the warmest setting possible, with a target temperature no colder than -5° C. If seeds are stored in freezers, use sealed plastic containers (to prevent desiccation) and monitor the formation of condensate and ice crystals. When removing the containers from the freezer, be sure the ice does not melt and wet the seeds, which can lead to rot.

Prior to storage (or at least prior to planting), it is best to clean and process the seeds to remove chaff, hair, awns and other appendages. Many pieces of specialized equipment exist for this purpose. For instance, grass seeds are often sent through a hammer mill to remove awns and lemma. However, much of this processing and cleaning is not strictly necessary, as most seeds can be stored and even planted with these structures attached. Often, the reason they are removed is to allow for accurate weighing, transferring and testing in commercial operations, and so they will flow freely in mechanized seeders. Those generally will not be major concerns in a project where hand planting methods (simple scattering of seeds) will be employed.

However, there are a few low-tech methods to clean and process seeds that are worth mentioning, and there is evidence that they can increase germination rates for some species (and they do make it easier to handle and sow seeds). For very small, hairy seeds, the hair and seed can be separated by agitating them in a household blender using the pulse feature at low speed. The blades should be covered with tape or a rubber coating to avoid macerating the seeds, and grains of rice can be added to improve the scouring action. After agitating, shake the mix through a fine screen or sieve to collect the seeds.

Scarification and Stratification

Many seeds of northern perennial plants will require either scarification (scoring of the seed coat) or stratification (cold, wet treatment to loosen the seed coat) to achieve germination. Their seeds have evolved a resistant seed coat that protects the inner endosperm and embryo from desiccation and mechanical damage. Before germination can occur, the seed coat must be broken down, softened or cracked. This allows the seed to absorb water (imbibition), which initiates the germination process. Essentially, it is a signal to the plant that conditions are right to start growing.

Seed collectors use a variety of scarification and stratification techniques to mimic this natural process. Very small seeds can be scarified using the same modified blender described above, but if large seeds (such as legumes) are placed in a blender, they tend to get macerated. A traditional scarification method for large seeds is to line a can or jar with coarse sandpaper, place the seeds in the container and shake it. Another

… But seeds in nature don’t get buried, … or do they?

People often ask: if seeds in nature just fall on the ground and germinate without being buried, why is it so important to harrow and cover the seeds that are broadcast in a revegetation project, especially if the seeds are locally-collected from native plants?

There are two reasons for this. First, natural plant populations produce a surplus of seeds and only a small percentage actually germinate and grow into adult plants. In contrast, the revegetation planner wants every seed sown to grow. Many hours and dollars will have gone into collecting, cleaning, storing and planting the seeds, so every seed counts; natural survivorship rates simply are not acceptable in this situation.

Second, seeds of northern plants have evolved a number of strategies to deal with winter dormancy. Many require scarification or stratification (see Section 4.6.1) to signal that winter is over, spring has arrived, and it is the right time to begin germinating. Yet scarification/stratification in nature requires good seed-to-soil contact. In northern systems, seed-to-soil contact is provided by the daily cycle of freezing and thawing in spring (frost-heaving), which effectively moves and churns ground surfaces, including any materials lying on them – like seeds. By the time summer has set in, seeds will be mixed with enough soil and water from this process to become scarified/stratified.

Revegetation planners can also take advantage of this process by sowing seeds in fall , a method called “fall seeding” or “frost seeding”. Frost seeding can be used for both commercial and locally-collected seeds, and is preferred by some experienced planners because it obviates the need for harrowing – the ground does all the work. The key to frost seeding is not to broadcast seeds too early, or too late in the season. The window of opportunity occurs just as the ground is freezing up but before the first significant snowfall. Techniques for frost seeding are discussed in Section 4.3.2.

method is to place the seeds along with pea gravel in a hobbyist's rock tumbler for a few hours (with frequent monitoring). Many seeds can be scarified using chemical treatments, but these involve species-specific techniques that should be researched individually.

Like mechanical scarification, cold stratification can be achieved in a number of ways, but it is important that the seed is exposed to both cold temperature and moisture in order to loosen up the seed coat. Simply putting seed in the freezer for a few weeks is not adequate. A common method is to place the seeds in a container lined with moist paper towels, moss, peat, vermiculite, or even sand, and then place the container is a very cold refrigerator for at least a month (the time period is species-specific). Ideally, the refrigerator should be kept between +1˚ to +3˚ C. The main problem encountered during stratification tends to be mould growth, so it is important to sterilize the moist medium (*e.g.*, vermiculite) in a hot oven (30 minutes at 100˚ C) before adding the seeds. The moisture level should also be monitored and kept constant.

Once seeds have been scarified or stratified, they have lost their protection against desiccation and will no longer store well, so they should be planted right away.

Methods and Timing for Sowing Locally-Collected Seeds

Many of the approaches to sowing locally-collected seeds are the same as those used for commercial seed. Both spring seeding and frost seeding methods can be used (see below). One difference is that the volume of locally-collected seed is usually so small that hand-seeding is common. Creative methods have been developed for spreading small quantities of seed, and more can be improvised as needed. For instance, salt and pepper shakers can be used to spread small-sized seeds (the planting rate can be controlled by taping over some holes). Small canisters can also be used for very small seeds by drilling appropriately sized holes in the lids and shaking out the seed. Larger seeds, such as those from legumes, can be broadcast by throwing handfuls at a time and keeping track of the density visually.

As with commercial seed, good seed-soil contact is critical for achieving high germination rates. When seeding small sites using spring-planting methods, this can be accomplished by raking seed into the ground with hand tools. On larger sites, a chain or tine harrow can be dragged over the site, just like when planting commercial seed. Many of the smaller harrows can even be pulled by hand. Sometimes, just thoroughly rolling the seedbed with a cultipacker or ATV tires is all that is necessary to work the seeds into the ground (frost-seeding obviates the need to rake and harrow).

Seeds of most Yukon grasses and forbs tend to mature in mid to late summer, so most seed collecting will occur from mid July through August. Generally, it is not advised to sow the seeds immediately after collecting them. For one, seeds do not mature synchronously (both among and between species), so there will likely be a need for multiple collecting bouts that correspond to different maturation times. In this case it will be more practical to spread seeds only after a large enough quantity has been collected.

However, the main reason not to sow the seeds right after collecting them in July or August is because it can lead to high winter mortality rates. If just left on the surface, without harrowing, few of the seeds will germinate, but harrowing the seed in July or August can signal the seeds to break their dormancy and initiate germination almost immediately, especially if the soil is moist. This is the right signal but at the wrong time, as it will be too late in the season for the plants to mature enough to survive winter. In northern systems, seeds have not evolved to germinate in the season they are shed from adult plants because they need an entire summer of growth to be equipped to survive winter (perennials) or develop seed (annuals) (see sidebar).

To avoid this unintended consequence, either store the seeds over winter and wait until the following spring to sow them, or follow procedures for frost seeding that were discussed under commercial seeding methods (Section 4.3.1). Frost seeding is the recommended approach when most of the mix contains legumes, because the freeze-thaw cycle of spring is the most effective way to expose them to a rigorous scarification/stratification, which they need to break their hard seed coats and initiate germination. Spring seeding is recommended for grasses and forbs that do not require hard scarification/stratification. If seeds are planted in spring but do not germinate that summer, there is a good chance some will germinate the following year, after experiencing a winter in the ground.

Further Information for Collecting and Sowing Local Seeds

There are a number of recommended resources with more detailed information about collecting, processing and storing seeds, and practitioners that undertake local seed collecting will want to consult them (see *References and Sources for Further Information*). One of the best is the *Native Plants Network*. Even though the *Network* is housed at the University of Idaho, it explicitly serves all of North America. It maintains a webpage (http://nativeplants.for.uidaho.edu/) with valuable and practical reference materials, including a database of detailed protocols for collecting, cleaning, storing and sowing seeds of many individual plant species. The *Native Plant Network* also publishes *Native Plants Journal* in which academics, professionals, and other enthusiasts publish short notes on techniques for seed collecting and propagation.

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FIG 4.28
Willow cuttings staked vertically through a jute-straw erosion control blanket.

4.6.2 Locally-Collected Woody Species: Cuttings, Transplants and Nursery Stock

This *Manual* has primarily emphasized revegetation methods that involve herbaceous plants, mostly grasses. Indeed, grasses are the workhorses of the revegetation industry, where the goal is often to establish ground cover quickly and cost-effectively. But there will be cases where the project goals go beyond expediency and low cost, or situations where woody species are the best solution.

One reason to plant woody species is to accelerate the process of natural succession in boreal zones (if that is a goal), because it can take ten years or more for woody species to become established on their own in Yukon. Another reason is visual. In some situations, woody species will be aesthetically more desirable, while in other situations woody species can be used as visual barriers to conceal unsightly features.

The most important application of woody species, however, is the staking of willow cuttings (poplar can also be used) to provide erosion protection on banks, dykes, levies, ditches and shores of water bodies (Fig. 4.28). Willow shrubs dissipate the energy of wave action and currents (erosion) better than herbaceous plants, plus they trap and retain sediments more effectively in flowing water. Willow is also the principle plant used in bioengineering projects where earthen retaining structures are reinforced with a fabric of live willow (see Bioengineering sidebar).

When prescribing woody species, revegetation planners should always specify the use of locally-sourced materials (*e.g.*, root stock, cuttings, seeds), not nursery stock produced from non-native propagules. The reason is because experience has shown that non-Yukon ecotypes of woody species do not grow well when planted in Yukon. Besides, it is usually less expensive to collect local materials and send them to an outside nursery for propagation than it is to buy off-the-shelf nursery stock.

Woody Species to Use for Revegetation

The two woody species most commonly chosen for revegetation work in Yukon are willow and poplar. The principle reason is that their woody stems have the ability to develop adventitious roots, which means that cuttings from adult plants that are staked into wet ground will develop roots and grow into a new plant (staking is explained below). Willow and poplar also spread rapidly and grow well in nutrient-poor soils.

When planting willow/poplar stakes, success rates are directly correlated to three key factors: 1) the presence of water (the site must be wet for much of the summer season), 2) adhering to proper techniques for cutting and staking, and 3) choosing the correct species because not all species will not grow from cuttings (see staking techniques below and sidebars). Staking projects in Yukon have had a poor track record, but in virtually all cases the failures can be attributed to neglecting one of those three key points. When performed properly, staking can be a highly successful and valuable technique in Yukon.

Two other woody species that have application in revegetation projects are alder and shrub birch. Alder is a nitrogen-fixer, so it grows well on very poor soils, but it should only be planted in moist sites and it does not tolerate alkaline conditions. For these reasons, it generally is not very successful in southern Yukon. Birch does not require as much soil moisture as alder, but it also grows best on acidic sites. In fact, birch has a tolerance to very low pH, which can be an asset. Even though birch does not require particularly nutrient-rich ground, it will not grow well on bare mineral soil. It is best to use birch only on sites where significant amounts of organic material have been spread, and on sites that are not too dry or alkaline. Birch will grow best in central and northern Yukon, but should not be excluded from consideration in southern Yukon.

Neither alder nor birch should be planted as straight cuttings (*i.e.*, they should not be staked). Instead, seeds must be collected and sent to a nursery for propagation. After about 6 – 12 months, seedlings will be returned for planting at the site. Birch and alder that are planted using this method usually have a high success rate because nurseries have developed good protocols to propagate these species. However, it is very important to harden-off the seedlings before they are planted. Hardening off is the process whereby young plants are slowly transitioned from warm, ideal greenhouse conditions (*e.g.*, controlled light regimes, no wind), which are optimized for rapid and healthy growth, to cold, windy and erratic conditions of an uncontrolled natural environment. This is accomplished by putting the plants outside in less-than-ideal conditions for increasing periods of time over the course of about two weeks. If greenhouse-reared seedlings are planted without hardening off in Yukon, survivorship rates can be very low.

Aspen is a woody species that grows extremely well and widespread in Yukon, especially on well-drained, non-acidic sites with poor to moderate soil development. In those regards, aspen is well-suited for use in revegetation work. However, aspen is rarely planted for a number of reasons. First, aspen seeds are very small and difficult to deal with after catkins are collected. They also loose viability rapidly when stored, often in as little as two weeks. Moreover, it is usually not worth the effort to actively collect aspen seeds because natural populations produce large numbers of seeds that are transported long distances by wind; so aspen seed likely will be landing on the revegetation site anyway. Regardless, aspen spread principally via rhizomes (cloning) and the best way to plant aspen is to propagate seedlings from root cuttings, which is fairly labour intensive and time consuming (see below). In the past, many practitioners would have argued that root propagation in a nursery was too much effort for a species that is generally regarded as low-value, but current thinking has changed considerably. For many projects today (*e.g.*, a mine reclamation), the establishment of aspen stands within a few years would be considered a very positive outcome, and further use of aspen is encouraged.

Planners are also encouraged to experiment with the propagation of other woody species in Yukon – it is a promising frontier in Yukon revegetation science.
Good candidates to consider for experimental propagation

Not all willows are the same

It is not uncommon to encounter a site where hundreds of willow cuttings have been carefully staked, only to find that 90-100% have failed to set root and died. Often, the cause can be traced to the wrong choice of willow species.

Yukon willows with a good propensity (>60% success) to develop adventitious roots include *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastata*, *S. arbusuloides*, *S. lucida*, and *S. pseudomyrsinites*. The two best species are *S. alaxensis* (felt-leaf willow) and *S. pulchra* (diamond-leaf willow); they are common in Yukon and should have a staking success rate of 80 – 90%.

Willow species to avoid are *S. glauca*, *S. barclayi*, *S. scouleriana*, *S. barrattiana*, *S. bebbiana*, *S. pseudomonticola*, and all prostrate or creeping species.

Identifying individual *Salix* species can be difficult, or even next to impossible at certain times of the year when flowers and leaves are absent. Here are two rules of thumb:

Species with a strong tendency to develop adventitious roots are those that grow in wet areas; so always avoid collecting willow stakes in dry upland areas. There is also a strong correlation between rooting ability and palatability to moose. Therefore, when in doubt, or when it is impossible to identify a willow to species, cut stakes from vigorous willow stands in wet areas that show signs of being browsed by moose. Alternatively, learn the key traits to identify stands of felt-leaf and diamond-leaf willow.

T. OMTZIGT

FIG 4.29
A properly prepared willow cutting, ready for staking. All twigs have been removed and the proximal (bottom) end has been cut at an acute angle.

and planting are: soapberry (*Shepherdia canadensis*) (a nitrogen-fixer), rose (*Rosa acicularis*), shrubby cinquefoil (*Potentilla fruticosa*), spiraea (*Spiraea beauverdiana*) and wolf willow/silverberry (*Elaeagnus commutata*) (a nitrogen fixer). Planners should consult the *Native Plant Network* for propagation and storage guidance for each species, and develop a relationship with a nursery to refine protocols.

Methods of Collection and Propagation for Woody Species

Woody species can be collected and propagated in three different ways:

- Cutting sticks from live (but dormant) plants and staking (planting) them on the site
- Collecting seeds, cuttings, or rootstock and propagating them into seedlings using a nursery
- Translocating live plants, usually *en masse*

Staking

Cuttings from the stems of many willow species and poplar have the ability to develop adventitious roots when planted in wet ground, and each successfully-rooted cutting will develop into a mature plant. Staking should only be done on sites that are very wet for most or all of the summer, and only certain species of willow should be used (see sidebar). Staking is a common technique used in stream and wetland restoration projects, but can be used on any moist site (see sidebar on bioengineering). The main application is on wet, steep banks where ground stabilization is required. Generally, it is not recommended for upland sites, except for wet draws and seeps.

It is important to collect the cuttings from donor plants when they are dormant, which will be in fall or early winter (avoid late winter harvesting). For willow, select large, robust donor plants growing in wet lowland areas. Do not collect from upland willow species (see sidebar). Cuttings can be made from young or old plants, but the particular branches they come from should be young wood, only 2 – 3 years old, and have visible leaf buds, which are an indicator of growth potential (the buds will not grow into roots). The cuttings should be moderately straight, 2 – 4 cm in diameter, 0.5 – 1.5 m long (though there really is no upper limit), and cut from healthy branches. All lateral twigs on the cuttings should be trimmed off at their base, and the proximal (down) end should be cut at an acute angle (Fig. 4.29). Some practitioners will seal the distal (up) cut end with latex paint or paraffin to prevent drying and cracking. The colour of the paint can also be used for denoting particular lots of cuttings and the "up" end when staking.

Because the cuttings will be harvested from plants that are dormant, it will necessarily be late in the season. If the ground is not yet frozen, it is best to plant the cuttings right away. If it will be more than a day before planting, store the cuttings in a bucket (proximal or future root side down) filled with water, or wrap them in wet burlap. If it is too late to plant in the current season, the cuttings can be stored overwinter and planted in spring. They should be stored cold so they remain dormant and to avoid rot and desiccation. The best method is to wrap them in burlap or plastic bags and store in a refrigerator set to around 0˚C.

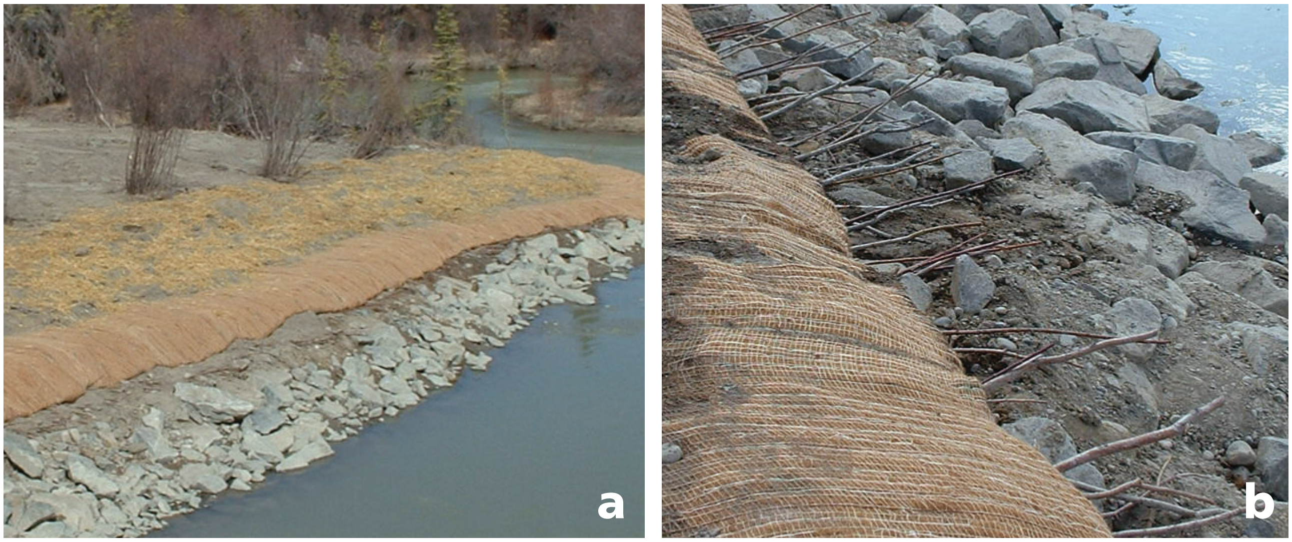

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FIG 4.30
A three-pronged approach to bank revegetation. A willow hedge was constructed closest to the water's edge using stakes and an erosion control blanket (closeup in b), followed by mulch and seeding above. The willow bushes above the mulch were translocated from a donor site just a short distance away.

A freezer set to the warmest setting can be acceptable, too. A low-tech storage method is to temporarily "stake" them in the snow on the shady side of a building, proximal side down, or put them in a bucket filled with snow and store them in an unheated outbuilding.

The conventional way to plant a cutting is to push ("stake") it vertically into the ground until half to two-thirds of the stick is underground, making sure it is planted with the proximal end down and the distal end up. To avoid damaging the cutting, it is common to use a piece of rebar or a "dibble" (a bar or pipe with a T-handle and a foot tang welded on) to make a hole first, and then stake the cutting in the hole (Fig. 4.33).

A less conventional, but equally successful, "staking" method is to plant cuttings horizontally, rather than vertically. With this method, a shallow (10 – 30 cm deep) trench or pit is dug, the cuttings are placed horizontally in the trench, and the trench is refilled with soil. No part of the cutting needs to be left projecting above the surface. New roots will form underground and new shoots will push up through the soil. Most shoots will form from buds that were on the cutting when it was buried.

The shape of the trench can be designed to influence the form and function of the growing stand. For instance, planting many horizontal sticks side-by-side and end-to-end in a wide trench will result in a thicker stand and more surface coverage than vertical staking. However, vertical staking often is the most efficient way to use a given number of sticks. The best approach can be to use a combination of vertical and horizontal planting (for more information, see Figs. 4.33 – 4.37 and sidebar discussing "bioengineering").

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FIG 4.31
Willow hedges and willow fascines being constructed for habitat enhancement and protection from erosion.

Nursery Propagation

Staking will only work for certain species of willow and poplar. For other woody species, it will be necessary to collect seeds, root stock or cuttings and have them propagated into seedlings in a nursery (see below). The use of nursery-generated seedlings for revegetation work in Yukon is still in the experimental phase. And, as emphasized in the previous section, the seedling industry has shifted away from the use of off-the-shelf nursery stock, to the use of seeds and cuttings that were collected locally.

Non-local ecotypes of woody species simply do not grow well in Yukon. However, it is perfectly acceptable to contract a greenhouse in Alberta or British Columbia, for instance, to perform the propagation work, as long as the material for propagation was collected near the future planting site in Yukon.

Contact the nursery well before the seedlings are needed because propagation will take at least four months and the nursery may need to schedule greenhouse space months ahead of time. The usual procedure is that seed stock and wood stock are collected in late summer or fall, and seedlings are ready for planting by spring of the following year. The nursery also may want to provide specific instructions for collecting source materials, but here are some general instructions and guidelines to be aware of:

Seeds: Methods for collecting seeds were discussed in the previous section. In theory, seeds can be collected from any species, though the best candidates for seed collection and propagation are birch, alder, poplar and aspen. Seeds are a good propagation material for these species because a few catkins will produce hundreds of seeds, and they are convenient to store and ship. (The propagation and planting of commercial species, such as spruce and pine, is considered to be a reforestation practice, which has different objectives than revegetation work.)

Cuttings: Rather than staking, cuttings from willow and poplar can be sent to a nursery for hormonally-stimulated root development. Not only will these stimulated cuttings have a higher survivorship than staked cuttings, but this approach allows for planting of willow species that do not readily form adventitious roots when staked. If cuttings are to be stored for the winter anyway, or it was not possible to identify the species of donor willow with certainty, then it may be a good strategy to simply send them to a nursery, where they can be stored in optimal conditions and returned with roots already started. This also takes away the unknown variable of over-wintering mortality during storage because only cuttings with roots will be returned from the nursery in spring; thus, only plants with a high chance of survival will be planted.

Root Cuttings: Some species, such as aspen, naturally propagate as clones – clusters of individual trees that emerge as adventitious shoots from lateral roots of the parent tree. Consequently, the best way to propagate such species is from root cuttings. An excellent reference for this method as applied to aspen is *Propagation Protocol for Aspen Using Root Cuttings* (Luna 2003), which is summarized as follows.

Root cuttings should be collected in early summer from young trees at the edge of an aspen cluster. Choose shallow lateral roots that are 1 – 15 cm from the surface, and 2 – 9 cm in diameter. Use a pruning shear to cut sections that are ~15 cm long, seal the ends with paraffin, and keep the cuttings slightly moist. The cuttings can be sent to a nursery or can be propagated by the collector.

If conducting the propagation oneself, place the cuttings horizontally in a moist bed made from a 50/50 mixture of sand and perlite. Adding a little bottom heat helps considerably to stimulate shoot growth. Shoots will emerge in two to three weeks and can be harvested with a razor blade when they are 2 – 3 cm tall. The ends are treated with common root-stimulating hormone (indole-3-butyric acid) and the shoots are placed back in a similar bedding material with bottom heat and kept at high humidity (often under a poly tent). Roots will start to grow from the shoots in two to three weeks. Once a large enough root mass has developed (a few weeks), plants should be hardened off for a two to three week period and then potted. The potted plants should be allowed at least 6 months to develop in a controlled environment, preferably a greenhouse. Realistically, the seedlings will be ready to plant in the spring after the roots were collected, essentially a year later.

Transplanting and Translocation

Direct transplanting is seldom used to achieve revegetation objectives, as it is relatively inefficient. However, there are a few exceptions and the method employed is best termed "translocation" rather than transplanting because it involves the coarse approach of moving whole sections of soil and vegetation *en masse*. Transplanting single trees or shrubs is essentially a landscaping technique, not a revegetation technique.

The usual method of translocation is rather crude, but effective: a large loader or excavator is used to scoop intact sections of soil and vegetation from a donor site and transport it to the revegetation site. It works best if the same piece of equipment is used to immediately place the material. This limits the distance considerably that material can be translocated. Transferring the mass to a truck and then using another piece of equipment to place it at the site usually just leads to the clump being broken up into a mass of organics.

Primarily, there are two situations where *en masse* translocation can be a useful tool in revegetation. One situation occurs when a very large (>50 ha) non-linear site is being revegetated with the goal of encouraging natural vegetation, such as during mine reclamation. On such large sites, the interior portions often are too far removed from native vegetation to receive naturally dispersed seeds of woody species. In that case, "islands" of translocated materials (whole sections of turf, plants and roots) can be strategically placed by a loader towards the centre of the site to provide native seed sources. The source of the translocated material can even be taken from the edge of the revegetation site.

The second situation where translocating can be a good strategy is when turf and woody plants are about to be destroyed anyway at another nearby site due to development activity (or further down the road in the case of road reconstruction). In these situations, it is advised to salvage as much organic material as possible from the second site and transport it to the first site. This method differs little from the general recommendation to spread organic materials on a revegetation site, except that it involves a deliberate attempt to leave as much vegetation intact and alive as possible.

As stated, translocation is not a mainstream technique in revegetation work, and in fact survivorship rates of translocated mature plants are often quite low. It works best for woody herbaceous plants and shrubs such as rose, cinquefoil, soapberry, pumpkin berry, cranberry, blueberry, willow and shrubby birch. The smaller the shrubs and the larger the clumps, the better chance they have of surviving, and herbaceous species tend to survive better than shrubs. So perhaps the best approach is to think of translocating as a means of strategically placing organic material that still has living plants and contains a high percentage of a targeted species. It also is the only effective way to introduce certain plants, such as shrubby *Ericaceae* (heath) species.

Bioengineering through willow staking

Bioengineering is a term used to describe methods of slope and bank stabilization that incorporate live willow stakes as structural elements in retaining walls, streambanks, terraces and similar earth works, though woody species other than willow can be used as well. As a bound network of wooden structural components, the willows provide a fabric that anchors the ground and entraps new sediments, which in turn provides stabile ground for other vegetation to grow. Because live willow stakes are used, the structure's effectiveness increases as the willows set adventitious roots and grow.

The main application of bioengineering methods is in wetland restoration and management, and stabilizing steep slopes. Entire manuals have been written on the subject, and some are recommended below. While a thorough discourse on the subject of bioengineering is beyond the scope of this *Manual*, the principles are being applied more commonly in Yukon revegetation projects – for instance, along roadsides where the right-of-way intersects a drainage, or along berms at reclaimed mine sites.

Bioengineering is really just the creative use of willow staking in three dimensions, and in conjunction with ground contouring; all of the principles of selecting and preparing stakes are the same as those described previously in this Chapter. The key to success will be choosing the right species of willow (see main text and previous sidebar) and only attempting these techniques on sites that are wet for most of the summer. Here are a few examples:

Vertical Staking (Fig. 4.32 – Fig. 4.33) can be done in a number of ways. Stakes can be distributed in a broad pattern over flat or sloping ground. On sloped ground, a biodegradable erosion control material, such as jute mesh, is often installed first and then stakes are pushed through the mesh. On gravel bars and shores of rivers, staking can be used to form a catchment for finer sediments, which will raise the elevation of the bar/shore and promote revegetation by herbaceous species. In this case, stakes should be planted somewhat diagonally, pointed up stream.

Horizontal Staking can be just as effective as vertical staking, or more effective if the goal is to obtain a very thick cover of willow. A shallow (10 – 30 cm) pit or trench is dug, cuttings are lain horizontally in the bottom, and then completely buried. The shape of the pit and density of cuttings can be manipulated to affect the eventual growth pattern. It is also common to use a combination of horizontal and vertical staking.

Fascines (Fig. 4.34) are bundles of cuttings that are tied together with sisal twine to create a plantable structure that resembles a long, flexible log. Typically, fascines are 10 – 30 cm in diameter and anywhere from one to ten meters long. They are deployed horizontally in long, shallow trenches dug into slopes and banks parallel to the contour. Fascines can be used to create small-scale terraces when installed in a parallel, step-like manner up a slope. They are simple to construct and can be quite effective, but a very large number of cuttings are required to construct each fascine. When making fascines, willow branches are cut longer than they would be when used for simple staking – often they are a meter or longer.

Brush (Hedge) Layering (Fig. 4.35) is a method of building a stratified bank or retaining wall along streambanks or wet slopes by alternating subhorizontal layers of willow stakes with layers of dirt fill wrapped in jute cloth. The stakes are buried with just the distal

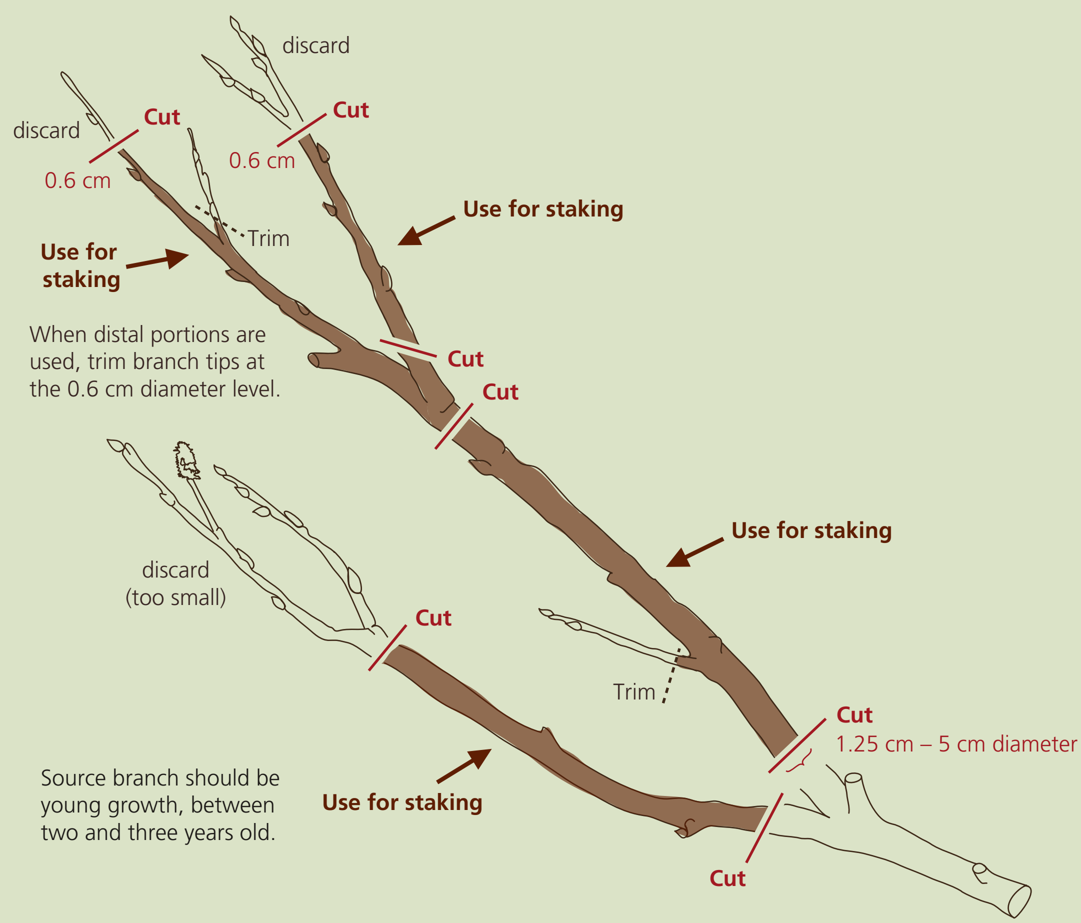
10 – 20 % of the tip projecting out from the bank, from which new shoots will form. Adventitious roots that grow from the buried section will form a network that holds the dirt in place.

Pole Drains (Fig. 4.36) are shallow trenches or mini-terraces in which horizontal stakes or fascines are buried to create a drainage network on slopes. The goal of the layout is to catch runoff water (sheet wash) in the willow-filled trenches and direct it offsite to reduce erosion. The configuration often consists of a series of parallel trenches running cross-slope but trending downhill. These trenches sometimes feed into a larger central trench that runs more directly downhill. Even just burying horizontal cuttings or fascines in any newly built channel or ditch that must run down a steep slope will help stabilize the channel. As with all bioengineering structures, the effectiveness of the system will increase as the willows grow.

Wattle Fences (Fig. 4.37) are short retaining walls built by driving vertical willow stakes into the ground to form a picket line and binding them together by weaving horizontal cuttings between the vertical stakes. Like fascines, they are constructed parallel to the slope and are often constructed in a series of small terraces.

Gulley Breaks are a type of wattle fencing constructed cross-channel in gullies that are susceptible to occasional torrential flow events. They function like straw bale check dams to reduce water velocity and minimize erosion in ditches. It does not require a large volume of cuttings to erect gully breaks, meaning they can be built quickly and efficiently when stands of the appropriate willow are growing nearby. This can be important in remote sites where straw bales would be expensive to transport, or in parks where straw bales and geotextile cloth (often used in the construction of check dams) may not be desirable.

Preparing dormant cuttings



ADAPTED FROM *STREAMBANK REVEGETATION AND PROTECTION: A GUIDE FOR ALASKA.* ALASKA DEPARTMENT OF FISH AND GAME

FIG 4.32

Live staking

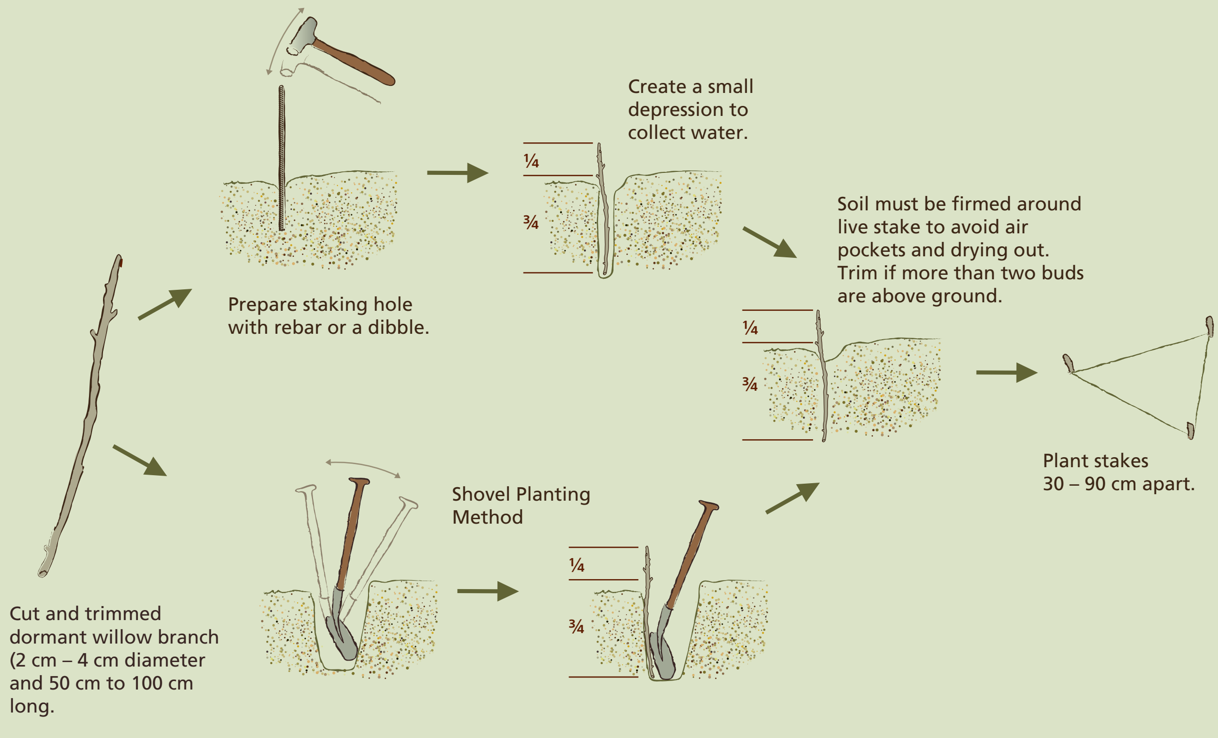


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FIG 4.33

Fascines

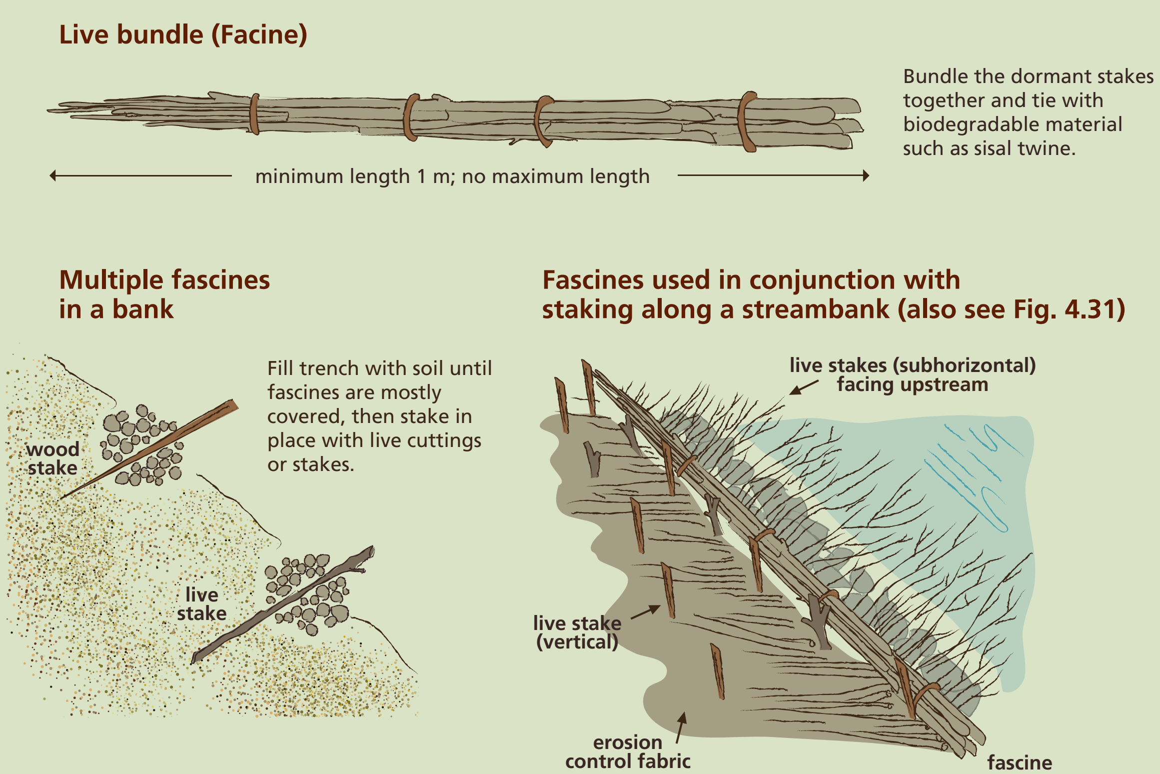

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FIG 4.34

Brush/hedge layering along a streambank

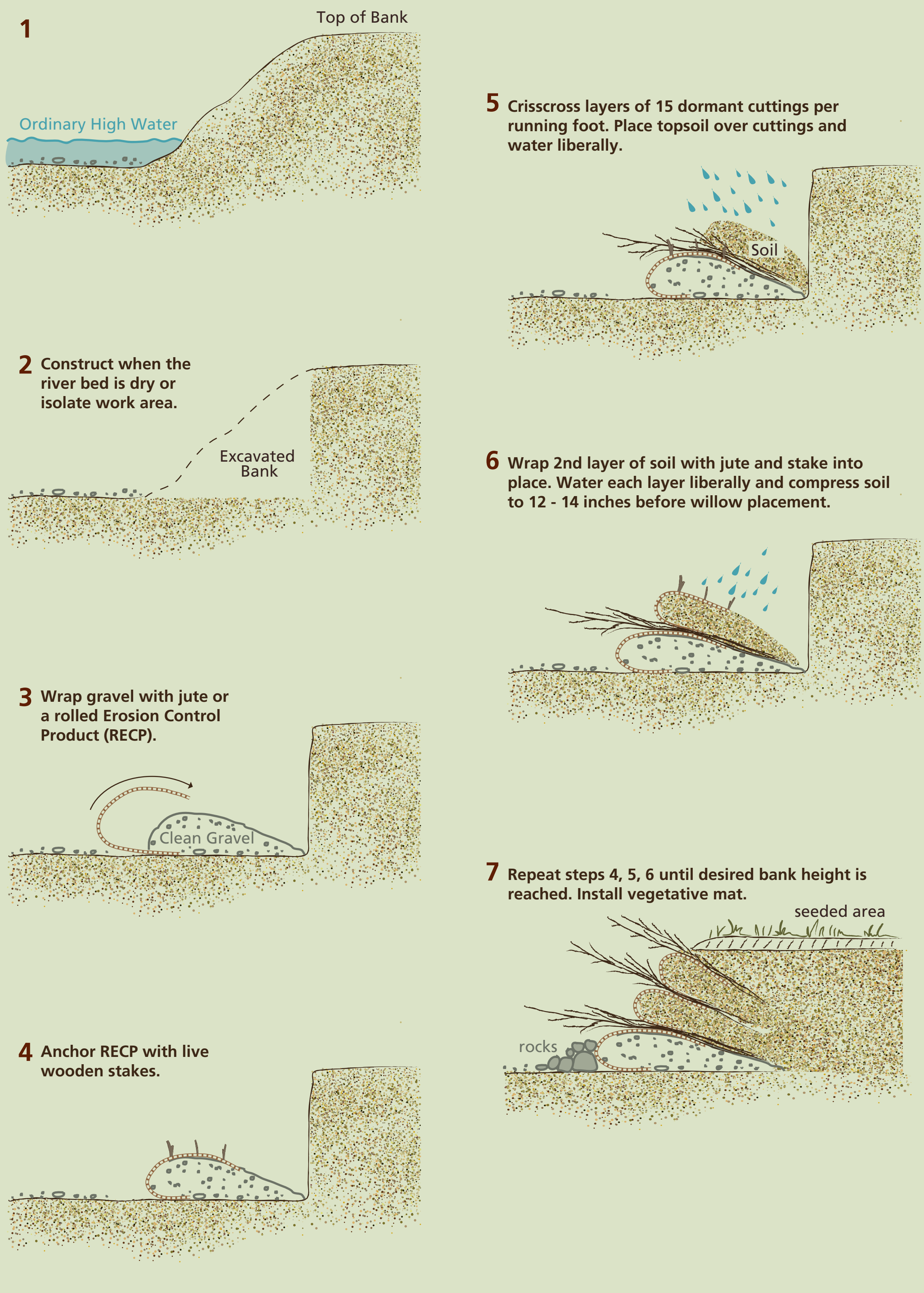

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FIG 4.35

Pole Drains

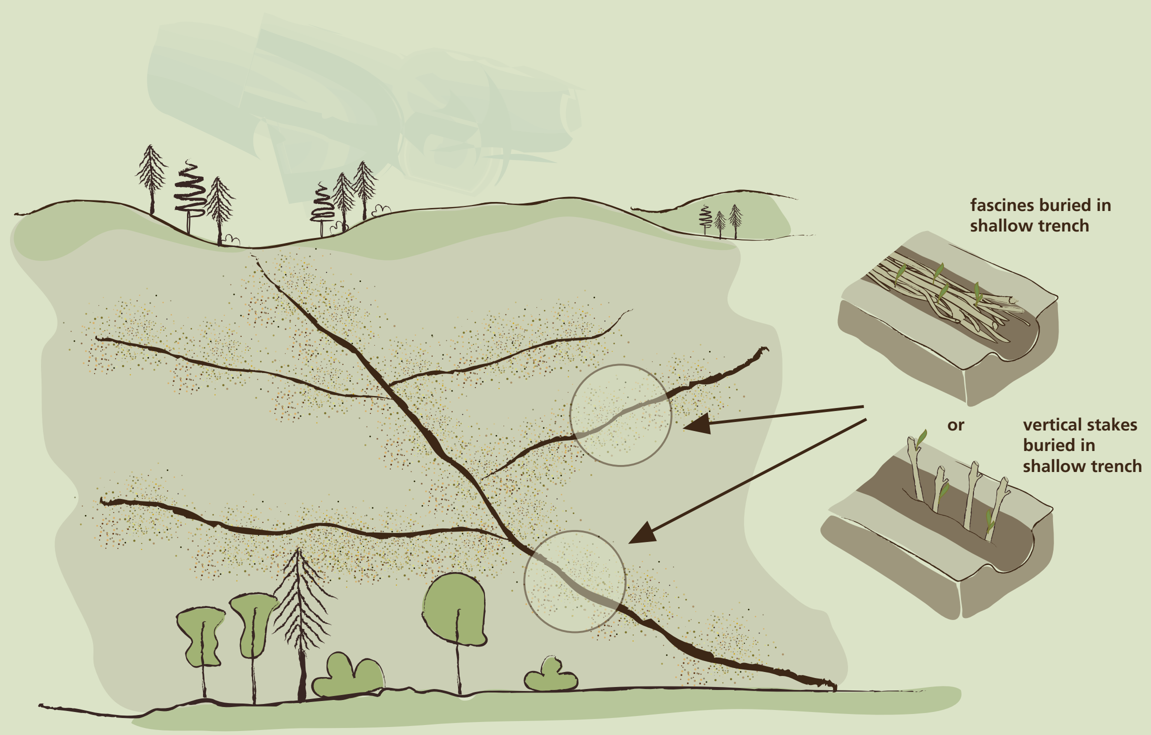

FIG 4.36

Wattle Fences

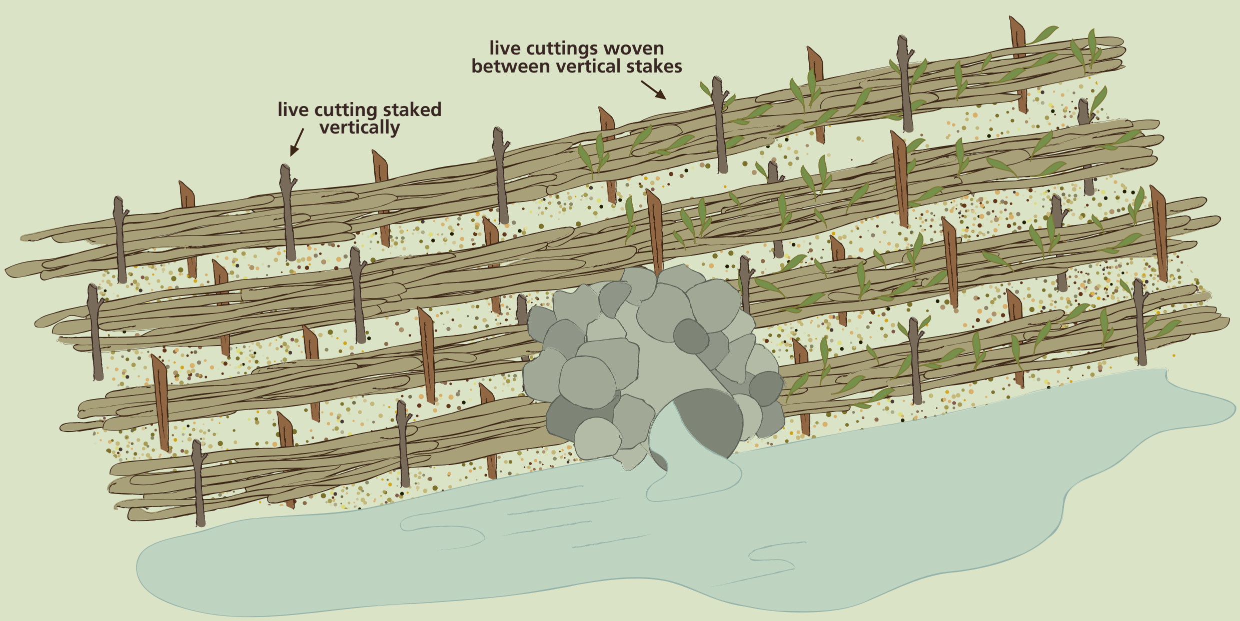

FIG 4.37

5 Revegetation Scenarios and Recommended Species for Yukon

The first four chapters of this *Manual* reviewed important principles and practices that are fundamental to planning and implementing revegetation work in Yukon. They emphasized the need for planners to assess each site individually, properly prepare the ground, and choose the right species for planting. This chapter applies those principles and practices to seven revegetation scenarios that encapsulate the most typical and the most challenging situations that planners are likely to encounter in this vast territory. The revegetation species currently recommended for use in Yukon are presented in the context of these scenarios.

5.1 The Scenarios

The seven scenarios examined in this chapter were designed to cover the most common site conditions that revegetation planners will encounter, but also some of the more challenging ones. They are defined by either a dominant site feature or their geographic location:

- Low Slope, Low to Mid Elevation Sites
- Steep Slopes
- Wet Sites
- Highway Rights-of-Way
- Disturbed Lowland Permafrost Sites
- Arctic Tundra and Northern Yukon Sites
- Alpine and Subalpine Sites

Each scenario discusses the challenges likely to be encountered and how to deal with them through proper ground preparation and by selecting the appropriate species for planting. Because real-world project may not correspond exactly to one of these scenarios, readers should review multiple scenarios when developing a plan for their site.

5.2 Recommended Species

This chapter also uses the seven scenarios to present the species currently recommended for revegetation work in Yukon. Species that are appropriate for the conditions are presented in tables at the end of each scenario. They are also summarized at the end of the chapter.

Species that were formerly recommended in *Guidelines for Reclamation/Revegetation in the Yukon* have been eliminated if trials or experience have shown them to be ineffective, unavailable or invasive. But new species have also been added to the list, and locally-collected species that are particularly effective are suggested in separate tables. In total, 23 commercial species are recommended for use in seed mixes (12 native, 11 non-native), along with a multitude of locally-collected species. Chapter 6 summarizes the adaptive traits (strengths and weaknesses) of the 23 commercial species to assist planners in developing custom mixes.

Chapter 4 discussed the questions that planners must ask when deciding whether to plant only native species or whether it is acceptable to include non-native species in the seed mix. When the decision is based on the potential genetic impact to local plant populations, planners essentially have four options:

Option 1: Plant only native commercial species listed in the tables and only purchase seed that was cultivated in or adjacent to Yukon (Alaska, Alberta). This is the standard practice in the revegetation industry, and it will have the best probability of successfully establishing plant cover consisting of nominally native species. However, planners should be aware that this practice does have the potential to introduce non-native genetic material (through hybridization with local populations) because the cultivated seeds will have new genotypes as a result of generations of propagation outside Yukon. Furthermore, in most cases the original seedstock for these cultivars was not collected in Yukon (there are exceptions – *e.g.*, violet wheatgrass).

Option 2: Plant non-native commercial species from the tables, with the intent that these plants will be replaced by local vegetation through natural succession. This can be a highly successful strategy, especially if the non-native species are seeded in combination with native species to function as nurse plants.

Option 3: Plant only seeds and cuttings of plants that have been collected locally. This strategy is the only way to be absolutely certain that no non-native species or genetics are introduced, and it can produce higher initial stand diversity. However, it is very labour intensive and requires advance planning because of the need to collect and prepare seeds or propagate plants in nurseries. This option can also be impractical for large sites.

Option 4: Design a species mix that incorporates aspects of all three options above, in order to mitigate the negative aspects of each one.

In each of the seven scenarios presented in this chapter, the species recommended for planting are listed in four separate tables in order to be the most useful to planners as they implement one of the four options above. These tables are:

- **Native Herbaceous Species from Commercial Seed** Seeds of species that are native to Yukon and grow well in the scenario conditions, but which are cultivated outside the territory.
- **Non-Native Herbaceous Species from Commercial Seed** Seeds of non-native species known to grow well in the scenario conditions; also chosen because they are non-invasive.
- **Locally-Collected Herbaceous Species** Native species that usually grow in the scenario area and for which it is practical to collect seeds. It is important to note that the species in these tables are suggestions only, and should be used as starting points for seed collecting. The tables include species that are prolific seed producers and can contribute substantively to ground cover, but seeds of any local species can be collected and planted.
- **Locally-Collected Woody Species** Local shrubby species that can be staked or grown into seedlings from cuttings or seeds.

The tables list a range of species to choose from, rather than prescribing a specific mix, because species should be selected based on their individual suitability for the actual site conditions (*e.g.*, acidic versus alkaline soils). To assist in the selection, specific tolerances and adaptations of each species are listed in the tables. Planners should also consult the species descriptions in Chapter 6. When a specific cultivar of a species is recommended, it is because that cultivar is known to do well in the North, and its seeds are commercially available. Use caution when considering cultivars that are not listed, as many cultivars were intentionally excluded from the lists because they grow poorly in Yukon.

Planners are also reminded that the target seeding rates (seed densities) in the tables are for 100% PLS (Pure Live Seed). Refer to the percent PLS provided by the seed supplier and adjust the rate using the information provided in Section 4.2.3.

How to calculate a seed mix application rate

1. Determine the area that will be seeded in m^2 (1 ha = 10,000m^2), because even though actual seed application rates will be calculated in kg/ha, recommended seed densities are prescribed in seeds/m^2.
2. Decide on the species to be planted using recommendations from Chapters 5 and 6.
3. Check seed availability with a seed supplier and obtain values for percent pure seed and percent viable seed for each species and each lot of seeds (values vary between lots).
4. Determine the desired density for each species (seeds/m^2) to suite the site conditions and project goals. If the total density for the seed mix will be 1500 PLS/ m^2, then each species will probably range from 150 to 600 PLS/m^2 (10% – 30%). The species-specific densities will be tailored to address site conditions, but also may take into account factors such as seed cost and availability.
5. Note the number of seeds per kilogram for each species, which is listed in Chapters 5 and 6. This information will be required to calculate the total weight of seed to apply.
6. Next, calculate the application rate for the each species using the following formula (note that this calculation will have to be made for each species in the mix):

$$\textbf{Amount (kg) of seed (per species)} = \frac{\text{area to be seeded (m}^2\text{) x desired seed density (PLS/m}^2\text{)}}{\text{\# of seeds/kg x percent seed purity x percent seed viability}}$$

Revegetation Scenarios and Seed Recommendation 5

Scenario 1 **Low Slope, Low to Mid Elevation Sites**

This scenario addresses relatively uncomplicated sites that are essentially flat, or have few slope issues, and are at low to mid elevation. They include sites such as gravel pits, abandoned roadways, and mine exploration sites.

Often, these sites will revegetate naturally and erosion will not be a major concern. However, management objectives often dictate that vegetation be re-established quickly or managed for a certain preferred vegetation type. When these sites occur near highways and settled areas, management to prevent the spread of invasive species should be a high priority. The visual appeal of the revegetation species selected for planting can be important if the site is in the public eye.

It is often feasible to stockpile organic materials on these sites during development. Thus, with proper planning, good organics can be reapplied to these sites, which will reduce the amount of seed and fertilizer required and improve the end results.

These uncomplicated sites are also conducive to using simple, low-cost methods for site preparation and seed application (*i.e.*, fewer requirements for specialized equipment). For example, tractors, ATVs and basic farm implements will often suffice.

Thorough soil preparation, application of organics and fertilizing will be key to successfully revegetating these sites. High seeding densities and thorough ground coverage will be important if invasive species are a concern; otherwise, seeding densities can be light because erosion will not be much of a concern and planners can often rely on a large amount of natural revegetation to occur. In fact, in some cases the main revegetation objective will be to simply increase the organic content of the soil and sow a minimum amount of seed in order to stabilize the site and facilitate natural revegetation.

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FIG 5.1
Flat, low-elevation sites are not without their challenges. This decommissioned gravel pit has almost no organics and will require an application of fertilizer to establish significant plant growth. On small sites, it can be worth the effort to transport organic fill to the site. These sites often have had heavy equipment traffic as well, which will necessitate thorough decompaction.

Site Preparation

- There should be minimal need for contouring or track-walking these sites.
- Inspect the site for areas where water will pool due to depressions or lack of percolation. Create ditches or other drainage structures as necessary, and fill-in low spots, but avoid compaction of the surface during these activities.
- In many cases, these sites will have experienced significant equipment traffic and it will be necessary to decompact the upper 30 – 40 cm of ground using toothed rippers (subsoilers) or other techniques (*e.g.*, ploughs or disk harrows) described in Chapter 3. Decompaction can be extremely important on these sites.
- If necessary, use disk harrows, tine harrows or hand tools to break up dirt clumps and even-out surface undulations that remain after decompaction.

Fertilizer and Organics

- Frequently these are development sites, and with prior planning it will be possible to stockpile and re-apply organic materials. If organic materials are only available in limited supply, then erosion-prone areas, clay-rich areas (*e.g.*, those easily crusted over), and slopes have the highest priority for application of organics. A second pass with a harrow may be necessary to spread and incorporate the organic materials into the mineral soil.
- Use the results of soil testing and guidelines in Chapter 3 to determine nutrient deficiencies and fertilizer needs for the soil. Fertilization will be critical on sites with bare mineral soil and no organics.
- On these sites, it should be relatively easy to operate equipment, so use a disk or tine harrow to work fertilizer into the top 5 - 15 cm of the surface.

Planting and Seed Mixes

- Low slope, low to mid elevation sites will be relatively forgiving in regards to seeding. Erosion protection and seed loss due to runoff should not be a major concern.
- Use an application rate of 1,500 seeds/m^2 on bare mineral soil or 750 seeds/m^2 when significant soil organics were applied or soils are still in place. If seeding with the intent to deter invasive species, ensure that seeding is even and no bare patches are left.
- Species diversity should be gauged to meet site objectives (see Chapters 2 and 4). These sites offer a good opportunity to plant a high diversity of species and to experiment with species, unless there are other limiting factors such as high salinity or permafrost.
- On larger sites, consider using a seed drill and the largest tractor/harrow available to increase work efficiency and minimize soil compaction. Seed quantities can be reduced to 750 seeds/m^2 when using a drill. On these sites, it may also be feasible to pull a seeder and harrow simultaneously. Seeding with a broadcast (cyclone) seeder is acceptable as well.
- For small areas, it may be most cost-effective to prepare the site and apply seed/fertilizer using hand tools or small implements drawn by an ATV.

Low Slope, Low to Mid Elevation Sites

Table 5.1

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m^2 on bare mineral soil **OR** 750 seeds/m^2 if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Rocky Mountain fescue *Festuca saximontana* (common)	**1,430,000**	Tolerant to dry alkaline soils, low nutrients and permafrost. Bunchgrass with rapid emergence in early spring. Do not use on wet or acidic sites.
Violet wheatgrass *Elymus alaskanus* (common)	**330,000**	Tolerant to alkaline soils, drought and low nutrients; also has considerable tolerance to permafrost and moderate tolerance to saline soils. Bunch forming with strong competitive ability.
Glaucous bluegrass *Poa glauca* (Tundra or common)	**2,904,000**	Tolerant to broad range of pH, drought, low nutrients and permafrost. Forms low growing bunches with a high root-shoot ratio, spreads aggressively through rhizomes, rapid emergence in early spring.
Slender wheatgrass *Elymus trachycaulus* (Revenue, Adanac, Highlander or common)	**349,800**	Tolerant to broad range of pH, dry ground and low nutrients. High tolerance to saline soil. Performs poorly on permafrost. Forms loose bunches and is short-lived, but exhibits rapid emergence.
Ticklegrass *Agrostis scabra* (common)	**11,000,000**	Tolerant to acidic soils, drought and low nutrients, and permafrost. Short-lived bunchgrass with early emergence. A common pioneering plant on dry flat ground.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	**3,300,000**	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost and wetness. Bunch forming, strong competitive ability and can form extensive cover. Not drought tolerant.
Fowl bluegrass *Poa palustris* (common)	**4,840,000**	Tolerant to acidic soils, low nutrients and wetness. Loosely tufted bunchgrass, rapid emergence, early spring growth, but shallow-rooted, generally short-lived and not aggressive. Not drought tolerant.
Bluejoint reedgrass *Calamagrostis Canadensis* (Sourdough or common)	**8,442,438**	Tolerant to slightly acidic soils, low nutrients, permafrost and wetness. Tall bunch grass with aggressive rhizomatous growth and extensive cover production. Early spring and late summer growth. Not drought tolerant. Limit to no more than 20% of seed mix.

Low Slope, Low to Mid Elevation Sites

Table 5.2

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m^2 on bare mineral soil **OR** 750 seeds/m^2 if organics in place

SPECIES (cultivar)	**# OF DS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	**539,407**	Tolerant to wide range of pH and permafrost. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Red top *Agrostis gigantea* (common)	**10,672,640**	Tolerant to acidic soils and wet or dry conditions. Medium stature rhizomatous bunchgrass, mildly aggressive. Forms good cover but only on low slopes/low elevation.
Canada bluegrass *Poa compressa* (Reubens, common)	**5,264,204**	Tolerant to alkaline soils, low nutrients, moderate drought. Medium height bunchgrass, rhizomatous, can form extensive cover but is slow growing.
Sheep fescue *Festuca ovina* (common)	**1,100,000**	Tolerant to neutral or slightly acidic soils, drought, and low nutrients. Needs well-drained granular soil. Forms short bunches, slow growing, aggressive rhizomes.

Low Slope, Low to Mid Elevation Sites

Table 5.3

LOCALLY-COLLECTED WOODY SPECIES

SPECIES	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Willow *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	Use only in wet locations and use only the species listed. Willow is the main plant used for staking of live/dormant cuttings and for bioengineered structures.
Poplar *Populus balsamifera*	Use only in wet/moist locations; easily established through staking of live/dormant cuttings.
Shrub birch *Betula glandulosa*	Use only plant seedlings grown in a nursery from locally-collected seed. Tolerant to acid soils. Use on moist sites with good organic content.
Alder *Alnus crispa* *Alnus tenuifolia*	Plant only seedlings grown in a nursery from locally-collected seed. Tolerant to slightly acidic soils and low nutrients. Use on moist/wet sites that are not alkaline.

Low Slope, Low to Mid Elevation Sites

Table 5.4

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m² on bare mineral soil **OR** 750 seeds/m² if organics are in place

SPECIES	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
any of the species listed in Table 5.1 can be collected and seeded, plus the following		
Northern rough fescue *Festuca altaica*	451,854	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Yukon wheatgrass *Elymus calderi*	—	Tolerant to alkaline soils, drought and low nutrients. Medium size rhizomatous grass, strong competitive ability, but low seed yield. Grows in granular soils and sand dunes at low elevations.
Macrourum's wheatgrass *Elymus macrourus*	374,782	Tolerant to drought, periodic wetness, low nutrients. Medium size bunchgrass, weakly rhizomatous, low seed yield. Most common in gravely/sandy areas along lakeshores, riverbanks and open slopes.
Northern brome *Bromus pumpellianus*	202,400	Tolerant to low nutrients, drought. Medium to tall grass, weakly tufted, stoloniferous. Grows in meadows, dry slopes at all elevations.
Sweetgrass *Hierochloë hirta* (formerly *H. odorata*)	242,000	Tolerant to drought and low nutrients. Short, fine grass with creeping rhizomes and strong competitive ability but poor seed yield. Grows in sandy meadows, streambanks, open forests at low elevation.
Nuttall's alkaligrass *Puccinellia nuttalliana*	4,648,140	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2 – 4 years). Mostly restricted to dry alkaline and saline areas.
Yellow locoweed *Oxytropis campestris*	521,400	Tolerant to drought and low nutrients. Low growing bunches. A nitrogen-fixing forb that provides a colourful flowering bloom. Found in dry, granular disturbed areas.
Showy locoweed *Oxytropis splendens*	1,548,800	Tolerant to drought and low nutrients. Low growing bunches. A nitrogen-fixing forb that provides a colourful flowering bloom. Found in dry, sandy disturbed areas.
Bear root *Hedysarum alpinum*	154,000	Tolerant to alkaline soils, drought and low nutrients. A nitrogen-fixing forb that provides a colourful flowering bloom. Grows in a variety of alkaline sediments in disturbed areas at low to high elevation, ranging from roadsides and riverbanks to open forest.
Mackenzie's hedysarum *Hedysarum Mackenzii*	101,889	Tolerant to alkaline soils, drought and low nutrients. A nitrogen-fixing forb that provides a colourful flowering bloom. Grows in a variety of alkaline sediments in disturbed areas at low to mid elevation, ranging from roadsides and riverbanks to open forest.
Arctic lupine *Lupinus arcticus*	22,733	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.
Yarrow *Achillea millefolium* and *Achillea sibirica*	6,274,426	Tolerant to alkaline soils, drought, low nutrients. A slender, colonizing forb with white flower heads that bloom late in summer. Mostly found in areas with well-drained but poorly developed soil. Produces tiny seeds in abundance.
Mountain avens *Dryas* spp.	—	Tolerant to alkaline soils, drought, low nutrients. Matt-forming, low stature forb that grows in very poor soils and calciferous disturbed areas at all elevations, including scree slopes and gravel.
Wormwood/sage *Artemisia* spp.	—	Tolerant to drought, low nutrients. Medium stature forb or short shrub. Wormwood species grow in a diversity of open/disturbed areas from riverbanks and grasslands to steep slopes and alpine/Arctic tundra. Mostly adapted to dry soils.

Scenario 2 **Steep Slopes**

Steep slopes are routinely encountered in Yukon projects, and can be quite challenging to revegetate. The main goal will usually be to stabilize the slope and inhibit erosion, yet erosion is the main reason these sites are so difficult to revegetate. Moreover, soils tend to be poorly developed on steep slopes, and they are usually very dry. All of these factors work against seed germination and plant growth. In southern Yukon, north-facing slopes are slightly less dry, and thus easier to revegetate. In central and northern Yukon, the coolness of north-facing slopes can impede germination and the warmth of south-facing sites can be an asset.

Mulching will help to stabilize slopes and retain seed, but mulch can actually deprive seeds of moisture on very dry slopes (it causes moisture to sheet off the slope, rather than get absorbed). Hydroseeding is often the only option because the mulch and seed are applied as one treatment, but hydroseeding must be used with caution on extremely dry slope where the slurry tends to crust-over. On large sites, where mulching and hydroseeding may be cost-prohibitive or unavailable, track-walking is an effective way to provide microsites for vegetation to grow, though there are grade limitations (see Chapter 3).

On slopes over 40% grade, establishing vegetation from seed will be difficult unless additional erosion control measures are implemented. These are discussed in Chapter 3 and include techniques such as stairstepping (terracing), bioengineering and the application of rolled erosion control products (RECPs).

Including one or two species of annual grasses in the seed mix is often effective at providing quick surface stabilization and organic material for subsequent plant growth. In cases where other species are not expected to take hold, alfalfa can be seeded as a last resort. Because steep slopes will frequently be water-limited, it is generally necessary to choose species that are adapted to dry conditions.

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FIG 5.2
Steep slopes in Yukon are often dry and lack significant organic material. Usually, erosion control is the primary objective, making it important to establish good plant cover quickly.

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FIG 5.3
Hydroseeding can be an effective option on steep slopes.

Site Preparation

- Site preparation and contouring strategies are very important on these sites to minimize erosion potential. Contour the surface in a way that avoids sharp cut banks, or terrace the slope. When terracing, minimize the area of each step rise by constructing as many terrace steps as possible.
- Tracked equipment should operate up and down the slope, not parallel to the slope contour. This way, the imprints from cleats left by the tracks create micro benches across slope (prevents erosion), rather than rills up and down the slope (promotes erosion).
- Soil decompaction often is less critical on slopes because they usually have not been exposed to traffic. Use a dozer with ripper teeth (subsoiler) if necessary, but track-walk the ground afterwards to reduce furrow size. If no decompaction is required (most cases), the slope should still be track-walked or roughened with an excavator bucket to create microsites for germination.
- Agricultural tractors are top-heavy and can be unsafe to operate on slopes. ATVs are safer, but even they can only be operated safely on moderate slopes. Consequently, ground work (tillage and harrowing) can be difficult, and even dangerous. Harrows can be pulled by tracked vehicles but track-walking alone may have to suffice as the only surface preparation.
- When the slope is too steep to harrow even with tracked vehicles, the surface should be scarified with an excavator bucket. But do not compact or glaze the surface with the bucket.
- Steep, erosion-prone slopes may require the installation of RECPs. Loose mulches should be used with caution on steep slopes because they often wash off and cause problems where they accumulate. The advantage of the RECPs is that they can be staked in position. Seed and fertilizer must be applied prior to the installation of RECPs.

Fertilizer and Organics

- Applying organic materials to slopes can greatly improve resistance to water erosion and it promotes plant germination. However, if organics are simply spread over the surface and not incorporated into the soil, they tend to wash downslope. Therefore, if the slope cannot be harrowed, apply organic materials prior to track-walking or bucket-scarifying.
- Use the results of soil testing and guidelines in Chapter 3 to determine nutrient deficiencies and fertilizer needs. Steep slopes in Yukon tend to have poor soil development and few organics. Consequently, a dose of fertilizer can be important to establish an effective ground cover in the first year.
- Fertilizer pellets will quickly erode off the slope if they are not incorporated into the soil. Therefore, as with the application of organic material, consider spreading fertilizer before track-walking if harrowing is not possible.
- If hydroseeding, the fertilizer will be applied as part of the seed-mulch slurry.

Planting and Seed Mixes

- Steep slopes suffer from significant seed loss due to runoff and from low germination rates. Therefore, the recommended seeding rate is 2,250 – 3,000 seeds/m^2; as with other sites, that rate can be cut in half if substantial organic materials in place.
- Maximizing species diversity is often less important than choosing 2 – 3 tenacious species that will take-hold on steep slopes.
- The grasses recommended in the seeding tables are mostly rhizomatous species because they tend to provide more extensive ground cover. The bunchgrasses in the tables are recommended for their drought-tolerance because slopes tend to be dry. A few species that grow well on wet sites are listed for application on steep banks along waterbodies and ditches.
- To establish rapid site cover, it can be very effective to add a fast growing annual grass to the seed mix. Annuals also function as nurse plants for perennials in the mix (perennials will confer long-term stabilization). However, annual grasses should not constitute more than 10% of the seed mix, to avoid choking-out perennials and native colonizers.
- If locally-collected seeds are sowed, an annual grass should still be considered for inclusion in the mix (up to 10%). It will confer the same benefits as when added to a commercial seed mix.
- In most cases, it is not practical to plant woody species on steep slopes because they are too dry. The exception is wet banks along watercourses and ditches. See Scenario 3 for additional guidance in these situations.
- Applying and covering seeds on steep slopes can be a challenge because it is often too dangerous to operate equipment. Hydroseeding can be the only practical option on large sites, but sometimes hand seeding and raking will be just as cost-effective.
- When hydroseeding, the recommended seeding rate is still 2,250 – 3,000 seeds/m^2 to account for seed damage and reduced germination rates that are the norm with hydroseeding.

Steep Slopes

Table 5.5

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 2,250 to 3,000 seeds/m² on bare mineral soil and/or hydroseeded slopes
OR 1500 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Rocky Mountain fescue *Festuca saximontana* (common)	**1,430,000**	Tolerant to dry alkaline soils, low nutrients, permafrost and high elevations. Bunch grass with rapid emergence in early spring. Do not use on wet or acidic sites.
Violet wheatgrass *Elymus alaskanus* (common)	**330,000**	Tolerant to alkaline soils, drought and low nutrients; also has considerable tolerance to permafrost and moderate tolerance to saline soils and high elevations. Bunch forming with strong competitive ability.
Glaucous bluegrass *Poa glauca* (Tundra or common)	**2,904,000**	Tolerant to broad range of pH, drought, low nutrients, permafrost and high elevations. Forms low growing bunches with a high root-shoot ratio, spreads aggressively through rhizomes, rapid emergence in early spring.
Slender wheatgrass *Elymus trachycaulus* (Revenue, Adanac, Highlander or common)	**349,800**	Tolerant to broad range of pH, dry ground and low nutrients. High tolerance to saline soil. Performs poorly on permafrost and high elevations sites. Forms loose bunches and is short-lived, but exhibits rapid emergence.

Steep Slopes

Table 5.6

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 2,250 to 3,000 seeds/m² on bare mineral soil and/or hydroseeded slopes
OR 1500 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Canada bluegrass *Poa compressa* (Reubens, common)	**5,264,204**	Tolerant to alkaline soils, low nutrients, moderate drought. Medium height bunchgrass, rhizomatous, can form extensive cover but is slow growing.
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	**539,407**	Tolerant to wide range of pH, permafrost and high elevations. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Alfalfa *Medicago sativa* (Rangelander, Rambler, Peace)	**498,960**	Tolerant to alkaline soils, low nutrients, drought. Forms extensive cover but is a wildlife attractant. Only recommended for difficult to vegetate slopes.
FAST GROWING ANNUALS FOR RAPID SITE COVER AND NURSE PLANTS (Select one species, but not more than 10% of mix)		
Annual rye *Lolium multiflorum*	**477,400**	Tolerant to a range of pH. Fast growing, extremely competitive. Wildlife attractant. Will not tolerate extreme heat, cold or drought.
Barley *Hordeum vulgare*	**29,920**	Moderately tolerant to alkaline and saline soils, drought. Wildlife attractant. Fast growing, extremely competitive.

Steep Slopes

Table 5.7

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 2,250 to 3,000 seeds/m² on bare mineral **OR** 1500 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
any of the species listed in Table 5.5		
Northern rough fescue *Festuca altaica*	**451,854**	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Northern brome *Bromus pumpellianus*	**202,400**	Tolerant to low nutrients, drought. Medium to tall grass, weakly tufted, stoloniferous. Grows in meadows, dry slopes at all elevations.
Macrourum's wheatgrass *Elymus macrourus*	**374,782**	Tolerant to drought, periodic wetness, low nutrients. Medium size bunchgrass, weakly rhizomatous, low seed yield. Most common in gravely/ sandy areas along lakeshores, riverbanks and open slopes.
Sweetgrass *Hierochloë hirta* (formerly *H. odorata*)	**242,000**	Tolerant to drought and low nutrients. Short, fine grass with creeping rhizomes and strong competitive ability but poor seed yield. Grows in sandy meadows, streambanks, open forests at low elevation.
Nuttall's alkaligrass *Puccinellia nuttalliana*	**4,648,140**	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2 – 4 years). Mostly restricted to dry alkaline and saline areas.
Wormwood/sage *Artemisia* spp.	—	Tolerant to drought, low nutrients. Medium stature forb or short shrub. Wormwood species grow in a diversity of open/disturbed areas from riverbanks and grasslands to steep slopes and alpine/Arctic tundra. Mostly adapted to dry soils.

Steep Slopes

LOCALLY-COLLECTED WOODY SPECIES

Locally Sourced Woody Species

Woody species are not recommended for planting on steep, dry slopes.
However, they are strongly recommended for steep, wet slopes such as ditches and riverbanks.
For those applications, see *Scenario 3: Wet Sites*.

Scenario 3 **Wet Sites**

Most revegetation sites in Yukon will suffer from a lack of moisture. Yet in the rare case that work occurs on a wet site, it is often too wet. Most commonly, wet sites are encountered when development occurs immediately adjacent to a watercourse, in ditches or other depressions, at the base of slopes, and in permafrost areas. In these cases, the soils often are cold, poorly drained, poorly aerated, have a high swollen clay content, and in many cases experience seasonal flooding, which often kills new vegetation because most plants cannot tolerate prolonged periods (more than two weeks) of submergence.

There are essentially two types of wet sites that will be encountered in revegetation projects: those that are seasonally wet because they occur in an impermeable depression, ditch, or flood zone, and those that are near or part of a natural water body. This distinction determines the type of ground preparation that is appropriate and the species selected for planting. For clay-rich depressions and overly compacted ground where water pools seasonally, the drainage can be improved by deep tilling and the addition of coarser sediments and organic materials. In these cases, the species chosen for planting simply need to be adapted to seasonally moist conditions, and short-term submergence.

In contrast, ground adjacent to true wetlands generally should not be deep-tilled, and species chosen for planting should tolerate periods of submergence. These sites respond well to staking of willow and poplar. In fact, if the site occurs along a watercourse, planners should always consider staking as a primary component of the revegetation plan, unless there are reasons not to promote the growth of woody species.

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FIG 5.4
Most species recommended for revegetation work in Yukon are adapted to dry conditions, but wet sites require a totally different species mix. In addition to seeding wet-adapted grasses, willows can be staked on sites that will be wet or moist all summer. On this creek bank, jute and straw underlayment was installed, covered with soil and seeded. Willows were staked only on the lower slope. Note how the grasses are only growing above the high water mark. Most grasses cannot survive long periods of submersion, but poor establishment of grasses on this bank is probably due to seed loss from river scouring. Staked willow is more resistant to erosion and can survive long periods of submersion. On this site, willow could have been staked more thickly and higher up the bank.

Site Preparation

- Be cognizant of regulations applying to any work that occurs in wetlands, especially the use of vehicles and motorized equipment, and the season when work is performed (note that not all wet sites will necessarily be classified as wetlands).
- Often, equipment cannot or should not be operated on wet sites because it leads to compaction and/or clod formation. The exception is contouring of banks and ditches or the emplacement of riprap. That work is best done with an excavator to avoid driving equipment in the wet area.
- Grading should be given careful attention on wet sites. If the site's wetness is being treated as problematic, then grade the site to create even runoff. Level-out depressions and contours to eliminate low (wet) and high (dry) areas. Consider creating drainage structures (*e.g.*, ditches) if it: a) is practical, b) helps regulate saturation levels for improved plant growth and c) does not cause harm to watercourses downstream.
- Some wet sites should be decompacted, while other should not (see scenario introduction). On seasonally-wet sites, wait for them to dry-out as much as possible before decompacting. This may mean postponing the work until the next summer. When adequately dry, toothed rippers (subsoilers), plows, disk harrows, or excavator buckets can be used to decompact. Do not till to a depth greater than it can be expected to dry. This recommendation assumes that the site's wetness should be remediated; that will not be the case if it is a functional wetland. Do not try to decompact wetlands and perennially-wet ground.
- If it is not a perennial wetland, add coarser sediments and organic material when possible to increase drainage properties, dilute the clay content and raise the grade. Be aware, however, that deep tilling can be counterproductive on sites that have thick clay layers, as tilling can sometimes just bring more clay to the surface. Thus, the decision to till, or not to till, and to what depth, depends largely on the clay content and the availability of coarse sediments and organics that can be added to the site.
- After decompaction, use equipment or hand tools to break up clods and even-out surface undulations. This step is very important on wet sites.
- If the site is near a watercourse or experiences seasonal runoff, it may be necessary to install erosion protection materials on slopes and banks adjacent to the site. This will prevent seasonal flooding and erosion from damaging prepared seedbeds.

Fertilizer and Organics

- While most Yukon sites will have depauperate soil organics, wet lowland sites can be the exception to this rule. But wet, organic-rich sites will rarely need revegetation work. The wet sites needing revegetation work will mostly be development sites where the organic material has been removed, or sterile fill material has been brought in. Applying organic materials to these sites functions just as much to increase tilth and drainage, as to increase fertility. This is especially true for clay-rich soils. In Yukon, a wet site with good organic content and/or fertilizing will revegetate rapidly. Fertilizer rates can be cut in half when organic content is high.
- Use the results of soil testing and guidelines in Chapter 3 to determine nutrient deficiencies and fertilizer needs. Use caution when applying fertilizer to wet sites to avoid contamination of watercourses. Fertilizer should not be applied within 30 m of a water body.
- Pay special attention to indicators of high salinity, as saline sites in Yukon occur in low-lying areas around former lakebeds.

Planting and Seed Mixes

- Germination and growth rates should be high on properly prepared wet sites, so there is no need to seed heavily. Consider 1,500 seeds/m^2 to be a maximum target density.
- Germination success will be highly dependent on site preparation, especially on clay-rich sites. Clods and hard clay surfaces must be broken-up. If necessary, run a roller/cultipacker or a chain/tine harrow over the surface before seeding.
- The species listed in the seeding tables will grow well on sites with high soil moisture, but they vary in their ability to grow on saturated or seasonally submerged soils, so choose species mixes to match the level of site moisture.
- High species diversity can be achieved on sites that are moist, but do not stay inundated for long periods. On these sites, consider planting four or more species, each with different adaptive traits, to account for fluctuation between wet and dry periods. On the other hand, only a few species, such as sloughgrass (*Beckmannia syzigachne*), will grow well on sites with frequent flooding and long periods of standing water. On these sites, there is no point planting species that are not tolerant to prolonged inundation.
- Annual grasses are seldom sown on wet/moist sites because they generally confer no advantages and may inhibit the growth of perennials. The only exception would be banks along waterbodies and ditches. Planting annual grasses on banks can provide an organic layer to bind the soil (erosion control) and provide germination sites for later successional species. But a better solution for steep wet banks is to apply RECPs in conjunction with willow staking and/or seeding (see Chapter 4 for bioengineering solutions).
- It is highly recommended to stake willow and poplar cuttings on very wet sites, unless woody plants are considered undesirable. They are especially helpful for stabilizing banks along watercourses and lessening the impact of flooding. Shrub birch seedlings will do well on sites that are moist, but not on sites that are saturated for long periods. Birch also requires higher soil organic content than willow or poplar, does not grow well in alkaline conditions, and should not be planted on steep slopes. Alder has requirements similar to birch but is less tolerant to very acidic sites.

Wet Sites

Table 5.8

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m² on bare mineral soil **OR** 750 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Polargrass *Arctagrostis latifolia* (Alyeska or common)	3,960,000	Tolerant to low-nutrient, wet, and acidic soil, as well as permafrost. Do not use on alkaline soils. Spreads through rhizomes and often develops late in summer.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	3,300,000	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost, wetness and high elevations. Bunch forming, strong competitive ability and can form extensive cover.
Fowl bluegrass *Poa palustris* (common)	4,840,000	Tolerant to acidic soils, low nutrients and wetness. Loosely tufted bunchgrass, rapid emergence, early spring growth, but shallow-rooted, generally short-lived and not aggressive.
Bluejoint reedgrass *Calamagrostis Canadensis* (Sourdough or common)	8,442,438	Tolerant to slightly acidic soils, low nutrients, permafrost and wetness. Tall bunch grass with aggressive rhizomatous growth and extensive cover production. Early spring and late summer growth.
American sloughgrass *Beckmannia syzigachne* (Egan or common)	2,723,600	Tolerant to a range of pH, low nutrients and wetness. Tall bunchgrass, grows mostly as an annual with high seed production. Commonly used in wetland restoration and will grow in almost any wet soil.

Wet Sites

Table 5.9

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m² on bare mineral soil **OR** 750 seeds/m² if organics are in place

SPECIES (*cultivar*)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	336,600	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	895,136	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Timothy *Phleum pratense* (Climax, Engmo)	2,559,400	Tolerant to acidic and alkaline soils. Grows best in cool, moist organic soils. Tall bunchgrass, rapid emergence, yields extensive cover. Wildlife attractant.
Canada bluegrass *Poa compressa* (Reubens, common)	5,264,204	Tolerant to alkaline soils, low nutrients, moderate drought. Medium height bunchgrass, rhizomatous, can form extensive cover but is slow growing.
Kentucky bluegrass *Poa pratensis* (Nugget)	3,057,648	Tolerant to moderate acidity, cold temperatures and wet soils. Long-lived species. Sod-forming turf grass, can be grown as far north as the Arctic coast.
Red top *Agrostis gigantea* (common)	10,672,640	Tolerant to acidic soils and wet or dry conditions. Medium stature rhizomatous bunchgrass, mildly aggressive. Forms good cover but only on low slopes/low elevation.

Wet Sites

Table 5.10

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 1,500 seeds/m² on bare mineral soil **OR** 750 seeds/m² if organics are in place

SPECIES	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
any of the species listed in Table 5.8		
Northern rough fescue *Festuca altaica*	**451,854**	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Northern bluegrass *Poa alpigena/Poa pratensis*	**3,057,648**	Tolerant to mildly acidic soils, low nutrients and permafrost. Low to medium stature grass, turf-forming, strongly rhizomatous and competitive. Grows in sandy areas along lakeshores and moist meadows; also moist sandy tundra.
Nuttall's alkaligrass *Puccinellia nuttalliana*	**4,648,140**	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2-4 years). Mostly restricted to dry alkaline and saline areas.
Arctic lupine *Lupinus arcticus*	**22,733**	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.

Wet Sites

Table 5.11

LOCALLY-COLLECTED WOODY SPECIES

SPECIES	REASONS TO USE AND RELEVANT CHARACTERISTICS
Willow *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	Only use in wet locations and only use the species listed. Willow is the main plant used for staking of live/dormant cuttings and for bioengineered structures.
Poplar *Populus balsamifera*	Only use in wet/moist locations; easily established through staking of live/dormant cuttings.
Shrub birch *Betula glandulosa* *Betula nana*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to acid soils. Use on moist sites with good organic content.
Alder *Alnus crispa* *Alnus tenuifolia*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to slightly acidic soils and low nutrients. Use on moist/wet sites that are not alkaline.

Scenario 4 **Highway Rights-of-Way**

Highways in Yukon are usually reconstructed on a 25 – 50 year cycle, and in any given year many kilometres of roadway will be under reconstruction or realignment. The 20 – 30 m wide right-of-way (ROW) along these roadways is often bladed or grubbed during reconstruction, in part to keep woody species from encroaching. Thus, the frequency and extent of annual road work makes ROWs one of the most common revegetation projects encountered in Yukon.

Highway ROWs warrant special consideration because the revegetation goals are numerous and specific: 1) prevent erosion along cut slopes, shoulders and ditches, 2) maintain roadbed stability, 3) provide drivers with adequate visibility and lines-of-sight, 4) create a visually-pleasing viewscape, 5) reduce wildlife hazards, and 6) prevent the spread of invasive plants.

One of the main challenges of revegetating ROWs is that ground conditions along a single ROW can be highly variable, ranging from steep dry slopes to wet lowlands. The key will be to write a prescription for each distinct area of the site and instruct crews how and where to implement them. Avoid one-size-fits-all prescriptions for the entire ROW. Nonetheless, in many cases much of the ROW will be gently sloping ground typical of the surrounding environment, and the recommended species and procedures in this scenario apply to those areas.

Trees and woody shrubs in the ROW impair driver visibility, which necessitates periodic mowing or grubbing. If mowing/grubbing needs to be done frequently, that equates to higher maintenance costs. Consequently, ROWs should be planted with dense stands of herbaceous species (grasses) to compete with woody species and slow their return. Active planting or promotion of woody species in ROWs is strictly limited to wet slopes and banks along wetlands, ditches and streams.

Roadways are a principle vector by which invasive plants spread in Yukon, and revegetation plans should be developed to discourage their growth. Ensure that seed suppliers will certify that their seed is free from seeds of plants known to be invasive in Yukon. Consult the Yukon Invasive Species Council for the current list. Invasive plants outcompete native plants in sterile gravels, so consider seeding aggressive, drought-resistant perennial grasses all the way up to the edge of the road surface, including the shoulder. Spreading fine materials and organics (even a thin layer) will help give native and commercial seeds a competitive edge over invasive species, as does the use of fertilizer.

Planners should also avoid planting species that are attractants to wildlife, particularly grazing ungulates, since they can be a traffic hazard. Choose less palatable grass species and avoid the use of legumes such as alfalfa.

The species recommended in the tables below have been selected in light of these special needs along roadways. They are hardy, competitive, drought-resistant, and not particularly palatable to grazers. Seeding at higher densities (> 2,500 seeds/m²) will help retard the spread of woody species in the ROW. Perhaps the biggest variable among the species listed in the tables is their differing tolerances to soil pH, so be sure to choose species in accordance with the site's pH.

In almost all cases, it will not be practical to collect seeds of local plants for sowing in the main ROW, simply because the area will be too large. The recommendations for locally-collected seeds should only be used for small sites. Woody species are not recommended for staking or planting in the main ROW, and should only be used for bank protection along waterways/ditches and in bioengineering applications on slopes.

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Fig 5.6
All types of site conditions can be encountered when revegetating highway right-of-ways, calling for the application of many different tools in the planners toolbox. Revegetating right-of-ways also requires advanced planning and logistics, because the work must be coordinated with road designers and contractors. The main objectives are to protect the roadbed, reduce road hazards, enhance visual aesthetics, reduce future maintenance costs, and exclude woody and invasive species.

Site Preparation

- Work with project managers and engineers early in the planning process so that the construction contract specifies the need for proper site grading and preparation to facilitate subsequent revegetation work. For instance, contractors should be made aware that they might be required to contour or track-walk the ROW at the end of construction in preparation for seeding.
- The contract/prescription should also specify how slash, debris and organic materials will be handled. With proper planning, it should be possible on most ROW projects to specify that organic materials be stockpiled and re-applied after construction. This will confer immeasurable advantage to revegetation success.
- The site should be graded to eliminate dips and rises that will lead to pooled water or alternating wet and dry spots. But leave the surface slightly roughened, to retain seed and water (avoid the creation of glazed, bladed surfaces).
- In many cases, it will be necessary to decompact surface soils, at least in some areas of the site (*e.g.*, areas where construction equipment was staged). Use toothed rippers (subsoilers) or other techniques described in Chapter 3.

Site Preparation *continued*

- Cut slopes, fill slopes and ditches may require track-walking to provide texture. On slopes that are too steep to operate equipment, use a toothed excavator bucket to scarify the surface. Be sure not to compact or glaze the surface with the bucket.
- If necessary, prepare a seedbed using a harrow pulled by a crawler, tractor, or ATV (do not operate wheeled tractors or ATVs on steep slopes or in ditches). As much as possible, use equipment already on-site for road construction to prepare the ROW surface before they are demobilized (*e.g.*, to grade, track-walk or harrow the ROW).
- Install erosion control materials on steep slopes (see Chapter 3).
- On large sites with low slope and few impediments, the most efficient method of decompaction and surface preparation (tilling) can be to use a large tandem disk harrow pulled by a crawler or large wheeled tractor. The main impediment to using large disk harrows will be rocks and debris in the ROW, which can damage or clog-up harrows.
- Even though it is not ideal, it is not uncommon for revegetation work in the ROW to occur more than two years after construction is completed. If this is the case, the site might need to be decompacted again before seeding. Heavy equipment may no longer be on-site, so decompact the site with the largest tractor and disk harrow or plough available. Do not simply fertilize and seed the surface and follow-up with a light harrowing.

Fertilizer and Organics

- With good planning, it should be feasible to stockpile and re-apply organic materials in ROWs. If organic materials are only available in limited supply, then erosion-prone areas, clay-rich area (*e.g.*, areas prone to cementation), and slopes have highest priority. Try to work the organic materials into the soil as much as possible.
- Use the results of soil testing and guidelines in Chapter 3 to determine nutrient deficiencies and fertilizer needs. Fertilizer will be critical on sites with bare mineral soil and no organics.
- Spread fertilizer and organics up to the edge of the road surface in order to give applied seeds a competitive advantage over invasive plants.
- If the ROW surface is rough and littered with organic debris, it may not be necessary to harrow after applying fertilizer; driving over the surface with tracked equipment often will suffice. If the surface is comprised mostly of organic-poor, bare mineral soil, then harrow the surface to incorporate the fertilizer into the top 5 – 10 cm of the surface.
- Avoid spreading fertilizer in a manner where it can wash off slopes and accumulate in ditches. This can be accomplished by harrowing or cultipacking the site immediately after fertilizing and seeding.
- Do not over-fertilize, as this will make the new plant growth more attractive to wildlife.
- If hydroseeding, the fertilizer will be applied as part of the seed-mulch slurry.

Planting and Seed Mixes

- Apply seed at a rate of 1,500 – 2,000 seeds/m^2 when few organics are present, and 1,000 – 1,500 seeds/m^2 when organic materials were re-spread. Seed densities may be increased in both cases to ensure a thorough cover of grasses that will slow the spread of woody and invasive species.
- Species diversity should be gauged to meet site objectives (see Chapters 2 and 4). In most cases, planting 4 – 5 species should be adequate to hedge against a bad growing season and will provide enough diversity to achieve aesthetic goals. Factors such as high salinity or permafrost may be reasons to reduce diversity (because only a few species are adapted to grow on these sites). On the other hand, ROWs offer good opportunities to experiment with revegetation species in the seed mix.
- Consider a seeding plan where only one or two species of low-growing, aggressive, rhizominous grasses are planted immediately adjacent to the road edge. These will serve to compete with invasive plants and will be the most likely to survive snow plowing and grading.
- In most cases, seeding will be done with a broadcast spreader. Usually, ROWs are too uneven and have too much surface debris to use a seed drill. However, on large sites with even, debris-free surfaces, it may be cost-effective to use a drill (seed quantities can be reduced by 500 seeds/m^2 when using a drill).
- Many ROWs will have obstacles such as large rocks or copses of trees remaining on the surface. When equipment must be operated around them, follow up with hand seeding.
- Hydroseeding is often used to seed steep slopes in a ROW because equipment can be operated from the roadway and because it takes a large project area to make hydroseeding cost-effective. See *Scenario 2 Wet Sites* for more information and limitations of hydroseeding.
- It is important to monitor revegetation progress in ROWs. Frequently, the planted vegetation will not take hold along problematic stretches of road and a second seeding is required. In these cases, a different seed mix may be indicated. In other cases, the surface will turn out not to be as stable as was thought, and erosion will have destroyed the seedbed. These surfaces will need to be stabilized and reseeded.

Highway Rights-Of-Way

Table 5.12

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 or more seeds/m² on bare mineral soil
OR 1,000 – 1,500 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Rocky Mountain fescue *Festuca saximontana* (common)	**1,430,000**	Tolerant to dry alkaline soils, low nutrients, permafrost and high elevations. Bunch grass with rapid emergence in early spring. Do not use on wet or acidic sites.
Violet wheatgrass *Elymus alaskanus* (common)	**330,000**	Tolerant to alkaline soils, drought and low nutrients; also has considerable tolerance to permafrost and moderate tolerance to saline soils and high elevations. Bunch forming with strong competitive ability.
Glaucous bluegrass *Poa glauca* (Tundra or common)	**2,904,000**	Tolerant to broad range of pH, drought, low nutrients, permafrost and high elevations. Forms low growing bunches with a high root-shoot ratio, spreads aggressively through rhizomes, rapid emergence in early spring.
Fowl bluegrass *Poa palustris* (common)	**4,840,000**	Tolerant to acidic soils, low nutrients and wetness. Loosely tufted bunchgrass, rapid emergence, early spring growth, but shallow-rooted, generally short-lived and not aggressive. Not drought tolerant.
Slender wheatgrass *Elymus trachycaulus* (Revenue, Adanac, Highlander or common)	**349,800**	Tolerant to broad range of pH, dry ground and low nutrients. High tolerance to saline soil. Performs poorly on permafrost and high elevations sites. Forms loose bunches and is short-lived, but exhibits rapid emergence.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	**3,300,000**	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost, wetness and high elevations. Bunch forming, strong competitive ability and can form extensive cover. Not drought tolerant.

Highway Rights-Of-Way

Table 5.13

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,500 or more seeds/m² on bare mineral soil
OR 1,000 - 1,500 seeds/m² if organics are in place

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	**539,407**	Tolerant to wide range of pH, permafrost and high elevations. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Canada bluegrass *Poa compressa* (Reubens, common)	**5,264,204**	Tolerant to alkaline soils, low nutrients, moderate drought. Medium height bunchgrass, rhizomatous, can form extensive cover but is slow growing.
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Sheep fescue *Festuca ovina/F. brachyphylla* (common)	**1,100,000**	Tolerant to neutral or slightly acidic soils, drought, low nutrients and high elevations. Needs well-drained granular soil. Forms short bunches, slow growing, aggressive rhizomes.

Highway Rights-Of-Way

Table 5.14

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 1,500 or more seeds/m² on bare mineral soil
OR 1,000 – 1,500 seeds/m² if organics in place

SPECIES	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
any of the species listed in Table 5.12		
Northern rough fescue *Festuca altaica*	451,854	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Northern brome *Bromus pumpellianus*	202,400	Tolerant to low nutrients, drought. Medium to tall grass, weakly tufted, stoloniferous. Grows in meadows, dry slopes at all elevations.
Sweetgrass *Hierochloë hirta* (formerly *H. odorata*)	242,000	Tolerant to drought and low nutrients. Short, fine grass with creeping rhizomes and strong competitive ability but poor seed yield. Grows in sandy meadows, streambanks, open forests at low elevation.
Nuttall's alkaligrass *Puccinellia nuttalliana*	4,648,140	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2-4 years). Mostly restricted to dry alkaline and saline areas.
Yellow locoweed *Oxytropis campestris*	521,400	Tolerant to drought and low nutrients. Low growing bunches. A nitrogen-fixing forb that provides a colourful flowering bloom. Found in dry, granular disturbed areas.
Showy locoweed *Oxytropis splendens*	1,548,800	Tolerant to drought and low nutrients. Low growing bunches. A nitrogen-fixing forb that provides a colourful flowering bloom. Found in dry, sandy disturbed areas.
Arctic lupine *Lupinus arcticus*	22,733	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.
Mountain avens *Dryas* spp.	—	Tolerant to alkaline soils, drought, low nutrients. Matt-forming, low stature forb that grows in very poor soils and calciferous disturbed areas at all elevations, including scree slopes and gravel.
Yarrow *Achillea millefolium* and *Achillea sibirica*	6,274,426	Tolerant to alkaline soils, drought, low nutrients. A slender, colonizing forb with white flower heads that bloom late in summer. Mostly found in areas with well-drained but poorly developed soil. Produces tiny seeds in abundance.
Wormwood/sage *Artemisia* spp.	—	Tolerant to drought, low nutrients. Medium stature forb or short shrub. Wormwood species grow in a diversity of open/disturbed areas from riverbanks and grasslands to steep slopes and alpine/Arctic tundra. Mostly adapted to dry soils.

Highway Rights-Of-Way

LOCALLY-COLLECTED WOODY SPECIES

Locally Sourced Woody Species

Woody species are not recommended for planting in highway right-of-ways, except in wet areas and along banks for erosion control. In those cases, see *Scenario 3: Wet Sites*.

Scenario 5 **Disturbed Lowland Permafrost Sites**

Permafrost presents a special challenge in Yukon revegetation projects. Consider this: on non-permafrost sites, the ground can be disturbed, graded, built-up, excavated, and shaped in various ways, but afterwards the ground material remains essentially the same static entity. However, when a permafrost site is disturbed, ground ice can begin to melt, setting in motion a cascade of events that can remain dynamic and uncontrollable for years. This scenario discusses actions that should be taken when a permafrost site with ground ice is disturbed. It begins with a short primer on permafrost, ground ice and the results of thermal destabilization.

The term permafrost simply refers to any ground that remains frozen below the surface year-round (mean annual ground temperature below 0˚C). In northern Yukon, essentially all the ground is underlain by permafrost. In central Yukon, perennially frozen ground has an extensive, but discontinuous, distribution. In southern Yukon, permafrost is sporadic, occurring mostly in alpine areas and a few cold lowland pockets (see Fig. 2.4).

It terms of revegetation and land development, the key issue when working on permafrost sites is not whether the ground is perennially frozen, but rather whether the ground contains significant quantities of ice (“ground ice”) and whether it has been disturbed to the point of melting (“thermokarsting”). These two topics warrant further elaboration:

Ground ice forms in a number of different ways. Frozen water between the interstices of ground particles is referred to as “pore ice.” In ground with only pore ice, the ground/water volume is essentially the same as if the ground was not frozen. But in most permafrost systems, unbound water molecules in the ground are mobile and migrate towards any freezing front or existing ice bodies. Through this processes, water segregate from soil particles and grows into relatively pure ice lenses. This type of ground ice is called “segregation ice.” Ice lenses can remain small, but numerous, or can grow into large ice bodies many cubic meters in size. In peatlands, especially in areas of discontinuous permafrost, ice lenses heave from seasonal frost action towards the surface causing the formation of ice-rich peat mounds called palsas. Pingos are large hills with cores of ice that form when unfrozen ground water in permafrost is forced upward by hydraulic pressure and freezes. Ice wedges are a common form of ground ice that form as surface snow and water fill ground cracks caused by thermal contraction. Ice wedges grow each year and can become quite large, but they only tend to form where mean annual ground temperatures are below -6°C. They are expressed on the surface as polygonal ground and are a prominent feature of lowland permafrost in northern Yukon.

The formation of ground ice is dependent on ground temperature and moisture content, but its manifestation is almost equally dependent on the host sediments and terrain features (*e.g.*, slope, aspect). Large ice bodies form more readily in fine-grained sediments such as silts, than in coarse-grained sediments such as gravels. In permafrost zones, flat lowlands with thick deposits of fine sediments will have more ground ice than slopes because the slopes are better-drained and receive more solar insolation (*i.e.*, they are warmer),

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FIG 5.7
Permafrost is problematic for development projects and revegetation when it contains significant volumes of ground ice. Disturbing ice-rich ground, especially the insulating layer of surface organics, can lead to uncontrolled melting and thermokarsting.

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FIG 5.8
Polygonal ground forms when ice wedges develop below the surface. Ice wedges grow as the ground thermally contracts each year and the cracks fill with snow and water, which then re-freeze. Ice wedges can grow to a very large size, and develop in areas of central and northern Yukon where annual ground temperatures are below -6°C. In Southern Yukon, Polygonal ground is rare and ice wedges encountered are relics from the Pleistocene epoch.

especially south-facing slopes. However, many north-facing slopes covered with thick mantles of fine sediments in central and northern Yukon contain large quantities of ground ice.

In permafrost ground with coarse sediments, ice formation is mostly limited to the granular interstices (pore ice) and formation of large ice bodies is inhibited. On these sites, ice will constitute a very small percentage of the ground volume. Most alpine areas in Yukon have a mean annual ground temperature below 0˚C but ice bodies are uncommon because alpine ground tends to have a thin mantle of coarse-grained sediment (*i.e.*, it is not far down to solid rock) and because they are well-drained (revegetation strategies for alpine and subalpine sites are discussed in Scenario 7). Even in cold lowland areas with extensive ground ice, the course gravels of old river channels will generally be free of large ice bodies.

Ground ice formation is actively occurring in the present climate of central and northern Yukon but very little in southern Yukon. However, a significant number of large ice bodies in Yukon are relics from the last Ice Age; even in areas where the modern climate is not cold enough to form ground ice, it is still cold enough to preserve ice bodies that formed during the Pleistocene. The location and occurrence of these relictual ice bodies can be nearly impossible to predict and they may be encountered nearly anywhere in the territory, including southern Yukon. Ice bodies, whether old or new, tend to remain stable as long as the annual ground temperature stays below freezing and the ice is insulated from summer heat by overlying organic matter.

While it is important that the revegetation planner in Yukon has a general understanding of permafrost dynamics, the complexities of ground ice formation and nomenclature are less important than the decisions that must be made when ground ice is encountered or known to be present in an area. A key factor is that annual ground temperatures are only slightly below 0°C in many areas of central and southern Yukon, with a trend towards warming. This means much of the permafrost in these areas is nearing thermal instability. Any disturbance to the ground, especially the removal of insulating organic matter and vegetation, usually is enough to upset the thermal balance and initiate melting. As the ground ice melts, the ground looses volume and slumps, often resulting in the formation of shallow ponds. This process is called thermokarting. It can begin almost immediately after

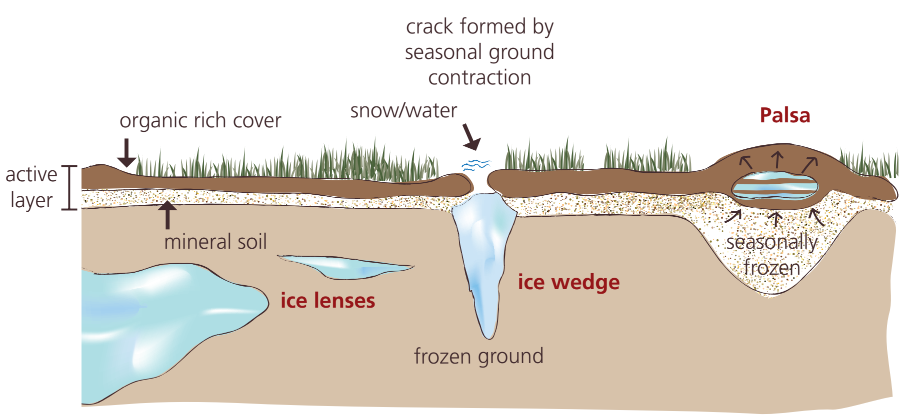

FIG 5.9
Ground ice in permafrost forms in different ways – here are three examples. Ice lenses are a type of segregation ice that form as unbound water molecules in the ground migrate towards a freezing front or existing ice bodies. Ice lenses can take on a variety of shapes and sizes. Ice wedges form when snow and ice fill-in ground cracks caused by thermal contraction. They also can grow to be quite large. Palsas are ice-rich peat mounds pushed upwards by frost heaving. They form as winter frost penetrates the ground and creates frozen zones that serve as nuclei for the formation of segregation ice; unfrozen water from below is drawn to the ice, pushing the mound upward.

ice-rich ground is disturbed, and it can continue for years until the site stabilizes again.

The general rule of development is to avoid disturbing the ground on permafrost sites, especially the removal of insulating ground cover (soils and organics). When they are disturbed, intentionally or not, they should be reclaimed and revegetated as soon as possible to minimize thawing and thermokarsting. Mostly, this means placing insulative materials over the disturbance, usually in the form of thick layers of soil and organic matter. If the disturbance occurs in early to mid-summer, it is important to reapply as much insulative material as possible, and as soon as possible. If the disturbance occurs in late summer or fall, then the site should be left exposed for the winter to promote deep frost penetration, with a thick layer of soil and organics applied as soon as possible the following spring.

Once soil and organics are in place, seed the site as soon as possible. These sites should respond well to frost seeding, and a second seeding can be important to ensure a good vegetative cover is established. Seed density should be at least 1,500 seeds/m^2. Including 10% annual grasses in the seed mix will help to quickly establish an insulative cover. The remaining species should be ones that germinate and grow well on cold sites with short growing seasons; generally, they do not need to be drought-resistant, as these lowland permafrost sites tend to be moist or wet.

If a site has undergone thermokarsting in the past, but currently is stable, then it can be treated like any other non-permafrost site. However, new ice lenses may have formed or buried pond ice may be present, so care should be taken when re-disturbing the ground or operating equipment.

Site Preparation

- Contouring, decompacting and other activities involving equipment operation on these sites may be counter-productive because they can increase the level of disturbance and rate of melting. Standing water and saturated ground will compound the problem.
- An exception would be if equipment has been recently operated on the site to the point of severely compacting the surface. Then, shallow harrowing will be beneficial for water drainage and seed germination.
- If standing water is beginning to accumulate from melted ice, consider creating drainage structures to help divert the water and dry out the site.
- The main preparation activity on disturbed permafrost sites will be to apply large amounts of soil and organic material to re-establish an insulative covering.

Fertilizer and Organics

- The most important action to take on these sites will be to spread as much soil and organic material as possible on the surface. This will act as insulation to help stop further melting. No amount will be too much, but it should be at least 20 cm thick. Timing is critical, so use one the following two approaches:

    a) If the disturbance occurred early in the summer, then begin remediation and spread organic material immediately. This will help prevent further thawing in the warm season.

    b) If the disturbance occurred late in the summer or fall, then do nothing until the following spring. This way, frost will penetrate deep into the ground over the course of the winter and help to reverse the thawing process (organic material insulates against winter cooling as well as summer warming). Spread soil and organic materials as thick as possible early in the following spring to retain the frost (before the ground thaws).

- Since organic material is applied principally to provide insulation, not tilth or fertility, any material will suffice: stumps, slash, rotting logs. Do not till the organic material into the soil, as this may actually reduce its insulation value.
- Fertilizer (especially nitrogen) can be used sparingly, and often omitted. It can be applied at the normal rate (calculated using guidelines in Chapter 3) on sites that are nutrient-deficient and fairly dry. On cold, saturated sites, apply fertilizer at half the calculated rate, since plants will grow slowly on cold, saturated ground. Do not apply fertilizer if there is significant standing water present for extended periods. When it is possible to apply thick layers of organic material for insulation, then it is usually unnecessary to fertilize.

Planting and Seed Mixes

- Thick stands of new vegetation will help insulate the ground and prevent further thawing. Consequently, seeding rates should be at least 1,500 seeds/m^2 (doubling the rate is not unreasonable) and it is important to ensure even coverage, with no bare patches.
- For the same reason, consider adding 10% annual grasses to the seed mix. It will help establish cover more quickly.
- Significant hand seeding may be required, since it may not be possible to operate equipment on the site. If it is possible to use equipment and a broadcast spreader, take care to spread seed evenly and follow up with hand seeding in areas that were missed (*e.g.*, where equipment was driven around obstacles like stumps).
- Consider spreading seed in fall just as the ground is beginning to freeze ("frost or fall seeding" – see Section 4.3.1). Frozen or semi-frozen ground means that equipment can be driven on the site, and the subsequent freeze-thaw cycle in spring will mechanically incorporate seed into the ground.
- If heavy, course organic materials were applied it may not be necessary or practical to harrow the seedbed after broadcasting. However, some action should be taken to increase seed-soil contact, such as rolling with a cultipacker or even driving equipment over the seeded ground.
- Do not spread seeds in areas of standing water. It is unlikely they will germinate.
- As with all sites, locally-collected seeds should be considered for addition to seed mixes whenever possible. However, on permafrost sites, it is critical that thick cover be established quickly, and it may not be practical to collect enough seeds to achieve that goal.
- Staking of woody species is not recommended as a primary tool for stabilizing disturbed permafrost sites. If the site will remain moist, then willow stakes as well as shrub birch or alder seedlings can be planted intermittently if they help to meet secondary project objectives.

Disturbed Lowland Permafrost Sites

Table 5.15

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF AT LEAST: 1,500 seeds/m^2 on all soils

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Polargrass *Arctagrostis latifolia* (Alyeska or common)	**3,960,000**	Tolerant to low-nutrient, wet, and acidic soil, as well as permafrost. Do not use on alkaline soils. Spreads through rhizomes and often develops late in summer.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	**3,300,000**	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost, wetness and high elevations. Bunch forming, strong competitive ability and can form extensive cover. Not drought tolerant.
Rocky Mountain fescue *Festuca saximontana* (common)	**1,430,000**	Tolerant to dry alkaline soils, low nutrients, permafrost and high elevations. Bunch grass with rapid emergence in early spring. Do not use on wet or acidic sites.
Fowl bluegrass *Poa palustris* (common)	**4,840,000**	Tolerant to acidic soils, low nutrients and wetness. Loosely tufted bunchgrass, rapid emergence, early spring growth, but shallow-rooted, generally short-lived and not aggressive. Not drought tolerant.
Bluejoint reedgrass *Calamagrostis canadensis* (Sourdough or common)	**8,442,438**	Tolerant to slightly acidic soils, low nutrients, permafrost and wetness. Tall bunch grass with aggressive rhizomatous growth and extensive cover production. Early spring and late summer growth. Not drought tolerant.
Ticklegrass Agrostis scabra (common)	**11,000,000**	Tolerant to acidic soils, drought, low nutrients, and permafrost. Short-lived bunchgrass with early emergence. A common pioneering plant on dry flat ground.
American sloughgrass *Beckmannia syzigachne* (Egan or common)	**2,723,600**	Tolerant to a range of pH, low nutrients and wetness. Tall bunchgrass, grows mostly as an annual with high seed production. Commonly used in wetland restoration and will grow in almost any wet soil.

Disturbed Lowland Permafrost Sites

Table 5.16

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF AT LEAST: 1,500 seeds/m² on all soils

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Timothy *Phleum pratense* (Climax, Engmo)	**2,559,400**	Tolerant to acidic and alkaline soils. Grows best in cool, moist organic soils. Tall bunchgrass, rapid emergence, yields extensive cover. Wildlife attractant.
Canada bluegrass *Poa compressa* (Reubens, common)	**5,264,204**	Tolerant to alkaline soils, low nutrients, moderate drought. Medium height bunchgrass, rhizomatous, can form extensive cover but is slow growing.
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	**539,407**	Tolerant to wide range of pH, permafrost and high elevations. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Sheep fescue *Festuca ovina* (common)	**1,100,000**	Tolerant to neutral or slightly acidic soils, drought, low nutrients and high elevations. Needs well-drained granular soil. Forms short bunches, slow growing, aggressive rhizomes.
FAST GROWING ANNUALS FOR RAPID SITE COVER AND NURSE PLANTS (Select one species, but not more than 10% of mix)		
Annual rye *Lolium multiflorum*	**477,400**	Tolerant to a range of pH. Fast growing, extremely competitive. Wildlife attractant. Will not tolerate extreme heat, cold or drought.
Barley *Hordeum vulgare*	**29,920**	Moderately tolerant to alkaline and saline soils, drought. Wildlife attractant. Fast growing, extremely competitive.

Disturbed Lowland Permafrost Sites

Table 5.17

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF AT LEAST: 1,500 seeds/m^2 on all soils

LOCAL SEED	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
any of the species listed in Table 5.15		
Northern rough fescue *Festuca altaica*	**451,854**	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Mountain timothy *Phleum alpinum* (formerly *P. commutatum*)	—	Tolerant to wetness, permafrost and high elevations. Medium stature bunchgrass with creeping rhizomes. Grows in moist alpine areas.
Northern bluegrass *Poa alpigena/Poa pratensis*	**3,057,648**	Tolerant to low nutrients and permafrost. Rhizomatous and high root-shoot ratio, strong competitive ability.
Nuttall's alkaligrass *Puccinellia nuttalliana*	**4,648,140**	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2-4 years). Mostly restricted to dry alkaline and saline areas.
Arctic lupine *Lupinus arcticus*	**22,733**	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.
Mountain avens *Dryas* spp.	—	Tolerant to alkaline soils, drought, low nutrients. Matt-forming, low stature forb that grows in very poor soils and calciferous disturbed areas at all elevations, including scree slopes and gravel.

Disturbed Lowland Permafrost Sites

Table 5.18

LOCALLY-COLLECTED WOODY SPECIES

SPECIES	REASONS TO USE AND RELEVANT CHARACTERISTICS
Willow *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	Only use in wet locations and only use the species listed. Willow is the main plant used for staking of live/dormant cuttings and for bioengineered structures.
Note: Birch and alder will grow on these sites, but because it takes over 6 months to a year to propagate seedlings it will not be practical to use them to remediate immediate threats of thermokarsting.	

Scenario 6 **Arctic Tundra and Stable Permafrost Sites**

The previous scenario provided an introduction to permafrost and ground ice, and discussed methods for revegetating sites where ground ice has been disturbed and thermokarsting is an imminent threat. In contrast, this scenario focuses on permafrost sites that are essentially stable. These sites will have a thin active layer (the layer above the frozen ground that thaws each summer), cold soils and a host of other permafrost-related features that typify revegetation sites in northern Yukon, and especially Arctic tundra. Many of the principles also apply to taiga sites. Ground ice normally will be present on these sites, but that will not be used as the defining trait.

Usually, the need to revegetate will be the result of a localized disturbance caused by roadwork along the Dempster Highway, airstrip maintenance, or mineral exploration activities (*e.g.*, drill pads, seismic lines). On many of these sites the active layer may not have been removed or disturbed, but new material such as gravel may have been added to the surface (in the far north, developers have learned to place gravel pads over the permafrost and not dig up the ground). In cases where natural or human-caused thermokarsting and mass wasting is occurring (*e.g.*, retrogressive thaw slumps), the information in this scenario should be used in conjunction with information presented in Scenario 5.

In some ways, stable permafrost sites are treated like non-permafrost sites. The key difference is that working and turning the soil on a non-permafrost site is almost always a good thing, whereas on a permafrost site it can cause much harm by initiating melting of ground ice followed by thermokarsting. Consider also that the goal of tilling and decompacting on non-permafrost sites, which is to loosen up the ground for water retention, aeration and root penetration, is nonsensical on frozen ground. The only surface work that will be beneficial on permafrost sites is a light harrowing or raking (only the top few centimetres), and even that is not always necessary.

In northern Yukon, many revegetation projects will be designed to encourage the return of natural vegetation. Collecting and sowing seeds of local plants is strongly advised for these sites, except for large projects (*e.g.*, the Dempster Highway right-of-way) where it is impractical, or where immediate erosion control is important. Many southern cultivars of commercial seed will be unsuited for planting in northern Yukon. However, Alaskan growers have developed northern cultivars that will do well on tundra and other permafrost sites in Yukon. Examples include: the *Nortran* cultivar of tufted hairgrass (also cultivated in Canada), and the *Tundra* cultivar of glaucous bluegrass.

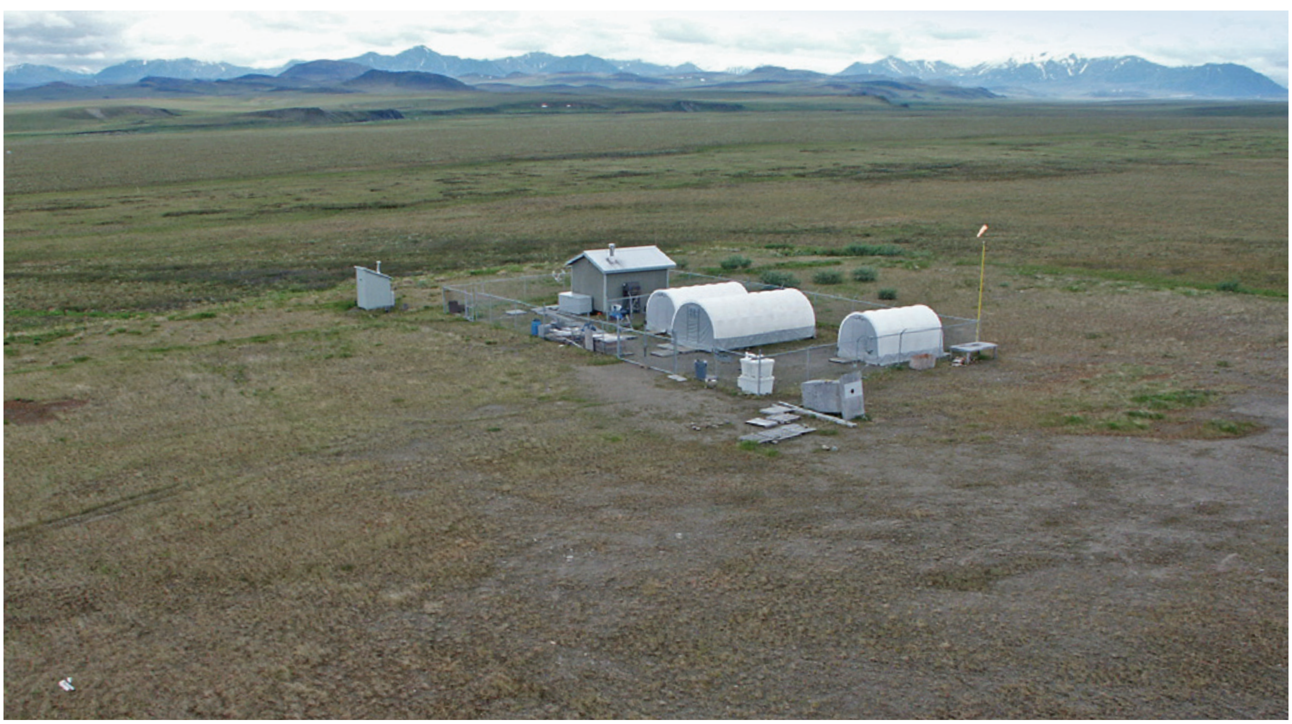

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FIG 5.10
Many revegetation projects on tundra sites will occur on permafrost ground that is thermally stable. Often they will be at development sites where a gravel pad was emplaced. The key to revegetating tundra and other permafrost sites will be to avoid disturbing the ground (no tilling or decompaction work) and choosing the right species for planting. The species recommended in the tables have been pre-selected for their ability to grow on cold ground with a thin active layer. Planners should choose species from those tables based mostly on the site's wetness and pH. These sites can be excellent candidates for sowing locally-collected seeds and taking advantage of natural revegetation.

All of the species recommended in the following tables have been chosen because they are known to grow on cold, permafrost sites in northern Yukon and on Arctic tundra. The primary bases for choosing species from the table will how well they correspond to the site's moisture level and pH. Lowland sites will call for more wet-adapted species, while drought-resistant species should be used on uplands and slopes. Generally, sites in uplands, mountains, and the morainal (glaciated) deposits of the eastern coastal plain will be alkaline; lowlands sites, especially those on the unglaciated western coastal plain, tend to be acidic.

Fertilizer can be useful on permafrost sites, but should be applied sparingly because tundra and taiga plants grow slowly, at a rate that is adaptive for low nutrient environments. Never exceed 50 kg per hectare of nitrogen.

Site Preparation

- On lowland sites, contouring, decompacting and other activities involving heavy equipment operation should generally be avoided because it can initiate permafrost melting and cause soil gelification. Ground preparation, including harrowing, should be limited to the upper 2 – 5 cm of soil.
- Granular sites in the Dempster ROW may require grading and contouring, but caution should be exercised when operating equipment off the roadbed to avoid disturbance of permafrost.
- If ground ice is encountered or actively melting, consult *Scenario 5* for advice on stabilizing the site.
- If standing water is beginning to accumulate from melted ice, consider creating drainage structures to help divert the water and dry-out the site.

Fertilizer and Organics

- The ground surfaces of naturally occurring taiga and lowland tundra communities tend to have large quantities of accumulated organic material. So unless the site being revegetated has been bladed or excavated, there may be significant organics already in-place. Higher elevation sites and slopes will have less organic accumulation. Try to match the organic content of the site to those of the surrounding ground surfaces, even if this means transporting organic material to the site. If this is not done, it will take decades for the vegetation on the site to develop into a plant community that matches the surrounding area.
- If little or no organic matter is available for application, use results of soil testing to calculate a fertilization rate according to guidelines in Chapter 3. Generally, the calculated rate should be cut in half for Arctic tundra sites. Never apply more than 50 kg/ha of nitrogen to these sites, as it can stimulate the vegetation to grow too quickly or thickly for the conditions and it can promote algae growth on the soil surface.
- Work the fertilizer lightly into the ground with rakes (small sites) or with a tine/chain harrow pulled by an ATV where practical.

Planting and Seed Mixes

- Generally, these sites should only be lightly seeded. A target of 1,000 seeds/m^2 is appropriate, but even half that density can be adequate. Higher densities can cause plants to be crowded, which can reduce individual survivorship.
- In these far northern localities, the genotypes of local plants can differ substantially from the genotypes of commercial cultivars, even if they are nominally the same species. Whenever possible these sites should be seeded with locally-collected seeds. This assumes that the site is small and that it is possible to be in the field to collect seeds at the appropriate time, and that immediate erosion-control is not the first priority.
- If immediate erosion-control is necessary, an annual grass can be added to the seed mix (no more than 10% of the mix), even if it is otherwise a mix of locally-collected seeds.
- These can be challenging sites for plant growth. Consequently, when seeding a commercial seed mix, choosing a few species that will have a good chance of success is more important than maximizing diversity.
- Significant hand seeding may be required, since it may not be possible to operate equipment on the site if it is remote.
- Often, there will be no alternative but to sow seeds in late summer or fall ("frost seeding" – see Chapter 4) because it can be difficult to access and work on these sites in spring.
- Work the seedbed lightly by hand using rakes (small sites) or with a tine/chain harrow pulled by an ATV where practical.
- Rarely will it be a good strategy to rely on staking or planting of woody species. The exception is along wet ditches and banks that require stabilization.

Arctic Tundra and Stable Permafrost Sites

Table 5.19

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,000 seeds/m² (low organic content) **OR** 500 seeds/m² (high organic content)

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Polargrass *Arctagrostis latifolia* (Alyeska or common)	**3,960,000**	Tolerant to low-nutrient, wet, and acidic soil, as well as permafrost. Do not use on alkaline soils. Spreads through rhizomes and often develops late in summer.
Violet wheatgrass *Elymus alaskanus* (common)	**330,000**	Tolerant to alkaline soils, drought and low nutrients; also has considerable tolerance to permafrost and moderate tolerance to saline soils and high elevations. Bunch forming with strong competitive ability.
Glaucous bluegrass *Poa glauca* (Tundra or common)	**2,904,000**	Tolerant to broad range of pH, drought, low nutrients, permafrost and high elevations. Forms low growing bunches with a high root-shoot ratio, spreads aggressively through rhizomes, rapid emergence in early spring.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	**3,300,000**	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost, wetness and high elevations. Bunch forming, strong competitive ability and can form extensive cover. Not drought tolerant.
Alpine bluegrass *Poa alpina* (Gruening or common)	**2,353,826**	Tolerant to mildly acidic conditions, low nutrients, permafrost and high elevations. Bunch forming, germinates quickly but not a strong competitor. Does not perform well when planted with annual ryegrass.
Spike trisetum *Trisetum spicatum* (common)	**5,500,000**	Tolerant to mildly acidic to mildly alkaline soils, drought, low nutrients, permafrost and high elevations. Short bunchgrass, good colonizer with vigorous seedlings that provide good initial cover.

Arctic Tundra and Stable Permafrost Sites

Table 5.20

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 1,000 seeds/m² (low organic content) **OR** 500 seeds/m² (high organic content)

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	Tolerant to acidic soils, low nutrients, limited drought. Tall sod-forming rhizomatous grass, strongly competitive, forms extensive cover. Despite its name, does not tolerate long periods of inundations.
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	Tolerant to strongly acidic soils, low nutrients, wetness. Tall rhizomatous bunchgrass, strong competitor on moist/wet soils.
Timothy *Phleum pratense* (Climax, Engmo)	**2,559,400**	Tolerant to acidic and alkaline soils. Grows best in cool, moist organic soils. Tall bunchgrass, rapid emergence, yields extensive cover. Wildlife attractant.
Kentucky bluegrass *Poa pratensis* (Nugget)	**3,057,648**	Tolerant to moderate acidity, cold temperatures and wet soils. Long-lived species. Sod-forming turf grass, can be grown as far north as the Arctic coast.
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	**539,407**	Tolerant to wide range of pH, permafrost and high elevations. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Sheep fescue *Festuca ovina* (common)	**1,100,000**	Tolerant to neutral or slightly acidic soils, drought, low nutrients and high elevations. Needs well-drained granular soil. Forms short bunches, slow growing, aggressive rhizomes.
FAST GROWING ANNUALS FOR RAPID SITE COVER AND NURSE PLANTS (Select one species, but not more than 10% of mix)		
Barley *Hordeum vulgare*	**29,920**	Moderately tolerant to alkaline and saline soils, drought. Wildlife attractant. Fast growing, extremely competitive.

Arctic Tundra and Stable Permafrost Sites — Table 5.21

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 500 - 1,000 seeds/m² (see text)

SPECIES	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
Collect any of the species listed in Table 5.19		
Northern rough fescue *Festuca altaica*	451,854	Tolerant to low nutrients, drought, high elevation and permafrost. Medium size bunchgrass with low seed yield, but spreads rhizomatously to form extensive cover as plants mature. Widespread, grows in open woods, alpine grasslands, tundra, at all elevations.
Arctic bluegrass *Poa arctica*	3,250,553	Tolerant to both acid and alkaline soils, mild drought. A medium stature loosely tufted, rhizominous bunchgrass. Widespread with many subspecies that grow in a wide range of tundra habitats, but mostly in dry to moist soils.
Northern bluegrass *Poa alpigena/Poa pratensis*	3,057,648	Tolerant to low nutrients and permafrost. Rhizomatous high root-shoot ratio and strong competitive ability.
Alpine sweetgrass *Hierochloë alpina*		Tolerant to drought and low nutrients. Short, grass with creeping rhizomes and strong competitive ability. Found on dry tundra and rocky alpine areas.
Nuttall's alkaligrass *Puccinellia nuttalliana*	4,648,140	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2 – 4 years). Mostly restricted to dry alkaline and saline areas.
Wormwood/sage *Artemisia* spp.	—	Tolerant to drought, low nutrients. Medium stature forb or short shrub. Wormwood species grow in a diversity of open/disturbed areas from riverbanks and grasslands to steep slopes and alpine/Arctic tundra. Mostly adapted to dry soils.
Arctic lupine *Lupinus arcticus*	22,733	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.
Mountain avens *Dryas* spp.	—	Tolerant to alkaline soils, drought, low nutrients. Matt-forming, low stature forb that grows in very poor soils and calciferous disturbed areas at all elevations, including scree slopes and gravel.

Arctic Tundra and Stable Permafrost Sites — Table 5.22

LOCALLY-COLLECTED WOODY SPECIES

SPECIES	REASONS TO USE AND RELEVANT CHARACTERISTICS
Willow *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	Only use in wet locations and only use the species listed. Willow is the main plant used for staking of live/dormant cuttings and for bioengineered structures.
Shrub birch *Betula glandulosa* *Betula nana*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to acid soils. Use on moist sites with good organic content.
Green alder *Alnus crispa*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to slightly acidic soils and low nutrients. Use on moist/wet sites that are not alkaline.

Scenario 7 **Alpine and Subalpine Sites**

Most high elevation sites in Yukon share a suite of characteristics that will affect plant growth and revegetation strategies: 1) very short growing season, 2) dry, well-drained substrates, 3) poorly developed or non-existent organic soils, 4) extreme nitrogen deficiency, and 5) coarse, granular substrates that often are rocky. Except near tree line, the natural vegetation usually is sparse, though plant diversity can be surprisingly high.

Permafrost may be present in any alpine or subalpine site in Yukon, though it seldom presents a problem because large bodies of ground ice generally do not form in coarse, granular (rocky), well-drained sediments (see discussion of permafrost and associated ice structures in Scenario 5). Even though portions of the ground can be perennially frozen and the active layer quite shallow, ice is mostly limited to small ice lenses and interstitial ice. Because ice forms a small percentage of the ground mass, and because the sediments have high competency, thermokarsting is seldom a problem in alpine and subalpine areas, even after a disturbance. Two possible exceptions to be aware of are relictual ice bodies in colluvium at the toe of slopes and mass wasting through solifluction.

Typical alpine/subalpine revegetation sites might include temporary drill pads, backfilled exploration trenches, decommissioned roads and trails, and areas damaged by off-road vehicle traffic. In these cases, runoff and erosion are the main site challenges.

Despite climatic and environmental hurdles, revegetation of alpine/subalpine sites can be quite successful. However, the higher the elevation, the more difficult it will be to establish new growth. The key is to choose the appropriate species for seeding and to apply fertilizer, though in modest amounts. Accordingly, species in the tables below have been selected for their a) ability to germinate in cold soils, b) rapid maturation in a short-growing season, c) tolerance to summer frost, and d) tolerance to nutrient-poor soils. Planners should choose from among species in the tables based mostly on the site's moisture level and pH (many of these sites will be very dry and alkaline, but not all).

Individual plants on alpine/subalpine sites should not be densely crowded because of competition for limited nutrients and water (even though fertilizer is applied as a boost in the first year, nutrients will become limiting in subsequent seasons). Therefore, it is important not to over-seed (maximum of 1,500 seeds/m^2) or over-fertilize alpine/subalpine sites (maximum of 50 kg/ha of N). Likewise, only sow annual grasses (maximum 10% of mix) where there is an erosion problem. Otherwise, they may impede the emergence of perennials.

These sites are prime candidates for collecting and sowing seeds of local forbs to recover the site's natural integrity. This is a realistic goal because the sites usually are small. In addition, local seeds in alpine/subalpine areas can be abundant and easy to collect. The genotypes of local plants also will have the greatest chance of survival, especially at higher elevations. Wetter subalpine sites can respond well to staked or transplanted shrubby species, but this strategy should only be used if the surrounding vegetation is shrubby.

Because of logistic limitations and ground sensitivity, much revegetation work on alpine/subalpine sites may have to be accomplished with hand tools, rather than motorized equipment. On large, road/trail-accessible sites, ATVs with small harrows and broadcast spreaders can be used quite effectively.

P. MATHEUS

FIG 5.11
Many alpine and subalpine sites are naturally dry and sparsely vegetated, though native plant diversity can be high. Tilling and decompacting are counterproductive on these sites because they bring rocks to the surface and dilute the already thin soils. It is important to test pH on alpine/subalpine sites. Many, but not all, will have alkaline soils. Use the descriptions in Chapter 6 to carefully choose species for these sites.

Site Preparation

- Generally, grading and decompacting granular surfaces on alpine/subalpine sites is not recommended. It is often impractical and counterproductive in terms of drainage, erosion and plant growth, because it can cause the thin layer of organics and soil to become buried deeper in the profile and bring rocky material to the surface.
- Access to the site may be limited, so much of the work may need to be done with hand tools rather than motorized equipment.
- If the project involves reclamation of exploration trenches or other diggings, they should be backfilled, either by hand or with available equipment. Likewise, materials in spoil piles should be spread.
- On the rare alpine/subalpine site with fine-textured sediments and road or trail access, mechanized equipment can be used to perform ground work and prepare seed beds.

Fertilizer and Organics

- Many alpine/subalpine sites will have surface coverings of coarse granular material, or even rock rubble. Seeds will have very low germination rates on course rock surfaces, so it is important to ensure that some fine materials, preferably high in organic content, are present on the surface, even if it is just a thin layer. If fine sediments and organics are absent, consider transporting them to the site.
- Backfill trenches and other diggings with the coarsest spoil materials first. Save fine sediments and organics for the surface of the backfill — they likely will be in short supply on the site and should not be buried in trenches.
- Fertilizer should be spread at a modest rate on alpine/subalpine sites. Aim for 50% of the calculated rates in Chapter 3. The reason for this is that plant growth in alpine/subalpine areas is often limited by cold soils, a short growing season, and low moisture just as much as by nutrient deficiencies. Plants limited by these other environmental factors may not be able to utilize higher amounts of fertilizer. In other cases, the boost of fertilizer may lead to a stand density that is not sustainable by the site once the fertilizer is exhausted.
- Work the fertilizer lightly into the ground with rakes (small sites) or with a tine/chain harrow pulled by an ATV where practical. Unlike lowland sites, it is usually better to work the ground as little as possible on alpine/subalpine sites.

Planting and Seed Mixes

- Do not attempt to sow seeds on sites covered only with coarse rock and no fine sediments. They will not germinate.
- Achieving good seed to soil contact and seed burial can be a challenge on these sites. After spreading seed, rake the site either by hand or, if practical, with a harrow pulled by an ATV. Even just driving over the seeds will help.
- Gauging the proper target density of seeds to sow will require careful judgement because germination and survival rates can be quite variable on alpine/subalpine sites. Germination and survival rates in general are low on cold, dry sites. Germination rates will be lowest on sites without good seed-to-soil contact. There may also be significant seed loss due to high winds or runoff. When conditions are optimal, seed at a rate of only 1,000 seeds/m^2 so growing plants are not crowded. If significant seed loss and mortality are likely, then seed at a rate of 1,500 seeds/m^2.
- Include 10% annual seeds in the mix only on sites that are prone to erosion. Otherwise, they will have a negative effect by competing with emerging perennials and native colonizers.
- It is critical to select species that are adapted to alpine/subalpine conditions, including the ability to germinate and mature in cold, nutrient-poor soils, and tolerate summer frosts and a short growing season. Drought-tolerance will be important on some sites, but not others. It is very important to test for pH and choose species accordingly.
- Collect and sow as many local seeds as possible because the genotypes growing near the site will have the highest chance of success, especially at higher elevations and in extreme environments. Consider also that forbs are as important as grasses in alpine communities, and the only way to sow seeds of forbs is to collect them locally.
- Shrubs will dominate the natural vegetation in some subalpine zones. Consider staking cuttings of locally-collected willow or seedlings of locally-collected shrub birch or alder, but only on subalpine sites that are very moist and have soils with at least 20% fine fractions.

Alpine and Subalpine Sites

Table 5.23

NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 750 - 1,500 seeds/m² (see text)

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Rocky Mountain fescue *Festuca saximontana* (common)	1,430,000	Tolerant to dry alkaline soils, low nutrients, permafrost and high elevations. Bunch grass with rapid emergence in early spring. Do not use on wet or acidic sites.
Violet wheatgrass *Elymus alaskanus* (common)	330,000	Tolerant to alkaline soils, drought and low nutrients; also has considerable tolerance to permafrost and moderate tolerance to saline soils and high elevations. Bunch forming with strong competitive ability.
Glaucous bluegrass *Poa glauca* (Tundra or common)	2,904,000	Tolerant to broad range of pH, drought, low nutrients, permafrost and high elevations. Forms low growing bunches with a high root-shoot ratio, spreads aggressively through rhizomes, rapid emergence in early spring.
Ticklegrass *Agrostis scabra* (common)	11,000,000	Tolerant to acidic soils, drought, low nutrients, and permafrost. Short-lived bunchgrass with early emergence. A common pioneering plant on dry flat ground.
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	3,300,000	Tolerant to extremely acidic soils, heavy metals, low nutrients, permafrost, wetness and high elevations. Bunch forming, strong competitive ability and can form extensive cover. Not drought tolerant.
Alpine bluegrass *Poa alpina* (Gruening or common)	2,353,826	Tolerant to mildly acidic conditions, low nutrients, permafrost and high elevations. Bunch forming, germinates quickly but not a strong competitor. Does not perform well when planted with annual ryegrass.
Spike trisetum *Trisetum spicatum* (common)	5,500,000	Tolerant to mildly acidic to mildly alkaline soils, drought, low nutrients, permafrost and high elevations. Short bunchgrass, good colonizer with vigorous seedlings that provide good initial cover.

Alpine and Subalpine Sites

Table 5.24

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS)

SEED AT A COMBINED RATE OF: 750 - 1,500 seeds/m² (see text)

SPECIES (cultivar)	**# OF SEEDS/KG**	**REASONS TO USE AND RELEVANT CHARACTERISTICS**
Creeping red fescue *Festuca rubra* (Arctared in northern Yukon) (Boreal in southern Yukon)	539,407	Tolerant to wide range of pH, permafrost and high elevations. Short loosely tufted bunchgrass, rapid emergence, aggressive rhizomes, strong competitor, forms extensive cover quickly.
Sheep fescue *Festuca ovina* (common)	1,100,000	Tolerant to neutral or slightly acidic soils, drought, low nutrients and high elevations. Needs well-drained granular soil. Forms short bunches, slow growing, aggressive rhizomes.
FAST GROWING ANNUAL FOR RAPID SITE COVER AND NURSE PLANTS (not more than 10% of mix; only use if erosion is a threat)		
Barley *Hordeum vulgare*	29,920	Moderately tolerant to alkaline and saline soils, drought. Wildlife attractant. Fast growing, extremely competitive.

Alpine and Subalpine Sites

Table 5.25

LOCALLY-COLLECTED, NATIVE HERBACEOUS SPECIES (SEEDS)

SEED AT A COMBINED RATE OF: 750 - 1,500 seeds/m^2 (see text)

SPECIES	# OF SEEDS/KG	REASONS TO USE AND RELEVANT CHARACTERISTICS
any of the species listed in Table 5.23		
Alpine sweetgrass *Hierochloë alpina*	—	Tolerant to low nutrients, permafrost, wet soil and high elevations. Bunch forming, low growing.
Mountain timothy *Phleum alpinum* (formerly *P. commutatum*)	—	Tolerant to wetness, permafrost and high elevations. Medium stature bunchgrass with creeping rhizomes. Grows in moist alpine areas.
Northern bluegrass *Poa alpigena/Poa pratensis*	**3,057,648**	Tolerant to low nutrients and permafrost. Rhizomatous and high root-shoot ratio, strong competitive ability.
Nuttall's alkaligrass *Puccinellia nuttalliana*	**4,648,140**	Tolerant to alkalinity up to pH 8.5, high salinity, drought, low nutrients. Short to medium height bunchgrass with rapid emergence, but is relatively short-lived (2-4 years). Mostly restricted to dry alkaline and saline areas.
Wormwood/sage *Artemisia* spp.	—	Tolerant to drought, low nutrients. Medium stature forb or short shrub. Wormwood species grow in a diversity of open/disturbed areas from riverbanks and grasslands to steep slopes and alpine/Arctic tundra. Mostly adapted to dry soils.
Arctic lupine *Lupinus arcticus*	**22,733**	Tolerant to low nutrients, permafrost, limited drought. A low-growing, nitrogen-fixing forb that provides a colourful flowering bloom. Grows mostly on moist soils in disturbed areas ranging from lowland riverbanks to alpine and tundra.
Mountain avens *Dryas* spp.	—	Tolerant to alkaline soils, drought, low nutrients. Matt-forming, low stature forb that grows in very poor soils and calciferous disturbed areas at all elevations, including scree slopes and gravel.

Alpine and Subalpine Sites

Table 5.26

LOCALLY-COLLECTED WOODY SPECIES

SPECIES	REASONS TO USE AND RELEVANT CHARACTERISTICS
Willow *Salix alaxensis*, *S. pulchra*, *S. planifolia*, *S. richardsonii*, *S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	Only use in wet locations and only use the species listed. Willow is the main plant used for staking of live/dormant cuttings and for bioengineered structures.
Shrub birch *Betula glandulosa*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to acid soils. Use on moist sites with good organic content.
Alder *Alnus crispa*	Only plant seedlings grown in a nursery from locally-collected seed. Tolerant to slightly acidic soils and low nutrients. Use on moist/wet sites that are not alkaline.

Summary of Recommended Species

Table 5.27

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS) AND APPLICABLE SCENARIOS

	SCENARIO	1	2	3	4	5	6	7
SPECIES (cultivar)	**# OF SEEDS/KG**	**LOW SLOPE, LOW-MID ELEVATION SITES**	**STEEP SLOPES**	**WET SITES**	**HIGHWAY RIGHT-OF-WAYS**	**DISTURBED PERMAFROST SITES**	**ARCTIC TUNDRA AND STABLE PERMAFROST SITES**	**ALPINE AND SUBALPINE SITES**
Rocky Mountain fescue *Festuca saximontana* (common)	1,430,000	x	x		x	x		x
Violet wheatgrass *Elymus alaskanus* (common)	330,000	x	x		x		x	x
Glaucous bluegrass *Poa glauca* (Tundra or common)	2,904,000	x	x		x		x	x
Slender wheatgrass *Elymus trachycaulus* (Revenue, Adanac, Highlander or common)	349,800	x	x		x			
Ticklegrass *Agrostis scabra* (common)	11,000,000	x				x		x
Tufted hairgrass *Deschampsia caespitosa* (Nortran or common)	3,300,000	x		x	x	x	x	x
Fowl bluegrass *Poa palustris* (common)	4,840,000	x		x	x	x		
Spike trisetum *Trisetum spicatum* (common)	5,500,000						x	x
Bluejoint reedgrass *Calamagrostis Canadensis* (Sourdough or common)	8,442,438	x		x		x		
Polargrass *Arctagrostis latifolia* (Alyeska or common)	3,960,000			x		x	x	
American sloughgrass *Beckmannia syzigachne* (Egan or common)	2,723,600			x		x		
Alpine bluegrass *Poa alpina* (Gruening or common)	2,353,826						x	x

Summary of Recommended Species

Table 5.28

NON-NATIVE HERBACEOUS SPECIES (COMMERCIAL SEEDS) AND APPLICABLE SCENARIOS

	SCENARIO	1	2	3	4	5	6	7
SPECIES (cultivar)	**# OF SEEDS/KG**	**LOW SLOPE, LOW-MID ELEVATION SITES**	**STEEP SLOPES**	**WET SITES**	**HIGHWAY RIGHT-OF-WAYS**	**DISTURBED LOWLAND PERMAFROST SITES**	**ARCTIC TUNDRA AND STABLE PERMAFROST SITES**	**ALPINE AND SUBALPINE SITES**
Kentucky bluegrass *Poa pratensis* (Nugget)	**3,057,648**			x			x	
Creeping red fescue *Festuca rubra* (Arctared for northern Yukon, Boreal for southern Yukon)	**539,407**	x	x		x	x	x	x
Canada bluegrass *Poa compressa* (Reubens or common)	**5,264,204**	x	x	x	x	x		
Streambank wheatgrass *Elymus lanceolatus* (Sodar)	**336,600**	x	x	x	x	x	x	
Meadow foxtail *Alopecurus pratensis* (common)	**895,136**	x	x	x	x	x	x	
Red top *Agrostis gigantea* (common)	**10,672,640**	x		x				
Timothy *Phleum pratense* (Climax, Engmo)	**2,559,400**			x		x	x	
Alfalfa *Medicago sativa* (Rangelander, Rambler or Peace)	**498,960**		x					
Sheep fescue *Festuca ovina* (common)	**1,100,000**	x			x	x	x	x
Annual rye *Lolium multiflorum*	**477,400**		x			x		
Barley *Hordeum vulgare*	**29,920**		x			x	x	x

Summary of Recommended Species

Table 5.29

LOCALLY-COLLECTED NATIVE HERBACEOUS SPECIES (SEEDS) AND APPLICABLE SCENARIO

	SCENARIO	1	2	3	4	5	6	7
SPECIES	**# OF SEEDS/KG**	**LOW SLOPE, LOW-MID ELEVATION SITES**	**STEEP SLOPES**	**WET SITES**	**HIGHWAY RIGHT-OF-WAYS**	**DISTURBED LOWLAND PERMAFROST SITES**	**ARCTIC TUNDRA AND STABLE PERMAFROST SITES**	**ALPINE AND SUBALPINE SITES**
Northern rough fescue *Festuca altaica*	451,854	x	x	x	x	x	x	
Yukon wheatgrass *Elymus calderi*	—	x						
Macrourum's wheatgrass *Elymus macrourus*	374,782	x	x					
Northern brome *Bromus pumpellianus*	202,400	x	x		x			
Sweetgrass *Hierochloë hirta* (formerly *H. odorata*)	242,000	x	x		x			
Alpine sweetgrass *Hierochloë alpina*	—						x	x
Mountain timothy *Phleum alpinum* (formerly *P. commutatum*)	—					x		x
Northern bluegrass *Poa alpigena/Poa pratensis*	3,057,648			x		x	x	x
Arctic bluegrass *Poa arctica*	3,250,553						x	
Nuttall's alkaligrass *Puccinellia nuttalliana*	4,648,140	x	x	x	x	x	x	x
Yellow locoweed *Oxytropis campestris*	521,400	x			x			
Showy locoweed *Oxytropis splendens*	1,548,800	x			x			
Bear root *Hedysarum alpinum*	154,000	x						
Mackenzie's hedysarum *Hedysarum Mackenzii*	101,889	x						
Yarrow *Achillea millefolium* and *Achillea sibirica*	6,274,426	x			x			
Mountain avens *Dryas* spp.	—	x			x	x	x	x
Arctic lupine *Lupinus arcticus*	22,733	x		x	x	x	x	x
Wormwood/sage *Artemesia* spp.	—	x	x		x		x	x

Summary of Recommended Species

Table 5.30

LOCALLY-COLLECTED WOODY SPECIES AND APPLICABLE SCENARIOS

SCENARIO / LOCAL WOODY SPECIES	1 LOW SLOPE, LOW-MID ELEVATION SITES	2 STEEP SLOPES	3 WET SITES	4 HIGHWAY RIGHT-OF-WAYS	5 DISTURBED LOWLAND PERMAFROST SITES	6 ARCTIC TUNDRA AND STABLE PERMAFROST SITES	7 ALPINE AND SUBALPINE SITES
Willow *Salix alaxensis, S. pulchra*, *S. planifolia*, *S. richardsonii, S. hastate*, *S. arbusuloides*, *S. lucida*, *S. pseudomyrsinites* (the two best species are *S. alaxensis* and *S. pulchra*)	x		x		x	x	x
Poplar *Populus balsamifera*	x		x				
Shrub birch *Betula glandulosa*	x		x			x	x
Dwarf birch *Betula nana*						x	
Green alder *Alnus crispa*	x		x			x	x
Grey alder *Alnus tenuifolia*	x		x				

6 Revegetation Species Descriptions

Alpine Bluegrass *Poa alpina* Native to Yukon

ALASKA PLANT MATERIALS CENTER, PALMER, AK

A. NERING, WILD ABOUT FLOWERS, AB

FORMER AND ALTERNATE SPECIES NAMES

None

GENERAL DESCRIPTION

A low growing (15 – 30 cm) strongly tufted perennial bunchgrass with a stout base and short, flat leaves. Long-lived, but somewhat slow-growing. Good colonizer, spreads by seeds rather than rhizomes. High root:shoot ratio. Found on dry slopes, meadows, rocky habitats, alpine and subalpine environments, dry arctic tundra.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes Canada, northern and alpine areas of the United States, including Alaska. Widespread in Yukon.

TOLERANCES AND RELEVANT TRAITS

An Arctic and alpine species tolerant to moderately acidic soils, low nutrients and drought. Moderate tolerance to saline soils. Performs well in areas with permafrost and at high elevations. Grows best in well-drained areas with coarse sediments, including rock, but will tolerate loam. Grows poorly when planted with annual ryegrass and in wet conditions or in very fine sediments. In rich soil, other species will outcompete alpine bluegrass. High palatability to wildlife.

USE IN REVEGETATION

Recommended for use on dry, acidic alpine and subalpine sites throughout Yukon and on arctic dry tundra. Germinates quickly and spreads well by seed, but not a very strong competitor. Therefore, do not plant with aggressive species like annual ryegrass or in wet conditions. An imperfect species for erosion control because it lacks creeping rhizomes, but its high root:shoot ratio is an asset.

SEEDS

The seeds are small.
Seeds per kg: 2,353,826

AVAILABLE CULTIVARS

The cultivar *Gruening* was developed in Alaska and is recommended for use in Yukon.

One cultivar has been developed in Alberta (*AEC Glacier Alpine*) but it has not been tested for use in Yukon. Alternatively, select "common" seed when purchasing seed from within Canada.

American Sloughgrass *Beckmannia syzigachne* Native to Yukon

B. BENNETT

FORMER AND ALTERNATE SPECIES NAMES

Beckmannia erucaeformis, Phalaris erucaeformis, sloughgrass

GENERAL DESCRIPTION

An annual (or weakly perennial) bunchgrass with high stature (up to 100 cm). Its dense, spikey florets and light green colour give the plant a distinctive look. Shallow roots, low root:shoot ratio. Functions as a colonizing grass of disturbed, wet meadows and sloughs that are subject to flooding. Establishes quickly (fast growing) and persists as a stand by self-seeding.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes Canada, most of northern and western United States, including Alaska. Widespread in Yukon.

TOLERANCES AND RELEVANT TRAITS

Adapted to wet, saturated soil conditions. Grows in acidic, neutral, alkaline, and saline soils as well as permafrost. Grows in almost any sediment type, but is adapted to poorly drained fine sediments (including clays). Performs poorly when planted in uplands.

USE IN REVEGETATION

Recommended for use in wet areas only. Outside Yukon, it is used primarily for wetland restoration. Will grow in almost any soil type (as long as it is wet) and can be used as far north as the Arctic Circle. Suitable for permafrost but only recommended for lowland sites. Generally will be replaced after 4 – 5 years by more competitive species. Can be an attractant to wildlife.

SEEDS

Seeds are small.
Seeds per kg: 2,723,600

AVAILABLE CULTIVARS

The cultivar *Egan* was developed in Alaska and is recommended for use in Yukon.

No cultivars have been developed in Canada. All seed in Canada is sold as "common".

Bluejoint Reedgrass *Calamagrostis canadensis* Native to Yukon

T. OMTZIGT

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Arundo canadensis, reedgrass, bluejoint, Canadian reedgrass, marsh pinegrass, meadow pinegrass

GENERAL DESCRIPTION

A perennial bunchgrass with high stature (up to 200 cm). This common, tall grass grows in and around forest openings, meadows and sloughs with abundant spring moisture. Initial growth form is in tufts, or even tussocks, but spreads by aggressive, creeping rhizomes. Is an aggressive colonizer and can become the dominant species if seeded too densely.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes Canada and most of the northern United States, including Alaska. Widespread in Yukon, but only abundant in seasonally moist-wet areas and therefore less common in southcentral Yukon.

TOLERANCES AND RELEVANT TRAITS

Needs good soil moisture but is tolerant to dry periods in summer. Tolerates acidic soils, slightly saline soils (pH 4.5 – 8.0), low nutrient conditions and partial shade (*i.e.*, light forest canopy). Will grow on permafrost ground. Performs exceptionally well on deep wet soils with good organic content.

USE IN REVEGETATION

Recommended for sites that are moist to wet for much of the early season. Once established it tolerates periods of summer dryness. Good choice for wet permafrost sites up to the Arctic Circle. Also should be considered for forest interfaces (it grows naturally in open woodlands). However, due to its aggressive spreading by rhizomes it can become the dominant species in a stand and choke-out other species, including woody plants. Therefore, consider limiting it to 10 – 20% of the seed mix, unless a pure stand of reedgrass is desired.

SEEDS

Seeds are very small and difficult to handle during planting, especially when mixed with larger seeds.
Seeds per kg: 8,442,438

AVAILABLE CULTIVARS

The cultivar *Sourdough* was developed in Alaska and is recommended for use in Yukon.

No specific cultivars have been developed in Canada; all seed in Canada is sold as "common".

Note: Second photo is *Calamagrotis stricta*, another native reedgrass with similar growth form.

Fowl Bluegrass *Poa palustris*

Native to Yukon

T. OMTZIGT

L. M. LANDRY

FORMER AND ALTERNATE SPECIES NAMES

Swamp meadowgrass, fowl meadowgrass

GENERAL DESCRIPTION

A loosely-tufted perennial bunchgrass with medium stature (30 – 70 cm) and fine erect stems. Grows in moist areas. Shallow-rooted but with rapid emergence and early spring growth. Can spread through stolons. Generally short-lived (3 – 5 years).

NATURAL DISTRIBUTION

Circumpolar, but limited to boreal and subarctic zones (non-arctic). North American distribution includes Canada and most of the United States, including Alaska. Widespread in Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to acidic soils (pH 4.9 – 7.5) and low nutrient conditions. Grows well in wet, fine soils. Will grow on permafrost. Not tolerant to drought or long periods of inundation. Palatable to wildlife.

USE IN REVEGETATION

Recommended for wet acidic sites with fine sediments, including poorly drained sites. Recommended for moist permafrost sites but not Arctic tundra. Quick-germinating species, but shallow-rooted and not aggressive, so not recommended for erosion control. Best used as a complimentary species in a wet-site seed mix as it usually only persists in a stand for three to five years.

SEEDS

Seeds are small and can be difficult to handle during planting, especially when mixed with larger seeds.
Seeds per kg: 4,840,000

AVAILABLE CULTIVARS

No cultivars have been developed and all seed grown in Canada is sold as "common".

Glaucous Bluegrass *Poa glauca*

Native to Yukon

YG ENVIRONMENT

ALASKA PLANT MATERIALS CENTER, PALMER, AK

FORMER AND ALTERNATE SPECIES NAMES

Blue meadowgrass, white bluegrass, timberline bluegrass

GENERAL DESCRIPTION

A low-growing perennial bunch grass with short stature (20 – 25 cm). Distinguished by its blue-green colour, spindly culms and leaves, and short dense tufts. Exhibits early spring growth. Spreads by seeds, not rhizomes, but still can develop into a semi-turf. Primarily a species of dry tundra and alpine-subalpine sites were it is competitive on well-drained ground, including gravel and slopes. A good pioneering grass that often establishes itself as isolated small tussocks on disturbed ground.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes Canada, western and northern United States, including Alaska. Widespread in Yukon, but most common in Arctic and subarctic areas and higher elevations.

TOLERANCES AND RELEVANT TRAITS

Tolerant to moderately acid to slightly alkaline soils (pH 5 – 8), low nutrient conditions and drought. Grows best in coarse, well-drained soils, including sand and gravel, but will grow in semi-moist conditions if not out-competed. Grows on permafrost ground and dry tundra conditions, and is a good competitor on high elevations sites.

USE IN REVEGETATION

Recommended for a wide range of sites in northern and southern Yukon, but especially suited for well-drained alpine/subalpine sites and dry tundra sites. Not a good choice for wet tundra. Tolerates a moderate range of pH, but performs best on acidic to neutral soils. Good competitor on sites with course sediments. Its ability to form a loose turf leads to good ground cover and erosion control.

SEEDS

Seeds are small
Seeds per kg: 2,904,000

AVAILABLE CULTIVARS

The cultivar *Tundra* was developed in Alaska and is recommended for use in Yukon. It is produced commercially in Alaska and western Canada

"Common" seed is also available from Canadian suppliers. Some is grown from seed collected in Yukon, but check with the seed supplier to ensure the actual origin of the seed.

Polargrass *Arctagrostis latifolia*

Native to Yukon

A. CESKA

A. CESKA

FORMER AND ALTERNATE SPECIES NAMES

Arctagrostis arundinacea, *A. anugstifolia*, *A. macrophylla*, *A. poaeoides*.

GENERAL DESCRIPTION

A perennial grass with variable stature (25 – 140 cm). Initially grows in solitary tufts and then spreads both rhizomatously and by seed. Often shows maximum growth in late summer. Found on damp and turfy tundra, heathland, open woodlands and along rivers. Often functions as a colonizer of disturbed areas.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes much of Canada and Alaska. Found throughout Yukon, but mostly on acidic tundra.

TOLERANCES AND RELEVANT TRAITS

Only grows on acidic soils (pH 4.9 – 6.8). Tolerant to low nutrient conditions and performs well in wet areas with permafrost. Poor drought tolerance. Grows on a wide range of sediment types, from fine silts to coarse sand and gravel. Wildlife attractant – it is a preferred forage of bears in summer.

USE IN REVEGETATION

Use should be limited to cool, wet acidic sites. It is particularly suited for use in lowland permafrost areas and wet tundra in northern Yukon. Do not use on alkaline sites. Even though the commercial seed is sourced from Alaska (no Canadian seed source), polargrass should be a constituent of any seed mix for wet acidic tundra.

SEEDS

Seeds are small.
Seeds per kg: 3,960,000

AVAILABLE CULTIVARS

The cultivar *Alyeska* was developed in Alaska and is recommended for use in Yukon.

At this time no Canadian seed source is available and seed would need to be sourced from Alaska.

Rocky Mountain Fescue *Festuca saximontana*

Native to Yukon

C. HOUWERS, BURNABY, BC

FORMER AND ALTERNATE SPECIES NAMES

This species has had a history of debated taxonomy. It has been incorrectly referred to or included as a sheep fescue (*Festuca ovina* subsp. *saximontana*) and alpine fescue (*Festuca brachyphylla* subsp. *saximontana*). See additional taxonomic notes in the description of sheep fescue.

GENERAL DESCRIPTION

A bluish-grey-green, densely-tufted, perennial bunch grass with short stature (20 – 50 cm). Rapid emergence in early spring but does not spread significantly by rhizomes. Found in a range of dry alkaline habitats, particularly mountain slopes and alpine fell fields.

NATURAL DISTRIBUTION

North America and Greenland. Found in most of Canada (especially western Canada); western and northern United States, including interior and southcentral Alaska. Widespread in southern and central Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to dry alkaline soils, low nutrient conditions, permafrost and high elevation. Will grow in very dry conditions. Rapid emergence and growth, early spring development. Not well-adapted to acidic or wet soils.

USE IN REVEGETATION

Recommended for use on dry alkaline sites, especially those in alpine or subalpine settings. A proven species for revegetation work in southern and central Yukon, but can be outcompeted by other species on moist sites. Not recommended for use in northern Yukon, moist tundra, or acidic soils. Include this species as the principle fescue in a mix when seeding a dry alpine/subalpine site that is alkaline.

SEEDS

Seeds are average to small size for a grass.
Seeds per kg: 1,430,000

AVAILABLE CULTIVARS

Two cultivars have been developed in Alberta, *ARC Butter* and *ARC Plateau*, but they have not been tested for use in Yukon. Alternatively, select "common" seed when purchasing seed within Canada.

Slender Wheatgrass *Elymus trachycaulus* Native to Yukon

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Agropyron trachycaulus, Agropyron pauciflorum, slender wild rye, bearded wheatgrass

GENERAL DESCRIPTION

A medium to high stature (30 – 90 cm), loosely-tufted perennial bunchgrass. Leaves are flat, prone to drooping slightly when mature, and can be reddish to purplish at the base. Short non-aggressive rhizomes; mostly spreads by seed. A pioneering grass on dry to moist ground in subalpine meadows, along riverbanks on hillsides and in some open forests. Growth form and size of plants is variable; smaller when growing in alpine. Relatively short-lived (3 – 5 years).

NATURAL DISTRIBUTION

North America and Greenland. Found throughout Canada as well as most of the United States (except the southeast), including Alaska. Widespread in Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to alkaline soils up to pH 9.0; also tolerates neutral and slightly acidic soils to pH 5.6, as well as saline soils. Tolerates moderately low nutrient conditions. Grows in dry to moist soils and tolerates moderate drought, but not a strong performer on extremely dry sites and not suited for wet sites. Grows well in any sediment that retains moisture (mostly loams). Performance declines with elevation and does not grow particularly well on permafrost sites.

USE IN REVEGETATION

Recommended for low-elevation alkaline or neutral pH sites throughout Yukon that tend towards dryness. Should be a major component of any mix seeded on saline sites. Responds well to moisture and fertilizer. Should be used cautiously on well-drained sites with coarse sediments, as they may be too dry. Germinates and establishes quickly, making it good for erosion control, but it is short-lived so should be planted with slow-growing species that will replace it after 3 – 5 years. Not recommended for permafrost, alpine/subalpine, or tundra sites.

SEEDS

The large-sized seeds are easy to handle during planting.
Seeds per kg: 349,800

AVAILABLE CULTIVARS

Adanac, *Revenue* and *Highlander* are recommended for use in Yukon. Common seed can also be used. *Adanac* is particularly tolerant to saline soils.

In Alaska, the cultivar *Wainwright* was developed in 1994 and now is one of the main revegetation species used in that state (Some botanists question whether the original seeds collected near Fairbanks were from a native population or one that had been introduced from elsewhere in North America).

Taxonomic note on wheatgrasses and the genus *Elymus*: The wheatgrasses are more properly termed "wild rye", which should not be confused with "ryegrass" (*Lolium*). While formerly assigned to the genus *Agropyron*, all species of wild rye native to Yukon are now placed in the genus *Elymus*. Note that most commercial seed is still labelled "wheatgrass" and sold under the genus *Agropyron*. For instance, slender wheatgrass is sold as *Agropyron trachycaulus*.

Spike trisetum *Trisetum spicatum* Native to Yukon

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

None

GENERAL DESCRIPTION

A short (10 – 50 cm) but erect perennial bunchgrass with a spiked appearance. Size and growth is highly variable and dependent on climate and elevation. Strongly tufted, weakly rhizomatous, mostly spreads by seed. Is found on dry tundra and dry alpine/subalpine slopes, meadows and ridges to at least 2,000 m. Often grows near high-elevation snow patches. Functions as an early colonizing species.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes Canada, Alaska, western United States. Widespread throughout Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to drought, low nutrient conditions and a pH range of 5.5 – 8.0. Grows best on coarse, well-drained sediments and will perform well on poorly developed shallow soils. Adapted to cold summers and extremely short growing seasons. Grows well on high elevations sites, dry tundra and on permafrost ground. A good pioneer plant of disturbed ground in those settings.

USE IN REVEGETATION

A special purpose plant recommended for dry, neutral pH, alpine/subalpine and dry tundra sites. Not recommended for use on poorly-drained fine soils or lowland setting where it will be outcompeted. Seedlings are vigorous when not outcompeted, providing good initial cover and erosion protection. But it spreads by seeds and will not spread rhizomatously to fill-in bare ground.

SEEDS

Seeds are small and can be difficult to handle during planting, especially when mixed with larger seeds.
Seeds per kg: 5,500,000

AVAILABLE CULTIVARS

ARC Sentinel is a cultivar of Alberta origin, but the performance of this variety in Yukon is not known. Alternatively, "common" seed can be used.

Ticklegrass *Agrostis scabra* Native to Yukon

T. OMTZIGT

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Rough bentgrass, hair bentgrass, hairgrass, rough hairgrass (note that the next species, tufted hairgrass (*Deschampsia caespitosa*) is a true hairgrass)

GENERAL DESCRIPTION

A low to medium stature (up to 50 cm), perennial bunchgrass with numerous narrow basal leaves. Forms small, dense tufts that do not spread rhizmatously; spreads by seed (seedheads break off and roll like tumbleweeds). A very common pioneering species found on disturbed ground of dry-moist open slopes and flat alluvial areas at low to mid elevations. Shows early spring growth and is often relatively short-lived (3 – 5 years).

NATURAL DISTRIBUTION

North American. Found in Canada, Alaska and most of the United States. Widespread throughout Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to very acidic soils (down to pH 4.0), heavy metals, and low nutrient conditions. Moderately saline-tolerant, and moderately drought tolerant but responds well to moist soils and fertilizer. Not flood-tolerant. Will grow on permafrost ground and at moderate elevations.

USE IN REVEGETATION

Recommended for dry to moist acidic sites with fine or coarse sediments. Not recommended for very dry sites. Capable of forming thick cover quickly. While permafrost-tolerant, it is not recommended for tundra sites in northern Yukon. Only use at higher elevations when the site is moist. Tolerance to heavy metals and very acidic sites makes ticklegrass suitable for use in mine reclamation.

SEEDS

The seeds are very small and difficult to handle during seeding, especially when mixed with larger-sized seeds.
Seeds per kg: 11,000,000

AVAILABLE CULTIVARS

No cultivars for specific use in the north have been developed. All seed in Canada is sold as "common".

Tufted Hairgrass *Deschampsia caespitosa* Native to Yukon

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Hairgrass, blue-green hair-grass, fescue-leaved hairgrass, salt and pepper grass, tussock grass

GENERAL DESCRIPTION

A medium stature (40 – 70 cm) strongly tufted perennial bunchgrass. Variable in size and stature depending on site conditions. Spreads by seed; rhizomes not aggressive. Is often found in moist areas such as meadows, draws, lakeshores, but will grow in almost any soil with moderate moisture. Grows from sea level to 4,200 m but performs best above 1,000 m.

NATURAL DISTRIBUTION

Northern hemisphere. One of the most widely distributed grasses on earth. North American distribution includes Canada, Alaska and most of the United States. Widespread throughout Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to acidic soils (pH 3.3 – 7.5), heavy metals, low nutrients, and a variety of moisture conditions. Tolerates seasonal flooding. Not very saline-tolerant and drought tolerance is moderate. Prefers fine to medium sediments but will grow on sands and gravels, especially when competition is low. Grows at high and low elevations and on permafrost ground. Strongly competitive and capable of producing extensive ground cover, but not a fast grower. Has a long lifespan and produces a lot of seed but functions mostly as a pioneer plant rather than forming permanent stands. Responds well to frost-seeding.

USE IN REVEGETATION

One of the most versatile revegetation species available for use in Yukon. Grows under a wide range of conditions and is recommended for all but the very driest sites. Its roots do not bind soil well, so it is not recommended for erosion control on steep banks. Grows best in moist soils but also performs acceptably on dry soils. Performs well in mine reclamation due to its tolerance of acidic, low nutrient soils and heavy metals.

SEEDS

The seeds are fairly small.
Seeds per kg: 3,300,000

AVAILABLE CULTIVARS

The cultivar *Nortran* was developed in Alaska and is recommended for use in Yukon (note that the Alaskan cultivar *Norcoast* was developed for application on Alaska's southern coast and is not appropriate for Yukon).

Nortran is also grown in Canada. Alternatively, common seed can also be used.

Violet Wheatgrass *Elymus alaskanus*

Native to Yukon

YG ENERGY, MINES & RESOURCES

FORMER AND ALTERNATE SPECIES NAMES

Agropyron violaceum, *Elymus violaceum*, Alaskan wheatgrass. Recent taxonomic revisions classify *E. violaceum* as a subspecies of *E. alaskanus*. Most suppliers still sell wheatgrass species under the genus *Agropyron* – see taxonomic note for the genus in the description of slender wheatgrass.

GENERAL DESCRIPTION

A medium to tall stature (30 – 100 cm), loosely tufted perennial bunchgrass. Strongly competitive species that produces extensive cover with a high root-shoot ratio. Natural colonizer of well-drained sandy to gravely soils at high and low elevations.

NATURAL DISTRIBUTION

Circumpolar. North American distribution includes most of Canada, Alaska, and much of western United States. Widespread throughout Yukon.

TOLERANCES AND RELEVANT TRAITS

Tolerant to alkaline soils, moderately saline soils, and low nutrient conditions. Not flood tolerant. Performs well in drought conditions and will grow on permafrost ground. Not particularly alpine-adapted but will grow at mid to high elevations. Not much autecological data exists for violet wheatgrass, but it has proven to be a hardy native grass well-suited to Yukon conditions.

USE IN REVEGETATION

Recommended for most types of dry, alkaline sites, including slopes. Can be included in mixes for subalpine, tundra (dry, alkaline), and northern Yukon sites. Good for erosion protection because it produces good ground cover quickly and a root system that holds soil well. A hardy and versatile species for revegetation work in Yukon. Also worth using because the foundation seed for commercial production was collected in Yukon.

SEEDS

The large-sized seeds are easy to handle during seeding.
Seeds per kg: 330,000

AVAILABLE CULTIVARS

No cultivars have been developed, but the foundation seed originates from Yukon. All seed in Canada is sold as "common" but can be traced to these Yukon collections. Check with the seed supplier to ensure the actual origin of the seed.

Alfalfa *Medicago sativa*

Not Native to Yukon

YG ENERGY, MINES & RESOURCES

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Lucerne (not to be confused with true Lucerne which is yellow alfalfa (*Medicago falcata*)).

GENERAL DESCRIPTION

A medium to high stature (40 – 100 cm), perennial legume with purple flowers. Long-lived and rhizomatous with ability to form extensive cover. A native of Eurasia, this plant was imported as an animal forage crop and is generally only seeded in agricultural fields.

NATURAL DISTRIBUTION

Native to Eurasia. Imported as a cool season forage crop for hay and pasture. Grown extensively in portions of North America as a forage crop.

TOLERANCES AND RELEVANT TRAITS

Tolerates mildly acidic to alkaline soils (pH 6.0 – 8.5) and drought conditions. As a nitrogen fixer it grows well in low nutrient soils. It is a persistent species but is not considered invasive because it does not spread on its own. Can be a strong wildlife attractant.

USE IN REVEGETATION

Recommended use is limited to slopes that are very difficult to revegetate. Alfalfa will often gain a foothold on slopes where nothing else will, especially dry, nutrient-poor slopes. Do not add to highway right-of-way mixes because of its attractiveness to wildlife.

SEEDS

The large-sized seeds are easy to handle during seeding.
Seeds per kg: 498,960

AVAILABLE CULTIVARS

The cultivars *Rangelander*, *Rambler* and *Peace* are recommended for use in Yukon.

Do not select yellow alfalfa (lucerne, *Medicago falcata*) as it is considered to be an invasive species in Yukon and can spread aggressively.

Annual Ryegrass *Lolium multiflorum* — Not Native to Yukon

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Lolium perenne ssp. *multiflorum*, annual rye, Italian ryegrass

GENERAL DESCRIPTION

A medium to high stature (50 – 100 cm), annual or biennial bunchgrass. Strongly competitive, very fast growing. Can produce a heavy plant cover depending on seeding density. Grows on a wide range of soils. Widely used as an agricultural forage crop and as a restoration/revegetation species.

NATURAL DISTRIBUTION

Native to Europe. Introduced to North America as a forage crop and widely used for pastures and lawns.

TOLERANCES AND RELEVANT TRAITS

Tolerates acidic to neutral soils (pH 5 – 8) and a range of conditions but grows best on fine, moist soils. Performs moderately well in wet soils, but does not withstand very hot, dry weather or severe cold. Responds very well to fertilizer and soils with high organic content. Do not frost-seed, as it has poor cold tolerance. Annual ryegrass is allelopathic (its roots excrete compounds that impede the growth of other plants) and an extremely strong competitor. Palatable to wildlife.

USE IN REVEGETATION

Along with barley, annual ryegrass is used for two purposes in revegetation: as a nurse crop for perennials and to establish rapid site cover for erosion control. Because it establishes rapidly, annual ryegrass can be used on disturbed permafrost sites and slopes as a stabilizing measure. However, it is not recommended for use in northern Yukon because it has poor cold-tolerance. A strong competitor, it will choke-out other species in the seed mix if planted too heavily; therefore seed mixes should not contain more than 10% annual grasses. Individual plants die after one year (sometimes two), after which they contribute organic material and structure to the soil.

SEEDS

The large-sized seeds are easy to handle during seeding.
Seeds per kg: 447,400

AVAILABLE CULTIVARS

Several cultivars are available but none are certified because it is difficult to maintain the genetic purity of this species. Also, no specific cultivar is recommended since the species is not meant to persist more then one season.

Barley *Hordeum vulgare* — Not Native to Yukon

R. OLD, XID SERVICES, PULLMAN, WA

FORMER AND ALTERNATE SPECIES NAMES

Common barley. Not to be confused with meadow barley, *Hordeum brachyantherum*, or foxtail barley/squirrel grass, *Hordeum jubatum*, which are native to Yukon.

GENERAL DESCRIPTION

A slightly tufted annual grass with tall stature (60 – 100 cm) and distinguished by its erect spiked inflorescence. It is widely cultivated (and most readily recognized) as a cereal crop in agricultural fields.

NATURAL DISTRIBUTION

Native to Eurasia. Introduced to North America and widely used as an agricultural crop.

TOLERANCES AND RELEVANT TRAITS

This species is moderately tolerant to drought, as well as acidic, alkaline (pH 5.5 – 8.5) and saline soils. Tolerates cold sites better than annual rye. Its shallow roots spread laterally and bind soil well on erosion-prone sites. It is palatable to wildlife and acts as a wildlife attractant.

USE IN REVEGETATION

Along with annual ryegrass, barley is used for two purposes in revegetation: as a nurse crop for perennials and to establish rapid site cover for erosion control. Because it establishes rapidly, barley can be used on disturbed permafrost sites and slopes as a stabilizing measure. Unlike annual ryegrass, it is suitable for use in northern Yukon because it has better cold-tolerance. A strong competitor, it will choke-out other species in the seed mix if planted too heavily, but not to the same extent as annual ryegrass; therefore seed mixes generally should not contain more than 10% annual grasses. Elsewhere, barley is planted at higher densities for erosion control. One successful strategy is to plant only barley in the first year and follow-up with a second planting of perennial grasses in the second year.

SEEDS

The very large seeds are easy to handle during seeding.
Seeds per kg: 29,920

AVAILABLE CULTIVARS

Several cultivars are available but no specific cultivar is recommended since the species is not meant to persist more than one season.

Canada Bluegrass *Poa compressa*

Not Native to Yukon

R. OLD, XID SERVICES, PULLMAN, WA

FORMER AND ALTERNATE SPECIES NAMES

None

GENERAL DESCRIPTION

A low to medium stature (15 – 60 cm), perennial sod-forming (weakly tufted) grass. Recognizable by its flattened culms (stems) and bluish-green colour. Forms an extensive creeping root and rhizome network that can yield extensive ground cover (high root:shoot ratio), but it can be slow to establish. Normally functions as a pioneer plant rather than establishing permanent stands. Used as a pasture grass and for lawns.

NATURAL DISTRIBUTION

Native to Eurasia, despite its name. Introduced widely throughout North America as a forage crop on dry pastures with poor soils. Still used as a forage crop and in lawns/landscaping.

TOLERANCES AND RELEVANT TRAITS

Tolerant to acidic soils, mildly alkaline soils (pH 5 – 8), mildly saline soils, and moderate drought. Often grows in poor soils where other plants fail to take hold. Grows best in fine sediments, but will tolerate coarser sediments.

USE IN REVEGETATION

Recommended for many applications, except alpine/subalpine sites and arctic tundra. While drought tolerant, it grows far better in moist soils. Relative to other species, it is a good performer on poorly drained, low-nutrient, clay-rich sites. Competes poorly on well-drained and sandy soils. Has a history of being used on mine tailings because of its tolerance to strong acid soils. Good erosion control species because of its fibrous roots, rhizomatous spreading and ability to form extensive cover.

SEEDS

The seeds are small.
Seeds per kg: 5,264,204

AVAILABLE CULTIVARS

The *Reubens* cultivar is recommended for use in Yukon.

Creeping Red Fescue *Festuca rubra*

Available Commercial Seed is Not Native to Yukon

YG ENERGY, MINES & RESOURCES

FORMER AND ALTERNATE SPECIES NAMES

Red fescue, Arctic red fescue

At least three native fescues in Yukon have been referred to as "creeping red fescue", including *F. rubra*, *F. richardsonii*, and *F. rubra* ssp. *arctica* (all three and others may be related subspecies and capable of hybridizing). However, the commercial seed that is sold as "creeping red fescue" probably should not be considered native. The cultivar *Boreal* (the principle cultivar sold in western Canada) was developed in Alberta, but from European germplasm. The cultivar *Arctared* was developed in Alaska, but from germplasm of uncertain origin (it may also be European).

GENERAL DESCRIPTION

A short to medium stature (20 – 60 cm), perennial, sod-forming grass. Distinguished by its extremely fine, bright green leaves. Variable in its morphology, which responds to local conditions. Loosely tufted or matted with strong sod forming habits. Spreads rhizomatously, is a strong competitor and can produce extensive cover. Deep rooted for a sod-forming grass. A natural colonizer of disturbed areas and long-lived.

NATURAL DISTRIBUTION

Circumpolar. Widespread in North America. Used as commercial forage crop for hay and pasture production on marginal lands; also used for lawns.

TOLERANCES AND RELEVANT TRAITS

Tolerant to acid soils (pH 4.5 – 7.5), heavy metals, low nutrients and drought, though it responds well to moist soils and can withstand periods of flooding. Moderately tolerant of weakly saline soils. Will grow well on permafrost ground and at high elevations.

USE IN REVEGETATION

Recommended for most types of applications in Yukon except for very wet sites. Prefers acidic, well-drained, sandy soils. Will grow on gravel. Responds well to fertilizer. Good for erosion-control due to its deep roots and strong rhizomatous growth habits. Its aggressive, sod-forming nature can be used to keep shrubs or trees from invading roadsides, but its aggressiveness can be problematic if trying to establish high species diversity. Has a successful history in mine reclamations because of its tolerance to acid soils and heavy metals.

SEEDS

The large-sized seeds are easy to handle during seeding.
Seeds per kg: 539,407

AVAILABLE CULTIVARS

Both cultivars recommended for use in Yukon were likely developed from non-native plants.

Arctared was developed in Alaska and should be used in northern Yukon.

The germplasm used to develop *Boreal* is from Europe, but is suitable for use in central and southern Yukon.

Kentucky Bluegrass *Poa pratensis* ssp. *pratensis* Available Commercial Seed is Not Native to Yukon

R. OLD, XID SERVICES, PULLMAN, WA

R. OLD, XID SERVICES, PULLMAN, WA

FORMER AND ALTERNATE SPECIES NAMES

Poa alpigena, Poa agassizensis, smooth meadow grass. The subspecies *P. pratensis* ssp. *alpigena* and *P. pratensis* ssp. *colpodea* are native to Yukon. However, the only commercial seed available is from *P. pratensis* ssp. *pratensis* (including the recommended cultivar *Nugget*), which was introduced from Eurasia.

GENERAL DESCRIPTION

A sod-forming perennial grass with medium to high stature (30 – 80 cm), though the native subspecies is short (20 – 30 cm). Rhizomatous with ability to form extensive cover, but shallow-rooted. Long-lived.

NATURAL DISTRIBUTION

The species is circumpolar and native to Yukon (*P. pratensis* ssp. *alpigena*), but the subspecies available as commercial seed is derived from the Eurasian subspecies *P. pratensis* ssp. *pratensis*. It was imported mostly as a lawn grass. The seeded plants may hybridize with native populations.

TOLERANCES AND RELEVANT TRAITS

Known for its tolerance to cool, moist/wet soils. Will tolerate limited drought and limited flooding. Best performance is in fine-grained (clayey-loamy) calcareous soils with neutral pH (6 – 7.5). Performs better on mineral soil than organic-rich soil and is extremely responsive to nitrogen fertilizing, especially when soils are moist. A somewhat weak competitor and can be slow to establish, unless fertilized.

USE IN REVEGETATION

Often considered to be more of a "reclamation" species than a "revegetation" species, Kentucky bluegrass is only recommended for special applications in Yukon. Performs well on cool, moist sites with acidic mineral soils that are fine-grained, but it has the tendency to become persistent. Has difficulty establishing when planted with many other species, so it should only be used in mixes with two to three other species. Sites seeded with Kentucky bluegrass should be fertilized. Very adaptive to cold sites – the native subspecies grows on the Arctic coast – but generally it is not recommended for alpine/subalpine sites because the soils are usually coarse and dry. Has been shown to grow well on mine sites with heavy metals, and has been used as a reclamation species on diesel-contaminated sites. When used in these applications, Kentucky bluegrass should be the dominant species in the mix.

SEEDS

The seeds are small.
Seeds per kg: 3,057,648

AVAILABLE CULTIVARS

Nugget is the only cultivar recommended for use in Yukon. It was developed in Alaska.

Meadow Foxtail *Alopecurus pratensis* Not Native to Yukon

R. OLD, XID SERVICES, PULLMAN, WA

FORMER AND ALTERNATE SPECIES NAMES

Foxtail

GENERAL DESCRIPTION

A medium to tall stature (60-130 cm), weakly-tufted perennial bunchgrass. Its growth form and seed head make meadow foxtail superficially resemble timothy grass. Spreads mostly by seeds but can form a loose turf through rhizomatous and stoloniferous propagation over time.

NATURAL DISTRIBUTION

Native to Eurasia. Introduced to North America as a cool season forage crop (hay and pasture), it is still widely planted in Canada and the northern United States.

TOLERANCES AND RELEVANT TRAITS

Tolerant to acidic soils (pH 4.5 – 7.5) and brief flooding. Not very drought tolerant. Performs best on moist, fine soils that are neutral or acid. Has good cold tolerance, but does not grow well at high elevation.

USE IN REVEGETATION

Recommended for use on moist to wet, acid or neutral sites with deep, fine soils. Can be used on permafrost ground and steep wet banks, but use should be limited to low and mid elevation sites. Will grow on wet tundra.

SEEDS

The fairly large-sized seeds are easy to handle during seeding.
Seeds per kg: 895,136

AVAILABLE CULTIVARS

No cultivars have been developed with specific application to the north. All seed in Canada is sold as "common".

Red Top *Agrostis gigantea*

Not Native to Yukon

R. OLD, XID SERVICES, PULLMAN, WA

R. OLD, XID SERVICES, PULLMAN, WA

FORMER AND ALTERNATE SPECIES NAMES

Red top bentgrass, carpet bentgrass

GENERAL DESCRIPTION

A sod-forming, perennial grass with variable stature (up to 50 – 80 cm, but usually shorter). Gets its name from the red colour of the loose panicle (seedhead). Shallow-rooted but spreads by creeping rhizomes and can form a dense turf.

NATURAL DISTRIBUTION

Eurasia and North Africa. Introduced to North America as a cool season grass for lawns, pastures and hay. Has become widespread in Canada as well as northern and western United States. It is still planted for lawns and hay production.

TOLERANCES AND RELEVANT TRAITS

Tolerant to very acidic soils (pH 4.5 – 7.0), nutrient poor soils, and heavy metals. Not drought-tolerant, but can withstand extended periods of flooding. Grows well on moist/wet sites with fine sediments, especially poorly drained clays and loams.

USE IN REVEGETATION

Recommended for acidic, nutrient-poor sites that are moist/wet, at low elevation, and have poorly-drained fine sediment structure. Good for erosion control on moist/wet sites. Recommended for mine reclamation because of its tolerance to acidic soils and heavy metals. Does not always establish quickly when seeded, but once some plants are established they spread quickly.

SEEDS

The seeds are very small.
Seeds per kg: 10,672,640

AVAILABLE CULTIVARS

No cultivars have been developed with specific application to the north. All seed in Canada is sold as "common".

Sheep Fescue *Festuca ovina*

Not Native to Yukon

S. FROEHLICH, PRAIRIE ORIGINALS, MB

FORMER AND ALTERNATE SPECIES NAMES Hard fescue

Festuca ovina is native to Eurasia, but it resembles many tufted, fine-leaved fescues in North America, some of which have been wrongly ascribed to "sheep fescue". This has led to some taxonomic confusion and the question of whether "sheep fescue" is native to North America. It is not native, and the commercial seed sold as "sheep fescue" in North America is derived from the Eurasian species *Festuca ovina*. *Festuca brachyphylla* (alpine fescue) is a closely related species that resembles sheep fescue and is native to Yukon. It would be an ideal native fescue to plant on acidic alpine/subalpine sites but its seed is not commercially available.

GENERAL DESCRIPTION

A fine-textured, grey-green, densely tufted, perennial bunchgrass with low stature (15 – 30 cm). Grows on sandy and rocky ground on tundra and on alpine/subalpine fell fields to at least 2,300 m. Forms a dense root system but does not spread rhizomatously.

NATURAL DISTRIBUTION

Native to Eurasia but introduced widely in North America for landscaping and erosion control. Similar looking native fescues in North America may be called "sheep fescue" but are not *Festuca ovina*. All commercial seed is derived from the Eurasian species.

TOLERANCES AND RELEVANT TRAITS

Tolerant to slightly acidic to neutral soils (pH 5.5 – 7.5), dry soils and low nutrient conditions. Shows moderate tolerance to heavy metals. Does not grow well in fine sediments or either alkaline or saline soils. Somewhat shade tolerant. Is outcompeted by other plants in moist, lowland environments. Long-lived but slow-growing and not very large. However, it produces good soil-holding ground cover.

USE IN REVEGETATION

Recommended for dry, slightly acidic to neutral pH sites with sandy to gravely soils. Include this fescue in a mix when seeding alpine/subalpine sites that are acidic or neutral pH, but choose *F. saximontana* for alkaline sites. Not a fast or aggressive grower, so not recommended for immediate erosion protection on steep slopes. However, its dense root mass provides good long-term erosion protection. Often co-seeded with taller, short-lived grasses for a mix that provides both short and long-term ground stability. Has been used with success in mining reclamation because of it tolerance to acidic conditions and heavy metals.

SEEDS

The seeds are average to small sized.
Seeds per kg: 1,100,000

AVAILABLE CULTIVARS

No cultivars for use in the north have been developed. All seed in Canada is sold as "common".

Streambank Wheatgrass *Elymus lanceolatus*

May be Native to Yukon

C. SKINNER, USDA-NRCS PLANTS ATABASE

S.HAGWOOD, USDA-NRCS PLANTS DATABASE

FORMER AND ALTERNATE SPECIES NAMES

Thickspike wheatgrass. See note on the genus *Elymus* under the description of slender wheatgrass. Yukon wheatgrass (*Elymus calderi*) is a closely related species or subspecies of *Elymus lanceolatus*. When streambank wheatgrass is seeded, it may hydridize with native Yukon wheatgrass.

GENERAL DESCRIPTION

Perennial, long-lived, sod-forming grass with low to medium stature (30-80 cm). Spreads aggressively by rhizomes but has thin leaves and stems so yields relatively less above-ground biomass than other plants (high root:shoot ratio). Contrary to its name, this grass grows in both dry and wet locations, often meadows, dunes and disturbed areas.

NATURAL DISTRIBUTION

North America. Native to western Canada and northwestern United States. While the native Yukon wheatgrass (*Elymus calderi*) is possibly a subspecies of streambank wheatgrass, the available seed is from a decidedly non-native subspecies.

TOLERANCES AND RELEVANT TRAITS

Tolerant of mildly acid to moderately alkaline soils (pH 6.0 – 8.5), and low nutrient conditions. Tolerates moderately saline soils and a range of moisture regimes, from dry to moist. It is very drought-tolerant, but grows best in well-drained sandy soils if precipitation is high. Also grows in silts and clays. Tolerant to short periods of inundation. Slow to grow, but once established is a strong competitor. Generally more successful at low to mid elevations.

USE IN REVEGETATION

Recommended for most dry sites that are near neutral pH and at low to mid elevation, but it will also grow well on moist sites. Not a good competitor when planted with more aggressive species because it is slow to establish. However, once established it will spread well by rhizomes. Excellent for use in stabilizing slopes and general erosion control if not put in a situation where it is outcompeted. Functions best for long-term site stability rather than rapid surface stabilization. Low palatability to wildlife makes it a good candidate for planting in highway right-of-ways. Not recommended for use at high elevation.

SEEDS

The large-sized seeds are easy to handle during seeding.
Seeds per kg: 336,600

AVAILABLE CULTIVARS

Sodar is the only cultivar recommended for use in Yukon.

Timothy *Phleum pratensis*

Not Native to Yukon

T. OMTZIGT

FORMER AND ALTERNATE SPECIES NAMES

Phleum nodosum, meadow cat-tail, herd grass

GENERAL DESCRIPTION

A tall (up to 150 cm) perennial bunchgrass. Solitary plants tends to grow in clumps (strongly tufted). Recognizable by its dense seedheads. Spreads by seed, not rhizomes. Compact, shallow roots and tall growth give it a low root:shoot ratio.

NATURAL DISTRIBUTION

Native to Eurasia. Introduced to North America where it is used as a cool season forage crop in hay and pasture production. Grown agriculturally throughout Canada and the northern United States. Grows feral along roadways, ditches, other waterways and in moist meadows, though not aggressively enough to be considered invasive.

TOLERANCES AND RELEVANT TRAITS

Tolerates acid to neutral soils (pH 4.5 – 7.0), and moderate levels of heavy metals. Does not tolerate alkaline soils, drought or extended periods of inundation. Grows best in moist fine sediments with moderate nutrient status and organic content. Very winter hardy and establishes well at high elevations, though it tends to produce seed poorly at high elevations and does not persist.

USE IN REVEGETATION

Recommended for moist, moderately flat (<8% slope), sites with fine-grained sediments (silts, loams, clays). Can be used on permafrost ground, on tundra and at moderate elevations (if they are moist). Do not use on alkaline or dry sites. Timothy establishes quickly and spreads by seed. Responds well to fertilizer. Not recommended for erosion control because it is shallow-rooted and does not spread by rhizomes – thus it is poor at binding soil. Suitable for mine reclamation because of its tolerance to acid soils and heavy metals.

SEEDS

The fairly large-sized seeds are easy to handle during seeding.
Seeds per kg: 539,407

AVAILABLE CULTIVARS

Climax and *Engmo* are two recommended cultivars for use in Yukon.

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Glossary

Acid soil: Soil with a pH less than 7.0 (though soils with pH 6.5 – 7.5 are generally considered to be neutral). Colloquialism for acid soil is "sour soil" (See also Table 2.1).

Active layer: The top layer of soil that thaws each summer on permafrost ground. Essentially all biological activity and soil processes occur in the active layer, as the ground beneath remains frozen.

Agronomic species: A plant species developed through selective breeding and propagation to be useful in agriculture, to the extent that it is distinct from the plant from which it was derived (though they usually are still capable of interbreeding).

Alkaline soil: Soil with a pH greater than 7.0 (though soil with pH 6.5 – 7.5 is generally considered to be neutral). Colloquialism for alkaline soil is "sweet soil" (See also Table 2.1).

Allelopathic plant: A plant that excretes substances into the ground that negatively affect the growth, reproduction and survival of neighbouring plants.

Autecology (autecological): Refers to the ecological relationship between just a single organism or species and its environment. The complimentary term is synecology, which refers to the relationship between multiple organisms (communities) in an ecosystem and their environment. How a species deals with water stress is an autecological trait; how two species compete for water falls within the realm of synecology.

Bare mineral soil: Soil consisting of sediments from weathered parent rock and containing no substantive quantities of organic material or leachate from upper soil horizons. Equivalent to the "C-Horizon" in a soil profile (See Fig. 3.3).

Biogeography: The geographical and temporal distribution of species. Biogeographers study distributional patterns as well as their causes and changes over time.

Breeder seed: Seed produced in limited quantities by the institution that developed a specific, true-breeding cultivar. The seed is sold to licensed producers to build up a stock of foundation seed for the registered cultivar (see Fig. 4.10).

Bunchgrass: A type of grass in which new tillers grow upward from buds in the base of the mother (main) stem rather than from creeping lateral rhizomes. As a result, the grass develops as a clump, also called a "tuft" or "bunch." Large tufts are sometimes called "tussocks." In contrast to bunchgrasses, sod-forming grasses grow rhizomatously and can develop into a turf.

Certified seed: Seed of a cultivar propagated from registered seed (sometimes from foundation seed) by a certified producer and available commercially for general use. Also referred to as "pedigreed seed" (see Fig. 4.10).

C:N ratio: Carbon to Nitrogen ratio of a plant or soil. For soil, the C:N ratio provides an indication of nitrogen availability and thus fertility. If C:N is higher than 35:1 then nitrogen is limited. For a plant, the C:N ratio is an indicator of its protein content and thus its quality as a forage. A lower C:N ratio indicates higher protein content.

Colonizing species: Plant species adapted to grow rapidly in (colonize) newly-disturbed ground. Also referred to as "pioneer plants." They exhibit traits associated with weediness such as rapid growth, fast turnover (short-lived), high seed production, and the ability to grow in low-nutrient soils. Some are able to fix nitrogen. Many species selected for revegetation applications are good colonizing species, especially when the goals are mainly to stabilize a surface until other species become established. However, pioneer plants generally are not persistent, and do not always provide thorough ground cover. Consequently, they should be co-planted with longer-lasting species or planted in conjunction with a plan for natural revegetation.

Common seed: When certified seed is used to propagate additional seed (rather than being planted for general use), the progeny are called "common" seed. Legally, common seed can be labelled with the same cultivar name as the certified seed but it cannot be sold as certified seed. The term is also appropriate for seed that was propagated directly from a wild plant source or from another seed with no specified pedigree. In these two cases, no cultivar name can be assigned to the progeny (see Fig. 4.10).

Conspecific: Belonging to the same species.

Culm: The stem of a grass or sedge, which is characteristically jointed.

Cultipacker: A heavy roller with short, blunt teeth (or parallel ridges) that is pulled by a tractor or ATV as a type of surface finisher after seeding. It lightly compacts the top few centimetres of surface soil, which has the effect of increasing seed-soil contact and thereby increasing germination rates. It also helps even-out the surface after plowing or harrowing. The holes left by the teeth or ridges improve water retention and absorption.

Cultivar: A subpopulation of a plant species developed through selective breeding and propagation for specific traits that breeds true in offspring. Once a truebreeding genetic line has been established, the cultivar can be registered with the Canadian Seed Growers' Association.

Decompact, decompaction: Deep tillage of soil that was previously compacted. Tillage usually extends to a depth of at least 20 cm and often over 40 cm.

Dehisce: The process of seed pods (or other plant structures) rupturing and opening at maturity to release seeds. Sometimes the process is explosive and seeds are propelled some distance from the plant.

Ecotype: A genetically distinct population of a species that is adapted to local conditions but still able to breed with other populations. The term is best applied to natural populations but it is also used to described populations developed by selective breeding for traits adaptive for specific environmental conditions.

Ecological restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is an intentional activity that initiates or accelerates whole ecosystem recovery with respect to species composition, community structure and ecological function. A restored ecosystem will be self-organized, self-sustaining. Not all revegetation projects have the goal of restoring a natural ecosystem. However, when ecological restoration is the larger project goal, it will greatly affect revegetation strategies.

Edaphic traits: Physical traits of soils that affect plant growth (such as mineralogy, grain size, pH) that are not related to or caused by climatic and environmental factors. The term can also be applied to plants or plant communities and refers to the type of soil conditions they grow in (*e.g.*, plants that grow on acidic, sandy soil).

Endemic species: A species that inhabits (is native to) a limited geographic area and does not exist outside that area. Example: Beard-tongue (*Penstemon gormanii*) is endemic to central Alaska and Yukon north to latitude 64°N; it grows nowhere else.

Facilitated Natural Revegetation: A revegetation strategy whereby levels of seeding, fertilizing and ground preparation are prescribed with the primary intent of fostering recolonization and succession by local native plants. Site work is designed to minimize ground disturbance and leave soil organic materials intact. Cultivated species often are planted as nursery plants and are seeded at rates high enough to stabilize ground surfaces but not choke out native species (See Section 2.2)

Foundation seed: The first generation progeny of seed grown from breeder seed. Foundation seed is grown to multiply the volume of seed that can be distributed to certified producers for large-scale production of registered seed (second generation progeny) (see Fig. 4.10).

Genetic contamination: The introduction of non-native germplasm or genotypes to a native population by planting cultivars or related species that are capable of hybridizing with or outcompeting native individuals of the population, thus causing a shift in the overall genetic composition of the native population. This term is more neutral than "genetic pollution" and only refers to intraspecific transfers of germplasm or transfers between closely related species.

Genetic pollution: The introduction of any germplasm, population, or species that is nonnative to an area. Often used in a negative sense and as a reference to any introduced species. A more neutral term referring to the introduction of foreign genetic material is "genetic contamination."

Genome: The collective hereditary content of an individual, population or species. Also used in reference to the full set of chromosomes in an individual, population or species.

Genotype The specific genetic "type" or constitution of an individual as defined by its allelic content and DNA sequence; can refer to an individual's entire genome, or just sections of DNA.

Germplasm: The cellular material in an organism that constitutes its collective genetic makeup and support structures. Also used to describe the cellular content of an organism's germ cells (protoplasm as well as genetic materials).

Ground ice: The term applied to ice bodies in permafrost ground (does not include seasonal ice). Examples include ice lenses, ice wedges and pore ice (See segregation ice and pore ice and Chapter 5).

Harrow: An agricultural implement with multiple tines, discs or chainlinks mounted on a frame and drawn over soil to level and loosen it and to break up clods or cover seed and fertilizer. Usually pulled by a tractor or ATV but sometimes pulled by hand.

Hybrid, hybridization: Offspring from the crossing of plants from one population or species with plants from another population or species. Hybridization is relevant to revegetation work because commercial plants that are seeded on a site can hybridize with local plants. This would constitute a genetic alteration of the native population. (see genetic contamination)

Indigenous plant: A plant species that naturally grows in (is native to) an area.

Innundation: Flooding, or the condition of standing water.

Introduced species: A species living outside its native distributional range, which has arrived in its new location by human activity, either deliberate or accidental. Similar terms included: alien, exotic, non-indigenous, or non-native species.

Invasive species: An organism that is introduced (non-native) and has negative effects on the economy, environment, or human health. Not all introduced species are invasive. The term "invasive" is reserved for the most aggressive introduced species that reproduce rapidly and cause major changes to the areas where they become established.

Macronutrients: A mineral nutrient that must be taken up by a plant in large quantities for growth and development (usually >50 mg of nutrient per kg of plant). As such, they are the nutrients most limiting to plant growth. Soil macronutrients include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S).

Micronutrients: A mineral nutrient that must be taken up by a plant for growth and development but only in small amounts (<50 mg of nutrient per kg of plant). Micronutrient deficencies are rarely limiting to plant growth in revegetation. The principle micronutrients are: chlorine (Cl), iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mb)and nickel (Ni).

Mulch: A coarse or fibrous, loose organic material placed on a soil surface to reduce erosion, retain moisture, and protect seedlings. The primary mulches used in Yukon are wood chips and straw. Also see Rolled Erosion Control Products.

Native plant: See indigenous plant.

Native cultivar: A cultivar developed from propagules of a local (native) population. Distinct from cultivars that are developed from nominally native species using propagules of a non-native population. Almost all commercial seed of "native" plants sold for use in Yukon are non-native cultivars.

Native genotype: The genotype of an indigenous population. A nominally native species grown from a non-native cultivar will not have a native genotype.

Natural seed bank: The naturally-occurring, viable seed that is present in the soil prior to planting. Many species produce an abundance of seeds that remain viable in or on the ground surface for years or decades. The natural seed bank is stimulated to germinate by exposure to water and air and by increased seed-soil contact. Often, the natural seed bank needs to undergo stratification or scarification as well, which usually doesn't occur if the seed is not near the surface.

Nitrogen fixer: A plant that is a symbiotic host to a bacterium capable of converting molecular nitrogen (N_2) from the atmosphere into a form (NH_4) that can be used by the host plant. When the host plant dies, its pool of nitrogen is added to the soil, thus enriching its nitrogen content. Some nitrogen-fixing bacteria are also free-living (*i.e.*, no plant host). All nitrogen-fixing bacteria (symbiotic or free-living) are generically called diazotrophs.

Non-native plant: A plant that does not naturally occur in a specific geographic area and is introduced. A plant that is not indigenous.

Non-native genetics: The genetic composition of a species or cultivar that has been introduced and differs from the genetic makeup of the indigenous population.

Noxious plant: A plant species designated by law as a species that causes harm to agricultural and/or horticultural crops, natural habitats and/or ecosystems, humans or livestock. Most noxious plants are introduced species. Occasionally some are native. Invasive species are classified as a subcategory of noxious plants.

Nurse plant (Nurse crop): Short-lived species that are included in a seed mix because they will provide ground cover and conditions that foster the growth of longer-lived, but slower-growing, species. Usually, the nurse plant is an annual grass and should not be planted too thickly, to avoid choking out the desired longterm species. Sometimes called a "cover crop," though cover crops are usually meant to be tilled into the ground after one season.

Organic material: This term is used in a number of contexts. Most often, it refers to the living and especially dead plant matter that has accumulated on a soil surface. In soils, organic matter is the non-mineral fraction that is derived from the decomposition of plant, animal, and microbial matter on the surface and leached into the soil. Both uses of the term can include the organic soil horizon.

Organic soil: In a soil profile, the A and O horizons collectively constitute the organic soil. It is the upper layer of soil that includes accumulated Organic material (O Horizon) as well as the humic layer (A1 Horizon) and leachate from decomposed organics (A2 Horizon). Plants depend on the organic soil as a source of nutrients for uptake by roots (See Fig. 3.3).

Overseeding: Sowing seeds over an existing stand of vegetation. Usually, this is done when the existing vegetation is too sparse or does not have the desired species composition. Often, no ground preparation is done prior to overseeding, but sometimes the ground is lightly harrowed afterwards.

Palatable: Having an agreeable taste. Applies to the attractiveness some plants have to herbivores because they have an agreeable taste.

Panicle: A type of inflorescence where the flowers are located at the end of stalks (pedicels). Collectively, the panicle is the group of flowers and stalks. It can have a diversity of shapes depending on stalk length. Colloquially, the panicle is a flower head.

Permafrost: Perennially frozen ground that remains below 0°C for more than two years. Note: while ground ice only forms and persists in permafrost, not all permafrost will contain ground ice (See Chapter 5, Scenario 5).

Persistent species: A species that is tenacious and not easily displaced by other species.

Phenotype: The physical and metabolic traits expressed by an organism as determined by the interplay between its genotype and the environment in which it developed.

Pore ice: Ice that exists in the interstices (pores) of sediments in permafrost ground. Pore ice does not add to the overall volume of the ground, so its melting does not result in significant slumping or thermokarsting.

Propagule: A plant used as parental stock for further propagation; can refer to the entire plant or to seeds, spores, wood cuttings, bulbs or roots derived from it.

Pure Live Seed (PLS): A calculated value for the percentage of seed in a seed lot that is viable and belongs to the designated species. All seed lots will have contaminants of non-specified seeds (weed seeds) and non-viable seeds. When formulating seed mixes, planners need to know the actual number of viable seeds in a mix, so they calculate PLS by multiplying the percent seed purity by the percent viable seed. These two values are determined by an independent testing lab, and by law, must be made available to seed purchasers upon request.

Purity (of seed): A measure of non-specified species (weed and other seeds) and material (plant debris, rocks) in a specific seed lot.

Reclamation: The shaping and reconstructing of features on a piece of altered land such that it is habitable for the same or similar plant and animal species that existed prior to the disturbance. The goal of reclamation is not necessarily to achieve the same community structure, ecosystem function, and diversity as the pre-existing ecosystem. Rather, it is to establish some stability and semblance of healthy biological function on the site; it is understood that site may have less diversity and biological complexity than a natural ecosystem, especially in the early stages. Actively revegetating the site is usually fundamental to the reclamation process, but reclamation also addresses larger issues such as the cleanup of contaminated materials, surface recontouring, landscape engineering and public safety.

Registered seed: Seed of a registered cultivar grown in volume as the first progeny of foundation seed (second generation of breeder seed). Generally, it is only sold to producers for production and sale of certified seed to endusers. Usually it is not available for purchase by consumers (see Fig. 4.10).

Rehabilitation: This term is often used synonymously with ecological restoration. However, it implies an effort to intentionally improve ecological conditions on a site without an original, pre-disturbance ecosystem available for reference. Usually this means that humans have lived in the area for such a long period and have altered the landscape to the extent that there is no surrounding original ecosystem towards which the site can be driven. Given this definition, there is little true rehabilitation work that occurs in Yukon.

Restoration: See ecological restoration.

Revegetation: A planned effort to re-establish plant growth on a disturbed site. Revegetation programs do not necessarily have an implied intent to achieve a natural ecological condition or a specific successional (seral) stage. Their goals often have more to do with stabilizing surfaces, increasing soil fertility, promoting native plant growth, or promoting the growth of certain plant types or species over others.

Rhizome: A horizontal underground stem from which new tillers (shoots) arise. Many grasses, especially sod-forming grasses, spread rhizomatously.

Rhizomatous growth: See sod-forming

Rolled Erosion Control Products (RECPs): Flexible sheet materials that contain a central layer of permeable fibres sandwiched between two layers of coarse mesh. Often, both the fibres and the mess are composed of organic materials so they decompose over time. Others are made from UV-stable synthetics (*e.g.*, polypropylene) and are intended for long-term use. RECPs are purchased in rolls containing a sheet that is typically about 2 m wide and 16m long. RECPs are excellent products for covering unvegetated cut or fill slopes where erosion control or soil stabilization is needed. They are used where temporary seeding and mulching alone are inadequate or where mulch must be anchored and other methods such as crimping or tackifying are unfeasible, such as directly adjacent to streams.

Saline soil: A soil containing unusually high concentrations of soluble salts, usually chloride and sulphide salts of Na^{+}, Mg^{++}, Ca^{++} and K^{+}. Soil salinity is measured by electrical conductivity and a soil is classified as "saline" if its conductivity exceeds 4 dS/cm at 25°C (soil tests will often return soil conductivity measurements). Most plants are not adapted to saline soils, as it interferes with water and nutrient uptake from the roots, but some plants are adapted to these conditions. A few pockets of saline soils exist in Yukon, mainly between Whitehorse and Kluane Lake. When revegetation planners encounter these sites, saline-adapted plants should be seeded. The saline tolerance of species used for revegetation are noted in Chapter 6 (See also Section 3.3.3).

Seed bank: See natural seed bank.

Seed drill: An agricultural implement used for sowing seed directly into the soil at precise depths. Seed drills are the most efficient means of planting seeds on prepared soil, but they have limited application in revegetation work because they cannot be operated on rough terrain or ground with coarse debris such as rocks and wood (See Section 4.5.2 in Chapter 4).

Segregation ice: A type of ground ice that forms in freezing or frozen ground as water molecules naturally migrate towards existing ice and freezing fronts in the ground – the water/ice essentially segregates from the sediment. Ice lenses are the most common form of segregation ice. They can grow over multiple seasons to become many cubic meters in size (See Chapter 5, Scenario 5).

Soil amendment: A material added to soil either to improve its physical or biological properties (soil conditioners) or to increase fertility (fertilizer and manure). Conditioners include materials such as peat and wood chips, which improve water retention, aeration and structure for roots. Mulch is not an amendment unless it is worked into the soil. Also see tilth.

Sod-forming grass: A grass that spreads through laterally-creeping rhizomes (rhizomatous growth) with new tillers growing upward from the rhizomes. The result is a sod, or turf, with a more continuous ground cover than that produced by bunchgrasses, which have open ground between tufts.

Solum: The upper portion of a soil profile, namely the A Horizon and B Horizon. Solum and soil are not synonymous. Soil includes all weathered material on the surface, whereas solum refers only to the horizons that are influenced by the processes of leaching and enrichment. Essentially all root activity and nutrient uptake occurs in the solum.

Scarification: The process of mechanically scoring or weakening the outer coat of a seed to end dormancy and initiate germination. Breaching the seed coat allows moisture to enter the seed, causing it to swell, end its dormancy and begin germinating. Seeds of many species require scarification before they will germinate. The process occurs naturally in wild populations, but must be simulated for many seeds that will be planted (See Section 4.6.1 and stratification).

Stratification: The process of exposing seeds to moisture and cold to soften the seed coat, which allows moisture to enter the seed, signals the end of dormancy and initiates germination. Seeds of many species require stratification before they will germinate. The process occurs naturally in wild populations, but must be simulated for many seeds that will be planted (See Section 4.6.1 and scarification).

Succession, successional: The process by which ecological communities change over time after a disturbance. In general, the process has predictable stages, starting with colonizing species and advancing to a climax community. Any given stage in succession is called a sere or seral stage.

Tackifier: Compounds added to hydroseeding slurries to increase the stickiness of the seed and mulch so it adheres to the ground surface. An example is natural plant gum.

Thermokarsting: A process of ground destabilization, degradation and erosion caused by the melting of ground ice in permafrost. Melting is usually initiated by a disturbance, often by excavating or removing soils and organic matter that are insulating ice bodies from warm ambient conditions. Once melting is initiated, it will continue until the ice has been thermally stabilized again. However, the process can cascade and be difficult to stop, as the initial melting can cause erosion and further thermal destabilization. Shallow ponds and small lakes can form if the meltwater is unable to percolate through frozen ground beneath. Thermokasting is problematic because the ground ice represents a significant portion of the ground volume, so when it melts the ground slumps.

Tiller: A shoot that grows from the base of a stem in grasses. In bunchgrasses, tillers grow from the base of the mother stem. In rhizomataous grasses, tillers can arise from lateral rhizomes (which are modified stems).

Tilth: The physical conditions of a soil that affect its ability to facilitate healthy plant growth, such as water water-holding capacity, nutrient mobility, aeration, and looseness for root penetration. Factors that determine tilth include sediment type, sediment size, pH and organic content – factors that mainly affect texture, structure and chemical reactivity. A soil with good tilth usually is loose, friable, organic-rich, and has loamy sediments.

Track-walking: Texturing a sloped surface by driving over it with a tracked vehicle, such as a crawler or dozer. The cleats on the tracks leave impressions which trap/retain water and seeds, thus preventing them from being washed off the slope. The tracked vehicle should always be driven up and down the slope, not parallel to it, so that cleat marks are aligned perpendicular to the slope. Track-walking is used on slopes that are too steep to harrow with wheeled vehicles (See Section 3.2.2).

Tuft: See bunchgrass.

Turf: See sod-forming grass.

Variety: A subpopulation of a plant species with physical traits or adaptations that are distinct from other populations and breed true in offspring. Often the term "variety" is used synonymously with "cultivar," but in the strict sense, "variety" is a term used to describe naturally occurring populations, whereas "cultivar" refers to true-breeding populations developed through selective breeding.

Viable seed: Seed that is in a healthy dormant state and capable of germinating when it receives the appropriate stimuli.

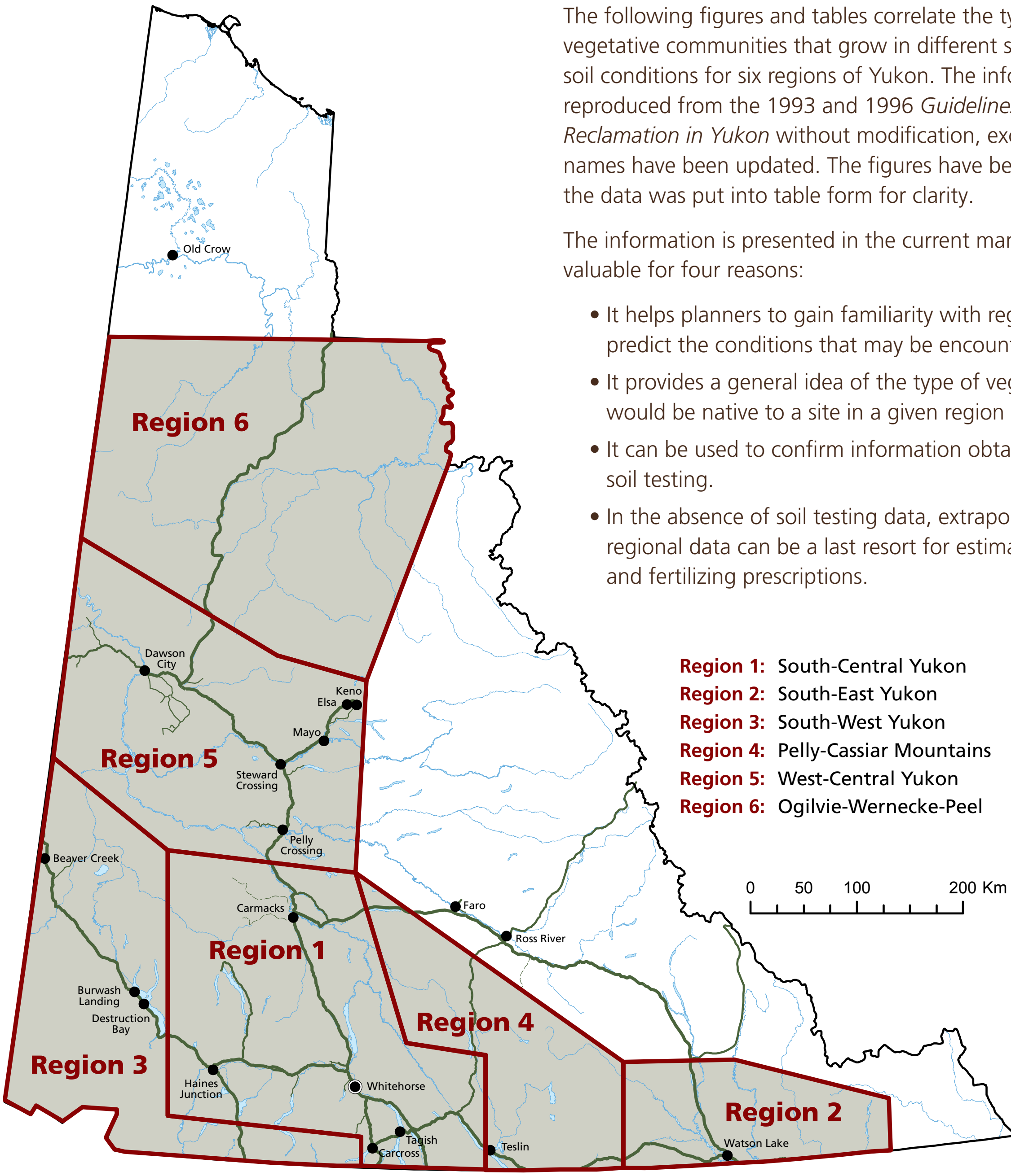
Appendix A

Vegetation and Landform Relationships

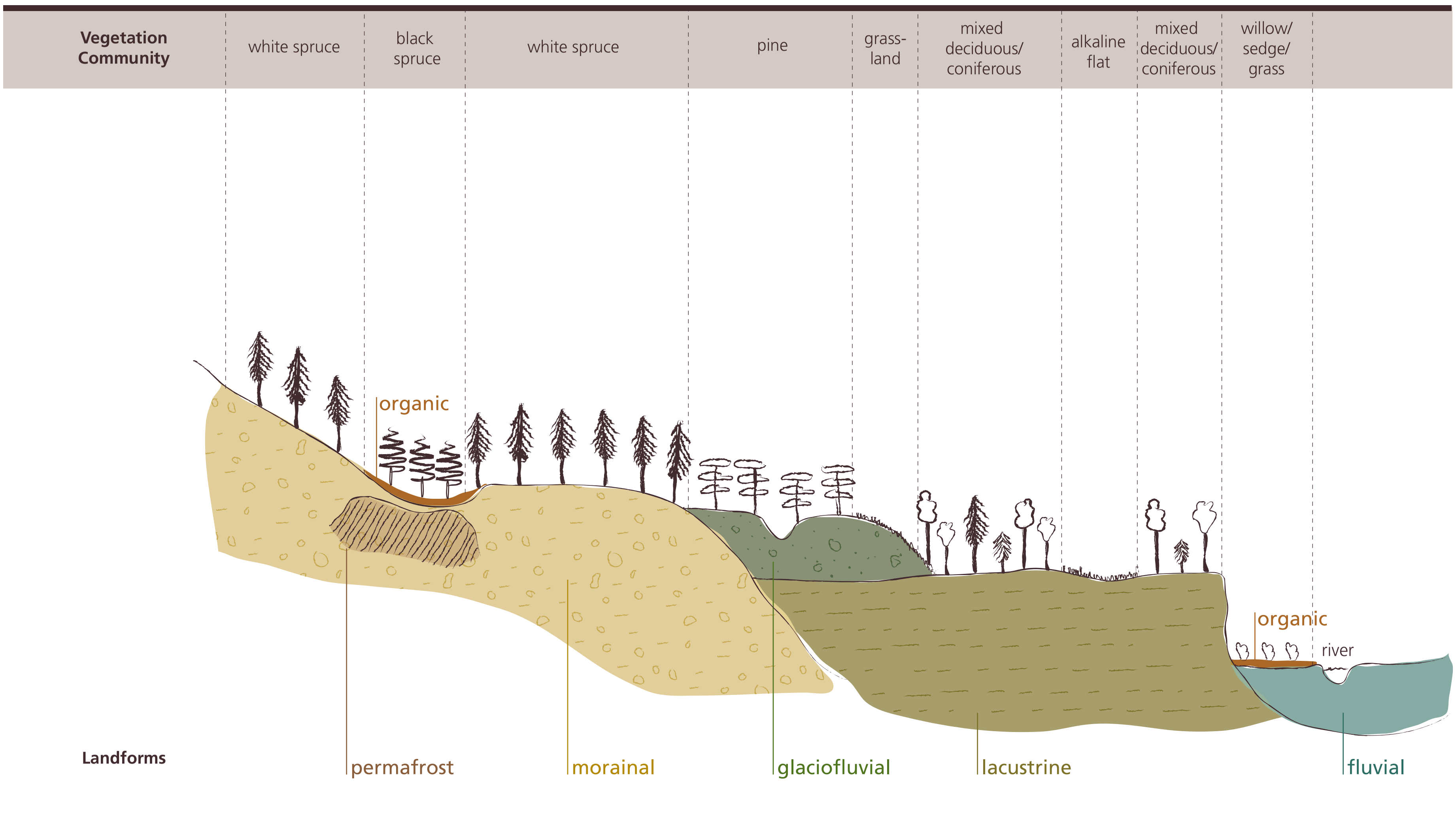
The following figures and tables correlate the types of natural vegetative communities that grow in different settings and soil conditions for six regions of Yukon. The information was reproduced from the 1993 and 1996 *Guidelines for Revegetation/ Reclamation in Yukon* without modification, except that species names have been updated. The figures have been redrawn and the data was put into table form for clarity.

The information is presented in the current manual because it is valuable for four reasons:

- It helps planners to gain familiarity with regional trends and predict the conditions that may be encountered at a site.
- It provides a general idea of the type of vegetation that would be native to a site in a given region and setting.
- It can be used to confirm information obtained through soil testing.
- In the absence of soil testing data, extrapolations from regional data can be a last resort for estimating seeding and fertilizing prescriptions.



Vegetation and Landform Relationships
Region 1: South-Central Yukon



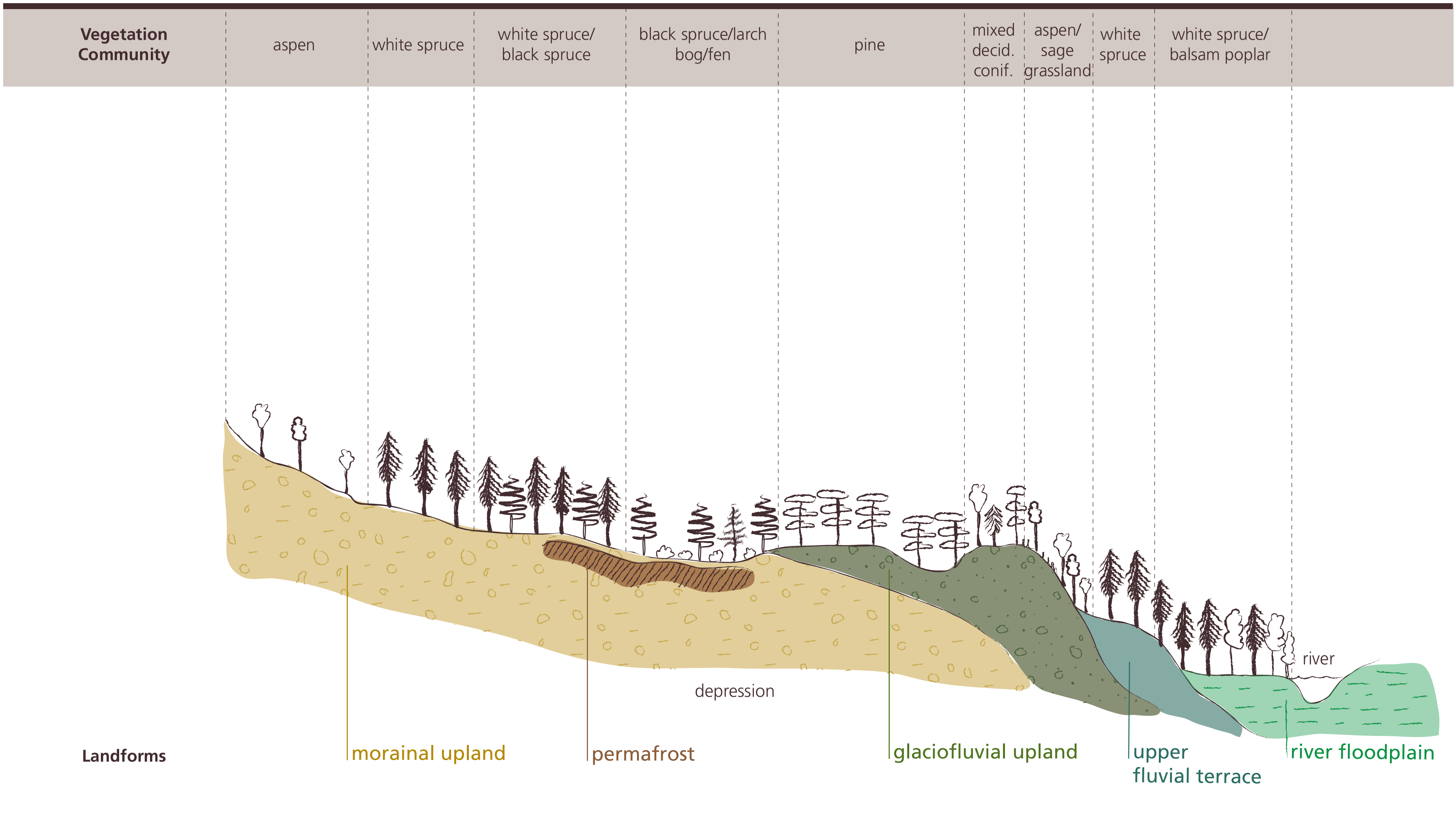
Regional Soil Characteristics for Region 1: South-Central Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Alkaligrass-foxtail barley	Glaciolacustrine and fluvial	Level to depressional	Poor to imperfect	Silty loam to clay	Clay	8.0-9.1 Strongly alkaline	High	Moderate to low	High to extremley high	Low	High	High
Description:	A halophytic graminoids community, dominated by alkaligrass and foxtail barley, which occurs in small depressions common throughout the Takhini Valley; forbs are sparse, but often exhibit similar tolerance toward saline and alkaline conditions. Species are typically arranged in concentric circles, a reflection of the ecological gradient.											
Characteristic Species:	Alkaligrass (*Puccinellia* spp.), foxtail barley (*Hordeum jubatum*).											
Associated Species:	Tufted hairgrass (*Deschampsia caespitosa*), arctic rush (*Juncus arcticus*), ticklegrass (*Agrostis scabra*), silverweed (*Potentilla diversifolia*), yarrow (*Achillea borealis*).											
Sage/grass	Colluvial, glaciofluvial, glaciolacustrine, morainal	Gentle to steep slopes with southerly aspects	Well to rapid	Loam to sand	Clay to gravelly sand	7.3-8.0 Mildly alkaline	Low to High	Moderate to high	Moderate to high	Moderate to high	Moderate to high	Moderate to high
Description:	Groundcover dominated by grass, with sage diagnostic among a diverse array of forbs; low, scattered aspen trees are common. Establishes under xeric conditions on steep, south-facing slopes.											
Characteristic Species:	Sage (*Artemisia frigida*), purple reedgrass (*Calamagrostis purpurascens*), northern rough fescue (*Festuca altaica*), three-toothed saxifrage (*Saxifraga tricuspidata*).											
Associated Species:	Aspen (*Populus tremuloides*), common juniper (*Juniper communis*), kinnikinnick (*Arctostaphylos uva-ursi*), Jacob's ladder (*Polemonium pulcherrimum*), crocus (*Pulsatilla patens*), stonecrop (*Sedum lanceolatum*), wild rye/wheatgrass (*Elymus* spp.).											
Willow/sedge	Fluvial	Level, depressional, undulating	Imperfect to poor; flooding possible	Moderately decomposed organics and/or clay	Clay to sand	6.4-7.6 Slightly alkaline to neutral	Very low	High	Moderate	Moderate	Moderate	High
Description:	Moderate to dense overstory of willow; groundcover dominated by sedge and moss; grass and horsetail common; forbs diverse and scant; sphagnum often present. Riparian vegetation established along lake margins and creek drainages.											
Characteristic Species:	Willow (*Salix* spp.), water sedge (*Carex aquatilis*), moss (bryophyte spp.).											
Associated Species:	Shrub birch (*Betula glandulosa*), shrubby cinquefoil (*Potentilla fruticosa*), nagoonberry (*Rubus acaulis*), sedge (*Carex* spp.), grass (*Poaceae* spp.), horsetail (*Equisetum* spp.), coltsfoot (*Petasites frigidus*), bluebell (*Mertensia paniculata*), sphagnum moss (*Sphagnum* spp.).											
Lodgepole pine	Glaciofluvial, fluvial, morainal	Level to terraces	Well to rapid	Sandy loam to loamy sand	Sandy loam to gravelly sand	5.3-6.3 Very strongly to slightly acid	Low	Low	Very low	Very low	Very low	Very low
Description:	Lodgepole pine dominates an open tree canopy which often includes white spruce and aspen; tall shrub understory sparse or absent; low shrubs include soapberry and rose; kinnikinick is a diagnostic and dominant groundshrub; grass, forbs and lichen are common but sparse. Develops on well-drained sites.											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (*Vaccinium vitis-idaea*).											
Associated Species:	White spruce (*Picea glauca*), aspen (*Populus tremuloides*), soapberry (*Shepherdia canadensis*), willow (*Salix* spp.), rose (*Rosa acicularis*), northern rough fescue (*Festuca altaica*), arctic lupine (*Lupinus arcticus*), fireweed (E*pilobium angustifolium*).											

Regional Soil Characteristics for Region 1: South-Central Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Black spruce	Lacustrine, morainal, fluvial	Depressions, lower slopes	Poor to moderately well	Fibric to mesic peat	Clay loam to gravelly sand	6.0-6.7 Slightly acid	Very low	Very high	Low	Very low	Low	Low
Description:	Black spruce diagnostic and dominant in a sparse tree and shrub understory; shrub birch, willow, Labrador tea and other low and prostrate ericaceous species commonly present; extensive moss groundcover often includes sphagnum.											
Characteristic Species:	Black spruce (*Picea mariana*), willow (*Salix* spp.), shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), feathermoss (bryophyte spp.).											
Associated Species:	Shrubby cinquefoil (*Potentilla fruticosa*), bog blueberry (*Vaccinium uliginosum*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), cloudberry (*Rubus chamaemorus*), lousewort (*Pedicularis* spp.).											
White spruce	Glaciolacustrine, morainal, fluvial		Moderately well to well	Clay loam to sandy loam	Clay to gravelly sandy loam	6.6-8.7 Neutral to strongly alkaline	Varies from low to high	Moderate to low	Low to very high	Very low	High	Low to high
Description:	White spruce dominant species in tree canopy, though pine and aspen are frequently present; shrub understory includes willow, soapberry and rose; on moister sites, groundcover is dominant by lowbush cranberry, horsetail, moss and forbs; kinnikinnick, twinflower and fescue dominate drier sites.											
Characteristic Species:	White spruce (*Picea glauca*), kinnikinnick (*Arctostaphylos uva-ursi*).											
Associated Species:	Aspen (*Populus tremuloides*), lodgepole pine (*Pinus contorta*), rose (*Rosa acicularis*), soapberry (*Shepherdia canadensis*), lowbush cranberry (*Vaccinium vitis-idaea*), twinflower (*Linnaea borealis*), horsetail *(Equisetum* spp.), northern rough fescue (*Festuca altaica*), bluebell (*Mertensia paniculata*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*).											
Mixed deciduous/coniferous	Lacustrine, morainal, fluvial	Fine to medium textured	Imperfect to well	Clay to gravelly sandy loam	Clay to gravelly sandy loam	6.5-7.4 Neutral to slightly alkaline	Low to moderate	Low	Low	High	Moderate	Low
Description:	This community is successional after fire. The canopy is usually dominated by pine and aspen, with willow common throughout the understory; white spruce appears in the low shrub layer later in succession, and eventually dominates most stands which reach maturity on these sites.											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), willow (*Salix* spp.)											
Associated Species:	White spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), highbush cranberry *(Viburnum edule*), rose (*Rosa acicularis*), soapberry (*Shepherdia canadensis*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (*Vaccinium vitis-idaea*), twinflower (*Linnaea borealis*), northern rough fescue (*Festuca altaica*), reedgrass (*Calamagrostis* spp.), wild rye/wheatgrass (*Elymus* spp.).											

Vegetation and Landform Relationships
Region 2: South-East Yukon



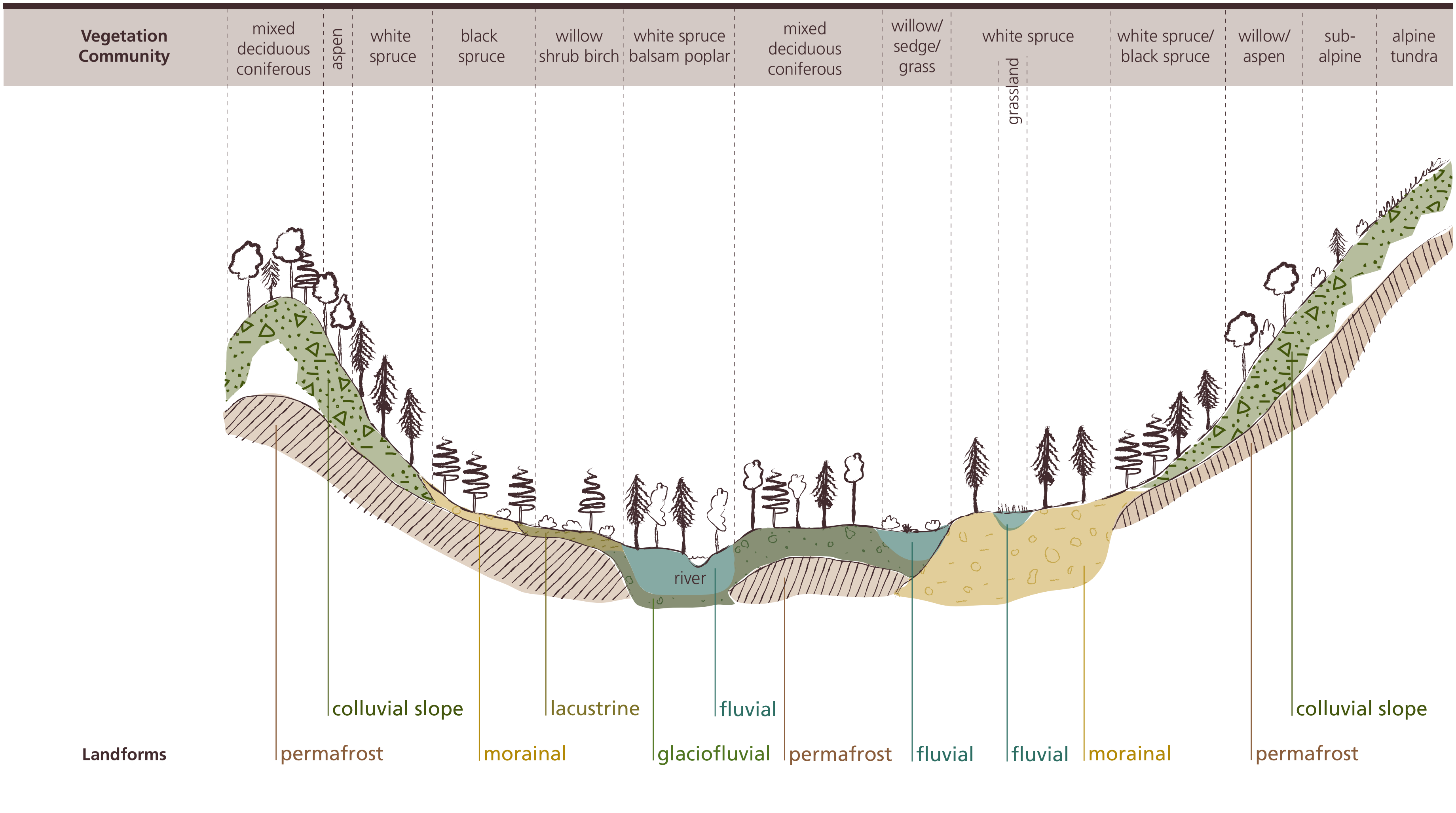
Regional Soil Characteristics for Region 2: South-East Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Aspen/soapberry	Morainal and glaciofluvial	Level to moderately steep south-facing slopes	Well	Silty loam to sandy loam	Gravelly sandy loam to loamy sand	6.6-7.8 Neutral to mildly alkaline	Moderate	Low	Low	Moderate	High	Moderate
Description:	Aspen dominates the tree canopy and is regenerating in the understory; soapberry and numerous low shrubs are present, kinnikinnick and fescue dominate the groundcover; forbs are diverse; lichen and moss are scant.											
Characteristic Species:	Aspen (*Populus tremuloides*), soapberry (*Shepherdia canadensis*).											
Associated Species:	White spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), willow (*Salix* spp.), rose (*Rosa acicularis*), highbush cranberry (*Viburnum edule*), lowbush cranberry (*Vaccinium vitis-idaea*), Jacob's ladder (*Polemonium pulcherrimum*).											
White spruce/ balsam poplar	Fluvial floodplains and low terraces		Moderately well to imperfect	Loamy sand to loam	Gravelly loamy sand to clay loam	6.6-7.8 Neutral to mildly alkaline	Medium	Low	Low	Moderate	High	Moderate
Description:	Open tree canopy is dominated by white spruce; mature balsam poplar co-dominate the stand; shrub assemblages variable and diverse, including willow, alder, highbush cranberry and red-osier dogwood; horsetail is prominent, and other forbs may be abundant and diverse; moss and lichen are frequently lacking due to frequent flooding and deposition.											
Characteristic Species:	White spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), rose (*Rosa acicularis).*											
Associated Species:	Alder (*Alnus* spp.), willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), highbush cranberry (*Viburnum edule*), northern red currant (*Ribes triste*), soapberry (*Shepherdia canadensis*), twinflower (*Linnaea borealis*), horsetail *(Equisetum* spp.), fireweed (*Epilobium angustifolium*), strawberry (*Fragaria virginiana*), toadflax (*Geocaulon lividum*), bluebell (*Mertensia paniculata*).											
Aspen/kinnikinnick	Variable	Moderate to steep south facing slopes	Well to rapid	Loam to gravelly loamy sand	Clay loam to gravelly loamy sand	7.4-8.5 High	High	Medium	Moderate	High	High	Moderate
Description:	Aspen dominates the sparse tree canopy and is regenerating in the shrub understory. Common low shrubs include soapberry, rose and juniper. Kinnikinnick and grass dominate the groundcover. This vegetation represents the climax community on the steep slopes where it occurs.											
Characteristic Species:	Aspen (*Populus tremuloides*), kinnikinnick (*Arctostaphylos uva-ursi*).											
Associated Species:	Soapberry (*Shepherdia canadensis*), rose (*Rosa acicularis*), common juniper (*Juniper communis*), northern rough fescue (*Festuca altaica*), sage (*Artemisia frigida*), prickly saxifrage (*Saxifraga tricuspidata*), death camas (*Zygadenus elegans*), crocus (*Pulsatilla patens*).											
Black spruce/larch	Bogs and fens; organic overlying morainal or fluvial	Depressional areas, lower slopes	Poor to very poor	Fibric to mesic peat to silt loam	Silty loam to loamy sand	6.5-5.6 Slightly acid to strongly acid	Low	High	Low	Low	Low	Low
Description:	Moderate to dense overstory of willow; groundcover dominated by sedge and moss; grass and horsetail common; forbs diverse and scant; sphagnum often present.											
Characteristic Species:	Willow (*Salix* spp.), water sedge (*Carex aquatilis*), moss (bryophyte spp.)											
Associated Species:	Shrub birch (*Betula glandulosa*), shrubby cinquefoil (*Potentilla fruticosa*), nagoonberry (*Rubus acaulis*), sedge *(Carex* spp.), grass *(Poaceae* spp.), horsetail *(Equisetum* spp.), coltsfoot (*Petasites frigidus*), bluebell (*Mertensia paniculata*), sphagnum moss (*Sphagnum* spp.)											

Regional Soil Characteristics for Region 2: South-East Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Lodgepole pine	Glaciofluvial,morainal, high alluvial terraces	Level to rolling	Well to rapid	Loam to sand	Sandy loam to gravelly sand	6.0-5.1 medium acid to strongly acid	Very low	Very low	Very low	Very low	Low	Low
Description:	Lodgepole pine dominates an open tree canopy which often includes white spruce and apsen; tall shrub understory sparse or absent; low shrubs include soapberry and rose, kinnikinnick is a diagnostic and dominant groundshrub; grass forbs and lichen are common but sparse. This community commonly establishes following fire and is eventually succeeded by white spruce, which appears in the shrub understory.											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (*Vaccinium vitis-idaea*).											
Associated Species:	White spruce (*Picea glauca*), aspen (*Populus tremuloides*), soapberry (*Shepherdia canadensis*), willow (*Salix* spp.), wild rose (*Rosa acicularis*), northern rough fescue (*Festuca altaica*), arctic lupine (*Lupinus arcticus*), fireweed (*Epilobium angustifolium*).											
White spruce/black spruce	Morainal	May be underlain by permafrost	Imperfect to poor	Mesic peat to sandy loam	Silty loam to gravelly loamy sand	6.1-7.3 Slightly acid to neutral	Low	High	Moderate to high	low	Low	Low
Description:	Open tree canopy dominated by white and black spruce; Labrador tea and other low ericaceous shrubs are abundant in the understory; continuous moss groundcover; sphagnum often present; forbs scant.											
Characteristic Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*).											
Associated Species:	Labrador tea (*Ledum groenlandicum*), willow (*Salix* spp.), rose (*Rosa acicularis*), bog blueberry (*Vaccinium uliginosum*), bearberry (*Arctostaphylos rubra*), crowberry (*Empetrum nigrum*), lowbush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*), sphagnum (*Sphagnum* spp.), reindeer lichen (*Cladina* spp.).											
White spruce	Morainal, fluvial	Level to rolling	Moderately well to well	Silty loam to gravelly sandy loam	Gravelly sandy loam	6.1-7.3 Slightly acid to neutral	Low	Low	Low	Low to moderate	Moderate	Low
Description:	White spruce dominate in tree canopy, though mature balsam poplar and aspen are frequently present; shrub understory includes willow, alder, highbush cranberry, Labrador tea, and rose; groundcover dominated by moss, lowbush cranberry, and horsetail; forbs diverse. This community represents a climax vegetation stage.											
Characteristic Species:	White spruce (*Picea glauca*), willow (*Salix* spp.).											
Associated Species:	Balsam poplar (*Populus balsamifera*), aspen (*Populus tremuloides*), hoary alder (*Alnus incana*), rose (*Rosa acicularis*), highbush cranberry (*Viburnum edule*), soapberry (*Shepherdia canadensis*), Labrador tea (*Ledum groenlandicum*), lowbush cranberry (*Vaccinium vitis-idaea*), twinflower (*Linnaea borealis*), horsetail (*Equisetum* spp.), bluebell (*Mertensia paniculata*), bunchberry (*Cornus canadensis*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*).											
Mixed deciduous/coniferous	Morainal, fluvial	Uplands	Moderately well to well	Silty loam	Gravelly loamy sand to silt loam	6.1-7.3 slightly acid to neutral	moderate	medium	Low	Moderate	High	Moderate
Description:	This is an early seral community which commonly establishes following fire disturbance. Pine, sage, and paper birch dominate the canopy, with willow occurring throughout the understory. Later in succession, white and black spruce appear in the low shrub layer and eventually dominate most of these sites.											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), willow (*Salix* spp.).											
Associated Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*), highbush cranberry (*Viburnum edule*), rose (*Rosa acicularis*), soapberry (*Shepherdia canadensis*), lowbush cranberry (*Vaccinium vitis-idaea*), twinflower (*Linnaea borealis*), fireweed (*Epilobium angustifolium*), bunchberry (*Cornus canadensis*), arctic lupine (*Lupinus arcticus*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*).											

Vegetation and Landform Relationships
Region 3: South-West Yukon



Regional Soil Characteristics for Region 3: South-West Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Willow/aspen	Colluvial, morainal, alluvial	Level to moderately sloping	Moderately well to imperfect	Silty loam to gravelly sandy loam	Silty loam to gravelly sandy loam	6.1-7.3 Slightly acid to neutral	Moderate	Moderate	Moderate	Very low	Very high	Very high
Description:	This early successional community is common on disturbed sites following fire. The canopy is comprised of low tree willows and aspen. Pine and spruce typically invade these sites and frequently appear in the shrub understory. Willow, rose, Labrador tea and soapberry are usually present. The groundcover is comprised of variable amounts of lowbush cranberry, kinnikinnick and moss. Stands of white or black spruce may eventually develop on these sites.											
Characteristic Species:	Willow (*Salix* spp.), aspen (*Populus tremuloides*).											
Associated Species:	White spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), rose (*Rosa acicularis*), Labrador tea (*Ledum groenlandicum*), soapberry (*Shepherdia canadensis*), kinnikinnick (*Arctostaphylos uva-ursi*), bearberry (*Arctostaphylos rubra*), lowbush cranberry (*Vaccinium vitis-idaea*), moss (bryophyte spp.).											
Sage/grass	Colluvial slopes over bedrock	Steep south facing	Rapid	Loam to gravelly sand	Gravelly loam to gravelly sand	7.4-7.8 Mildly alkaline	Moderate to high	Moderate	High	Low	High	High
Description:	Sage is diagnostic among a diverse array of drought-tolerant forbs; sparse low shrubs include juniper; groundcover dominated by grass. Establishes under xeric conditions on steep, south-facing slopes.											
Characteristic Species:	Sage (*Artemisia frigida*), purple reedgrass (*Calamagrostic purpurascens*), fescue (*Festuca* spp.).											
Associated Species:	Kinnikinnick (*Arctostaphylos uva-ursi*), prickly saxifrage (*Saxifraga tricuspidata*), Jacob's ladder (*Polemonium pulcherrimum*), crocus (*Pulsatilla patens*), death camas (*Zygadenus elegans*), wild rye/wheatgrass (*Elymus* spp.).											
Willow/shrub birch	Aeolian veneer of morainal, glaciofluvial, fluvial	Underlain by permafrost	Poor to very poor	Fibric peat to loam	Silty loam to gravelly sandy loam	5.6-6.5 Medium to slightly acid	Medium	Moderate to high	Low	Low	Moderate	Moderate
Description:	Willow and shrub birch co-dominate in a well-developed shrub overstory. Low ericaceous shrubs and scattered conifers are common. Graminoids scant; variable moss and lichen groundcover.											
Characteristic Species:	Willow (*Salix* spp.), shrub birch (*Betula glandulosa*).											
Associated Species:	Black spruce (*Picea mariana*), Labrador tea (*Ledum groenlandicum*), shrubby cinquefoil (*Potentilla fruticosa*), bluebell (*Vaccinium uliginosum*), lowbush cranberry (*Vaccinium vitis-idaea*), bearberry (*Arctostaphylos rubra*), cloudberry (*Rubus chamaemorus*), sedge (*Carex* spp.), cottongrass (*Eriophorum* spp.), polargrass (*Arctagrostis latifolia*), moss (bryophyte spp.), reindeer lichen (*Cladina* spp.).											
Willow/sedge	Alluvial	Drainage channels	Poor to very poor	Mesic peat	Mesic peat to loam	7.4-7.8 Mildly alkaline	Low	High	Low	Low	High	High
Description:	Moderate to dense overstory of willow; groundcovery dominated by sedge and moss; grass and horsetail common; forbs diverse and scant; sphagnum often present. Riparian vegetation established along lake margins and creek drainages, which will regenerate if the present moisture regime persists.											
Characteristic Species:	Willow (*Salix* spp.), water sedge (*Carex aquatilis*), moss (bryophyte spp.).											
Associated Species:	Shrub birch (*Betula glandulosa*), shrubby cinquefoil (*Potentilla fruticosa*), nagoonberry (*Rubus acaulis*), sedge (*Carex* spp.), grass (*Poaceae* spp.), horsetail (*Equisetum* spp.), coltsfoot (*Petasites frigidus*), bluebell (*Mertensia paniculata*).											

Regional Soil Characteristics for Region 3: South-West Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Black spruce	Colluvial, morainal, fluvial	Northerly aspects, lower slopes	Poor to moderately well; frequent permafrost	Fibric peat over loam to sand	Silty loam to gravelly loamy sand	6.5-6.7 Neutral	Low	High	Low	Low	Moderate	Moderate
Description:	Black spruce diagnostic and dominant in a sparse tree and shrub understory; shrub birch, willow, Labrador tea and other low and prostrate ericaceous species commonly present; extensive moss groundcover often includes sphagnum.											
Characteristic Species:	Black spruce (*Picea mariana*), willow (*Salix* spp.), shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), feathermoss (*Hylocomium splendens*, *Pleurozium schreberi*).											
Associated Species:	Shrubby cinquefoil (*Potentilla fruticosa*), bluebell (*Mertensia paniculata*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), cloudberry (*Rubus chamaemorus*), lousewort (*Pedicularis* spp.), sphagnum moss (*Sphagnum* spp.).											
White spruce	Colluvial, alluvial fans, morainal	Most slopes and rolling terrain	Well to imperfect	Loam	Loam to gravelly sand	6.1-7.3 Slightly acid to neutral	Medium	Varibale (low to high)	Low to moderate	Very low	Moderate	High
Description:	White spruce dominant in tree canopy, though balsam poplar and aspen are frequently present; shrub understory includes willow, alder, shrub birch and Labrador tea; groundcover dominated by moss, lowbush cranberry and horsetail; forbs sparse and diverse. This community represents a climax vegetation stage.											
Characteristic Species:	White spruce (*Picea glauca*), willow (*Salix* spp.), feathermoss (*Hylocomium splendens*, *Pleurozium schreberi*).											
Associated Species:	Aspen (*Populus tremuloides*), alder (*Alnus* spp.), shrub birch (*Betula glandulosa*), soapberry (*Shepherdia canadensis*), rose (*Rosa acicularis*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), lowbush cranberry (*Vaccinium vitis-idaea*), wintergreen (*Pyrola* spp.), toadflax (*Geocaulon lividum)*.											
Black spruce/white spruce	Alluvial fans, moraines, colluvium	Lower slopes	Moderately well (probably permafrost)	Silty loam to sandy loam	Silty loam to gravelly loamy sand	6.1-7.3 Neutral to slightly acid	Very low	High	Moderate	Low	Moderate	Moderate
Description:	Open tree canopy dominated by white and black spruce; Labrador tea and other low ericaceous shrubs are abundant in the understory; continuous moss groundcover; sphagnum often present; forbs scant.											
Characteristic Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*).											
Associated Species:	Labrador tea (*Ledum groenlandicum*), willow (*Salix* spp.), rose (*Rosa acicularis*), bluebell (*Mertensia paniculata*), bearberry (*Arctostaphylos rubra*), crowberry (*Empetrum nigrum*), lowbush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*), feathermoss (*Hylocomium splendens*, *Pleurozium schreberi*), sphagnum moss (*Sphagnum* spp.), reindeer lichen (*Cladina* spp.).											
White spruce/balsam poplar	Floodplains of large creeks and rivers		Moderately well to rapid	Sandy loam	Sandy loam	5.6-6.5 medium to slightly acid	Very low	High	Low	Low	Low	Low
Description:	Open tree canopy is dominated by white spruce; mature balsam poplar co-dominate the stand; shrub assemblages variable and diverse, including willow, alder, highbush cranberry and red-osier dogwood; horsetail is prominent, and other forbs may be abundant and diverse; moss and lichen are often lacking due to frequent flooding and											
Characteristic Species:	White spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), rose (*Rosa acicularis*).											
Associated Species:	Alder (*Alnus* spp.), willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), highbush cranberry (*Viburnum edule*), northern red currant (*Ribes triste*), soapberry (*Shepherdia canadensis*), twinflower (*Linnaea borealis*), horsetail (*Equisetum* spp.), fireweed (*Epilobium angustifolium*), strawberry (*Fragaria virginiana*), toadflax (*Geocaulon lividum*), bluebell (*Mertensia paniculata*).											

Regional Soil Characteristics for Region 3: South-West Yukon

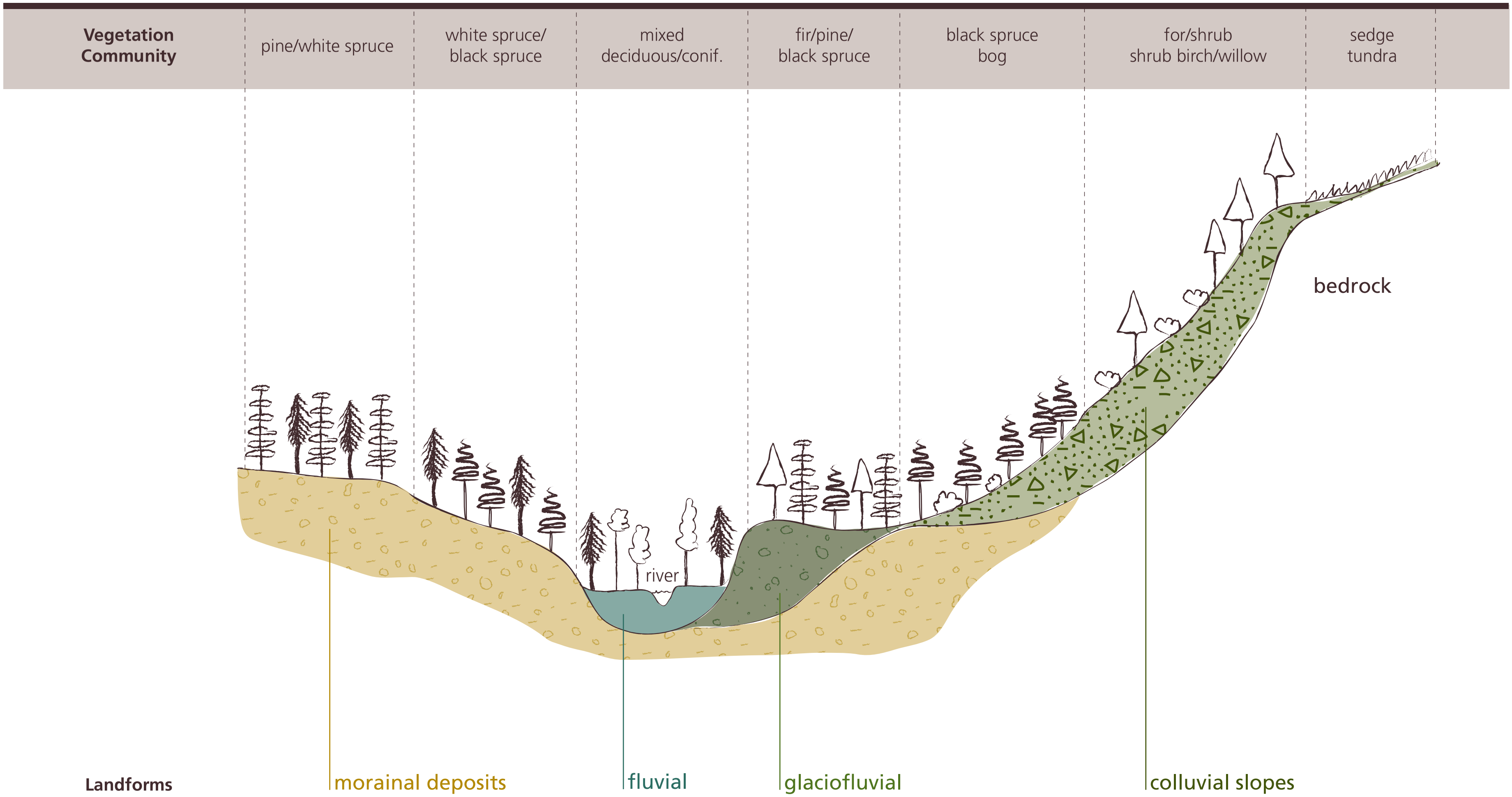
Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Mixed deciduous/ coniferous	Colluvial, morainal, glaciofluvial	Slopes and rolling uplands	Moderately well	Sandy loam to loam	Loam to clay loam	6.3-7.3 Neutral	Medium	Low	Low	High	Low	Low

Description: This seral community typically establishes following fire. The tree canopy is dominated by aspen, willow and paper birch. Pine is absent except in the easternmost part of Region 3. White and black spruce eventually invade these sites and comprise the climax vegetation cover.

Characteristic Species: Aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), willow (*Salix* spp.)

Associated Species: White spruce (*Picea glauca*), black spruce (*Picea mariana*), alder (*Alnus* spp.), shrub birch (*Betula glandulosa*), soapberry (*Shepherdia canadensis*), rose (*Rosa acicularis*), lowbush cranberry (*Vaccinium vitis-idaea*), bearberry (*Arctostaphylos rubra*), arctic lupine (*Lupinus arcticus*), cottongrass (*Eriophorum* spp.), dog ear lichen (*Peltigera* spp.), feathermoss (*Hylocomium splendens*, *Pleurozium schreberi*).

Vegetation and Landform Relationships
Region 4: Pelly/Cassiar Mountains



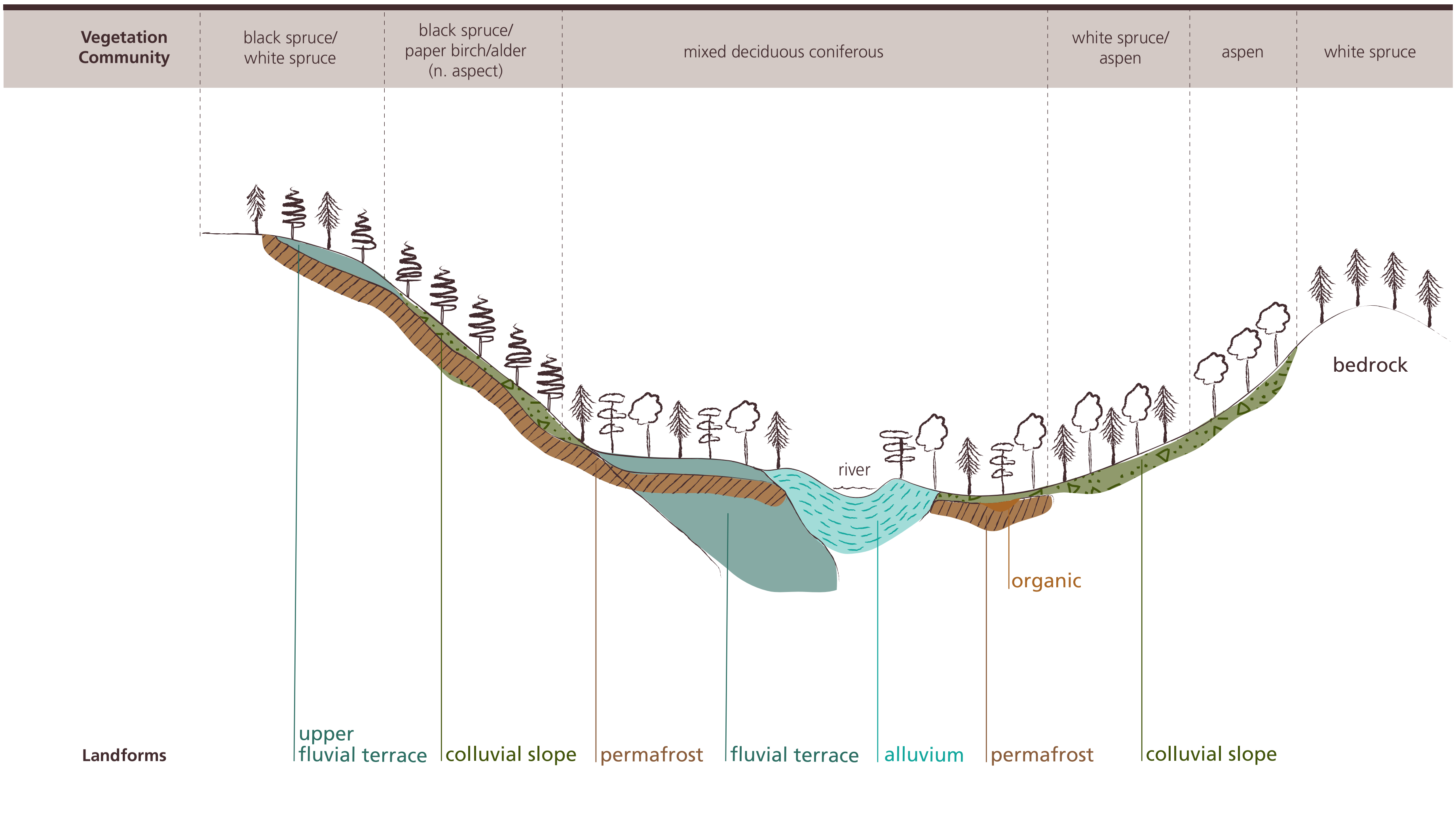
Regional Soil Characteristics for Region 4: Pelly-Cassiar Mountains

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Black spruce	Morainal and colluvial	Lower slopes, depressions	Imperfect to poor	Fibric peat, sandy loam	Sandy loam to loamy sand	6.5-5.1 Slightly acid to strongly acid	Low	High	Low	Low	Low	Low
Description:	Black spruce diagnostic and dominant in a sparse tree and shrub understory; shrub birch, willow, Labrador tea and other low ericaceous species commonly present; extensive moss groundcover often includes sphagnum.											
Characteristic Species:	Black spruce (*Picea mariana*), Labrador tea (*Ledum groenlandicum*), feathermoss (*Hylocomium splendens, Pleurozium schreberi*).											
Associated Species:	Willow (*Salix* spp.), shrub birch (*Betula glandulosa*), shrubby cinquefoil (*Potentilla fruticosa*), crowberry (*Empetrum nigrum*), bog cranberry (*Oxycoccus microcarpus*), bearberry (*Arctostaphylos rubra*), cloudberry (R*ubus chamaemorus*), sphagnum moss (*Sphagnum* spp.), reindeer lichen (*Cladina* spp.).											
Mixed deciduous/coniferous	Morainal and fluvial	Valleys (at lower elevations)	Well to moderately well	Silty loam to sandy loam	Silty loam to gravelly sandy loam	6.6-7.8 Neutral to mildly alkaline	Medium	Medium	Low	Low	Moderate	Low
Description:	This is an early seral community which establishes after fire. The canopy is dominated by pine, aspen and balsam poplar. Paper birch is common on wetter sites. Willow occurs throughout the understory. Later in succession, white and black spruce appear in the low shrub layer and eventually dominate most stands which reach maturity on											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), apsen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), willow (*Salix* spp.).											
Associated Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*), alder (*Alnus* spp.), rose (*Rosa acicularis*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (Vaccinium vitis-idaea), bunchberry (*Cornus canadensis*), feathermoss (*Hylocomium splendens, Pleurozium schreberi*).											
White spruce/lodgepole pine	Glaciofluvial, fluvial terraces	Level to gently sloping	Well to rapid	Sandy loam	Sandy loam to gravelly sand	6.1-7.3 Slightly acid to neutral	Low	Low	Low	Moderate	Moderate	Low
Description:	Open tree canopy dominated by pine and white spruce. Shrub understory diverse and well developed, including rose and willow. Groundcover is mainly comprised of kinnikinnick, lowbush cranberry and twinflower. Grass and forbs are sparse. This is a successional vegetation type which establishes after fire.											
Characteristic Species:	White spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), willow (*Salix* spp.).											
Associated Species:	Aspen (*Populus tremuloides*), Labrador tea (*Ledum groenlandicum*), rose (*Rosa acicularis*), twinflower (*Linnaea borealis*), lowbush cranberry (*Vaccinium vitis-idaea*), northern rough fescue (*Festuca altaica*), arctic lupine (*Lupinus arcticus*), fireweed (*Epilobium angustifolium*), moss (bryophyte spp.).											
White spruce/black spruce	Morainal and colluvial	Lower slopes	Well to imperfect; permafrost commonly present	Sandy loam	Sandy loam	6.1-7.8 Slightly acid to mildly alkaline	Low	Moderate	Moderate	Low	Low	Low
Description:	Open tree canopy dominated by white and black spruce; Labrador tea and other low ericaceous shrubs are abundant in the understory; continuous moss groundcover; sphagnum often present; forbs scant.											
Characteristic Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*).											
Associated Species:	Labrador tea (*Ledum groenlandicum*), willow (*Salix* spp.), rose (*Rosa acicularis*), bluebell (*Mertensia paniculata*), bearberry (*Arctostaphylos rubra*), crowberry (*Empetrum nigrum*), lowbush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*), sphagnum moss (*Sphagnum* spp.), reindeer lichen (*Cladina* spp.).											

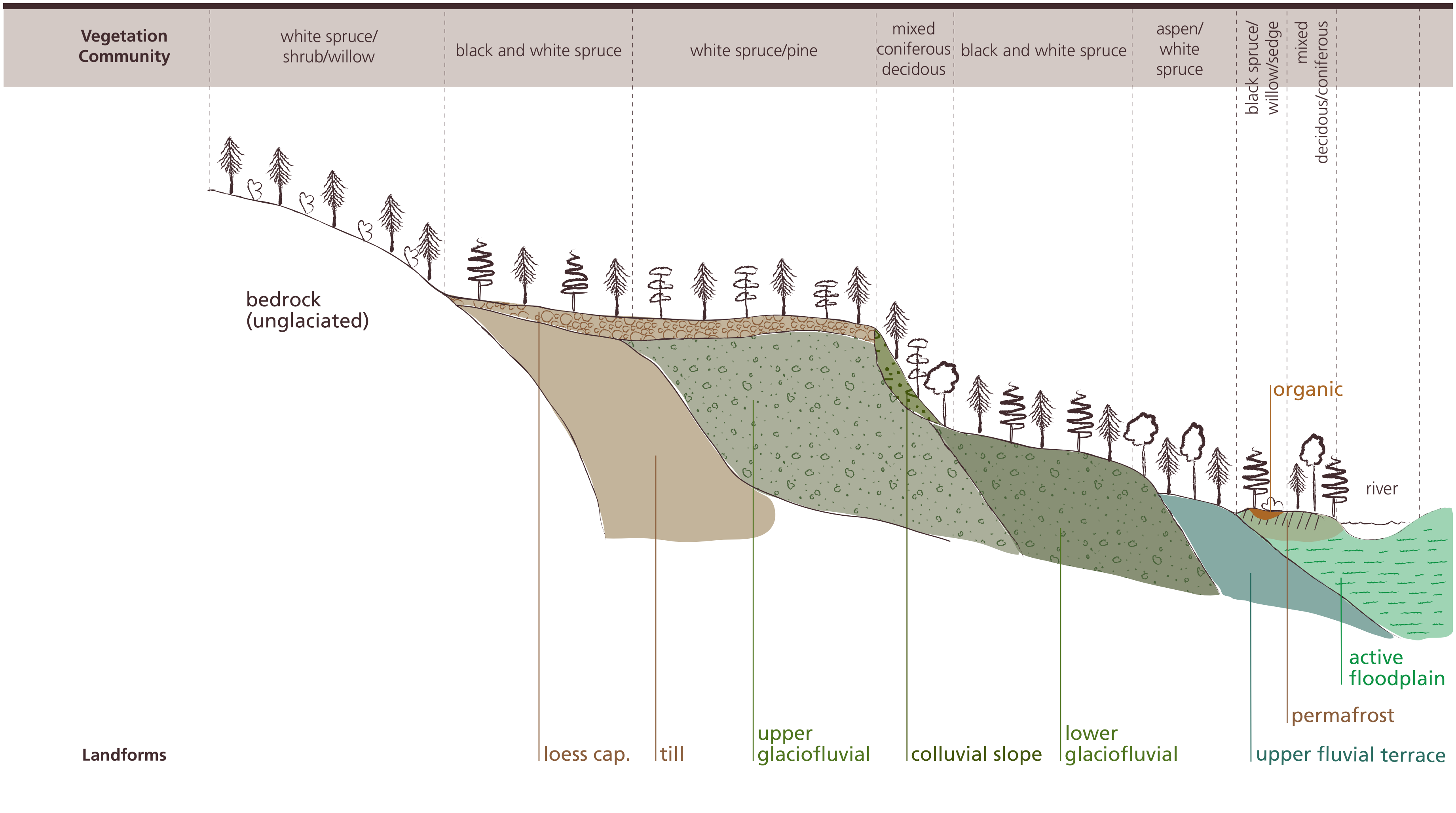
Regional Soil Characteristics for Region 4: Pelly-Cassiar Mountains

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Alpine fir	Morainal, colluvial, glaciofluvial	Over bedrock	Moderate to well	Sandy loam to loamy sand	Gravelly sand loam over bedrock	6.1-7.8 Slightly acid to mildly alkaline	Neutral	Low	Low	Low	Low	Low
Description:	This community comprises the climax vegetation at higher elevations; alpine fir dominant throughout the canopy and shrub understory; low ericaceous shrubs common; herbs scant but diverse; moss layer extensive overlain by variable cover of lichen.											
Characteristic Species:	Alpine fir (*Abies lasiocarpa*), shrub birch (*Betula glandulosa*), crowberry (*Empetrum nigrum*), feathermoss (bryophyte spp.), reindeer lichen (*Cladina* spp.).											
Associated Species:	White spruce (*Picea glauca*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), spirea (*Spiraea beauverdiana*), bog blueberry (*Vaccinium uliginosum*), lowbush cranberry (*Vaccinium vitis-idaea*), arctic lupine (*Lupinus arcticus*).											
Alpine fir/shrub birch-willow	Colluvial, morainal	Especially cooler aspects in the subalpine	Moderate to well	Silty loam to loamy sand	Loam to sandy loam	6.1-7.3 Slightly acid to neutral	Low	Low	Low	Low	Low to moderate	Low
Description:	A stable community, common at subalpine elevations; tree canopy of alpine fir varies in density; shrub understory is well-developed, dominated by shrub birch and willow; low ericaceous shrubs common over groundcover of moss and lichen.											
Characteristic Species:	Alpine fir (*Abies lasiocarpa*), shrub birch (*Betula glandulosa*), willow (*Salix* spp.), crowberry (*Empetrum nigrum*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*), reindeer lichen (*Cladina* spp.).											
Associated Species:	White spruce *(Picea glauca)* , Labrador tea *(Ledum groenlandicum)* , spirea *(Spireaea beauverdiana)* , bog blueberry *(Vaccinium uliginosum)* , lowbush cranberry *(Vaccinium vitis-idaea)* , arctic lupine *(Lupinus arcticus).*											
Sedge/cottongrass	Colluvial, bedrock	Alpine to subalpine	Well to poor	Mesic peat to loam	Loam to gravelly sand	6.1-6.5 Slightly acid to mildly alkaline	Low	High	Low	Low	Low	Low
Description:	A stable community, common at subalpine elevations; tree canopy of alpine fir varies in density; shrub understory is well-developed, dominated by shrub birch and willow; low ericaceous shrubs common over groundcover of moss and lichen.											
Characteristic Species:	Alpine fir (*Abies lasiocarpa*), shrub birch (*Betula glandulosa*), willow (*Salix* spp.), crowberry (*Empetrum nigrum*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*), reindeer lichen (*Cladina* spp.).											
Associated Species:	White spruce (*Picea glauca*), Labrador tea (*Ledum groenlandicum*), spirea (*Spiraea beauverdiana*), bog blueberry (*Vaccinium uliginosum*), lowbush cranberry (*Vaccinium vitis-idaea*), arctic lupine (*Lupinus arcticus*).											

Vegetation and Landform Relationships
Region 5A: Klondike Valley



Vegetation and Landform Relationships
Region 5B: West-Central Yukon–Stewart Valley



Regional Soil Characteristics for Region 5: West-Central Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Grassland	Glaciofluvial, colluvial	Very steep sloping	Well to rapid	Organic to loam	Sand to gravel	7.3-8.0 Slightly alkaline	Low to high	Moderate to high	Moderate to high	Moderate to high	Moderate to high	Moderate to high
Description:	The community overstory is dominated by graminoids and forbes; community edges may contain some aspen seedlings, an occasional kinnikinnick or rose plant; very exeric sites are dominated by sage, Gorman's beard tongue or prickly saxifrage; slightly moister sites contain purple reedgrass, Yukon wheatgrass, glaucous bluegrass and sedges;											
Characteristic Species:	Yukon wheatgrass (*Elymus calderi*), purple reedgrass (*Calamagrostis purpurascens*), sage (*Artemisia frigida*), glaucous bluegrass (*Poa glauca*), Gorman's beard tongue (*Penstemon Gormanii*).											
Associated Species:	Prickly saxifrage (*Saxifraga tricuspidata*), flax (*Linum perenne*), androsace (*Androsace septentrionalis*), crocus (*Pulsatilla patens*), pussytoes (*Antennaria rosea*), sedge (*Carex* spp.).											
Aspen	Fluvial, glaciofluvial	Undulating to moderately rolling	Moderate to well	Silty clay loam	Sand to gravelly sand	6.3-7.7 Neutral to alkaline	Moderate	Low	Low	Moderate	High	Moderate
Description:	Aspen dominates an open tree canopy which may include occasional white spruce and balsam poplar; shrubs include soapberry, rose, willow and Labrador tea; kinnikinnick and twinflower are common groundshrubs; grasses, forbs and lichens are common. This vegetation often occurs as a stable community adjacent to grasslands on south-facing slopes, or as an early successional community following fire.											
Characteristic Species:	Aspen (*Populus tremuloides*), kinnikinnick (*Arctostaphylos uva-ursi*), rose (*Rosa acicularis*), purple reedgrass (*Calamagrostis purpurascens*), soapberry (*Shepherdia canadensis*).											
Associated Species:	White spruce (*Picea glauca*), willow (*Salix* spp.), northern fescue (*Festuca altaica*), arctic lupine (*Lupinus arcticus*), Labrador tea (*Ledum groenlandicum*), bunchberry (*Cornus canadensis*), twinflower (*Linnaea borealis*), northern twinflower (*Linnaea borealis*).											
Lodgepole pine	Glaciofluvial, morainal	Level terraces	Well to rapid	Sandy loam to loamy sand	Sandy loam to gravelly sand	5.3-6.3 acid to slightly acid	Low	Low	Very low	Very low	Very low	Very low
Description:	Lodgepole pine dominates an open tree canopy which can include white spruce and aspen; a tall shrub understory is sparse or absent; low shrubs include soapberry and rose; kinnikinnick is a diagnostic and dominant groundshrub; grasses, forbs and lichens are common but sparse; community develops on well-drained sites.											
Characteristic Species:	Lodgepole pine (*Pinus contorta*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (*Vaccinium vitis-idaea*), purple reedgrass (*Calamagrostis purpurascens*).											
Associated Species:	White spruce (*Picea glauca*), aspen (*Populus tremuloides*), soapberry (*Shepherdia canadensis*), willow (*Salix* spp.), rose (*Rosa acicularis*), northern rough fescue (*Festuca altaica*), arctic lupine (*Lupinus arcticus*), fireweed (*Epilobium angustifolium*), bear root (*Hedysarum alpinum*).											
Black spruce	Morainal, colluvial, lacustrine	Depressional to level	Very poor to poor	Organic	Organic (permafrost)	6.0-6.7 Slightly acid to neutral	Very low	Very high	Low	Very low	Low	Low
Description:	Black spruce dominates the tree canopy; which may also include white spruce and paper birch; a wide range of shrubs and dward shrubs includes Labrador tea, willows, blueberry, shrubby cinquefoil, lowbush cranberry; crowberry and northern bearberry; forbs and graminoids are limited – the most common are sedges and bluejoint											
Characteristic Species:	Black spruce (*Picea mariana*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), sedge (*Carex* spp.), bluejoint reedgrass (*Calamagrostis canadensis*).											
Associated Species:	White spruce (*Picea glauca*), bog blueberry (*Vaccinium uliginosum*), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), tufted hairgrass (*Deschampsia caespitosa*), northern rough fescue (*Festuca altaica*).											

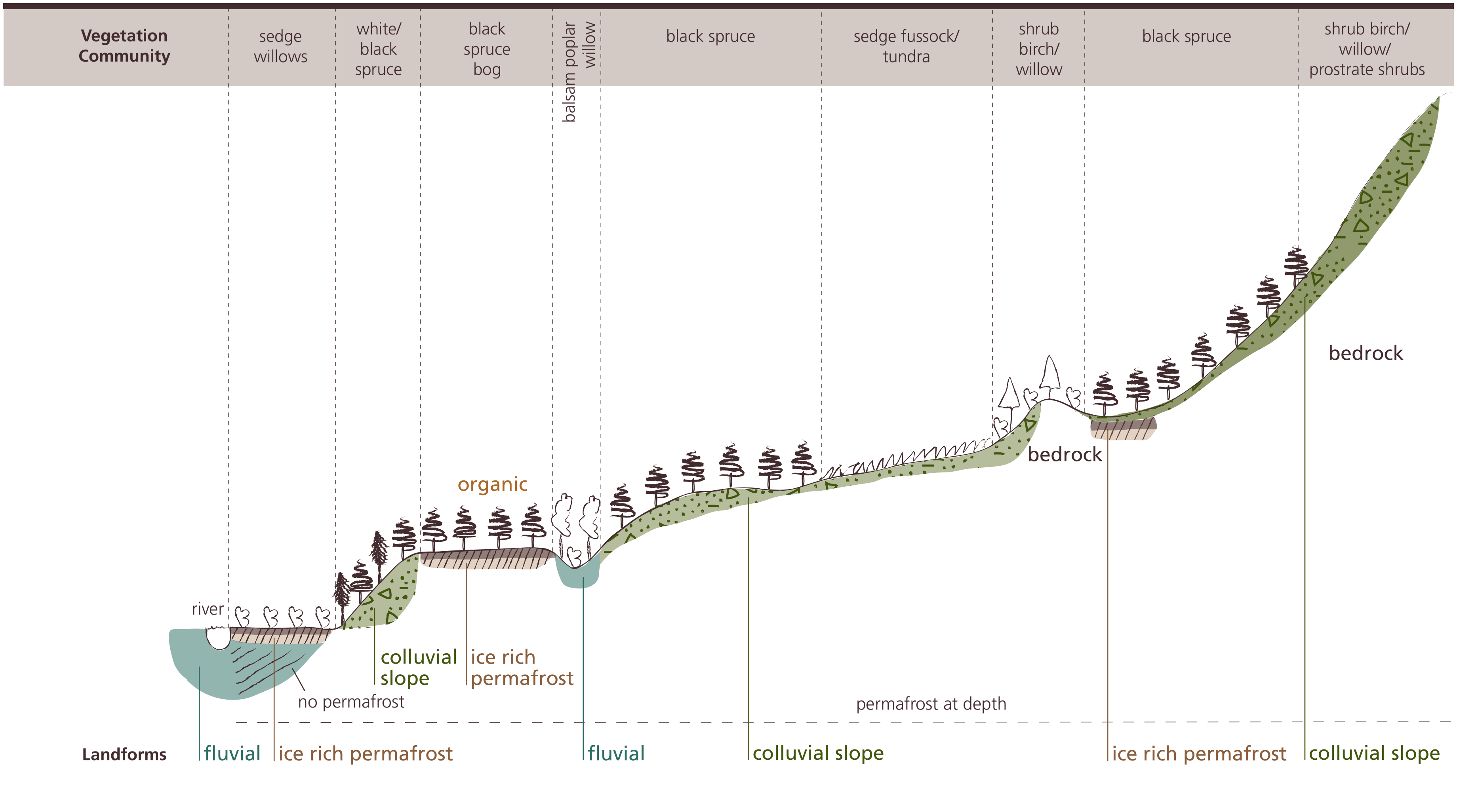
Regional Soil Characteristics for Region 5: West-Central Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
White spruce	Glaciofluvial, morainal, fluvial	Gently rolling	Moderate to well	Loam to clay loam	Sandy loam to gravelly sand	7.5-8.4 Alkaline to highly alkaline	Low to high	Moderate	Low to high	Very low	High	Low to high
Description:	White spruce is the dominant tree in the canopy; pure stands are rare; the canoy may include aspen, lodgepole pine, black spruce; shrubs include soapberry, rose and willows; groundshrubs such as kinnikinnick and lowbush cranberry are common; arctic lupine, purple reedgrass and violet wheatgrass are the most abundant herbs; community occurs on mesic to dry sites.											
Characteristic Species:	White spruce (*Picea glauca*), soapberry (*Shepherdia canadensis*), kinnikinnick (*Arctostaphylos uva-ursi*), willow (*Salix* spp.), purple reedgrass (*Calamagrostis purpurascens*).											
Associated Species:	Rose (*Rosa acicularis*), Labrador tea (*Ledum groenlandicum*), lowbush cranberry (*Vaccinium vitis-idaea*), twinflower (*Linnaea borealis*), arctic lupine (*Lupinus arcticus*), violet wheatgrass (*Elymus alaskanus*).											
White spruce/black spruce	Morainal, glaciofluvial, fluvial	Nearly level, upland	Imperfect to moderate	Organic	Sandy gravel	6.2-7.1 Slightly acid to neutral	Low	High	Moderate to high	Low	Low	Low
Description:	White and black spruce dominate the tree canopy; white spruce is more prominent on higher, drier sites, and black spruce more prominent at moister, lower elevations; the diverse shrub layer includes Labrador tea, willow, kinnikinnick, rose, shrubby cinquefoil, lowbush cranberry, blueberry and crowberry; an equally diverse herb stratum includes species such as bearberry, numerous sedges and numerous grasses.											
Characteristic Species:	White spruce (*Picea glauca*), black spruce (*Picea mariana*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), sedge (*Carex* spp.), bluejoint reedgrass (*Calamagrostis canadensis*).											
Associated Species:	Bog blueberry (*Vaccinium uliginosum*), kinnikinnick (*Arctostaphylos uva-ursi*), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), northern rough fescue (*Festuca altaica*), bear root (*Hedysarum alpinum*).											
Willow/shrub birch	Lacustrine, fluvial	Depressional to level	Poor to imperfect	Organic to loam	Sandy loam to gravelly sand	5.6-6.3 Acid to neutral	Moderate	Moderate to high	Low	Low	Moderate	Moderate
Description:	Canopy is comprised of medium to tall shrubs, with a scattered occurrence of white or black spruce; dominant shrubs are shrub birch and several willows; other shrubs include blueberry, Labrador tea and shrubby cinquefoil; crowberry and lowbush cranberry are common dwarf shrubs; herb layer is limited in diversity, dominated by grasses such as bluejoint reedgrass and sedges.											
Characteristic Species:	Shrub birch (*Betula glandulosa*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), bluejoint reedgrass (*Calamagrostis canadensis*), sedge (*Carex* spp.).											
Associated Species:	Shrubby cinquefoil (*Potentilla fruticosa*), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), tufted hairgrass (*Deschampsia caespitosa*), ticklegrass (*Agrostis scabra*), cottongrass (*Eriophorum* spp.).											

Regional Soil Characteristics for Region 5: West-Central Yukon

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Mixed deciduous/white spruce	Fluvial, morainal	Gently rolling	Moderate to well	Loam to clay	Sandy loam to gravel	6.5-7.4 Neutral to slightly alkaline	Low	Low to moderate	Low	Moderate	Moderate	Low
Description:	The canopy is usually dominated by white spruce, aspen and balsam poplar; may also include black spruce, paper birch or lodgepole pine; diverse shrub layer includes willows alder and rose; kinnikinnick and lowbush cranberry are very common groundshrubs; most prevalent grasses are slender wheatgrass, purple reedgrass and glaucous bluegrass; bear root and arctic lupine are prominent legumes, variousl milk vetches are less common.											
Characteristic Species:	White spruce (*Picea glauca*), aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), willow (*Salix* spp.), rose (*Rosa acicularis*), kinnikinnick (*Arctostaphylos uva-ursi*).											
Associated Species:	Bog blueberry (*Vaccinium uliginosum*), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), slender wheatgrass (*Elymus trachycaulus*), glaucous bluegrass (*Poa glauca*), purple reedgrass (*Calamagrostis purpurascens*), arctic lupine (*Lupinus arcticus*), bear root (*Hedysarum alpinum*).											
Willow/sedge	Fluvial	Very gently sloping	Poor to imperfect	Organic	Organic	6.4-7.6 Neutral to alkaline	Very low	High	Moderate	Moderate	Moderate	High
Description:	The tree overstory is usually restricted to various species of tall willows, but may include scattered balsam poplar; the shrub layer includes shorter willows, shrub birch, Labrador tea, shrubby cinquefoil and crowberry; northern bearberry is a prominent ground shrub; forbs are uncommon but graminoids include sedges, bluejoint reedgrass and tufted hairgrass.											
Characteristic Species:	Willows (*Salix alaxensis* , *S. arbusculoides* , *S. bebbiana* , *S. scouleriana*), sedge (*Carex* spp.).											
Associated Species:	Shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), bluejoint reedgrass (*Calamagrostis canadensis*), shrubby cinquefoil (*Potentilla fruticosa*), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), tufted hairgrass (*Deschampsia caespitosa*), bear root (*Hedysarum alpinum*).											
White spruce/balsam poplar	Lacustrine, fluvial	Nearly level	Imperfect to well	Silty clay	Silty sand; gravel	6.6-7.4 Neutral to slightly alkaline	Moderate	Low	Low	Moderate	High	Moderate
Description:	The open tree canopy is largely comprised of white spruce and balsam poplar; common shrubs include alder, willow, rose, shrubby cinquefoil and highbush cranberry; lowbush cranberry and kinnikinnick provide ground cover; legumes are not common but may include bear root and alpine milk vetch; graminoids such as sedges rushes and numerous grasses are diverse but sparse.											
Characteristic Species:	White spruce (*Picea glauca*), balsam poplar (*Populus balsamifera*), alder (*Alnus* spp.), willow (*Salix* spp.), bluejoint reedgrass (*Calamagrostis canadensis*), sedge (*Carex* spp.).											
Associated Species:	Highbush cranberry (*Viburnum edule*), shrubby cinquefoil (*Potentilla fruticosa*), rose (*Rosa acicularis*), lowbush cranberry (*Vaccinium vitis-idaea*), tufted hairgrass (*Deschampsia caespitosa*), bear root (*Hedysarum alpinum*), alpine milk vetch (*Astragalus* spp.), ticklegrass (*Agrostis scabra*).											

Vegetation and Landform Relationships
Region 6: Ogilvie-Wernecke-Peel Region



Regional Soil Characteristics for Region 6: Ogilvie-Wernecke-Peel Region

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Mountain avens	Colluvial, morainal	Rolling to level	Well to rapid	Silty sand	Gravel and cobbles	6.6-7.2 Neutral	High	Low	Low	Low	Moderate	Low
Description:	This community has no trees other than occasional stunted white spruce; common shrubs include mountain avens, Lapland rosebay, white heather and alpine bearberry; less common are kinnikinnick, shrubby cinquefoil, bog blueberry, netted willow and Drummond's dryas; herbs include cottongrass, sedges, northern rough fescue, hairy											
Characteristic Species:	Mountain avens (*Dryas intergrifolia* and *D. octopetala*), Lapland rosebay (*Rhododendron lapponicum*), white heather (*Cassiope tetragona*), alpine bearberry (*Arctostaphylos rubra*), sedge (*Carex* spp.).											
Associated Species:	Cottongrass (*Eriophorum* spp.), bog blueberry (*Vaccinium uliginosum*), netted willow (*Salix reticulata*), northern rough fescue (*Festuca altaica*), hairy wild ryegrass (*Elymus innovatus*), Drummond's dryas (*Dryas Drummondii*), bear root (*Hedysarum* spp.), lichens (*Cetraria* spp. and *Cladina rangiferina*).											
Black spruce	Fluvial, glaciofluvial, colluvial	Depressional to level, some moderate slopes	Very poor to poor	Organic	Clay,silt or sand	3.2-5.5 Extremely to strongly acid	Very low	Very high	Low	Very low	Low to moderate	Low
Description:	Black spruce dominates the tree canopy which may also include limited amounts of tamarack or paper birch; a wide range of shrubs and ground shrubs includes Labrador tea, willow, bog blueberry, lowbush cranberry, cloudberry, crowberry and bog rosemary; forbs and graminoids are limited – the most common are sedges, horsetails, cottongrass and bluejoint reedgrass; mosses are common.											
Characteristic Species:	Black spruce (*Picea mariana*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), sedge (*Carex* spp.), bluejoint reedgrass (*Calamagrostis candensis*).											
Associated Species:	Tamarack (*Larix laricina*), paper birch (*Betula papyrifera*), lowbush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*), crowberry (*Empetrum nigrum*), bog blueberry (*Vaccinium uliginosum*), bog rosemary (*Andromeda polifolia*), cottongrass (*Eriophorum* spp.), sphagnum moss (*Sphagnum* spp.), feathermoss (*Hylocomium splendens*, *Pleurozium schreberi*), wetland moss (*Aulacomium palustre*).											
White spruce/black spruce/paper birch	Morainal, glaciofluvial, colluvial	Nearly level to steep	Imperfect to moderately well	Organic and clay	Clay to sandy gravel	3.6-6.5 Extremely acid to neutral	Low	Moderate to high	Low to moderate	Low	Moderate	Low
Description:	White spruce dominates the tree canopy but black spruce and/or paper birch are commonly present; a diverse shrub layer includes Labrador tea, willow, alder, Alaska spiraea, rose, black currant, lowbush cranberry, cloudberry, crowberry and twinflower; the herb stratum is limited in diversity; bluejoint reedgrass and polargrass are common. Moss and lichen cover is low.											
Characteristic Species:	White spruce (*Picea glauca),* black spruce (*Picea mariana*), paper birch (*Betula papyrifera*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), lowbush cranberry (*Vaccinium vitis-idaea*), Bluejoint reedgrass (*Calamagrostis canadensis*).											
Associated Species:	Alaska spirea (*Spiraea beauverdiana*), crowberry (*Empetrum nigrum*), alder (*Alnus* spp.), rose (*Rosa acicularis*), twinflower (*Linnaea borealis*), cloudberry (*Rubus chamaemorus*), black currant (*Ribes hudsonianum*), polargrass (*Arctagrostis latifolia*).											

Regional Soil Characteristics for Region 6: Ogilvie-Wernecke-Peel Region

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Willow/shrub birch	Lacustrine, fluvial	Depressional to level	Poor to imperfect	Organic (some clay loam)	Clay loam	3.3-5.8 Extremely to slightly acid	Moderate	Moderate to high	Low	Low	Moderate	Moderate
Description:	The canopy is comprised of medium and tall shrubs; trees are limited to the occasional stunted white or black spruce; dominant shrubs are shrub birch and several willows; other shrubs include bog blueberry, Labrador tea and shrubby cinquefoil; cloudberry, crowberry and lowbush cranberry are common ground shrubs; herbs are low in diversity and frequency; to bluejoint reedgrass, cottongrass and tufted hairgrass.											
Characteristic Species:	Shrub birch (*Betula glandulosa*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), bog blueberry (*Vaccinium uliginosum*), cottongrass (*Eriophorum* spp.), bluejoint reedgrass (*Calamagrostis canadensis*), cloudberry (*Rubus chamaemorus*).											
Associated Species:	Shrubby cinquefoil (Potentilla fruticosa), lowbush cranberry (*Vaccinium vitis-idaea*), crowberry (*Empetrum nigrum*), northern bearberry (Arctostaphylos rubra), tufted hairgrass (*Deschampsia caespito* sa).											
White spruce	Glaciofluvial, morainal, fluvial, colluvial	Gently rolling to steep	Imperfect to well	Organic and sand or clay	Clay loam to coarse sand	4.6-7.1 Very strongly acid to neutral	Low to high	Moderate	Very low	Very low	Moderate to high	Low to high
Description:	White spruce dominates the tree canopy, which frequently includes; paper birch or balsam poplar; shrubs include soapberry, rose, alder, shrubby cinquefoil and willows; ground shrubs include northern bearberry, lowbush cranberry and crowberry; arctic lupine, bluejoint reedgrass, fireweed, bear root and horsetails are common herbs. Feather mosses are characteristic on closed canopy sites.											
Characteristic Species:	White spruce (*Picea glauca*), arctic lupine (*Lupinus arcticus*), soapberry (*Shepherdia canadensis*), bearberry (*Arctostaphylos rubra*), willow (*Salix* spp.), Bluejoint reedgrass (*Calamagrostis canadensis*).											
Associated Species:	Paper birch (*Betula papyrifera*), rose (*Rosa acicularis*), Labrador tea (*Ledum groenlandicum*), lowbush cranberry (*Vaccinium vitis-idaea*), alder (*Alnus* spp.), horsetail (*Equisetum* spp.), bear root (*Hedysarum* spp.), shrubby cinquefoil (*Potentilla fruticosa*), feathermoss (*Hylocomium splendens* , *Pleurozium schreberi*).											
Willow	Fluvial	Depressional to level	Poor to imperfect	Silt and sand	Sand to gravel	4.8-7.2 Very strongly acid to neutral	Low	Low	Low	Low	Moderate	Moderate
Description:	The overstory is dominated by tall and medium willow, but may also include scattered shrub birch and alder; other shrubs include Labrador tea, shrubby cinquefoil and bog blueberry; crowberry, nagoonberry and northern bearberry are prominent ground shrubs; common herbs include horsetail and larkspur and graminoids such as sedges, bluejoint reedgrass and northern bluegrass.											
Characteristic Species:	Willow (*Salix* spp.), horsetail (*Equisetum* spp.), larkspur (*Delphinium glaucum*), sedge (*Carex* spp.).											
Associated Species:	Shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), bog blueberry (*Vaccinium uliginosum*), Bluejoint reedgrass (*Calamagrostis canadensis*), shrubby cinquefoil (*Potentilla fruticosa*), bearberry (*Arctostaphylos rubra*), crowberry (*Empetrum nigrum*), nagoonberry (*Rubus acaulis*), northern bluegrass (*Poa alpigena*).											

Regional Soil Characteristics for Region 6: Ogilvie-Wernecke-Peel Region

Vegetation Community	Landform/ Genetic Material	Modifiers	Drainage	Soil Texture		Other Soil Properties			Available Nutrients			
				Top 30 cm	> 30 cm	pH	$CaCO_3$	Organic Matter	N	P	K	S
Balsam poplar	Fluvial	Nearly level	Well to rapid	Sand	Sand to gravel	6.3-7.4 Neutral to slightly alkaline	Moderate	Low	Low	Moderate	High	Moderate
Description:	The open tree canopy is comprised mainly of balsam poplar, with occasional occurrence of white spruce and aspen; common shrubs include alder, willows, rose, soapberry and highbush cranberry; lowbush cranberry and bearberry provide ground cover; common forbs are horsetail, larkspur, bear root and arctic lupine; graminoids include tufted hairgrass, bluejoint reedgrass, violet wheatgrass, slender wheatgrass, sedges and rushes.											
Characteristic Species:	Balsam poplar (*Populus balsamifera*), alder (*Alnus* spp.), willow (*Salix* spp.), Bluejoint reedgrass (*Calamagrostis canadensis*), horsetail (*Equisetum* spp.), sedge (*Carex* spp.).											
Associated Species:	White spruce (*Picea glauca*), highbush cranberry (*Viburnum edule*), soapberry (*Shepherdia canadensis*), rose (*Rosa acicularis*), lowbush cranberry (*Vaccinium vitis-idaea*), tufted hairgrass (*Deschampsia caespitosa*), bear root (*Hedysarum* spp.), arctic lupine (*Lupinus arcticus*), larkspur (*Delphinium glaucum*).											
Tamarack	Glaciofluvial, lacustrine, organic features	Depressional to level	Poor to imperfect	Organic	Clay and silt	4.0-6.0 Extremely acid to medium acid	Very low	Very high	Low	Very low	Low to moderate	Low to moderate
Description:	Tamarack dominates a sparse tree canopy, which usually includes scattered black spruce; shrubs are limited in diversity, and include Labrador tea, willows, bog blueberry, shrub birch; the ground shrub layer is dense and includes lowbush cranberry, bog cranberry, crowberry, cloudberry and the occasional dwarf birch; forbs, which include coltsfoot and graminoids are low in frequency and occurrence.											
Characteristic Species:	Tamarack (*Larix laricina*), willow (*Salix* spp.), Labrador tea (*Ledum groenlandicum*), lowbush cranberry (*Vaccinium vitis-idaea*) shrub birch (*Betula glandulosa*).											
Associated Species:	Black spruce (*Picea mariana*), bog blueberry (*Vaccinium uliginosum*), crowberry (*Empetrum nigrum*), bog cranberry (*Oxycoccus microcarpus*), cloudberry (*Rubus chamaemorus*), coltsfoot (*Petasites frigidus*), sphagnum moss (*Sphagnum* spp.).											
Cottongrass/Labrador tea	Lacustrine, organic features	Depressional to level	Poor to imperfect	Peat	Sand to gravel	3.4-3.9 Extremely acid	Low	High	Low	Low	Low	Low
Description:	This community has no trees or tall shrubs, although the occasional stunted black spruce or shrub birch may occur; ground shrubs include Labrador tea, crowberry, lowbush cranberry, dwarf birch, cloudberry and bearberry; dominant herbs are cottongrass and sedges; bluejoint reedgrass, polargrass and coltsfoot also occur; sphagnum and peatmoss are common.											
Characteristic Species:	Cottongrass (*Eriophorum* spp.), sedge (*Carex* spp.), sphagnum moss (*Sphagnum* spp.), Labrador tea (*Ledum groenlandicum*), dwarf birch (*Betula nana*), lowbush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*).											
Associated Species:	Bog blueberry (*Vaccinimum uliginosum*), Bluejoint reedgrass (*Calamagrostis canadensis*), crowberry (*Empetrum nigrum*), bearberry (*Arctostaphylos rubra*), coltsfoot (*Petasites frigidus*), polargrass (*Arctagrostis latifolia*), prostrate willows (*Salix* spp.), peat moss (*Drepanocladus* spp.).											

Appendix B

Sample Revegetation Contract Document

Ideally, the revegetation planner will be personally involved in the implementation of the revegetation plan that he or she has developed. In many projects, however, the practitioner develops the overall plan, including prescriptions for fertilizer, seed mixes and surface treatments, but the implementation is completed by a contractor. Furthermore, in many cases revegetation work is just a component of a larger construction or reclamation project, and the revegetation planner will be asked to provide language for a revegetation sub-section of the larger project contract.

The following is an example of a contract document that was developed for the revegetation component of a large mining reclamation project in Yukon. It is based on an actual contract but has been modified to reflect the principles outlined in this *Manual*.

Note that the contract prescribes the exact fertilizer and seeding mixes to be used, as well as surface treatments and other aspects of materials handling and expected workmanship. It also contains specific language describing how and when the work is to be performed. In this example, all site assessments and testing, including soil testing, were conducted by the planner, not the contractor. In fact, the planner would have needed to collect that site information before developing the contract specifications. In some projects, however, even the site assessment and development of treatment prescriptions will be out-sourced, but often as a separate contract.

Monitoring is critical on revegetation sites. In almost all cases, monitoring will be the responsibility of the planner and contracting agency, not the contractor.

PART 1 – GENERAL

1.1 Documents

1. This section of the Specification forms part of the Contract Documents and is to be read, interpreted and coordinated with all other parts.

1.2 General Description

1. The revegetation Works entail surface preparation (decompaction, tillage, seed bed preparation), fertilizing, and seeding 33.2 ha of variably sloped land on the reclaimed Killjoy Mine. The aerial extent and topography is indicated on construction drawing KM-8. Approximately 9.6 ha is steep ground on which no machinery can operate; it shall be hydroseeded. Approximately 23.6 ha are low slope and can be worked with machinery; it shall be mechanically decompacted and a seed bed shall be prepared, after which it will be fertilized and seeded.
2. The Works described in this Specification will be completed in one season (May – October).
3. The Works to be carried out under this Section of the contract consist of furnishing all labour, material, and equipment and the performance of all Works necessary to complete the seeding and fertilizing as shown on the drawings, and as specified herein, which will include, but is not limited to the following:
    a. Supply and delivery of seed
    b. Supply and delivery of fertilizer
    c. Supply and delivery of mulch and tackifier
    d. Surface preparation of areas to be seeded and fertilized
    e. Apply seed and fertilizer by mechanical methods
    f. Apply seed, mulch and tackifier by hydraulic methods (*i.e.*, hydroseeding).

1.3 Definitions

1. The following words and terms shall have the meaning set out below:
    a. **Engineer:** the Yukon Government Engineer responsible for management and decision-making on this project.
    b. **Fertilizing:** Applying chemical fertilizer in dry (pellet) form by mechanical spreaders.
    c. **Hydroseeding:** Applying seed, mulch, fertilizer and tackifier in a water based slurry that is projected through a nozzle by pump pressure.
    d. **Mechanical Seeding:** Applying seed in dry form by mechanical spreaders.
    e. **Seed Bed:** The top 10 cm of surface soil that is loosened and decompacted through fine tillage to accept fertilizer and seed so that both may be easily incorporated by harrowing.
    f. **Subsoiler:** A mechanical device drawn by a tracked vehicle or tractor and used to decompact ground through deep (>30 cm) tilling of the soil; examples are "ripper teeth" drawn by a tracked vehicle or large chisel ploughs pulled by a tractor.

1.4 Timing and Ground Conditions

1. Timing of seeding and fertilizing Works shall be coordinated with the completion of other site reclamation Works.
2. Before the initiation of each Major Work component (*i.e*, decompacting, harrowing, hydroseeding, fertilizing, seeding), "go ahead" approval must be received from the Engineer to ensure that appropriate site surface conditions exist.
3. No seeding or fertilizing of any type shall occur between July 7 and September 1.
4. The hydroseeding of steep slopes (9.6 ha) shall occur immediately after the completion of final grading in June.
5. Mechanical seeding and fertilizing shall occur in May / June, or in September / October.
6. Seeding and fertilizing shall be performed under calm wind conditions and on dry ground free of frost, snow, ice and standing water (Frost seeding will not be allowed without prior approval by the project Engineer).

1.5 Submittals

1. The Contractor shall notify the Engineer outlining his/her intended methods for seeding and fertilizing at least seven days prior to the commencement of Work, including, but not limited to the following details:
    a. Type of equipment and plan for deployment.
    b. Work schedule including work area(s), volume, storage area(s) and hours of operations.
    c. A work plan to carry out the specific work.
    d. Certificates of analysis from an accredited laboratory that provide seed purity and germination values for each seed species. Certificates shall be less than one year old.
    e. Origin of the seed shall be Western Canada, Yukon, or Alaska. A statement of the origin of the seed must be included.
2. Delivery
    a. Provide to the Engineer before and as a condition of use, a shipping bill issued by the supplier of the material, designating the supplier, the manufacturer, the type of material, and a certification of the net weight or volume of material in each container.
3. Daily Progress Reports
    a. Provide a daily report of work completed. Include in the report:
        i. Approximate area hydroseeded, mechanically seeded and fertilized.
        ii. The amount of materials used for each area.
        iii. The coverage in kg/ha for each material used for each area.
    b. Retain all empty containers of used materials for each day work until the Engineer has counted and marked the empty containers. Dispose of all empty containers after they have been counted.

PART 2 – EXECUTION

2.1 Preparation

1. No work shall be undertaken by the Contractor when, in the opinion of the Engineer or Contract Manager, the weather or soil is unsuitable or unfavourable for a particular class of work.
2. The Contractor shall be responsible for surveying and staking the seeding area to ensure the area seeded is the same as designated in this Specification (33.2 ha). No additional payment will be made for increased quantities or areas greater than this Specification unless approved by the Engineer or Contract Manager. This provision is included to ensure that the prescribed seeding and fertilizer application rates are achieved.

2.2 Materials

1. Protect all materials (seed, fertilizer, mulch, tackifier) from moisture and contamination as required during transportation and storage.
2. Any material which has become wet or otherwise damaged during delivery or storage, or does not meet the requirements specified shall be rejected and the Contractor shall immediately remove rejected material from the project area.
3. Deliver and store seed and fertilizer in original container showing:
    a. Analysis of seed mixture
    b. Fertilizer chemical analysis
    c. Year of production
    d. Net weight
    e. Date when tagged and growing location
    f. Name and address of distributor
4. Seed
    a. Seed must meet the requirements of the *Canada Seeds Act* for Certified Canada #1 seed for certified cultivars, or Canada Common #1 for common cultivars.
    b. Measurements are based on uncoated seed. Coated seed is permitted, if the total number of seeds per species remains as specified.
    c. The seed selections must meet the following purity and germination requirements:
        i. Species must not exceed the following limits for noxious or invasive weeds per 25 grams: 0 primary, 1 secondary, 25 total, and 0 sweet clover.
        ii. Minimum percent of Pure Life Seed must be 70%.

2.3 Equipment

1. All equipment shall be in good, clean condition with no leaks.
2. All equipment shall be equipped with required safety devises.
3. Store, refuel and maintain equipment in a responsible manner that is consistent with *Best Management Practices for Works Affecting Water in Yukon* (available from Yukon Department of Environment, Water Resources Branch).
4. Equipment, fuel, lubricants and other chemicals shall be staged and stored more than 30 m from any water body and in a designated location approved by the Engineer.

2.4 Workmanship

1. Clean up debris and excess fertilizer spilled; dispose of deleterious materials in an approved manner.
2. Work shall be performed with attention to detail and with all reasonable effort to affect good vegetative cover at the site.

PART 3 – HYDROSEEDING

3.1 General

1. Delivery and storage:
    a. Deliver wood-fibre mulch and tackifier in moisture-proof containers indicating manufacturer, content and net air-dry mass.
2. Mulch:
    a. The material used for mulching shall be natural wood fibre or specially processed wood fibre prepared for use in hydroseeding equipment, and of a type of approved by the Engineer.
    It shall contain no growth or germination inhibiting factors, and shall form after application a blotter-like ground cover that will allow retention and percolation of water.
    b. Mulch material shall have properties enabling it to be evenly dispersed and suspended when agitated in water.
3. Tackifier:
    a. The tackifier shall be free flowing non-corrosive biodegradable organic powder produced from a natural plant gum or approved equivalent.
4. Fertilizer:
    a. Supply complete fertilizer blend:
        i. 90 kg/ha of 11-48-3, or equivalent blend
        ii. Date of manufacture must demonstrate that the fertilizer is less than 1 year old.
        iii. Fertilizer shall meet requirements of the *Canada Fertilizer Act* and Fertilizer Regulations.
5. Water:
    a. Water used for hydroseeding and mulching shall be free of any impurities that would inhibit germination or otherwise adversely affect growth.
    b. The water source must be approved by the Engineer prior to use.

3.2 Surface Preparation

1. The sloped surface has been determined to have a grade ranging from 12 – 23 %; the Contractor is to verify that no slopes exceed 25% and submit verification or discrepancies to the Engineer.
2. Do not operate wheeled vehicles on the slope at any time or in any manner.
3. Tracked vehicles should only be operated up and down the slope, not cross-slope.
   Proper rollover protection devises must be in place and inspected daily.
4. The slope shall be track-walked by driving a large tracked vehicle up and down the slope, leaving cleat marks from the tracks perpendicular to the slope. The entire sloped surface should be track-walked, except where deemed too dangerous, but no area should be tracked more than once (to avoid compaction).

3.3 Hydroseeding Specification

1. The entire designated high-slope area (9.6 ha) shall be hydroseeded to a density of 3,000 Pure Live Seeds per square meter (PLS/m^2) with the following seed mix:

    Annual Rye (*Lolium multiflorum*, no specified cultivar): 300 PLS/m^2

    Rocky Mountain Fescue (*Festuca saximontana*, common): 700 PLS/m^2

    Glaucous Bluegrass (*Poa glauca*, Tundra or common): 700 PLS/m^2

    Tufted Hairgrass (*Deschampsia caespitosa*, Nortran or common): 600 PLS/m^2

    Ticklegrass (*Agrostis scabra*, common): 700 PLS/m^2

$$\textbf{kg of seed (per species)} = \frac{\textbf{area to be seeded (m}^2\textbf{) x desired seed density (PLS/m}^2\textbf{)}}{\textbf{number of seeds/kg x percent seed purity x percent seed viability}}$$

2. Equipment:
    a. Equipment for hydroseeding and mulching shall be capable of mixing the seed, mulch, fertilizer and tackifier as herein described, and evenly distributing the mixtures for efficient treatment of the selected areas.

b. The equipment shall have a built-in agitation system with an operating capacity sufficient to agitate, suspend and homogeneously mix a slurry of materials in the amounts specified.

c. The slurry tank shall have working capacity of at least 4,500 litres, and the pump shall be capable of maintaining a continuous, non-fluctuating stream of solution. Distribution lines shall be of large enough diameter to prevent blockage, and the discharge lines shall be equipped with appropriate nozzles.

d. The equipment shall be capable of hydroseeding to the extremities of all areas designated for hydroseeding, with no unevenness of coverage

3. Hydroseeding operations:

a. Thoroughly mix seed, mulch, fertilizer and tackifier uniformly distribute the mixture by means of an approved hydroseeder over the area designated by the Engineer.

b. Apply mulch material, with a minimum of 3% tackifier, at a rate of 1,500 kg/ha of plan area.

c. Hydroseed under calm conditions and on ground free of frost, snow, ice and standing water.

d. Measure the calculated quantities of each of the materials to be charged into the hydroseeder, either by mass or by a system of mass-calibrated volume measurement approved by the Engineer, and provide all equipment required for this purpose.

PART 4 – MECHANICAL FERTILIZING AND SEEDING

4.1 Surface Decompaction

1. Prior to fertilizing and seeding, the surface of the 23.6 hectare low-slope area shall be decompacted to a depth of no less than 40 cm.
2. The top 40 cm of ground is to be mechanically decompacted by means of deep tillage using either:

a. a subsoiler or multi-shanked ripper mounted on or drawn by a track-type tractor ("cat") and

i. with a horsepower rating not less than 120 hp

ii. with a minimum of three shanks (teeth) on the subsoiler, spaced not more than 40 cm measured between wings of the shanks.

b. a subsoiler or deep chisel plough drawn by a wheeled tractor and

i. with a horsepower rating not less than 110 hp, and with dual or triple rear wheels.

ii. In the case of a chisel plough, with an in-line tine spacing not to exceed 30 cm; in the case of a subsoiler, with shanks spaced not more than 40 cm.

c. substitutions of other equipment for decompaction require prior approval by the Engineer.

3. Decompaction Work shall not occur when the ground is wet or frozen.
4. Decompaction Work shall not occur more than 30 days prior to seed bed preparation.
5. Approval to begin decompaction must be received by the Engineer.

4.2 Seed Bed Preparation

1. The upper 10 cm of the decompacted 23.6 hectare surface is to be lightly disked or harrowed to a finer texture in order to break up clods and to receive and incorporate fertilizer and seed.
2. Soil bed shall be prepared by means of a tine or disk harrow pulled by tractor or ATV and

a. the tines of a tine harrows shall have an in-line tooth spacing not to exceed 10 cm.

b. disk harrows shall be tandem or greater and have a disk spacing not to exceed 30 cm.

3. Harrowing shall not occur on wet or frozen ground.
4. Seed bed shall not be prepared more than 14 days prior to fertilizing and seeding operations.
5. Obtain Engineer's approval of seed bed prior to commencement of fertilizing and seeding operations.

4.3 Fertilizer Specification

1. Calibration of equipment

a. Calibrate spreader to ensure specified application rates are achieved.

b. Submit results of calibration to Engineer.

2. Supply and mechanically broadcast fertilizer to the following specifications:

   a. Apply 90kg/ha of 11-48-3-0, or equivalent blend. Variations from this blend require prior approval by the Engineer.

b. Fertilizer shall meet requirements of the *Canada Fertilizer Act and Fertilizer Regulations*.

c. Fertilizer shall be applied evenly to the surface with a broadcast spreader or equivalent. Alternative equipment and methods require prior approval by the Engineer.

d. Immediately (within 24 hours) after applying fertilizer, treat the entire surface with a tine or disk harrow in order to mechanically incorporate fertilizer into soil to a minimum depth of 2 cm and maximum depth of 10 cm.

e. It is acceptable to configure equipment so that fertilizer application and harrowing are accomplished simultaneously (*i.e.*, harrow pulled behind broadcaster).

4.4 Seeding Specification

1. Calibration of equipment
   a. Calibrate spreader to ensure specified application rates are achieved
   b. Submit results of calibration to Engineer.
2. Supply and sow seeds to the following specifications:
   a. Sow the following seed mix at a rate of 1,500 Pure Live Seed per hectare:

      Slender Wheatgrass (*Elymus trachycaulus*; Revenue, Adanac or Highlander): 300 PLS/m^2

      Rocky Mountain Fescue (*Festuca saximontana*, common): 300 PLS/m^2

      Glaucous Bluegrass (*Poa glauca*, Tundra or common): 300 PLS/m^2

      Tufted Hairgrass (*Deschampsia caespitosa*, Nortran or common): 300 PLS/m^2

      Ticklegrass (*Agrostis scabra*, common): 300 PLS/m^2

$$\textbf{kg of seed (per species)} = \frac{\textbf{area to be seeded (m}^2\textbf{) x desired seed density (PLS/m}^2\textbf{)}}{\textbf{number of seeds/kg x percent seed purity x percent seed viability}}$$

   b. Seed shall be applied evenly to the surface using a broadcast spreader or equivalent. Use of a seed drill or other seeder is acceptable with prior approval by the Engineer. If a seed drill or equivalent is used, the seed application rate may be reduced to 750 Pure Live Seed per hectare.
   c. Immediately (within 12 hours) cover and incorporate seed into seed bed to a minimum depth of 0.5 cm and a maximum depth of 2.0 cm by means of harrowing. Tine, disk or chain harrows may be used, either alone of in combination.
   d. It is acceptable to configure equipment so that seed application and harrowing are accomplished simultaneously *(i.e.*, harrow pulled behind broadcaster).
   e. No harrowing or further surface treatment is required after seeding if seeds were sown with a drill seeder or equivalent.

4.5 Decommissioning and Demobilizing

1. All debris, wrapping and shipping materials shall be removed from the site and disposed of in an appropriate manner.
2. Equipment on site, such as harrows, shall be used to smooth over and landscape ruts, uneven ground and other marks left by equipment either in or outside the treatment area. Spot seed areas where vegetation was damaged by work performed. Spot seeding shall utilize the same seed mix that was applied to the low slope area.
3. Other than for purposes described in paragraph 2 above, no equipment shall be driven on the site after it has been seeded.
4. Equipment shall not be left on site for a significant period (greater than 1 week) after the work is completed.
5. Equipment staging areas shall be inspected for fuel/lube spills and treated according to the fuel spill plan for the project.
6. Work site is subject to final inspection and approval by the Engineer.

Slope and Grade Reference

Slopes are reported in three ways:

Ratio (rise:run in m or ft)
Percent (or *grade*=rise/run x 100)
Degrees (also called the *angle*)