SECTION 3: MAKING PRE-TREATMENT SILVICULTURE PRESCRIPTIONS

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1 INTRODUCTION

This chapter describes the process used to develop the generic prescription flowcharts and how to apply them. The flowcharts follow immediately after the text. The text and flowcharts are aligned to enable practitioners to follow a specific flowchart while reading this chapter. To choose which flowchart to follow the silviculturist should place the site being prescribed on the modified edatopic grid and use that location plus the reforestation objective to select the appropriate flowchart.

The approach taken is one of identifying and remediating constraints on tree establishment and growth. This approach is premised on Blackman's Law of Limiting Factors[1] which posits that growth in plants is limited to the rate set by the "lowest" limiting factor. Further, Blackman demonstrated experimentally that removal of a single limiting factor while increasing growth did not result in optimum growth due to the "next lowest" limiting factor then setting the rate of growth. Therefore, to successfully ensure plant survival and growth the silviculturist must identify the suite of key limiting factors inherent to the site and ameliorate all of them to an extent sufficient to result in the level of growth desired. In this context, survival is simply the least common denominator of growth – without survival there can be no growth.

The approach taken to making the initial silvicultural prescription, then, is to identify the suite of constraints that trees attempting to establish and grow on the site will encounter. These include both the abiotic and biotic factors that influence the ecosystem. (***An abiotic factor is a nonliving condition or thing, such as climate or habitat, that influences or affects an ecosystem and the organisms in it: Abiotic factors can determine which species of organisms will survive in a given environment***.[2] ***A biotic factor is a living thing, such as an animal or plant, that influences or affects an ecosystem***.[3]) By addressing both major categories of constraint the silviculturist can enable desired tree species to establish and grow (at desired or expected rates) on the site.

Blackman's Law of Limiting Factors also demonstrates another important consideration in the amelioration of constraints: amelioration of key or major constraints will not result in unlimited growth as other, less prominent constraints will then act to limit growth. This means, in effect, that the silviculturist must decide what level of amelioration of constraints will suffice to achieve the desired objective.

By taking this approach the silviculturist is able to more efficiently achieve desired objectives AND mitigate the risk inherent in working with natural systems. Efficiency here refers to both cost effectiveness and time demand posed by silvicultural activities. In most cases, silvicultural practice is limited by financial resources and the availability of human resources to achieve desired outcomes. This approach accepts those realities and seeks to empower the silviculturist to succeed in that context.

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[1] http://www.biologydiscussion.com/photosynthesis/blackmans-law-of-limiting-factors-and-his-criticism-photosynthesis/23006
[2] www.dictionary.com/browse/abiotic-factor
[3] www.dictionary.com/browse/biotic-factor

2 SET OBJECTIVES

Alberta has led Canada in developing reforestation standards[4] that measure reforestation success against forest management planning assumptions. That is, the silviculturist is expected to establish stands that quantitatively attain the composition, structural and growth expectations that were used to forecast harvest levels in the forest management planning process. Reforestation success, then, is stands of a composition and structure growing at rates used to project the future fibre supply as measured in an assessment at 14 years after harvest. By including composition and structural objectives the reforestation standard implicitly addresses the range of ecological goods and services beyond simple fibre supply, including habitat for an array of both plant and animal species, water quality, water quantity, air quality, and a wide array of human cultural benefits and uses.

While laudable, the Reforestation Standard for Alberta places substantial responsibility on the silviculturist to develop both long and short term reforestation objectives. The silvicultural prescription must link the site to be reforested to the forest management planning objectives and to provincial minimum standards for reforestation. The forest management planning objectives determine fibre production requirements (i.e. growth) and provincial reforestation standards set composition objectives. Composition objectives may also be determined by forest management plan "transition" rules that set out changes in composition as part of the management planning process. Composition expectations are defined by species dominance:

- Conifer refers to stands that are dominantly coniferous in composition with only "incidental" (<20%) deciduous composition;
- Conifer leading or Coniferous-Deciduous have, at least, 50% coniferous composition and 20% deciduous composition;
- Deciduous leading stands have, at least 50% deciduous composition and 20% coniferous composition; and
- Deciduous stands are dominantly deciduous in composition with only "incidental" (<20%) coniferous composition.

These broad compositional categories are refined in the forest management planning process based on species and often site or growth capability. The silviculturist must effectively translate management planning expectations into measurable short-term (5-8 year) and medium-term (14 year) objectives of species composition, density and height growth that will result in species mixtures and growth outcomes that meet forest management planning expectations when modelled at 14 years after harvest. The easiest approach to setting silviculture objectives is to first consider what it would take to replace the stand that was harvested and then amend that "base prescription" to meet management planning expectations.

[4] http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15749/$FILE/ReforestationStandardAlberta-web.pdf

It is critical when making mixedwood silvicultural prescriptions that the silviculturist recognize that deciduous silviculture is largely "subtractive" in nature. Because aspen reforestation depends almost entirely on regeneration from rootstocks present on the site the silviculturist can do very little to increase aspen abundance or distribution on the site. Conversely, many silvicultural treatments used to enhance coniferous abundance or growth may, deliberately or inadvertently, reduce aspen abundance or distribution.

Conversely, coniferous regeneration is largely additive; silviculturists have an abundance of tools and techniques to increase the abundance of coniferous trees and to enhance their growth on reforestation sites. As mentioned above, when deploying conifer enhancement treatments in a mixedwood context the silviculturist must consider their impact on deciduous regeneration success.

Reforestation objectives should describe reforestation outcomes in terms of:

- Coniferous species – describe the dominant coniferous species desired on the site; this may be a single species or a mixture of coniferous species. The conifer objective should include desired density and growth at assessment time.
- Deciduous species – while aspen is generally the desired deciduous species it must be explicitly included in the reforestation objective to ensure it is given adequate consideration in developing the reforestation prescription.
- Species composition –describes the proportion of hardwood and softwood species desired in the forest community being established. Species composition can be quantitatively expressed as desired stocking (site occupancy) levels of hardwood and softwood species at assessment times.
- Species aggregation – describes the smaller scale relationship between the species compromising the new stand. Aggregations can be:
  - Intimate – where species occur in close proximity throughout the new stand.
  - Aggregated – where species are found in clumps that are distributed across the area occupied by the new stand.
  - Segregated – where a portion of the reforested area is occupied only by deciduous species and another portion of the reforested area is occupied by coniferous species. In general, segregated aggregations are not treated as mixedwoods from a management planning perspective.

3 PRINCIPLES IN MAKING SILVICULTURAL PRESCRIPTIONS

The following principles were used to develop the generic prescriptions provided in the flowcharts contained in this section of the Guide. These same principles should be used by the silviculturist to refine the generic prescriptions into specific prescriptions for individual sites.

1. <u>Management of biological systems is generally more successful if it relies on a sequence of interventions rather than a single overwhelming treatment.</u> This means that silvicultural practice is more likely to be successful (and cost effective) if it uses a series of "nudges" to shift the plant

community on the reforestation site toward the objective. “Nudges” are treatments that do not set out to achieve the desired outcome in a single treatment. For example, using a line mounder to address cold, wet soil while planning to follow with a conifer release herbicide to control reedgrass is a “nudge”; whereas using a hoe mounder to make large heavily mineral soil capped mounds is a single treatment approach to addressing cold, wet soil and reedgrass.

2. Manage overarching constraints first. Overarching constraints are the big factors that effectively define the site. Most often, they are abiotic in nature and set the bounds for what species are able to establish and grow on the site. In the Guide, the following abiotic constraints have been treated as overarching: lack of soil nutrients, cold soil, wet soil, and lack of soil moisture. Overarching constraints are, in effect, those constraints that define the overall ability of the site to sustain a forested condition. Only by addressing these overarching constraints can the silviculturist direct the site toward a desired forest condition. This contention is illustrated by the shrublands or Boreal savannahs that arose from early reforestation efforts in Boreal Alberta.
3. Aspen regeneration relies on the existing clonal root mass of aspen which is highly susceptible to damage by forest harvesting or reforestation activities. Relying on natural regeneration of aspen means that harvesting and reforestation activities must anticipate potential negative impacts on aspen and seek to prevent them. In particular, soil compaction during harvest or reforestation, or herbicide treatments for competition control can compromise successful aspen regeneration.
4. Anticipate the likely impact of managing overarching constraints on other biotic components of the new forest. Many other plant species (besides trees) are constrained by the same overarching constraints that limit tree survival and growth – these species respond (often more quickly than coniferous trees) to amelioration of overarching constraints. If the silviculturist does not anticipate the impact of the changes in other biotic components of the forest ecosystem they may overwhelm desired tree species before a reactive response can ameliorate them. Marsh reedgrass is an archetypal example of such biotic components, particularly when shearing or mixing site adjustment treatments are used to ameliorate the constraint(s) of wet or/and cold soils.
5. Treatments selected to “nudge” plant communities should be integrated to ensure effectiveness and efficiency. Nudging plant community development in a desired direction will be more successful if treatments are selected to complement each other and sustain the movement of the plant community. Constraints to forest establishment and growth are frequently not overcome. Rather, they are ameliorated, which means they are likely to reassert themselves at some point. By selecting complementary treatments, the period of amelioration is extended and desired plant species are given more of an opportunity for long-term success. As discussed in the previous principle other plant species often benefit from amelioration of constraints. Integration of treatments supports the silviculturist in anticipating and ameliorating these emergent challenges. Frequently, integration of treatments will result in a multiplicative impact on the long-term performance of trees. For example, using a raised microsite to ameliorate cold, wet soil followed by planting seedlings physiologically conditioned to grow roots in preference to tops for the first growing season, and following with a herbicide treatment a few seasons

after planting to reduce reedgrass competition can result in many-fold greater growth of white spruce than simply raising the microsite to ameliorate cold, wet soil and planting with seedlings designed to grow both tops and roots immediately. Note that this pre-supposes good stock handling and storage during implementation of the planting prescription; maintenance of stock quality and vigor during deployment is key tenet of successful silviculture.

6. Identify potential stochastic risk factors and consider them in the prescription. Stochastic risk factors may or may not occur during the timeframe when seedlings or suckers are susceptible to them. They include both abiotic (winter injury, intermittent flooding, frost heaving) and biotic (ungulate browsing, rodent girdling, insect predation) factors. Because these factors are stochastic they are more easily overlooked than overarching constraints. However, if they occur stochastic factors may compromise success of reforestation. Most often, they do not result in complete failure; rather, they result in variation of success across the site. Silvicultural prescriptions to address stochastic risk factors may be contradictory. For example, delaying herbicide tending of conifers to release them from aspen competition can be used to mitigate potential of winter injury by raising trapping snow, thus providing conifers snow cover under dry winter conditions. However, this may exacerbate the potential for rodent girdling of the conifer by providing them cover to access conifer seedlings.
7. Look beyond the establishment phase when developing the initial silvicultural prescription. When prescribing initial treatments, anticipate "nudges" that may occur after the establishment phase and do not compromise the ability to deliver them. Site adjustment treatments, in particular, can make movement on foot in treated areas difficult and potentially dangerous; so, if ground-based follow up treatments (e.g. patch spraying of herbicides) are anticipated select a site adjustment treatment that does not entirely compromise access on foot.
8. Monitor frequently and quantitatively. The Boreal forest is characterized by substantial variation in growing conditions from year to year. Figure 3-1 shows how the scale of variation in total May through September precipitation for the Peace River, Alberta weather station over a 50-year period as an example.

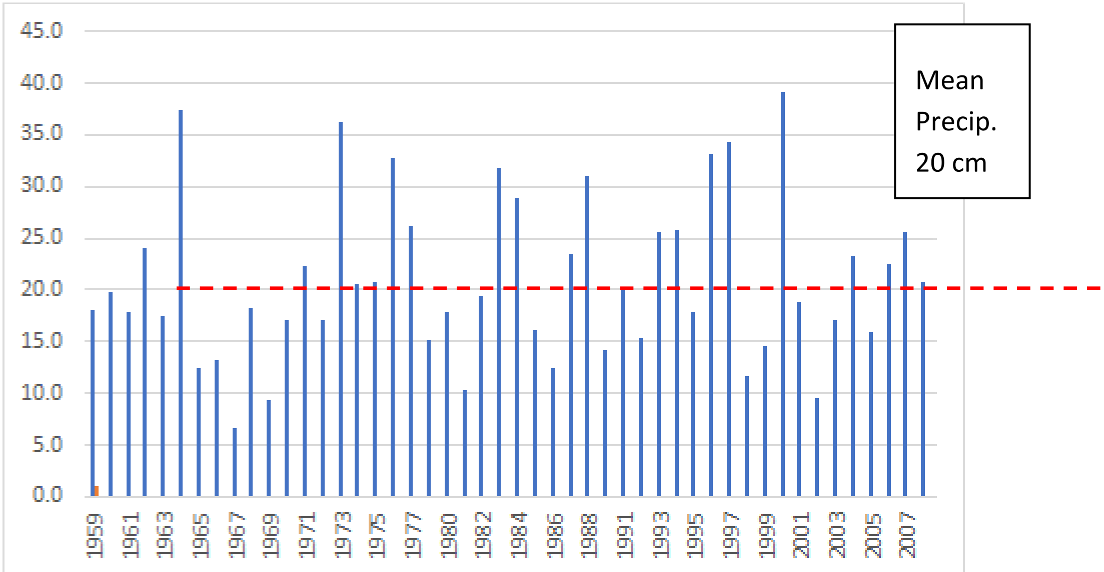

Figure 3.1 Peace River Precipitation (cm) May to September 1959 to 2017.

This high variability in annual growing conditions in the Boreal causes reforestation success to fluctuate dramatically. The fluctuations in reforestation success mean the silviculturist must monitor reforestation outcomes frequently with an eye to remediation of failures caused by environmental variability.

4 PRESCRIPTION PROCESS

The flowcharts accompanying this chapter (Appendix 3) provide generic guidance based on site position on the edatopic grid. They were developed using the process shown in Figure 3.2. The silviculturist should apply the process (or one of their own) using actual site information to either develop a stand-alone prescription or to amend/modify the generic prescription to make it site-specific. Figure 3.3 presents the modified edatopic grid that was used to develop the generic prescriptions. Table 3.1 provides practitioners who use an ecosite layer to provide initial site assessments with a translation from ecosite phase to the modified edatopic grid.

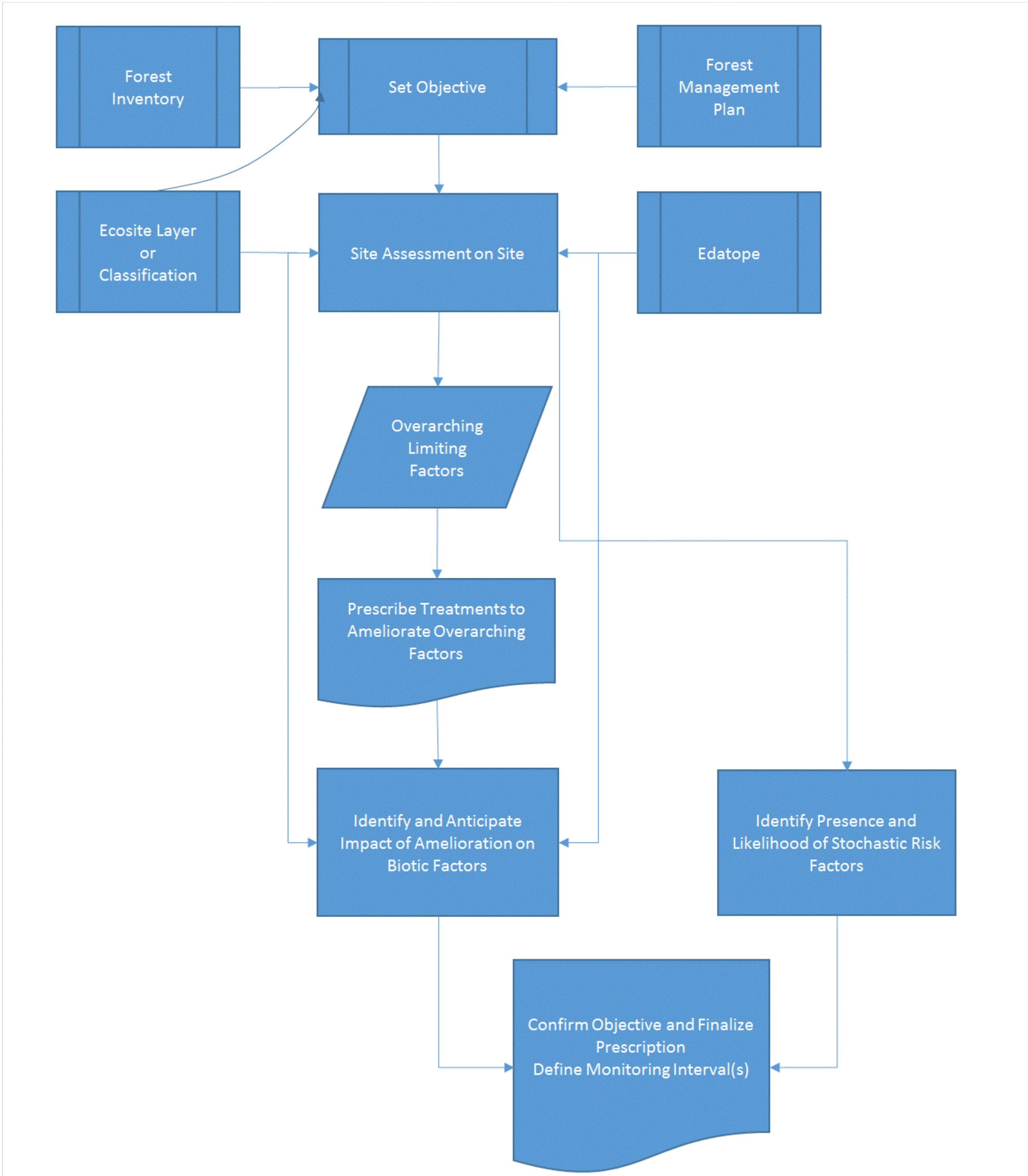

Figure 3.2. Generalized Approach to Developing a Silvicultural Prescription.

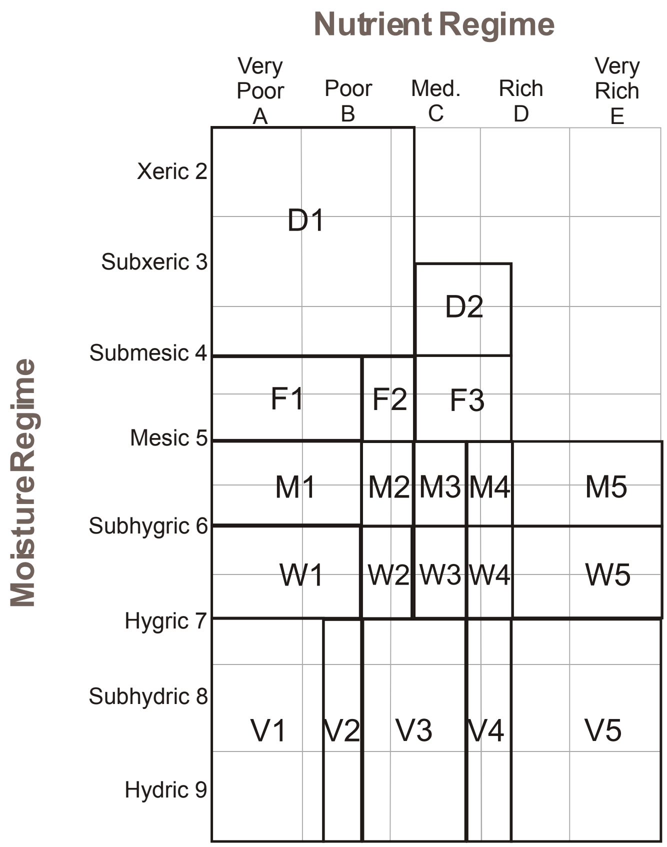

Figure 3.3. Modified Edatopic Grid Underpinning Generic Prescription Flowcharts (D=dry; F=fresh; M=moist; W=wet; V=very wet).

Table 3.1. Translation of Ecosite to Edatope with suggested composition options.

	Ecosite		Composition Options			
Edatope	**WC**	**North**	**C**	**CD**	**DC**	**D**
D1	a,b	a,c	√	√		
D2	c	b	√	√	√	
F1	d	c	√	√	√	√
F2	e	d	√	√	√	√
F3	f	e	√	√	√	√
M1-2	d/h	g	√	√	√	√
M3-4	e/i	g	√	√	√	
M5	f/i	f	√	√	√	
W1-2	h	g/i	√	√	√	
W3-4	i	h/j	√	√		
W5	i	f/k	√	√		
V1-5	k,j,l,m,n	l,j,k,l				

The prescription process starts with a clearly stated objective that defines composition, species (particularly conifer species) and aggregation. The generic prescription flowcharts were developed based on the assumption that range of very dry or very wet sites are unsuitable to growing commercially viable aspen – on these sites (see Table 3.1) Deciduous and Deciduous leading objectives were excluded and only Conifer and Conifer leading objectives were included in the prescription process for these site types. The following steps describe how to develop a silviculture prescription or how to refine the generic prescriptions to make them more site specific and, therefore, operationally viable.

4.1 SET OBJECTIVE

As described above the silvicultural objective is the means of linking site and forest management planning assumptions. Forest management planning sets out reforestation expectations based on the forest inventory (what was harvested from the site), while site characteristics determine what is achievable – particularly in terms of composition and conifer species selection. The more specific the objective the less latitude the silviculturist has in developing the silvicultural prescription and in adapting the prescription to the stochastic factors which influence silvicultural success. It is suggested that the silviculturist set clear objectives as to composition and conifer species while allowing some latitude in tree performance. That is, even on potentially high quality sites the silviculturist should allow some latitude for the impact of stochastic factors on stand performance.

For purposes of the Guide, objectives were set as composition, leading or dominant conifer species, and aggregation. Where the potential to pursue enhanced conifer growth (over natural stands) is present the generic prescriptions offer flexible treatments that might enhance growth.

4.2 ASSESS SITE

Ecosite layers or edatopic classification provide a generic approximation of site. That is, the silviculturist can identify what major constraints are likely to be encountered. The silviculturist should not rely on likely site characteristics to develop the prescription for the following reasons:

1. Ecosite layers are derived from Alberta Vegetation Inventory (AVI) data and thus are constrained in resolution and reliability to the bounds set by AVI. AVI, while a tremendous tool for forest management planning, lacks the resolution to be used for site specific prescription.
2. Cutblocks, though commonly used as the unit of silvicultural prescription, frequently include more than a single site type. If a cutblock contains more than one site type the silviculturist should develop prescriptions for each site type AND map the boundaries of each site type to guide implementation to the specific prescriptions.
3. Generic mapping of site is generally unlikely to identify the stochastic factors that might limit regeneration success – frost pockets, episodic flooding, winter injury.

4. While generic site description will identify some potentially limiting biotic factors e.g. aspen or balsam poplar competition with coniferous seedlings, it will not identify ALL potentially limiting biotic factors, e.g. marsh reedgrass, raspberry, ericaceous competitors.

The Guide contains a detailed approach to site assessment (Section 10.0). The Guide uses a wide range of indicators to diagnose constraints. This approach, while apparently independent of site classification, is simply a shortcutting approach. The indicators used in the Guide are the same as those used for site classification which is, in turn, used to provide a shorthand assessment of potentially limiting factors.

Table 3.2 identifies the likely constraining factors associated with the edatopic grid presented in Figure 3.2. The silviculturist should not rely on remote assessment (like the edatopic grid) to develop the silvicultural prescription. The remote assessment should be use to develop the preliminary objective and to anticipate likely constraints, which are then confirmed to exist through direct assessment of the site.

Table 3.2. Over-arching Constraints Likely Associated with Edatope.

	Overarching Abiotic Factors				Overarching Biotic Factors				
Edatope	**NR Low**	**MR Low**	**MR High**	**Cold Soil**	**Ericads**	**Herbaceous**	**Reedgrass**	**Shrubs**	**Trees**
D1	√	√			√				
D2		√			√	√			
F1	√	√			√				
F2	√	√			√	√			
F3		√			√	√		√	
M1-2	√				√	√	√	√	√
M3-4						√	√	√	√
M5						√	√	√	√
W1-2	√		√	√			√	√	√
W3-4			√	√			√	√	√
W5			√	√			√	√	√
V1-5	√		√	√			√	√	√

The recommended approach to site assessment is to sample frequently across the harvest unit area rather than intensively in a single spot. Frequent, distributed sampling will facilitate identification of all site types across the unit, facilitating mapping site distribution and thereby ensuring application of appropriate prescriptions across the harvest unit.

At each assessment point soil quality, depth, likelihood of poor drainage (seasonal or long-term) and species present should be assessed. This information, along with slope position, landform and landscape positioning, will support determination of overarching abiotic factors, stochastic abiotic factors and biotic factors. Field assessments should include estimation of the foregoing list of limiting factors which should be confirmed by the silviculturist on reviewing the site assessment (unless the site assessment was made by an experienced silviculturist).

In reviewing the site assessment, the silviculturist should identify the presence and severity of limiting factors. Presence of limiting factors establishes the need for amelioration, while severity governs both intensity and urgency of amelioration efforts. Severity of limiting factors can also be used to assess risk inherent to the site and in the silviculture prescription. Generally speaking, the more severe the limiting factors the greater the risk inherent to the site and the higher the likelihood of treatment failure. Treatments may not fail specifically due to the risk but, even if the proximal cause of failure is another factor, severity of the site predisposed the treatment to failure.

Overarching constraints are diagnosed first as these constraints will inevitably have a substantial impact on the success of reforestation efforts and on the success and productivity of the new forest. In fact, the overarching constraints might be described as the fundamental nature of the site. These factors (cold soil, wet soil, lack of soil nutrients) must be ameliorated if reforestation is to succeed.

Stochastic factors should be diagnosed next. These factors (episodic flooding, winter injury, frost pockets, frost heaving) are stochastic in the sense that while the silviculturist can identify that they are likely to occur on a specific site, there is no certainty of their occurring or not occurring during the establishment timeframe when their occurrence might compromise seedling success. A decision to ameliorate stochastic factors, then, is based on the silviculturist's interpretation of how likely they are to occur in the critical timeframe and the risk tolerance of the silviculturist and the employer. More discussion of how to assess these risks is included in the Guide (Section 5).

Presence or likelihood of biotic constraints should be assessed next. Biotic constraints include both competing vegetation (Section 5) and other biological factors that might constraint reforestation success. Competition potential can be assessed by presence of potential competitors, for example, mere presence of marsh reedgrass in a pre-harvest stand is a clear indication of high likelihood of severe reedgrass competition in the reforested stand.

Competition potential also has a clear linkage to site quality (Figure 3.4). Those sites with few constraining factors are much more likely to have high levels of competition than are sites with constraining factors resulting in less tree growth than on lower quality sites.

Figure 3.4. Differences in white spruce growth on rich (left) and medium (right) quality sites in the absence of competition control.

4.3 DECIDUOUS PROPAGULE POTENTIAL

The silviculturist should use the site assessment data – including the age, condition, density and distribution of aspen to estimate the deciduous propagule potential. The Deciduous Propagule Potential tool (DPP) is a stand-alone Excel application that integrates the site and stand factors contributing to deciduous suckering after harvest to estimate the potential for deciduous reproduction. DPP is given as *Excellent, Good, Fair, Poor* or *Unlikely*. In general, a DPP of Good or Excellent provides assurance that a Deciduous or either mixedwood compositional objective can be met. A DPP of Fair or Poor suggests that attaining a Deciduous or Deciduous leading mixedwood outcome may be difficult or impossible; while a DPP of unlikely suggests the silviculturist will most likely succeed if a Coniferous objective is pursued. Conversely the DPP can be used to estimate the likelihood of deciduous nurse potential (DPP Fair or better) or competitive pressure on coniferous seedlings in Conifer or Conifer leading objective stands (DPP Fair or better).

4.4 RE-VISIT OBJECTIVE

Upon completion of the site assessment, including translation into risk factors, the silviculturist should revisit the objective for the site. In particular, the deciduous component of the objective should be assessed for whether or not it is achievable in view of the constraints identified and the deciduous propagule potential diagnosed on the site. The review of objective is not suggested as a cost-saving approach. Rather it is a recognition that on some very difficult sites the silviculturist may not be able to re-establish the sort of forest that was harvested, due either to site constraints or to lack of deciduous propagule potential. In recognizing this beforehand, the silviculturist is empowered to develop a prescription with a greater likelihood of success. Should the silviculturist decide to amend the objective, it is recommended that this be undertaken with a clear understanding of how landscape scale composition balancing of reforested stands will be maintained.

4.5 PRESCRIBING TREATMENTS

Treatments should address overarching constraints first; the prescription should then be adjusted to address stochastic constraints and the specific needs of the compositional objective. The Guide does not prescribe specific treatment actions; instead it supports the silviculturist in determining the effect needed to ameliorate a specific constraint. The Guide then provides the silviculturist information needed to determine how to achieve the desired effect. This approach was taken for two reasons:

1. There are frequently several treatments that will provide the same (or ecologically similar) effects. This approach allows the silviculturist flexibility in determining which treatment to employ.
2. Silvicultural treatments evolve over time due to changes in prime movers, evolution of equipment and availability of new products or methods. This approach allows silviculturists to adopt new techniques without compromising the ecological fundamentals of the Guide.

The following decision rules were used in developing the generic prescription flowcharts.

4.5.1 LOW SOIL NUTRIENTS

Low soil nutrients are generally associated with coarse textured or poorly developed soils low in soil organic matter and capped with a thin forest floor. While mixing site adjustment treatments (Section 7) may slightly improve availability of nutrients, the more common approach to ameliorating low soil nutrient is to direct plant smaller conifer seedlings of a species that tolerates low nutrients: pine (lodgepole or jack) on drier sites and black spruce or lodgepole pine on wetter sites. On sites, wetter than mesic the need to ameliorate soil moisture constraints may trump low soil nutrients; if so, the resulting use of site adjustment should attempt to leave forest floor material available for planting at the microsites it creates. Sites with low soil nutrients are generally not favorable to deciduous regeneration so are usually best suited to Conifer or Conifer-leading reforestation objectives. These sites are frequently populated by ericads (Section 5) which exacerbate the lack of nutrients due to their high efficiency in capturing soil nitrogen; if ericads are present the silviculturist may wish to employ a chemical site preparation treatment to control them prior to planting.

4.5.2 LOW SOIL MOISTURE

Low soil moisture is frequently found in concert with low soil nutrients on coarse textured soils or/and on slopes. Site adjustment treatments are not recommended as they are likely to impair whatever moisture holding capacity is provided by forest floor (similarly harvesting should be managed to minimize disruption of the forest floor). Coniferous regeneration treatment is most frequently direct planting of seedlings physiologically conditioned for dry sites. This conditioning (Section 8) includes:

1. Smaller seedlings with a high root: shoot ratio.
2. Seedlings set up in the nursery to grow only roots during the first growing season after planting (i.e. summer planting).
3. Seedlings with a high level of suberin on needle surfaces.

Pine (lodgepole or jack) is best suited to very dry sites.

These sites are generally inimical to aspen regeneration so are best suited to Conifer or Conifer-leading objectives.

4.5.3 HIGH SOIL MOISTURE

"Wet" soils are one of the most common reforestation challenges in Alberta's boreal forest regions. Low evaporation potential, relatively high summer rainfall rates and soils with limited drainage capacity combine to create a situation where soils are frequently at or above field capacity during the growing season (Section 10). Saturated soils prevent gas exchange between roots and the soil – effectively drowning the tree. White spruce is not able to tolerate more than 10 to 14 days of root saturation.

Aspen suckers respire at much higher rate than white spruce seedlings so are even less able to tolerate saturation. Thus, high soil moisture is an unalloyed challenge to successful mixedwood forest regeneration.

Raising the seedling microsite by using either raised-mixed or raised-inverted site adjustment treatments (Section 7) will provide planting spots for coniferous seedlings. Planting a seedling of the species appropriate to the nutrient regime that is physiologically conditioned to grow roots (Section 8) during the first growing season is recommended. Seedlings set up to grow roots first are better able to tolerate competition due to much of the initial competition in the boreal forest being between roots due to the shallow, relatively poor soils commonly encountered. Use a raised-mixed site adjustment will also stimulate aspen suckering that often results in abundant and uniform aspen in the new stand, providing the silviculturist the opportunity to attain any desired compositional objective. The stimulation of aspen suckering by raised-mixed site adjustment treatments enables the silviculturist to pursue mixedwood objectives on sites that may be marginally too wet for aspen, especially if these sites have become wetter due to the water table rising as a result of reduced transpiration on the site following harvest.

On a cautionary note, raised-mixed site adjustments frequently stimulate a substantial flush of competing vegetation (Section 5) from the seedbank (raspberry, birch, alder, honeysuckle) and from root reproductive structures (marsh reedgrass, aspen). This phenomenon is most pronounced when soil nutrients are not limiting. When this flush of competition occurs on a site with a Conifer or Conifer-leading objective the solution is straightforward; the silviculturist simply deploys a foliar herbicide treatment targeting the competing vegetation within one to 3 years after planting.

The situation becomes considerably more challenging when the objective is to establish a Deciduous-leading mixedwood, particularly if the structural objective is to create an intimate mixture. In this case the silviculturist has two options. The first is to delay planting conifer and use spot application of herbicide at the end of the first growing season after site adjustment to control competition on planting spots. The second option is to use targeted patch or spot application between one and 3 growing seasons after planting. Both options involve ground-based application using backpack application technology.

If the objective is a Deciduous-leading mixedwood with an aggregated structure the silviculturist is frequently able to use patch herbicide application for conifer release targeting areas of heavy herbaceous competition and avoiding treatment of dense, successful aspen regeneration.

4.5.4 COLD SOIL

"Cold" soils, alone or in concert with wet soils, are likely the most common reforestation challenge in Alberta's boreal forest. Soils are cold due to a number of factors, alone or in combination (Section 7 and Section 10). These factors include: presence of a dense marsh reedgrass thatch; wet soil; and presence of a thick, organic forest floor. In other words, soil can be cold because:

1. It is insulated from atmospheric warmth by an organic cover or by aspect, or
2. Because its temperature is mediated by abundant soil moisture; or
3. Both of the above are true.

Cold soils limit growth of conifer roots and prevent aspen suckering (Section 10). As with wet soil, the most effective means of ameliorating cold soil is to use either raised-mixed or raised-inverted site adjustment treatment. Regardless of site adjustment technique chosen, ensure that any insulating layer on the forest floor is disrupted and any insulation is broken up. This applies to forest floor organic material, marsh reedgrass thatch or humic upper soil profile components.

The same recommendations for stock selection and the same cautions regarding competing vegetation as expressed for wet soil apply.

4.5.5 COLD, WET SOILS

If a combination of cold and wet soil conditions form the major abiotic constraint use of raised-inverted site adjustment is suggested. Raised inverted treatment has the benefit of ensuring that insulating layers are disrupted and that micro-sites that will be mostly free of competition for a growing season or two are created. If cold, wet soils are the major abiotic constraint to reforestation it is recommended that a Conifer or Conifer-leading mixedwood objective be pursued. Cold, wet soils are essentially inimical to aspen regeneration. Planting stock selection for cold, wet soils is similar to that for wet or cold soils with the even greater emphasis on ensuring the seedling is physiologically conditioned to grow only roots during the first growing season and that the seedling be very sturdy (high root: shoot ratio, low height: diameter ratio).

4.5.6 SITES WITHOUT MAJOR ABIOTIC CONSTRAINTS

Sites where soil moisture, soil nutrients and soil temperature are not limiting (commonly referred to as modal sites) present the silviculturist the opportunity to pursue any compositional and structural objective desired. Conversely, these sites are highly likely to present substantial competitive challenge to trees – from herbaceous vegetation, shrubs and other tree species. The silviculturist may choose to take advantage of such sites by using a modest site adjustment treatment (i.e. mixing, small raised-mixed or small raised-inverted) to further enhance microsites for planted trees. Similarly, large planting stock can (possibly should) be deployed on such sites to assist planted trees in overcoming competing vegetation.

On such sites, the silviculturist should anticipate the need to control competition within a few years of planting. On Conifer and Conifer-leading sites this likely best achieved by a prompt, broadcast herbicide application. On Deciduous leading sites, particularly if the structural objective is to create an intimate mixture, the silviculturist is more constrained as herbicide use is likely to compromise reaching the objective. In this case the silviculturist has two options. The first is to delay planting conifer and use spot application of herbicide at the end of the first growing season after site adjustment to control competition on planting spots. The second option is to use targeted patch or spot application between one and 3 growing seasons after planting. Both options involve ground-based application using backpack application technology.

If the objective is a Deciduous-leading mixedwood with an aggregated structure the silviculturist is frequently able to use patch herbicide application for conifer release targeting areas of heavy herbaceous competition and avoiding treatment of dense, successful aspen regeneration.

4.5.7 BIOTIC CONSTRAINTS – COMPETITION

The Guide provides the silviculturist with considerable guidance on why, when, and how to control competition (Section 4 and Section 5). The initial prescription should anticipate competition, consider competition in the selection of site adjustment treatments, and plan to monitor and control competition early in the establishment of the new stand. Prompt treatment of competition has two major benefits: first, it frees conifers from competition before their growth has been substantially depressed; and second, if herbicides are used there is more likelihood of some aspen recovery after treatment if herbicides are used with two to three years of harvest.

The relationship between aspen and white spruce in mixedwoods is complex (Section 4 and Section 5) and is dealt with at length in the Guide. When making the reforestation prescription the silviculturist should consider both the nurse value of aspen in protecting white spruce from other stressors (marsh reedgrass competition, winter injury, frost damage) and the competitive cost in terms of white spruce growth. It is beyond the scope of these rules to do anything more than refer the silviculturist to the Guide and recommend that they develop a site and objective based approach to managing competition in mixedwood stands.

Marsh reedgrass is an unalloyed competitor; it frequently forms a disclimax plant community after harvest (Section 5). The silviculturist must recognize the tremendous competitive impact of marsh reedgrass on Conifer and mixedwood objectives. The reforestation prescription must address this competitive challenge and prepare to address it promptly.

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Ericaceous species have only begun to be recognized as posing a tremendous long-term competitive challenge to conifers (Section 5). This competitive challenge is exacerbated by limited control options available for ericads. These are limited to mixing site adjustment treatments and site preparation herbicide applications. Mixing treatments are successful in breaking up the ericaceous root mat thus breaking the hold on upper soil horizons ericads frequently have after harvesting. Site preparation herbicide treatments are very effective at controlling ericads; site preparation treatments must be used as any herbicide treatment that will control ericads will either kill or substantially depress white spruce seedlings.

Other competing species the silviculturist is referred, again, to the Guide (Section 5) for suggestions on how to assess and control other common boreal competitors and how control strategies might impact mixedwood objectives.

4.5.8 BIOTIC CONSTRAINTS – BROWSING

Browsing is most commonly considered to be an ungulate impact on aspen sucker regeneration. While not directly related to site there is anecdotal evidence to suggest that aspen browsing is most common on sites where it occurs in association with marsh reedgrass, i.e. edatopes M3-5, and W3-5. When making Deciduous or mixedwood prescriptions on these edatopes the silviculturist should be aware of the potential for browsing to limit deciduous regeneration success. The only viable solution on sites with heavy browsing is to change the reforestation objective to a composition less dependent on deciduous species (e.g. from Deciduous to Deciduous leading mixedwood).

Browsing can also impact coniferous species (in particular, but not limited to, lodgepole pine). Browsing in this case is snowshoe hares or mule deer browsing nutrient loaded seedlings, as these seedlings have high sugar levels in the foliage for a season or two after planting. If aware that browsing of conifer is a problem, the silviculturist can either change species from pine to white spruce (provided the site is suitable to white spruce) or, if the browsed seedlings are white spruce, use seedlings that have been subjected to a reduced nutrient regime prior to hardening-off in the nursery. Another strategy for minimizing snowshoe hare browsing is to severely control herbaceous and low shrub vegetation (hare cover) thereby reducing their ability to approach seedlings.

4.5.9 BIOTIC CONSTRAINTS – GIRDLING

Girdling is generally mice or voles eating the bark of planted seedlings under the snow. It is not a frequent problem in cutblocks reforested promptly after harvest – however it can become a problem in afforestation of previously cleared lands or if reforestation is delayed sufficiently for a mouse/vole population to develop prior to planting. The best solution to girdling is prevention through prompt reforestation.

4.5.10 STOCHASTIC CONSTRAINTS – WINTER INJURY, FROST HEAVE AND FROST DAMAGE

The Guide (Section 9 and 10) provides detailed guidance on how to identify sites with the potential for stochastic constraints and how these constraints might be either avoided or ameliorated. Because these constraints are stochastic (i.e. they may or may not occur during the period when the young stand is susceptible to them) the decision to address them in the reforestation prescription is driven by their likelihood of occurrence and the silviculturist's risk tolerance. Thus, guidance on whether or not to address these constraints is beyond the scope of these rules.

Winter injury of planted white spruce can be ameliorated by retention of aspen (when it is a competitor) for sufficient time (2 or 3 growing seasons) for the white spruce roots to fully egress the planting plug and for the seedling to thus come into synchronicity with the planting site. Winter injury can be avoided by changing planted species to black spruce, provided the site is suitable and black spruce meet management planning expectations. Early winter injury (winter after planting) can be avoided through use of smaller planting stock. Clearly, all of these choices have other effects on reforestation success and long-term outcomes.

Frost damage may occur over several years after planting. The impact of frost damage is likely to be greater if it occurs soon after planting. Again, retention of aspen as "nurse species" will to, some extent, mitigate frost damage at the cost of some lost white spruce growth. Again, changing planted species to black spruce will mitigate frost damage, provided black spruce aligns with management planning objectives.

Frost heave of planted seedlings is a function of both site (wet soils) and site adjustment treatment (use of scalping to remove the forest floor). Hence, avoiding the use of scalping on wet soils will prevent frost heaving.