SECTION 9: Winter Injury and Temporary Saturation of the Rooting Zone

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9 WINTER INJURY AND TEMPORARY SATURATION OF THE ROOTING ZONE

Winter injury and temporary saturation of the rooting zone are two often overlooked factors which may impact successful establishment of crop trees, particularly white spruce. This section discusses how to identify the presence of these factors and what actions may be taken to ameliorate their impact. Additional information is provided in Section 8.

9.1 WINTER INJURY AND ITS EFFECTS

Foliage and, in extreme cases, buds of spruce seedlings are subject to severe desiccation by winter winds if they are exposed to these winds after seedling root activity ceases. Figure 9.1 illustrates slight winter desiccation damage to a white spruce seedling.

Damage can also occur when warm winter days result in reduced cold-hardiness of needles, shoots, and buds. Winter injury is the term used more widely to describe damage to seedlings resulting from desiccation and/or winter damage from reduced cold tolerance (see Grossnickle 2000 pages 159-172).

Figure 9.1. Slight Winter Desiccation damage near tip of seedling.

The needles, buds and shoots of the current year are most susceptible to winter injury, making planted seedlings particularly vulnerable during the first winter after planting. Note that winter injury is not simply a foliar phenomenon, as buds and stems can also be damaged. If buds are desiccated, seedling growth will be reduced and form may be affected, especially if terminal buds are lost resulting in multiple tops when upper branch buds compete for dominance. Finally, seedling survival may be jeopardized in extreme cases winter desiccation of sufficient severity or if desiccation occurs in two or more consecutive years. If stems are affected, seedlings can take several years to recover from winter desiccation damage (Kabzems and Haeussler 2005).

Figures 9.2 and 9.3 illustrate moderate and severe winter desiccation damage to white spruce seedlings.

Figure 9.2. Moderate winter desiccation damage (note extensive discoloration of foliage).

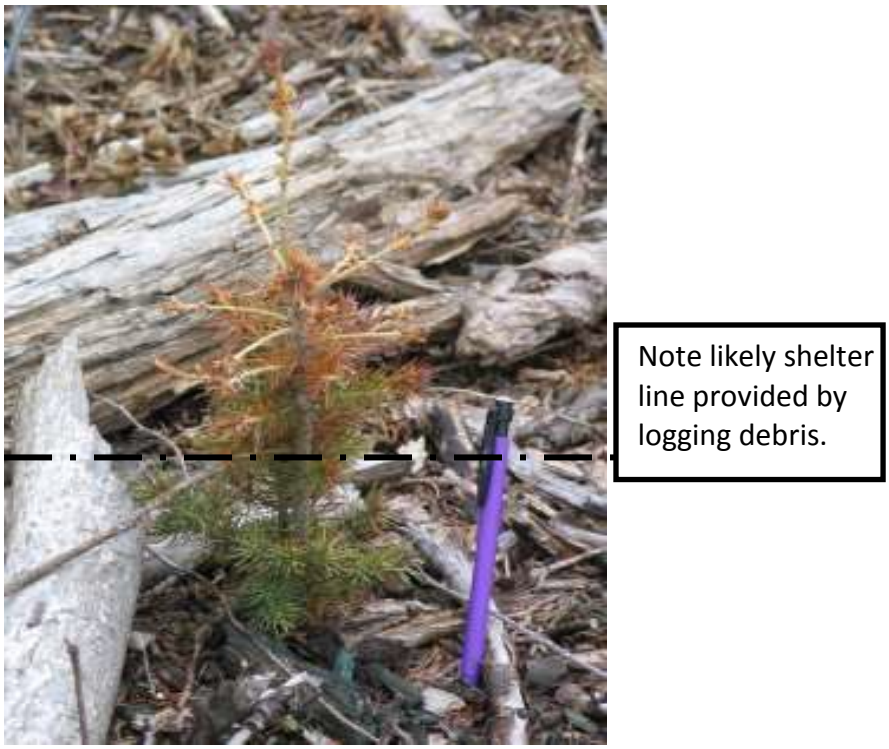

Figure 9.3. Severe winter desiccation damage (note loss of foliage and buds and dehydration of stem tissue).

9.1.1 CAUSES OF WINTER INJURY

Winter desiccation risk is driven by seedling condition, precipitation (both growing season rain and winter snow), wind conditions, micro-topography and meso-topography. It is caused by loss of moisture from foliage, buds, and, in severe cases, stems when roots are dormant (frozen) and therefore unable to replace moisture loss (Colombo *et al*. 2003, Kraskowski *et al*. 1993).

Dehardening of foliage, buds and twigs can occur when above-freezing daytime temperatures occur during the winter. See Grossnickle 2000 pages 162-163, Perkins et al. 1993, Strimbeck et al 1993, Strimbeck et al. 1995, Strimbeck and DeHayes 2000.

Kabzems and Haeussler (2005) found winter desiccation damage to white spruce seedlings for the first two to three years after planting. This is consistent with outcomes of operational practice in Alberta's boreal forest.

Formaniuk (2007 *pers. Comm.*) and McDonald (2004 *pers. Comm.*) suggest that white spruce seedlings are more susceptible to winter desiccation prior to root egress from the planting plug. They suggest emergence from the planting plug coincides with the spruce seedling becoming more driven by the environment of the planting site. It might also be related to a reduction in nutrient loading of the

seedling. Colombo *et al*. (2003) found black spruce resistance to winter desiccation was highest in seedlings subjected to a hardiness regime based on natural decline in day-length, cool temperatures and no fertilization (as compared to regimes with reduced day length with or without warm temperatures and fertilization.) This regime also produced the least seedling growth the following growing season.

Krasowski (1996) suggests that naturally regenerated seedlings suffer less winter injury due to a greater abundance of roots near the soil surface, where water is available, compared to the root systems of containerized seedlings which are located at some depth into frozen soil. This has also lead to the suggestion to use seedlings with short plugs, and the use of air-pruned root systems developing with use of jiffy pellet systems and other nursery practices.

Seedling susceptibility to dehydration is directly linked to seedling moisture status – when seedlings enter the winter under moisture stress they are more susceptible to dehydration than when they are fully hydrated (Kraskowski *et al*. 1993). Wind plays an important role as dry winter winds increase moisture loss driving the dehydration process along with moisture status (Kraskowski *et al ibid*). Sites which are exposed to wind will also experience snow drifting and loss of snow from exposed areas. Blowing snow will also result in abrasion of wax on needles, contributing to the level of injury. Solar radiation, especially bright sunlight reflected from surrounding snow, also contributes to desiccation and dehardening.

Snow depth may be the single most important factor in determining the risk of winter desiccation. If seedlings are below snow they are not exposed to, winds (and solar radiation reflected off snow) that drive moisture loss and hence cause desiccation (Kraskowski *et al ibid*) or to warm air temperatures which will lead to dehardening. Warm winds can also contribute to desiccation by reducing snowpack and thus exposing seedlings to dehydration prone conditions and warming. If a seedling is not protected beneath snow, micro-topographic relief can provide some protection from winter desiccation if seedlings are planted on the leeward and north side of small lifts in topography, stumps, coarse woody debris , or other forms of shelter. However, care should be taken when using micro-topographic relief to ameliorate potential winter desiccation that susceptibility to frost damage is not increased.

The presence of deciduous stems and other woody vegetation that is taller than the spruce seedlings results in substantial reductions in winter injury. Even when 1 m tall aspen are located 2 m away from planted spruce (in spot treatments) the occurrence of winter injury is reduced. Spruce growing in areas with reasonable amounts of aspen regeneration (10,000 stems/ha or more) generally suffer little winter injury. Relationships between aspen density and winter injury are not yet known.

Meso-topography can contribute significantly to risk of winter desiccation through locating openings that create wind funnels. Figure 9.4 illustrates how cutblock location could result in creation of wind funnel whereby dominant seasonal winds (over winter) and chinook winds could be funneled across the opening by two small streams and their channels located upwind of the potential block location.

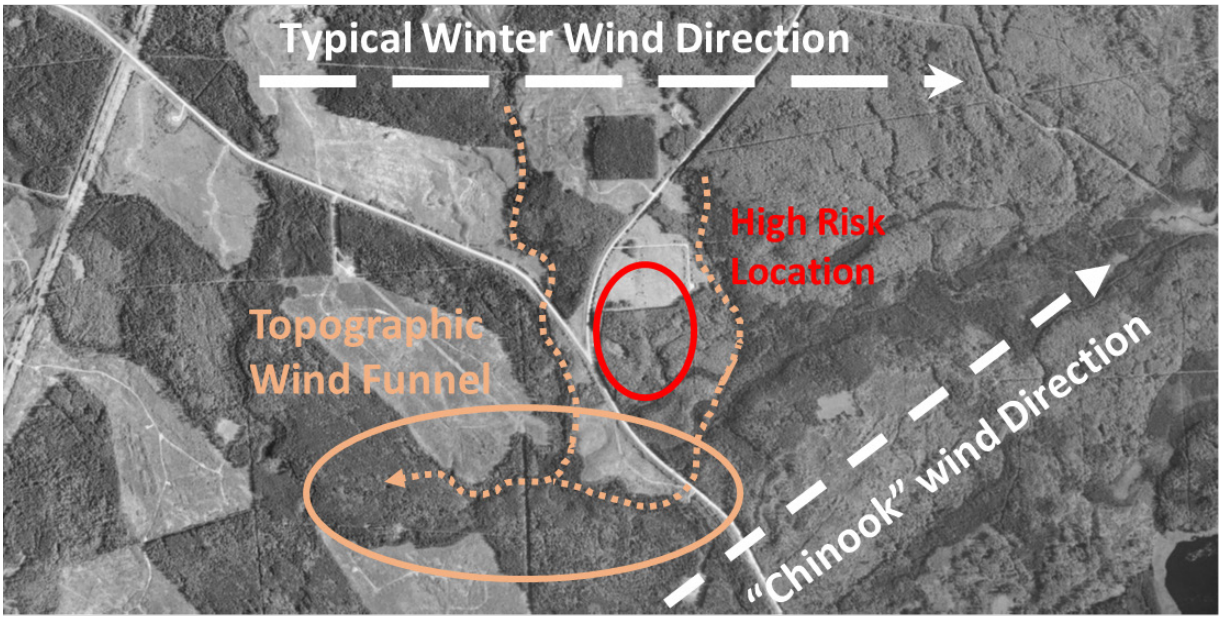

Figure 9.4. Example of potential topographic wind funnel.

9.1.2 IDENTIFYING INJURY RISK PRIOR TO HARVEST

Figure 9.4 shows how topography, drainage, and cutblock design can contribute to risk of winter desiccation. In addition, general climatic trends, (e.g. prolonged drought, low winter snowfalls, and local wind patterns) can combine to increase risk of winter desiccation. When a cutblock or series of cutblocks are identified as having a heightened risk of winter desiccation, adjustments to the reforestation plan to reduce this risk might be in order.

Particular risk factors to look for in identifying risk of winter injury are upper and mid-slope positions with a southerly aspect. These slope positions are prone to more and higher speed winds. Winter thaw or near thaw conditions are more frequent and more intense on south-facing slopes. Thus, both temperature and wind conditions contribute to increased likelihood of winter injury in these positions. As shown in Figure 9.4, this can be exacerbated by the presence of topographic features which act to channel wind toward the slope at risk (i.e. wind funnels). Wind funnels are most often ridgelines or stream channels that influence wind direction and intensity. Conversely, mid-slope and lower positions, and/or north aspects, have very low risk due to good snow retention and low winter heat loading (limited direct sunlight).

9.1.3 REDUCING RISK OF WINTER INJURY

If a pre-harvest assessment identifies substantial risk of winter injury due to meso-topographic conditions creating a wind funnel or due to site position and exposure, changes to site adjustment, planting regime, or management objective may be considered as a means of reducing risk:

1. Setting a mixedwood composition objective (particularly an intimate aggregation) will result in aspen stems acting to trap snow, reduce direct sunlight, moderate temperature fluctuations, and move the boundary layer of wind activity upward away from the white spruce seedlings. Since damage appears to decline with age, in blocks designated as conifer blocks, delaying aspen removal until age 4 or 5 may be another effective strategy.
2. Planting smaller seedlings will reduce the likelihood of their emergence from the snow pack. Further, planting summer seedlings results in smaller seedlings since there is little if any height growth after planting. Summer planting may also provide foliage which has stronger dormancy and cold resistance. It also emphasizes root growth, and hence rapid emergence from the planting plug, shortening the time until seedlings are at reduced risk.
3. Linear mixing site adjustment treatments (i.e. ripping, power disk trenching) deployed perpendicular to direction of most frequent winter winds – if practical – can provide possible upwind shelter if seedlings are planted on the leeward side of spoil banks raised by treatment (or planting on the north side of raised microsites to ensure seedlings are in the shade through the winter).
4. Retaining slash cover to increase snow retention and planting on the north side of stumps, slash and other obstacles

Figure 9.5 shows generalized wind velocity and direction for Alberta during the critical months for winter desiccation. Snow depths and drought condition can be assessed locally or determined on a regional scale using Environment Canada's climate data systems (http://climate.weather.gc.ca/historical_data/search_historic_data_e.html). The likelihood of chinook winds occurring and their possible frequency or intensity is best assessed locally based on recent winter climatic history.

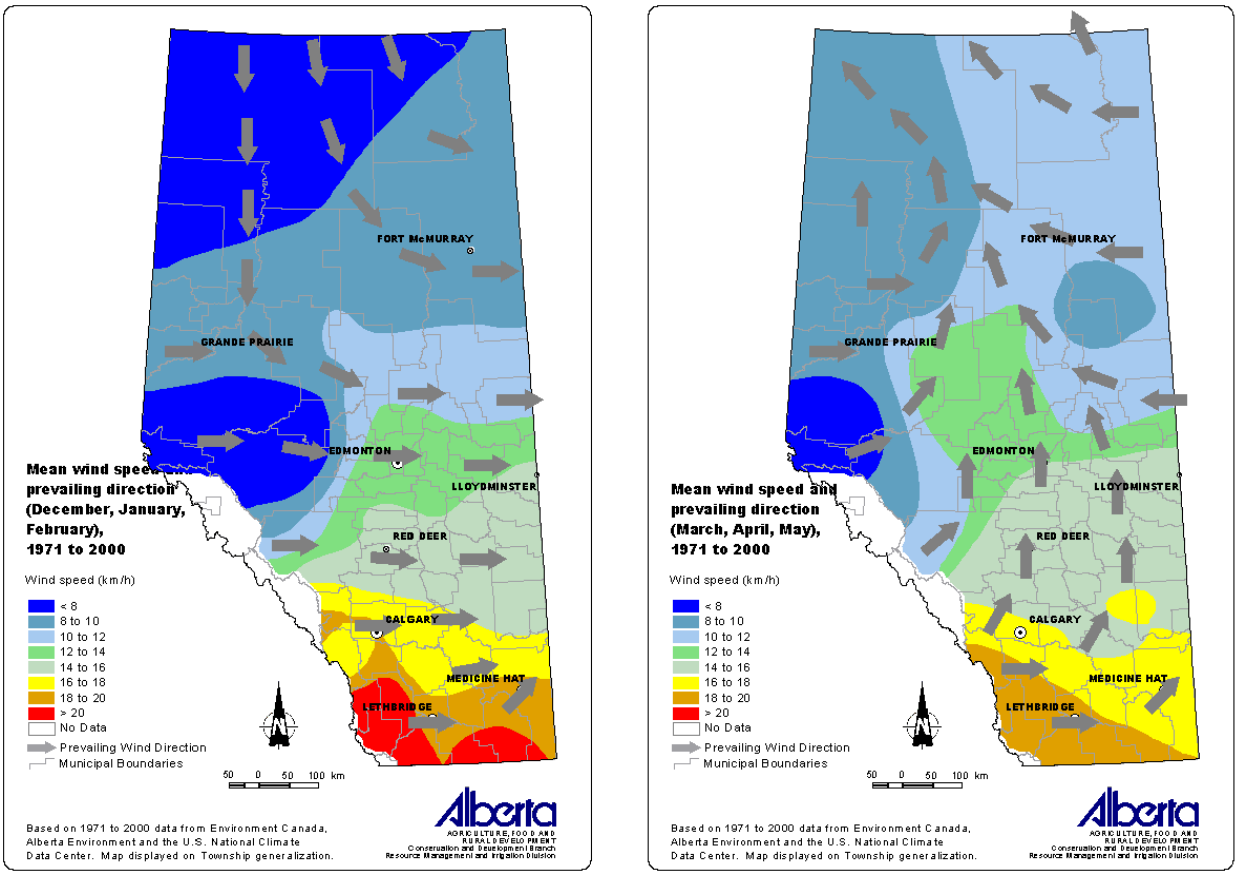

Figure 9.5. Generalized wind speed and direction Dec –Feb and Mar – May for Alberta (Source – Agro-climatic atlas of Alberta, Alberta Agriculture, Food and Rural Development, 2006).

A summary of key factors discussed above to assess risk of winter desiccation and to reduce the risk of winter desiccation is provided in Figures 9.6 and 9.7.

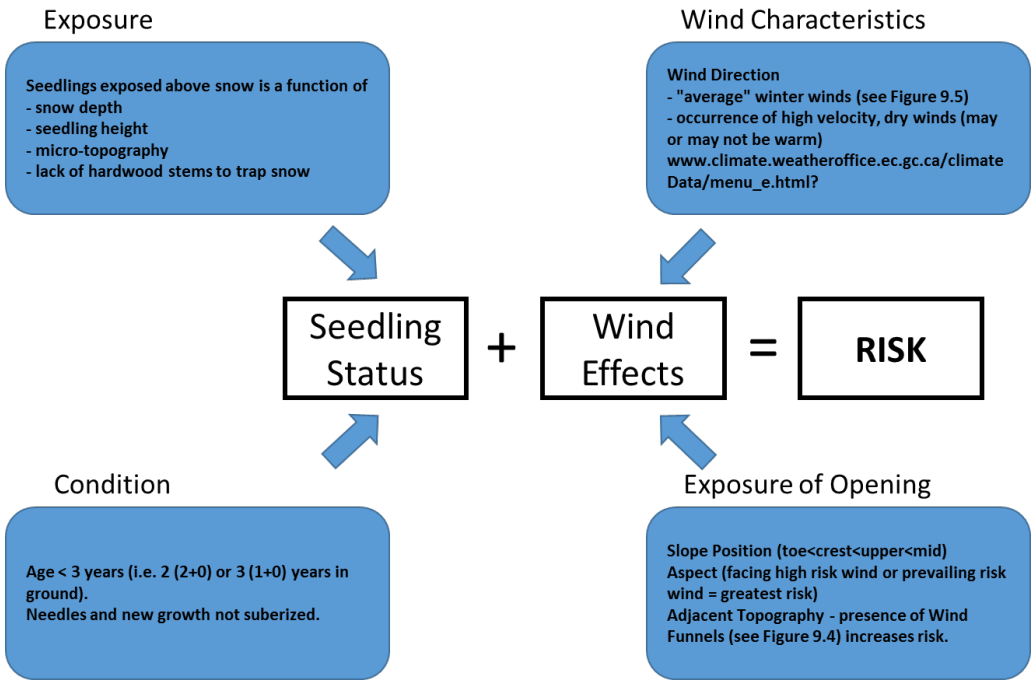

Figure 9.6. Summary of factors for assessing the risk of winter desiccation.

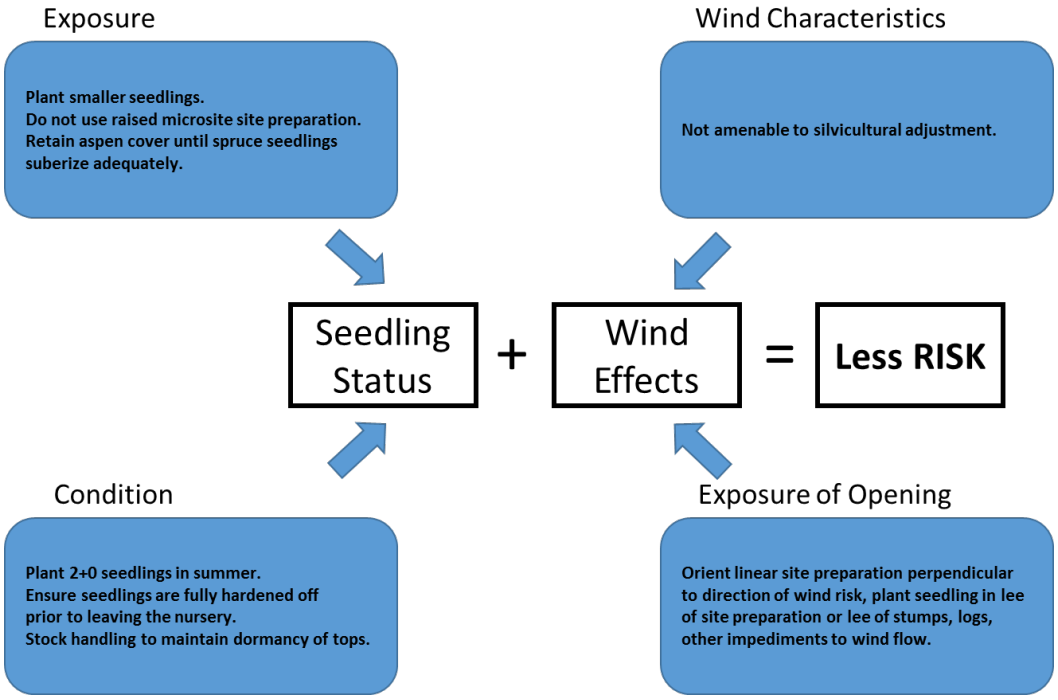

Figure 9.7. Summary of factors for reducing the risk of winter desiccation.

9.2 TEMPORARY SATURATION AND ITS EFFECT ON SEEDLING SURVIVAL

Temporary saturation (colloquially referred to as flooding) is a frequent occurrence on boreal forest sites. Lees (1963) found white spruce seedlings exposed to flooding or saturated soil for more than 14 days during the growing season drowned. Unlike on "truly" wet sites, temporary saturation can occur on mesic or even somewhat dry sites. In fact, the importance of temporary rooting zone saturation arises from its occurrence on "dryer" sites; rooting zone saturation can cause spruce seedling mortality resulting in stocking voids on sites diagnosed as having slight or no limitations to establishment due to excessive moisture. Within an opening, stocking voids caused by temporary rooting zone saturation can be of sufficient extent and distribution to jeopardize composition and/or mixture objectives.

Temporary rooting zone saturation results in white spruce temporarily encountering the same limitations to survival and establishment they would encounter on a much wetter site. That is, water in the soil prevents roots from respiring; this lack of respiration results in seedling death. Unlike "wet" sites, temporarily saturated areas are easily overlooked during the site assessment process due to their commonly small size and their temporary nature. In fact, temporarily saturated areas are often misdiagnosed as competition induced mortality at the establishment, composition and performance phases.

9.2.1 CAUSES OF TEMPORARY SATURATION

Rooting zone saturation risk is driven by site drainage characteristics, particularly:

1. ***Impediments to drainage.*** Shallow impeding layers or hardpans slow drainage, resulting in accumulation of moisture in the upper soil profile and hence saturation.
2. ***Changes in micro-topography***. Much of the Boreal biome is characterized by water tables less than 50 cm below the soil surface. Given the shallow rooted nature of many boreal plant species, a 50 cm rooting zone is sufficient for both establishment and growth. However, even slight drops in micro-topography may suffice to bring roots in contact with saturated soil.
3. ***Seasonal impediments to drainage***. Soils thaw from the surface down resulting in conditions where the rooting zone may be thawed but frozen soil below prevents downward percolation of soil water, causing saturation.
4. ***Changes in soil structure***. Inappropriate site adjustment or other activities exposing heavy mineral soils can result in loss of soil structure and reduced water percolation. Both mechanical damage and direct exposure to rain can impact soil structure.

In summary, temporary rooting zone saturation can be caused by slowed percolation of soil water or a thinning of the root zone, either of which bring white spruce roots into somewhat sustained contact with saturated soil. Therefore, to diagnose the risk of soil saturation, the silviculturist must be attuned to subtle changes in soil drainage. These include: Slight changes in micro-topography – frequently seen

as small “bowls” or puddles in the forest floor after a summer rain event. Often encountered as slight depressions when walking linear disturbances such as seismic exploration lines or pipelines.

1. Intermittent presence of soil saturation as indicated by plant species. For example, small, dense patches of reedgrass, alder, cow parsnip, and similar “wet site” species on an otherwise mesic site.
2. Indirect indicators such as presence of small stocking voids or grass patches in the forest canopy of otherwise mesic forest stands.

Figure 9.7 offers guidance in diagnosing the presence of temporary saturation risk in a pre- harvest (T2) assessment.

9.2.2 MANAGING TEMPORARY SATURATION

If a pre-harvest assessment identifies potential locations of temporary rooting zone saturation, changes to site adjustment or management objective may be considered as a means of reducing risk. Practitioners are cautioned that prior to adjusting prescriptions it is advisable to get some understanding of the scale (size and number) of potential temporary saturation areas in the planned harvest opening:

- **Compositional.** Setting a mixedwood composition objective (particularly an intimate aggregation) may result in aspen acting to provide more rapid transpiration activity on site preventing or reducing the intensity or duration of saturation events.
- **Site Adjustment.** Using raised or raised-mixed site adjustment treatments will result in white spruce roots being above the saturated zone. Care should be taken to ensure that only areas likely to be subject to saturation will be treated with raised microsite site adjustment as treating mesic areas will almost assuredly subject seedlings to drought stress.
- **Conifer Species Selection.** Using “mixed bag” planting prescriptions and instructing planters to plant black spruce seedlings in depressional areas may assist in overcoming temporary saturation.
- **Avoidance.** Teach harvesting operators to identify depressions likely subject to saturation and locate structural retention patches around these depressions.

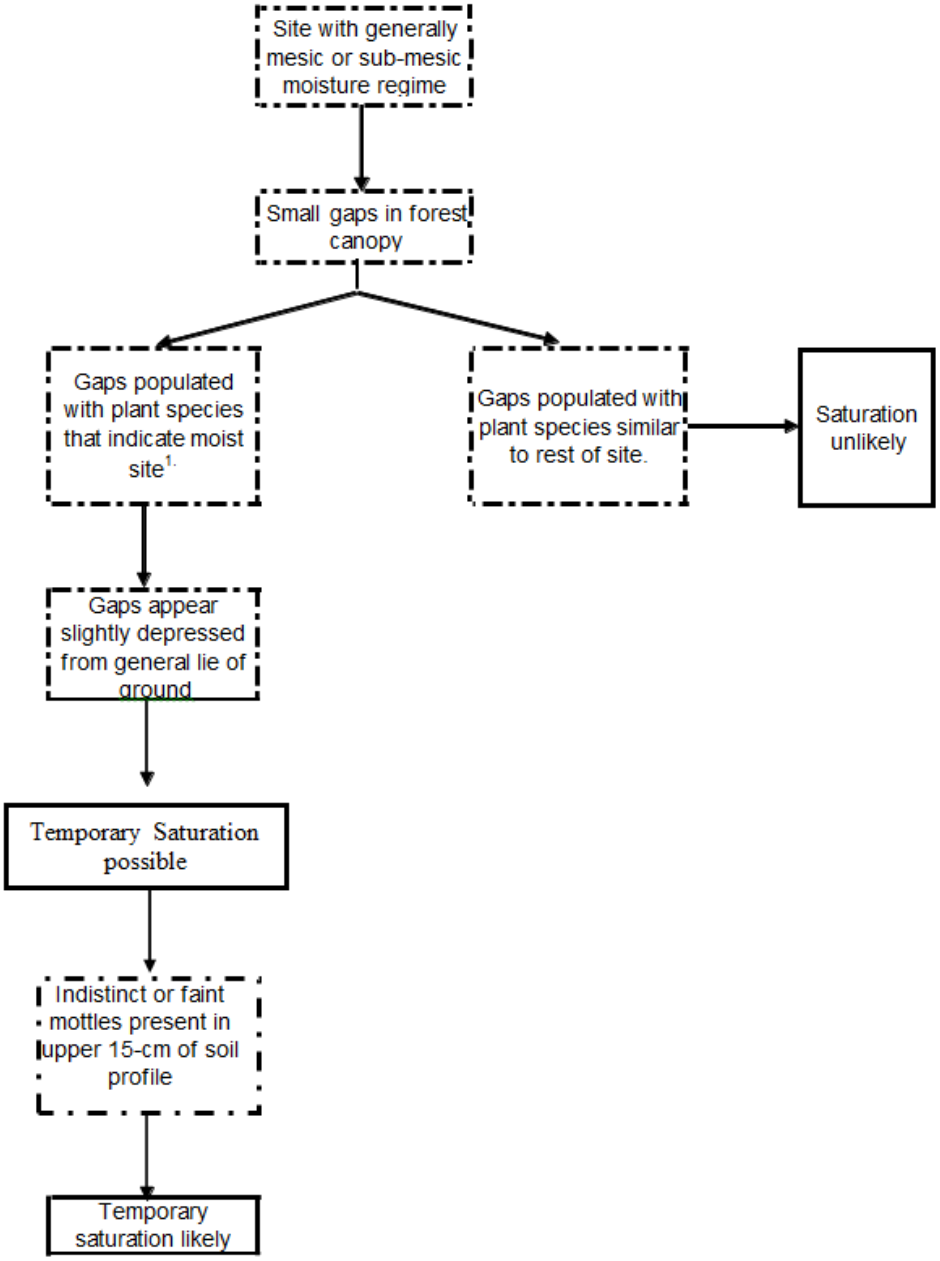

Figure 9.8. Diagnosing Risk of Temporary Saturation.

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