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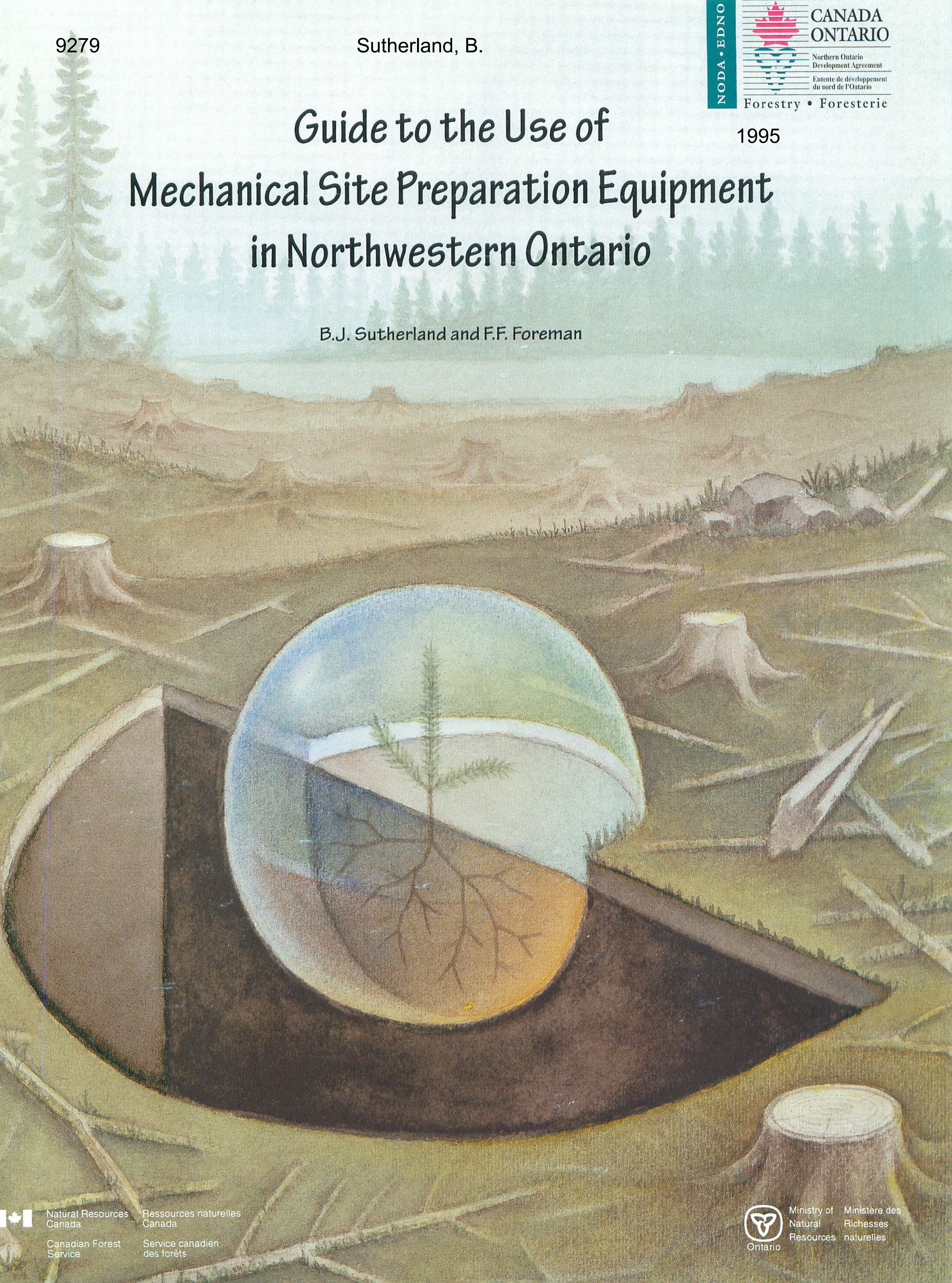
Guide to the Use of Mechanical Site Preparation Equipment in Northwestern Ontario

B.J. Sutherland and F.F. Foreman



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A four-year, $95 million initiative funded equally by the Government of Canada and the Government of Ontario.

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- to undertake programs of applied research and technology transfer that provide information in support of sustainable forestry in Ontario;
- to provide improved capability to forest managers through improved decision-support systems, advanced silvicultural training, development of alternative forest management techniques, collection and publication of forestry information and expanded economic analysis of the forest sector;
- to support the economic development of aboriginal people through on-reserve forest management programs, access to off-reserve resources and enhanced forestry training; and
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Management and Evaluation

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- mettre en œuvre des programmes de recherche appliquée et de transfert de technologie qui fournissent de l'information destinée à soutenir la "foresterie durable" en Ontario;
- rehausser les compétences des gestionnaires de forêts, par l'amélioration des systèmes d'aide à la décision et de la formation en sylviculture, la mise au point de nouvelles techniques de gestion forestière, la cueillette et la publication d'informations sur la foresterie et l'expansion de l'analyse économique du secteur forestier;
- soutenir le développement économique des Premières Nations, en mettant en œuvre des programmes de gestion forestière dans les réserves, en autorisant l'accès des autochtones à des ressources situées à l'extérieur des réserves et en améliorant la formation en foresterie; et
- favoriser une compréhension plus approfondie de la forêt, des valeurs qu'elle génère et des contributions du Canada et de l'Ontario à son utilisation durable.

Programmes:

Développement forestier durable
Développement forestier par les autochtones
Communications, sensibilisation et éducation
Gestion et évaluation

GUIDE TO THE USE
OF MECHANICAL SITE PREPARATION EQUIPMENT
IN NORTHWESTERN ONTARIO

B.J. Sutherland and F.F. Foreman

Canadian Forest Service–Sault Ste. Marie
Natural Resources Canada
Sault Ste. Marie, Ontario

1995

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ABOUT THIS GUIDE

This guide will help forest management personnel in northwestern Ontario to select and use mechanical site preparation equipment in order to produce growing conditions suitable for germination and growth of seedlings. Information in the guide has been subdivided into three sections, starting with the fundamental principles underlying site preparation and progressing to practical application and results from use of various implements.

Section A

Planning for site preparation requires a basic understanding of the biological requirements for and constraints to tree seedling growth and seed germination. To serve as a review of these processes, Section A discusses six of the more important microclimatic variables and outlines the positive and, in some cases, negative effects of mechanical site preparation on each of them.

Section B

Site preparation equipment is represented by a variety of implements, most of which are capable of producing several types of soil disturbance. To assist with the proper selection and use of equipment, Section B presents a breakdown of the disturbance patterns by category (microsite conditions) produced by implements used in northwestern Ontario. Using cross-sectional schematic profiles, six categories are defined, and the most common of these (i.e., screefing, trenching, and inverting) are presented using silvicultural requirements for the four major coniferous crop species in northwestern Ontario. Recommended and nonrecommended planting and seeding locations are identified.

Section C

Numerous site-related factors can influence the performance of site preparation equipment. Harvesting method and degree of utilization, as well as soil and terrain features, are examples of factors that can affect the trafficability and effectiveness of site preparation equipment. To provide the reader with representative examples of postharvest site conditions and site preparation results achieved, Section C presents a photo-series of typical site preparation case studies from across northwestern Ontario. This section employs many of the conventions used in the *Field guide to the forest ecosystem classification* [FEC] *for northwestern Ontario* (Sims et al. 1989) and the *Northwestern Ontario forest ecosystem interpretations* (Racey et al. 1989). Each photo set, identified by an FEC vegetation type and treatment unit designation, documents pre– and post–site preparation conditions after harvesting and includes a rating of the site's plantability and receptivity achieved by the site preparation implement.

SECTION A: BIOLOGICAL CONSIDERATIONS FOR GOOD SITE PREPARATION

Introduction

Postharvest site preparation is a key step in the overall silvicultural planning cycle, which consists of harvesting, site preparation, reforestation (planting/seeding), and stand tending (Otchere-Boateng and Herring 1990). The goal of site preparation is to create an environment that favors crop tree performance, from successful seed germination or seedling survival and establishment to rapid growth promotion. All environmental influences must be considered when designing silvicultural treatments that promote the early growth of planted conifers. According to Sutton (1985), site preparation may be necessary to attain any of the following objectives: to facilitate regeneration operations so as to improve planting quality and reduce establishment costs; to redistribute, align, and, in some cases, reduce slash; to reduce competition from residual vegetation; and to expose or cultivate mineral soil. According to Kennedy (1988), site preparation can also reduce the amount of organic matter and modify the microclimate (microenvironment).

The desired product of site preparation is the creation of microsites that are suitable for planting or seeding. Stathers et al. (1990) described a microsite as "A portion of a site that is uniform in microtopography and surface soil materials. It can range in size from less than 1 m^2 [for seed, considerably less than] to occasionally over 5 m^2. Microsites are dynamic in that their characteristics are ever-changing, imperceptibly or suddenly." Factors responsible for this dynamic are macro- and microclimate and microtopography (Figure 1a).

Macroclimate, the larger-scale (10–1000 km) atmospheric conditions that largely determine microclimatic conditions, consists of solar radiation (sunshine), precipitation, wind speed, and the temperature and humidity of the overlying air mass (Spittlehouse and Stathers 1990).

Microclimate is the small-scale climate that develops upwards and downwards from the ground surface, where radiant energy and precipitation are received and dissipated. Microclimate fluctuates more or less greatly depending on weather conditions, terrain, cover of vegetation, and soil properties (Caborn 1973). Microclimate will certainly be influenced by site preparation.

Microtopography, the shape of the ground surface, is often characterized by mounds and depressions (Stathers et al. 1990). Mounds and depressions influence the climatic regime owing to variations in their heights and frequencies, which, along with slope and aspect, tend to establish a mosaic of moisture, temperature, and nutrient conditions across a site. For example, removal of the insulating organic layer to expose the more conductive underlying mineral soil can significantly influence the daytime and nighttime (diurnal and nocturnal) soil temperature and nocturnal air temperature of the microclimate around a seedling (Figure 1b).

Major Factors Affecting Survival and Growth

Improving a forest environment for regeneration by site preparation is accomplished by relieving the constraints to seed germination or seedling establishment and/or performance. Newly planted seedlings, for example, are vulnerable because the microclimate of the planting site is most extreme, invading plant species may create severe competition for resources, and seedlings may not be completely acclimated to site conditions and may also be stressed during the transplanting process (Hobbs 1982). Fleming (1990) identified near-surface moisture deficits, root zone moisture deficits, and low surface and soil subsurface temperatures as major constraints to seedlings on many upland cutovers. Other stresses registered by seedlings reflect imbalances and/or extremes in light, nutrients, and soil or atmospheric chemistry (Levitt 1972). Microclimatic components that can constrain seed germination or seedling establishment and/or performance and that can be influenced by or influence the choice of the site preparation method are soil moisture and temperature, air temperature, and light. Other constraints are soil fertility, thickness of the unincorporated organic layer (humus, LFH, duff, or peat layers), and the biotic variables of harvesting residue and noncrop vegetative competition (Sutton 1989).

Soil temperature and moisture are two of the most important constraints to tree seedlings during the establishment phase[1] and are highly interrelated (Voorhees et al. 1981): a change in one variable causes changes in the other. Heat and moisture are coupled in terms of their effect on plant growth and their role in establishing the microclimate at a specific site; however, water is frequently the most important environmental factor that influences the day-to-day variation in tree growth (Spittlehouse and Childs 1990).

On the basis of a literature search of sources relevant to northwestern Ontario, the many variables that influence seed germination or seedling establishment are discussed below in terms of the relative importance of each constraint to the growth and survival of trees, the influence of various environmental factors, and how each constraint can be ameliorated by mechanical site preparation. A summary of the relative influence of various types of mechanical site preparation on microsite constraints is presented in Table 1. For a more complete treatment of this subject area, the reader is referred to the Literature cited section.

Soil moisture

To attain high rates of seed germination, sustained, adequate levels of soil moisture are required. According to Örlander et al. (1990), "seed should lie on a moist substrate with a relative humidity of 100%" to permit high rates of germination. For seedlings, water is the most important substance taken up by roots (Lavender 1990); water affects root growth and function directly and other factors, such as seedling nutrition, root aeration, mechanical impedance, and soil temperature,

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[1] Fryk, J. 1986. Adapted site preparation in Sweden. Paper presented to 8th annual workshop, IUFRO SI. 05-12, 22–26 August 1986, Grande Prairie, AB, and Dawson Creek, BC.

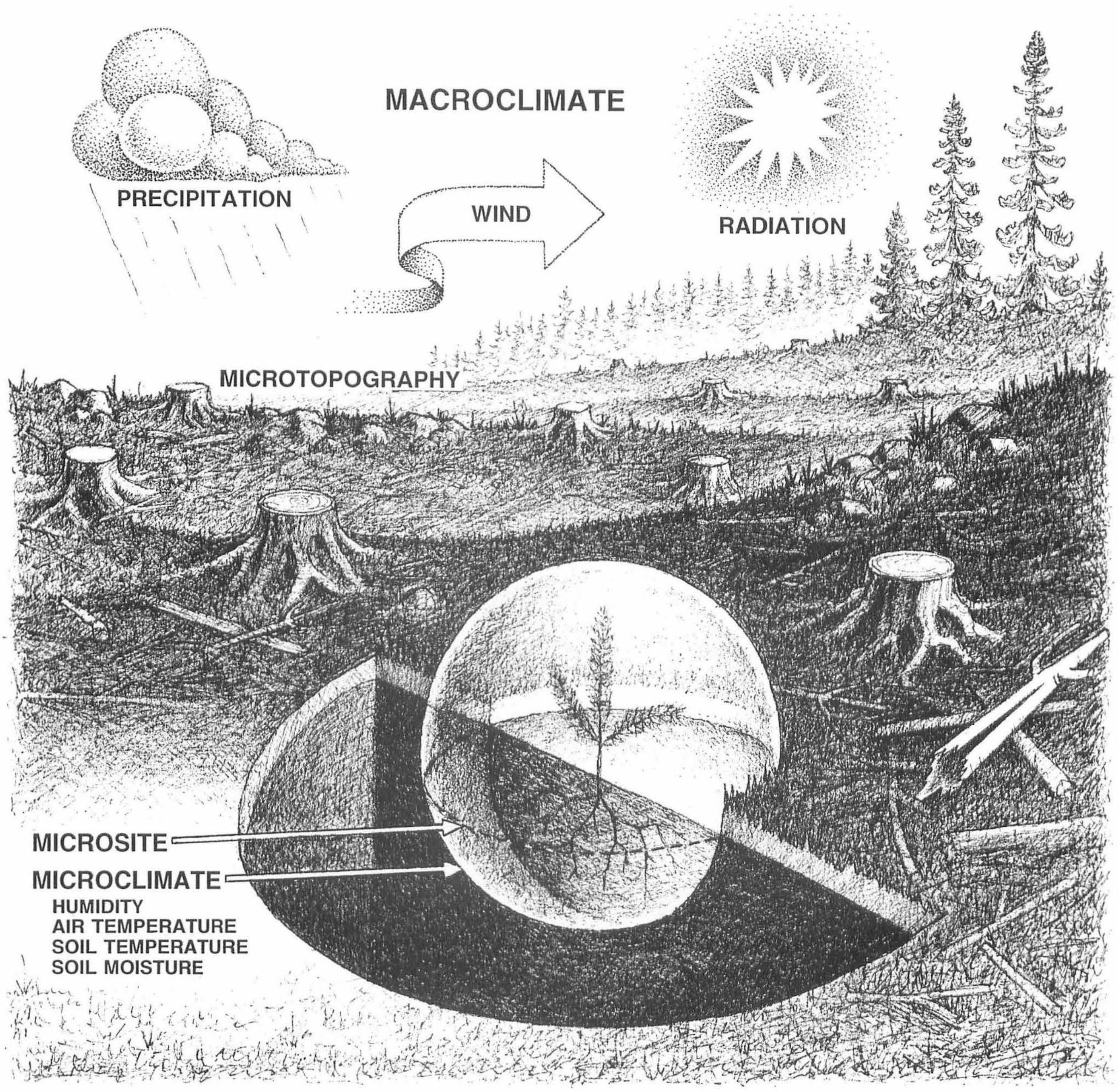
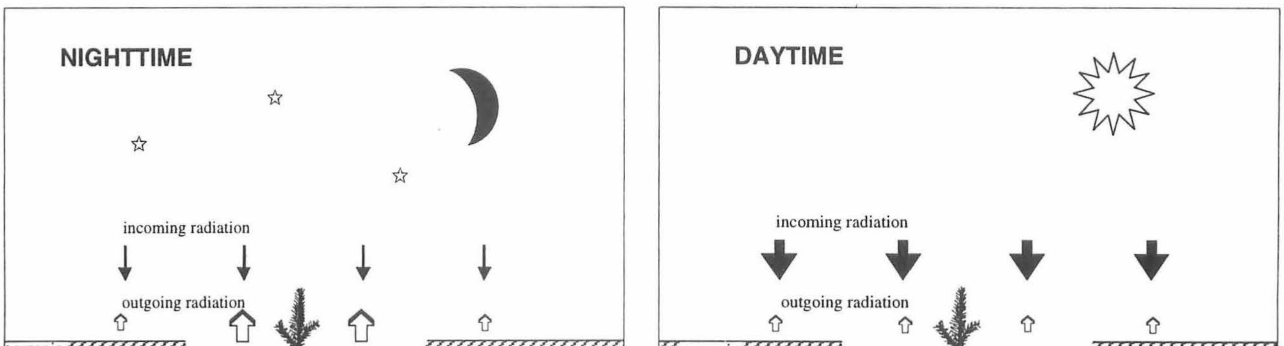


Figure 1a. Seedling environment.

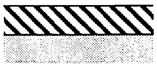
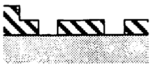
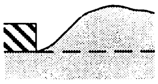
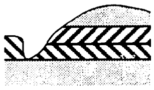
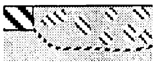
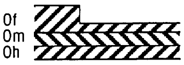
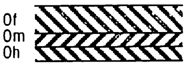


Air temperature higher above exposed mineral soil as heat conducted back to atmosphere at night.

Soil temperature higher on exposed mineral soil compared with soil temperature under the undisturbed organic layer.

Figure 1b. Effect of mineral soil exposure on soil and air temperature.

Table 1. Relative influence of microsite categories on site factors.

Microsite description Effect of microsite on site factor: + = promotes (++ = strongly) 0 = no effect – = discourages (– – – = strongly) ▒ mineral ▨ organic		**Site factors**[a]				
		Soil moisture	**Soil temperature**	**Short-term nutrient availability**	**Frost hazard**	**Frost heave**[b]
All soils						
Undisturbed mature stand		0	0	0	0	0
Upland mineral soils						
Overstory removed, organic and mineral layers undisturbed (e.g., cutover)		+	+	+	++	0
L layer and part of F layer removed or displaced (e.g., shallow screef)		– – to +[c] + fine	+ to ++	– coarse	– to 0 + fine	– coarse
LFH removed, mineral soil intact (e.g., screef)		+ – fine	+	– – coarse	– ++ fine	+ coarse
LFH removed, some mineral soil removed (e.g., deep screef)		+ to ++ – fine	+	– – coarse	– to + ++ fine	+ coarse
LFH removed, mineral mound on mineral soil		– coarse + fine	++	– coarse + fine	– –	–
LFH and mineral layers inverted (mineral mound on organic layer)		– – to –[d]	++	+	– –	– – to –
LFH and mineral mixed (e.g., tilling)		+ + fine	+ to ++	++ coarse	– –	– to +[e]
Lowland organic soils[f]						
Part of Of removed (e.g., shearblading)		+	+	+	–	0 to ++[e]
Drainage of layer (e.g., ditching)		– –	++	++	+	– – to 0

[a] Refers to soil surface conditions. Coarse and fine refer to soil texture.

[b] Assumes soils prone to frost heave (see Appendix A).

[c] Poorly decomposed organic matter may be prone to periodic drying.

[d] Moisture availability of subsoil may be enhanced by capillary discontinuity of organic layer (McMinn and Hedin 1990).

[e] Can increase or decrease with changes in hydraulic conductivity.

[f] Assumes organic surface conditions; Of, Om, and Oh represent fibric, mesic, and humic horizons, respectively.

indirectly (Eavis and Payne 1969). Consequently, the initial survival and growth of seedlings depend on the establishment and maintenance of functional connections throughout the soil–plant–atmosphere continuum (Margolis and Brand 1990). Newly planted seedlings can exploit the moisture in only a small volume of soil (Spittlehouse and Stathers 1990). An imbalance in soil water relations results in slower growth and has the following effects (Lavender 1990):

- A shortage of moisture induces seedlings to close their stomata to limit water loss, which, in turn, limits photosynthesis.

- An excess of moisture reduces the oxygen required for root development by the creation of an anaerobic environment; it also causes the release of toxic substances by soil microorganisms that are highly injurious to seedling root systems.

Soil moisture regime is the actual rise and fall of available soil moisture (Hills 1952); the major controlling factors were summarized by Spittlehouse and Stathers (1990):

Weather (macroclimate)

- Some part of the precipitation enters the soil; solar radiation, temperature, humidity (vapor pressure deficit), and wind speed determine the evaporative demand for moisture.

Site

- The slope position and microtopography affect the movement of water within and out of the soil, whereas slope and aspect affect the amount of solar radiation received.

- The vegetational cover competes for moisture through uptake and transpiration and by intercepting precipitation, some of which evaporates before reaching the soil.

- Soil water retention and availability are affected by soil texture[2] (pore size distribution determines the amount of soil water available to the plant); soil gravel and stone content, which affects the available water storage capacity[3] (water available for use by plants); hydraulic conductivity[4] (ability of the soil to conduct water); and root zone depth. Soil texture is one of the more useful variables for predicting soil water relations. Appendix A gives examples of how changes in soil texture alter soil water relations, the potential for frost heaving, and surface soil erosion and compaction.

- Soil bulk density affects pore space; increasing bulk density (e.g., by compaction) reduces water storage and decreases infiltration and drainage capabilities.

- The stone or coarse fragment content of the soil affects water storage, which decreases with increasing coarse fragment content.

- Soil organic matter content can improve soil structure, making drainage and air permeability easier (Olsson 1986). A thick humus layer can increase the soil's resistance to compaction (Racey et al. 1989). Loose, undecomposed organic matter (e.g., a surface litter layer) has a poor water storage capacity. Smith (1962) stated that organic seedbeds do not provide as stable a moisture source as does mineral soil.

Positive effects of site preparation on soil moisture

Site preparation treatments modify the soil moisture regime either by conserving the available water or by removing the excess water (Spittlehouse and Stathers 1990). For seed germination, the near-surface availability of soil moisture must be assured. For planting, the goal is to influence the moisture conditions around seedling roots, primarily by providing the planting spot with relatively high and secure moisture availability without risking oxygen deficiency (Örlander et al. 1990).

Moisture conservation can be accomplished by:

- reducing transpirational losses through the removal or killing of competing vegetation (Bäcke et al. 1978; Spittlehouse and Childs 1990). Moisture deficits in the rooting zone of conifers are largely the result of transpiration by competing vegetation rather than evaporation (Spittlehouse 1988; Fleming 1990).

- exposing mineral soil through the removal of the surface organic layers or moss cover. The periodic and rapid drying of organic matter and feathermoss or reindeer moss layers makes such material a poor seedbed for jack pine (*Pinus banksiana* Lamb.) compared with mineral soil (Chrosciewicz 1990). Scalping, screefing, trenching, or inverting to produce a depressed planting spot (below the original soil surface) can be particularly effective in the case of planting by conserving soil moisture in dry climates, as snow and rainfall accumulate in a depression (McMinn and Hedin 1990). Even small microdepressions in the soil surface can improve moisture supply for seed located therein (Örlander et al. 1990). In mounds, soil moisture may be enhanced below the inverted layers owing to capillary discontinuity in the humus layer and the fact that transpirational losses from vegetation are reduced once vegetation is controlled (McMinn and Hedin 1990).

- mulching to reduce evaporation. A dried surface soil layer or undisturbed organic layer (Cochran 1969; Spittlehouse and Childs 1990) can be effective on coarse-textured soils in a dry environment (Spittlehouse 1988; Stathers and Spittlehouse 1990). Soil evaporative losses can also be reduced by partial removal or manipulation of the vegetative overstory (Sutton 1993).

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[2] Water storage capacity is greatest in loams, intermediate in clay, and least in sand.

[3] Available water storage capacity is the difference between field capacity and permanent wilting point. Field capacity is the amount of water remaining in a freely draining soil within a few days after a saturating rainfall, by which time drainage of the pores has become negligible. Permanent wilting point is the water potential at which the soil is too dry for plants to extract water.

[4] Hydraulic conductivity depends on soil texture and structure, bulk density, water content, water temperature, and soil profile discontinuities.

- incorporation of the humus layers with the mineral soil by mixing. This was found to increase the soil's water-holding capacity in the rooting zone (Morris and Lowery 1988; Grossnickle and Heikurinen 1989; Stathers and Spittlehouse 1990). According to Dominy (1993), it will also improve soil moisture by reducing the density of competing vegetation, particularly in coarser-textured soils. On fine-textured soils, mixing can increase the infiltration of moisture (Ballard 1982) and can avoid capillary discontinuity in raised beds (McMinn 1989). In the southern United States, soils on moderate to steep slopes subjected to compaction and puddling were similarly improved by cultivation (discing, bedding, and subsoiling) (Morris and Lowery 1988). Örlander et al. (1990) stated that mixing ameliorates soil physical conditions and improves oxygen availability for long periods of time. Few studies have been conducted in Ontario on mixing as a site preparation treatment. Grossnickle and Heikurinen (1989), in a study of bareroot jack pine and white spruce (*Picea glauca* [Moench] Voss) on a loamy fine sand, found the least water stress and greatest stomatal "optimization" in mixed soils, with the most stress in either bare mineral soil or control site preparation treatments.

- compacting soils to improve capillarity. This can help to increase available water capacity in sandy soils (R.L. Fleming, Canadian Forest Service–Sault Ste. Marie, pers. commun.).

Moisture removal can be accomplished by:

- localized drainage (e.g., mounds or berms). Any site preparation method that produces raised planting spots, such as mounding (McMinn and Hedin 1990) or plowing, will drain microsites and create drier and thus warmer and better-aerated planting spots for seedlings (Draper et al. 1985; Örlander et al. 1990). The initial benefits of raised (mounded) microsites have been well documented for the cold, wet soils of Sweden at high latitudes[5] (Örlander et al. 1990). Mounding has also been advocated as having the potential for improving the survival and performance of outplanted seedlings in cold climates in parts of British Columbia (Parolin et al. 1981; McMinn 1983; Haeussler 1989). However, few studies on mounding have been initiated in Ontario, and the results to date have been less than conclusive. Sutton (1993), in a literature review of the mounding site preparation method, concluded that the long-term effects of mounding on tree and stand stability and the physical and biological effects on the site are not well documented.

- overall site drainage. This technique is used on lowland peat soils to lower groundwater levels, thereby providing a greater volume of aerated peat for the tree roots to exploit (Jeglum 1985). A greater volume of exploitable peat volumes ensures a better nutrient supply to the roots because of increased biological activity and mineralization and because the deeper peat layers that become available to the seedling are often nutritionally richer than the surface layers. Another benefit is that lowering the water level allows the peat to warm up faster and reach higher temperatures earlier in the season (Jeglum 1985).

Negative effects of site preparation on soil moisture

Given the many factors that influence soil moisture, it can be difficult to achieve and maintain the positive effects of site preparation. Some of the negative effects of mechanical site preparation are as follows:

- Droughty conditions can sometimes be made worse. Studies in British Columbia have indicated that raised planting spots may desiccate during dry periods, particularly in coarse-textured soils (Macadam 1989; McMinn and Hedin 1990). On these soils, inverted mounds may further accentuate desiccation because of the capillary discontinuity created by the inverted organic layer (cf. Sutton 1993). Experience in Sweden with mounding indicates that in fine-textured soils, capillary discontinuity can result in an even greater risk of desiccation owing to the higher hydraulic conductivity at the surface (compared with that of coarse-textured soils), which can result in faster drying of the mineral cap (Örlander et al. 1990). To overcome problems associated with mound desiccation, Örlander (1984), in studying water relations in Scots pine (*Pinus sylvestris* L.), suggested deep planting to place at least part of the seedling root system deeper than the upturned humus layer.

- Depressed site-prepared microsites may be subject to seasonal moisture stresses as well as frost heaving. The risk of frost heaving may be increased, particularly on fine-textured soils (von der Gonna and Lavender 1989; McMinn and Hedin 1990). The potential for frost heaving after mounding is not clear. An increase in frost-heaving potential is possible on mounds of fine-textured soil (Thorsen 1978) and for mounded mineral soil over mineral soil (Adelsköld and Örlander 1989). A decrease is predicted for mounding in general (Bäcke et al. 1986) and on inverted humus mounds (Örlander et al. 1990). In British Columbia, frost heaving has not been a problem following site preparation by inversion, even when mineral caps are fine-textured (McMinn and Hedin 1990).

- Complete exposure of mineral soil can lead to modification in surface structure. Savill and Evans (1986) found that rainfall can modify the soil surface by creating a seal that can retard infiltration, promote surface flow, and lead to erosion. Sutton (1984a) reported that mounds of fine-textured soils created by hand were resistant to rewetting once they had dried.

- Soil pore structure can be adversely affected. There is ample evidence that soil disturbance and compaction caused by forest crop harvesting and extraction adversely affect tree growth and the long-term productivity of a site, but individual effects are variable and have not yet been well quantified (Wingate-Hill and Jakobson 1982). Wingate-Hill and Jakobson (1982) provided recommendations on the choice of machines and running gear to reduce soil damage under various soil conditions, as well as on operation methods. Hunt (1987) summarized the adverse effects of mechanical site preparation treatments on soil bulk density, primarily from studies in Nordic countries; as with harvesting equipment, the results

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[5] Edlund, L.; Jönsson, F. 1986. Swedish experience with ten years of mounding site preparation. Paper presented to 8th annual workshop, IUFRO SI. 05-12, 22–26 August 1986, Grande Prairie, AB, and Dawson Creek, BC.

were variable. Stransky (1981), reporting on the effects of increased soil bulk density on southern pine species, stated that negative effects may be masked by the initial positive response of seedlings to reduced woody competition. In Canada, Stiell (1976) pointed out that scraping a fine-textured soil surface (e.g., by blading) can cause glazing, the closure of the soil pores at the surface, and inhibition of water penetration.

- Soil rooting volume may be limited. Continuously plowed furrows may restrict tree root extension across furrows where soil water tables are high (Ballard 1982). This may limit rooting volume and lead to future windthrow problems (Anderson 1967; Ballard 1982).

Soil temperature

Soil temperature influences seedling growth and survival by influencing physiological processes such as respiration and water uptake by roots (Örlander et al. 1990). Constraints on plant growth arise from temperature extremes (Richards et al. 1952; Cooper 1973). Fluctuations in soil temperature tend to be greatest at or near the soil surface, which can be of crucial importance, especially when a prescription calls for regeneration by seeding.[6]

Low soil temperature:

- is a major constraint on rooting depth and root growth (Sutton 1969; Grossnickle and Blake 1985).

- is probably the most important environmental factor that influences the rate of water uptake (Kramer 1940). Newly planted seedlings initially have poor contact between their roots and the soil. This can be further aggravated by low soil temperature, which increases the viscosity of water and thus its resistance to flow (Running and Reid 1980; Grossnickle 1988a). Higher soil temperature stimulates rapid root development and thus promotes good root–soil contact, which can help alleviate seedling water stress (Grossnickle 1988b). The optimal soil temperature ranges for root growth of boreal spruce and pine species are approximately 20–25 and 25–30°C, respectively (Heninger and White 1974; Söderström 1976; Dobbs and McMinn 1977).

- at the soil surface increases the risk of frost damage occurring to aerial tissues and is associated with frost heaving, a major cause of seedling mortality (Schramm 1958; Heidmann 1976). Air temperatures of approximately -3°C during the growing season will result in frost damage to foliage or succulent stem tissue (Stathers and Spittlehouse 1990).

Solar radiation has the greatest influence of all factors on soil temperature. The amount of solar radiation absorbed by the soil is affected by the albedo[7] (reflectance) of the surface material (i.e., a dark surface absorbs more energy) and by the amount of light intercepted by a surface layer such as vegetation or a mulch[8] (e.g., organic material or dry, coarse sand).

High soil surface temperatures under boreal conditions are most common near seedlings and young plants, whose succulent stems are in contact with an exposed and highly insolated surface soil of low heat conductivity that can warm rapidly (R.F. Sutton, Canadian Forest Service–Sault Ste. Marie, pers. commun.), such as dry, coarse sand or duff (Cochran 1969). Seedlings are at risk of damage from high temperatures primarily in a zone about 1 cm above and below ground level (Lavender 1990).

Spittlehouse and Stathers (1990) stated that soil temperatures are determined by weather (macroclimate), in the form of solar radiation and precipitation (soil moisture content), and site characteristics; site affects soil temperature through its location (slope and aspect), ground cover (vegetation and duff), and the physical properties of the soil (soil texture and moisture).

Heat storage, heat transfer, and temperature within the soil profile are determined by the thermal conductivity[9] and volumetric heat capacity[10] of the soil (both increase as the soil water content increases). Consequently, wetter soils (fine-textured soils are often wetter than coarse soils) warm more slowly and are generally colder than drier soils in the same area. Coarse-textured soils tend to create a surface mulch more readily than do fine-textured soils. Thermal diffusivity[11] is an index of how readily changes in surface temperature are transmitted deeper into the soil profile. Temperature changes are transmitted slowly through very dry or very wet soils.

Positive effects of site preparation on soil temperature

Two major goals of mechanical site preparation are to facilitate soil warming in the rooting zone and to reduce surface temperature extremes (Örlander et al. 1990; Spittlehouse and Stathers 1990), which, in turn, can cause seedling heat or cold stresses (Childs and Flint 1987).

Soil temperature can be increased by:

- removing the vegetation that shades the soil or reducing the thickness of the insulating organic layer. This will cause soil warming as a result of increased solar radiation and thermal diffusivity (Draper et al. 1988; Sutton 1989; McMinn and Hedin 1990; Spittlehouse and Stathers 1990). Soil warming will be greatest where the original organic layers were thickest (Brand 1991).

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[6] Sutton, R.F. 1988. Silvicultural prescriptions: implications. Paper presented to 8th annual workshop, IUFRO Sl. 05-12, 22–26 August 1986, Grande Prairie, AB, and Dawson Creek, BC.

[7] Albedo is the ratio of the amount of solar radiation reflected by a surface to the amount incident on the surface.

[8] Unless moist, extreme surface temperatures predominate (Cochran 1969), "mulch" represents a surface organic or mineral layer that has low thermal conductivity and consequently reduced heat storage or transfer to lower layers.

[9] Thermal conductivity is a measure of the ability of soil to conduct heat.

[10] Volumetric heat capacity is the amount of heat required to change the temperature of a unit volume of soil.

[11] Thermal diffusivity is the ratio of thermal conductivity to volumetric heat capacity.

- cultivating the soil (e.g., rototilling). This can promote soil warming (Thomson and McMinn 1989) by reducing soil bulk density and thus improving drainage and aeration (Stathers and Spittlehouse 1990).

- manipulating microtopography through site preparation to favor microsites with a southerly aspect[12] (Örlander et al. 1990). The importance of aspect is more profound at higher latitudes, where a surface with a slope of 1° to the south is equivalent, in terms of insolation received, to level ground 100 km farther south (Shul'gin 1965).

- draining microsites (e.g., by mounding or plowing), which has proven effective in raising the soil temperature in the rooting zone over that of scalped patches or furrows where low soil temperature is the result of high soil moisture content (McMinn 1982; Hunt 1987; McMinn and Hedin 1990). This may be particularly true at higher latitudes (cf. Binder et al. 1989; von der Gonna and Lavender 1989).

Surface temperature extremes can be decreased by:

- removing the surface organic layer. Exposed mineral soil will maintain lower surface temperatures because heat is quickly conducted away from the surface (Cochran 1969). Heat conductance is further enhanced by soil moisture, which increases thermal conductivity and causes cooling through evaporation (Geiger 1957). The net result is to reduce temperature extremes (Cochran 1969; Spittlehouse and Stathers 1990). Additional protection from excessive insolation can be achieved with a roughened mineral soil surface, as was demonstrated in a trial by Shirley (1933). In that trial, conducted in the Great Lakes states, discing increased the amount of shade and consequently the survival for red pine (*Pinus resinosa* Ait.) seedlings.

- leaving the insulating surface organic layer intact. This can inhibit frost heaving in susceptible soils (Butt 1988). In such cases, partial removal of the organic layer may result in desirable soil warming while still providing protection from frost heaving.

- partially removing or manipulating the vegetative overstory. This will reduce the amount of shortwave radiation received by the soil surface (Sutton 1989; Stathers and Spittlehouse 1990). Redistributing logging debris to provide partial shade to microsites will accomplish the same objective.

- mixing the organic horizons deeply into the mineral soil in coarse-textured soils. This may avoid the usual extremes of soil surface temperature and moisture that are characteristic of the undisturbed organic layer (Salonius 1983; Dominy 1993). However, subsequent compaction to decrease the soil airspace that results from mixing may be required to increase thermal conductivity and volumetric heat capacity (Cochran 1969) and thus reduce temperature extremes.

Negative effects of site preparation on soil temperature

As with soil moisture, site preparation treatments aimed at ameliorating soil temperature constraints to seed germination and seedling growth may produce unwanted results if some factors are not considered. Some negative impacts are as follows:

- Differences between day and night temperatures may increase. Örlander et al. (1990) reported that in Sweden, the site preparation method that gives the highest soil temperatures during the day also results in the greatest differences between day and night temperatures. If the temperature periodically falls below freezing during the growing season, frost damage is possible (Stathers 1989; cf. Sutton 1993). A microsite that warms up earlier in the season, as could be the case for a mounded site, may prompt earlier flushing of seedlings, which could then be susceptible to frost damage (Sutton 1993).

- A droughty, nutrient-impoverished microsite could be created by removal of the organic layers on coarse-textured soils, such as sands (Ezell and Arbour 1985). This may negate any improvements gained by increasing soil temperature.

- The problem of high soil surface temperatures may be made worse (Sutton 1989) by soil cultivation that loosens the soil structure and increases air content (e.g., mixing) (Cochran 1969; Cooper 1973), thus lowering the volumetric heat capacity and/or heat conductivity of the surface layer. This can reduce the suitability of a seedbed.

Despite the potentially negative effects described above, the positive effects of exposing mineral soil (raising soil temperature and removing competing vegetation) generally outweigh such drawbacks (Dobbs and McMinn 1977).

Nutrient availability

Mineral nutrients obtained from the soil are essential to all metabolic processes in trees (Lavender 1990). In particular, root growth and development, and, consequently, whole plant growth and development from germination onwards, are strongly influenced by soil fertility (Sutton 1991a). Nitrogen, phosphorus, and carbon are particularly important elements. Margolis and Brand (1990) stated that rapid early growth of a seedling requires that considerable nitrogen resources, other than what is stored in the plant, be quickly found, absorbed, assimilated, and transported to areas in need. Confounding this high nitrogen requirement for establishing seedlings is the need to conserve the site's nutrient pool for long-term stand productivity (Bäcke et al. 1986).

Many boreal forest stands occur on soils that are low in mineral nutrients; the most fertile zones are the surface organic layer and the first 10–20 cm of mineral soil (Lavender 1990). Nutrient capital and availability are affected by:

- the soil texture. In coarse-textured sands, for example, the nutrient capital can be limited to the organic layer (Foster and Morrison 1989), whereas soils with finer material tend to have a higher nutrient capital in the mineral horizons (Gordon 1981). Soils with a low nutrient capital include extremely shallow soils, coarse-textured soils that are excessively drained, and soils low in organic matter (Morrison 1980).

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[12] Sutton, 1988.

- the form of humus (as defined in Ontario Institute of Pedology 1985). This gives an indication of nutrient availability. "Moder" and "Mull" forms of humus indicate greater availability than a "Mor" form (Stathers et al. 1990). In northwestern Ontario, the less fertile Mor humus (and, more specifically, fibrimors and humifibrimors) predominates (R.A. Sims, Canadian Forest Service–Sault Ste. Marie, pers. commun.).

- the relative amounts of mineral soil and organic matter. Nutrients stored in an organic form in the humus layer (Morris and Lowery 1988) and in logging debris are returned to the soil after decomposing into a form usable to plants via mineralization processes (Hendrickson et al. 1986). Nitrogen, in particular, tends to occur in a less available organic form (Morris and Lowery 1988) and, as a result, is often the most limiting of mineral nutrients (Van Cleve et al. 1981, 1983). Highly humified organic materials consisting of buried leaves, wood, bark, and partially humified forest floor material play an important role in the regulation of nutrient cycling (Dominy 1993). This finely divided organic matter favors several positive soil processes — namely, soil aggregation, water-holding capacity, aeration, cation exchange capacity, and nutrient conservation — and can increase the soil's ability to retain nutrients (Sands 1983).

- plants and soil organisms. Neighboring vegetation can influence nutrient availability directly by competing for soil nutrients and indirectly by influencing soil moisture and temperature. Some nitrogen-fixing plants such as alder (*Alnus* spp.) can supply nitrogen to black spruce (*Picea mariana* [Mill.] B.S.P.) (Vincent 1964). The activity of earthworms, decay fungi, and other microorganisms is essential for soil fertility (Alexander 1961). In particular, mycorrhizal fungi have a symbiotic relationship with tree roots and can enhance nitrogen and phosphorus uptake, particularly in low-phosphate soils (Curl and Truelove 1986).

- microclimatic factors. Low soil temperatures beneath the insulating forest floor typify undisturbed boreal forest sites; as a result, nitrogen is mineralized slowly and thus accumulates as a reservoir in an organic form (Foster and Morrison 1989). Warming of the forest floor following removal of the overstory by logging or by silvicultural practices such as herbiciding has several positive effects on nutrient availability: organic nitrogen is mineralized more rapidly in both the humus layer and decomposing slash (Örlander et al. 1990); ectomycorrhizal fungi growth is enhanced,[13] as is that of tree roots, both of which increase the area of root–soil contact and thus the absorption of water and nutrients; and warmer soil temperatures lower the viscosity of water and improve its ability to move and supply nutrients between root cells.[14] Increasing light intensity improves a plant's nutritional status through increased photosynthesis (Margolis and Brand 1990).

Positive effects of site preparation on nutrient availability

A primary objective of mechanical site preparation is to strike a balance between enhancing short-term nutrient availability of seedlings and preserving the longer-term nutrient capital of the site.

Nutrient availability can be enhanced by:

- removing or reducing the insulating effect of the organic layer. Mixing (Salonius 1983), inverting (Draper et al. 1985), and trenching, for example, all enhance soil warming and, consequently, nutrient mineralization. Results from studies in Sweden (Rosén and Lundmark-Thelin 1986) and Finland[15] show that the mineralization of nitrogen, potassium, and phosphorus is increased for at least 3 years after site preparation (mineral mounds on humus) on sandy soils. Warming the soil also promotes tree root growth, which allows roots to quickly reach the more fertile undisturbed organic material nearby (Sutton 1991a). This assumes that the cleared areas are relatively small.

- mixing the organic surface layer with the underlying mineral soil. Mixing may further enhance nutrient availability in soils of low fertility by encouraging the spread of mycorrhizae into the mineral soil (cf. Harvey et al. 1976a, 1980). (The effects of site preparation on mycorrhizal fungi need to be better defined by researchers.) Cultivation can also improve aeration and assist microbial activity in soils that either suffer from compaction or have impenetrable layers (Harvey et al. 1976b).

- raising and cultivating (loosening) the soil. Bedding, for example, as practised in the southern United States, can enhance nutrient uptake for many years in soils that suffer from poor water movement and aeration (Morris and Lowery 1988).

- reducing competing vegetation on a site. This serves to reduce one source of competition for soil nutrients and, as a result of increased light, enhances carbon uptake for crop trees.

Mechanical site preparation has an impact on the nutrient reserves of a site, primarily through the displacement or redistribution of the reserves stored in logging debris and in the organic and upper soil layers, and through the increased availability of nutrients as a result of mineralization. Unfortunately, neither newly germinated tree seeds nor planted stock are initially able to use all of the large nutrient reserves made available as a result of site preparation. Consequently, nutrient loss by leaching may result (McMinn and Hedin 1990). The following techniques have been employed to preserve the site's nutrient capital:

- spot scarifying only the small area in which an individual seedling will be planted. This will minimize losses due to leaching (McMinn and Hedin 1990) and will also conserve the nutrient reserves in the undisturbed organic layer, in

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[13] Ibid.

[14] Ibid.

[15] Malkonen, E. 1986. A review of soil preparation in Finland. Paper presented to 8th annual workshop, IUFRO SI. 05-12, 22–26 August 1986, Grande Prairie, AB, and Dawson Creek, BC. [Cited by Örlander et al. 1990, original not seen.]

logging debris (Tappeiner 1971; McMinn 1982; Alm and Long 1988), and in the existing vegetation (Dominy 1993) close to the growing seedling. The incidence of erosion, another source of nutrient loss, is also reduced (Racey et al. 1989).

- mixing (Moehring 1977; cf. Foster and Morrison 1989) or inverting the more fertile surface organic layers and the underlying mineral soil (McMinn 1986), instead of completely removing the organic layer. This will preserve the longer-term nutrient status of the site and can enhance tree growth. Slowing the mineralization of soil nutrients during the initial years of plantation development, when conifers are small and understory vegetation is sparse, may preserve these nutrients until crop trees are older and better able to exploit available nutrients (Dominy 1993). Mixing that incorporates the surface organic materials deep into the mineral soil can have a moderating effect on the rate of mineralization of nutrients by avoiding the temperature extremes commonly observed on the exposed surface organic layers (Salonius 1983). Buried wood and bark can also conserve soil fertility, as the microbial activity that accompanies their decomposition can temporarily immobilize nutrients (Binkley 1986).

- reducing the depth of removal of the organic and mineral soil horizons. This will help conserve nutrients, which can be particularly important when the subsoil is infertile (Ballard 1982).

Negative effects of site preparation on nutrient availability

The negative consequences of mechanical site preparation, in terms of overall net losses of site productivity, have not been well defined for boreal forest conditions. Experience from other regions or countries, however, can provide general guidelines that are applicable to the boreal forest.

In summarizing soil treatment guidelines, Haines et al. (1975) advised, "Do as much as necessary but as little as possible."

In Sweden, Örlander et al. (1990) recommended that "harsh" site preparation methods (continuous disc trenching or tilt plowing) be avoided "on poor site types with thin humus layers, dry or coarse textured soils" in favor of "milder" treatments such as mounding, or mounding and ditching.

Morris and Lowery (1988) were less definitive; in discussing results from studies in the southern United States, they stated that "On sites low in organic matter, and where large [nitrogen] deficiencies occur, [nitrogen] availability and plantation productivity may eventually be reduced by treatments that remove or displace large amounts of [nitrogen]."

Utzig and Walmsley (1988) concluded that, on the basis of results from past studies on seedling growth following mechanical site preparation in British Columbia, windrowing results in the most consistent reduction of tree growth, compared with less severe forms of mechanical disturbance. MacKinnon and McMinn (1988), after summarizing the effects of various forms of mechanical site preparation on vegetation and the growth of spruce in north-central British Columbia, concluded that although blade scarification reduced competing vegetation, it also decreased spruce performance for up to 13 years following treatment. Ballard (1982), in discussing soil implications of site preparation, pointed out that scalping of the forest floor temporarily eliminated the mycorrhizae-forming fungi and resulted in short-term deficiencies in phosphorus uptake.

In Ontario, Foster and Morrison (1989) and Wood and Dominy (1988) gave examples of how duff removal on infertile sites before planting had a negative effect on tree growth after 8 and 19 years, respectively. Incorporating duff and fine woody debris into mineral soil by mixing, for example, may not be an adequate sink for nutrients released immediately after mixing (Krause and Ramlal 1987). This implies that long-term growth may be reduced by mixing (Dominy 1993).

With much of northwestern Ontario dominated by low-fertility soils, many of which are also shallow and coarse-textured, special care must be exercised in prescribing and executing mechanical site preparation. The question of which site preparation methods are harsh or detrimental can be considered within the context of soil and site fertility and the relative degree of disturbance, as depicted by the mechanical microsite categories displayed in Table 1.

Extremely shallow soils have a limited store of nutrients and are sensitive to disturbance, as are coarse-textured, excessively well drained soils, whose limited nutrient reserves reside principally in the surface organic layer and in logging debris. Any treatment of such sites should retain as much of the organic layer and any logging debris as possible or mix the organic and mineral soil layers together. Conversely, in deeper, fine-textured soils with a greater or better-distributed nutrient capital, treatments that remove the surface organic layer and some mineral soil are not as detrimental.

Air temperature

Air temperature influences seedling growth and survival by its effects on photosynthesis, respiration, and transpiration (Spittlehouse and Stathers 1990). Growth rates for most tree species are optimal in the 15–25°C range. Damage from summer frost is a potential problem once air temperature falls below 0°C (Stathers 1989). In addition to low air temperature, the extent of frost damage depends on the frost hardiness of the species, the rate of freezing and thawing, and the duration of the lowest temperatures reached (Sakai and Larcher 1987), as well as the phenological stage of the trees (cf. Stathers 1989).

Solar radiation, the reflectance and conductivity of surface material, and the degree of vegetative cover are some of the factors that affect air temperature (Spittlehouse and Stathers 1990). Solar radiation heats the ground surface during the day. During the night, the air layer closest to the ground cools because outgoing longwave radiation exceeds incoming radiation (Örlander et al. 1990). Surface cooling is greatest when soil is covered by an organic layer or grass (Stathers 1989; Örlander et al. 1990).

Positive effects of site preparation on air temperature

Some positive effects of site preparation on air temperature include:

- lowering high daytime temperatures. Mechanical site preparation can have only a minimal effect on ameliorating high daytime air temperatures. Redistributing slash or leaving a partial cover of vegetation will provide shade and reduce air temperature extremes around seedling microsites.

- raising low nocturnal temperatures. Stathers (1989) noted several techniques that reduce the frequency and severity of summer frost damage resulting from low nighttime temperatures. Those related to mechanical site preparation are as follows:

  - increased mixing of the cold air layer near the ground with the warmer overlying layers, which probably results in the most frost protection.

  - increased diurnal (daytime) heat storage and nocturnal (nighttime) heat release from the soil profile and vegetation canopy.

  - reduced ponding of cold air. Frost pockets are created by cold air accumulating in depressions or at the foot of slopes.

Site preparation generally, and mounds and berms in particular, enhance microtopographic features that stimulate air mixing. Removal of the organic layer and exposure of mineral soil will facilitate the daytime storage and subsequent nocturnal warming of air around tree seedlings. The degree of frost protection offered will depend on the area of exposure (e.g., patch scarification versus blading) (Örlander et al. 1990) and the microtopography (aspect and microrelief). Nocturnal temperatures can also be improved by maintaining a partial vegetation canopy (Sutton 1984b). The canopy provides much warmer conditions than does a clear sky, resulting in a much greater flux of longwave radiation toward the ground (Spittlehouse and Stathers 1990). Removing vegetation that impedes air drainage and site preparation that promotes air mixing will retard the ponding of cold air (Stathers 1989). Caution must be exercised when using site preparation methods that produce microsite conditions such as depressions or trenches that can pond cold air. In these situations, plantable microsites should be selected on a raised microrelief (e.g., mounds).

Solar radiation/light

Most of the sun's energy heats the soil and air and evaporates water (Stathers et al. 1990). Although only 2% of the sun's energy is used in photosynthesis (Spittlehouse and Stathers 1990), 30–50% of direct summer sunlight intensity is required to achieve maximum rates of photosynthesis (Stathers et al. 1990). The efficiency of nutrient utilization increases with increasing light intensity (Brand 1991), which, in turn, increases the efficiency of using light. Heavily shaded seedlings, such as by vegetation, accumulate little biomass, grow slowly, and have a spindly growth form (Spittlehouse and Stathers 1990). In these conditions, warming of the rooting zone by solar radiation is also reduced. In studying the effects of light on the 10-year survival and growth of coniferous plantations in the Great Lakes states, Perala (1982) reported that conifer height growth generally decreased at sunlight levels below 45% of full intensity, and weight gain was greatest at 100% of full sunlight.

Weather factors, such as the extent of cloud cover and the season of the year, regulate how much light is available. However, neither can be influenced by mechanical site preparation.

Site factors such as slope and aspect can have a major influence on the amount of solar radiation that a microsite receives to produce soil warming.

As mentioned above, vegetation cover is a site factor that greatly influences the intensity of light received by a seedling for photosynthesis (Spittlehouse and Stathers 1990; Brand 1991). Overstory removal results in a considerable increase in solar radiation and light irradiance, which can result in severe stress to newly established seedlings (Grossnickle 1988c). Conversely, the competing volunteer vegetation that often establishes and flourishes on cutovers can quickly overtop conifer crop trees and greatly diminish the amount of light available for (conifer) photosynthesis and soil warming. "Light levels are usually suboptimal in tall, dense canopies that completely cover the ground. If the vegetation canopy is dense but patchy or discontinuous, light levels in the open areas are usually adequate for seedlings" (Spittlehouse and Stathers 1990). The species of vegetation present can influence the amount of light received by a seedling as a result of differences in the timing and rates of plant development, as well as in the heights and densities of the leaf canopy.

Positive effects of site preparation on solar radiation/light

The use of mechanical site preparation to modify site factors that influence soil temperature and moisture evaporation has been discussed in the previous sections on soil temperature and soil moisture. The amount of light available to seedlings for photosynthesis is best controlled by altering the vegetation canopy that overtops the seedlings. The effects of mechanical site preparation on vegetation are discussed in the section below on vegetative competition.

Noncrop vegetation

Noncrop woody and herbaceous vegetation can have either positive or negative effects on crop trees. As identified in previous sections, the positive effects may include contributions to biological recycling of nutrients; reduced leaching of nutrients; improvement of soil stability against erosion; moderation of soil and air temperatures at and near the surface (e.g., vegetation can reduce evaporative losses from the soil and reduce the risk of summer frost damage); reduction of pest damage to crop trees if the vegetation is used as an alternative food source (Haeussler and Coates 1986); and reduction of long-term competition by a cover crop of low-growing plants that may prevent invasion of longer-lived, more aggressive species (cf. Zabkiewicz 1991).

The negative effects of noncrop vegetation on the survival and growth of coniferous regeneration may include competition for light, moisture, nutrients, and sometimes space; smothering of seedlings by fallen leaves or nonwoody vegetation flattened by snow; creation of a physical impediment to activities such as site preparation and planting; provision of food and/or cover for animal pests; allelopathic effects on crop trees (cf. Sutton 1985); abrasion and whipping; increased fire danger (Bell 1991); and the adverse modification of soil conditions (including temperature) under certain circumstances.

Major disturbances such as fire or clear-cutting remove some portion of the surface plant community while leaving the physical, chemical, and biological characteristics of the soil largely intact (Stathers et al. 1990). Following disturbance, ground surfaces ranging from undisturbed organic material to exposed mineral soil receive increased levels of solar radiation, and this tends to stimulate residual plant material by favoring photosynthesis and elevating soil temperatures in the plant rooting zone (Stathers et al. 1990). Species composition can be changed by disturbance[16] as a result of seeding-in by airborne seed, stimulation of dormant seed banks, and suppression or removal of existing species.

The patterns of change in plant communities as a result of major disturbances are called secondary succession. They are influenced by the number, distribution, and condition of roots and other plant parts able to regenerate the plant that remain viable in the soil following a disturbance (bud banks); viable seeds that remain within the ecosystem (seed banks); seeds that arrive from adjacent areas (seed rain); and the competition or growth dynamics of each plant (Stathers et al. 1990).

Bell (1991) pointed out that vegetative reproduction mechanisms (sprouts, layers, underground stems [rhizomes], root suckers) generally dominate the resurgence processes of vegetation following a disturbance, rather than reproduction by seed. Vegetative reproduction does not depend on seedbed conditions and has the advantage of a ready supply of food and moisture from the already established root system of the parent plant (Zasada 1971).

Positive effects of site preparation on controlling noncrop vegetation

Young coniferous seedlings are extremely vulnerable to noncrop vegetation, especially on fertile sites such as some boreal mixedwood stands. On a boreal mixedwood site in Ontario, Brand (1991) recorded a 300% increase in biomass since the time of planting for black spruce and jack pine paperpot seedlings by the end of the second growing season, after total vegetation control. Silvicultural management of vegetation does not usually involve eradication of weeds, unlike typical agricultural practice (Lawrence and Walstad 1978); rather, the aim is to delay vegetation development and thus prolong the "prerelease" interval. Walstad and Kuch (1987) stated that vegetation management for forest tree stand establishment encompasses a variety of cultural treatments. Although it is recognized that plants considered as weeds may in some cases be desirable in another location or at another time, treatments should be integrated in such a fashion that they:

- inhibit the establishment of weeds, thereby reducing the need for subsequent control measures.
- reduce the size or numbers of weeds only to a level below which they will have little effect on crop performance.
- avoid unnecessary diminution of ecological (botanical) diversity in order to reduce any long-term ecological imbalance.
- mesh with other components of the forest management system.

Mechanical site preparation is one of several management alternatives for vegetation control. It can be used either alone or in combination with other site preparation techniques, such as the application of herbicides or the use of prescribed fire. When used alone, mechanical site preparation has a larger treatment window than either herbicides or prescribed burning, and it offers the dual advantage of exposing mineral soil and controlling vegetation (Cantrell 1985). The effect of mechanical site preparation treatments on the composition and structure of existing vegetation on upland sites can be categorized in terms of the depth and area of treatment (adapted from Delong 1989) as follows:

- removal of surface vegetation: Trees and shrubs are pushed aside or sheared off, but some low shrubs, herbs, and most of the humus are left intact (e.g., winter shearing or corridoring). Thus, there is little change to the floristic composition, but their height and cover are reduced. Shearblading on lowland organic soils removes the top of *Sphagnum* hummocks (the Of layer) as well, and this creates a mosaic of sheared *Sphagnum* hummocks interspersed with feathermoss in the depressions.
- localized removal of subsurface vegetation: Patches or narrow strips of mineral soil are exposed either by removing the surface organic layer or by mixing the surface organic layer with the underlying mineral soil (e.g., spot scarifying, inverting, mounding on upland soils, disc trenching or drag units of barrels and/or tractor pads and/or anchor chains). The composition and structure of vegetation outside the disturbed area are unchanged; initially, there will be no vegetation on the mineral soil. The species composition of the vegetation that develops on the mineral soil often differs from that of the pretreatment vegetation.
- extensive removal of subsurface vegetation: Large areas of mineral soil are exposed (e.g., by angle- or V-blade windrowing or corridoring), which drastically changes the composition and structure of the competing vegetation. Areas of mineral soil are soon occupied by pioneer species, often by seeding-in. Sprouting of the vegetation originally growing on the site depends on the presence of root systems that have remained in the soil after site preparation.

The response of various species of vegetation to mechanical disturbance depends on the reproductive characteristics of the species (sexual and/or vegetative) and, in the case of vegetative reproduction, on the depth or location of the parent root systems (Buse and Bell 1992). Published information on the response of various species of vegetation to mechanical site preparation in northwestern Ontario is sparse. However, an attempt has been made to predict the relative response of vegetation to various mechanically produced microsite categories based on both the reproductive method and rooting depth of common noncrop vegetation species (Table 2), as follows:

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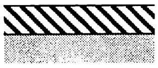
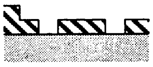
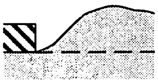
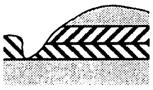
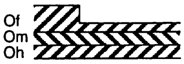
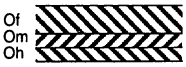
[16] Vanden Born, W.H.; Malik, N. 1984. Herbicide use in North American forestry: a literature search and an assessment of its environmental impact and its future potential for forest management in the Prairie provinces of Canada. Department of Plant Science, University of Alberta, Edmonton, AB. Unpublished report. 124 p.

Table 2. Relative influence of microsite categories on noncrop vegetation.

Microsite description		**Vegetative reproduction**			**Sexual reproduction**	
		from shoots	**from roots**		**wind-borne**	**seed bank**
Effect on competing vegetation: + = promotes (++ = strongly) 0 = no effect – = discourages (– – = strongly) ░ mineral ▨ organic		(e.g., *Acer, Alnus, Betula, Cornus, Ledum, Corylus, Salix*)	in organic layer (e.g., graminoids, *Vaccinium*)	in mineral soil (e.g., *Populus, Rosa, Rubus, Salix*)	seed (e.g., graminoids, *Betula, Epilobium, Populus*)	(e.g., *Cornus, Prunus, Rosa, Rubus, Vaccinium*)
All soils						
Undisturbed mature stand		0	0	0	0	0
Upland mineral soils						
Overstory removed, organic and mineral layers undisturbed (e.g., cutover)		++	+	+	0 to +[a]	+
L layer and part of F layer removed or displaced (e.g., shallow screef)		+	+	+	+	++
LFH removed, mineral soil intact (e.g., screef)		– – to –[b]	–	++	++	–
LFH removed, some mineral soil removed (e.g., deep screef)		– –	– –	– – to –[c]	++	– –
LFH removed, mineral mound on mineral soil		– –	– –	– – to –[d]	+	– –
LFH and mineral layers inverted (mineral mound on organic layer)		+ to ++	– to +[e]	– to +	+	– to +[f]
LFH and mineral mixed (e.g., tilling)[g]		– to +	– to +	– to +	++	++
Lowland organic soils[h]						
Part of Of removed (e.g., shearblading)		–[i]	– to +[j]	not applicable	+	+
Drainage of layer (e.g., ditching)		+	+	not applicable	0	+

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[a] Will promote if organic layer is shallow and/or moist.

[b] Control of sprouting is improved for species that tend to root in the organic layer.

[c] Control of sprouting depends on removal of root systems.

[d] Control depends on removal of root systems below ground and mineral mound sufficiently deep to suppress sprouting.

[e] Control of sprouting increases with increased depth of capping.

[f] A thin cap of mineral soil tends to encourage germination of seeds in the organic layer; a thick cap discourages germination.

[g] Control depends on degree of mix: fine mixing (e.g., rototilling) discourages, coarse mixing (e.g., single-pass discing) encourages.

[h] Of, Om, and Oh represent fibric, mesic, and humic organic horizons, respectively.

[i] Will promote *Ledum* and *Vaccinium* species.

[j] Control depends on degree of removal of root systems and stimulation of residuals.

- Removal of the vegetation layer only can result in a poorer seedbed for the regeneration of willow (*Salix* spp.) and birch (*Betula* spp.) compared with mechanically exposed mineral soil, as found by MacKinnon and McMinn (1988) in their trial in north-central British Columbia.

- Removal of the organic layer will interfere with the reestablishment of plant species that reproduce either vegetatively from roots located in the organic layer (cf. Coates and Haeussler 1986; Brand 1991) or from seed stored in the organic layer.

- Removal of the surface mineral soil and the organic layer (i.e., LFH) (e.g., by plowing) (Haeussler and Coates 1986) will discourage vegetative sprouting from the more deeply rooted plant species such as aspen (*Populus* spp.) (cf. Hambly 1985).

- Removal of the surface vegetation layer and/or disturbance or partial removal of the organic layer (Zasada and Argyle 1983) are successful ways of promoting the natural regeneration of poplar (cf. Perala 1977).

- A mineral cap over an inverted mound of humus tended to suppress resprouting of competing vegetation in studies in British Columbia (McMinn and Hedin 1990). Further, revegetation by wind-borne seed on mounds or berms may be inhibited owing to lower soil moisture and higher soil surface temperature (cf. Örlander et al. 1990). The influence of mounding on vegetation control has not been evaluated in Ontario. However, Sutton and Weldon (1993) acknowledged the greater response of jack pine seedlings to mounding on grassy sites compared with nongrassy sites in another study (Sutton 1991b).

- Mixing of the surface mineral and organic layers can influence vegetation response differently depending on the intensity of mixing and the aggressiveness of the competing vegetation (McMinn and Hedin 1990). Intensive mixing (roots and other plant parts chopped finely enough to inhibit resprouting) would be required on rich sites having aggressive competition. The size of the area mixed must be sufficient to minimize the effects of vegetative reproduction along the undisturbed edge. Several studies, including one by Basham (1982), have reported that discing reduces aspen sucker development through damage to root systems. Peterson and Peterson (1992), however, pointed out the need for more trials in the western provinces to verify the effects of discing on aspen reproduction. Site preparation should be conducted in the late summer or early fall to ensure minimal presence of weeds the next spring at time of planting (Ontario Ministry of Natural Resources 1993).

The timing and sequencing of treatments can also influence the vegetational response. Double-discing during the growing season, with the second treatment done 1 month after the first, has proven effective in controlling regrowth of aspen and grass in Alberta (Dorion 1989), presumably because of the considerably reduced vigor of resprouting after the second pass.

Negative effects of site preparation on controlling noncrop vegetation

Mechanical site preparation for vegetation control may be disadvantageous, in that:

- It often results in only short-term vegetation control (MacKinnon and McMinn 1988) and can promote vegetative resprouting (Table 2). Vegetative sprouting of noncrop plants such as aspen is best encouraged by shearing plant stems off above the root collar, as in the case of shearblading on frozen soils (Perala 1977), and/or disturbing but not completely removing the organic layer (Zasada and Argyle 1983). Campbell (1981) recorded a stimulation of *Aster* spp. regrowth following root raking in a trial in north-central Ontario. Partial or coarse mixing of the surface mineral and organic layers can stimulate rather than reduce vegetative sprouting; likewise, sprouting can be enhanced on thin mineral caps on inverted humus mounds (McMinn and Hedin 1990). Timing of treatment can also affect sprouting response. Sprouting of aspen, for example, is more vigorous following disturbance from scarification conducted during the early spring or the late fall than after summer scarification (Heeney et al. 1980).

- Damage to stems and roots as a result of mechanical disturbance promotes decay in some species. Basham (1982) reported that damage to 3-year-old aspen from scarification and logging increased the risk of stem and root rots in the survivors.

- It may promote germination of windblown or seed bank species. Leaving the surface organic layer intact will assist revegetation by plant species with seed banks in the organic layer and upper mineral soil; seed germination is facilitated by the increased light and temperature that result (Sutton 1985; Kramer and Johnson 1987). Conversely, the removal of organic matter to expose mineral soil will favor the germination of windblown seeds on the exposed mineral soil.

- It may lead to site degradation. Severe treatments that remove or displace the surface organic and mineral soil layers may result in nutrient removal and other site degradation, such as soil erosion and compaction (Malik and Vanden Born 1986). This can exacerbate the effects of extremes of surface temperature and moisture.

- The extent of the treatment may be limited by slopes or rough terrain (Cantrell 1985), by remote or scattered locations (Otchere-Boateng and Herring 1990), or by fresh-to-wet soils prone to compaction (Malik and Vanden Born 1986).

- It is usually more expensive than the alternatives, such as chemicals or prescribed fire (Cantrell 1985).

- It can destroy advance regeneration.

The effectiveness of mechanical site preparation in releasing the crop from vegetative competition will depend on the area disturbed, the severity of the disturbance, and the delay between site preparation and seeding or planting. In a study of backlog (not satisfactorily restocked) areas in the northern interior of British Columbia, Butt (1988) attributed competing vegetation problems to either no site preparation or excessive treatment delays. Mechanically prepared spots, either mounds or scalps, were found to be too small to provide effective vegetation control. Wood and Campbell (1988) cited several authors who attributed reduced outplant performance to the import of vegetation that became established because of delays in planting following a major site disturbance, such as logging or site preparation.

Combining mechanical and chemical site preparation to control noncrop vegetation

The vegetation control aspect of mechanical site preparation has, in recent years, been supplemented with other site preparation treatments, primarily the use of chemicals (herbicides) and prescribed fire. These treatments can follow or precede mechanical site preparation or, in the case of herbicides, can be carried out simultaneously with mechanical site preparation.

Mechanical site preparation that removes surface vegetation and/or exposes mineral soil can facilitate follow-up chemical site preparation using root-contact herbicides such as hexazinone and simazine, because more chemical reaches the soil surface (Desrochers and Dunnigan 1991).

Mechanical site preparation can be conducted prior to prescribed fire, as in the example of tramping (knocking down with heavy equipment) budworm-killed balsam fir (*Abies balsamea* [L.] Mill.) to improve fuel conditions prior to burning (McRae 1986) or following prescribed burning to increase the production or stocking of receptive seedbed (cf. Smith 1984).

Combining mechanical and chemical site preparation in one operation (e.g., the Bräcke Herbicider) has the following advantages: reduced treatment costs compared with two separately scheduled operations; shortened delay between harvesting and reforestation because only one event needs to be scheduled (Alm and Long 1988); and reduced chemical usage because the spray nozzle is directed to the targeted vegetation, with consequent improved accuracy of application (Desrochers and Dunnigan 1991).

The disadvantages of combining mechanical and chemical site preparation are as follows: in order to maximize the efficacy of herbicides, the time window for effective treatment is reduced compared with that for mechanical site preparation alone; variation in ground speed of site preparation equipment can result in over- and/or underapplication of herbicides (Galloway 1988); less effective control of vegetation can result if herbicides are applied at the same time as mechanical site preparation; the guidelines of Campbell (1981) indicate that, with a foliar-absorbed herbicide, maximum weed control is achieved when the herbicide treatment is delayed until after mechanical treatment, when regrowth has occurred; for soil-active herbicides, the most effective treatment is to apply herbicides soon after mechanical treatment, before weed growth begins. However, a soil settling period between mechanical and chemical treatments is advised, because soil-active herbicides are more effective when applied to a stable surface.

SECTION B: MECHANICAL SITE PREPARATION CATEGORIES

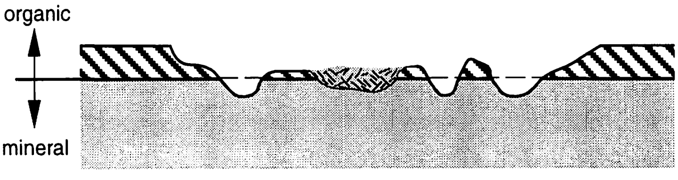
Introduction

Site preparation equipment produces a variety of microsite conditions that can be categorized by their cross-sectional profiles. Six general categories are discussed here: upland screefing, lowland screefing, inverting, trenching, mixing, and subsoiling. Each is described briefly along with examples of equipment capable of producing that category of disturbance. A more detailed representation of the cross-sectional profiles commonly produced in northwestern Ontario follows the general description.

Mechanical Site Preparation Category, by Cross-Sectional Profile

Screefing – upland

Upland screefing is removal or displacement of the organic layer to expose and/or lightly disturb (scarify) the underlying mineral soil.

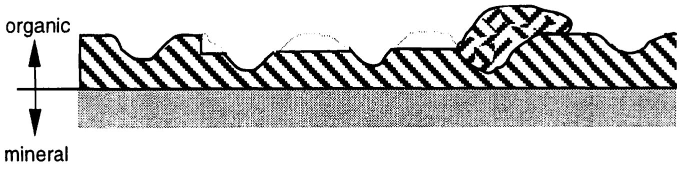


Caution: avoid extensive removal of organic material, particularly on infertile, coarse-textured soils with a thin organic layer, and on silty or clayey soils prone to glazing (closure of soil pore structure) or frost heave.

Examples of equipment: tractor-mounted blades (straight/angled) or V-blades, light barrel drags, anchor chains or tractor pads, blades/blade attachments (e.g., blade rakes, Young's teeth), plows (e.g., Cazes and Heppner), disc or cone trenchers (e.g., TTS Delta, Silva Wadell) on shallow settings, and spot scarifiers (e.g., Bräcke or Leno, and the motor-manual La Taupe scarifier).

Screefing – lowland

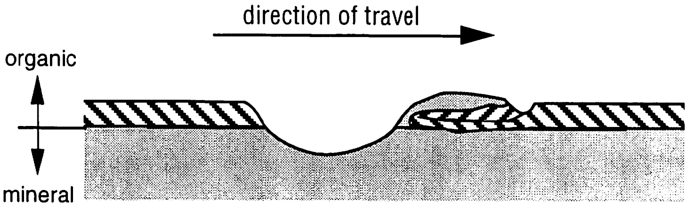
Lowland screefing is removal of the upper portion of the organic layer without disturbing or exposing the underlying mineral soil.



Examples of equipment: shearblades (e.g., Rome, Fleco, and Superior V-blade).

Inverting

The organic layer is inverted but left intact or is broken (either with or without the underlying mineral soil cap) over the adjacent and undisturbed LFH layer. The product consists of a screefed or scalped spot or strip and can include mounded mineral soil over mineral soil and/or mounded mineral soil over the inverted LFH.

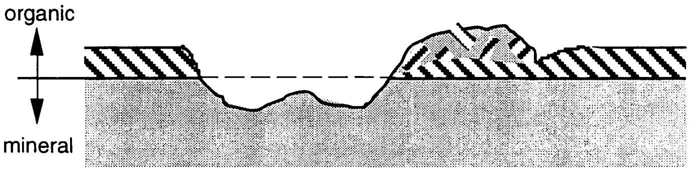


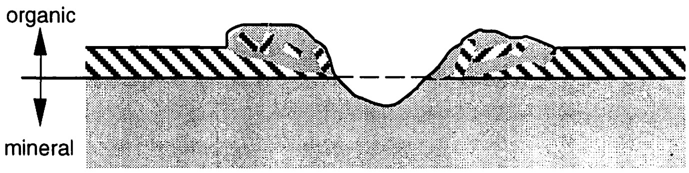
Caution: mounded mineral soil may be prone to periodic desiccation.

Examples of equipment: disc trenchers: spot inverting (e.g., Bräcke, Leno, Donaren 870 H) and continuous inverting (e.g., mold-board plows).

Trenching

In trenching, the organic layer and some underlying mineral matter are removed and deposited in berms beside the resulting trench. The layers are in a roughly mixed state over the undisturbed forest floor beside the trench.



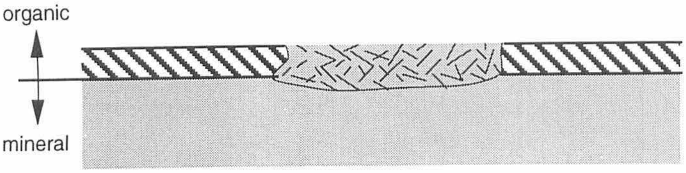


Caution: side berms may be prone to periodic desiccation.

Examples of equipment: disc trenchers (e.g., TTS–35/Delta, Donaren 180D, 180L, and 280D), cone trenchers (e.g., Silva Wadell), or heavy barrel drags.

Mixing

Mixing is the incorporation of the organic layer into the underlying mineral soil.

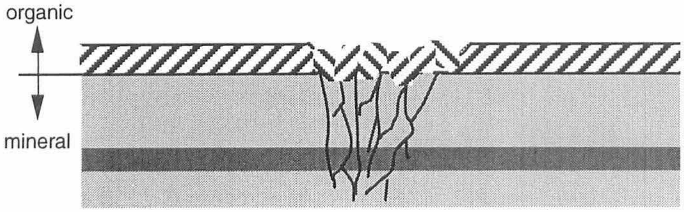


Caution: coarse mixing may encourage the resprouting of noncrop vegetation.

Examples of equipment: agricultural-type discs (e.g., Rome, Crabe), bedding plows (e.g., Eden, Rome), and rotary mixers (e.g., Madge Rotoclear).

Subsoiling

Subsoiling is fracturing of the mineral soil's structure without the mixing of horizons. It may be the first stage of a two-step site preparation process in which the second stage would result in plantable or seedable microsites.



Examples of equipment: ripper teeth or a winged subsoiler.

Microsite Requirements of Crop Trees, by Site Preparation Category

The microsite requirements for planting and seeding the four major coniferous crop trees in northwestern Ontario are summarized in a series of profile diagrams of the machine microsite categories. Summary notes indicate recommended and nonrecommended locations on a profile for regeneration by seeding or planting. The notes summarize relevant literature as well as experience-based opinion solicited from company and government silvicultural representatives from across northwestern Ontario. Only the equipment cross-sectional profiles most commonly produced in northwestern Ontario (i.e., screefing, inverting, and trenching) are displayed.

The purpose of this section is to assist the user in prescribing biologically appropriate mechanical site preparation under a variety of site and soil conditions. It assumes that the tree species and method of regeneration have been chosen and that the soil texture, moisture regime, and landform features that dominate the site are known.

In each diagram, numbered locations represent acceptable planting or seeding positions, whereas numbered locations with a ¤ background represent locations that are not recommended. The Ⓛ, Ⓕ , Ⓗ and designations refer to the litter, fermentation, and humus layers, respectively.

Note: The interval between mechanical site preparation and seeding or planting of crop trees has important implications for the success of the regeneration effort. Microsites can either degrade over time or mature and be improved after a period of settling or weathering. Revegetation of mineral soil microsites, for example, can negatively affect seedling survival, and the vegetation can often compete with the crop tree for resources such as moisture and nutrients. Periods of settlement can have beneficial effects on ensuring the continuity of soil moisture supply, for example, on mounded microsites. Microsite aging prior to regeneration is dependent on several variables (e.g., microsite size, soil parameters, and crop tree species). Documentation to support this subject area is incomplete, and, as a result, no recommendations are provided in this guide.

Jack pine or black spruce (planting) — Deep sands – dry to fresh

Sample tools: Drag units consisting of light barrels, tractor pads, or anchor chains; light disc or cone trenching with limited penetration and minimized soil exposure in frozen soils; spot scalping (e.g., Bräcke) or boot screefing.

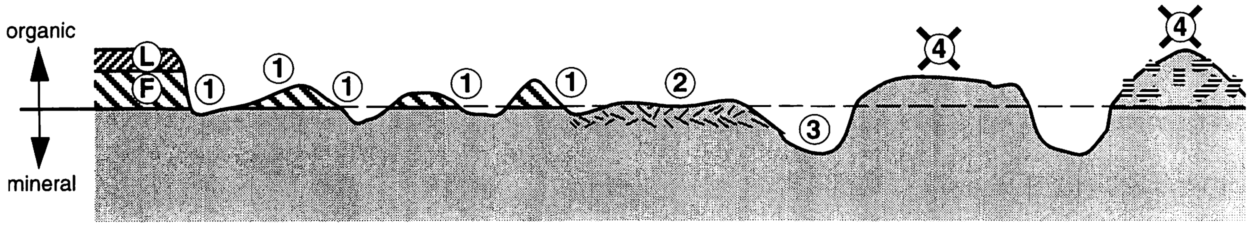
① Planting position should be in mineral soil but close to nutrient-rich organic material. Minimize the area and depth of exposed mineral soil, particularly on outwash sands, gravel, and eolian sands of low nutrient status. Plant no higher than the original mineral/organic interface.

② Mixed mineral/organic microsites are also desirable because they preserve the soil's nutrient status.

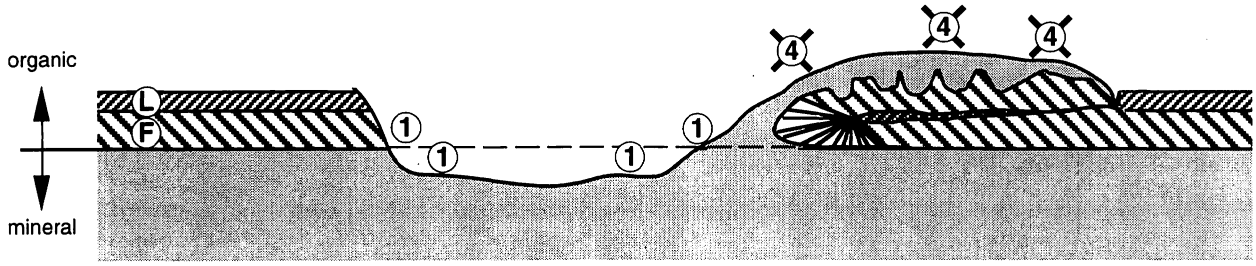
③ Plant in depressions, if well drained and if excessive sedimentation does not pose a problem.

④ Don't plant on mounded mineral soil or loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

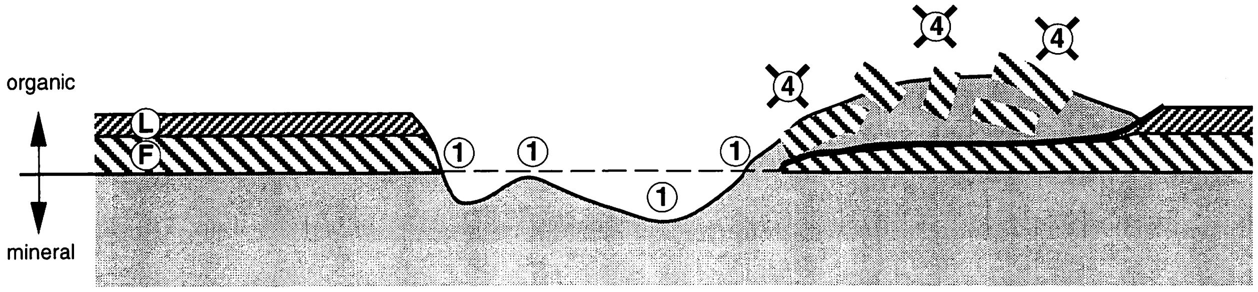
Screefing



Inverting (scalping)



Trenching



Jack pine or black spruce (planting) — Deep sands and coarse loams – moist

Sample tools: Barrel drags (heavy or light, with or without anchor chains and/or tractor pads, depending on surface conditions), disc or cone trenchers, spot scalping (e.g., Bräcke), blades, Young's teeth and plows. For inverting and trenching equipment, slopes may be prone to erosion.

① Plant close to the mineral/organic interface.

② Plant on mixed mineral/organic microsites.

③ Plant on mounded mineral soil on a firm mineral soil base.

④ Plant on the scalp/trench area, level with or slightly below the mineral/organic interface. Competing vegetation from the sides may favor the hinge area.

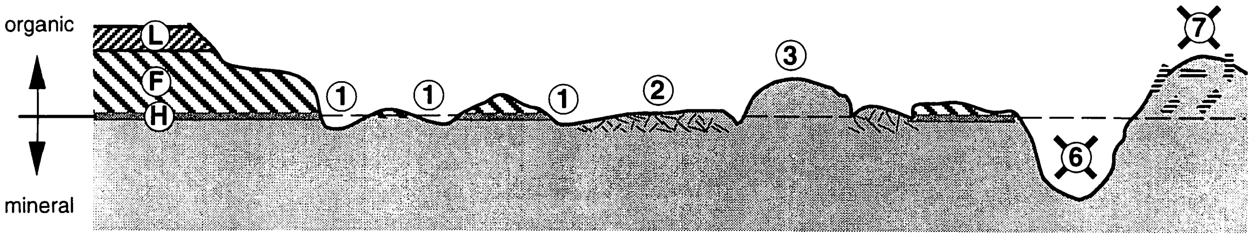
⑤ Plant on mounded mineral soil over inverted organic matter if the rooting zone isn't prone to desiccation.

⑥ Don't plant in depressions (areas with microrelief >10 cm below the mineral/organic interface); cold air often ponds here, subjecting seedlings to low soil temperatures, frosting or frost heaving, and flooding.

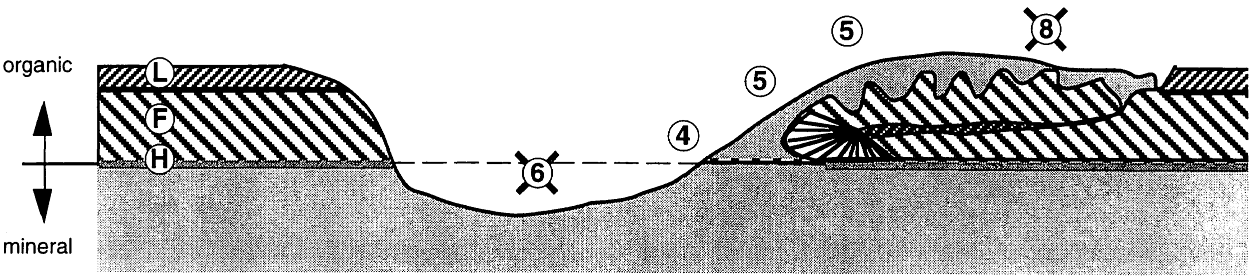
⑦ Don't plant on loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

⑧ Don't plant on an inverted organic layer with no mineral cap.

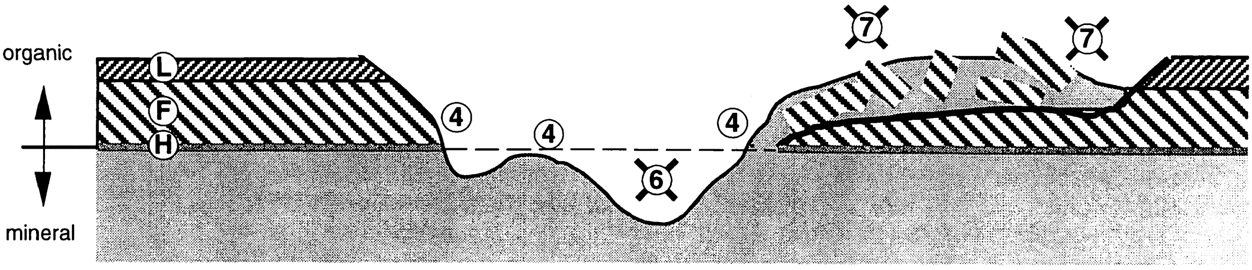
Screefing



Inverting (scalping)



Trenching



Jack pine or black spruce (planting) Silts and clays

Sample tools: Barrel drags (heavy or light, with or without anchor chains and/or tractor pads, depending on surface conditions), spot scalping (e.g., Bräcke) and disc or cone trenchers, blades, plows, and Young's teeth at a shallow setting.

① Plant close to the mineral/organic interface. Minimize mineral soil exposure on clays to reduce the incidence of soil baking and frost heaving and to prevent increased competition from annual and perennial plants.

② Plant on mixed mineral/organic microsites if the mixing is sufficient to reduce the risk of frost damage and to inhibit vegetative resprouting.

③ Plant on mounded mineral soil on a firm mineral soil base.

④ Plant in the scalp/trench area, level with or slightly below the mineral/organic interface. Encroachment of competing vegetation from the sides may favor planting on the hinge area.

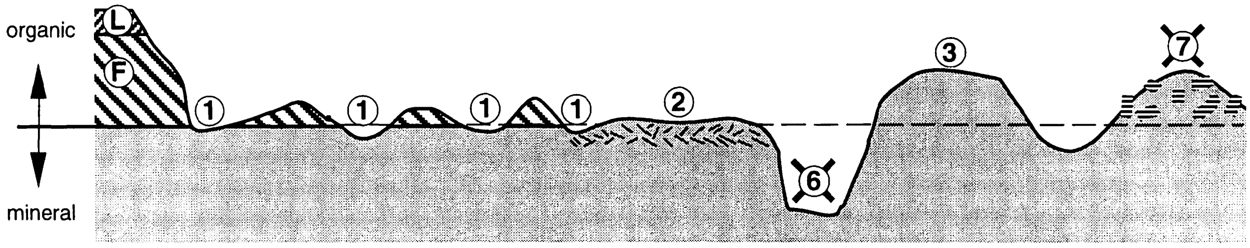
⑤ Plant on mounded mineral soil over inverted organic matter if the rooting zone isn't prone to desiccation.

⑥ Don't plant in depressions (areas with microrelief >10 cm below the mineral/organic interface); cold air often ponds here, subjecting seedlings to low soil temperatures, frosting or frost heaving, and flooding.

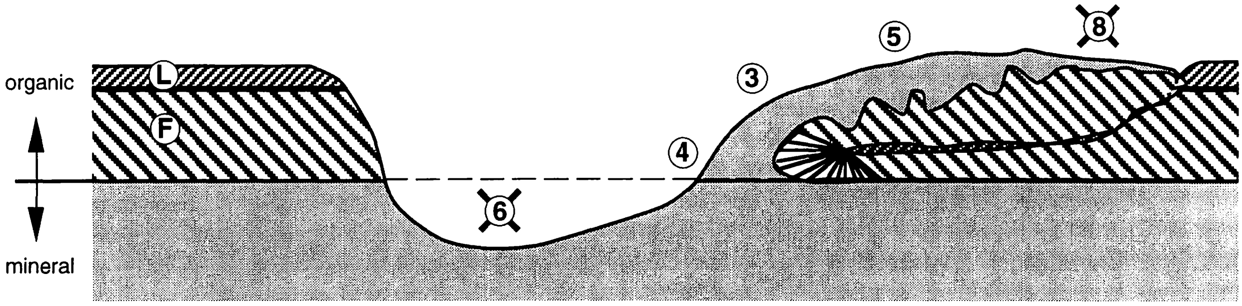
⑦ Don't plant on loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

⑧ Don't plant on an inverted organic layer with no mineral soil cap.

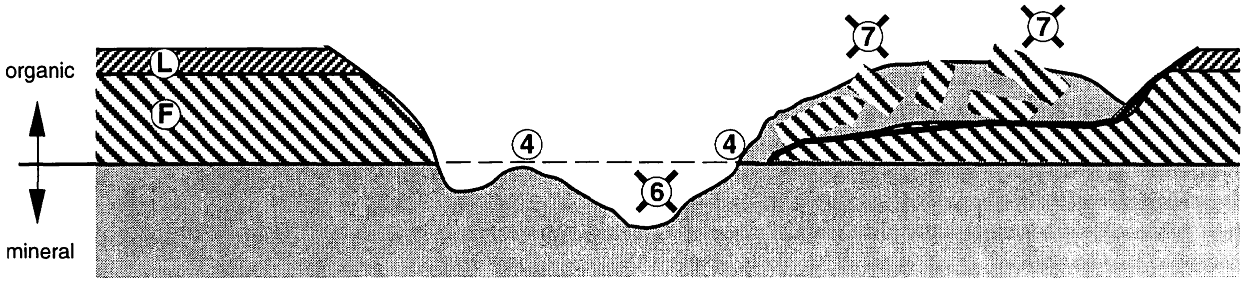
Screefing



Inverting (scalping)



Trenching



Jack pine (seeding) — Deep sands – dry to fresh

Sample tools: Drag units consisting of light barrels, tractor pads, or anchor chains; light disc or cone trenching or spot scalping (e.g., Bräcke). Inverting and trenching equipment should be adjusted to the shallowest setting.

① Seed on exposed mineral soil with a firm base. On upland sites with shallow, raw humus, deep mineral profiles, and a soil moisture regime <3, the best seedbed is alternating exposed mineral soil and thin residual humus in approximately similar areal distribution.

② Seed on a thin (<1.5 cm) mix of FH and mineral horizons that readily forms a firm base.

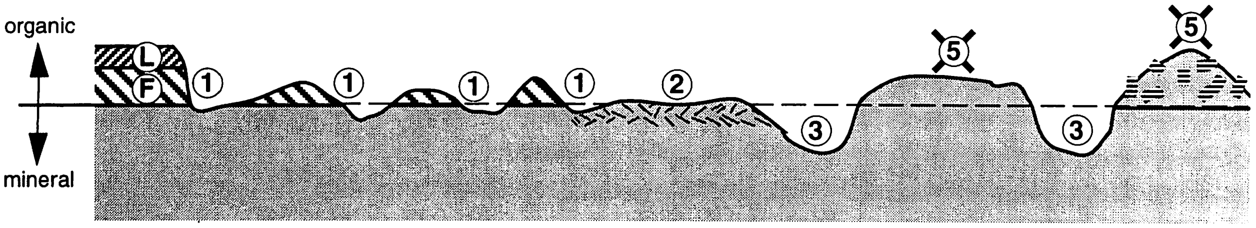
③ Seed in depressions, if well drained and if excessive sedimentation does not pose a problem.

④ Seed anywhere in the scalp/trench but no higher than the original mineral/organic interface. Avoid slopes prone to erosion.

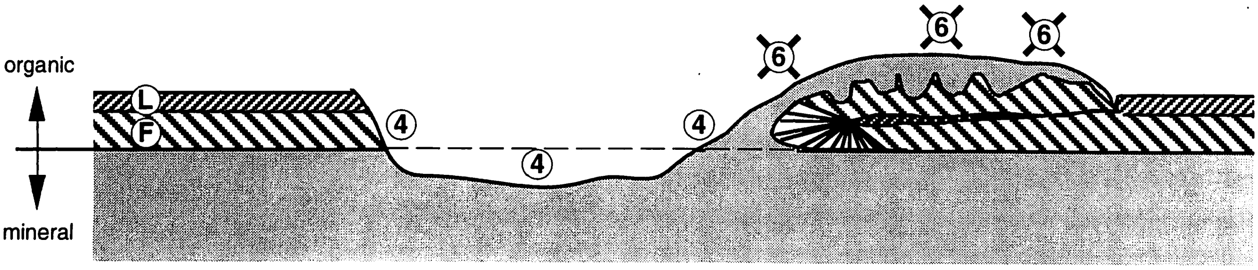
⑤ Don't seed on mounded mineral soil or loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

⑥ Microsites above the mineral/organic interface, including those on the inverted organic material, are subject to desiccation.

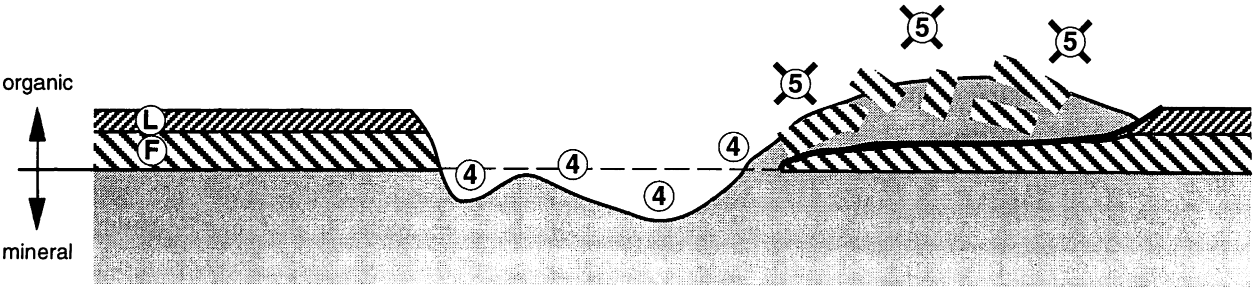
Screefing



Inverting (scalping)



Trenching



Jack pine (seeding) — Deep sands and coarse or fine loams – moist

Sample tools: Barrel drags (heavy or light, with or without anchor chains and/or tractor pads, depending on surface conditions), disc or cone trenchers, spot scalping (e.g., Bräcke), blades, Young's teeth, and plows. Slopes may erode after treatment with inverting or trenching equipment.

Note: The best seedbed is alternating mineral soil and thin residual humus in approximately similar areal distribution.

① Seed on F material (loose moss or litter removed) on deep soils with a high water table, moisture regime >4, and a deep, raw humus or lowland peat.

② Seed on exposed mineral soil with a firm base.

③ Seeding on moderately thick (1.5–3 cm) FH material on a firm mineral soil base is marginal.

④ Seed on thin (<1.5 cm) FH/mineral soil mixtures that readily form a firm base.

⑤ Seeding on moderately thick (1.5–3 cm) FH/mineral soil mix that readily forms a firm base is marginal.

⑥ Mounded mineral soil on a firm mineral soil base provides a marginal seedbed.

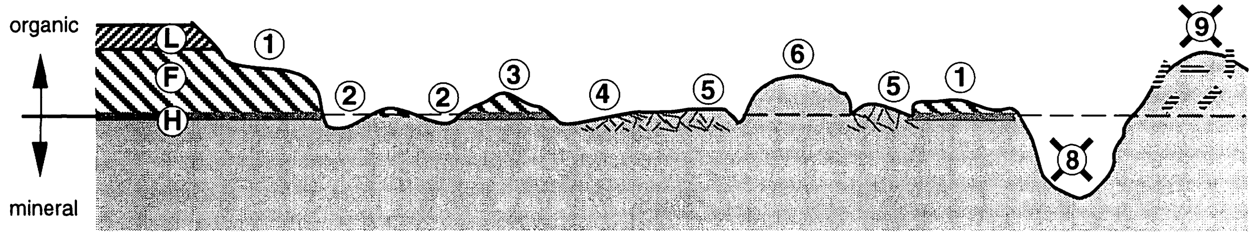
⑦ Seed in the scalp/trench area level with or slightly below the mineral/organic interface.

⑧ Don't seed in depressions (areas with microrelief >10 cm below the mineral/organic interface); cold air often ponds here, subjecting seedlings to low soil temperatures, frosting or frost heaving, and flooding.

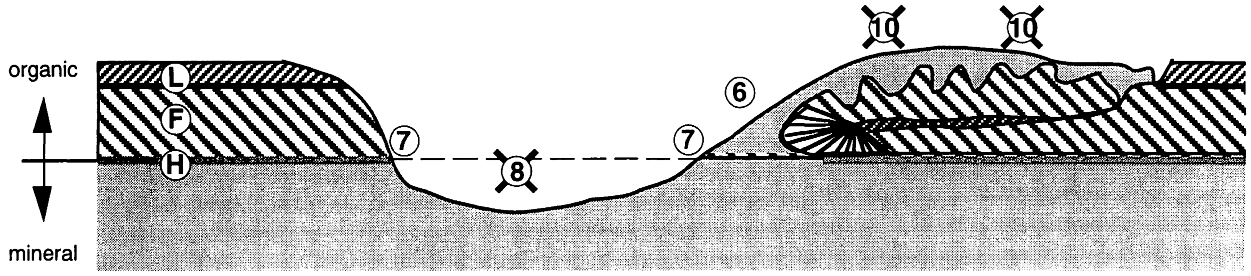
⑨ Don't seed on loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

⑩ Don't seed anywhere on thin soil over the inverted organic layer, which is prone to desiccation.

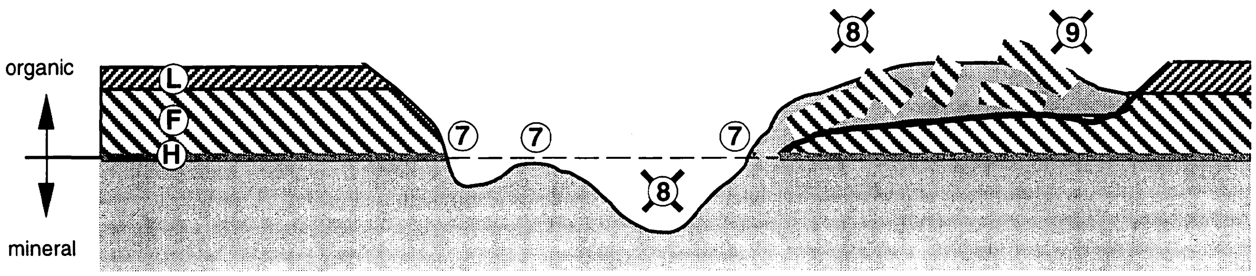
Screefing



Inverting (scalping)



Trenching



Jack pine or black spruce (seeding or planting) — Shallow soils < 100 cm

Sample tools: Barrel drags (heavy or light, with or without anchor chains and/or tractor pads, depending on surface conditions), shallow disc or cone trenching, or spot scalping (e.g., Bräcke). In cobbly or stony soils, treatments may have to be heavier (e.g., heavy drags or a disc trencher set with a more aggressive disc angle or more downward pressure) to achieve suitable results. Slopes may erode after treatment with inverting or trenching equipment.

Note: Seedbed requirements are similar to those for screefing on moist, deep sands and coarse and fine loamy sands for jack pine and black spruce. Very shallow soils and boulder pavements (including complexes of SS1–SS4 with deeper soils) frequently are dry to moist (0–5) and very rapidly to imperfectly drained. Moist, imperfectly-drained soils occur in depressions in the bedrock, sometimes frequently, which hold runoff. Should these sensitive complexes require regeneration, direct seeding of jack pine may, with variable success, be the only cost effective regeneration method available for some sites with very shallow soils.

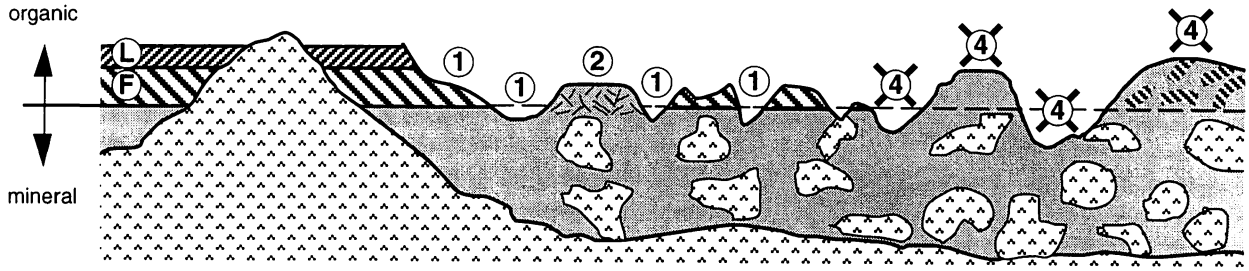
① Plant close to the mineral/organic interface. In soils with excessive bedrock outcrops or many surface boulders, where planting opportunities may be rare, planting deeper into the B horizon may be justified.

② A thin organic layer mixed with an underlying mineral soil, which conserves moisture and nutrients, is the microsite of preference for seeding or planting.

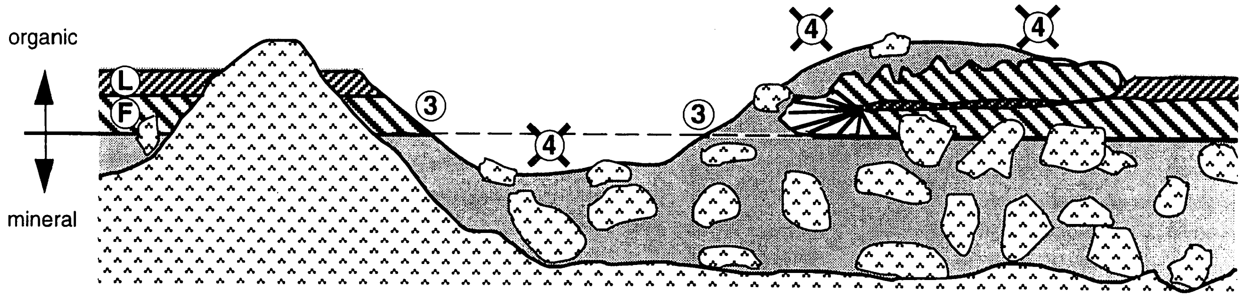
③ Seed or plant in the scalp/trench area, level with or slightly below the mineral/organic interface. Encroachment of vegetative competition from the sides may favor planting in the hinge area.

④ Soil moisture can be highly variable in shallow soils, depending on microrelief and time of year. Water ponding can occur in depressions, and moisture deficits can occur on berms.

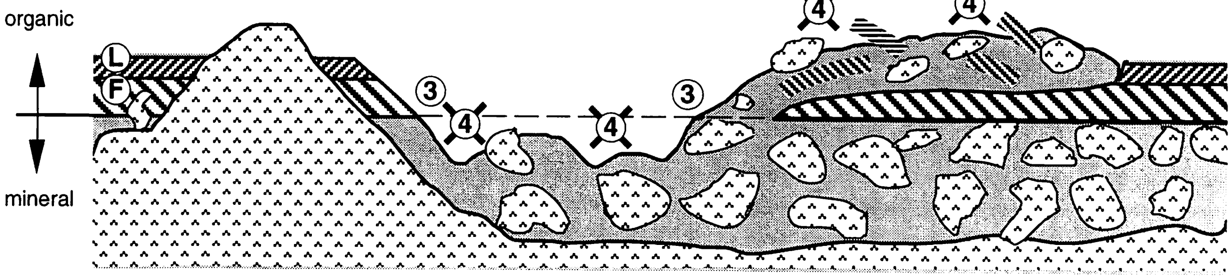
Screefing



Inverting (scalping)



Trenching



Black spruce (seeding or planting) Deep sands and coarse or fine loams – moist – seeding

Sample tools: Barrel drags (heavy or light, with or without anchor chains and/or tractor pads, depending on surface conditions), disc or cone trenchers, spot scalping (e.g., Bräcke), Young's teeth, blades, and plows. Slopes may erode after treatment with inverting or trenching equipment.

Note: For seeding, it is best to provide numerous microniches with small depressions, microhummocks, and hollows. Survival increases where slash and light vegetation cover provide partial shade to reduce evaporation and ameliorate seedbed temperature.

① Seed 5 cm above to 10 cm below the mineral/organic interface. This includes the H, Hi, Ah, F, Ae, and upper B horizons or any mixture thereof and pioneer mosses (e.g., *Polytrichum, Pohlia, Ceratadon*).

② Seeding on moist sites, F and H horizons <5 cm above the mineral/organic interface, gives the best results.

③ Seeding on drier sites, mineral soil <10 cm below the mineral/organic interface, gives the best results.

④ Seed in the scalp/trench area, level with or slightly below the mineral/organic interface.

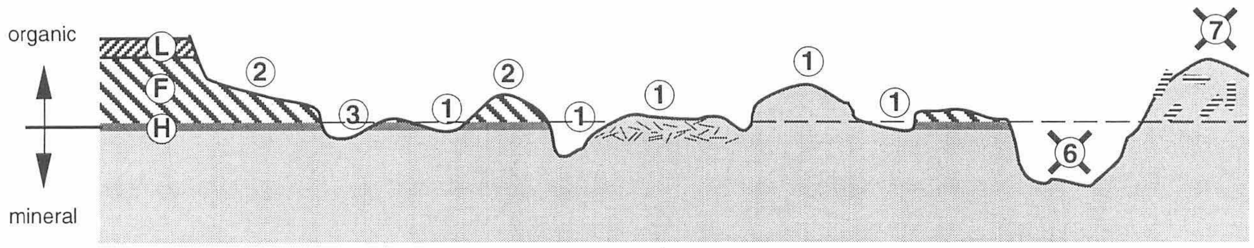
⑤ Seed on mounded mineral soil on a firm mineral soil base on moist soils.

⑥ Don't seed in depressions (areas with microrelief >10 cm below the mineral/organic interface); cold air often ponds here, subjecting seedlings to low soil temperatures, frosting or frost heaving, and flooding.

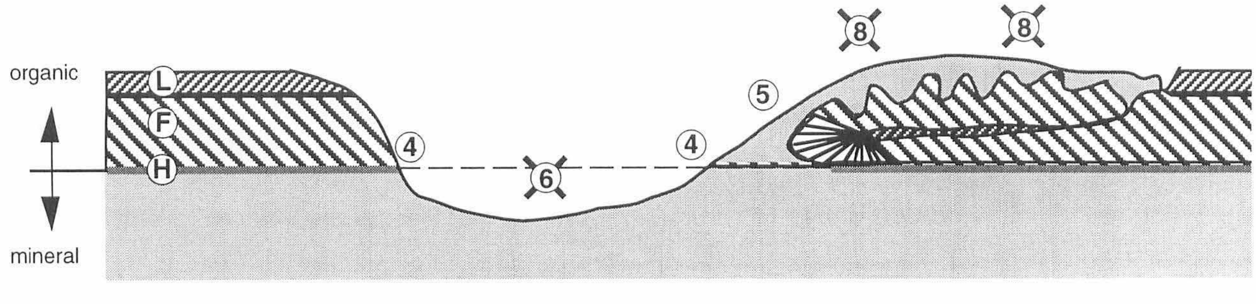
⑦ Don't seed on loose coarse mixtures of mineral and organic material, logging debris, or loose uncompacted feathermoss, prone to desiccation.

⑧ Don't seed anywhere on thin soil over the inverted organic layer, which is prone to desiccation.

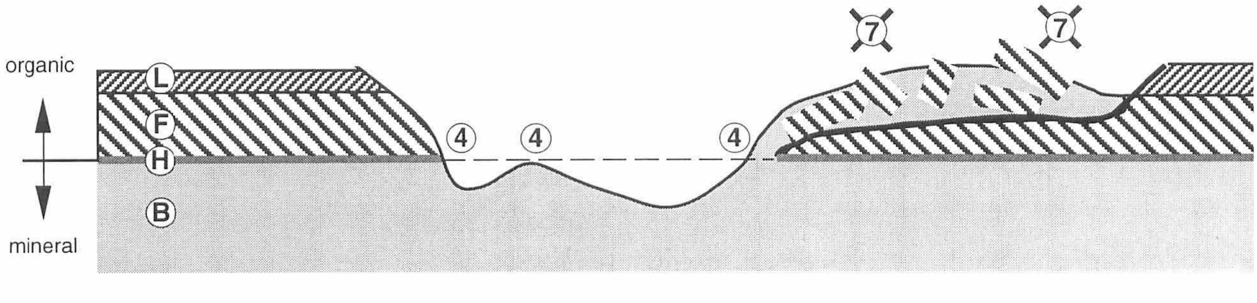
Screefing



Inverting (scalping)



Trenching



Black spruce (seeding or planting) Lowlands (organic soils – wet) – seeding or planting

Sample tools: Shearblading (e.g., Rome, Fleco and Superior V-blade).

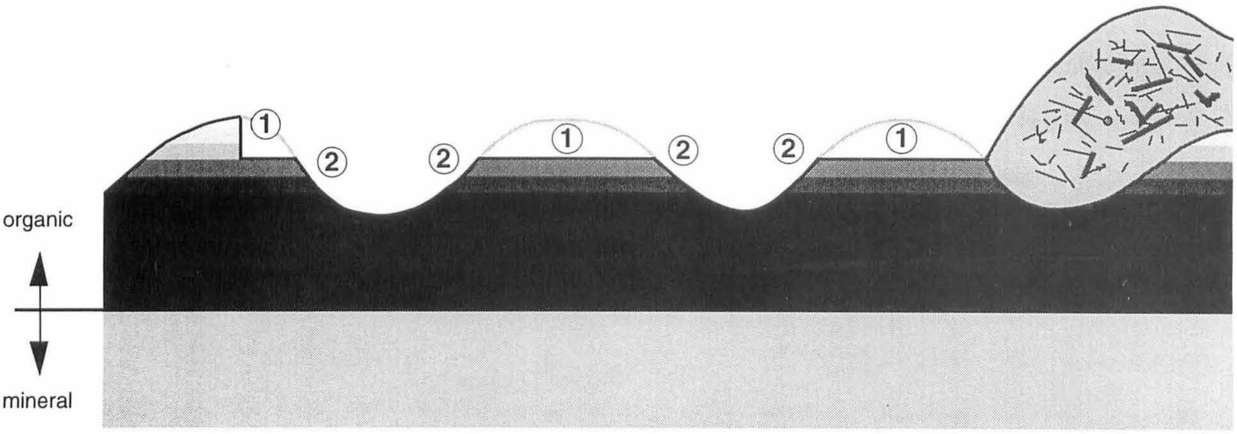
Note: Shearblading is not recommended when the water level is close to the surface or when the existing numbers of advanced conifer regeneration are adequate. Optimum results from shearblading are obtained when the ground is frozen. Om and Oh horizons are generally marginal to poor seedbeds as a result of vegetative condition, frost heave potential and spring flooding. Mineral soil is a poor planting microsite because of its potential for frost heaving or flooding.

① The goal is to shear off the tops of *Sphagnum* hummocks and remove slash, but not to expose the deeper Om or Oh horizons.

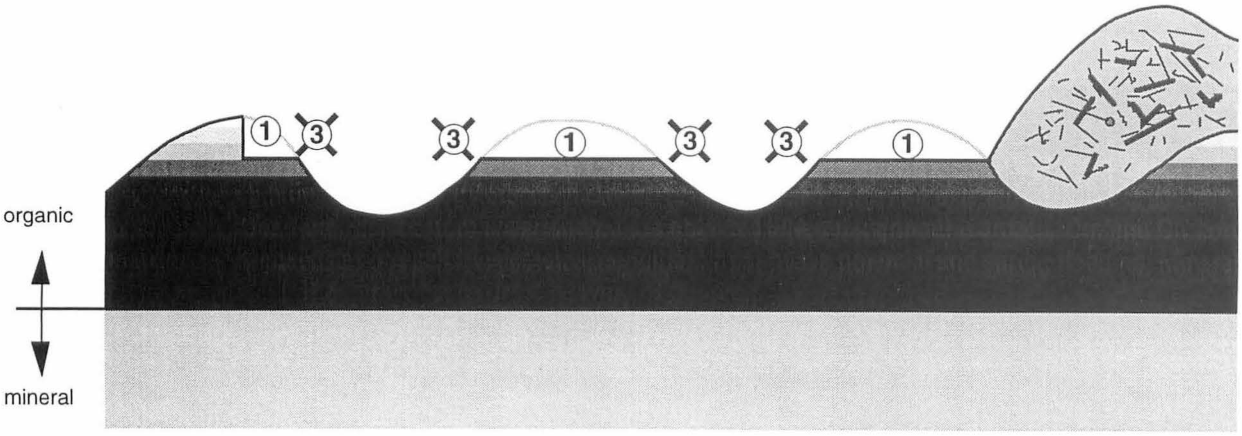
② Black spruce should be planted in feathermoss, live *Sphagnum* or partly decomposed *Sphagnum* peat.

③ Feathermoss is a poor seedbed because of its poor water retention and transfer capacities.

Shearblading: Planting



Shearblading: Seeding



Red pine (seeding or planting) — Deep, coarse sands – dry to fresh

Sample tools: Drag units consisting of barrels, tractor pads, or anchor chains, blades, disc or cone trenchers, and spot scalping (e.g., Bräcke). In cobbly or stony soils, treatments may have to be heavier (e.g., heavy drags or a disc trencher set with a more aggressive disc angle or more downward pressure) in order to achieve suitable results. Slopes may erode after treatment with inverting or trenching equipment.

① Site preparation should remove thick, insulating LFH layers and competing vegetation. Avoid severe disturbance of the mineral soil.

② The best germination conditions for seeds consist of partial shade, light vegetation cover, and litter, with some exposed mineral soil or *Polytrichum* moss. After germination, the best initial growth occurs without competing vegetation.

③ Effective mixing of the humus and the upper mineral soil layers can create a warm, moist, and protected seedbed.

④ Plant or seed in the scalp/trench area, level with or slightly below the mineral/organic interface. Encroachment of competing vegetation from the sides may favor the hinge area.

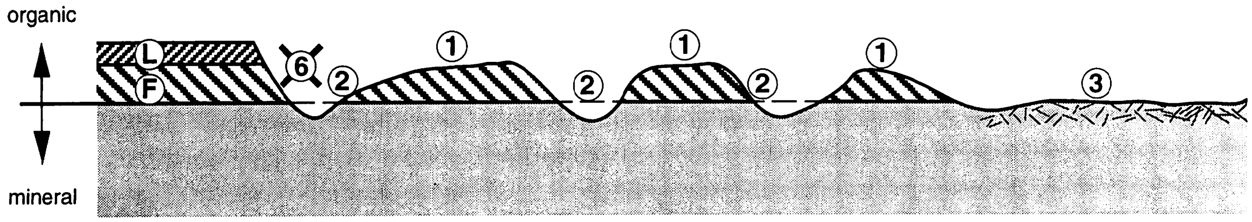
⑤ Plant at the bottom of the scalp/trench, if excessive sedimentation does not pose a problem.

⑥ Don't plant immediately adjacent to encroaching vegetation.

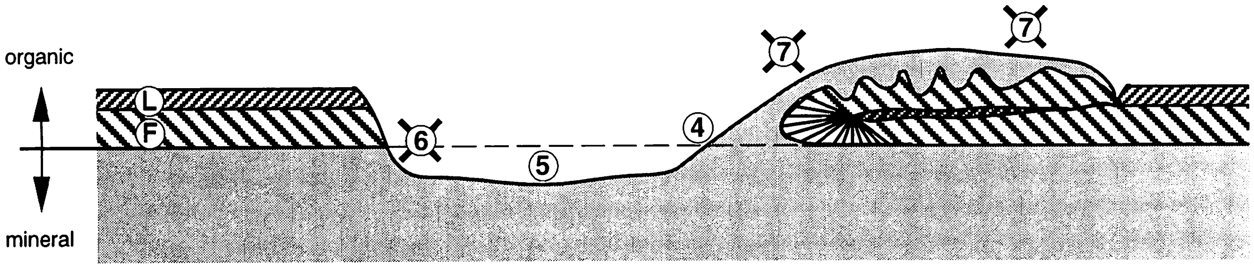
⑦ Don't plant or seed anywhere above the mineral/organic interface, where periodic desiccation may occur.

⑧ Don't seed on loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

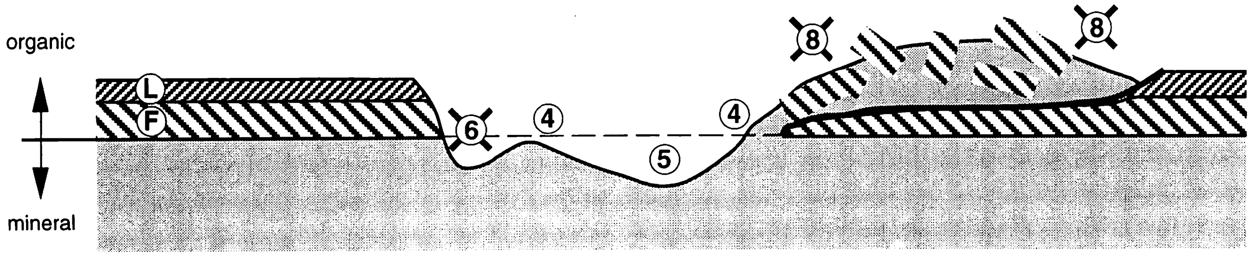
Screefing



Inverting (scalping)



Trenching



White spruce (planting) Coarse loams and fine silts – fresh to moist

Sample tools: Blades, Young's teeth, or plows on a shallow setting; drag units of light barrels, tractor pads, or anchor chains, or light disc or cone trenching or spot scalping (e.g., Bräcke).

Note: On fine-textured soils, do not expose large expanses of bare mineral soils, for that would exacerbate problems of frost heaving, extremes of heat, soil baking, and intense competition from annual and perennial plants. Retention of intact organic or Ah horizons is desirable for seedling growth. Minimal ground disturbance from spot or intermittent site preparation treatments may help to minimize the increase in vegetative competition compared with continuous strip treatments.

① White spruce grows best when planted in mineral soil covered with a thin duff layer and surrounded by light brush competition. The goal is to reduce the organic layer thickness to <8 cm.

② Plant where effective mixing of organic materials with surface mineral soil is sufficient to reduce the likelihood of frost damage and to inhibit vegetative resprouting.

③ Plant on mounded mineral soil on a firm mineral soil base if frost heaving won't be a problem.

④ Plant seedlings in the scalp/trench area, level with or slightly below the mineral/organic interface. Encroachment of competing vegetation from the sides may favor the hinge area.

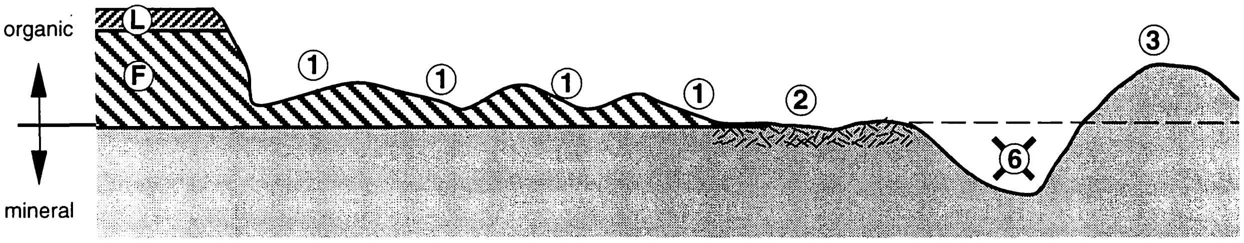
⑤ Plant seedlings on mounded mineral soil over an inverted organic substrate if the rooting zone isn't prone to desiccation.

⑥ Don't plant in depressions (areas with microrelief >10 cm below the mineral/organic interface); cold air often ponds here, subjecting seedlings to low soil temperatures, frosting or frost heaving, and flooding.

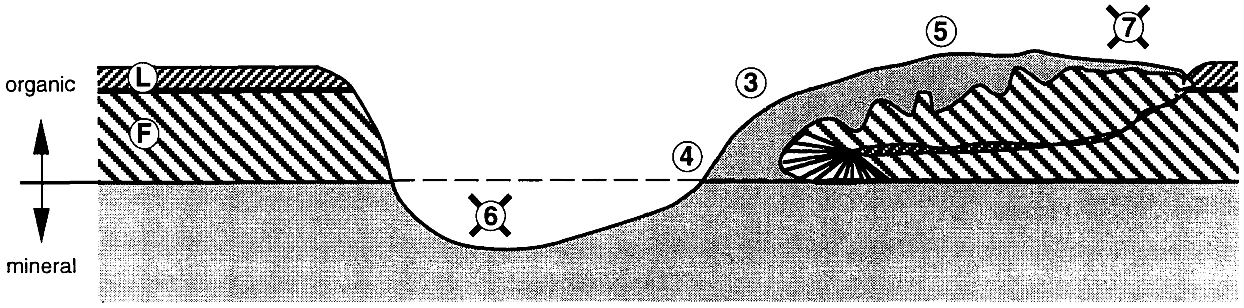
⑦ Don't plant on an inverted organic layer with no mineral soil cap.

⑧ Don't plant on loose coarse mixtures of mineral and organic material and logging debris prone to desiccation.

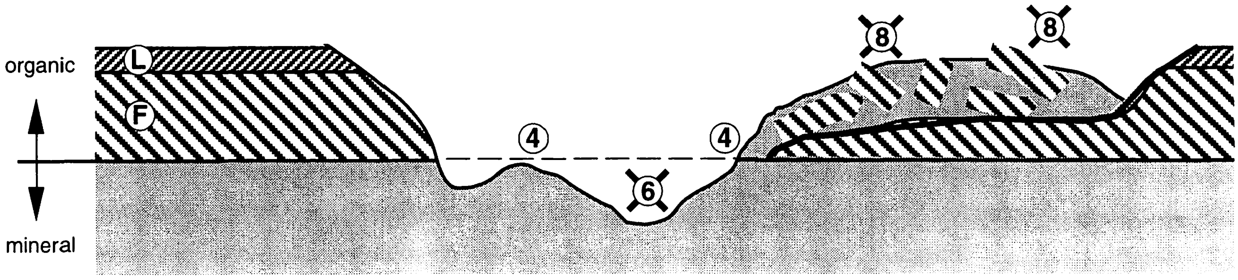
Screefing



Inverting (scalping)



Trenching



SECTION C: PHOTO-SERIES OF MECHANICAL SITE PREPARATION TREATMENTS IN NORTHWESTERN ONTARIO

Introduction

The process of selecting a particular site preparation method is not limited to the biological considerations described in this guide. In fact, nonbiological factors (e.g., economics or limitations to the use of certain site preparation methods) can have a significant impact on the final selection of ameliorative site preparation treatments. During 1990 and 1991, a series of 48 plots was established across northwestern Ontario to document representative examples of (i) current postharvest site conditions, and (ii) the quality and quantity of microsites produced by specific mechanical site preparation treatments on these sites. The pictorial and quantitative information collected from each plot is presented in plate sets.

The plots provide postharvest examples of 24 vegetation types (V-types) and 10 treatment units (TUs). The *Field guide to the forest ecosystem classification* [FEC] *for northwestern Ontario* (Sims et al. 1989) contains 38 V-types that have been grouped into 11 treatment units (Racey et al. 1989). Readers interested in comparing by V-type the typical preharvest site conditions with the postharvest and subsequent post–site preparation conditions presented herein are referred to *A photo-series for assessing fuels in natural forest stands in northern Ontario* (Stocks et al. 1990).

The site preparation implements included in the sample were a straight dozer blade, Young's utility dozer teeth, the Cazes and Heppner plow, three configurations of the Bräcke patch scarifier, three drag configurations (light, medium, and heavy), four disc trenchers (Donaren 180, TTS–35, TTS Delta [passive], TTS Delta [power]), and the Silva Wadell powered cone scarifier.

Site selection

The overall sampling strategy was to sample a variety of site conditions in stands scheduled for normal operational treatment by a variety of implements commonly used in northwestern Ontario. Sampling intensity was at least one plot in each treatment unit in which site preparation normally occurs. Of the 48 plots established, 24 of the 38 V-types and 10 of the 11 treatment units were sampled. Treatment Unit K (V-type 38) sites are generally unmerchantable and therefore not harvested. Some treatment units contain subunits called phases (Racey et al. 1989), not all of which were sampled. One example of a Treatment Unit A V-type exists among the 48 plots (plate set 1). Because this V-type (V-1) is very close in relative position to several V-types in Treatment Unit D in the ordination diagram (Racey et al. 1989), Treatment Units A and D were combined. Likewise, Treatment Units B and C were combined owing to the relative similarity between V-4 and several V-types in Treatment Unit B.

The plots were distributed across northwestern Ontario (Figure 2) in the vicinity of Red Lake (6), Sioux Lookout (3), Kenora (3), Fort Frances (3), Dryden (6), Atikokan (7), Graham (1), Thunder Bay (3), Nipigon (6), Manitouwadge (4), and Geraldton (6).

Sampling methodology

On-site plot location

Once a postharvest cut block was located, an assessment plot consisting of one equilateral triangle, 30 m to the side, was established at a position considered representative of the predominant site condition in the cut block. Representativeness was defined in terms of the predominant FEC V-type and topographical features present. Transitional vegetation, soils, and topography were avoided whenever possible, as were situations that might require excessive maneuvering of equipment in the plot (e.g., edges of cut blocks, end of an equipment pass, or a major insurmountable obstacle). Late in the field project, plots were selected based on the need to sample certain V-type and implement combinations, even though the V-type may not have been predominant on the site. The final plot selection had to meet the criterion that the site preparation treatment was a normally accepted prescription for this condition.

Photography

Following a modified version of the procedures used in the *Forest managers photo guide to prescribed burn planning* (Wearn et al. 1982), three photos were taken at each plot. A postharvest, pretreatment photo was taken from each apex of the triangle facing the center of the opposite side of the triangle. To provide scale, a range pole was located precisely 10 m from the apex (camera position) on the line of sight between the apex and the center of the opposite side. The range pole is 2 m high, with the lower metre painted white alternating with red in 20-cm segments, whereas the upper metre consists of white and red 50-cm segments. Following treatment, the apex that presented the better view of site preparation results was selected and the scene of the pretreatment photograph rephotographed. Thus, both of these photos framed the same view — namely, a landscape shot centered on and encompassing the triangle and including the cut boundary against a distant horizon. A third photo consisted of an oblique shot framing a close-up of the average site-prepared microsite condition. To give scale to the microsite shot, a 1-m scale painted white and red in 20-cm segments was placed normal to the line of sight and 5 m from the camera position. All photographs were taken in a standardized fashion. Variations in lighting conditions, time of year, and stage of leaf development confounded this process to some degree for photo results both within and between plots.

Pretreatment assessment

Factors such as residual trees, slope, and ground roughness (stumps, stones, boulders, rock outcrops, both natural and human-made mounds and depressions) that may affect operation of the equipment within each plot were quantified using the methods of the *Standard assessment procedures for evaluating silviculture equipment* (Sutherland 1986). Downed woody residue was quantified using the line intersect method (McRae et al. 1979) along the plot (an equilateral triangle) boundaries,

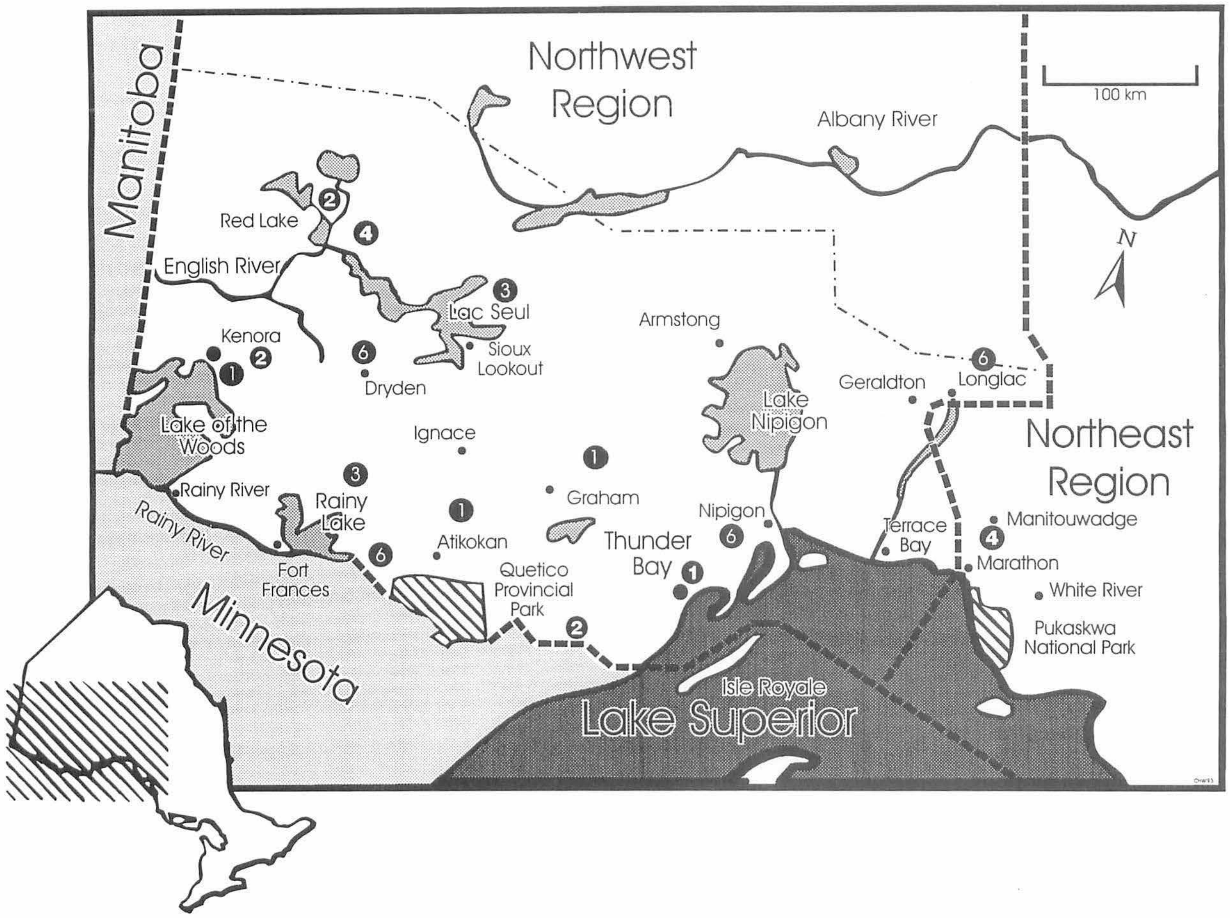


Figure 2. Approximate location of 48 plots in northwestern Ontario.

which were divided into 5-m segments. Topographical features (Bélise 1980) such as slopes, rock outcrops, and boulders for both the plot and vicinity (a plot-centered area of about 4 ha) were estimated. Landform (i.e., origin of soil) (Sims and Baldwin 1991) for both the plot and vicinity were noted. At each apex of the triangle, the FEC soil type and specific parameters affecting site preparation (litter, fermentation, humus, and mineral soil depths; surface mineral soil texture and stoniness, coarse fragments, drainage, and moisture regime) were determined (Sims et al. 1989). When soil parameter values varied too much among the apexes of a triangle, further sampling was done to determine the more common values for the plot.

Three subplots (113-cm radius) to assess woody and herbaceous vegetation were located at the centers of each side of the triangle. Occasionally it was necessary to supplement subplot data with an overview survey of the plot surface to obtain representative information (e.g., a clump of *Corylus cornuta*). Because of both date of assessment and time elapsed since harvest, vegetation development varied between plots. Thus, data collected may understate both the diversity and abundance of both species currently recognized as conifer crop tree competitors (Bell 1991) and other vegetation. Because of this concern, only the number of competitor species noted is presented as an indication of site vegetation diversity.

The plot FEC V-type was determined on-site using both the keys provided by Sims et al. (1989) and the data collected. Because these plots were in harvested areas, it was necessary to substitute relative proportion (%) of species stump basal area in the plot for species crown cover composition when entering the keys. Final V-type determination was a subjective judgment based on the data as recorded in field notes, the keys, and the V-type fact sheets (Sims et al. 1989).

Because harvesting and subsequent site preparation activities often occur within cut blocks made up of Forest Resources Inventory (FRI) stands, it was necessary to note (any) other associated V-types that form the mosaic of a single FRI stand. Other V-types in the sampled cut block were determined subjectively after an extensive walk-about in the cut block.

The vegetation (and biological) community is dynamic (cf. Elliot et al. 1993), and, for some of the plots presented (e.g., plate set 19), a transition in V-type may be occurring.

Posttreatment assessment

Using the methods of the *Standard assessment procedures for evaluating silviculture equipment* (Sutherland 1986), each plot was evaluated for the quantity, distribution, and quality of plantable and/or seedable microsites plus other disturbance created by the implement, the prime mover, or the harvesting process. Fifty 2-m^2 quadrats in a grid pattern, at right angles to machine travel, were evaluated for microsite disturbance in each plot. Approximately 50 2-m-long furrow segments were evaluated over the same area to determine the proportion (%) of furrow length that was mineral soil ≥15 cm wide, the proportion (%) of furrow length that was rock and/or water, and, depending on the implement used, between-furrow or between-planting-row spacing. The use of the term furrow will include row, as in the case of intermittent site preparation equipment (e.g., Bräcke). Finally, the availability and quality of plantable spots were assessed along the furrows or rows made by the site preparation implement in the plot. The criterion for acceptable planting spots was taken from *A guide for contract tree planting* (Ontario Ministry of Natural Resources 1987). At least 50 attempts at planting using a planting spade were assessed per plot with a normal spacing of 2.0 m ± 0.5 m. In the case of failure (i.e., an unacceptable planting spot), beginning at 1.5 m from the last acceptable planting spot, the next acceptable planting spot was sought. Reasons for unacceptable planting attempts were recorded for the normal interval of 2.0 m ± 0.5 m. The in-furrow or in-row spacing between acceptable planting spots was also recorded.

Layout of the photo-series plate sets

General

The plot photos and information (summarized data) are presented in plate sets. Each set contains plate A, presenting the postharvest pretreatment photo and information, and a facing plate B, presenting the two posttreatment photographs, site preparation product information, and a summary text. The plate sets have been arranged by FEC treatment unit and within each treatment unit by decreasing numbers of acceptable planting spots achieved per hectare. Each treatment unit plate set has a lead-in write-up, summarized from Racey et al. (1989), describing vegetation and soil properties, equipment trafficability, and silvicultural recommendations that relate to mechanical site preparation for that treatment unit. Completing each write-up is a summary that reflects observed trends and recommendations derived from the plot information collected. Caution is advised when comparing plots within treatment units. The number of plots within each treatment unit is not indicative of the relative occurrence of that condition within the treatment unit. As stated previously under Sampling methodology, plot locations were selected to sample a range of V-type and equipment combinations.

Terminology

A glossary that follows the plate sets includes terms associated with the FEC and the applied engineering art of site preparation. In addition, a list of the scientific and common names of all trees, shrubs, and herbs given in Section C and a compilation of common terminology (including abbreviations and symbols used in Section C) follow the plate sets.

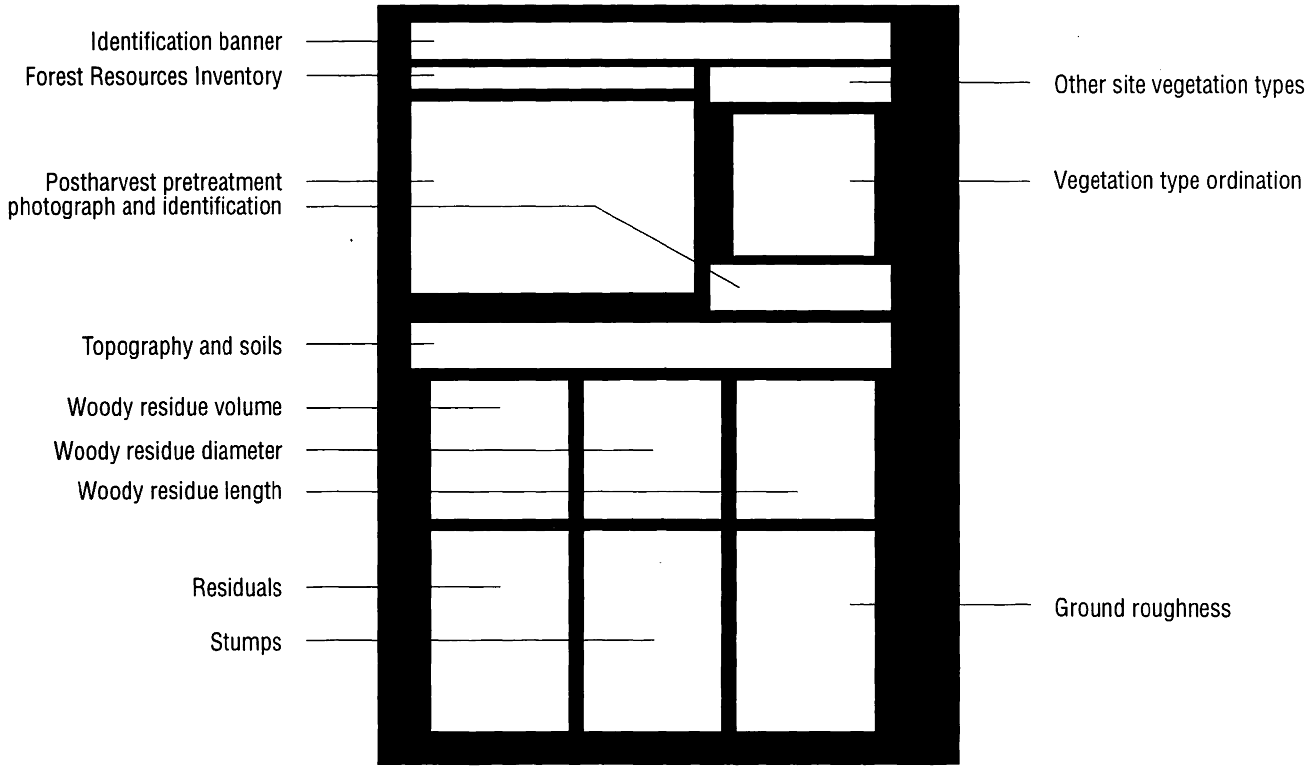
Identification banner **(Plate A)**

The sequence of information, beginning at the top left, presented in the banner for plate A is the plate identification followed by the FEC V-type and name as classified for conditions on the plot. Finally, in the right-hand corner, the FEC Soil Type numbers are listed for the soils as classified at the three corners of the plot triangle.

Forest Resources Inventory (FRI)

The FRI designation (from forest stand map) for the general area containing the plot is presented.

Plate A Layout



Other site vegetation types

If different from the plot, V-types on the surrounding cutover outside the plot are listed.

Vegetation type ordination

The position of the plot V-type relative to other FEC V-types is indicated on an ordination diagram.

Postharvest pretreatment photograph and identification

The date of photography, elapsed time from harvest, and harvesting system including major equipment used are given with the photograph.

Topography and soils

Following the guidelines established by the Ontario Institute of Pedology (1985), general topographical information for the cut block and soil information specific to the plot are provided. **Area topography** is the general slope class for the cut block including the plot. **Bedrock outcrops**, **boulders** (≥60 cm diameter), and **stones** (<60 cm diameter) are presented as a class description for the combined rating of percent area and spacing of exposed bedrock, boulders, and stones assessed on the plot and vicinity (a plot-centered area of about 4 ha). **Plot slopes** are the type of slopes and the range of slope readings along the plot triangle boundaries. **Plot slope position** is given relative to the general topography. **Landform** (Sims et al. 1991) is the dominant landform type within which the soils of the plot have developed. **Soil depth** and thickness of the **litter**, **fermentation**, and/or **humus** layers are presented as the maximum and minimum readings among all three plot corners. Predominant **soil texture** of the C horizon and **texture of surface mineral soil** horizon (0–10 cm) are presented. When textural classes differ between two or among three plot corners, both or all three are presented. Soil **coarse fragments** (>2 mm and <30 cm in diameter) are expressed as a volumetric percentage by visual estimation and presented by class (Sims et al. 1989) based on core samples from the three plot corners. Soil **drainage** and **moisture regime** are presented as a range of readings from all three plot corners.

Woody residue

Downed woody residue, assessed on the plot, has been summarized by way of a frequency distribution histogram of volume, diameter, and length classes. The frequency distribution by **volume** class is presented as a proportion of the perimeter bounding the plot. Inset are (1) average total volume (standard deviation), (2) the proportion of conifer and hardwood, and (3) the proportion of large (≥5 cm in diameter) and small (0.5–4.9 cm in diameter). The frequency distribution of woody residue by **diameter** class is presented as a piece count per 20 m of transect length. **Length** class is presented in a similar manner, but piece count has been converted from the actual tally of piece count intercepted along all three sides of the plot (triangle). As a result, a slightly overstated rating of piece count exists in cases where the same piece crossed two sides of the plot (triangle) and is tallied twice.

Residuals

A frequency distribution histogram of residual trees (stems/ha) remaining on the plot by species, diameter, and height class is presented.

Stumps

A frequency distribution histogram of stumps (no./ha) on the plot by species and diameter class is presented.

Ground roughness

A frequency distribution of ground roughness by three height classes (i.e., H20 = 10–30 cm, H40 = 31–50 cm, and H60 = 51–70 cm; Berg 1992) is presented in numbers of obstacles per hectare. Occasionally, obstacles belonging to H80 and H100 were encountered and are included with H60. In the upper histogram, each ground roughness height class has been subdivided into six types of obstacles that represent ground surface irregularity (i.e., berms and ruts, natural pits and mounds, stumps by three diameter classes produced during harvesting, and boulders). The lower histogram represents the sum total of five of the types. Stumps in the 5- to 11-cm-diameter class are excluded, as they are not considered an impediment to either the prime mover or the site preparation implements sampled in the study. In recording ground roughness for harvesting operations, the convention according to Berg (1992) and Mellgren (1980) is to combine the height and frequency distribution of obstacles to one overall class value. Pending development of a classification system for silviculture, it was felt that the increased sensitivity of site preparation equipment to ground roughness compared with harvesting equipment warranted inclusion of the components that make up ground roughness, including stumps.

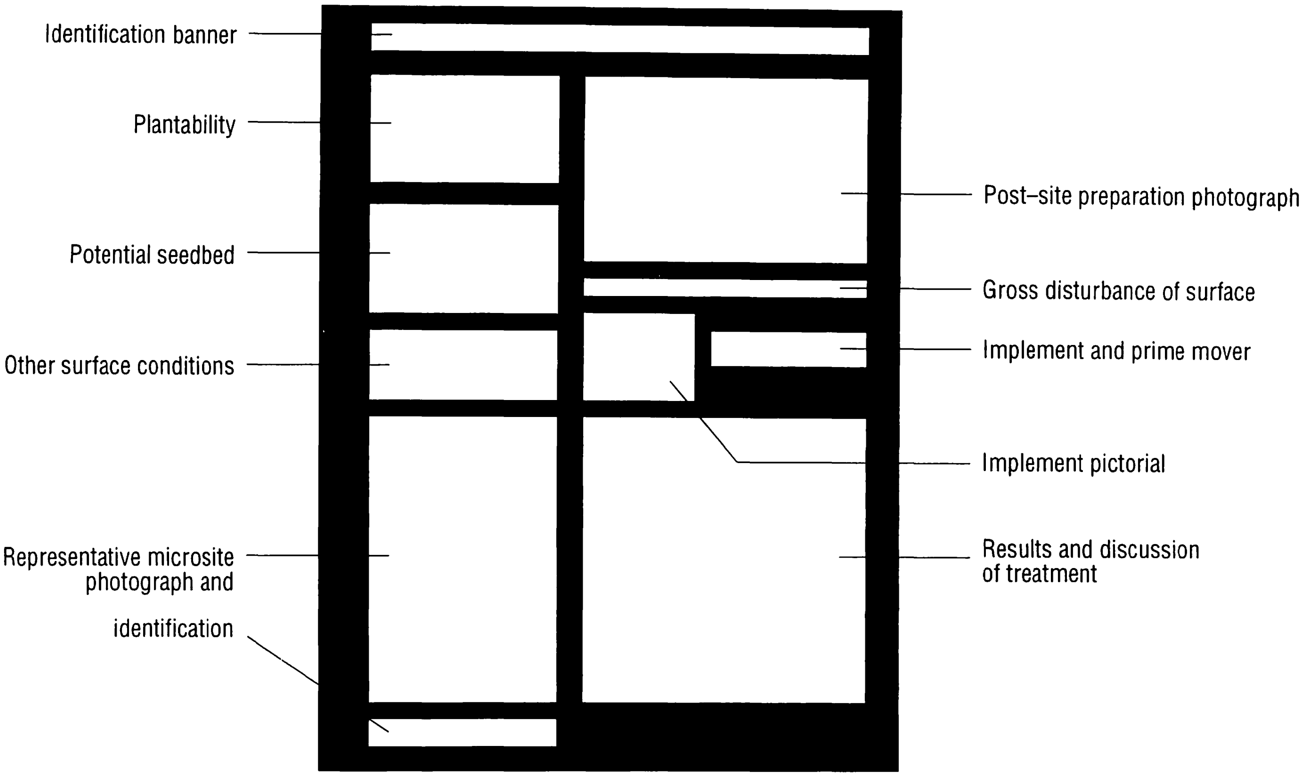
Identification banner **(Plate B)**

The sequence of information, beginning at the top left, presented in the banner for plate B begins with the treatment unit that contains the plot V-type. Following this (center of banner) is the microsite condition (Section B) assigned to the plot treatment. Finally, the plate identification number is located in the right-hand corner.

Plantability

Plantability is presented as a frequency distribution histogram by microdisturbance class of the number of planting spots per hectare. Color coding is used to group the classes into two categories: green signifies microdisturbance classes that are plantable without reservation, whereas yellow signifies microdisturbance classes that are plantable under certain conditions (e.g., favorable soil moisture). Listed across the top is the combined average number of planting spots per hectare, the average furrow spacing (between-furrow distance), and the average planting spot spacing (m) between plantable spots along the furrow. For furrow and planting spot spacing, the value in parentheses to the left of the mean is the sample size, whereas the number in parentheses to the right is the standard deviation.

Plate B Layout



Potential seedbed

Potential seedbed is presented as a frequency distribution histogram by microdisturbance class of the proportion (%) of the total surface area assessed. Actual values (standard deviation) are provided to the right of each bar of the histogram; for 45 of the plots presented, the sample size was 50; for the other 3 plots (plate sets 1, 44, and 46), the sample size was 100. As with plantability, color is used to group the classes into two categories: green for microdisturbance classes that represent good seedbed without reservation, and yellow for microdisturbance classes that represent good seedbed under certain conditions (e.g., favorable soil moisture).

Post-site preparation photograph

Framing the same view as the postharvest pretreatment photograph, this photo was taken following treatment by mechanical site preparation.

Gross disturbance of surface

The average amount of disturbance from both logging and site preparation activity is presented as a proportion (%) of total area assessed (n = 50 quadrats, each 2 m^2). The values in parentheses are standard deviations.

Other surface conditions

The length of furrow that either was exposed mineral soil ≥15 cm wide or consisted of rock or water is given as a proportion (standard deviation) of the total of 100 m of furrow length assessed. Following this, disturbed surface conditions that were neither plantable nor seedable are presented as a proportion (%) of the total surface area assessed.

Implement pictorial

An illustration of the site preparation implement is provided; some implements are shown as attachments to the prime mover. These illustrations may not depict exactly the equipment used.

Implement and prime mover

The site preparation implement used to treat the area containing the plot is specified by model name and configuration; following this is the type of prime mover used (tractor or skidder) as categorized by the machine's power rating in kilowatts (kW) and weight in tonnes (t).

Representative microsite photograph and identification

A photograph is provided that shows representative examples of the most common types of microdisturbance on the plot recorded during the posttreatment assessment. Accompanying the photograph is the date of photography and assessment (includes both photographs on the plate), elapsed time from the date of site preparation treatment to the date of assessment, and the elapsed time from time of harvest to the time of site preparation treatment.

Results and discussion of treatment

The results of the site preparation treatment in terms of the quality, quantity, and spacing of microsites produced for planting or seeding are summarized and discussed using relevant data from all graphs and other descriptive material contained on both plates A and B. This information is used to estimate the likelihood of success and/or failure of planting or seeding jack pine and/or black spruce.

The predictive comments found in this section are based on the experience of the authors combined with an understanding of the subject area from the relevant literature. In addition to the literature cited elsewhere in this manual, the following references were also included: Schramm (1958); Heidmann (1976); Daniel (1978); Stiell (1978); Smith (1980); Ryan et al. (1985); Sutton (1986, and unpubl. data); Fleming et al. (1987); Groot (1988); Baldwin et al. (1990); Forestry Canada (1992); Louter et al. (1993); and Fleming and Mossa (1994, 1995).

Forty-Eight Specific Cases of Site Preparation

Overview

Following is a summary of the 48 plots presented in the plate sets. The criterion of success is the number of acceptable planting spots per hectare (Ontario Ministry of Natural Resources 1987). However, for alternative regeneration methods (e.g., direct seeding), it is necessary to consider (i) the percentage of furrow length that is mineral soil ≥15 cm wide; (ii) the percentage of surface that is exposed mineral soil; (iii) the percentage of surface that is organic or organic–mineral mix ≤2 cm deep over mineral soil; and (iv) the percentage of surface that is organic or organic–mineral mix more than 2 cm deep over mineral soil.

Both the number of acceptable planting spots per hectare and the percent surface disturbance are quite sensitive to changes in between-furrow mean spacing, as illustrated in Figures 3 and 4. Absolute values cannot be read from Figures 3 and 4 at the scale presented; however, at a more readable scale (e.g., poster size), actual values are easily read. The number of acceptable planting spots per hectare is also sensitive to changes in the in-furrow and/or in-row acceptable planting spot mean spacing (Figure 3). Operating practice, including both driving patterns and operator's attitudes and habits, and machine settings may influence both mean between-furrow spacing and in-furrow and/or in-row acceptable planting spot spacing. Site factors that may influence operating practice and subsequent product include absent to shallow mineral soil, site moisture regime and/or drainage class, stoniness, boulders, bedrock outcrops, slopes, stumps, residuals, loadings of woody residue, and the presence of vegetation that may hide the other obstacles from the machine operator. Generally, a combination of two or more site factors that impede site preparation was often required to reduce the number of acceptable planting spots. Obviously, absent or shallow mineral soil will reduce the number of acceptable planting spots significantly.

To provide insight into the relationship between success and site factors, two tabulations of the plate set data are presented in the appendixes: ranking by increasing potential stocking, i.e., the number of acceptable planting spots per hectare (Appendix B-1); and ranking by implement (Appendix B-2).

The same data are also presented by treatment unit in the summary discussion (Tables 3–10) that precedes each treatment unit set of plates. Use of shading in Appendix B-1, Appendix B-2, and Tables 3–10 indicates values of interest (e.g., limitations) to the site preparation practitioner.

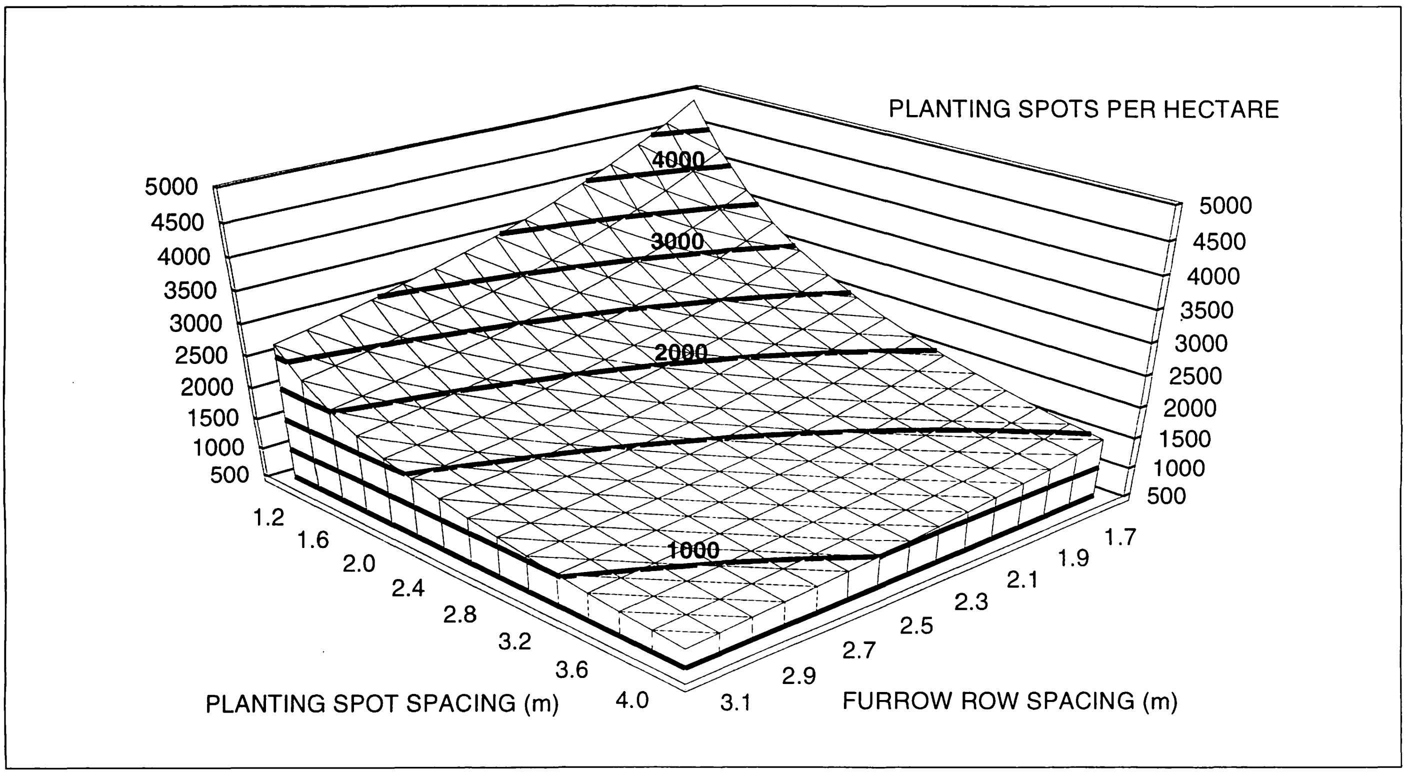


Figure 3. Convex surface illustrating the relationship between number of planting spots per hectare, in-furrow mean planting spot spacing, and between-furrow mean spacing.

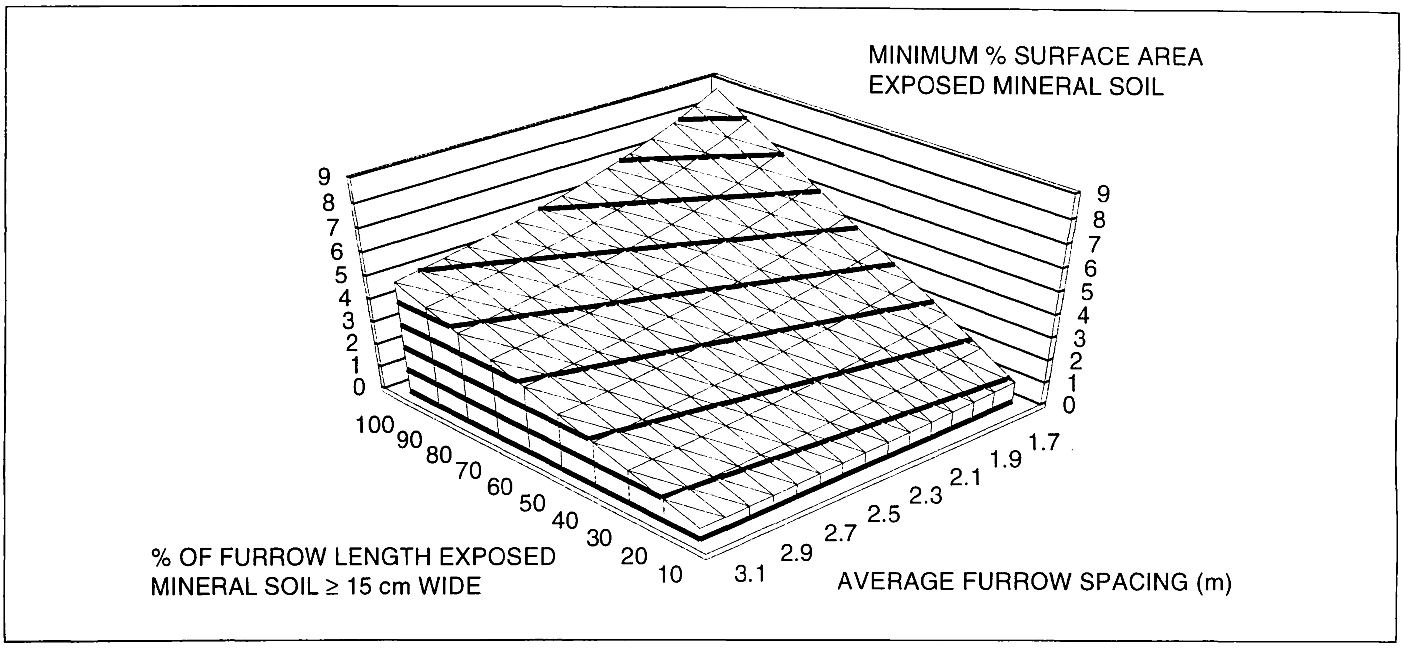


Figure 4. Convex surface illustrating the relationship between the minimum percentage of area that is exposed mineral soil, relative to the percentage of furrow length that is exposed mineral soil ≥15 cm wide, and between-furrow mean spacing.

Ranking by potential stocking

Appendix B-1, which orders the plate sets by increasing numbers of acceptable planting spots per hectare, shows that, of the site preparation results presented in the 48 plate sets, 3 have a stocking potential of <45%, 4 of 45–55%, 4 of 55–65%, 13 of 65–75%, 9 of 75–85%, 6 of 85–95%, and 9 of >95%.

The 24 plots with a stocking potential of **≥75% (≥1876 acceptable planting spots per hectare)** generally had deep to moderately shallow soil (shallowest mineral soil depth recorded is 20 cm) and seldom had rock outcrops; boulders and/or stones were not common, and heavier (larger) prime movers were used. Opportunities exist in some plots for decreasing between-furrow spacing and thus increasing the number of plantable spots per hectare.

The 13 plots with a potential stocking of **65–75% (1626–1875 acceptable planting spots per hectare)** include 9 sites (plate sets 5, 6, 9, 36, 37, 40, 43, 44, and 48) with, generally, moderately shallow to deep soils with none to occasional rock outcrops, but some had boulders and/or stones, residuals, and moderate to moderately heavy loads of woody residue. For some of these 9 sites, opportunities exist for decreasing between-furrow and/or between-row mean spacing and/or in-furrow or in-row mean acceptable planting spot spacing. However, this may increase operating costs.

The remaining 4 plots with a potential stocking of 65–75% and the 11 plots with a stocking potential **<65% (≤1625 acceptable planting spots per hectare)** had, generally, shallow soils and combinations of slopes, rock outcrops, boulders, stones, residuals, and loadings of woody residue that probably preclude greater success.

Ranking by site preparation implement

Appendix B-2 orders data by decreasing numbers of acceptable planting spots per hectare for each implement.

The **Donaren 180 disc trencher** is represented by 13 plots with the number of acceptable planting spots per hectare ranging from 1683 to 2540. A complex of site factors, including absent to shallow mineral soil, slopes, rock outcrops, boulders, stones, residuals, and woody residue, influenced the four plots (plate sets 15, 16, 37, and 40) with the lowest (1683–1736) number of planting spots per hectare. On four of the remaining nine plots (plate sets 25, 26, 27, and 34), the between-furrow spacing of 2.29–2.54 m was a function of operating practice rather than site factors. However, site factors may have influenced operating practice and between-furrow spacing on four plots (plate sets 6, 15, 37, and 40). One plot (plate set 10) presents a site with few impediments to site preparation and a driving practice that produced a between-furrow spacing of 1.93 m and yielded 2540 acceptable planting spots per hectare.

The **TTS Delta (power) disc trencher** is represented by five plots (plate sets 2, 13, 22, 23, and 46). Four plots had moderately shallow to deep soils, and 2116–2464 acceptable planting spots per hectare were produced; two plots (plate sets 2 and 22) had moderately heavy loadings of woody residue. The fifth plot (plate set 46) yielded 250 acceptable planting spots per hectare and was located on a site with absent to moderately shallow mineral soil, moderate plot slopes, moderate rock outcrops, and boulders and stones varying from slight to very stony; it is doubtful whether any mechanical site preparation equipment could do better on this site.

The **TTS Delta (passive) disc trencher** is represented by two plots (plate sets 32 and 33) that had deep sandy soils and negligible trafficability impediments for the 150-kW, 13-t prime mover; 2359 and 2564 acceptable planting spots per hectare were produced.

The **TTS-35 disc trencher** is represented by five plots (plate sets 3, 4, 5, 7, and 20); 1483–2114 acceptable planting spots per hectare were produced. Mineral soil depth ranged from deep to moderately deep. Where combinations of boulders, stones, large high stumps, residuals, and moderate to moderately heavy loadings of woody residue occurred, fewer than 2000 acceptable planting spots per hectare were produced.

The **Silva Wadell powered cone scarifier** is represented by three plots (plate sets 12, 30, and 45). Soil depth ranged from very shallow to moderately deep. One plot (plate set 12) on moderately rolling terrain, with moderately deep soil and a moderate (122 m^3/ha) woody residue loading, yielded 2168 acceptable planting spots per hectare. The other plots (plate sets 30 and 45) had shallow soil, moderate terrain, rock outcrops, boulders, and stones, various combinations of which significantly impeded site preparation and reduced the production of acceptable planting spots per hectare to 992 and 761, respectively.

Three configurations of the **Bräcke patch scarifier** are represented by six plots (plate sets 1, 17, 18, 29, 36, and 43). Soil depth varied from shallow to deep. Three plots (plate sets 1, 17, and 29) that had combinations of steeper topography, bedrock outcrops, boulders, stones, residuals, and moderate to moderately heavy loadings of woody residue yielded 1332–1562 acceptable planting spots per hectare. Also, on three plots (plate sets 17, 36, and 43), the machine mattocks were set to give a spacing of more than 2 m between scalps; two plots (plate sets 36 and 43) with 1752 and 1855 acceptable planting spots per hectare had no noteworthy impediments to larger machinery. The sixth plot (plate set 18) also had few impediments to site preparation; however, with the machine set for 2-m patch spacing, 2249 acceptable planting spots per hectare were produced.

Light drags are represented by three plots (plate sets 28, 35, and 38). Soil depth varied from very shallow (discontinuous) to moderately deep. Topography was rolling, sometimes broken, with slopes varying from gentle to very strong. Rock outcrops varied from slight to extreme, with boulders and/or stones together never less than moderate. Loadings of woody residue were light to moderately light. The number of acceptable planting spots per hectare ranged from 1220 to 1777. However, the intent was to aerial broadcast seed these sites to jack pine. Although the percentage of area suitable for seeding jack pine (mineral soil and organic or organic–mineral mix ≤2 cm deep over mineral soil) was less than commonly recommended, seedbed was concentrated on those portions of the site that are stockable. Also, broadcast seed that falls on rock may be washed or blown to suitable seedbeds on the perimeters of the exposed rock. Similar local areas that have received this prescription tend to be as well or better stocked than if planted.

The one plot (plate set 31) where a **medium drag** was used presents a site with a deep, sandy soil that was prepared for aerial broadcast seeding of jack pine. It had 2737 acceptable planting spots per hectare.

Heavy drags are represented by six plots (plate sets 11, 21, 24, 41, 42, and 47), sites that had mineral soil depths ranging from very shallow to deep. Two sites (plate sets 41 and 42) with 1594 and 1142 acceptable planting spots per hectare had shallower soils, bedrock outcrops, boulders, and stones. The other four sites (plate sets 11, 21, 24, and 47) with 2204–2603 acceptable planting spots per hectare had soil depths ranging from moderately shallow to deep and up to two other impediments, such as moderate to moderately heavy loadings of woody residue, residuals, and stones.

The **Cazes and Heppner plow (highly modified)** is represented by two plots (plate sets 8 and 9) with deep, sandy loam soils, a scattered to moderate number of boulders, and a slightly deeper than average (6–17 cm) LFH layer. Residual tall, woody shrubs prevailed over much of the cut blocks. Local experience has demonstrated that the sandy loam in the area is subject to erosion when the mineral soil is exposed. Hence, the local prescription is to prepare access for tree planters and remove some of the LFH layer with minimal exposure of mineral soil. Planting spots are prepared by "easy boot screefing" (assessor's field notes) of the shallow FH horizons left after site preparation. The data collected, which reflect the sampling process, indicate 1100–1300 acceptable planting spots per hectare. Based on actual planting experience on these sites, it is estimated that the number of planting spots per hectare ranges from 1500 to 2100.

The **Young's utility dozer teeth** is represented by one plot (plate set 19), and a **straight dozer blade** is represented by one plot (plate set 44). On both plots, the soil was moderately deep, but the Young's teeth plot had more boulders and stones and greater slope. The common features of the two plots were the longer elapsed time (43–70 months) since harvest and the well-developed woody regrowth and/or tall residual woody shrubs. The Young's teeth produced 1929 acceptable planting spots per hectare with 16% mineral soil exposure, and the straight blade produced 1650 acceptable planting spots per hectare with about 25% mineral soil exposure.

Treatment Units A and D

Treatment Unit A: Miscellaneous Hardwoods and Mixedwoods

Treatment Unit A contains a variety of hardwood and mixedwood stands of balsam poplar, black ash, or a mixture of other hardwood species, such as bur oak, red ash, red maple, yellow birch, or basswood, typically occurring in small, localized pockets in northwestern Ontario.

Treatment Unit D: Balsam Fir–White Spruce Conifer and Mixedwood

Treatment Unit D contains highly diverse upland conifer mixedwood stands containing merchantable balsam fir, white spruce, and associated secondary species, including white cedar, trembling aspen, and black spruce. These sites are highly productive and tend to be shrub rich, except where a dense canopy prevents light penetration.

Phase D1: Fresh soils
Phase D2: Moist soils

Equipment trafficability

Wet, organic, and fine-textured soils on Treatment Unit A and phase D2 fine-textured soils on Treatment Unit D are susceptible to compaction, rutting, and erosion on slopes greater than 10%. Damage from puddling is a risk on some sites. Extensive slash resulting from residual balsam fir and understory species could limit the effectiveness of some site preparation and tending. Potential for stand decadence and residual, nonmerchantable material may limit operability. Prescribed burning may be necessary on Treatment Unit D for slash reduction to make a site operable after harvest.

Competition

On Treatment Unit A, extremely heavy competition from trembling aspen, balsam poplar, *Acer spicatum, Cornus stolonifera, Alnus rugosa*, red maple, *Corylus cornuta*, and *Calamagrostis canadensis* can be expected. On Treatment Unit D, moderate to heavy levels of competition can be expected on phase D1 from trembling aspen, *Alnus crispa, Acer spicatum, Corylus cornuta*, white birch, balsam fir, and *Calamagrostis canadensis*. Very heavy competition can be expected on phase D2 from the same species listed for phase D1 (substitute *Alnus rugosa* for *Alnus crispa*). Included would be *Rubus idaeus* and graminoids. According to Walsh and Krishka (1991), in a study of early stand development following harvesting in northwestern Ontario, potential competitors of concern might include *Populus tremuloides, Diervilla lonicera, Rubus idaeus, Aster macrophyllus, Fragaria* spp., and grasses.

Comments

Stand conversion in these sites is generally expensive, requiring extensive site preparation and tending.

Summary

A summary of Treatment Units A and D is presented in Table 3.

A TTS–35 disc trencher was used on four different plots in Treatment Units A and D (plate sets 3, 4, 5, and 7). Plantability ranged from a high of 2114 acceptable planting spots per hectare (plate set 3) to 1557 acceptable planting spots per hectare (plate set 7). The plot represented by plate set 7 had gentle to moderate topography, very gentle to moderate plot slopes, and numerous boulders and stones that, when combined with the stumps, gave 1250 ground roughness class 2 and 3 obstacles per hectare. The ground roughness plus the moderately heavy (152 m^3/ha) loading of woody residue limited disc penetration, both increasing in-furrow acceptable planting spot distance to 3.31 m and reducing area of mineral soil exposure to 4%. Here, use of a powered disc trencher (e.g., plate set 39, TU G) or a heavy drag (e.g., plate set 24, TU E) may have given better results.

A Bräcke 2-row and 3-row was used on the plot presented in plate set 1. This is the only plot (of the complete set of 48 plots) that had "to be forced" into a V-type and treatment unit. Although it keys out as a V-1 based on the basal area of the stumps on the plot, white cedar was present. Suggested alternative V-types include V-14, V-15, and V-21. The area topography was rolling with gentle to moderate complex slopes (very gentle to moderate complex plot slopes), the LFH depth ranged from 7 to 25 cm, and mineral soil depth ranged from 24 to 62 cm, with rock outcrops >75 m apart, boulders 2–10 m apart, stones 1–2 m apart, about 275 residuals >10 cm in diameter per hectare, and a moderate loading of woody residue; here, 1562 acceptable planting spots per hectare, 9.1% mineral soil exposure, 0.5% organic and/or organic–mineral mix ≤2 cm deep, and 9.0% organic and/or organic–mineral mix >2 cm deep were produced. It is doubtful if other affordable methods of site preparation would have given better results.

On the plot presented in plate set 6, the Donaren 180 disc trencher produced a between-furrow spacing of 2.33 m that is a function of operating practice rather than site factors. Decreasing between-furrow spacing would increase both the number of planting spots per hectare and mineral soil exposure.

The TTS Delta (power) disc trencher used on the plot presented in plate set 2 produced 2424 acceptable planting spots per hectare but 4.6% mineral soil exposure. The only limit to machine operation was the moderately heavy (152 m^3/ha) loading of woody residue.

The intent of the prescription on the plots presented in plate sets 8 and 9 was minimum mineral soil exposure and access for planters. The numbers of planting spots per hectare presented (1269 and 1098) reflect the assessment sampling method, where the center of each pass of the Cazes and Heppner plow was assessed for planting spots. In practice, trees are planted along the edges of the variable but broader disturbance produced by the Cazes and Heppner plow, and it is estimated that the number of planting spots available range from 1800 to 2100 and from 1500 to 1800, respectively, for the two plots (plate sets 8 and 9), values that bracket reported numbers of seedlings actually planted in the areas. "Easy boot screefing" (assessor's field notes) by the planter is required at most planting spots.

Table 3. Data from plate sets for Treatment Units A and D ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
1	1562	27	9.1	0.5	9.0	7–25	24–62	g→m	2–13	n.l.	M→V
2	2424	22	4.6	1.9	13.5	7–10	>100	g→vg	0–3	0	0
3	2114	62	7.1	1.3	3.0	5–8	50–75	g	1–2	0	M
4	2013	62	12.8	1.3	1.9	4–14	>100	g	1–3	0	0
5	1812	48	6.9	1.1	2.9	6–13	>100	g	0–2	0	0
6	1803	17	3.1	0.4	7.0	7–14	>100	vg→m	2–3	0	0
7	1557	35	4.0	0.6	2.1	3–7	>100	g→m	3–12	0	M→V
8	1269[a]	6	2.4	0.7	30.4	9–17	>100	vg	0–3	0	S
9	1098[b]	15	2.2	1.0	31.5	6–11	>100	g	2–5	0	0→S

[a] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1800–2100/ha.

[b] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1500–1800/ha.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
625	123	9–13	n.r.	mD	SiS, gSiL, cSL	V-1 (A/D)	2.91	n.r.	110/136	10	Bräcke	1
600	152	12	5	vF	mS	V-25 (D)	2.16	1.91	123	15.4	TTS (pow)	2
550	54	12–15	2	mM, vM, mD	fSCL, L	V-14 (D)	2.03	2.33	107	10.5	TTS-35	3
150	41	20–27	12	F→vF	gSifS, SiL, SivfS	V-14 (D)	2.30	2.16	107	10.5	TTS-35	4
650	82	21–27	10	mD→mF	SimS, LmS, LfS	V-14 (D)	2.30	2.40	107	10.5	TTS-35	5
600	92	16–21	6	M→vF	CL→ SiCL	V-15 (D)	2.33	2.38	170	13.8	Don180	6
1250	152	6–11	4	mF	fSCL	V-16 (D)	1.94	3.31	107	10.5	TTS-35	7
700	67	10–13	6	**mM**→M	SL	V-25 (D)	3.92	2.01	160	22.8	C & H	8
325	64	11–14	3	F	SL	V-14 (D)	4.51	2.02	160	22.8	C & H	9

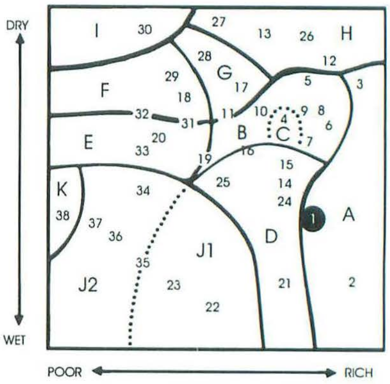
PLATE
1A

V1 Balsam Poplar Hardwood and Mixedwood

SS5, SS5, SS5

FRI: $Sb_5B_4Ce_1$, age 97, height 14 m, stocking 0.7, site class 2

Other site vegetation types: very heterogeneous cut block, predominantly Treatment Units A and D with some Treatment Units B, C, E, and, rarely, J



Photographed and assessed: 11 May 1991
Time elapsed since harvest: 8–12 months
Harvest method: full-tree with a Koehring feller–forwarder

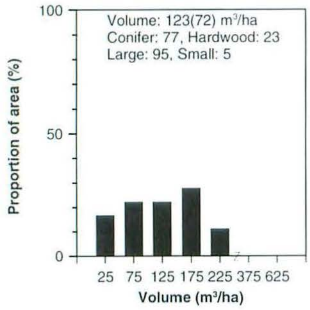
Area topography: gentle to moderate
Bedrock outcrops: none locally
Plot slopes: complex, 2–13%
Plot slope position: mid (lower)
Landform: ground moraine
Soil depth: 24–62 cm

Soil texture: gravelly medium sand, gravelly fine sand, gravelly silty loam
Boulders: slight to moderate
Stones: moderate to very
Coarse fragments: <20%
Litter: 4–11 cm

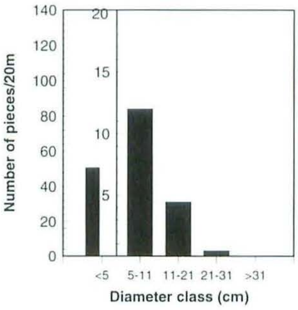
Fermentation layer: 3–14 cm
Humus: none
Texture of surface mineral soil: silty sand, gravelly silty loam, coarse sandy loam
Drainage: rapid to very rapid
Moisture regime: moderately dry

Woody Debris

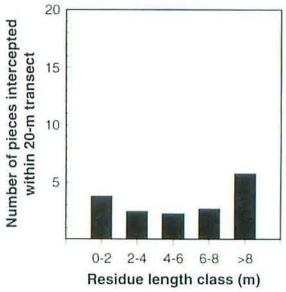
Distribution Volume



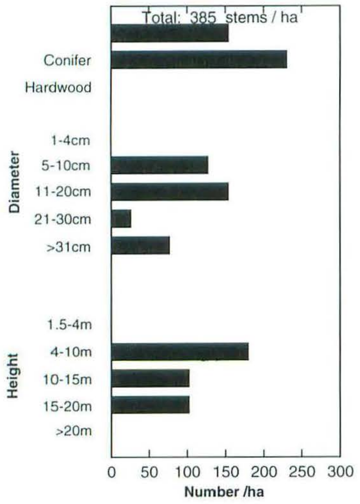
Diameter Distribution



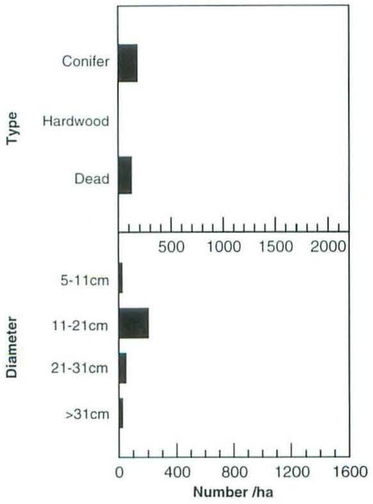
Length



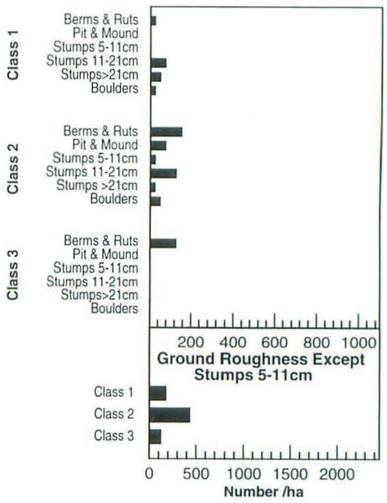
Residuals



Stumps

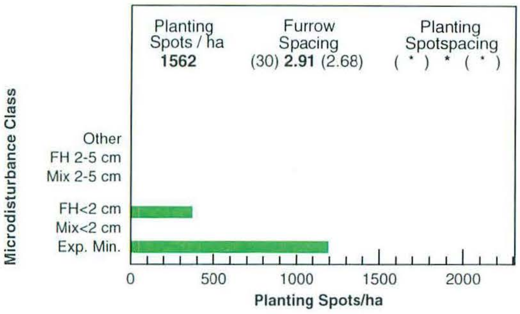


Ground Roughness

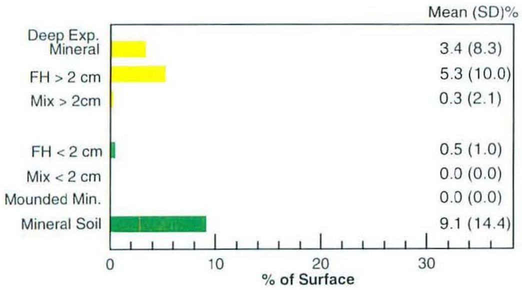


Inverting

Plantability



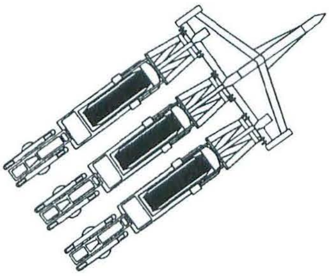
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	27	(30)
Furrow length (%), rock and/or water	5	(15)
Other surface conditions (% of surface):		
spoil bank	56	(32)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	14.9	(26.9)
rock and/or water	3.9	(8.4)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 4–5 September 1991
Time from site preparation to assessment: 2.5–3 months
Time from harvest to site preparation: 9–13 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	8.4	(27.4)
site preparation	70	(35)



Implements: Bräcke Badger (3 mattock wheels at 1.0-m spacing) and Bräcke 2-row (2 mattock wheels at 2.0-m spacing)

Prime movers: 136-kW, 10-t skidder, and 110-kW, 10-t skidder

A Bräcke 3-row and a Bräcke 2-row running side by side were used to achieve a minimum of 70% coverage. Despite residuals, a moderate to heavy load of fresh woody residue, locally complex slopes, and boulders and stones, a between-rows-of-scalps mean spacing of 2.91 m was achieved. Because of the complex terrain, the rows of scalps were serpentine, with numerous crossovers, making them impossible to follow for any distance; hence, a 20 m x 20 m grid containing 100 contiguous 2-m^2 quadrats was assessed for plantability and to determine the areal percentage of substrate classes. Unacceptable planting spots resulted from excessive organic matter depth, woody residue, and/or stone-limited shallow penetration by the planting spade. Of the about 1560 acceptable planting spots per hectare, 1190 were in mineral soil and 370 were in organic matter ≤2 cm deep over mineral soil. A vegetation assessment was not done. Site conditions and the literature suggest both diverse and vigorous competition development that may be a problem for both planted seedlings and germinants. The moderately dry moisture regime is too dry for seeding spruce and is near the dry end of the acceptable range for seeding jack pine; also, both harvesting and site preparation may impact the preharvest drainage pattern, effecting changes in site moisture regime for several years. Good seedbed comprised 9.6% of the surface, and 9.0% was conditional. Uneconomic application rates of jack pine seed on this relatively fertile site may yield a mixedwood forest that does not satisfy minimum conifer stocking standards. Compare with plate sets 7, 17, 37, 39, and 41.

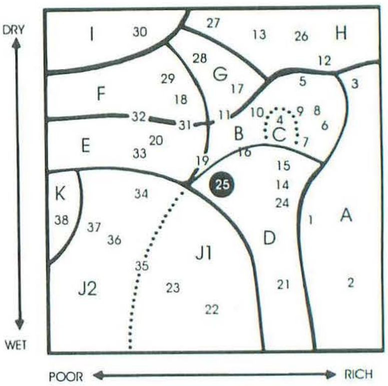
PLATE
2A

V25 White Spruce – Balsam Fir / Feathermoss

S7, S7, S7

FRI: $Sb_6Bw_2Po_1Sw_1$, age 150, height 20 m, stocking 0.5, site class 1

Other site vegetation types: Balsam Fir–White Spruce Mixedwood/Feathermoss, Balsam Fir Mixedwood, and, occasionally, White Spruce Mixedwood



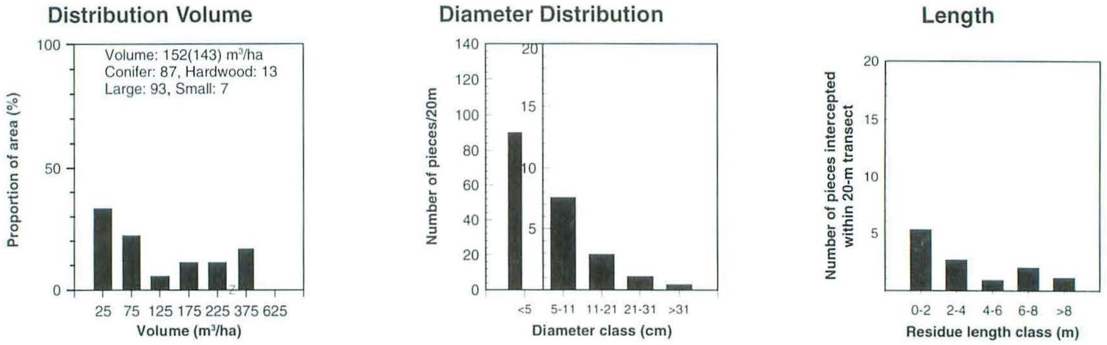
Photographed and assessed: 27 September 1990
Time elapsed since harvest: 1–2 months
Harvest method: conventional full-tree by cut and skid

Area topography: gentle to very gentle
Bedrock outcrops: none
Plot slopes: simple, 0–3%
Plot slope position: mid
Landform: lacustrine deposit
Soil depth: >100 cm

Soil texture: stratified at 1 m, with clay over fine sand
Boulders: none
Stones: none
Coarse fragments: none
Litter: 2–3 cm

Fermentation layer: 4–6 cm
Humus: 1 cm
Texture of surface mineral soil: medium sand (uniformly)
Drainage: moderately well to imperfect
Moisture regime: very fresh

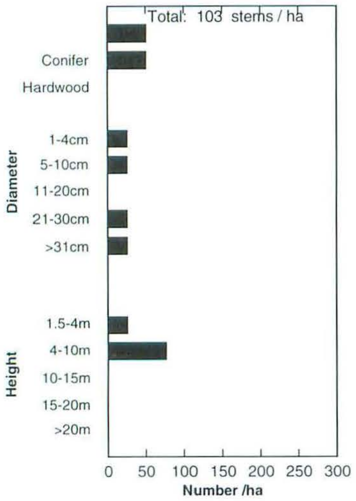
Woody Debris


Distribution Volume

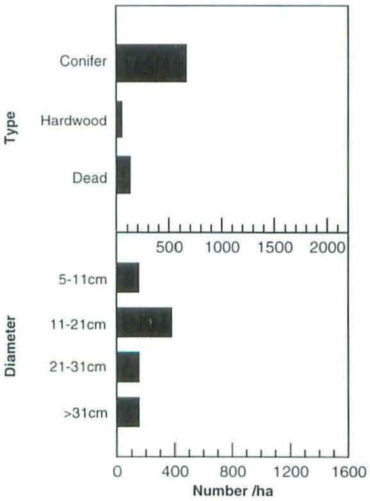
Diameter Distribution

Length

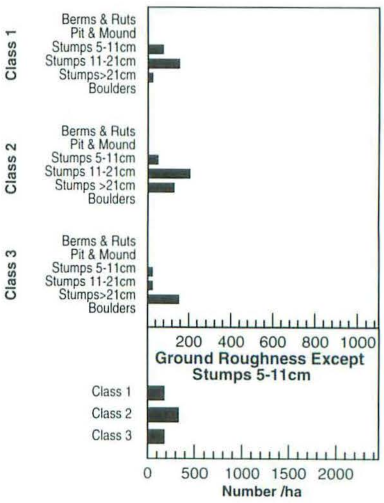
Residuals



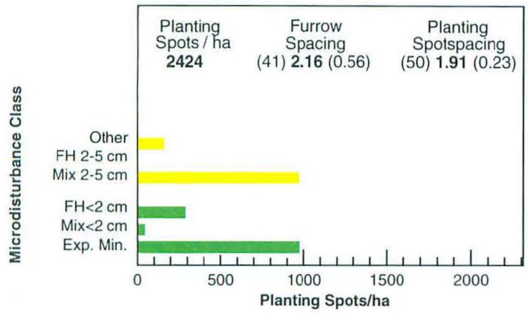
Stumps



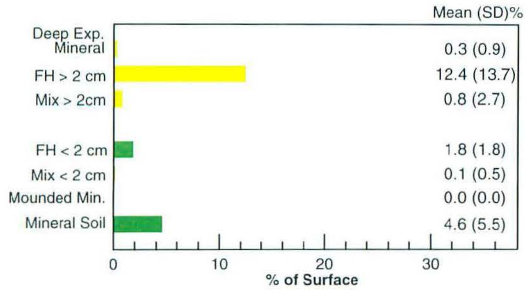
Ground Roughness



Plantability



Potential Seedbed



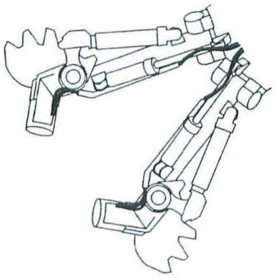
Furrow length (%), mineral soil ≥15 cm wide	22	(32)
Furrow length (%), rock and/or water	0	(0)

Other surface conditions (% of surface):

spoil bank	41	(26)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	11.4	(8.9)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 2 August 1991
Time from site preparation to assessment: 4–6 weeks
Time from harvest to site preparation: about 12 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	73	(27)



Implement: TTS Delta (power) disc trencher

Prime mover: 123-kW, 15.4-t skidder

The between-furrow mean spacing of 2.16 m was a function of operating practice, influenced by a moderately (occasionally very) heavy load of woody residue, by scattered large-diameter high stumps, and by scattered residuals. The in-furrow acceptable planting spot mean spacing was 1.91 m. Of the about 2425 acceptable planting spots per hectare, 970 were in mineral soil, 325 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 970 were in an organic–mineral mix 2–5 cm deep over mineral soil, and 160 were in other acceptable conditions. Five competitor species were noted during a vegetation assessment on 27 September, 1–2 months after harvest. Initial competition development may not be a problem for either planted stock or jack pine germinants; however, by years 5–7, competition may be limiting conifer growth. The moisture regime was highly suitable for germination and establishment of spruce from seed and was toward the moist end of the acceptable range for jack pine. Good seedbed comprised 6.5% of the surface, and 13.5% was conditional. For both spruce and jack pine, the relatively low amounts of seedbed may require uneconomic rates of broadcast seed application to assure stocking standards. Fragile spruce germinants may also have difficulty coping with the competition development or may be smothered by litter fall. Compare with plate sets 11, 18, 31, 33, and 39.

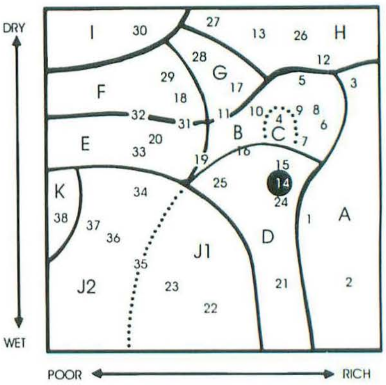
PLATE
3A

V14 Balsam Fir Mixedwood

SS8, SS8, SS5

FRI: $B_6Sw_2Po_1Bw_1$, age 59, height 20 m, stocking 1.0, site class X

Other site vegetation types: none on this cut block



Photographed and assessed: 16 May 1991
Time elapsed since harvest: 8–11 months
Harvest method: full-tree with feller–buncher and grapple skidder

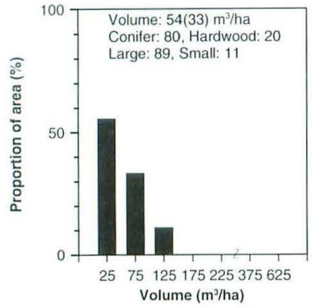
Area topography: gentle
Bedrock outcrops: none
Plot slopes: complex, 1–2%
Plot slope position: toe to upper (flat)
Landform: ground moraine
Soil depth: 50–75 cm

Soil texture: silty very fine sand, very fine sandy loam, fine sandy loam
Boulders: none
Stones: moderate
Coarse fragments: 6–20%
Litter: 1–2 cm

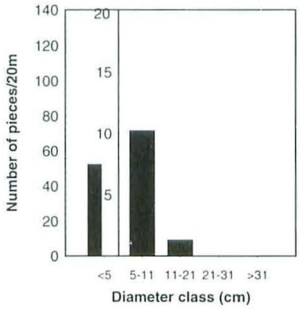
Fermentation layer: 2–3 cm
Humus: 2–3 cm
Texture of surface mineral soil: fine sandy clay loam and loam
Drainage: moderately well, poor and/or imperfect, rapid
Moisture regime: moderately moist, very moist, moderately dry

Woody Debris

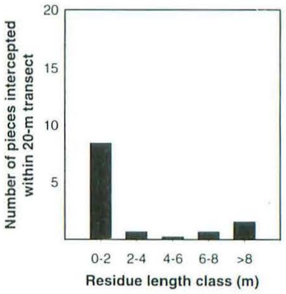
Distribution Volume



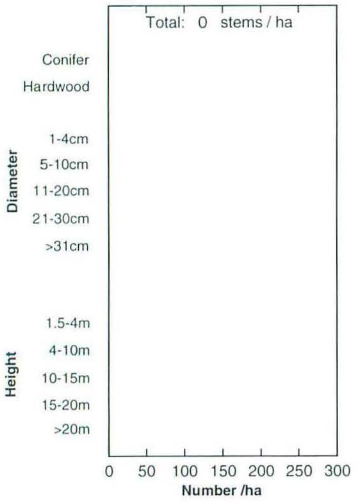
Diameter Distribution



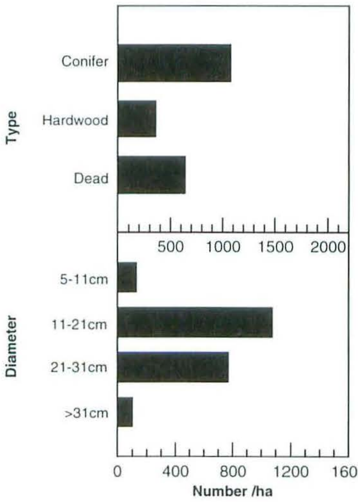
Length



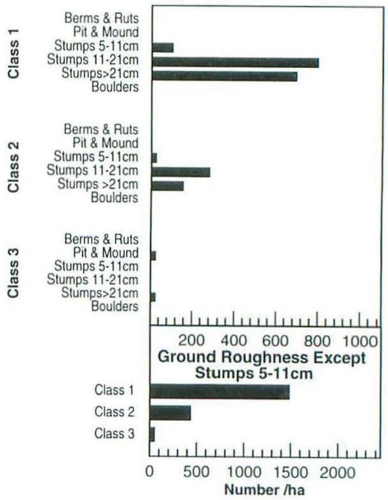
Residuals



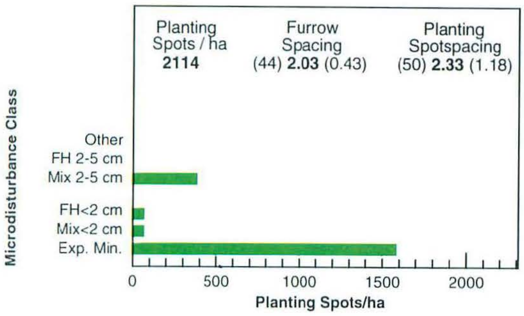
Stumps



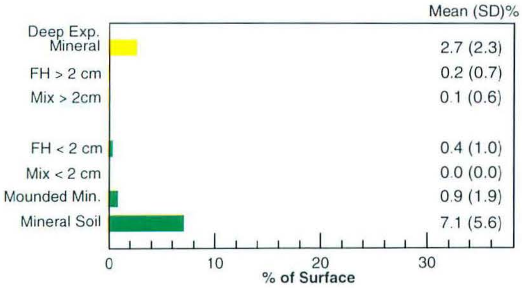
Ground Roughness



Plantability



Potential Seedbed



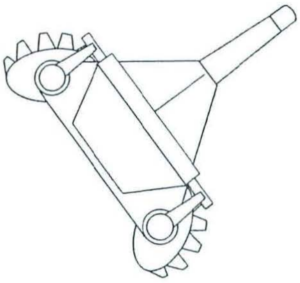
Furrow length (%), mineral soil ≥15 cm wide	62	(32)
Furrow length (%), rock and/or water	0	(0)

Other surface conditions (% of surface):

spoil bank	52	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.6	(1.7)
rock and/or water	0.4	(1.2)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 11 and 12 September 1991
Time from site preparation to assessment: 1–2 weeks
Time from harvest to site preparation: 12–15 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.4	(2.8)
site preparation	63	(19)



Implement: TTS–35 disc trencher

Prime mover: 107-kW, 10.5-t skidder

The between-furrow mean spacing of 2.03 m was a function of operating practice on a site with relatively few impediments to site preparation. Stone-limited shallow planting spade penetration and the presence of woody residue increased the in-furrow acceptable planting spot mean spacing to 2.33 m. Of the about 2115 acceptable planting spots per hectare, 1585 were in mineral soil, 140 were in organic matter or an organic-mineral mix ≤2 cm deep over mineral soil, and 390 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil. *Acer spicatum* and *Rubus idaeus* were noted during a vegetation assessment during mid-June, 9–12 months after harvest, but the photos indicate that sedge and aspen are present. Well-planted, vigorous stock adapted morphologically and physiologically for this site may outgrow red raspberry and sedge but not the aspen nor the likely ingress of birch and cherry; hence, tending may be required within 4–7 years. The greater part of the site mosaic has a moisture regime suitable for seeding spruce but less suitable for seeding jack pine. Good seedbed comprised 8.4% of the surface area, and 3.0% was conditional, insufficient for broadcast seeding except at uneconomic application rates. The finer-textured surface mineral soil may also encourage frost heaving of germinants and, possibly, seedlings. Compare with plate sets 12, 14, 21, 22, and 27.

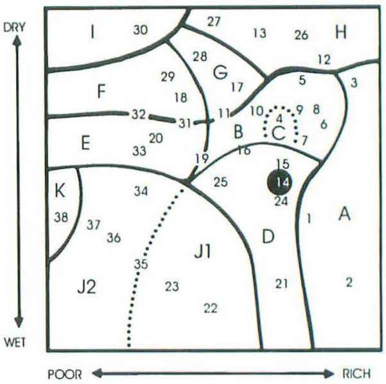
PLATE
4A

V14 Balsam Fir Mixedwood

S2, S4, S3

FRI: B_7Bw_3, age 63, height 16 m, stocking 0.8, site class X

Other site vegetation types: none locally in this cut block



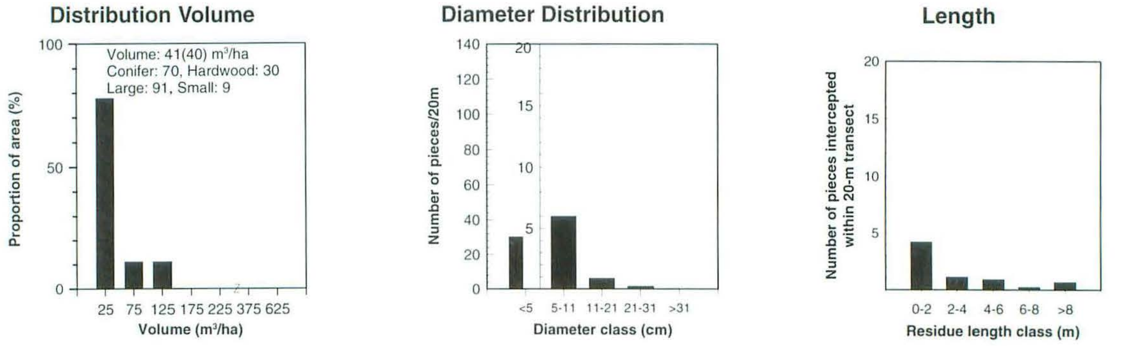
Photographed and assessed: 13 May 1991
Time elapsed since harvest: 17–23 months
Harvest method: full-tree by conventional cut and skid

Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 1–3%
Plot slope position: lower slope (flat)
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: very fine sand, silt, silty very fine sand (stratified, gravel above)
Boulders: none
Stones: none
Coarse fragments: none
Litter: 1–5 cm

Fermentation layer: 3–9 cm
Humus: none
Texture of surface mineral soil: gravelly silty fine sand, silty loam, silty very fine sand
Drainage: well to imperfect
Moisture regime: fresh to very fresh

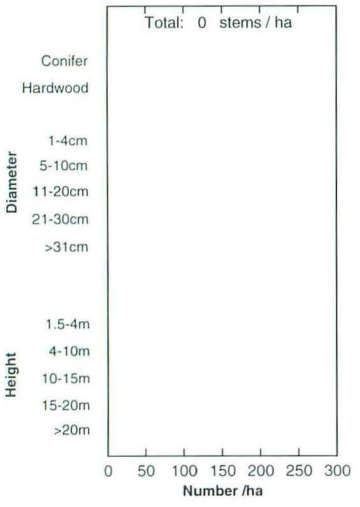
Woody Debris


Distribution Volume

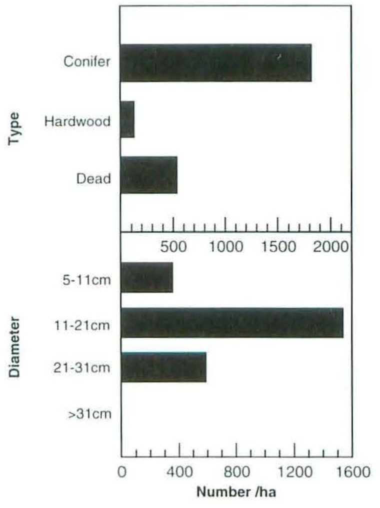
Diameter Distribution

Length

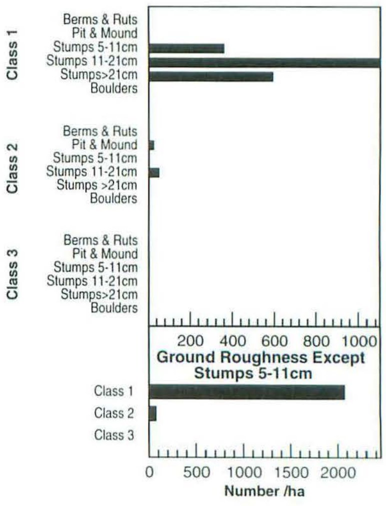
Residuals



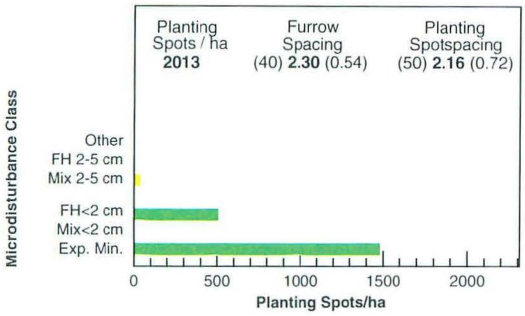
Stumps



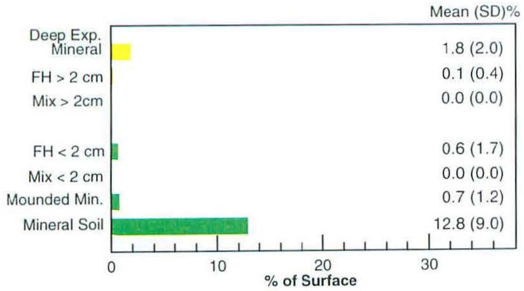
Ground Roughness



Plantability



Potential Seedbed



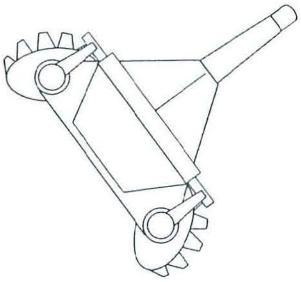
Furrow length (%), mineral soil ≥15 cm wide	62	(36)
Furrow length (%), rock and/or water	0	(0)

Other surface conditions (% of surface):

spoil bank	34	(17)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.1	(14.0)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 11–12 September 1991
Time from site preparation to assessment: 1–2 weeks
Time from harvest to site preparation: 20–27 months

Gross disturbance of surface (%):	mean	(sd)
other (mostly harvesting)	0	(0)
site preparation	50	(20)



Implement: TTS–35 disc trencher

Prime mover: 107-kW, 10.5-t skidder

The between-furrow mean spacing of 2.30 m was a function of operating practice that may have been influenced by the numerous stumps. The in-furrow acceptable planting spot mean spacing was increased to 2.16 m by the presence of roots and stumps. Of the about 2015 acceptable planting spots per hectare, 1475 were in mineral soil, 505 were in organic matter ≤2 cm deep over mineral soil, and 35 were in an organic–mineral mix 2–5 cm deep over mineral soil. Twelve competitor species were noted during a vegetation assessment in mid-June, 18–24 months after harvest. It is uncertain whether well-planted, vigorous stock adapted morphologically and physiologically for this site could compete with the expected competition development. Tending will be required. The fresh to very fresh moisture regime was favorable for seeding jack pine but was at the dry end of the acceptable range for seeding spruce. Good seedbed comprised 14.1% of the surface, and 1.9% was conditional, which is adequate for broadcast seeding at higher application rates. However, it is doubtful that a stand that satisfies conifer stocking standards would be established by seeding; competition for light, smothering by litter fall, and potential frost heaving on finer-textured soils may prevent the establishment of fragile germinants. Compare with plate sets 12, 18, 22, and 31.

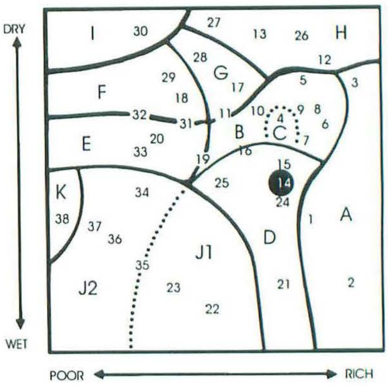
PLATE 5A

V14 Balsam Fir Mixedwood

S2, S4, S3

FRI: B_7Bw_3, age 63, height 16 m, stocking 0.8, site class X

Other site vegetation types: none locally in this cut block



Photographed and assessed: 13 May 1991
Time elapsed since harvest: 17–23 months
Harvest method: full-tree by conventional cut and skid

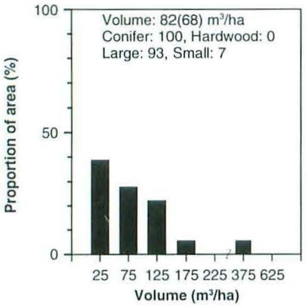
Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 0–2%
Plot slope position: upper
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: very gravelly medium sand, coarse gravel, very gravelly coarse sand
Boulders: none
Stones: none
Coarse fragments: 21–>50%
Litter: 3–4 cm

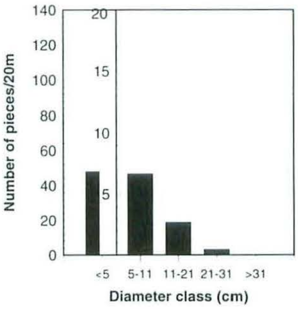
Fermentation layer: 3–9 cm
Humus: none
Texture of surface mineral soil: silty medium sand, loamy medium sand, loamy fine sand
Drainage: rapid to very rapid
Moisture regime: moderately dry to moderately fresh

Woody Debris

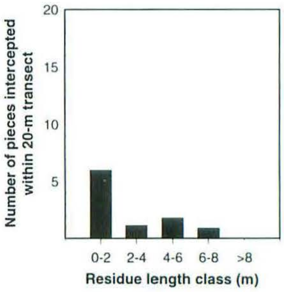
Distribution Volume



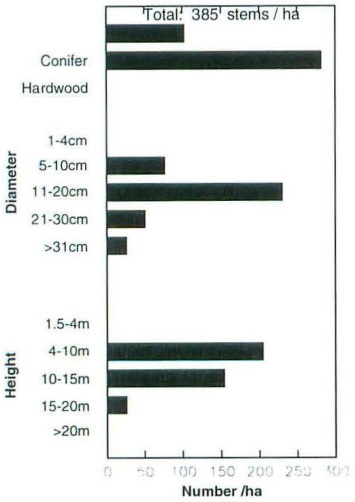
Diameter Distribution



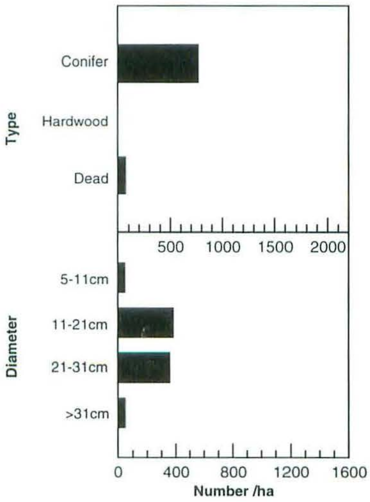
Length



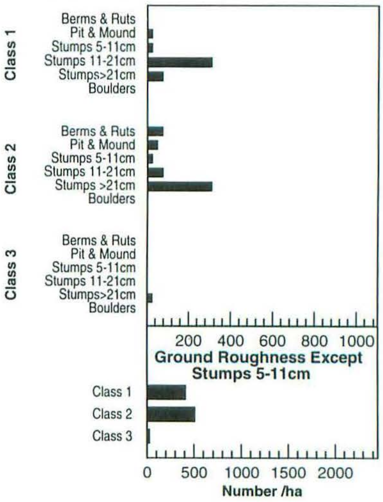
Residuals



Stumps

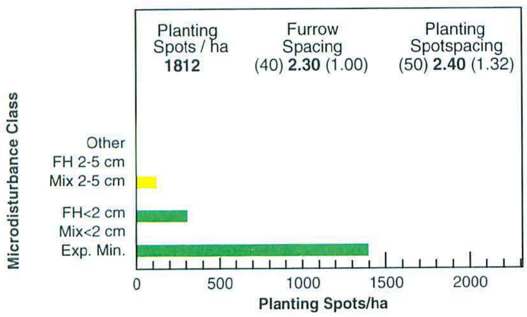


Ground Roughness

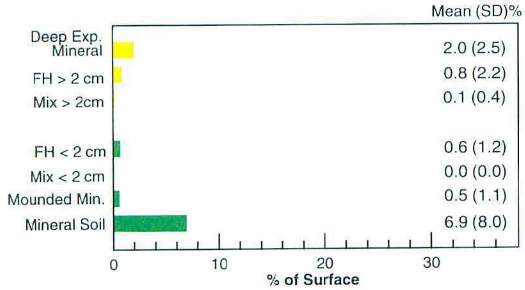


Trenching

Plantability



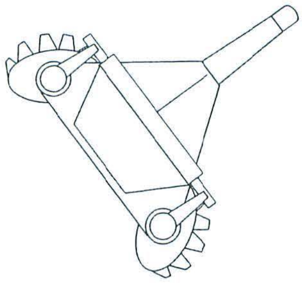
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	48	(36)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	38	(23)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.0	(2.9)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0.1	(0.7)

Photographed and assessed: 11 and 12 September 1991
Time from site preparation to assessment: 1–2 weeks
Time from harvest to site preparation: 21–27 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.3	(2.3)
site preparation	48	(26)



Implement: TTS–35 disc trencher

Prime mover: 107-kW, 10.5-t skidder

The between-furrow mean spacing of 2.30 m was a function of operating practice on a relatively gentle site that has some ground roughness and (mostly) birch residuals at a spacing of about 6 m. The in-furrow acceptable planting spot mean spacing of 2.40 m was due to the presence of woody residue. Of the about 1810 acceptable planting spots per hectare, 1390 were in mineral soil, 300 were in organic matter ≤2 cm deep over mineral soil, and 120 were in an organic–mineral mix 2–5 cm deep over mineral soil. Ten competitor species were noted during a vegetation assessment in mid-June, 18–24 months after harvest. It is uncertain whether well-planted, vigorous stock adapted morphologically and physiologically to this site will cope with the expected competition development. Tending will probably be required. Only parts of the site mosaic were sufficiently moist to support seeding spruce, but most of the site mosaic has a moisture regime adequate for seeding jack pine. Good seedbed comprised 8.0% of the surface, and 2.9% was conditional. Inadequate amounts of seedbed and the potential competition development preclude establishing a stand by seeding that will satisfy minimum conifer stocking standards. Fragile germinants may have difficulty coping with competition development, including competition for both light and moisture, and may be smothered by litter fall. Compare with plate sets 15, 22, 31, and 37.

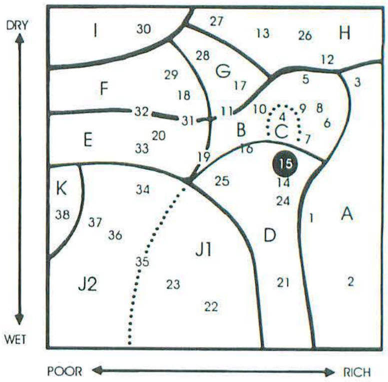
PLATE
6A

V15 White Spruce Mixedwood

S10, S10/S6, S9

FRI: $Po_5Bw_3B_1Sb_1$

Other site vegetation types: Trembling Aspen Mixedwood



Photographed and assessed: 1 June 1991
Time elapsed since harvest: 14–18 months
Harvest method: conventional tree-length by cut and skid

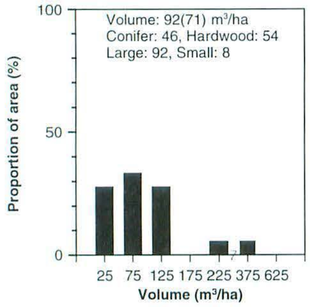
Area topography: very gentle to moderate
Bedrock outcrops: none
Plot slopes: simple, 2–3%
Plot slope position: lower to flat
Landform: glaciolacustrine deposit
Soil depth: >100 cm

Soil texture: silty loam to loam
Boulders: none
Stones: none
Coarse fragments: 0–20%
Litter: 2–4 cm

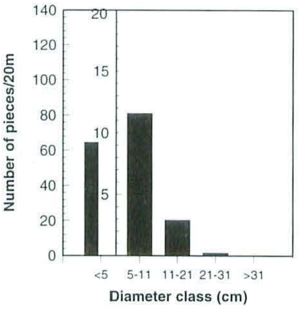
Fermentation layer: 4–8 cm
Humus: 1–2 cm
Texture of surface mineral soil: clay loam to silty clay loam
Drainage: imperfect to poor
Moisture regime: moist to very fresh

Woody Debris

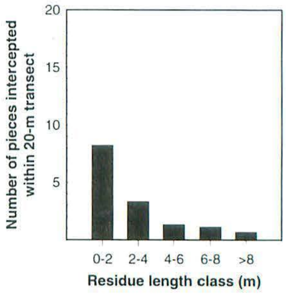
Distribution Volume



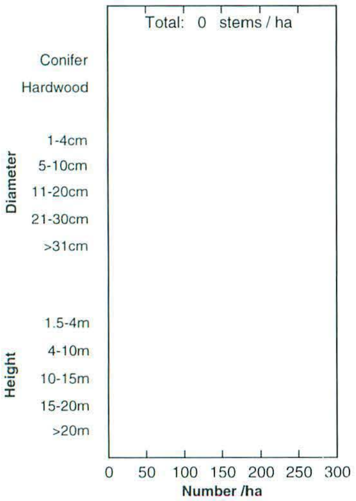
Diameter Distribution



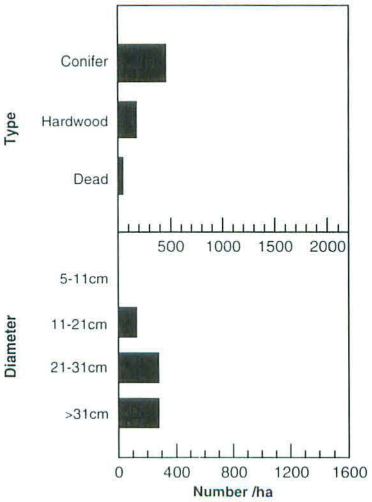
Length



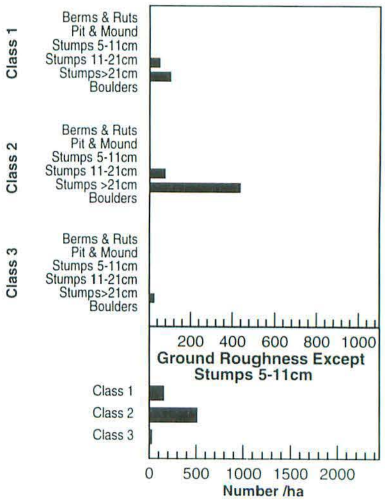
Residuals



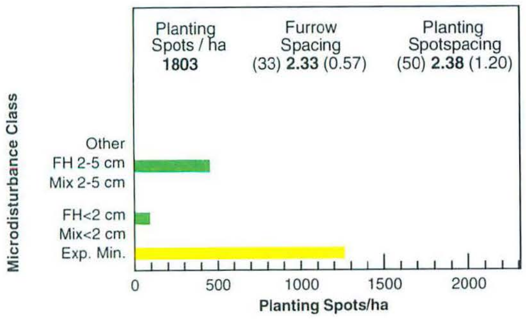
Stumps



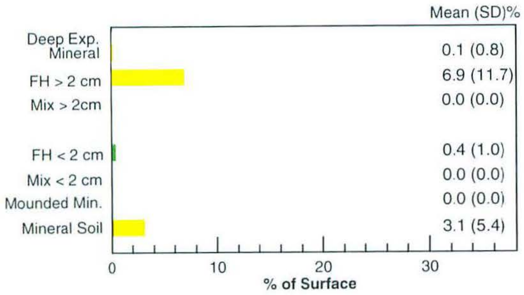
Ground Roughness



Plantability



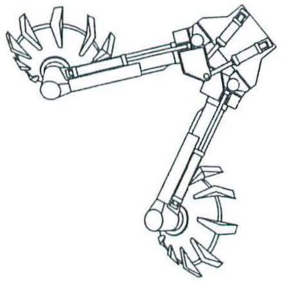
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	17	(28)
Furrow length (%), rock and/or water	25	(41)
Other surface conditions (% of surface):		
spoil bank	32	(25)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	6.3	(7.4)
rock and/or water	21.7	(28.3)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 19 August 1991
Time from site preparation to assessment: 7–9 weeks
Time from harvest to site preparation: 16–21 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	71	(30)



Implement: Donaren 180 disc trencher

Prime mover: 170-kW, 13.8-t skidder

The between-furrow mean spacing of 2.33 m was a function of an operating practice that may have been influenced by large stumps masked by *Populus* suckers and the drainage or moisture regime (i.e., reduced trafficability). About 22% of furrow length was water, increasing the in-furrow acceptable planting spot mean spacing to 2.38 m. Of the about 1800 acceptable planting spots per hectare, 1260 were in mineral soil, 90 were in organic matter ≤2 cm deep over mineral soil, and 450 were in organic matter 2–5 cm deep over mineral soil. Six competitor species were noted during a vegetation assessment on 1 June, 14–18 months after harvest. It is likely that rapid competition development will be a problem on this moist, fertile, clay loam to loam site. Fine-textured soils are not preferred by jack pine. The moist to very fresh moisture regime was acceptable for germination and establishment of spruce. Good seedbed comprised 3.5% of the surface, and 7.0% was conditional. It is unlikely that direct seeding will establish a stand that satisfies minimum conifer stocking standards; there is a potential for frost heaving on fine-textured soils, and fragile germinants will have difficulty coping with competition development and/or may be smothered by litter fall. Compare with plate sets 10, 13, and 14.

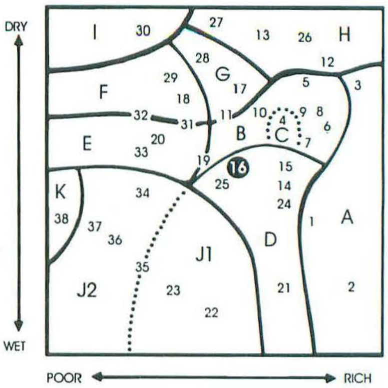
PLATE
7A

V16 Balsam Fir - White Spruce Mixedwood / Feathermoss

S3, S3, S3

FRI: $Po_7B_2Bw_1$, age 59, height 25 m, stocking 0.9, site class 1

Other site vegetation types: Balsam Fir Mixedwood



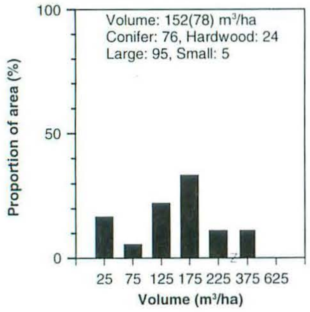
Photographed and assessed: 16 May 1991
Time elapsed since harvest: 2–7 months
Harvest method: full-tree by conventional cut and skid

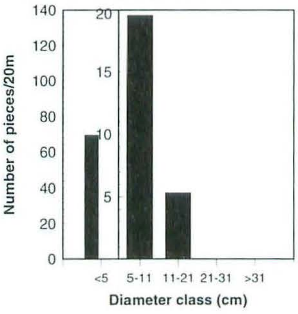
Area topography: gentle to moderate
Bedrock outcrops: none
Plot slopes: simple, 3–12%
Plot slope position: mid
Landform: ablation till
Soil depth: >100 cm

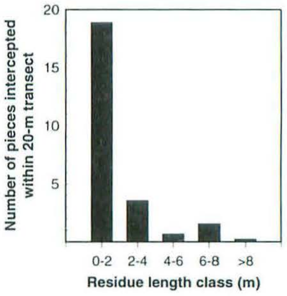
Soil texture: loamy medium sand, loamy fine sand (most common), silty very fine sand
Boulders: slight to moderate
Stones: moderate to very
Coarse fragments: 21–50%
Litter: 1–3 cm

Fermentation layer: 2–4 cm
Humus: none
Texture of surface mineral soil: fine sandy clay loam
Drainage: rapid
Moisture regime: moderately fresh

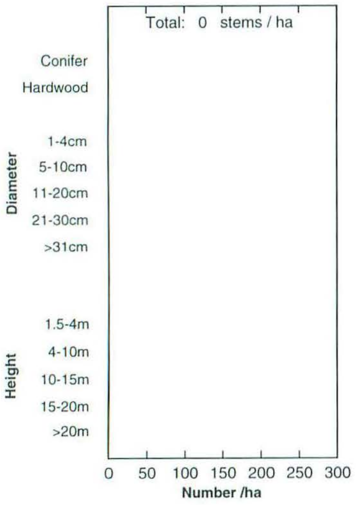
Woody Debris


Distribution Volume

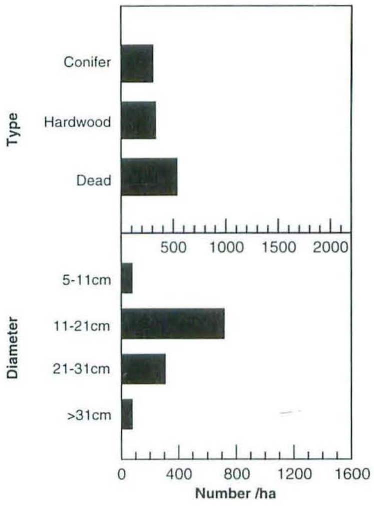

Diameter Distribution


Length

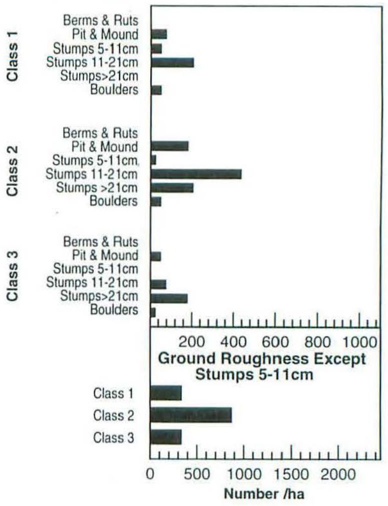
Residuals



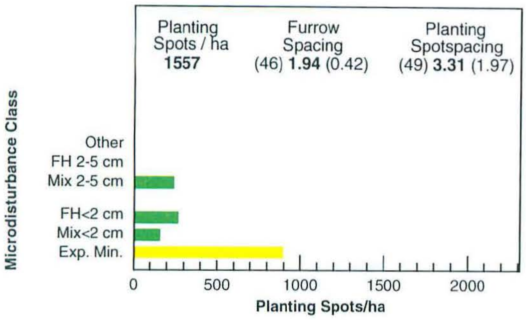
Stumps



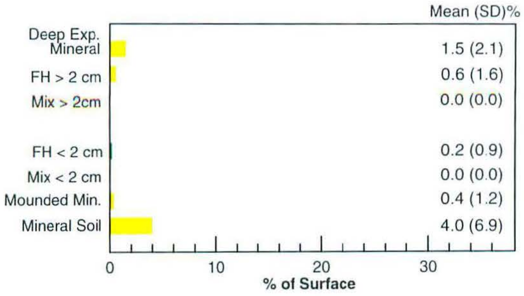
Ground Roughness



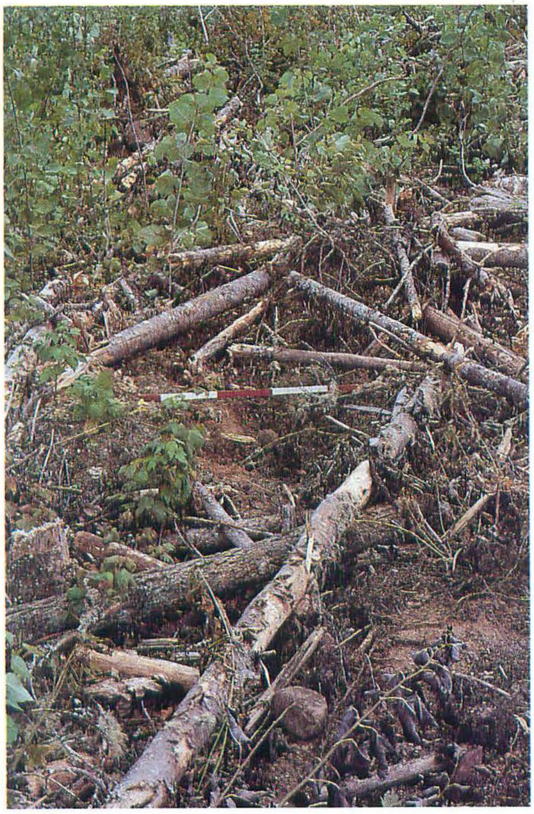
Plantability



Potential Seedbed

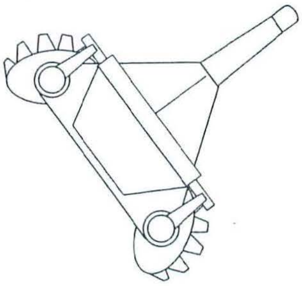


Furrow length (%), mineral soil ≥15 cm wide	35	(31)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	55	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.5	(1.9)
rock and/or water	0.5	(1.1)
shallow (<10 cm) mineral soil over organic	0.5	(1.5)



Photographed and assessed: 9–11 September 1991
Time from site preparation to assessment: 1–2 weeks
Time from harvest to site preparation: 6–11 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	1.0	(7.1)
site preparation	62	(19)



Implement: TTS–35 disc trencher

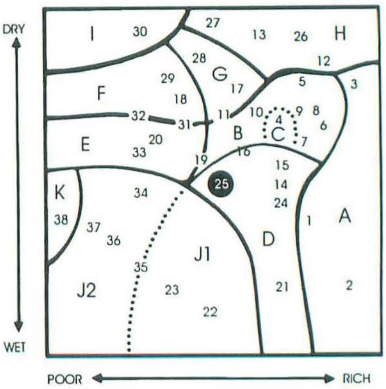
Prime mover: 107-kW, 10.5-t skidder

The moderately heavy load of woody residue and noticeable ground roughness did not prevent operating practice that gave a between-furrow mean spacing of 1.94 m. The in-furrow acceptable planting spot mean spacing was increased to 3.31 m by stone-limited shallow planting spade penetration, woody residue in the furrow, and the presence of competing vegetation. Of the approximately 1555 acceptable planting spots per hectare, 895 were in mineral soil, 420 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, and 240 were in an organic–mineral mix 2–5 cm deep over mineral soil. Four competitor species were noted during a vegetation assessment in mid-June, 3–8 months after harvest; however, the photos indicate that aspen, *Acer spicatum*, and red raspberry will be the primary competitors. Well-planted, vigorous stock adapted morphologically and physiologically for this moderately fresh site, with its very stony, fine sandy clay loam soil, may not do well (both survival and growth) against the competition development. Tending will be required. The fresh moisture regime was at the dry end of the acceptable range for seeding spruce but was attractive for seeding jack pine. Good seedbed comprised 4.6% of the surface, and 2.1% was conditional. The scarcity of seedbed, the competition, and the potential frost heaving of germinants preclude establishing a stand by seeding that will satisfy conifer stocking standards. Compare with plate sets 40 and 41.

V25 White Spruce - Balsam Fir / Feathermoss S8, S8, S8

FRI: $B_5Sw_2Bw_1Po_1Sb_1$, age 120, height 15 m, stocking 0.7, site class 2

Other site vegetation types: Black Spruce/Labrador Tea/ Feathermoss (Sphagnum), Balsam Fir Mixedwood, and White Spruce Mixedwood



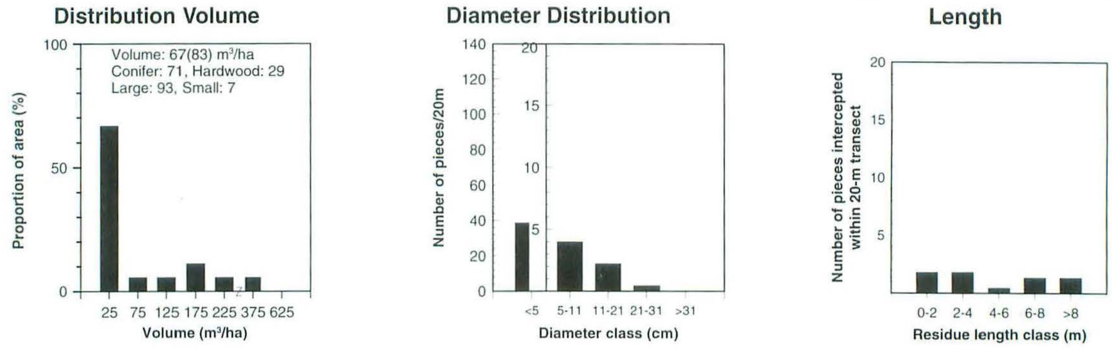
Photographed and assessed: 16 October 1990
Time elapsed since harvest: 9–12 months
Harvest method: full-tree using a Koehring feller–forwarder

Area topography: very gentle
Bedrock outcrops: none
Plot slopes: simple, 0–3%
Plot slope position: flat (plateau)
Landform: ground moraine
Soil depth: >100 cm

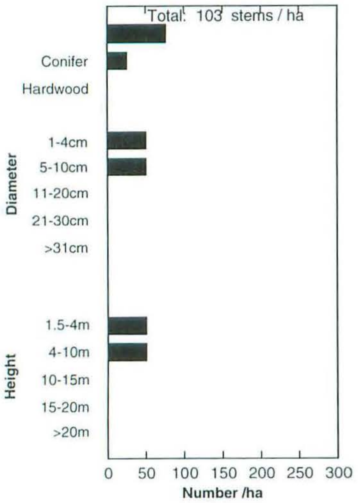
Soil texture: silty fine sand (uniformly)
Boulders: slight
Stones: slight
Coarse fragments: 6–20%
Litter: 1–4 cm

Fermentation layer: 6–10 cm
Humus: 2–3 cm
Texture of surface mineral soil: sandy loam
Drainage: moderately well (most common) to imperfect
Moisture regime: moderately moist (most common) to moist

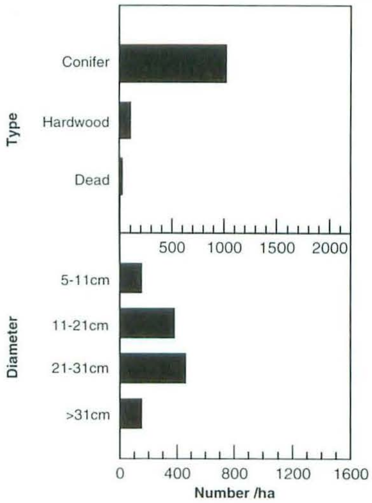
Woody Debris



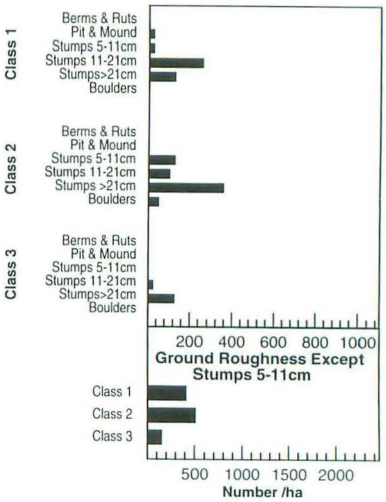
Residuals



Stumps

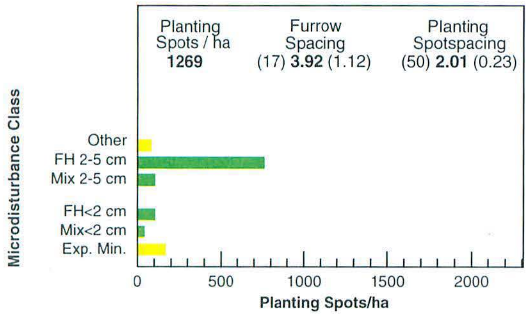


Ground Roughness

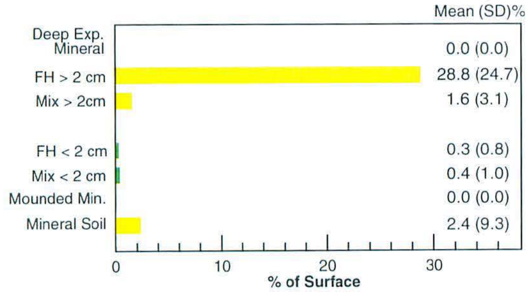


Screefing

Plantability



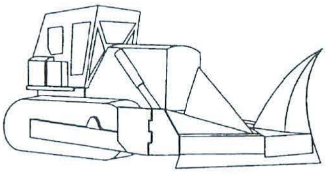
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	6	(19)
Furrow length (%), rock and/or water	1	(4)
Other surface conditions (% of surface):		
spoil bank	33	(29)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.9	(10.1)
rock and/or water	1.2	(3.2)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 9 July 1991
Time from site preparation to assessment: 7–8 months
Time from harvest to site preparation: 10–13 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	2.0	(6.9)
site preparation	73	(31)



Implement: Cazes and Heppner plow (highly modified)

Prime mover: 160-kW, 22.8-t bulldozer

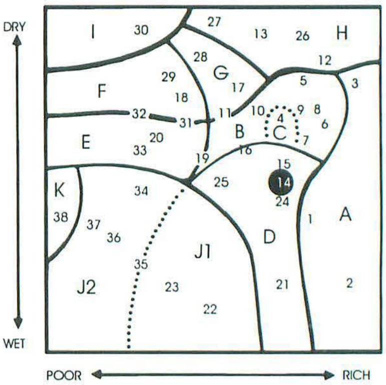
This prescription's goal was minimal exposure of mineral soil with sufficient duff removal and improved access to facilitate planting. The scarified strip center-to-center mean spacing of 3.92 m was a function of operating practice. Field notes indicate that acceptable planting spots were created by "easy boot screefing" to give an in-row planting spot mean spacing of 2.01 m. Of the approximately 1270 acceptable planting spots per hectare, 170 were in mineral soil, 150 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 865 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 85 were in other acceptable conditions. However, by staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots could be increased to 1800–2100/ha. Six competitor species were noted during a vegetation assessment on 16 October, 9–12 months after harvest. Although this prescription may minimize both planting check and frost heaving and promote both the establishment and vigorous growth of planted seedlings, it may also encourage rapid and vigorous competition development, particularly grass and alder. The moisture regime was adequate for the establishment of spruce by direct seeding but is too wet for jack pine to thrive. Good seedbed comprised 3.1% of the surface, and 30.4% was conditional. Owing to the scarcity of good seedbed and the inability of fragile germinants to cope with competition development and/or smothering by litter, it is unlikely that direct seeding will produce a stand that satisfies conifer stocking standards. Compare with plate sets 3 and 14.

PLATE
9A

V14 Balsam Fir Mixedwood S2, S2, S2

FRI: $B_5Sw_2Bw_1Po_1Sb_1$, age 120, height 15 m, stocking 0.7, site class 2

Other site vegetation types: White Spruce–Balsam Fir/ Shrub Rich, Trembling Aspen–Black Spruce–Jack Pine/ Low Shrub



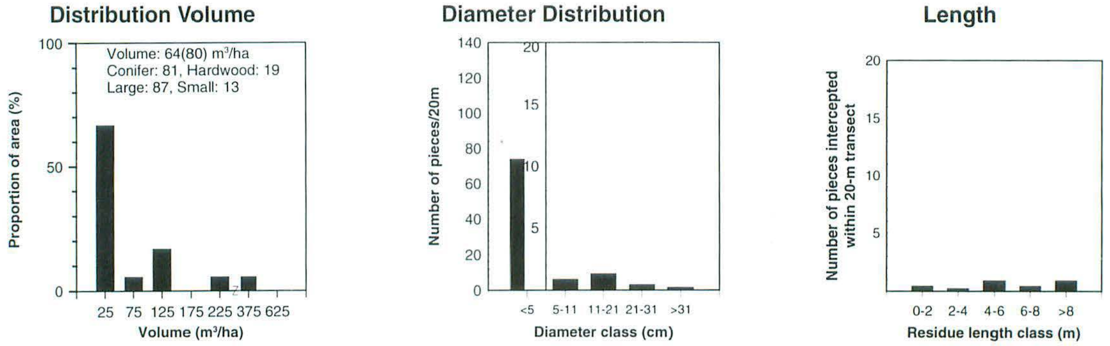
Photographed and assessed: 17 October 1990
Time elapsed since harvest: 10–13 months
Harvest method: full-tree with a Koehring feller–forwarder

Area topography: gentle (plateau)
Bedrock outcrops: none
Plot slopes: simple, 2–5%
Plot slope position: lower
Landform: ground moraine
Soil depth: >100 cm

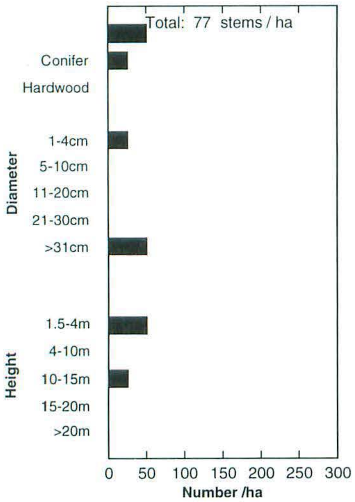
Soil texture: fine sand
Boulders: slight to moderate
Stones: none to slight
Coarse fragments: 6–35%
Litter: 2–3 cm

Fermentation layer: 2–4 cm
Humus: 2–4 cm
Texture of surface mineral soil: sandy loam
Drainage: rapid
Moisture regime: fresh

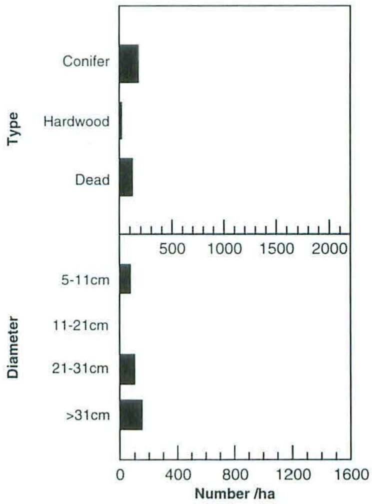
Woody Debris



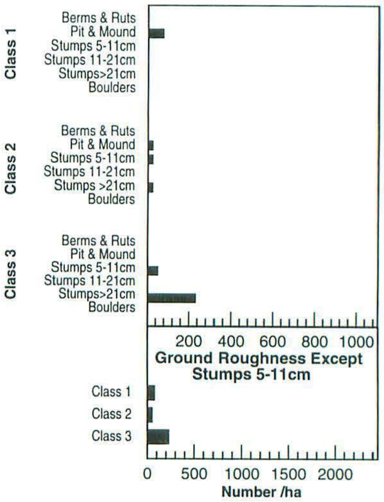
Residuals



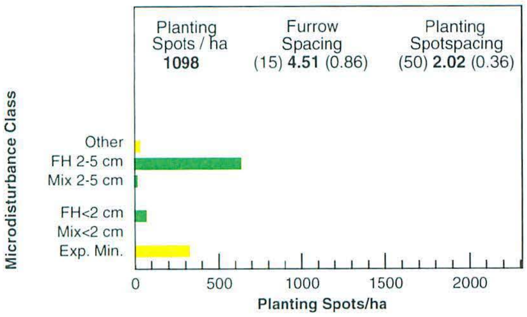
Stumps



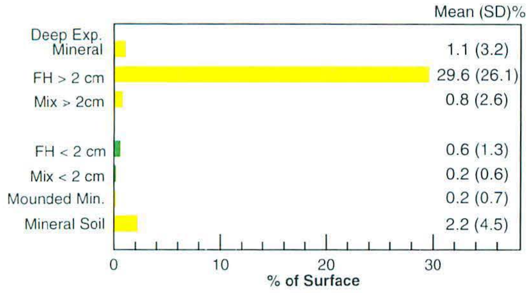
Ground Roughness



Plantability



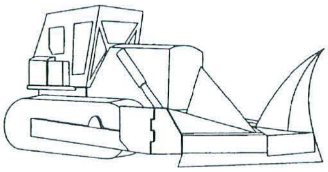
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	15	(27)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	29	(25)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.4	(8.5)
rock and/or water	0.4	(0.9)
shallow (<10 cm) mineral soil over organic	0.4	(2.2)

Photographed and assessed: 10 July 1991
Time from site preparation to assessment: 7–8 months
Time from harvest to site preparation: 11–14 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	69	(31)



Implement: Cazes and Heppner plow (highly modified)

Prime mover: 160-kW, 22.8-t bulldozer

This prescription's goal was minimal exposure of mineral soil with sufficient duff removal and improved access to facilitate planting. The scarified strip center-to-center mean spacing of 4.51 m was a function of operating practice on a site with large stumps, residuals, a moderately light (occasionally very heavy) loading of woody residue, and a well-developed residual shrub layer plus woody regrowth. Field notes indicated that acceptable planting spots were created by "easy boot screefing" to give a mean in-row acceptable planting spot distance of 2.02 m. Of the approximately 1100 acceptable planting spots per hectare noted, 330 were in mineral soil, 75 were in organic matter ≤2 cm deep over mineral soil, 660 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 35 were in other acceptable conditions. However, by staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots can be increased to 1500–1800/ha. Three competitor species were noted during a vegetation assessment on 17 October, 10–13 months after harvest. Although this prescription may minimize both planting check and frost heaving, it has not controlled abundant existing competitors and may enhance competition. Good seedbed comprised 3.2% of the surface, and 31.5% was conditional. Although the fresh moisture regime was adequate for seeding spruce and optimal for seeding jack pine, both existing and potential competition plus a scarcity of good seedbed preclude establishing a stand by seeding that will satisfy conifer stocking standards. Compare with plate sets 5, 14, 19, 37, and 40.

Treatment Units B and C

Treatment Unit B: Aspen Hardwood and Mixedwood

Stands range from pure aspen to aspen mixed with white birch, balsam fir, jack pine, black spruce, or white spruce. The understory is usually productive, with a dense, tall and low shrub layer.

Phase B1: Dry–fresh soils
Phase B2: Moist soils

Treatment Unit C: White Birch Hardwood and Mixedwood

Stands are typically dominated by white birch, with varying degrees of white spruce, balsam fir, black spruce, jack pine, and, occasionally, trembling aspen. These stands vary from shrub rich to relatively shrub poor.

Equipment trafficability

Phase B2 clayey and fine loamy soils are susceptible to compaction and erosion. Excessive slash from limbs or unmerchantable trees may hinder efforts to expose mineral soil through mechanical site preparation. On Treatment Unit C conditions, site preparation may be limited by coarse fragments and boulders on talus slopes or morainal deposits.

Competition

Very heavy competition can be expected in phase B2, requiring more effort to establish crop trees in a stand conversion program. According to Walsh and Krishka (1991), in a study of early stand development following harvesting in northwestern Ontario, potential competitors of concern are *Corylus cornuta, Populus tremuloides, Diervilla lonicera, Rubus idaeus, Aster macrophyllus,* and grasses.

Summary

A summary of Treatment Units B and C is presented in Table 4.

Eight plots from Treatment Unit B (plate sets 10–17) and three plots from Treatment Unit C (plate sets 18–20) were sampled. The number (diversity) of competitor species noted ranged from 4 to 10, and 8 of the plots had 8 or more competitor species present. Many of the photographs also suggest an abundance of competitor species.

The plot represented by plate set 10 had negligible impediments to site preparation by heavy equipment. The Donaren 180 disc trencher mounted on a 170-kW, 13.8-t skidder produced 2540 acceptable planting spots per hectare, 10.0% mineral soil exposure, 4.1% organic and/or organic–mineral mix ≤2 cm deep, and 16.8% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 11 had approximately 125 residuals >10 cm in diameter per hectare and a heavy loading of woody residue. The heavy drag drawn by a 239-kW, 33.7-t bulldozer produced 2317 acceptable planting spots per hectare, 8.2% mineral soil exposure, 2.0% organic and/or organic–mineral mix ≤2 cm deep, and 12.6% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 12 had moderately deep soil, gentle to moderate topography, gentle plot slopes, rock outcrops 25–75 m apart, larger stumps giving approximately 600 ground roughness class 2 and 3 obstacles per hectare, and a moderate loading of woody residue. The Silva Wadell powered cone scarifier on a 104-kW, 14.5-t skidder produced 2168 acceptable planting spots per hectare, 9.4% mineral soil exposure, 2.4% organic and/or organic–mineral mix ≤2 cm deep, and 4.1% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 13 had larger stumps that gave about 675 ground roughness class 2 and 3 obstacles per hectare, about 55 residuals >10 cm in diameter per hectare, and a moderately light loading of woody residue. The TTS Delta (power) disc trencher on a 123-kW, 15.4-t skidder produced 2116 acceptable planting spots per hectare, 9.3% mineral soil exposure, 1.5% organic and/or organic–mineral mix ≤2 cm deep, and 1.4% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 14 had shallow to deep soil, gentle to steep topography, very gentle plot slopes, rock outcrops >75 m apart, stones and boulders 10–30 m apart, about 100 residuals >10 cm in diameter per hectare, and a moderate loading of woody residue. A Donaren 180 disc trencher on a 186.5-kW, 25-t skidder produced 2085 acceptable planting spots per hectare, 5.6% mineral soil exposure, 1.5% organic and/or organic–mineral mix ≤2 cm deep, and 9.0% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 15 had shallow to moderately deep soil, gentle to strong (some ledges) topography, gentle plot slopes, rock outcrops 25–75 m apart, stones <2 m apart, about 250 residuals >10 cm in diameter per hectare, and a light loading of woody residue. A Donaren 180 disc trencher on a 186.5-kW, 25-t skidder produced 1709 acceptable planting spots per hectare, 5.2% mineral soil exposure, 1.2% organic and/or organic–mineral mix ≤2 cm deep, and 7.4% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 16 had discontinuous, shallow to moderately shallow mineral soil, gentle to moderate topography, moderate plot slopes, rock outcrops 25–75 m apart, stones 2–10 m apart, about 250 residuals >10 cm in diameter per hectare, and a light loading of woody residue. A Donaren 180 disc trencher on a 186.5-kW, 25-t skidder produced 1683 acceptable planting spots per hectare, 2.7% mineral soil exposure, 1.3% organic and/or organic–mineral mix ≤2 cm deep, and 6.3% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 17 had deep mineral soil, nearly level to moderate topography, nearly level plot slopes, rock outcrops 25–75 m apart, stones varying from <2 to ≤10 m apart that, when combined with stumps, gave about 600 ground roughness class 2 and 3 obstacles per hectare, about 145 residuals >10 cm in diameter per hectare, and a heavy loading of woody residue. A Bräcke 3-row with the mattocks set 2.0 m apart on the drawbar and machine set to make scalps more than 2 m apart drawn by a 152-kW, 13.3-t skidder produced 1343 acceptable planting spots per hectare, 1.2% mineral soil exposure, 0.7% organic and/or organic–mineral mix ≤2 cm deep, and 6.3% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 18 had moderately deep to deep mineral soil, very gentle to gentle slopes, rock outcrops >75 m apart, stones 10–30 m apart, and a light loading of woody residue. The Bräcke 2-row (Herbicider) with mattocks 2.0 m apart on the drawbar and machine set to make scalps at 2-m intervals drawn by a 107-kW, 10.5-t skidder produced 2249 acceptable planting spots per hectare, 3.0% mineral soil exposure, 1.2% organic and/or organic–mineral mix ≤2 cm deep, and 9.6% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 19 had moderately shallow to deep mineral soil, gentle to strong topography, gentle to moderate plot slopes, boulders and stones 2–10 m apart that, combined with stumps, gave about 600 ground roughness class 2 and 3 obstacles per hectare, and a light loading of woody residue 5–6 years old. Young's utility dozer teeth on a 224-kW, 31-t bulldozer produced 1929 acceptable planting spots per hectare, 16.2% mineral soil exposure, 1.5% organic and/or organic–mineral mix ≤2 cm deep, and 13.4% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 20 had deep mineral soil, nearly level to gentle topography, very gentle plot slopes, larger birch stumps and stump clusters that gave about 725 ground roughness class 2 and 3 obstacles per hectare, about 80 residuals >10 cm in diameter per hectare, and a moderately light to moderate loading of woody residue. A TTS–35 disc trencher drawn by a 107-kW, 10.5-t skidder produced 1483 acceptable planting spots per hectare, 8.9% mineral soil exposure, 0.7% organic and/or organic–mineral mix ≤2 cm deep, and 2.1% organic and/or organic–mineral mix >2 cm deep.

Table 4. Data from plate sets for Treatment Units B and C ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
10	2540	69	10.0	4.1	16.8	7–10	>100	g	1–4	0	0
11	2317	52	8.2	2.0	12.6	8–16	80–>100	g	2–4	0	S
12	2168	42	9.4	2.4	4.1	5–10	38–90	g→m	1–6	S	0
13	2116	46	9.3	1.5	1.4	6–10	95–>100	g→m	0–1	0	0
14	2085	38	5.6	1.5	9.0	5–6	35–>100	g→ste	2–4	0	S
15	1709	35	5.2	1.2	7.4	5–6	25–70	g→str	7–8	S	X→S
16	1683	32	2.7	1.3	6.3	7–9	0–55	g→m	11	S	M
17	1343	20	1.2	0.7	6.3	8–14	>100	g→m	1–2	S	V→E
18	2249	33	3.0	1.2	9.6	5–11	50–>100	g	2–5	0	S
19	1929	58	16.2	1.5	13.4	5–9	40–>100	g→str	6–21	0	M→S
20	1483	51	8.9	0.7	2.1	5–13	>100	g	1–3	0	0

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
275	99	16–20	7	**vF**, M	SiL→SiC	V-9 (B)	1.93	2.04	170	13.8	Don180	10
250	173	12–13	8	**mM** (vM →mD)	**mS**, cS	V-11 (B)	2.18	1.98	239	33.7	drag (H)	11
600	122	24–25	4	vF (mF→ mM)	SifS, SivfS	V-11 (B)	1.98	2.33	104	14.5	Wadell	12
675	59	22–24	8	F	C	V-19 (B)	2.10	2.25	123	15.4	TTS (pow)	13
250	104	23–26	9	**M**→mD	SiC, SL	V-9 (B)	2.22	2.16	186.5	25	Don180	14
475	34	18–20	9	mF	SL, LvfS	V-5 (B)	2.50	2.34	186.5	25	Don180	15
425	48	16–18	9	mF→D	absent→L	V-6 (B)	2.10	2.83	186.5	25	Don180	16
600	184	1–1.5	5	mF	LmS	V-8 (B)	2.25	3.31	152	13.3	Bräcke	17
175	36	16–20	8	vF→mF →D	gSifS, SiL	V-4 (C)	2.03	2.19	107	10.5	Bräcke	18
600	50	66–70	8	**mF** (mD →vF)	LvfS, SiL	V-4 (C)	2.09	2.48	224	31	Y-teeth	19
725	100	17–24	10	mD→vF	vgcS, mS, SimS	V-4 (C)	2.40	2.81	107	10.5	TTS-35	20

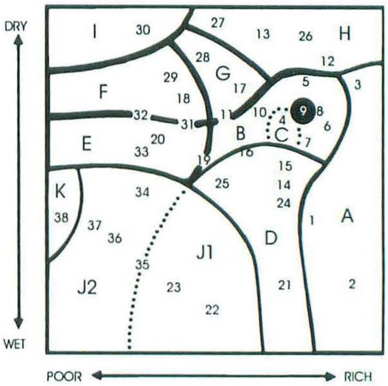
PLATE
10A

V9 Trembling Aspen Mixedwood

S6, S6, S10

FRI: $Po_5Bw_3B_1Sb_1$, age 69, height 18 m, stocking 0.4, site class 3

Other site vegetation types: none locally



Photographed and assessed: 31 May 1991
Time elapsed since harvest: 14–18 months
Harvest method: conventional tree-length during the winter

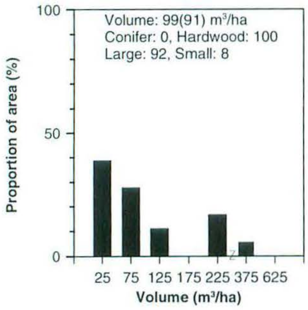
Area topography: gently rolling
Bedrock outcrops: none
Plot slopes: simple, 1–4%
Plot slope position: toe slope to flat
Landform: glaciolacustrine deposit
Soil depth: >100 cm

Soil texture: loam to clay
Boulders: none
Stones: none
Coarse fragments: none
Litter: 2–3 cm

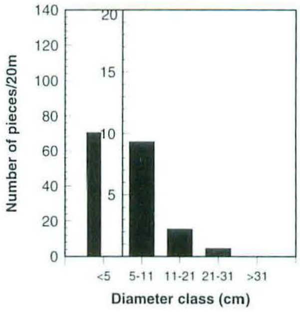
Fermentation layer: 5–6 cm
Humus: trace to 1 cm
Texture of surface mineral soil: silty loam to silty clay
Drainage: moderately well to imperfect
Moisture regime: very fresh (most common) with moist

Woody Debris

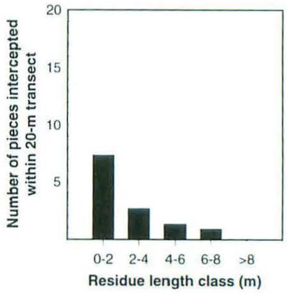
Distribution Volume



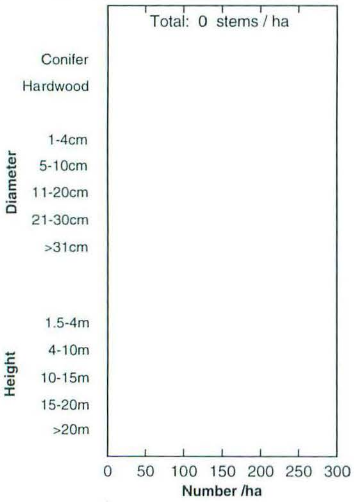
Diameter Distribution



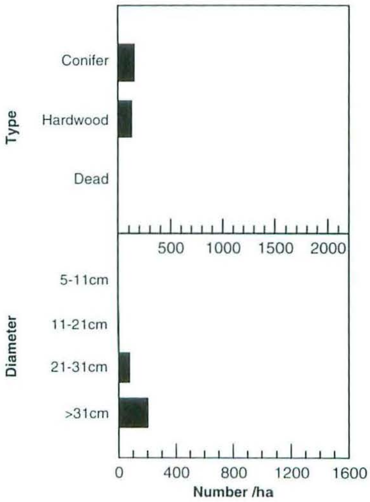
Length



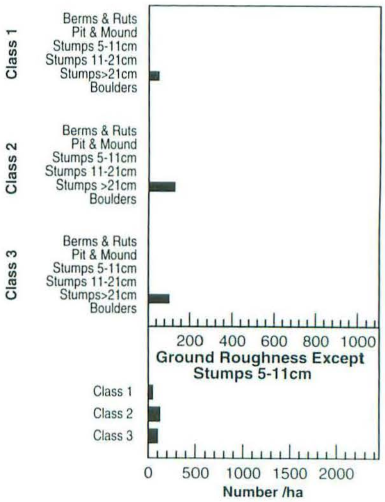
Residuals



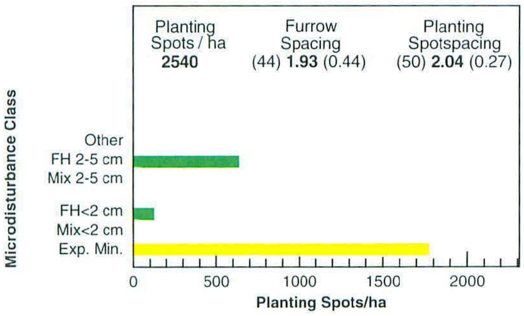
Stumps



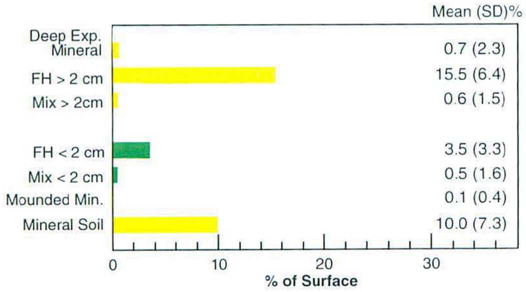
Ground Roughness



Plantability



Potential Seedbed



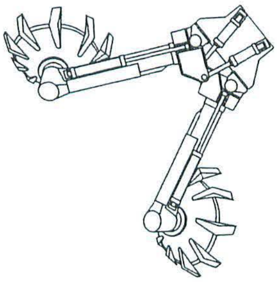
Furrow length (%), mineral soil ≥15 cm wide	69	(34)
Furrow length (%), rock and/or water	0	(1)

Other surface conditions (% of surface):

spoil bank	33	(23)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.0	(3.6)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 28 July 1991
Time from site preparation to assessment: 4–6 weeks
Time from harvest to site preparation: 16–20 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	67	(24)



Implement: Donaren 180 disc trencher

Prime mover: 170-kW, 13.8-t skidder

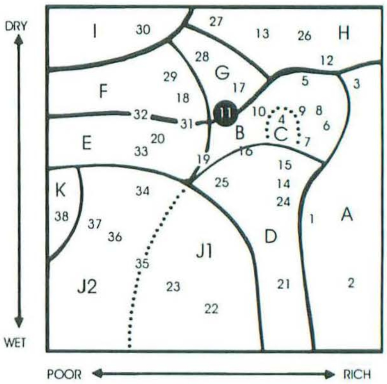
The between-furrow mean spacing of 1.93 m was a function of operating practice on a site with large stumps and a moderately light to moderate (but occasionally very heavy) loading of woody residue. The in-furrow acceptable planting spot mean spacing was 2.04 m. Of the 2540 acceptable planting spots per hectare, 1780 were in mineral soil, 125 were in organic matter ≤2 cm deep over mineral soil, and 635 were in organic matter 2–5 cm deep over mineral soil. Seven competitor species were noted during a vegetation assessment on 31 May, 14–18 months after harvest. Well-planted, vigorous stock adapted morphologically and physiologically for this fertile site with fine-textured, very fresh to moist soil will have difficulty coping with the competition development within 3–5 years. The moisture regime was attractive for seeding spruce but tends to be too wet for jack pine. Good seedbed comprised 14.1% of the surface, and 16.8% of the surface was conditional. However, it is unlikely that direct seeding will establish a stand that satisfies conifer stocking standards because of potential frost heaving of germinants on finer-textured soil and because fragile germinants may not cope with competition development and/or smothering from litter fall. Compare with plate sets 3, 13, 18, and 21.

PLATE
11A

V11 Trembling Aspen – Conifer / Blueberry / Feathermoss S10, SS5, SS8

FRI: $Sb_6Po_1Bw_1B_1Pj_1$, age 130, height 20 m, stocking 0.5, site class 1

Other site vegetation types: Black Spruce Mixedwood/ Feathermoss and Black Spruce/Labrador Tea/Feathermoss (Sphagnum)



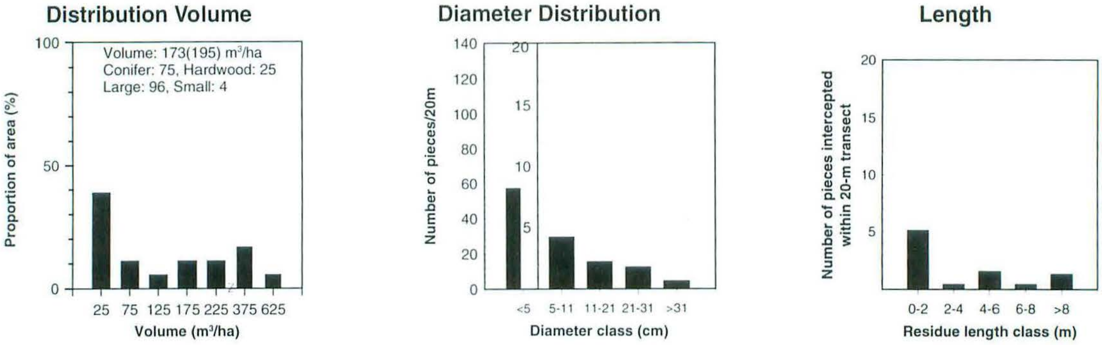
Photographed and assessed: 29 August 1990
Time elapsed since harvest: 2–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 2–4%
Plot slope position: lower
Landform: glaciofluvial deposit
Soil depth: 80–>100 cm

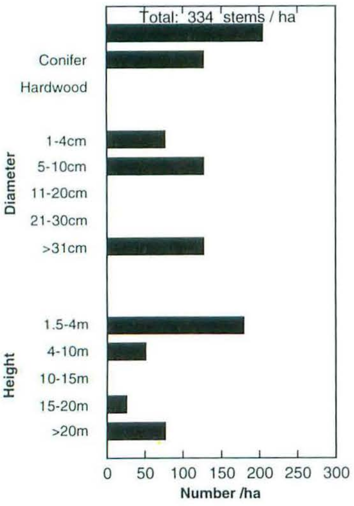
Soil texture: clay loam and medium sand, coarse sand, very coarse sand (soil stratified)
Boulders: none
Stones: slight
Coarse fragments: 0–50%
Litter: 2–5 cm

Fermentation layer: 5–7 cm
Humus: 1–4 cm
Texture of surface mineral soil: medium sand more common than coarse sand
Drainage: imperfect to rapid
Moisture regime: moderately moist (very moist to moderately dry)

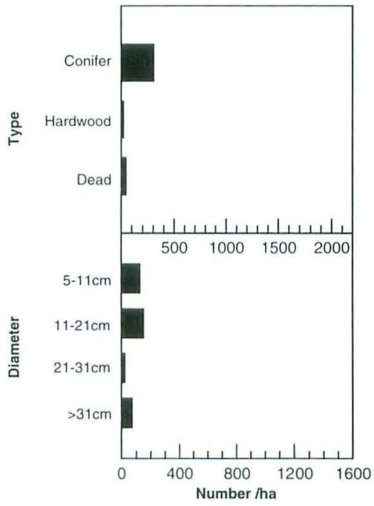
Woody Debris



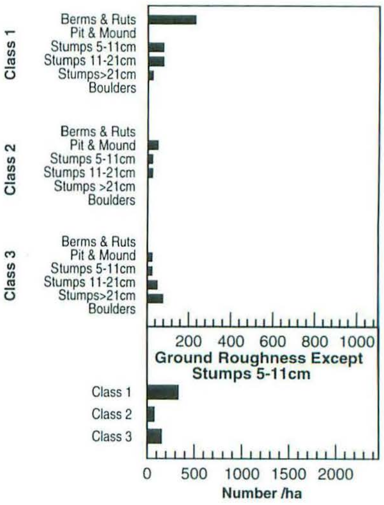
Residuals



Stumps

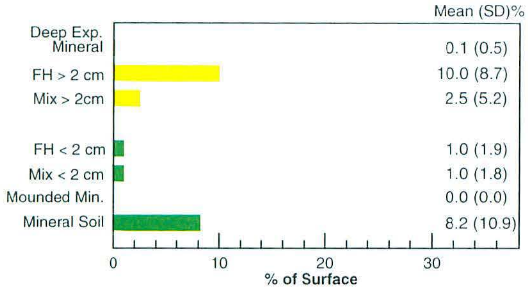


Ground Roughness

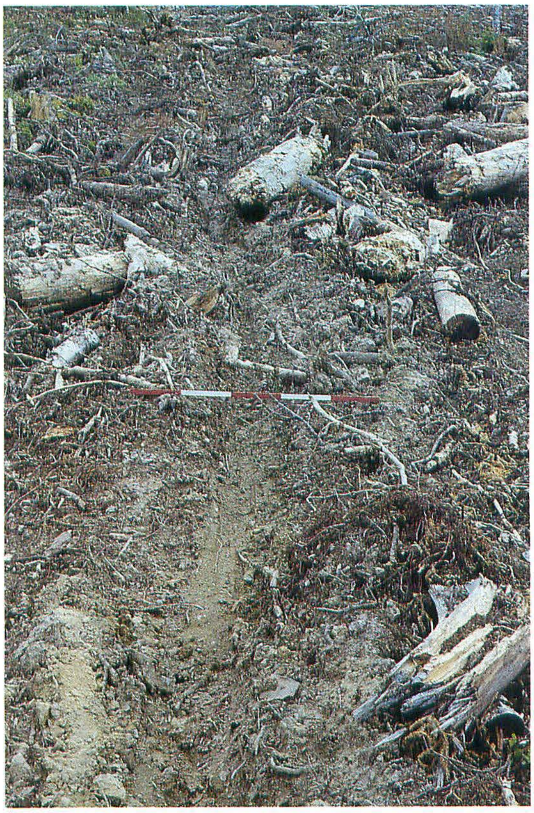


Plantability

Potential Seedbed

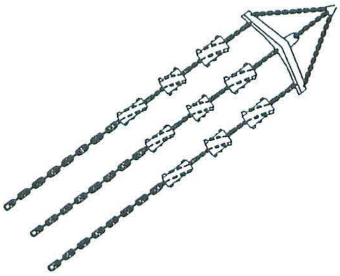


Furrow length (%), mineral soil ≥15 cm wide	52	(41)
Furrow length (%), rock and/or water	20	(35)
Other surface conditions (% of surface):		
spoil bank	41	(27)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.9	(6.8)
rock and/or water	6.4	(12.0)
shallow (<10 cm) mineral soil over organic	0	(0)



Photographed and assessed: 31 July 1991
Time from site preparation to assessment: 3–6 weeks
Time from harvest to site preparation: 12–13 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	9.4	(21.7)
site preparation	74	(32)



Implement: heavy drags

Prime mover: 239-kW, 33.7-t bulldozer

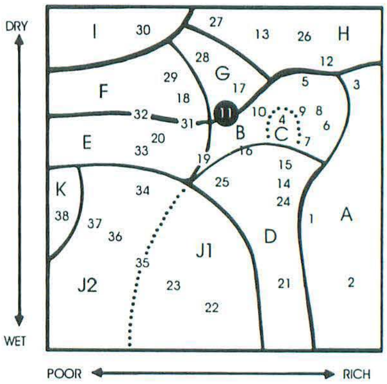
The between-furrow mean spacing of 2.18 m was a function of operating practice on a site with a moderately heavy loading of woody residue (about 22% of the surface had a very heavy loading) and scattered residuals. The in-furrow acceptable planting spot mean spacing was 1.98 m. Of the approximately 2315 acceptable planting spots per hectare, 1585 were in mineral soil, 190 were in organic matter ≤2 cm deep over mineral soil, 465 were in organic matter 2–5 cm deep over mineral soil, and 75 were in other acceptable conditions. Eight competitor species were noted during a vegetation assessment on 29 August, 2–3 months after harvest. Well-planted, vigorous (white) spruce stock adapted morphologically and physiologically for this very moist to moderately dry site may, depending on abundance and vigor of aspen and/or graminoid development, cope with the competition. Portions of the site mosaic were too moist for jack pine seeding, and portions were too dry for black spruce seeding, with the remainder suitable for both species. Good seedbed comprised 10.2% of the surface area, and 12.6% was conditional. However, even at uneconomic application rates, direct seeding is unlikely to produce a stand that satisfies stocking standards; fragile germinants may not be able to cope with the competition development and/or may be smothered by litter fall. Compare with plate sets 2, 21, 22, 24, and 26.

PLATE
12A

V11 Trembling Aspen – Conifer / Blueberry / Feathermoss SS7, SS8, SS8

FRI: $Sb_8Pj_1Po_1$, age 100, height 18 m, stocking 0.8, site class 2

Other site vegetation types: Jack Pine–Black Spruce/Blueberry/Lichen and Black Spruce Mixedwood



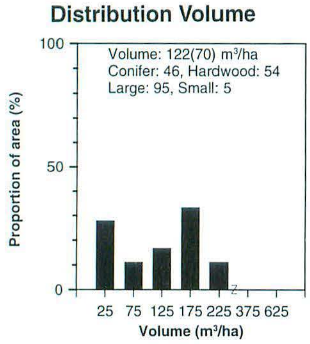
Photographed and assessed: 29 May 1991
Time elapsed since harvest: about 21 months
Harvest method: full-tree by feller–buncher

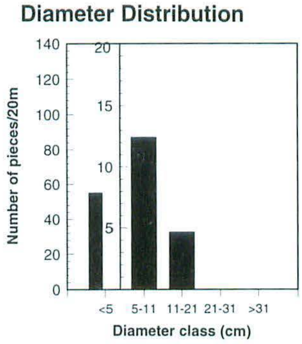
Area topography: gentle to moderate
Bedrock outcrops: about 1% of area
Plot slopes: simple, 1–6%
Plot slope position: middle
Landform: glaciolacustrine deposit
Soil depth: 38, 63, and 90 cm

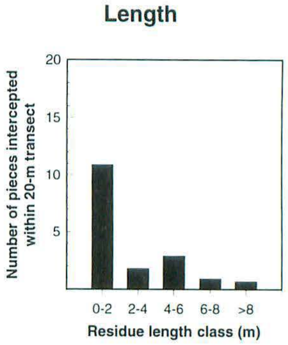
Soil texture: silty loam, silty fine sand, and silty clay (soil stratified)
Boulders: none (occasional in area)
Stones: none
Coarse fragments: 10–50%
Litter: 2–4 cm

Fermentation layer: 3–6 cm
Humus: none
Texture of surface mineral soil: silty fine sand and silty very fine sand
Drainage: moderately well (rapid to imperfect)
Moisture regime: very fresh (moderately fresh to moderately moist)

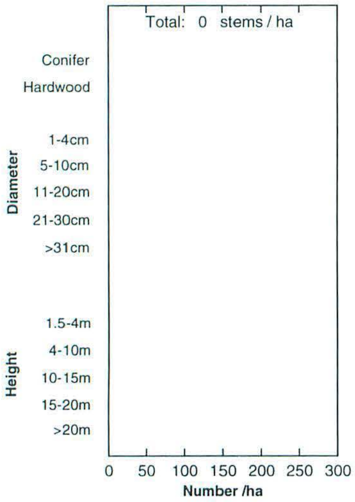
Woody Debris



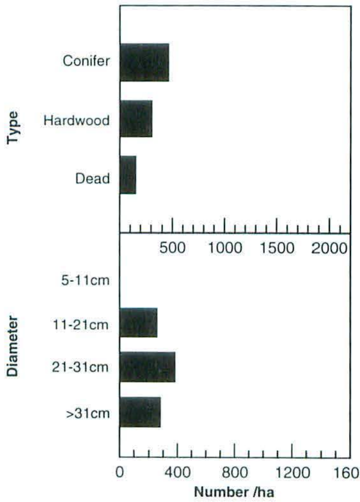




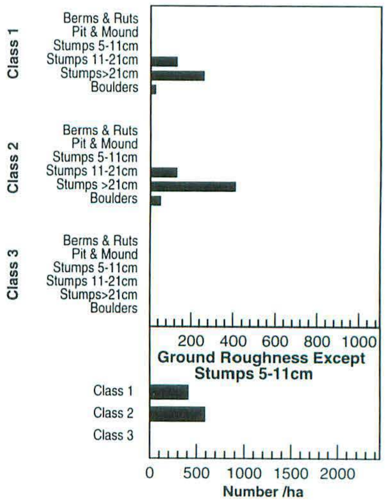
Residuals

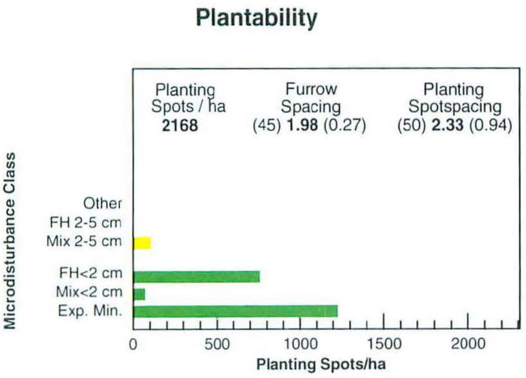


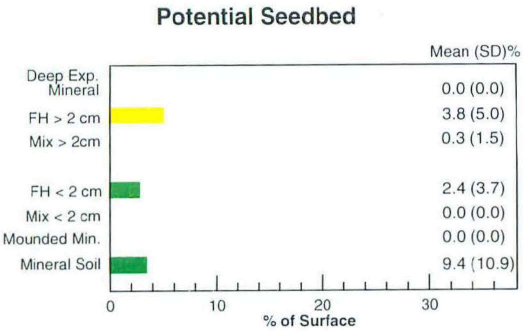
Stumps



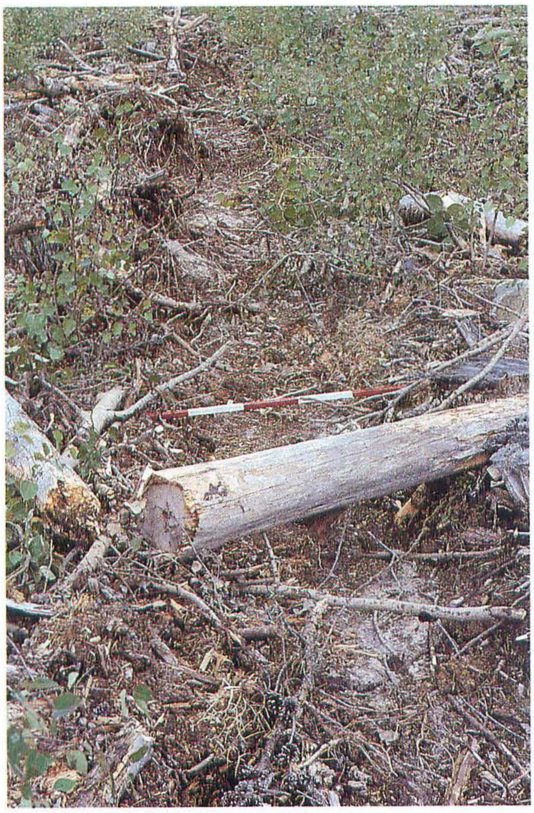
Ground Roughness




Plantability

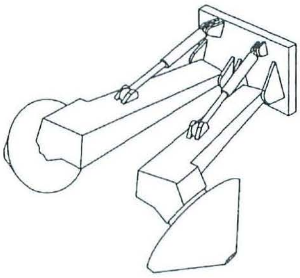

Potential Seedbed

Furrow length (%), mineral soil ≥15 cm wide	42	(40)
Furrow length (%), rock and/or water	3	(13)
Other surface conditions (% of surface):		
spoil bank	55	(22)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.5	(4.9)
rock and/or water	1.6	(7.5)
shallow (<10 cm) mineral soil over organic	0	(0)



Photographed and assessed: 8 September 1991
Time from site preparation to assessment: 2–5 weeks
Time from harvest to site preparation: 24–25 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	1.0	(5.3)
site preparation	71	(19)



Implement: Silva Wadell powered cone scarifier

Prime mover: 104-kW, 14.5-t skidder

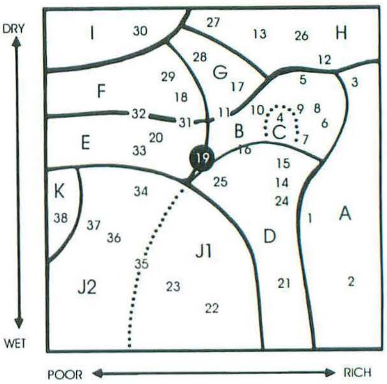
The between-furrow mean spacing of 1.98 m was a function of operating practice. The in-furrow acceptable planting spot spacing of 2.33 m resulted from the 3% of furrow length that was either naturally or machine-exposed rock, in-furrow woody residue, and shallow soil. Of the approximately 2170 acceptable planting spots per hectare, 1230 were in mineral soil, 830 were in an organic–mineral mix or in organic matter ≤2 cm deep over mineral soil, and 110 were in an organic–mineral mix 2–5 cm deep over mineral soil. Four competitor species were noted during a vegetation assessment on 29 May, about 21 months after harvest. Well-planted, vigorous (white) spruce stock adapted morphologically and physiologically for this site may, depending on abundance and vigor of aspen and/or graminoid development, cope with the competition on this fertile site. The moderately fresh to moderately moist moisture regime is acceptable for seeding spruce and is toward the wet end of the acceptable range for jack pine. Although good seedbed comprised 11.8% of the surface and 4.1% was conditional, it is unlikely that direct seeding, even at uneconomic rates of seed application, will produce a stand that satisfies conifer stocking standards because of potential frost heaving on fine-textured soils; also, fragile germinants may fail to cope with the competition development and/or smothering by litter. Compare with plate sets 3, 4, 14, and 18.

PLATE
13A

V19 Black Spruce Mixedwood / Herb Rich SS7, S6, S6

FRI: $Sb_6Po_3Pj_1$, age 110, height 15 m, stocking 0.7, site class 2

Other site vegetation types: Jack Pine Mixedwood/ Shrub Rich and Trembling Aspen–Black Spruce–Jack Pine/Low Shrub



Photographed and assessed: 1 October 1990
Time elapsed since harvest: 11–14 months
Harvest method: full-tree by feller–buncher and grapple skidder

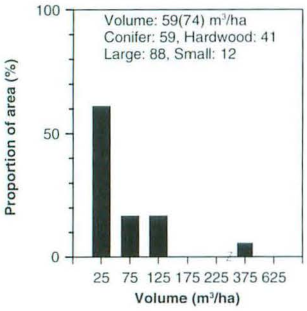
Area topography: gentle to moderate
Bedrock outcrops: >75 m apart
Plot slopes: simple, 0–1%
Plot slope position: flat
Landform: lacustrine deposit
Soil depth: 95, 103, and >100 cm

Soil texture: clay, occasionally fine sand
Boulders: none
Stones: none
Coarse fragments: none
Litter: 2 cm

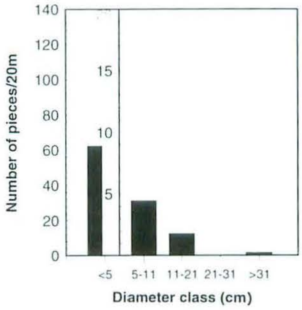
Fermentation layer: 3–6 cm
Humus: 1–2 cm
Texture of surface mineral soil: clay
Drainage: moderately well (uniformly)
Moisture regime: fresh (uniformly)

Woody Debris

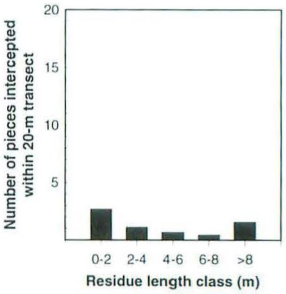
Distribution Volume



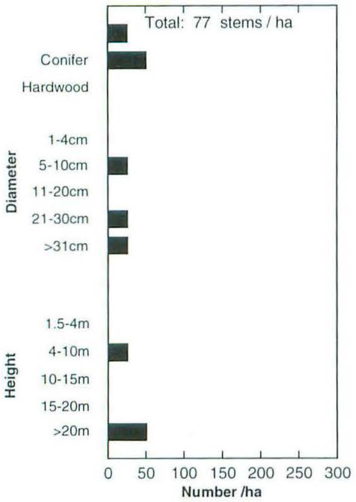
Diameter Distribution



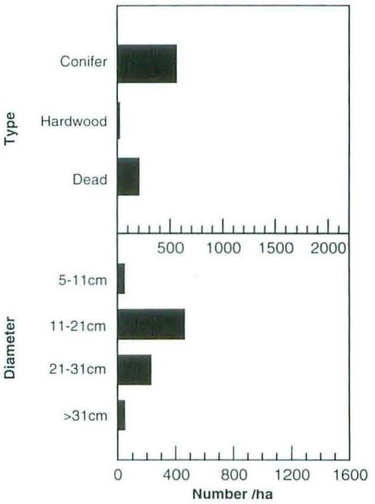
Length



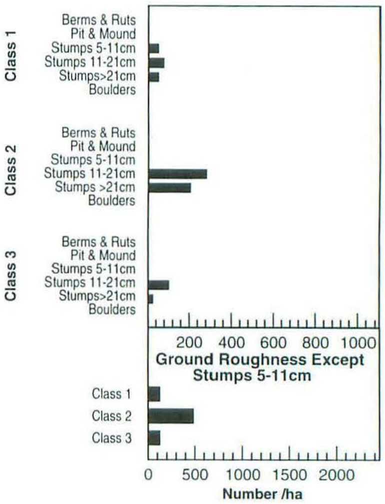
Residuals



Stumps

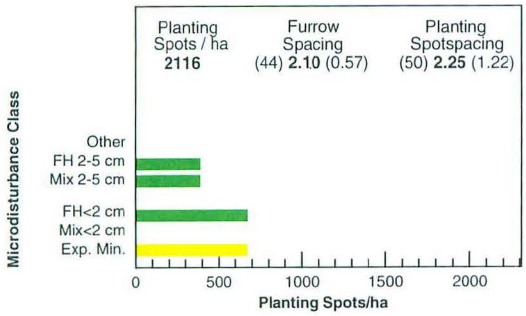


Ground Roughness

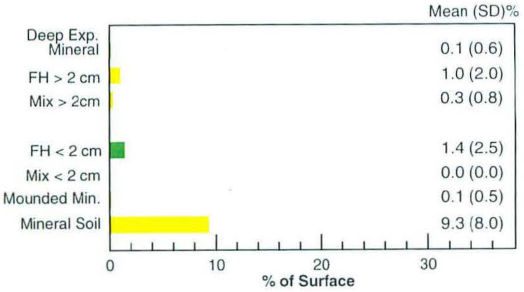


Trenching

Plantability



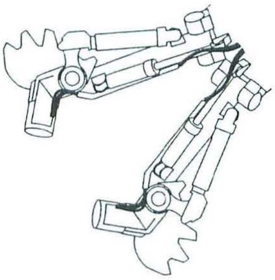
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	46	(34)
Furrow length (%), rock and/or water	5	(12)
Other surface conditions (% of surface):		
spoil bank	36	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	10.1	(16.6)
rock and/or water	2.9	(8.7)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 10 October 1991
Time from site preparation to assessment: 4–9 weeks
Time from harvest to site preparation: 22–24 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.2	(1.4)
site preparation	62	(21)



Implement: TTS Delta (power) disc trencher

Prime mover: 123-kW, 15.4-t skidder

The between-furrow mean spacing of 2.10 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was increased to 2.25 m, as approximately 5% of furrow length was water and 6% of planting attempts were unacceptable because of woody residue. Of the approximately 2115 acceptable planting spots per hectare, 670 were in mineral soil, 670 were in organic matter ≤2 cm deep over mineral soil, and 775 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil. Eight competitor species were noted during a vegetation assessment on 1 October, 11–14 months after harvest. Depending upon the development of aspen and/or graminoids, competition may be a problem for both planted stock and germinants. The fresh moisture regime is at the dry end of the acceptable range for seeding spruce and is acceptable for jack pine; however, jack pine does not prefer fine-textured soil. Good seedbed comprised 10.8% of the surface area, and 1.4% was conditional; it is unlikely that direct seeding at economic rates of seed application will produce a stand that satisfies conifer stocking standards because of the scarcity of good seedbed for spruce, potential frost heaving on the finer-textured soil, potential competition development, and smothering of fragile germinants by litter fall and accumulation. Compare with plate sets 6, 10, and 14.

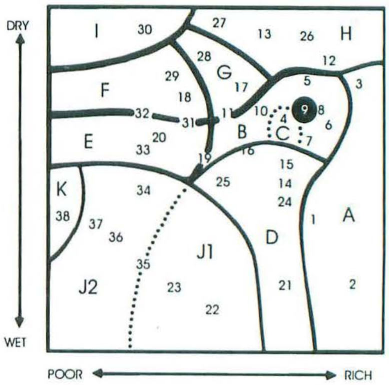
PLATE
14A

V9 Trembling Aspen Mixedwood

S6, S6, SS6

FRI: PFR $Po_5Sb_2Pj_2Bw_1$, age 70, height 21 m, stocking 0.9, site class 3

Other site vegetation types: none nearby



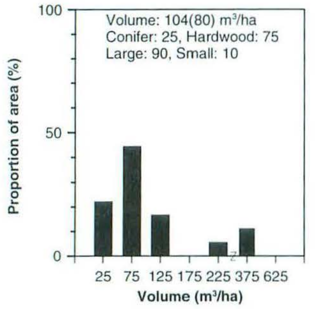
Photographed and assessed: 13 August 1990
Time elapsed since harvest: 23–25 months
Harvest method: conventional cut and skid

Area topography: gentle to steep
Bedrock outcrops: >75 m apart
Plot slopes: simple, 2–4%
Plot slope position: toe, depression, upper
Landform: not recorded
Soil depth: 35–>100 cm

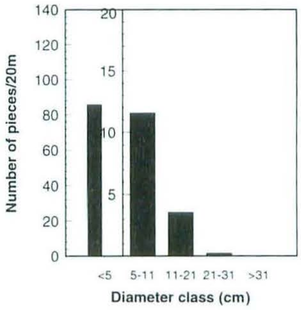
Soil texture: silty clay, medium sand
Boulders: slight
Stones: slight
Coarse fragments: 1–20%
Litter: 2 cm

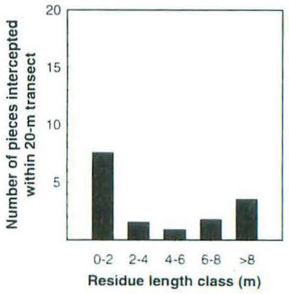
Fermentation layer: 3 cm
Humus: trace to 1 cm
Texture of surface mineral soil: silty clay, and sandy loam to a lesser extent
Drainage: moderately well (common) to rapid
Moisture regime: moist (common) to moderately dry

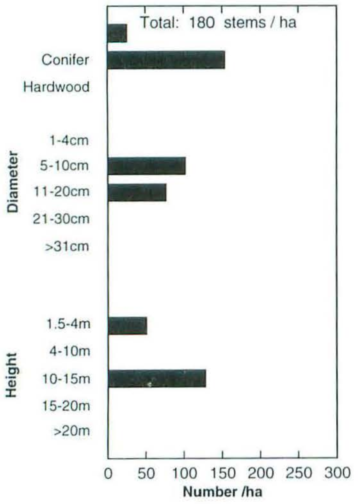
Woody Debris


Distribution Volume

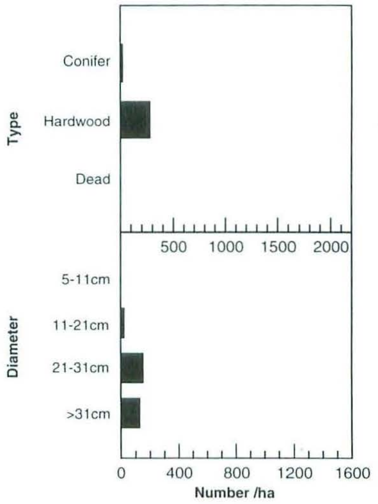
Volume: 104(80) m³/ha
Conifer: 25, Hardwood: 75
Large: 90, Small: 10

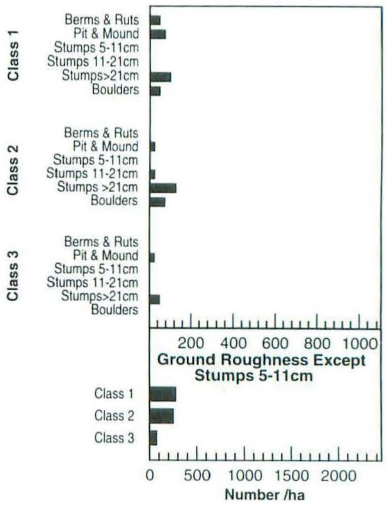

Diameter Distribution


Length

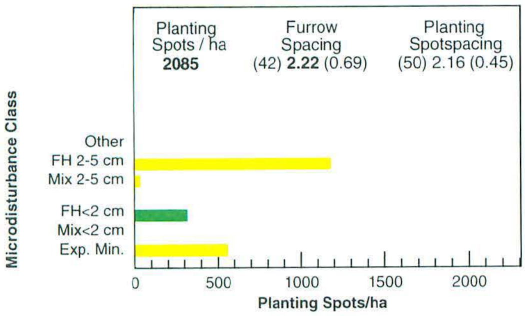

Residuals

Total: 180 stems / ha

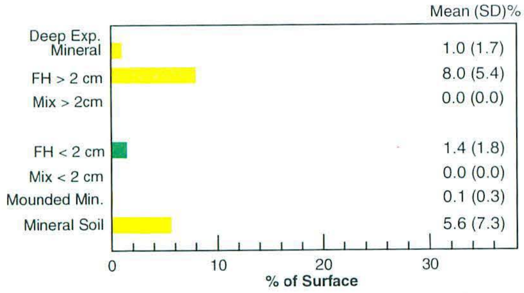

Stumps


Ground Roughness

Plantability



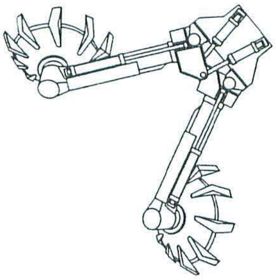
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	38	(32)
Furrow length (%), rock and/or water	0	(3)
Other surface conditions (% of surface):		
spoil bank	27	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.4	(1.8)
rock and/or water	1.3	(3.6)
shallow (<10 cm) mineral soil over organic	0.1	(0.8)

Photographed and assessed: 27 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 23–26 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	6.7	(17.6)
site preparation	46	(21)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

The between-furrow mean spacing of 2.22 m was a result of operating practice that may have been influenced by the moderate (occasionally very heavy) load of woody residue and ground roughness that was masked by both the well-developed woody regrowth and residual shrubs plus residual trees. The in-furrow acceptable planting spot spacing of 2.16 m was due to the presence of competitor species. Of the approximately 2085 acceptable planting spots per hectare, 555 were in mineral soil, 315 were in organic matter ≤2 cm deep over mineral soil, and 1215 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil. Nine competitor species were noted during a vegetation assessment on 13 August, 23–25 months after harvest. Competition development may be a severe problem even for well-planted, vigorous stock adapted morphologically and physiologically for this site; tending may be required within 3–5 years. The moisture regime was generally suitable for seeding spruce and was suitable for seeding jack pine on parts of the site mosaic; however, jack pine does not prefer fine-textured soil. Good seedbed comprised 7.1% of the surface, and 9.0% was conditional. Scarcity of seedbed, potential frost heaving on the finer-textured soils, competition development, and smothering of fragile germinants by litter fall may preclude establishing a stand by seeding that satisfies conifer stocking standards. Compare with plate sets 3, 6, 10, and 12.

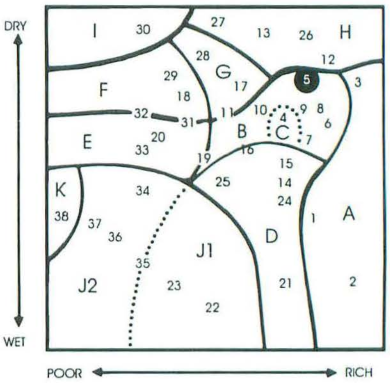
PLATE
15A

V5 Aspen Hardwood

SS6, SS6, SS6

FRI: PFR Po$_5$Sb$_2$Pj$_2$Bw$_1$, age 70, height 18 m, stocking 0.9, site class 3

Other site vegetation types: Trembling Aspen Mixedwood may occupy more than half of the cut block



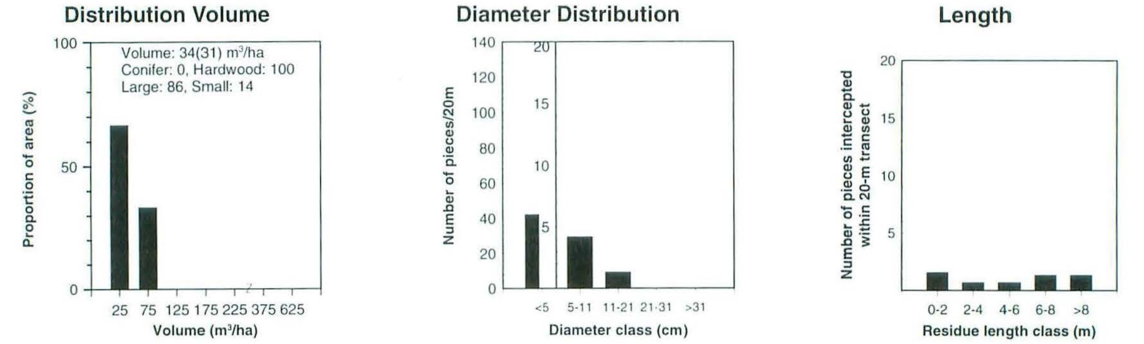
Photographed and assessed: 13 August 1990
Time elapsed since harvest: 17–19 months
Harvest method: full-tree with feller–buncher and grapple skidder

Area topography: gentle to strong (some ledges <10 m)
Bedrock outcrops: slight
Plot slopes: simple, 7–8%
Plot slope position: toe, upper, upper
Landform: lacustrine deposit and spillway
Soil depth: 25–70 cm (continuous)

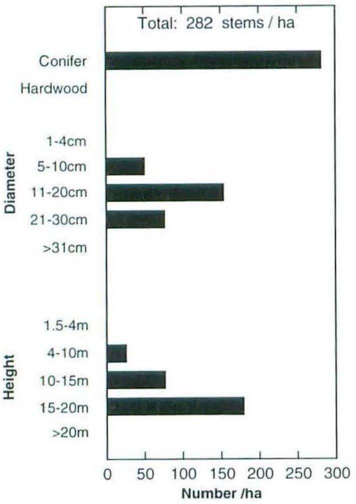
Soil texture: loamy fine sand, loamy fine sand, loamy very fine sand
Boulders: absent on plot
Stones: excessive to slight
Coarse fragments: <20%
Litter: 2 cm

Fermentation layer: 3 cm
Humus: trace to 1 cm
Texture of surface mineral soil: sandy loam, sandy loam, loamy very fine sand
Drainage: rapid (uniformly)
Moisture regime: moderately fresh (uniformly)

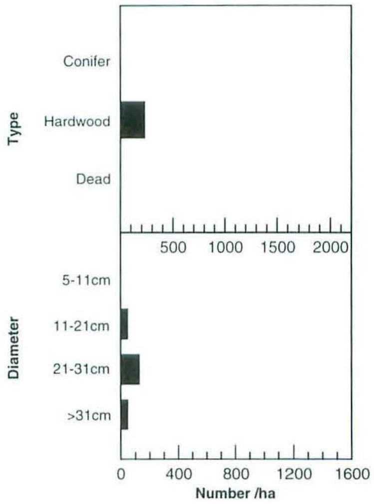
Woody Debris



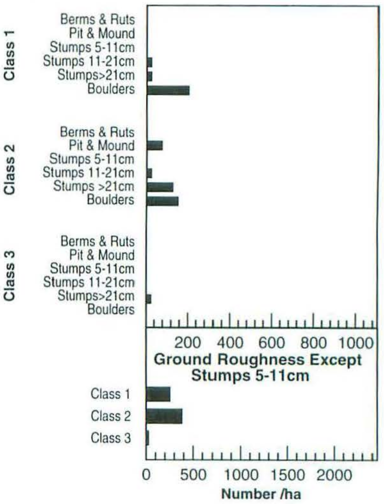
Residuals



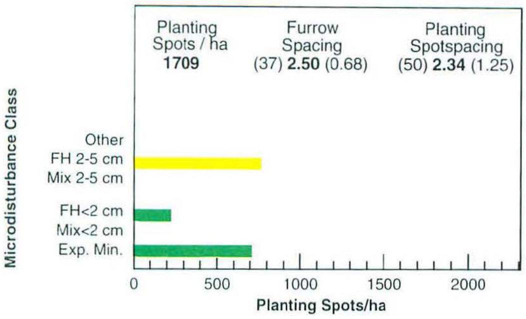
Stumps



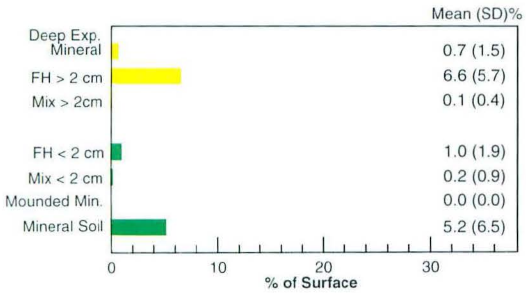
Ground Roughness



Plantability



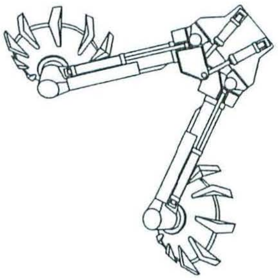
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	35	(34)
Furrow length (%), rock and/or water	7	(21)
Other surface conditions (% of surface):		
spoil bank	15	(14)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.7	(2.3)
rock and/or water	3.0	(8.3)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 28 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 18–20 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	3.5	(5.4)
site preparation	32	(19)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

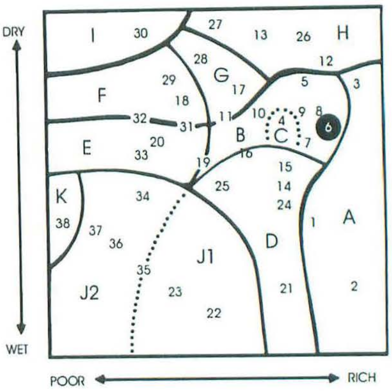
The area's topography, compounded by visibility-limiting woody regrowth and/or residual shrubs and residuals, probably influenced operating practice, which gave a between-furrow mean spacing of 2.50 m. The in-furrow acceptable planting spot mean spacing was increased to 2.34 m by the 7% of furrow length that was either natural or machine-exposed rock and shallow soil. Of the approximately 1710 acceptable planting spots per hectare, 715 were in mineral soil, 225 were in organic matter ≤2 cm deep over mineral soil, and 770 were in organic matter 2–5 cm deep over mineral soil. Nine competitor species were noted during a vegetation assessment on 13 August, 17–19 months after harvest; competition development will be a severe problem for all stock planted on this fertile site. The moderately fresh moisture regime is toward the dry end of the acceptable range for seeding jack pine and tends to be too dry for seeding spruce. Good seedbed comprised 6.4% of the surface, and 7.4% was conditional; the scarcity of seedbed and both existing and developing competition preclude establishment of a stand by seeding that satisfies conifer stocking standards. Compare with plate sets 12, 26, and 28.

PLATE 16A

V6 Trembling Aspen (White Birch) – Balsam Fir / Mountain Maple SS1, SS6, SS3, (SS6)

FRI: $B_3Po_3Bw_2Sw_1Sb_1$, age 50, height 11 m, stocking 0.5, site class 1

Other site vegetation types: Balsam Fir Mixedwood and Trembling Aspen Mixedwood



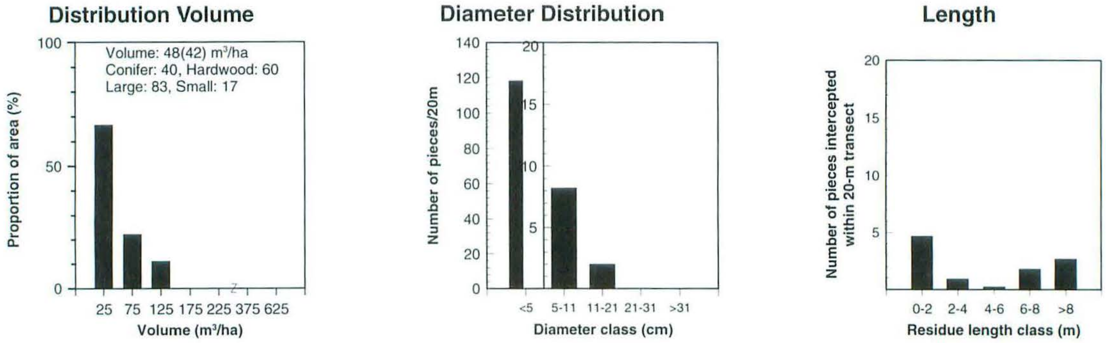
Photographed and assessed: 16 August 1990
Time elapsed since harvest: 16–17 months
Harvest method: conventional cut and skid

Area topography: gentle to moderate
Bedrock outcrops: slight
Plot slopes: simple, 11%
Plot slope position: upper, lower, upper
Landform: glacial drift
Soil depth: 0–55 cm

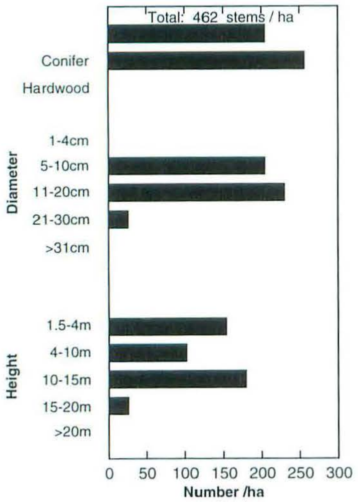
Soil texture: sandy loam (uniformly); surface cover a continuous, strong organic mat
Boulders: none locally
Stones: moderate
Coarse fragments: 1–5%
Litter: 2 cm

Fermentation layer: 4–6 cm
Humus: 1 cm
Texture of surface mineral soil: absent to loam over bedrock
Drainage: rapid to very rapid
Moisture regime: moderately fresh to dry

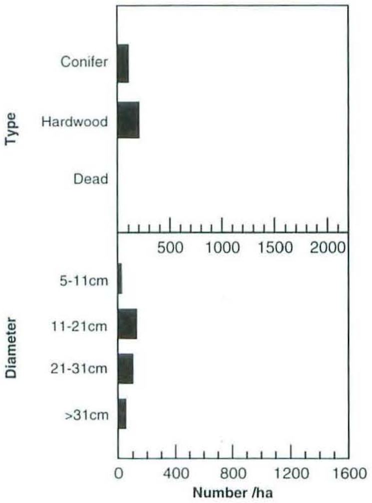
Woody Debris



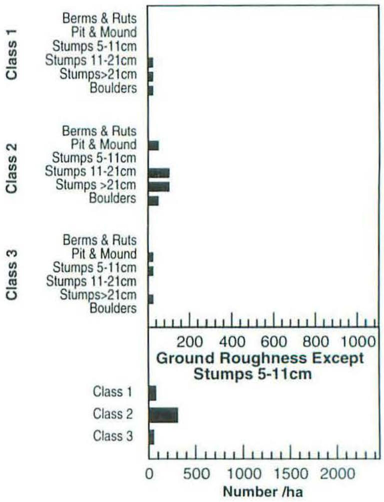
Residuals



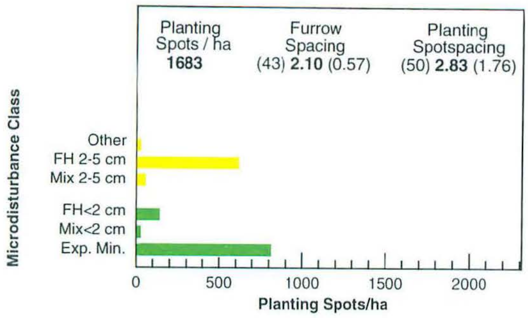
Stumps



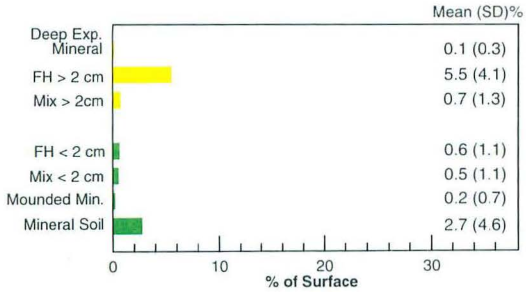
Ground Roughness



Plantability



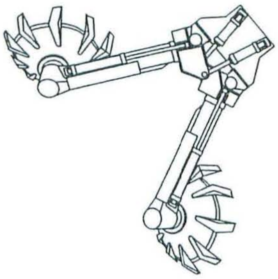
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	32	(31)
Furrow length (%), rock and/or water	32	(39)
Other surface conditions (% of surface):		
spoil bank	36	(21)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.0	(2.4)
rock and/or water	12.2	(17.0)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 22 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 16–18 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.3	(2.1)
site preparation	62	(20)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

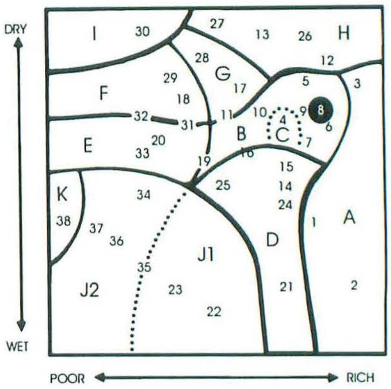
The absent to shallow mineral soil, residuals, well-developed woody regrowth and residual shrubs, and stones were the impediments to effective site preparation. The between-furrow mean spacing of 2.10 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was increased to 2.83 m by the 32% of the furrow length that was natural or machine-exposed rock, shallow soil, and woody residue. Of the approximately 1685 acceptable planting spots per hectare, 810 were in mineral soil, 170 were in an organic–mineral mix or organic matter ≤2 cm deep over mineral soil, 675 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil, and 30 were in other acceptable conditions. Nine competitor species were noted during a vegetation assessment on 16 August, 16–17 months after harvest. Considering the apparent fertility of this site and the competitor species present, competition will be a severe problem for crop trees. The moisture regime was attractive for seeding jack pine but generally too dry to seed spruce. Good seedbed comprised 4.0% of the surface, and 6.3% was conditional. The limited availability of acceptable seedbed and both the existing and developing competition will preclude establishing a stand by direct seeding that satisfies conifer stocking standards. Compare with plate sets 29, 38, and 42.

PLATE
17A

V8 Trembling Aspen (White Birch) / Mountain Maple S1, S1, S1

FRI: $Po_6Sb_3Sw_1$, age 87, height 26 m, stocking 0.9, site class 2

Other site vegetation types: Trembling Aspen–Conifer/ Blueberry/Feathermoss and Jack Pine Mixedwood/Shrub Rich



Photographed and assessed: 16 September 1990
Time elapsed since harvest: 1 month
Harvest method: full-tree by feller–buncher and grapple skidder

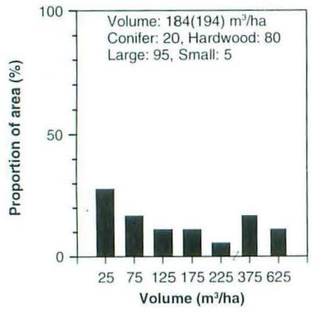
Area topography: gentle to moderate
Bedrock outcrops: slight
Plot slopes: simple, 1–2%
Plot slope position: crest
Landform: ablation till
Soil depth: >100 cm

Soil texture: very coarse sand (uniformly)
Boulders: none locally
Stones: very to exceedingly
Coarse fragments: 1–5%
Litter: 1–4 cm

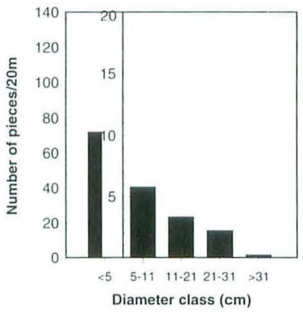
Fermentation layer: 6–9 cm
Humus: 1 cm
Texture of surface mineral soil: loamy medium sand (uniformly)
Drainage: very rapid
Moisture regime: moderately fresh

Woody Debris

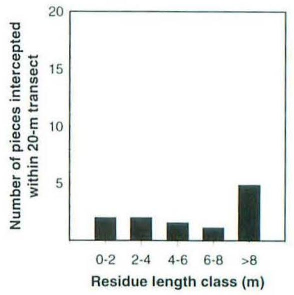
Distribution Volume



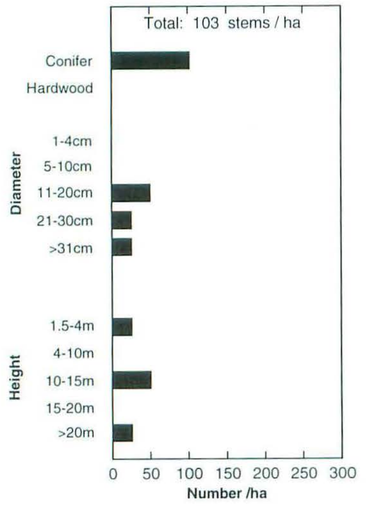
Diameter Distribution



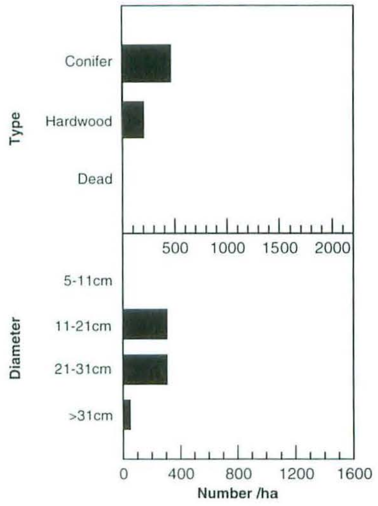
Length



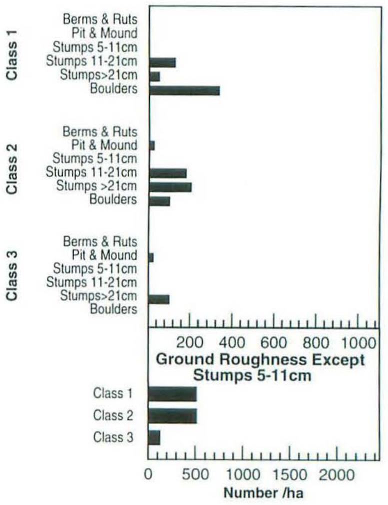
Residuals



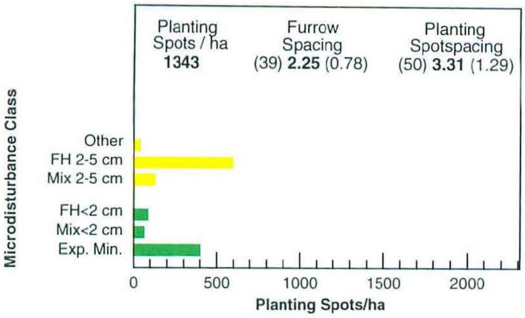
Stumps



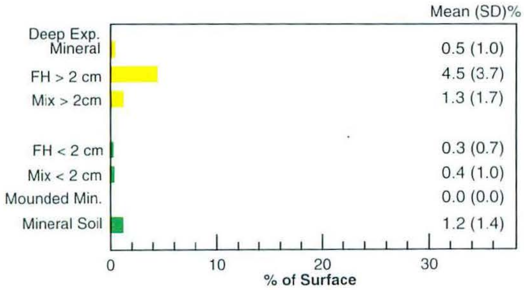
Ground Roughness



Plantability



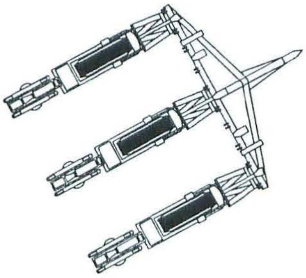
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	20	(17)
Furrow length (%), rock and/or water	11	(12)
Other surface conditions (% of surface):		
spoil bank	11	(10)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.4	(1.8)
rock and/or water	5.2	(4.6)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 21 June 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 4–6 weeks

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	2.0	(4.2)
site preparation	26	(16)



Implement: Bräcke 3-row (mattock wheels at 2.0 m)

Prime mover: 152-kW, 13.3-t skidder

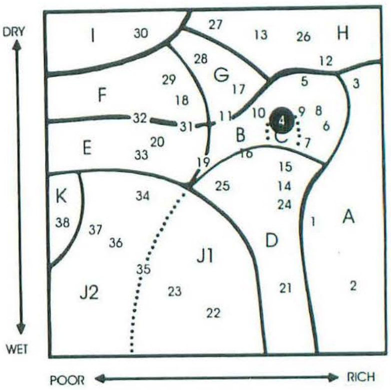
The between-rows-of-scalps mean spacing of 2.25 m was a function of both operating practice and implement configuration on this site, which has a moderately heavy average load of woody residue (about 28% of the surface area has very heavy residue), about 100 residuals per hectare, noticeable ground roughness, and a very stony soil. The in-rows-of-scalps acceptable planting spot mean spacing of 3.31 m may be, in part, a function of the implement's setting, as field notes indicated that "in many cases scalps were centred 2.5–3.0 m apart." Approximately 22% of scalps were not plantable, primarily because of woody residue but also because stoniness limited planting depth. Of the approximately 1345 acceptable planting spots per hectare, 400 were in mineral soil, 160 were in an organic–mineral mix or organic matter ≤2 cm deep over mineral soil, 740 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil, and 45 were in other acceptable conditions. Five competitor species were noted during a vegetation assessment on 16 September, about 1 month after harvest. Competition development will rapidly become a severe problem on this site. The moisture regime was attractive for seeding jack pine but toward the dry end of the acceptable range for seeding spruce. Good seedbed comprised 1.9% of gross surface area, and 6.3% was conditional; both the scarcity of seedbed and the competition development preclude establishing a stand by seeding that will satisfy conifer stocking standards. Compare with plate sets 7, 21, 37, and 39.

V4 White Birch Hardwood and Mixedwood

S2, SS5, S2

FRI: $B_4Bw_4Po_1Sw_1$, age 44, height 19 m, stocking 0.9, site class X

Other site vegetation types: Trembling Aspen Mixedwood



Photographed and assessed: 17 May 1991
Time elapsed since harvest: 15–19 months
Harvest method: full-tree with feller–buncher and grapple skidder

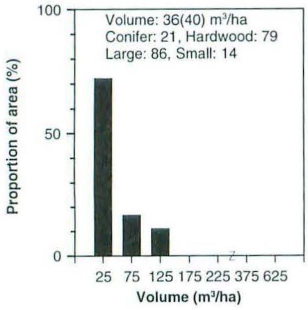
Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 2–5%
Plot slope position: mid to toe
Landform: glaciofluvial deposit
Soil depth: 50–>100 cm

Soil texture: gravelly silty fine sand more common than silty very fine sand
Boulders: none
Stones: slight
Coarse fragments: 20–>50%
Litter: 1–3 cm

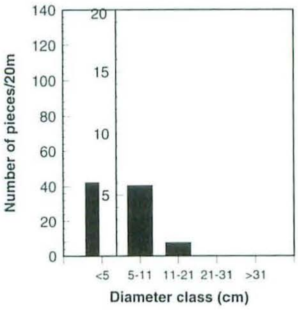
Fermentation layer: 4–7 cm
Humus: 0–1 cm
Texture of surface mineral soil: gravelly silty fine sand to silty loam
Drainage: moderately well to imperfect, occasionally rapid
Moisture regime: very fresh to moderately fresh to dry

Woody Debris

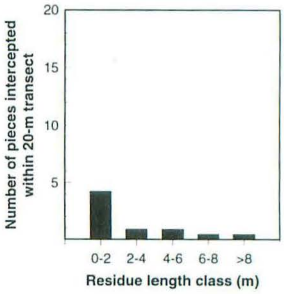
Distribution Volume



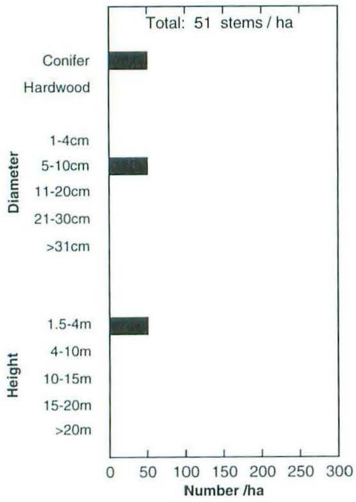
Diameter Distribution



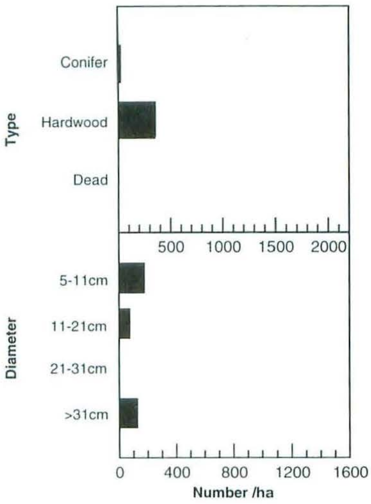
Length



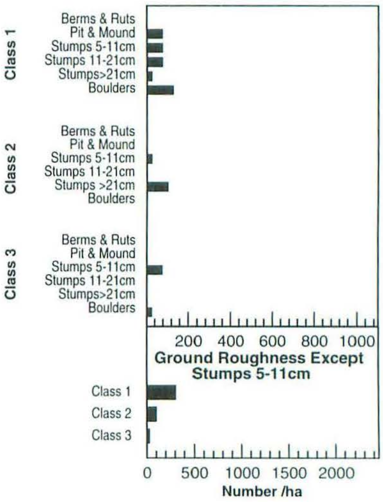
Residuals



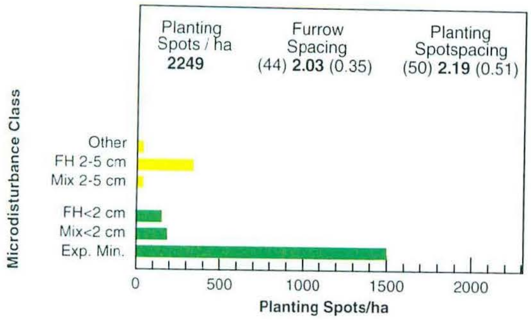
Stumps



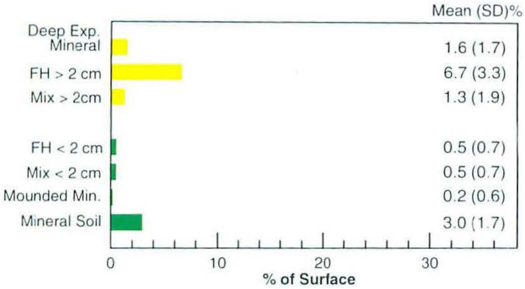
Ground Roughness



Plantability

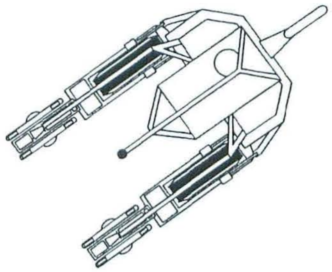


Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	33	(17)
Furrow length (%), rock and/or water	4	(12)
Other surface conditions (% of surface):		
spoil bank	24	(9)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.5	(1.6)
rock and/or water	2.3	(3.8)
shallow (<10 cm) mineral soil over organic	0.3	(1.0)

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.2	(0.8)
site preparation	42	(12)



Implement: Bräcke Herbicider with mattock wheels at 2.0-m spacing on drawbar

Prime mover: 107-kW, 10.5-t skidder

Photographed and assessed: 5 July 1991
Time from site preparation to assessment: 1–3 weeks
Time from harvest to site preparation: 16–20 months

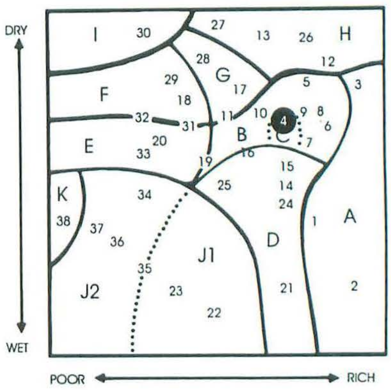
The between-rows-of-scalps mean spacing of 2.03 m was a function of operating practice. The in-row-of-scalps acceptable planting spot mean spacing of 2.19 m tended to be related more to the machine setting (adjustment) for scalp spacing function than to site conditions. Of the approximately 2250 acceptable planting spots per hectare, 1495 were in mineral soil, 340 were in an organic–mineral mix or organic matter ≤2 cm deep over mineral soil, 375 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil, and 40 were in other acceptable conditions. Eight competitor species were noted during a vegetation assessment in mid-June, 16–20 months after harvest. The local patch application of herbicide to planting spots with the Bräcke Herbicider during site preparation probably will suppress the density and stocking of competition sufficiently to permit well-planted, vigorous stock adapted morphologically and physiologically for this site to hold its own against competition development. The site's moisture regime was attractive for seeding jack pine but generally too dry for seeding black spruce. Good seedbed comprised 4.2% of the surface area, and 9.6% was conditional. The small amount of good seedbed and competition development may preclude establishing a stand by seeding that satisfies conifer stocking standards. Compare with plate sets 4, 8, 9, 15, and 19–21.

V4 White Birch Hardwood and Mixedwood

SS5, SS5, S8

FRI: Bw_8B_2, age 73, height 14 m, stocking 0.7, site class 3

Other site vegetation types: Balsam Fir Mixedwood



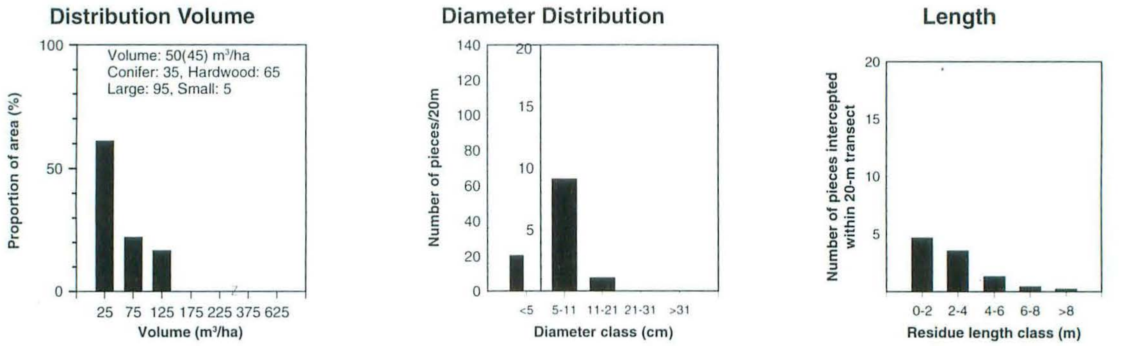
Photographed and assessed: 22 August 1990
Time elapsed since harvest: about 5.5 years (and about 4 years after a barrel drag site preparation that was not followed by planting owing to a shortage of planting stock)
Harvest method: cut and skid

Area topography: gentle to strong
Bedrock outcrops: >75 m apart
Plot slopes: simple, 6–21%
Plot slope position: mid
Landform: ablation till
Soil depth: 40–>100 cm

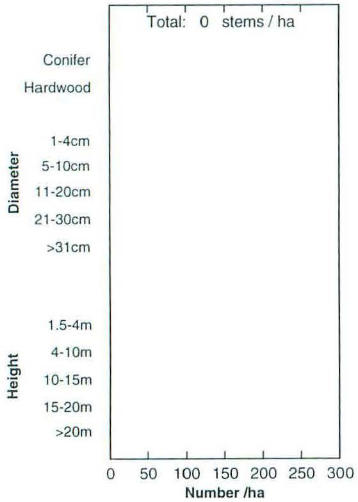
Soil texture: fine sand, very fine sand, silty sand
Boulders: slight to moderate
Stones: moderate to slight
Coarse fragments: 6–35%
Litter: 2–3 cm

Fermentation layer: 2–4 cm
Humus: 1–2 cm
Texture of surface mineral soil: loamy very fine sand and silty loam
Drainage: rapid to moderately well
Moisture regime: moderately fresh (moderately dry to very fresh)

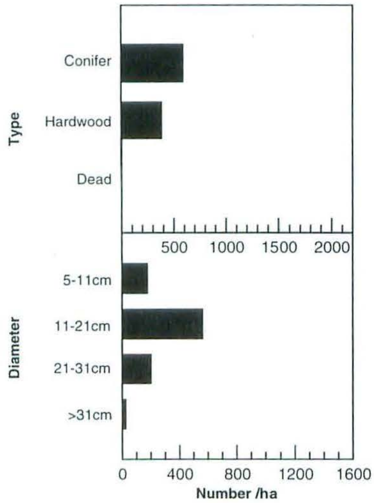
Woody Debris



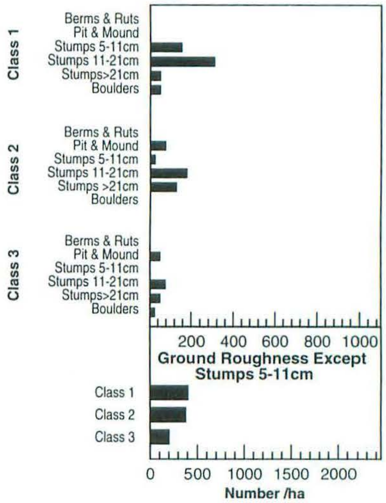
Residuals



Stumps

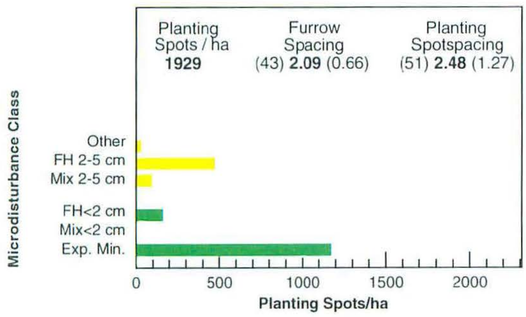


Ground Roughness

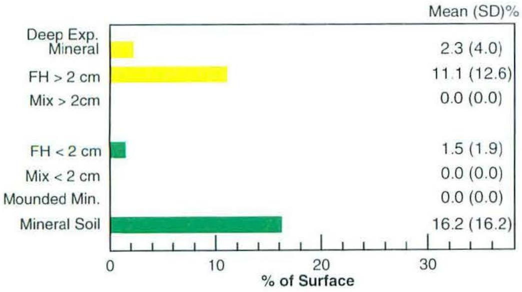


Screefing / Trenching

Plantability



Potential Seedbed



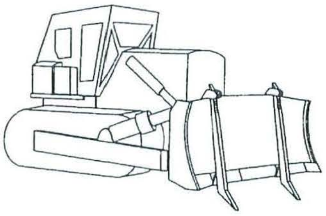
Furrow length (%), mineral soil ≥15 cm wide	58	(37)
Furrow length (%), rock and/or water	5	(35)

Other surface conditions (% of surface):

spoil bank	24	(22)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.7	(1.5)
rock and/or water	3.7	(4.8)
shallow (<10 cm) mineral soil over organic	0.1	(0.7)

Photographed and assessed: 21 May 1991
Time from site preparation to assessment: about 7 months
Time from harvest to site preparation: 5.5–6 years and 4–4.5 years after initial site preparation with a barrel drag

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	6.8	(12.5)
site preparation	60	(31)



Implement: Young's utility dozer teeth

Prime mover: 224-kW, 31-t bulldozer

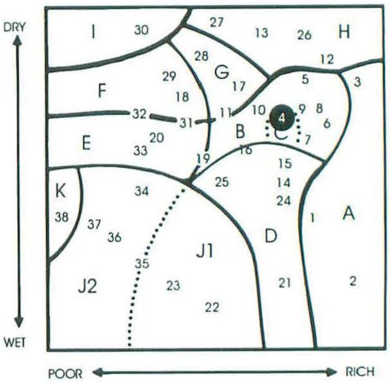
The between-planting-rows mean spacing of 2.09 m was a function of operating practice. The in-row acceptable planting spot mean spacing was increased to 2.48 m by stone-limited planting spade penetration and, to a lesser degree, by woody residue. Of the approximately 1930 acceptable planting spots per hectare, 1170 were in mineral soil, 160 were in organic matter ≤2 cm deep over mineral soil, 570 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 30 were in other acceptable conditions. Eight competitor species were found during a vegetation assessment on 22 August, about 5.5 years after harvest; it may be noted from both recent disturbance history and the vegetation shown in the photos that a transition from V-4 to V-8 may have occurred. Competition development will be a severe problem for either planted stock or germinants; tending will be required in 3–5 years. The moisture regime was attractive for seeding jack pine but tended to be too dry for seeding spruce. Good seedbed comprised 17.7% of the surface, and 13.4% was conditional, sufficient to support broadcast seeding of jack pine; however, the potential for frost heaving on the finer-textured soil, for direct competition, and for smothering of fragile germinants by litter fall may reduce the likelihood of establishing a stand by broadcast seeding that satisfies conifer stocking standards. Setting out jack pine– or, possibly, black spruce–seeded shelters by hand on selected microsites may be an alternative to planting. Compare with plate set 44.

PLATE
20A

V4 White Birch Hardwood and Mixedwood S2, S1, S1

FRI: Sb$_7$B$_2$Ce$_1$, age 79, height 11 m, stocking 0.5, site class 2

Other site vegetation types: White Spruce Mixedwood and Balsam Fir Mixedwood



Photographed: 20 April 1991 **and assessed:** 24 May 1991
Time elapsed since harvest: 15–19 months
Harvest method: conventional tree-length by cut and skid

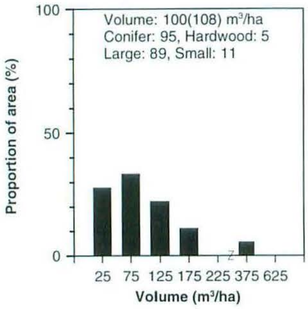
Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 1–3%
Plot slope position: mid
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: very gravelly coarse sand more common than very fine sand
Boulders: none
Stones: none
Coarse fragments: 20–>60%
Litter: 2–4 cm

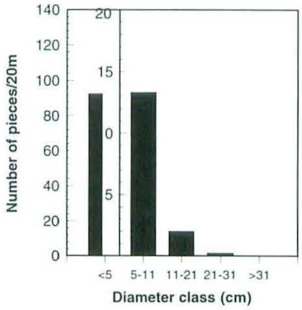
Fermentation layer: 3–9 cm
Humus: none
Texture of surface mineral soil: very gravelly coarse sand, medium sand, and silty medium sand
Drainage: rapid to very rapid to moderately well
Moisture regime: moderately dry to very fresh

Woody Debris

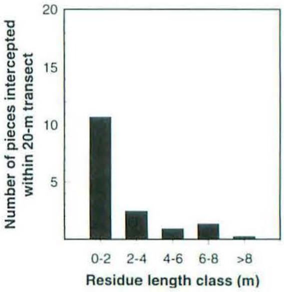
Distribution Volume



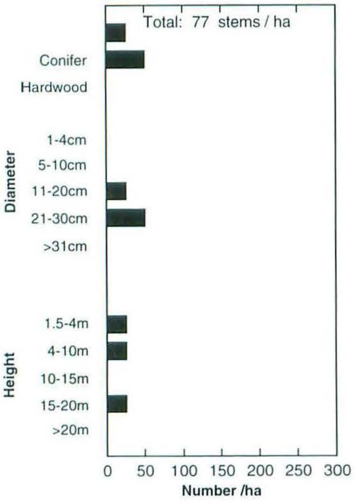
Diameter Distribution



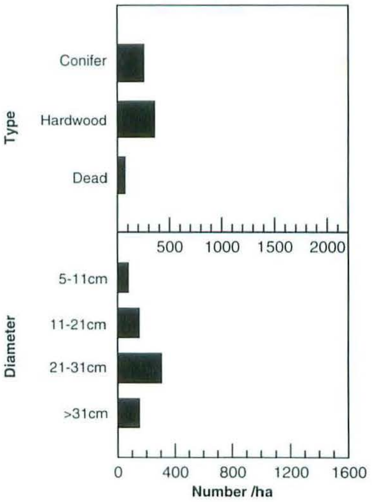
Length



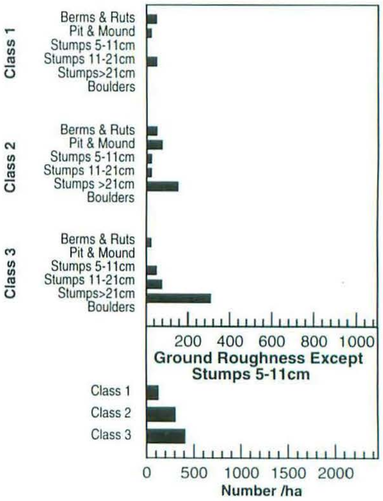
Residuals



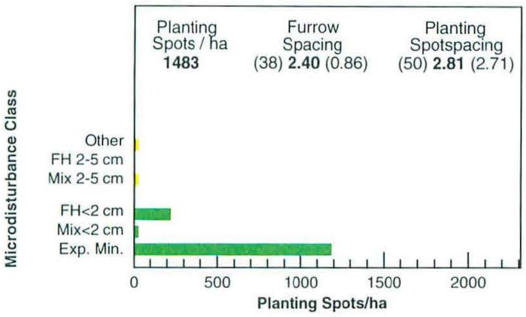
Stumps



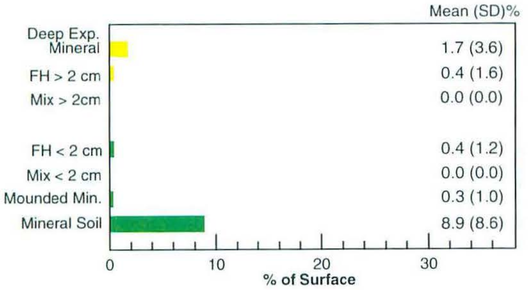
Ground Roughness



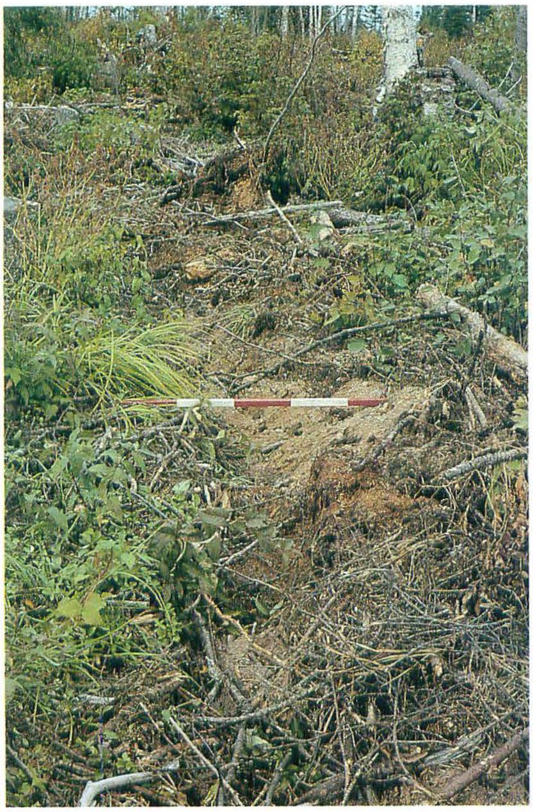
Plantability



Potential Seedbed

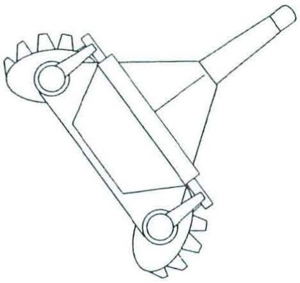


Furrow length (%), mineral soil ≥15 cm wide	51	(36)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	47	(25)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.6	(8.3)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0.4	(1.7)



Photographed and assessed: 11 September 1991
Time from site preparation to assessment: 1–2 weeks
Time from harvest to site preparation: 17–24 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	59	(26)



Implement: TTS–35 disc trencher

Prime mover: 107-kW, 10.5-t skidder

The between-furrow mean spacing of 2.40 m was the result of operating practice influenced by ground roughness (mostly clusters of birch stumps) and the scattered residuals combined with the moderately light to occasionally very heavy load of woody residue. The in-furrow acceptable planting spot mean spacing was increased to 2.81 m by combinations of woody residue, stumps, and roots. Of the approximately 1480 acceptable planting spots per hectare, 1185 were in mineral soil, 245 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 25 were in organic matter 2–5 cm deep over mineral soil, and 25 were in other acceptable conditions. Ten competitor species were noted during a vegetation assessment in late June, 15–18 months after harvest. Well-planted, vigorous stock adapted morphologically and physiologically to this site may have difficulty coping with the competition development. The moisture regime was attractive for seeding jack pine, and portions of the site may support germination and establishment of seeded black spruce. Good seedbed comprised 9.6% of the surface, and 2.1% was conditional. The amount of seedbed was inadequate to produce a stand with high jack pine stocking when broadcast sown at common jack pine seeding rates. It is likely that competition development and heavy litter fall will prevent establishment of either species sufficient to satisfy stocking standards. As an alternative to planting, setting out jack pine–seeded shelters on selected microsites may have some potential. Compare with plate sets 2, 11, 14, and 34.

Treatment Unit E

Treatment Unit E: Black Spruce–Jack Pine/Feathermoss

Treatment Unit E contains even-aged black spruce and jack pine stands with a poorly to moderately well developed shrub layer. Feathermoss cover is often high.

Phase E1: Dry soils
Phase E2: Fresh soils
Phase E3: Moist soils

Equipment trafficability

Phase E1 sites pose very few limitations to equipment. Phase E2 sites can be susceptible to compaction and rutting, particularly on fine-textured soils of lacustrine or fluvial origin. On phase E3 sites, moist, poorly drained soils are prone to compaction or rutting problems. Low load-bearing equipment or winter operation may reduce the potential for site degradation.

Competition

On phase E1 sites, moderate competition can be expected from *Alnus crispa*, trembling aspen, and *Salix* spp. On phase E2 sites, moderate to heavy competition can be expected from *Calamagrostis canadensis*, trembling aspen, *Alnus rugosa*, and *Alnus crispa*. On phase E3 sites, some competition from *Alnus rugosa* can be expected. According to Walsh and Krishka (1991), in a study of early stand development following harvesting in northwestern Ontario, competitors with the highest index value on Treatment Unit E were *Vaccinium* spp., *Ledum groenlandicum*, *Salix* spp., *Alnus crispa*, *Aster macrophyllus*, and grasses.

Comments

Delicate scarification on phase E2 sites is effective in maintaining site quality while producing suitable seedbeds and planting sites.

Summary

A summary of Treatment Unit E is presented in Table 5.

Ten plots were sampled (plate sets 21–30).

Three plots (plate sets 23, 25, and 27) had peaty-phase surfaces over finer-textured mineral soils. Each had a moderately light loading of woody residue.

The plot represented by plate set 23 was site-prepared in late July, 15–19 months after harvest with a TTS Delta (power) disc trencher on a 186.5-kW, 22.3-t skidder; 2381 acceptable (by local definition) planting spots per hectare, negligible mineral soil exposure, negligible amounts of organic and/or organic–mineral mix ≤2 cm deep, and 7.2% organic and/or organic–mineral mix >2 cm deep were produced.

The plots represented by plate sets 25 and 27 were site-prepared during late April through early May during the spring thaw when the surface was tillable and the ice lenses were still capable of supporting the machinery and limiting tillage depth. Both sites were prepared with a Donaren 180 disc trencher on a 185-kW, 17.5-t skidder. The plot represented by plate set 25, with about 220 residuals >10 cm in diameter per hectare, had a between-furrow mean spacing of 2.33 m and yielded 2135 acceptable planting spots per hectare, 1.9% mineral soil exposure, 1.0% organic and/or organic–mineral mix ≤2 cm deep, and 18.6% organic and/or organic–mineral mix >2 cm deep. The plot represented by plate set 27, with about 40 residuals >10 cm in diameter per hectare, had a between-furrow mean spacing of 2.54 m and yielded 1949 acceptable planting spots per hectare, 0.1% mineral soil exposure, negligible amounts of organic and/or organic–mineral mix ≤2 cm deep, and 17.3% organic and/or organic–mineral mix >2 cm deep. It is suggested that the between-furrow mean spacing for these plots (plate sets 25 and 27) is a function of operating practice rather than site conditions.

Heavy drags drawn by a 239-kW, 33.7-t bulldozer were used to treat the plots represented by plate sets 21 and 24. Each had moderate loadings of woody residue. The plot represented by plate set 21 had about 60 residuals >10 cm in diameter per hectare, moderately deep to deep soil, very gentle to gentle slopes, rock outcrops 25–75 m apart, stones 2–30 m apart, and about 800 ground roughness class 2 and 3 obstacles per hectare (including stumps) and yielded 2603 acceptable planting spots per hectare, 6.7% mineral soil exposure, 4.5% organic and/or organic–mineral mix ≤2 cm deep, and 16.4% organic and/or organic–mineral mix >2 cm deep. The plot represented by plate set 24 had shallow to moderately deep mineral soil, gentle slopes, rock outcrops 25–75 m apart, boulders 10–30 m apart, and stones 1–10 m apart and yielded 2204 acceptable planting spots per hectare, 1.5% mineral soil exposure, 2.1% organic and/or organic–mineral mix ≤2 cm deep, and 13.6% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 26 had negligible impediments for the Donaren 180 disc trencher on a 185-kW, 17.5-t skidder. The 2.29-m between-furrow mean spacing was a result of operating practice; 2110 acceptable planting spots per hectare, 5.9% mineral soil exposure, 2.8% organic and/or organic–mineral mix ≤2 cm deep, and 15.9% organic and/or organic–mineral mix >2 cm deep were produced.

The plot represented by plate set 28 had shallow to moderately deep soil, gentle to very strong topography, very gentle to gentle plot slopes, rock outcrops 25–75 m apart, boulders 10–30 m apart, and stones 1–10 m apart. Light drags drawn by a 164-kW, 10-t skidder produced 1766 acceptable planting spots per hectare, 5.7% mineral soil exposure, 3.5% organic and/or organic–mineral mix ≤2 cm deep, and 4.4% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 29 had discontinuous, shallow to moderately shallow mineral soil, very gentle to moderate topography, very gentle to moderate plot slopes, rock outcrops 2–10 m apart, boulders 10–30 m apart, and stones 2–30 m apart. A Bräcke Badger drawn by a 136-kW, 10-t skidder produced 1332 acceptable planting spots per hectare, 2.3% mineral soil exposure, 1.1% organic and/or organic–mineral mix ≤2 cm deep, and 5.9% organic and/or organic–mineral mix >2 cm deep.

The plot represented by plate set 30 had moderately shallow mineral soil, gentle to moderate topography, gentle to moderate plot slopes, rock outcrops 25–75 m apart, and boulders and stones 1–2 m apart that, together with stumps, give about 1875 ground roughness class 2 and 3 obstacles per hectare. A Silva Wadell powered cone scarifier on a 104-kW, 14.5-t skidder produced 992 acceptable planting spots per hectare, 5.9% mineral soil exposure, 1.7% organic and/or organic–mineral mix ≤2 cm deep, and 3.6% organic and/or organic–mineral mix >2 cm deep. It is doubtful if other affordable mechanical site preparation equipment would produce different results.

Table 5. Data from plate sets for Treatment Unit E ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
21	2603	58	6.7	4.5	16.4	8–12	70–>100	g	1–3	S	M→S
22	2464	21	2.8	1.0	12.9	8–13	40–65	g	1–5	M	S
23	2381	1	0	0	7.2	13–21	40–>100	vg	0–1	0	0
24	2204	51	1.5	2.1	13.6	8–14	20–70	g	2–8	S	M→V
25	2135	17	1.9	1.0	18.6	12–21	>100	vg→g	0–2	0	0
26	2110	55	5.9	2.8	15.9	7–15	>100	vg	0–2	0	0
27	1949	0	0.1	0	17.3	30–32	>100	vg	2–6	0	0
28	1766	51	5.7	3.5	4.4	6–11	10–70	g→v-str	1–4	S	M→V
29	1332	20	2.3	1.1	5.9	6–10	10–45 (dis)	vg→m	2–13	V	S→M
30	992	35	5.9	1.7	3.6	11–15	42–59	g→m	6–12	0→S	M→V

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
800	102	11–13	4	**vM** (mM & F)	**SiL**, LmS	V-20 (E)	1.95	1.97	239	33.7	drag (H)	21
600	156	18–20	6	vF→mF	mS→LmS	V-20 (E)	2.06	1.97	186.5	22.3	TTS (pow)	22
1125	75	15–19	2	mM→vF	mS, L, mS	V-33 (E)	2.10	2.00	186.5	22.3	TTS (pow)	23
525	101	10–13	4	**D**→mF	LcS, LfS, LmS	V-33 (E)	2.11	2.15	239	33.7	drag (H)	24
400	77	2–3	3	vM, M, vF	Si	V-19 (E)	2.33	2.01	185	17.5	Don180	25
75	58	2–3	1	**M**, mM	fS, vfS	V-32 (E)	2.29	2.07	185	17.5	Don180	26
350	60	2–3	2	F, M, vF	L, CL, SiCL	V-19 (E)	2.54	2.02	185	17.5	Don180	27
300	43	12–14	3	F, **mF**, mD	SL, LfS, L	V-20 (E)	2.17	2.61	164	10	drag (L)	28
475	44	11–14	3	vF, **mD**, D	SL, LmS	V-31 (E)	1.59	4.72	136	10	Bräcke	29
1875	56	26–29	4	**D**→mF	Si, SifS, SivfS	V-20 (E)	2.36	4.27	104	14.5	Wadell	30

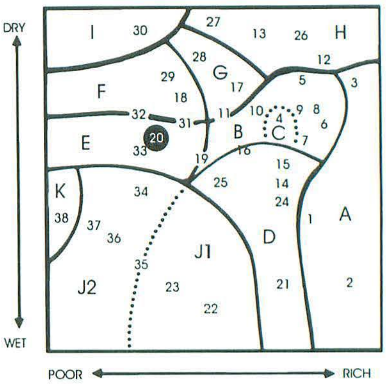
PLATE
21A

V20 Black Spruce Mixedwood / Feathermoss

S7, S1, SS8

FRI: $Sb_6Po_1Bw_1B_1Pj_1$, age 130, height 20 m, stocking 0.5, site class 1

Other site vegetation types: Black Spruce/Labrador Tea/ Feathermoss (Sphagnum), Black Spruce/Feathermoss, and Black Spruce–Jack Pine/Tall Shrub/Feathermoss



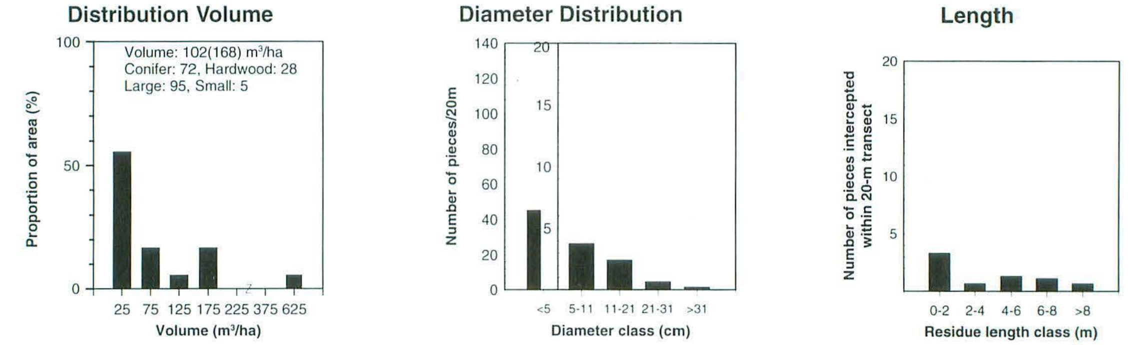
Photographed and assessed: 29–30 August 1990
Time elapsed since harvest: 2–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle
Bedrock outcrops: slight
Plot slopes: simple, 1–3%
Plot slope position: mid
Landform: glaciofluvial deposit
Soil depth: 70–>100 cm

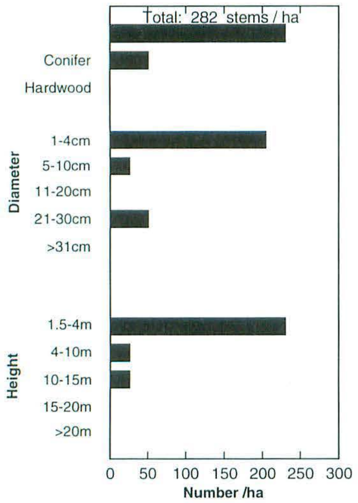
Soil texture: silty loam and medium sand, medium sand, silty medium sand
Boulders: none
Stones: moderate to slight
Coarse fragments: 6–50%
Litter: 2–3 cm

Fermentation layer: 6–8 cm
Humus: trace to 1 cm
Texture of surface mineral soil: silty loam more than loamy medium sand
Drainage: moderately well to well
Moisture regime: very moist (common), moderately moist, and fresh present

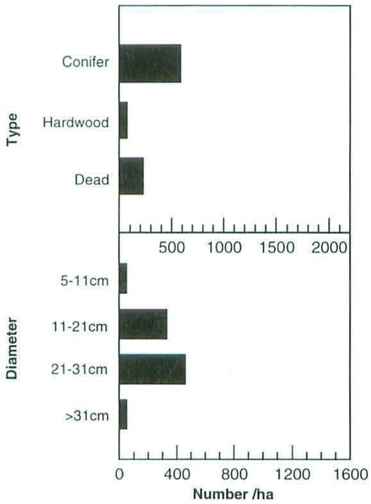
Woody Debris



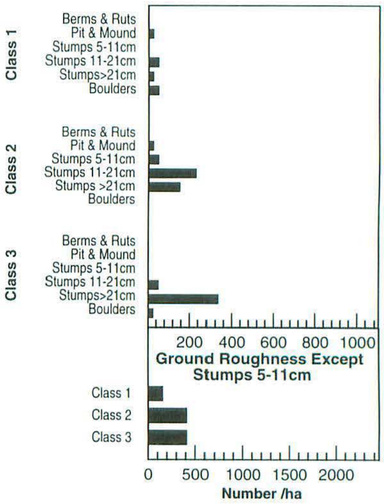
Residuals



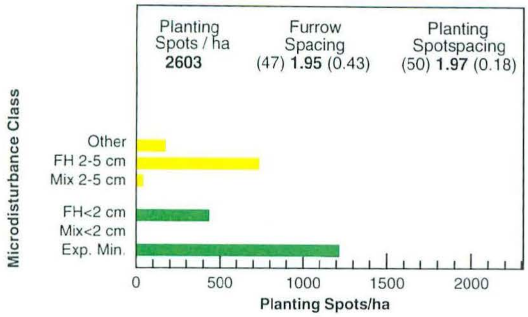
Stumps



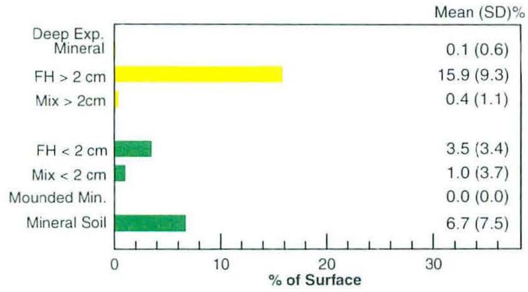
Ground Roughness



Plantability

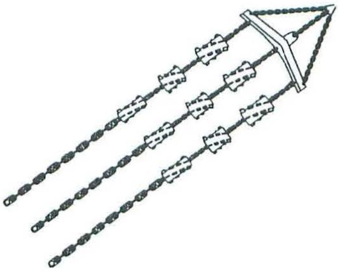


Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	58	(37)
Furrow length (%), rock and/or water	0	(1)
Other surface conditions (% of surface):		
spoil bank	54	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	9.2	(10.3)
rock and/or water	1.9	(3.3)
shallow (<10 cm) mineral soil over organic	0	(0)

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.5	(3.5)
site preparation	92	(14)



Implement: heavy drags

Prime mover: 239-kW, 33.7-t bulldozer

Constraints to site preparation include the light to moderate loads of woody residue (with occasional concentrations of moderately heavy and extremely heavy residue) and ground roughness. The between-furrow mean spacing of 1.95 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 1.97 m. Of the approximately 2605 acceptable planting spots per hectare, 1215 were in mineral soil, 435 were in organic matter ≤2 cm deep over mineral soil, 780 were in organic matter or organic–mineral mix 2–5 cm deep over mineral soil, and 175 were in other acceptable conditions. Four competitor species were noted during a vegetation assessment on 29 August, 2–3 months after harvest. Well-planted, vigorous stock adapted morphologically and physiologically to this site may cope with the competition development. The site's moisture regime is favorable for seeding black spruce, and parts of the site mosaic will support jack pine seeding. Good seedbed comprised 11.2% of the surface, and 16.4% was conditional. Except in years when weather in the germination and establishment seasons is unfavorable, appropriate rates of broadcast application for black spruce and jack pine seed may yield a stand that satisfies or exceeds minimum conifer stocking standards, with a potential for both high stocking and excessive density. However, the effects of both competition development and frost heaving on fine-textured soils must be considered with a direct-seeding option. A cautionary note: graminoids, including Canada blue-joint, are occasionally present on the cut block. As an alternative to planting, seeded shelters set out on selected microsites may have potential. Compare with plate sets 20, 22, 31, and 34.

Photographed and assessed: 31 July 1991
Time from site preparation to assessment: 3–5 weeks
Time from harvest to site preparation: 11–13 months

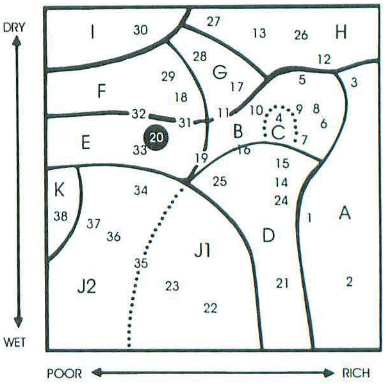
PLATE
22A

V20 Black Spruce Mixedwood / Feathermoss

SS8, SS8, SS8

FRI: Sb$_6$Pj$_1$B$_1$Sw$_1$Po$_1$, age 130, height 19, stocking 0.3, site class 1

Other site vegetation types: Black Spruce Mixedwood/ Herb Rich



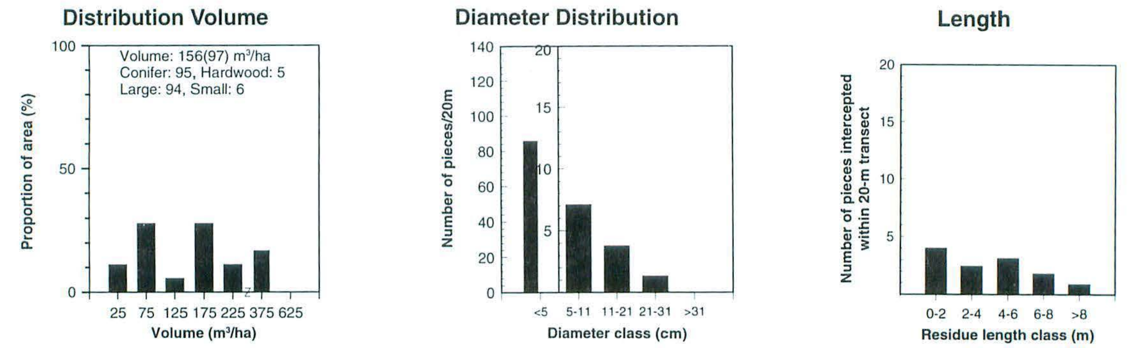
Photographed and assessed: 27 August 1990
Time elapsed since harvest: 6–8 months
Harvest method: both full-tree feller–buncher with grapple skidder and conventional tree-length cut and skid

Area topography: gentle
Bedrock outcrops: moderate
Plot slopes: simple, 1–5%
Plot slope position: mid to lower
Landform: ground moraine
Soil depth: 40–65 cm

Soil texture: medium sand more common than coarse sand
Boulders: slight
Stones: slight
Coarse fragments: 5–20%
Litter: 2–3 cm

Fermentation layer: 6–8 cm
Humus: 0–2 cm
Texture of surface mineral soil: medium sand to loamy medium sand
Drainage: moderately well to well
Moisture regime: very fresh to moderately fresh

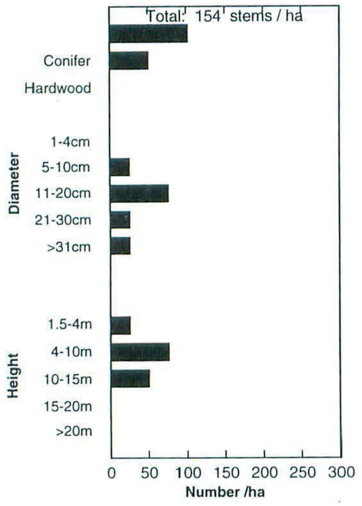
Woody Debris


Distribution Volume

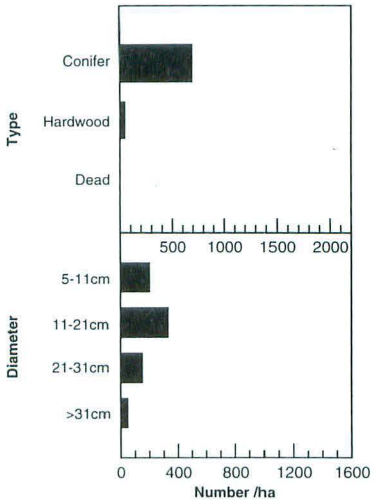
Diameter Distribution

Length

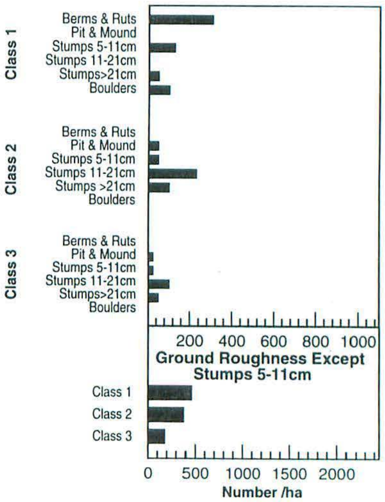
Residuals



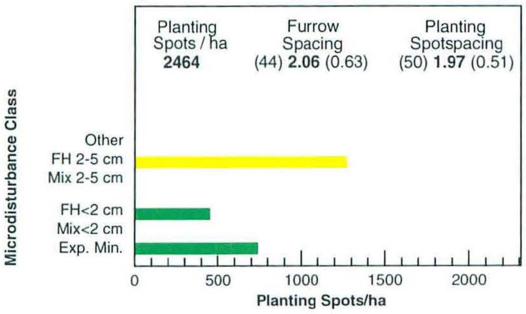
Stumps



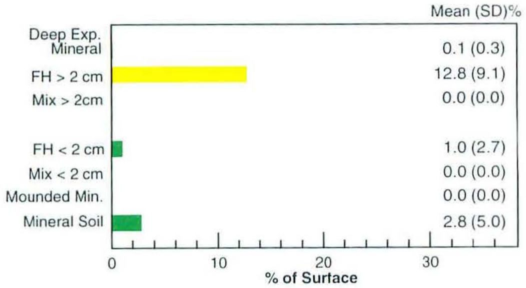
Ground Roughness



Plantability



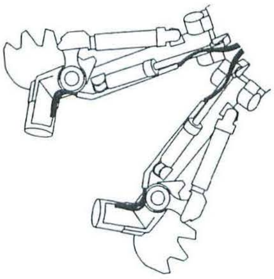
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	21	(27)
Furrow length (%), rock and/or water	2	(8)
Other surface conditions (% of surface):		
spoil bank	31	(21)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	7.2	(6.3)
rock and/or water	3.7	(5.8)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 27 August 1991
Time from site preparation to assessment: 1–3 weeks
Time from harvest to site preparation: 18–20 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	58	(26)



Implement: TTS Delta (power) disc trencher

Prime mover: 186.5-kW, 22.3-t skidder

The moderately heavy to very heavy load of woody residue, residuals, and ground roughness were the constraints to site preparation. The between-furrow mean spacing of 2.06 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 1.97 m. Of the approximately 2465 acceptable planting spots per hectare, 740 were in mineral soil, 450 were in organic matter ≤2 cm deep over mineral soil, and 1275 were in organic matter 2–5 cm deep over mineral soil. Six competitor species, including grasses, were noted during a vegetation assessment on 27 August, 6–8 months after harvest. There is the potential for light to moderate competition development, particularly grasses. The site's moisture regime was suitable for seeding both black spruce and jack pine. Good seedbed comprised 3.8% of the surface, and 12.9% was conditional, inadequate to support broadcast seeding of black spruce or jack pine except at uneconomic seed application rates. If necessary, manually set out seed spots or seeded shelters on selected microsites may offer some success as a relatively undesirable alternative to well-planted, vigorous planting stock adapted morphologically and physiologically to this site. Both fragile germinants and young seedlings may be smothered by litter or choked out by the competition development on this relatively fertile site. Compare with plate sets 2, 21, 24, and 39.

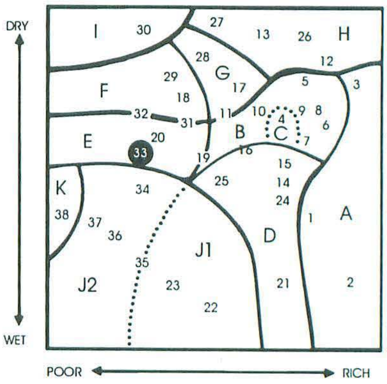
PLATE
23A

V33 Black Spruce / Feathermoss

S11/SS8, S11/S10, S11/SS8

FRI: Sb_{10}, age 130, height 19, stocking 0.3, site class 1

Other site vegetation types: Black Spruce/Labrador Tea/ Feathermoss (Sphagnum)



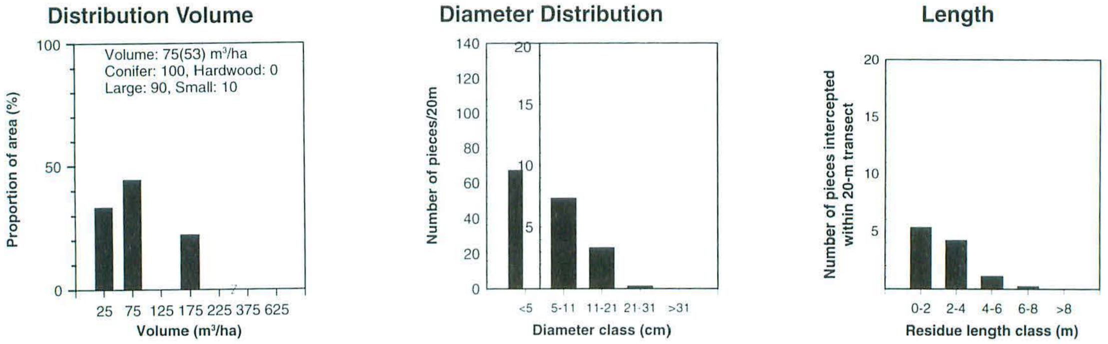
Photographed and assessed: 6 June 1991
Time elapsed since harvest: 14–18 months
Harvest method: full-tree by feller–buncher

Area topography: very gentle
Bedrock outcrops: none
Plot slopes: simple, 0–1%
Plot slope position: flat
Landform: ground moraine
Soil depth: 40, >100, and 45 cm

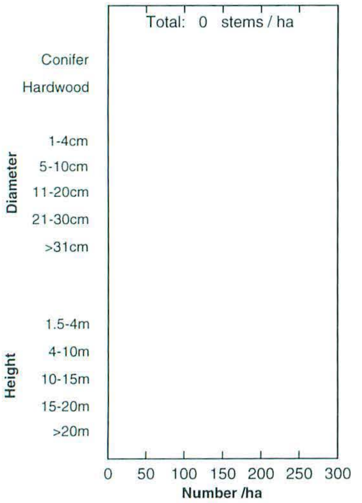
Soil texture: medium sand, silty very fine sand, fine sand
Boulders: none
Stones: none
Coarse fragments: 0–5%
Litter: 0–1 cm

Fermentation layer: 12–18 cm
Humus: 1–2 cm
Texture of surface mineral soil: medium sand, loam, medium sand
Drainage: imperfect to moderately well
Moisture regime: moderately moist to very fresh

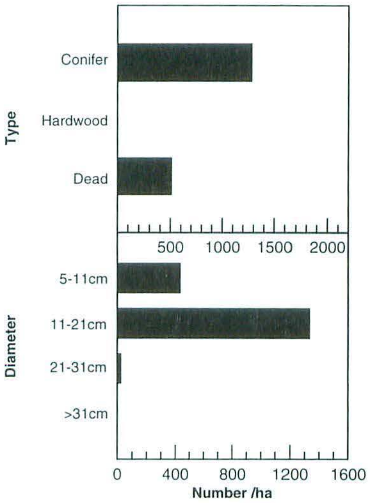
Woody Debris



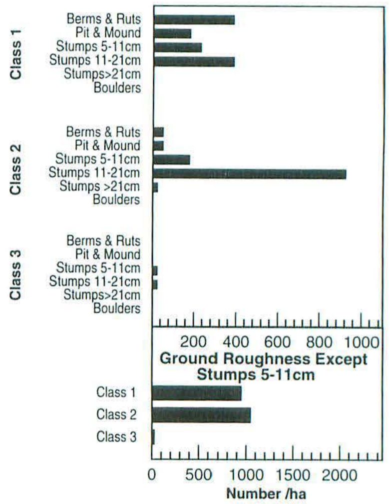
Residuals



Stumps

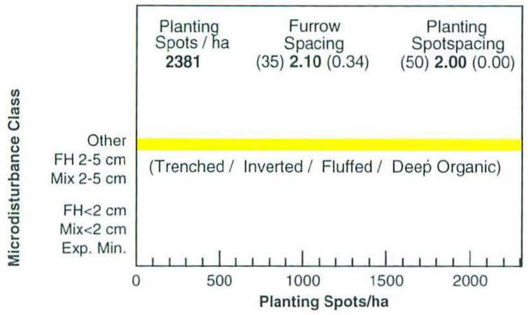


Ground Roughness

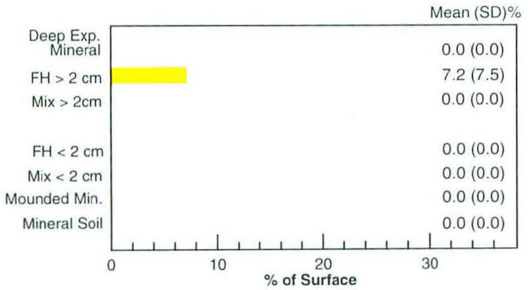


Trenching

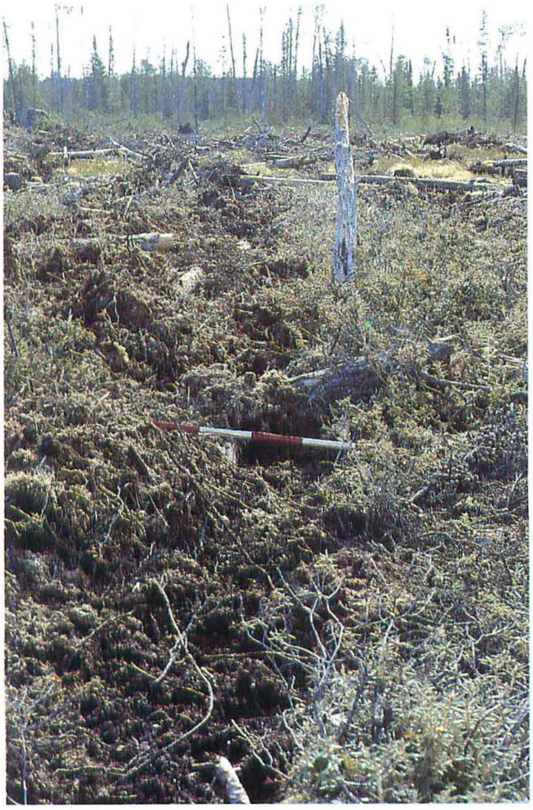
Plantability



Potential Seedbed

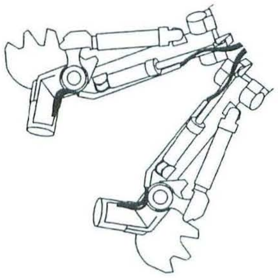


Furrow length (%), mineral soil ≥15 cm wide	1	(4)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	38	(21)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.9	(5.0)
rock and/or water	0.2	(0.7)
shallow (<10 cm) mineral soil over organic	0	(0)



Photographed and assessed: 14 August 1991
Time from site preparation to assessment: 3–5 weeks
Time from harvest to site preparation: 15–19 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	49	(24)



Implement: TTS Delta (power) disc trencher

Prime mover: 186.5-kW, 22.3-t skidder

The peaty-phase organic layer, moisture regime, and drainage were the primary impediments to site preparation and were complicated by the moderately light, occasionally moderately heavy, load of woody residue and the stump field. The between-furrow mean spacing of 2.10 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.00 m. Approximately 2380 acceptable planting spots per hectare (definition based on local experience) were all situated in organic matter >5 cm deep over mineral soil. Two competitor species were noted during a vegetation survey on 6 June, 14–18 months after harvest. It is possible that competition development, particularly sedges, will be enhanced by this treatment on this site. Sites with peaty-phase surfaces generally are not suitable for jack pine but commonly are planted or sown with black spruce. Disturbed organic matter >2 cm deep over mineral soil comprised 7.2% of the surface. It is currently unknown if this specific disturbance of this specific peaty-phase organic surface produces an acceptable seedbed for black spruce. Both undisturbed and disturbed feathermoss peat have limited to no value as seedbed for black spruce, whereas both undisturbed and properly disturbed *Sphagnum* peat may be good black spruce seedbed. Compare with plate sets 25, 27, 47, and 48.

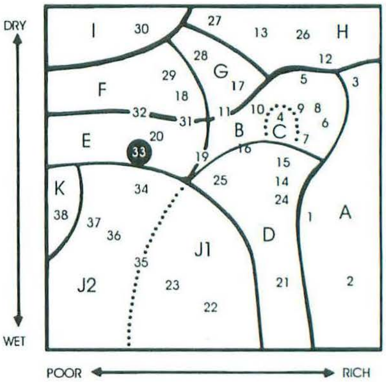
Note: Field notes state that <5% of the area for both the plot and the vicinity is *Sphagnum*.

PLATE 24A

V33 Black Spruce / Feathermoss SS5, SS5, SS5

FRI: Pj_8Sb_2, age 120, height 20 m, stocking 0.6, site class 2

Other site vegetation types: Black Spruce–Jack Pine/Tall Shrub/Feathermoss and Jack Pine–Black Spruce/Ericaceous Shrub/Feathermoss



Photographed and assessed: 28 August 1990
Time elapsed since harvest: 9–12 months
Harvest method: full-tree with feller–buncher and grapple skidder

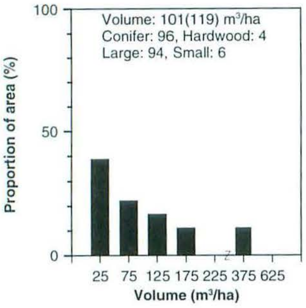
Area topography: gentle
Bedrock outcrops: slight
Plot slopes: simple, 2–8%
Plot slope position: mid
Landform: ground moraine
Soil depth: 20–70 cm

Soil texture: coarse sand, very fine sand (most common), and medium sand
Boulders: slight
Stones: moderate to very
Coarse fragments: 6–35%
Litter: 2–5 cm

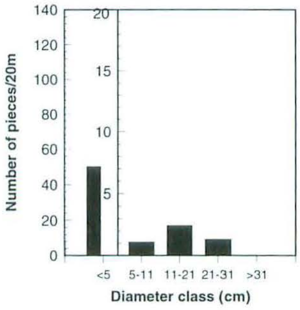
Fermentation layer: 5–7 cm
Humus: 1–2 cm
Texture of surface mineral soil: loamy coarse sand (less common), loamy fine sand, loamy medium sand
Drainage: very rapid (more common) to rapid
Moisture regime: dry (more common) to moderately fresh

Woody Debris

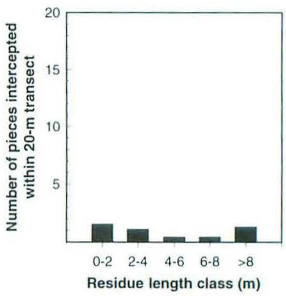
Distribution Volume



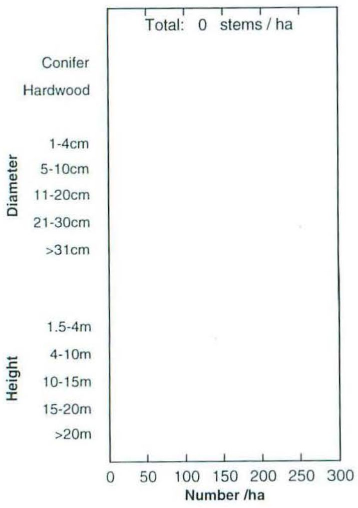
Diameter Distribution



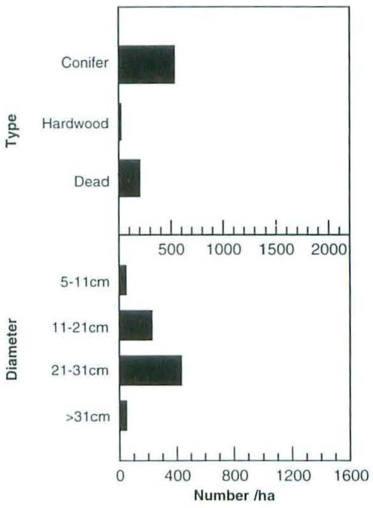
Length



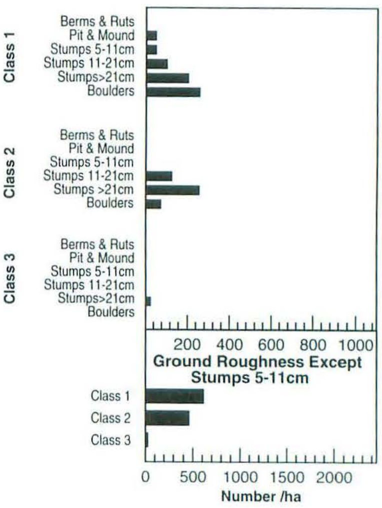
Residuals



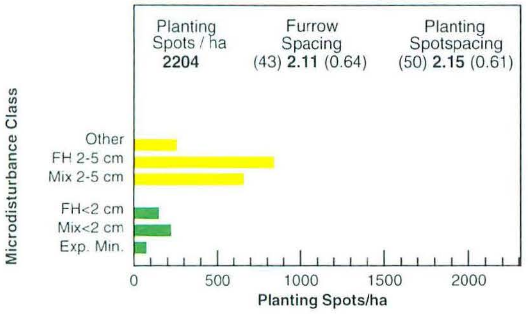
Stumps



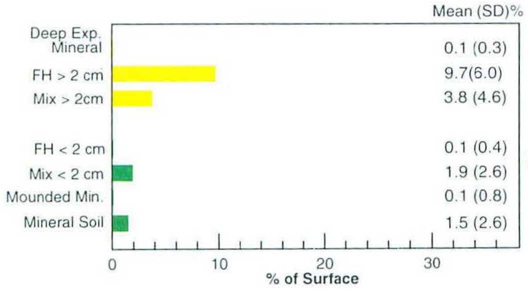
Ground Roughness



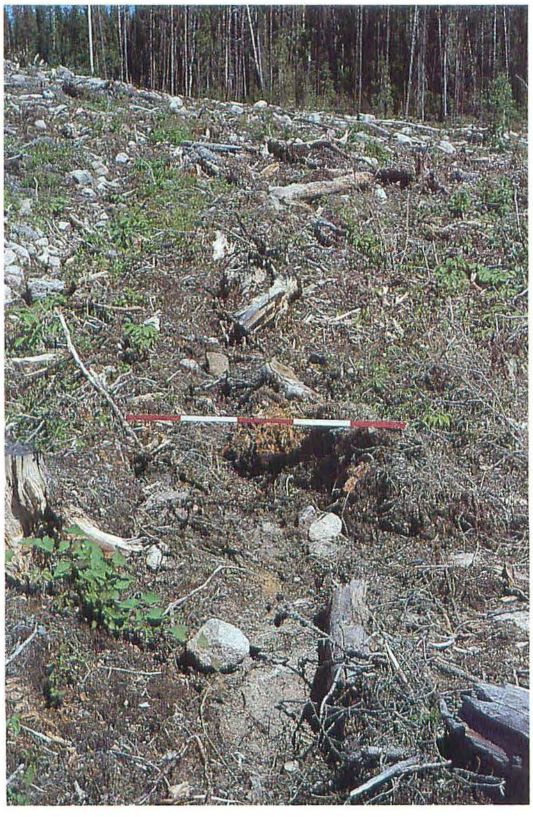
Plantability



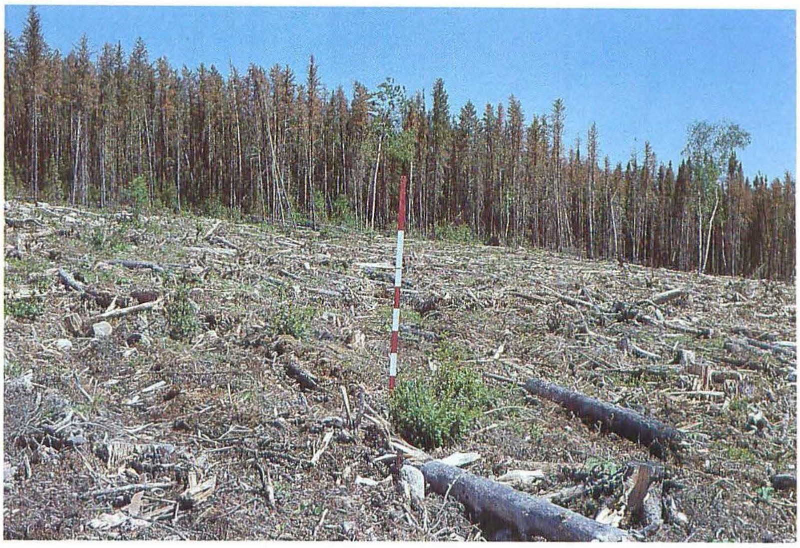
Potential Seedbed



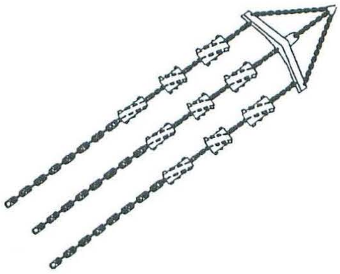
Furrow length (%), mineral soil ≥15 cm wide	51	(37)
Furrow length (%), rock and/or water	11	(15)
Other surface conditions (% of surface):		
spoil bank	28	(15)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1	(1.5)
rock and/or water	3.5	(2.3)
shallow (<10 cm) mineral soil over organic	0	(0)



Photographed and assessed: 4 June 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 10–13 months



Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.8	(2.1)
site preparation	49	(18)



Implement: heavy drags

Prime mover: 239-kW, 33.7-t bulldozer

Stones and the moderately light (occasionally moderately heavy to very heavy) loading of woody residue were the only noticeable impediments to site preparation. The between-furrow spacing of 2.11 m was a function of operating practice. The in-furrow acceptable planting spot spacing was increased to 2.15 m by the 11% of the furrow length that was natural or machine-exposed bedrock, plus soil too shallow to plant and the presence of woody residue. Of the approximately 2210 acceptable planting spots per hectare, 75 were in mineral soil, 370 were in an organic–mineral mix or organic matter ≤2 cm deep over mineral soil, 1505 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 260 were in other acceptable conditions. Four competitor species, including grasses, were noted during a vegetation assessment on 28 August, 9–12 months after harvest. Competition development may not be a problem for planted seedlings but possibly reduces the chance of stand establishment by any type of direct seeding, depending on ingress and development of grasses and field bindweed. This site is generally too dry to support seeding black spruce but is acceptable for seeding jack pine. Good seedbed comprised 3.6% of the surface, and 13.6% was conditional. The amount of seedbed is not adequate to support broadcast seeding of jack pine except at uneconomic seed application rates. Setting out either bare seed spots or seeded shelters on selected microsites may be a possible alternative if planting stock is in short supply. Compare with plate sets 7, 12, 16, 22, and 37.

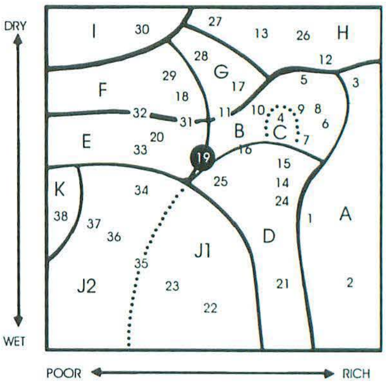
PLATE
25A

V19 Black Spruce Mixedwood / Herb Rich

S11/S9, S11/S10, S11/S10

FRI: Sb10, age 140, height 15 m, stocking 0.6, site class 2

Other site vegetation types: not recorded



Photographed and assessed: 19 April 1991
Time elapsed since harvest: about 2 months
Harvest method: full-tree by feller–buncher and grapple skidder

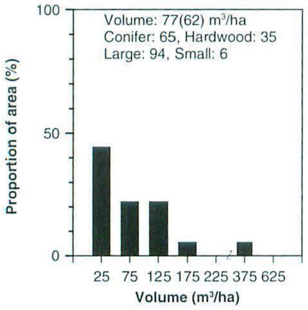
Area topography: very gentle to gentle
Bedrock outcrops: none
Plot slopes: simple, 0–2%
Plot slope position: flat to lower slope
Landform: lacustrine deposit
Soil depth: >100 cm

Soil texture: silt, gravelly clay, and silty clay (stratified)
Boulders: none
Stones: none
Coarse fragments: none
Litter: 2–4 cm

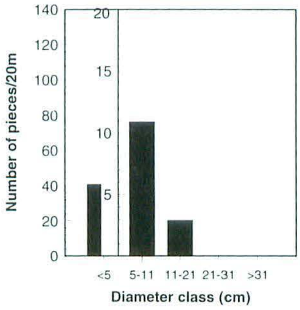
Peaty phase: 10–17 cm
Texture of surface mineral soil: silt
Drainage: moderately well to imperfect
Moisture regime: very moist, moist, very fresh

Woody Debris

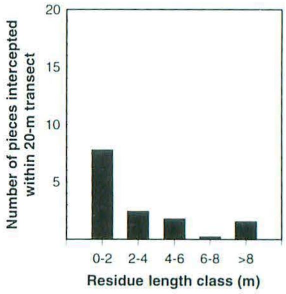
Distribution Volume



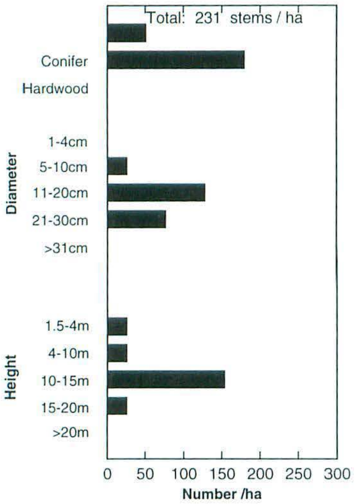
Diameter Distribution



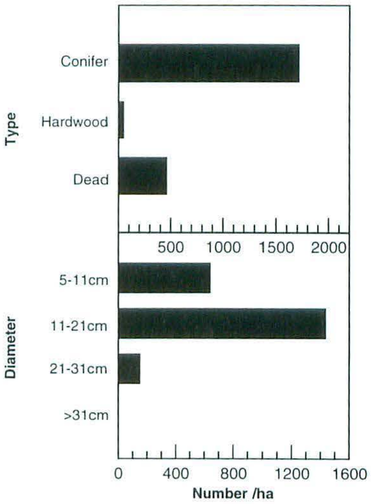
Length



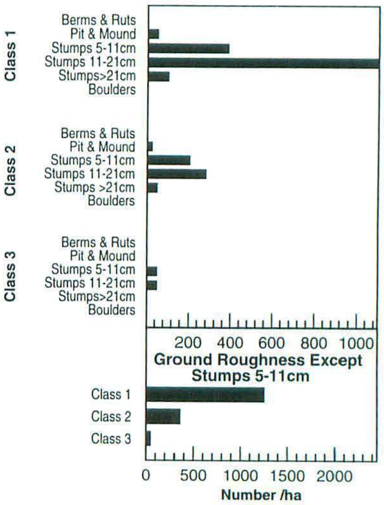
Residuals



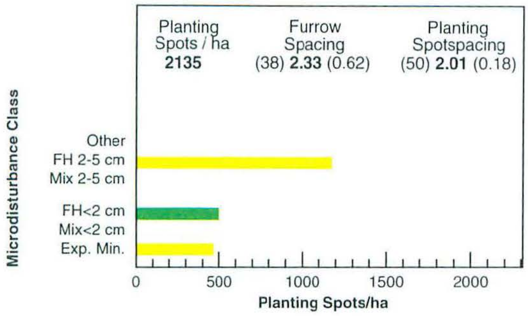
Stumps



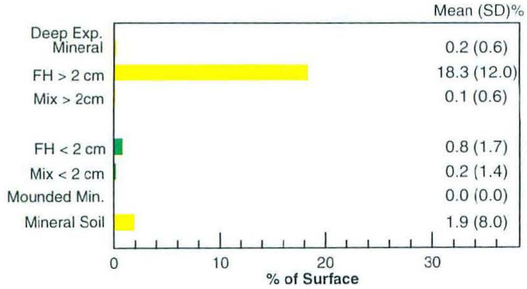
Ground Roughness



Plantability

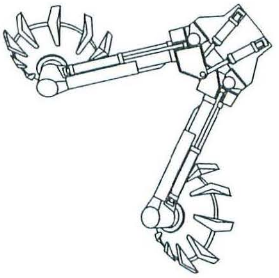


Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	17	(25)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	31	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.5	(3.6)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	57	(19)



Implement: Donaren 180 disc trencher (on ice lenses)

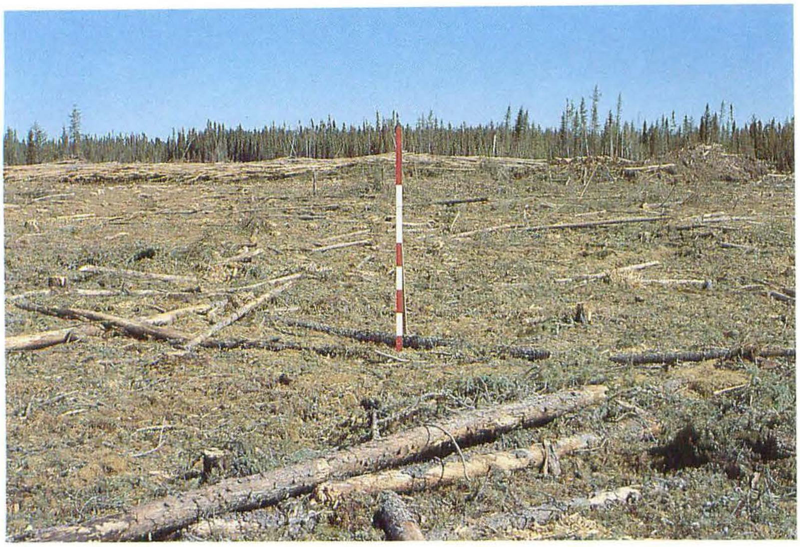
Prime mover: 185-kW, 17.5-t skidder

Drainage, moisture regime, and the shallow peaty-phase organic layer were the primary impediments to site preparation, but the situation was complicated by the moderately light (occasionally very heavy) load of woody residue, the residuals, and the stump field. The local innovative approach was to disc trench during the spring thaw, when the surface was tillable and the subsurface ice lenses were still capable of both supporting the machinery and limiting the depth of penetration of the tilling discs. The between-furrow mean spacing of 2.33 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.01 m. Of the 2135 acceptable planting spots per hectare, 465 were in mineral soil, 495 were in organic matter ≤2 cm deep over mineral soil, and 1175 were in organic matter 2–5 cm deep over mineral soil. Three competitor species were noted during a vegetation survey on 19 April, about 2 months after harvest. Competition development, particularly sedges, may be enhanced by this treatment on this site. Peaty-phase soils are not preferred by jack pine and are commonly planted or seeded with black spruce. Good seedbed comprised 2.9% of the surface, and 18.6% was conditional. Note that 19.4% of the surface was disturbed organic matter. It is currently unknown if this specific peaty-phase organic surface disturbed in this manner produces an acceptable seedbed for black spruce. Compare with plate sets 23, 27, 47, and 48.

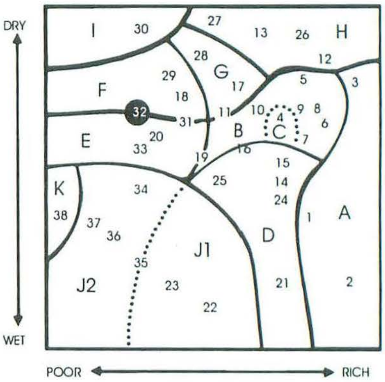
Photographed and assessed: 18 July 1991
Time from site preparation to assessment: 10–13 weeks
Time from harvest to site preparation (from mid-April to early May): 7–14 weeks

V32 Jack Pine – Black Spruce / Ericaceous Shrub / Feathermoss S7, S7, S8

FRI: Po7Sb3, age 90, height 20 m, stocking 0.9, site class 2



Other site vegetation types: not recorded, as 97% of stump basal area in the plot is jack pine, which is representative of the vicinity



Photographed and assessed: 18 April 1991
Time elapsed since harvest: about 2 months
Harvest method: full-tree by feller–buncher and grapple skidder

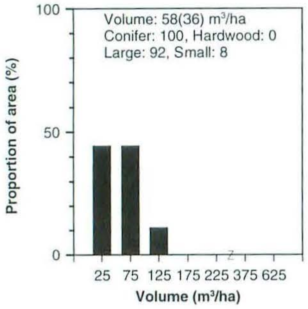
Area topography: very gentle
Bedrock outcrops: none
Plot slopes: simple, 0–2%
Plot slope position: lower
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: fine sand, very fine sand (most common), and loamy very fine sand (soil stratified)
Boulders: none
Stones: none
Coarse fragments: 0–20%
Litter: 2 cm

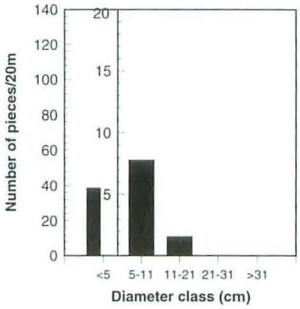
Fermentation layer: 5–13 cm
Humus: none
Texture of surface mineral soil: fine sand and very fine sand
Drainage: moderately well, imperfect, poor
Moisture regime: moist more common than moderately moist

Woody Debris

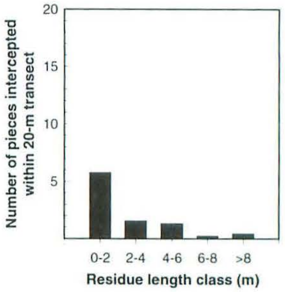
Distribution Volume



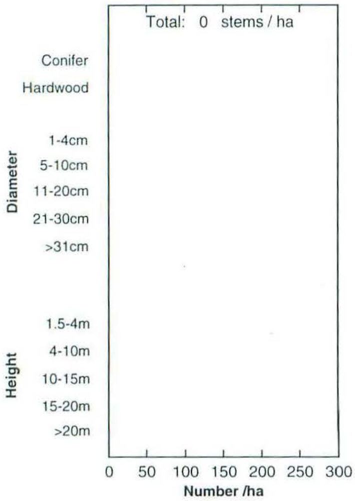
Diameter Distribution



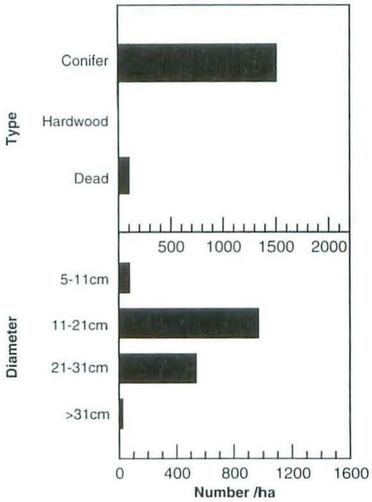
Length



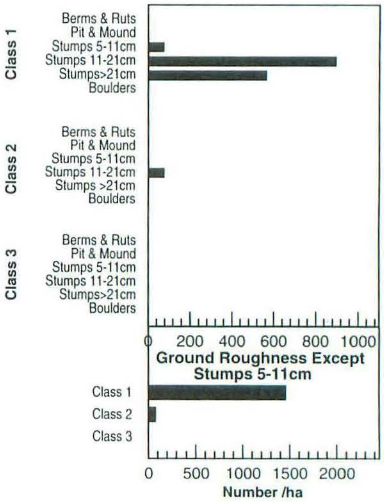
Residuals



Stumps

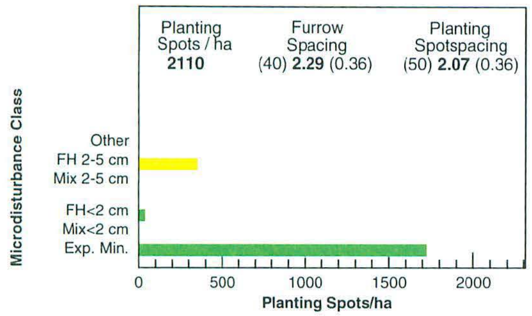


Ground Roughness

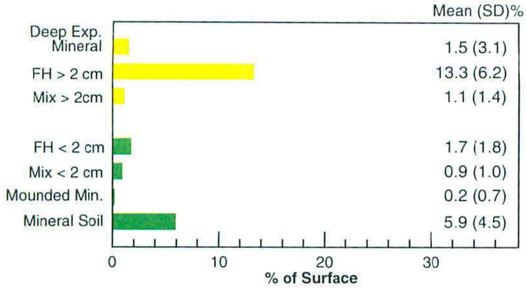


Trenching

Plantability



Potential Seedbed

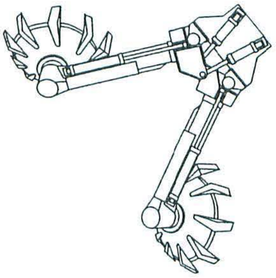


Furrow length (%), mineral soil ≥15 cm wide	55	(30)
Furrow length (%), rock and/or water	0	(0)

Other surface conditions (% of surface):

spoil bank	38	(25)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.7	(3.2)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	66	(25)



Implement: Donaren 180 disc trencher (on ice lenses)

Prime mover: 185-kW, 17.5-t skidder

Trafficability limitations due to drainage and moisture regime were the only noteworthy constraints to site preparation. The local innovative approach was to disc trench during the spring thaw when the surface was tillable and the subsurface ice lenses were still capable of both supporting the machinery and limiting the depth of penetration of the tilling discs. The between-furrow mean spacing of 2.29 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.07 m. Of the 2110 acceptable planting spots per hectare, 1725 were in mineral soil, 35 were in organic matter ≤2 cm deep over mineral soil, and 350 were in organic matter 2–5 cm deep over mineral soil. One competitor species was noted during a vegetation assessment on 18 April, about 2 months after harvest. It is doubtful that competition development will be a problem in the short term to either seedlings or germinants on this site. The moisture regime (at assessment) approaches the optimum for broadcast seeding of black spruce but is near the wet end of the acceptable range for seeding jack pine; however, from nearby roads and a borrow pit, it is noted that the site is underlain by coarse sands and fine gravels; as the (jack pine stumps) root system desiccates and shrinks, for a period of time there is the potential for this site to become rapidly drained with a dry moisture regime. Although only 8.7% of the surface was good seedbed, the site was sufficiently moist (at assessment) that the conditional seedbed (15.9%) may support germination and establishment of jack pine on normally unacceptable substrate, excepting, perhaps, years with very dry germination and establishment seasons. Compare with plate sets 21, 31, 33, and 39.

Photographed and assessed: 7 July 1991
Time from site preparation to assessment: 8–11 weeks
Time from harvest to site preparation (from mid-April to early May): 7–14 weeks

Note: The FRI stand description may be in error.

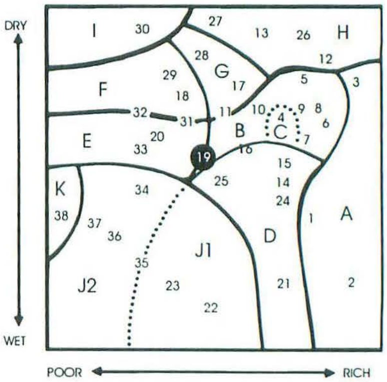
'LATE
27A

V19 Black Spruce Mixedwood / Herb Rich

S11/S5, S11/S10, S11/S5

FRI: Sb$_9$Po$_1$, age 120, height 12 m, stocking 0.8, site class 3

Other site vegetation types: not recorded



Photographed and assessed: 18 April 1991
Time elapsed since harvest: about 2 months
Harvest method: full-tree harvest by feller–buncher and grapple skidder

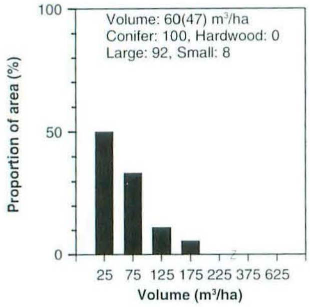
Area topography: very gentle
Bedrock outcrops: none
Plot slopes: simple, 2–6%
Plot slope position: upper to mid
Landform: lacustrine deposit over till
Soil depth: >100 cm

Soil texture: gravelly silty clay loam and very gravelly silty clay loam (soil stratified)
Boulders: slight
Stones: none
Coarse fragments: 30–>50%
Litter: 3 cm

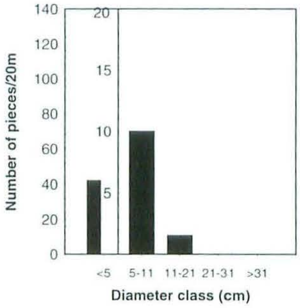
Peaty phase: 27–29 cm
Texture of surface mineral soil: loam, clay loam, silty clay loam
Drainage: moderately well, imperfect, poor
Moisture regime: fresh, moist, very fresh

Woody Debris

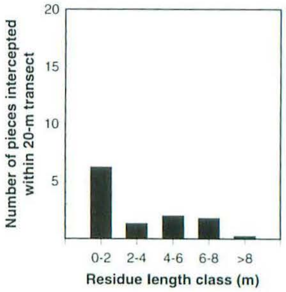
Distribution Volume



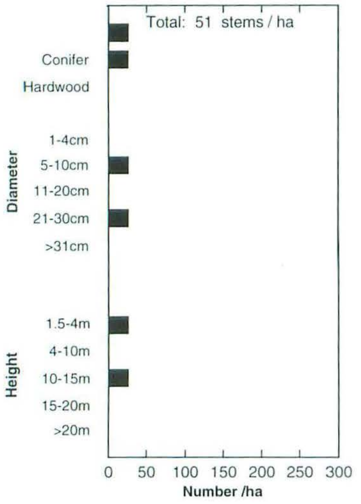
Diameter Distribution



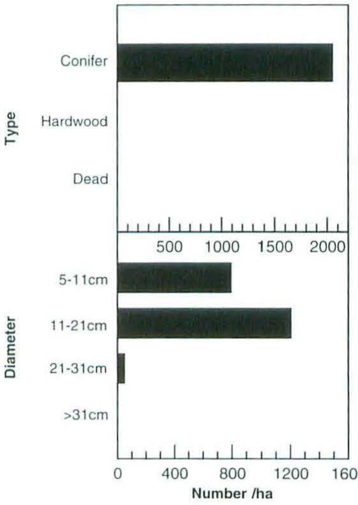
Length



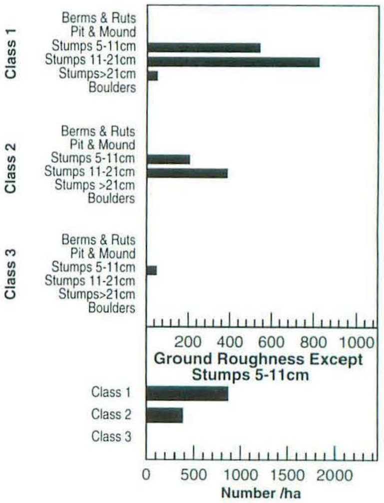
Residuals



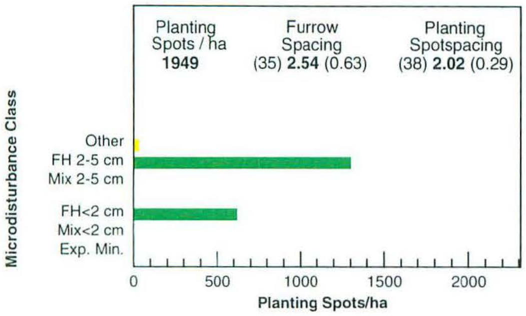
Stumps



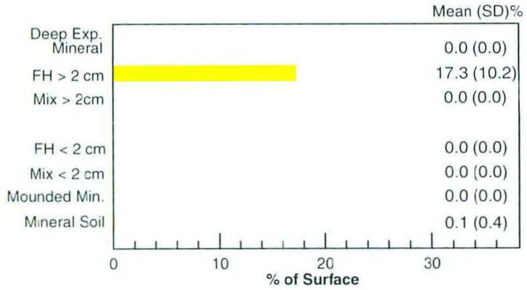
Ground Roughness



Plantability

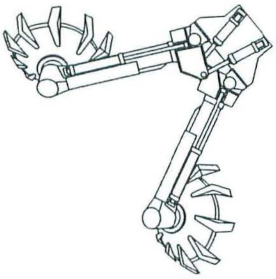


Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	0	(3)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	23	(16)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.3	(3.9)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	44	(20)



Implement: Donaren 180 disc trencher (on ice lenses)

Prime mover: 185-kW, 17.5-t skidder

The peaty-phase organic layer, drainage, and moisture regime were constraints to site preparation. The local innovative approach was to disc trench during the spring thaw when the surface was tillable and the subsurface ice lenses were still capable of both supporting the machinery and limiting the depth of penetration of the tilling discs. The between-furrow mean spacing of 2.54 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.02 m. Of the approximately 1950 acceptable planting spots per hectare, 620 were in mineral soil, 1300 were in organic matter 2–5 cm deep over mineral soil, and 30 were in other acceptable conditions. Two competitor species were noted during a vegetation assessment on 18 April, about 2 months after harvest. Competition development, particularly sedges, may be enhanced. Peaty-phase soils are not preferred by jack pine and are commonly planted or seeded with black spruce. Disturbed organic matter >2 cm deep over mineral soil comprised 17.3% of the peaty-phase surface. It is currently unknown if this specific peaty-phase organic surface disturbed in this manner produces an acceptable seedbed for black spruce. Compare with plate sets 23, 25, 47, and 48.

Photographed and assessed: 19 July 1991
Time from site preparation to assessment: 9–14 weeks
Time from harvest to site preparation (from late April to early May): 9–12 weeks

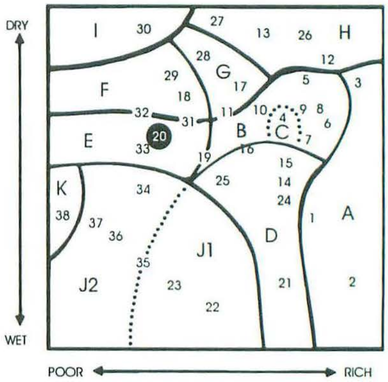
ATE
8A

V20 Black Spruce Mixedwood / Feathermoss

SS6, SS5, SS3

FRI: $Pj_5Bw_2Po_2Sb_1$, age 65, height 16.5 m, stocking 0.7, site class 2

Other site vegetation types: Jack Pine Mixedwood/ Feathermoss and Black Spruce–Jack Pine/Tall Shrub/ Feathermoss



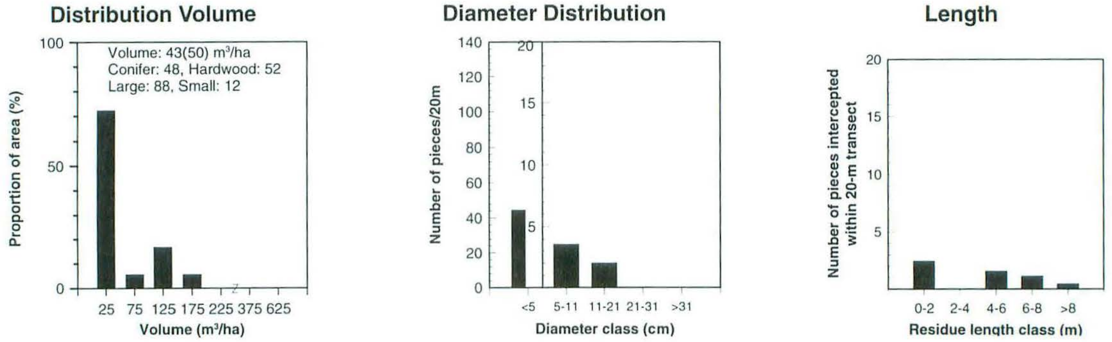
Photographed and assessed: 29 September 1990
Time elapsed since harvest: 1–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle to very strong
Bedrock outcrops: slight (on plot) to very
Plot slopes: simple, 1–4%
Plot slope position: mid
Landform: shallow glacial drift
Soil depth: 10–70 cm

Soil texture: silty very fine sand (more common) and medium sand (soil stratified)
Boulders: slight
Stones: moderate to very
Coarse fragments: 6–35%
Litter: 2–4 cm

Fermentation layer: 4–7 cm
Humus: none
Texture of surface mineral soil: sandy loam, loamy fine sand, loam
Drainage: rapid (common) to well
Moisture regime: fresh, moderately fresh (common), moderately dry

Woody Debris

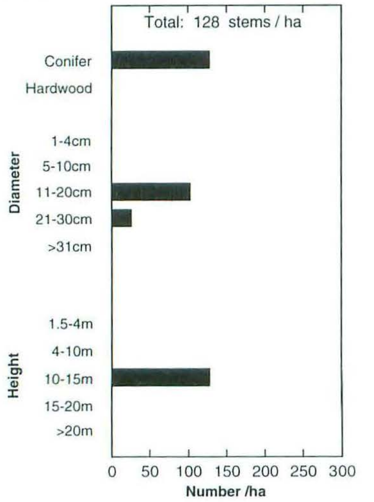


Distribution Volume

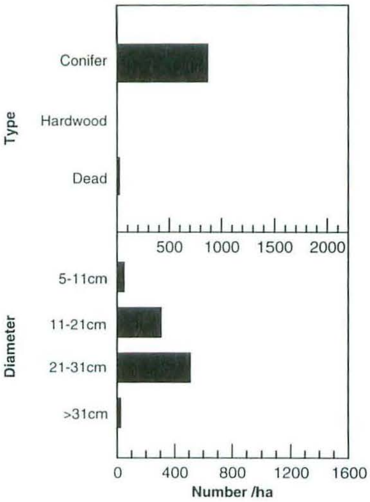
Diameter Distribution

Length

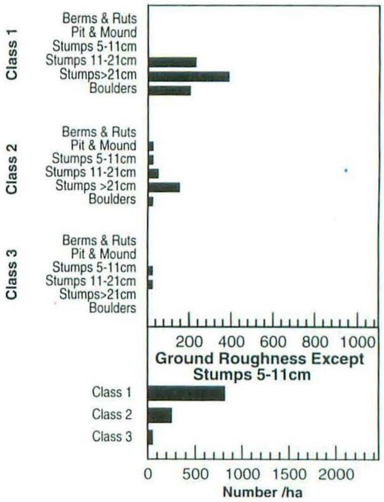
Residuals



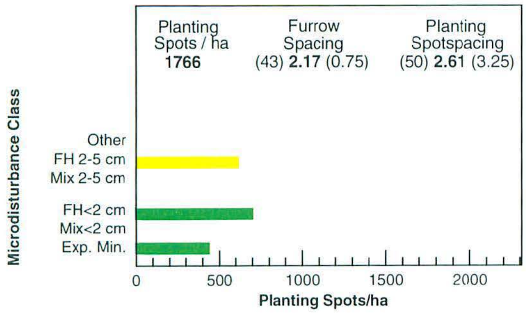
Stumps



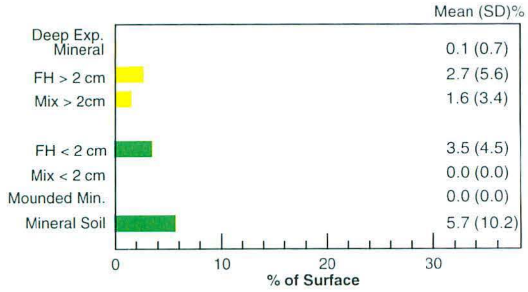
Ground Roughness



Plantability



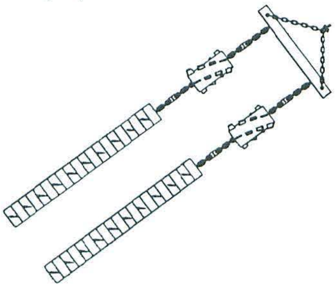
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	51	(48)
Furrow length (%), rock and/or water	18	(30)
Other surface conditions (% of surface):		
spoil bank	21	(14)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	8.3	(12.2)
rock and/or water	1.1	(3.7)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 9 October 1991
Time from site preparation to assessment: 5–7 weeks
Time from harvest to site preparation: 12–14 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	8.7	(15.0)
site preparation	35	(17)



Implement: light drags

Prime mover: 164-kW, 10-t skidder

The between-furrow mean spacing of 2.17 m resulted from operating practice that may have been influenced by the bedrock-controlled topography and the shallow soils. The in-furrow acceptable planting spot mean spacing was increased to 2.61 m by the 18% of furrow length that was natural or machine-exposed bedrock plus soil too shallow to plant. Of the approximately 1765 acceptable planting spots per hectare, 440 were in mineral soil, 705 were in organic matter ≤2 cm deep over mineral soil, and 620 were in organic matter 2–5 cm deep over mineral soil. Three competitor species were noted during a vegetation assessment on 29 September, 1–3 months after harvest. Suckering of *Populus* spp. may be significant on scattered portions of this site. The moisture regime was variable at a 2-m^2 scale and was generally acceptable for seeding jack pine, and the greater part of the site mosaic was sufficiently moist to support seeding black spruce. Good seedbed comprised 9.2% of the surface, and 4.4% was conditional. The limited availability of seedbed may limit the success of broadcast seeding of black spruce and jack pine except at uneconomic seed application rates. Also, within aspen-dominated pockets, fragile germinants may not cope with the potential competition development and/or may be smothered by litter fall. Compare with plate sets 29, 30, 35, 38, 45, and 46.

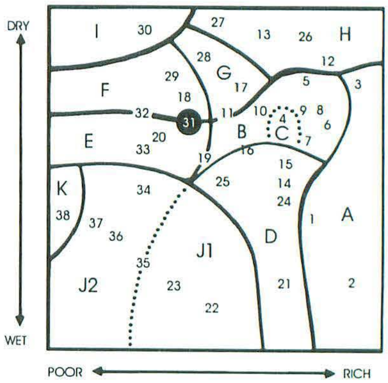
PLATE
29A

V31 Black Spruce – Jack Pine / Tall Shrub / Feathermoss

SS8, SS6, SS3

FRI: $Sb_7Po_2Bw_1$, age 120, height 15 m, stocking 0.5, site class 2

Other site vegetation types: Black Spruce Mixedwood/ Feathermoss and, in depressions, Black Spruce/ Feathermoss



Photographed and assessed: 16 October 1990
Time elapsed since harvest: 1–4 months
Harvest method: full-tree by feller–buncher and grapple skidder

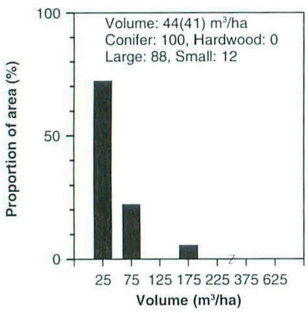
Area topography: very gentle to moderate
Bedrock outcrops: very
Plot slopes: simple, 2–13%
Plot slope position: mid to upper
Landform: shallow glacial drift
Soil depth: 10–45 cm, discontinuous

Soil texture: medium sand
Boulders: slight
Stones: slight to moderate
Coarse fragments: 6–20%
Litter: 1–3 cm

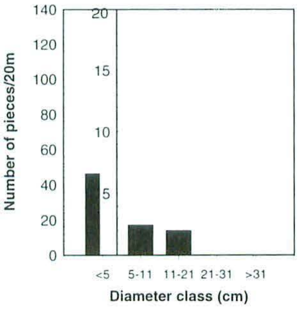
Fermentation layer: 4–6 cm
Humus: 1 cm
Texture of surface mineral soil: sandy loam and loamy medium sand
Drainage: moderately well, rapid, very rapid
Moisture regime: very fresh, moderately dry (common), dry

Woody Debris

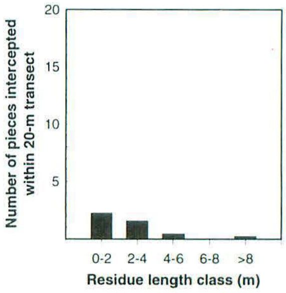
Distribution Volume



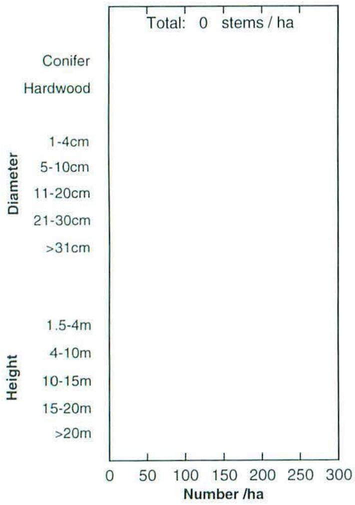
Diameter Distribution



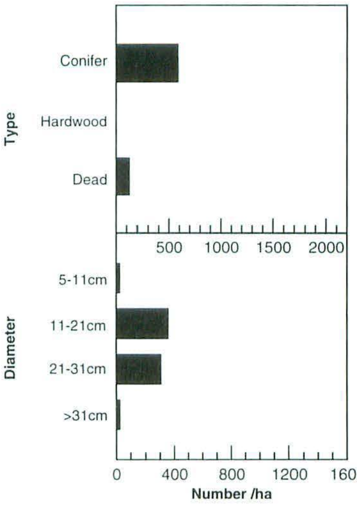
Length



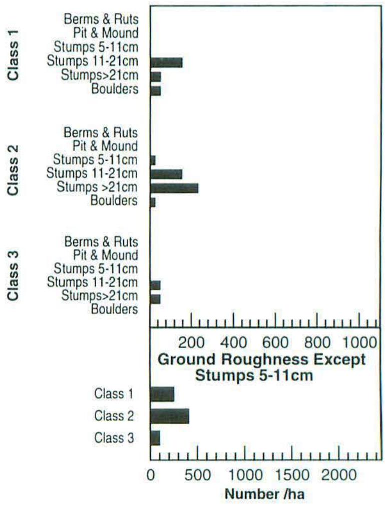
Residuals



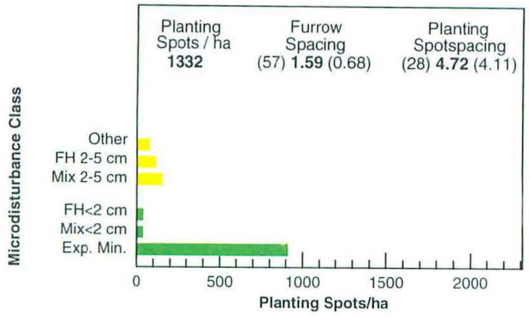
Stumps



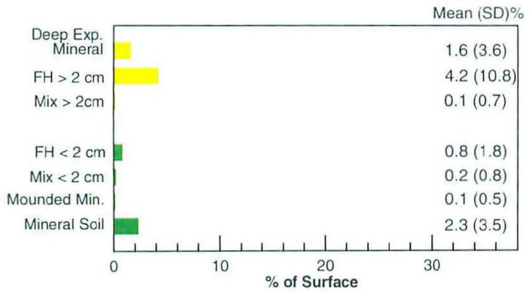
Ground Roughness



Plantability



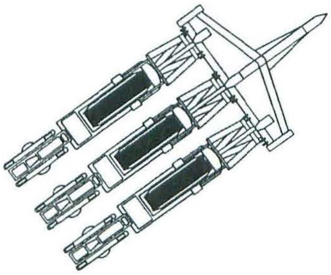
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	20	(25)
Furrow length (%), rock and/or water	22	(27)
Other surface conditions (% of surface):		
spoil bank	47	(25)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.0	(15.6)
rock and/or water	5.4	(13.0)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 28 September 1991
Time from site preparation to assessment: 4–5 weeks
Time from harvest to site preparation: 11–14 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	2.2	(8.4)
site preparation	63	(30)



Implement: Bräcke Badger (3 mattock wheels at 1-m spacing)

Prime mover: 136-kW, 10-t skidder

The between-rows-of-scalps mean spacing of 1.59 m resulted from operating practice that was influenced by the discontinuous, shallow to (barely) moderately shallow soil on the constant, often moderate slopes of the bedrock-controlled topography and ground roughness. The in-rows-of-scalps acceptable planting spot mean spacing was increased to 4.72 m by the 22% of the in-rows-of-scalps length that was either natural or machine-exposed bedrock, along with inadequate soil depth and the occasional presence of woody residue. Of the approximately 1330 acceptable planting spots per hectare, 915 were in mineral soil, 75 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 265 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 75 were in other acceptable conditions. Three competitor species, including grasses, were noted during a vegetation assessment on 16 October, 1–4 months after harvest. Competition development will be variable, as all three phases of Treatment Unit E were present in a close association mosaic. The moisture regime was variable at a 2-m^2 scale and was generally acceptable for seeding jack pine, but only portions of the site mosaic may be amenable to seeding black spruce. Good seedbed comprised 3.4% of the surface, and 5.9% was conditional. Hence, only uneconomic rates of broadcast seed application for either species will offer any opportunity of success in years with favorable weather in the germination and establishment seasons. If necessary, manual application of seed spots or seeded shelters on selected microsites may be an alternative to planting. Compare with plate sets 29, 30, 35, 38, 45, and 46.

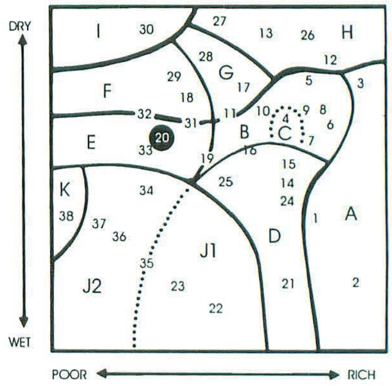
PLATE
30A

V20 Black Spruce Mixedwood / Feathermoss

SS8, SS5, SS8

FRI: $Sb_4Pj_2Po_2B_1Bw_1$, age 100, height 17 m, stocking 0.8, site class 1

Other site vegetation types: not recorded



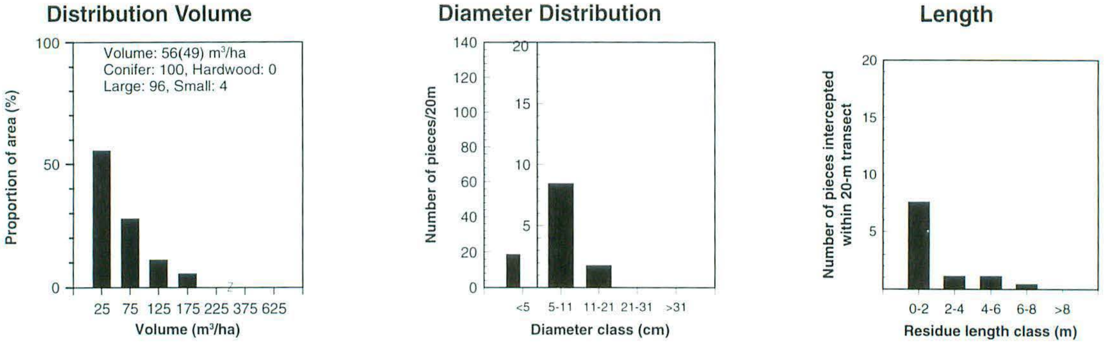
Photographed and assessed: 28 May 1991
Time elapsed since harvest: 24–26 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle to moderate
Bedrock outcrops: none to slight
Plot slopes: simple, 6–12%
Plot slope position: mid to upper
Landform: wave-washed ground moraine
Soil depth: 42–59 cm

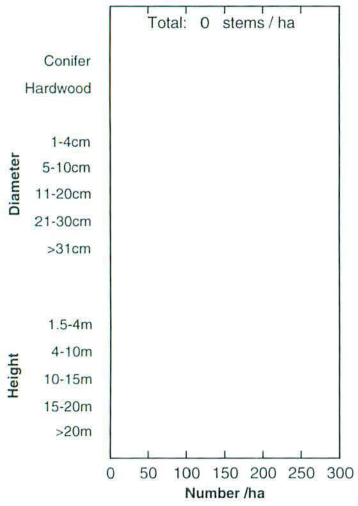
Soil texture: gravelly silty loam, silty medium sand, gravelly very fine sand
Boulders: moderate to very
Stones: moderate to very
Coarse fragments: none
Litter: 3–5 cm

Fermentation layer: 8–10 cm
Humus: none
Texture of surface mineral soil: silt, silty fine sand, silty very fine sand
Drainage: very rapid (common) to moderately well
Moisture regime: dry (common) to moderately fresh

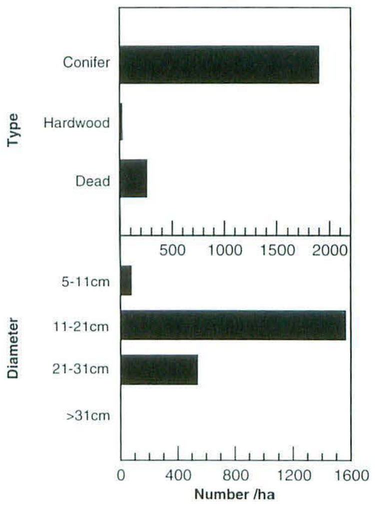
Woody Debris



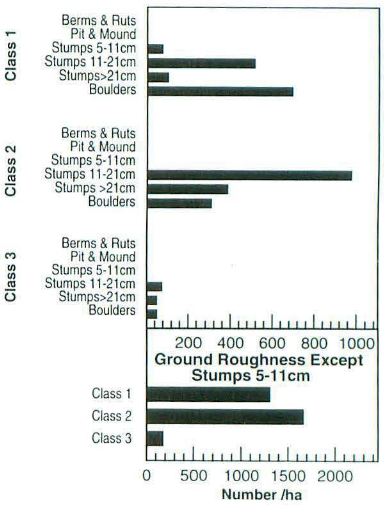
Residuals



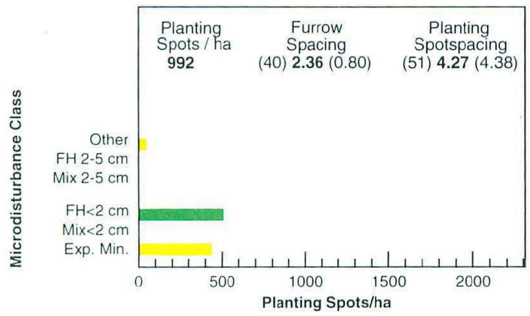
Stumps



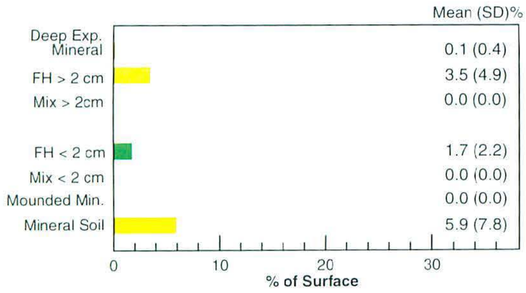
Ground Roughness



Plantability



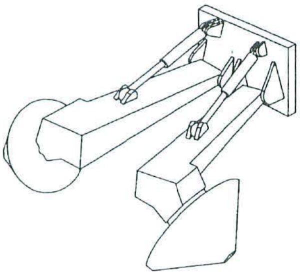
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	35	(32)
Furrow length (%), rock and/or water	3	(16)
Other surface conditions (% of surface):		
spoil bank	42	(23)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.2	(2.1)
rock and/or water	1.8	(4.4)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 6 September 1991
Time from site preparation to assessment: 2–5 weeks
Time from harvest to site preparation: 26–29 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	1.7	(5.4)
site preparation	54	(25)



Implement: Silva Wadell powered cone scarifier

Prime mover: 104-kW, 14.5-t skidder

The between-furrow mean spacing of 2.36 m resulted from operating practice that may have been influenced by the combination of ground roughness (boulders) and moderate slopes. The in-furrow acceptable planting spot mean spacing of 4.27 m resulted from the 3% of furrow length that is rock, plus failed planting attempts because of shallow soil over boulders (39%), woody residue (4%), and presence of competing vegetation (2%). Of the approximately 995 acceptable planting spots per hectare, 440 were in mineral soil, 505 were in organic matter ≤2 cm deep over mineral soil, and 50 were in other acceptable conditions. Four competitor species, including grasses, were noted during a vegetation assessment on 28 May, about 24–26 months after harvest. Competition development, especially grasses, could pose a problem on portions of this dry to moderately fresh, fine-textured soil. The greater part of this plot is too dry to seed black spruce but is acceptable for seeding jack pine. Good seedbed comprised 7.6% of the surface, and 3.6% was conditional. Except in years with favorable weather in the germination and establishment seasons, it is unlikely that even uneconomic rates of broadcast seed application will establish a stand that satisfies minimum conifer stocking standards. However, if frost heaving is not a local problem on the fine-textured soil, manual application of mini-plug container stock, seed spots, seeded shelters, etc. on selected microsites may have the potential to produce better conifer stocking than planting either common container or bareroot stock. Compare with plate sets 28, 29, 35, 38, 45, and 46.

Treatment Unit F

Treatment Unit F: Jack Pine/Feathermoss

Treatment Unit F typically contains even-aged jack pine or jack pine–black spruce stands with extensive feathermoss ground cover. Jack pine dominates all stands.

Equipment trafficability

No limitations to equipment are anticipated.

Competition

Competition may occur from *Alnus crispa* or trembling aspen but typically is not heavy. According to Walsh and Krishka (1991), *Betula papyrifera*, ferns, *Actaea rubra*, *Polygonum convulvus*, and grasses may also pose a problem on Treatment Unit F.

Comments

These sites respond well to light drags for distribution of slash, as well as exposure of mineral soil for seeding or planting to jack pine.

Summary

A summary of Treatment Unit F is presented in Table 6.

Eight plots were sampled (plate sets 31–38). For the size of prime movers used, few impediments to site preparation existed in the plots presented in plate sets 31–34 and 36.

The plot presented in plate set 31 represents the classic jack pine aerial broadcast seeding site. The medium (verging on heavy) drags drawn by 224-kW, 32.0-t and 250-kW, 36.8-t bulldozers running side by side produced 2737 acceptable planting spots per hectare, 10.2% mineral soil exposure, and 5.8% organic or organic–mineral mix ≤2 cm deep over mineral soil.

The plots presented in plate sets 32 and 33 were site-prepared with the TTS Delta (passive) disc trencher mounted on a 150-kW, 13.2-t skidder. Both plots were similar, with deep soil, gentle slopes, light loadings of woody residue, and negligible ground roughness. On the plot presented in plate set 32, 2564 acceptable planting spots per hectare, 13.9% mineral soil exposure, and 5.6% organic or organic–mineral mix ≤2 cm deep over mineral soil were produced. On the plot represented by plate set 33, 2359 acceptable planting spots per hectare,

Table 6. Data from plate sets for Treatment Unit F ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
31	2737	87	10.2	5.8	18.9	6–9	>100	vg→g	1–2	0	0
32	2564	87	13.9	5.6	12.2	5–6	>100	g	1	0	0
33	2359	35	6.0	4.1	17.9	6–10	>100	g	1	0	0
34	2006	58	12.2	2.7	7.2	4–10	>100	g→m	0–2	0	M
35	1777	38	9.1	2.7	5.7	4–8	4–50 (dis)	g→m	0–4	M→V	M
36	1752	44	9.3	1.8	7.6	8–10	50–>100	g→m	1–4	S	S
37	1736	31	5.2	0.9	6.4	6–11	>100	vg→g	0–5	0	M→S
38	1220	26	4.9	1.7	2.2	3–7	25–60 (dis)	vg→m	1–4	V→E	M→V

6.0% mineral soil exposure, and 4.1% organic or organic–mineral mix ≤2 cm deep over mineral soil were produced.

Although the plot represented by plate set 34 had approximately 975 ground roughness class 2 and 3 obstacles per hectare and a moderately light to moderate loading of woody residue, it is doubtful if these impediments affected the progress of the 186.5-kW, 25-t skidder with the Donaren 180 disc trencher. A between-furrow spacing of 2.53 m produced 2006 acceptable planting spots per hectare, 12.2% mineral soil exposure, and 2.7% organic or organic–mineral mix ≤2 cm deep over mineral soil.

The plot represented by plate set 36 had a moderately light loading of fresh woody residue and about 800 ground roughness class 2 and 3 obstacles per hectare, mostly large stumps. A Bräcke 3-row patch scarifier with the mattocks set 2.0 m apart on the drawbar and the machine patch scalping interval set longer than 2 m was drawn by a 152-kW, 13.3-t skidder; 1752 acceptable planting spots per hectare, 9.3% mineral soil exposure, and 1.8% organic or organic–mineral mix ≤2 cm deep over mineral soil were produced.

The plot represented by plate set 37 had deep soil, very gentle to gentle slopes, stones and boulders 2–30 m apart and large stumps giving about 825 ground roughness class 2 and 3 obstacles per hectare, and a moderately heavy (occasionally very heavy) loading of woody residue. However, the mean between-furrow spacing of 2.41 m may have been a function of operating practice with the Donaren 180 disc trencher mounted on a 186.5-kW, 25-t skidder; 1736 acceptable planting spots per hectare, 5.2% mineral soil exposure, and 0.9% organic or organic–mineral mix ≤2 cm deep over mineral soil were produced.

The plots represented by plate sets 35 and 38 had very shallow to moderately deep mineral soil, very gentle to moderate slopes, rock outcrops ranging from <2 to <25 m apart, plus stones and/or boulders 2–10 m apart. Both sites were treated with light drags drawn by a 164-kW, 10-t skidder. Between-furrow spacing was 2.14 m and 1.91 m, respectively. The plot represented by plate set 35 yielded 1777 acceptable planting spots per hectare, 9.1% mineral soil exposure, and 2.9% organic or organic–mineral mix ≤2 cm deep over mineral soil. The plot represented by plate set 38 yielded 1220 acceptable planting spots per hectare, 4.9% mineral soil exposure, and 1.7% organic or organic–mineral mix ≤2 cm deep over mineral soil. The differences in product may be attributed to more mineral soil cover and less bedrock exposure on the site represented by plate set 35.

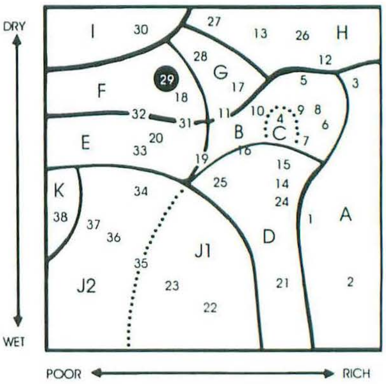
Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m³/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime.	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
800	44	4–6	6	mD→F	LmS & LfS	V-29 (F)	1.80	2.03	224 & 250	32.0 & 36.8	drag (M)	31
175	34	4–7	3	**mD**→mF	fS	V-29 (F)	1.94	2.01	150	13.2	TTS (pas)	32
50	43	4–8	1	mD	mS, cS, LcS	V-29 (F)	2.13	1.99	150	13.2	TTS (pas)	33
975	99	13–14	5	**mD**→mF	cS, mS	V-29 (F)	2.53	1.97	186.5	25	Don180	34
725	16	12–14	3	**mD** (D→F)	SL, L	V-31 (F)	2.14	2.63	164	10	drag (L)	35
800	64	1–3	2	**F** (mD→vF)	**mS**, fS	V-29 (F)	2.13	2.68	152	13.3	Bräcke	36
825	165	11–12	6	**mD**→mF	LcS	V-18 (F)	2.41	2.39	186.5	25	Don180	37
375	63	13–16	8	**mF**→mD	**SL**, L	V-32 (F)	1.91	4.29	164	10	drag (L)	38

PLATE
31A

V29 Jack Pine / Ericaceous Shrub / Feathermoss S1, S1, S1

FRI: Pj$_{10}$, age 50, height 17 m, stocking 1.2, site class 2

Other site vegetation types: occasional inclusions of Jack Pine/Low Shrub and Jack Pine–Black Spruce/ Ericaceous Shrub/Feathermoss



Photographed and assessed: 11 September 1990
Time elapsed since harvest: 3–5 months
Harvest method: full-tree by feller–buncher and grapple skidder

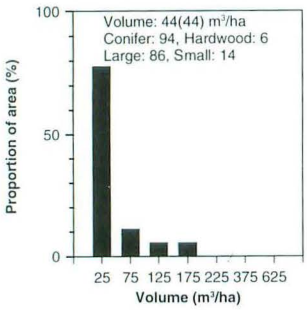
Area topography: very gentle to gentle
Bedrock outcrops: none
Plot slopes: simple, 1–2%
Plot slope position: flat
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: coarse sand, occasionally medium sand
Boulders: none
Stones: none
Coarse fragments: 6–35%
Litter: 2–3 cm

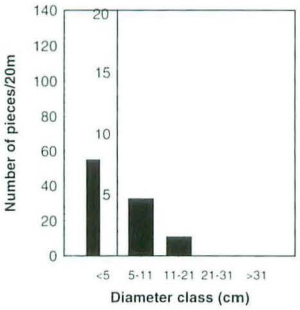
Fermentation layer: 3–5 cm
Humus: trace to 1 cm
Texture of surface mineral soil: loamy medium sand and loamy fine sand
Drainage: rapid to well
Moisture regime: moderately dry to fresh

Woody Debris

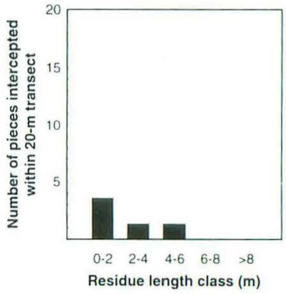
Distribution Volume



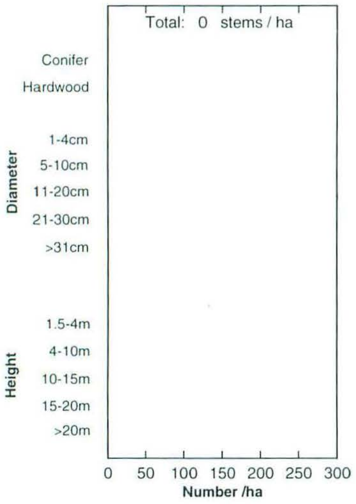
Diameter Distribution



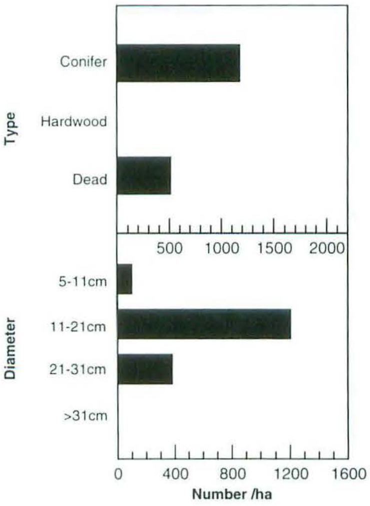
Length



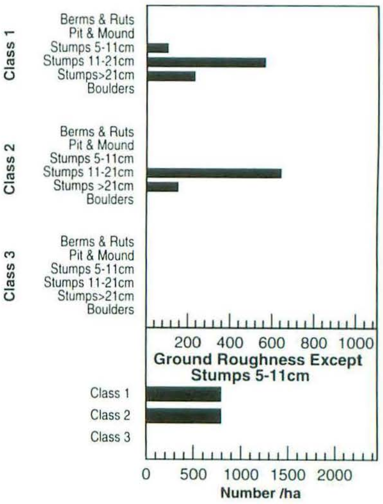
Residuals



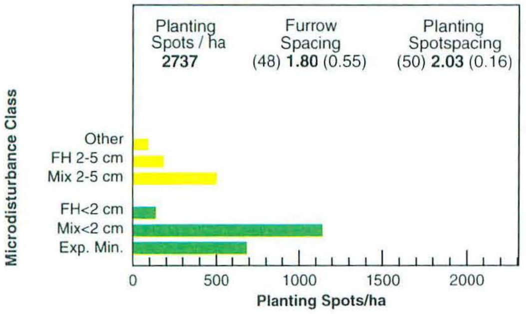
Stumps



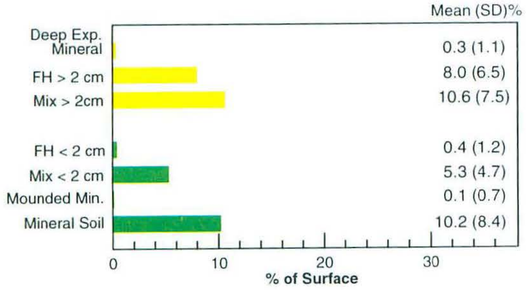
Ground Roughness



Plantability



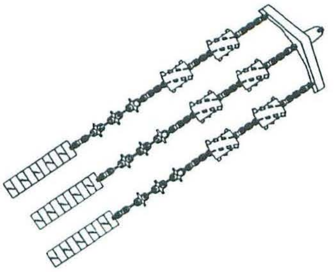
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	87	(27)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	46	(16)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.7	(2.3)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 25 June 1991
Time from site preparation to assessment: about 8 months
Time from harvest to site preparation: 4–6 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.2	(1.4)
site preparation	84	(17)



Implement: medium (tending toward heavy) drags

Prime mover: 224-kW, 32.0-t bulldozer and 250-kW, 36.8-t bulldozer

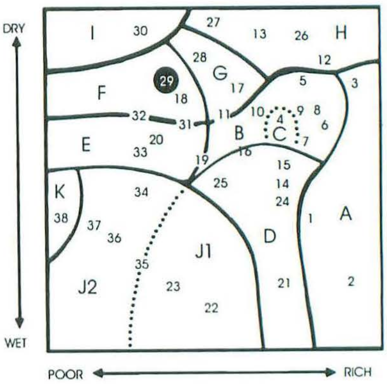
The between-furrow mean spacing of 1.80 m was a function of drag configuration and operating practice. The in-furrow acceptable planting spot mean spacing was 2.03 m. Of the approximately 2740 acceptable planting spots per hectare, 685 were in mineral soil, 1280 were in an organic-mineral mix or organic matter ≤2 cm deep over mineral soil, 685 were in an organic–mineral mix or organic matter 2–5 cm deep over mineral soil, and 90 were in other acceptable conditions. Six competitor species were noted during a vegetation assessment on 11 September, 3–5 months after harvest. Both planted and seeded jack pine will cope with the probably slow competition development; however, delayed seeding may permit green alder (in particular) and/or other species (ingress of graminoids) to dominate the seedbeds. The moderately dry to fresh moisture regime is too dry to seed black spruce but was acceptable for seeding jack pine. Good seedbed comprised 16.0% of the surface, and 18.9% was conditional. Although the 10.5% mineral soil exposure was below the 15–25% recommended for aerial seeding of jack pine, it was reasonably well distributed. When the other good seedbeds and the 18.9% conditional seedbeds are added, it is probable, except under the poorest weather conditions for germination and establishment, that conifer stocking standards will be achieved by broadcast seeding of jack pine at common application rates; improving weather conditions should yield high stocking and, potentially, excessive density. This example represents the classic jack pine aerial broadcast seeding site. Compare with plate sets 2, 22, 32–34, and 39.

PLATE
32A

V29 Jack Pine / Ericaceous Shrub / Feathermoss S1, S1, S1

FRI: Pj_9Sb_1, age 60, height 16 m, site class 2

Other site vegetation types: none recorded



Photographed and assessed: 13 September 1990
Time elapsed since harvest: 3–6 months
Harvest method: full-tree by chainsaw and cable skidder

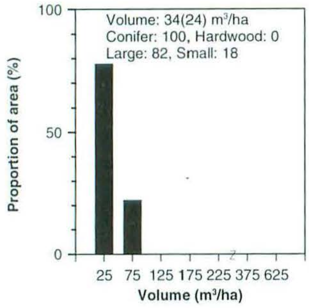
Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 1%
Plot slope position: flat
Landform: glaciofluvial deposit
Soil depth: >100 cm

Soil texture: coarse sand
Boulders: none
Stones: none
Coarse fragments: 21–50%
Litter: 1–2 cm

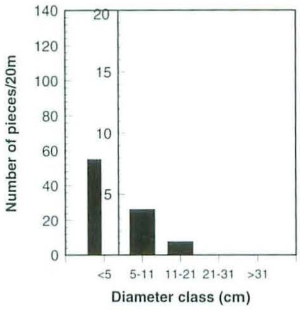
Fermentation layer: 4 cm
Humus: none
Texture of surface mineral soil: fine sand
Drainage: very rapid (common) to rapid
Moisture regime: moderately dry (common) to moderately fresh

Woody Debris

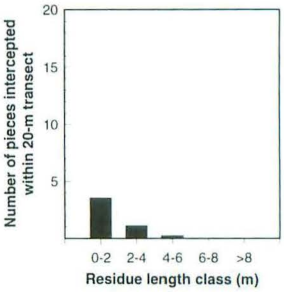
Distribution Volume



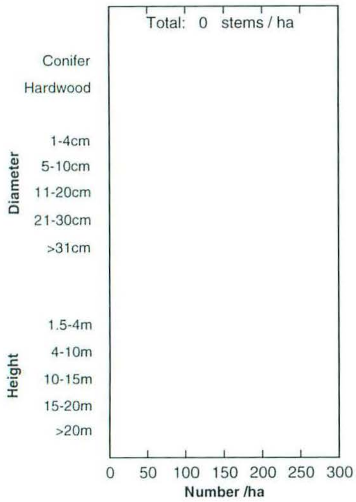
Diameter Distribution



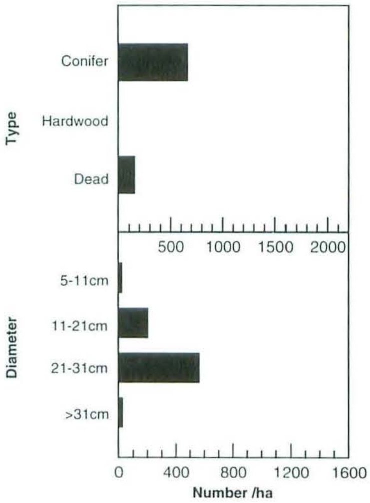
Length



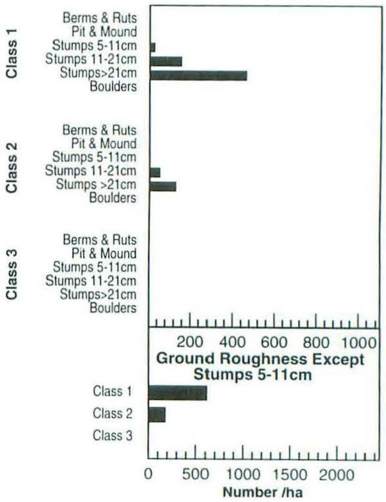
Residuals



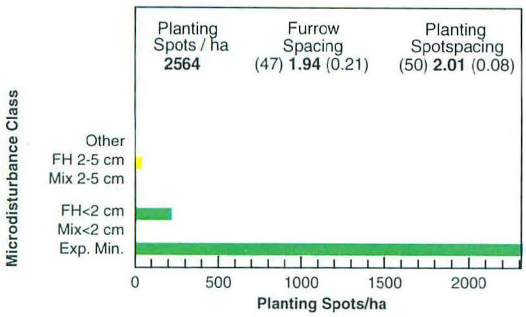
Stumps



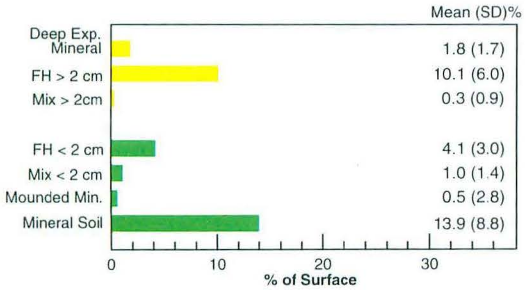
Ground Roughness



Plantability



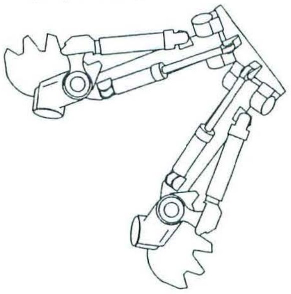
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	87	(22)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	31	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.2	(3.7)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 4 August 1991
Time from site preparation to assessment: 9–10 months
Time from harvest to site preparation: 4–7 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.3	(2.1)
site preparation	66	(21)



Implement: TTS Delta (passive) disc trencher

Prime mover: 150-kW, 13.2-t skidder

The between-furrow mean spacing of 1.94 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.01 m. Of the approximately 2565 acceptable planting spots per hectare, 2310 were in mineral soil, 215 were in organic matter ≤2 cm deep over mineral soil, and 40 were in organic matter 2–5 cm deep over mineral soil. Three competitor species, including graminoids, were noted during a vegetation assessment on 13 September, 3–6 months after harvest. Both planted and seeded jack pine should compete with the slow competition development on this site. The moderately dry to moderately fresh moisture regime is too dry for seeding black spruce and toward the dry end of the acceptable range for seeding jack pine. Good seedbed comprised 19.5% of the surface, and 12.2% was conditional; together, these include 15.7% mineral soil exposure. Common broadcast seed application rates for jack pine should assure good to high stocking of jack pine except in years with unsuitable weather during the germination and establishment seasons; optimum weather conditions for germination and establishment may encourage excessively dense stands. These site preparation results approach the optimum for broadcast seeding of jack pine. It should be noted that this site was concurrently seeded with jack pine during site preparation using a prototype row seeder attached to the passive disc trencher. Compare with plate sets 2, 22, 31, 33, 34, and 39.

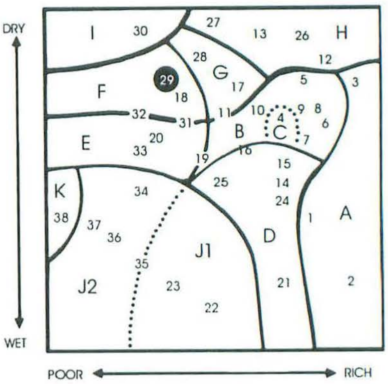
PLATE
33A

V29 Jack Pine / Ericaceous Shrub / Feathermoss

S1, S1, S1

FRI: Pj_9Sb_1, age 60, height 16 m, site class 2

Other site vegetation types: none recorded



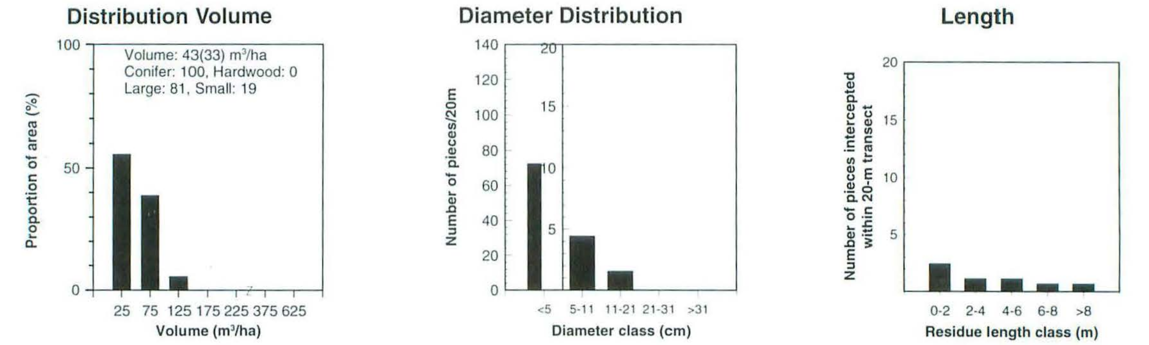
Photographed and assessed: 13 September 1990
Time elapsed since harvest: 3–7 months
Harvest method: tree-length by chainsaw and cable skidder

Area topography: gentle
Bedrock outcrops: none
Plot slopes: simple, 1%
Plot slope position: flat
Landform: glaciofluvial deposit
Soil depth: >100 cm

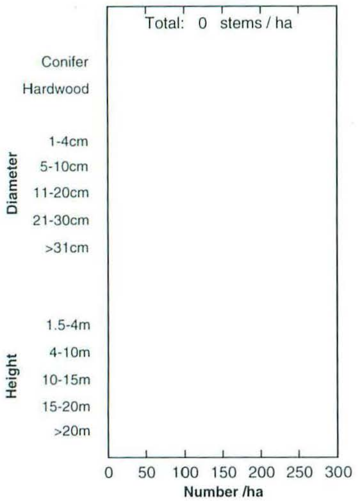
Soil texture: coarse sand
Boulders: none
Stones: none
Coarse fragments: 21–50%
Litter: 2–4 cm

Fermentation layer: 4–6 cm
Humus: none
Texture of surface mineral soil: medium sand, coarse sand, and loamy coarse sand
Drainage: very rapid (common) to rapid
Moisture regime: moderately dry

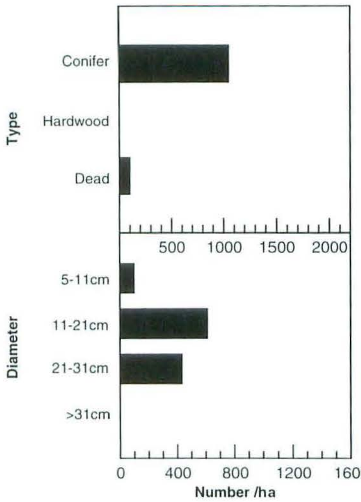
Woody Debris



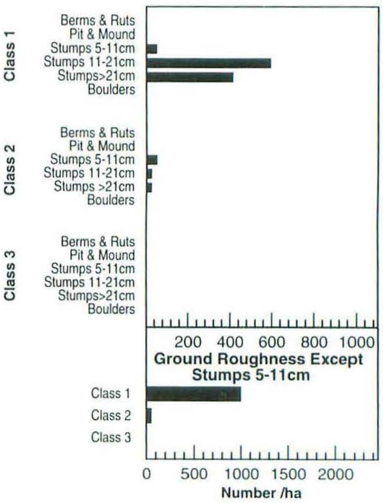
Residuals



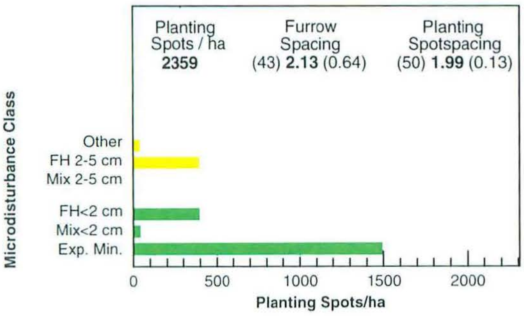
Stumps



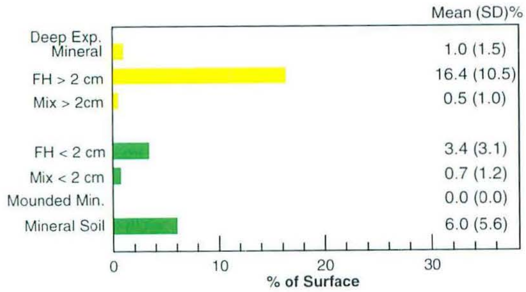
Ground Roughness



Plantability

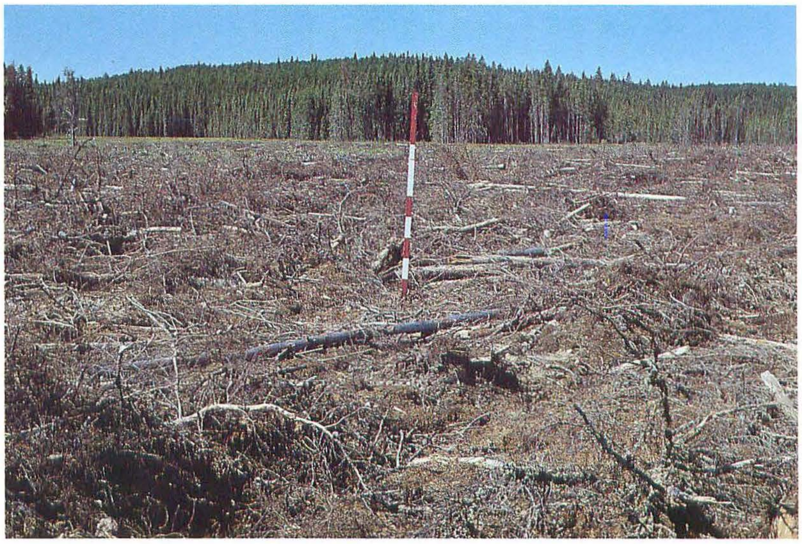


Potential Seedbed

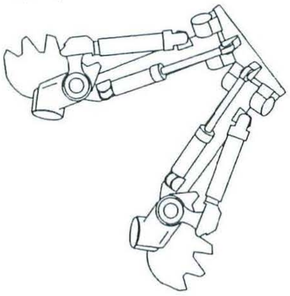


Furrow length (%), mineral soil ≥15 cm wide	35	(42)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	47	(22)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.6	(4.4)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 3 August 1991
Time from site preparation to assessment: 9–10 months
Time from harvest to site preparation: 4–8 months



Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	80	(21)



Implement: TTS Delta (passive) disc trencher

Prime mover: 150-kW, 13.2-t skidder

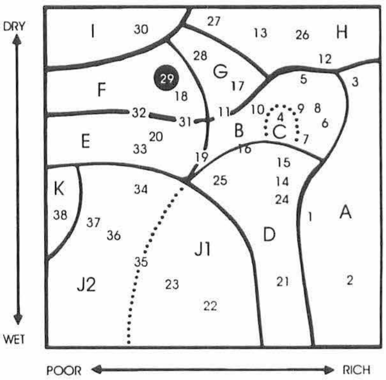
The between-furrow mean spacing of 2.13 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 1.99 m. Of the approximately 2360 acceptable planting spots per hectare, 1495 were in mineral soil, 435 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 395 were in organic matter 2–5 cm deep over mineral soil, and 35 were in other acceptable conditions. One competitor species was noted during a vegetation assessment on 13 September, 3–7 months after harvest. Both planted and seeded jack pine, including volunteers from the numerous jack pine cones remaining on the site from the tree length harvest, should compete with the probably slow competition development. The moderately dry moisture regime was too dry for seeding black spruce and toward the dry end of the acceptable range for seeding jack pine. Good seedbed comprised 10.1% of the surface, and 17.9% was conditional. Considering both the moderately dry moisture regime and the 7% mineral soil exposure, if weather during the germination and establishment seasons is unfavorable, conifer stocking standards may not be met with common broadcast seeding rates for jack pine. However, with better than average weather, both the good and the conditional seedbeds together may assure high stocking and excessive density from broadcast-sown jack pine at common rates of application. It should be noted that this site was concurrently seeded with jack pine during site preparation using a prototype row seeder attached to the passive disc trencher. Compare with plate sets 2, 22, 31, 32, 34, and 39.

PLATE 34A

V29 Jack Pine / Ericaceous Shrub / Feathermoss S1, S1, S1

FRI: $Pj_8Po_1Bw_1$, age 105, height 20 m, stocking 0.9, site class 2

Other site vegetation types: Jack Pine Mixedwood/ Shrub Rich, Jack Pine Mixedwood/Feathermoss, plus islands of others



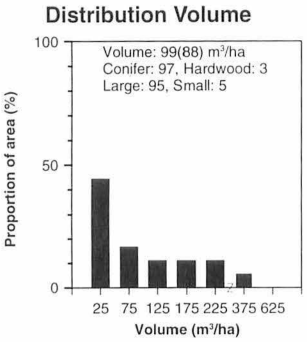
Photographed and assessed: 17 September 1990
Time elapsed since harvest: 12–13 months
Harvest method: full-tree by Koehring feller–forwarder

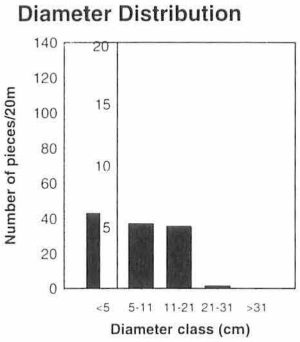
Area topography: gentle to moderate
Bedrock outcrops: none
Plot slopes: simple, 0–2%
Plot slope position: lower to flat
Landform: glaciofluvial deposit
Soil depth: >100 cm

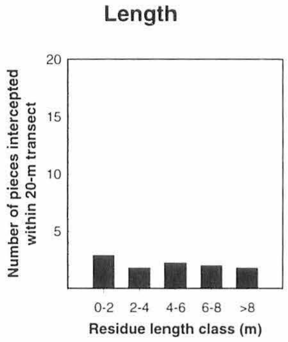
Soil texture: coarse sand
Boulders: none to slight
Stones: moderate
Coarse fragments: 21–50%
Litter: 1–4 cm

Fermentation layer: 3–6 cm
Humus: none
Texture of surface mineral soil: coarse sand and medium sand
Drainage: very rapid (common) to rapid
Moisture regime: moderately dry (common) to moderately fresh

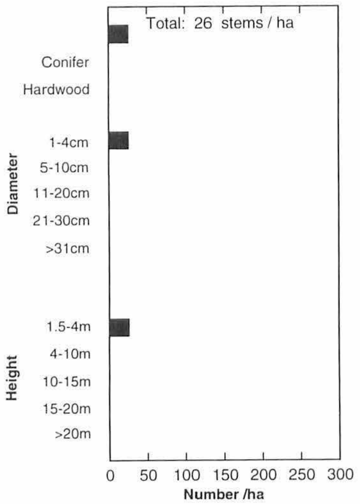
Woody Debris



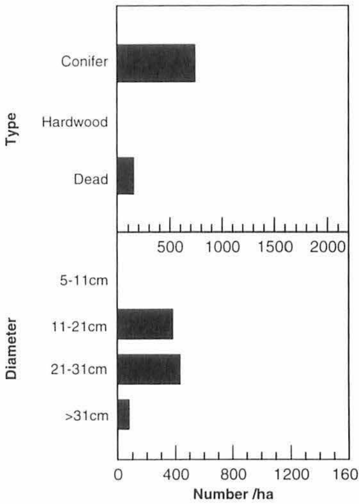




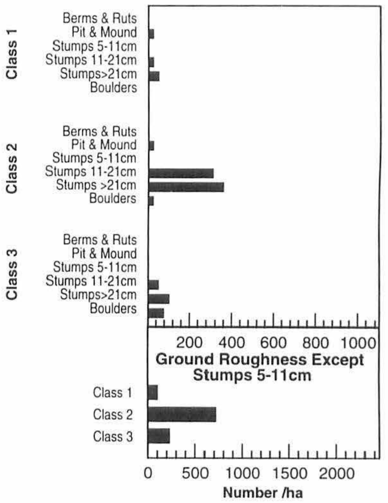
Residuals



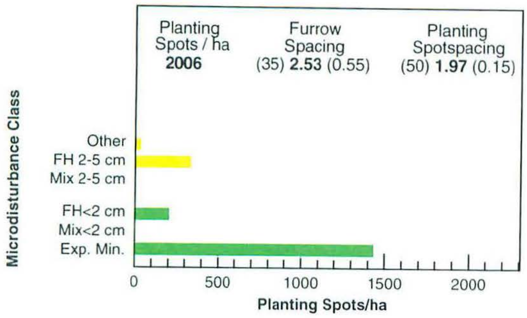
Stumps



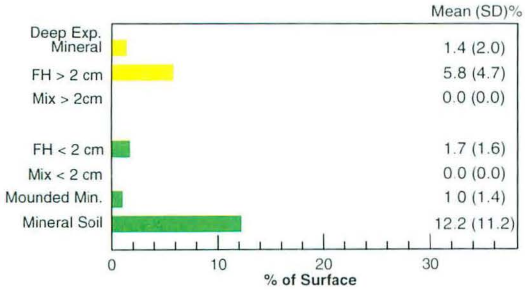
Ground Roughness



Plantability



Potential Seedbed

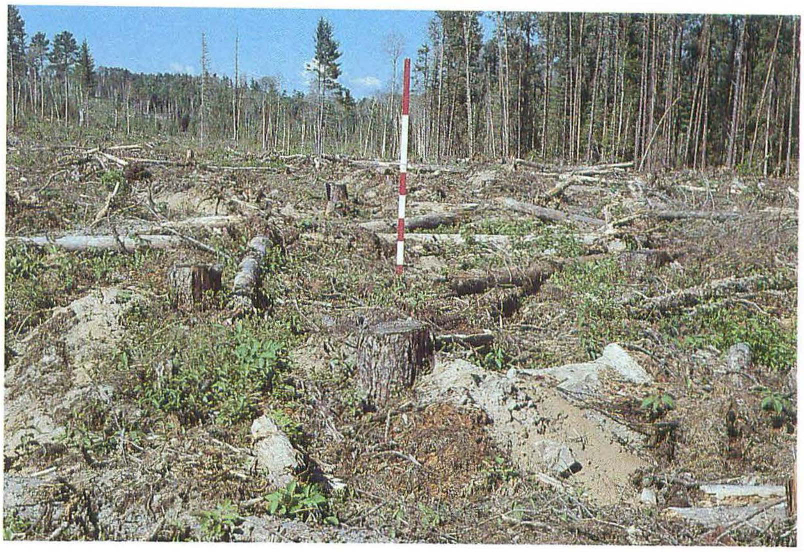


Furrow length (%), mineral soil ≥15 cm wide	58	(39)
Furrow length (%), rock and/or water	0	(0)

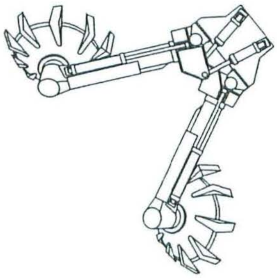
Other surface conditions (% of surface):

spoil bank	32	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.6	(2.7)
rock and/or water	0.2	(1.1)
shallow (<10 cm) mineral soil over organic	1.0	(2.0)

Photographed and assessed: 10 June 1991
Time from site preparation to assessment: about 8 months
Time from harvest to site preparation: 13–14 months



Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	2.7	(9.8)
site preparation	58	(20)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

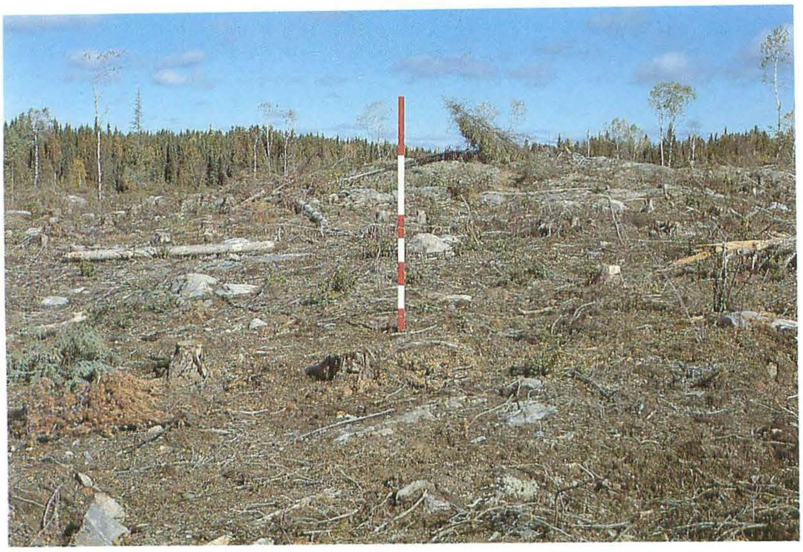
The between-furrow mean spacing of 2.53 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 1.97 m. Of the approximately 2005 acceptable planting spots per hectare, 1435 were in mineral soil, 200 were in organic matter ≤2 cm deep over mineral soil, 335 were in organic matter 2–5 cm deep over mineral soil, and 35 were in other acceptable conditions. Five competitor species were noted during a vegetation assessment on 17 September, 12–13 months after harvest. Both planted and seeded jack pine should compete with the slow competition development. The moderately dry to moderately fresh moisture regime was too dry for seeding black spruce and was toward the dry end of the acceptable range for seeding jack pine. Good seedbed comprised 14.9% of the surface, and 7.2% was conditional. Variability in stocking and density of jack pine resulting from seeding at common application rates will tend to be a function of the weather during the germination and establishment seasons. Aerial broadcast seeding of jack pine is a common prescription when both these site conditions and site preparation results occur. Compare with plate sets 2, 22, 31–33, and 39.

PLATE
35A

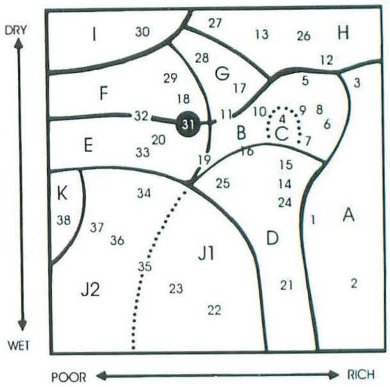
V31 Black Spruce – Jack Pine / Tall Shrub / Feathermoss

SS2, SS6, SS6

FRI: $Pj_4Sb_3Bw_2Po_1$, age 65, height 15 m, stocking 0.7, site class 3



Other site vegetation types: Jack Pine–Black Spruce/ Ericaceous Shrub/Feathermoss and Jack Pine–Black Spruce/Blueberry/Lichen



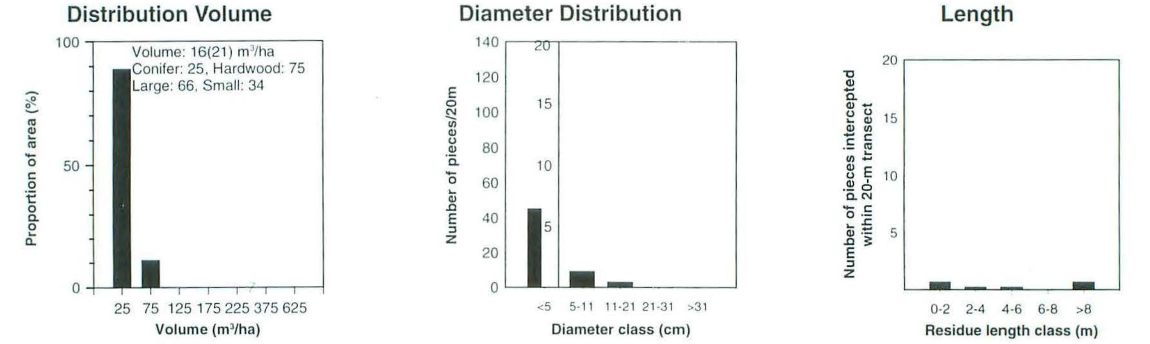
Photographed and assessed: 30 September 1990
Time elapsed since harvest: 1–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle to moderate
Bedrock outcrops: moderate to very
Plot slopes: simple, 0–4%
Plot slope position: mid to upper
Landform: shallow glacial drift
Soil depth: 4–50 cm, discontinuous

Soil texture: very coarse sand more common than loamy coarse sand
Boulders: moderate to very
Stones: moderate
Coarse fragments: 0–20%
Litter: 1–2 cm

Fermentation layer: 3–6 cm
Humus: none
Texture of surface mineral soil: sandy loam and loam
Drainage: very rapid, well, rapid
Moisture regime: dry, fresh, moderately fresh (moderately dry [common])

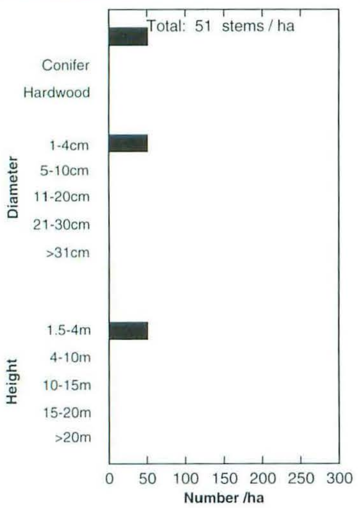
Woody Debris


Distribution Volume

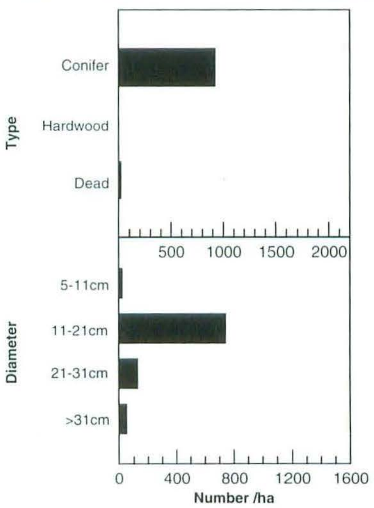
Diameter Distribution

Length

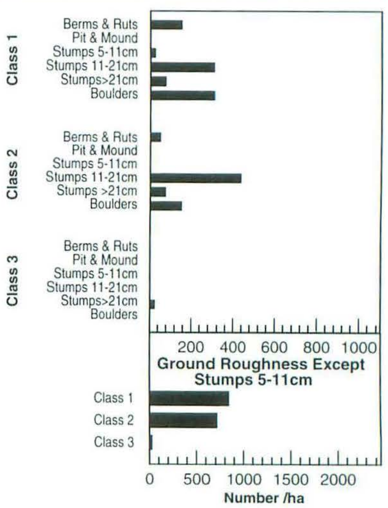
Residuals



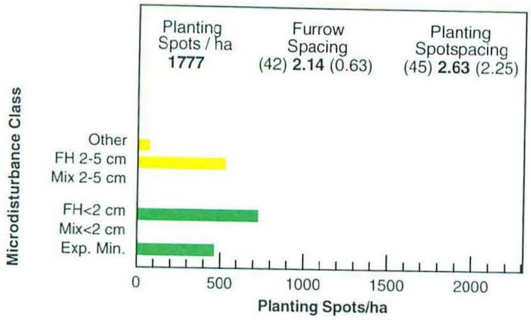
Stumps



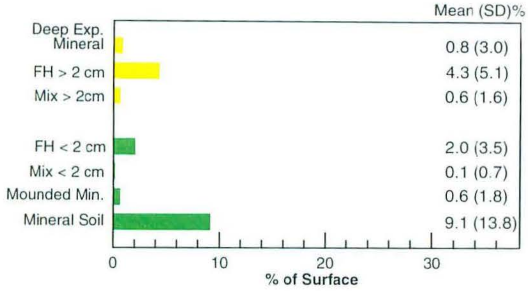
Ground Roughness



Plantability



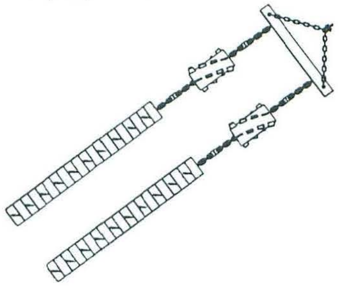
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	38	(39)
Furrow length (%), rock and/or water	20	(29)
Other surface conditions (% of surface):		
spoil bank	20	(13)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.3	(6.5)
rock and/or water	11.0	(18.6)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 7 October 1991
Time from site preparation to assessment: 4–9 weeks
Time from harvest to site preparation: 12–14 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	8.9	(16.9)
site preparation	41	(18)



Implement: light drags

Prime mover: 164-kW, 10-t skidder

The impediments to site preparation (discontinuous, shallow to moderately shallow soil, boulders, bedrock outcrops, and occasional short, steep slopes) did not prevent an operating practice that gave a between-furrow mean spacing of 2.14 m. The in-furrow acceptable planting spot mean spacing was increased to 2.63 m owing to the 20% of furrow length that was natural or machine-exposed bedrock, plus the too-shallow soil and occasional presence of woody residue. Of the approximately 1775 acceptable planting spots per hectare, 460 were in mineral soil, 725 were in an organic–mineral mix ≤2 cm deep over mineral soil, 525 were in an organic–mineral mix 2–5 cm deep over mineral soil, and 65 were in other acceptable conditions. Three competitor species were noted during a vegetation assessment on 30 September, 1–3 months after harvest. It is unlikely that competition development will be a problem for well-planted jack pine. The greater part of this site was too dry for seeding black spruce but was acceptable for jack pine. Good seedbed comprised 11.8% of the surface, and 5.7% was conditional. Excepting unsuitable weather during the germination and establishment seasons, conifer stocking standards may be met by seeding jack pine at common application rates. Desirable weather may enable seeded jack pine to take advantage of both the good and the marginal seedbeds, resulting in relatively (considering area lost to bedrock) high stocking and pockets of excessive density; however, seeding should not be delayed, as the potential ingress of green alder and/or other species may take over available seedbeds. Compare with plate sets 28–30, 38, 45, and 46.

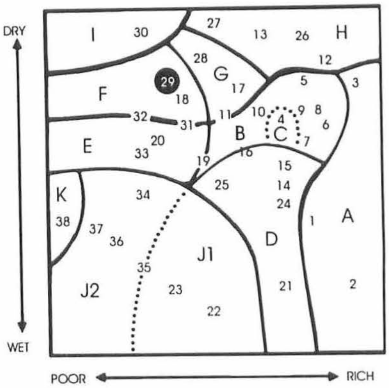
LATE
36A

V29 Jack Pine / Ericaceous Shrub / Feathermoss

S2, SS5, S2

FRI: Pj10, age 75, height 21 m, stocking 1.0, site class 1

Other site vegetation types: not recorded (area contains smaller jack pine stands separated by several types of mixedwood and hardwood)



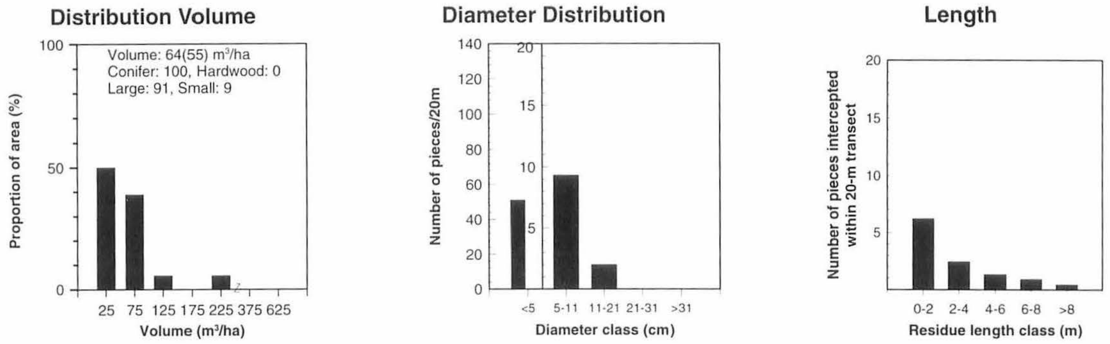
Photographed and assessed: 15 September 1990
Time elapsed since harvest: 1–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle to, rarely, moderate
Bedrock outcrops: slight
Plot slopes: simple, 1–4%
Plot slope position: mid
Landform: ground moraine
Soil depth: 50–>100 cm

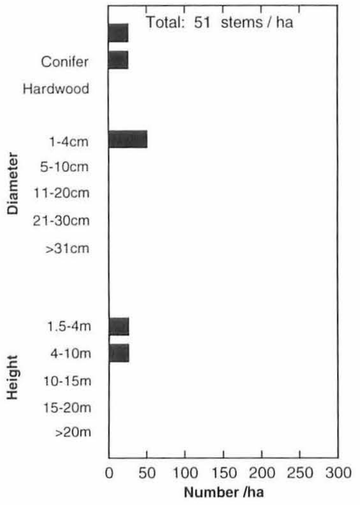
Soil texture: fine sand
Boulders: slight
Stones: slight
Coarse fragments: 0–35%
Litter: 3–4 cm

Fermentation layer: 5–6 cm
Humus: none
Texture of surface mineral soil: medium sand (common) and fine sand
Drainage: rapid (common) to moderately well
Moisture regime: fresh (common), moderately dry to very fresh

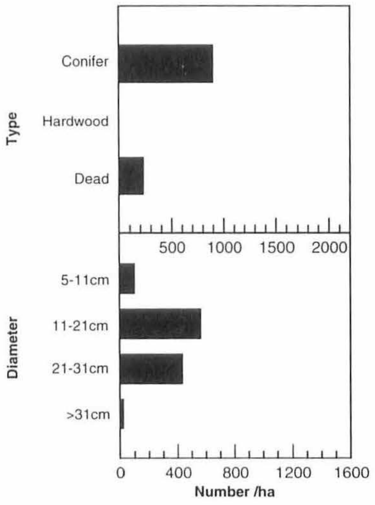
Woody Debris


Distribution Volume
Diameter Distribution
Length

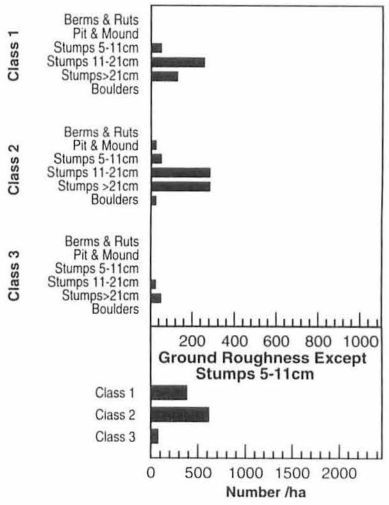
Residuals



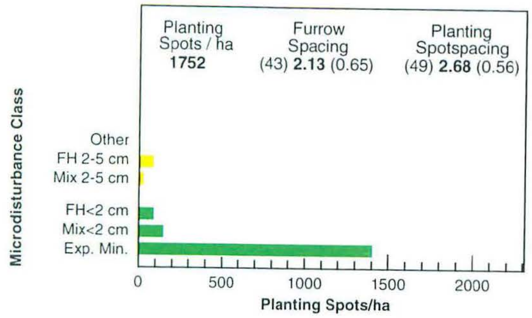
Stumps



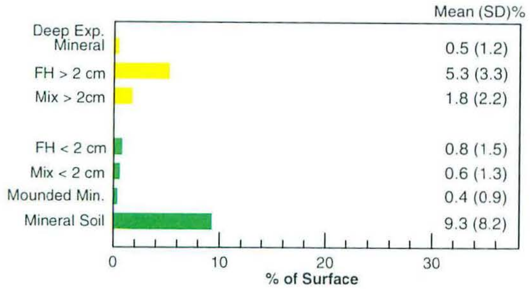
Ground Roughness



Plantability



Potential Seedbed



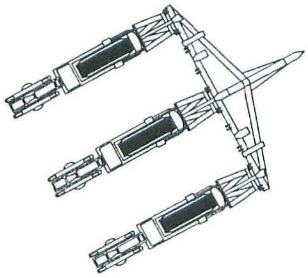
Furrow length (%), mineral soil ≥15 cm wide	44	(25)
Furrow length (%), rock and/or water	0	(0)

Other surface conditions (% of surface):

spoil bank	25	(16)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.8	(2.3)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	1.0	(2.1)

Photographed and assessed: 20 June 1991
Time from site preparation to assessment: about 10 months
Time from harvest to site preparation: 1–3 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	3.2	(5.8)
site preparation	48	(20)



Implement: Bräcke 3-row (mattock wheels at 2.0-m spacing)

Prime mover: 152-kW, 13.3-t skidder

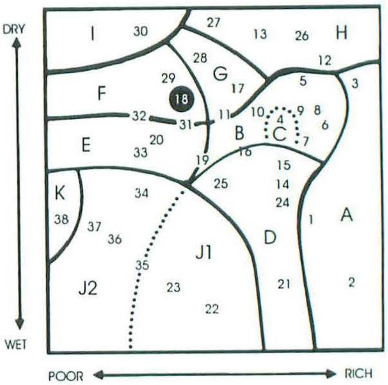
The between-rows-of-scalps mean spacing of 2.13 m was more a function of machine configuration and operating practice than of the moderately light (rarely heavy) loading of woody residue, which was less than 3 months old at the time of site preparation, and of ground roughness. The in-rows-of-scalps acceptable planting spot mean spacing was 2.68 m. Notes by the assessor indicated that "in many cases scalps were centred 2.5–3.0 m apart," which suggests that the machine was set for longer than 2.0-m spacing; also, woody residue prevented planting on 71 scalps per hectare. Of the approximately 1755 acceptable planting spots per hectare, 1400 were in mineral soil, 235 were in an organic–mineral mix or organic matter ≤2 cm deep over mineral soil, and 120 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil. Two competitor species were noted during a vegetation assessment on 15 September, 1–3 months after harvest. Competition development is unlikely to be an immediate problem for either planted jack pine seedlings or germinants on this site. Most of the site mosaic was too dry for seeding black spruce but was acceptable for seeding jack pine. Good seedbed comprised 11.1% of the surface, and 7.6% was conditional. Broadcast seeding of jack pine at higher than common application rates may establish a stand that satisfies conifer stocking standards. Compare with plate sets 4 and 5 and the other plate sets of this treatment unit.

V18 Jack Pine Mixedwood / Feathermoss

S1, S1, S1

FRI: $Pj_8Po_1Bw_1$, age 105, height 20 m, stocking 0.9, site class 2

Other site vegetation types: Jack Pine Mixedwood/ Shrub Rich, Jack Pine/Ericaceous Shrub/Feathermoss, and patches of Red Pine Mixedwood



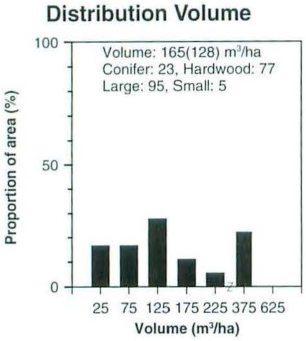
Photographed and assessed: 18 September 1990
Time elapsed since harvest: 10–11 months
Harvest method: full-tree by Koehring feller–forwarder

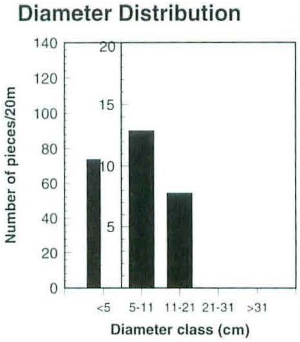
Area topography: very gentle to gentle
Bedrock outcrops: none
Plot slopes: complex, 0–5%
Plot slope position: mid
Landform: glaciofluvial deposit
Soil depth: >100 cm

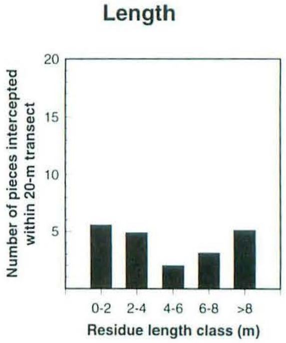
Soil texture: coarse sand
Boulders: slight
Stones: moderate to slight
Coarse fragments: 6–50%
Litter: 1–4 cm

Fermentation layer: 4–6 cm
Humus: 1 cm
Texture of surface mineral soil: loamy coarse sand
Drainage: very rapid (common) to rapid
Moisture regime: moderately dry (common) to moderately fresh

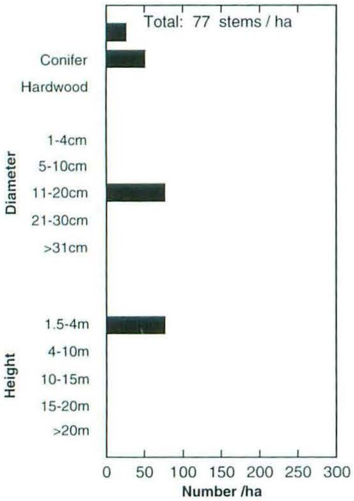
Woody Debris


Distribution Volume

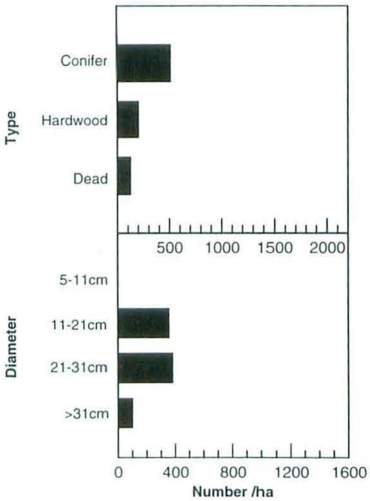

Diameter Distribution


Length

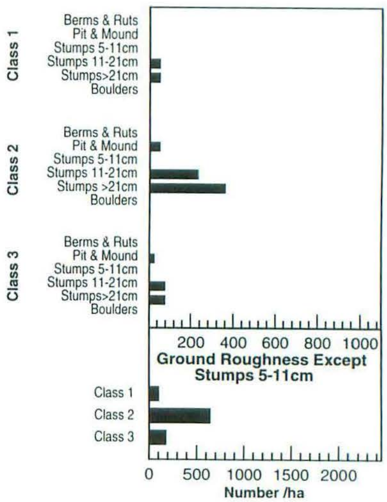
Residuals



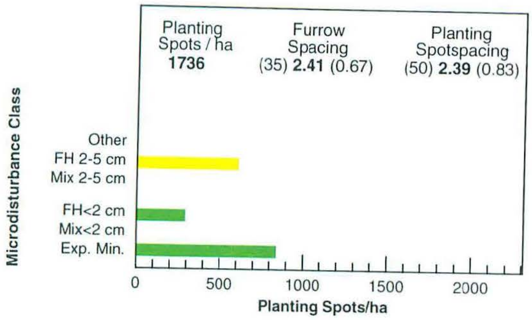
Stumps



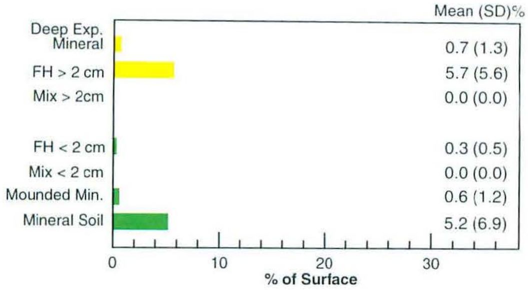
Ground Roughness



Plantability



Potential Seedbed



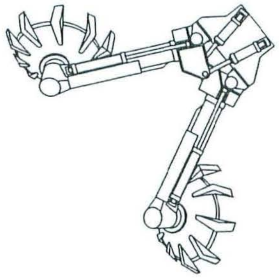
Furrow length (%), mineral soil ≥15 cm wide	31	(32)
Furrow length (%), rock and/or water	9	(18)

Other surface conditions (% of surface):

spoil bank	22	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.8	(2.7)
rock and/or water	2.7	(3.8)
shallow (<10 cm) mineral soil over organic	0.1	(0.4)

Photographed and assessed: 8 June 1991
Time from site preparation to assessment: about 8 months
Time from harvest to site preparation: 11–12 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	4.9	(7.7)
site preparation	40	(26)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

The beneficial burn over a portion of the site occurred after site preparation — during reduction of roadside piles of woody residue using fire, when the fire escaped. The between-furrow mean spacing of 2.41 m may have been more a function of operating practice than of the residuals, the stump field, and the moderately heavy (occasionally very heavy) load of woody residue. The in-furrow acceptable planting spot mean spacing was increased to 2.39 m by the 9% of furrow length that was stone, plus stone-limited shallow planting spade penetration and the presence of woody residue. Of the approximately 1740 acceptable planting spots per hectare, 840 were in mineral soil, 290 were in organic matter ≤2 cm deep over mineral soil, and 610 were in organic matter 2–5 cm deep over mineral soil. Six competitor species were noted during a vegetation assessment on 18 September, 10–11 months after harvest. It should be noted that the fire may stimulate the seed banking species, including field bindweed, pin cherry, and red raspberry, and also provide favorable seedbed for white birch. Well-planted, vigorous stock adapted morphologically and physiologically for this site may, with difficulty, cope with the competition development. The moderately dry to moderately fresh moisture regime was too dry for seeding black spruce but was acceptable for seeding jack pine. Good seedbed comprised 6.1% of the surface, and 6.4% was conditional, which is not sufficient to assure jack pine establishment that will satisfy conifer stocking standards except at high rates of seed application. However, when favorable weather occurs in the germination and establishment seasons, the good and conditional seedbed together are adequate to ensure minimum acceptable jack pine stocking of germinants at common rates of broadcast seed application. Manual application of seed spots, seeded shelters, etc. on selected microsites may also be an alternative. Problems associated with competition development must be considered with any seeding option on this site. Compare with plate sets 2, 7, 11, 17, and 22.

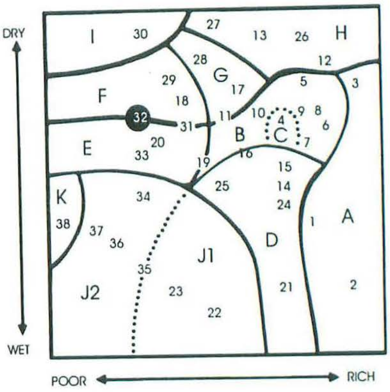
PLATE
38A

V32 Jack Pine – Black Spruce / Ericaceous Shrub / Feathermoss

SS6, SS6, SS6

FRI: $Pj_4Sb_3Bw_2Po_1$, age 65, height 15 m, stocking 0.7, site class 3

Other site vegetation types: Black Spruce–Jack Pine/Tall Shrub/Feathermoss, Jack Pine Mixedwood/Shrub Rich, and Jack Pine Mixedwood/Feathermoss



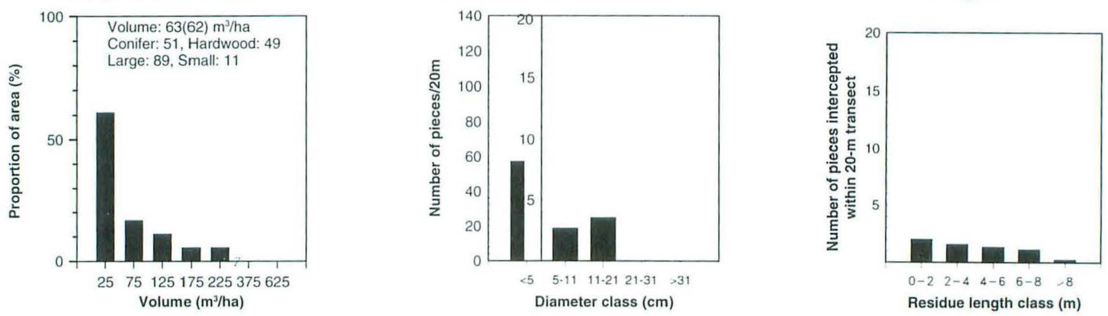
Photographed and assessed: 30 September 1990
Time elapsed since harvest: 2–5 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: very gentle to moderate
Bedrock outcrops: very to exceeding
Plot slopes: complex, 1–4%
Plot slope position: mid to upper
Landform: shallow glacial drift
Soil depth: 25–60 cm (discontinuous)

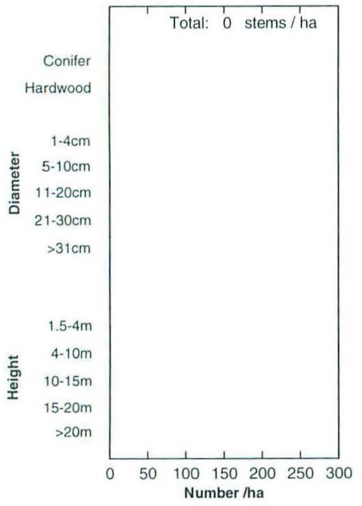
Soil texture: loam (common) and fine sand
Boulders: slight to none
Stones: moderate (common) to very
Coarse fragments: 6–20%
Litter: 1–2 cm

Fermentation layer: 2–4 cm
Humus: 0.1–1 cm
Texture of surface mineral soil: sandy loam (common) and loam
Drainage: rapid
Moisture regime: moderately fresh (common) to moderately dry

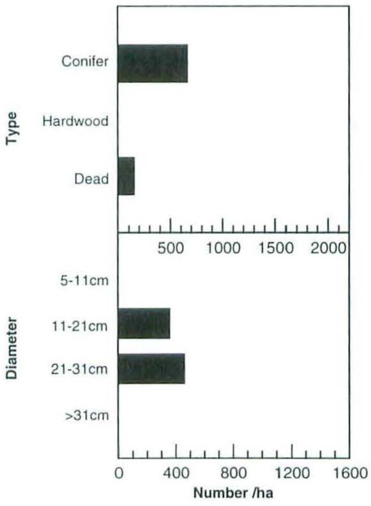
Woody Debris


Distribution Volume
Diameter Distribution
Length

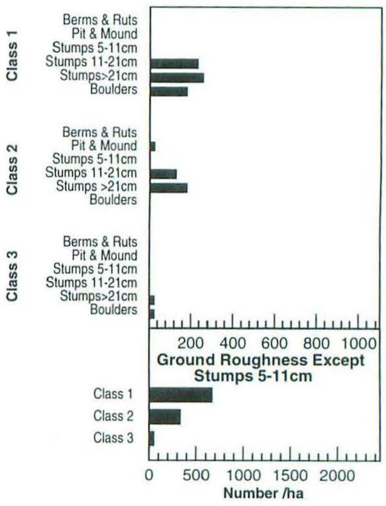
Residuals



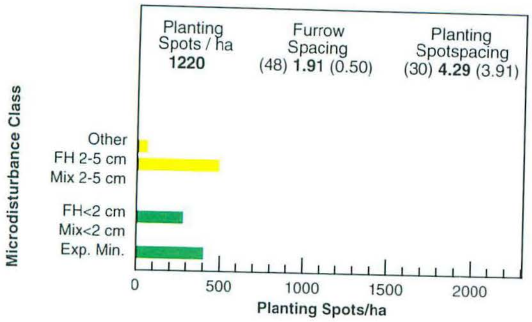
Stumps



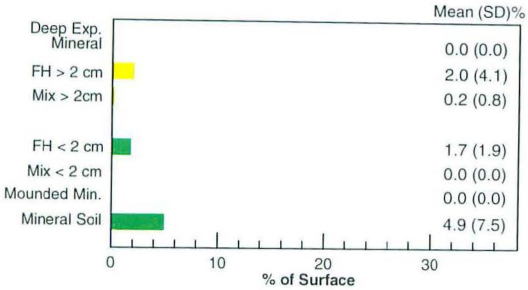
Ground Roughness



Plantability



Potential Seedbed



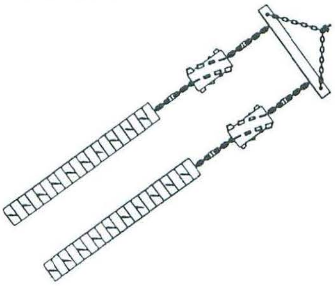
Furrow length (%), mineral soil ≥15 cm wide	26	(31)
Furrow length (%), rock and/or water	26	(33)

Other surface conditions (% of surface):

spoil bank	22	(15)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.8	(8.7)
rock and/or water	8.6	(12.5)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 7 October 1991
Time from site preparation to assessment: 5–8 weeks
Time from harvest to site preparation: 13–16 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	6.7	(17.1)
site preparation	37	(16)



Implement: light drags

Prime mover: 164-kW, 10-t skidder

The moderate to gentle, bedrock-controlled, complex terrain was the dominant feature of this site. The between-furrow spacing of 1.91 m was a function of operating practice. The in-furrow acceptable planting spot spacing was increased to 4.29 m by the 26% of furrow length that was natural and machine-exposed bedrock, soil too shallow to plant, and the occasional presence of woody residue. Of the 1220 acceptable planting spots per hectare, 395 were in mineral soil, 275 were in organic matter ≤2 cm deep over mineral soil, 490 were in organic matter 2–5 cm deep over mineral soil, and 60 were in other acceptable conditions. Eight competitor species were noted during a vegetation assessment on 30 September, 2–5 months after harvest. It is uncertain whether competition development will be a problem for planted seedlings on this moderately fresh to moderately dry, discontinuous sandy loam. The moisture regime was too dry for seeding black spruce but was acceptable for seeding jack pine. Good seedbed comprised 6.6% of the surface, and 2.2% was conditional. The utility of the limited amount and distribution of seedbed was increased by the combination of exposed rock in a complex terrain. In other words, many sown jack pine seeds may be washed or blown off the bedrock to seedbed at the perimeter of the exposed rock. Also, similar local sites have undergone this treatment with subsequent aerial seeding of jack pine; generally, the subsequent jack pine stocking approaches or exceeds the potential stocking from planting. Compare with plate sets 28–30, 34, 45, and 46.

Note: Alternatively, the V-type may be Jack Pine–Black Spruce/Blueberry/Lichen.

Treatment Unit G

Treatment Unit G: Jack Pine/Shrub Rich

Treatment Unit G contains jack pine stands with some trembling aspen component and a generally rich, diverse, low-shrub component.

Equipment trafficability

No limitations to equipment are anticipated.

Competition

Corylus cornuta, *Alnus crispa*, and trembling aspen will occur to varying degrees, particularly on V-11. According to Walsh and Krishka (1991), *Betula papyrifera*, ferns, *Actaea rubra*, *Polygonum convulvus*, and grasses may also pose a competition problem on Treatment Unit G.

Summary

A summary of Treatment Unit G is presented in Table 7.

Four plots (plate sets 39–42) were sampled. These plots had several features in common: soils were moderately deep to shallow; stones and boulders were common (spacing between stones and boulders ranged between 1 and <30 m); surface mineral soil texture was loamy; fresh moisture regimes dominated; and a diversity (7–11) of competitor species was present.

The plot presented in plate set 39 represents a site with moderate to strong topography, very gentle to moderate plot slopes, rock outcrops 25–75 m apart, stones 10–25 m apart, and a moderate to moderately heavy loading of woody debris. A Donaren 180 disc trencher on a 186.5-kW, 25-t skidder produced 2439 acceptable planting spots per hectare, 5.0% mineral soil exposure, and 1.3% organic and organic–mineral mix ≤2 cm deep.

Table 7. Data from plate sets for Treatment Unit G ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
39	2439	30	5.0	1.3	8.6	5–9	40–65	m→str	2–10	S	M
40	1731	35	5.4	0.9	9.4	5–14	90	g→m	7–8	S	V→M
41	1594	29	2.9	2.8	16.0	4–7	35–77	g→m	n.r.	S→M	S→M
42	1142	20	1.9	1.6	6.1	4–6	5–90 (dis)	g	1–3	S→M	S→V

The plot presented in plate set 40 represents a site with moderately deep soil, gentle to moderate topography, gentle plot slopes, rock outcrops 25–75 m apart, and stones and boulders about 2 m apart; these, combined with stumps, gave a ground roughness of about 750 class 2 and 3 obstacles per hectare. A Donaren 180 disc trencher on a 186.5-kW, 25-t skidder produced 1731 acceptable planting spots per hectare, 5.4% mineral soil exposure, and 0.9% organic and organic–mineral mix ≤2 cm deep. However, the between-furrow spacing of 2.33 m may be a result of operating practice.

The plot presented in plate set 41 represents a site with shallow to moderately deep soil, gentle to moderate topography, rock outcrops 10–75 m apart, stones and boulders 2 m (uncommon) to 30 m apart, and about 100 residuals >10 cm in diameter per hectare. A heavy drag drawn by a 224-kW, 34.1-t bulldozer produced 1594 acceptable planting spots per hectare, 2.9% mineral soil exposure, and 2.8% organic and organic–mineral mix ≤2 cm deep. Between-furrow spacing was 2.05 m, but in-furrow acceptable planting spot mean spacing was 3.06 m owing to the 12% of furrow length that was either natural or machine-exposed bedrock, rock and stone that limited spade penetration (unacceptable shallow planting), the presence of woody residue, and ponded water.

The plot presented in plate set 42 represents a site with low-relief, bedrock-controlled topography, discontinuous, very shallow to moderately deep soil, very gentle to gentle slopes, rock outcrops 10–75 m apart, boulders and stones 1–30 m apart, and a moderately light loading of woody residue. A heavy drag drawn by a 224-kW, 34.1-t bulldozer produced 1142 acceptable planting spots per hectare, 1.9% mineral soil exposure, and 1.6% organic and organic–mineral mix ≤2 cm deep. Few (cost-effective) opportunities for improving these results are available.

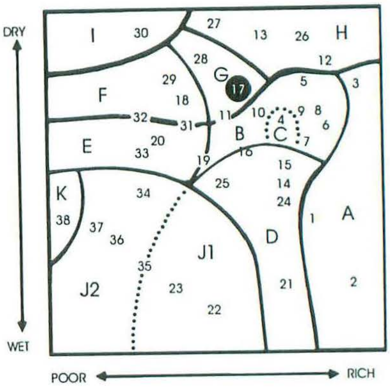
Moisture regimes and surface mineral soil textures on these sites are favorable for direct seeding of either jack pine or black spruce. However, availability of acceptable seedbeds and potential competition problems minimize, if not preclude, the likelihood that the direct-seeding option will establish stands that satisfy minimum stocking standards.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
250	149	2–3	9	mF	LvfS	V-17 (G)	2.02	2.03	186.5	25	Don180	39
750	88	12–13	9	F	SL	V-17 (G)	2.33	2.48	186.5	25	Don180	40
300	51	9–11	11	vF, mF, mM	SL	V-17 (G)	2.05	3.06	224	34.1	drag (H)	41
100	68	15	7	**vF**→mD	**SL**, L	V-28 (G)	3.16	2.77	224	34.1	drag (H)	42

V17 Jack Pine Mixedwood / Shrub Rich SS5, SS5, SS5

FRI: $Po_4Sb_2Bw_2Jp_2$, age 65, height 19, stocking 0.9, site class 3

Other site vegetation types: much of the cut block is Trembling Aspen–Black Spruce–Jack Pine/Low Shrub



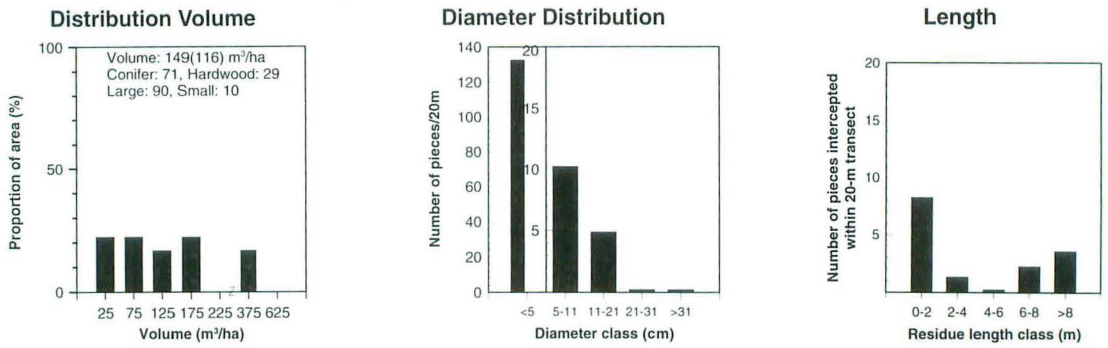
Photographed and assessed: 14 August 1990
Time elapsed since harvest: about 2 months
Harvest method: cut and skid (including horses and older machinery)

Area topography: moderate to strong
Bedrock outcrops: slight
Plot slopes: simple, 2–10%
Plot slope position: upper to crest
Landform: glacial drift
Soil depth: 40–65 cm

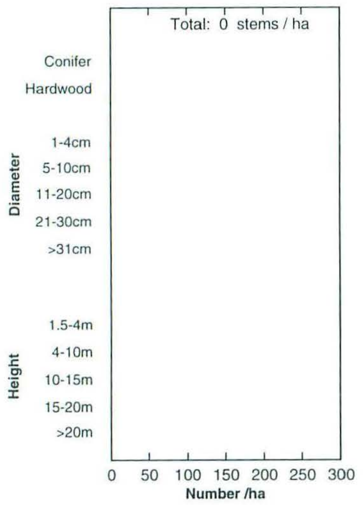
Soil texture: very fine sand
Boulders: none
Stones: moderate
Coarse fragments: 6–20%
Litter: 2 cm

Fermentation layer: 3–6 cm
Humus: trace to 1 cm
Texture of surface mineral soil: loamy very fine sand
Drainage: rapid
Moisture regime: moderately fresh

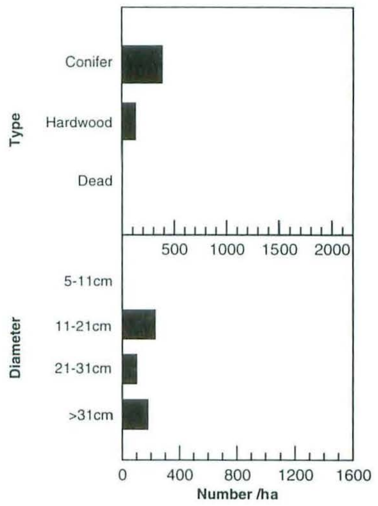
Woody Debris



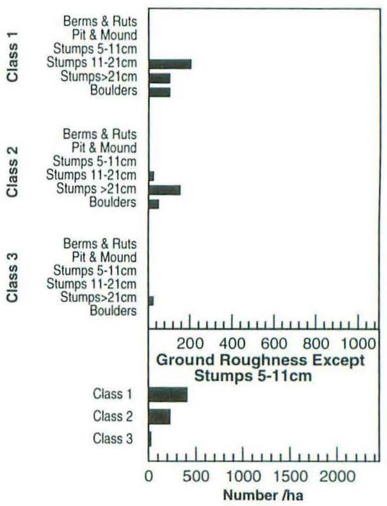
Residuals



Stumps

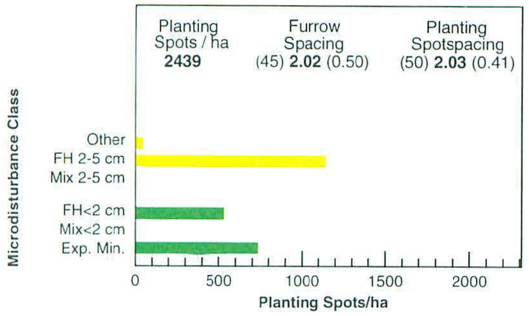


Ground Roughness

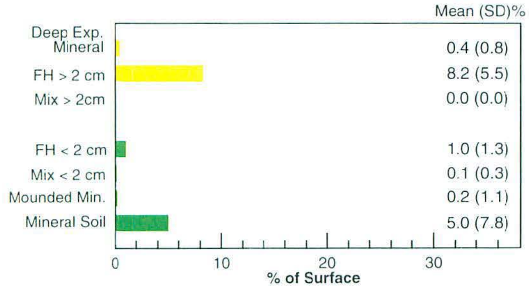


Trenching

Plantability



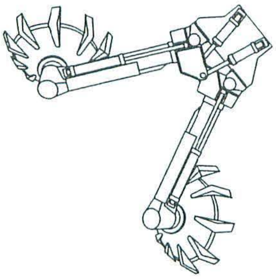
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	30	(30)
Furrow length (%), rock and/or water	2	(8)
Other surface conditions (% of surface):		
spoil bank	30	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.8	(6.9)
rock and/or water	1.2	(1.5)
shallow (<10 cm) mineral soil over organic	1.4	(3.8)

Photographed and assessed: 28 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 2–3 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	13.9	(22.3)
site preparation	52	(24)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

The combination of slopes, a moderate to occasionally very heavy loading of woody residue, and ground roughness did not prevent operating practice from achieving a between-furrow mean spacing of 2.02 m. The in-furrow acceptable planting spot mean spacing was 2.03 m. Of the approximately 2440 acceptable planting spots per hectare, 730 were in mineral soil, 530 were in organic matter ≤2 cm deep over mineral soil, 1140 were in organic matter 2–5 cm deep over mineral soil, and 40 were in other acceptable conditions. Nine competitor species were noted during a vegetation survey on 14 August, about 2 months after harvest. Competition development will likely become a problem for planted stock and germinants on this moderately fresh, loamy very fine sand. The moisture regime was too dry for seeding black spruce but was acceptable for seeding jack pine. Good seedbed comprised 6.3% of the surface, and 8.6% was conditional. However, the distribution and limited availability of seedbed, as well as potential competition development, may preclude establishing a stand that satisfies conifer stocking standards by broadcast seeding of jack pine, even at uneconomic rates of seed application. If necessary, manually set out seed spots, seeded shelters, etc. on selected microsites may be considered as an alternative to planting. Compare with plate sets 10, 21, 22, and the other plate sets of Treatment Unit G.

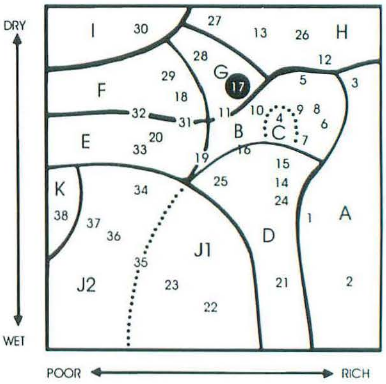
PLATE
40A

V17 Jack Pine Mixedwood / Shrub Rich

SS5

FRI: Pj9Pr1, age 95, height 20 m, stocking 0.9, site class 2

Other site vegetation types: Balsam Fir Mixedwood



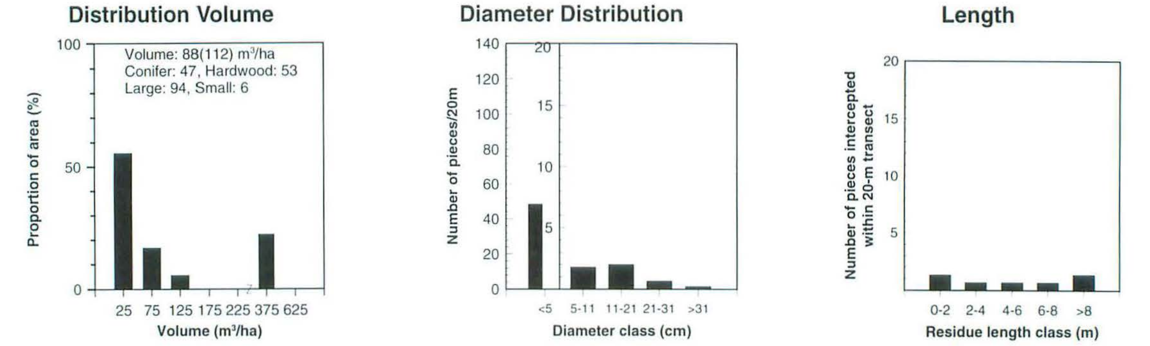
Photographed and assessed: 15 September 1990
Time elapsed since harvest: 11–12 months
Harvest method: full-tree by Koehring feller–forwarder

Area topography: gentle to moderate
Bedrock outcrops: slight
Plot slopes: simple, 7–8%
Plot slope position: mid to upper
Landform: ablation till
Soil depth: 90 cm

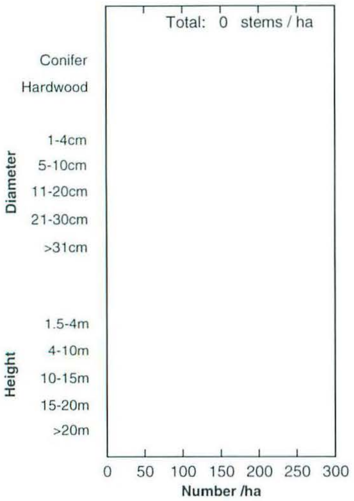
Soil texture: fine sand
Boulders: slight to moderate
Stones: very (common) to moderate
Coarse fragments: 36–50%
Litter: 1–6 cm

Fermentation layer: 3–6 cm
Humus: 1–2 cm
Texture of surface mineral soil: sandy loam
Drainage: well
Moisture regime: fresh

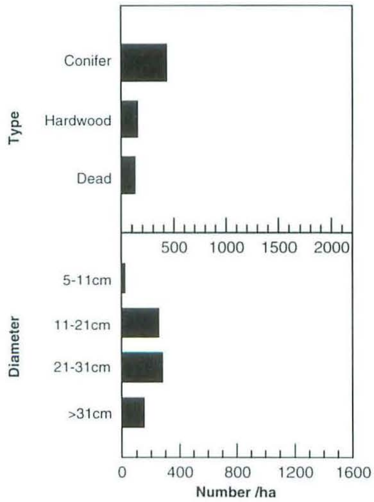
Woody Debris



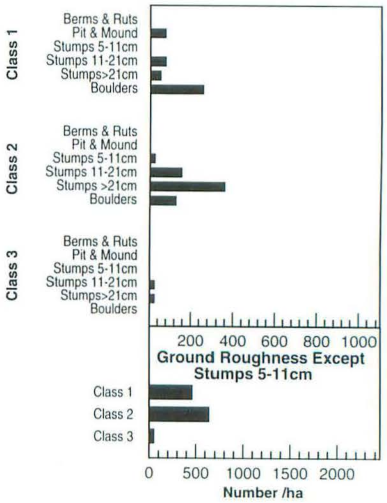
Residuals



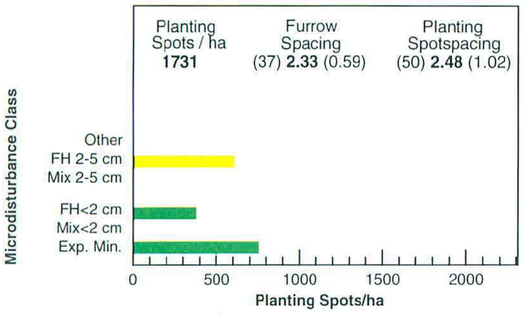
Stumps



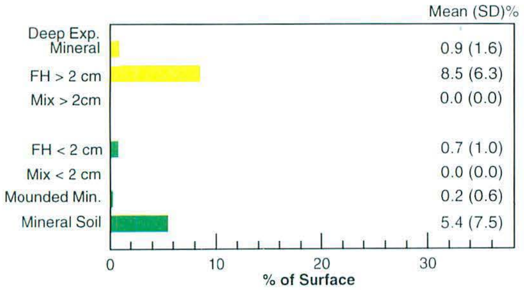
Ground Roughness



Plantability



Potential Seedbed



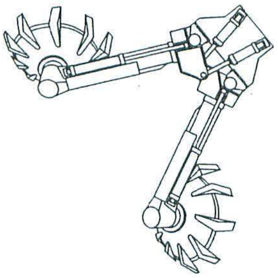
Furrow length (%), mineral soil ≥15 cm wide	35	(32)
Furrow length (%), rock and/or water	8	(13)

Other surface conditions (% of surface):

spoil bank	23	(20)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.8	(4.0)
rock and/or water	4.7	(5.2)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 9 June 1991
Time from site preparation to assessment: about 8 months
Time from harvest to site preparation: 12–13 months

Gross disturbance of surface (%):	mean	(sd)
other (mostly harvesting)	0	(0)
site preparation	46	(22)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

The between-furrow mean spacing of 2.33 m was a result of operating practice that may have been influenced by the combined effect of ground roughness, slopes, and the moderately light (occasionally heavy) loads of woody residue. The in-furrow acceptable planting spot mean spacing was increased to 2.48 m by the 8% of furrow length that was bedrock plus the 17% of planting attempts that were not accepted because of shallow soil and, occasionally, woody residue. Of the approximately 1730 acceptable planting spots per hectare, 750 were in mineral soil, 375 were in organic matter ≤2 cm deep over mineral soil, and 605 were in organic matter 2–5 cm deep over mineral soil. Nine competitor species were noted during a vegetation assessment on 15 September, 11–12 months after harvest. It is likely that competition development will be a problem for both seedlings and germinants on this fresh sandy loam; tending may be required in 4–7 years. The moisture regime is acceptable for seeding jack pine and at the dry end of the acceptable range for spruce. The approximately 5.6% of the surface that was mineral soil plus the 0.7% that was organic matter ≤2 cm deep over mineral soil were potential seedbed for jack pine and black spruce. This site was too dry for the deeper organic materials to have any value as seedbed. Because of the limited amount and distribution of seedbed and potential competition development, it is unlikely that uneconomic rates of broadcast seed application will produce a stand that satisfies conifer stocking standards. If necessary, manual placement of seeded shelters, etc. on selected microsites may be considered as a possible alternative. Compare with plate sets 7, 19, 28, 37, 39, and 41–43.

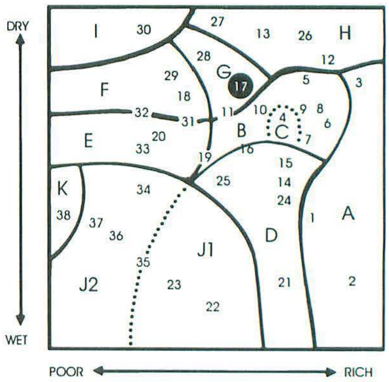
PLATE
41A

V17 Jack Pine Mixedwood / Shrub Rich

SS8, SS6, SS8

FRI: $Po_4Pj_3Sb_2Bw_1$, age 70, height 19, stocking 0.8, site class 3

Other site vegetation types: Trembling Aspen Mixedwood



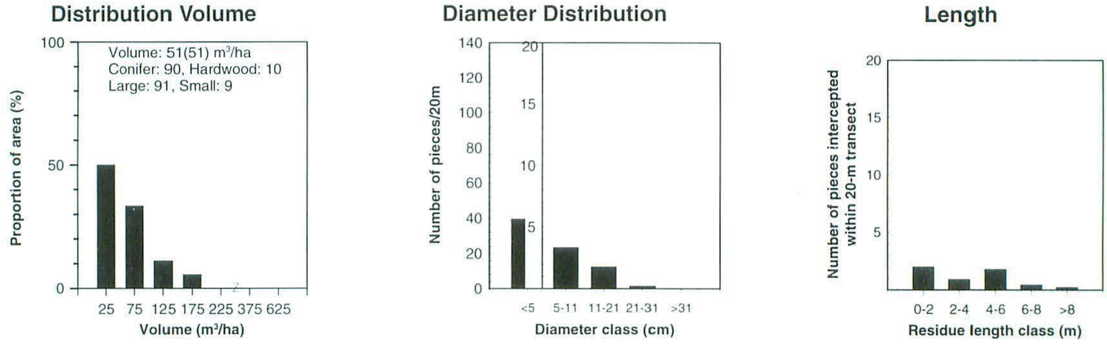
Photographed and assessed: 11 August 1990
Time elapsed since harvest: 9–11 months
Harvest method: tree-length with chainsaw and cable skidder

Area topography: gentle to moderate
Bedrock outcrops: slight to moderate
Plot slopes: not recorded
Plot slope position: mid to upper
Landform: ground moraine
Soil depth: 35–77 cm

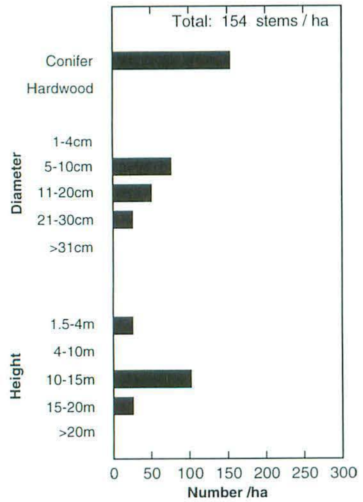
Soil texture: loamy very fine sand (common), sandy loam
Boulders: slight
Stones: slight to moderate
Coarse fragments: 21–50%
Litter: 2–3 cm

Fermentation layer: 2–4 cm
Humus: trace
Texture of surface mineral soil: sandy loam
Drainage: moderately well (common) to rapid
Moisture regime: very fresh, moderately fresh, moderately moist

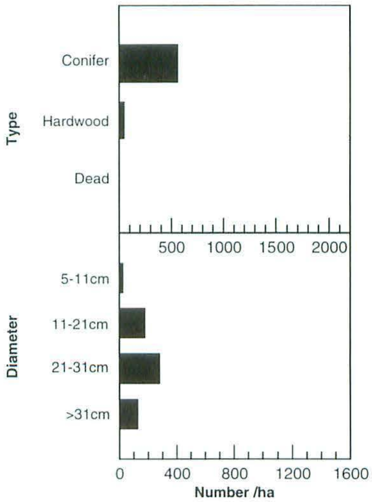
Woody Debris



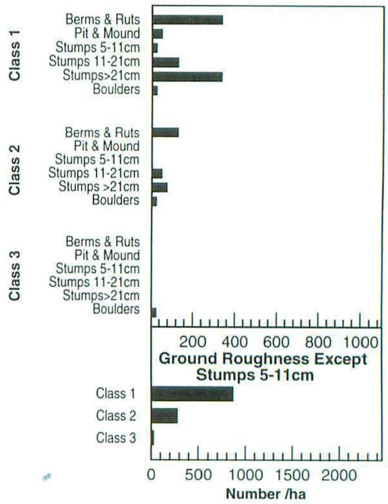
Residuals



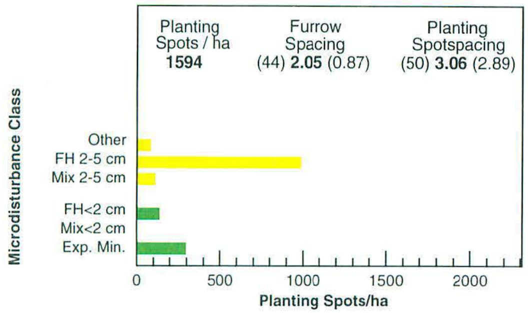
Stumps



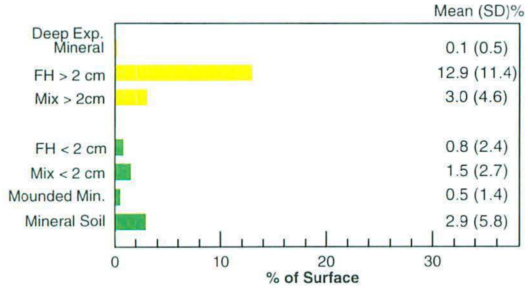
Ground Roughness



Plantability



Potential Seedbed



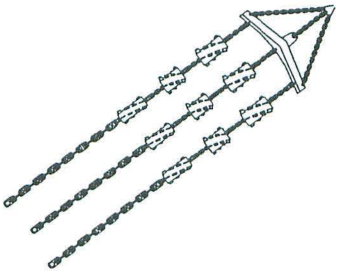
Furrow length (%), mineral soil ≥15 cm wide	29	(32)
Furrow length (%), rock and/or water	12	(34)

Other surface conditions (% of surface):

spoil bank	27	(21)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.5	(4.9)
rock and/or water	4.2	(9.6)
shallow (<10 cm) mineral soil over organic	0.5	(2.1)

Photographed and assessed: 23 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 9–11 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	2.9	(6.8)
site preparation	55	(23)



Implement: heavy drags

Prime mover: 224-kW, 34.1-t bulldozer

The between-furrow mean spacing of 2.05 m was a function of operating practice. The in-furrow acceptable planting spot spacing was increased to 3.06 m by the 12% of furrow length that was either natural or machine-exposed bedrock, soil too shallow to plant, and the presence of woody residue and water. Of the about 1590 acceptable planting spots per hectare, 290 were in mineral soil, 130 were in organic matter ≤2 cm deep over mineral soil, 1090 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 80 were in other acceptable conditions. Eleven competitor species were noted during a vegetation assessment on 11 August, 9–11 months after harvest. Competition development will become a problem on this fertile, moderately fresh to moderately moist sandy loam. The variable moisture regime is acceptable, generally, for seeding spruce and, over much of the site, toward the wet end of the acceptable range for jack pine; however, both drainage and moisture regime may be amended for a period of time by the effects of harvesting and site preparation on the loamy shallow soil. The 3.4% of the surface that was mineral soil and the 2.3% that was organic matter and/or organic–mineral mix ≤2 cm deep over mineral soil may be good seedbed for jack pine and black spruce. The 16.0% of surface that was an organic–mineral mix or organic matter >2 cm deep over mineral soil may be acceptable seedbed for black spruce, depending on other local microsite conditions (including microsite moisture regime and composition of the organic matter). However, fragile germinants may be choked out by the competition development or smothered by litter fall. Compare with plate sets 7, 16, 17, 28, 39, 40, 42, and 43.

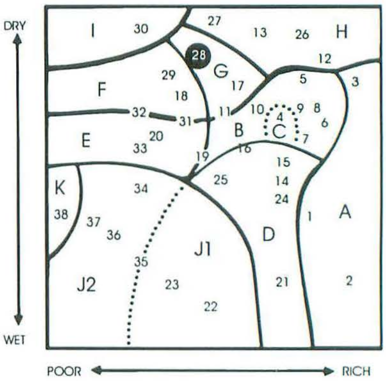
PLATE
42A

V28 Jack Pine / Low Shrub

SS8, SS2, SS6

FRI: $Pj_8Po_1Sb_1$, age 75, height 19, stocking 0.9, site class 2

Other site vegetation types: Jack Pine Mixedwood/ Shrub Rich and Trembling Aspen Mixedwood both occur on lower ground



Photographed and assessed: 12 August 1990
Time elapsed since harvest: 13–15 months
Harvest method: by feller–buncher with woody residue distributed in (large) piles over the site

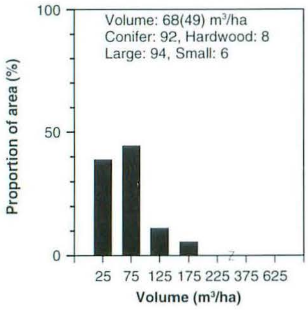
Area topography: gentle
Bedrock outcrops: slight to moderate
Plot slopes: simple, 1–3%
Plot slope position: crest and toe
Landform: ground moraine
Soil depth: 5–90 cm (discontinuous)

Soil texture: loamy medium sand (common), loamy fine sand
Boulders: slight
Stones: slight to very
Coarse fragments: 1–20%
Litter: 1–3 cm

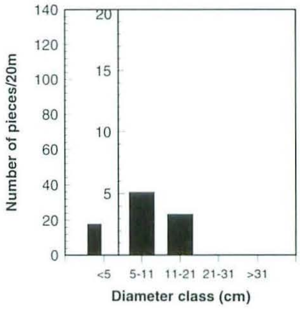
Fermentation layer: 3 cm
Humus: trace
Texture of surface mineral soil: sandy loam (common), loam
Drainage: moderately well (common) to rapid
Moisture regime: very fresh (common) to moderately dry

Woody Debris

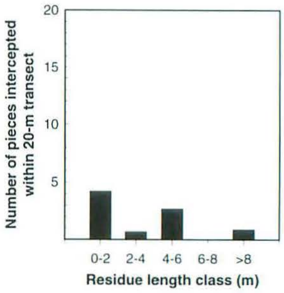
Distribution Volume



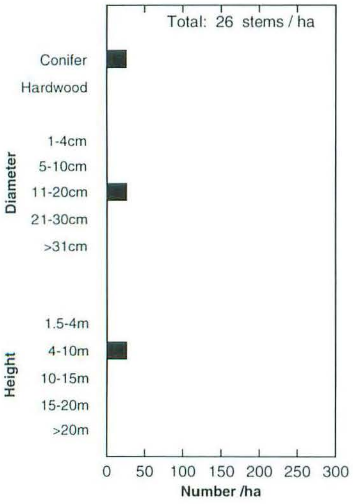
Diameter Distribution



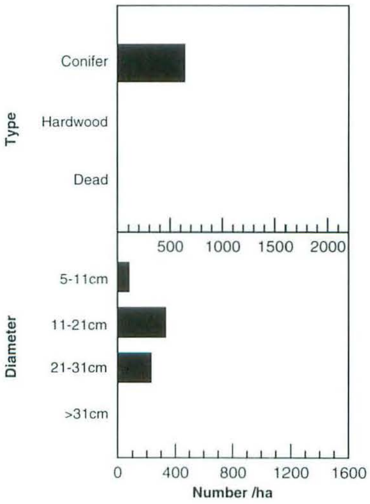
Length



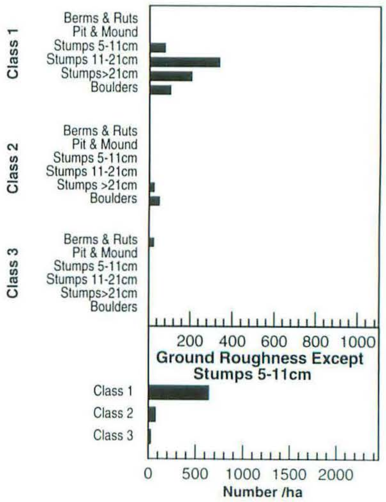
Residuals



Stumps

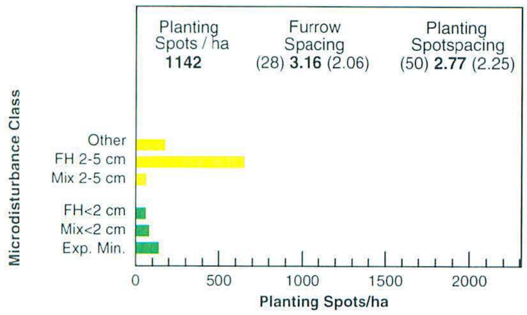


Ground Roughness

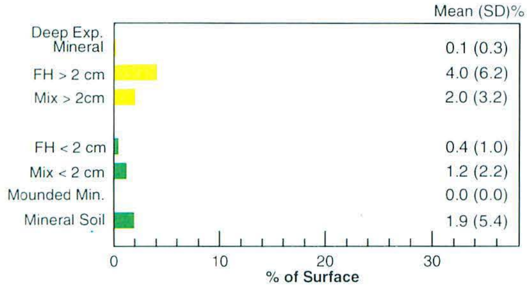


Screefing / Trenching

Plantability



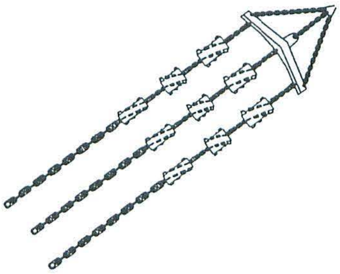
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	20	(29)
Furrow length (%), rock and/or water	24	(36)
Other surface conditions (% of surface):		
spoil bank	14	(17)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.9	(2.5)
rock and/or water	12.2	(18.1)
shallow (<10 cm) mineral soil over organic	0.2	(1.4)

Photographed and assessed: 25 May 1991
Time from site preparation to assessment: about 9 months
Time from harvest to site preparation: 15 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.7	(3.6)
site preparation	36	(28)



Implement: heavy drags

Prime mover: 224-kW, 34.1-t bulldozer

The between-furrow mean spacing was increased to 3.16 m by operating practice that was influenced by the low-relief, bedrock-controlled topography. The in-furrow acceptable planting spot mean spacing was increased to 2.77 m primarily by the 24% of the furrow length that was natural and machine-exposed bedrock, but also because of soil too shallow to plant and the presence of stones and woody residue. Of the approximately 1145 acceptable planting spots per hectare, 135 were in mineral soil, 135 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 705 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 170 were in other acceptable conditions. Seven competitor species were noted during a vegetation assessment on 12 August, 13–15 months after harvest. It is likely that competition development may become a problem on this very fresh to moderately dry sandy loam. The moisture regime is generally acceptable for seeding jack pine, but parts of the site are too dry to seed black spruce; however, both drainage and moisture regime may be amended for a period of time by the effects of harvesting and site preparation on this loamy, discontinuous, very shallow to moderately deep soil. Good seedbed comprised 3.5% of the surface, and 6.1% was conditional. Because of the small amount of acceptable seedbed and other site conditions such as moisture regime and potential competition development, uneconomic rates of seed application probably will not establish a stand that satisfies conifer stocking standards. Compare with plate sets 7, 16, 17, 28, and 39–41.

Treatment Unit H

Treatment Unit H: Red or White Pine Conifer and Mixedwood

Treatment Unit H contains red and white pine stands, ranging from pure conifer to mixedwoods, with varying degrees of shrub richness. Red pine stands are often shrub poor. Stands may contain a substantial component of trembling aspen, jack pine, white spruce, or balsam fir.

Equipment trafficability

Shallow soils or considerable surface stoniness may limit some site preparation equipment.

Competition

Typically low levels of competition can be expected, but *Acer spicatum*, *Corylus cornuta*, and trembling aspen may become abundant after harvest of V-12 and V-13 because of a higher hardwood component and a denser shrub layer.

Comments

Minimal site disturbance may assist regeneration to red or white pine. Clearcuts can often be successfully regenerated by planting red pine on exposed mineral soil.

Summary

A summary of Treatment Unit H is presented in Table 8.

Two plots (plate sets 43 and 44) were sampled.

Table 8. Data from plate sets for Treatment Unit H ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
43	1855	59	14.0	1.8	5.9	5–10	>100	vg→g	1–4	0	0
44	1650	51	25.5	3.2	10.2	6–8	35–80	g→m	2	S	S

The plot presented in plate set 43 represents V-27 (Red Pine Conifer) on the very gentle to gently rolling, deep, moderately dry to dry medium sand of beach origin. The woody residue loading was moderately light. The LFH (duff) depth of 5–10 cm contained few roots; 47% of the plot surface had been disturbed during harvesting. It is likely that manual site preparation during tree planting either with the planting spade or by boot screefing would have been adequate. However, a 152-kW, 13.3-t skidder pulling a Bräcke 3-row patch scarifier with the mattocks set 2.0 m apart on the drawbar and machine patch scalping interval set longer than 2 m produced 1855 acceptable planting spots per hectare. Between-planting row spacing was 2.09 m, and in-row acceptable planting spot spacing was 2.58 m; 14.0% of the plot surface was exposed mineral soil.

The plot presented in plate set 44 represents a V-26 (White Pine Conifer) old-growth stand harvested 4–5 years prior to site preparation. The site was rolling, with gentle to moderate slopes. The soil was moderately deep and moderately fresh, and the C-horizon consisted of silt and very fine sand. Rock outcrops were 25–75 m apart. Stones and boulders were 10–30 m apart. The impediments to site preparation included an estimated 425 ground roughness class 2 and 3 obstacles per hectare (approximately 200 large stumps per hectare, plus stones and boulders) and the approximately 30% of area that had a heavy to extremely heavy loading of woody residue, all masked by the well-developed canopy of woody regrowth and residual shrubs. A straight blade on a 224-kW, 34.1-t bulldozer was used to push the woody residue, woody regrowth, and residual shrubs, including the root mat, into small to moderate-sized piles that often were placed over large stumps or boulders; 1650 acceptable planting spots per hectare were produced, and 25.5% of the surface was mineral soil exposed, mostly, at the organic/mineral interface.

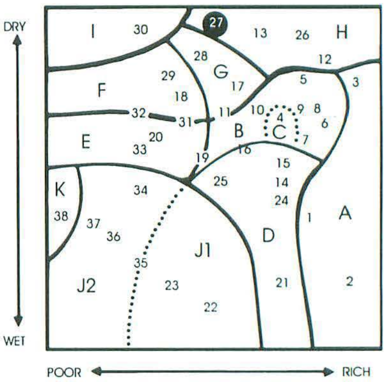
Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
250	78	2–5	1	mD→D	mS	V-27 (H)	2.09	2.58	152	13.3	Bräcke	43
425	120	43–61	9	mF	SiL	V-26 (H)	n.a.	2.31	224	34.1	S-blade	44

PLATE
43A

V27 Red Pine Conifer S1, S1, S1

FRI: $Pj_8Sb_1Po_4$, age 85, height 24 m, stocking 1.0, site class 1

Other site vegetation types: none



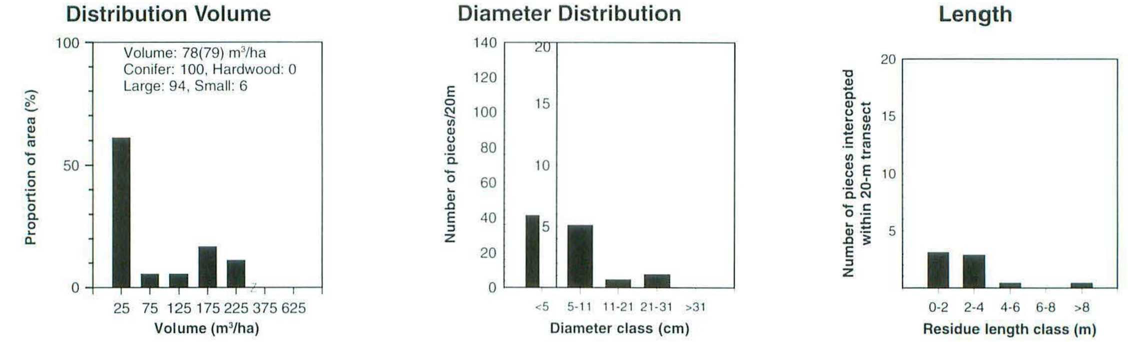
Photographed and assessed: 14 September 1990
Time elapsed since harvest: 1–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: very gentle to gentle
Bedrock outcrops: none
Plot slopes: simple, 1–4%
Plot slope position: flat
Landform: lacustrine (beach) deposit
Soil depth: >100 cm

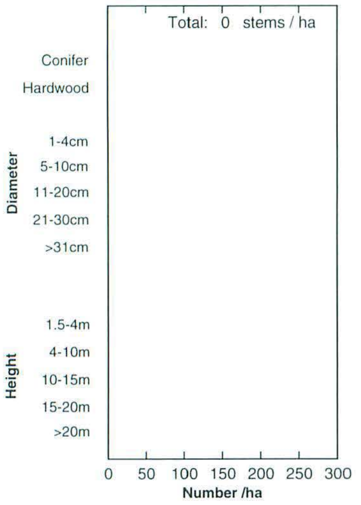
Soil texture: medium sand (common) and coarse sand
Boulders: none
Stones: none
Coarse fragments: 0–5%
Litter: 4 cm

Fermentation layer: 1–5 cm
Humus: trace to 1 cm
Texture of surface mineral soil: medium sand
Drainage: rapid
Moisture regime: moderately dry (common) to dry

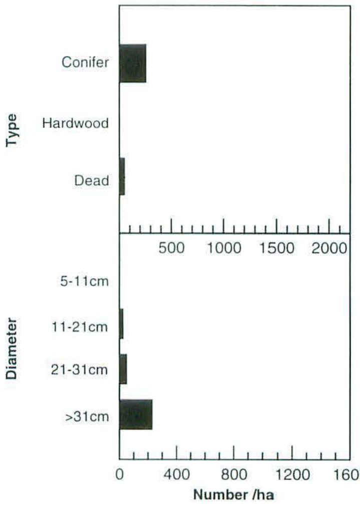
Woody Debris



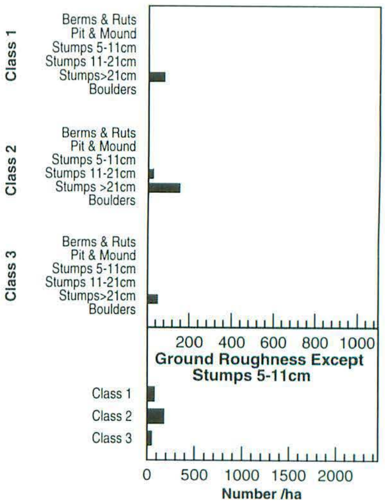
Residuals



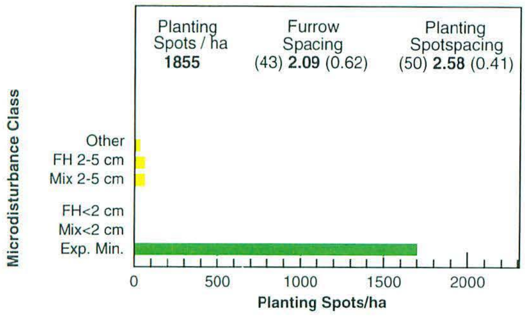
Stumps



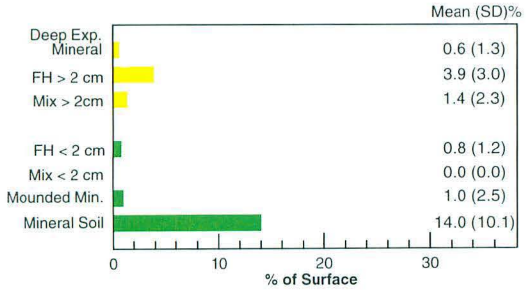
Ground Roughness



Plantability

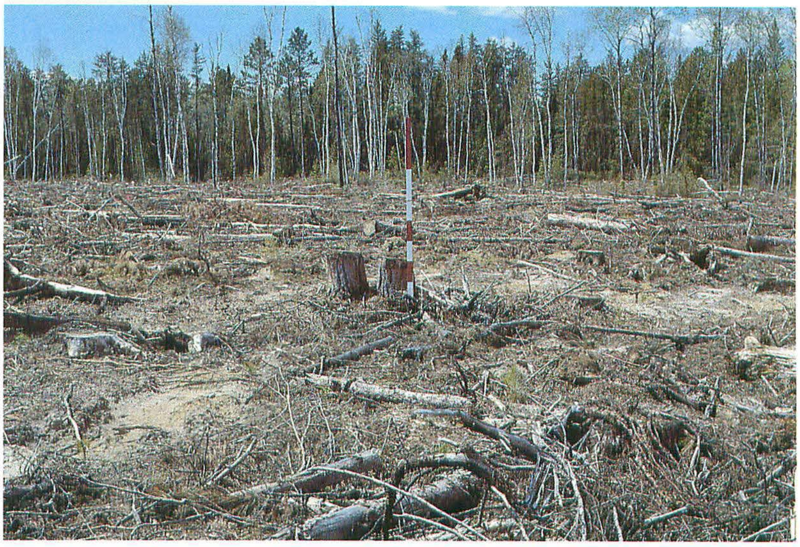


Potential Seedbed

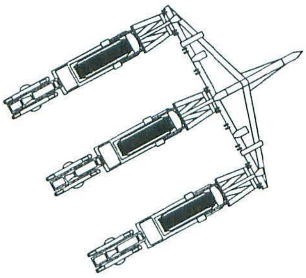


Furrow length (%), mineral soil ≥15 cm wide	59	(31)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	23	(18)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.3	(2.7)
rock and/or water	0	(0)
shallow (<10 cm) mineral soil over organic	1.2	(2.1)

Photographed and assessed: 19 June 1991
Time from site preparation to assessment: about 10 months
Time from harvest to site preparation: 2–5 months



Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	17.8	(22.0)
site preparation	47	(15)



Implement: Bräcke 3-row (mattock wheels at 2.0-m spacing)

Prime mover: 152-kW, 13.3-t skidder

Few impediments to site preparation existed on this site. It is likely that "boot and shovel" screefing by a planter of bareroot stock may produce acceptable planting spots. The between-rows-of-scalps mean spacing of 2.09 m was a function of operating practice and implement configuration. The in-rows-of-scalps acceptable planting spot mean spacing of 2.58 m was probably a function of the implement's setting (i.e., "in many cases scalps were centred 2.5–3.0 m apart," as per assessor's field notes). Of the about 1850 acceptable planting spots per hectare, 1700 were in mineral soil, 120 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 30 were in other acceptable conditions. One competitor species was noted during a vegetation assessment on 14 September, 1–3 months after harvest. Competition development may be slow on this dry, medium sand site. The site moisture regime is too dry to seed spruce and at the dry end of the acceptable range for jack pine. Good seedbed comprised 15.8% of the surface for pine, and 5.9% was conditional. A good portion of the seedbed was produced by harvesting activity rather than by site preparation. Although the amount and distribution of seedbed were favorable for seeding jack pine, the site's moisture regime may preclude success by broadcast seeding in years with germination and/or establishment seasons that are too dry, too hot, or both. Compare with plate sets 2, 4, 26, 31–34, and 39.

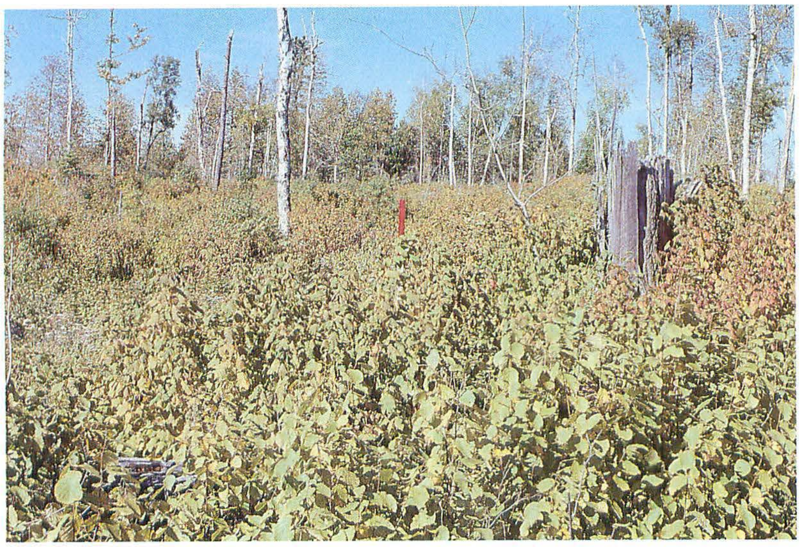
Note: The FRI stand description is in error; the correct classification is either Pr_{10} or Pr_9Bw_1.

PLATE
44A

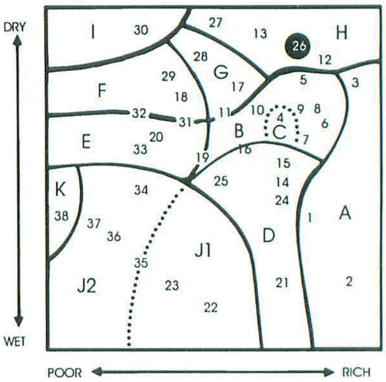
V26 White Pine Conifer

SS7, SS7, SS7

FRI: $B_4Sb_2Pw_2Ce_1Bw_1$, age 200, height 33 m, stocking 0.6, site class 1



Other site vegetation types: this plot represents islands (about 2–5 ha) of older, closed-canopy white pine within a heterogeneous forest well represented by the FRI stand description



Photographed and assessed: 10 September 1990
Time elapsed since harvest: 30–48 months
Harvest method: both log-length and (some) tree-length by chainsaw and cable skidder

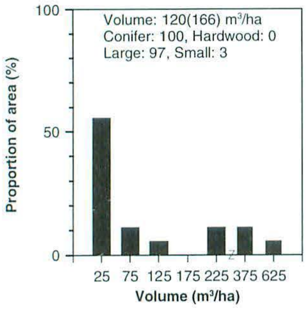
Area topography: gentle to moderate
Bedrock outcrops: slight
Plot slopes: simple, 2%
Plot slope position: upper
Landform: ground moraine
Soil depth: 35–80 cm

Soil texture: silt, very fine sand
Boulders: slight
Stones: slight
Coarse fragments: 1–20%
Litter: 2–3 cm

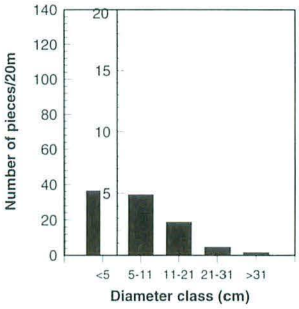
Fermentation layer: 3–4 cm
Humus: 1 cm
Texture of surface mineral soil: silty loam
Drainage: well to rapid
Moisture regime: moderately fresh

Woody Debris

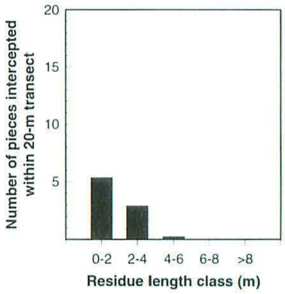
Distribution Volume



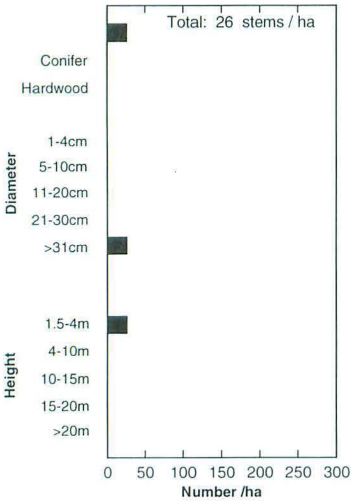
Diameter Distribution



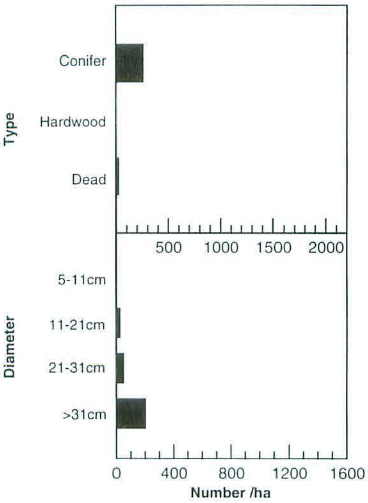
Length



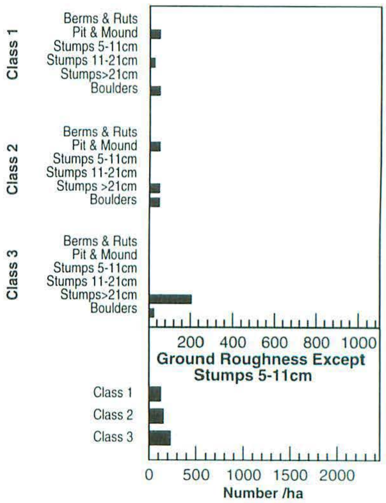
Residuals



Stumps

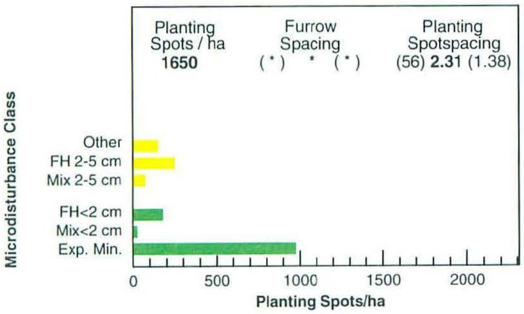


Ground Roughness

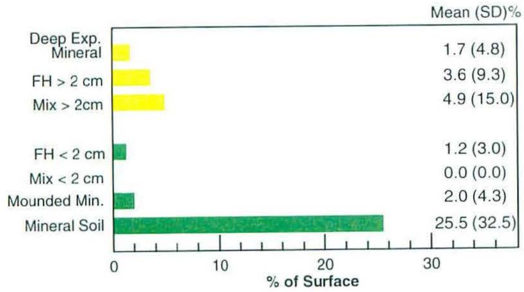


Screefing

Plantability



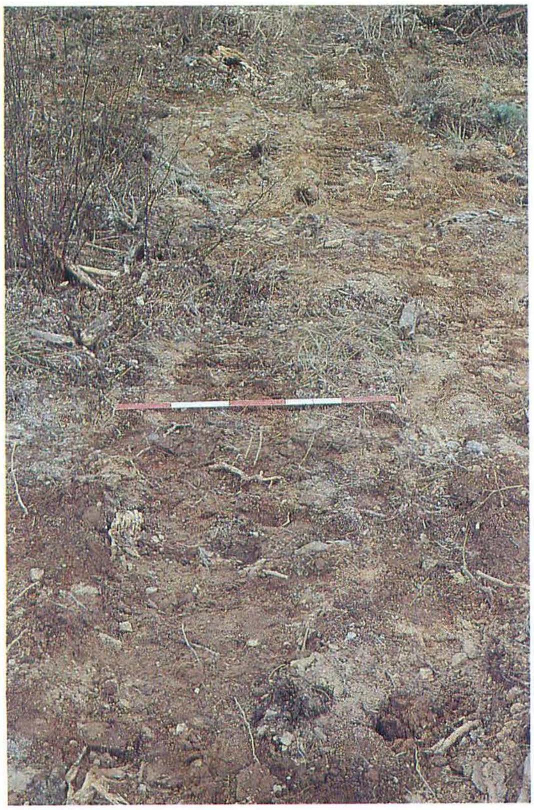
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	51	(48)
Furrow length (%), rock and/or water	0	(0)

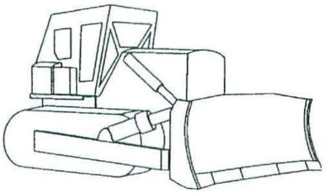
Other surface conditions (% of surface):

spoil bank	38	(32)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	1.0	(7.1)
rock and/or water	1.1	(5.7)
shallow (<10 cm) mineral soil over organic	0.6	(2.3)



Photographed and assessed: 12 and 13 October 1991
Time from site preparation to assessment: 7–10 days
Time from harvest to site preparation: 43–61 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	80	(35)



Implement: 5-m straight blade

Prime mover: 224-kW, 34.1-t bulldozer

The well-developed canopy of woody regrowth and residual shrubs totally masked from the machine operator the approximately 30% of the surface area that had a heavy to extremely heavy load of woody residue, about 200 high, large-diameter stumps per hectare, and occasional boulders. Careful screefing removed only the root and organic mat (note the eluviated soil horizon) into local concentrations of spoil bank. The assessment consisted of a 20 m x 20 m grid of contiguous 2-m^2 quadrats (100 samples). Of the 1650 acceptable planting spots per hectare, 975 were in mineral soil, 200 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 325 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 150 were in other acceptable conditions. Nine competitor species were noted during a vegetation assessment on 10 September, about 30–48 months after harvest; competition development may become a problem. The moisture regime is attractive for seeding jack pine but is at the dry end of the acceptable range for seeding spruce. Good seedbed comprised 28.7% of the surface, and 10.2% was conditional. However, because of the distribution and concentration of seedbed, the conifer stocking potential from seeding was probably less than 60–70%; excessive density of germinants is likely in stocked areas. It should be noted that if seed from any source is delayed for 2 or more years, competition development, particularly grass species, may reduce the amount of acceptable seedbed and smother or choke out fragile germinants. The local forester advised that leaving seed trees has become common on these sites. Compare with plate sets 9 and 19.

Treatment Unit I

Treatment Unit I: Jack Pine–Black Spruce/Blueberry/Lichen

These stands are poorly stocked, herb- and shrub-poor black spruce or jack pine stands. Forest floor cover is typically lichen and blueberry.

Phase I1: Very shallow soils
Phase I2: Deep–moderately deep sandy soils

Equipment trafficability

Very shallow or bouldery soils pose significant limitations to site preparation equipment, particularly on rugged terrain.

Competition

Very little shrub competition is expected, particularly on deep, rapidly drained soils. Competition control should not be required on phase I2.

Comments

Sites are well suited for aerial or natural seeding to jack pine, with a minimal amount of mineral soil exposure. Minimal site preparation not only will reduce the risk of vegetation competition but will enhance opportunities for the regeneration of lichen in caribou range. Phase I1 may not be suitable for site preparation or planting because of shallow soils and extensive bedrock. Very shallow soils are fragile and highly susceptible to erosion.

Table 9. Data from plate sets for Treatment Unit I ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil $\geq$15 cm wide	% area that is exposed mineral soil	% area that is FH $\leq$2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
45	761	18	3.5	2.9	5.1	5–10	1–23 (dis)	vg→m	1–5	S→M	S
46	250	4	0.2	0.1	2.0	7–9	0–70 (dis)	m→str	0–17	S→M	V→M

Summary

A summary of Treatment Unit I is presented in Table 9.

Two plots (plate sets 45 and 46) were sampled. Both are characterized by rock outcrops and very shallow to moderately deep soils.

The plot presented in plate set 45 represents a phase I1 site, with black spruce the predominant preharvest species. The plot had discontinuous, very shallow to shallow soil, very gentle to moderate topography, and nearly level to very gentle plot slopes, with stones 10–30 m apart. The Silva Wadell powered cone scarifier on a 104-kW, 14.5-t skidder produced 761 acceptable planting spots per hectare. Between-furrow spacing was 2.01 m, but the in-furrow acceptable planting spot spacing was 6.54 m owing to natural and machine-exposed bedrock and/or soil too shallow to allow a tree to be planted. It is doubtful whether other affordable mechanical site preparation methods could have given better results.

The plot presented in plate set 46 represents an anomaly that keys to V-30 based on stump basal area (≤2% hardwood and ≥20% exposed bedrock). However, the apparent fertility and the diversity and abundance of competitor species, including *Corylus cornuta*, suggest that V-17 would be the more appropriate V-type. The site had discontinuous, very shallow to moderately deep soil with a sandy loam on the surface, moderate to strong topography, moderately complex plot slopes, stones and boulders ranging from 1–2 m apart (common) to 10–30 m apart that, together with stumps, gave about 1050 ground roughness class 2 and 3 obstacles per hectare, and about 40 residuals >10 cm in diameter per hectare. A TTS Delta (power) disc trencher on a 142-kW, 13-t skidder produced about 250 acceptable planting spots per hectare owing to rock outcrops and shallow soil. It is doubtful that other affordable mechanical site preparation equipment could produce better results on this site.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
250	50	23–25	1	D→M	SiL, cS, SimS	V-30 (I)	2.01	**6.54**	104	14.5	Wadell	45
1050	68	12–14	7	D→mD	SL	V-30 (I)	7.27	n.r.	142	13	TTS (pow)	46

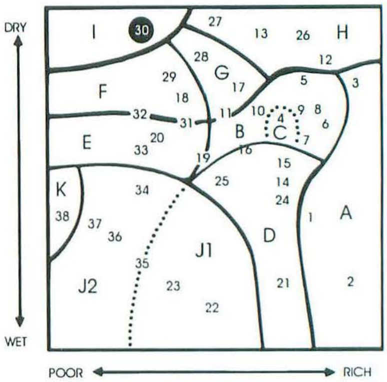
PLATE
45A

V30 Jack Pine – Black Spruce / Blueberry / Lichen

SS3, SS2, SS5

FRI: Sb$_8$Jp$_1$Po$_1$, age 100, height 18 m, stocking 0.8, site class 2

Other site vegetation types: Trembling Aspen–Conifer/Blueberry/Feathermoss, Black Spruce Mixedwood, White Spruce Mixedwood



Photographed and assessed: 28–29 May 1991
Time elapsed since harvest: 20–22 months
Harvest method: full-tree by feller–buncher and grapple skidder

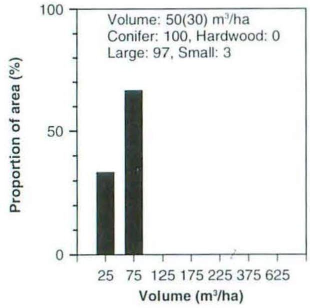
Area topography: very gentle to moderate
Bedrock outcrops: slight to moderate
Plot slopes: simple, 1–5%
Plot slope position: upper to crest
Landform: wave-washed glacial drift
Soil depth: 1–23 cm (discontinuous)

Soil texture: silty loam, coarse sand, very fine sand
Boulders: none
Stones: slight
Coarse fragments: not recorded
Litter: 2–4 cm

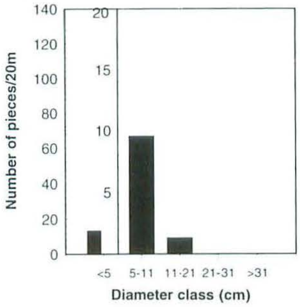
Fermentation layer: 3–6 cm
Humus: none
Texture of surface mineral soil: silty loam, coarse sand, and silty medium sand
Drainage: very rapid (common) to imperfect
Moisture regime: dry (common) to moist

Woody Debris

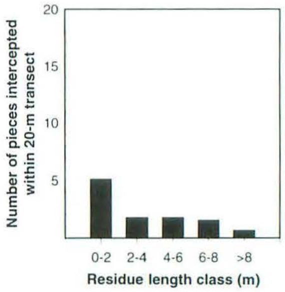
Distribution Volume



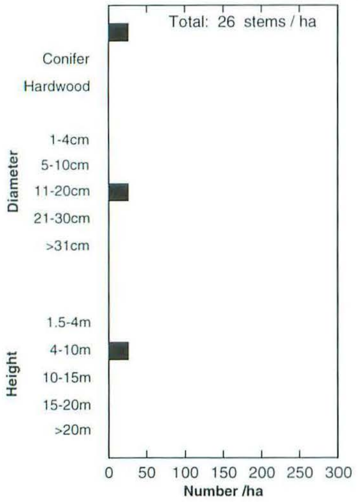
Diameter Distribution



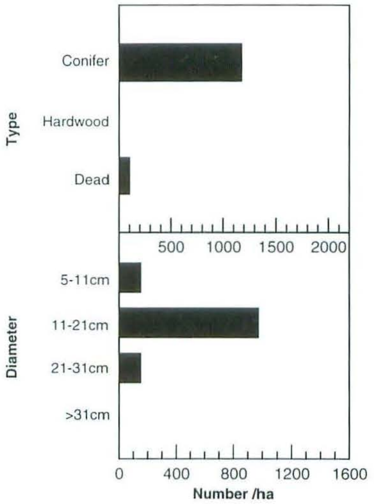
Length



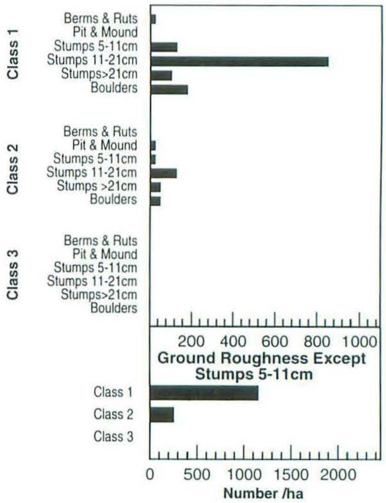
Residuals



Stumps

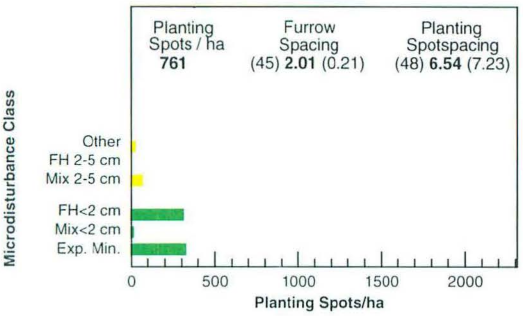


Ground Roughness

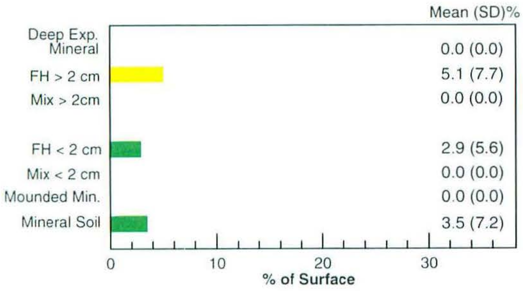


Screefing

Plantability



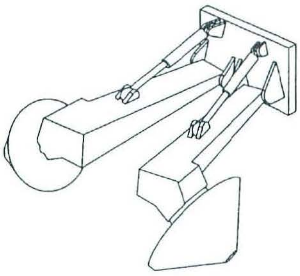
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	18	(28)
Furrow length (%), rock and/or water	49	(42)
Other surface conditions (% of surface):		
spoil bank	32	(22)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	2.5	(4.0)
rock and/or water	10.7	(15.6)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 7 September 1991
Time from site preparation to assessment: 3–5 weeks
Time from harvest to site preparation: 23–25 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.4	(2.8)
site preparation	54	(27)



Implement: Silva Wadell powered cone scarifier

Prime mover: 104-kW, 14.5-t skidder

The very shallow, discontinuous mineral soil, the exposed bedrock, and the light to moderately light load of woody residue were the constraints to site preparation. The between-furrow spacing of 2.01 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was increased to 6.54 m by the 49% of furrow length that was either naturally or machine-exposed bedrock and soil too shallow to plant. Of the about 765 acceptable planting spots per hectare, 330 were in mineral soil, 330 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 75 were in an organic–mineral mix 2–5 cm deep over mineral soil, and 30 were in other acceptable conditions. One competitor species was noted during a vegetation assessment on 29 May, 20–22 months after harvest. Competition development is not expected to be a problem. The greater part of the site is too dry to seed black spruce and is at the dry end of the acceptable range for jack pine. Because of the variability in moisture regime at the 2-m^2 level and both the limited availability (6.4% good and 5.1% conditional) and distribution of seedbed, rather high, possibly uneconomic rates of broadcast seed application of black spruce or jack pine may be required to assure acceptable conifer stocking over all of the site. However, on the parts of the site mosaic that have a possibility of being stocked, adequate seedbed exists to permit broadcast sowing of jack pine and, perhaps, black spruce at economic application rates with a reasonable likelihood of acceptable conifer stocking on those parts of the site. Compare with plate sets 17, 29, 30, 35, 38, 42, and 46.

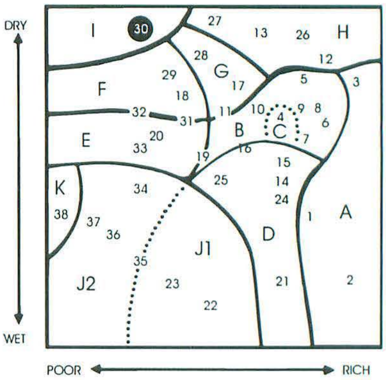
PLATE
46A

V30 Jack Pine – Black Spruce / Blueberry / Lichen

SS2,SS5,SS3

FRI: PFR Pj_9Po_1, age 83, height 15, stocking 0.9, site class 3

Other site vegetation types: Jack Pine/Ericaceous Shrub/Feathermoss



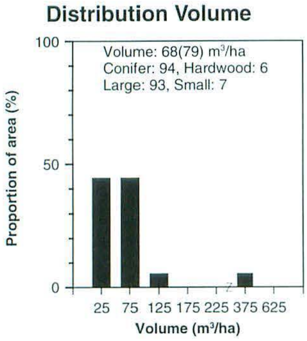
Photographed and assessed: 25 September 1990
Time elapsed since harvest: 2–4 months
Harvest method: a combination of full-tree and tree-length by feller–buncher, chainsaw, and both grapple and cable skidders

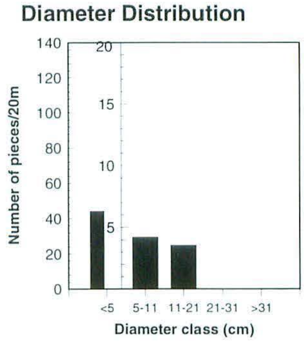
Area topography: moderate to strong
Bedrock outcrops: slight to moderate
Plot slopes: complex, 17%
Plot slope position: mid
Landform: shallow glacial drift
Soil depth: 0–70 cm (discontinuous)

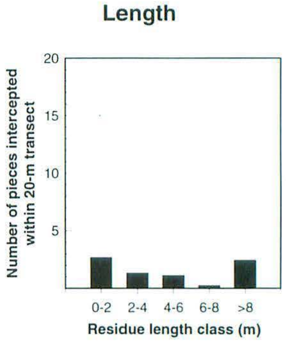
Soil texture: coarse sand
Boulders: slight to very
Stones: very (common) to moderate
Coarse fragments: 6–>50%
Litter: 2 cm

Fermentation layer: 5–6 cm
Humus: trace to 1 cm
Texture of surface mineral soil: sandy loam
Drainage: very rapid (common) to rapid
Moisture regime: dry (common) to moderately dry

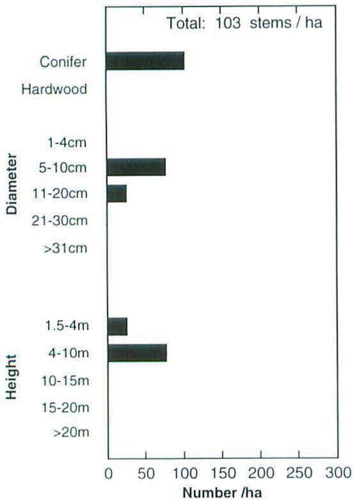
Woody Debris


Distribution Volume

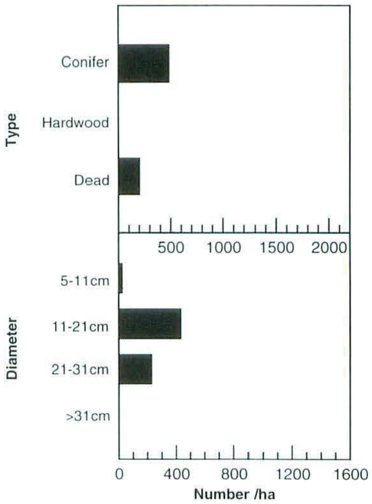

Diameter Distribution


Length

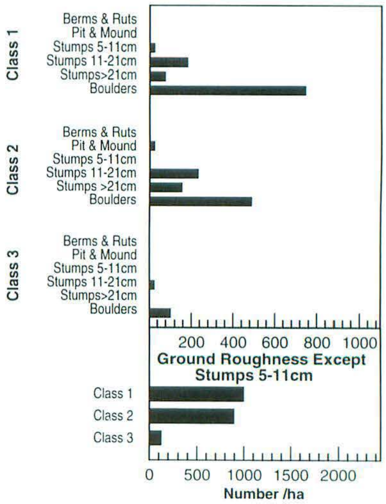
Residuals



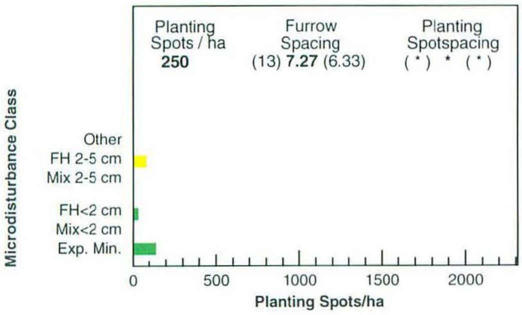
Stumps



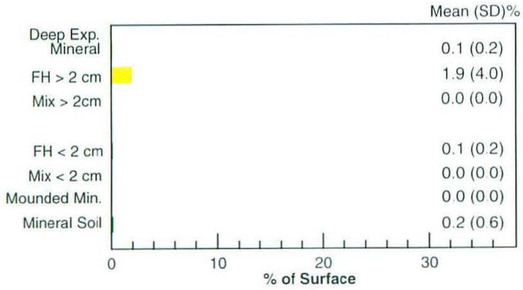
Ground Roughness



Plantability



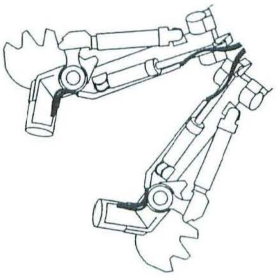
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	4	(13)
Furrow length (%), rock and/or water	22	(38)
Other surface conditions (% of surface):		
spoil bank	2	(5)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	0.6	(1.4)
rock and/or water	8.4	(15.3)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 16 August 1991
Time from site preparation to assessment: 3–4 weeks
Time from harvest to site preparation: 12–14 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	13	(22)



Implement: TTS Delta (power) disc trencher

Prime mover: 142-kW, 13-t skidder

Discontinuous, shallow soil, moderate slopes in complex terrain, residuals, and ground roughness combined to limit trafficability and tillage. This site was assessed using a 20 m x 20 m grid of contiguous 2-m^2 quadrats (100 quadrats). Of the 250 acceptable planting spots per hectare, 138 were in mineral soil, 28 were in organic matter ≤2 cm deep over mineral soil, and 84 were in organic matter 2–5 cm deep over mineral soil. Seven competitor species were noted during a vegetation assessment on 25 September, 2–4 months after harvest; competition development may be a problem. The moisture regime is too dry to seed black spruce and at the dry end of the acceptable range for jack pine. Good seedbed (as conventionally defined in the literature) comprised only 0.3% of the surface, and 2.0% was conditional. However, experience-based observation suggests that both exposed mineral soil and organic soils forming perimeters of bedrock outcrops may have some value as seedbed; experience suggests that some stocking of jack pine may occur from aerial broadcast seeding of jack pine at common application rates, even though the scarcity of seedbed (as conventionally defined), the moisture regime, and potential competition development preclude any seeding option. With the possible exception of prescribed fire and broadcast seeding, it is unlikely that any currently available, cost-effective technology is capable of regenerating this site, which is both fragile and exceedingly harsh on machinery. However, both the diameter distribution and number of stumps per hectare plus the tally of competitor species suggest that this particular example is a relatively productive site. Compare with plate sets 17, 29, 30, 35, 38, 42, and 45.

Note: This plot keyed to a V-30 based on the fact that ≤2% of the stump basal area on the plot was hardwood and ≥20% of plot surface was exposed bedrock. However, the apparent fertility and the diversity and abundance of competitor species, including *Corylus cornuta*, suggest that V-17 would be the more appropriate V-type.

Treatment Unit J

Treatment Unit J: Black Spruce/Wet Organic

Phase J1: Lowland black spruce, white cedar, or tamarack with a shrub layer of *Alnus rugosa*. Usually occurs on organic sites with extensive *Sphagnum* cover. Typically deep, very moist to wet organic soils.

Phase J2: Typically black spruce/*Sphagnum* associations on organic soils. This phase is similar to J1 but lacks a well-developed shrub layer of *Alnus rugosa*. Predominantly deep, very moist to wet organic soils and peaty-phase mineral soils. Deep, moderately moist and moist mineral soils occur more frequently than in phase J1.

Equipment trafficability

These sites are susceptible to puddling and rutting from most equipment.

Comments

Winter blading may be an appropriate method of mechanical site preparation on these sites, to prepare either seedbed or planting spots. Removal of existing vegetation may cause the water table to rise, altering the productivity of some sites.

Table 10. Data from plate sets for Treatment Unit J ordered by stocking potential, i.e., the number of acceptable planting spots per hectare.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
47	2439	37	4.2	1.8	25.5	25–45	25–40	g	0–3	S	S
48	1866	35	4.1	1.0	11.6	20–26	>100	level	0–1	0	0

Summary

A summary of Treatment Unit J is presented in Table 10.

Two plots were sampled (plate sets 47 and 48), both phase J2 sites located on typical S11 moist, peaty-phase soils.

One plot (plate set 47) was located on an upper slope with a moderately shallow to moderately deep morainal deposit of fine sand. Excepting the ericaceous shrub root mat, this site had few impediments to site preparation. The heavy drag drawn by a 239-kW, 33.7-t bulldozer produced more than 2400 acceptable planting spots per hectare.

The other plot (plate set 48) was located on an old lake bottom on a deep, silty very fine sand. The peaty-phase organic layer was mostly *Sphagnum*. The Donaren 180 disc trencher mounted on a 186.5-kW, 25-t skidder easily coped with the stump field (1875 ground roughness class 2 and 3 obstacles per hectare). The between-furrow spacing of 2.34 m was a function of operating practice. However, the imperfect drainage caused about 3% of the furrow length to be flooded, which, together with debris, increased in-furrow planting spot spacing to 2.29 m.

Two competitor species were noted on the plot located on the upper slope, and four (including graminoids) on the lake bottom. It is suggested that competition to planted crop trees may not be a problem on the upper slope site but may be a problem on the lake bottom site if the graminoids flourish.

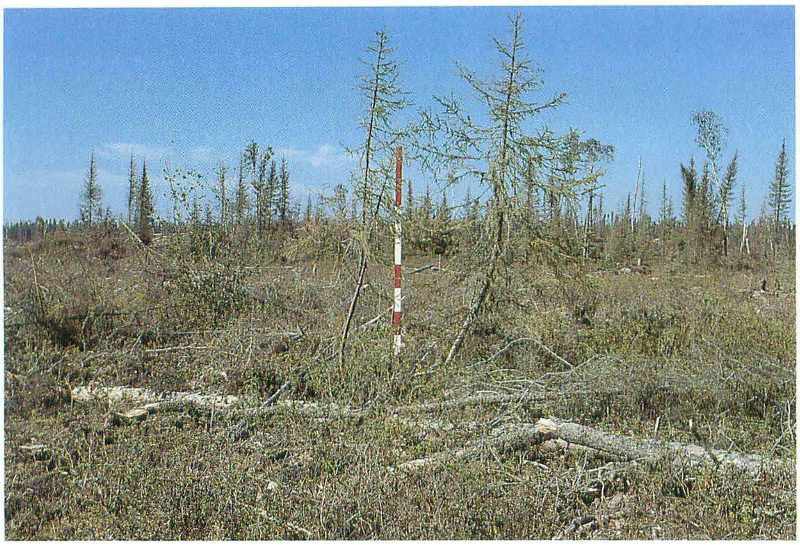
Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
600	72	12–13	2	M→mF	LmS	V-34 (J)	2.03	2.02	239	33.7	drag (H)	47
1875	44	7–11	4	M→mM	SiCL, vfS, LvfS	V-34 (J)	2.34	2.29	186.5	25	Don180	48

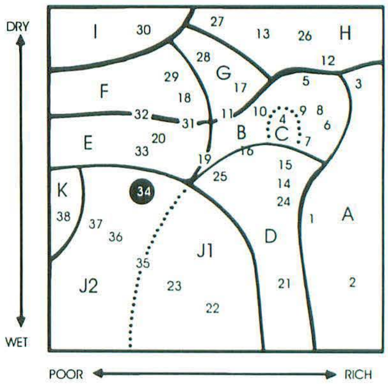
PLATE
47A

V34 Black Spruce / Labrador Tea / Feathermoss / (Sphagnum) S11/SS5, S11/SS8, S11/SS9

FRI: Sb$_5$Pj$_3$Po$_1$Bw$_1$, age 155, height 17 m, stocking 0.6, site class 2

Other site vegetation types: Black Spruce/Bunchberry/Sphagnum (Feathermoss)





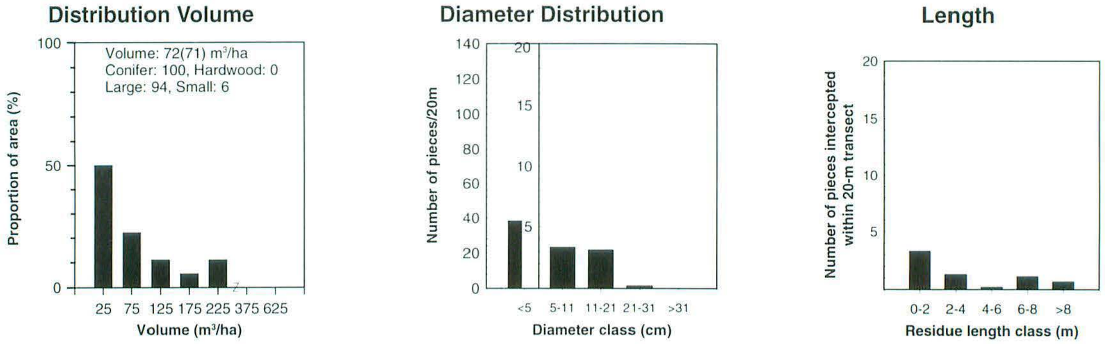
Photographed and assessed: 30 August 1990
Time elapsed since harvest: 2–3 months
Harvest method: full-tree by feller–buncher and grapple skidder

Area topography: gentle
Bedrock outcrops: slight
Plot slopes: simple, 0–3%
Plot slope position: upper
Landform: ground moraine
Soil depth: 25–40 cm

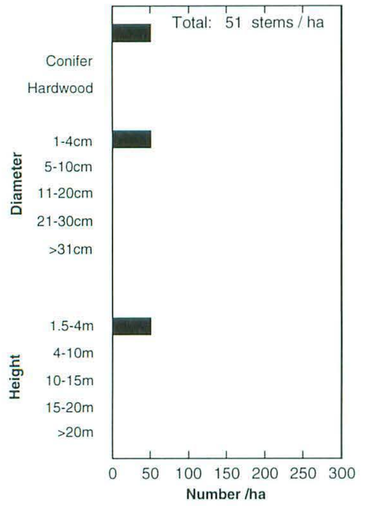
Soil texture: fine sand
Boulders: none
Stones: slight
Coarse fragments: 6–20%
Litter: negligible

Peaty phase: 25–45 cm feathermoss (shallower) and *Sphagnum*
Texture of surface mineral soil: loamy medium sand
Drainage: imperfect (common) to well
Moisture regime: moist to moderately fresh

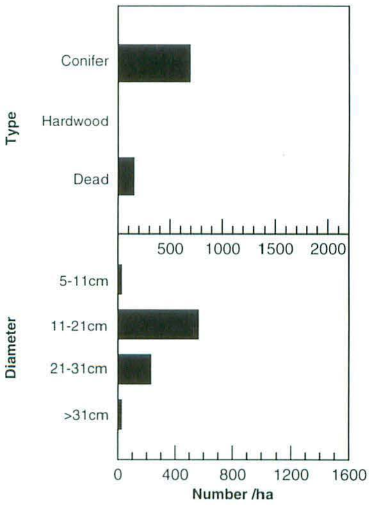
Woody Debris


Distribution Volume
Diameter Distribution
Length

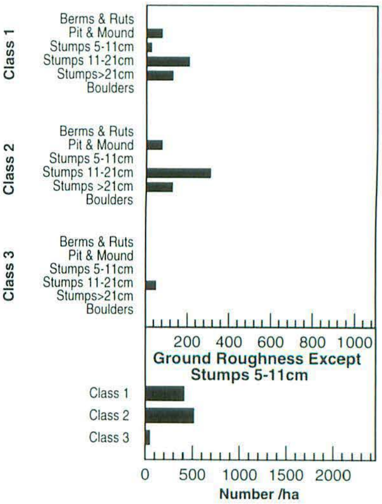
Residuals



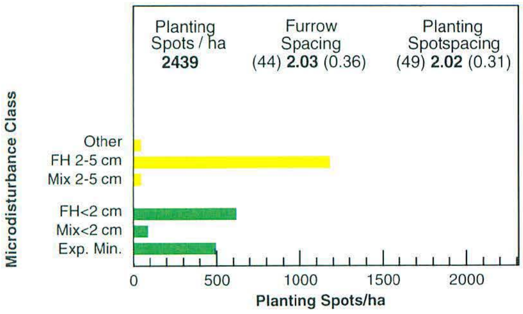
Stumps



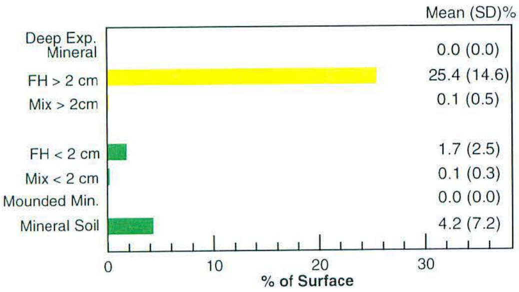
Ground Roughness



Plantability



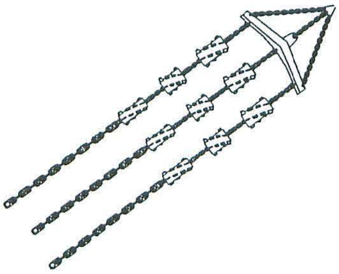
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	37	(42)
Furrow length (%), rock and/or water	0	(0)
Other surface conditions (% of surface):		
spoil bank	47	(19)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	4.8	(5.6)
rock and/or water	1.8	(3.8)
shallow (<10 cm) mineral soil over organic	0	(0)

Photographed and assessed: 1 August 1991
Time from site preparation to assessment: 4–6 weeks
Time from harvest to site preparation: 12–13 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0.8	(4.0)
site preparation	86	(15)



Implement: heavy drags

Prime mover: 239-kW, 33.7-t bulldozer

The peaty-phase organic surface, drainage, and site moisture regime, complicated by the moderately light to occasionally heavy load of woody residue, were the impediments to site preparation. The between-furrow spacing of 2.03 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was 2.02 m. Of the about 2440 acceptable planting spots per hectare, 490 were in mineral soil, 690 were in organic matter or an organic–mineral mix ≤2 cm deep over mineral soil, 1220 were in organic matter or an organic–mineral mix 2–5 cm deep over mineral soil, and 40 were in other acceptable conditions. Two competitor species were noted during a vegetation assessment on 30 August, 2–3 months after harvest. Well-planted, vigorous black spruce stock adapted morphologically and physiologically to this moderately infertile site may cope with the probably slow competition development. Peaty-phase soils are not favored by jack pine and are commonly planted or seeded with black spruce. Approximately 4% of the surface was mineral soil and 1.7% was organic matter ≤2 cm deep over mineral soil, both relatively good seedbeds for black spruce. About 25% of the surface was screefed organic horizons >2 cm deep. Depending on the ratio of *Sphagnum* moss (relatively good seedbed) to feathermoss (poor to very poor seedbed), seeding black spruce may be an alternative to planting on this site. Compare with plate sets 23, 25, 27, and 48.

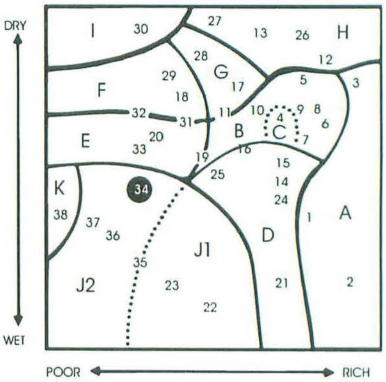
Note: This plot keys to V-34, as the (surface) ratio of feathermoss to *Sphagnum* is ≥2:1. However, the underlying "peaty phase" appears to be *Sphagnum*, suggesting that V-36 may be more appropriate.

PLATE
48A

V34 Black Spruce / Labrador Tea / Feathermoss / (Sphagnum) S11/S9, S11/S9, S11/S9

FRI: Sb_{10}, age 88, height 17 m, stocking 1.4, site class 1

Other site vegetation types: none recorded



Photographed and assessed: 11 September 1990
Time elapsed since harvest: 6–10 months
Harvest method: full-tree by feller–buncher and grapple skidder

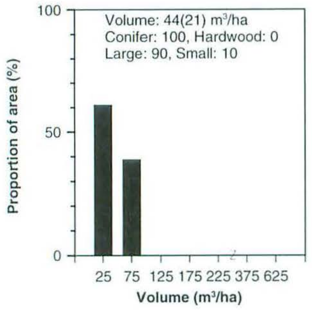
Area topography: nearly level
Bedrock outcrops: none
Plot slopes: simple, 0–1%
Plot slope position: flat
Landform: lacustrine deposit
Soil depth: >100 cm

Soil texture: silty very fine sand
Boulders: none
Stones: none
Coarse fragments: 0–5%
Litter: negligible

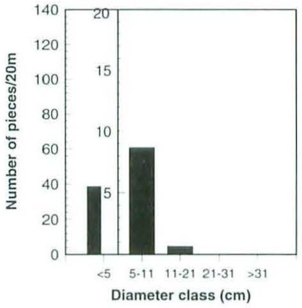
Peaty phase: 20–26 cm
Texture of surface mineral soil: silty clay loam, very fine sand, loamy very fine sand
Drainage: imperfect
Moisture regime: moist to moderately moist

Woody Debris

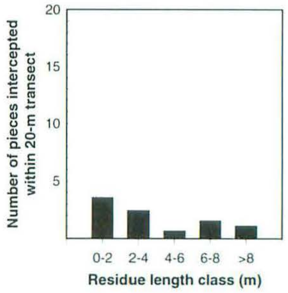
Distribution Volume



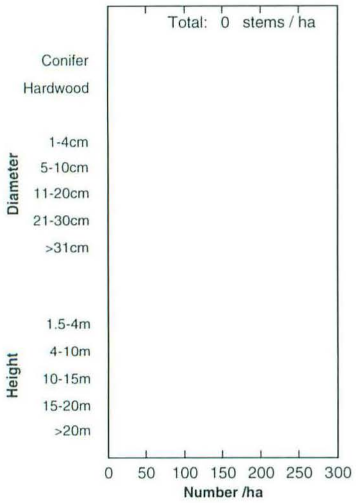
Diameter Distribution



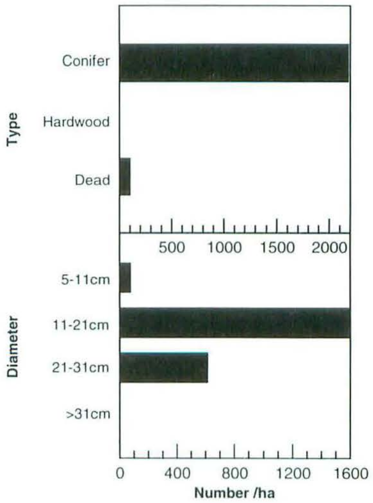
Length



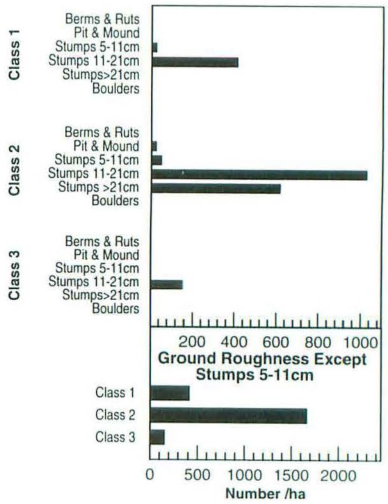
Residuals



Stumps

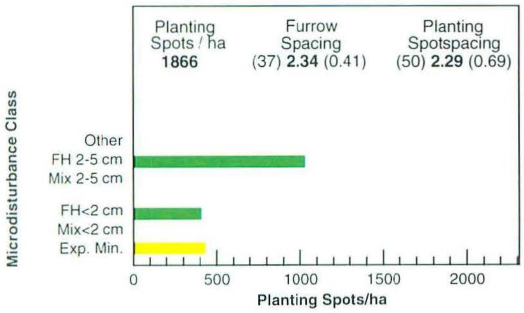


Ground Roughness

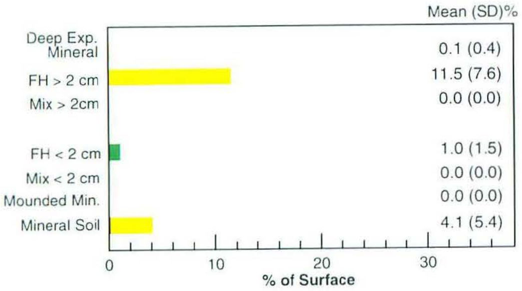


Trenching

Plantability



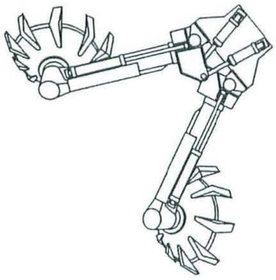
Potential Seedbed



Furrow length (%), mineral soil ≥15 cm wide	35	(35)
Furrow length (%), rock and/or water	3	(8)
Other surface conditions (% of surface):		
spoil bank	43	(24)
site preparation overlain by woody residue, stumps, roots, etc., from adjacent pass	3.6	(3.0)
rock and/or water	1.6	(3.0)
shallow (<10 cm) mineral soil over organic	0.1	(0.5)

Photographed and assessed: 7 June 1991
Time from site preparation to assessment: about 8 months
Time from harvest to site preparation: 7–11 months

Gross disturbance of surface (%):	**mean**	**(sd)**
other (mostly harvesting)	0	(0)
site preparation	65	(20)



Implement: Donaren 180 disc trencher

Prime mover: 186.5-kW, 25-t skidder

The peaty-phase organic surface, imperfect drainage, moisture regime, and stump field were the constraints to site preparation. The between-furrow mean spacing of 2.34 m was a function of operating practice. The in-furrow acceptable planting spot mean spacing was increased to 2.29 m by the 3% of furrow length that was water plus the presence of woody residue. Of the approximately 1865 acceptable planting spots per hectare, 435 were in mineral soil, 405 were in organic matter ≤2 cm deep over mineral soil, and 1025 were in organic matter 2–5 cm deep over mineral soil. Four competitor species were noted during a vegetation assessment on 11 September, 6–10 months after harvest. Competition development, particularly grasses and sedges, may become a problem. Peaty-phase soils are not favored by jack pine and are commonly planted or seeded to black spruce. Although 4.2% of the surface was fine-textured mineral soil, it was located in the bottom of trenches on an imperfectly drained site, and its value as seedbed for black spruce may be reduced. Frost heaving on fine-textured soils of fragile germinants and, perhaps, of planting stock may be a problem. About 12.5% of the surface is disturbed organic soil that, depending on whether it is a feathermoss or *Sphagnum* peat, may be an acceptable spruce seedbed. Biologically, deeper trenching may not be the most appropriate treatment for imperfectly drained peaty-phase sites. Compare with plate sets 23, 25, 27, and 47.

Species List

Trees

Abies balsamea (L.) Mill.	Balsam fir
Acer rubrum L.	Red maple
Betula lutea Michx. f.	Yellow birch
Betula papyrifera Marsh.	White birch
Fraxinus nigra Marsh.	Black ash
Fraxinus pennsylvanica Marsh.	Red ash
Larix laricina (Du Roi) K. Koch	Tamarack (or eastern larch)
Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) B.S.P.	Black spruce
Pinus banksiana Lamb.	Jack pine
Pinus resinosa Ait.	Red pine
Pinus strobus L.	White pine
Populus balsamifera L.	Balsam poplar
Populus tremuloides Michx.	Trembling aspen (or aspen)
Quercus macrocarpa Michx.	Bur oak
Thuja occidentalis L.	Eastern white cedar
Tilia spp.	Basswood

Shrubs

Acer spicatum Lam.	Mountain maple
Alnus crispa (Ait.) Oursh	Green alder
Alnus rugosa (Du Roi) Spreng.	Speckled alder
Arctostaphylos uva-ursi (L.) Spreng.	Bearberry
Chamaedaphne calyculata (L.) Moench	Leatherleaf
Cornus stolonifera Michx.	Red osier dogwood
Corylus cornuta Marsh.	Beaked hazel
Diervilla lonicera Mill.	Bush honeysuckle
Ledum groenlandicum Oeder	Labrador tea
Prunus pensylvanica L.Fil.	Pin cherry
Rubus idaeus L. var. *strigosus* (Michx.) Maxim.	Wild red raspberry
Salix spp.	Willow
Vaccinium spp.	Blueberry

Herbs

Actaea rubra (Ait.) Willd.	Red baneberry
Aster macrophyllus L.	Large-leaved aster
Cornus canadensis L.	Bunchberry
Fragaria spp.	Strawberry
Fragaria vesca L.	Woodland strawberry
Fragaria virginiana Duchesne	Common strawberry
Polygonum convulvus (L.)	Black bindweed

Others

Calamagrostis canadensis (Michx.) Beauv.	Canada blue-joint grass
Carex spp.	Sedges (assorted species)
Graminoid spp.	Grass (assorted species)

Common Terminology

Rock outcrops

0	nonrocky
S	slightly rocky
M	moderately rocky
V	very rocky
E	exceedingly rocky
X	excessively rocky
n.l.	none locally

Stones and boulders

0	nonstony
S	slightly stony
M	moderately stony
V	very stony
E	exceedingly stony
X	excessively stony

Moisture regime

D	Ø	dry
mD	0	moderately dry
mF	1	moderately fresh
F	2	fresh
vF	3	very fresh
mM	4	moderately moist
M	5	moist
vM	6	very moist
mW	7	moderately wet
W	8	wet
vW	9	very wet

Area topography (slope class and range)

l	0–0.5%	level
nl	0.5–2.0%	nearly level
vg	2–5%	very gentle
g	5–9%	gentle
m	9–15%	moderate
str	15–30%	strong
vstr	30–45%	very strong
e	45–70%	extreme
ste	70–100%	steep
vste	>100%	very steep

Drainage

VR	very rapid
R	rapid
W	well
MW	moderately well
I	imperfect
P	poor
VP	very poor

Texture of mineral soil

C	clay
SC	sandy clay
SCL	sandy clay loam
CL	clay loam
Si	silt
SiS	silty sand
SiC	silty clay
SiCL	silty clay loam
L	loam
SL	sandy loam
LS	loamy sand
S	sand
vfS	very fine sand
fS	fine sand
mS	medium sand
cS	coarse sand
vcS	very coarse sand
g	prefix indicating "gravelly"

Symbols and miscellaneous abbreviations

>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
%	percentage of
,	comma separating terms indicates sampling order, unweighted
→	indicates descending order of prevalence, i.e., "from x to y"
boldface	(in tables) it is estimated that probably more than 40% of site (plot-centered area of about 4 ha) mosaic has this specific condition
shading	(in tables) indicates values of interest to the site preparation practitioner
ha	hectare
kW	kilowatt
m	metre
t	tonne
n.a.	not applicable
n.r.	not recorded
dis	discontinuous

Names of implements

drag (H)	heavy drag
drag (L)	light drag
drag (M)	medium drag
Wadell	Silva Wadell powered cone scarifier
Bräcke	Bräcke patch scarifier
TTS-35	TTS–35 line/drawbar-towed passive disc trencher
TTS (pas)	TTS Delta (passive) disc trencher
TTS (pow)	TTS Delta (power) disc trencher
Don180	Donaren 180 disc trencher
C & H	Cazes and Heppner plow (highly modified)
S-blade	straight blade (on bulldozer)
Y-teeth	Young's utility dozer teeth

Vegetation types

V-1	Balsam Poplar Hardwood and Mixedwood
V-2	Black Ash Hardwood and Mixedwood
V-3	Other Hardwoods and Mixedwoods
V-4	White Birch Hardwood and Mixedwood
V-5	Aspen Hardwood
V-6	Trembling Aspen (White Birch)–Balsam Fir/Mountain Maple

V-7	Trembling Aspen–Balsam Fir/Balsam Fir Shrub
V-8	Trembling Aspen (White Birch)/Mountain Maple
V-9	Trembling Aspen Mixedwood
V-10	Trembling Aspen–Black Spruce–Jack Pine/Low Shrub
V-11	Trembling Aspen–Conifer/Blueberry/Feathermoss
V-12	White Pine Mixedwood
V-13	Red Pine Mixedwood
V-14	Balsam Fir Mixedwood
V-15	White Spruce Mixedwood
V-16	Balsam Fir–White Spruce Mixedwood/Feathermoss
V-17	Jack Pine Mixedwood/Shrub Rich
V-18	Jack Pine Mixedwood/Feathermoss
V-19	Black Spruce Mixedwood/Herb Rich
V-20	Black Spruce Mixedwood/Feathermoss
V-21	Cedar (incl. Mixedwood)/Mountain Maple
V-22	Cedar (incl. Mixedwood)/Speckled Alder/Sphagnum
V-23	Tamarack (Black Spruce)/Speckled Alder/Labrador Tea
V-24	White Spruce–Balsam Fir/Shrub Rich
V-25	White Spruce–Balsam Fir/Feathermoss
V-26	White Pine Conifer
V-27	Red Pine Conifer
V-28	Jack Pine/Low Shrub
V-29	Jack Pine/Ericaceous Shrub/Feathermoss
V-30	Jack Pine–Black Spruce/Blueberry/Lichen
V-31	Black Spruce–Jack Pine/Tall Shrub/Feathermoss
V-32	Jack Pine–Black Spruce/Ericaceous Shrub/Feathermoss
V-33	Black Spruce/Feathermoss
V-34	Black Spruce/Labrador Tea/Feathermoss (Sphagnum)
V-35	Black Spruce/Speckled Alder/Sphagnum
V-36	Black Spruce/Bunchberry/Sphagnum (Feathermoss)
V-37	Black Spruce/Ericaceous Shrub/Sphagnum
V-38	Black Spruce/Leatherleaf/Sphagnum

Soil types

S1	Dry/Coarse Sandy
S2	Fresh/Fine Sandy
S3	Fresh/Coarse Loamy
S4	Fresh/Silty–Silt Loamy
S5	Fresh/Fine Loamy
S6	Fresh/Clayey
S7	Moist/Sandy
S8	Moist/Coarse Loamy
S9	Moist/Silty–Silt Loamy
S10	Moist/Fine Loamy–Clayey
S11	Moist/Peaty Phase
S12F	Wet/Organic [Feathermoss]
S12S	Wet/Organic [Sphagnum]
SS1	Discontinuous Organic Mat on Bedrock
SS2	Extremely Shallow Soil on Bedrock
SS3	Very Shallow Soil on Bedrock
SS4	Very Shallow Soil on Boulder Pavement
SS5	Shallow–Moderately Deep/Sandy
SS6	Shallow–Moderately Deep/Coarse Loamy
SS7	Shallow–Moderately Deep/Silty–Fine Loamy–Clayey
SS8	Shallow–Moderately Deep/Mottles–Gley
SS9	Shallow–Moderately Deep/Organic–Peaty Phase

Treatment units

TU A	Miscellaneous Hardwoods and Mixedwoods (includes V-1, V-2, V-3)
TU B	Aspen Hardwood and Mixedwood (includes V-5, V-6, V-7, V-8, V-9, V-10, V-11, V-19)
TU C	White Birch Hardwood and Mixedwood (includes only V-4)
TU D	Balsam Fir–White Spruce Conifer and Mixedwood (includes V-14, V-15, V-16, V-21, V-24, V-25)
TU E	Black Spruce–Jack Pine/Feathermoss (includes V-19, V-20, V-31, V-32, V-33)
TU F	Jack Pine/Feathermoss (includes V-18, V-29, V-31, V-32)
TU G	Jack Pine/Shrub Rich (includes V-11, V-17, V-28)
TU H	Red or White Pine Conifer and Mixedwood (includes V-12, V-13, V-26, V-27)
TU I	Jack Pine–Black Spruce/Blueberry/Lichen (includes only V-30)
TU J	Black Spruce/Wet Organic (includes V-22, V-23, V-35 in phase J1 and V-34, V-35, V-36, V-37 in phase J2)
TU K	Black Spruce/Leatherleaf/Sphagnum (includes only V-38)

Glossary

Terminology used in Section C follows, wherever possible, the conventions of the *Forest ecosystem classification for northwestern Ontario* (Sims et al. 1989) and the associated set of publications. However, some words and phrases used in Section C are from other sources. The definitions and/or explanations of terms and phrases used are given below, and the source reference, including the page number(s), where appropriate, is cited.

acceptable planting spot: the conventions for determining acceptability of planting spot used in the assessments include (1) a minimum distance of ≥1.4 m from any other selected acceptable planting spot, (2) freedom from competing vegetation for a radius of ≥15 cm, (3) good (preferred) planting spot microsites, including (i) mineral soil exposed and/or displaced ≤10 cm below the organic/mineral interface, (ii) mounded mineral on mineral, and (iii) organic and/or organic–mineral mix ≤2 cm deep over mineral soil, and (4) conditional acceptable planting spots that included organic and/or organic–mineral mix 2–5 cm deep over mineral soil, or mineral soil caps ≥10 cm deep with a minimum area of 1200 cm^2 over either LFH or inverted LFH that is settled to a firm base (Ontario Ministry of Natural Resources 1987). Compare with *unacceptable planting spots*; see also *plantability*.

area topography: refers to the slopes and terrain both on the plot and in the vicinity (i.e., a plot-centered area of about 4 ha). Two slope types (simple and complex) and 10 classes of slope—i.e., level (0–0.5%), nearly level (0.5–2%), very gentle (2–5%), gentle (5–9%), moderate (9–15%), strong (15–30%), very strong (30–45%), extreme (45–70%), steep (70–100%), and very steep (>100%)—are recognized (p. 2, Ontario Institute of Pedology 1985; p. 89, Sims et al. 1989; also Bélise 1980). Where necessary, the modifying term *broken* is used to reflect shorter and/or abrupt changes in slope and is usually associated with bedrock-controlled topography.

bedrock outcrop: either exposed parent bedrock or very large boulders of indeterminate size; notation includes nonrocky (<2% of surface, outcrops ≥75 m apart), slightly rocky (2–10% of surface), moderately rocky (10–25% of surface), very rocky (25–50% of surface), exceedingly rocky (50–90% of surface), and excessively rocky (>90% of surface) (Bélise 1980).

berm: a form of ground roughness created by harvesting activity: berms are created when soil and/or soil–detritus mix are pushed and/or scraped into raised piles or extruded from ruts to create relatively firm ridges higher than the natural forest floor. See *rut*.

boulder: a coarse fragment ≥60 cm in diameter (p. 4, Ontario Institute of Pedology 1985; Caterpillar Tractor Co. 1985). Average (stone) diameters of ≤25 cm and/or ≤30 cm are not considered an impediment to the heavy, high-powered, prime mover–implement combinations commonly used in northwestern Ontario.

boulder pavement: characterized by large stones and boulders with little or no mineral soil matrix in the interstices (p. 77, Sims et al. 1989).

coarse fragments: soil particles with a diameter >2 mm (p. 4, Ontario Institute of Pedology 1985; p. 88, Sims et al. 1989).

cobble: a coarse fragment 8–25 cm in diameter (p. 4, Ontario Institute of Pedology 1985); the term *stoniness* is preferred to cobbliness.

competition development: both woody and nonwoody vegetation may develop from either recently sown seed or seed banked over time in either the mineral soil or organic surface horizon, or by vegetative reproduction, including sprouts, layers, underground stems (rhizomes), and root suckers (p. 4, Bell 1991).

density: number of plants of a species per unit area (e.g., 4412 jack pine trees per hectare); compare with *stocking* (Foreman and Riley 1979).

drainage: the frequency and duration of the periods when the soil is free of saturation or partial saturation. Drainage is a measurable characteristic (including rapidity and extent) but is generally assessed from profile morphology, e.g., gleying and color, and landform (p. 81, Ford-Robertson 1971). Drainage must be considered together with soil texture when estimating limits to machine trafficability, tillage, and site damage. Notation includes very rapid, rapid, well, moderately well, imperfect, poor, and very poor (p. 149, Sims et al. 1989; Bélise 1980).

eluviated: the surface layer of mineral soil that has been leached by percolating water (paraphrased from Ford-Robertson 1971).

fermentation layer: organic horizon characterized by an accumulation of partly decomposed organic matter derived mainly from leaves, twigs, and woody material (p. 159, Sims et al. 1989).

free-to-grow (FTG): the condition of a forest stand when it is established and acceptable for entry into the productive timber land base. The stand must meet these criteria: minimum stocking, desired species composition, minimum height development, and freedom from competition that impedes growth (Forestry Canada 1992).

FRI (Forest Resources Inventory): information from the Ontario Ministry of Natural Resources FRI forest stand map is presented for the stand in which the plot was located. Age has been adjusted to the age of the stand when harvested. In some instances, the FRI and V-type bear little resemblance to each other. The FRI is often determined from photo interpretation with limited ground-truthing and may be in error; apparent and obvious errors in the FRI notation are noted. Also, many stands at the FRI level of stratification and/or mapping are an aggregation of several FEC V-types that recur in the mosaic of vegetation types that makes up the delineated FRI stand.

germinant: (strictly) a seed in the process of germination (p. 118, Ford-Robertson 1971), but used here to include all current-year seedlings from the time of radical emergence to hardening off.

gravel: coarse fragments >2.0 mm and ≤8 cm in diameter (p. 4, Ontario Institute of Pedology 1985).

gross disturbance of surface: total disturbance of the forest floor including harvesting activity, site preparation, and other disturbance.

ground roughness: based on the height and/or depth and frequency per hectare of obstacles on the surface that may impede trafficability of equipment (p. 29, Sutherland 1986) and/or affect the functioning of site preparation implements and their product; includes surface stones and boulders, stumps, pits and mounds, berms, and ruts. The classes of ground roughness that are calculated using these data (i.e., class 1 [H20] is a very even ground surface, class 2 [H40] is intermediate, and so on until class 5 [H100]) are based on a system designed for rating ground roughness for harvesting equipment (Anon. 1969; Berg 1992; cf. Mellgren 1980). In contrast, site preparation equipment is more sensitive to different types of ground roughness obstacles than is harvesting equipment. Consequently, whereas a class 1 or class 2 rating may represent few impediments to harvesting equipment, the opposite may be true for site preparation equipment, depending on either the type of obstacle or equipment. Unfortunately, the class designation reveals little about the nature of the obstacles encountered (e.g., stumps, pits, or mounds). Because of this, ground roughness has been presented in this guide as a frequency distribution, by height class, of the components normally used to calculate the conventional rating of ground roughness. The exception to this is the inclusion of stumps and berms and ruts produced during harvesting, which are not considered in the calculation of ground roughness in Mellgren (1980). Stump diameter, height, and frequency can have a formidable impact on the proper functioning of site preparation equipment.

humus: organic horizon characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible (p. 159, Sims et al. 1989).

implement: a device either pushed or trailed (may be towed or attached directly) by a prime mover (wheeled or tracked forwarders, skidders, and tractors) with an end tool that performs tillage and/or site preparation of the forest floor.

inverting: the organic layer is inverted intact or in a broken fashion (with or without the underlying mineral soil capping) over the adjacent and undisturbed LFH. Product consists of a screefed or scalped spot or strip and can include mounded mineral soil over mineral soil and/or mounded mineral soil over the inverted LFH (see Section B of this manual).

landform: landform features are shapes that have been produced in the landscape by natural processes operating on or near the earth's surface (p. 1, Sims and Baldwin 1991). In the cases presented, landform is the dominant landform type in the local area within which the soils of the plot have developed (i.e., the mode of deposition of soil parent material). Notation of common landform features in northwestern Ontario includes ground moraine (subglacial till), drumlins, ablation (supraglacial) till, shallow drift overlying bedrock, end moraines, eskers, kames and crevasse fillings, outwash deposits, glaciolacustrine and glaciomarine deposits, alluvial deposits, colluvial deposits, eolian deposits, and organic terrain (p. 17, Sims and Baldwin 1991: see also p. 160–161, Sims et al. 1989; p. 7, Baldwin et al. 1990).

LFH: acronym for **L**itter, **F**ermentation, and **H**umus, the commonly found layers of organic material over the mineral substrate; also known collectively as *duff.*

litter: organic horizon characterized by an accumulation of mainly leaves, twigs, and woody materials; most of the original structures are easily discernible (p. 159, Sims et al. 1989).

mean spacing: the average distance between furrows or rows of planting spots and/or in-furrow or in-row planting spots, determined from the data set of measurements made for each parameter: i.e., if a column of data contains X1, X2, X3, ..., Xn, the mean equals the sum of X1, X2, X3, ..., Xn divided by n, where n is the number of samples.

mechanical site preparation: disturbance of the forest floor with mechanical implements (distinct from manual or motor-manual disturbance) to facilitate (forest) regeneration, either by planting or by seed applied by nature or humans. Mechanical site preparation includes creating favorable microsites and improving access.

minimum conifer stocking standards: may vary by V-type, species, and the objectives of the local management plan. For the northwestern and north-central regions of Ontario, the suggested minimum *"free-to-grow"* stocking for spruce and jack pine is 40% on a 2-m^2 basis (Ontario Ministry of Natural Resources 1988).

mixedwood: any stand where the absolute crown cover of either conifer or hardwood is ≥2% on a representative sample plot of 10 m^2 (cf. p. 20, Sims et al. 1989).

moisture regime: an integration of all the variations in soil moisture supply throughout the entire growing season (p. 147, Sims et al. 1989). There are 11 classes of moisture regime, including dry, moderately dry, moderately fresh, fresh, very fresh, moderately moist, moist, very moist, moderately wet, wet, and very wet (p. 150–151, Sims et al. 1989).

operating practice: determined by one or more of the following: (i) the local prescription, (ii) the terms of the site preparation contract (including sanctions), (iii) operating skill and (iv) driving practice of machine operator, and (v) on-site monitoring and (vi) supervision. (The case studies show that a contractor using the same implement–prime mover–operator treating comparable sites with similar prescriptions but in separate management units and with different contract sanctions produced different results: the difference in between-furrow spacing varied such that *the number of acceptable planting spots satisfied minimum contract specifications* in each case.)

peaty phase: "mineral soils that are transitional to organic soils but don't meet the 40 cm minimum peat depth criterion" (p. 78, Sims et al. 1989).

pit and mound: a form of ground roughness that consists of uneven terrain, composed of highs and depressions: the depressions (frequently) are cavities left by blown-over trees. Pit-and-mound relief frequently indicates poor drainage or thin soil (p. 23, Beattie et al. 1983).

plantability: the number of *acceptable planting spots* per hectare available on a site (p. 68–73, Sutherland 1986; see also section B of this manual; for local cut points see Ontario Ministry of Natural Resources 1987); see also *unacceptable planting spots.*

planting spade: in the northwestern region of Ontario, the common wedge-shaped planting spade used to plant bareroot stock.

plot slope: slope of the ground over a plot surface measured in percent with a clinometer, supplemented by a notation as to whether complex or simple.

plot slope position: relative position of the sample plot in the terrain: crest, upper slope, middle slope, lower slope, toe, depression, level (p. 3, Ontario Institute of Pedology 1985; Bélise 1980).

residual: any woody stem left standing on a site following a harvest, >1 cm in diameter at breast height (about 140 cm high) and >1.5 m tall.

rut: a depression in the natural forest floor created, most commonly (but not exclusively), by excessive ground pressure exerted by the wheels or tracks of prime movers. See *berm.*

screefing (lowland): the removal of the upper portion of the organic layer along with partial compaction of the lower portion without disturbing or exposing the underlying mineral soil (see Section B of this manual).

screefing (upland): the removal or displacement of the organic layer to expose and/or disturb lightly (scarify) the underlying mineral soil (see Section B of this manual).

seedbed, good and conditional: varies by species and site conditions, including organic horizons present, texture of surface mineral soils, and moisture regime. For *jack pine,* includes exposed, coarse-textured mineral soils and organic or organic–mineral mix settled to a firm base less than 2 cm deep over mineral soil (cf. Riley 1980). The capacity of a substrate to support establishment of jack pine varies with change in moisture regime and/or weather conditions during the germination and establishment seasons. Dry and moderately dry sites require favorable weather conditions for jack pine to germinate and become established. As the moisture regime increases through moderately fresh to moist, jack pine may establish from seed with less favorable seedbeds and/or less favorable weather (cf. Chrosciewicz 1990). In northwestern Ontario, jack pine infrequently establishes on fine-textured soils (e.g., clay, silt) and/or very moist to very wet moisture regimes. *Black spruce* seedbed requirements differ between uplands and lowlands. On uplands with coarse-textured soils, receptive seedbed for black spruce are primarily those located just above and below the mineral soil/humus interface. Very little establishment can be expected on undisturbed surfaces or *thick organic horizons.* Seedling establishment is often better on shallow mineral than on *thin organic layer* seedbeds, but seedling growth is as good or better on thin organic layer than on shallow mineral seedbeds. Better seedling establishment can usually be expected on sites with moist soil moisture regimes than on sites with dry or fresh soil moisture regimes (cf. Fleming and Mossa 1994; Fleming et al. 1987). For both uplands and lowlands, exposed, fine-textured mineral soils (clays and silts) have little value (in northeastern Ontario) as black spruce seedbed. On lowlands (peatlands), poorly decomposed *Sphagnum* peat and sheared *Sphagnum* are the most receptive seedbeds for black spruce. Displaced, poorly decomposed *Sphagnum* peat is a poorer seedbed than the same substrate *in situ.* Black spruce also establishes well on living *Sphagnum* moss, although rapidly growing moss species can engulf seedlings. In contrast with *Sphagnum* moss or peat seedbeds, the surface layer of feathermosses and feathermoss peats (equivalent to organic matter in the fermentation layer of upland feathermoss sites) dries rapidly even on peatland sites and is not a favorable substrate for the establishment of black spruce from seed (cf. Groot and Adams 1994; Groot 1988).

seedlings: refers to nursery- and/or greenhouse-grown bareroot and container stock several months to a year or more old. Contrast with the more fragile *germinant* resulting from direct seeding.

shallow (soil): soils with a depth of 1 m or less (p. 73, Sims et al. 1989). Notated as very shallow (0–20 cm) and shallow to moderately deep (21–100 cm) (p. 77, Sims et al. 1989).

slope, complex: slope having both concave and convex surfaces, sometimes convoluted (p. 2, Ontario Institute of Pedology 1985). Ten degrees of slope are recognized, i.e., level (0–0.5%), nearly level (0.5–2%), very gentle (2–5%), gentle (5–9%), moderate (9–15%), strong (15–30%), very strong (30–45%), extreme (45–70%), steep (70–100%), and very steep (>100%) (p. 2, Ontario Institute of Pedology 1985; p. 89, Sims et al. 1989; see also Bélise 1980).

slope, simple: slope with surfaces that are more or less a uniform plane, but may be convex. Ten degrees of slope are recognized, i.e., level (0–0.5%), nearly level (0.5–2%), very gentle (2–5%), gentle (5–9%), moderate (9–15%), strong (15–30%), very strong (30–45%), extreme (45–70%), steep (70–100%), and very steep (>100%) (p. 2, Ontario Institute of Pedology 1985; p. 89, Sims et al. 1989; see also Bélise 1980).

soil depth (cm): if <1 m, actual depth to bedrock, as determined using an auger or by soil pit excavation; if >1 m, reported as such.

soil, mineral: the mantle of unconsolidated material overlaying the bedrock (Agriculture Canada 1972); may consist of mineral soil particles with diameters ranging from <0.0002 mm (fine clay) to >60 cm (boulders) and/or organic matrix; see *landform.*

soil, organic: soil materials that have developed predominantly from organic deposits (i.e., containing >17% organic carbon or approximately 30% organic matter by weight) (p. 161, Sims et al. 1989).

soil texture: the nomenclature that describes soil, includes mineral soil particle size and organic soils. Notation for mineral soil includes fine clay (<0.0002 mm), clay (<0.002 mm), silt (0.002–0.05 mm), very fine sand (0.05–0.10 mm), fine sand (0.10–0.25 mm), medium sand (0.25–0.5 mm), coarse sand (0.5–1.0 mm), very coarse sand (1.0–2.0 mm), gravel (2.0 mm – ≤8 cm), cobble (8–25 cm), stones (≥8 cm – ≤60 cm), and boulders (≥60 cm). Notation for organic soil includes litter, fermentation, and humus, which are described in detail in the references (p. 4 and 29, Ontario Institute of Pedology 1985; also p. 142 and 159–160, Sims et al. 1989).

soil type: directly characterized in terms of a few critical parameters (e.g., moisture regime, parent material texture, depth to bedrock). There are 13 S-Types (Soil Types with ≥100 cm of mineral or organic substrate) and 9 SS-Types (very shallow to moderately deep Soil Types with <100 cm of mineral or organic substrate) (p. 73, Sims et al. 1989).

standard deviation (sd): characterizes the dispersion of individual values about the mean. Calculated using *Minitab*^{R}, which uses the convention: "if the column of data contains X1, X2, ..., Xn with mean $\bar{x}$, then STDEV calculates squareroot (sum$(X - \bar{x})^2)/(n - 1)$) (Minitab Inc. 1988). **Note:** many standard deviation values presented in the plate sets are large relative to the mean. This is the nature of the parameter(s) being quantified, and, generally, the sample size is adequate (experience-based opinion and calculation: increasing sample sizes will not, generally, change the value of the standard deviation).

stocking: a measure of the proportion of the area actually occupied by (crop) trees in terms of stocked quadrats, i.e., quadrats having at least one living crop tree (cf. p. 259, Ford-Robertson 1971); may be expressed in terms of percent, species, and quadrat size (e.g., 67% stocked to jack pine on a 2-m^2 quadrat basis); compare with *density* (Appendix A, Foreman and Riley 1979).

stone: a coarse fragment ≥8 – ≤60 cm (p. 4, Ontario Institute of Pedology 1985; p. 142, Sims et al. 1989; Caterpillar Tractor Co. 1985). Compare with *boulder* and *cobble*.

stone-limited: indicates a soil penetration problem, usually the inability to create an acceptable planting spot with a planting spade; may be a mix of very coarse gravel, cobbles, stones, and, possibly, boulders, but not bedrock.

stump: any standing woody stem ≤1.5 m tall and ≥5 cm in diameter 30 cm above the surface.

stumps (dead): sound stumps that existed on the site from any disturbance prior to harvest that may impede site trafficability and/or site preparation.

treatment unit(s): management-oriented aggregations of defined soil and vegetation conditions that possess similar species composition, productivity, and macroclimatic or ecological properties (p. 2-1, Racey et al. 1989).

trenching: the organic layer is removed along with some underlying mineral matter and deposited, roughly mixed, in a side-berm on the undisturbed forest floor (see Section B of this report).

unacceptable planting spots: a planting attempt failure caused by one or more of the following conditions: (1) loadings of woody residue, other detritus, litter, or organic matter >5 cm deep requiring excessive effort by a planter to clear, (2) soil too shallow to plant, (3) inadequate (<15 cm) planting spade penetration caused by bedrock/boulders, stones, roots, etc., (4) competing vegetation rooted in the 30-cm^2 microsite, (5) presence of water, (6) shallow (<10 cm) cap of mineral soil over undisturbed or inverted surface organic layers, (7) except on some dry sites, a planting surface more than 10 cm below the mineral/organic interface, and (8) spoil bank, which includes mounded duff and/or a loose mix of duff and/or debris and/or mineral soil or any of these over debris (p. 68–73, Sutherland 1986; see also section B of this manual; for local cut points see Ontario Ministry of Natural Resources 1987). Compare with *acceptable planting spots*; see also *plantability*.

uneconomic (seed rates, seed application rates, etc.): used in relation to direct seeding, particularly rates of seed application. Viable seed is a relatively scarce resource requiring effort to collect, store, and deliver where and when needed. Further, production of seed in the forest is not a regular occurrence, i.e., good seed production years occur sporadically. Hence, the direct seeding option must be considered both biologically and economically when prescribing. Use of the term *uneconomic* is an experience-based estimate of the relative total stand establishment costs, including necessary tending using seeding technology versus planting technology, and the likelihood of establishing a stand that satisfies stocking standards for the site being discussed. (This may not correspond to a standard interpretation of the term uneconomic.)

V-type or vegetation type: the *Forest ecosystem classification for northwestern Ontario* (Sims et al. 1989) recognizes 38 more or less distinct associations of forest canopy, woody shrubs, forbs and graminoids, mosses, etc., each association accompanied by descriptions of landform features, slope positions, soil textures, and moisture conditions.

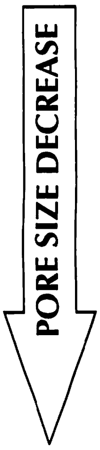
vegetation assessment: determines number of competitor species present (Bell 1991). This exercise refers to a separate assessment in three circular plots, each 2-m^2, for presence by species of woody shrubs, forbs, and graminoids. In addition, competitor species were recorded that were readily apparent on the larger (390 m^2) sample plot but were not present on the circular plots. Because of the variation in time elapsed since harvest and/or date of assessment, the data collected may understate the number of competitor species present. Both length of elapsed time since harvest and date of assessment are presented. However, the number (diversity) of competitor species together with other site information may assist estimation of future competition problems. Readers will have to make their own judgment as to the utility of the information and estimates of future competition problems.

viable seedling: a *germinant* (in the forest) that has developed sufficiently that it has a reasonable expectation of survival.

woody residue: includes sound material downed both during harvest and by nature prior to harvest. Woody residue may be a significant impediment to some site preparation equipment combinations depending on volume, volume distribution and/or concentration, species mix, diameter distribution, and length distribution. Woody residue loading is discussed as being light (0–50 m^3/ha or 0–2 kg/m^2), moderately light (51–100 m^3/ha or 2–4 kg/m^2), moderate (101–150 m^3/ha or 4–6 kg/m^2), moderately heavy (151–200 m^3/ha or 6–8 kg/m^2), heavy (201–250 m^3/ha or 8–10 kg/m^2), and very heavy (>250 m^3/ha or >10 kg/m^2).

Appendix A. Soil texture and soil water relations

(a) Relative effects of mineral–organic soil pore size distribution on available soil water storage and hydraulic conductivity for deep, unstratified soils.[1]



Soil texture	Available water storage[2]	Hydraulic conductivity or soil water movement	
		Wet conditions	Dry[3] conditions
Coarse sandy or gravelly or poorly decomposed organic material	Lower	High	Low[4]
Loams	Higher	Intermediate	Low
Fine clayey or silty or well-decomposed organic material	Intermediate[5]	Low	Low

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[1] Defined as mineral soil depth >120 cm or if organic matter depth is >40 cm (Ontario Institute of Pedology 1985). Shallow or stratified soils can strongly influence soil water relationships regardless of pore size distribution.

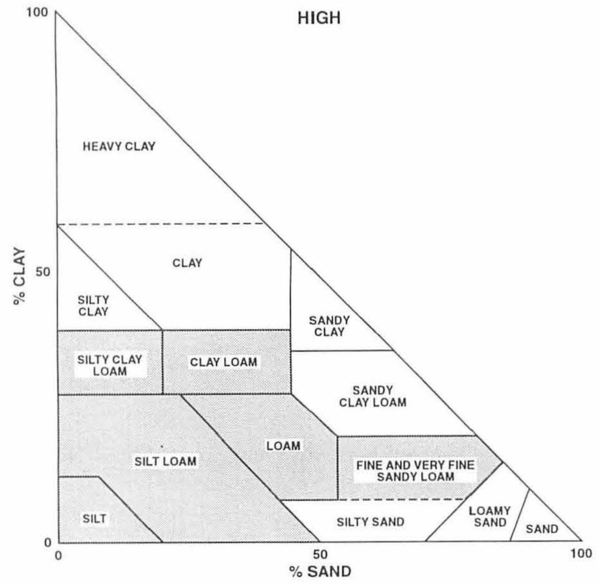
[2] Storage capacity becomes critical during periods of infrequent rainfall (Spittlehouse and Stathers 1990).

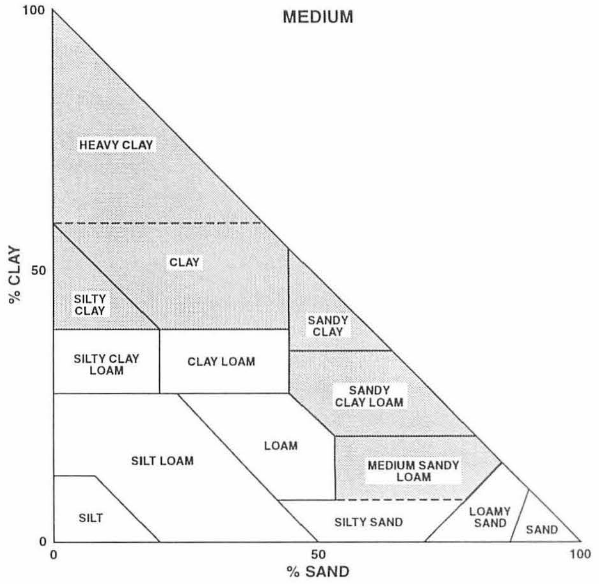
[3] Below field capacity.

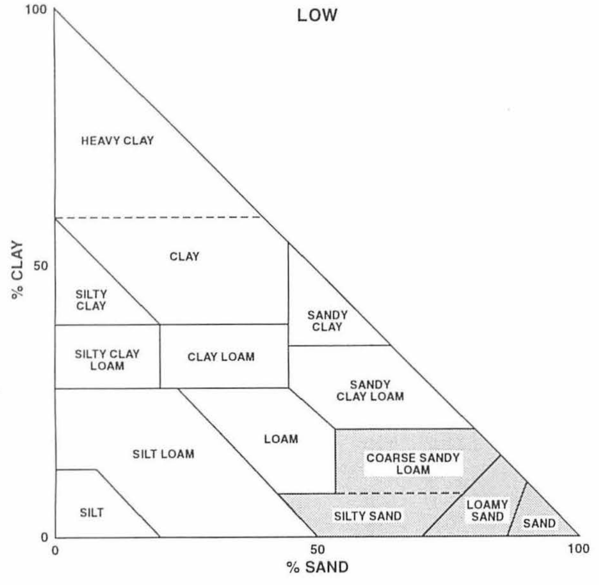
[4] Once soil moisture goes below field capacity, large pores dry out and conductivity drops rapidly (Spittlehouse and Stathers 1990).

[5] Water storage capacity is high, but water is tightly held and not available to plants (Spittlehouse and Stathers 1990).

(b) Soil texture and frost heave potential (adapted from soil survey staff, U.S. Department of Agriculture 1971, cited by Butt 1988, original not seen).





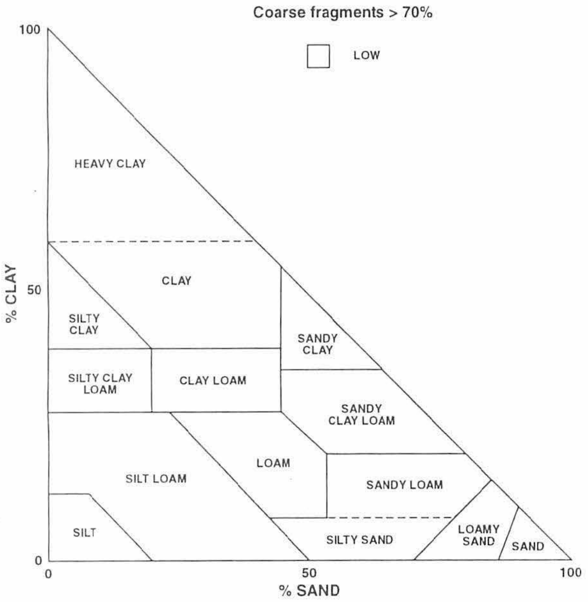


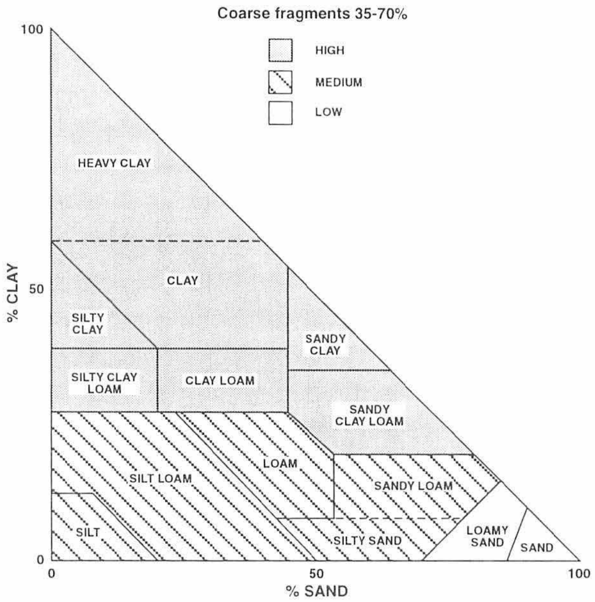
Note:

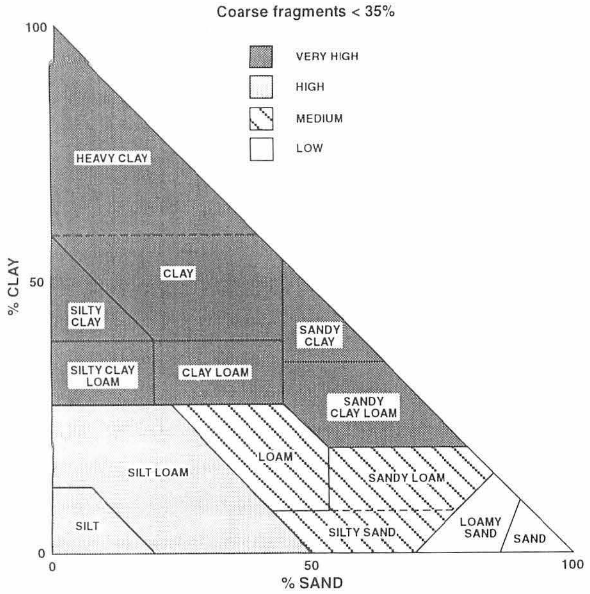
"Soils with high unsaturated hydraulic conductivity (i.e. those offering relatively little resistance to unsaturated capillary flow) and high moisture availability are most susceptible to frost-heaving." (Butt 1988)

In soils that are prone to frost heaving, the potential can be reduced by avoiding planting on bare mineral soil (Butt 1988) or by maintaining brush and ground cover (Singh 1976; Comeau et al. 1982).

(c) Soil texture and compaction[1] hazard rating (adapted from Curran et al. 1990).







Note:

Assumes surface soil texture (0–30 cm) and moist soil (loose soil squeezed in the hand forms a cast, but surface does not glisten when shaken or squeezed).

Low soil moisture or frozen ground can lower the hazard rating.

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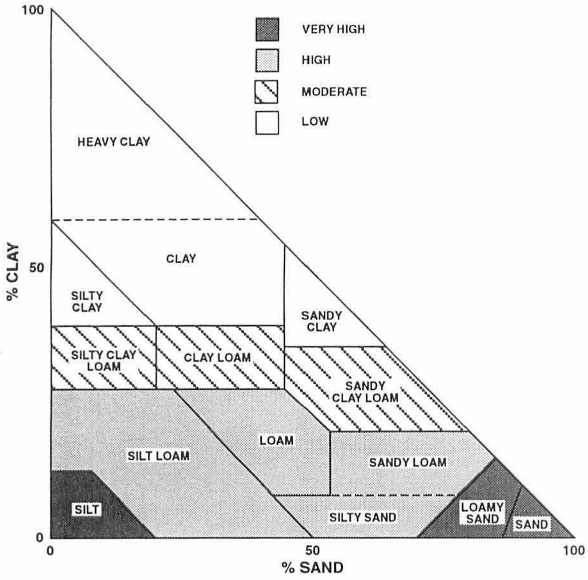
[1] Other site management factors affect compaction (Racey et al. 1989; Curran et al. 1989).

(d) Soil texture and surface soil erosion[1] hazard rating (adapted from Curran et al. 1990).



Note:
Assumes that the protective vegetation and forest floor are removed. Surface erosion of forest soils remains low so long as surface organic layers remain intact. The frequency, intensity, and duration of rainfall influence an area's susceptibility to soil erosion.

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[1] Other site management factors affect erosion (Racey et al. 1989; Curran et al. 1989).

Appendix B-1. Ranking of photographic plate set results by stocking of plantable spots.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
<45% stocking, i.e., ≤1125 acceptable planting spots per hectare											
46	250	4	0.2	0.1	2.0	7–9	0–70 (dis)	m→str	0–17	S→M	V→M
45	761	18	3.5	2.9	5.1	5–10	1–23 (dis)	vg→m	1–5	S→M	S
30	992	35	5.9	1.7	3.6	11–15	42–59	g→m	6–12	0→S	M→V
45–55% stocking, i.e., 1126–1375 acceptable planting spots per hectare											
42	1142	20	1.9	1.6	6.1	4–6	5–90 (dis)	g	1–3	S→M	S→V
38	1220	26	4.9	1.7	2.2	3–7	25–60 (dis)	vg→m	1–4	V→E	M→V
29	1332	20	2.3	1.1	5.9	6–10	10–45 (dis)	vg→m	2–13	V	S→M
17	1343	20	1.2	0.7	6.3	8–14	>100	g→m	1–2	S	V→E
55–65% stocking, i.e., 1376–1625 acceptable planting spots per hectare											
20	1483	51	8.9	0.7	2.1	5–13	>100	g	1–3	0	0
7	1557	35	4.0	0.6	2.1	3–7	>100	g→m	3–12	0	M→V
1	1562	27	9.1	0.5	9.0	7–25	24–62	g→m	2–13	n.l.	M→V
41	1594	29	2.9	2.8	16.0	4–7	35–77	g→m	n.r.	S→M	S→M
65–75% stocking, i.e., 1626–1875 acceptable planting spots per hectare											
9	1098[a]	15	2.2	1.0	31.5	6–11	>100	g	2–5	0	0→S
44	1650	51	25.5	3.2	10.2	6–8	35–80	g→m	2	S	S
16	1683	32	2.7	1.3	6.3	7–9	0–55	g→m	11	S	M
15	1709	35	5.2	1.2	7.4	5–6	25–70	g→str	7–8	S	X→S
40	1731	35	5.4	0.9	9.4	5–14	90	g→m	7–8	S	V→M
37	1736	31	5.2	0.9	6.4	6–11	>100	vg→g	0–5	0	M→S
36	1752	44	9.3	1.8	7.6	8–10	50–>100	g→m	1–4	S	S
28	1766	51	5.7	3.5	4.4	6–11	10–70	g→v-str	1–4	S	M→V
35	1777	38	9.1	2.7	5.7	4–8	4–50 (dis)	g→m	0–4	M→V	M
6	1803	17	3.1	0.4	7.0	7–14	>100	vg→m	2–3	0	0
5	1812	48	6.9	1.1	2.9	6–13	>100	g	0–2	0	0
43	1855	59	14.0	1.8	5.9	5–10	>100	vg→g	1–4	0	0
48	1866	35	4.1	1.0	11.6	20–26	>100	level	0–1	0	0

[a] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1500–1800/ha.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
<45% stocking, i.e, ≤1125 acceptable planting spots per hectare												
1050	68	12–14	7	**D→mD**	SL	V-30 (I)	7.27	n.r.	142	13	TTS (pow)	46
250	50	23–25	1	**D**→M	SiL, cS, SimS	V-30 (I)	2.01	6.54	104	14.5	Wadell	45
1875	56	26–29	4	**D**→mF	Si, SifS, SivfS	V-20 (E)	2.36	4.27	104	14.5	Wadell	30
45–55% stocking, i.e., 1126–1375 acceptable planting spots per hectare												
100	68	15	7	**vF**→mD	**SL**, L	V-28 (G)	3.16	2.77	224	34.1	drag (H)	42
375	63	13–16	8	**mF**→mD	**SL**, L	V-32 (F)	1.91	4.29	164	10	drag (L)	38
475	44	11–14	3	vF, **mD**, D	SL, LmS	V-31 (E)	1.59	4.72	136	10	Bräcke	29
600	184	1–1.5	5	mF	LmS	V-8 (B)	2.25	3.31	152	13.3	Bräcke	17
55–65% stocking, i.e., 1376–1625 acceptable planting spots per hectare												
725	100	17–24	10	mD→vF	vgcS, mS, SimS	V-4 (C)	2.40	2.81	107	10.5	TTS-35	20
1250	152	6–11	4	mF	fSCL	V-16 (D)	1.94	3.31	107	10.5	TTS-35	7
625	123	9–13	n.r.	mD	SiS, gSiL, cSL	V-1 (A/D)	2.91	n.r.	110/136	10	Bräcke	1
300	51	9–11	11	vF, mF, mM	SL	V-17 (G)	2.05	3.06	224	34.1	drag (H)	41
65–75% stocking, i.e., 1626–1875 acceptable planting spots per hectare												
325	64	11–14	3	F	SL	V-14 (D)	4.51	2.02	160	22.8	C & H	9
425	120	43–61	9	mF	SiL	V-26 (H)	n.a.	2.31	224	34.1	S-blade	44
425	48	16–18	9	mF→D	absent→L	V-6 (B)	2.10	2.83	186.5	25	Don180	16
475	34	18–20	9	mF	SL, LvfS	V-5 (B)	2.50	2.34	186.5	25	Don180	15
750	88	12–13	9	F	SL	V-17 (G)	2.33	2.48	186.5	25	Don180	40
825	165	11–12	6	**mD**→mF	LcS	V-18 (F)	2.41	2.39	186.5	25	Don180	37
800	64	1–3	2	**F** (mD→vF)	**mS**, fS	V-29 (F)	2.13	2.68	152	13.3	Bräcke	36
300	43	12–14	3	F, **mF**, mD	SL, LfS, L	V-20 (E)	2.17	2.61	164	10	drag (L)	28
725	16	12–14	3	**mD** (D→F)	SL, L	V-31 (F)	2.14	2.63	164	10	drag (L)	35
600	92	16–21	6	M→vF	CL→SiCL	V-15 (D)	2.33	2.38	170	13.8	Don180	6
650	82	21–27	10	mD→mF	SimS, LmS, LfS	V-14 (D)	2.30	2.40	107	10.5	TTS-35	5
250	78	2–5	1	**mD→D**	mS	V-27 (H)	2.09	2.58	152	13.3	Bräcke	43
1875	44	7–11	4	M→mM	SiCL, vfS, LvfS	V-34 (J)	2.34	2.29	186.5	25	Don180	48

Appendix B-1 (cont'd)

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
75–85% stocking, i.e., 1876–2125 acceptable planting spots per hectare											
8	1269[b]	6	2.4	0.7	30.4	9–17	>100	vg	0–3	0	S
19	1929	58	16.2	1.5	13.4	5–9	40–>100	g→str	6–21	0	M→S
27	1949	0	0.1	0	17.3	30–32	>100	vg	2–6	0	0
34	2006	58	12.2	2.7	7.2	4–10	>100	g→m	0–2	0	M
4	2013	62	12.8	1.3	1.9	4–14	>100	g	1–3	0	0
14	2085	38	5.6	1.5	9.0	5–6	35–>100	g→ste	2–4	0	S
26	2110	55	5.9	2.8	15.9	7–15	>100	vg	0–2	0	0
13	2116	46	9.3	1.5	1.4	6–10	95–>100	g→m	0–1	0	0
3	2114	62	7.1	1.3	3.0	5–8	50–75	g	1–2	0	M
85–95% stocking, i.e., 2126–2375 acceptable planting spots per hectare											
25	2135	17	1.9	1.0	18.6	12–21	>100	vg→g	0–2	0	0
12	2168	42	9.4	2.4	4.1	5–10	38–90	g→m	1–6	S	0
24	2204	51	1.5	2.1	13.6	8–14	20–70	g	2–8	S	M→V
18	2249	33	3.0	1.2	9.6	5–11	50–>100	g	2–5	0	S
11	2317	52	8.2	2.0	12.6	8–16	80–>100	g	2–4	0	S
33	2359	35	6.0	4.1	17.9	6–10	>100	g	1	0	0
>95% stocking, i.e., ≥2376 acceptable planting spots per hectare											
23	2381	1	0	0	7.2	13–21	40–>100	vg	0–1	0	0
2	2424	22	4.6	1.9	13.5	7–10	>100	g→vg	0–3	0	0
39	2439	30	5.0	1.3	8.6	5–9	40–65	m→str	2–10	S	M
47	2439	37	4.2	1.8	25.5	25–45	25–40	g	0–3	S	S
22	2464	21	2.8	1.0	12.9	8–13	40–65	g	1–5	M	S
10	2540	69	10.0	4.1	16.8	7–10	>100	g	1–4	0	0
32	2564	87	13.9	5.6	12.2	5–6	>100	g	1	0	0
21	2603	58	6.7	4.5	16.4	8–12	70–>100	g	1–3	S	M→S
31	2737	87	10.2	5.8	18.9	6–9	>100	vg→g	1–2	0	0

[b] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1800–2100/ha.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m³/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
75–85% stocking, i.e., 1876–2125 acceptable planting spots per hectare												
700	67	10–13	6	**mM**→M	SL	V-25 (D)	3.92	2.01	160	22.8	C & H	8
600	50	**66–70**	8	**mF** (mD →vF)	LvfS, SiL	V-4 (C)	2.09	**2.48**	224	31	Y-teeth	19
350	60	2–3	2	F, M, vF	L, CL, SiCL	V-19 (E)	**2.54**	2.02	185	17.5	Don180	27
975	99	13–14	5	**mD**→mF	cS, mS	V-29 (F)	**2.53**	1.97	186.5	25	Don180	34
150	41	20–27	12	F→vF	gSifS, SiL, SivfS	V-14 (D)	**2.30**	2.16	107	10.5	TTS-35	4
250	**104**	23–26	9	**M**→mD	SiC, SL	V-9 (B)	2.22	2.16	186.5	25	Don180	14
75	58	2–3	1	**M**, mM	fS, vfS	V-32 (E)	**2.29**	2.07	185	17.5	Don180	26
675	59	22–24	8	F	C	V-19 (B)	2.10	2.25	123	15.4	TTS (pow)	13
550	54	12–15	2	mM, vM, mD	fSCL, L	V-14 (D)	2.03	**2.33**	107	10.5	TTS-35	3
85–95% stocking, i.e., 2126–2375 acceptable planting spots per hectare												
400	77	2–3	3	vM, M, vF	Si	V-19 (E)	**2.33**	2.01	185	17.5	Don180	25
600	**122**	24–25	4	vF (mF→mM)	SifS, SivfS	V-11 (B)	1.98	**2.33**	104	14.5	Wadell	12
525	**101**	10–13	4	**D→mF**	LcS, LfS, LmS	V-33 (E)	2.11	2.15	239	33.7	drag (H)	24
175	36	16–20	8	vF→mF→D	gSifS, SiL	V-4 (C)	2.03	2.19	107	10.5	Bräcke	18
250	**173**	12–13	8	**mM** (vM →mD)	**mS**, cS	V-11 (B)	2.18	1.98	239	33.7	drag (H)	11
50	43	4–8	1	**mD**	mS, cS, LcS	V-29 (F)	2.13	1.99	150	13.2	TTS (pas)	33
>95% stocking, i.e., ≥2376 acceptable planting spots per hectare												
1125	75	15–19	2	mM→vF	mS, L, mS	V-33 (E)	2.10	2.00	186.5	22.3	TTS (pow)	23
600	**152**	12	5	vF	mS	V-25 (D)	2.16	1.91	123	15.4	TTS (pow)	2
250	**149**	2–3	9	mF	LvfS	V-17 (G)	2.02	2.03	186.5	25	Don180	39
600	72	12–13	2	M→mF	LmS	V-34 (J)	2.03	2.02	239	33.7	drag (H)	47
600	**156**	18–20	6	vF→mF	mS→LmS	V-20 (E)	2.06	1.97	186.5	22.3	TTS (pow)	22
275	99	16–20	7	**vF**, M	SiL→SiC	V-9 (B)	1.93	2.04	170	13.8	Don180	10
175	34	4–7	3	**mD**→mF	fS	V-29 (F)	1.94	2.01	150	13.2	TTS (pas)	32
800	**102**	11–13	4	**vM** (mM & F)	**SiL**, LmS	V-20 (E)	1.95	1.97	239	33.7	drag (H)	21
800	44	4–6	6	mD→F	LmS & LfS	V-29 (F)	1.80	2.03	224 & 250	32.0 & 36.8	drag (M)	31

Appendix B-2. Ranking of photographic plate set results by implement.

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
Donaren 180 disc trencher											
10	2540	69	10.0	4.1	16.8	7–10	>100	g	1–4	0	0
39	2439	30	5.0	1.3	8.6	5–9	40–65	m→str	2–10	S	M
25	2135	17	1.9	1.0	18.6	12–21	>100	vg→g	0–2	0	0
26	2110	55	5.9	2.8	15.9	7–15	>100	vg	0–2	0	0
14	2085	38	5.6	1.5	9.0	5–6	35–>100	g→ste	2–4	0	S
34	2006	58	12.2	2.7	7.2	4–10	>100	g→m	0–2	0	M
27	1949	0	0.1	0	17.3	30–32	>100	vg	2–6	0	0
48	1866	35	4.1	1.0	11.6	20–26	>100	level	0–1	0	0
6	1803	17	3.1	0.4	7.0	7–14	>100	vg→m	2–3	0	0
37	1736	31	5.2	0.9	6.4	6–11	>100	vg→g	0–5	0	M→S
40	1731	35	5.4	0.9	9.4	5–14	90	g→m	7–8	S	V→M
15	1709	35	5.2	1.2	7.4	5–6	25–70	g→str	7–8	S	X→S
16	1683	32	2.7	1.3	6.3	7–9	0–55	g→m	11	S	M
TTS Delta (power) disc trencher											
22	2464	21	2.8	1.0	12.9	8–13	40–65	g	1–5	M	S
2	2424	22	4.6	1.9	13.5	7–10	>100	g→vg	0–3	0	0
23	2381	1	0	0	7.2	13–21	40–>100	vg	0–1	0	0
13	2116	46	9.3	1.5	1.4	6–10	95–>100	g→m	0–1	0	0
46	250	4	0.2	0.1	2.0	7–9	0–70 (dis)	m→str	0–17	S→M	V→M
TTS Delta (passive) disc trencher											
32	2564	87	13.9	5.6	12.2	5–6	>100	g	1	0	0
33	2359	35	6.0	4.1	17.9	6–10	>100	g	1	0	0
TTS–35 disc trencher											
3	2114	62	7.1	1.3	3.0	5–8	50–75	g	1–2	0	M
4	2013	62	12.8	1.3	1.9	4–14	>100	g	1–3	0	0
5	1812	48	6.9	1.1	2.9	6–13	>100	g	0–2	0	0
7	1557	35	4.0	0.6	2.1	3–7	>100	g→m	3–12	0	M→V
20	1483	51	8.9	0.7	2.1	5–13	>100	g	1–3	0	0

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
Donaren 180 disc trencher												
275	99	16–20	7	**vF**, M	SiL→SiC	V-9 (B)	1.93	2.04	170	13.8	Don180	10
250	**149**	2–3	9	mF	LvfS	V-17 (G)	2.02	2.03	186.5	25	Don180	39
400	77	2–3	3	vM, M, vF	Si	V-19 (E)	**2.33**	2.01	185	17.5	Don180	25
75	58	2–3	1	**M**, mM	fS, vfS	V-32 (E)	**2.29**	2.07	185	17.5	Don180	26
250	**104**	23–26	9	**M**→mD	SiC, SL	V-9 (B)	2.22	2.16	186.5	25	Don180	14
975	99	13–14	5	**mD**→mF	cS, mS	V-29 (F)	**2.53**	1.97	186.5	25	Don180	34
350	60	2–3	2	F, M, vF	L, CL, SiCL	V-19 (E)	**2.54**	2.02	185	17.5	Don180	27
1875	44	7–11	4	M→mM	SiCL, vfS, LvfS	V-34 (J)	**2.34**	**2.29**	186.5	25	Don180	48
600	92	16–21	6	M→vF	CL→SiCL	V-15 (D)	**2.33**	**2.38**	170	13.8	Don180	6
825	**165**	11–12	6	**mD**→mF	LcS	V-18 (F)	**2.41**	**2.39**	186.5	25	Don180	37
750	88	12–13	9	F	SL	V-17 (G)	**2.33**	**2.48**	186.5	25	Don180	40
475	34	18–20	9	mF	SL, LvfS	V-5 (B)	**2.50**	**2.34**	186.5	25	Don180	15
425	48	16–18	9	mF→D	absent→L	V-6 (B)	2.10	**2.83**	186.5	25	Don180	16
TTS Delta (power) disc trencher												
600	**156**	18–20	6	vF→mF	mS→LmS	V-20 (E)	2.06	1.97	186.5	22.3	TTS (pow)	22
600	**152**	12	5	vF	mS	V-25 (D)	2.16	1.91	123	15.4	TTS (pow)	2
1125	75	15–19	2	mM→vF	mS, L, mS	V-33 (E)	2.10	2.00	186.5	22.3	TTS (pow)	23
625	59	22–24	8	F	C	V-19 (B)	2.10	2.25	123	15.4	TTS (pow)	13
1050	68	12–14	7	**D**→mD	SL	**V-30 (I)**	**7.27**	n.r.	142	13	TTS (pow)	46
TTS Delta (passive) disc trencher												
175	34	4–7	3	**mD**→mF	fS	V-29 (F)	1.94	2.01	150	13.2	TTS (pas)	32
50	43	4–8	1	**mD**	mS, cS, LcS	V-29 (F)	2.13	1.99	150	13.2	TTS (pas)	33
TTS-35 disc trencher												
550	54	12–15	2	mM, vM, mD	fSCL, L	V-14 (D)	2.03	**2.33**	107	10.5	TTS-35	3
150	41	20–27	12	F→vF	gSifS, SiL, SivfS	V-14 (D)	**2.30**	2.16	107	10.5	TTS-35	4
650	82	21–27	10	mD→mF	SimS, LmS, LfS	V-14 (D)	**2.30**	**2.40**	107	10.5	TTS-35	5
1250	**152**	6–11	4	mF	fSCL	V-16 (D)	1.94	**3.31**	107	10.5	TTS-35	7
725	100	17–24	10	mD→vF	vgcS, mS, SimS	V-4 (C)	2.40	**2.81**	107	10.5	TTS-35	20

Appendix B-2 (cont'd)

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
Silva Wadell powered cone scarifier											
12	2168	42	9.4	2.4	4.1	5–10	38–90	g→m	1–6	S	0
30	992	35	5.9	1.7	3.6	11–15	42–59	g→m	6–12	0→S	M→V
45	761	18	3.5	2.9	5.1	5–10	1–23 (dis)	vg→m	1–5	S→M	S
Bräcke patch scarifier											
18	2249	33	3.0	1.2	9.6	5–11	50–>100	g	2–5	0	S
43	1855	59	14.0	1.8	5.9	5–10	>100	vg→g	1–4	0	0
36	1752	44	9.3	1.8	7.6	8–10	50–>100	g→m	1–4	S	S
1	1562	27	9.1	0.5	9.0	7–25	24–62	g→m	2–13	n.l.	M→V
17	1343	20	1.2	0.7	6.3	8–14	>100	g→m	1–2	S	V→E
29	1332	20	2.3	1.1	5.9	6–10	10–45 (dis)	vg→m	2–13	V	S→M
Light drag											
35	1777	38	9.1	2.7	5.7	4–8	4–50 (dis)	g→m	0–4	M→V	M
28	1766	51	5.7	3.5	4.4	6–11	10–70	g→v-str	1–4	S	M→V
38	1220	26	4.9	1.7	2.2	3–7	25–60 (dis)	vg→m	1–4	V→E	M→V
Medium (tending toward heavy) drag											
31	2737	87	10.2	5.8	18.9	6–9	>100	vg→g	1–2	0	0
Heavy drag											
21	2603	58	6.7	4.5	16.4	8–12	70–>100	g	1–3	S	M→S
47	2439	37	4.2	1.8	25.5	25–45	25–40	g	0–3	S	S
11	2317	52	8.2	2.0	12.6	8–16	80–>100	g	2–4	0	S
24	2204	51	1.5	2.1	13.6	8–14	20–70	g	2–8	S	M→V
41	1594	29	2.9	2.8	16.0	4–7	35–77	g→m	n.r.	S→M	S→M
42	1142	20	1.9	1.6	6.1	4–6	5–90 (dis)	g	1–3	S→M	S→V

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (kW)	Weight of prime mover (t)	Implement name	Plate set no.
Silva Wadell powered cone scarifier												
600	122	24–25	4	vF (mF→ mM)	SifS, SivfS	V-11 (B)	1.98	2.33	104	14.5	Wadell	12
1875	56	26–29	4	**D**→mF	Si, SifS, SivfS	V-20 (E)	2.36	4.27	104	14.5	Wadell	30
250	50	23–25	1	**D**→M	SiL, cS, SimS	V-30 (I)	2.01	6.54	104	14.5	Wadell	45
Bräcke patch scarifier												
175	36	16–20	8	vF→mF →D	gSifS, SiL	V-4 (C)	2.03	2.19	107	10.5	Bräcke	18
250	78	2–5	1	**mD→D**	mS	V-27 (H)	2.09	2.58	152	13.3	Bräcke	43
800	64	1–3	2	**F** (mD→vF)	**mS**, fS	V-29 (F)	2.13	2.68	152	13.3	Bräcke	36
625	123	9–13	n.r.	mD	SiS, gSiL, cSL	V-1 (A/D)	2.91	n.r.	110/136	10	Bräcke	1
600	184	1–1.5	5	mF	LmS	V-8 (B)	2.25	3.31	152	13.3	Bräcke	17
475	44	11–14	3	vF, **mD**, D	SL, LmS	V-31 (E)	1.59	4.72	136	10	Bräcke	29
Light drag												
725	16	12–14	3	**mD** (D→F)	SL, L	V-31 (F)	2.14	2.63	164	10	drag (L)	35
300	43	12–14	3	F, **mF**, mD	SL, LfS, L	V-20 (E)	2.17	2.61	164	10	drag (L)	28
375	63	13–16	8	**mF**→mD	**SL**, L	V-32 (F)	1.91	4.29	164	10	drag (L)	38
Medium (tending toward heavy) drag												
800	44	4–6	6	mD→F	LmS & LfS	V-29 (F)	1.80	2.03	224 & 250	32.0 & 36.8	drag (M)	31
Heavy drag												
800	102	11–13	4	**vM** (mM & F)	**SiL**, LmS	V-20 (E)	1.95	1.97	239	33.7	drag (H)	21
600	72	12–13	2	M→mF	LmS	V-34 (J)	2.03	2.02	239	33.7	drag (H)	47
250	173	12–13	8	**mM** (vM →mD)	**mS**, cS	V-11 (B)	2.18	1.98	239	33.7	drag (H)	11
525	101	10–13	4	**D**→mF	LcS, LfS, LmS	V-33 (E)	2.11	2.15	239	33.7	drag (H)	24
300	51	9–11	11	vF, mF, mM	SL	V-17 (G)	2.05	3.06	224	34.1	drag (H)	41
100	68	15	7	**vF**→mD	**SL**, L	V-28 (G)	3.16	2.77	224	34.1	drag (H)	42

Appendix B-2 (cont'd)

Plate set no.	No. of planting spots/ha	% furrow that is mineral soil ≥15 cm wide	% area that is exposed mineral soil	% area that is FH ≤2 cm deep	% area that is FH >2 cm deep	Depth of LFH (cm)	Depth of mineral soil (cm)	Area topography	Plot slopes (%)	Rock outcrops	Stones
Cazes and Heppner plow (highly modified)											
8	1269[a]	6	2.4	0.7	30.4	9–17	>100	vg	0–3	0	S
9	1098[b]	15	2.2	1.0	31.5	6–11	>100	g	2–5	0	0→S
Young's utility dozer teeth											
19	1929	58	16.2	1.5	13.4	5–9	40–>100	g→str	6–21	0	M→S
Straight dozer blade											
44	1650	51	25.5	3.2	10.2	6–8	35–80	g→m	2	S	S

[a] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1800–2100/ha.
[b] By staggering the planting spots along the opposite edges of the scarified strip, the number of acceptable planting spots may be increased to 1500–1800/ha.

Ground roughness class 2&3 obstacles (no./ha)	Woody residue (m^3/ha)	Time from harvest to site preparation (months)	No. of competitor species	Moisture regime	Surface mineral soil texture	FEC V-type (TU)	Between-furrow mean spacing (m)	In-furrow planting spot mean spacing (m)	Power of prime mover (KW)	Weight of prime mover (t)	Implement name	Plate set no.
Cazes and Heppner plow (highly modified)												
700	67	10–13	6	**mM**→M	SL	V-25 (D)	3.92	2.01	160	22.8	C & H	8
325	64	11–14	3	F	SL	V-14 (D)	4.51	2.02	160	22.8	C & H	9
Young's utility dozer teeth												
600	50	66–70	8	**mF** (mD →vF)	LvfS, SiL	V-4 (C)	2.09	2.48	224	31	Y-teeth	19
Straight dozer blade												
425	120	43–61	9	mF	SiL	V-26 (H)	n.a.	2.31	224	34.1	S-blade	44

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