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WHITE SPRUCE REGENERATION ON THE PEACE AND SLAVE RIVERS

by

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ABSTRACT

Descriptions are given of the forests, geography, climate, character of the floods and alluvial deposits and soils and sites of the Peace and Slave River lowlands in northern Alberta and the Northwest Territories. The importance of fire, logging, floods and small mammals on regeneration of the forests is discussed.

Most virgin stands of white spruce, Picea glauca, originated after fire. Regeneration on clear-cut areas was inadequate eight years after logging, and most seedlings were located on mineral soil seedbeds. Slash burning is not practiced. Alluvial deposits accompanying floods bury the raw humus layer and provide a mineral soil seedbed. Small mammals are present in sufficient numbers to consume much of the seed on cut-over areas. Snowshoe hares, Lepus americanus, are destructive to young trees and seedlings.

Seedlings developed adventitious roots in raw humus, feather moss and in alluvium deposited by floods. Survival and growth of juvenile white spruce are dependent upon the development of adventitious roots.

Regeneration silviculture -- recommended for white spruce -- places emphasis on the autecology of the spruce seedling and the special environmental conditions in the Peace and Slave River lowlands.

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J.W. Bruce Wagg[1]

INTRODUCTION

Stands of large white spruce occupy the alluvial soils along the Peace and Slave Rivers in northern Alberta and the Northwest Territories. For many years the wood has been used as fuel by local inhabitants and by steamships plying the rivers, as well as for lumber for local building.

With increased logging activity in 1951 a need arose for observations of white spruce regeneration on cut-over areas, and surveys were made in 1957-58. The preliminary reports contained evidence that some areas were regenerating -- others were not. Though regeneration surveys of cut-over areas indicate the abundance of regeneration, they do not lead to an understanding of the regeneration problem. During 1959 cut-over and burned-over areas were studied as to factors influencing regeneration on the alluvial soils. Albeit periodic floods and deposition of alluvium influence the regenerative capacity of the area, many regenerative factors are similar to other Boreal spruce forests.

In this report field observations on development of white spruce seedlings combined with information on stand development and disturbance, seedling preferences, seed source, animal influences and experience in growing white spruce in other areas have been used to analyze the regeneration problem and to suggest an approach to regeneration silviculture for the alluvial white spruce forests.

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STUDY AREA

Figure 1A, which represents an area between 57.5° and 62.5° north latitude and 109° and 116° west longitude, illustrates the Peace and Slave River lowlands. Most of the study was confined to the lower Slave River in Figure 1B and the lower Peace River in Figure 1C.

Forest

Although the alluvial deposits are relatively level, the older and higher point bar deposits support either pure white spruce or spruce mixed with a few balsam poplar. On younger and lower deposits, next to the river, the forest is entirely balsam poplar. The white spruce stands on the Peace River reach a maximum basal area of 156 square feet per acre at 160 years (Lacate et al 1958). The dominant height is 110 feet and the volume of trees over eight inches d.b.h. is 30,900 f.b.m. per acre. Most stands are even-aged with the greatest areal extent within an age class of 100 to 200 years. Extensive, contiguous stands occur near the mouth of the Peace River and between Fifth Meridian and the Gypsum Cliffs. The white spruce stands of the lower Slave River are less extensive and scattered on the islands and along the river shore.

The lower Peace River forests were first intensively exploited for lumber in 1951 across from Rocky Point, and later at Scow Island. Subsequently large timber berths have been let between Gypsum Cliffs and Fifth Meridian. Although lumbering developed first on the Slave River, it never reached the size of operation that is now on the Peace River. This is because of the lesser areal extent of the stands and the greater distance of southern markets.

Geography and Geology

Areas examined lie between Fifth Meridian, at the western boundary of Wood Buffalo National Park, and the west end of Lake Athabasca on the Peace River, and northward to the mouth of the Slave River at Great Slave Lake.

The abbreviated geological description is from Camsell and Malcom (1921), Cameron (1922), Raup (1935) and the Atlas of Canada (1957). The Slave River divides the sedimentary and metamorphic rocks of Precambrian time on the east from those of Paleozoic time on the west. The area about the Slave River from Fort Smith to Great Slave Lake, and about the lower Peace and Athabasca Rivers, is alluvium formed during the Pleistocene by the recession of glacial lakes. The Slave River lowlands were formed by the recession of a southern arm of Great Slave Lake which extended southward to near Fort Smith. The Peace River lowland appeared with the recession of the western arm of Lake Athabasca which extended up the river beyond Fort Vermilion.

The lower Peace River has cut a broad, meandering channel through the glacio-lacustrine sands except at the Gypsum Cliffs area where it has been confined by 100-foot cliffs of Devonian limestone. It flows into the Slave River, the Rivière des Rochers through the Revillon Coupé, or Lake Athabasca through the Chenal des Quatre Fourches. The direction of flow in the Revillon Coupé and the Chenal des Quatre Fourches is reversible depending upon the level of Lake Athabasca. The Slave River runs northward

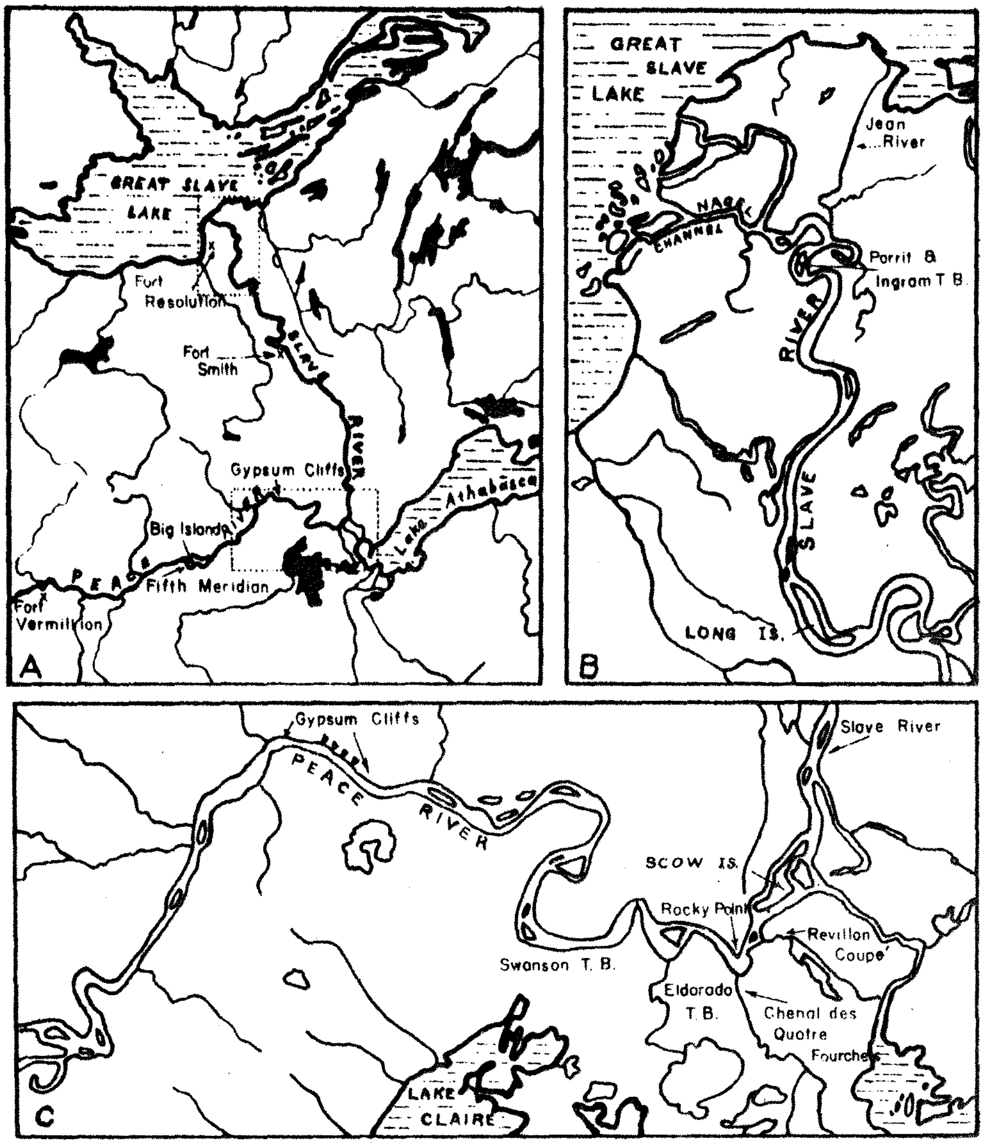

Figure 1. Location of study area.

A. Lower Peace and Slave River lowland, ca. 57.5°--62.5° north latitude and 109°--116° west longitude. The dotted lines represent the areas of Figures B and C.

B. Lower Slave River.

C. Lower Peace River.

through a crow's-foot delta into Great Slave Lake. Both rivers are alkaline and heavily laden with alluvium.

Terraces of the old river channels in the lowlands indicate either a general erosion of the glacio-lacustrine material or a gradual uplift of the area in recent times. The well-developed meanders of the rivers cut former river channels as they migrate downstream. The process of cutting on the outside of the meanders with new point bar deposits on the inside has formed the alluvial soil on which the white spruce has developed.

Climate

The region has a northern continental climate — with long, cold winters and short, warm summers. The summary in Table 1 indicates general climatic conditions in the area while Figure 2 diagrams the average monthly temperature and precipitation at Fort Smith between 1951 and 1960.

Table 1. Climatic Summary for the Peace and Slave Rivers Area (after Day and Leahey 1957).

Description	Location		
	Fort Vermilion	Fort Smith	Fort Resolution
Elevation	950'	680'	520'
Beginning of vegetative period *	May 5	May 12	May 17
End of vegetative period	Sept. 25	Sept. 22	Sept. 23
Yearly precipitation	12.1"	13.0"	11.6"
Mean annual temperature	27° F.	25° F.	23° F.

* Vegetative period is considered as the period during which the mean temperature is at or above 42° F.

The seasonal distribution of the low annual precipitation is of importance to white spruce regeneration. The average monthly precipitation gradually increases from a low in March to a maximum in July, and about half the annual precipitation falls during the growing season. The increase in rainfall in June and July is partly responsible for the establishment and growth of spruce on the alluvial soils.

Spring floods, characteristic of the easterly and northerly flowing Peace and Slave Rivers, are due to ice dams that form either along or near the mouths of the rivers. Damming is caused by the ice on the lakes breaking up later than on the rivers. While floods occur annually, major floods do not occur regularly.

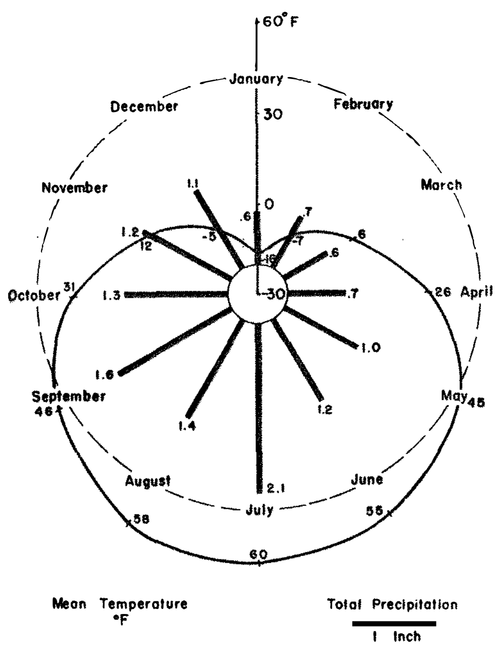

Figure 2. Average monthly temperature and precipitation at Fort Smith from data for the years 1951 to 1960 (Anon. 1951-60).

Soils and Site

Site classifications have been developed for this area based on the soil development by Day and Leahey (1957) and based on land-type by Lacate et al (1958). Although Day and Leahey described the lower Slave River and Lacate the lower Peace River, parts of the two areas are sufficiently similar to be integrated.

The soils have developed on glacio-lacustrine sediments and recent alluvial deposits of the Peace and Slave Rivers. Soils — found within the permafrost region — on glacio-lacustrine sediments belong to the Resolution series and on point bar deposits to the Jean series.

With the exception of the Resolution soil, the glacio-lacustrine soils are the high terrace land-type and are described within the Norberta and Fort Smith soil series. Black spruce and tamarack grow on the imperfectly- to poorly-drained Norberta and jack pine and aspen on the well-drained Fort Smith soil.

The middle terrace soils have an alluvial cap over glacio-lacustrine sands and correspond with the Clewi soil series. Buried organic layers occur in the alluvial deposit but are not found in the underlying lacustrine sands. The usually well-drained soils are not as productive as the Slave soil due to the low fertility and excessive drainage of the underlying sands. Trembling aspen and white spruce are found on this soil. Figure 3 shows a typical middle terrace or Clewi soil.

The soil series on the alluvial land-type correspond with the nature of the deposit. The imperfectly- to poorly-drained Grand Detour soil supports sedge and has developed on backswamp deposits; the Nyarling, which supports black spruce and tamarack, has developed on abandoned channel deposits. The

Recent Alluvial soils, which are inundated annually, support willow and speckled alder. The Little Buffalo soil, developed on levées, produces some large spruce but is limited to small areas along the Little Buffalo River. A similar soil is found on levées of the Chenal des Quatre Fourches and the Revillon Coupé. Most stands of large white spruce or balsam poplar are on the Slave soil series which has developed on point bar deposits. All alluvial soils are subject to annual or periodic flooding and alluvial deposits.

Figure 4 illustrates and describes a profile of the Slave soil on the west side of Scow Island. The Slave soils are variable but the upper profile is characterized by alternating bands of alluvium and humus overlying alluvial sands. The drainage is good to imperfect.

ECOLOGICAL STATUS AND REGENERATION POTENTIAL

Succession on Alluvial Soils

The ecology of white spruce forests on alluvial soils has been discussed by Raup (1935, 1946), Horton (Lacate et al 1958) and Jeffrey (1961). This review eludicates the patterns of forest succession which influence white spruce regeneration on the important Slave and Recent Alluvium soil series and the less important Little Buffalo series. Forest succession on the alluvial soils is confused by pedoacretion which accompanies annual or periodic floods.

Annual pedoacretion is the result of migration of the meanders of the river toward the mouth with the continual cutting away of the old lacustrine and alluvial deposits and the redeposition of alluvium as new point bar deposits. The colonization of new alluvium on annually-flooded

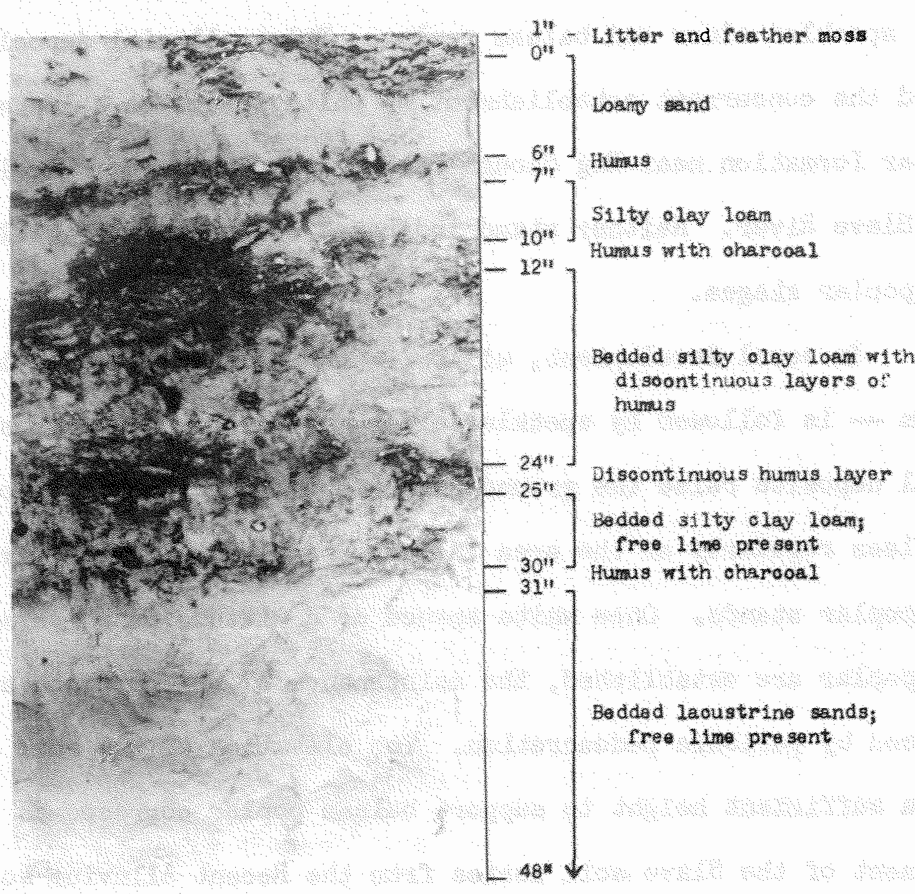

Figure 3. Profile and description of the Clewi or middle terrace soil which is characterized by alternating bands of alluvium and humus over lacustrine sands.

areas and the change in the plant associations as more alluvium is deposited follows a concurrent or seral pattern.

White spruce may colonize limited areas, which have been quickly elevated above the river by thick alluvial deposits, concurrently with willow, speckled alder and balsam poplar. Thick alluvial deposits have predated the concurrent establishment of white spruce on a low and recent point bar formation near Big Slough on the Peace and along Nagel Channel of the Slave River. Neither stand indicated the precursory willow and balsam poplar stages.

In seral development, willow -- the pioneer tree species on new alluvium -- is followed by speckled alder and balsam poplar as subsequent alluvial deposits raise the ground higher above the river. Pedoacretion occurs less regularly as the area is raised and white spruce invades the balsam poplar stands. Once white spruce or a mixture of white spruce and balsam poplar are established, the maintenance of white spruce soil is influenced by periodic pedoacretion. The elevation of the soil from sand bar to a sufficient height to support balsam poplar corresponds to the development of the Slave soil series from the Recent Alluvium soil series.

Most spruce stands on the alluvial soils are the result of a catastrophe which removed the original stand. While fire has been common and has operated as the main stand removal agency (Horton, Lacate et al 1958), Jeffrey (1961) indicated windthrow origin for some spruce stands. The origin of a new stand of white spruce subsequent to the removal of the old stand can be influenced by the deposition of alluvium following the catastrophe. The implications of fire followed by alluvial deposits are discussed later.

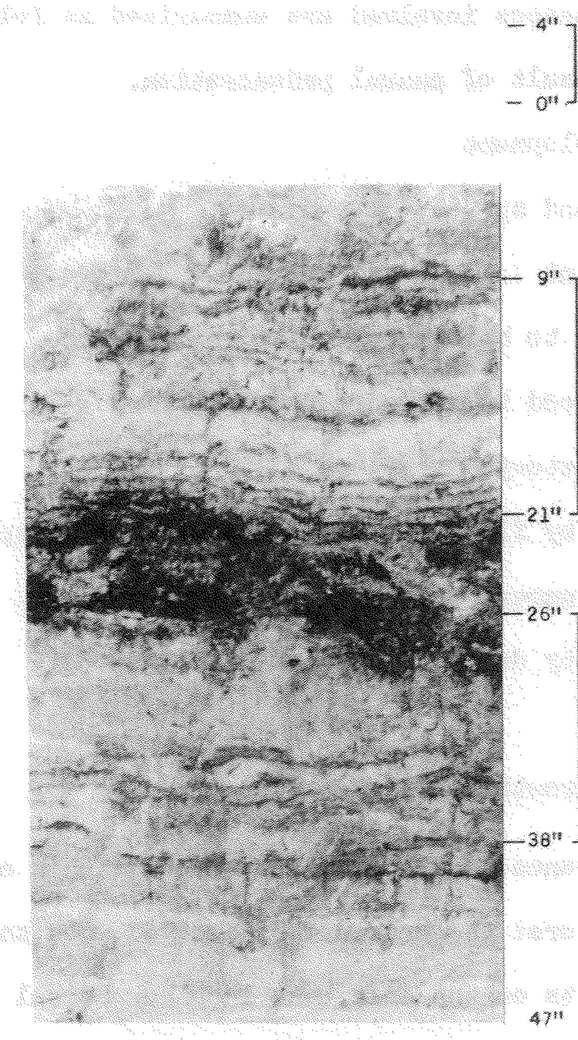

Figure 4. Profile and description of the Slave or alluvial-point bar soil which is characterized by alternating layers of alluvium and humus.

Natural removal of white spruce through brown cubical butt rot accompanied by windthrow appears to be of limited importance in the succession of the white spruce stands.

The ecological processes involved are summarized as follows:

A. Forest succession as a result of annual pedoacretion.

1. Concurrent development

Willow, alder and spruce.

2. Seral development

Willow to alder to balsam poplar to white spruce.

B. Forest succession influenced by periodic pedoacretion.

1. Recent stand history

Spruce removed by fire, windthrow and logging to spruce.

2. Natural stand removal

Spruce removed by decay to spruce.

Advance Growth of White Spruce

The presence of advance growth of white spruce within stands depends largely upon two factors: the presence of decayed wood and the occurrence of alluvial deposits on the area. As in other Boreal Forests, most seedlings within stands are on decayed wood except in those areas that have been subjected to periodic floods within the last two decades. On flooded areas, as south of Big Island on the Peace River, young trees on recent alluvium were abundant within the stand. Growth is better on alluvial deposits than on decayed wood. At times seedlings established on decayed wood re-root in a subsequent alluvial deposit, and increase their rate of growth.

Except in stands of irregular structure or uniform by groups, the advance reproduction is seldom sufficient to form a new stand after logging.

Influence of Wild Fires on Regeneration

Horton (Lacate et al 1958) observed many white spruce stands of fire origin on the alluvial soils of the Peace River. The more recent burns, including the 1938 burn at Fifth Meridian, the 1933 burn south of Big Island and the 1918 burn on northern end of Scow Island, have been reforested by white spruce.

The occurrence of earlier fires -- prior to 1762 on Long Island in the Slave River -- was indicated by a 197-year-old white spruce stand established on a burned layer of humus and charcoal at the 36- to 37-inch-depth in the soil profile. Similarily, a mottled orange and yellow layer with charcoal at the 18- to 19-inch-depth in the soil profile documented a fire about 1779 on the Peace River near Trident Creek. Observations on Chenal des Quatre Fourches, Revillon Coupé and Scow Island indicate that a large portion of the delta of the Peace River burned between 1780 and 1810.

Whilst these fires prepared the areas for regeneration by removal of the stands, it is not explicit that a suitable seedbed was left for regeneration. The consumption of organic matter by different fires varies over a wide range; and in Alaska, Lutz (1956) observed that burning, intense enough to kill trees, exposed mineral soil on 30 to 40 percent of the burned area. Fire per se does not always provide suitable conditions for regeneration (Holman and Parker 1940).

The only recent burn was observed about Trident Creek of the Peace River; a portion is illustrated in Figure 5. The fire originated in the upland forest and spread through the lowlands to the Peace River in the summer of 1955. It burned through the tree crowns and left most of the litter and feather moss unburned, though occasionally stumps and decayed logs were destroyed. Although the fire did not provide suitable conditions for immediate re-establishment of white spruce, the flood of 1958, which deposited alluvium on part of the area, did provide a receptive seedbed.

The uniformity of reproduction stands along with the presence of thick layers of scorched and unburned humus in the soil profile, might indicate that the periodic alluvial deposits are more effective than fire for sustaining white spruce. Petrini (1934) and Hesselman (1937) observed that seedlings make their appearance on the most thoroughly burnt spots of a fire area and this would tend to produce a clumped distribution of trees.

Fire in the regeneration of white spruce on the alluvial soils is considered in its dual capacity: stand removal and seedbed preparation. Where fire is only the stand removal agent, flooding with accompanying deposits of alluvium is considered the regenerative agent. Many authors have found mineral soil to be a preferable seedbed for spruce either *per se* or as the result of burning (LeBaron 1945, Godman 1953, Teikmanis 1954, Place 1955 and Rowe 1955).

Although there is conflicting evidence in the literature as to the value of burning in regeneration silviculture, fire is considered a worthwhile technique, particularly, in the deep moss phases of the white spruce forest. The exposure of mineral soil for a seedbed is paramount on alluvial soils, and could be accomplished effectively by burning during the fall of year. Teikmanis (1954) recommends the practice of burning clear-cut areas to destroy the moss and encourage regeneration for the spruce forests of northern Sweden. Siren (1955) recommends burning in similar forests of northern Finland.

Figure 5. Portion of the 1955 Trident Creek burn in mature white spruce on alluvial soil of the Peace River photographed in the spring of 1959. The raw humus layer was virtually unburned.

Influence of Logging

The harvesting of white spruce on the alluvial soils of the Peace and Slave River lowlands is based on economic selection. In most cases, this results in a continuous clear cutting of the spruce stands. The largest clear-cut areas are on the Peace River: Figure 6 shows a portion on the Eldorado Mining and Refining Company timber berth. The lesser vegetation is more luxuriant with each succeeding year after logging, and the shrubs provide almost complete coverage within five years. The main shrubs are red osier, prickly rose and squawberry; dwarf raspberry and the sprouts of speckled alder and balsam poplar are abundant on the scarified sections of the areas. Horsetail is common throughout. When exposed to direct insolation the feather mosses wither and die and become incorporated into the raw humus layer.

Stands on Nagel Channel, lower Slave River, Chenal des Quatre Fourches and Revillon Coupé which have been partial cut appear to be uneven-aged by groups. These areas are characterized by a ridge and depressional topography with the large white spruce on the ridges. Logging of the large white spruce, typifies a system of economic partial cutting by groups and patches (Figure 7). Conditioned by the size of the openings, the lesser vegetation may remain similar to that of uncut stands or approach the composition found on clear-cut areas.

Seed Source

Most clear-cut areas have either seed trees or a peripheral seed source, but windthrow and wind breakage are progressively overtaking the residual trees. A seed source may be absent where cutting boundaries abutt the rivers and balsam poplar stands. On the partial-cut areas, seed source is abundant with groups of uncut spruce within five chains of the centre of the cut patches.

The maximum five-chain dispersal distance from a seed source (Rowe 1955) could not be disputed for white spruce on the alluvial soils (cf. e.g. Squillance 1954). On the 1955 Trident Creek burn where alluvium from the 1958 flood provided a mineral soil seedbed about groups of live white spruce, one-year-old seedlings were found in diminishing numbers up to five chains from the seed source.

Figure 6. Portion of the Eldorado Mining and Refining Company timber berth, clear cut in the winter of 1958-59 and photographed in the spring of 1959.

Seedbed Conditions

Two 10-acre blocks were examined in the spring following winter logging and the seedbeds were classified by disturbance and the nature of the germination medium. The disturbances were described as: (I) scarified by removal or mixing of the components, (II) undisturbed without mixing or removal of the components, (III) logs, (IV) uprooted stumps and (V) waste area from piled or windrowed mixtures of slash, litter, humus and mineral soil. The seedbed materials are recorded as: (m) mineral soil, (l) undecomposed litter, (s) deep slash, (h) humus and dry feather moss with or without litter, (p) feather mosses with or without litter, (d) decayed wood and (w) sound wood.

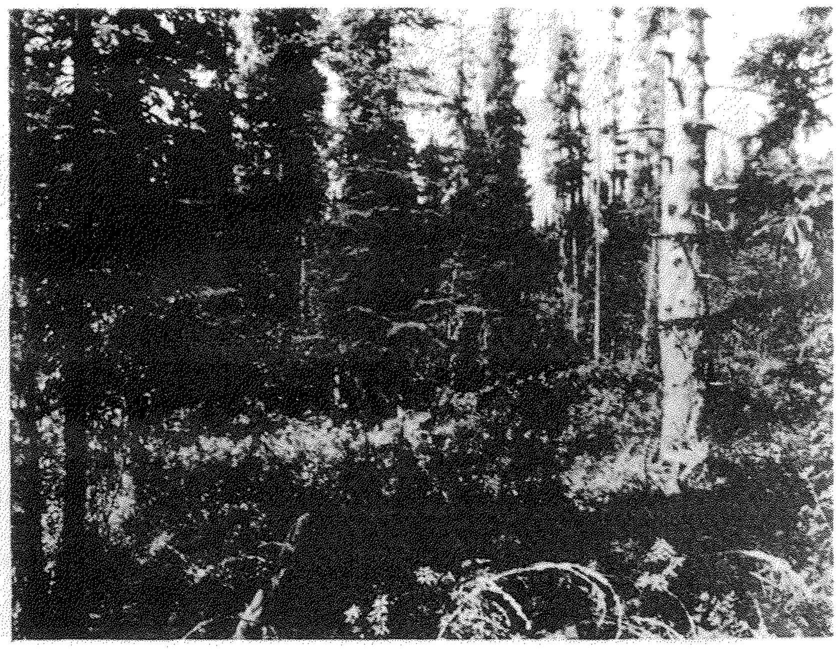

Figure 7. Portion of the Porritt and Ingram timber berth on the Slave River, partial cut in the winter of 1951-52 and photographed in the summer of 1959.

Seedbeds were recorded by circular milacre plots and described for the condition most abundant on the plot. A combination of terms indicates a mixing of the materials rather than a side-by-side association. The results of the small sample are given in Table 2.

Table 2. Relative Abundance of Seedbeds on Two Ten-Acre Areas Logged in 1958-59.

Seedbed		Block	
Code	Description	1	2
		Percent	Percent
I-m	disturbed - soil	9	4
I-ml	disturbed - soil/litter	5	10
I-mlh	disturbed - soil/litter/humus	30	30
II-p	undisturbed - feather moss	41	45
III-d	logs - decayed wood	3	5
IV-m	uprooted stumps - soil	2	3
V-s	waste - deep slash	10	3

Forty-four percent of the seedbeds on both areas were disturbed during logging, but mineral soil was exposed on less than 10 percent. The exposed mineral soil included the skid roads, skid trails and the main roads. In Block I the slash was windrowed rather than scattered, resulting in more waste area or type V seedbeds.

In partial-cut stands the relative abundance of different seedbeds varied with the size of the openings. While the removal of individual and small groups of trees exposed small amounts of mineral soil about skid trails, the undisturbed feather moss and decayed wood seedbeds predominated and showed little deterioration from desiccation. In the larger openings, the seedbeds were similar to those of clear-cut areas.

Seed source is more abundant on partial cuts.

Influence of Flooding and Alluvial Deposits

Depending upon the height of an area above the river and whether ice dams form during the spring break-up to impound the waters, an area may be subject to annual or periodic floods. The floods and concomitant alluvium effect the seedbeds, development of seedlings and trees and the small mammal populations on the inundated areas.

Seedbed conditions

The major spring flood of 1958 on the lower Peace River covered some of the older and higher point bar areas supporting white spruce. Within stands and on cut-over areas the depth of the alluvial deposits varied from a film covering individual leaves and needles to deposits several inches thick. The alkaline flood waters and alluvial film could either speed up the deterioration of the buried raw humus or temporarily inhibit the development of feather moss. Where the raw humus and feather moss have been buried, a mineral soil seedbed results. Figure 8 represents a common seedbed which developed from a 3.5-inch-deposit of alluvium over feather moss and litter on a 1956-57 clear cut. The feather moss and litter at the 3.5- to 4.5-inch-depth overlies sandy loam from 4.5 to 14.5 inches and another humus layer from 14.5 to 15.5 inches. Beneath are alternating layers of silty clay and humus which indicate the periodic development of mineral soil seedbeds.

Regeneration

The effect of water impoundment on hardwoods has been studied by

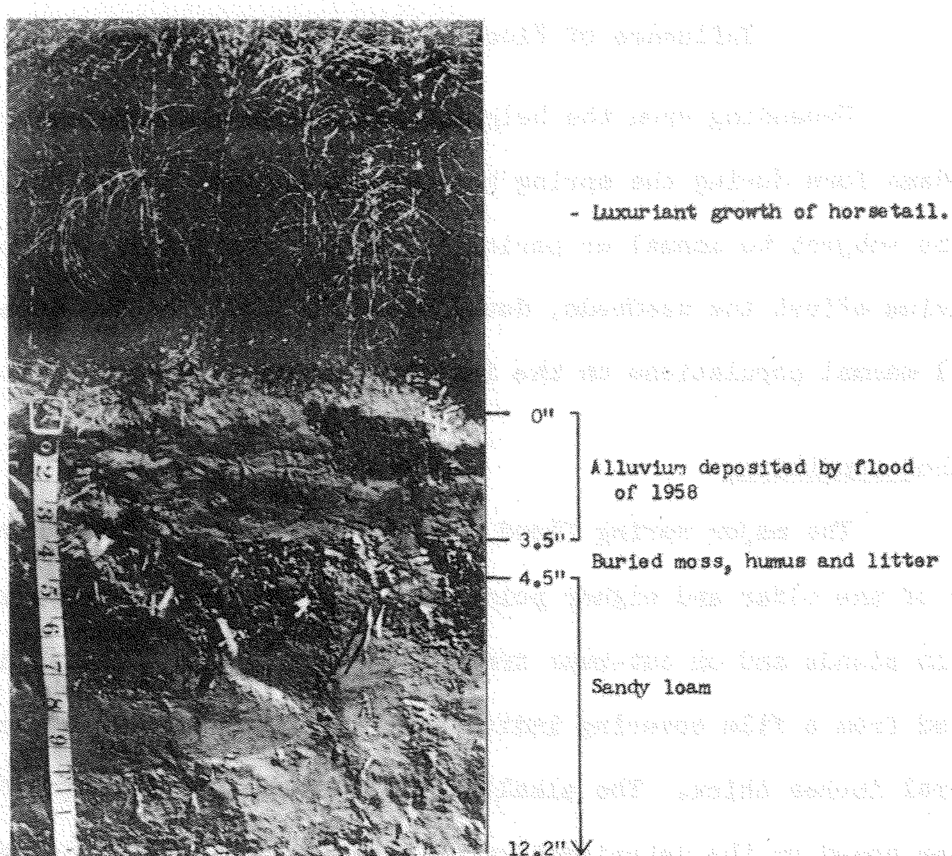

Figure 8. Seedbed developed on alluvium deposited during the flood of the Peace River in 1958. Picture taken in 1959 near Camp 3 of the Swanson Lumber Company.

Hosner (1958) and Green (1947), but little information is available for conifers. From the observations of Ahlgren and Hansen (1957), it seems that floods of one month duration caused about 10 percent mortality of white spruce 1 to 2 feet in height. The mortality would be expected to increase rapidly if the trees were inundated for a longer period.

Sukačev (1953) has recognized that the phenological development of willow is later on areas subject to flooding and considers it may be an adaptation of the species for survival. The possibility of flood-plain ecotypes of white spruce is a consideration in the selection of seed for either seeding or planting on the alluvial soils of the Peace and Slave Rivers.

Perhaps on these areas the deposition of alluvium is of greater concern than actual flooding. White spruce seedlings survived the 1958 flood except those completely buried, as along the Chenal des Quatre Fourches. Two-year-old white spruce seedlings which were buried to the base of the cotyledons did not exhibit morbidity. In some cases a silt film covered the needles, but it is uncertain whether this would interfere with photosynthesis enough to cause death.

Seedlings appear to survive flooding, if flooding occurs prior to the vegetative period, as in 1958, and providing the seedlings are not buried deeper than to the base of the cotyledons by the accompanying alluvial deposit. Since the alluvium in the 1958 flood was light -- less than one inch over most of the forest areas (and a survey indicates that thin alluvial deposits are characteristic on old point bars) -- then it is deducible that flooding and alluvial deposits are not detrimental to one- and two-year-old seedlings. There was no evidence of seedlings being washed out by running flood waters on the older point bar deposits.

Small Mammals

The flood of 1958 may have reduced the population of seed-eating small mammals. McCarley (1939) found that a flood for eight days had no detrimental effect on populations of the cotton mouse and the red mouse, but a 21-day flood reduced the population by 70 percent. Deer mice are known at times to be arboreal which enables them to survive short floods at least.

Rate of Alluvial Deposition

On some areas the rate of point bar increment may be determined from the multi-layered root systems of white spruce. In a similar manner Capps (1916) made use of the multi-layered root form of spruce to estimate the rate of peat build-up in Alaska.

The buried multi-layered root system of a mature white spruce on Long Island in the Slave River is illustrated in Figure 9. By sectioning the core of the stump, it was concluded the tree became established at a current depth of 37 inches which also corresponds with an interrupted layer of charcoal and burned humus. Since the age of the tree at time of harvest was 197 years, 37 inches of alluvium had been deposited by several floods during this period.

The occurrence of an old fire may be documented by a burned humus and charcoal layer in the soil profile; and assuming that the present mature stand became established on the burned layer in the soil, then it is possible to estimate the rate of deposition of alluvium during the development of the present stand. Such observations indicate an 18-inch deposit in 180 years at Big Island, 21-inch deposit in 150 years at Scow Island and a 28-inch

Figure 9. Rate of deposition of alluvium on Long Island in the Slave River as evidenced by the multi-layered root development of white spruce.

deposit in 160 years on the Chenal des Quatre Fourches. The rate of deposition would vary with the height of the area above the river, periodicity and duration of floods.

Influence of Small Mammals

Although small mammals assist in the establishment of white spruce on some areas and tend to change the composition of the stands in others, the influence of small mammals is probably most significant in cut-over and burned-over areas by the depredation of seed and seedlings.

Forest Composition

On an area beside Nagel Channel of the Slave River, white spruce balsam poplar and speckled alder were found growing together. Snowshoe hares had fed heavily upon the shite spruce with the most severe damage occurring under the cover of speckled alder and very light damage occurring in an adjacent meadow. The feeding killed the white spruce and the snowshoe hare has assisted in maintaining the alder-balsam poplar association.

Forest Establishment

Small mammals, including mice, chipmunks and squirrels, s tore seeds in numerous small caches and may, at times, be factors in the regeneration of forests. The role as regeneration agents, has been noted by Moore (1940) for Douglas fir. On the Peace and Slave River lowlands, red squirrel middens are a potential seed source and sites of spruce regeneration.

Figure 10 illustrates the grouping of white spruce reproduction in the former sites of red squirrel caches on the Revillon Coupé. Toward the center of the figure and to the left of the base of a 160-year-old white spruce was the remnants of a current cone cache. The focus of the cache has moved along decayed willow logs, now partially covered with feather moss, toward the base of the tree. The seedlings tend to clump together in a line along the logs. The white spruce reproduction is growing under dying willow on a seedbed of decayed wood and feather moss sparsely covered with litter and vegetated by wintergreen and twinflower. The locations of older cone cache areas are indicated in the lower left of the figure by dense groups of 15- to 25-year-old white spruce and in the upper right of the figure by a group of 40- to 50-year-old white spruce.

The grouping of white spruce in similar small patches of various age classes is common along the Revillon Coupé and points to the activity of red squirrels in the regeneration of this area.

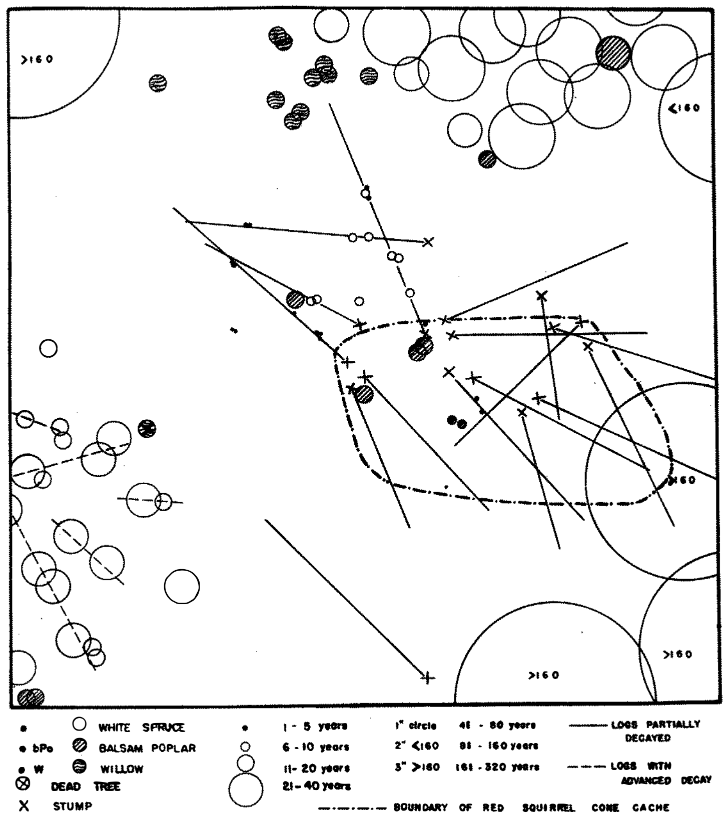

Figure 10. Diagram of white spruce reproduction established on sites of red squirrel cone caches.

Red squirrels frequently cache cones beneath decaying logs which maintain a higher moisture content in their environs than feather moss or other seedbeds. White spruce reproduction, originating from midden areas, may be established along the trunks of fallen trees or the stems of dead willows from the center of the clone, and be distributed in either linear or star-shaped patterns.

As undecomposed cone scales provide a poor germinating medium, the seedlings are limited to decayed wood and to raw humus and feather moss seedbeds at the periphery of the midden. The grouping of seedlings within the midden indicates an original development from seed spots about the cache rather than from random naturally distributed seeds. In the groups that remain, one seedling is dominant.

Seed

Preble (1908) suggests that white spruce seed is the main winter food of the red squirrel and that this food is replaced in the diet by the flowering catkins of balsam poplar by the middle of May. The report by Novikov (1953) that belka, the European squirrel, could eat 350 staminate flowers of spruce in one day coincides with observations by the author regarding the daily consumption of white spruce flowers by the red squirrel. It is worthy of note that damage to a seed crop is not confined to the period of seed maturation and dissemination but also occurs during the flowering stage. Two ten-acre areas sampled on 1958-59 cut overs for cone caches showed an average of one major red squirrel cache per acre. These were major accumulations in middens that had been used for several years and not isolated groups of two or three cones chinked haphazardly about the area. On line traverse one red squirrel was observed every ten chains or one per acre. This corresponds to the distribution of cone caches and indicated only one squirrel is associated with each cache (cf. e.g. Hatt 1943).

The deer mouse and the red-backed mouse will reduce the regeneration potential. Both species are active under the snow which makes them potential destroyers of white spruce seed throughout the fall and winter.

In cage feeding these animals will eat 2,000 white spruce seeds each day. The least chipmunk is not abundant and probably has little influence on the regeneration of the alluvial forests. The red-backed mouse also feeds on vegetation, and the author has observed this species eating white spruce seedlings. Soper (1942) records the short-tailed meadow vole abundant in the area; the meadow voles, as a group, can be very destructive to young seedlings.

In September 1959, two ten-acre cut-over areas were trapped for small mammals. One area bordering an undisturbed stand of immature white spruce east of Baril River was clear cut in the winter of 1957-58; the other area in a large clear cut west of the Eldorado Airport was logged in the winter of 1953-54. Snap traps, placed in a grid at one chain intervals for a total of 100 traps per ten acres, were baited with a mixture of rolled oats and peanut butter and set for three consecutive nights.

The deer mouse and the red-backed mouse were the most abundant small mammals taken in the snap traps. Part of the variation in the number of animals caught on the two areas was due to the pilfering and interference by birds on the area near the airport. The results of the trapping are presented in Table 4.

Table. 4. Total Catch of Small Mammals on Ten-Acre Eldorado Clear-cut Areas.

Species	Area	
	Baril River	Airport
	Number	Number
Cinereus shrew	1	0
Red-backed mouse	31	4
Deer mouse	13	31
Total	45	35

Flooding on the Airport area may have been of greater duration than on the Baril Creek area since the latter lacked of silt, logs and debris that would have been deposited by running water. From the trapping, it may be concluded that flooding does not destroy the small mammal population beyond the first year; and even then the effect is dependent upon the period of inundation.

It is difficult to evaluate the importance of birds as consumers of white spruce seed. The following species were noted on the clear-cut areas in flocks or singly: orange-crowned warbler, white-throated sparrow, Dakota song sparrow and slate-coloured junco. The white-winged crossbill is probable in the area and has been found to be destructive of cone crops by Reinikainen (1937) in Finland.

Seedlings

Observations were not made on damage to germinants of white spruce, although red-backed mice, short-tailed meadow voles and sparrows are known to feed on the young seedlings.

Snowshoe hares feed on white spruce throughout the Peace and Slaves River lowlands. The resinous buds and new growth of vigorous young trees provide spring food when in reach of the animals. Young white spruce are also eaten during the winter. On the cut-over areas, 40 percent of the two- and three-year-old seedlings were damaged; and 3 percent had been killed. Damage was spotty with the white spruce seedlings eaten in groups.

Cut-over areas with abundant grasses and herbs for summer food and shrubs for protection and winter food may favour an increase in the population of snowshoe hares. Soper (1942) records the greatest density of snowshoe hares in mixed wood areas rather than in dense stands; mixed wood areas, similar to cut-over areas, have a more abundant and varied food supply.

PROPERTIES OF SEEDBEDS

Mineral soil, raw humus and feather moss seedbeds are common to all Boreal Forest areas. On the Peace and Slave River lowlands -- periodic alluvial deposits, seasonal distribution of a low annual rainfall and presence of soil frost — modify the properties of these seedbeds and affect forest regeneration.

Mineral Soil

When exposed to direct insolation, in clear-cut areas, mineral soils are warmed enough to permit seed germination; within stands however, the soil frost may keep the surface too cold for adequate germination.

Except on compacted roadways, mineral soils are covered by a luxuriant growth of horsetail which provides shade and reduces the probability of seedling mortality from excessive surface soil temperatures. Seedlings without plant cover and exposed to excessive diurnal temperature changes tend to heave with frost. Horsetail matures in the early summer and does not compete with seedlings for soil moisture stored from the spring run-off. In July soil moisture is replenished by rainfall. Dew is retained longer on seedbeds shaded by horsetail than on exposed seedbeds.

Undecomposed Litter

The litter seedbed on clear-cut areas dries rapidly and excessive surface temperatures inhibit seedling establishment. When the litter is composed of small branches and larger slash over mineral soil, as is common on some parts of the cut-over areas, the mineral soil acts as the seedbed and the litter as a protection for the seedling against direct insolation. A mulch of litter tends to conserve moisture in the underlying soil.

Raw Humus

Although raw humus is considered a poorer seedbed than mineral soil in this area, the observations agree with Meshechok (1956) who considers humus to be a better seedbed than feather moss due to improved moisture conditions.

Unless long periods are to be tolerated for obtaining white spruce regeneration through maturation of the humus (Petrini 1934), the raw humus layer will need amelioration. While the incorporation of the broad leaves of shrubs slowly assist the maturation of raw humus, the more rapid amelioration processes such as burning, scarification or liming (Hartmann _et al_ 1956) should be considered. A mild natural liming accompanies the flooding of the forest areas by Peace and Slave Rivers.

Feather Moss

Hylocomium splendens, and to a lesser degree _Pleurozium schreberi_ and _Ptilium crista-castrensis_, may form an almost continuous carpet within white spruce stands. Since soil frost is prevalent, the depression of temperatures in the germinating layer may limit the development of white spruce regeneration (cf. e.g. Mork 1933). The annual growth of the feather moss increases the depth of the raw humus layer which through insulation maintains and raises the soil frost nearer to the surface (cf.e.g. Tyrtikov 1957).

The feather mosses on clear-cut areas either wither and die in exposed situations or remain in a semi-thrifty condition about the stems of larger shrubs. Tamm (1950) associated the dying of feather moss in openings with a reduced rate of photosynthesis accompanying desiccation, also to a reduction in the supply of one or more nutrients formerly provided by the litter and rain washings from the crowns of the trees in the overstory.

Feather moss is not as desirable a seedbed as mineral soil, a fact that has already been shown by Place (1955) in the Maritime Provinces. This quality is substantiated further in Scandanavian and Russian literature (cf. e.g. Sirén 1955).

Decayed Logs

Decayed logs are an effective seedbed under white spruce and balsam poplar where the stand climate prevents rapid drying. Mork (1933) points out that the mean diurnal temperature of the germination layer of rotted stumps and windfalls is higher than mineral soil in both stands and cut-over areas. This may be a further advantage of decayed logs over other seedbeds in white spruce stands, but on clear cuts the increase in temperature combined with a rapid rate of drying limits seedling establishment.

Hygroscopic Seedbeds

Mnium affine in watercourses and other moist and boggy areas is not an important seedbed. Seedlings exhibited poor growth and chlorotic foliage from nutrient deficiency and lack of root aeration (cf. e.g. Nekrasova 1955).

ROOTING CHARACTERISTICS OF WHITE SPRUCE

The root system of white spruce is plastic in the seedling stage with the relative development of the tap-root and lateral long roots varying between mineral soil and organic materials. The plasticity is maintained throughout the juvenile and immature stages, and the root form of an individual is modified by environmental changes which induce the formation of a secondary or adventitious root system or the rejuvenation of the primary system. The root form of mature trees is characterized by either development of strong shallow lateral roots or of superimposed lateral roots which constitute the deep multi-layered root form.

Root Form of Seedlings

On mineral soil seedbeds, one- and two-year-old seedlings developed an elongated tap-root with numerous small lateral long roots which reached their greatest length in the upper one inch of the soil. The extension of the tap-root is possibly the response to the droughty soil of exposed situations, for the soil dries rapidly after the spring thaw and the cessation of spring and summer rain storms. The tap-roots of two-year-old seedlings ranged from 1.3 to 5.5 inches in length. The shorter root is generally the result of breakage of the tap-root. Upon drying, the surface soil may crack into polygonal blocks with horizontal cleavage about an inch below the surface. This ruptures or injures the root systems of seedlings, leaving them to die from drought.

In raw humus the seedling tap-root is short and aborted, but it may develop laterally either in the raw humus or mineral soil beneath. An extensive system of lateral long roots is common in the raw humus layers and also may coincide with the presence of humus in mineral soil. Certainly the roots develop laterally in buried layers of humus and old decayed root channels.

White spruce seedlings established on decayed wood tend to follow the cleavage lines. Root systems on stumps develop vertically with a long tap-root, and those on logs develop horizontally with numerous lateral long roots. If wood is well decomposed there are many abundant lateral short roots with multiple bifurcations associated with the mycelial felts of saprophytic fungi. In wood that does not have appreciable decomposition, the roots are slender with few branches.

Development of Adventitious Roots

Adventitious roots develop from the stem and branches of trees when these parts have been covered by a material that provides moisture, aeration, darkness and warmth. Meyer (1938) observed the development of adventitious roots by spruce in compost and later experimentally induced their development on the trunk of a spruce tree. Although the phenomena has been recognized for a long time, its silvicultural significance to forest trees has only recently been discussed by Koščeev (1952, 1953) and Krasiljnikov (1956).

Pursuant with observations on layering of white spruce, Bannan (1942) connected the origin of adventitious roots with the dormant buds associated with the parenchymous gaps directly above the terminal ring scars on branches. The association of adventitious roots with parenchymous tissues has also been noted by Ivanov (1939) and Koščeev (1953).

Krasiljnikov (1956) noted that adventitious roots commonly formed on the stem and occasionally on the hypocotyl of Siberian pine, and in addition Koščeev (1953) records their development from callous stem tissue. Sirén (1950) refers to some roots, which develop from the primary root system as adventitious roots. In this paper, adventitious roots are considered to be those that develop from the stem above the hypocotyl to form a secondary root system. They commonly form on seedling and juvenile white spruce throughout the Peace and Slave River lowlands as a response to new alluvial deposits, increase of raw humus and growth of feather moss.

Figure 11 illustrates the development of adventitious roots above the hypocotyl and near a terminal ring scar in raw humus by a five-year-old white spruce. This seedling was growing within a white spruce stand where soil frost was still present in the lower humus layers in July.

The seedling in Figure 12 developed adventitious roots above the hypocotyl in the raw humus layer at 0.7 inches and in the relatively loose layer of feather moss at stem nodes to a height of 3.7 inches. Although adventitious roots in the uppermost whorl were associated with relatively large interspaces in the feather moss which is a much looser and drier medium than raw humus, they grew up to eight inches long and formed numerous lateral short roots near the stem. They could be considered semi-aerial roots.

Figure 13 illustrates the development of adventitious roots in an alluvial deposit from the stem and branches of an eight-year-old white spruce seedling established on mineral soil. The young tree was buried to a depth of 5.3 inches by the concomitant alluvium of the flood in 1958. Some of the branches developed adventitious roots at 6.6, 4.2, 4.0, 3.6, and 2.8 inches. These roots developed either from the apex of the branches or from nodes along the branches (cf. e.g. Krasiljnikov 1956). In addition, adventitious roots developed directly from the stem at 3.6 and 1.9 inches, and above the hypocotyl at 0.9 inches. Not all the buried branches developed

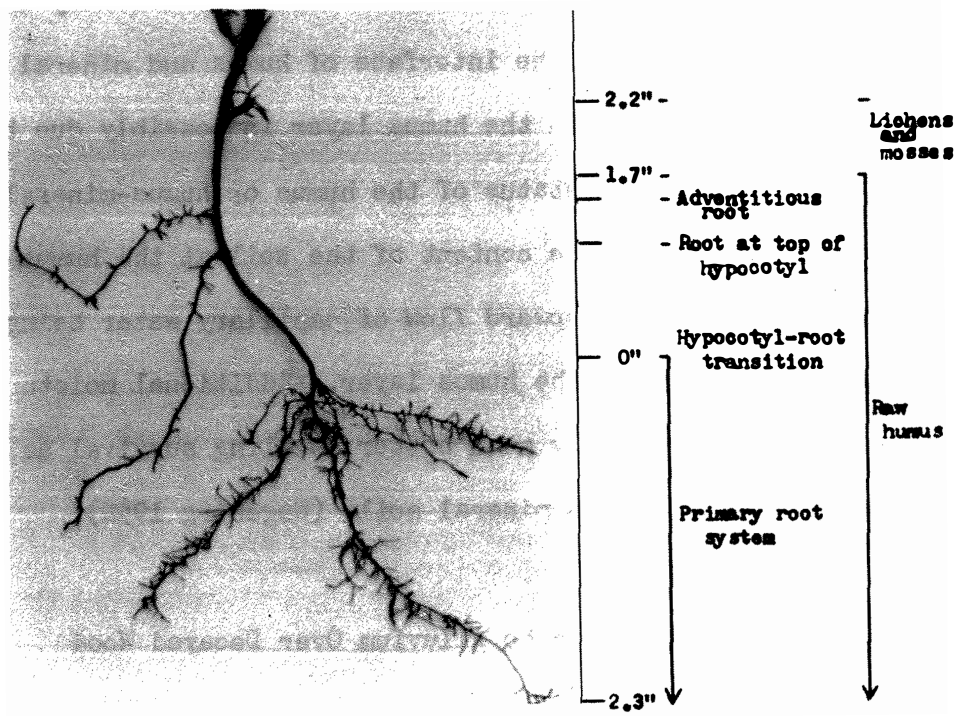

Figure 11. Development of adventitious roots above the hypocotyl by a five-year-old white spruce growing in raw humus.

a root function as some died at 5.4 and 3.6 inches.

It appeared, in the case of alluvial deposits with a depth of one half to one inch, that the adventitious roots extended laterally into the buried humus layers or followed the interface of humus and mineral soil. The association of the roots with the humus layer is possibly due to an improved nutrient and moisture status of the humus or humus-mineral soil interface. The improved moisture content of the soil at the humus-mineral soil interface is owing to the upward flow of capillary water being slowed down by the mulching effect of the humus layer. Additional moisture in the humus alone would not necessarily mean better seedling survival as wilting point is higher in humus than in mineral soils (Segeberg 1958).

Root Form Distinctive to Alluvium Over Decayed Wood

The modification of the root form of seedlings on decayed wood after the deposition of alluvium is of silvicultural importance. Adventitious roots may develop in the new alluvium, and the primary root system may become rejuvenated and extend new lateral roots into the alluvial layer from near the point of transition from hypocotyl to root. Figure 14 illustrates the second condition, or rejuvenation, of the primary root system by a three-year-old white spruce seedling.

Subsequent to the 1955 fire at Trident, the 1958 flood deposited a cap of alluvium one half to one inch deep, over a 12-inch log which supported white spruce seedlings, and on the raw humus and silty clay loam layers adjacent to the log. The primary root system extended into the fresh alluvium by developing near the hypocotyl-root transition, three new lateral long roots which followed the alluvial layer overlaying the burned surface of the decayed log. Below the uppermost lateral root, which was 10.8 inches in length, were two additional lateral roots, nearly opposite, that developed near the transition of the hypocotyl to the root.

In other similar cap-like deposits, or instances where the decayed log has been completely buried by alluvium, adventitious roots develop directly from the stem into the body of the mineral soil.

Modification of Root Form

The modification of root form of juvenile white spruce on the alluvial soils of the Peace and Slave River lowlands is coincident with the formation of adventitious roots (which is a response to the development of feather moss, particularly on imperfectly-drained soils in the presence of soil frost, and to alluvial deposits). Juvenile trees, develop a strong lateral and superficial root system in feather moss and raw humus and a multi-layered root system in areas subjected to frequent alluvial deposits. In either case the lateral root development is associated with the humus layers in the soil.

Although seedlings rooted in decayed wood will extend roots into a subsequent overlaying alluvial deposit, this modification of root form does not persist to maturity. Either further alluvial deposits bury the decayed wood or the build up of raw humus accompanied by decomposition of the wood, permit a lateral extension of the root system and the development of the shallow lateral root form in mature trees. An arched or "cats-paw" form of root system was not observed on the alluvial soils.

Figure 15 summarizes the formation of a secondary root system by juvenile white spruce. It shows the development of adventitious roots in humus and alluvium, their association with the buried humus layers, and the beginning of a multi-layered root form. The seedling became established on an alluvial deposit at a current depth of 3.3 inches and subsequently

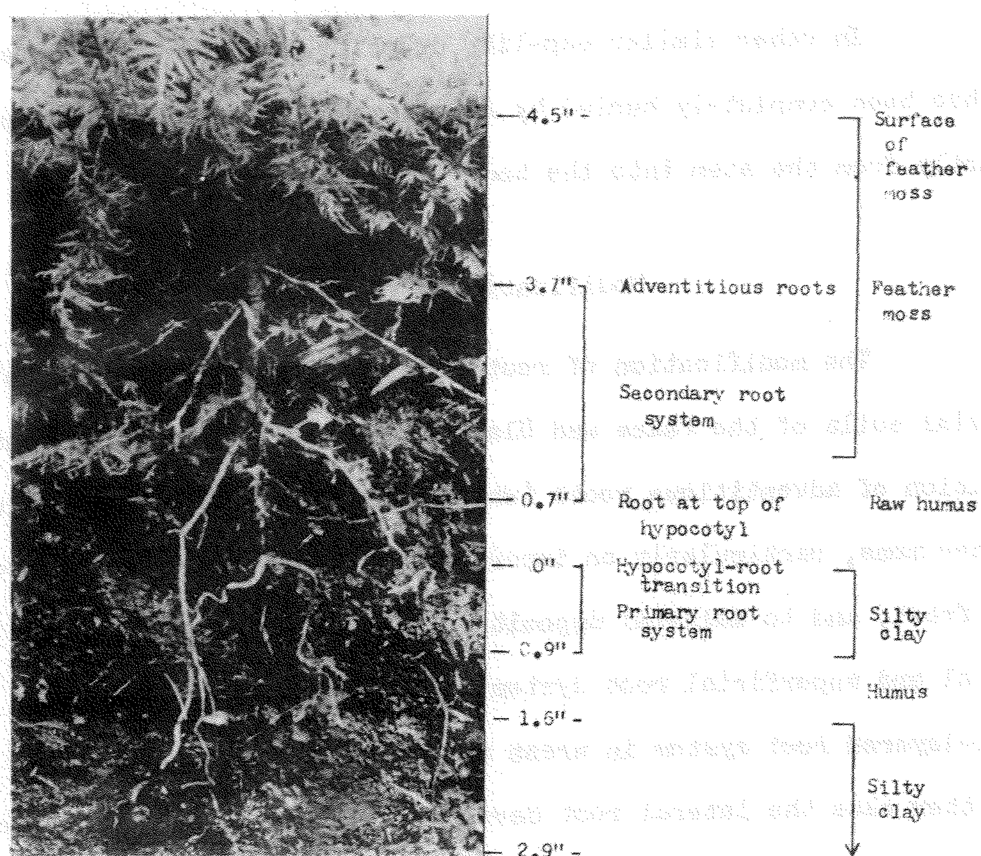

Figure 12. Development of adventitious roots in feather moss by a 15-year-old white spruce established on raw humus.

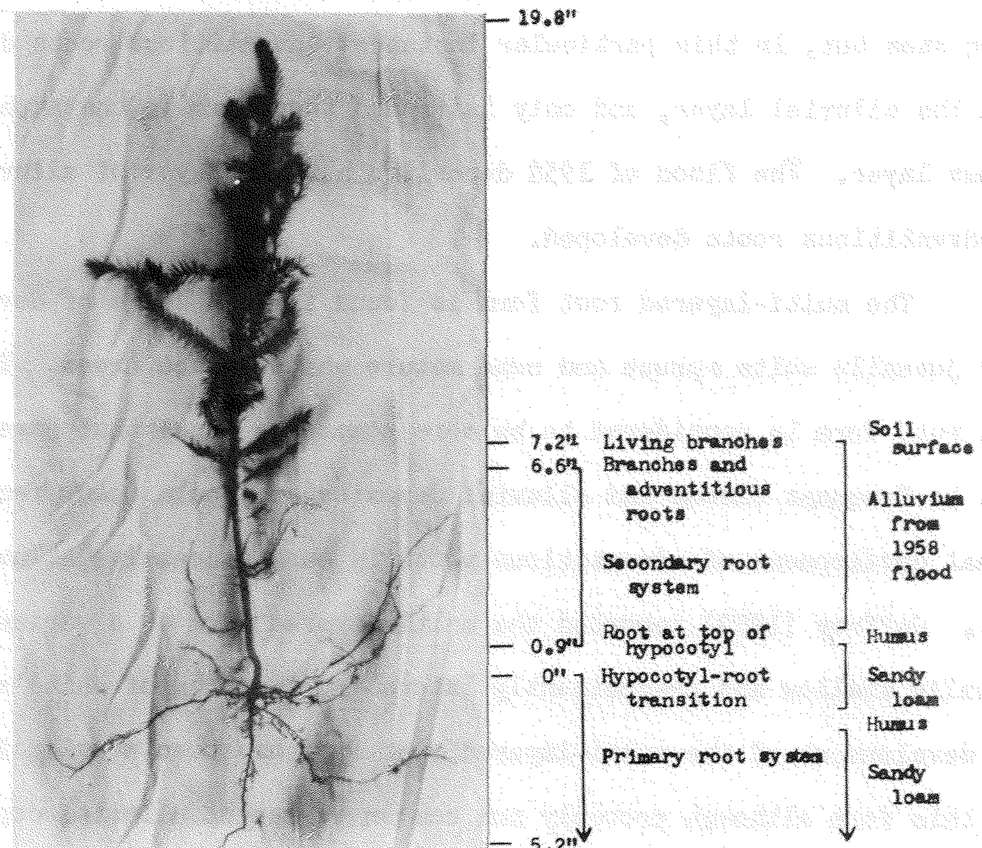

Figure 13. Development of adventitious roots by an eight-year-old white spruce in alluvium deposited during the flood of 1958 along the Chenal des Quatre Fourches.

developed adventitious roots above the hypocotyl in the raw humus layer that formed over the deposit. Another alluvial deposit buried part of the seedling stem but, in this particular instance, adventitious roots did not form in the alluvial layer, and only later did they form in the superimposed raw humus layer. The flood of 1958 deposited a third layer of alluvium in which adventitious roots developed.

The multi-layered root form is found in some stage of development in many juvenile white spruce and some mature white spruce trees. The multi-layered root form is considered to be more common on areas that have been subject to frequent floods and alluvial deposits and would occur from the continual development of adventitious roots in each successive alluvial deposit. Jeffrey (1959) reported the multi-layered form as a variant of the usually shallow and predominantly lateral root system of white spruce. As the development of the multi-layered root form has been previously outlined, this form although probably not common to recent alluvial deposits must be considered characteristic of them.

The usual development of the mature white spruce root system, with strongly developed laterals from which sinker roots develop to variable depths, is also common to the alluvial soils of the Peace and Slave Rivers. The strongly buttressed root is believed to be the result of adventitious roots developing in raw humus, feather moss or thin alluvial deposits on older alluvial soils of higher point bar formation.

Importance of Adventitious Roots

Little is known about the adventitious rooting characteristic of white spruce other than its occurrence in 2- to 132-year-old trees, and its association with the occasional form of layered reproduction. Yet to be studied is the age of greatest development of adventitious roots and the

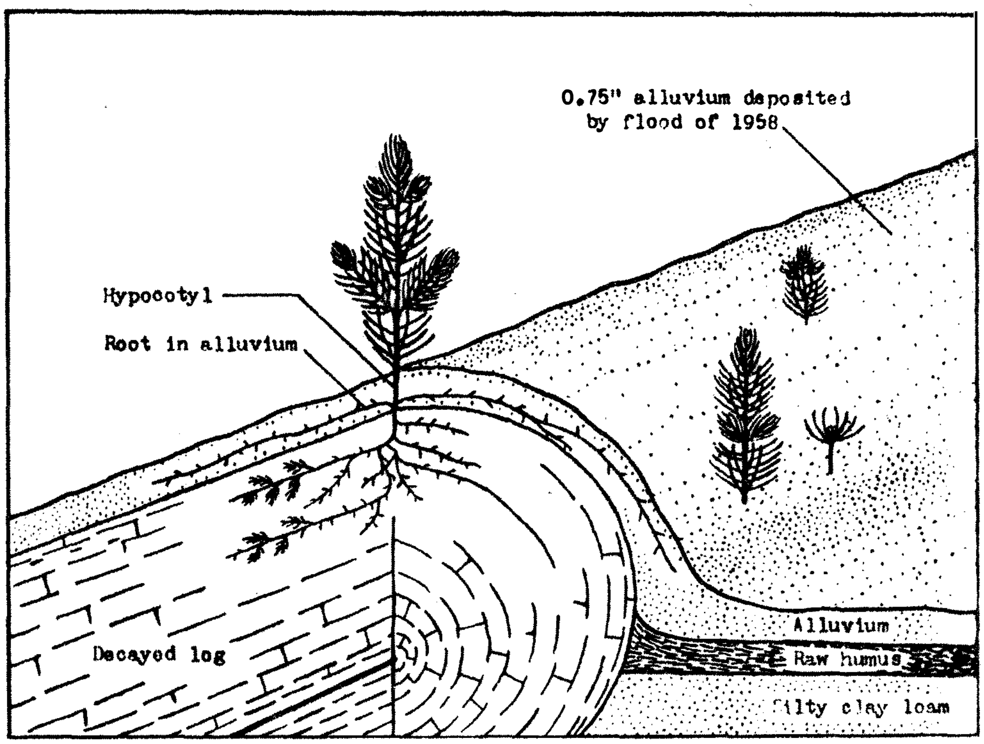

Figure 14. Rejuvination in alluvium of the primary root system of a three-year-old white spruce established on decayed wood.

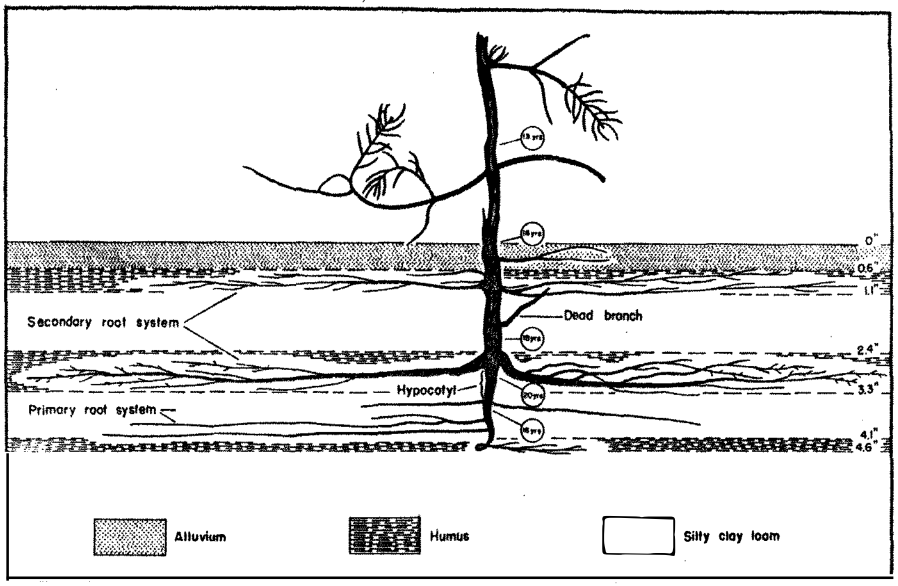

Figure 15. Beginning of the multi-layered root form through the development of the secondary root system in alluvium and humus by a 20-year-old white spruce.

importance to silviculture.

According to Koščeev (1953) adventitious roots form on all woody plants in northern Russia. They arise on the butt under moss cover to replace parts of the root system that have died from excessive moisture, moss growth and the development of peat. He suggests that the cessation in the development of adventitious roots by Norway spruce at an age of 40 to 45 years could explain the dieback of mature spruce on waterlogged sites. Krasiljnikov (1956) discusses the adventitious root system of Siberian pine and maintains that only trees that have developed adventitious roots reach timber size in the central Sayan Mountains. The formation of these roots, which is a response to soil frost and growth of moss, ceases between 40 and

60 years, and 60-year-old trees developed a surface root system to a depth of 12 to 16 inches.

While the white spruce of the Peace and Slave River lowlands develop adventitious roots in raw humus and feather moss, an additional important stimulus for the formation of the secondary root system is the periodic deposition of alluvium. Adventitious rooting of white spruce on the alluvial soils ensures an active feeding root system above the level of soil frost. Otherwise, the older and lower systems of primary and secondary roots would be enveloped in frozen soil with the resulting cessation of growth and death of the trees. For this reason development of the secondary root system is considered more important to the growth of white spruce on the Jean soil, which has a greater development of feather moss and soil frost, than on the Slave soil.

After successive alluvial deposits and re-rooting of the trees, a multi-layered root occurs which is anchored firmly by soil frost at the lower depths in the soil; thus, the mature trees are windfirm.

For seedlings established on decayed wood, the periodic deposition of alluvium over the decayed wood provides, at an earlier age, a mineral soil contact with the tree and the stimulus for the formation of adventitious roots. The seedlings respond by extending their root system into the new alluvium which results in a greater height growth than when growing solely in decayed wood.

The rare occurrence of layering of white spruce in feather moss, which has been reported previously by Cooper (1911) and Bannon (1942), is the result of the development of adventitious roots from branches. Reproduction of white spruce by layering is of casual occurrence and negligible importance in the Peace and Slave River lowlands.

While the importance of adventitious roots to survival and growth of trees has been associated with soil frost, waterlogged soil, alluvial deposits and an increase in depth of feather moss and raw humus, it is yet of further significance. Even where the primary root system has not been inhibited by physical properties of the soil, white spruce develops a secondary root system of adventitious roots above the root collar in association with the humus layers. This is related to the improved nutrient status of the humus (cf. e.g. Sirén 1950). The adventitious roots tended to be associated with the buried humus layers in the alluvial soils, which indicates further that adventitious roots occur in the more fertile layers of the soil. The fertile layers are responsible for the maximum possible growth. This is contrasted with the primary root system lying deeper within the less fertile mineral soil.

DISCUSSIONS AND CONCLUSIONS

Low regenerative capacity of white spruce is associated with the mature forests of the Peace and Slave River lowlands. This characteristic of the Boreal Forest, which has been adequately documented by Sirén (1955), is associated with the temperature and moisture characteristics of the raw humus and feather moss seedbeds.

The soils of the region have developed on lacustrine and alluvial deposits with the older alluvial soils of the Slave soil series on point bar deposits supporting most of the large white spruce. Soil frost, which is present within the forest stands, tends to dissipate after fire or logging. Whilst the climate is arid, about half of the annual precipitation of 13 inches occurs during the growing season; thus the growth of white spruce is not reduced by summer drought. The rivers are subject to spring floods which at times cover the higher areas of the lowlands and deposit alluvium throughout the white spruce stands.

Of the two separate phases in the development of the white spruce forests, one is the result of pedoacretion which elevates the area above the river, with the forest developing through seral stages of willow, alder, balsam poplar to white spruce. The second method of development or maintenance of white spruce forests depends largely on the same factors that influence natural succession after fire in other Boreal Forests but with one important addition, namely, the periodic deposition of alluvium by floods.

Mineral soil is indicated as a more effective seedbed than litter, raw humus or feather moss, not only by the ecological development of white spruce stands of the primary succession but also through observations of seedbed preference on clear-cut areas. The arid climate of the area promotes rapid drying of the well-drained seedbeds with the most deliterious effect on exposed raw humus and feather moss. Ancillary to the dryness of the seedbeds is the relatively slow rate of decomposition of raw humus. Where advance growth has not developed on alluvium following flooding, the reproduction is established mostly on decayed wood within stands.

Fire has been important in the lowland areas as a stand removal agent, and where fire has consumed the raw humus layer to expose a mineral soil seedbed, it has been a regenerative agent. Elsewhere the periodic floods with the accompanying alluvial deposits have been the principal regenerative agent.

The seedbeds of clear-cut areas are not suitable for regeneration immediately after logging, for not enough mineral soil is exposed. Either scarification or control burning should be considered as a treatment following logging.

Although the alluvial deposits may bury seedlings, this damage is outweighed by the benefits to spruce regeneration accrued from the alluvium as a mineral soil seedbed. Thin deposits, being alkaline, help to decompose the organic material. Following alluvial deposits, a luxurious growth of horsetail protects seedlings from direct insolation, conserves surface soil moisture and matures before the period of low soil moisture. Horsetail is present in a less thrifty condition on most seedbeds prior to alluvial deposits.

The varying hare damages seedlings and young trees, and the red squirrel destroys white spruce seed. While the amount of depredation of seed and seedlings by deer mice, red-backed mice and meadow voles is uncertain, these animals do not appear to be limiting the re-establishment of white spruce stands.

The development of adventitious roots by juvenile white spruce in mineral soil, raw humus and feather moss is of silvicultural importance. When partially buried by alluvium, the trees produce adventitious roots from the stem and branches to adapt to the new environment. The deposition of alluvium on white spruce established on decayed wood provides mineral soil for adventitious root development and subsequently improved seedling growth. Seedlings established in raw humus and feather moss develop adventitious roots from the stem, as the stem is continually buried deeper by growth of the moss. As the depth of the humus and moss increases, soil frost rises and continual re-rooting of the white spruce is necessary for survival and growth. The lower part of the root system of mature trees, which develop a multi-layered root through re-rooting after each successive alluvial deposit, is bound by soil frost. This contributes to windfirmness.

Adequate seed and a mineral soil seedbed, provided by alluvium, burning or scarification, are the prime requisites for obtaining white spruce regeneration. No part of an area considered for natural regeneration should be farther than five chains from a seed source; an if it should become necessary, the seed may be protected from small mammals by baiting with thallous sulphate or sodium fluoroacetate (cf. e.g. McGregor 1958).

The rehabilitation of non-stocked burned-over and cut-over areas without an adequate seed source is a more difficult problem. At present, direct seeding is the most applicable method of reforesting brulés. When a mineral soil seedbed is present, the area can be broadcast seeded in the fall of the year, using seed treated with tetramine or endrine for small mammal protection at the rate of one pound of seed per acre (cf. e.g. Pesterev 1952, Hooven 1958 and Kolehmainen 1958). On areas with a non-receptive raw humus seedbed, spot seedling on small scarified spots should be considered (cf. e.g. Jakovlev 1952 and Preobraženskii 1952).

Planting does not appear to be a practical regeneration technique for the forests of the Peace and Slave River lowlands at the present time owing to the problems of handling and transporting the stock. Nevertheless, planting would have two advantages: planted trees are not apt to be buried by alluvium and the ability of spruce to develop adventitious roots would allow deep planting of nursery stock to establish early contact with better moisture conditions (Koščeev 1952).

Flooding with the accompanying alluvium could bury both seed and seedling during some years; however, since severe floods are of periodic occurrence, the effectiveness of direct seeding is not precluded in most years.

SUMMARY

During the summer of 1959 observations were made on white spruce regeneration on the alluvial soils in the lower Peace and Slave River forests. The continuous clear-cut areas along the Peace River and some of the smaller clear-cut and partial-cut areas along the Slave River were studied as well as a few burned-over areas.

A brief description is provided of the forests, geography, climate, character of the floods and alluvial deposits, soils and sites of the area. The Slave Soil series, which is subjected to periodic floods, supports the best stands of large white spruce.

The ecological development of the white spruce forests is discussed as well as the influence of fire, logging, floods and small mammals on the regeneration of the forests.

Since white spruce regeneration on burned-over and cut-over areas of the Slave Soil series was inadequate, the nature of the seed source and seedbeds on the areas after fire and logging is discussed. The importance of the role of flooding and pedoacretion in the forest succession and regeneration of white spruce is presented.

The influence of small mammals and birds on the regeneration and development of the white spruce forests is considered. Red squirrels, deer mice and red-backed mice are present in sufficient numbers to consume much of the seed on cut-over areas. Regeneration about cone caches on raw humus seedbeds was observed in immature and mature stands. Snowshoe hares are destructive to young trees and seedlings, particularly in the brush-covered areas within stands of white spruce or on cut-over areas.

Most of the white spruce seedlings on cut-over and burned-over areas

were found on mineral soil seedbeds rather than on litter, raw humus, feather moss or decayed wood. Within immature and mature white spruce stands when a mineral soil seedbed was absent, the seedlings were established principally on decayed wood and occasionally on raw humus.

Seedlings growing in raw humus or feather moss developed adventitious roots from the stem or branches as these materials became thicker and covered the stems and branches of the seedlings. Similarly, adventitious roots developed in alluvium deposited about the seedlings during floods. Survival and growth of juvenile white spruce are dependent upon the development of adventitious roots, and wind firmness of large trees upon the formation of a multi-layered adventitious root system.

Regeneration silviculture -- recommended for white spruce -- places emphasis on the autecology of the spruce seedling and the special environmental conditions in the Peace and Slave River lowlands.

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APPENDIX

Scientific Names of Trees, Plants, Mosses, Animals and Birds

Trees (after Fernald 1950 and others)

Balsam poplar	*Populus balsamifera* L.
Black spruce	*Picea mariana* (Mill.) BSP.
Engelmann spruce	*Picea engelmannii* Parry
Long-beaked willow	*Salix bebbiana* Sarg.
Norway spruce	*Picea abies* (L.) Karst.
Scots pine	*Pinus sylvestris* L.
Siberian pine	*Pinus sibirica* (Rupr.) Mayr.
Siberian spruce	*Picea obovata* Ledeb.
Speckled alder	*Alnus tenuifolia* Nutt.
Spruce	*Picea abies*, *P. obovata*
Tamarack	*Larix laricinia* (Du Roi) K. Koch
Trembling aspen	*Populus tremuloides* Michx.
White spruce	*Picea glauca* (Moench) Voss

Plants (after Fernald 1950)

Dwarf raspberry	*Rubus pubescens* Raf.
Horsetail	*Equisetum pratense* Ehrh.
Northern twinflower	*Linnaea borealis* L.
Prickly rose	*Rosa acicularis* Lindl.
Red osier	*Cornus stolonifera* Michx.
Sedge	*Carex atherodes* Spreng.
Squashberry	*Viburnum edule* (Michx.) Raf.
Wintergreen	*Pyrola* spp.

Mosses

Feather moss	Hylocomium splendens (Hedw.) BSG.
Mnium	Mnium affine Bland.
----------	Pleurozium schreberi (Brid.) Mitt.
Plume moss	Ptilium crista-castrensis (Hedw.) DeNot.
----------	Sphagnum spp.

Mammals (after Rand 1948 and others)

Belka (European squirrel)	Sciurus vulgaris L.
Cinereus shrew	Sorex cinereus Kerr
Cotton mouse	Peromyscus gossypinus (Le Conte)
Deer mouse	Peromyscus maniculatus (Wagner)
Least chipmunk	Eutamias minimus (Bachman)
Red-backed mouse	Clethrionomys gapperi (Vigors)
Red mouse	Peromyscus nuttalli (Harlan)
Red squirrel	Tamiasciurus hudsonicus (Erxleben)
Short-tailed meadow vole	Microtus pennsylvanicus (Ord.)
Snowshoe hare	Lepus americanus Erxleben

Birds (after Salt and Wilk 1958 and others)

Dakota song sparrow	Melospiza melodia judii Bishop
Orange-crowned warbler	Vermiovora celta celta (Say)
Slate-colored junco	Junco hyemalis hyemalis (L.)
White-throated sparrow	Zonotrichia albicollis (Gmelin)
White-winged crossbill	Loxia leucoptera leucoptera Gmelin