BLACK STURGEON BOREAL MIXEDWOOD RESEARCH PROJECT

ESTABLISHMENT REPORT

John B. Scarratt

Canadian Forest Service
Great Lakes Forestry Centre
Sault Ste. Marie, Ontario

Natural Resources Canada | Ressources naturelles Canada
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POSTSCRIPT TO THE REPORT

Shortly after this report was completed, a severe wildfire burned extensive areas of forest in the central block of the Black Sturgeon Forest. Included among these were the research sites described in this report. Although many of the experimental areas were burned, and the associated areas of residual forest destroyed, in ecological terms, this was not as serious as it first appeared. As discussed in Section 2.5 of this report, fire has always been a natural and integral element of boreal forest ecology, and historically has been the principal agent of periodic forest rejuvenation in boreal mixedwoods. In the aftermath of the 1982-1995 spruce budworm (*Choristoneura fumiferana* Clem.) infestation, the forests of the Lake Nipigon area, with their large component of budworm-killed balsam fir (*Abies balsamea* [L.] Mill.), had long been vulnerable to the risk of devastating wildfires (see page 7 of report). Already, in 1996, two fires along the northern boundary of the central block had between them burned 16,000 ha of forest and cutover. From an ecological standpoint, given the coincidence of favourable fuel and climatic conditions, the fire of May 1999 was neither an unnatural event, nor totally unexpected.

Although the loss of investment in some of the studies already under way was unfortunate, this is not the end of the project. Certainly, the experimental infrastructure has been dramatically altered, but at the same time, the fire has created an ecologically significant "new beginning" on most experimental areas. Building on the information already collected, this presents many new research opportunities. Some existing studies have already been redirected, and it is expected that new studies will be initiated to take advantage of the changed ecological situation.

In this revised research environment, much of the baseline information recorded in this Establishment Report is still valid, and will be of continuing value to project participants as a record of past disturbances and site conditions. In order to retain and record the rationale for the project, as well as the descriptions of the founding experimental treatments, the report is presented unchanged from its original (i.e., pre-fire) form. For information regarding specific impacts of the fire upon the research infrastructure or individual studies, or for information on subsequent project developments, the Project Coordinator should be contacted at the address given on page ix of the report.

The early onset of a dry spring resulted in above average fire occurrences in Manitoba and Ontario during May of 1999. Nipigon fire #10 (NIP 10) started on May 2, 1999, one of 54 forest fire events that occurred in northern Ontario over the May 1 weekend during a period of extreme fire danger. One of these fires, on the southeast shore of Lake Nipigon, was initially larger than NIP10 and forced the evacuation of the community of Beardmore.

NIP10 started in the vicinity of Church Lake (Fig. i), just north of the southern boundary of the central block of the Black Sturgeon Forest limit. Initially the fire was small, and was twice held. However, under the influence of strong southerly winds (Fig. ii) it became a more serious fire on May 3, extending some 22 km northwards to Roland Lake. The fire continued to expand northwards and westwards on May 4, reaching west to Frazer Lake and north to within 4 km (Krug Lake) of McIntrye Bay on Lake Nipigon.

On May 5 the winds veered from southerly to southeasterly (Fig ii) and strengthened considerably. Under these conditions, the fire expanded rapidly westwards, engulfing the research sites in its path. By the end of the day, the fire had burned up to the Black Sturgeon Road between Eskwanonwatin Lake and the southern end of Black Sturgeon Lake, and to the eastern shore of Black Sturgeon Lake almost to the northern boundary of the limit (Fig. i). On May 6 heavy rain extinguished the fire. In the four days that the fire was active, 50,000 ha of forest and cutover were burned.

More detailed information on the fire may be obtained from the Ontario Ministry of Natural Resources, Fire Management Centre.

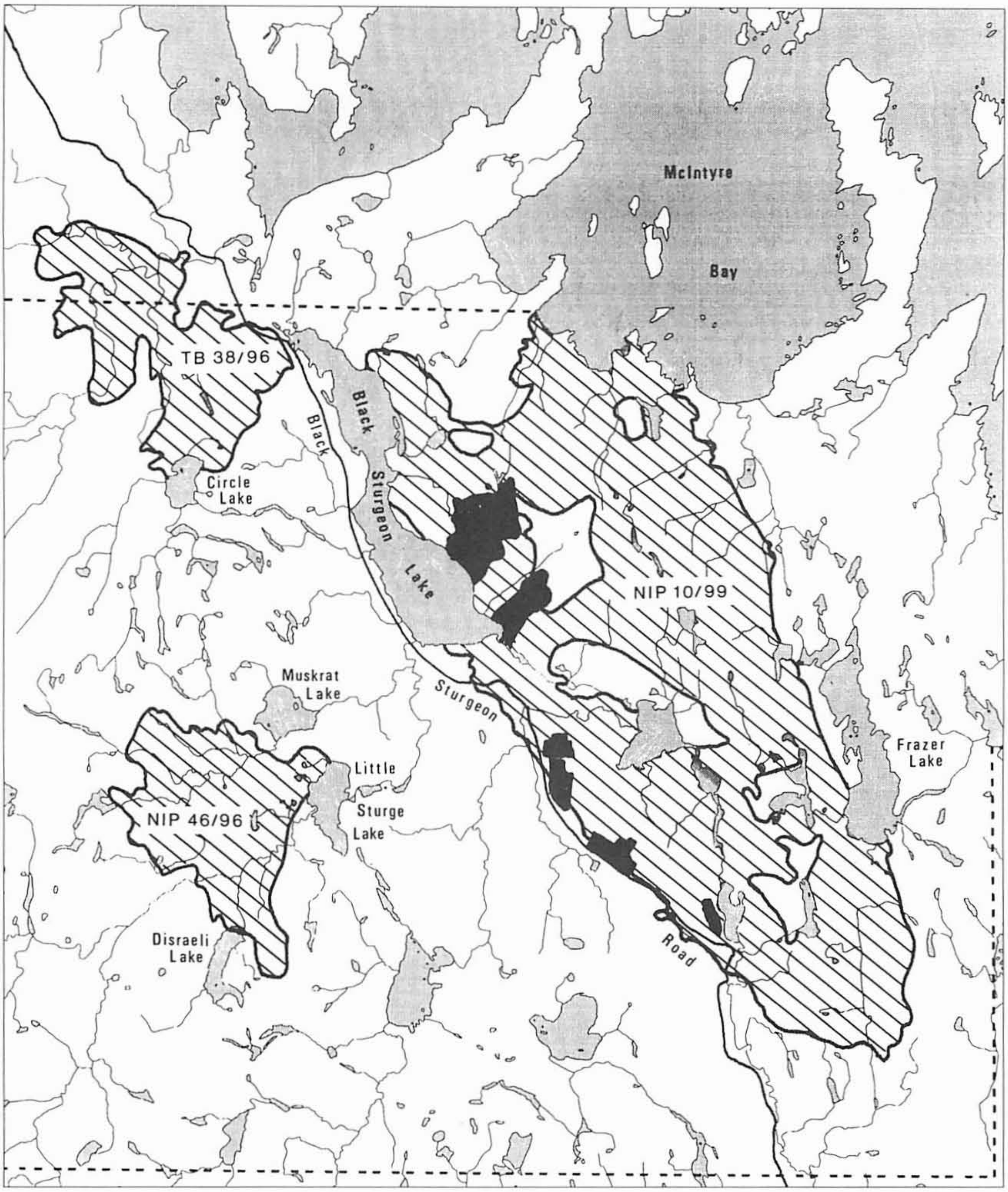

Figure i. Extent of the 1999 Black Sturgeon fire (NIP 10/99). The two fires of 1996 (see footnote 4, Section 2.5.1) are also delineated (NIP 46/96 and TB 38/96). Broken lines indicate the boundaries of the central block of the Black Sturgeon Forest limit. Experimental areas of the Black Sturgeon Boreal Mixedwood Project are delineated in solid black.

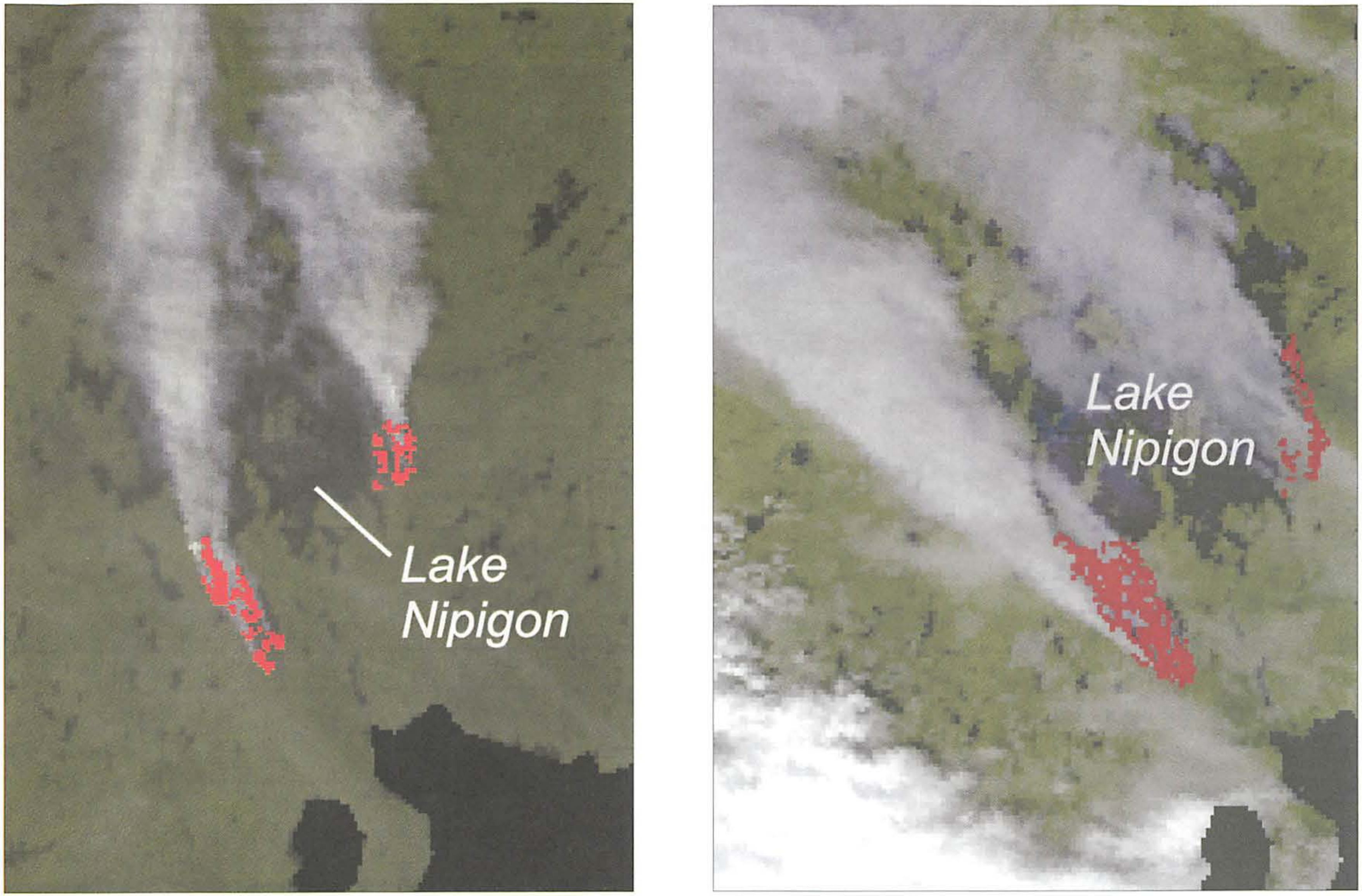

Figure ii. Radarsat image of Nipigon Fire 10/99 on May 4 (left) and May 5, 1999 (right). Note change in wind direction on May 5. Source: Natural Resources Canada, Canada Centre for Remote Sensing/Canadian Forest Service, Fire m3 System Project (http://fms.nofc.cfs.nrcan.gc.ca/firem3/maps/regional/ont_19990504.jpg and ont_19990505.jpg)

Scarratt, J.B. 2000. The Black Sturgeon Boreal Mixedwood Research Project: Establishment Report. Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON.

ABSTRACT

A multidisciplinary, multi-agency project has been established in the Black Sturgeon Forest near Thunder Bay, Ontario, to study the long-term effects of disturbance on stand-level forest succession, ecosystem processes, and wildlife dynamics in a second-growth boreal mixedwood forest. The goals are to compare forest and ecosystem responses to conventional and alternative silvicultural treatments, to fire, and to other disturbance factors. The aim is to gain a better understanding of the complex ecological relationships that exist within boreal mixedwood ecosystems. The knowledge gained will help to establish a stronger ecological foundation for the sustainable management of these forests for timber and non-timber values.

Initiated in 1993, the project currently comprises three main components that evaluate the ecological impacts and responses to clearcut and shelterwood harvesting regimes, to prescribed fire, and to different mechanical site preparation treatments. In each project component, individual studies evaluate the impacts of disturbance on forest dynamics, vegetation succession, soils, biological diversity, etc. A fourth component, concerned with the response of aquatic ecosystems to forest disturbance, is in the final stages of pretreatment baseline data collection, prior to installation of harvesting treatments.

This Establishment Report provides details of the main treatments for each project component, supplemented by maps and other descriptive information, together with sources of pre- and post-disturbance baseline data. The report also contains extensive background information on the geology, soils, climate, ecology, and forest history of the research site.

Keywords: alternative forestry practices, alternative silviculture, aquatic ecosystems, biological diversity, boreal mixedwoods, ecosystem processes, fire ecology, forest dynamics, forest succession, forest renewal, harvesting, impacts of forestry practices, integrated resource management, partial cutting, prescribed burning, site preparation, wildlife dynamics.

RÉSUMÉ

Un projet multidisciplinaire et interorganisme a été établi dans la forêt de Black Sturgeon, près de Thunder Bay (Ontario), pour étudier les effets à long terme des perturbations sur la succession forestière, les processus écosystémiques et la dynamique des espèces sauvages à l'échelle des peuplements dans une forêt mixte boréale de seconde venue. Plus précisément, les objectifs sont de comparer les réactions de la forêt et des espèces sauvages aux traitements sylvicoles (traditionnels et de substitution), au feu et à d'autres sources de perturbations, afin de mieux comprendre les relations écologiques complexes qui existent au sein des écosystèmes de la forêt mixte boréale. Les connaissances acquises renforceront la base écologique pour l'aménagement durable de ces écosystèmes en tenant compte de toutes les fonctions de la forêt, y compris la production de bois.

Entrepris en 1993, le projet comporte actuellement trois volets principaux, qui correspondent aux perturbations dont les répercussions écologiques sont évaluées : exploitation (coupe à blanc et coupes progressives), feu (brûlage dirigé), et préparation du terrain (traitements mécaniques) . Dans chaque volet, des études ciblées évaluent les impacts des perturbations sur la dynamique forestière, la succession de la végétation, les sols, la biodiversité, etc. Il existe également un quatrième volet consacré à la réaction des Écosystèmes aquatiques aux perturbations forestières. Ce dernier se trouve aux dernières étapes de la collecte des données de base avant la réalisation des traitements (coupes).

Ce rapport d'implantation présente de manière détaillée les principaux traitements étudiés dans chaque volet, notamment à l'aide de cartes et d'autres données descriptives, et précise les sources de l'information de référence sur les conditions avant et après les perturbations. Il contient également d'abondantes données de base sur la géologie, le climat, l'écologie et l'histoire de la forêt étudiée.

Mots clés : pratiques forestières de substitution, pratiques sylvicoles de substitution, écosystèmes aquatiques, diversité biologique, forêt mixte boréale, processus écosystémiques, pyroécologie, dynamique forestière, succession forestière, régénération forestière, récolte, impacts des pratiques forestières, gestion intégrée des ressources, coupe partielle, brûlage dirigé, préparation du terrain, dynamique des espèces sauvages.

ACKNOWLEDGMENTS

The Black Sturgeon Boreal Research Project is a partnership between the Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, the Ontario Ministry of Natural Resources, and Bowater Inc. of Thunder Bay, Ontario. Funding for initial establishment of the project and its component studies came from a variety of sources. These included: the Canadian Forest Service, Sault Ste Marie; Ontario Ministry of Natural Resources; the Northern Ontario Development Agreement, Northern Forestry Program (NODA/NFP); the Forestry Practices Initiative of the federal Green Plan; the provincial Sustainable Development Initiative; and the Forest Engineering Research Institute of Canada, Eastern Division. Establishment of the harvesting component was funded principally through the NODA/NFP, with generous financial support from Bowater Inc. of Thunder Bay, Sturgeon Timber Ltd. of Dorion, Ontario, and the Canadian Forest Service, Sault Ste. Marie to help defray the additional costs incurred in laying out the harvesting treatments. The Ontario Ministry of Natural Resources bore the costs incurred during the planning and conduct of the prescribed burn.

The Black Sturgeon Project could not have been established without the support and cooperation of numerous individuals, many not directly involved in the research program — government staff, forest industry personnel, harvesting machine operators, students, and others. Special thanks go to Paul Addison, Margaret Carruthers, Dave Cleavely, Terry Curran, Alan Harris, Don Harris, John Harris, Keith Harris, Ed Hyland, Bob Johnson, Bill Klages, Roy Klein, Ed Klemmer, Don Lupponen, Don Macalpine, Jim Miller, Bill Murphy, Bill Roll, Gordon Simpson, Brian Sykes, and Paul Ward for their support and encouragement in the establishment of this project. Thanks are also extended to those research staff who were instrumental in surveying and laying out the experimental infrastructure, often under trying conditions; Allan Cameron, Bruce Canning, Fred Foreman, Mark Johnston, Jean-Denis Leblanc, Steve Taylor, Brad Sutherland, Bill Towill. To the management and staff of Bowater Inc. of Thunder Bay and Sturgeon Timber Ltd. of Dorion, we express our deep gratitude for their firm commitment to the project at a time (1993/94) when the forest industry in Ontario was experiencing a severe economic downturn.

As identified in the text, some of the information and/or data included in this report was contributed by participating researchers. Thanks are extended both to these individuals, and to those who contributed information to the baseline database. The assistance of Kathy Campbell, Chuck Jones and Kevin Lawrence of the Great Lakes Forestry Centre with the reproduction of satellite images and other figures is gratefully acknowledged.

NOTE

The Black Sturgeon Boreal Mixedwood Research Project is one of several Canadian Forest Service (CFS) research sites in forested ecozones across the country concerned with issues of forest ecosystem management and the impacts of forestry practices. As such, it is an important element in the Forest Ecosystem Research Network of Sites (FERNS), a national network of research sites focussed on the study of sustainable forest management practices and ecosystem processes at the stand level.

The FERNS network promotes multidisciplinary research in areas of concern, and serves to improve linkages among research sites, as well as providing a forum for information exchange and data sharing. The Black Sturgeon Boreal Mixedwood Project is unique within the network, in that it is the only one in which different operational-scale harvesting and burning treatments were established in a common cover type at the same time. General information on FERNS, together with descriptions of this and other research sites within the network, can be found on the Internet at http://www.pfc.cfs.nrcan.gc.ca/ecology/ferns/index.html

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Further information and updates on the Black Sturgeon Boreal Mixedwood Research Project may be obtained by contacting the project coordinator, as follows:

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Natural Resources Canada
Canadian Forest Service
Great Lakes Forestry Centre
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Sault Ste. Marie, Ontario P6A 2E5

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SECTION 1 - INTRODUCTION

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1.1 BOREAL MIXEDWOODS CHARACTERIZED

Boreal mixedwoods are a prominent feature of Ontario's northern landscape, where they are an important element in the mosaic of diverse forest associations that make up the boreal forest and contribute to its broad aesthetic appeal. Occupying the more fertile upland sites, mixedwoods are potentially some of the most productive forests in the boreal zone, not just in terms of timber yields, but also in terms of their biological diversity and their capacity for supporting high wildlife populations. Consequently, sustainable management of these forests has become a critical issue in recent years for a broad range of interest groups.

Boreal mixedwoods take many forms, encompassing stands with varying proportions of two or more of five defining species: white spruce (*Picea glauca* [Moench] Voss)[1], black spruce (*Picea mariana* [Mill.] BSP), balsam fir (*Abies balsamea* [L.] Mill.), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). A number of secondary tree species may also be present, especially in the southern parts of the boreal zone at the transition with the Great Lakes-St. Lawrence Forest Region (Rowe 1972). These include jack pine (*Pinus banksiana* Lamb.), white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), eastern hemlock (*Tsuga canadensis* [L.] Carrière), eastern white cedar (*Thuja occidentalis* L.), largetooth aspen (*Populus grandidentata* Michx.), balsam poplar (*Populus balsamifera* L.), black ash (*Fraxinus nigra* Marsh.), and white elm (*Ulmus americana* L.).

Mixedwood stands typically occur in upper and midslope positions on gently to moderately sloping terrain, occasionally extending to lower slope positions where conditions allow (Gordon 1981). The fullest expressions of the mixedwood condition are found on a broad range of fresh to moist, rich sites, represented by well-drained to imperfectly drained, intermediate to finely textured soils (loams to clays) that commonly support rich herb and shrub vegetation (Pierpoint 1981). Drier, less rich sites and very moist to somewhat wet sites complete the range of boreal mixedwood sites (*ibid.*), usually with reduced tree species composition, less rich understory vegetation, and lower productivity. White birch and jack pine are often important components of mixedwood stands on drier, coarser soils.

In Ontario, boreal mixedwoods are complex and dynamic forest associations. In general, the main associations represent different successional stages of the mixedwood condition — as pioneer species give way to later successional species, stands convert to other types. However, species composition, stand structure, and successional dynamics can vary tremendously, both spatially and over time, depending not only upon local soil and site conditions but also on the nature, severity, timing, and frequency of past disturbances. Hence the difficulty, and illogicality, of attempting to define boreal mixedwoods solely on the basis of current stand composition, which may be the result of some past coincidence of essentially random events (e.g., seed supply, climate, disturbance) and which, in a successional sense, also may be ephemeral. In these circumstances, only a site-based definition can adequately circumscribe the various expressions and dynamics of boreal mixedwoods on the landscape, and at the same time provide a logical basis for classifying individual stands. Rather than a classification based on specific stand composition, we therefore recognize a range of *mixedwood sites* that are capable of supporting closed canopies dominated by one or more of the five defining species at specific stages in the successional development of stands (see MacDonald 1995 for a more detailed discussion).

Non-tree species should also be included in the concept of boreal mixedwoods, not only from an ecological viewpoint, but also because they can be a significant consideration in the management of mixedwoods (MacLean 1960; Armson 1988; Peterson 1988; Wedeles et al. 1995a). Competition from shrubs and non-woody species can present a major obstacle to the establishment and growth of tree regeneration, while many non-tree species are

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[1]Throughout this report, botanical nomenclature for trees and shrubs follows the familiar standard set by Farrar (1995); for other vascular plants, the nomenclature follows Morton and Venn (1990).

important providers of habitat or food for wildlife (Wedeles et al. 1995; Wedeles and Van Damme 1995). Shrubs such as mountain maple (*Acer spicatum* Lamb.) and beaked hazel (*Corylus cornuta* Marsh.) are characteristic understory species, especially on more fertile sites, and often form a low light-excluding canopy in older stands. The typically species-rich herb and lesser shrub vegetation may include wild sarsaparilla (*Aralia nudicaulis* L.), large-leaved aster (*Aster macrophyllus* L), blue bead lily (*Clintonia borealis* [Aiton] Raf.), bunchberry (*Cornus canadensis* L.), bush honeysuckle (*Diervilla lonicera* Miller), twinflower (*Linnaea borealis* ssp. *longifolia* [Torrey] Hultén), wild lily-of-the-valley (*Maianthemum canadense* Desf.), prickly wild rose (*Rosa acicularis* Lindley), dwarf raspberry (*Rubus pubescens* Raf.), and starflower (*Trientalis borealis* Raf. ssp. *borealis*), plus various feathermoss species.

Prior to European settlement and the commercial exploitation of northern forests, periodic catastrophic disturbance was a defining feature of the boreal zone. Natural disturbances such as extensive wildfires and insect infestations, especially of the spruce budworm (*Choristoneura fumiferana* Clem.), were an integral part of the ecology of upland boreal forests (Rowe 1972), ensuring their periodic renewal, driving the successional cycle, and maintaining their spatial and temporal diversity (see Sections 2.5 and 2.6 for a more detailed discussion). This cycle of disturbance, involving the progressive succession of pioneer and later successional species followed by renewed disturbance, had continued since the last glaciation, with periodic catastrophic destruction being the principal agent of forest renewal.

Most of the forests that exist today reflect the considerable impact of recent human intervention in modifying natural forest succession. At first, slash burning following clearance of land for settlement simply increased the incidence of wildfires. But in this century, other human activities — principally harvesting and strict fire protection — have wrought subtle ecological changes. The result is a significant increase both in the area of mixedwood cover types and their hardwood content, reflecting a greater proportion of early successional stands. The increased content of trembling aspen in second-growth[2] stands coupled with its high regenerative capacity not only poses problems in terms of wood utilization and conifer regeneration, but also increases the potential for disease and pest problems (e.g., forest tent caterpillar: *Malacosoma disstria* Hbn.). At the same time, fire protection has favoured the regeneration of balsam fir, greatly increasing its presence in many second-growth stands and thereby increasing the susceptibility of these stands to periodic spruce budworm infestations. Despite silvicultural efforts to re-establish spruce after harvesting, a recent regeneration audit (Hearnden et al. 1992) indicates that the trend to early successional mixedwood types is likely to continue under present forest management policies and practices.

A revealing commentary on these recent compositional changes can be found in the name given to certain mixedwood slope forest types in earlier times. In the 1940s and 1950s the management and perpetuation of boreal *"spruce-fir complex"* forests excited considerable interest among foresters and researchers in Ontario (e.g., Long 1946; Larsson and Wilkes 1947; Larsson and Lyon 1948; Candy 1951; Hosie 1953, 1954; Place 1955; Ghent 1957; MacLean 1959, 1960; Switzer 1960; Haddock 1961; Hughes 1967). This term implies mixedwood stands with substantially higher conifer contents, especially of spruce, than found today. These previously unmanaged stands, commonly at the late-successional stage, were usually the product of previous major disturbances such as fire. They were often characterized by high white spruce contents (Mulloy 1930; MacLean 1960) and, despite the difficulties of regenerating the spruce, were recognized to have high commercial potential. Today, however, the term *"spruce-fir"* is rarely encountered in Ontario, for these original forests are mostly gone, to be replaced by early and mid-successional second-growth *"boreal mixedwoods"* with greatly increased proportions of trembling aspen.

Rowe (1972) records the occurrence of spruce-fir-hardwood mixedwoods in all nine sections of the Boreal Forest Region in Ontario (B.4, B.5, B.7, B.8, B.9, B.10, B.11, B.14, and B.22a). The forest type appears to reach its optimum development in Sections B.8, B.9, B.11, and B.14 (i.e., northwestern Ontario), elsewhere being restricted to areas with more favourable soil and climatic conditions. However, even in the Claybelt (B.4) improved drainage, due either to slight changes in relief or to shallowly buried coarse drift, is often reflected in the development of fine mixedwood stands. Although not commercially significant, mixed conifer-hardwood stands *"in quality similar to those within the Northern Clay Section"* may also be found on alluvial river-bank levees in the Hudson Bay lowlands where more favourable drainage conditions prevail (*ibid.*).

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[2]Throughout this report, *"second-growth"* refers to the forest that developed following the first commercial logging of the original forest, or following forest fires that have occured since the beginning of active forest management.

The present area of boreal mixedwood forest in Ontario is estimated at some 15.8 million hectares, or 53 percent of the total productive forest within the boreal zone (Towill 1996). Despite the importance of the timber harvest from this huge forest resource to the provincial economy, mixedwoods have long suffered from a lack of strategic management. The ecological complexity of these forests and the successional changes induced by harvesting have undoubtedly inhibited past management and silvicultural efforts. With the traditional focus on exploitation and perpetuation of the spruce component, clearcutting followed by attempted conversion to conifers has long been the preferred management choice for mixedwood stands, despite high costs and uncertain benefits. Until recently, this situation was compounded by a lack of markets for the hardwood component. Only in recent years, with changing social and market forces (environmental concerns, demands for sustainable management, emergence of strong markets for poplar fibre, and new harvesting and processing technologies) has the way been opened to alternative approaches that may be more ecologically acceptable.

1.2 CHANGING MANAGEMENT CRITERIA

As in many other parts of Canada, there has been much debate, both public and political, concerning the future of Ontario's forests. Although this debate is undoubtedly far from over, in the past decade it has already brought about a number of critical changes that promise to profoundly affect the manner in which these forests are managed and used. These include decisions and policy changes resulting from the provincial Class Environmental Assessment of Timber Management on Crown Lands in Ontario (1988-1992), the setting of a new business relationship with the forest industry, the promulgation of a new Crown Forest Sustainability Act (1995), the issue of forest certification, and the Lands for Life debate (1999). In this new forest policy environment, the forest industry is being challenged as never before to shift its focus from purely consumptive timber values to a more comprehensive approach that recognizes the importance and benefits of a broad range of other forest values — social, economic, biological, and environmental. This is reflected both in the growing commitment to promote sustainable, ecosystem-based forestry practices, and increased support for the concept of integrated resource management.

The current interest in Ontario's boreal mixedwoods (e.g., Smith and Crook 1996) exemplifies this changed outlook. This is part of a national resurgence of interest in mixedwood management, reflected in numerous position papers and symposium proceedings, that dates from the 1980s (Weingartner and Basham 1979; Whitney and McClain 1981; Wein et al. 1983; Kabzems et al. 1986; Samoil 1988; Peterson et al. 1989a, 1989b; Shortreid 1991; Stelfox 1995).

Initially, the impetus for more intensive management of boreal mixedwoods was timber-oriented, a situation fuelled in more recent years by the rapidly increasing demand for aspen fibre. Although wildlife values have always been an important consideration in discussions on mixedwood management, interest in the merits and preservation of other non-timber values began to emerge as a serious management issue only in the late 1980s. Subsequently, with this more ecologically focussed outlook, sustainable management of the entire forest resource complex emerged as the Holy Grail of the 1990s, paralleling calls for silvicultural practices that emulate natural ecosystem dynamics (e.g., Bergeron and Harvey 1998). While the sustainable management of forests is by no means a revolutionary concept among foresters, especially those acquainted with early European forest management principles (e.g., Knuchel 1953), until relatively recently it was concerned primarily with the sustainability of timber yields. Over the past decade, however, changes in public attitudes to forest management and use have increased our appreciation of the importance of non-timber forest values and the need to adopt much more inclusive forest sustainability policies. In northern Ontario, this is especially true in the management of mixedwood forests.

Boreal mixedwoods, because of their diversity, aesthetic appeal, and rich flora and fauna, probably elicit broader interest — in terms of recreational, spiritual, and biological values — than any other boreal forest type in Ontario. As a result, demands for the stewardship of non-timber values are likely to be increasingly influential in future decisions relating to mixedwood management. If we are to continue to practice economic forestry in these cover types, it is clearly essential that capabilities be developed for applying a more holistic approach to forest management that can accommodate the often divergent needs and goals of different interest groups, and at the same time address broader environmental concerns. Contrary to the views of some environmental advocates, maintaining the desirable ecological features of boreal mixedwoods (e.g., biodiversity, wildlife habitat) will require no less active forest management, including the appropriate use of fire, than will timber production goals.

Although the application of these ideas will inevitably bring changes in forest management, it does not imply a need for any wholesale abandonment of current practices. Integrated resource management does not mean that we will manage for everything, everywhere, all the time. Rather, it means that individual mixedwood stands should be managed in a manner that best satisfies currently prescribed goals and priorities, both of which may vary in space and time for the same block of forest. Because land use policies rarely allow for a division of the land base to permit single-use management, the focus of forest management must be on balancing and integrating the needs of all users of the forest. Thus, in areas designated primarily for timber production, current practices will probably persist well into the foreseeable future, albeit under stricter control and employing more environmentally sensitive harvesting technologies. However, in those areas where timber production is declared secondary to non-timber values or where clearcutting is specifically prohibited (e.g., riparian and wildlife reserves, visually sensitive landscapes, public-access areas), alternative practices may be more appropriate, especially ones that retain varying levels of stand structure or that deliberately encourage mixedwood succession.

1.3 PROJECT OVERVIEW

Despite government commitments to implement sustainable, ecosystem-based forest resource management, in reality the basic biological and ecological knowledge needed to guide such management is often woefully lacking. This is especially true of such complex and dynamic ecosystems as boreal mixedwoods, for which a much better understanding of the component ecosystems is needed — their structure and function, their response to natural and human disturbances, and the interrelationships among different ecosystem elements (e.g., vegetation, nutrients, wildlife, pests and diseases, etc.). Such knowledge and understanding is crucial to building a strong foundation for the development of ecosystem-based management strategies that not only will maintain or enhance biological diversity and ecological values, but also satisfy demands for timber and other economic resource benefits.

The Black Sturgeon Boreal Mixedwood Research Project was established in 1993 to address these needs through multidisciplinary research that focuses on long-term ecosystem response to disturbance and silvicultural manipulation in second-growth mixedwood stands (Scarratt 1996). The long-term impacts of human intervention have been little studied in boreal ecosystems. While the broad objective is to increase our overall understanding of ecological processes and relationships in boreal mixedwoods, the thrust of the project is defined by a number of more specific questions with forest management implications, *viz:*

- What are the impacts of current and alternative forest management practices upon boreal mixedwood ecosystems, their biological diversity and productivity, and the sustainability of timber and non-timber values?
- Can mixedwoods be managed continuously as mixedwoods with predefined stand composition?
- Are canopy retention systems that preserve some level of stand structure a viable silvicultural and ecological alternative to clearcutting for managing boreal mixedwoods?
- To what extent does clearcutting mimic the ecological impacts of natural fire disturbance on mixedwood sites?
- How can we best manage mixedwoods for ecological, environmental and recreational values while assuring continuity of timber supplies?

The project is located in the Black Sturgeon Forest, approximately 120 km northeast of Thunder Bay, Ontario (Fig. 1.1), an area with a high proportion of mixed forests. Important contributory factors in the selection of this location were the long history of federal and provincial research in the area (some of it dating back to the mid-1940s), the importance of boreal mixedwoods in the industrial economy of the Thunder Bay region, and the forest's proximity to prospective provincial government and academic research partners. While past research on the biology and population dynamics of the spruce budworm is perhaps the best known and certainly of longest duration in the Black Sturgeon Forest, much other forestry and wildlife research has been conducted in the area over the years. The knowledge generated by this concentration of past research activities is a valuable legacy for the new project (see Section 7.0).

The project is located in stands that were first harvested in the early to mid-1940s. Forest conditions and the management problems they pose are typical of second-growth mixedwoods throughout much of boreal Ontario. These include greatly increased proportions of trembling aspen and balsam fir compared to the original coniferous or mixed forest, reduced spruce contents and conifer values, and a host of silvicultural problems relating to under-utilization of the hardwood component. Furthermore, prolific aspen regeneration after clearcutting, and the associated costs of controlling it, greatly constrain the manager's ability to maintain an acceptable spruce component in future stands. At the same time, the increased balsam fir content of second-growth stands, coupled with this species' high regenerative capacity relative to spruce and its susceptibility to spruce budworm attack, greatly exacerbate management difficulties. This last is exemplified in the Black Sturgeon Forest, where an extended spruce budworm outbreak has significantly reduced the merchantable value of many stands in recent years (see Section 2.6).

Figure 1.1 Geographic location of the Black Sturgeon Boreal Mixedwood Research Project (indicated by ★).

Despite their relatively young age (≈55 years in 1993), these budworm-infested mixedwood stands were scheduled to be commercially clear-cut in 1994-95 to salvage as much as possible of the conifer while it was still in a merchantable condition. The increased market demand for the aspen component made this a viable option. These circumstances presented an opportunity to explore the long-term ecological consequences of alternative harvesting and silvicultural strategies for second-growth stands within an operational context. The timing was also fortuitous from an ecological perspective, for it coincided with the end of the recent spruce budworm outbreak and a period of maximum fire hazard for this forest. As such, it represented a significant natural milestone in the development of these stands which, in the absence of fire protection, could have led to another of the periodic cataclysmic wildfires that these forests have experienced in the past (such fires occurred elsewhere in the Black Sturgeon Forest in 1996 — see Section 2.5.1). Even in the absence of fire, the compositional and structural changes resulting from the heavy conifer mortality mark the beginning of a new phase of stand succession for non-harvested stands that can be expected to change the character of the forest significantly over the next few years.

The Black Sturgeon Project adds human intervention to these natural disturbances, perhaps opening the way to different successional pathways. Currently (1999), the project comprises three active multidisciplinary components that seek to determine the impacts and ecosystem responses to different harvesting and silvicultural treatments, *viz:*

- Harvesting impacts component: examines the impacts of alternatives to clearcutting, and subsequent regeneration treatments, on forest succession, tree regeneration, residual stand growth, and a broad range of ecosystem elements. (Section 3.0)
- Fire ecology component: examines the impacts of large-scale prescribed fire on vegetation succession and soil nutrient dynamics. (Section 4.0)
- Site preparation alternatives component: examines the effects of intensive mechanical soil mixing versus surface organic matter removal on spruce regeneration, vegetation regrowth, and soil processes, and on the abundance and diversity of soil invertebrates and soil microflora. (Section 5.0)

A planned fourth component, concerned with the effects of current and alternative harvesting practices on the aquatic habitats and associated biota of forest headwater streams, is currently at the stage of pre-harvest baseline data collection. It is scheduled to be harvested in 2000/2001. A brief description is given in Section 6.0

This report records reference information with respect to initial establishment of the Black Sturgeon Boreal Mixedwood Research Project. It commences with a description of the general characteristics of the research site (Section 2.0), followed by descriptions of the three active project components (Sections 3.0 to 5.0), the proposed aquatic ecosystem responses component (Section 6.0), and miscellaneous research studies (Section 7.0). Sections 3.0 to 5.0, supplemented by appendices, provide details of pre-disturbance stand characteristics, project layouts and treatments, harvesting records, and immediate post-disturbance site and stand conditions. Relevant baseline databases are noted where these are available for general distribution (Appendix 7). Individual studies within the project are not described, for these are continually changing. However, a listing of studies active during the period 1993-98 is provided in Appendix 6; updated listings with study abstracts are available from the Project Coordinator.

SECTION 2 - GENERAL DESCRIPTION OF RESEARCH SITE

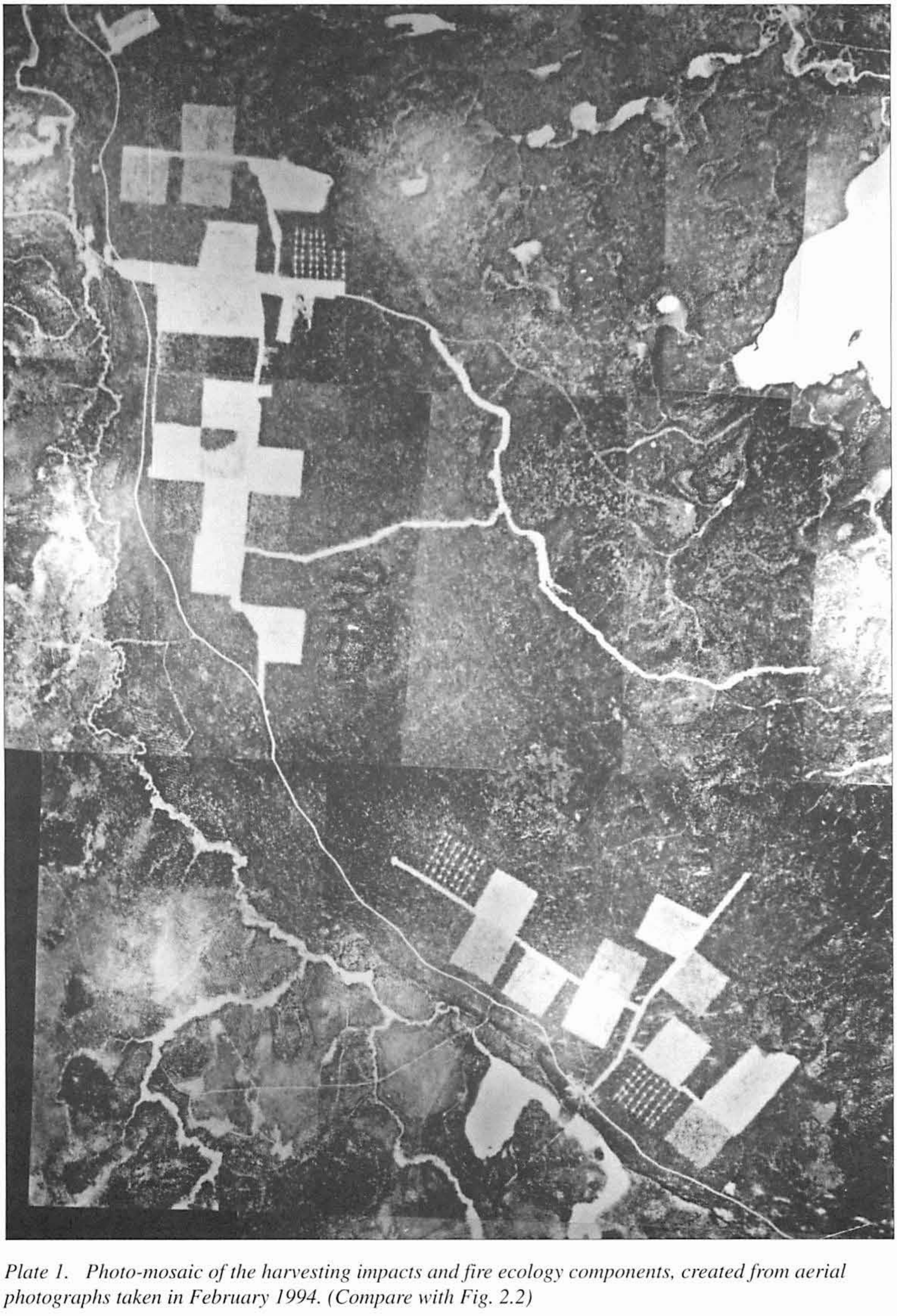

Plate 1. Photo-mosaic of the harvesting impacts and fire ecology components, created from aerial photographs taken in February 1994. (Compare with Fig. 2.2)

SECTION 2 - GENERAL DESCRIPTION OF RESEARCH SITE

2.1 LOCATION

The main research site, comprising the harvesting impacts, fire ecology, and site preparation alternatives project components, is situated in the Black Sturgeon River valley approximately 120 km northeast of Thunder Bay, Ontario (Fig. 2.1). It is located within the Central Block (hereafter referred to as the Black Sturgeon Forest) of the Black Sturgeon Limits licenced to Bowater Inc. of Thunder Bay. Centred on latitude 49°11.4'N and longitude 88°42.5' W (project headquarters), the site is bisected by the western boundary of Adamson Township, running northwards from its intersection with the main Black Sturgeon logging road. For the purposes of this report, the research site is defined as the plateau and mixedwood slopes lying immediately to the east of the Black Sturgeon road, between the Nonwatin River in the north and Eskwanonwatin Lake in the south. In addition to the three project components established on the site, large areas of adjacent forest were clearcut operationally between 1993 and 1996.

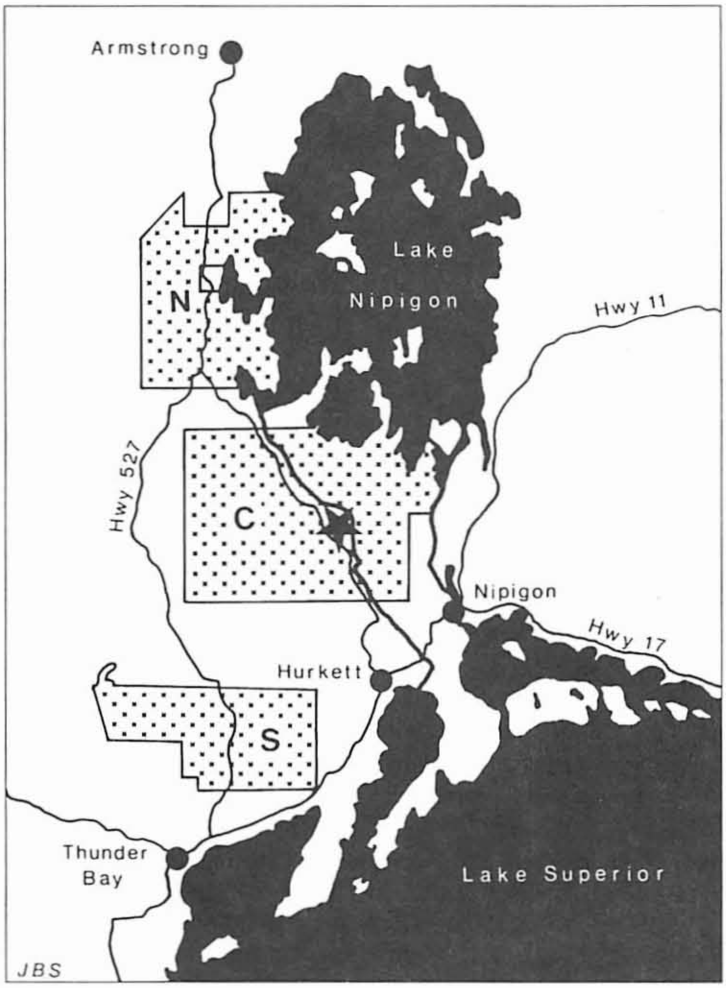

Figure 2.1. Location of the Black Sturgeon Boreal Mixedwood Research Project (indicated by ★) in relation to local features. (Three separate blocks of forest constitute the Black Sturgeon Limits, viz: N = North Block [Gull Bay]; C = Central Block [Black Sturgeon Forest]; S = South Block [Current River])

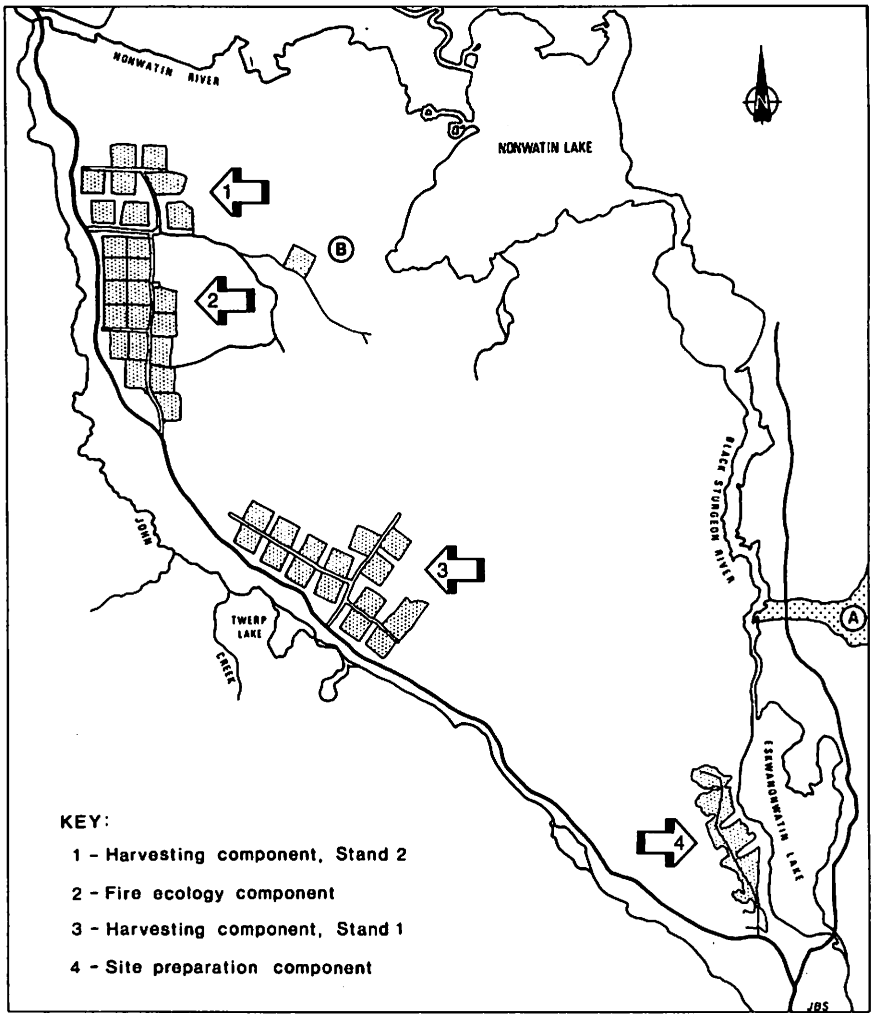

Figure 2.2 The research site, showing locations and layout of harvested compartments for the main project components. (A = reference watershed of aquatic ecosystem responses component - see Section 6.2; B = bird monitoring plot (OBP) - see Section 7.1.2)

The locations of the three active project components are indicated in Figure 2.2; the area covered by this map extends from kilometre 38 to kilometre 57 on the Black Sturgeon road north of its intersection with the Trans-Canada Highway (Hwy. 17) at the community of Hurkett. The photo-mosaic in Plate 1 shows the harvesting impacts and fire ecology components as viewed from the air in February 1994. The scheduled fourth component of the project (aquatic ecosystem responses to harvesting) is located further north and comprises three watersheds on the southeastern shore of Black Sturgeon Lake (see Fig. 6.1).

Map coverage of the site for various physical and land resource categories is listed in Appendix 1.

2.2 GEOMORPHOLOGICAL AND TOPOGRAPHICAL SETTING

2.2.1 Geology

This sub-section is based largely on Coates (1972).

The Black Sturgeon Forest, and much of the area south of Lake Nipigon, is underlain by bedrock of Precambrian age, which has been deeply eroded by glacial activity and meltwater overflow from the Nipigon basin. In most places, the bedrock is covered by glacial deposits and recent swamp deposits.

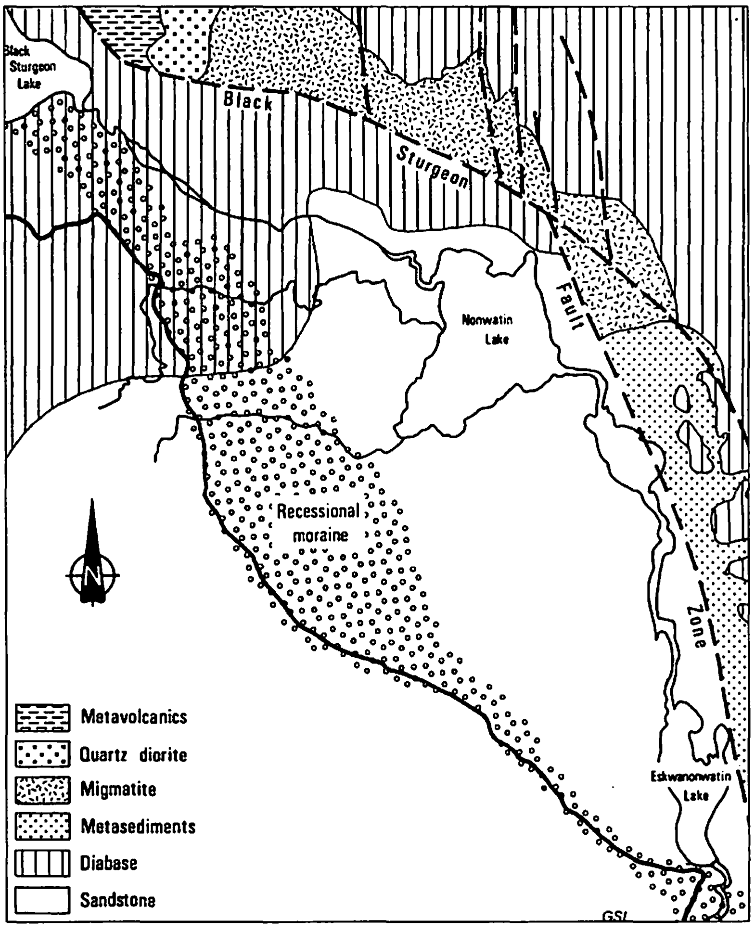

Figure 2.3 Surficial geology of the research site, showing location of recessional moraine.

The oldest rocks in the vicinity of the research site are steeply dipping clastic sedimentary and volcanic rocks of Archean age. These outcrop as a narrow band of high ground to the north and east of the Black Sturgeon Fault (Fig. 2.3), evident in the escarpment to the east of the Black Sturgeon River valley, and extending northwards to form the hills east of the southern half of Black Sturgeon Lake. The Archean was a time of great volcanic activity and the deposition of immense thicknesses of sediments. The resulting rocks were subsequently folded, faulted, metamorphosed, and intruded by granitic rocks during the late-Archean Kenoran Orogeny (Stockwell et al. 1970). Archean metavolcanic (metamorphosed volcanic) rocks, mostly medium to dark grey-green horneblende and chlorite schists, occur immediately northeast of the southern end of Black Sturgeon Lake. Metasedimentary rocks of similar age occur east of Nonwatin and Eskwanonwatin Lakes, where they outcrop on the fault escarpment. The dominant rock-type is a greywacke type, biotite-quartz-feldspar gneiss. Between these two areas of distinct rock types there occurs a complex of hybrid (i.e. mixed) metavolcanics and metasediments with granitic intrusions, called migmatite.

After the Kenoran Orogeny the Archean rocks were deeply eroded and the resulting basins filled with Proterozoic sedimentary deposits (Stockwell et al. 1970). Over much of the area south of Lake Nipigon, including the Black Sturgeon Forest and the research site, the Archean basement complex is directly overlain by younger Precambrian (Proterozoic) rocks formed from these deposits. These are mostly unmetamorphosed, flat-lying or gently sloping sedimentary rocks of the Sibley Group. They comprise principally sandstones, siltstones, mudstones, and shales. Layers of limestone and dolomitic mudstones are present throughout these deposits, especially at higher levels in the stratigraphic section. Intrusive Keweenawan diabase sills are intercalated throughout the Sibley sedimentary rocks and along the unconformity at the base of these sediments.

While sediments within the Sibley Group include white quartz sandstones, for the most part they tend to be various shades of red. The principal rock types are dark red to purple mudstones and shales that were laid down in the shallow waters of a lake or inland sea, and red sandstones deposited by rivers as flood-plain detritus (Pye 1969). The red colour of these rocks, which gives the surficial glacial deposits on the research site their distinctive colour, is due to the presence of small amounts of haematite.

The area underlain by sedimentary rocks of the Sibley Group is roughly oval in shape, approximately 20 by 40 km in extent, and bounded on the east by the Black Sturgeon Fault, extending north to Nonwatin Lake and west to Sturge Lake. Further to the north and west, extensive areas of the Black Sturgeon Forest, including Black Sturgeon Lake, are underlain by Keweenawan diabase (Fig. 2.3) which covers the Sibley sedimentary rocks in a continuous sheet that appears to be over 30 m thick (Coates 1972).

(Section 2.2.1 was prepared with the assistance of G.S. Lucuik, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario)

2.2.2 Recent glacial history

Most of North America north of 40°N was heavily glaciated during the Pleistocene era. However, the ice coverage was neither continuous nor permanent on all affected areas for the entire glacial period. Over the million-year course of the Pleistocene there were four main periods of glaciation, each of approximately 100,000 years duration, separated by long interglacial periods when the glaciers retreated. The climate during these interglacial periods was as warm or warmer than today, and under such conditions a rich and varied flora and fauna must have occupied most parts of Canada (Prest 1970).

Because each glacial advance obliterated evidence of the previous glaciation, the glacial history of the Great Lakes basin is known with any measure of certainty only for the fourth and final period — the Wisconsin glaciation. This began about 100,000 years ago (Prest 1970), blanketing the entire basin with a thick covering of ice until about 15,000 B.P (before present). Re-emergence of the land from this mantle of ice dates from perhaps only 14,000 years B.P. at the southern edge of the Great Lakes basin to as recently as 9,000 years B.P. at its northern edge (Prest 1970; Bailey and Smith 1981). Far from the ice retreating from the basin at a uniform rate, however, the progress of deglaciation showed considerable fluctuation. Depending on climatic conditions, it was marked by periods when the ice was static for lengthy intervals, periods when retreat of the ice accelerated, and periods when the ice re-advanced.

The glacial history of the area occupied by the Black Sturgeon Forest is not specifically addressed in the literature, and what follows is deduced from descriptions of inferred events over broader areas (e.g. Zoltai 1965; Terasmae 1967; Prest 1970; Saarnisto 1974, 1975; Bailey and Smith 1981; Clayton 1983; Teller and Thorleifson 1983; Farrand and Drexler 1985; Teller 1985). The simplified chronology given below attempts to harmonize the views of these and other writers, bearing in mind that estimated dates given in the literature are not always in agreement. For a graphic overview of the glacial chronology of the Great Lakes basin the reader should refer to the series of paleogeographical maps of ice-margin boundaries delineated in Prest (1970).

Glaciers last filled the Lake Superior basin, which includes the Black Sturgeon Lake area, about 11,800 years ago, during the southwesterly Valders readvance of the Wisconsin glacier (Wright and Watts 1969; Prest 1970; Saarnisto 1974). Evidence from radiocarbon dating of lakes samples and analysis of pollen samples for eastern North America indicates an abrupt change in climate between 11,000 and 10,000 years ago (Broecker et al. 1960; Ogden 1967), which precipitated a rapid retreat of the ice. There was a progressive deglaciation of the Great Lakes basin during late-Wisconsin and early Holocene times (Saarnisto 1975), with the Lake Superior basin being one of the last portions to be released from the ice (Prest 1970). By 11,600-11,500 B.P. proglacial Lake Duluth, later (10,300 years B.P.) to become Lake Minong, occupied the western part of the Superior basin. This marked the first appearance of a permanent lake in the Superior basin as the ice retreated northwards (Bailey and Smith 1981). Continued deglaciation and crustal rebound caused water levels in the basin to fall rapidly through several post-Lake Minong stages that were characterized by a succession of ice- and moraine-dammed lakes with ever-changing levels, extents, and outlets. During this time, drainage patterns and directions often changed dramatically when ice-dams collapsed or when new spillways were opened up as the receding glacier exposed fresh drainage channels.

By about 8500 B.P., the ice had retreated north of the Nipigon basin and the height of land separating the Superior and Hudson Bay (Lake Agassiz) watersheds (Teller and Thorleifson 1983; Teller 1985), leaving behind Lake Kelvin, the precursor of modern Lake Nipigon, and Lake Houghton (post-Lake Minong), the precursor of Lake Superior, to the south. It is clear that, up until this time, huge water discharges from Lake Agassiz played a major role in shaping the topography of the Black Sturgeon watershed. During the period 9500-8700 B.P., various connections existed between the Lake Superior basin and the giant Lake Agassiz basin to the west (Zoltai 1965; Prest 1970; Saarnisto 1974, 1975; Farrand and Drexler 1985). Teller and Thorleifson (1983) mapped five successive groups of channel complexes that carried overflow from the Agassiz basin eastwards into the Nipigon (Lake Kelvin) basin and thence southwards into Lake Superior (Lake Minong-Houghton). They have postulated catastrophic floodwater surges into the Nipigon basin as each of these channel complexes was freed of its ice barrier. These events discharged huge volumes of water into the Nipigon basin over relatively short periods, which then overflowed into the Superior basin via a sixth channel complex, shaping the land south of present-day Lake Nipigon. Initially, the overflow from Lake Kelvin (Nipigon) to Lake Minong-Houghton (Superior) traversed the area now occupied by the Black Sturgeon Forest via the Wolf, Wolfpup, Shillabeer, and Black Sturgeon spillways (see Fig. 7 in Teller and Thorleifson 1983). Later, with the continued eastward retreat of the ice from the Nipigon moraine (Zoltai 1965), the Nipigon, Cash, and Pijitiwabik spillways also came into play (Teller and Thorleifson 1983). The extent and paleoecological importance of these early lake connections is emphasized by Bailey and Smith (1981), who reviewed the chronology of inferred post-glacial lakes and their past significance as fish habitats and species dispersal routes among now-disconnected drainage systems. Lakes Nipigon and Superior reached their modern configuration only after 6,000 B.P. (Bailey and Smith 1981).

Although Lake Kelvin discharged into Lake Superior through both the Black Sturgeon and the Nipigon spillways about 9500 years ago, they probably functioned at different times (Zoltai 1965). "*The Black Sturgeon spillway was initiated when the morainic dam, restricting Lake Kelvin from occupying the formër basin of Lake Sturge, was breached. The Nipigon spillway, initially blocked by glacial drift, may have functioned together with the Black Sturgeon outlet, but took over completely when the Black Sturgeon, its sill eroded to bedrock, was closed by differential uplift*" (*ibid.*). According to Mollard and Mollard (1981), the abandoned river channel between Lake Nipigon and Black Sturgeon Lake is now marked by an alluvial plain. However, examination of 1:50,000 topographical maps (NTS, Sheet 52 H/7, 2nd ed.; 1977) show this to be only partly true. In reality, the old channel, some 6 km long, is now filled with a chain of small lakes and swamps at its southern end, while a long (3 km) finger-like extension of Black Sturgeon Bay on Lake Nipigon fills the northern end. Except for a portage of about 1 km in the middle, presumably marking the location of the bedrock sill, the channel can be easily traversed by canoe (Epps[3], personal communication). The old channel appears to be located on the Black Sturgeon Fault Zone (Coates 1972, Map 2233).

Glaciation during the Pleistocene era stripped the bedrock of its previously weathered mantle, smoothed and planed elevated areas, and ground out new drainage channels. At the same time, old river valleys that were parallel to the direction of ice movement (mainly southwesterly) were gouged and deepened. Then, as the glaciers retreated and lake levels dropped, they left a discontinuous mantle of glacial tills, outwash deposits and old lake deposits over the eroded bedrock (Zoltai 1965). This mantle was often resorted and redistributed when ice barriers collapsed, releasing new surges of floodwaters, changing drainage channels, and modifying the topography. Morainic, glaciofluvial and glaciolacustrine deposits of varying depth, as well as recent swamp deposits now cover large areas of the Black Sturgeon Forest limit (Mollard and Mollard 1981).

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[3]Sandy Epps, Outward Bound Wilderness School, Thunder Bay, Ontario.

2.2.3 General topography and drainage

The total area of the Black Sturgeon Forest is 2712 km^2, of which approximately 85% is forested. Of the total area, 71% lies within the Black Sturgeon River watershed. The northeastern portion of the limit (19%) drains into the Nipigon River, while a small area (10%) in the northwestern corner of the limit is tributary to the Poshkokagan River and drains into Lake Nipigon (all figures from 1970 Forest Management Plan).

As described in the preceding section, the Black Sturgeon River basin is a product of deep glacial erosion and melt-water overflow from the Nipigon basin. The terrain is characterized by mostly heavily wooded, gently rolling hills with few bedrock exposures, interspersed with large areas of lake and wetland in the northern portion of the basin. In contrast, the land to the east of the Black Sturgeon River is several hundred feet higher, with much more bedrock exposure, and falls steeply to the river. The characteristic landform of this eastern area is the mesa or cuesta, formed by brittle layers of diabase that form protective caps over the less resistant sedimentary rocks. At a number of points between Lake Nipigon and Eskwanonwatin Lake (as well as in the lower reaches of the Black Sturgeon valley), this higher land comes into close proximity with the Black Sturgeon River in the form of a prominent escarpment with often dramatic cliffs. This escarpment marks the Black Sturgeon Fault zone (Fig. 2.3), which extends northwest to the shores of Lake Nipigon and southeast to the point at which the Black Sturgeon River crosses the Trans-Canada Highway.

The Black Sturgeon River basin contains numerous lakes, of which the largest is Black Sturgeon Lake. From the latter, the Black Sturgeon River flows southwards through the Nonwatin, Nonwatinose and Eskwanonwatin Lakes, immediately to the east of the research site (Fig. 2.3), and eventually discharges into Black Bay on Lake Superior, just south of the Trans-Canada Highway. The main catchment for the basin lies to the west of the river, drained by mostly northeast-flowing streams, some fed by major lakes (e.g., Circle, Muskrat, Little Sturge, and Sturge Lakes) and, especially in the northwestern portion of the catchment, extensive areas of swamp. A number of shorter, steeper streams flow into the river from the northeast; three of the streams flowing into Black Sturgeon Lake comprise the research watersheds for the aquatic ecosystem responses component of the project (see Section 6.0 and Fig. 6.1). Drainage from the northeastern portion of the limit (i.e., east of the Black Sturgeon River basin) discharges into Lake Superior via the Nipigon River. The Wolf and Wolfpup Lakes, which once carried glacial meltwater flowing from Lake Kelvin (Nipigon) across the present-day Black Sturgeon Forest area (see Section 2.2.2), now drain directly into Lake Superior and are no longer connected to the Black Sturgeon watershed.

2.2.4 The research site

Both the harvesting impacts component and the fire ecology component of the project lie on a large recessional moraine of glaciofluvial origin, underlain by sedimentary rocks of the Sibley Group. Classified by Mollard and Mollard (1981) as a pitted and kettled delta moraine with primarily low local relief and good internal drainage, the research site appears as a relatively extensive elevated plateau when viewed from the air, dropping off abruptly to the west and east. Zoltai (1965; Fig. 3) considered it part of the Nipigon Moraine that extends in an arc for about 155 miles (249 km) along the west side of Lake Nipigon. He was probably describing the research site when he wrote that *"South of Black Sturgeon Lake it reaches the width of 1 mi and extends up to 125 ft above the surrounding country. Here the top of the moraine is remarkably level, with only minor irregularities"*. Saarnisto (1974) estimated the age of the Nipigon Moraine at 9500 years.

Most of the experimental areas are quite flat, at an elevation of ≈290 m. A few of the treatment compartments in the harvesting impacts component exhibit large depressions (e.g., Compartment 1-9), old drainage channels (Compartments 2-2 and 2-7), or morainic ridges and hummocks (Compartments 1-11, 2-1, and 2-5). The composition of the glacial overburden, derived largely from rocks of the Sibley group, shows considerable textural variation across the site. It comprises mostly coarse red sands, gravels and shales with variable amounts of silt and small cobbles. The large boulder content is generally low, although a number of large glacial erratics are to be found on the surface throughout the experimental areas.

The site preparation alternatives component is situated immediately west of Eskwanonwatin Lake on an undulating plain of glaciolacustrine origin, at an elevation of ≈240 m. The sediments are comprised mainly of stone-free silts and fine sands.

The aquatic ecosystem responses component of the project transects the Black Sturgeon Fault zone, the research watersheds rising from Black Sturgeon Lake (≈260 m) to an elevation of ≈380 m. At lower levels the sites are situated on a narrow band of Proterozoic Keweenawan diabase that occurs along the southeastern shore of Black Sturgeon Lake; on the higher ground to the northeast of the fault zone the research sites are underlain by Archean metavolcanics and metasediments (see Section 2.2.1 and Coates 1972).

2.3 SOILS OF THE RESEARCH SITE

2.3.1 Introduction

Soils of the Black Sturgeon Forest are generally very productive by northwestern Ontario standards. Carbonate rocks in the glacial overburden, derived from sedimentary deposits of the underlying Sibley Group (see previous section), probably contribute to this high fertility.

The harvesting impacts and the fire ecology components of the project are confined to an extensive glaciofluvial deposit (a recessional moraine) as described in Section 2.2.4 and illustrated in Figure 2.3. The area between this deltaic deposit and the Black Sturgeon River to the east is largely occupied by an extensive glaciolacustrine plain which extends southward to the vicinity of Eskwanonwatin Lake. The site preparation alternatives component of the project, immediately west of Eskwanonwatin Lake, is situated on the southernmost part of this glaciolacustrine plain. There are minor inclusions of ground moraine throughout the experimental area, though none of the main study plots are located on such materials.

2.3.2 Glaciofluvial deposit

In general, this deposit is characterized by deep, well-drained, cherty sands and gravels, with a 15-20 percent (volume basis) coarse fragment content. The parent material appears to be derived mainly from sandstone and other sedimentaries, largely of Sibley origin, that include sufficient carbonate rock to produce measurably higher base concentrations than otherwise might be expected in soils of the Precambrian Shield. Surface relief is generally low with kettling here and there and some gullying, especially towards the east of the research site. The dominant soil texture over the entire area is sandy loam with small inclusions of loamy sands and loams. Dominant profile types are Ferro-humic Podzols and Dystric Brunisols. Forest cover over the greater part of the area is a fairly consistent mixedwood, with small areas of pure conifer that owe their existence more to stand history than to site differences. Soil properties from a pit under a relatively pure spruce stand adjacent to Compartment 1-4 of the harvesting impacts component are given in Table 2.1. More detailed information on mineral and organic soil properties for individual compartments of this component is given in Appendices 2.2 and 2.3.

Table 2.1. Chemical properties, glaciofluvial soil.

Depth	pH_{H2O}	pH_{CaCl2}	OM_{loi}	OM_{wo}	Tot. N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Exch. Na	CEC
cm			%	%	mg/g	µg/g	----------	----------	cmol$_{(+)}$/kg	----------	----------
LFH	3.78	3.44	29.52	28.72	4.47	71.27	1.17	8.32	2.07	0.58	24.2
0-10	5.38	4.54	6.67	1.62	0.56	16.63	0.24	4.30	1.74	0.12	9.91
10-20	5.63	4.84	4.21	1.71	0.41	29.82	0.20	3.78	1.33	0.07	6.18
20-30	5.70	4.90	2.29	1.25	0.30	27.86	0.18	2.98	1.04	0.11	4.56
30-40	5.81	5.00	1.71	0.75	0.19	24.26	0.16	2.40	0.84	0.04	3.33
40-50	5.80	5.05	2.00	0.74	0.18	24.79	0.16	2.27	0.70	0.06	2.81
50-60	5.75	4.95	1.67	0.64	0.16	23.63	0.19	3.00	1.16	0.14	4.24
60-70	5.92	5.20	1.98	0.61	0.18	16.33	0.21	3.88	1.42	0.10	4.14
70-80	6.10	5.21	1.48	0.45	0.12	10.75	0.20	4.18	1.60	0.12	3.67
80-90	6.07	5.24	1.37	0.59	0.13	12.24	0.20	4.13	1.61	0.13	3.80
90-100	5.90	5.05	1.62	0.75	0.17	13.52	0.21	3.61	1.43	0.10	4.38

Values for pH in H_2O (Table 2.1) indicate a soil extremely acid in the forest floor (LFH), but only medium to slightly acid throughout the underlying mineral soil. As usual, pH values in 0.01*M* $CaCl_2$ are slightly lower than the pH in H_2O values. The low pH of the forest floor of this particular exposure reflects the almost pure coniferous cover at this point. Under mixedwood cover, especially where trembling aspen is prominent in the overstory, forest floor pHs are typically in the pH 4.5-5.5 range (see Appendix 2.3) due to the propensity of that species to cycle calcium (Ca). Values for wet oxidizable organic matter (OM_{wo}), which is a measure of reactive organic matter, are typical of boreal soils. Differences between these values and the loss-on-ignition organic matter values (OM_{loi}) indicate a relatively high proportion of recalcitrant organic matter, presumably charred matter left from old fires. This is particularly pronounced in the uppermost 10 cm of the mineral profile and may reflect one of the small localized fires, associated with early logging activities that are believed to have occurred sporadically throughout the research site some 50 years earlier. Total nitrogen (N) concentrations are typical of boreal soils. Available (Bray & Kurtz No. 1 extractable) phosphorus (P) concentrations are high, as are concentrations of exchangeable potassium (K), Ca and magnesium (Mg).

2.3.3 Glaciolacustrine deposit

On this site, immediately to the west of Eskwanonwatin Lake, the soils are comprised of mainly deep, stone-free silty clay loams. While the surface is primarily glaciolacustrine, there appears to be some post-glacial gullying as well as reworking by wind. The parent material lacks the red sandstone chert component that is prominent in much of the deltaic deposit (above) but presumably contains some carbonate material. Drainage varies from well-drained to imperfectly drained, and the relief from undulating to rolling. Dominant profile types are Dystric Brunisols and Humo-ferric Podzols. Pure spruce stands on this soil are more likely a response to site differences, mainly drainage, than is the case on the glaciofluvial deposit. Forest floor organic matter contents are in the order of 60,000 kg ha^{-1} under mixedwood cover, and substantially more in wetter areas. Soil properties from a pit in an uncut strip of forest to the east of Block D of the site preparation alternatives component (Fig. 5.1) are given in Table 2.2.

Table 2.2. Chemical properties, glaciolacustrine soil.

Horizon	pH_{H2O}	pH_{CaCl2}	OM_{loi}	OM_{wo}	Tot. N	Avail. P	Exch. K	Exch. Ca	Exch. Mg	Exch. Na	CEC
			%	%	mg/g	µg/g	----------	----------	cmol(+)/kg	----------	----------
L	5.52	5.30	88.36	71.28	20.38	275.05	2.53	49.98	6.80	0.66	69.24
H	5.72	5.50	85.85	71.77	20.44	279.20	2.34	51.26	7.31	0.44	61.67
Bf	5.42	4.85	4.06	2.14	0.86	11.20	0.17	7.53	1.16	0.11	8.71
BC	5.82	5.20	2.75	1.16	0.46	12.52	0.11	4.34	0.67	0.14	5.78
C	5.93	5.25	1.16	0.32	0.28	9.83	0.08	3.84	0.77	0.11	4.98

Values for pH in H_2O indicate a soil strongly acid in the uppermost horizons, grading to medium acid deeper in the profile. Wet oxidizable organic matter levels (OM_{wo}) are characteristic of boreal soils in general, and differences between these values and the loss-on-ignition organic matter values (OM_{loi}) again indicate a relatively high proportion of recalcitrant organic matter. Total nitrogen is typical of boreal soils. Available P concentrations are high, though not so high as in the glaciofluvial soils (Table 2.1). Likewise, concentrations of exchangeable K, Ca and Mg are high, though there is some variability. Substantially higher concentrations of Ca and Mg were measured in soils from the northeast corner of Block D than elsewhere on this site.

(Section 2.3 contributed by Dr. I.K. Morrison, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario)

2.4 CLIMATE

The research site falls within the Height-of-Land Climatic Region (Chapman 1953). The closest permanent weather station with a climate representative of the Black Sturgeon Forest is located at Cameron Falls, some 26 km due east in the Nipigon River basin (49°09'N; 88°21'W; elevation 229 m) (Environment Canada 1993). The seasonal climatic regimes of the two areas are probably very similar. At Cameron Falls, the annual mean daily maximum and minimum temperatures are 7.6 and -4.1°C, respectively, with a mean daily mean of 1.8°C. Annual degree-days above 5°C total 1377, with 1678 degree-days below 0°C. The frost-free period averages 101 days. Total precipitation averages 831.4 mm annually, of which 232.2 mm falls as snow. Potential evapotranspiration is estimated at approximately 480 mm per annum (Chapman 1953). Length of growing season is between 150 and 160 days (Chapman and Thomas 1968). Thunder Bay provides the closest sunshine records, with a total of 2183.3 hours of sunshine annually, of which 1239.5 hours occur during May through September. The above summary statistics are broken down by months in Appendix 3.

To provide a regional context for the climate of the research site, Figures 2.4 to 2.7 illustrate provincial patterns for a number of critical climatic variables — temperature, length of growing season, precipitation (after Mackey and McKenney 1994; Mackey et al. 1996).

Climatic conditions have been monitored on the research site since 1994. Five automatic weather stations are maintained on three of the experimental treatment areas to monitor various air and soil climatic variables. The data is available on request; see Section 3.8.3 for further information.

2.5 FOREST ECOLOGY

2.5.1 General character of the forest and disturbance history

The Black Sturgeon Forest falls within the Lake Nipigon Ecoregion of the Boreal Shield Ecozone (Ecological Stratification Working Group 1995) and within the B.9 Superior Forest Section of Rowe's (1972) Boreal Forest Region. Rowe (*ibid.*) described the forests of this Section as being *"extremely variable, ranging from mixed types with luxuriant shrub undergrowth to floristically poor, single-dominant coniferous types"*.

Because of its glacial history, rolling to severely broken topography, multiple lakes and drainage channels, and highly variable soils, the Black Sturgeon Forest is a microcosm of Rowe's Superior Section, reflected in the complex mosaic of cover types to be found within its boundaries. Highly productive mixed forests comprised of varying proportions of white spruce, balsam fir, white birch and trembling aspen are characteristic of the deeper, more fertile upland soils, and can range from hardwood-rich to conifer-rich mixedwoods depending on past history and the stage of succession. Typically, mixed forests are found on fresh to moist, rich, medium to finely textured soils occupying upper to mid-slope positions. Birch, together with black spruce and jack pine, becomes a more prominent component of mixed forests on drier, or less rich soils. Species diversity generally declines under more extreme soil conditions, giving way to jack pine cover types on shallower or coarser soils and black spruce cover types on imperfectly drained to wet sites.

While the ability of sites to support mixedwoods is broadly governed by local soil and site conditions, external factors can play an important role in determining individual stand composition and its future successional pathway. In particular, the nature and frequency of past disturbances, predisturbance stand composition, and the time elapsed since the last major disturbance all have a major influence on patterns of forest development on a given site.

Although the Black Sturgeon forest is typically boreal in character, a number of species typical of the Great Lakes-St. Lawrence Forest Region are found throughout the river basin. Black ash (*Fraxinus nigra* Marsh.) occurs sporadically in river valleys, while white pine (*Pinus strobus* L.) and to a lesser extent red pine (*Pinus resinosa* Ait.) occur locally throughout mixed stands on glacial terraces. White pine also has a major presence on rocky outcrops, and is particularly evident on the cliffs and ridges bordering the Black Sturgeon River valley. In the early decades of this century, before the intrusion of commercial logging, there were apparently extensive stands of white pine on the valley floor in the lower (i.e., southern) reaches of the river.

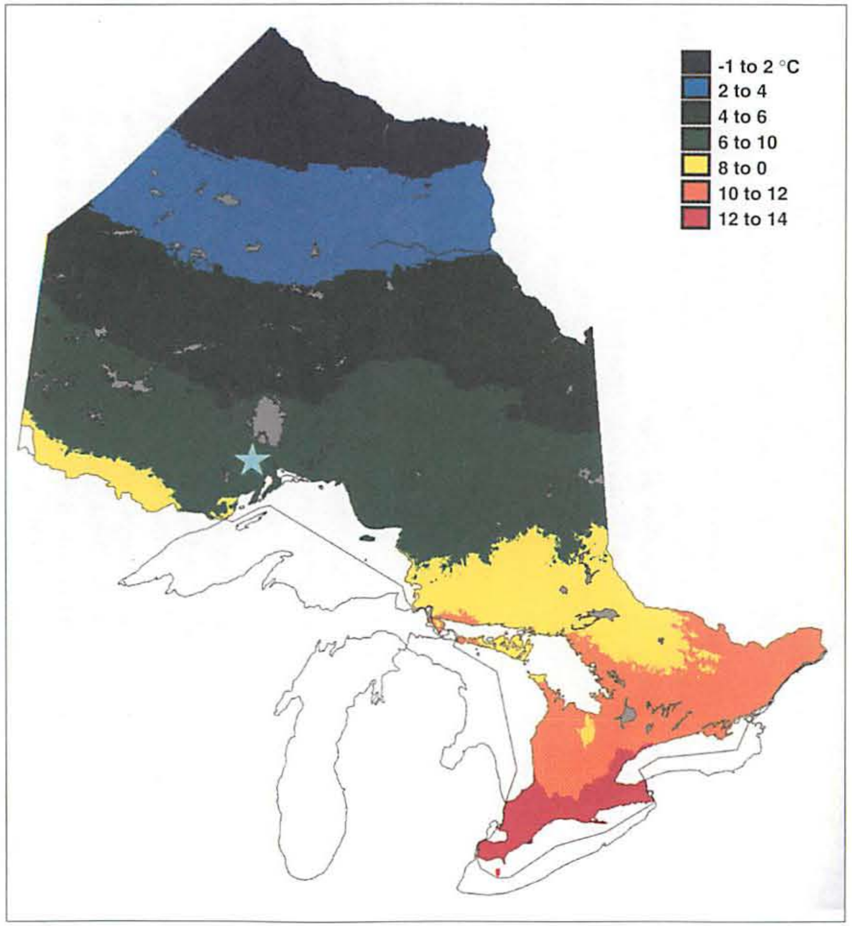

Figure 2.4 Annual mean maximum temperatures (°C) in Ontario (research site indicated by ★). (After Mackey and McKenney 1994; Mackey et al. 1996)

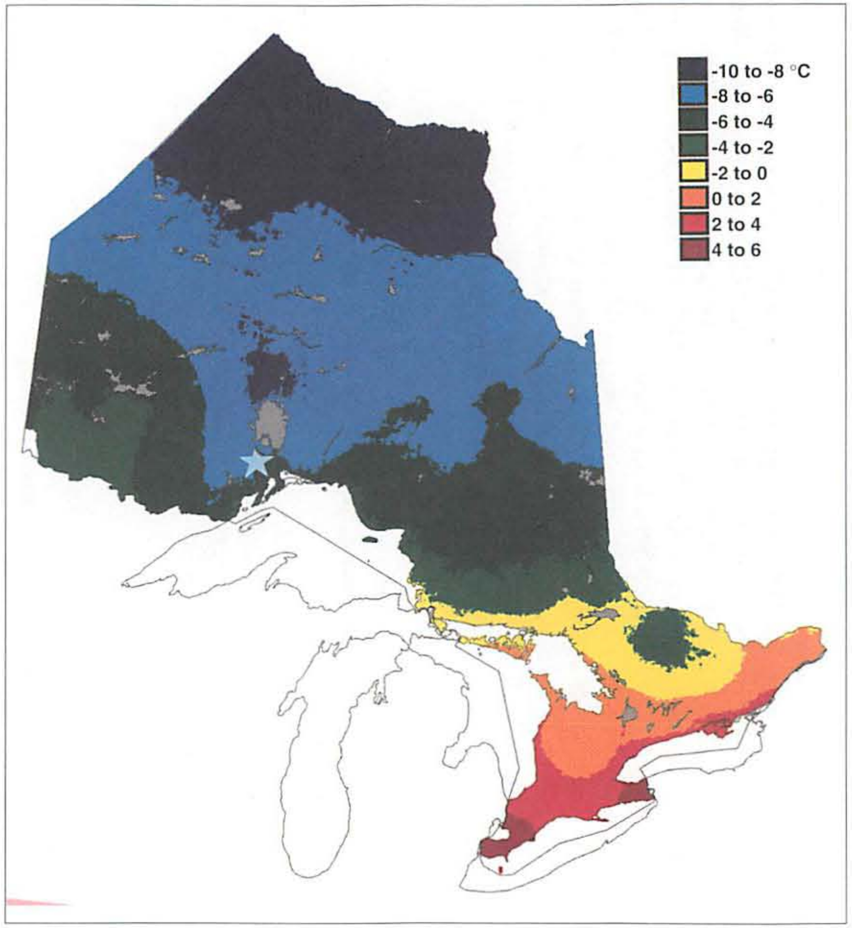

Figure 2.5 Annual mean minimum temperatures (°C) in Ontario (research site indicated by ★). (After Mackey and McKenney 1994; Mackey et al. 1996)

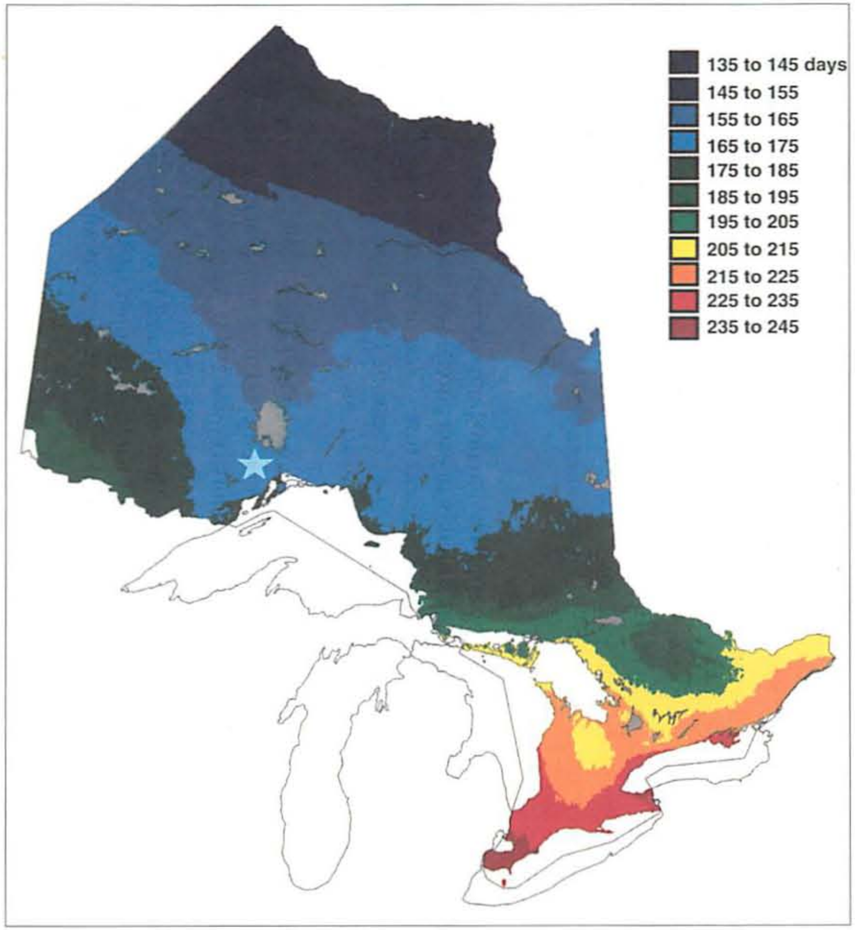

Figure 2.6 Average length of growing season (days >5°C) in Ontario (research site indicated by ★). (After Mackey and McKenney 1994; Mackey et al. 1996)

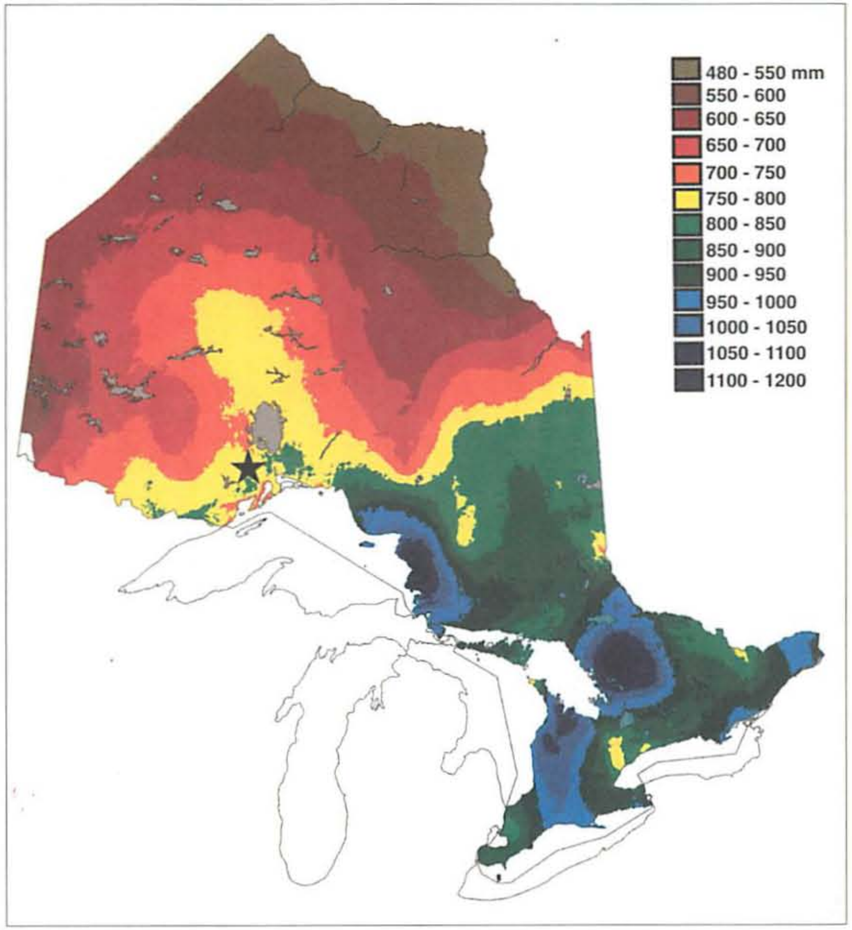

Figure 2.7 Annual total precipitation (mm) in Ontario (research site indicated by ★). (After Mackey and McKenney 1994; Mackey et al. 1996)

As discussed later in this section, it appears that the first loggers in the Black Sturgeon watershed found a forest that was largely mature to overmature, with a high proportion of coniferous stands, many composed of balsam fir and white spruce, and considered by Ghent (1957) to represent a more or less stable climax on the upland sites. In the ensuing 60 years most of the easily accessible, merchantable, natural stands in the Black Sturgeon Forest have been systematically harvested, and the forest now comprises a high proportion of second-growth stands. As in other areas of the boreal zone, harvesting activities and the absence of wildfires have brought about increases both in the incidence of mixedwood stands on upland sites and in their hardwood contents.

The first harvest of spruce-fir-mixedwood stands in the Black Sturgeon Forest began south of Eskwanonwatin Lake in the mid-1930s (see Section 2.7) and progressed northwards through the area on which the research site is now located during the 1940s. In 1993, Bowater Inc. returned to the resultant mid-rotation, second-growth stands of this area for a second harvest (see Section 2.7.1).

The role of fire in mixedwood ecology

In pre-settlement times, two natural phenomena — wildfires and spruce budworm *(Choristoneura fumiferana* Clem.) outbreaks — were integral elements in the ecology of boreal mixedwoods. Both played a fundamental role in periodically rejuvenating the forest, driving the successional cycle, and maintaining ecosystem diversity (including wildlife elements). Indeed, it has been suggested that without the cleansing effect of a severe fire the likely natural succession in overmature stands on productive mixedwood sites would be towards a mountain maple/beaked hazel thicket, with the occasional remnant tree (probably white spruce) protruding through the shrub canopy (Rowe 1961; Day and Harvey 1981; Wedeles et al. 1995a). Examples of such cover types occur in northwestern Ontario where upland sites have escaped burning for more than 200 years (Wedeles et al. 1995a).

As late as 1960, MacLean suggested that most mixedwood stands then present in northern Ontario were the product of fires that had occurred since 1800. Kelsall et al. (1977) concluded that the boreal forest *"evolved in response and adaptation to forest fires"* and that ecologically it is *"a fire-dependent system that would lose its character, vigour, and faunal and floral diversity in the absence of fire."* Similar hypotheses have been expressed by other writers (e.g., Mutch 1970; Rowe 1970; Wright and Heinselman 1973; Rowe et al. 1975). Rowe (1970) regarded the prevalence of charcoal in the soils of northern forests as clear evidence of the universal, historical presence of fire, corroborating the views of early writers such as Bell (1889). Certainly, analyses of charcoal deposits in lake sediments in the Great Lakes region confirm that periodic wildfires have been a factor in these forests since the last glaciation (Raymond 1915 and Potzger 1950, cited in Alexander and Euler 1981; Swain 1973). Although aboriginal man undoubtedly caused many of these fires, until the arrival of Europeans most major fires were probably caused by lightning. In northeastern Minnesota, Swain (1973) found an average fire-return interval of 60 to 70 years, with an approximate range of 20 to 100 years. This agrees well with Ward and Tithecott's (1993) estimated range of 20-135 years for Ontario's boreal forests. Day and Harvey (1981) have suggested a fire frequency of 75±50 years for boreal mixedwoods in Ontario.

Today, of course, with the advent of effective fire suppression programs, periodic large-scale wildfires are no longer an active ecological factor in managed boreal forests. Only in exceptional fire seasons are large tracts of forest likely to be burned in a manner and on a scale similar to historical times. Yet, as noted in Section 4.1, because of fire's elemental role in past boreal forest ecology, prescribed (i.e., controlled) fire could potentially play a much more significant role in the management of boreal mixedwood ecosystems.

The ecological role of fire in boreal mixedwoods has been reviewed by Larsen (1980), Alexander and Euler (1981), and Day and Harvey (1981). Certain characteristics of mixedwood tree and plant species are clearly adaptive mechanisms to ensure survival in a fire-dependent community (Fowle 1983). These include suckering in aspen, cone serotiny in black spruce and jack pine, and the persistence of certain species in the soil seed bank. Other traits serve to increase the flammability of the forest and aid renewal. Thus, the flammable bark of white birch and the resinous nature of balsam fir may increase the destructive potential of wildfires (Mutch 1970; Day and Harvey 1981), thereby helping to clear the ground of woody debris and accumulated organic matter, exposing mineral soil and preparing a site for regeneration.

The spruce budworm epidemics that periodically devastate boreal forests can also contribute to the role of fire in forest renewal and succession by increasing available fuels and making mixed forests more fire-prone (Flieger 1971; Stocks 1985). As with fire, historical records and tree ring analyses indicate that periodic budworm outbreaks have always been a factor in the ecology of boreal mixedwoods in central and eastern Canada (Blais 1962, 1968), potentially recurring on a 35-40 year cycle (Royama 1984; Régnière and Lysyk 1995). But because fire does not necessarily always immediately follow a spruce budworm outbreak, the successional and ecological outcome of these two events can differ significantly, for given stand conditions and fire characteristics, depending on whether they occur independently (i.e., fire alone or budworm alone) or in association (i.e., fire in recently budworm-killed stands). Historically, however, it is likely that fire was a frequent sequel to spruce budworm outbreaks in north-western Ontario. As noted by Johnston (1996a), discussing the interaction of fire and budworm outbreaks, *"northern Ontario lies at the intersection of spruce budworm outbreaks and high levels of fire disturbance — and therefore at the point of maximum interaction of the two."*

Fires create conditions that are usually favourable for the reproduction of pioneer species — black spruce, jack pine, trembling aspen, and white birch (Day and Harvey 1981). Early post-fire succession is influenced both by the original composition and condition of a stand, and by fire intensity *(ibid.)*. Prolific suckering of aspen is a common outcome on the more fertile mixedwood sites, often producing a dense pioneer-hardwood monoculture that only slowly converts to a mixedwood condition. Under certain circumstances, where it is sufficiently intense to expose a mineral soil seedbed, fire may favour white spruce reproduction, provided that it coincides with a good seed year. Balsam fir, however, is highly susceptible to destruction by fire (Damman 1964; Bakuzis and Hansen 1965), which destroys both fir reproduction and fir seed sources (MacLean 1960; Methven and Murray 1974; Day and Harvey 1981).

Whereas fire tends to perpetuate stands dominated by early successional species, protection from fire maximizes later successional phases. The exclusion of fire also creates conditions unfavourable to regeneration of the spruces, but favourable to balsam fir, which reproduces more readily under moderate shade and is not particularly demanding in its seedbed requirements compared to the spruces. Over time, this eventually leads to an increase in the mature fir content of stands, thereby increasing their susceptibility to the spruce budworm. Such stands often have dense thickets of fir advance growth in the understory. In the absence of fire, this advance growth can respond rapidly to increased light conditions and improve its position with respect to associated species when stands begin to break up with overmaturity or in the wake of spruce budworm outbreaks (see Section 2.6.3).

Stand succession in undisturbed mixedwood stands, and following fire or harvesting, is discussed more fully by MacLean (1960), Rowe (1961), Heinselman (1973, 1981), Noble and Slatyer (1980), Alexander and Euler (1981), Day and Harvey (1981), Yang and Fry (1981), Bergeron and Dubuc (1989), Robertson (1994), Frelich and Reich (1995), Johnston (1996a, 1996b), Wedeles et al. (1995a), Twolan-Strutt and Welsh (1996, 1997).

Fire incidence in the Black Sturgeon Forest

Rowe (1972) notes that, historically, the B.9 Superior Forest Section *"has been subjected to severe burning which has everywhere favoured an increase in the proportion of trembling aspen, white birch and pine"*. The Black Sturgeon Forest undoubtedly shared in these events, as evidenced by the common presence of charcoal in the upper mineral soil profile. But systematic recording of forest fires (>200 ha) in Ontario began only in 1917 (Donnelly and Harrington 1978), and few specific references to earlier fires in the Black Sturgeon area have been found in the literature or early records. The condition of the pre-1940s forest (Section 2.5.2) suggests that over large areas of the Black Sturgeon limit the last major fires probably occurred between 150 and 200 years ago.

Reports by early explorers, fur traders, and Jesuit missionaries attest to the extensive wildfires that periodically engulfed the northern forests — fires that often *"stretched from horizon to horizon"*. Alexander Mackenzie, for example, wrote in his diary that he saw vast fires along the north shore of Lake Superior, which impeded his fur trading progress in 1788 and 1799 (McClement 1969). In the past century, Bell (1889), during 20 years of travel conducting geological surveys in the north, encountered frequent and often extensive forest fires. It is possible that wildfires burned parts of the Black Sturgeon Forest during the exceptionally dry year of 1871, when disastrous firestorms swept from the prairies through the northern forests of Minnesota, Wisconsin, and Michigan following months of drought (McClement 1969). The northern United States and southern Canada were described at this time as *"one huge tinderbox"* from the Rockies to the Atlantic *(ibid).* Phillips and Benner (1918), reporting on their survey of the boundaries of the Black Sturgeon Forest limit, recorded that *"a fire of considerable extent has passed over portions of the limit about forty years ago."* This would seem to be about the right time frame. Extensive second-growth stands of this vintage were noted between Leckie Lake and the Spruce River on the southern boundary, between Mortar Lake and Little Poshkokagan Lake on the western boundary, and between the Lake Nipigon portage and McIntyre Bay on the northern boundary. Although it is not clear whether these observations denote a single fire or a number of separate fires, it is evident that a significant portion of the western side of the limit was burned in the 1880s.

In this century, no extensive wildfires have been recorded within the boundaries of the Black Sturgeon Forest prior to the fires of 1996[4]. MacDougall (1903), in his survey of the meridian from McIntyre Bay to Dorion (the present western boundary of Innes, Graydon, Adamson, Cockeram, McMaster, and Glen townships) specifically noted that *"no traces of fire were to be seen"* north of the present northwestern corner of McMaster township (just west of Fox Lake). The area seems to have been spared the destructive fires that ravaged northeastern Ontario in the first two decades of the century, as well as the fires that plagued northwestern Ontario, including the Thunder Bay area, during the summer of 1910 (Mauro 1981; Saunders 1995). Aside from small, localized fires that are known to have originated from logging camps and harvesting activities in the 1940s, Donnelly and Harrington (1978) record only one major fire within the forests' boundaries during the period 1921-76. This escape fire, located about 4 km west of the research site, destroyed Camp 10 and roughly 2500 ha of lowland black spruce forest that was being harvested along Nonwatin Creek in 1953. Although anecdotal evidence suggests that small escape fires were by no means rare on the present research site during the first harvest, the only recorded evidence is for a 16 acre (6.5 ha) fire that occurred in 1941 on a fresh cutover (Moran 1962); the location appears to have been outside the experimental areas proper, just north of Compartment 1-6 of the harvesting impacts component (probably within the area operationally clearcut in 1996).

2.5.2 Pre-harvest forest conditions on the research site

As noted in Section 2.3, the harvesting impacts and fire ecology components of the project are situated on an extensive glaciofluvial deposit, whereas the site preparation alternatives component is located at a lower elevation on glaciolacustrine materials beside Eskwanonwatin Lake. Based on forest resource inventory data and early regeneration reports, the difference in soil conditions appears to have been reflected in generally larger trees on the Eskwanonwatin site in the past, with more white spruce and a significant component of balsam poplar (*Populus balsamifera* L.), as well as a more dense and vigorous shrub understory.

The original (pre-1940) forest

Information on forest conditions on the research site at the time of the first harvest is hard to find. Little documentary evidence is available, and verbal evidence is often contradictory because of the almost 60 years that have elapsed since harvest. Some information can be gleaned from harvest records and regeneration survey reports, although most references to the pre-harvest forest are sketchy and rarely site-specific. Until more detailed descriptions can be found, the best source of information are the maps appended to the 1962 regeneration resurvey report (Moran 1962), which indicate pre-harvest forest types.

The earliest reports on the forests of the Black Sturgeon Forest were found in the Crown Land Survey Reports for the area. While the descriptions lack detail and are confined to what was visible from the survey lines, they do provide

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[4]Two fires within the Black Sturgeon watershed burned a total of 15,850 ha between June 12 and August 22, 1996 (72 days). The Disraeli Lake/Muskrat fire (Nipigon #46), some 15 km to the west of the research site, burned 6,950 ha, while the Poshkokagan fire (Thunder Bay #38) to the northwest of Black Sturgeon Lake burned 8,900 ha. The two fires destroyed approximately 6,400 ha of young spruce and pine plantations on Bowater limits planted between 1987 and 1996. On these old cutovers the fires consumed all vegetation, organic matter, and most remaining woody debris. Much of the mature forest burned was mixedwood with large amounts of budworm-killed balsam fir.

a useful picture of the overall condition of the forest and indications of fire history (see previous section). The survey line (MacDougall 1903) for the meridian from Dorion to McIntyre Bay on Lake Nipigon (the present western boundary of Innes, Graydon, Adamson, Cockeram, McMaster, and Glen townships) passed through the research site, crossing the present Black Sturgeon Road close to old Camp 7. MacDougall reported that "*going north* [from Nonwatin Lake] *the country is heavily timbered with large birch, spruce, poplar, tamarac, banksian pine and in places cedar, these averaged from 15 to 20 inches in diameter; no traces of fire were to be seen; the same timber continued south for 13 miles, except a large spruce swamp* [east of Shillabeer Lake] *in which the trees were generally small and scattered; the last 14 miles south* [south of southwest corner of Cockeram township], *has been overrun by fire some thirty years ago, the timber is mostly small scattered poplar, banksian pine and scrub.*" It is clear from these observations that the research site and areas to the north supported mostly fairly mature mixedwood forests at the turn of the century.

The first timber survey of the Black Sturgeon Forest Pulp and Timber Limit was conducted by the John Schroeder Lumber Company of Milwaukee, Wisconsin for the Great Lakes Paper Company in 1930, under the direction of L.M. Whittier. The report describes the general character of the forest, and summarizes the estimated volumes and values of pulpwood and timber reserves within the limit by species. It also makes a number of proposals for harvesting and transporting wood to the mill, including one for the construction of a railway up the Black Sturgeon River valley from Hurkett, and another for the construction of a flume from Lake Nipigon into Black Sturgeon Lake (to enable logs from the Poshkokagan watershed to be driven down the Black Sturgeon River). According to the report, the predominant species on the uplands was white spruce, generally of very good size for pulp, and with a higher proportion of sawlog material than on most other timber limits in the region. "*Large bodies of this species were found throughout the limit especially in the southern, central, and eastern portions of the tract, either in pure stands or more often in mixed stands with balsam.*" Scattered white pine and red pine were found throughout the forest, while "*There are some exceptionally good stands of jack pine ... particularly along Larson Creek, the Black Sturgeon River between Black Sturgeon and Nonwatin Lakes, and in the country around Circle and Turtle Lakes. These stands will average 3 to $3^1/_2$ ties to the tree, and of very good quality. (These stands will be large enough for pulp manufacture in about 15 to 20 years, or for excelsior right now)*" Also "*There is a goodly amount of poplar all through the limit, and occurring in nearly pure stands in some burned-over portions in the northern portions.*" In an unattributed early company report on the Black Sturgeon Forest, it is noted that "*it is one of the best timbered sections in the district.*"

In its regeneration survey reports, the Great Lakes Paper Company (the forerunner of Bowater Inc.) recognized four "former forest types" on upland cutovers, viz: S (softwood), MS (mixed softwood), M (mixedwood), and H (hardwood)[5]. Maps in Moran (1962) show that the original forest on the research site comprised an intricate mosaic of these successional variants, and that none of the current experimental areas were then occupied by a single cover type. While the general nature of the forest is described below, the original cover types on individual experimental harvest treatment compartments can be readily determined from maps if desired. In addition to the cover types noted, there were scattered white pine throughout the research site, some of which probably still remain.

According to Moran's maps (1962), within the boundaries of Stand 1 of the harvesting impacts component (Fig. 2.2) the original forest comprised a high proportion of mixed softwood (MS) to the northwest of old Camp 7, interspersed with small stands of softwood (S) and mixedwood (M), and with a large stand of pure jack pine on the northern perimeter. North and east of Camp 7 the forest was mostly mixedwood (M) with some mixed softwood (MS). Clearly, jack pine was a significant component of the original forest on Stand 1, just as it was in the second-growth forest that succeeded it. Many residual stumps of large jack pine dating from that time are still to be found throughout the area. Stand 2, in contrast, was mostly mixedwood (M) with a fairly substantial area of softwood (S) on the west side of the present experimental area, parallelling the Black Sturgeon Road.

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[5]S (softwood: at least 75% softwood, with spruce and/or balsam fir forming at least 75% of the softwood. Spruce component usually white spruce.); MS (mixed softwood: at least 75% softwood, with spruce and/or balsam fir forming only 25-75% of the softwood. Other softwood almost always jack pine.); M (mixedwood: spruce and/or balsam fir comprise less than 75%, but at least 25% of the stand.); H (hardwood: hardwood species comprise at least 75% of the stand).

Immediately south of the present airstrip, the area occupied by the fire ecology component (Fig. 2.2) supported a large area of softwood (S) with small islands of mixedwood (M) and pure black spruce. South of burn treatment compartments 3 and 7 (see Fig. 4.1) the forest was mostly mixed softwood (MS) interspersed with stands of softwood (S).

Unfortunately, the maps provide no indication of original forest types on the areas west of Eskwanonwatin Lake, harvested in 1937-38, where the site preparation alternatives component is now located. However, an earlier regeneration survey report (Silversides 1945) indicates that these upland sites supported mostly mixedwood stands, in which the poplar and birch were overmature and defective. Extremely heavy windfall of poplar was recorded in areas adjacent to Eskwanonwatin Lake at that time *(ibid.)*, which may account for the areas of unmerchantable timber mapped by Moran (1962) at the southwestern end of the lake. All indications point to mixedwood stands that were perhaps overmature and beginning to break up, especially as anecdotal reports speak of large white spruce being harvested from this area.

Further evidence that the original forest on the entire research site was mature to overmature at time of harvest is provided by Ward (1950). He cites an average age of 105 years for upland spruce harvested from the Camp 7 cutting chance in 1944-45, with the balsam fir averaging 85 years and the jack pine 115 years. For all upland stands harvested in the Black Sturgeon Forest that year (Camps 3, 6, 7, 8, 10, 11, 12, 16) the average age of spruce was 110-120 years for jack pine, and 80-90 years for balsam fir. Some spruce were recorded with average ages between 140 and 150 years. Black spruce on the swamp sites averaged 110-120 years. The consistency of the data for different logging camps implies an extensive forest of fairly uniform age, with large spruce and pine present on many upland areas. Whether this means that the forest had a common origin following a major disturbance (e.g., an extensive wildfire in the 1830s) is open to conjecture. However, it is worth noting that the Forest Management Plan prepared in 1970 states that in the 1930s the Black Sturgeon Forest limit was considered to be mostly even-aged and mature. A later report from the 1970s favoured the view that parts of the mature forest were very much overmature, and that stand origin *"was perhaps from a series of fires and/or in combination with insect infestations extending back 150 years or more."*

The first harvest

The research site was first harvested between 1937 and 1945 by methods described in Section 2.7.2. Both pulpwood and sawtimber were cut, the latter often including large jack pine. Post-harvest regeneration reports make clear that in the pulpwood cuts the area was "cut-clean", leaving standing only scattered poplar and birch (often overmature and defective). There were very few residual conifers, indicating that all merchantable balsam fir was harvested. Contemporary photographs show that the post-harvest appearance of these sites was very similar to that of present-day clearcuts. In contrast, where an area was harvested solely for sawtimber, usually only the spruce and pine were harvested, leaving the balsam fir and hardwoods standing.

In the early years of harvesting at Black Sturgeon, when the men had to walk daily to their work, each of the camps was centred on a "logging chance" of 1.75 miles radius (2.8 km; approx. area 25 km^2). The research site was mostly harvested by crews from Camps 1, 6, and 7. The logging chances for these camps also included adjacent areas which supported both upland forest and lowland black spruce. Although it is not possible to segregate the production figures for the research site or for the upland areas as a whole, it is nevertheless instructive to compare species production by camps. Even though the inclusion of lowland black spruce production obviously inflates the proportion of spruce harvested, the production figures in Table 2.3 provide additional insight into the composition and size of the conifer component of the original forest on the research site.

Table 2.3. Pulpwood and sawlog production by Camps 1, 6, and 7.[a]

Cutting season	Pulpwood (cords)[b]			Sawlogs (fbm)[c]		
	Spruce	Fir	Total	Spruce	Pine	Total
Camp 1						
1939-40	10,781	445	11,226	7,302	6,263	13,565
1940-41	160	—	160	1,665,788	686,559	2,352,347
Totals	10,941	445	11,386	1,673,090	692,822	2,365,912
Camp 6						
1939-40	1,070	6	1,076	22,509	75,862	98,371
1940-41	9,370	1,889	11,259	528,717	1,569,977	2,098,694
1942-43	1,485	1,441	2,926	1,177,006	893,953	2,070,959
1943-44	7,935	866	8,801	462,701	917,979	1,380,680
1944-45	6,150	2,122	8,272	21,904	402,037	423,941
1945-46	5,085	1,069	6,154	669,844	413,527	1,083,371
Totals	31,095	7,393	38,488	2,882,681	4,273,335	7,156,016
Camp 7						
1940-41	6,805	3,594	10,339	755,720	1,967,026	2,722,746
1942-43	12,204	156	12,360	284,726	342,591	627,317
1943-44	2,237	33	2,270	—	—	—
1944-45	12,441	1,334	13,775	58,422	179,774	238,196
1945-46	20,601	545	21,146	27,271	135,076	162,347
1946-47	11,972	567	11,639	37,528	113,653	151,181
Totals	65,360	6,229	71,589	1,163,667	2,738,120	3,901,787

[a]Source: Great Lakes Paper Company Ltd cut file.
[b]1 cord = 128 cu. ft. (3.625 m^3) (overall measure of stacked wood; average actual wood volume 85 cu. ft. or 2.41 m^3)
[c]fbm = foot board measure; an estimate of the quantity of sawn lumber in a log. A board 1 in. x 12 in. x 12 ft. long equals 12 board feet (= one cu. ft. or 0.028,317 m^3)

Development of the second-growth forest

Regeneration surveys following harvest of the original forest (e.g., Silversides 1945; Ward 1950; Brokx 1961; Moran 1962; Linke and Ostapiuk 1973) all speak of prolific balsam fir regeneration on harvested upland sites in the Black Sturgeon Forest. Most of this regeneration was present as advance growth before harvest. Early reports indicate that most areas were poorly stocked to spruce. The regeneration on many upland areas was completely dominated by fir (Ward 1950), much of it growing in dense clumps. Even where spruce regeneration was numerically adequate, its distribution was usually poor and the stocking inadequate (Silversides 1945).

On upland areas cut by Camp 1 during 1937-38 and 1939-40 (this includes the Eskwanonwatin Lake site), Silversides (1945) could find no relationship between the composition of the original stands and the composition of the regeneration, except that in all cases the proportion of balsam fir had increased greatly. In the 1945 survey, fir densities as high as 6793 stems/ha were found on former softwood (S) cover types cut in 1940-41, contrasting with only 1483 stems/ha of spruce. On former mixedwood (M) sites the figures were 4354 and 467 stems/ha for fir and spruce, respectively. Seventeen years later, a resurvey of the same mixedwood sites (Moran 1962) revealed relatively little change, with 2735 stems/ha of fir (61% stocking), 465 stems/ha of spruce (17% stocking), 487 stems/ha of poplar (21% stocking), and 220 stems/ha of birch (7% stocking). The overall stocking for spruce and/or balsam fir was 65 percent.

The regeneration resurvey of 1962 (Moran 1962) indicated a similar situation on former mixedwood (M) sites cut for pulpwood by Camp 7 between 1940 and 1950. Here, there were 2540 stems/ha of fir (61% stocking), 245 stems/ha of spruce (21% stocking), 494 stems/ha of poplar (18% stocking), and 531 stems/ha of birch (21% stocking), with a spruce and/or fir stocking of 64 percent. Conifer numbers were appreciably higher on former mixed softwood (MS) sites, boosting overall spruce and/or fir stocking to 84 percent, mainly through an increase in spruce stocking, viz: 4329 stems/ha for balsam fir (61% stocking), 2026 stems/ha for spruce (56% stocking), 507 stems/ha for poplar (21% stocking), and 91 stems/ha for birch (4% stocking). Unfortunately, none of the data is segregated by year of harvest, so it is not possible to cite specific figures for the research site. However, the preceding summary data probably reflects fairly accurately the situation on the site.

The regeneration survey reports make clear that dense shrub growth was a common feature on recent cutovers. Together with the lack of spruce seed trees, it was often blamed for the poor spruce stocking on upland sites. Five years after harvest, Silversides (1945) wrote of a solid cover of hazel, raspberry, and mountain maple. Later writers offered similar observations, but none mentioned aspen as part of the shrub cover. From 1950 onwards, however, poplar (aspen) and birch were enumerated as part of the regeneration survey. Judging from the figures given, aspen regeneration was not especially prolific, reflecting perhaps the overmaturity of this species in the original stand. For Camps 6 and 7, on harvest cuts where the original forest had been 100-110 years old, Ward (1950) reported an average of 1000 stems/ha of aspen on former mixed softwood (MS) sites and 1902 stems/ha on former mixedwood (M) sites five years after harvest.

Forest conditions prior to the second harvest

Whatever the reality of the early development of the second growth forest, by the time of the most recent (1975) forest resource inventory stand composition on the upland portions of the research site (Fig. 2.8) averaged 50% trembling aspen, 30% balsam fir, 10% white spruce, and 10% black spruce, with white birch and jack pine locally abundant. However, pre-harvest surveys carried out in 1993 revealed a significant compositional shift during the intervening 18-year period, mainly due to the negative impact of the recent (1982-95) spruce budworm outbreak upon balsam fir and white spruce. By 1993, much of the balsam fir in the upper canopy was either dead or moribund, with many large white spruce also dying. As a result, average stand composition (volume basis) on the upland areas at time of harvest was 60% trembling aspen, 12% balsam fir, 11% white spruce, 3% black spruce, and 9% white birch, with jack pine locally abundant in Compartments 1-1, 1-2, 1-3, 1-4, 1-6, 1-7, 1-8 and 1-10 of the harvesting impacts component of the project (old Camp 7 area). For more detailed stand composition data see the pre-harvest characterization of treatment compartments for the harvesting impacts component. (Appendix 2.1).

Pre-harvest (1993) inventory data (Table 3.3 and Appendix 2.1) revealed an average living merchantable volume of 190 m^3/ha (solid measure; 21 cords/acre) within Stands 1 and 2 of the harvesting impacts component. A further 56 m^3/ha of dead wood was also present, of which 59 percent was balsam fir.

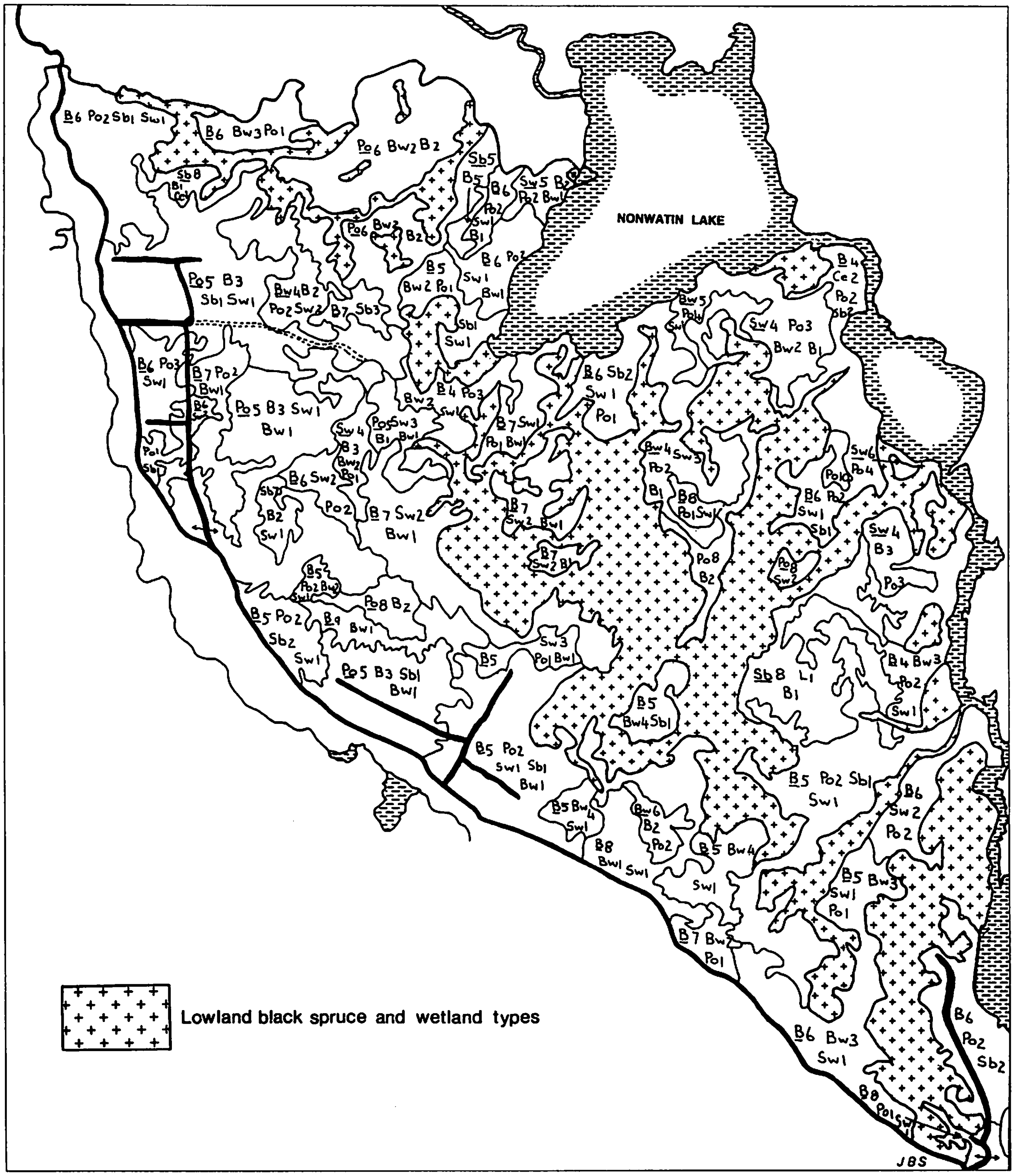

Figure 2.8 Forest composition of the research site, according to the Forest Resource Inventory of 1975. (Bf = balsam fir; Bw = white birch; Ce = white cedar; L = eastern larch; Po = poplar; Sb = black spruce; Sw = white spruce) Locations of the main project components are indicated by the positions of their internal service roads (see Fig. 2.2 for the locations of individual treatment compartments).

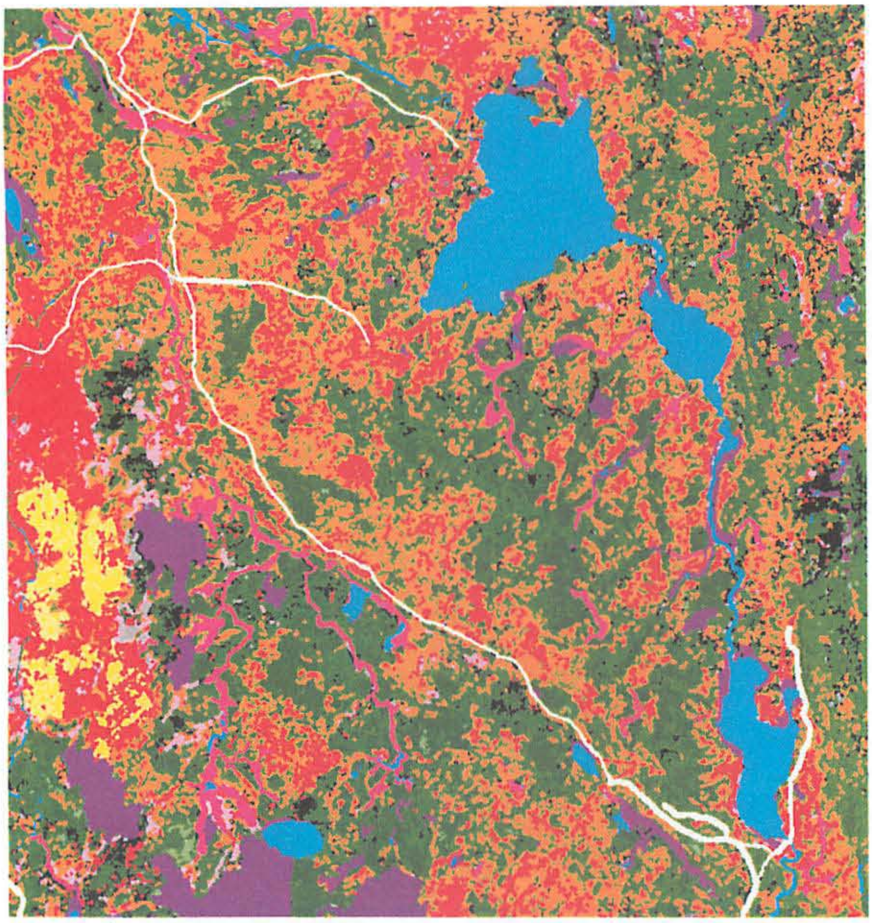

Figure 2.9 Vegetation classification of research site based on Landsat TM satellite image of June 20, 1992.

The Landsat satellite image in Figure 2.9 illustrates the distribution of different forest cover types on the research site in June 1992 (compare with Figure 2.2 to determine positions of research plots). This confirms the dominance of hardwood cover types on the upland areas, and shows the locations of areas with a higher conifer content. In areas classified as "dense mixed-hardwood" the second-growth forest of 1993 was mostly two-tiered, with aspen, white spruce, balsam fir, and sometimes jack pine in the upper canopy. Dead and nearly dead balsam fir with minor amounts of white spruce and black spruce formed the secondary canopy. In many areas, beaked hazel (*Corylus cornuta* Marsh.) and mountain maple (*Acer spicatum* Lamb.) formed dense thickets in the shrub layer.

Pre-harvest surveys (Appendix 2.1) revealed relatively sparse vegetative ground cover overall. On average, about 40 percent of the ground was covered with hardwood litter, with herbs and feathermoss the next most common categories at about 30 percent each. Where the balsam fir was heavily defoliated or where dead fir had begun to break up, raspberry (*Rubus* spp.), beaked hazel, and mountain maple were quick to establish themselves in response to the increased light intensities. Thus, even those areas that have been reserved as uncut controls may be expected to undergo rapid compositional and structural changes as the balsam fir collapses in the wake of the spruce budworm epidemic. In the absence of suitable seedbeds (lack of disturbance) and spruce seed rain (the spruce budworm outbreak suppressed all conifer seed production for more than a decade), the two most likely successional scenarios in uncut areas are: (i) an increase in the hardwood and shrub content, and (ii) rapid development of a balsam fir understory from the released fir advance growth, where it exists, in response to breakup of the canopy.

The fresh, well-drained, and relatively fertile soils of the research site supported pre-harvest stands which fell predominantly within the herb- and shrub-rich mixedwood cover types (V6, V7, V9, V11, V16) of the Forest Ecosystem Classification (FEC) for Northwestern Ontario (Sims et al. 1989). Data collected in the harvesting impacts component of the project illustrate the range of pre-harvest cover types present on the site. Appendix 2.4 tabulates the V-type classification for each of the 210 permanent sample plots within this component, while Table 2.4 summarizes the data by harvest treatment compartments, grouping V-types into three major categories — mainly hardwood,

Table 2.4. Pre-harvest occurrence (percent) of FEC V-type groups by stand and compartment.[a]

Stand/ compartment	Group 1[a] Mainly hardwood	Group 2[a] Conifer mixedwood	Group 3[a] Mainly conifer
1-1	70	30	-
1-2	80	10	10
1-3	90	10	-
1-4	90	10	-
1-5	80	20	-
1-6	20	40	40
1-7	80	10	10
1-8	70	20	10
1-9	80	10	10
1-10	80	10	10
1-11	80	10	10
1-12	80	10	10
1-13	100	-	-
1-14	70	30	-
Stand 1 mean	76	16	8
2-1	70	-	30
2-2	80	-	20
2-3	60	40	-
2-4	70	10	20
2-5	60	30	10
2-6	80	20	-
2-7	100	-	-
Stand 2 mean	74	14	12
Overall mean	75%	15%	10%

[a]Average incidence (percent) of specified cover types on ten 10x10m permanent sample plots per compartment. The FEC groupings, based on Sims *et al.* 1989, are represented by the following V-types:

Group 1 - Mainly hardwood

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

Group 2 - Conifer 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

Group 3 - Mainly conifer

V-24	White spruce - balsam fir/shrub rich
V-25	White spruce - balsam fir/ feathermoss
V-32	Jack pine - black spruce/ericaceous shrub/feathermoss
V-36	Black spruce/bunchberry/sphagnum (feathermoss)

conifer mixedwood, and mainly conifer. Reflecting differences in soil and moisture conditions, the pre-harvest forest of the site preparation alternatives component (Eskwanonwatin Lake) was somewhat more conifer-rich (V14, V15, V24) than that of the upland areas, with appreciable amounts of balsam poplar (*Populus balsamifera* L.) also present.

2.6 SPRUCE BUDWORM IN THE BLACK STURGEON FOREST

2.6.1 Historical perspective

Historical records and tree ring analysis indicate that periodic spruce budworm (*Choristoneura fumiferana* Clem.) outbreaks have always been a factor in the ecology of balsam fir and the boreal mixedwoods of eastern North America (Blais 1962, 1968). This may be an example of plant-insect co-evolution (Blais 1985). Current research in northwestern Ontario and elsewhere in eastern Canada suggests that spruce budworm populations fluctuate on a 35-40 year cycle (Royama 1984; Régnière and Lysyk 1995), reflecting the age at which balsam fir becomes susceptible to attack. Outbreaks occurred in the Black Sturgeon Forest in about 1800-1810 and again in 1862-1872 (Elliott 1960). Further outbreaks were recorded in northwestern Ontario in the 1920s, but there are no records of defoliation in the Black Sturgeon Forest at that time (Brown 1970). The first well-recorded outbreak in northwestern Ontario that affected the Black Sturgeon area occurred in 1940-50. By the time that budworm populations began to decline in 1948 and 1949, the area of heavy defoliation extended roughly 260 km from east to west and 160-190 km from north to south, completely surrounding Lake Nipigon (Belyea 1952). This outbreak had collapsed by 1955, and the budworm became extremely scarce. In one year during the 1960s over 3,000 branches of spruce and balsam fir were sampled, but only five budworm larvae were found (Sanders 1967). The most recent outbreak began in 1982 and reached its peak in the late 1980s.

Industrial concern over the potential impact of the 1940 spruce budworm outbreak in the Lake Nipigon area led the federal government in 1944 to initiate a budworm research program at Black Sturgeon Lake. A field station was established in 1945, which served as the focus for an extensive multidisciplinary research program. Although the field station was closed in 1969, research continued in the area, with the result that there has been an almost continuous record of spruce budworm research in the Black Sturgeon Forest from 1944 through 1997. A summary of this research is given in Section 7.1

A valuable summary of the life history, ecology, and population dynamics of the spruce budworm will be found in Sanders (1991).

2.6.2. The 1982-1995 outbreak

The most recent spruce budworm outbreak in the Black Sturgeon Forest was part of a larger outbreak that started in the early 1980s. At its peak, this outbreak extended over much of northwestern Ontario, from the Manitoba border through to the Kapuskasing and Wawa areas.

The 1970s saw a steady increase in budworm populations at Black Sturgeon, and in 1980 the first defoliation was detectable from the air. This outbreak reached its peak in 1986-87 and populations again began to decline in the early 1990s. The spruce budworm feeds primarily on balsam fir and white spruce, and by 1990 the current shoots of both species were almost completely defoliated. This resulted in extensive tree mortality, and by the end of the outbreak in 1995 more than 80 percent of the balsam fir and 50 percent of the white spruce were dead. Black spruce suffered some damage, but little mortality. During the period 1986 through 1989 heavily damaged stands that were destined for harvest in the near future were protected by the aerial application of *Bacillus thuringiensis* (Section 2.6.4). After 14 years of high budworm population densities and heavy defoliation the outbreak finally collapsed, partly because the insects had consumed their food source.

When the new budworm outbreak started in the 1980s the Canadian Forest Service began an intensive study of insect populations, both at Black Sturgeon and at other sites in eastern Canada. In some of the eastern studies collapse of the populations was apparently caused by an increase in parasitism of large larvae and pupae (Régnière[6], personal

[6] Dr. J. Régnière, Canadian Forestry Service, Laurentian Forestry Centre, Ste. Foy, Québec

communication), which was probably accelerated by intensive predation by specialised budworm-feeding birds (Welsh 1985). However, the same sequence of events did not occur in the Black Sturgeon Forest. The usual parasites and diseases were present, but they had only a limited impact as the outbreak aged. Long-term censuses of bird populations in the area (see Section 7.1.2) showed that there were about twice as many nesting birds present during the outbreak as there were before, with large increases in four species of budworm-feeding warblers — Cape May (*Dendroica tigrina*), blackburnian (*Dendroica fusca*), bay-breasted (*Dendroica castanea*) and Tennessee warblers (*Vermivora peregrina*) (Welsh 1985). But, without a reduction in budworm numbers by parasitism or disease, it is unlikely that feeding by birds will have had sufficient impact to significantly reduce budworm numbers (Crawford and Jennings 1989).

2.6.3 Stand succession

As a major factor affecting the ecology of balsam fir and white spruce in eastern Canada, the spruce budworm is an integral part of the boreal forest, with a profound impact on stand succession (Baskerville 1975; MacLean 1984). Cycles of budworm outbreaks, propagating even-aged stands heavy in balsam fir, which are highly susceptible to further outbreaks, have been continuing for many hundreds of years, and evidence for them dates back to the seventeenth century (Blais 1962).

Most of the stands affected by spruce budworm in the Black Sturgeon Forest during the recent outbreak were mixedwoods, comprised of approximately one half hardwood (white birch and aspen) and one half conifer. Of the latter, 80 percent was balsam fir, with 10 percent each of white spruce and black spruce, respectively. One of the less obvious consequences of the prolonged outbreak, with significant ecological implications, was that there was no flowering or seed production in balsam fir and white spruce for 10 years or more prior to the collapse of the outbreak (see footnote, Section 3.7). The spruce budworm suppresses seed production in two ways. In the earlier stages of an outbreak, budworm larvae show a feeding preference for the nutritious staminate flowers of fir and spruce (Blais 1952), and can cause serious damage to flowers and developing cones. Concurrently, as an outbreak develops, host trees are physiologically weakened by progressive defoliation, their growth is checked (Blais 1958, 1964; MacLean, 1981, 1985), and they cease to produce flowers (Ghent 1958).

In many stands the next generation of shade-tolerant balsam fir advance growth was already well established before the outbreak, some of it as much as 30 years old. Budworm larvae, falling from the overstory, had little impact on this regeneration, and as the dead fir overstory breaks up the young fir can be expected to respond rapidly to the increased light. In early- to mid-successional stands the result will be a stand dominated by aspen and scattered white spruce, with a vigorous understory of balsam fir. Forty years from now we anticipate that the aspen will be overmature and beginning to break up, giving way to another stand dominated by balsam fir, ripe for yet another budworm outbreak. Thus, the cycle is perpetuated.

This cycle can be modified by fire. For a short period at the end of a budworm outbreak the stands are highly flammable (Stocks 1985), and in the past extensive fires often followed a spruce budworm outbreak (Flieger 1971). Fire usually kills any balsam fir regeneration present, and may favour natural regeneration of the spruces and jack pine where fires are sufficiently intense to remove organic soil layers and expose mineral soil. Records show that the original stands in the Black Sturgeon Forest contained far more spruce and jack pine than we see in today's second growth stands, which have a significantly increased balsam fir content. The continued exclusion of fire from boreal mixedwoods, either through fire protection or an unwillingness to use prescribed burning as a silvicultural tool in mixedwood management, will clearly favour balsam fir, leading to an increase in the vulnerability of these forests to spruce budworm infestations.

(Sections 2.6.1 to 2.6.3 were contributed by Dr. C.J. Sanders, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario)

2.6.4 Forest protection on the research site

Extensive areas, including much of the research site were aerially sprayed with *Bacillus thuringiensis* in early June of 1987 and 1989 in an attempt to protect high-value stands from further spruce budworm damage. While many areas were sprayed in both years, some areas received only a single application, depending on the degree of overlap between applications (Fig. 2.10). Spray details may be found in reports to the Fifteenth and Seventeenth Annual Forest Pest Control Forums, held in Ottawa, November 17-19, 1987 and November 14-15, 1989, respectively.

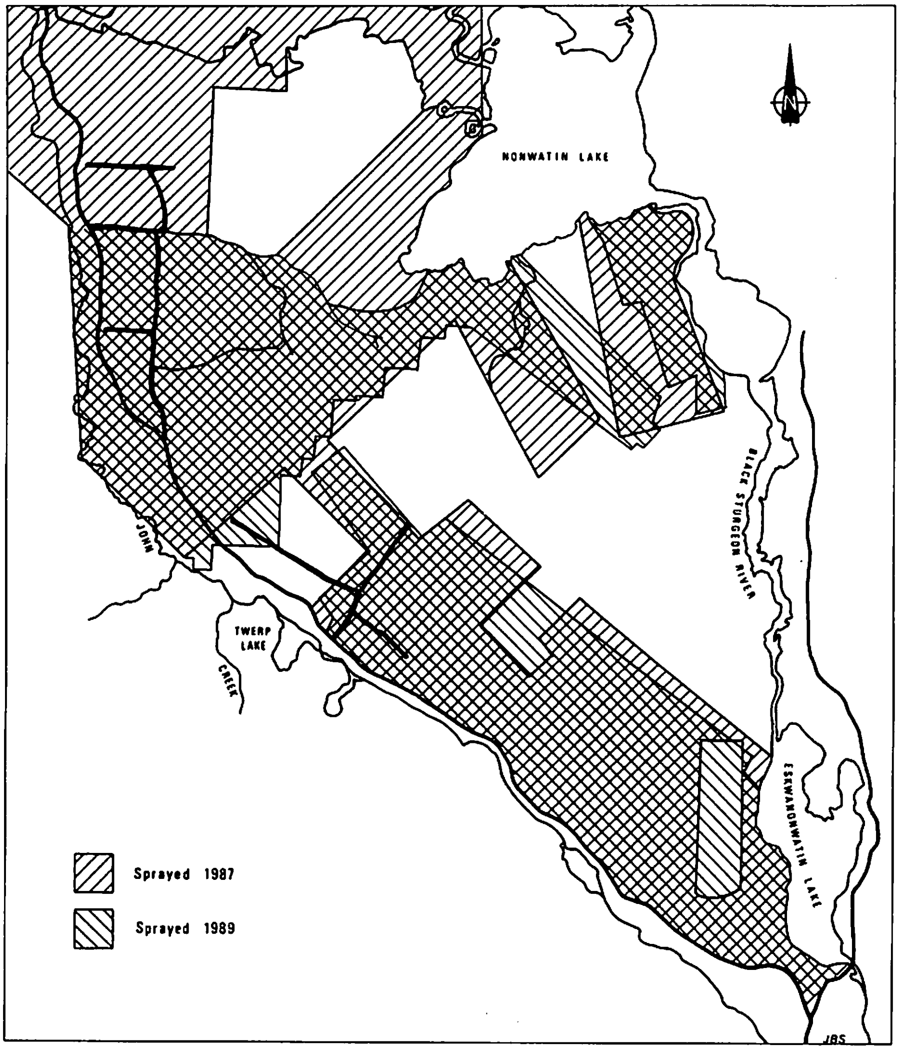

Figure 2.10 Protective spraying (Bacillus thuringiensis) of the research site against the spruce budworm. Locations of the main project components are indicated by the positions of their internal service roads (see Fig. 2.2 for the locations of individual treatment compartments).

2.7 PREVIOUS HARVESTING OPERATIONS

The first harvest on the research site in the 1940s was essentially a clearcutting operation. From an ecological perspective, it marked the beginning of the mid-successional, second-growth forest that was harvested in 1993. This section completes the historical record for the project, and is intended to give a flavour of the harvesting operations that were the first major human disturbance on the site. Much of the material was gathered through interviews with loggers and foresters who worked in the Black Sturgeon Forest during the 1940s and 1950s. To keep the flavour of the time, original timber measures are used in this section (1 cord = 3.625 m^3).

2.7.1 General chronology

While there is some indication that cutting of sawlogs and railway ties may have begun as early as the 1890s in the lower Black Sturgeon River valley, the early history of logging in the Black Sturgeon Forest proper is obscure. Company records speak of tie and sawlog operations at the southern end of Eskwanonwatin Lake and downstream on both sides of the river to below old Camp 5 between the turn of the 20th century and World War I. These were probably all selective, high-grading cuts, harvesting large white spruce from the uplands adjacent to the river. Brief references have also been found to very old cuts south of Shillabeer Lake and west of Fog Lake in old timber berths TB08 and TB09 (later incorporated into the Black Sturgeon Forest limit). It is believed that these operations employed a horse and capstan setup to haul the logs to waterways.

Compared with other areas of northern Ontario, logging operations of any sizeable extent started rather late in the Black Sturgeon Forest. They began only in 1934-35, when the Pigeon Timber Company, operating as a contractor for the Great Lakes Paper Company Ltd. (now Bowater Inc.) established Camps 4 and 5 on the Black Sturgeon River between Eskwanonwatin Lake and the southern boundary of the limit. From these camps, they began to harvest the slopes west of the river and northwards towards Eskwanonwatin Lake. In 1937, Pigeon Timber built Camp 1 and a sluice dam at the southern end of Eskwanonwatin Lake, the latter to control water levels for the log drives. Harvesting of the swamps and mixedwoods to the west of Eskwanonwatin Lake began in 1937-38. The Great Lakes Paper Company took over the Pigeon Timber camps in 1941, and thereafter managed its own harvesting operations. Much of the early harvest in the Black Sturgeon Forest was carried out by seasonal contract loggers from Quebec.

Harvesting progressed northwards along the Black Sturgeon River and through the research site during the 1940s, past Nonwatin Lake and up the west side of Black Sturgeon Lake. Extensive areas were also harvested to the west of the research site, along the John and Sprout Creeks, as well as along the upper reaches of the Nonwatin River. In the 1950s, harvesting operations shifted further west, to areas in the vicinity of Shillabeer, Sturge and Disraeli Lakes, and to the north and northeast of Black Sturgeon Lake. During the harvesting seasons 1934-35 to 1959-60 (there was no cutting in 1935-36 and 1938-39) a total of 2,084,000 cords of pulpwood was harvested in the Black Sturgeon River watershed (Great Lakes Paper Company cutting records). Largely due to heavy budworm damage in upland stands in the 1950s, wood yields fell from an average of 20 cords/acre (49 cords/ha) in 1938 to less than 12 cords/acre (20 cords/ha) in 1958.

All the wood harvested from the above areas was transported by water, via lakes and streams feeding into the Black Sturgeon River, by which the logs eventually reached Lake Superior. Some 16 principal dams were constructed within the watershed to impound sufficient water for the river drives, and for rafting and towing on some of the larger lakes. Logging activities continued in the Muskrat and Little Sturge Lake areas until 1965, when the Black Sturgeon river drives ended.

From 1966 to 1972, logging activities were concentrated on the eastern side of the limit, in the Nipigon River watershed west of Pine Portage and the Nipigon River. This was one of the company's first commuter operations. For most of this period, logs were trucked to the rail spur at Cameron Falls and then transported by rail to the mill in Thunder Bay. In the final year, however, logs were transported the entire distance by truck, even though the Abitibi Paper Company continued log drives on the Nipigon River until 1971, both for its own wood and that of the Great Lakes Paper Company.

In 1972, harvesting operations were again shifted, this time to the extensive areas of forest on the west side of the limit, operating out of Camp 45 at kilometre 90 on the recently constructed Spruce River Road (Highway 527). Operations continued in this western area until September 1992, when the camp closed, with logs being transported by road directly to the mill in Thunder Bay.

With the completion of logging in the Camp 45 area, most of the original forest on the limit had been exhausted. Attention then turned to some of the older second-growth mixedwood stands south of Nonwatin Lake, first harvested in the 1940s, that had suffered severe damage in the 1982 spruce budworm outbreak. In 1992, harvesting started in areas to the west of Eskwanonwatin Lake and along the southern boundary of the limit in the Shillabeer and Sturge Lake areas. Most of the research site was harvested in 1993. Subsequently (1994-97), extensive areas of second-growth mixedwood with high balsam fir mortality were harvested between the research site and the Black Sturgeon River, as well as to the north and west of the research site. These were exclusively commuter operations based out of Dorion (Sturgeon Timber Ltd.).

2.7.2 The first harvest of the research site

The research site was among the first areas to be harvested in the Black Sturgeon Forest, during the later years of the horse-logging era. Although the level of mechanization was at first minimal, harvesting of the site coincided with the transition to motorized log hauls as well as technological improvements in water transportation.

The progressive harvesting of the research site is illustrated in Figure 2.11; most of the experimental areas were cut between 1937 and 1945. First to be harvested (1937-38) were areas west of Eskwanonwatin Lake, where the site preparation alternatives component of the project is now located. Stand 1 of the harvesting impacts component was cut mostly in 1940-41, with Compartments 1-9, 1-11, 1-12, and 1-13 cut in 1941-42. At the airstrip, Stand 2 of the harvesting impacts component was cut over an extended period: Compartments 2-1 and 2-7 in 1939-40, and the rest of the compartments between 1942 and 1945. Various map records (e.g., Moran 1962) indicate that, as suspected from the condition of the forest in 1993, the rear portions of Compartments 2-4 and 2-5 were left uncut. This accounts for the concentrations of large, heavily branched white spruce that were encountered in the rear of these compartments in 1993 — trees that were probably of unmerchantable size in the 1940s, and possibly owed their existence to some earlier localized site disturbance. Stands of the fire ecology component were harvested in 1940-41 and 1941-42.

The early logging camps were generally about 6 km apart, usually centred on a logging chance of approximately 1.75 miles radius (2.8 km; approx. area 25 km^2). Thus, the principal camps involved in harvesting the research site were Camps 1, 6, 7, 26, and 27 (Fig. 2.11). There were also seasonal river drive camps along the Black Sturgeon River. While Camp 1 was for many years the administrative and service centre for the Black Sturgeon operations, the smaller camps, each of which accommodated 70-80 men, had a relatively short life. Camp 7 appears to have continued in use longer than most.

2.7.3. Cutting and skidding

The research site was harvested principally for pulpwood (8-foot), although the area yielded substantial quantities of spruce and pine sawlogs (16-foot) in addition (see Table 2.3). One interviewee recalled large numbers of white pine being harvested in the Camp 7 area in 1942, specifically for use as boom timbers for rafting wood on Lake Superior. As a rule, cutting operations were laid out to take account of the topography and for ease of skidding and hauling. Where the land was reasonably flat, as on the upland areas of the research site, a more or less systematic block layout was adopted. Since the maximum skidding distance with horses was 300 feet (91m), areas to be harvested for pulpwood were usually divided into strips 10 chains (660 feet; 200 m) wide with a strip road down the centre which connected into the road network. Each cut and skid gang, or sometimes individual pulpwood cutters, were allocated separate cutting blocks within a strip.

Layout of the harvest areas, strip cruises, and demarcation of the cutting blocks were generally completed by late July. In the 1940s and 1950s, harvesting usually started in mid-August (depending on market demand) and extended through to about Christmas, or until such time as the snow became too deep to operate. In the early days, most timber was cut with a wood-framed bucksaw, later replaced with a steel-framed 50-inch (1.3 m) Swede saw, and delimbed with a $3^1/_2$ to 4 pound (1.6-1.8 kg) axe. Average productivity was $1^1/_2$ to 2 cords per man/day, necessitating large numbers of woods workers and a camp system to house them. Contrast this with the average 60 cords per man/day that might be expected in today's feller-buncher operations in second-growth mixedwoods at Black Sturgeon, or the 300 cords per man/day that might be achieved in productive pine stands. Larger trees, such as large pine or the occasional large white spruce, were cut with a two-man crosscut saw, a third man often delimbing with an axe and saw. Power saws did not appear on the scene until the early 1950s, well after the research site was first harvested.

Horses were used extensively for skidding and hauling in these early logging operations. They were generally boarded on farms in the Dorion/Hurkett farm belt during the summer months when there was no cutting, and were

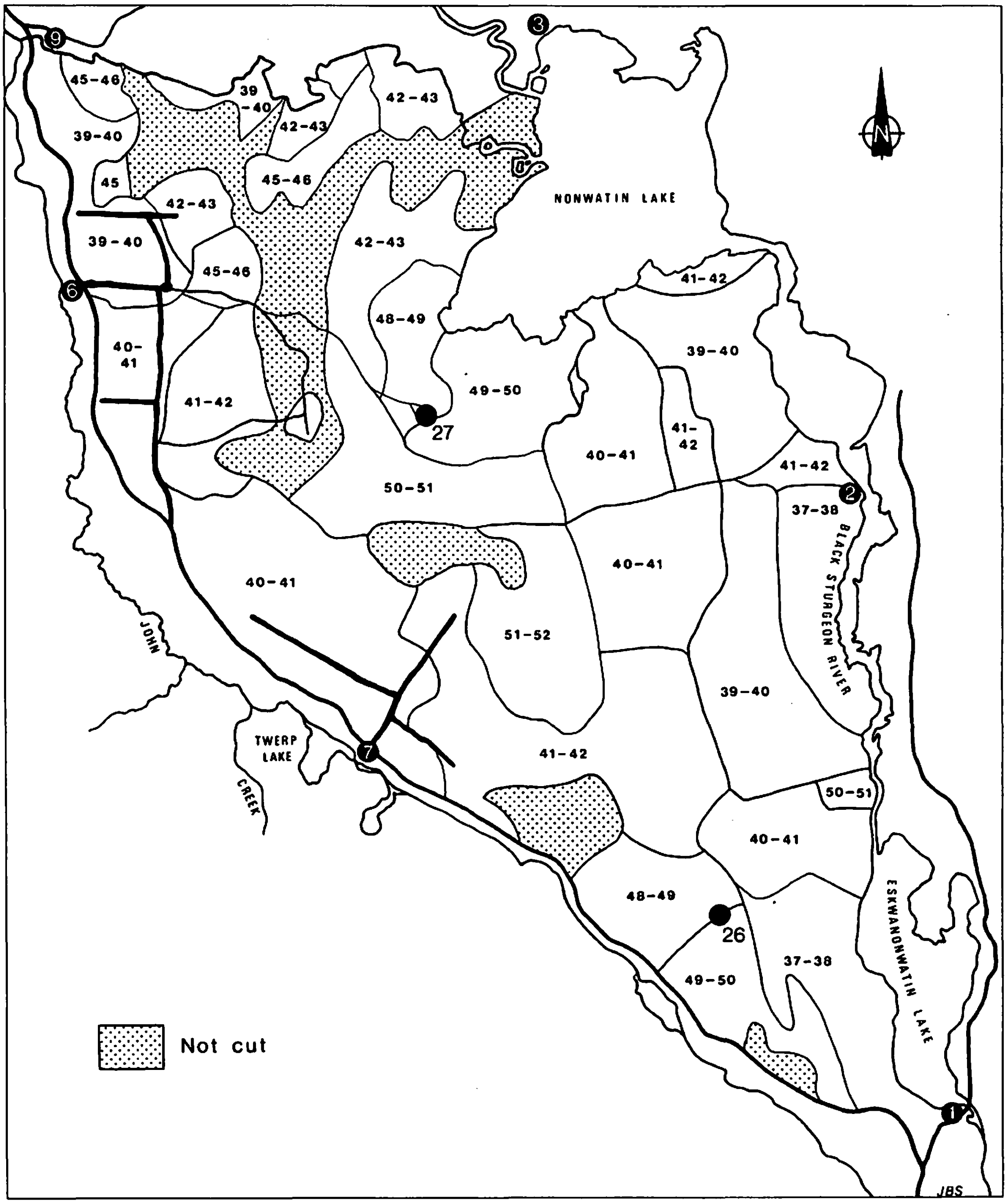

Figure 2.11 Dates of first harvest (1940s) of the research site, showing position of logging camps (black dots, with camp numbers indicated). Locations of the main project components are indicated by the positions of their internal service roads (see Fig. 2.2 for the locations of individual treatment compartments).

brought out to the logging camps in August at about the same time that the cutters were hired. During the cutting operations, both pulpwood and sawlogs were skidded by horse to the strip roads, where they were piled separately by hand. Then, with the arrival of snow and over the Christmas period, the haul roads were broken open and iced in readiness for the winter log haul. A horse-drawn water tank on a sled was used to apply the water for this purpose. The log haul usually started shortly after Christmas and was generally completed by mid-March, well before spring breakup. Each camp would haul between 7,000 and 10,000 cords of wood to landings on the Black Sturgeon River, its tributaries and lakes during this period.

For a short time, from 1937 to 1942, horses were used for the entire log haul where distances were relatively short. Pulpwood logs stacked along the strip roads were hand-loaded onto horse-drawn sleighs, each with a capacity of 3-5 cords, which were then hauled onto the main roads and thence to the river or lake landings. Sawlogs were loaded onto the sleighs with the aid of a horse-operated "side-jammer" winch; pulpwood was generally loaded by hand. From 1942 to 1949, horses were used to haul loaded sleighs only as far as the main roads. Here, the sleighs were marshalled into trains that were hauled by crawler tractor (later by 3-ton truck) to the landings. Sleigh trains might be made up of 7-9 sleighs when hauling 8-foot pulpwood, or 3-4 sleighs when hauling 16-foot sawlogs. After 1951 (well after harvesting of the research site was completed), horses were used only for skidding logs to the strip roads. Their use in the Black Sturgeon Forest was phased out entirely in 1961, at about the time that the first articulated skidders were being introduced to replace the caterpillar-style tractors. The advent of skidders revolutionized logging operations by introducing the capacity for tree-length skidding, with bucking at centralized landings. This meant that tree fellers were no longer required to be skilled in making logs, and henceforth cutting to sawlog or pulpwood dimensions was done by a single cutter at the landing.

2.7.4 River and lake transport

In its report of 1930 on logging conditions in the Black Sturgeon Pulp and Timber Limit, the John Schroeder Lumber Company of Milwaukee, Wisconsin reported to the Great Lakes Paper Company that *"The Black Sturgeon River, with* [the construction of] *a dam on Black Sturgeon Lake, will make one of the best driving streams in the country because of its high banks, clean gravel bottom, freedom from sand bars and large reefs of rocks, and the absence of bad falls or rapids."* This was the era of river drives, and of the various alternatives discussed in the report for delivering wood from Black Sturgeon to the mill in Thunder Bay (old Fort William), water transportation was judged to be the cheapest and most economical method.

From 1937, when the Pigeon Timber Company started harvesting at the southern end of Eswanonwatin Lake, to 1965, when the Great Lakes Paper Company finished harvesting the central and southern portions of the Black Sturgeon watershed, all wood was transported by water, via streams and lakes feeding into the Black Sturgeon River and thence to Lake Superior. Some 16 main dams were constructed within the watershed to control water levels for the river drives, and for rafting logs on the larger lakes. The Nonwatin River, for example, now mostly a slow and meandering stream, supported several dams that permitted logs to be driven from Sturge Lake to Nonwatin Lake. Similarly, logs from the Little Sturge and Muskrat Lakes were driven to Black Sturgeon Lake down the Spruce and Muskrat Rivers. Logs were rafted on the Black Sturgeon, Nonwatin, and Eskwanonwatin Lakes, but for the rest of their journey they floated free, aided by the log drivers. In later years, as techniques and equipment improved, logs were driven free on Eskwanonwatin Lake, with the shores of the lake boomed off to confine the logs to the main channel.

Wood from the research site was hauled either to the southern shore of Nonwatin Lake or to the northern end of Eskwanonwatin Lake. Camp 7 appears to have been the approximate dividing point for these two hauls from the plateau area; in general, log hauls were limited to a 3-mile (4.8 km) radius of the lake dump site. At Nonwatin Lake, and initially at Eskwanonwatin Lake also, logs were piled on the lake ice in patterns designed to make up rafts, each containing 3,000 to 4,000 cords of wood. The snow cover on access routes to these dump sites was compacted by horse-drawn ploughs (later by bulldozers) to encourage frost penetration. When the haul was finished, usually by the end of March, boom logs, anchored to a shore cable, were towed onto the ice and chained together to encircle the wood piled in raft lots. After the spring breakup in early May, the resultant rafts were winched across the lake by a Russell 20 "alligator" warping tug, and the logs released into the Black Sturgeon River. The rafts were generally winched, rather than towed, across the lakes from anchored positions, the tugs being equipped with 1700 feet (518 m) of 3/8-inch (9.5 mm) steel cable.

Until 1960, the Eskwanonwatin Lake dam, first built in 1937, was the last dam on the Black Sturgeon River. Once the logs were flushed through this dam they had to be driven 50 km or more downriver to Black Bay on Lake Superior. At the mouth of the Black Sturgeon River, the logs were assembled into rafts which were then towed by large lake tug some 66 miles (106 km) to the company's water lot in Thunder Bay east (old Port Arthur). A lake raft might contain upwards of 8,000 to 10,000 cords. At Port Arthur, the rafts were broken up into smaller "pockets" for towing a further 9 miles (14.5 km) to the mill wood pond and jackladder on the Kaministiquia River in old Fort William. The river drives ended in 1965 with the completion of harvesting in the Black Sturgeon River watershed.

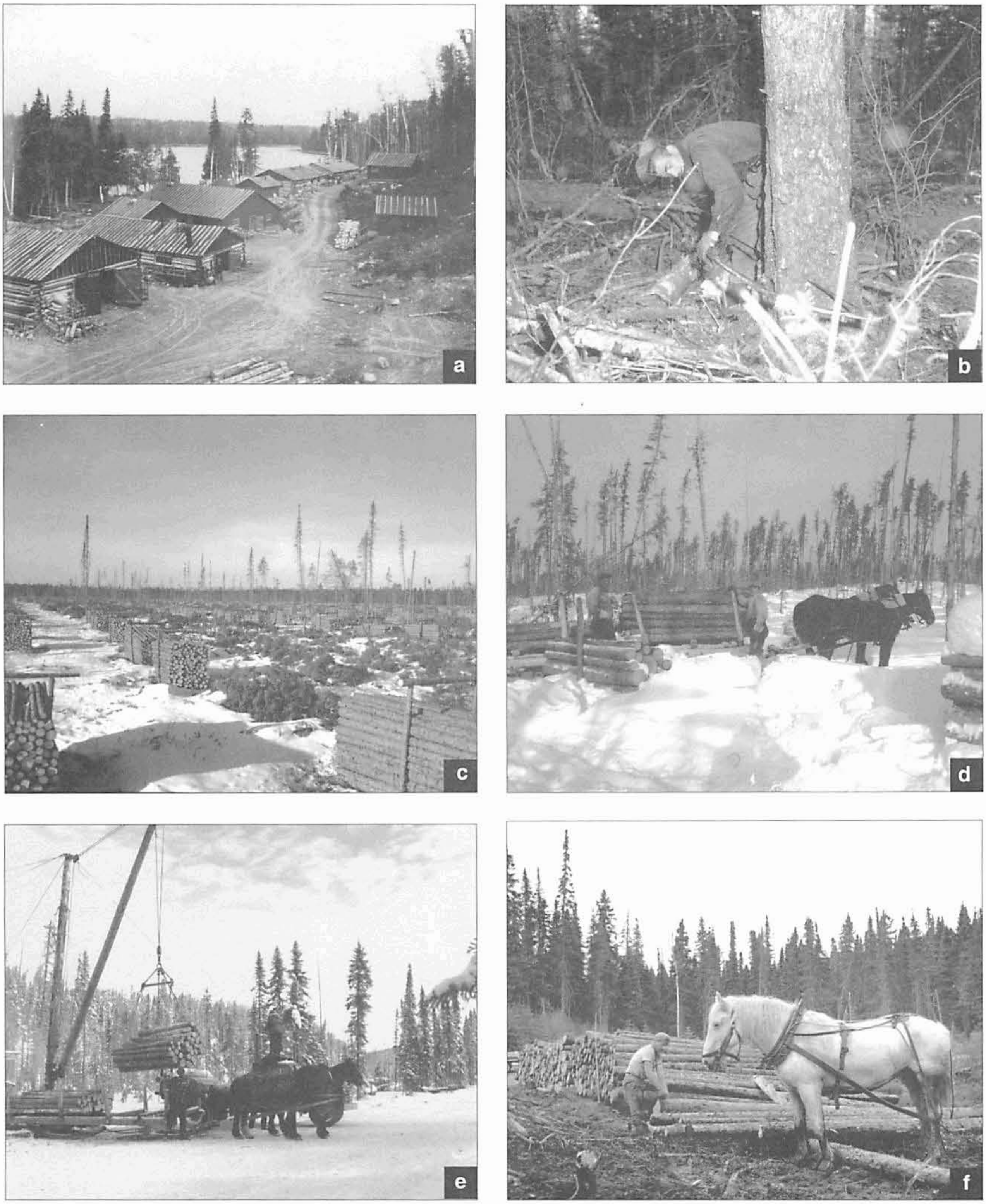

Plate 2. Harvesting in the Black Sturgeon Forest during the 1940s and early 1950s: a. Camp 8 in 1939 (Arnott Whitney); b. Felling with Swede saw; c. Pulpwood piled along skidways; d. Loading pulpwood sleighs by hand; e. Loading pulpwood sleighs with horse-operated jammer winch; f. Skidding and piling sawlogs. Photos 2b to 2f courtesy of Thunder Bay Historical Museum Society, Great Lakes Paper Company collection.

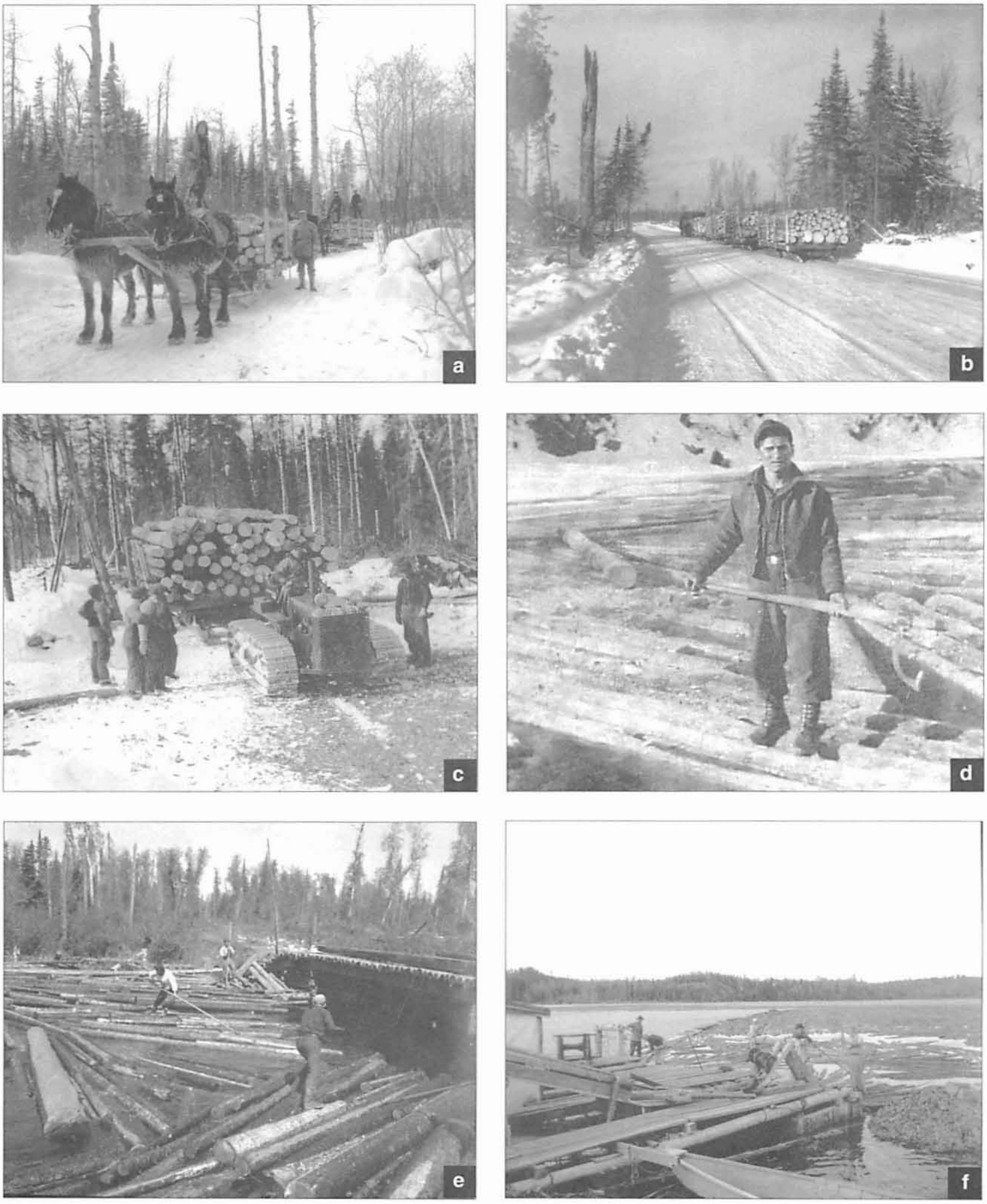

Plate 3. Harvesting in the Black Sturgeon Forest during the 1940s and early 1950s: a. Horse-drawn sleigh train on secondary haul road; b. Sleigh train on main haul road, drawn by 3-ton truck; c. Crawler tractor hauling sawlogs (Arnott Whitney); d. River drive, 1942 (Bill Angeloff); e. Clearing log jam on Black Sturgeon River; f. Jack ladder for sawlogs at Eskwanonwatin Lake dam. Photos 3a, 3b, 3e, 3f courtesy of Thunder Bay Historical Museum Society, Great Lakes Paper Company collection.

SECTION 3 - HARVESTING IMPACTS COMPONENT

Plate 4 Harvesting impacts component: aerial view of Stand 1 taken on May 30, 1996 (north at left).

SECTION 3 – HARVESTING IMPACTS COMPONENT

3.1 INTRODUCTION

The past decade has seen major shifts in society's attitudes towards forest land management. Driven by public sentiment, environmental concerns, and changing government policies with respect to natural resources, the forest industry faces growing pressure to develop more environmentally acceptable alternatives to traditional harvesting methods. Although, as noted in the Introduction (Section 1.2), this should not be interpreted as a call for the wholesale abandonment of current forestry practices, it has become increasingly evident that forest managers need to develop a more refined set of management tools to help them achieve their operational goals while responding to society's needs and expectations. From an industry perspective, the incentives are twofold: (i) to reduce or avoid the perceived negative impacts of clearcutting, and (ii) to develop capabilities for managing forests in a more ecologically sensitive manner, either to satisfy specific non-timber goals or to provide the operational flexibilities needed for applying ecosystem management.

In this climate of changing policies, broadened management goals, and increased public expectations, the need for alternative harvesting and silvicultural options is probably greatest in mixed forests. In boreal mixedwoods, a new philosophy is emerging, which favours management strategies aimed at encouraging the development of healthy mixedwood ecosystems, as opposed to the management (i.e., control) of existing mixedwoods to maximize economic benefits (mainly timber). Because of the ecological complexity and multiple-use potential of mixedwoods, the challenge now is to develop techniques that collectively can satisfy ecological, economic, and social goals — for commodities, recreational opportunities, aesthetic values, wildlife habitat, biodiversity, etc. — while maintaining the long-term health and diversity of the forest. In reality, because different management goals may need quite different operating strategies, this implies the need for a range of techniques that can be adjusted locally to meet specific goals under a variety of site conditions.

Because the controversy over clearcutting has become such an emotive issue for environmentalists and the public at large, harvesting systems that retain some level of stand structure are widely seen as desirable alternatives to current practices. Of the classical silvicultural systems (Troup 1952; Smith 1986; Matthews 1989), shelterwood methods are appealing options for satisfying environmental and biological goals. Compared to clearcutting, partial cutting and shelterwood forestry, together with implied natural regeneration, are perceived as less destructive, more natural, better for wildlife, and less disruptive of ecosystem integrity. To a greater or lesser degree, depending on forest type, such ideas have merit, although proponents often fail to balance the perceived benefits of such alternative practices against potential economic, operational, and long-term ecological realities.

The question for this project component is whether partial cutting can be used in second-growth boreal mixedwoods to meet integrated resource management goals on a sustainable basis. Is partial cutting an operationally viable, silviculturally appropriate, and ecologically sound strategy for managing such forests? Certainly, one of the major silvicultural concerns is whether partial cutting with subsequent natural or artificial regeneration treatments can successfully perpetuate mixedwoods with an economically viable spruce component. However, while this is a critical area of investigation from an operational perspective, the project deliberately seeks to avoid a narrowly silvicultural focus. Recognizing that the stewardship of forest resources involves more than just timber production, the emphasis is on understanding the broad ecological impacts of partial cutting compared to clearcutting. This includes impacts upon vegetation succession, biodiversity, wildlife population dynamics, and other ecosystem elements, in addition to traditional stand management issues. At this early stage in the evaluation of alternative practices, a thorough understanding of these impacts, and of their effect on relationships among different forest values, is a crucial first step in developing integrated resource management strategies for mixedwoods.

The broad objectives of this project component are:

1. To evaluate the potential of partial cutting as an alternative harvesting method in second-growth boreal mixedwoods;
2. To determine the short- and long-term implications of partial cutting for forest renewal, forest succession, and other forest values;
3. To compare the ecological impacts of partial cutting versus clearcutting on ecosystem function, ecosystem dynamics, and biological diversity.

Phase I (Section 3.3) was initiated in 1993, with the harvesting of replicated treatment compartments. Phase II (Section 3.7), involving the site preparation of selected compartments and the installation of regeneration experiments, commenced in late summer of 1995.

3.2 EXPERIMENTAL DESIGN

3.2.1 Stand selection criteria

With provision for protective buffers, the design called for an area of roughly 400 ha of relatively homogeneous second-growth mixedwood forest comprising aspen, spruce and balsam fir as the principal tree species. Adding to the challenge of the search, good summer road access, with guaranteed long-term accessibility, was essential.

The selected area of forest would include stands of similar age, composition and condition, occurring on similar soil types, and having moderate, relatively uniform topography throughout. Aspen would be a major component of the stand (>50%), and of such quality and vigour that residual trees might be expected to show a reasonable growth response to thinning for 10 years or more after harvesting. The balsam fir component would be in merchantable condition, and there would be sufficient spruce (preferably white spruce) to furnish a good distribution of retained potential seed trees on partially cut areas. Coniferous advance growth would be present on prospective harvest blocks, thereby permitting an evaluation of the impacts of harvesting operations on existing regeneration; while spruce was preferred, it was recognized that balsam fir advance growth was more likely to be found in the desired amounts in second-growth mixedwoods.

The sites finally selected for this project component present remarkably uniform conditions. As noted in Section 2.2.4, they lie on an extensive recessional moraine, characterized by generally flat terrain and deep, well-drained sands and gravels. The soils are mostly sandy loams, with variable amounts of silt and small cobbles, but few large stones or boulders (Section 2.3.2). At time of harvest, they supported second-growth mixedwood stands that were quite uniform, both in composition and structure (Section 2.5.2), with moderate amounts of balsam fir advance growth. These stands were harvested for the first time between 1939 and 1942 (see Section 2.7 and Fig. 2.11).

3.2.2 Study area

Because of topographic restrictions imposed by the shape and size of the recessional moraine, it was not possible to accommodate the entire harvesting experiment within a single contiguous block. Consequently, the experiment is located on two comparable sites roughly 6.5 km apart (Fig. 2.2). Stand 1, comprising two sets (replicates) of harvesting treatments, is centred on old Camp 7 (49°11.2'N, 88°42.6'W), approximately 47 km north of Hurkett on the Black Sturgeon Road (Section 2.1). Stand 2 comprises a single set of treatments, and is located some 7 km further north, immediately north of the airstrip (49°14.2'N, 88°45'W). See *General Description of Research Site* (Section 2) for relevant characteristics and descriptions of the research site.

3.2.3 Harvesting treatments and experimental design

Because harvesting method can have significant silvicultural and ecological implications for future stand management, the harvesting treatments were chosen with a view to creating a range of post-harvest disturbance conditions. Treatments included the following comparisons, geared to the production of pulpwood:

- partial cutting versus clearcutting;
- tree-length versus full-tree harvesting;
- "soft" logging versus conventional logging.

The post-harvest conditions created by these harvesting treatments are described in Section 3.6 (see also Sections 3.3.1 and 3.3.2); they include differences in site disturbance, amounts and distributions of logging debris, extent of destruction of ground vegetation and advance regeneration, and residual tree species, densities, and volumes.

Harvesting was carried out during late fall of 1993 and early winter of 1994. Six harvesting treatments were applied, with uncut controls, each replicated three times, *viz:*

1: Clearcutting:
- 1i[a] Standard feller-buncher and grapple skidder[b] (*full-tree extraction*)
- 1ii Single-grip feller-delimber and grapple skidder[c] (*tree-length extraction)*

2: Partial cutting:
- 2i Standard feller-buncher and grapple skidder[b] (*full-tree extraction*)
- 2ii Single-grip harvester and forwarder[d] (*cut-to-length system*)
- 2iii Manual felling and cable skidding[e] (*partially delimbed full-tree extraction*)

3: Patch cutting:
- 3 Manual felling and cable skidding[e] (*partially delimbed full-tree extraction*)

4: Uncut control

[a] Treatment numbers (1i, 1ii, 2i .... 4) provide cross-reference to Table 3.1 and Appendix 8.
[b] Harricana feller-buncher (mounted on John Deere 693 excavator carrier) and John Deere 648 grapple skidder.
[c] Ultimate 4500 single-grip processor (mounted on Caterpillar 227 excavator) and John Deere 648 grapple skidder.
[d] Timberjack 1270 single-grip harvester and Timberjack 1010 loader/forwarder.
[e] Manual felling by chainsaw, with extraction by Clark 664 cable skidder.

The general arrangement of treatment compartments within Stands land 2 is indicated in Figures 3.1 and 3.2, respectively. A conventional randomised block design, with three replications of seven treatments, was originally planned, with two contiguous blocks at Stand 1, and the third block at Stand 2. However, through a mis-communication, two harvesting treatments were switched between the blocks at Stand 1, with the result that both full-tree partial cuts (Treatment 2i) ended up next to each other. Also, because of labour difficulties, it was possible to install only one manual-cut treatment (Treatment 3) at Stand 1. Consequently, with these minor variations, the final assignment of treatment compartments to blocks was as follows:

Block	Treatment compartments
1	1-1, 1-2, 1-4, 1-5, 1-7, 1-8
2	1-3, 1-9, 1-10, 1-11, 1-12, 1-13, 1-14
3	2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7

Harvesting treatments are listed by compartment and block in Table 3.1, together with dates for the commencement and completion of harvesting. Information on compartment layout and demarcation is given in Section 3.2.4; detailed compartment maps showing the locations of the principal study plots are described in Section 3.8.1 and presented in Appendix 8. Plate 4 shows, in aerial view, a portion of Stand 1 two years after harvest.

Both harvested treatment compartments and uncut controls have an area of 10 ha, with minimum 100 m wide uncut buffer strips between compartments. The patch cuts were established as a link with related research studies of white spruce regeneration in aspen ecosystems being conducted in the Chapleau area (Groot et al. 1997). Small, 21 m diameter clearcuts (equivalent to average stand height) were made at 50-m center-to-center spacing along 5 m wide skid trails cut 50 m apart (see Appendix 8). All merchantable trees were harvested from the patches and skidways, removing approximately 20 percent of the standing volume from each 10 ha compartment. [See Losee (1966) for discussion of a similar treatment applied to a 70-year black spruce-feathermoss forest type.]

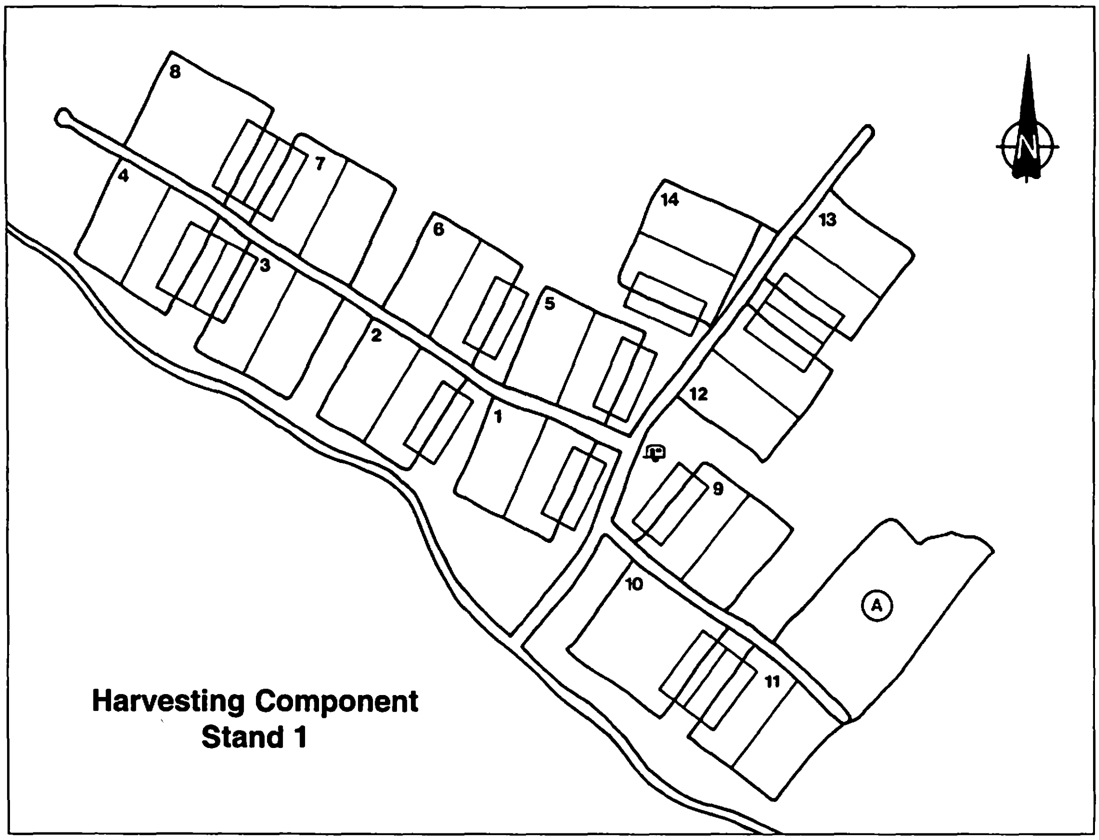

Figure 3.1 Treatment compartment layout for Stand 1. See Table 3.1 for list of treatments by compartment number; rectangles straddling the lateral compartment boundaries represent areas dedicated to small mammal trapping. [A = operational clearcut]

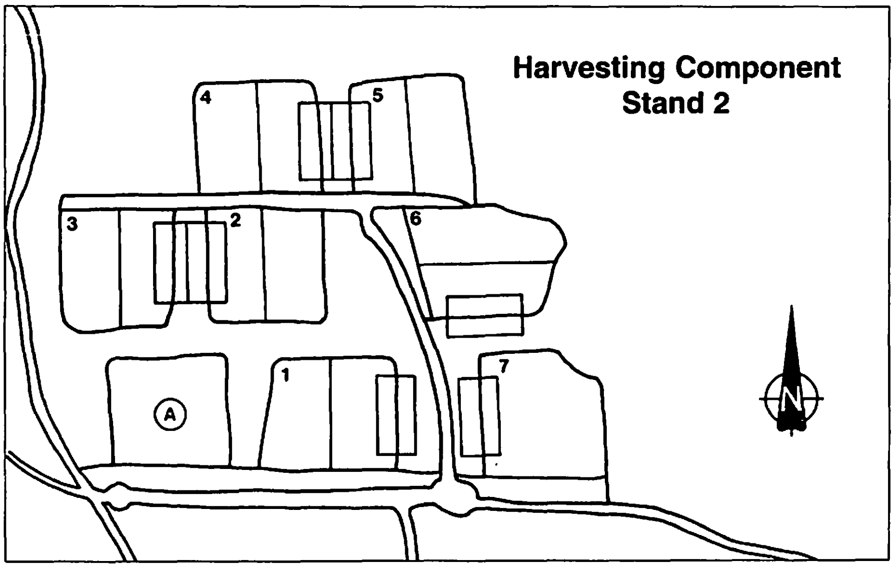

Figure 3.2 Treatment compartment layout for Stand 2. See Table 3.1 for list of treatments by compartment number; rectangles straddling the lateral compartment boundaries represent areas dedicated to small mammal trapping. [A = uncut compartment with supplementary budworm

Table 3.1 Allocation of harvesting treatments to compartments.

Compartment[a] (block)	Treatment	Harvesting method (treatment)[b]	Started	Completed[c]
1-1 (1)	1i	Full-tree clearcut (feller-buncher)	06-10-93	26-10-93
1-2 (1)	2i	Full-tree partial cut (feller-buncher)	15-10-93	11-11-93
1-3 (2)	2i	Full-tree partial cut (feller-buncher)	15-10-93	05-11-93
1-4 (1)	4	Uncut control	-	-
1-5 (1)	2ii	Partial cut, delimbed and slashed on site (CTL[d])	23-11-93	01-12-93
1-6 -	-	Uncut - no treatment applied	-	-
1-7 (1)	1ii	Tree-length clearcut (single-grip harvester)	11-11-93	26-11-93
1-8 (1)	3	Patch cuts (tree-length, manual felling)	29-10-93	09-11-93
1-9 (2)	1ii	Tree-length clearcut (single-grip harvester)	29-10-93	09-11-93
1-10 (2)	3	Patch cuts (tree-length, manual felling)	09-11-93	02-12-93
1-11 (2)	2ii	Partial cut, delimbed and slashed on site (CTL[d])	01-12-93	17-12-93
1-12 (2)	2iii	Full-tree partial cut (manual felling)	05-11-93	10-12-93
1-13 (2)	4	Uncut control	-	-
1-14 (2)	1i	Full-tree clearcut (feller-buncher)	22-10-93	01-11-93
2-1 (3)	1ii	Tree-length clearcut (single-grip harvester)	06-10-93	28-10-93
2-2 (3)	2ii	Partial cut, delimbed and slashed on site (CTL[d])	17-12-93	08-01-94
2-3 (3)	2iii	Full-tree partial cut (manual felling)	30-09-93	05-11-93
2-4 (3)	2i	Full-tree partial cut (feller-buncher)	29-09-93	15-10-93
2-5 (3)	4	Uncut control	-	-
2-6 (3)	1i	Full-tree clearcut (feller-buncher)	28-09-93	06-10-93
2-7 (3)	3	Patch cuts (tree-length, manual felling)	13-10-93	27-10-93

[a]Throughout this report, reference to compartments takes the form S-B, where S = stand number and B = compartment number (e.g., Compartment 1-8). Numbers in parentheses denote assignment of compartments to statistical blocks.
[b]For complete description of harvesting treatments refer to text.
[c]Felling only; skidding may have continued beyond the specified completion date.
[d]CTL = cut-to-length harvesting system.

3.2.4 Treatment compartment layout and demarcation

Each 10 ha treatment compartment, including uncut controls, measures 315x320 m and is set back approximately 20 m from the service roads (Fig. 3.3). As noted above, the treatment compartments are separated by uncut buffer strips of minimum width 100 m. The two corners on the face of each compartment (i.e., adjacent to the road) are demarcated by yellow-painted 10x10 cm wooden posts. The centre point of the compartment face is marked with a similar post on which is mounted a sign describing the harvest treatment. From this centre post (all compartments except Treatment 3 and patch cuts) a cleared access path runs to the rear of the compartment; this pathway is maintained manually and by the local application of Vision® as required. The rear corners of the compartments are demarcated by large trees with painted trunks; where necessary (e.g., uncut control compartments), pink flagging is used to mark compartment boundaries.

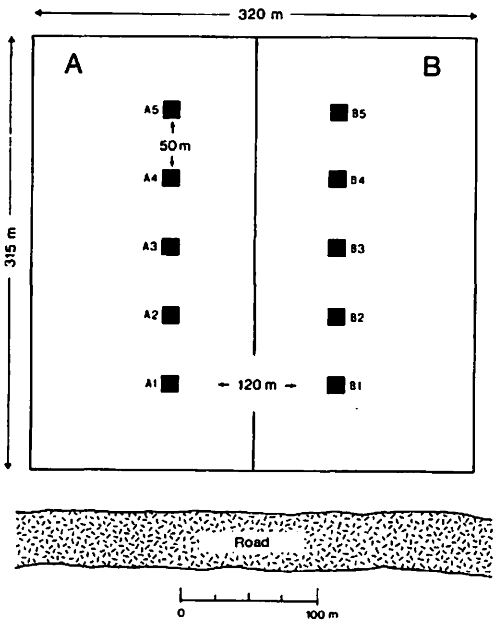

Figure 3.3 Generalized layout of treatment compartments, showing arrangement of permanent sample plots (PSPs).

The access path separates each compartment into two halves, designated side A and side B (Fig. 3.3). One half of the compartment (usually, but not consistently, side A) will receive no further treatment after harvest, and is available only for monitoring studies that do not disturb the site (this side of the compartment is indicated in Figures 3.1 and 3.2 by the presence of the small mammal trapping networks). The other half is available, after consultation with the Project Coordinator and subject to the agreement of other study leaders, for compatible additional stand/site manipulations or sampling[7].

Five 10x10 m permanent sample plots (PSPs) are located in each half of all treatment compartments for pre-harvest and long-term post-harvest vegetation measurements and stand inventory monitoring (excludes post-harvest monitoring in Treatment 3). PSPs were re-established at the same location immediately after harvest. Nominal PSP spacing is indicated in Figure 3.3; plot corners are demarcated by blue-painted aluminum stakes, with an iron rail spike buried below the ground surface at the centre of each PSP to facilitate plot relocation. Blue-painted and numbered wooden direction signs to PSPs are located along the central access pathway in each compartment.

3.3 PHASE I – HARVESTING

3.3.1 Harvesting guidelines

Clearcutting: The clearcut compartments were harvested operationally, with the instruction that all merchantable timber, including balsam fir, should be removed. This resulted in true clearcuts with few residual standing trees, and most of the dead and unmerchantable balsam fir knocked down. The one exception was Compartment 1-14, in the centre of which a large amount of white birch remained after harvest; this birch was removed in a separate harvesting operation in May 1994, before the installation of study plots.

Skidder operators were instructed that, wherever possible, they were to extract trees perpendicular to the face of the cut-block and to avoid skidding to only one or two roadside points. This was done to ensure reasonably uniform skidding disturbance across the compartments and to avoid the risk of creating a few heavily travelled skid trails. Because of the manner in which the felling machines harvested and bunched cut trees (in strips perpendicular to the road), most skidding followed the desired pattern, although the intensity of skidder traffic obviously declined from front to rear of the compartments. Operators were instructed to skid trees clear of the compartment face and onto the roadside reserve for further processing (delimbing, slashing, or chipping) to avoid accumulations of processing debris within the treatment compartment boundaries.

Partial cutting aimed to remove about two-thirds of the merchantable volume, including all merchantable balsam fir, retaining a uniform canopy of good quality aspen with a scattering of potential white spruce seed trees. A uniform distribution of residual aspen was important, since this would form the bulk of the residual canopy. Felling machine operators were instructed to select for retention only the most vigorous aspen trees with good stem and crown form, harvesting mainly trees of lower vigour, and those with heavy branches, stem defects, or bearing bracket fungi (*Phellinus tremulae* [Bondarstev] Bondarstev & Borisson). All merchantable balsam fir was to be harvested, and no special efforts were to be taken to preserve unmerchantable fir during harvesting or skidding. Guidelines for the retention of white spruce seed trees (2-3 large trees per hectare with well-formed crowns) allowed black spruce to be substituted where there was insufficient white spruce of the required size or quality.

No preselection or marking of trees was carried out prior to harvest. Rather, cutters were instructed in the general goals of the project, and a small area of adjacent forest was harvested according to the guidelines to serve as a demonstration area. For logistic reasons, on-the-job-training was the norm, and constant supervision of the felling operations was maintained to guide the decisions of operators, none of whom had previously been exposed to the special needs of partial cutting. Because machine operators were unable to make the required judgements regarding stem and crown form at night, partial cutting was conducted only during daylight hours; feller-bunchers were assigned to an adjacent clearcutting area (Compartment A in Fig. 3.1) for the night shifts.

Skidding guidelines were similar to those for the clearcut compartments, adjusted to the partial cutting situation. Thus, the harvesters generally operated in strips perpendicular to the road (face of the compartment), with bunches

[7]Note: Substantial areas of this half of several clearcut compartments were site prepared in 1995 under Phase II of the project. See Section 3.7 and Appendix 8 for details.

of harvested trees (in the case of feller-bunchers) laid into the untravelled areas at 45° to the direction of travel. The feller-buncher operators were instructed to leave 2-m-high rub posts wherever necessary to minimize skidding damage. Skidder operators were instructed to adopt techniques that would avoid or minimize damage to residual trees, and to use the rub posts to facilitate turning their loads. In the case of the manual full-tree harvest only (Treatment 2iii), cutters were allowed to trim the tops of harvested aspen trees to facilitate extraction by the smaller skidders.

Patch cutting: As noted in Section 3.2.3, the patch cuts consisted of small, 21 m diameter clearcuts (equivalent to average stand height) at 50 m center-to-center spacing along 5 m wide skid trails cut 50 m apart. Skidder-width trails were first cut from the road to the rear of the compartments and the harvested trees were removed. Circular patches were then cut at 50 m intervals along the trails, starting from the front of a compartment. All merchantable trees were harvested from the patches and trails, removing approximately 20 percent of the standing volume from each 10 ha compartment.

3.3.2 Harvesting operations

General observations

Much as it was desired that harvesting be operationally realistic in the context of a pulpwood operation, in practice various operating delays and constraints forced treatment changes and compromises not envisaged in the original project plan. While this does not alter the broad scope of the project, it is worth recording these factors, for they significantly influenced the manner of harvesting, *viz:*

- None of the harvester or skidder operators had any previous experience of partial cutting. In this regard, all operators were at the beginning of the learning curve for this harvesting method, and it quickly became evident that operator motivation and proficiency in handling their equipment were critical elements in achieving the desired results. It took most operators two to three days to adapt to the objectives of partial cutting, and to come to terms with such alien concepts as leaving the larger, better-quality trees and avoiding damage to residuals.
- Because the woods operations of Bowater Inc. were unionized, the harvesting was plagued by high operator turnover and related delays. This not only created difficulties resulting from differing levels of operator motivation and proficiency, but also meant that there was a recurring need for on-site training, with little opportunity to benefit from operators with newly acquired skills.
- Equipment availability problems and equipment diversions to other operations sometimes meant that harvesting of treatment compartments took much longer than expected. This accounts for the delays evident in Table 3.1 which, combined with a late startup date, had the overall effect of extending harvesting well into the early winter months (the original schedule had called for harvesting to start in August and to be completed by the end of October).

As noted earlier, despite their relatively young age (≈55 years), the heavily budwormed mixedwood stands of the research site were scheduled to be commercially clear-cut in 1994-95 in a salvage operation intended to maximize conifer recovery while it was still in merchantable condition. As on adjacent areas, this would have been a full-tree pulpwood operation using feller-bunchers and grapple skidders; trees would have been skidded to roadside to be mechanically delimbed and slashed into 8-ft pulpwood lengths. This was essentially the same harvesting method used for clearcutting in Treatment 1i and, with appropriate modification, for partial cutting in Treatment 2i also. Towards the end of the harvesting project shortwood production ceased and whole-tree chipping at roadside was introduced; however, this had no impact on the harvesting of the project cut-blocks.

Evaluation of harvesting operations

Staff of the Forest Engineering Research Institute of Canada, Eastern Division (FERIC–East) assisted in system selection, harvest planning, and on-site training. They also conducted machine productivity and post-harvest surveys to assess the operational effectiveness and impacts of the different harvesting systems used in the partial cutting treatments. Unfortunately, because of operator inexperience with partial cutting, high operator turnover, and excessive downtime, the data on productivity, costs and damage to residual trees were felt not to reflect operational reality. However, the studies did help to identify areas of concern and, as part of the operational learning curve, served to introduce woods staff and operators to the possibilities and realities of partial cutting in mixedwood stands. Harvesting evaluation results are reported in Gingras (1994, 1995).

Performance of harvesting equipment

The following notes are based on casual observations made during supervision of the harvesting operations; for a more detailed discussion and quantitative observations see Gingras (1994, 1995). It should be noted that conditions on the research site were exceptionally favourable for harvesting, characterized by freely drained soils and mostly flat terrain. This meant a low potential for rutting of the site and generally easy terrain conditions for maneuvering equipment during partial cutting and skidding.

While the relatively small size of trees affected productivity in all harvest treatments, including on clearcuts, the large amounts of dead and unmerchantable balsam fir presented a greater obstacle for some systems than for others. The feller-bunchers were most effective in crushing or mowing down unmerchantable fir thickets during the course of harvesting, producing a much cleaner post-harvest residual stand appearance than other partial cut treatments. Dead fir presented difficult working conditions in the manual felling treatment, and proved a major obstacle to operation of the Timberjack 1270 single-grip harvester (cut-to-length). Because the processor head of the latter was relatively light, it had difficulty crushing dead fir, and was unable to mow down fir thickets in the same manner as the feller-bunchers. As a result, the immediate post-harvest residual stands for this treatment were aesthetically less attractive than those in the feller-buncher compartments owing to the dead and unmerchantable balsam fir left standing (although most of this material had collapsed by the end of the following summer).

Feller-buncher and grapple skidder:

Although used here for both clearcutting and partial cutting, the combination of Harricana sawhead and John Deere 693 carrier is optimized for clearcutting. In a partial cutting situation, the harvester suffers from a wide tail-swing, lack of rear view (for backing up), lack of skylight (for viewing the tree canopy), low maneuverability, and limited boom reach. Operators were forced to adopt a back-and-forth mode of operation to select, cut, and extract trees, and often had to leave the cab to view tree crowns when selecting trees for harvest or retention. Without great care, residual trees were also frequently damaged during backing up or by tail swing when turning the cab.

Despite these drawbacks, in the hands of an experienced and motivated operator, the feller-buncher could be remarkably effective in partial cutting. Compared with the Timberjack 1270 single-grip harvester, it was better able to hold stems vertical after cutting, and had greater control over tree placement when setting down bunches of trees between residual trees in patterns that facilitated their future extraction. This feature helped minimize damage to stems and crowns of residual trees. Despite delays due to extra time spent on stem selection, extra care needed in bunching, extra travel time, and a general lack of experience, productivity was only about 15% lower than in the clearcutting operation (Gingras 1995). Because of excessive tail swing, the machines could only work on the upward trip and had to return empty to the road after every strip was harvested so as to leave the butt ends of the bunches facing the road. However, an advantage of this mode of operation was that on the return pass it was possible for a conscientious operator to remove additional trees required to improve tree spacing.

Productivity studies (Gingras 1994) showed that the operation of the John Deere 648 skidders was generally not negatively affected by partial cutting, and that a careful operator could extract bunches of trees without too much damage to residuals. However, reduced productivity might be expected in long-term operations because of the greater care needed to avoid damage on uneven terrain. In this operation, the skidder operators themselves removed tire chains in order to reduce damage to the surface roots and butts of residual trees; on uneven ground this might not be possible.

In contrast to the situation in clearcutting, it quickly became apparent that harvester and skidder operators must work as a team in partial cutting operations in order to achieve desired results with a minimum of damage. Thus, the planning and execution of the harvest, the identification of extraction routes, the location of rub trees, and the alignment of bunched trees should be based on a mutual understanding by harvester and skidder operators of both silvicultural and operational goals.

Feller-delimber and grapple skidder:

It was originally intended that the tree-length feller-delimber (Ultimate 4500) would be used for both clearcut and the partial cut treatments. Based on experience in the clearcut treatment, it quickly became evident that this equipment was not capable of implementing the partial cuts, mainly because of the difficulty of cutting and processing tree-length trees with residual standing trees present.

Even in the clearcutting operation, the Ultimate 4500 was not well matched with its carrier (Caterpillar 227), which had a very wide tail swing. Productivity was low, partly because the harvester head could cut and process only one tree at a time and did not operate efficiently in small timber, and partly because of delays caused by the large amounts of standing dead balsam fir. The Ultimate did not have the same capability as the feller-buncher for mowing down unmerchantable and dead balsam fir, and had to spend a large amount of time crushing fir in order to gain access to trees to be harvested.

Cut-to-length system:

The Timberjack 1270 single-grip harvester and Timberjack 1010 shortwood loader/forwarder were brought in to replace the Ultimate 4500 when it became apparent that the latter was unsuitable for partial cutting. The equipment was operator-owned, but the operator had no previous experience of partial cutting.

The harvester had excellent maneuverability and, because the boom had a reach of 8.3 m (27 ft), could operate at relatively wide trail spacings. Cab design gave the operator very good all-round visibility, including tree crowns, enabling him to make selection decisions from the cab. The long, narrow boom facilitated individual tree selection, with potentially far less damage to residuals because of the capability for reversing the cutting head to approach a tree from various angles. However, because the head could cut and process only one tree at a time, productivity was lower than anticipated, mainly due to the small size of timber and the large amounts of dead balsam fir present. The harvester head had difficulty crushing dead balsam fir, and was unable to mow down fir thickets in the same manner as the feller-buncher. As a result, considerably more unmerchantable and dead material was left standing than in the feller-buncher compartments.

Although the cut-to-length compartments showed the lowest levels of damage to residual tree stems, the harvester was not as adept as the feller-buncher at holding trees vertical after cutting. This sometimes led to difficulties in controlling the downing and placement of cut trees for delimbing and slashing, with the tops of harvested trees (especially aspen) often becoming tangled in the crowns of residual trees. As a result, aspen residuals probably suffered substantially more crown damage in the cut-to-length compartments than in the feller-buncher compartments. Breakage of aspen branches was noted to be particularly heavy when air temperatures dropped to the -20°C range and branches became brittle.

The cut-to-length system created very little ground disturbance outside the trails over which the machines travelled. Except for the presence of large amounts of unconsolidated logging debris (Section 3.6.4), this left most of the balsam fir advance growth and any shrub growth intact and undamaged. However, the inability of the harvester head to process large aspen tops meant that the amount and size of hardwood slash left on the ground was generally greater than with other systems. This inevitably resulted in some loss of merchantable volume. Within the travelled machine trails, deep consolidated slash mats (Section 3.6.4) generally eliminated ground disturbance, but created a problem for future regeneration, and a major obstacle for site preparation.

The loader/forwarder had good productivity due to the favourable terrain and short forwarding distances. It was well-suited to the partial cuts because of its maneuverability, and its efficiency in loading wood from between residual trees. Because it generally travelled on the slash mats created by the harvester, the forwarder contributed little to ground disturbance.

Manual felling and cable skidder

Manual felling would not normally be considered for operational-scale partial cutting in boreal mixedwoods for safety reasons and because of potentially low productivity. It was included among the harvest treatments for this project, however, to determine whether it might bring about an improvement in the quality of the residual stand compared to machine harvesting. For a silviculturally aware cutter, manual felling offers the best opportunity to optimize tree selection and the spatial distribution of residual trees. Unfortunately, the cutters for this treatment had the greatest difficulty of all operators in translating treatment goals into practice, while careless skidding resulted in high levels of damage to residual trees. Perhaps because of the generally small size of trees and the resulting low productivity, it was difficult to keep cutters motivated in following harvesting guidelines. The situation was exacerbated by the presence of large amounts of dead balsam fir, which not only made for difficult working conditions but also made the task of tree selection much more difficult. Discussions with the cutters suggested that selection decisions would have been easier, and better results might have been obtained had they been operating in more mature stands with larger trees.

Additional observations on partial cutting

Although the machine productivity data were less useful than hoped for, a number of important lessons were learned during harvesting of the partial cuts. As noted earlier, none of the harvester and skidder operators had any previous experience of partial cutting in mixedwood stands. Like most loggers in boreal Ontario, they were versed in a traditional production-oriented clearcutting culture, and often had difficulty adapting to the operational and silvicultural strictures of partial cutting. Without constant supervision the partial cuts would quickly have turned into high-grading operations, despite clear guidelines to retain better quality trees and to optimize the condition of the residual stand. To be effective, it is clear that shelterwood harvesting calls for a major change in operating philosophy both on the part of machine operators and forest managers. This can be achieved only through education and training of operators and supervisors. Even then, incentive programs may be needed that emphasize the silvicultural effectiveness of a harvesting operation, based on the quality and composition of the residual stand, residual tree spacing, the amount of damage to residuals, and protection of advance growth where called for. Operators need to understand, for example, that if residual trees are of poor quality or are damaged during extraction, the whole harvesting operation may be compromised.

While training in appropriate machine operating techniques is obviously needed to ensure the proper application of shelterwood harvesting regimes and to minimize damage to residual trees, experience in this project demonstrated the critical need to instill in machine operators and their supervisors a basic level of silvicultural awareness. In a partial cutting situation, especially in mixedwoods, decisions on which trees to harvest and which trees to retain clearly call for an understanding of simple biological and ecological principles, as well as the effects of harvesting on site conditions and ecosystem components. While the availability of harvesting equipment adapted to partial cutting is increasing rapidly, this will be of little benefit until we are able to establish a pool of skilled and motivated operators who understand the silvicultural and biological goals of selective felling as well as the ecological effects of alternative harvesting strategies.

To the need for training must be added the need for careful pre-planning and supervision of shelterwood harvests. Experience in this project indicates that the layout and pre-location of harvesting and skid trails must be viewed as an integral part of the overall harvesting prescription. In an operational situation, these plans will be influenced by stand composition, terrain conditions, and choice of harvesting system, with due consideration for silvicultural objectives. The choice of harvesting and skidding equipment may itself be governed by regeneration prescriptions or the requirement for understorey protection, for example.

As noted earlier, it is essential that harvester operator and skidder operator work as a team during partial cutting operations. Together with the on-site supervisor, they should participate in harvest pre-planning and development of the harvesting prescription. It is also important that they continue to communicate throughout the harvesting operation to ensure that the prescription is being met. The amount of damage to residual trees during skidding can be greatly diminished by careful planning of extraction routes, the placement of tree bunches after cutting, and the wise retention and use of rub posts (or strategic rub trees that are removed during the final stages of extraction).

Volumes harvested

Wood harvested from the project was piled at roadside separately for each compartment as it was harvested. Here it was scaled by staff of Bowater Inc. before being transported to their Thunder Bay mill. Estimated harvest volumes by compartment are given in Table 3.2.

Table 3.2 Volume removals from the 10 ha harvested compartments (m^3 solid measure).

Compartment	Spruce	Balsam fir	Jack pine	Poplar	Total
		Stand 1			
1-1	200	100	100	800	1,200
1-2	200	100	100	500	900
1-3	100	100	100	500	800
1-5	600	100	200	200	1,100
1-7	200	100	200	800	1,300
1-8	100	100	100	200	500
1-9	400	100	200	800	1,500
1-10	100	100	100	100	400
1-11	300	200	100	400	1,000
1-12	500	300	-	400	1,200
1-14	400	300	-	900	1,600
Clearcut A	1,200	200	300	600	2,300
		Stand 2			
2-1	700	300	-	600	1,600
2-2	500	200	-	400	1100
2-3	500	500	-	500	1500
2-4	500	500	-	500	1500
2-6	400	400	-	800	1600
2-7	100	100	-	200	400
Totals	7000	3800	1500	9200	21500

3.4 PRELIMINARY SITE SURVEY

A preliminary vegetation survey and forest inventory of the areas subsequently designated Stands 1 and 2 was conducted in May 1993 to characterize the site and to facilitate decisions relating to road alignments and the location of prospective treatment compartments. The forest inventory was based on a systematic 1% point sampling prism sweep, using a 2 m^2/ha basal area factor prism. Vegetation and regeneration surveys conducted on 2.5 m radius plots centred on sampling points spaced at 200 m intervals along cruise lines 100 m apart (Fig. 3.4). At Stand 1 the baseline bearing was 10°East, and cruise line bearings 54°West ($_n$N series) and 127°East ($_n$S series), respectively. At Stand 2 the baseline was parallel to the airstrip, and cruise lines ran due north.

The survey was designed to collect information on stand type distribution, stand quality, and tree volumes, viz: FEC vegetation type; vegetation cover by species (herbs, mosses and lichens, shrubs); tree inventory; aspen and balsam fir tree quality; occurrence, size, and distribution of coniferous regeneration. General topographical information was also collected as the survey crews progressed through the stands.

Data from this survey, together with calculated basal area and volume estimates for the principal tree species, are available in database directory **~\excel\presurv** (see Appendix 7).

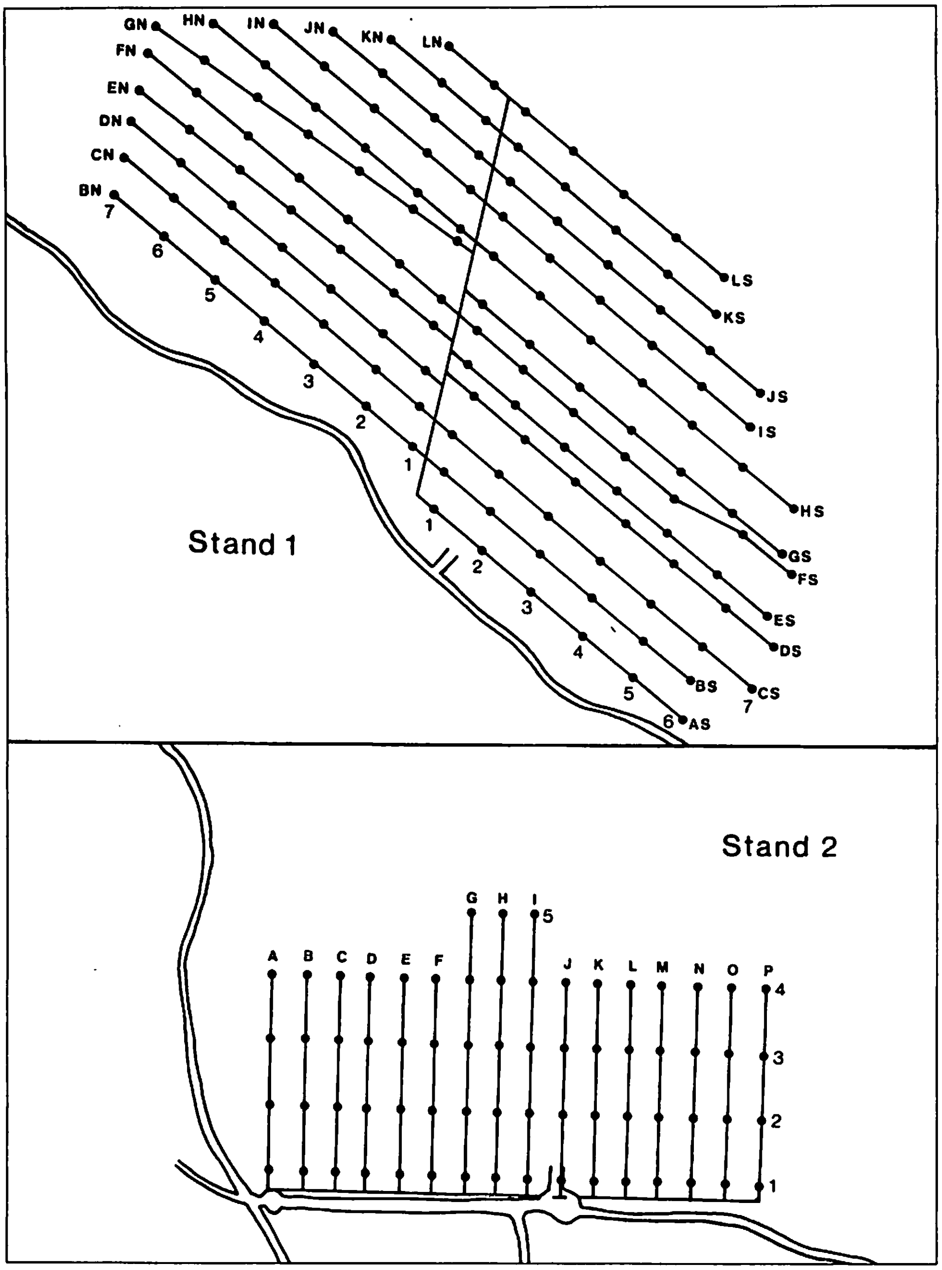

Figure 3.4 Configuration of transect lines and sampling points for preliminary site survey. (Letters and numbers identify sampling points for users of the survey database files)

3.5 PRE-HARVEST CHARACTERIZATION OF TREATMENT COMPARTMENTS

Extensive sampling of the experimental areas was carried out by participating scientists in the summer prior to harvest to characterize pre-harvest baseline forest conditions for their particular areas of interest. Relevant databases may be obtainable for specific areas of study by contacting the appropriate study leader (see Appendix 6 for a list of studies). General pre-harvest baseline information was collected from all 21 treatment compartments during August 1993. This was more detailed than the preliminary site survey, and consisted of vegetation and soil surveys, stand inventories, and other site information. The results are important, both as a basis for judging the long-term impacts of harvesting and for monitoring long-term changes in the undisturbed forest. As noted in Section 3.2.4, ten (10) systematically located 10x10 m permanent sample plots (PSPs) were established in each treatment compartment for pre- and post-harvest monitoring (Fig. 3.3). These were the basic sampling unit for the vegetation and cover assessments. Tree inventories were based on a prism sweep (2 m²/ha basal area factor) from the centre of each PSP. Soil samples (one per PSP) were taken for mineral and organic soil analyses. Supplementary soil samples (organic layer and the top 5 cm of mineral soil) were taken (one per PSP from each of 6 randomly selected PSPs per treatment compartment) for characterization and quantification of the seed bank (Section 3.5.5). Hemispherical canopy photographs were taken from the centre of each PSP to quantify canopy cover (Section 3.5.3).

Much of the general baseline data is available in the following database directories (individual files are listed in Appendix 7):

~\excel\preharv (FEC vegetation type, forest floor [*type and cover*], dominant vegetation [*species and cover by stratum*], coniferous regeneration [*species, distribution and cover by height class*], tree inventory [*heights, basal areas, and volumes by species and dominance class for living and dead trees*], and estimated canopy cover);

~\excel\soils (organic layer and mineral soil analyses);

~\excel\canopy (hemispherical photo data, with raw data from image analysis, and calculated percent canopy cover).

Additional data on pre-harvest stand structure collected as part of the songbird/small mammal studies (Abraham and Rodgers, Appendix 6) is available in database directory **~\excel\structur.**

Some of the information from these surveys is summarized in Appendix 2.1 (compartment descriptions), Appendices 2.2 and 2.3 (soil properties), and Appendix 2.4 (FEC vegetation type characterization). Supplementary observations and data for a number of additional stand parameters are summarized in the sub-sections that follow.

Table 3.3 Pre-harvest stand volume summary.[a]

Species	Living trees		Dead trees		Living + Dead	
	Volume m^3/ha	Percent by vol.	Volume m^3/ha	Percent by vol.	Volume m^3/ha	Percent by vol.
			Stand 1			
Po	133.88	65.19	9.12	16.69	143.00	55.07
Bw	12.51	6.09	1.84	3.39	14.35	5.53
Bf	22.59	11.00	33.69	62.03	56.28	21.67
Sw	16.10	7.84	4.76	8.76	20.86	8.03
Sb	6.01	2.93	0.87	1.60	6.88	2.65
Pj	14.29	6.96	4.03	7.42	18.32	7.05
Totals	205.38		54.31		259.69	
			Stand 2			
Po	99.66	56.82	3.76	6.44	103.42	44.24
Bw	22.49	12.82	8.51	14.58	31.00	13.26
Bf	23.21	13.23	33.15	56.80	56.36	24.11
Sw	27.92	15.92	10.56	18.09	38.48	16.46
Sb	1.88	1.07	1.67	2.86	3.55	1.52
Pj	0.24	0.14	0.71	1.22	0.95	0.41
Totals	175.40		58.36		233.76	

[a]Means derived from tree inventories based on a prism sweep (2 m^2/ha basal area factor) from the centre of ten PSPs per treatment compartment on 14 compartments (Stand 1) and 7 compartments (Stand 2), respectively. (Po = trembling aspen; Bw = white birch; Bf = balsam fir; Sw = white birch; Sb = black spruce; Pj = jack pine)

3.5.1 Tree inventory

Results of the pre-harvest tree inventory are summarized for individual treatment compartments in the compartment descriptions (Appendix 2.1). Volume summaries by species for Stands 1 and 2 are given in Table 3.3.

The full pre-harvest inventory data and volume calculations are available in database directory **~\excel\preharv** (see Appendix 7).

3.5.2 Vegetation and stand structure

General descriptions of pre-harvest vegetation are given in Section 2.5.2; see also Figures 2.8 and 2.9 for forest resource inventory and vegetation classification maps for the research area.

The treatment compartments supported stands which fell mostly within the herb- and shrub-rich mixedwood cover types of the Forest Ecosystem Classification (FEC) for Northwestern Ontario (Sims et al. 1989). The V-type classification recorded for each of the 210 PSPs is tabulated in Appendix 2.4, while Table 2.4 summarizes the occurrence of cover types by broad V-type categories ("mainly hardwood", "conifer mixedwood", and "mainly conifer").

Trembling aspen was the dominant tree species, averaging 48.6±9.8% and 40.3±92% of all living trees in Stands 1 and 2, respectively (Appendix 2.1) (63.7% and 55.5%, respectively, on a volume basis). White birch was present in all compartments, but was especially abundant in Compartments 1-11, 1-12, 1-14, 2-1, 2-2, 2-5, 2-6, and 2-7. In contrast to Stand 1, most of the birch in Stand 2 was large and decadent. Balsam fir was the most common coniferous species, averaging 27.3±11.1% of all living trees in Stand 1 and 24.1±7.1% in Stand 2; on a volume basis, the figures were 10.7% and 12.9%, respectively. Note, however, the large amounts of dead balsam fir present (Table 3.3). Jack pine formed a significant component of the stand in Compartments 1-1, 1-2, 1-3, 1-4, 1-6, 1-7, 1-8, and 1-10. Very little jack pine was present in Stand 2.

In 1993, at the time of the pre-harvest surveys, the spruce budworm outbreak was in its final stages. After more than a decade of heavy budworm attack, much of the balsam fir in the upper and secondary canopies was either dead or moribund (reflected in Tables 3.3 and 3.4), with many large white spruce also dying. Dead trees accounted for

Table 3.4 Summary of balsam fir condition by stand and treatment compartment:[a]

Stand/ compartment	Average condition[b]	Standard deviation	Stand/ compartment	Average condition[b]	Standard deviation
1-1	3.4	0.7	2-1	3.2	0.4
1-2	2.7	0.5	2-2	3.0	0.5
1-3	3.0	0.5	2-3	2.7	0.5
1-4	3.0	0.5	2-4	2.8	0.4
1-5	3.3	0.5	2-5	2.9	0.3
1-6	3.3	0.8	2-6	3.1	0.3
1-7	3.5	0.5	2-7	3.3	0.5
1-8	4.0	0			
1-9	3.1	0.7			
1-10	2.4	0.5			
1-11	3.0	0			
1-12	3.2	0.6			
1-13	3.1	0.6			
1-14	2.9	0.3			
Stand 1 average	3.1		Stand 2 average	3.0	

[a]Based on assessment of all balsam fir >2 m height within ten 10x10 m PSPs per treatment compartment.
[b]Averages for trees classified as follows: 1 = no budworm damage; 2 = moderate foliage mortality; 3 = heavy foliage mortality, tree dying or dead; 4 = tree dead and beginning to break up.

60.0% and 58.8%, respectively, of total balsam fir volumes in Stands 1 and 2. As a proportion of total standing volume (all species), dead fir represented 12.4% and 13.6% of Stands 1 and 2, respectively. In many areas the dead fir was beginning to break up, thereby allowing more light to penetrate into the stand and setting the stage for a future rapid surge in the growth of understory species.

At this stage in stand development, understory vegetation varied considerably not only between compartments but often within compartments also. Whereas some compartments supported little shrub growth, in others the presence of dense thickets of mountain maple and beaked hazel in the shrub layer made travel difficult. The heaviest concentrations of shrubs were found in Compartments 1-9, 1-12, 1-13, 1-14, 2-1, 2-2, 2-4, 2-5, and 2-6 (see Appendix 2.1).

With the exception of areas beneath older gaps in the canopy (i.e., predating breakup of the balsam fir overstory), ground cover was relatively sparse in all treatment compartments. Overall, vegetation (mosses, lichens, prostrate herbs) covered only 37% of the forest floor in Stand 1 and 27% in Stand 2. Undecomposed litter occupied the largest proportion of the forest floor (Table 3.5). As might be expected from the composition of the stand, this was mostly hardwood litter. Conifer litter was much less common, and where it was present was often associated with the presence of older balsam fir thickets. In aggregate, mosses and lichens were the second most common forest floor type, mostly (≈90%) made up of feathermoss species. Downed woody material of various types was the third most common category of ground cover.

Pre-harvest vegetation and stand structure data is available in database directories **~\excel\preharv** and **~\excel\structur** (see Appendix 7).

3.5.3 Canopy cover measurements

Hemispherical (fisheye) canopy photographs were taken at the end of August 1993 to quantify pre-harvest canopy cover in the proposed treatment compartments. The photographs provide archival images of canopy conditions at time of harvest, while the canopy cover estimates derived therefrom provide a relative index of the light environment within compartments. For general principles of the methodology used see Becker et al. (1989) and Rich (1990).

Photographs were taken from the centre of five PSPs per treatment compartment, all on the protected side of the compartment supporting the small mammal trapping networks (see Section 3.2.4). A 35 mm Canon T90 single-lens reflex camera was used, fitted with a Canon 7.5 mm, f/5.6 fish-eye lens with 180° field of view. The camera was mounted on a 1.5 m tall tripod, pointing vertically upwards. A small bubble level was used to ensure a horizontal film plane, and the camera was oriented with the aid of a compass so that the control panel (i.e., top of camera and film frame) always faced north. The camera had a databack, which aided both in identifying photographs and in determining their orientation.

Photographs were taken with black and white film (Kodak Plus-X Pan.) using exposure settings determined from a hand-held light meter. Because photographs with high contrast were preferred for subsequent image scanning, three exposures bracketing the metered reading were made at each location. Wherever possible, photographs were taken under overcast sky conditions, before 10:00 a.m. and after 2:00 p.m.

After processing, photographs were scanned on an Abaton 300 scanner (*Abaton Technology Corp., Fremont, CA*) using the software program COLORLAB 3.1 (*Computer Presentations, Inc., Cincinnati, OH*) in the greyscale mode at 300 dpi resolution. Scanned images were then edited on a high resolution monitor using the GIS program IDRISI 4.0 (*Clark Univ. Labs. for Cartographic Technology and Geographic Analysis*). Briefly, this involved converting the greyscale images to images in which all pixels were displayed as either black (foliage) or white (sky). Where the threshold value for conversion classified pixels incorrectly (i.e., as foliage or sky) pixel values were changed on-screen by reference to the original photograph. The edited images were then used to compute the proportion of foliage (i.e., canopy cover).[8]

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[8]For more detailed information on methodology contact Dr. A.R. Rodgers, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario (art.rodgers@mnr.gov.on.ca)

Table 3.5 Pre-harvest forest floor cover by stand and treatment compartment.[a]

Stand/ compartment	Exposed bedrock	Exposed mineral soil	Bare organic soil	Hardwood litter	Conifer litter	Prostrate herbs	Feathermoss	Sphagnum	Other bryophytes	Lichens	Downed woody material
1-1	-	0.4	1.1	42.9	5.0	3.4	30.0	0.1	1.9	1.3	13.9
1-2	-	0.2	0.8	31.2	7.8	4.0	41.2	0.3	2.0	1.1	11.4
1-3	-	0.4	1.7	39.7	6.0	3.8	32.0	-	1.6	2.0	12.8
1-4	-	-	0.9	35.7	6.6	3.9	36.8	-	3.0	1.4	11.5
1-5	0.2	0.2	0.5	35.5	6.6	0.2	32.9	0.4	0.8	0.6	22.1
1-6	-	-	0.8	32.0	6.4	1.9	42.4	1.0	1.0	1.0	13.5
1-7	-	0.4	1.8	33.0	5.9	3.4	40.5	1.0	1.0	1.0	12.0
1-8	-	-	0.6	34.3	2.0	3.7	40.0	-	2.0	1.6	15.8
1-9	-	1.4	0.1	40.5	9.5	3.5	27.6	1.0	1.4	1.0	14.0
1-10	-	-	0.4	48.8	9.9	1.0	23.6	1.0	2.0	1.0	12.3
1-11	-	-	-	52.5	7.0	0.6	19.5	1.4	2.0	1.0	16.0
1-12	-	1.0	1.0	38.5	8.1	1.0	36.0	0.8	1.9	1.0	10.7
1-13	-	0.1	0.2	58.0	10.3	0.5	14.1	1.0	2.0	1.0	12.8
1-14	-	-	0.2	44.0	11.0	0.4	24.4	0.8	1.6	0.8	16.8
Stand 1 mean	<0.5	<0.5	0.7	40.5	7.3	2.2	31.5	0.6	1.7	1.1	14.0
2-1	0.2	0.8	0.2	33.0	12.7	1.0	31.6	1.1	2.1	1.0	16.3
2-2	-	0.1	-	43.0	13.0	1.0	18.5	1.0	1.6	1.0	20.7
2-3	-	0	-	38.5	13.0	1.0	25.5	1.0	2.0	1.0	18.0
2-4	-	0	-	48.5	13.6	-	17.8	0.9	1.2	0.9	17.1
2-5	0.1	0.1	-	49.0	15.6	-	13.7	0.7	0.8	0.7	19.3
2-6	-	0	0.1	46.0	14.2	0.8	17.4	0.9	1.7	1.0	17.9
2-7	-	0.1	0.2	39.5	10.6	0.3	33.7	0.9	1.9	0.9	11.8
Stand 2 mean	<0.5	<0.5	<0.5	42.5	13.2	0.6	22.6	1.0	1.6	0.9	17.3

[a]Means of percent cover for ten 10x10 m PSPs per treatment compartment

Average values for canopy cover by treatment compartment are given in Table 3.6. For the most part, values were quite high with low variability between the five sampling points. However, it is important to remember that the photographs were taken from 1.5 m above ground level, and usually below the canopy of any mature shrub layer that was present. Therefore, these figures should be considered in conjunction with the structural data in Appendix 2.1. A heavy tall shrub layer was commonly present under older gaps in the tree canopy, thereby masking these upper canopy gaps and reducing the amount of light reaching the ground. The lower values for canopy cover in Compartments 1-5, 1-6, 1-9, and 1-11, especially, reflect more recent tree canopy reduction resulting from spruce budworm damage or mortality in balsam fir. Where such canopy gaps occurred above PSPs, a tall shrub layer had not yet developed and the given values are more truly representative of the upper tree canopy cover.

Canopy cover data for individual PSPs is available in database directory **~\excel\canopy** (see Appendix 7). Original photographs and negatives are held in an archive by the Project Coordinator.

See Section 3.6.6 for post-harvest canopy cover measurements.

3.5.4 Soil properties

As described in Section 2.3, the treatment compartments are situated on an extensive recessional moraine that is characterized by deep, well-drained, cherty sands and gravels with a significant coarse fragment content. The soils are described in more detail in Section 2.3.2. Summary data on mineral soil and organic soil horizon properties

Table 3.6 Pre-harvest canopy cover estimates.[a]

Stand/ compartment	Average percent cover	Standard deviation	Stand/ compartment	Average percent cover	Standard deviation
1-1	91.1	1.4	2-1	92.9	3.0
1-2	92.4	3.2	2-2	92.8	2.3
1-3	92.8	1.9	2-3	94.4	2.2
1-4	93.2	1.3	2-4	94.9	9.6
1-5	82.2	5.7	2-5	93.7	1.2
1-6	88.7	5.4	2-6	89.8	3.4
1-7	91.4	4.8	2-7	93.7	1.2
1-8	91.4	2.5			
1-9	82.8	7.2			
1-10	86.3	3.4			
1-11	85.0	1.7			
1-12	91.2	1.9			
1-13	91.7	2.7			
1-14	91.2	3.7			
Stand 1 average	89.4		Stand 2 average	81.2	

[a]Average percent cover on five PSPs per treatment compartment.

derived from the pre-harvest soil survey are given in Appendices 2.2 and 2.3, respectively. The full dataset is available in database directory ~**\excel\soils** (see Appendix 7).

3.5.5 Soil seed bank

Species regenerating after forest disturbance may originate from airborne seeds (seed rain), from the vegetative reproduction of residual species on the site, or from viable seeds (seed bank) present in the organic layer and upper mineral soil of the forest floor. The seed bank, because it allows certain species to survive in the soil for extended periods, facilitates rapid colonization after disturbance and is therefore an important contributor to early post-disturbance vegetation composition and diversity (Leck et al. 1989; Hills and Morris 1992). Indeed, plant species that are rare or absent in the pre-harvest forest may quickly develop from long-buried seeds after a major disturbance and come to dominate the pioneer vegetation community. While a knowledge of seed longevity in the soil is important for understanding and predicting post-harvest vegetation succession and population dynamics, little is known regarding seed bank dynamics following harvesting in boreal mixedwood forests.

Soil samples were collected in early September 1993 to characterize the pre-harvest distributions of seed bank species within the soil profile. Using a 7 cm diameter steel borer, three soil samples were collected at each of six of the ten PSPs in the 21 treatment compartments (three randomly selected PSPs from each side of the compartment), for a total of 18 cores per compartment. Core depth was adjusted to include the organic layer and some mineral soil (average depth of organic layer was 5.3±0.7 cm, and mineral layer 3.9±0.6 cm). Moistened samples were stored in a coldroom (2°C) for three months to stratify any contained seed before moving them to a greenhouse for the germination phase. One of the three samples from each sampling point was separated into organic and mineral soil layers and the layers crumbled and germinated separately; the other two core samples were left intact for germination.

A total of 1253 seedlings, of seed and vegetative origin, emerged from the 504 pre-harvest soil samples (Table 3.7). More than twice as many seedlings emerged when the soil samples were separated and crumbled for the germination test than from the intact soil cores, suggesting that some species may have needed light for germination or that germinants died before they were able to penetrate to the surface of intact cores. By contrast, slightly more seedlings of vegetative origin emerged from the intact cores.

Because of insufficient development or early mortality, large numbers of seedlings could not be identified as to species or genus. Of the remainder, 244 seedlings of 33 identified species emerged from the intact soil cores, more than half (52%) being of vegetative origin. The organic soil samples produced 115 seedlings of 20 identified species. Although many seedlings (37%) were again of vegetative origin, the lower figure may reflect the loss of viable root fragments that probably occurred when the soil samples were crumbled. The mineral soil yielded only 70 seedlings of 7 identified species, with seedlings of *Carex* spp. being the most common (84%).

When the numbers of identified and unidentified seedlings are added, it becomes clear that dicotyledons were present mainly in the organic layer. Seedlings of some species (e.g., *Aralia nudicaulis, Betula papyrifera, Cornus canadensis, Maianthemum canadense, Populus tremuloides, Rubus idaeus*)[9] originated both from seed and vegetatively from root fragments or other vegetative propagules. While forest herbs were well-represented, a number of species not found in the pre-harvest vegetation survey (Section 3.5.2) were present in the seed bank. These included species normally found in open areas, such as *Epilobium* spp., *Corydalis sempervirens*, and *Lactuca biennis*. No coniferous species emerged from any of the soil samples, reflecting both the influence of the extended spruce budworm infestation in suppressing spruce and fir seed production, and the short life of coniferous seeds in the soil.

Graminoids, which were poorly represented in the vegetation survey, were especially numerous in the mineral soil layer, which was otherwise species-poor. Seeds of *Carex houghtoniana* were found only at the mineral soil/organic soil interface, suggesting that they originated from the time of some past site disturbance that exposed mineral soil, such as an earlier fire on the study area or following logging in the 1940s. *Carex houghtoniana* typically forms robust clumps on open mineral soil, but quickly disappears with the development of a shrub or tree canopy. The fact that it was not found during the pre-harvest vegetation survey supports the view that buried seeds of this species can remain viable in the soil for decades.

For a full discussion of pre- and post-harvest seed bank species in the harvesting treatments see Qi and Scarratt (1998).

3.5.6 Aerial photographs

Black and white and infra-red aerial photography of the research site were carried out prior to road and treatment compartment layout in June 1993. Photographs are held in an archive by the Project Coordinator.

3.6 POST-HARVEST SITE AND STAND CONDITIONS

In the spring following harvest, permanent sample plots, regeneration assessment plots, and vegetation assessment plots were re-established at their original pre-harvest locations. At the same time, permanent photo-points were established in Stand 1 to record changes in stand structure over time (Section 3.8.2) and animal exclosures were constructed in two clearcuts to provide estimates of browse activity (see Appendix 8).

3.6.1 Residual standing volumes and tree inventory

All post-harvest inventories are based on the 10 systematically located 10x10 m permanent sample plots (PSPs) established within each treatment compartment prior to harvest (Section 3.2.4; Fig. 3.3). In June 1994, immediately after re-establishing these PSPs, all living and dead standing trees within the plots were numbered with aluminum tags and measured. Windblown (toppled trees and broken stems) and other fallen trees were recorded and measured, but not numbered. All trees >5 cm diameter were measured using a steel diameter tape. Individual tree heights were estimated separately for each species and stand from height/diameter functions derived from sample height measurements taken with a Haga hypsometer within the full range of tree diameter classes for each species. Total estimated volumes were calculated using Honer's standard volume equations (Honer et al. 1983).

Summarized volume estimates for residual living, dead, and windblown trees within the partial cutting treatments and uncut controls are given in Table 3.8. Detailed inventory data for individual treatment compartments are given in

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[9]For full botanical nomenclature see Morton and Venn (1990).

Table 3.7 Seedling emergence from pre-harvest soil seed bank samples. (D = dicotyledons; M =monocotyledons; V = vegetative origin)

Species[a]	Organic layer			Mineral layer			Intact cores		
	D	M	V	D	M	V	D	M	V
Acer spicatum	1	-	-	-	-	-	-	-	-
Aralia hispida	1	-	-	-	-	-	-	-	-
Aralia nudicaulis	-	-	2	-	-	4	1	-	5
Aster macrophyllus	-	-	-	-	-	-	-	-	6
Betula papyrifera	7	-	-	-	-	-	21	-	3
Carex houghtoniana	-	21	-	-	47	-	-	14	-
Carex spp.	-	14	-	-	12	-	-	3	-
Cinna latifolia	-	-	-	-	-	-	-	2	-
Clintonia borealis	-	-	-	-	-	-	-	-	11
Coptis trifolia	-	-	1	-	-	-	-	-	7
Cornus canadensis	1	-	8	-	-	3	3	-	10
Corydalis sempervirens	1	-	-	-	-	-	-	-	-
Diervilla lonicera	-	-	-	-	-	-	4	-	1
Epilobium angustifolium	-	-	-	-	-	-	2	-	-
Epilobium glandulosum	2	-	-	-	-	-	2	-	-
Fragaria vesca	-	-	2	-	-	-	1	-	2
Galium boreale	-	-	-	-	-	-	1	-	-
Galium triflorum	2	-	-	-	-	-	3	-	-
Geranium bicknellii	2	-	-	-	-	-	1	-	-
Goodyera spp.	-	-	-	-	-	-	-	-	1
Lactuca spp.	-	-	-	-	-	-	1	-	-
Linnaea borealis	-	-	-	-	-	-	3	-	-
Lonicera canadensis	-	-	-	-	-	-	-	-	1
Maianthemum canadense	-	9	19	-	-	1	-	27	38
Mitella nuda	-	-	-	-	-	-	10	-	-
Populus tremuloides	1	-	3	1	-	-	6	-	7
Ribes spp.	-	-	-	-	-	-	-	-	1
Rosa acicularis	-	-	-	-	-	-	-	-	1
Rubus idaeus	4	-	2	-	-	-	4	-	11
Rubus pubescens	1	-	1	-	-	-	-	-	8
Schizachne purpurascens	-	1	-	-	-	-	-	-	-
Streptopus roseus	-	-	-	-	-	-	-	-	1
Trientalis borealis	-	-	-	-	-	-	-	-	3
Vaccinium angustifolium	-	-	4	-	-	-	-	-	2
Vaccinium myrtilloides	-	-	-	-	-	2	-	-	3
Viola renifolia	-	-	-	-	-	-	1	-	1
Viola spp.	4	-	1	-	-	-	7	-	4
Unidentified	343	45	45	106	125	14	104	27	15
Total emerged seedlings	370	90	88	107	184	24	175	73	142
Grand totals		548			315			390	

[a]For full botanical nomenclature see Morton and Venn (1990).

Appendix 4, broken down by species. One figure in Table 3.8 that bears comment is the relatively high volume of residual dead trees in Treatment 2ii of Stand 2 (i.e., Compartment 2-2). From Appendix 4 it will be seen that this can be partly explained by the presence of large decadent white birch, not destroyed during harvesting, in the more northerly compartments of Stand 2 (see also Section 3.5.2).

Post-harvest inventory data, volume calculations, tree mortality, and blowdown data for 1994 and subsequent years are available in database directory **~\excel\inventry** (see Appendix 7).

Table 3.8 Post-harvest volume summary by harvesting treatment.

Harvesting treatment		Mean volumes (m^3/ha)			
		Living trees	Dead trees	Windblown trees	Totals
		Stand 1			
Shelterwood cut:	2i[a]	104.62	2.28	1.72	108.62
"	2ii[a]	81.41	12.71	0.91	95.03
"	2iii	91.14	4.97	0.32	96.43
Uncut controls:	4[a]	310.82	47.83	0	358.65
		Stand 2			
Shelterwood cut	2i	115.35	12.92	0	128.27
"	2ii	119.43	61.88	2.62	183.93
"	2iii	92.36	8.24	0	100.60
Uncut control	4	295.21	47.32	0	342.53

[a]Data are means for two compartments per treatment.

Additional data on residual tree volumes and inventory recovery following harvesting is being collected as part of studies of organic matter decomposition, element cycling and soil properties under the different harvesting regimes. This work is described more fully in Section 3.6.3.iii.

3.6.2 Logging damage

i. Damage to residual trees

FERIC study

Post-harvest assessments of logging damage to residual trees were conducted in May 1994 (Gingras 1994). Four-metre wide cruise strips, 25 m apart and oriented perpendicular to the direction of machine travel, were established in all partial cut compartments. Residual trees in these cruise strips were tallied and visually inspected for any wounds. Wounds were classified in terms of their location, dimensions (longest and shortest axes), severity (proportion of inner sapwood exposed), and extent of horizontal girdling (length of girdling÷stem circumference). Where there was more than one wound per tree, data were accumulated for that tree.

Assessment results are summarized by treatment compartment in Table 3.9. The proportion of damaged trees was relatively high in the manual cuts (Treatment 2iii), and wounds were fairly large, with a large proportion of inner wood exposed. The proportion of girdling was also high (20%) compared with other treatments. These findings reflect the observed lack of care on the part of skidder operators in minimizing rubbing of trees along the extraction trails.

In the feller-buncher compartments (Treatment 2i) the proportion of wounded trees declined as the operators gained more experience, ranging from 30% in the first compartment cut to 11% in later weeks. The size of wounds was also highest in the first compartment cut. Wound locations on trees in this compartment suggest that a lot of damage was caused by the grapple skidder wheels rubbing trees adjacent to the skidding trails. In later compartments, skidder operators removed the tire chains in an effort to reduce the amount of rub damage, and also became more adept at using rub posts to guide the extraction and turning of tree loads. Some stem damage was attributed to the harvester felling head rubbing on residual trees, and to tail swing impacts from the feller-buncher carrier. While the severity of damage was high in all feller-buncher compartments, the extent of girdling was lower (15%) than in the manually cut compartments.

The single-grip, cut-to-length compartments (Treatment 2ii) had the lowest levels of damage, with an average 5% wounded trees in the two compartments surveyed. The average size of wound was also much smaller than in other

Table 3.9 Damage to residual trees within partial-cutting compartments.[a]

Harvesting treatment:	2i			2ii		2iii	
Compartment location:	1-2	1-3	2-4	1-5	1-11	1-12	2-3
Number of trees sampled	252	334	246	273	319	270	232
Number of damaged trees	29	53	75	14	16	55	42
Proportion of damaged trees (%)	11.5	16.0	30.0	5.0	5.0	20.0	18.0
Average DBH of wounded trees (cm)	20.1	19.0	27.5	15.4	16.1	19.1	17.0
Average size of wound (cm^2)	220	115	665	40	40	115	220
Average wound location index[b]	2.1	2.1	1.6	2.2	2.1	1.9	1.9
Average inner sapwood exposure (%)	85	75	70	70	35	75	65
Girdling proportion (%)[c]	19	13	14	7	13	17	22

[a]Data provided by J-F. Gingras, Forest Engineering Research Institute of Canada, Pointe Claire, Québec.
[b]Average of location tally data: 1 = stump height and below; 2 = between top root and DBH; 3 = above DBH.
[c]Average horizontal girdling distance (length of girdling divided by stem circumference).

treatments. The wound location index suggests that the main source of damage was the boom of both harvester and forwarder; the forwarder bunk pickets possibly also caused damage during travel. Although one of the compartments was harvested in late December, when the frozen bark may have been more vulnerable to damage, the severity of damage was still low.

Permanent sample plots

Logging damage to residual trees in the partial cuts was recorded during the 1994 post-harvest inventory. The results are summarized in Table 3.10; a more detailed breakdown by species and treatment compartment is given in Appendix 5.

The results indicate similar trends to the FERIC data, although the values are somewhat different. By its nature, this was a much more restricted survey than the FERIC study (440 versus 1926 trees sampled), so that the results are perhaps less representative of the situation over entire compartments. However, the results are part of the ongoing stand inventory, and offer an opportunity to monitor the long-term effects of logging damage. Note that individual trees are tagged and numbered (Section 3.6.1), permitting their future development and/or mortality to be followed.

Table 3.10 Incidence of damage to residual trees in permanent sample plots of partial cuts (summary).[a]

Harvesting treatment:	2i			2ii			2iii	
Compartment location:	1-2	1-3	2-4	1-5	1-11	2-2	1-12	2-3
Number of trees sampled	35	45	27	89	69	60	51	64
Number of damaged trees	10	12	2	15	14	3	4	5
Proportion of damaged trees (%)	28.6	26.7	7.4	16.8	20.3	5.0	7.8	7.8
Average number of wounds per tree	1.5	1.9	3.5	1.7	1.5	2.7	2.0	2.2
Average size of wound (cm^2)	100.7	190.5	241.0	61.9	66.9	66.7	121.8	51.5

[a]For a more detailed breakdown of the damage assessment data see Appendix 5.

Microbial investigations

Additional data on the occurrence, size, and location of 200 harvesting wounds (stem, butt, and root) on residual conifers in the partial cuts is included in a detailed study of wound-infecting microorganisms conducted by Dumas and McLaughlin[10] (see Appendix 6). Wound size was determined in 1994 by first photographing all wounds and

[10]McLaughlin, J.A.; Dumas, M.T. Biodiversity of microbials inhabiting tree wounds and their influence on stem decay development. Nat. Resour. Can. For. Serv., Sault Ste. Marie, ON. Unpub. file rep.

then using a planimeter to calculate their area. The investigation monitors subsequent wound healing, microbial colonization and succession at wound sites, tree infection and mortality.

Further details may be obtained by contacting Dr. M.T. Dumas, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (mdumas@nrcan.gc.ca)

ii. Destruction of advance growth

As part of long-term studies of natural regeneration on the harvested compartments, an initial objective was to determine the fate of pre-established coniferous advance growth. Pre-harvest stocking and density of balsam fir and spruce advance growth were assessed during the summer of 1993 on four 10x20 m plots within each treatment compartment (Appendix 8), each subdivided into 50 2x2 m quadrats. To better quantify the potential for seedling destruction during harvesting, plots were deliberately selected which had >80% stocking of coniferous advance growth and whose locations were likely to receive disturbance representative of the harvesting system. In the spring following harvest, plots were re-established, permanently marked, and reassessed.

Provisional data published by Leblanc (1996) indicate pre-harvest stocking levels within the assessment plots of 83-93% for balsam fir and 21-34% for spruce. These translate into seedling densities ranging from 16,120 to 23,400 stems/ha for balsam fir, and 1,000 to 2,600 stems/ha for spruce. However, it must be emphasized that these densities were specific to the selected assessment plots. Average densities across entire treatment compartments were substantially lower.

Comparison of post-harvest stocking data (Table 3.11) with the above figures demonstrates the extent of seedling destruction under the different harvesting treatments. Destruction was highest on the clearcuts (Treatments 1i and 1ii), with a slightly higher figure in the full-tree treatment than in the tree-length treatment. This might be attributable to the additional impact of skidding intact tree crowns. Partial cutting resulted in appreciably lower levels of seedling destruction, even in the feller-buncher treatment (Treatment 2i). As might be expected from the mode of operation of the single-grip harvester and forwarder, seedling destruction was lowest in the cut-to-length treatment (Treatment 2ii).

Table 3.11 Post-harvest stocking of advance growth.

Harvesting treatment	Gross stocking %		Relative stocking % [a]		Relative seedling density % [b]	
	Balsam fir	Spruce	Balsam fir	Spruce	Balsam fir	Spruce
1i	22	6	25	30	8	23
1ii	25	8	29	32	9	13
2i	60	11	64	52	38	37
2ii	71	23	79	68	58	53
2iii	60	16	70	59	48	50

[a]Number of post-harvest stocked quadrats expressed as a percentage of number before harvesting.
[b]Number of post-harvest seedlings expressed as a percentage of number before harvesting.

For more detailed information contact J.-D. Leblanc, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (dleblanc@nrcan.gc.ca)

3.6.3 Site disturbance and related harvesting impacts

i. FERIC site disturbance study

Ground disturbance assessments were conducted in May 1994, at the same time that the assessments of logging damage were carried out (Gingras 1994, 1995). Cruise lines were established at 25 m spacing, perpendicular to the direction of machine travel and parallel to the road, across all surveyed compartments. Circular ground disturbance assessment plots 4 m^2 in area (2.256 m diameter) were located at 25 m spacing along these cruise lines. Visual estimates of the proportion of each plot occupied by one or more of eight disturbance classes, as defined by Case and Donnelly (1979), were recorded.

The results indicate generally low soil disturbance levels with all harvesting systems (Table 3.12). This reflects the excellent ground conditions in the study area (flat terrain with well-drained soils). Because harvesting spanned the period September to January (Table 3.1), some compartments were frozen and snow-covered at time of harvest, which may have protected them from the full impact of harvesting traffic. However, the sites were probably not totally immune from disturbance until the onset of an extended cold spell (-20°C to -30°C) and heavy snow on December 26, shortly before harvesting was completed (see Table 3.1).

Clearcutting with feller-buncher and grapple skidder (Treatment 1i) resulted in fairly high levels of mineral soil exposure compared to other systems, although there was virtually no deep mineral soil exposure (>10 cm depth). These compartments also showed the greatest evidence of machine travel. In both clearcutting treatments (1i, 1ii) the large amounts of slash left on site probably served to reduce the intensity of soil disturbance during skidding.

In the partial cuts, feller-buncher and grapple skidder (Treatment 2i) again resulted in the highest levels of mineral soil exposure, although much less than on the clearcuts. Cut-to-length harvesting (Treatment 2ii) had the least impact on the ground surface, with no significant mineral soil exposure and the lowest levels of organic layer disturbance. Although the cut-to-length compartments were mostly frozen at time of harvest, the long harvester boom and the fact that both harvester and forwarder travelled on the same slash-covered trails greatly diminished the potential for ground disturbance compared to other treatments.

ii. Supplementary ground disturbance assessment

Immediate post-harvest assessments of logging damage to advance growth and regeneration (Leblanc, Appendix 6) showed a strong correlation with local site disturbance. However, because assessment plots represented a relatively small area of each harvested compartment, there was a concern that recorded levels of site disturbance within these plots might be unrepresentative of disturbance over the compartment at large. This, it was feared, might lead to false conclusions regarding the overall extent and nature of seedling damage. Consequently, in order to provide a basis for extrapolating damage results to the compartment level, a retrospective supplementary ground disturbance assessment was conducted in June 1995.

The assessment procedure was similar to that carried out by FERIC, though it was more detailed and intensive. All harvested compartments except the patch cuts (Treatment 3) were assessed. Within each compartment, five assessment transects 325 m in length were established 50 m apart, perpendicular to the direction of machine travel. Disturbance sampling was carried out at 2 m spacing along these transects, resulting in between 749 and 962 sampling points per harvested compartment. At each sampling point, ground disturbance and logging slash were assessed within 10 cm and 15 cm diameter plots, respectively, as well as evidence of machine travel, *viz*:

Ground disturbance: i - undisturbed or lightly compacted moss or herbaceous plants; ii - undisturbed litter; iii - disturbed/exposed FH horizon; iv - disturbed/exposed mineral soil; v - disturbed/exposed mineral soil base.

Logging slash: i - no slash; ii - fine slash, light density; iii - fine slash, high density (heavy); iv - coarse slash, light density; v - coarse slash, high density (heavy).

Machine travel: i - plot outside of machine trails; ii - edge of prime mover track; iii - within prime mover track area; iv - between prime mover tracks; v - incursion trails.

Two groupings of data that were found to correlate well with logging damage to seedlings are included in Table 3.13 (i. ground disturbance combined with slash density and, ii. machine travel combined with slash density). The most striking feature of data in Table 3.13 is the predominance of light logging slash in both categories of disturbance and machine travel. Treatment 1ii (tree-length harvesting) is the principal exception, reflecting the fact that trees were delimbed on site and that the slash tended to be concentrated in windrows. This may have protected the forest floor from disturbance during machine travel. Although cut-to-length harvesting (Treatment 2ii) concentrated heavy logging slash on the harvester trails, this is not immediately evident from the data because of the low incidence of trails.

Table 3.12 Site disturbance within harvested compartments[a]

Harvesting treatment:	1i			1ii		2i			2ii		2iii	
Compartment location:	1-1	1-14	2-6	1-7	1-9	1-2	1-3	2-4	1-5	1-11	1-12	2-3
Number of $4m^2$ plots:	135	130	216	131	130	130	130	156	127	130	130	90
Disturbance proportions (%)												
- undisturbed ground surface	4	1	13	24	26	5	28	55	69	54	56	46
- organic layers disturbed	56	52	69	41	54	64	44	40	18	17	34	45
- mineral soil deposits	0	0	5	0	0	0	0	0	0	0	0	0
- shallow mineral soil exposure	8	21	2	2	2	9	3	2	1	0	1	1
- deep mineral soil exposure	0	1	0	0	1	0	0	0	0	0	0	0
- mixed mineral/organic soils	0	0	4	2	3	0	6	0	0	0	1	3
- erosion features[b]	1	3	0	1	0	2	1	0	0	0	1	0
- non-assessable[c]	31	22	7	30	14	20	8	3	12	29	7	5
Proportion of area with trails	91	96	n/a[d]	33	n/a[d]	91	45	36	16	26	37	n/a[d]

[a]Data provided by J-F Gingras, Forest Engineering Research Institute of Canada, Pointe Claire, Québec.
[b]e.g., rills, gullies, etc.
[c]Non-assessable because of heavy slash, or not-perturbable (i.e., stumps, boulders, etc.).
[d]Not assessed.

Table 3.13 Supplementary assessment of site disturbance, slash coverage, and incidence of machine trails.[a]

Stand/ compartment	Not disturbed		Disturbed		Not travelled		Travelled	
	Light slash[b] %	Heavy slash[c] %	Light slash %	Heavy slash %	Light slash %	Heavy slash %	Light slash %	Heavy slash %
Treatment 1i								
1-1	31.2	6.7	55.6	6.5	n/a	n/a	n/a	n/a
1-14	40.2	5.4	52.2	2.3	48.6	5.9	43.8	1.8
2-6	55.5	4.5	38.9	1.1	61.3	4.9	33.1	0.7
Means	41.3	5.6	49.5	3.5	54.6	5.4	38.7	1.3
Treatment 1ii								
1-7	51.0	15.1	28.2	5.7	53.2	18.6	25.1	3.0
1-9	39.9	13.3	43.0	3.8	41.7	14.3	41.2	2.8
2-1	58.6	15.1	25.0	1.3	57.1	15.5	26.0	1.4
Means	49.8	14.5	32.1	3.6	49.7	15.3	32.7	2.2
Treatment 2i								
1-2	56.2	7.4	33.0	3.4	48.2	8.0	40.1	3.8
1-3	59.3	4.7	35.2	0.8	49.1	3.6	45.4	1.9
2-4	71.1	3.1	25.3	0.4	50.2	1.9	46.3	1.7
Means	62.5	5.0	30.9	1.5	49.3	4.1	44.3	2.3
Treatment 2ii								
1-5	74.9	8.8	14.4	1.8	65.9	6.2	23.5	4.4
1-11	68.8	9.8	18.1	3.2	57.7	5.8	29.2	7.3
2-2	76.4	11.3	10.1	2.3	65.1	5.8	23.2	5.8
Means	73.4	10.0	14.2	2.5	62.7	6.0	25.5	5.9
Treatment 2iii								
1-12	60.9	4.0	33.2	1.9	55.3	3.1	38.8	2.9
2-3	61.6	6.1	31.8	0.5	57.4	4.8	36.1	1.7
Means	61.2	5.0	32.5	1.2	56.3	3.9	37.4	2.3

[a]Data provided by J.-D. Leblanc, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.
[b]Light density of fine and/or coarse slash.
[c]High density of fine and/or coarse slash.

Comparison of mean totals (light slash and heavy slash combined) for disturbed and travelled categories indicates subtle differences between harvesting treatments, *viz:*

	Percent disturbed	Percent travelled
Treatment 1i	53.0	40.0
Treatment 1ii	35.7	34.9
Treatment 2i	32.4	46.6
Treatment 2ii	16.7	31.4
Treatment 2iii	33.7	39.7

The fact that the value for "disturbed" exceeds that for "travelled" in Treatment 1i indicates that even outside the machine trails there was appreciable ground disturbance. This may reflect the additional impacts of skidding heavily branched aspen crowns across the site during full-tree extraction. The similar values in Treatment 1ii present an interesting contrast, reflecting the fact that harvesting was generally carried out in strips and that skidding was largely confined to these harvested strips by the windrows of slash. Tree-length skidding in this treatment will also have had less impact on areas outside the skid trails than full-tree extraction. To varying degrees the results in the three partial cuts were opposite to those in Treatment 1i, indicating a generally lower incidence of ground disturbance on travelled areas. In Treatment 2i this may be explained by the lower incidence of disturbance on the many light entry trails ("incursion trails"), off the main trails, where the harvester had to advance into the stand to select individual trees for cutting.

For further details or access to the disturbance assessment records contact J.-D. Leblanc, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (dleblanc@nrcan.gc.ca)

iii. Impacts of harvesting on biomass production and nutrient cycling

Research conducted by Morrison (Appendix 6) provides supplementary data on certain immediate post-harvest site conditions described elsewhere in this section (residual tree volumes and tree inventories – Section 3.6.1; logging debris and downed woody material – Section 3.6.4), as well as their change over time. This information is collected as part of studies into the impacts of harvesting on net primary production (NPP), organic matter decomposition, and nutrient cycling under different harvesting regimes.

To monitor recovery of NPP and nutrient cycles in relation to harvesting treatment, three-plot clusters of 0.04 ha PSPs were established in two compartments each of the following five treatments, all in Stand 1: clearcut with full-tree (Treatment 1i) and tree-length (Treatment 1ii) variants, partial cut with full-tree (Treatment 2i) and cut-to-length (Treatment 2ii) variants, and uncut control (Treatment 4). Trees were tallied, and basal areas and volumes calculated in the same manner as that used for the 10x10 m PSPs described in Section 3.6.1. Tree biomass by components was calculated using appropriate regressions (power functions) of dry weight on diameter (DBH_{ob}) by species for all trees >5 cm DBH_{ob}. A separate regression was used for standing dead trees.

Following harvest, plots were assessed and trees categorized as live standing, live fallen, cut-and-removed, dead standing, or dead fallen. Sapling (principally trembling aspen shoots, but other tree species also) and lesser vegetation recovery in terms of biomass was also assessed. Randomly located 5 m^2 permanent sub-plots were established on each of the 0.04 ha PSPs. Stand tables of basal diameter (to 0.1 cm) were determined for each sub-plot in 1996 and 1998. Biomass per area, separated into woody and leafy matter, was determined by relating basal diameter to dry weight/basal diameter regressions constructed from separate samplings conducted during the same years. Chemical analyses of leafy and woody materials from on-plot samplings permitted calculation of per-area carbon, nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur contents, plus other elements. Lesser vegetative regrowth was determined by on-plot destructive samplings of 0.90 m diameter randomly located quadrats on each of the 0.04 ha PSPs, followed by chemical analysis. Other work associated with these plots includes soil sampling and analysis, annual litter production, decomposition of leaf litters using litterbags, and decomposition of coarse woody debris.

For further information on this work and the availability of baseline data, contact Dr. I.K. Morrison, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (imorriso@nrcan.gc.ca)

3.6.4 Logging debris and downed woody material

Residual logging debris (slash) on the harvested compartments was quantified by the line intersect method used to determine fuel loadings on sites destined for prescribed burning (McRae et al. 1979). Four assessment triangles, each measuring 15 m per side, were used in each of the clearcuts and partial cuts. Two uncut control compartments were similarly evaluated for comparison. The patch cuts (Treatment 3) were not assessed. Assessment triangles were located randomly in each harvested or uncut compartment, except in the cut-to-length partial cuts, which presented a special situation. Here, because the slash was concentrated within the harvester and forwarder trails, two triangles per compartment were located in the centre of the forwarder trails and a further two between the trails. Assessments were carried out in June 1994.

Assessment results are summarized in Table 3.14. To give perspective to these figures, McRae[11] (personal communication) suggests the following criteria in rating fuel loadings for prescribed burning. For the 0-6.9 cm diameter size class: 0-1.5 = low; 1.5-2.5 = medium (normal); >2.5 = high. For the >7.0 cm diameter size class: 0-3 = low; 3-8 = medium (normal); >8 = high. At low fuel loadings, fuel continuity on the ground may be insufficient to maintain fire spread in a prescribed burn. By these standards, the two uncut controls (Compartments 1-4 and 2-5) had low slash loadings, made up mostly of dead and fallen balsam fir. Harvesting operations increased slash amounts

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[11]D.J. McRae, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

Table 3.14 Post-harvest slash loadings, June 1994.[a]

Stand/ compartment	Harvesting method	Average slash load (kg/m^2)[b]		
		0-6.9 cm diam.	>7.0 cm diam.	Total
1-1	Full-tree clearcut (feller buncher)	2.45	3.82	6.27
1-2	Full-tree partial cut (feller buncher)	2.98	3.41	6.39
1-3	Full-tree partial cut (feller buncher)	2.41	3.04	5.45
1-4	Uncut control	0.82	1.23	2.05
1-5A	Partial cut, delimbed and slashed on site (CTL)[c]	2.36	2.77	5.13
1-5B	Partial cut, delimbed and slashed on site (CTL)[d]	4.88	3.63	8.51
1-7	Tree-length clearcut (single-grip harvester)	3.28	4.22	7.50
1-9	Tree-length clearcut (single-grip harvester)	3.67	3.78	7.45
1-11A	Partial cut, delimbed and slashed on site (CTL)[c]	2.81	2.41	5.22
1-11B	Partial cut, delimbed and slashed on site (CTL)[d]	5.81	2.61	8.42
1-12	Full-tree partial cut (manual felling)	2.56	3.19	5.75
1-14	Full-tree clearcut (feller buncher)	2.16	4.92	7.08
2-1	Tree-length clearcut (single-grip harvester)	3.73	6.04	9.77
2-2A	Partial cut, delimbed and slashed on site (CTL)[c]	2.80	5.20	8.00
2-2B	Partial cut-delimbed and slashed on site (CTL)[d]	4.96	3.85	8.81
2-3	Full-tree partial cut (manual felling)	2.11	2.21	4.32
2-4	Full-tree partial cut (feller buncher)	1.65	2.73	4.38
2-5	Uncut control	0.56	1.12	1.68
2-6	Full-tree clearcut (feller buncher)	2.80	3.47	6.27

[a]Methodology after McRae *et al.* (1979).
[b]Four assessment triangles per compartment, except as noted hereunder.
[c]Cut-to-length harvest; two assessment triangles per compartment between forwarder trails (i.e., between areas of maximum slash accumulation).
[d]Cut-to-length harvest; two assessment triangles per compartment in centre of forwarder trails (i.e., within areas of maximum slash accumulation).

by up to five times (average increase 3.4 times). Within the 0-6.9 cm diameter class, slash loadings were normal to above-normal on most compartments, with full-tree logging leaving generally lower amounts of slash than tree-length logging. The cut-to-length treatments (Compartments 1-5, 1-11, 2-2) were an exception, exhibiting a large disparity between sampling locations, with exceptionally high loadings of fine materials in the slash concentrations on the harvester/forwarder trails. In the >7.0 cm diameter class, all harvesting treatments produced slash loadings within the normal range.

For the most part, logging debris was not considered a significant obstacle to silvicultural operations (e.g., site preparation, planting), except in the cut-to-length compartments. Here, the heavy concentrations of consolidated slash on the harvester/forwarder trails and the unconsolidated piles of tree tops and fallen balsam fir between the trails would have presented major obstacles to site preparation. While the unconsolidated materials might be expected to break up within a few years, the slash mats of the harvester/forwarder trails are unlikely to disintegrate for many years.

The full dataset upon which Table 3.14 is based is available in database directory **~\excel\slash** (see Appendix 7).

Additional data on the amounts and distributions of logging debris is collected as part of studies of organic matter decomposition, element cycling and soil properties under the different harvesting regimes, described more fully in Section 3.6.3.iii. For further information contact Dr. I.K. Morrison, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (imorriso@nrcan.gc.ca)

3.6.5 Blowdown

Blowdown, defined as toppling or stem breakage in living trees, is systematically monitored only in the PSPs. The numbers of dead trees falling (deadfalls) are also recorded. Assessments are conducted annually in spring and fall.

Blowdown data from the September 1994 PSP inventory (Appendix 4) are summarized in Table 3.15, together with blowdown and deadfall figures for 1995, 1996, and 1998. No trees were lost in the uncut controls in the first post-harvest year and, contrary to fears about early post-harvest stand instability, only 2.7% of total trees in PSPs in the partial cuts succumbed to blowdown. With the exception of Compartment 1-11, which suffered a freak windstorm in 1995, cumulative blowdown in the partially cut compartments remained relatively low over the next four years. Much of the blowdown that did occur was in balsam fir. Many of these trees were undoubtedly predisposed to wind damage because of the debilitating effects of the recent lengthy spruce budworm infestation and secondary infection by *Armillaria ostoyae* (Romagnesi) Herink. Much of the fir would eventually have collapsed in any event. The unusually high volume loss in Compartment 1-12 in 1995 was mainly attributable to blowdown of three large white spruce. Similarly, much of the loss in Compartment 1-2 in 1998 was due to blowdown of large white spruce and poplar, while in Compartment 1-13 a large white birch deadfall accounted for 78% of the volume loss.

A large proportion of the deadfalls recorded were balsam fir, averaging 59% and 73% of trees in PSPs of the partial cuts and uncut controls, respectively. As noted elsewhere, this marked the final collapse of the budworm-killed fir.

3.6.6 Canopy cover measurements

i. Hemispherical canopy photographs

Post-harvest hemispherical canopy photographs were taken in the partial cuts and uncut controls at the end of August 1994. Field methods and image analysis procedures were as described in Section 3.5.3. Average values for canopy cover by treatment compartment are given in Table 3.16. Compared with pre-harvest values (Table 3.6), reductions in percent cover in the partial cuts averaged 28% in the feller-buncher compartments (Treatment 2i), 25% in the manually cut compartments (Treatment 2iii), and 18% in the single-grip harvester compartments (Treatment 2ii). Note that collapse of the dead and dying mid-size balsam fir left standing in Treatment 2ii (see Section 3.3.2) would eventually lead to further reductions in canopy cover in that treatment.

Canopy cover data for individual PSPs is available in database directory **~\excel\canopy** (see Appendix 7). The negatives are held in an archive by the Project Coordinator.

Table 3.16 Post-harvest canopy cover estimates.[a]

Stand/ compartment	Average percent cover[b]	Standard deviation	Percent canopy reduction
Partial cuts			
1-2	68.1	4.6	26.3
1-3	63.3	5.4	31.8
1-5	66.9	10.8	18.6
1-11	70.6	5.1	16.9
1-12	66.3	5.2	27.3
2-2	71.7	7.8	22.7
2-3	75.7	3.5	19.8
2-4	69.4	8.8	26.9
Uncut controls			
1-4	88.6	2.5	-
1-13	87.3	6.1	-
2-5	93.4	2.1	-

[a]Partial cuts and uncut controls only; average percent cover on five PSPs in each treatment compartment.
[b]See Table 3.6 for comparison with pre-harvest values.

Table 3.15 Blowdown and deadfalls in permanent sample plots.

Stand/ compartment	Total trees in 1994 inventory	Blowdown 1994			Blowdown and deadfalls 1995			Blowdown and deadfalls 1996			Blowdown and deadfalls 1998[a]		
		Total number of trees	Mean height (m)	Total volume (m^3/ha)	Total number of trees[b]	Number of balsam fir[b]	Total volume (m^3/ha)	Total number of trees[b]	Number of balsam fir[b]	Total volume (m^3/ha)	Total number of trees[b]	Number of balsam fir[b]	Total volume (m^3/ha)
Uncut controls													
1-4	211	-	-	-	5 (1)	5 (1)	1.300	8	8	1.208	9	8	4.078
1-6	144	-	-	-	1	1	0.256	3 (3)	-	5.394	8	7	3.536
1-13	182	-	-	-	4	4	3.420	1 (1)	-	0.305	8	4	16.138
2-5	112	-	-	-	-	-	-	2 (1)	-	3.970	3	1	4.923
Means	162.2	0		0	2.25	2.25	1.244	2.25	2.0	2.719	7.0	5.0	7.169
Partial cuts													
1-2	35	1	16.4	2.94	3 (2)	-	2.473	-	-	-	6 (2)	1	15.302
1-3	45	1	10.5	0.50	1	1	0.093	-	-	-	2	-	5.084
1-5	89	1	12.8	0.62	6 (1)	5 (1)	2.373	9 (7)	5 (3)	3.285	11	7	4.638
1-11	69	5	9.3	1.20	2 (1)	2 (1)	0.530	16 (14)	14 (12)	5.402	2	2	1.140
1-12	51	2	9.9	0.32	8 (6)	2	19.797	4 (4)	-	5.684	1	1	2.480
2-2	60	2	15.2	2.62	2 (1)	1	1.282	-	-	-	1 (1)	1 (1)	0.600
2-3	64	-	-	-	3	3	0.634	1	1	0.096	3	3	0.660
2-4	27	-	-	-	1 (1)	-	2.260	1	-	1.045	-	-	-
Means	55.0	1.5		1.025	3.25	1.75	3.680	3.88	2.5	1.939	3.25	1.88	3.738

[a]Includes figures for 1997.

[b]Figures in brackets indicate blowdown of living trees included in the totals.

Hemispherical canopy cover photographs were also taken in August 1994 at other stations within the various treatment compartments as part of the small mammal and bird monitoring studies (Abraham and Rodgers, Appendix 6). Data for these stations is available in database file **~\excel\canopy\mamm94.xls** (see Appendix 7). Negatives are held in an archive by the Project Coordinator.

ii. Leaf area index

Data on leaf area indices (LAI) in the partial cuts and uncut controls collected during late August and early September 1995 (Groot, Appendix 6) are summarized in Table 3.17. These measurements provide an estimate of total leaf area within the understory vegetation and upper canopy directly above a given point on the ground. Because leaves within different vegetation layers inevitably overlap, values >1 can be expected under most stand conditions.

LAI measurements were taken with an LAI-2000 Plant Canopy Analyzer (*LI-COR, Inc., Lincoln, NE*). In simplest terms, the LAI-2000 measures the attenuation of light as it passes through the canopy. By measuring this attenuation at several angles from the zenith, allowances are made for foliage orientation. The LAI-2000 measures the attenuation of diffuse sky radiation at five zenith angles simultaneously with an LAI-2050 Optical Sensor. A single measurement consists of 10 simultaneous readings; five of these readings are the signals from a sensor below the vegetation layer(s) of interest, and the other five are made with a reference sensor above the vegetation to measure total incoming radiation. In practice, several below-canopy readings are usually made to obtain an average value.

Table 3.17 Leaf area index (LAI) measurements.

Stand/ compartment	Overstorey LAI[a]	Understorey LAI[b]	Total LAI[b]
Clearcuts			
1-1	-	-	1.6
1-7	-	-	1.6
1-9	-	-	2.5
2-1	-	-	1.1
2-6	-	-	1.3
Means			1.6
Partial cuts			
1-2	0.9	0.5	1.4
1-3	1.1	0.2	1.3
Means	1.0	0.4	1.4
Uncut controls			
1-4	3.0	0.2	3.2
1-13	3.4	1.0	4.4
Means	3.2	0.6	3.8

[a]Mean of 50 samples per compartment; sensor 2 m above ground.
[b]Mean of 75 samples per compartment; sensor at ground level.

In this study, LAI measurements were made along five 50 m transects running parallel to the road in each of two partial cuts (Compartments 1-2 and 1-3) and two uncut controls (Compartments 1-4 and 1-14). Measurements were also taken beneath the regrowth vegetation on five clearcuts. For total LAI, five groups of readings, 10 m apart, were made at ground level along each transect. Each group comprised three readings spaced one metre apart, for a total of 75 readings per compartment. Overstory measurements were made on the same transects, but 10 individual readings were taken above the understory vegetation (2 m above ground) at 5 m spacing along the transects, for a total of 50 readings per compartment. Simultaneous reference readings of full radiation were made with a second sensor located above the regrowth vegetation in adjacent clearcuts.

For more information, contact Dr. A. Groot, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (agroot@nrcan.gc.ca)

3.6.7 Aerial photographs

Post-harvest black and white aerial photography of the research site was carried out in late March 1994, followed by infra-red aerial photography in mid-July 1994. Photographs are held in an archive by the Project Coordinator. Additional black and white coverage of the experimental sites is included in aerial photography undertaken by Bowater Inc. and the Ontario Ministry of Natural Resources at various times in 1995, 1996, and 1997.

3.7 PHASE II – SITE PREPARATION AND REGENERATION

The second phase of research began in 1995 with the initiation of forest renewal studies. Depending on forest management goals and individual stand/site characteristics, a number of different renewal strategies are possible following partial cutting in boreal mixedwoods. The ecological outcome will not necessarily always be the same. From a common beginning, some strategies may direct subsequent stand development along significantly different successional pathways, perhaps even leading to the development of pure hardwood stands.

In this project, where harvesting resulted in partial cuts dominated by mid-rotation trembling aspen, the goal is to reinstate a mixedwood condition, maintaining tree species diversity by enhancing the economically desirable conifer component of residual stands. Hence the emphasis on spruce regeneration. In the absence of significant amounts of spruce advance growth, new regeneration sources must be promoted. Although a scattering of potential spruce seed trees were retained during harvesting (Section 3.3.1) to provide for the possibility of natural regeneration, a lack of seed production in the immediate post-harvest years (Section 3.5.5) eliminated this as a practical regeneration option[12]. From an operational perspective, natural regeneration of white spruce is especially problematic, depending as it does on the unpredictable coincidence of harvesting with a good cone crop on retained seed trees, favourable climatic conditions for seed dispersal and germination, and the availability of suitable seedbeds. Even where these conditions are satisfied, successful natural regeneration depends on young seedlings being able to survive predators and environmental stresses, as well as being able to compete with other, perhaps more aggressive plant species.

Of the two artificial regeneration alternatives — planting and seeding — planting probably offers the best prospect for successfully re-establishing spruce under an aspen overstory, although some direct seeding techniques (e.g., seed shelters) are worthy of trial. In the regeneration studies described here we opted for the planting of large, overwintered container-grown stock to promote rapid initial seedling establishment in the face of anticipated heavy vegetation competition. Although supplementary site preparation is normally considered an essential part of the regeneration prescription for harvested boreal mixedwood sites, forest managers have little such experience under partially cut stands. Not only is there a need for fundamental biological research to define basic site preparation requirements under partial cuts, but any prescriptions developed therefrom must satisfy a number of additional operational criteria, viz: ease of equipment access, minimize damage to residual trees and tree roots, minimize any unnecessary site disturbance, avoid damage to existing advance growth of desirable species, provide effective control of unwanted vegetation.

3.7.1 Site preparation of partial cuts and clearcuts

The main regeneration study in the harvesting impacts component was installed in 1995. It compares the effects and responses to conventional and alternative site preparation treatments under partially cut versus clearcut stand conditions — on the growth and development of spruce planting stock and competing vegetation, on organic matter decomposition and mineral element mobilization, and on the presence and spread of root decay fungi (Sutherland 1996) (Sutherland et al. Appendix 6). This work complements studies initiated in 1992 under the site preparation alternatives component of the project (Section 5.0; Appendix 6).

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[12]The first evidence of a recovery in the coning capacity of white spruce was noted in 1996. Light-to-moderate cone production was present on trees behind Compartments 1-6 to 1-8, and in Compartments 2-2, 2-3, and 2-4. Light coning was also noted on some black spruce and balsam fir trees.

Commencing July 25, 1995, experimental site preparation treatments were conducted on a series of 20 to 35 m^2 plots in three partial cuts (Treatment 2i: Compartments 1-2, 1-3, 2-4) and three clearcuts harvested by the full-tree system (Treatment 1i: Compartments 1-1, 1-14, 2-6). Treatments were installed in the non-reserved half of each compartment, as follows:

- no site preparation (boot screef and plant);
- high speed mechanical soil mixing in strips using a Meri Crusher, model MJ.80 (1.0 m strip width; depth of mixing 10-15 cm);
- mechanical spot screefing (1x1 m patches) of organic layers using a Kubota R 420 wheeled loader with a backhoe bucket;
- spot mounding of mineral soil over the undisturbed organic layer into 75- to 80 L mounds (approximate area 2,500 cm^2 x 30-40 cm high) using a Kubota backhoe;
- mixed mounds (80 L) manually prepared from mixed soil produced by the Meri Crusher;
- herbicide (Vision®) applied to entire plot at 5 L/ha (1.78 kg a.i./ha) using a backpack sprayer.

The layout of treatment plots in relation to other research plots and installations is delineated in the compartment diagrams at Appendix 8.

Between August 11-14, 1995, following completion of experimental plot treatments, the remaining non-reserved areas of clearcut Compartments 1-1, 1-14, 2-6, and the entire non-reserved areas of clearcut Compartments 1-7, 1-9, 2-1 were operationally site-prepared with a 2-row Bräcke cultivator set at 2x2 m scalp spacing. Herbicide (Vision® @ 5 L/ha; 1.78 kg a.i./ha) was applied concurrently to roughly two-thirds of the site-prepared area on each compartment by Bräcke-mounted sprayer (TeeJet 8005 nozzles). This combined mechanical/chemical site preparation treatment traversed all PSPs and some vegetation and regeneration plots on the non-reserved sides of the clearcut compartments. Affected plots were re-established immediately after site preparation was completed. Treatment boundaries and associated plot locations are illustrated in the compartment diagrams (Appendix 8). These operationally treated areas provide a useful context for comparing results of the experimental treatments.

3.7.2 Planting of partial cuts and clearcuts

Experimental site preparation plots in the partial cuts and full-tree clearcuts were planted with one-year-old overwintered container-grown white spruce and black spruce in late May and early June of 1996. Seedlings were grown from seed in Multipot® #4 containers (149 cc capacity; *Can-Am Containers, Springhill, Nova Scotia)* at the Great Lakes Forestry Centre in Sault Ste. Marie, and were sorted for uniformity before planting. Average seedling dimensions (n = 50) at time of planting were as follows :[13]

	White spruce	Black Spruce
Shoot height (cm)	18.8±3.1	25.4±3.2
Root collar diameter (mm)	3.5±0.3	2.8±0.4
Total dry weight (g)	2.7±0.4	3.0±0.9
Shoot/root ratio	1.7±0.3	2.3±0.5
Root area index (cm^2)	68.8±7.7	61.1±10.8

The operationally site-prepared areas in the clearcuts were planted with one-year-old container-grown black spruce in late June 1996. Seedlings were supplied by A&R Greenhouses of Hurkett, Ontario, and had been grown from seed in Styroblock® 165 containers (40 cc capacity; *Beaver Plastics, Edmonton, Alberta*). They had been extracted from the containers in November 1995, wrapped in bundles of 25, and cold-stored (2°C) overwinter for shipping in the spring of 1996. Although seedling dimensions at time of planting were not recorded, minimum target dimensions for seedling production in the nursery were: shoot height 10 cm, root-collar diameter 1.5 mm, total dry weight 0.4 g.

[13]Ontario Ministry of Natural Resources seedlots 3425001/801027 (1980) and 3425003/891022 (1988) of white spruce and black spruce, respectively. Sown in greenhouse January 25 and seedlings moved outdoors June 21, 1995; seedlings shipped April 1996 and held at A&R Greenhouses in Hurkett (40 km south of planting site) until time of planting.

Complementing the experimental plots in the full-tree clearcuts, supplementary plots to monitor comparative seedling performance were also established within the operationally site-prepared areas in the three tree-length clearcuts (Compartments 1-7, 1-9, 2-1; see Appendix 8). These plots were planted with the same white spruce and black spruce Multipot® stock as used in the partial cuts and full-tree clearcuts.

Further information on site preparation treatments, planting, etc., may be obtained from F. Foreman, Canadian Forest Service, Great Lakes Forestry Service, Sault Ste. Marie, Ontario (fforeman@nrcan.gc.ca), or from the Project Coordinator.

3.7.3 Patch cuts

For completeness it may be noted that the skid trails and circular clearings within the patch-cut compartments were site-prepared at the same time as the main clearcuts as part of an independent white spruce regeneration study (Groot, Appendix 6). As illustrated in the diagrams for Compartments 1-8, 1-10, and 2-7 (Appendix 8), site preparation treatments were: i. no site preparation; ii. mechanical site preparation only using Bräcke cultivator; iii. Bräcke site preparation with concurrent herbicide application (Vision® @ 5 L/ha, = 1.78 kg a.i./ha); iv. herbicide only (Vision® @ 5 L/ha, = 1.78 kg a.i./ha), applied with backpack sprayer; v. as for treatment iv, with follow-up annual herbicide applications (Vision® @ 3.75 L/ha, = 1.33 kg a.i./ha). Treated areas were planted with one year old container-grown white spruce (same as described in previous section) in June 1996.

For further information contact Dr. A. Groot, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (agroot@nrcan.gc.ca)

3.8 TREATMENT COMPARTMENT DIAGRAMS

3.8.1 Demarcation and layout

The generalized layout and demarcation of the main treatment compartments is described in Section 3.2.4 together with the locations of common research plots. Within this framework, the compartment to compartment presence, location, and size of other research plots differs from study to study. Approximate locations of some of the more permanent research plots and their spatial relationship to major compartment features (site preparation, PSPs, etc.) are illustrated in the individual compartment diagrams in Appendix 8. Plot research topic and method of demarcation are described briefly in the introductory text to the appendix.

Note that all plot markers are colour coded to indicate the type of plot and the responsible study leader. A full list of post and flagging colour allocations is available from the Project Coordinator, who should be consulted before any new studies are established or sampling is carried out.

3.8.2 Permanent photo points

A visual record of successional changes in stand composition and structure over time can be a valuable adjunct to quantitative vegetation descriptions. To provide a general record of post-harvest vegetation changes and stand development in harvested compartments and uncut areas, 25 permanent photo points have been established along the roads in Stand 1. At each station, colour photographs of stand conditions are taken at one or more specified compass bearings and camera focal lengths, usually during the first two weeks of August. Figure 3.5 indicates the locations and numbering of these photo points; the arrows indicate the general viewpoint of each photograph.

Colour slides are presently available for 1994, 1995, 1996, 1997, 1998, and 1999 (post-fire). The slide collection is maintained by the Project Coordinator.

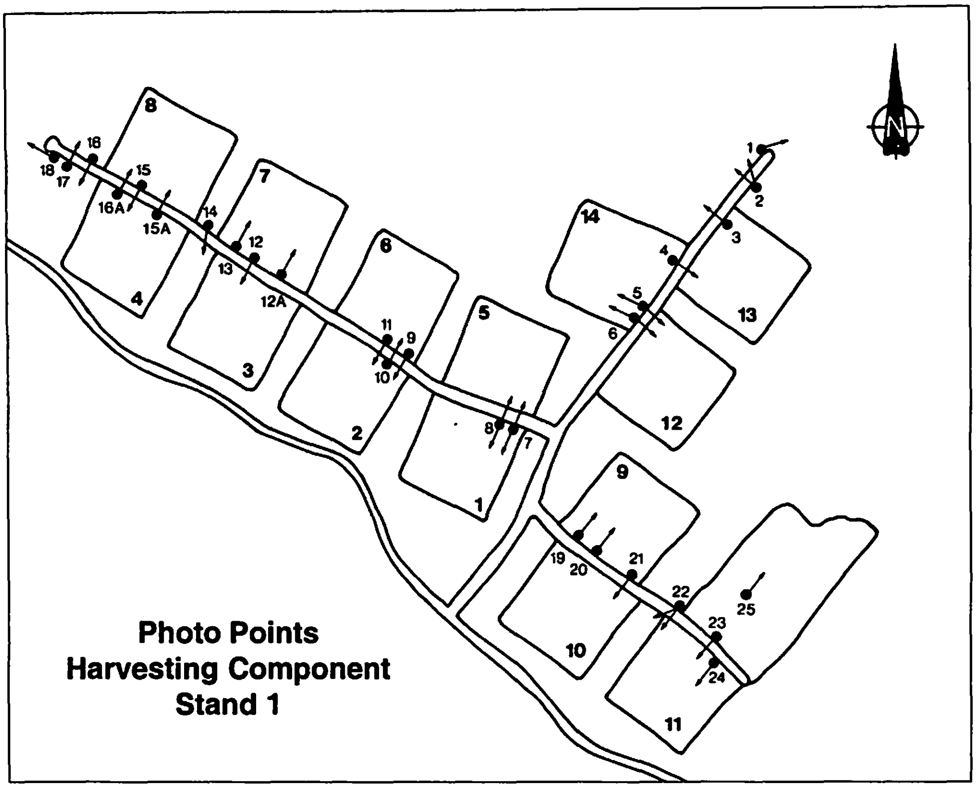

Figure 3.5 Location of permanent photo-points for Stand 1 vegetation succession monitoring

3.8.3 Weather stations

Four automatic weather stations (Models CR-10 and CR-21x) (*Campbell Scientific [Canada] Corp., Chatham, ON*) are maintained on the project, one each in Compartments 1-1 (clearcut), 1-3 and 2-4 (partial cuts) of the harvesting impacts component, and one in Compartment B/C (clearcut) of the site preparation alternatives component (Section 5.0). Recorded parameters include air temperature, relative humidity, precipitation, wind speed, wind direction, solar radiation, soil temperature. An additional recorder is installed in Compartment 1-1 to collect more intensive soil temperature data from site-prepared areas.

For further details and access to the weather data contact N. Boyonoski, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario (nboyonos@nrcan.gc.ca), or the Project Coordinator.

SECTION 4 - FIRE ECOLOGY COMPONENT

Plate 5. Fire ecology component: aerial view of burned compartments taken one day after prescribed burn on May 30, 1996 (north at right).

SECTION 4 – FIRE ECOLOGY COMPONENT

This component of the Black Sturgeon Boreal Mixedwood Research Project is primarily an initiative of research establishments within the Ontario Ministry of Natural Resources' (OMNR) Northwestern Region (i.e., Centre for Northern Forest Ecosystem Research and Northwest Region Science and Technology). Although administered by OMNR staff, it is an integral part of the overall project, with links to both the harvesting impacts component and the site preparation alternatives components in several areas of study. Information given in this section describes the layout, primary treatments, and baseline data for the installation, with a minimum of discussion.

For further information on the project component as a whole, or to enquire about site access for proposed new studies, contact W.D. Towill, Ontario Ministry of Natural Resources, Northwest Region Science and Technology, Thunder Bay, Ontario (bill.towill@mnr.gov.on.ca). For questions regarding specific studies (Appendix 6) and baseline database files (Appendix 7) contact J.A. Elliott, Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario (julie.elliott@mnr.gov.on.ca).

4.1 INTRODUCTION

Fire is a natural phenomenon in the boreal forest. Historically, it has been the most frequent agent of disturbance in northwestern Ontario (Ward and Tithecott 1993). For thousands of years before the advent of logging, wildfires were the principle agent of forest renewal, and played a fundamental role both in regulating forest productivity and in maintaining long-term ecosystem diversity and stability. Although the character of individual stands may differ significantly depending on fire frequency and intensity, the boreal forest as a whole is well-characterized as "*a fire- dependent system that would lose its character, vigour, and faunal and floral diversity in the absence of fire*" (Kelsall et al.1977).

Despite its elemental role in boreal forest ecology, fire has been little used as a silvicultural tool in boreal mixedwoods, except to eliminate logging debris in advance of other operations. Yet prescribed fire could potentially play a much more significant role in the management of these ecosystems. For example, it might be used to eliminate or reduce unwanted balsam fir regeneration on harvested sites, to manage the interaction of vegetation competition with crop trees, to improve wildlife habitat or the availability of food for wildlife, and to promote increased biodiversity. Before prescribed burning can be used more broadly as a silvicultural tool in boreal mixedwoods, however, a much better understanding of the impacts of fire on ecosystem-level processes is needed.

Because fire was historically an important factor in the periodic renewal and perpetuation of boreal mixedwoods, a perennial issue in the management of these ecosystems is the extent to which harvesting practices can mimic the ecological effects of fire. Although harvesting may successfully duplicate the impacts of fire upon ecosystem structure, the effects on ecosystem function may be quite different (Johnston 1996b). This reinforces the need to better understand the relative impacts of fire and harvesting on ecosystem-level processes, not only to enable us to harness the full benefits of prescribed fire, but also to help in developing more ecologically sound forestry practices.

The fire ecology component, through its various studies (Appendix 6), focusses on the long-term impacts of quantified prescribed fire on soil chemistry and nutrient dynamics, forest regeneration, and vegetation succession, including the relationship between species re-establishment and fire intensity. A broad objective is to integrate soils, vegetation, and seed bank data into a succession model that will eventually enable forest managers to predict the response of boreal mixedwood ecosystems to disturbance by fire. These studies allow a comparison of the ecological impacts of fire and harvesting under similar site and forest conditions. An additional, short-term goal was to document fire behaviour in a mixedwood stand type where high levels of budworm-killed balsam fir were the dominant and potentially explosive fuel type.[14]

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[14]Anon. 1994. Nonwatin Lake Prescribed Burn Plan, Nipigon District. Unpub. rep., Ont. Min. Nat. Resour., Geraldton Fire Mgmt. HQ., Nipigon District, Geraldton, ON. xiii+93 p. + attach. and maps.

This project component was harvested at the same time as the harvesting impacts component of the project, in late fall of 1993. It was originally planned that the prescribed burn would be carried out in spring and late summer of 1994. However, because of logistic difficulties and unsuitable burning conditions in 1994 and 1995, the prescribed burn was delayed until the spring of 1996 (Section 4.2.2).

4.2 EXPERIMENTAL DESIGN

4.2.1 Study area

The fire ecology component (49°13'N, 88°45'W) is situated approximately 52 km north of the community of Hurkett on the Black Sturgeon Road (Section 2.1; Fig. 2.1). It lies immediately south of the airstrip and Stand 2 of the harvesting impacts component (Fig. 2.2). The study area, screened by a narrow reserve of uncut trees, is bounded on its western side by the main Black Sturgeon Road, and is bisected by the secondary Airport Road (Fig. 4.1). See *General Description of Research Site* (Section 2) for relevant characteristics and descriptions of the study area.

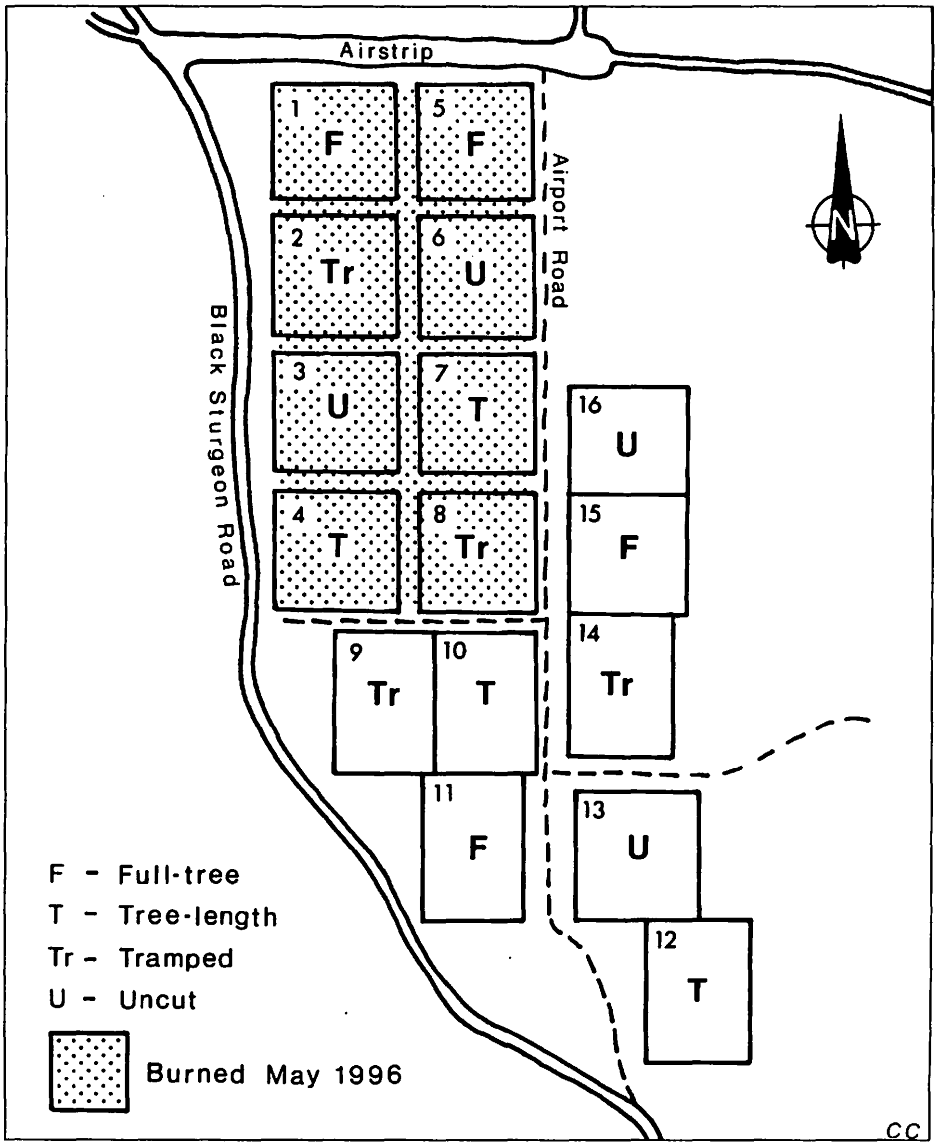

Figure 4.1 Layout of harvested compartments in relation to prescribed burn. (See Section 4.2.1 for more complete description of harvesting treatments)

4.2.2 Harvesting and harvest compartment layout

In accordance with the original plan, the experimental area was divided into 16 compartments, each of nine hectares (300x300 m). It was originally planned that eight of these compartments would be burned in the spring of 1994 (shaded area in Fig. 4.1), with the remainder being burned at an anticipated lower fire intensity in late summer of the same year. Within the two proposed burn areas, different harvesting treatments and stand manipulations were intended to create fuel conditions that would produce fires of varying behaviour and intensity, viz:

1. Full-tree clearcut: felling by Harricana feller-buncher (mounted on John Deere 693 excavator carrier), full-tree extraction by John Deere 648 grapple skidder, delimbing and slashing at roadside.
2. Tree-length clearcut: felling by Harricana feller-buncher (mounted on John Deere 693 excavator carrier), manual topping and delimbing, tree-length extraction by John Deere 648 grapple skidder.
3. Partial tramping of 50% of dead balsam fir with a Clark 664 cable skidder, intended to simulate natural stand breakup in the later stages of a spruce budworm infestation.
4. Uncut control (the dead, standing balsam fir to provide the primary fuel source).

Each treatment was applied to two of the eight compartments in each burn area (Fig. 4.1). Through an error in communication, all conifers were pushed over in Compartment 8 of the tramping treatment, leaving only hardwoods standing on about 70% of the compartment (evident in post-burn aerial view, Plate 5) and consequent heavy fuel loadings. This is commonly referred to as the "super-tramped" compartment.

Compartment boundaries and the internal road system were established during the summer of 1993. Harvesting commenced in October 1993, and was completed on December 14, 1993. As in the harvesting impacts component, wood was piled at roadside separately for each harvested compartment, where it was scaled by staff of Bowater Inc. Estimated volumes harvested from the compartments are summarized in Table 4.1

Table 4.1 Volume removals from the 9 ha harvested compartments (m^3 solid measure)[a].

Compartment	Spruce	Balsam fir	Jack pine	Poplar	Total
1 + 5	1400	400	-	1200	3000
4	500	100	100	900	1600
7	700	-	100	200	1000
10 + 11	1300	200	700	1000	3200
12	400	100	-	800	1300
15	700	200	-	700	1600
Totals	5000	1000	900	4800	11700

[a]Divide figures by 9 for volumes per hectare.

4.2.3 Prescribed burn

As noted above, it was originally planned that half of the treatment compartments would be burned in spring and half in late summer of 1994 to achieve differences in fire behaviour and intensity, with commensurate reductions in forest floor organic materials and woody fuel consumption. The gross area of burn in each season would have been approximately 80 ha. Unfortunately, logistic problems and unfavourable weather conditions prevented burning from being carried out either in 1994 or 1995.

By the spring of 1996 logging slash on the harvested compartments had become very dry and volatile. However, prolific post-harvest suckering of trembling aspen and other hardwoods had already reached a height of about two metres, and would have presented a potential barrier to an effective burn once the leaves had flushed. In the event of suitable burning conditions, an early spring burn in 1966 was therefore regarded as the only viable option for completing the experimental treatments.

Revised plans for 1996 called for the burning of Compartments 1 to 11 only (i.e., the area between the Black

Sturgeon Road and Airport Road) over a period of two days. In preparation, previously bulldozed firebreaks (4-6 m wide) were cleared of encroaching vegetation and fallen trees in early May. Favourable burning conditions emerged on May 29, 1996 (Table 4.2), and Compartments 1 to 8 (80 ha; shaded area in Fig. 4.1) were burned in a single fire that same evening. Hand ignition by drip torch commenced at 17.40 hrs, and burning was completed by 20.30 hrs (duration 2.8 hrs).[15] Compartments 9 to 11 could not be burned due to time constraints on the first day, and ignition had to be abandoned on the second day because of an increased fire hazard. These compartments therefore remain unburned. The OMNR Northwest Region fire team planned and conducted the prescribed burn, with assistance from local district staff.

Table 4.2 On-site weather, fuel, and fire indices at time of prescribed burn ignition.[a]

Weather readings at 17.00 hrs EST		Fuel moisture codes and fire indices at 17.00 hrs EST		
Temperature (°C)	24.4	Fine fuel moisture code	94.1	extreme
Relative humidity (%)	15.0	Organic layer moisture code	29.3	medium
Wind direction (degrees)	45.0	Drought code	63.1	low
Wind speed (km/hr^{-1})	2.9	Initial spread index	7.2	high
24-hr rainfall	0.0	Build-up index	29.7	high
		Fire weather index	15.5	high

[a]Source: Johnston and Elliott 1998.

4.3 PRE-HARVEST SITE CONDITIONS

Pre-harvest site and forest conditions were essentially the same as those in the harvesting impacts component. The site straddles the same recessional moraine (Section 2.2.4), and is characterized by essentially flat terrain and deep, well-drained mixtures of sand, clay, and gravel (Section 2.3.2). There is no exposed bedrock and very few surface boulders.

Prior to harvest the site supported second-growth mixedwood stands, first harvested in 1940-41 (Fig. 2.11), with an overstory of mainly trembling aspen. Although these stands had a moderate conifer component (white spruce, black spruce, balsam fir), the dominant FEC V-types (Sims et al. 1989) were V6 (trembling aspen [white birch] - balsam fir/mountain maple) and V7 (trembling aspen - balsam fir/balsam fir shrub). As in most mixedwood stands throughout the Black Sturgeon Forest, the balsam fir had experienced heavy mortality from the ongoing spruce budworm infestation (Section 2.6). In 1993, much of the dead fir was beginning to break up or to blow over, leading to the opening of gaps in the mid- and upper canopies.

Pre-harvest assessment data for prospective treatment compartments, including information on stand structure, vegetation cover, tree inventory, live and dead biomass, and soil organic layers are available in database file **~\excel\preburn\ preveg.xls** (see Appendix 7). Tree data are based on sixteen 10x10 m plots within each treatment compartment (Fig. 4.2). All trees >130 cm in height were measured and their condition assessed. Shrub cover (%) was measured on a 2x2 m sub-plot nested within each 10x10 m plot, while herb cover was measured on a 1x1 m sub-plot nested within each shrub plot. Because of a shortage of manpower, no intermediate vegetation assessments were made between the pre-harvest and post-burn vegetation assessments.

[15]Hyland, E.; Johnson, R. 1996. Nonwatin Lake Prescribed Burn, Post Burn Report. Unpub. rep., Ont. Min. Nat. Resour., Geraldton Fire Mgmt. HQ., Nipigon District, Geraldton, ON. 24 p.

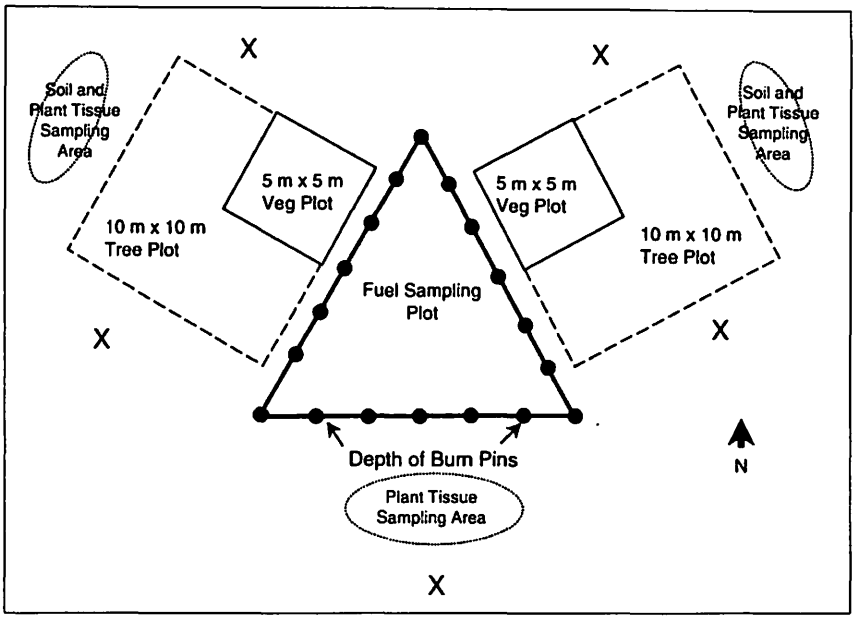

Figure 4.2 Layout of fuel, soil, and vegetation sampling areas (five such sampling areas are located in each of treatment Compartments 1 to 8, 10 and 16). X = biomass sampling areas.

4.4 PRE-BURN CONDITIONS

4.4.1 Logging debris and fuel loadings

Fuel loadings on those areas scheduled for spring burning were quantified during May 1994 using the line intersect method as described by McRae et al. (1979). Five assessment triangles with 15 m sides (Fig. 4.2) were established on each of Compartments 1 to 8, and woody fuel loadings (kg/m^{-2}) were determined for slash size classes 0-0.5 cm, 0.5-0.9 cm, 1.0-2.9 cm, 3.0-4.9 cm, 5.0-6.9 cm and 7.0 cm (Johnston and Elliott 1998). Each of the 40 fuel triangles was marked to facilitate easy re-establishment after the fire. Because the spring burn had to be abandoned in 1994, fuel loadings on Compartments 9 to 16 were not measured as planned.

Woody fuel (slash) loading data for Compartments 1 to 8 are summarized in Table 4.3. Total fuel loadings (woody fuel, forest floor organic material [duff], and foliage) are summarized in Table 4.4. The full dataset from which Table 4.3 is derived is available in database file **~\excel\preburn\prefuel.xls** (see Appendix 7).

4.4.2 Organic layer depth

Forest floor organic layer (duff) depths were measured at five points along each side of the fuel triangles (Fig. 4.2) in accordance with McRae et al.(1979). For the 40 triangles on Compartments 1 to 8 depths ranged from 4.5-11.0 cm (see Table 4.7), with an average depth of 7.62±1.37 cm. The complete dataset is available in database file **~\excel\preburn\ preveg.xls** (see Appendix 7). Additionally, soil cores were taken near each fuel triangle for seedbank quantification (see Section 4.5.3).

Table 4.3 Pre-burn woody fuel (slash) loading by size class (kg/m^{-2})[a,b]

Compartment	Harvesting treatment	Slash diameter class (cm)							
		0 - 0.49	0.5 - 0.99	1.0 - 2.99	3.0 - 4.99	5.0 - 6.99	Total fine 0 - 6.99	Heavy ≥7.0	Total
1	Full-tree	0.172±0.032	0.227±0.069	0.695±0.152	0.876±0.120	1.194±0.249	3.165±0.451	4.149±0.784	7.314
2	Tramped	0.143±0.043	0.119±0.033	0.215±0.087	0.268±0.111	0.381±0.190	1.125±0.344	1.309±0.904	2.435
3	Uncut[c]	0.095±0.033	0.093±0.032	0.186±0.043	0.150±0.102	0.317±0.118	0.841±0.154	0.973±0.968	1.814
4	Tree-length	0.364±0.158	0.275±0.018	0.812±0.126	0.709±0.346	0.883±0.386	3.044±0.662	2.777±1.250	5.820
5	Full-tree	0.248±0.089	0.250±0.064	0.842±0.344	0.797±0.229	1.090±0.356	3.228±0.675	3.359±1.315	6.586
6	Uncut[c]	0.129±0.037	0.106±0.064	0.204±0.129	0.243±0.077	0.286±0.140	0.968±0.306	1.447±0.746	2.415
7	Tree-length	0.289±0.102	0.280±0.056	0.605±0.108	0.518±0.188	0.876±0.307	2.569±0.513	3.806±2.683	6.375
8	Tramped[d]	0.394±0.165	0.275±0.139	0.781±0.392	0.324±0.173	0.800±0.345	2.574±1.030	7.337±2.030	9.911

[a]Summarized from data provided by T. Blake, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.
[b]n = 5
[c]Woody fuel in uncut compartments was that measured on the ground.
[d]"Super-tramped" (see Section 4.2.1)

Table 4.4 Pre-burn fuel loadings by type (kg/m^{-2})[a]

Compartment	Harvesting treatment	Downed woody material[b]	Forest floor organic material	Foliage[b]	Total fuel
1	Full-tree	7.3	9.3	0.12	16.7
2	Tramped	2.4	7.5	0.11	10.0
3	Uncut	1.8	7.8	0.76	10.4
4	Tree-length	5.8	6.5	0.35	12.6
5	Full-tree	6.6	8.8	0.22	15.6
6	Uncut	2.4	8.6	0.12	11.1
7	Tree-length	6.4	9.6	0.20	16.2
8	Tramped[c]	9.9	6.0	0.21	16.1

[a]n=5
[b]Downed woody material and foliage in uncut compartments was that measured on the ground.
[c]"Super-tramped" (see Section 4.2.1)

4.5 POST-BURN CONDITIONS

4.5.1 Reductions in woody fuels and organic matter

Measurements of residual fuel materials were made at each fuel triangle in Compartments 1 to 8 immediately following the fire to determine fuel consumption and reductions in the depth of the organic, duff layer. The results, summarized in Tables 4.5 and 4.6 indicate substantial variability in fuel reductions both within and between harvesting treatments. Much of the within-treatment variability was probably a result of the uneven distribution of logging residues on the harvested compartments and their ability to carry a hot fire. In all harvesting treatments, the fine materials (0-6.99 cm) were consumed more completely than heavy materials (7.0 cm). On a proportional basis, woody fuel consumption was highest in the full-tree and tree-length treatments (Table 4.5). However, in actual amounts (Table 4.6) consumption was greatest on the "super tramped" compartment due to the abnormally heavy accumulation of fuels over much of the compartment (Table 4.3).

Table 4.5 Woody fuel consumption by size class (percent)[a,b]

Compartment	Harvesting treatment	Slash diameter class (cm)						
		0 - 0.49	0.5 - 0.99	1.0 - 2.99	3.0 - 4.99	5.0 - 6.99	Total fine 0 - 6.99	Heavy ≥7.0
1	Full-tree	81.5±2.5	94.9±1.9	88.7±6.3	71.5±4.7	83.7±5.5	84.1±2.8	71.1±4.3
2	Tramped	75.8±9.9	86.3±5.2	65.1±12.4	51.5±20.7	63.2±19.7	69.2±6.0	55.0±12.2
3	Uncut	72.1±9.7	86.1±5.4	69.0±20.4	53.0±9.9	79.4±13.3	66.1±16.5	50.9±17.4
4	Tree-length	89.7±4.3	95.9±2.2	89.4±6.4	86.2±7.3	91.8±5.3	90.6±2.8	73.3±6.3
5	Full-tree	93.7±6.8	93.9±6.0	86.9±8.8	69.4±19.9	82.2±8.5	85.2±6.5	72.6±5.1
6	Uncut	81.4±8.7	79.6±17.4	67.0±12.5	67.2±12.7	83.3±15.3	75.7±7.3	66.8±18.7
7	Tree-length	94.6±1.8	96.1±2.9	91.5±3.0	75.2±14.2	88.9±6.0	89.3±4.6	78.1±11.3
8	Tramped[c]	94.6±1.7	96.7±2.5	91.6±7.3	59.9±16.9	90.5±6.3	86.4±3.2	61.1±7.2

[a]Derived from data in Hyland, E.; Johnson, R. 1996. Nonwatin Lake Prescribed Burn, Post Burn Report. Unpub. rep., Ont. Min. Nat. Resour., Geraldton Fire Mgmt. HQ., Nipigon District, Geraldton, ON. 24 p.
[b]n = 5
[c]"Super-tramped" (see Section 4.2.1)

Table 4.6 Comparison of pre-burn and residual post-burn slash loadings by major size classes (kg/m^{-2})[a,b]

Compartment	Harvesting treatment	Slash diameter class (cm)					
		Total fine 0 - 6.99		Heavy ≥ 7.0		All classes	
		Pre-burn	Post-burn	Pre-burn	Post-burn	Pre-burn	Post-burn
1	Full-tree	3.165±0.451	0.521±0.129	4.149±0.784	1.181±0.172	7.314	1.702
2	Tramped	1.125±0.344	0.373±0.158	1.309±0.904	0.571±0.395	2.435	0.944
3	Uncut	0.841±0.154	0.252±0.107	0.973±0.968	0.530±0.589	1.814	0.782
4	Tree-length	3.044±0.662	0.306±0.163	2.777±1.250	0.756±0.418	5.820	1.062
5	Full-tree	3.228±0.675	0.520±0.133	3.359±1.315	0.879±0.227	6.586	1.399
6	Uncut	0.968±0.306	0.238±0.124	1.447±0.746	0.645±0.428	2.415	0.883
7	Tree-length	2.569±0.513	0.298±0.108	3.806±2.683	0.954±0.824	6.375	1.252
8	Tramped[c]	2.574±1.030	0.273±0.121	7.337±2.030	2.723±0.489	9.911	2.996

[a]Derived from data in Hyland, E.; Johnson, R. 1996. Nonwatin Lake Prescribed Burn, Post Burn Report. Unpub. rep., Ont. Min. Nat. Resour., Geraldton Fire Mgmt. HQ., Nipigon District, Geraldton, ON. 24 p.
[b]n = 5
[c]"Super-tramped" (see Section 4.2.1)

The forest floor organic layer was not completely consumed in any of the harvesting treatments. Especially under the heavier slash accumulations, the organic layer was probably not completely dry at the time of the fire, and this may have retarded burn rates in the duff. Reductions in forest floor organic depth were greatest in the tree-length compartments, followed by the full-tree compartments (Table 4.7), reflecting differences in fuel loadings. For the same reason, forest floor reductions were greater on the "super tramped" compartment than on the less heavily tramped compartment and the uncut compartments.

Table 4.7 Reductions in depth of forest floor organic layer (duff)[a,b]

Compartment	Harvesting treatment	Pre-burn duff depth (cm)	Post-burn duff depth (cm)	Duff reduction (%)
1	Full-tree	8.17±0.74	4.89±0.76	40.32±5.63
2	Tramped	7.71±2.28	5.77±2.48	27.60±14.27
3	Uncut	7.53±0.41	5.85±0.35	22.16±5.33
4	Tree-length	6.75±0.60	2.38±0.94	65.22±11.46
5	Full-tree	7.98±1.16	4.08±1.25	49.74±8.99
6	Uncut	8.04±1.10	5.99±1.04	25.57±5.68
7	Tree-length	8.47±1.55	4.28±1.72	50.98±11.97
8	Tramped[c]	6.30±1.52	2.96±1.82	56.47±20.03

[a]Derived from data in Hyland, E.; Johnson, R. 1996. Nonwatin Lake Prescribed Burn, Post Burn Report. Unpub. rep., Ont. Min. Nat. Resour., Geraldton Fire Mgmt. HQ., Nipigon District, Geraldton, ON. 24 p.
[b]n = 5
[c]"Super-tramped" (see Section 4.2.1)

For a more complete discussion of these results see Johnston and Elliott (1998). Full details of post-burn fuel loadings and organic layer depths are available in database files **~\excel\postburn\postfuel.xls** and **~\excel\postburn\ ashdata.xls**, respectively (see Appendix 7).

4.5.2 Ash, soil, and plant nutrients

Ash samples (3) were collected for nutrient analysis from the apex of each fuel triangle within 24 hours of burn completion, for a total of 120 samples. Soil samples, comprising 10x10 cm samples of the unburned forest floor and 10x10 cm samples of the upper 10 cm of mineral soil, were collected from areas adjacent to the fuel triangles (Fig. 4.2) during the last week of August 1996 and again in 1997. Plant samples were also collected at this time for stem and foliar analysis of five species that reproduce either from seed or vegetatively (trembling aspen, pin cherry, raspberry, geranium, bunchberry). All samples were analyzed by methods described in Kalra and Maynard (1991).

A more detailed description of methodology, with an extensive discussion of post-burn soil chemistry and nutrient dynamics, is given in Johnston and Elliott (1998).

Full data for the chemical analyses of post-burn ash samples are available in database file **~\excel\postburn\ashdata.xls** (see Appendix 7). Data for post-burn soil and plant nutrient analyses (1996 and 1997) are available in database file **~\excel\postburn\postsoil.xls** and **~\excel\postburn\postplnt.xls.**

For additional information contact J.A. Elliott, Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. (julie.elliott@mnr.gov.on.ca)

4.5.3 Vegetation succession

In addition to its focus on the long-term impacts of quantified prescribed fire on soil chemistry and nutrient dynamics, long-term monitoring of post-harvest and post-burn vegetation succession and tree regeneration is a major thrust of this project component. Vegetation assessment plots (5x5 m) were established immediately after the fire on the west and east sides of each fuel triangle in the burned Compartments 1 to 8, as well as in Compartment 10 (tree-length harvested/unburned) and Compartment 16 (uncut/unburned) (i.e., 10 plots per compartment, for a total of 100 plots). Plots in Compartments 10 and 16 were set up as if fuel triangles were present (see Section 4.4.1).

Post-burn vegetation assessments, including percent cover of all tree, shrub and herb species, were carried out in July 1996; they were repeated in 1997 and 1998. Once the tree species begin to approach 1.3 m in height, the plots will be enlarged to 10x10 m for future assessments. In 1997, destructive sampling of vegetation was carried out on five 5x5 cm plots adjacent to each of the vegetation assessment plots (Fig. 4.2; total 250 samples for estimating individual species' biomass and nutrient loadings).

Seedbank data is being collected as part of the vegetation studies. To quantify the pre-burn seedbank, five soil cores (10x10 cm of the organic layer, and 10 cm^3 of underlying mineral soil) were collected adjacent to each fuel triangle in Compartments 1 to 8 (25 cores per compartment). Samples were germinated in a greenhouse for species identification and quantification of seedling emergence. Post-burn seedbank samples (two cores per fuel triangle) were collected from the same locations in October 1996 and the spring of 1997 for comparison with the pre-burn seedbank and vegetation data. Data on the post-burn seedbank are available in database file **~\excel\postburn\seedbank.xls.**

For further information or for access to assessment data contact J.A. Elliott, Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. (julie.elliott@mnr.gov.on.ca)

4.6 AERIAL PHOTOGRAPHS

Black and white and infra-red aerial photography of the research site were carried out prior to road and treatment compartment layout in June 1993. Post-harvest black and white aerial photography was carried out in March 1994. This was followed by infra-red photography in mid-July 1994. These photographs are held in an archive by the Project Coordinator.

Additional black and white coverage of the experimental sites is included in aerial photography undertaken by Bowater Inc. and the Ontario Ministry of Natural Resources at various times in 1995, 1996, and 1997.

SECTION 5 - SITE PREPARATION ALTERNATIVES COMPONENT

SECTION 5 – SITE PREPARATION ALTERNATIVES COMPONENT

This multidisciplinary project component was established in 1992 to investigate and compare the ecological impacts of soil mixing as an alternative to conventional site preparation methods (screefing, and herbicide application) after clearcutting a boreal mixedwood site. Information presented in this section describes the layout and primary treatments for the installation, with a brief note on the availability of pre- and post-harvest baseline data. The introductory remarks are based on Sutherland (1996).

For enquiries on the project component as a whole contact the research group leader, Dr. I.K. Morrison, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario (imorriso@nrcan.gc.ca), or the Project Coordinator. More detailed information on the primary site preparation treatments, treatment layout, and pre-harvest conditions may be obtained from F.F. Foreman at the same address (fforeman@nrcan.gc.ca). For information on individual studies contact the appropriate study leader (Appendix 6).

5.1 INTRODUCTION

A major challenge in the management of boreal mixedwoods is the question of how best to regenerate spruce on clearcuts without further altering or degrading ecosystem integrity. Especially on the more fertile mixedwood sites, site preparation (i.e., soil scarification) and treatments to manage post-harvest vegetation regrowth after clearcutting are essential elements of artificial regeneration programs for spruce. Current site preparation practices in boreal mixedwoods typically involve some form of organic matter removal (e.g., blade screefing or disc trenching) in strips or patches, exposing the mineral soil or inverting it over the undisturbed organic horizons. Such treatments are commonly combined with one or more herbicide applications to discourage competing vegetation. Mechanical site preparation alone has demonstrated little or, at best, short-term control of competing vegetation and has also been criticized on the grounds that it promotes nutrient depletion, and so threatens long-term sustainability (MacKinnon and McMinn 1988).

In 1991, the Forest Engineering Research Institute of Canada (FERIC) undertook the development of an alternative site preparation device, namely a high-speed rototiller capable of working under a broad range of forest site conditions (Cormier 1994). Mixing the surface organic layers into the underlying mineral soil has shown promise for delaying the establishment and growth of competing vegetation following harvesting (McMinn and Hedin 1990), thereby reducing the need for herbicides. It may also improve soil conditions, such as aeration and moisture relationships, for conifer regeneration (Örlander et al. 1990). By mixing the organic layer with the mineral soil rather than removing it (as in blade screefing) long-term nutrient levels and relationships in the soil are preserved, with potential benefits for tree growth (Moehring 1977; Foster and Morrison 1989). Incorporating surface organic materials deep into the mineral soil may also have a moderating effect on nutrient mineralization rates by avoiding the temperature extremes commonly experienced in exposed surface organic layers (Salonius 1983). Wood and bark can also conserve soil fertility when buried, as the microbial activity that results from their decomposition can temporarily immobilize nutrients (Binkley 1986).

Despite the apparent benefits of soil mixing as a site preparation technique, little is known about the biological consequences of its use in the mor-type soils typical of boreal forests where, under natural conditions, there is normally little mixing of the organic forest floor with the mineral soil.

Studies under the umbrella of this multidisciplinary project component compare the relative efficiencies of high-speed mechanical soil mixing, screefing, and herbicide treatments in controlling competing vegetation. They also examine the effects of the different treatments on organic matter decomposition and nutrient mobilization, survival and growth of planted spruce seedlings, and on the abundance, diversity, and community structure of soil invertebrates and soil microflora (Sutherland 1996). Individual studies are listed in Appendix 6.

5.2 EXPERIMENTAL DESIGN

5.2.1 Study area

The site preparation alternatives component is located in Adamson Township, about 1 km west of Eskwanonwatin Lake (49°10'N; 88°38'W), and approximately 40 km north of the community of Hurkett on the Black Sturgeon Road (Section 2.1; Figs. 2.1 and 2.2). See *General Description of Research Site* (Section 2) for relevant characteristics and descriptions of the study area.

Whereas the harvesting impacts and fire ecology components of the project are situated on a large, elevated recessional moraine, the site preparation component lies some 60 m lower on an undulating plain of lacustrine origin bordering Eskwanonwatin Lake. The soils are classified primarily as Dystric Brunisols and Humo-ferric Podzols in profile (Agriculture Canada Expert Committee on Soil Survey 1987), and are developed in deep, stone-free silty clay loams. See Section 2.3.3 for additional details and analytical data.

Prior to harvest the site was occupied by a thrifty, uneven-aged, second-growth mixedwood of mainly trembling aspen and balsam fir with admixed white spruce, white birch, and balsam poplar. As noted in Section 2.5.2, this forest was more conifer-rich and characterized by generally larger trees and a more dense understory than found on the upland areas, reflecting more favourable soil and moisture conditions on this highly fertile site. According to the forest ecosystem classification system for northwestern Ontario (Sims et al. 1989), vegetation types ranged from V14 (balsam fir mixedwood) to V15 (white spruce mixedwood) and V24 (white spruce-balsam fir/shrub rich). This second-growth forest was somewhat older than that encountered in the harvesting and fire ecology components, it being one of the first areas harvested when logging started in the Black Sturgeon Forest (1937-38; see Fig. 2.11).

5.2.2 Harvesting and harvest block layout

The study area was operationally clearcut during late fall of 1992 using a conventional full-tree system (Harricana feller-buncher mounted on John Deere 693 excavator carrier, and John Deere 648 grapple skidder) with delimbing at roadside. The harvested area (Fig. 5.1) follows the contour of the lacustrine plain, and falls gently eastwards to Eskwanonwatin Lake. Three uncut control blocks, each nominally 100 m wide, lie across the contours and serve to separate the study area into a number of smaller clearcuts, three of which accommodate the site preparation treatments.

5.2.3 Site preparation treatments

Site preparation was conducted during the spring of 1993 on a series of 10x10 m plots randomly assigned to each of the four experimental blocks (Fig 5.1, A, B, C, D). The site preparation treatments were as follows:

- No site preparation, boot-screef and plant (control). (CC)
- Removal of surface organic layer in 80 to 100 cm wide strips (strip-screef) using an excavator bucket. (SS)
- Total removal of organic layer from plot (area-screef) using an excavator bucket. (WAS)
- Mixing of surface organic layer with the underlying mineral soil in 80 cm wide by 20 cm deep strips (strip-mix) using the FERIC prototype high-speed rototiller (Cormier 1994). This treatment was repeated five times at different combinations of mixing speed and mixing depth, as noted below. (SM)
- Mixing of surface organic layer with the underlying mineral soil on total area of plot (area-mix) using the FERIC prototype high-speed rototiller, as above (one mixing rate/depth combination only). (WAM)
- Mixed mounds produced by hand shovelling mixed soil (taken from the area-mixed plots) into 80 L forms.
- Herbicide application (hexazinone [Velpar L®] @ 13 L/ha; 3.1 kg a.i./ha) to total area of plot using a backpack sprayer.
- Herbicide application as above, with follow-up chemical tending in the 2nd and 4th growing seasons after planting (glyphosate [Vision®] @ 5 L/ha; 1.78 kg a.i./ha).

The high speed prototype rototiller was adjustable in three operating modes: speed of mixing rotor (rpm), depth of mixing (cm), and forward travel speed of mixing rotor (S = slow = 20-25 m/min.; F = fast = 40-45 m/min.). In the strip-mixed plots, five different combinations of these variables (rpm x mixing depth x travel speed), were applied to entire plots, replicated in each of the four experimental blocks, viz: 90-20-S; 120-10-S; 120-20-S; 120-20-F; 150-20-F. On the area-mixed plots, only the 120-20-S settings were used.

On the area-mixed plots, the tires of the skidder prime mover used with the prototype rototiller caused excessive soil compaction. This necessitated a secondary treatment consisting of surface remixing over the entire plot using a wheeled motor-manual rototiller.

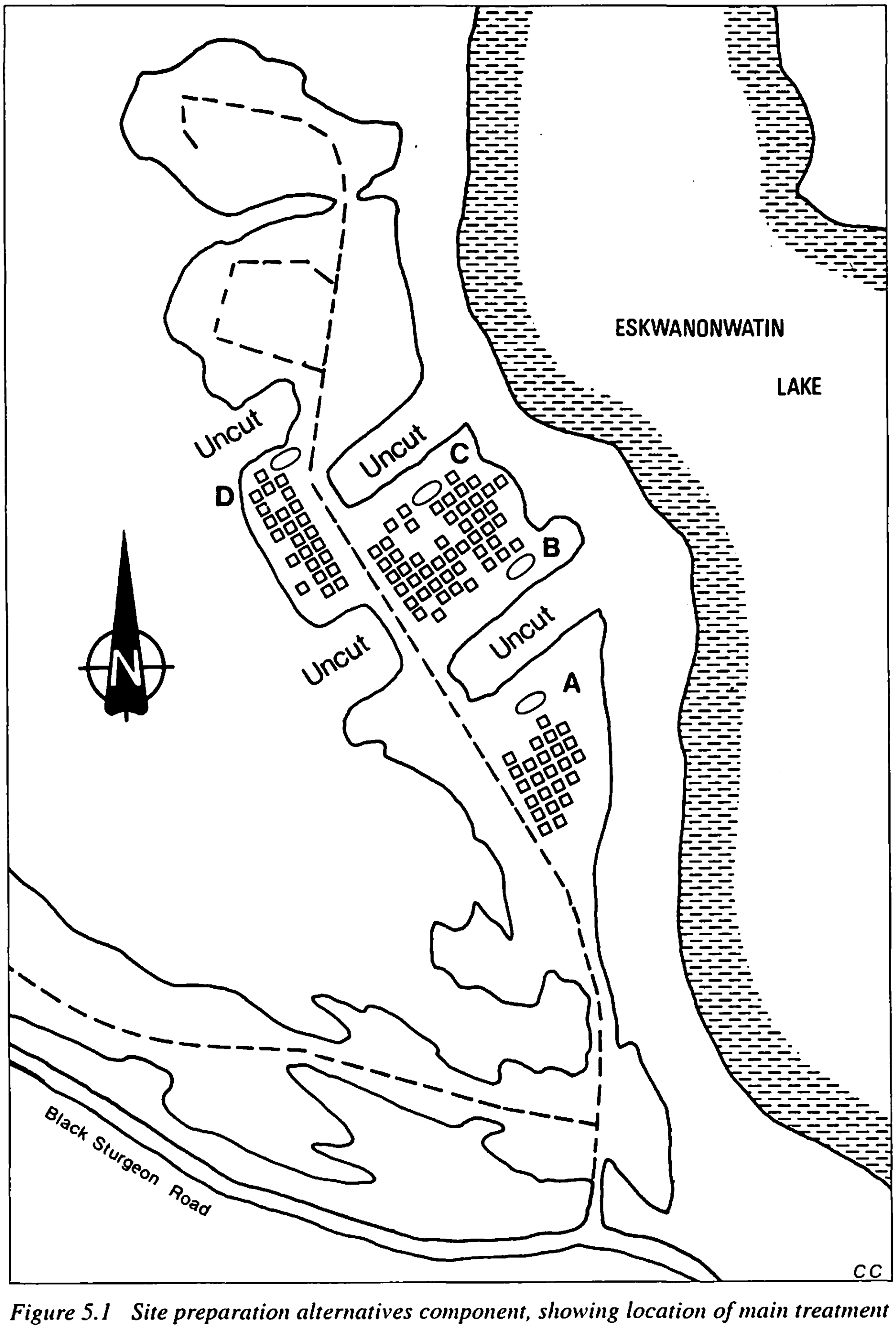

Figure 5.1 Site preparation alternatives component, showing location of main treatment plots within the harvested areas.

5.2.4 Planting

Between June 14-19, 1993, one week after completion of the mechanical site preparation treatments and five weeks after the herbicide treatment, all 10x10 m site preparation plots were planted with black spruce container stock. In the control (boot-screef and plant) plots, both black spruce and white spruce container stock were planted. Seedlings were grown from seed[16] in Super "Stubby" Leach Cells (115 cc capacity; *RL Single Cell Cone-tainer™ System, Canby, Oregon)* at the Great Lakes Forestry Centre in Sault Ste Marie. Average seedling dimensions (n=50) at time of shipping were as follows:

	Black spruce	White spruce
Shoot height (cm)	20.4±1.9	15.5±1.8
Root collar diameter (mm)	2.19±0.2	2.33±0.2
Total dry weight (g)[a]	1.345	1.495
Shoot/root ratio	2.49	2.05
Root area index (cm^2)	34.4±7.5	38.2±7.4

[a]Average weight of 50 bulked seedlings.

Seedlings were planted at approximately 2 m spacing, resulting in 30-50 seedlings per 10x10 m plot. Because the short period between site preparation and planting did not allow time for natural settling of the mixed plots, the planting spots (approximately 60 cm diameter) were compacted by foot before planting to eliminate any air pockets in the soil.

5.3 BASELINE INFORMATION

5.3.1 Pre-harvest inventory and vegetation

A detailed pre-harvest cruise of the site was conducted in August, 1992. This recorded all living and dead trees, by species, diameter class, and height class, on a series of 44 sample plots (10x10 m). Equal numbers of plots (11) were randomly located in each of the four prospective experimental blocks.

For the vegetation survey, each 10x10 m plot was subdivided into four 5x 5 m quadrants. Shrubs and herbaceous species were recorded by frequency of occurrence and percent cover within each quadrant. The vegetation type on each sample plot was classified according to the northwestern Ontario forest ecosystem classification system (Sims et al.1989).

Prior to harvesting, the most common non-crop species found in the understory were mountain maple (*Acer spicatum* Lamb.), beaked hazel (*Corylus cornuta* Marsh.), prickly wild rose (*Rosa acicularis* Lindley), wild red raspberry (*Rubus idaeus* L. ssp. *melanolasius* [Dieck] Focke), and various graminoids. Mountain maple was particularly well developed in blocks A, B, and C. This can be attributed to increased light in the understory resulting from the large amount of dead or severely defoliated balsam fir in the overstory.

5.3.2 Post-treatment vegetation

Monitoring of vegetation development on the site-prepared treatment plots is concerned both with determining trends in succession and quantifying levels of vegetative competition experienced by planted trees. Shortly after planting, 15 representative trees were selected from the 30-35 planted on each plot for future monitoring of their growth and development. These 15 trees also provide the focus for periodic vegetation assessments, based on tree-centred circular sampling areas with a radius of 1.13 m (4 m^2). Within each sampling area, non-crop species are quantified by leaf area (cover) and height class. The product of average leaf area and average height of each non-crop species is the vegetation index for that species. This index provides a useful means for comparing the relative

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[16]Same seedlots as used in harvesting impacts component (Section 3.7.2); sown in greenhouse April 24 and moved outdoors August 19, 1992; shipped May 1993.

amount (volume) of growing space occupied by individual non-crop species, and for quantifying competition and its impact on crop-tree development (Towill and Archibald 1991). Vegetation assessments were conducted, or are planned, for the first, second, third, fifth, eighth, tenth, and fifteenth growing seasons.

In addition to the above, research by Morrison (Appendix 6) to monitor recovery of net primary production (NPP) and nutrient cycles following harvesting includes periodic measurements of vegetative biomass regrowth. While trembling aspen shoots currently make up most of this regrowth, other tree species, including planted black spruce, are included in these measurements, as well as lesser vegetation. One randomly located 5 m^2 permanent sub-plot was established on one selected 10x10 m plot in each of the experimental blocks, representing the following treatments: whole-area screef (WAS), strip screef (SS), whole-area mix (WAM), strip mix (SM), and non-site-prepared control (CC). Stand tables of basal diameter (to 0.1 cm) were determined for each sub-plot in 1995 and 1997. Biomass, separated into woody and leafy matter, per area was determined by relating basal diameter to dry weight/basal diameter regressions constructed from separate samplings during the same years. Chemical analyses of leafy and woody materials from on-plot samplings permitted calculation of per-area nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur contents, plus other elements. Lesser vegetative regrowth was determined by on-plot destructive samplings of two 0.90 m diameter randomly located quadrats per plot, followed by chemical analysis. Pre-treatment NPP and element contents were equated to growth and nutrient contents of vegetation in 0.04-ha permanent sample plots established in adjacent uncut control blocks.

Screefing treatments (WAS, SS) generally encouraged hardwood shoot growth both in terms of stem numbers and per area biomass; whereas mixing treatments (WAM, SM) generally suppressed hardwood shoot growth. Lesser vegetation biomass was suppressed only by the whole area screef (WAS). In 1997, lesser vegetation biomass was greatest on the whole-area mixed (WAM) plots. In terms of annual aboveground NPP, highest weights were associated with the non-site-prepared control (CC): 4.6 tonnes/ha in 1995; 5.4 tonnes/ha in 1997. In terms of overall production, treated plots were generally similar, though production was allocated differently among hardwood woody and leafy production and lesser vegetation. Mineral nutrient quantities in leafy tissues approached or exceeded pre-harvest levels within the first four years following harvest, suggesting early recovery of organic-mineral cycling.

Further details of this work may be obtained by contacting Dr. I.K. Morrison, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (imorriso@nrcan.gc.ca)

5.3.3 Seedling growth

Weather conditions immediately after planting were unusually favourable, and at the end of the first growing season seedling survival averaged 99%. This favoured seedling establishment, with the result that survival still averaged 93% by the end of the third growing season.

The 15 selected seedlings in each plot (see Section 5.3.2) were measured shortly after planting (total height, root-collar diameter) and again at the end of the first growing season (total height, height increment, root-collar diameter). Remeasurements (same three growth parameters) were conducted, or are planned, at the end of the second, third, fifth, eighth, tenth, and fifteenth growing seasons.

For further information regarding the surveys summarized in Sections 5.3.1, 5.3.2, and 5.3.3, or for access to data, contact Fred Foreman, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (fforeman@nrcan.gc.ca)

5.3.4 Climate

An automatic weather station (Model CR-10; Campbell Scientific [Canada] Corp., Chatham, ON) is maintained in Block B/C of the project. Recorded parameters include air temperature, relative humidity, precipitation, wind speed, wind direction, solar radiation, and soil temperature.

For further details and access to the weather data contact Nick Boyonoski, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (nboyonos@nrcan.gc.ca)

SECTION 6 - AQUATIC ECOSYSTEM RESPONSES COMPONENT

SECTION 6 – AQUATIC ECOSYSTEM RESPONSES COMPONENT

6.1 INTRODUCTION

As discussed more fully in Section 1, increased environmental awareness and expressions of public concern are having a significant impact on the development and redirection of forest management programs in Canada. In particular, large-scale clearcutting is criticized as an unacceptable management strategy that is at odds with forest sustainability and the protection of ecosystem integrity. Critics commonly call for the use of alternative harvesting practices, such as tree-retention systems, which they perceive as being more environmentally benign and more natural.

In response to these issues, the Black Sturgeon Boreal Mixedwood Project is concerned with evaluating the ecological impacts of alternative forestry practices, and determining their potential application in the management of boreal mixedwoods. In certain situations, there is also a need for studies to confirm that such alternative practices are in fact providing significant environmental protection compared with conventional practices. The impact of harvesting upon aquatic ecosystems is a case in point. Because water bodies are such an important feature of forested landscapes in boreal Ontario, studies are needed that include assessments of potential adverse effects on aquatic habitats and their associated biota.

To address these concerns, a multidisciplinary, watershed-level research component was added to the Black Sturgeon Boreal Mixedwood Project in 1994. The primary objective is to determine whether alternative harvesting systems can be effective in mitigating the potential adverse effects on aquatic ecosystems of traditional harvesting practices in boreal mixedwoods. The research is designed to compare the effects of strip cutting and clearcutting upon the ecological integrity of headwater streams and their surrounding watersheds. It is planned that one watershed will be clearcut in the conventional manner, two will be strip-cut, and a fourth will be left uncut to serve as a reference control. The project is currently in the pre-treatment baseline data collection phase, with harvesting scheduled for 2000/01.

6.2 EXPERIMENTAL DESIGN

6.2.1 Description of study areas

The main study area is located at the southern end of Black Sturgeon Lake, approximately 60 km north of the community of Hurkett on the north shore of Lake Superior. Areas to be harvested comprise three discrete watersheds (Fig. 6.1) that discharge into the east side of Black Sturgeon Lake (outfall of most northerly stream at 49°19.7'N, 88°49.6'W), extending inland some 3-4 km from the shoreline. These lie approximately 8 km north of the fire ecology component (airstrip), although there is presently (1999) no direct road access. The reference watershed (see Fig. 2.2), which will not be harvested, is located further south on the east side of the Black Sturgeon River, midway between Nonwatinose Lake and Eskwanonwatin Lake (outfall at 49°11.3'N, 88°37.5'W).

Within the area of the three experimental watersheds (1, 3, 4), the topography is characterized by rolling hills that rise from Black Sturgeon Lake (≈260 m) to an elevation of ≈380 m. Locally, areas of broken topography with bedrock exposure are not uncommon, while the soils are generally shallow. The watersheds drain large, relatively flat areas with few distinct channels in the upper reaches, although stream channels become more distinct as the gradient increases in the lower and middle sections. The three watersheds transect the Black Sturgeon Fault Zone (see Fig. 2.3) and, except for a narrow band of younger Proterozoic diabase that runs parallel to the shore of the lake, are underlain by metamorphosed Archean volcanic and sedimentary deposits (Coates 1972). The general geology of the area and its glacial history are reviewed in Section 2.2 (*Geomorphological and Topographical Setting*).

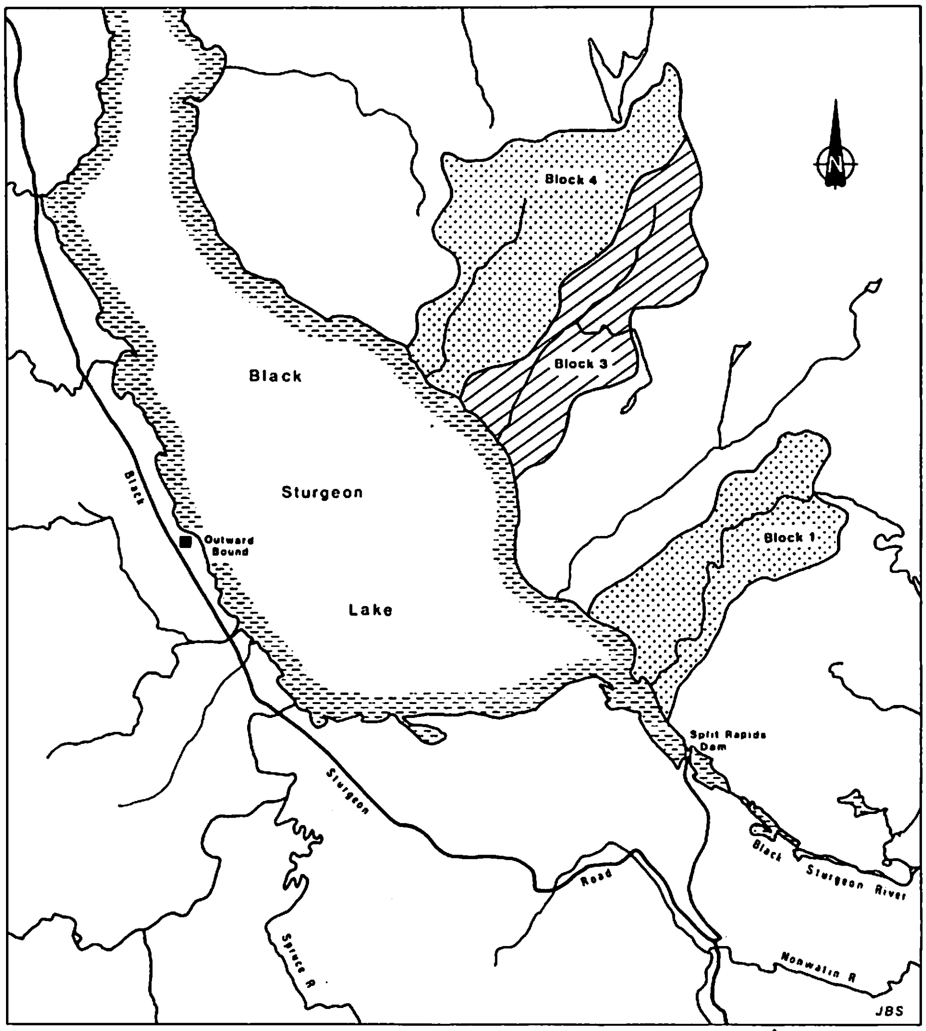

Figure 6.1 Aquatic ecosystem responses component: location of the experimental watersheds.

The reference watershed (Fig. 2.2) also traverses the Black Sturgeon Fault Zone. The stream in this watershed flows into the east side of the Black Sturgeon River, just north of Eskwanonwatin Lake. From the river, it rises in a northeasterly direction through about 250 m of elevation over its length of about 3 km. In its lower reaches, in a narrow band parallelling the Black Sturgeon River, it is underlain by Proterozoic sediments of the Sibley Group. East of the fault zone, the watershed is underlain mostly by Archean metasediments. Hills on the northern and northeastern flanks of the stream basin are capped by Proterozoic diabase, which outcrops extensively as areas of broken rock in the north-central portion of the watershed.

Watersheds 3 and 4 (Fig. 6.1), or the greater parts thereof, were previously harvested during 1960-61 and 1961-62. In Watershed 1, only the lower portions adjacent to the lake have been harvested previously, during 1940-41, extending inland approximately 1 km from the lake shore. Most of the reference watershed was previously harvested in 1939-40, it being one of the first areas to be harvested in the Black Sturgeon Forest (see Section 2.7). While the reference watershed and Watershed 1 will have been horse-logged, there is less certainty about Watersheds 3 and 4. Horse logging was phased out entirely in the Black Sturgeon Forest in 1961, and it is likely that mechanical skidders were used in these later harvests.

Because of differences in site and harvesting history, forest conditions in the four watersheds tend to be quite variable, both in terms of stand composition and stand age. Watersheds 1 and 4 have the greatest variation, supporting both virgin stands, ranging in age from 85 to 150 years, and second-growth stands originating from the

1940-41 and 1961-62 harvests. Watershed 3 was mostly harvested in 1960-61, and has the youngest and most uniform age structure. The reference watershed includes some virgin stands at higher elevations, of estimated age 120-140 years, but in lower areas supports mostly second-growth stands dating from the 1939-40 harvest.

At the time of the 1975 Forest Resource Inventory (FRI), despite substantial variations in stand composition, the three experimental watersheds supported stands that were essentially coniferous in nature, with high proportions of balsam fir (Table 6.1). White birch was the principal hardwood species present, occurring in stands of all ages, sometimes forming 30% or more of a stand. In contrast, the poplar component was low overall, and never exceeded 10% of the few second-growth stands in which it was present. As a result of the recent spruce budworm outbreak, most of the balsam fir and much of the older white spruce have been killed over the past decade, resulting in stands which are now understocked and suffering encroachment by woody shrubs. Black spruce makes up a large proportion of the remaining coniferous component in many stands.

In comparison with the experimental watersheds, forest cover on the reference watershed is characterized by a generally higher proportion of hardwoods. Both at the time of the 1975 FRI (Table 6.1) and today, trembling aspen is a significant component of stands at lower elevations in the watershed, extending down to the Black Sturgeon River.

The locations of specific stand types identified in the 1975 FRI of the experimental watersheds (Table 6.1) are shown in Fig. 6.2. The Landsat satellite image taken in June 1992 (Fig. 6.3) gives a more recent picture of the general distribution of forest cover types on the same areas. For a comparable image of the reference watershed, see Fig. 2.9.

6.2.2 Proposed harvesting and post-harvest treatments

Because the measurement of system-level responses requires that treatments be applied on a whole-stream or catchment basis, each of the three watersheds will be harvested as completely as possible, with no special restrictions regarding stream protection. Watershed 1 (480 ha) will be conventionally clearcut in a full-tree operation using feller-bunchers and grapple skidders, with delimbing and chipping at roadside. Watersheds 3 and 4 (≈490 ha and ≈720 ha, respectively) will be strip cut, also using feller-bunchers and grapple skidders. Although final cutting guidelines have yet to be determined, strips will be harvested in a manner that permits additional research on the effects of strip width on the performance of planted white spruce seedlings. Previous research (Groot et al.1997) has indicated that strip widths equivalent to stand height provide most favourable conditions for the survival and growth of white spruce seedlings. Thus, subject to operational constraints, it is planned that groups of four or five adjacent strips of the same width (8m to 24m, in increments of 4m) will be established and replicated in each of Watersheds 3 and 4.

Harvesting is scheduled to begin in the fall of 2000, with completion by March 31, 2001. Watershed 1 (clearcut) and Watershed 4 (strip-cut 1) will be harvested under frost-free conditions, while Watershed 3 (strip-cut 2) will be harvested in winter when the ground is covered with snow. The objective is to create site disturbance conditions that range from high impact on the clearcut watershed to zero impact on the unharvested control, with intermediate levels of disturbance on the strip-cut watersheds.

Post-harvest treatments are still at the planning stage. Operational site preparation will include mechanical scalping with chemical vegetation control, possibly in the spring following harvest. While white spruce will be planted experimentally in the strip cuts, it is expected that black spruce will be planted operationally over the remainder of the harvested areas. The reference watershed (≈200 ha) will remain undisturbed.

Table 6.1 Composition of principal stands on the research watersheds identified in the 1975 Forest Resource Inventory.

Stand number	Stand age in 1975	Stand composition[a]
Watershed 1	(≈480 ha)	
223	45	$Bf_4\ Sw_2\ Po_2\ Pj_1\ Ce_1$
225	39	$Bf_6\ Ce_2\ Pw_1\ Bw_1$
226	60	$Ce_6\ Bf_1\ Sb_1\ Sw_1\ A_1$
227	40	$Bf_5\ Bw_4\ Sw_1$
228	40	$Bf_5\ Ce_2\ Sw_1\ Po_1\ Bw_1$
229	40	$Bf_6\ Sb_2\ Sw_1\ Po_1$
231	60	$Bf_3\ Sw_3\ Bw_3\ Sb_1$
232	60	$Sb_5\ Bw_3\ Sw_2$
233	70	$Sb_9\ Bw_1$
234	125	$Sb_9\ Bw_1$
235	95	$Sb_4\ Bw_4\ Bf_1\ Sw_1$
236	100	$Bw_7\ Bf_2\ Sw_1$
Watershed 3	(≈490 ha)	
95	25	$Sb_5\ Bf_3\ Bw_2$
96	40	$Bf_4\ Sb_2\ Sw_2\ Bw_2$
110	90	$Sw_4\ Bf_3\ Bw_3$
115	90	$Sb_4\ Sw_2\ Bw_2\ Bf_1\ Ce_1$
116	40	$Bf_4\ Sb_2\ Sw_2\ Bw_2$
117	45	$Bf_4\ Sb_3\ Bw_2\ Sw_1$
118	15	$Sb_6\ Bf_3\ Bw_1$
219	45	$Bf_6\ Po_2\ Sw_1\ Pw_1$
220	40	$Bw_6\ Bf_2\ Sw_1\ Po_1$
221	50	$Sw_4\ Bf_2\ Pw_2\ Ce_2$
222	40	$Bf_6\ Sw_2\ Bw_2$
Watershed 4	(≈720 ha)	
86	60	$Sb_6\ Bf_3\ Bw_1$
91	10	$Sb_6\ Pj_3\ Bf_1$
92	110	$Sb_5\ Bf_3\ Bw_2$
93	20	$Sb_7\ Bf_3$
94	25	$Sb_5\ Bf_3\ Bw_2$
98	60	$Bf_4\ Sb_2\ Ce_2\ Sw_1\ Bw_1$
119	15	$Sb_6\ Bf_3\ Bw_1$
120	60	$Sb_4\ Bf_3\ Bw_2\ Ce_1$
121	10	$Bf_5\ Sb_5$
122	35	$Bf_5\ Sb_2\ Sw_2\ Bw_1$
123	75	$Sb_5\ Bf_4\ Bw_1$
125	125	$Sb_7\ Bf_1\ Sw_1\ Bw_1$
127	40	$Bf_5\ Sw_2\ Bw_2\ Sb_1$
Watershed C	(≈210 ha)	
131	62	$Sb_4\ Bw_3\ Bf_2\ Sw_1$
132	70	$Sb_5\ Bf_3\ Bw_2$
133	20	$Bf_4\ Po_4\ Sw_1\ Bw_1$
136	100	$Sb_6\ Bw_3\ Bf_1$
220	20	$Po_6\ Bf_4$
221	120	$Po_6\ Bf_2\ Sw_2$

[a] Bf = balsam fir; Sb = black spruce; Sw = white spruce; Pj = jack pine; Pw = white pine; Ce = white cedar; Po = trembling aspen; Bw = white birch; A = black ash.

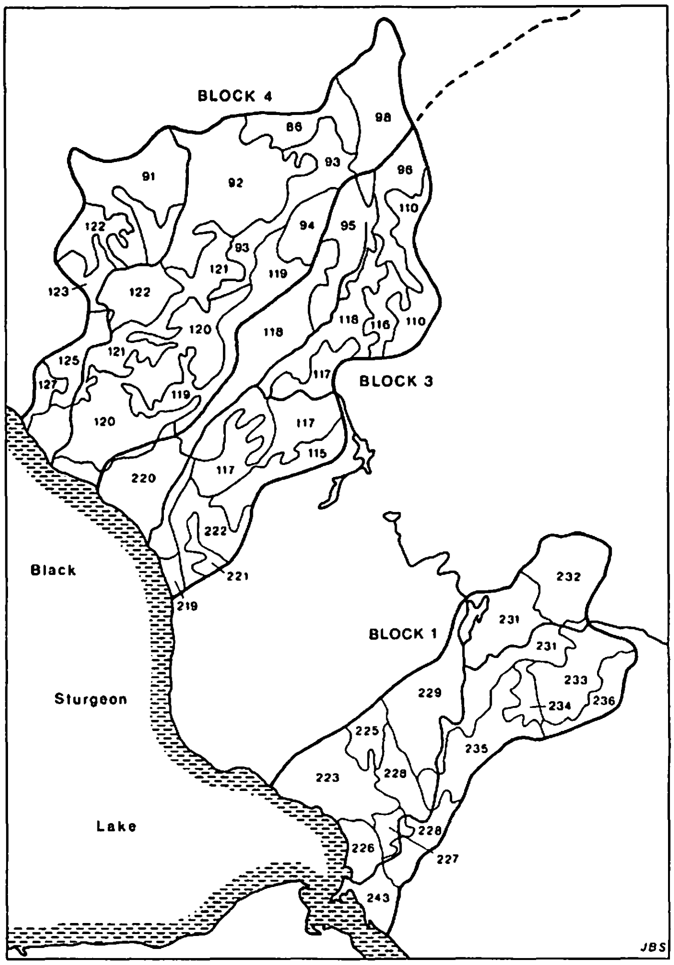

Figure 6.2 Forest cover types on the experimental watersheds, as identified in the 1975 Forest Resource Inventory (see Table 6.1 for tree composition of individual stands).

6.2.3 Progress to end of 1998

Watershed boundaries were determined and mapped from aerial photographs. Ground surveys were conducted in 1998 to decide which of the strip-cut watersheds should be harvested in winter, and which should be harvested under frost-free conditions. This was based on site characteristics. Watershed 3 appeared to have a greater proportion of wet areas, and was selected for winter harvest to reduce travel through wet sections during harvest operations. Watershed boundaries will be demarcated and harvest strips laid out during 1999. The harvest strips and the tertiary road network in the partial cut blocks will be oriented to maximize operational efficiency and to reduce visual impacts from the western shore of Black Sturgeon Lake.

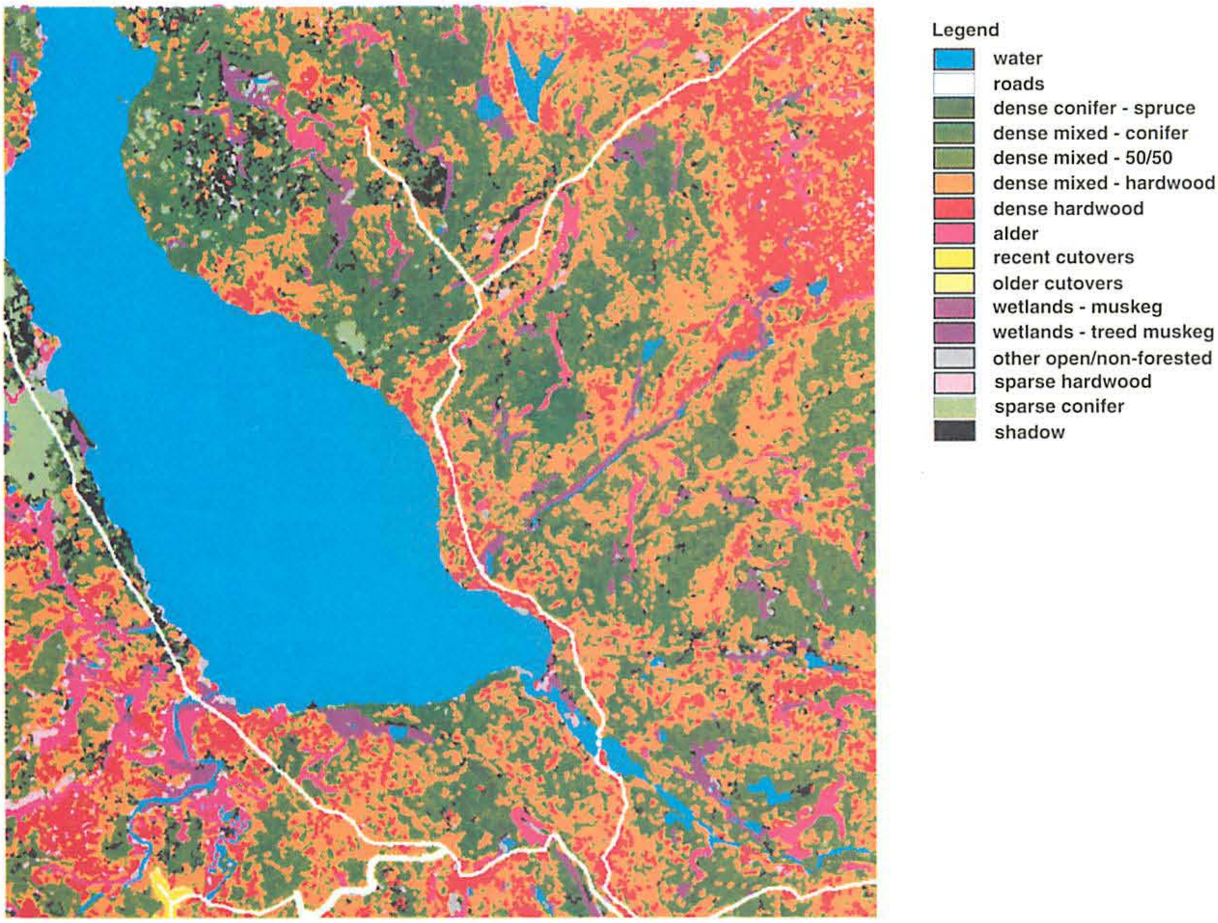

Figure 6.3 Vegetation classification for the area of the experimental watersheds, based on Landsat TM satellite image of June 20, 1992.

Because the overall experimental approach with respect to measuring aquatic ecosystem responses on the impacted areas calls for comparisons with pre-disturbance conditions (Stewart-Oaten et al. 1986), reliable pre-harvest baseline data is essential. The ecological response variables to be measured in the four headwater streams were selected from the literature on previous impact studies of forest harvesting (e.g., Hartman 1982; Campbell and Doeg 1989). They include (but are not limited to): effects on the diversity and abundance of benthic invertebrates, groundwater inputs and stream temperatures, water quality parameters and nutrients, stream hydrology, sediment loading, suspended particulate matter, organic matter processing, nutrient release and movement in adjacent land, and vegetation response. These are considered the best indicators and measures of disturbance, and are critical structural and functional elements of lotic ecosystems in forested areas. Baseline data on a number of these variables has been collected annually since 1994.

The primary emphasis in measuring responses to harvesting is on the use of aquatic insects as bio-indicators of stream quality and disturbance in the watersheds. Because the ecology of aquatic insects in forest streams is strongly linked to influences and inputs from the surrounding watershed, disturbances to forested watersheds can result in decreased stream habitat quality which in turn can cause adverse effects on stream insect communities. These insect communities are often more sensitive to environmental disturbance than fish populations. Stream insect communities of these watersheds are being quantitatively sampled by a modified Surber technique (Merritt et al.1984) in the early summer and fall of each year. Insects are sorted from stream debris, counted and identified to the lowest possible taxon (usually genus) by microscopic examination.

For further information on this project component contact D. Kreutzweiser, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario (dkreutzw@nrcan.gc.ca), or the Project Coordinator.

SECTION 7 - SPRUCE BUDWORM AND RELATED RESEARCH IN THE BLACK STURGEON FOREST

SECTION 7 – SPRUCE BUDWORM AND RELATED RESEARCH IN THE BLACK STURGEON FOREST

The history of biological and forestry research in the Black Sturgeon Forest goes back more than 50 years. Field studies on the ecology of the spruce budworm (*Choristoneura fumiferana* Clem.) were of longest duration. These began in the 1940s, complementing a comprehensive laboratory program established concurrently at the Forest Insect Laboratory in Sault Ste. Marie. As well as studies of the budworm's life history and population dynamics, the work at Black Sturgeon included extensive research into the impacts of budworm outbreaks on the forest itself, especially its productivity, regeneration, succession, and stand dynamics. Although the field program reached its peak during the 1950s and 1960s, some investigations continued well into the 1990s.

While perhaps best-known within the scientific community for this long history of budworm research, the Black Sturgeon Forest has been host to a broad range of other research over the years, mostly conducted by federal and provincial government scientists. This research has included studies concerned with boreal forest ecology, soil nutrition, logging, silvicultural techniques, forest growth and yield, insects and diseases, and fish and wildlife issues. Many of these studies have contributed significantly to our knowledge and understanding of different aspects of boreal mixedwood ecology. The area has also been the subject of extensive geological research (see Section 2.2).

Although many of the earlier studies were concluded long ago, in a few instances not only do the original plots still exist, but the old datasets are extant. Especially in the case of ecological and regeneration studies, the continued availability of these plots, some established more than 50 years ago, presents a rare opportunity to study long-term successional and structural changes in different stand types. Because of the time elapsed since some of these plots were first established, there is also an opportunity to explore the impact of repeated spruce budworm infestations.

Because of its importance to our understanding of boreal forest ecology, and to demonstrate the original context for old studies that are of current interest, this section begins with a brief historical account of the budworm research program of which most old studies were an integral part. The old plots that have been identified for remeasurement or that appear worthy of preservation are briefly described; anyone wishing to conduct research in these plots should first contact the Project Coordinator. Although no exhaustive search for relevant old studies has been made, opportunities may exist for capitalizing on the survival of other old experimental plots in the area, and these may be brought to the attention of the Project Coodinator.

7.1 SPRUCE BUDWORM AND ASSOCIATED RESEARCH

Much of the material presented in this section is based on file reports prepared by C.J. Sanders. With spruce budworm research at Black Sturgeon now in abeyance, and research staff either retired or transferred, it is inevitable that memories of the program will quickly fade. This brief history is intended partly as a reminder of the scientific contributions achieved by the budworm program during the five decades prior to initiation of the Black Sturgeon Boreal Mixedwood Research Project. Dr. Sanders, who conducted budworm research in the Black Sturgeon Forest from 1965 until his retirement in 1997, is now Scientist Emeritus at the Great Lakes Forestry Centre, and an authority both on the spruce budworm and the history of the research program at Black Sturgeon. He may be contacted for further information at the Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. (csanders@nrcan.gc.ca)

7.1.1 Spruce budworm research

Before the 1940s, spruce budworm outbreaks in northern Ontario were of no great concern to the forest industry because, with the emphasis on pine sawlogs, the main host trees (balsam fir and white spruce) were of little commercial importance. The situation changed with the budworm outbreak of 1940-50, which caused much greater concern within the forestry community (Elliott 1960). The pulp and paper industry had expanded rapidly after World War II, and white spruce in particular, and balsam fir to a lesser degree, were now important pulping species. In response to industrial concern over potential fibre losses the federal government, in cooperation with the provincial Department of Lands and Forests, established the Forest Insect Laboratory in Sault Ste. Marie in 1944 to study the spruce budworm problem. At the same time several field stations were established in strategic locations throughout eastern Canada to study the budworm in situ. One of these was on Black Sturgeon Lake.

The original Black Sturgeon field station (BSLFS) was established in 1945 just north of the present Lakehead University Research Station, but because of high water levels the following spring was moved south 3.5 km to its present location. This station was staffed continuously each summer until 1969, but was later ceded to the Canadian Outward Bound Wilderness School. Even so, research continued, so that from 1944 to 1997 there has been an almost continuous record of spruce budworm research in the.Black Sturgeon Forest, as outlined below.

Years 1944-55: Much of the early budworm research in the Black Sturgeon Forest concentrated on the basic biology of the insect and its parasites (bacteria, fungi, viruses), on the development of sampling techniques, and on the impact of the budworm on the forest (regeneration, stand structure, timber losses). Detailed descriptions of the research conducted during these years can be found in the Annual Technical Reports of the Forest Insect Laboratory, Sault Ste. Marie (held in the library of the Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie – accession CAN/Fo/FIL–BCXD), and in various published reports. Progress is also reported in early issues of *"Forest Insect Investigations, Bi-monthly Progress Reports"* (Dominion Department of Agriculture, Research Branch, Forest Biology Division; later Canada Department of Forestry, Forest Biology Division).

Research on budworm control measures started in 1945, with parasite release work and some of the first aerial applications of DDT. Two areas were sprayed with DDT in 1945, one just west of Black Sturgeon Lake encompassing Circle Lake, the other to the south between Muskrat, Shillabeer and Disraeli Lakes. Another area, around Eaglehead Lake, was sprayed in 1946. The provincial government was responsible for the spray operations and was well aware of the potential environmental hazards. Consequently, a team of experts from throughout North America was contracted to study the effects of DDT on the fauna of the area, including fish, aquatic invertebrates, amphibians, reptiles, birds, and mammals (Johnson 1949). This very thorough multidisciplinary investigation established important baseline information for the area, and concluded that the environmental effects were negligible (*ibid.*)

The budworm outbreak in the Lake Nipigon/Black Sturgeon area had collapsed by the mid-1950s, and by 1958 insect populations were reduced to endemic levels, while most of the merchantable susceptible trees had been destroyed (Fye 1963). In one year during the 1960s, Sanders (1967) reported that over 3,000 branches were sampled but only five budworm larvae were found. After the collapse of the outbreak, budworm research at BSLFS was reduced to mostly follow-up studies on the progression of white spruce tree mortality (Thomas 1958), whereas laboratory studies on chemical and biological control agents, and budworm genetics and physiology continued at the Forest Insect Laboratory in Sault Ste. Marie.

Years 1960-82: Despite the intensive research programs conducted in Ontario and New Brunswick during the 1940s and 1950s, they had failed to determine the causes of spruce budworm outbreaks. It was concluded that the question could best be answered by studying the biology of the budworm during its low-density endemic population phase. Consequently, new studies along these lines were initiated at BSLFS in 1961, and continued with various degrees of intensity until the beginning of the 1982-95 outbreak. Initially, these new studies were conducted in five sampling areas, chosen to represent a range of regenerating and relict stands that had their origins in the recently collapsed budworm outbreak (Fye 1963). However, by 1965 it became evident that more intensive sampling was needed to obtain meaningful larval density estimates, and to permit effective investigations of survival, parasitism, etc. From 1966 onwards, therefore, budworm sampling was focussed on just two areas close to BSLFS, labelled BAA and BAB (Fig. 7.1).

BAA is located west of the Black Sturgeon Road, just north of the entrance to the old BSLFS (Canadian Outward Bound Wilderness School) (Fig. 7.1). This stand (#207, 1975 FRI base map 493884), of approximately 90 ha, was harvested in 1948-49 following extensive tree mortality during the 1940-50 spruce budworm outbreak. In the 1975 Forest Resource Inventory, stand composition is given as Bf_6 Po_2 Sw_1 Sb_1, age 27, with average height 12.5 m. Jack pine was virtually absent, even though it was present in the original stand. For more recent descriptions of BAA see Lethiecq and Régnière (1988) and Section 7.1.3

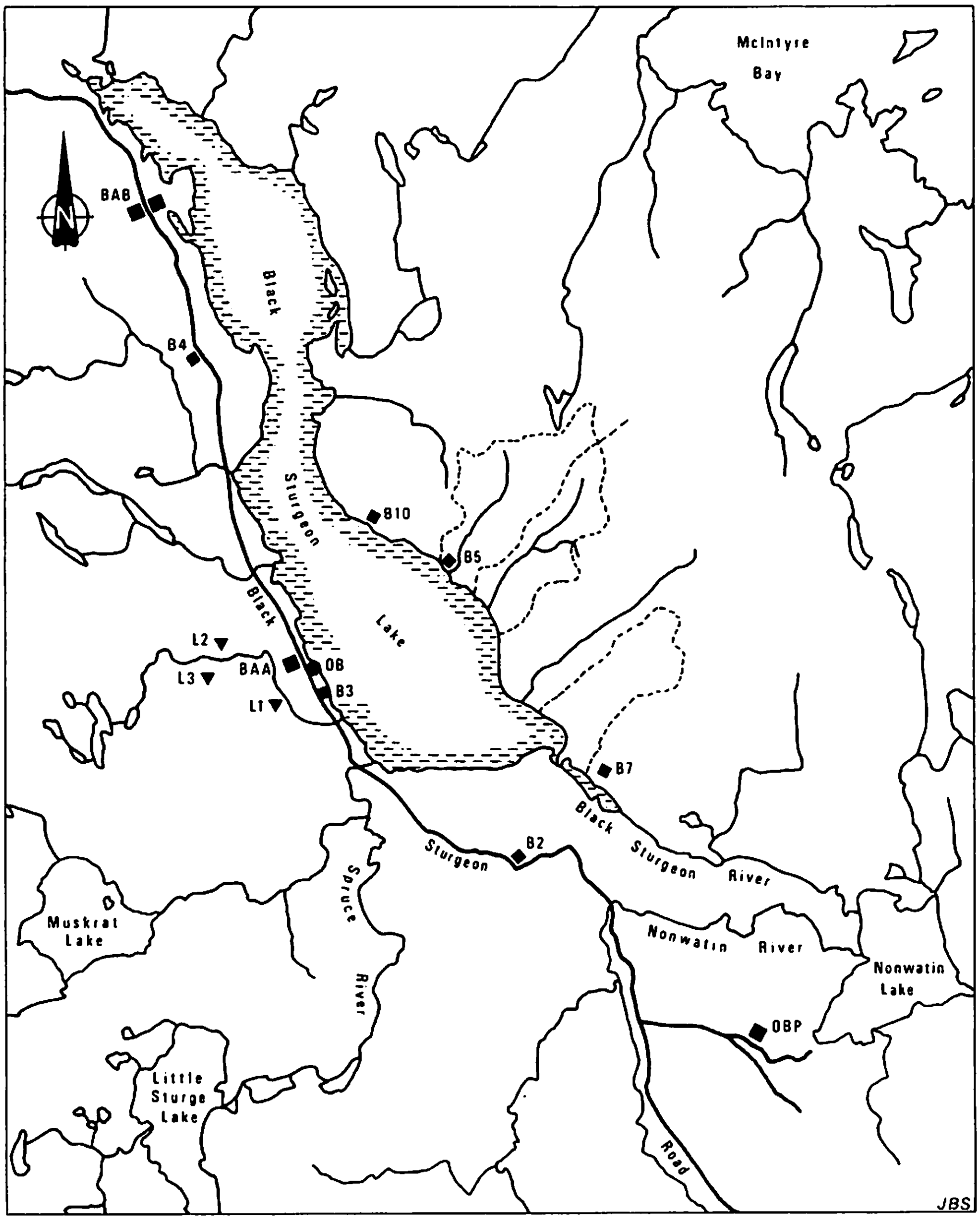

Figure 7.1 Locations of old research plots around Black Sturgeon Lake, described in Section 7: budworm sampling plots (BAA, BAB), bird monitoring plot (OBP), and conifer regeneration study plots ("Ghent plots" - B2, B3, ... B10; "Lyons plots" - L1, L2, L3). OB indicates the location of the Canadian Outward Bound Wilderness School (old BSLFS: Black Sturgeon Lake Field Station).

BAB is an irregularly shaped stand (#195/196, 1975 FRI base map 494884), straddling the Black Sturgeon Road, approximately 10 km north of the old BSLFS. It resulted from a fire in the 1930s, and was known as the "regeneration plot" in earlier studies. Stand composition in 1975 was Sw_9 Bf_1, age 60, of average height 14.6 m. This stand survived the 1940-50 budworm outbreak with only minor damage and growth loss, and has not been harvested. However, budworm sampling was discontinued in 1975 because the size of the trees was making sampling difficult.

A third plot, labelled OBP for Old Bird Plot, was laid out in stand #4 (1975 FRI base map 492883) in 1966 (Fig. 7.1). This was established principally to study changes in bird populations in relation to budworm populations. OBP was chosen to represent as closely as possible the mature stands surveyed for bird populations by Kendeigh in the 1940s (Kendeigh 1947), but which were destroyed by a wildfire in the 1950s. The stand has never been harvested, and represents one of the oldest surviving uncut mixedwood stands in the Black Sturgeon Forest. In 1967 it was dominated by 100 to 120 year old aspen over 30 m tall, ranging in diameter to at least 60 cm. Large balsam fir and white spruce up to 40 cm diameter were also present, while the shrub layer was dominated by mountain maple. By 1985 almost half the aspen were dead, and large balsam fir and white spruce now made up 70% of the total basal area of 24 m^2/ha. Bird censuses have been conducted in both OBP and BAA from 1966 to the present (Section 7.1.2).

Years 1982-97: A dramatic increase in budworm populations began in the early 1980s, and by 1982 a new outbreak was under way in the Black Sturgeon area (Section 2.6.2). As part of a new coordinated effort to unravel the dynamics of budworm populations, the Canadian Forestry Service set up study areas in New Brunswick, Quebec, and Ontario. These included plot BAA at Black Sturgeon. Intensive studies of budworm population dynamics were conducted in this plot from 1982 to 1997. Also during this period, in BAA and elsewhere in the Black Sturgeon Forest, studies were conducted on larvae and moth dispersal, and parasite biology, including the inundative release of *Trichogramma minutum*.

During the course of these studies BAA was severely impacted by the renewed budworm outbreak. By 1993 the total living basal area in the plot had been reduced to just over 20 m^2/ha (down from 42.9 m^2/ha in 1980), with 80% of the balsam fir and 30% of the white spruce dead. Aspen was now the dominant tree species, comprising about one third of the total living basal area.

Although currently not used for budworm research, BAA and OBP remain available for other non-destructive research. Since they are still used for bird censuses (Section 7.1.2) and vegetation studies (Section 7.1.3), anyone wishing to conduct new studies in these plots should first contact the Project Coordinator.

7.1.2 Breeding bird censuses

Interest in the impact of bird predation on budworm populations led to the start of breeding bird censuses in 1966. These have been conducted in BAA and OBP from 1966 to the present. Results of the first four years' surveys (1966-69) are given in Sanders (1970). In the period 1970-95, censuses were carried out by a number of researchers from the Canadian Forest Service and the Canadian Wildlife Service; data for this period are now being prepared for publication by C.J. Sanders and D.A. Welsh.

For census purposes, a square plot of approximately 10 ha (322x322 m) was laid out in each of BAA and OBP. Access trails, labelled A through I, were cut at 40 m intervals running from roadside to the rear of each plot. Aluminum stakes, marked 0 through 8, are set into the ground at 40 m intervals along these trails. Sanders makes the point that the trails were laid out with chain and compass, and that distances and directions are not precise. The objective was to provide easy access for the bird censuses, not anticipating that the same plots and lines might still be in use 30 years later. In the 1980s, to facilitate studies related to spruce budworm pheromone research, a further 11 lines were added to the north of the existing lines in BAA, also 322 m long and 40 m apart. A 30 m wide protective buffer was established around OBP in 1995, protecting an area of approximately 14.5 ha; areas surrounding this plot were harvested in 1996.

7.1.3 Vegetation sampling in BAA and OBP

Sampling of vegetation, trees, shrubs, and herbs in BAA, BAB, and OBP was carried out by C.J. Sanders in 1967, 1977, 1980, 1985, 1993, and 1995 (Table 7.1) in support of the long-term monitoring of spruce budworm populations and bird censuses. This provides valuable information on the development of these stands and changes in stand structure (particularly relevant in OBP, which is now overmature and experiencing major changes in stand composition and structure). Sampling details and summarized results are available in a file report (C.J. Sanders. *Vegetation sampling in spruce budworm plots at Black Sturgeon Lake*), available through the Project Coordinator.

The information is also available in digital form in database directories **~\wpdocs\budwormplots.wpd** and **~\sigma\budwormplots** (see Appendix 7). The vegetation of BAA was also described by J.-L. Lethiecq in 1985 (Lethiecq and Régnière 1988).

Table 7.1 Summary of vegetation sampling at Black Sturgeon Lake, 1966-95[a]

Year	BAA	BAB	OBP
1967 (Sanders)	**Trees** (≥3" DBH) a) two cruise lines, each 16 chains long x 16 feet wide. b) three 30x30 foot plots. **Shrubs** Percent occurrence in thirteen 10x10 foot plots. **Herbs** Percent occurrence in sixteen 3x3 foot plots.	**Trees** (≥3" DBH) Six cruise lines, 16 feet wide, total length 46 chains. **Shrubs** Percent occurrence in twenty 10x10 foot plots. **Herbs** Percent occurrence in ten 3x3 foot plots.	**Trees** (≥3" DBH) Twelve 45x45 foot plots. **Shrubs** Percent occurrence in twenty-four 10x10 foot plots. **Herbs** Percent occurrence in twenty-four 3x3 foot plots.
1977 (Sanders)	**Trees** (≥2.5 cm DBH) Sixteen 30x30 foot plots.		
1980 (Sanders)	**Trees** (≥2.5 cm DBH) Twelve variable radius plots (BA factor 5).	**Trees** (≥2.5 cm DBH) Ten variable radius plots (BA factor 10)	
1985 (Sanders)	**Trees** (≥2.5 cm DBH) 49 variable radius plots (BA factor 10). **Shrubs** Cover and height in same 49 plots.		**Trees** (≥2.5 cm DBH) 49 variable radius plots (BA factor 10). **Shrubs** Cover and height in same 49 plots.
1985 (Lethiecq)	**Trees** One 500 m^2 plot. **Regeneration** Ten 5 m^2 plots. **Shrubs/herbs** Abundance/dominance in ten 5 m^2 plots.		
1987 (Sanders)	**Trees** (≥2.5 cm DBH) Six PSPs. 5.64 fixed radius (100 m^2), measured annually to assess defoliation and mortality.		
1993 (Sanders)	**Trees** (≥2.5 cm DBH) 49 plots, 5.64 m fixed radius (100 m^2).		
1995 (Sanders)	**Trees** (≥2.5 cm DBH) 49 plots, 5.64 m fixed radius (100 m^2). **Shrubs** Cover and height in same 49 plots.		**Trees** (≥2.5 cm DBH) 49 plots, 5.64 m fixed radius (100 m^2). **Shrubs** Cover and height in same 49 plots.

[a]Original units of measurement, as used in the file report, are reported in this table (1 chain = 20.117 m; 1 foot = 0.305 m; BA factors measured in square feet).

7.2 CONIFER REGENERATION RESEARCH

7.2.1 "Ghent plots"

Concern over the impacts of spruce budworm infestations on stand succession and forest productivity led in 1948 to the initiation of studies into the origin and development of regeneration in budworm-devastated stands (Prebble 1949). Similar studies were established concurrently at Cedar Lake, in northwestern Ontario, at Black Sturgeon Lake, and at Laniel-Temagami in Quebec. These were designed to study short- and long-term successional trends, and regeneration history, in a range of stand types with a high balsam fir content that had suffered budworm damage. The 1940-1950 budworm outbreak was still in progress when the plots were established.

At Black Sturgeon Lake, eleven study plots were established in 1948 by E.B. Ayer, selected to represent various stages of boreal forest succession. These were square or rectangular plots averaging one acre (0.405 ha) in area. Each plot was divided into chain-square (one-tenth acre; 20.117x20.117m) blocks, the overall dimensions of the plots being simple multiples of the number of chain-square blocks (e.g., 2x5, 3x3, 3x4) depending on local stand conditions (Ghent et al. 1957). Within each block, 10 randomly located milacre ($4.047m^2$) quadrats (10% sample) were adopted as the basic sampling unit for seedling counts. Site and vegetation descriptions for these plots are given in Ghent et al. (1957).

Regeneration tallies were conducted at all three research sites in Ontario and Quebec in 1950 and 1955. Trends in forest succession in the first decade following budworm devastation were reported by Ghent et al. (1957). In a second paper, Ghent (1958) described the results of age, height growth, and related studies on balsam fir seedlings, and in two further papers (Ghent 1963, 1969) discussed problems of sampling precision and seedling distribution relating to regeneration surveys. Following the collapse of the budworm outbreaks, significant changes in stand structure occurred as a result of the increased growth of balsam fir advance growth and the ingress of shrub species. Consequently, in 1961 all plots were retallied to determine current stand composition, and to assess the importance of seed production by older advance growth relative to that of residual seed trees. The results are reported in Fye and Thomas (1962, 1963).

Most of the regeneration plots at Black Sturgeon have been relocated since 1994. Of the original 11 plots, six (Fig. 7.1) are still intact and remain undisturbed since they were first established. These are prime candidates for re-evaluation and resurrection as permanent plots for long-term monitoring of changes in stand structure and species composition in relation to stand age and budworm outbreaks. Plot and block markers have been re-established. A seventh plot, at the Poshkokagan River crossing, has suffered disturbance of a few blocks, but is otherwise intact. The remaining four plots have either been harvested or have suffered excessive disturbance.

Because of the early association of A.W. Ghent with these regeneration plots, the seven plots that have been re-established are now referred to as the "Ghent plots" for ease of identification. Not only are these plots potentially valuable from an ecological perspective because of their known disturbance history, but the original field tally sheets and data summaries are still available, as well as the published results of the early regeneration studies. The number and configuration of the square-chain blocks in each of these plots is as follows:

Plot number	Number of blocks
B2	10 (2x5)
B3	12 (3x4)
B4	12 (3x4)
B5	20 (4x5)
B7	12 (3x4)
B8	10 (2x5)
B10	16 (4x4)

For further information on these plots and the availability of archived data, contact the Project Coordinator.

7.2.2 "Lyons plots"

At about the same time that the "Ghent plots" were established (1948), staff of the then Ontario Department of Lands and Forests also set out a series of plots in the vicinity of Black Sturgeon Lake to gather data on forest regeneration following harvesting. These were located in lowland black spruce and upland spruce-fir (mixedwood) cover types in the cutting area of old Camp 21, just to the west of the lake. Seven transects of differing configurations were laid out, to serve as baselines along each of which ten 20x20 m (1 chain x 1 chain) permanent sample plots were established. The three transects in mixedwood cover types have been relocated and markers re-established. Because of the past association of N.F. Lyon with these study areas, they are now referred to as the "Lyons plots" (Fig. 7.1 - L1, L2, L3).

At the time of their establishment, the three transects were distinguished on the basis of stand composition and topographic features as either "spruce-fir mixed slope" or "spruce-fir slope". Transects L1 and L2 (spruce-fir mixed slope) supported white spruce, black spruce, and balsam fir in mixture with overmature aspen and scattered white birch and balsam poplar. Transect L3 (spruce-fir slope) supported an almost exclusively coniferous stand, made up of white spruce, black spruce, and balsam fir, with a few very scattered aspen and white birch. All stands were believed to have originated with a fire that occurred approximately 160 years prior to plot establishment (i.e., circa 1780). All three transects lay within the area that was heavily defoliated during the 1940-1950 spruce budworm outbreak.

Following harvesting, site modification treatments (soil preparation and burning) appear to have been carried out on certain of the plots. Regeneration tallies were conducted in 1948, 1949, 1950, 1951, 1956, 1961, and 1966. For further information on these plots and the availability of archived data, contact W.D. Towill, Ontario Ministry of Natural Resources, Northwest Region Science and Technology, Thunder Bay, Ontario. (bill.towill@mnr.gov.on.ca)

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APPENDICES 1 - 7

APPENDIX 1.

SOURCES OF LAND RESOURCE INFORMATION FOR THE RESEARCH SITES.

Information type	Description[a]	Agency
1. General and topographical maps		
Ontario Base Maps (OBM) 492883, 492884, 493883, 493884.	1:20,000	Ontario Ministry of Natural Resources
Provincial Series Maps, Sheet 52H/SE, Frazer Lake.	1:100,000 scale maps without contours.	Ontario Ministry of Natural Resources
Territorial Series Maps, Sheet 23-6.	1:600,000	Ontario Ministry of Natural Resources
National Topographic Map Series, Sheet NTS 52H/2 (Shillabeer Lake), and Sheet NTS 52H/7 (Black Sturgeon Lake).	1:50,000 scale maps with contours.	Canada Department of Energy, Mines and Resources
Ontario Land Inventory (OLI), Sheet 52H, Nipigon.	1:250,000 and 1:50,000 scale NTS maps with various land resource overlays (e.g., bedrock geology, soil types, soil texture, soil depth, wildlife habitat, etc.)	Ontario Ministry of Natural Resources, Ontario Centre for Remote Sensing
2. Bedrock geology		
Geology of the Black Sturgeon River Area, District of Thunder Bay, Maps 2233 (Black Sturgeon Lake), 2234 (Frazer Lake) and 2236 (Shillabeer Creek).	1:63,360 showing bedrock types and other geological features	Ontario Department of Mines and Northern Affairs (*see* Coates 1972)
3. Surficial geology		
Surficial Geology of Northern Ontario. Ontario Geological Survey, Map 2518.	1:1,200,00	Ontario Department of Northern Development and Mines.
Northern Ontario Engineering Geology Terrain Study (NOEGTS), Data Base Map, Sheet NTS 52H/SE, Frazer Lake. Ontario Geological Survey, Map 5052.	1:100,000 scale maps showing landform, mode of deposition, texture, drainage and topography.	Ontario Ministry of Northern Development and Mines. (*see* Mollard and Mollard 1981)
4. Forestry		
Forest Resource Inventory (FRI) Maps 492883, 492884, 493883, 493884.	1:15,840 scale maps with detailed stand data: species composition, height, age, and stocking. The most recent FRI maps for the research site date from 1975.	Ontario Ministry of Natural Resources

[a] OBM, OLI and FRI information is also available in digital format.

APPENDIX 2

PRE-HARVEST CHARACTERIZATION OF HARVESTING IMPACTS COMPONENT TREATMENT COMPARTMENTS

The compartment descriptions on the following pages are based on data collected during the summer of 1993, either from four 10x10m vegetation plots per compartment (marked "V" on compartment maps in Appendix 8) or from the pre-harvest survey of ten 10x10m permanent sample plots (PSPs) per compartment as noted in Section 3.5. Data for the descriptive parameters in Appendices 2.1 to 2.4 were derived as follows:

Appendix 2.1 – Compartment descriptions.

The next 21 pages contain pre-harvest compartment descriptions. Information collected June and July 1993.

Description: Forest Ecosystem Classification (FEC) vegetation types (V-types) after Sims et al (1989) (see also Appendix 2.4). FRI label = average species composition for ten PSPs per compartment (Po = aspen poplar; Bw = white birch; Bf = balsam fir; Sb = black spruce; Sw = white spruce; Pj = jack pine). FEC treatment unit = management-oriented general stand classification after Racey et al (1989).

Forest floor: Data for "Herbs" and "Graminoids" are averages for four vegetation plots per compartment. Other data are averages for ten PSPs per compartment.

Stand structure: Average occurrence of woody plants by canopy class in four vegetation plots per compartment.

Trees: Average dimensions and volumes of tree species for ten PSPs per compartment, based on prism sweep with an angle gauge of basal area factor $2m^2/ha$. "Relative abundance" = total number of trees by species in each category.

Vegetation cover: Percent cover for all species exceeding two percent cover; averages for four vegetation plots per compartment. The relative abundance figures indicate the average number of species within each life-group occurring on four vegetation plots per compartment.

Appendix 2.2 – Mineral soil properties.

Organic matter content: Average values for samples (10-15 cm depth) taken at each of four vegetation plots per compartment. Analysis by wet oxidation method (Walkley 1947).

pH: Average values for samples (10-15 cm depth) taken at each of four vegetation plots per compartment. Measurement in 0.01*M* $CaCl_2$.

Soil textural analysis: Averages values for samples (5-15 cm depth) taken at each of four vegetation plots per compartment. Analysis by Bouyoucos Hydrometer Method (Bouyoucos 1962).

Mineral soil elements: Average values for samples (10-15 cm depth) taken at each of four vegetation plots per compartment. Samples were air-dried, sieved to pass a 2 mm sieve, and the 2 mm fraction analyzed as follows (after Kalra and Maynard 1991): total nitrogen by semi-automatic Kjeldhal procedure, using a Tecator Kjeltec Auto 1030 Analyzer; available phosphorus by inductively coupled argon plasma (ICAP) emission spectrometry after extraction with Bray and Curtis No. 1 extractant; exchangeable potassium, calcium and magnesium by ICAP following extraction with unbuffered 1*M* NH_4Cl extractant; cation exchange capacity (CEC) of residual soil by H+ displacement of NH_4+.

Appendix 2.3 – Organic soil horizon properties.

Depth of organic layer: Average values for ten PSPs per compartment.

Humus form: Average condition for four vegetation plots per compartment (based on revised humiform key of Sims and Baldwin 1996).

Organic matter content: Average values based on pooled L, F and H horizons of three samples taken at each of four vegetation plots per compartment. Analysis by wet oxidation method (Walkley 1947).

pH: Average values based on pooled L, F and H horizons of three samples taken at each of four vegetation plots per compartment. Measurement in a 1:1 soil:water mix and in 0.01*M* $CaCl_2$.

Organic soil elements: Average values based on pooled L, F and H horizons of three samples taken at each of four vegetation plots per compartment. Applicable analytical procedures as for mineral soil elements.

Appendix 2.4 – FEC V-type characterization of permanent sample plots.

FEC V-type characterization of each PSP within the harvested compartments (after Sims et al 1989).

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 1

Description - The compartment is mostly flat. V7 is well represented with smaller amounts of V4, V6, V8, V9, V16 and V14. The compartment has a uniform, continuous cover of aspen with balsam fir in the understorey. FRI label - $Po_6\ Bf_2\ Bw_1\ Sw_1$. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.4
Loose rock and stones	0	Feathermoss	30.0
Exposed mineral soil	0.4	Sphagnum	0.1
Bare organic soil	1.1	Other bryophytes	1.9
Hardwood litter	42.9	Lichens	1.3
Conifer litter	5.0	Downed woody material	13.9

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	40.0	2.0	8.3	4.8	3.5
Conifer	7.0	6.3	6.3	0.8	1.8

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	43	18.7	8.6	91.22
White birch	8	15.6	1.6	12.22
Balsam fir	32	10.7	6.4	26.30
White spruce	14	12.1	2.8	13.74
Black spruce	1	15.7	0.2	1.18
Jack pine	6	18.0	1.2	10.07
Totals			20.8	154.73
Dead				
Trembling aspen	2	18.7	0.4	4.22
Balsam fir	62	10.7	12.4	50.02
White spruce	3	12.1	0.6	2.73
Jack pine	5	18.0	1.0	8.39
Totals			14.4	65.36

Vegetation - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and graminoids		Bryophytes and lichens	
Populus tremuloides	40.0	Acer spicatum	2.5	Aralia nudicaulis	5.8	Pleurozium schreberi	35.0
Abies balsamea	9.3	Abies balsamea	2.5	Cornus canadensis	4.5	Hylocomium splendens	2.3
Betula papyrifera	6.3	Corylus cornuta	2.0	Linnaea borealis	3.8	Ptilium crista-castrensis	2.0
Picea glauca	4.0						
Pinus banksiana	4.0						

Relative abundance: woody species - 12, herbs and graminoids - 17, bryophytes and lichens - 11

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 2

Description - The compartment is flat. Over half the compartment is V7; the rest of the compartment is comprised of V9, V10 and Vll. A fair amount of jack pine is present. The shrub layer is not well developed. FRI label - Po_6 Bf_1 Sb_1 Sw_1 Pj_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	4.0
Loose rock and stones	0	Feathermoss	41.2
Exposed mineral soil	0.2	Sphagnum	0.3
Bare organic soil	0.8	Other bryophytes	2.0
Hardwood litter	31.2	Lichens	1.1
Conifer litter	7.8	Downed woody material	11.4

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	27.5	2.5	0.8	5.8	2.0
Conifer	3.0	9.8	4.0	11.0	4.5

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	64	20.3	12.8	143.04
White birch	3	16.1	0.6	4.50
Balsam fir	27	11.4	5.4	20.47
White spruce	4	16.8	0.8	13.21
Black spruce	10	14.0	2.0	10.72
Jack pine	17	15.7	3.4	27.78
Totals			25.0	219.72
Dead				
Trembling aspen	5	20.3	1.0	11.41
Balsam fir	46	11.4	9.2	39.29
Jack pine	5	15.7	1.0	7.30
Totals			11.2	58.00

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	28.3	Abies balsamea	10.8	Aralia nudicaulis	7.3	Pleurozium schreberi	38.8
Abies balsamea	9.0	Picea glauca	2.8	Cornus canadensis	5.0	Hylocomium splendens	2.0
Betula papyrifera	2.5					Dicranum polysteum	1.1
Picea glauca	2.8						
Picea mariana	3.8						
Pinus banksiana	6.0						

Relative abundance: woody species - 12, herbs and graminoids - 18, bryophytes and lichens - 13

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 3

Description - The compartment is flat and quite uniform. Almost the entire compartment falls into V7. Aspen dominates the canopy throughout the compartment. The shrub layer is poorly developed. FRI label - Po_8 Bf_1 Sw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.8
Loose rock and stones	0	Feathermoss	32.0
Exposed mineral soil	0.4	Sphagnum	0
Bare organic soil	1.7	Other bryophytes	1.6
Hardwood litter	39.7	Lichens	2.0
Conifer litter	6.0	Downed woody material	12.8

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	52.5	0.5	1.8	6.5	1.8
Conifer	1.3	11.5	3.5	4.5	0.5

Trees

Species	Relative abundance	Mean height m	Basal area m²/ha	Volume m³/ha
Living				
Trembling aspen	81	19.8	16.2	177.64
White birch	5	16.5	1.0	7.56
Balsam fir	33	11.2	6.6	36.76
White spruce	7	13.2	1.4	6.92
Black spruce	1	12.8	0.2	0.96
Jack pine	3	19.2	3.8	5.45
Totals			29.2	235.29
Dead				
Trembling aspen	4	19.8	0.8	8.90
Balsam fir	63	11.2	12.6	53.05
Jack pine	2	19.2	0.4	3.58
Totals			13.8	65.53

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	51.8	Abies balsamea	4.5	Aralia nudicaulis	2.3	Pleurozium schreberi	22.5
Abies balsamea	13.5			Cornus canadensis	6.0	Rhytidiadelphus triquestris	14.0
Betula papyrifera	3.5			Linnaea borealis	6.0		
Pinus banksiana	2.5						

Relative abundance: woody species - 11, herbs and graminoids - 16, bryophytes and lichens - 15

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 4

Description - The compartment is flat. V7 and V8 predominate. Aspen dominates the upper canopy, with some jack pine; there is a fairly continuous coniferous secondary canopy. *Pleurozium schreberi* covers about one third of the forest floor. FRI label Po_7 Bf_1 Pj_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.9
Loose rock and stones	0	Feathermoss	36.8
Exposed mineral soil	0	Sphagnum	0
Bare organic soil	0.9	Other bryophytes	3.0
Hardwood litter	35.7	Lichens	1.4
Conifer litter	6.6	Downed woody material	11.5

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	41.3	0	0.5	5.5	4.3
Conifer	1.3	33.8	5.8	3.8	5.0

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	78	19.6	15.6	172.46
White birch	4	14.8	0.8	5.51
Balsam fir	34	10.6	6.8	27.18
White spruce	7	12.1	1.4	6.74
Black spruce	8	14.0	1.6	8.39
Jack pine	28	15.5	5.6	41.09
Totals			31.8	261.37
Dead				
Trembling aspen	7	19.6	1.4	15.43
Balsam fir	33	10.6	6.6	26.33
Jack pine	4	15.5	0.8	5.76
Totals			8.8	47.52

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	41.8	Abies balsamea	24.5	Aralia nudicaulis	4.0	Pleurozium schreberi	47.5
Abies balsamea	24.5	Diervilla lonicera	3.8	Cornus canadensis	5.8	Dicranum polysetum	6.3
Picea glauca	3.8			Linnaea borealis	2.5	Ptilium crista-cristata	2.0
Picea mariana	5.0			Aster macrophyllus	2.5		
Pinus banksiana	5.0						

Relative abundance: Woody species - 9, herbs and graminoids - 16, bryophytes and lichens - 13

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 5

Description - Most of the compartment is flat, but there a few ≈2m hummocks and a couple of large glacial erratics. Most of the compartment is V6 or V9 because of the ample shrub layer, with some V7 and V11. A well-developed herb layer is also present. FRI label - Po_6 Bf_1 Sw_1 Sb_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0.2	Prostrate herbs	0.2
Loose rock and stones	0	Feathermoss	32.9
Exposed mineral soil	0.2	Sphagnum	0.4
Bare organic soil	0.5	Other bryophytes	0.8
Hardwood litter	35.5	Lichens	0.6
Conifer litter	6.6	Downed woody material	22.1

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	50.0	4.3	0.5	27.0	7.6
Conifer	7.5	15.8	3.8	3.0	2.1

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	60	18.3	12.0	126.09
White birch	9	12.4	1.8	10.42
Balsam fir	18	10.5	3.6	13.92
White spruce	17	17.7	3.4	22.59
Black spruce	8	16.0	1.6	9.61
Jack pine	3	20.8	0.6	5.81
Totals			23.0	188.44
Dead				
Trembling aspen	2	18.3	0.4	4.12
White birch	1	12.4	0.2	1.16
Balsam fir	34	10.5	6.8	26.75
White spruce	5	17.7	1.0	6.64
Black spruce	3	16.0	0.6	3.61
Jack pine	3	20.8	0.6	5.81
Totals			9.6	48.09

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	51.0	Abies balsamea	5.1	Aralia nudicaulis	13.8	Pleurozium schreberi	23.0
Abies balsamea	20.0	Acer spicatum	12.3	Cornus canadensis	14.7	Rhytidiadelphus triquetris	2.8
Betula papyrifera	3.5	Corylus cornuta	12.0	Clintomia borealis	4.5	Ptilium crista-cristata	2.3
Picea glauca	10.8	Lonicera canadensis	5.8	Linnaea borealis	3.3		
Picea mariana	3.3	Diervilla lonicera	4.8	Rubus pubescens	2.8		
Pinus banksiana	6.0						

Relative abundance: woody species - 11, herbs and graminoids - 15, bryophytes and lichens - 15

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 6

Description - The compartment is mostly flat with some minor elevations. V7 and V11 predominate; some parts of the compartment are dominated by conifers (V16 or V17). The herb layer is well-developed. FRI label - Po_3 Sw_2 Sb_2 Pj_2 Bf_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	1.9
Loose rock and stones	0	Feathermoss	42.4
Exposed mineral soil	0	Sphagnum	1.0
Bare organic soil	0.8	Other bryophytes	1.0
Hardwood litter	32.0	Lichens	1.0
Conifer litter	6.4	Downed woody material	13.5

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	40.0	1.3	0.3	23.5	2.3
Conifer	5.0	30.0	9.3	4.0	8.0

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	44	17.9	8.8	93.38
White birch	4	14.7	0.8	5.45
Balsam fir	15	9.3	3.0	11.00
White spruce	18	13.8	3.6	18.06
Black spruce	17	15.4	3.4	19.53
Jack pine	24	18.9	4.8	42.38
Totals			24.4	189.80
Dead				
Trembling aspen	4	17.9	0.8	8.06
Balsam fir	44	9.3	8.8	30.77
White spruce	1	13.8	0.2	1.04
Jack pine	4	18.9	0.8	7.03
Totals			10.6	46.90

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	38.8	Abies balsamea	6.3	Aralia nudicaulis	15.8	Pleurozium schreberi	17.5
Abies balsamea	12.3	Picea mariana	5.8	Cornus canadensis	5.8	Hylocomium splendens	3.1
Betula papyrifera	2.5	Corylus cornuta	13.5	Linnaea borealis	4.3		
Picea glauca	3.3	Diervilla lonicera	4.0	Maianthemum canadense	2.1		
Picea mariana	19.0						
Pinus banksiana	10.0						

Relative abundance: woody species - 11, herbs and graminoids - 21, bryophytes and lichens - 15

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 7

Description - Mostly flat terrain with a 2m deep trough down the centre. V-types are mostly V7 or V11, with some V4, V10, and V16. The aspen canopy is patchy; balsam fir thickets fill the gaps, but are now mostly dead. Thick low-shrub layer is present outside the balsam fir thickets. FRI label - Po_5 Pj_2 Bw_2 Bf_1. FEC Treatment Unit - B1, with some D1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.4
Loose rock and stones	0	Feathermoss	40.5
Exposed mineral soil	0.4	Sphagnum	1.0
Bare organic soil	1.8	Other bryophytes	1.0
Hardwood litter	33.0	Lichens	1.0
Conifer litter	5.9	Downed woody material	12.0

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	22.5	0.8	0	18.8	19.5
Conifer	16.3	6.8	25.0	3.8	5.8

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	46	16.4	9.2	94.89
White birch	8	10.4	1.6	9.97
Balsam fir	28	8.3	5.6	17.21
White spruce	6	14.3	1.2	6.27
Black spruce	11	13.1	2.2	10.22
Jack pine	14	16.1	2.8	23.85
Totals			22.6	162.41
Dead				
Trembling aspen	3	16.4	0.6	5.54
White birch	1	10.4	0.2	0.97
Balsam fir	51	8.3	10.2	31.71
White spruce	1	14.3	0.2	1.07
Black spruce	1	13.1	0.2	0.98
Jack pine	8	16.1	1.6	12.02
Totals			13.0	52.29

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	15.0	Abies balsamea	6.8	Aralia nudicaulis	17.3	Pleurozium schreberi	46.3
Abies balsamea	32.5	Picea mariana	2.3	Cornus canadensis	9.5	Hylocomium splendens	3.3
Betula papyrifera	8.3	Vaccinium angustifolium	10.3	Linnaea borealis	8.0		
Picea mariana	4.0	Diervilla lonicera	6.0	Clintonia borealis	2.2		
Pinus banksiana	8.8	Lonicera canadensis	4.3				
		Corylus cornuta	3.1				
		Ribes triste	2.8				
		Rosa acicularis	2.5				

Relative abundance: woody species - 12, herbs and graminoids - 19, bryophytes and lichens - 17

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 8

Description - The compartment is relatively flat. It is dominated by V11, with small pockets of V7, V10, V14, and V16. There are some canopy gaps, and the low shrub and herb layers are quite rich. FRI label - Po_5 Bf_1 Sw_1 Sb_1 Pj_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.7
Loose rock and stones	0	Feathermoss	40.0
Exposed mineral soil	0	Sphagnum	0
Bare organic soil	0.6	Other bryophytes	2.0
Hardwood litter	34.3	Lichens	1.6
Conifer litter	2.0	Downed woody material	15.8

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	15.0	15.0	0	27.5	15.0
Conifer	28.8	17.5	11.8	4.8	4.3

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	49	19.5	9.8	107.60
White birch	11	14.7	2.2	14.32
Balsam fir	10	10.8	2.0	7.78
White spruce	1	16.5	0.2	1.24
Black spruce	11	14.3	2.2	11.17
Jack pine	11	17.6	2.2	17.82
Totals			18.6	159.93
Dead				
Trembling aspen	5	19.5	1.0	10.97
Balsam fir	62	10.8	12.4	50.40
Black spruce	3	14.3	0.6	3.22
Jack pine	3	17.6	0.6	4.91
Totals			14.6	69.50

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	13.8	Abies balsamea	5.5	Aralia nudicaulis	8.3	Pleurozium schreberi	46.3
Abies balsamea	8.8	Picea mariana	3.8	Cornus canadensis	15.5	Dicranum polysetum	7.0
Betula papyrifera	16.3	Diervilla lonicera	15.2	Linnaea borealis	15.5	Ptilium crista-cristata	3.1
Picea glauca	15.0	Betula papyrifera	5.3	Coptis trifolia	3.8		
Picea mariana	21.3	Corylus cornuta	4.8	Clintonia borealis	2.3		
Pinus banksiana	12.5	Lonicera canadensis	4.1	Rubus pubescens	2.1		
		Vaccinium myrtilloides	3.8				
		Acer spicatum	3.3				

Relative abundance: woody species - 12, herbs and graminoids - 18, bryophytes and lichens - 16

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 9

Description - The compartment is flat at the rear, but the front pitches sharply from the road into a 10 m deep depression in the right front corner. Most of the compartment falls into V6, V7, V10, or V11, depending on the amount of tall shrubs, which in places form dense patches. The aspen canopy is discontinuous. FRI label - Po_5 Sw_2 Bf_1 Bw_1 Sb_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	3.5
Loose rock and stones	0	Feathermoss	27.6
Exposed mineral soil	1.4	Sphagnum	1.0
Bare organic soil	0.1	Other bryophytes	1.4
Hardwood litter	40.5	Lichens	1.0
Conifer litter	9.5	Downed woody material	14.0

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	20.0	17.5	24.3	29.3	11.0
Conifer	10.3	13.3	11.8	2.8	0.6

Trees

Species	Relative abundance	Mean height m	Basal area m²/ha	Volume m³/ha
Living				
Trembling aspen	76	18.6	15.2	166.54
White birch	6	12.7	1.2	7.17
Balsam fir	27	11.6	5.4	23.44
White spruce	25	14.9	5.0	31.60
Black spruce	5	15.4	1.0	5.44
Jack pine	2	15.2	0.4	2.82
Totals			28.2	237.01
Dead				
Trembling aspen	2	18.6	0.4	4.19
White birch	5	12.7	1.0	5.92
Balsam fir	21	11.6	4.2	18.26
White spruce	10	14.9	2.0	11.19
Black Spruce	1	15.4	0.2	1.16
Totals			7.8	40.72

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	30.0	Abies balsamea	14.1	Aralia nudicaulis	4.0	Pleurozium schreberi	34.0
Abies balsamea	7.8	Acer spicatum	36.0	Cornus canadensis	4.5	Rhytidiadelphus triquetris	11.3
Betula papyrifera	17.5	Corylus cornuta	19.8	Linnaea borealis	3.8	Ptilium crista-castrensis	3.5
Picea glauca	10.0	Diervilla lonicera	5.3	Lonicera canadensis	3.8	Hylocomium splendens	3.3
Picea mariana	5.0	Lonicera canadensis	3.6				

Relative abundance: woody species - 12, herbs and graminoids - 17, bryophytes and lichens - 23

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 10

Description - Most of the compartment is flat, except for the front, left corner which falls steeply to the road. V-types include V6, V7, V9, and V10, depending on the amount of tall shrubs and conifer content. FRI label - Po_5 Bf_2 Sw_1 Sb_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	1.0
Loose rock and stones	0	Feathermoss	23.6
Exposed mineral soil	0	Sphagnum	1.0
Bare organic soil	0.4	Other bryophytes	2.0
Hardwood litter	48.8	Lichens	1.0
Conifer litter	9.9	Downed woody material	12.3

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	31.3	11.3	3.8	23.8	11.8
Conifer	17.5	18.8	9.3	1.5	7.0

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	74	19.5	14.8	162.17
White birch	9	14.1	1.8	12.03
Balsam fir	44	9.3	8.8	30.60
White spruce	8	15.9	1.6	9.54
Black spruce	5	13.6	1.0	4.99
Jack pine	12	19.2	2.4	21.37
Totals			30.4	240.70
Dead				
Trembling aspen	8	19.5	1.6	17.57
White birch	2	14.1	0.4	2.62
Balsam fir	17	9.3	3.4	11.84
Totals			5.4	32.03

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	23.8	Corylus cornuta	17.0	Aralia nudicaulis	7.5	Pleurozium schreberi	27.5
Abies balsamea	15.0	Abies balsamea	14.8	Cornus canadensis	7.5	Ptilium crista-castrensis	12.1
Betula papyrifera	18.8	Diervilla lonicera	8.6	Linnaea borealis	2.8	Rhytidiadelphus triquetris	5.0
Picea glauca	3.8	Acer spicatum	5.3			Hylocomium splendens	2.0
Picea mariana	17.5	Lonicera canadensis	4.3				
		Populus tremuloides	2.6				

Relative abundance: woody species - 12, herbs and graminoids - 17, bryophytes and lichens - 23

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 11

Description - This compartment has the most severe terrain of Stands 1 and 2. There is a deep trough, about 10 m deep, across the front of the compartment, falling sharply from the road. Most of the compartment falls into V6, V7, or V9. Patches of dense, tall shrubs were present. FRI label - Po_6 Sw_2 Bf_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0.6
Loose rock and stones	0	Feathermoss	19.5
Exposed mineral soil	0	Sphagnum	1.4
Bare organic soil	0	Other bryophytes	2.0
Hardwood litter	52.5	Lichens	1.0
Conifer litter	7.0	Downed woody material	16.0

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	40.0	4.5	4.3	37.5	10.5
Conifer	7.5	3.5	12.5	0.8	0.8

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	52	19.0	10.4	110.86
White birch	16	7.9	3.2	15.35
Balsam fir	41	10.2	8.2	31.35
White spruce	22	14.2	4.4	26.27
Black spruce	1	12.2	0.2	0.92
Totals			26.4	184.75
Dead				
Trembling aspen	5	19.0	1.0	10.69
White birch	2	7.9	0.4	1.47
Balsam fir	30	10.2	6.0	23.05
White spruce	3	14.2	0.6	3.19
Jack pine	1	17.7	0.2	1.65
Totals			8.2	40.05

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	21.3	Corylus cornuta	20.3	Cornus canadensis	10.8	Pleurozium schreberi	15.3
Abies balsamea	12.8	Acer spicatum	9.0	Linnaea borealis	8.0	Rhytidiadelphus triquetris	4.0
Betula papyrifera	25.0	Diervilla lonicera	7.2	Aralia nudicaulis	4.5	Ptilium crista-castrensis	3.3
Picea glauca	7.5	Lonicera canadensis	4.8	Clintonia borealis	3.3		
Picea mariana	3.3	Sorbus americana	3.5				

Relative abundance: woody species - 11, herbs and graminoids - 16, bryophytes and lichens - 16

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 12

Description - The compartment is flat. V-types are mostly V6 and V8, with a tall, dense shrub layer. A few large canopy gaps are present, with very dense shrubs beneath. FRI label - Po_4 Sw_4 Bf_1 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	1.0
Loose rock and stones	0	Feathermoss	36.0
Exposed mineral soil	1.0	Sphagnum	0.8
Bare organic soil	1.0	Other bryophytes	1.9
Hardwood litter	38.5	Lichens	1.0
Conifer litter	8.1	Downed woody material	10.7

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	19.5	12.0	23.8	36.8	7.6
Conifer	16.3	12.5	5.8	3.0	0.3

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	44	20.0	8.8	97.00
White birch	18	14.4	3.6	24.34
Balsam fir	15	17.9	3.0	18.35
White spruce	33	17.1	6.6	43.87
Black spruce	1	13.6	0.2	1.02
Jack pine	1	18.1	0.2	1.69
Totals			22.4	186.27
Dead				
Trembling aspen	1	20.0	0.2	2.25
White birch	2	14.4	0.4	2.69
Balsam fir	38	17.9	7.6	51.01
White spruce	22	17.1	4.4	28.31
Totals			12.6	84.26

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	35.0	Acer spicatum	33.1	Aralia nudicaulis	7.3	Pleurozium schreberi	6.5
Abies balsamea	10.8	Corylus cornuta	26.3	Cornus canadensis	6.0	Rhytidiadelphus triquetris	5.0
Betula papyrifera	16.3	Diervilla lonicera	7.3	Clintonia borealis	4.3	Plagiomnium cuspidatum	3.5
Picea glauca	2.5	Abies balsamea	3.4	Linnaea borealis	3.8		
Picea mariana	5.0			Lycopodium clavatum	2.2		

Relative abundance: woody species - 8, herbs and graminoids - 18, bryophytes and lichens - 16

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 13

Description - The compartment is flat at the front, but the rear third slopes sharply to the south. Almost the entire compartment is V6, and has the most dense tall shrub layer in Stand 1. FRI label - Po_7 Bf_2 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0.5
Loose rock and stones	0	Feathermoss	14.1
Exposed mineral soil	0.1	Sphagnum	1.0
Bare organic soil	0.2	Other bryophytes	2.0
Hardwood litter	58.0	Lichens	1.0
Conifer litter	10.3	Downed woody material	12.8

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	37.5	20.2	40.0	42.3	31.2
Conifer	0	23.3	10.0	4.0	2.5

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	93	19.9	18.6	206.35
White birch	13	15.0	2.6	17.74
Balsam fir	16	12.6	3.2	15.32
White spruce	9	14.4	1.8	10.03
Totals			26.2	249.44
Dead				
Trembling aspen	4	19.9	0.8	8.94
White birch	4	15.0	0.8	5.59
Balsam fir	25	12.6	5.0	23.59
White spruce	7	14.4	1.4	7.59
Black spruce	2	14.2	0.4	2.13
Totals			8.4	47.84

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	35.0	Acer spicatum	56.8	Aster macrophyllus	7.5	Pleurozium schreberi	8.8
Abies balsamea	13.8	Corylus cornuta	17.0	Aralia nudicaulis	3.5	Rhytidiadelphus triquetris	7.3
Betula papyrifera	22.5	Diervilla lonicera	8.8	Cornus canadensis	3.3		
Picea glauca	9.5	Abies balsamea	5.5	Clintonia borealis	3.3		
Picea mariana	10.0	Lonicera canadensis	5.3	Linnaea borealis	2.5		

Relative abundance: woody species - 9, herbs and graminoids - 17, bryophytes and lichens - 14

PRE-HARVEST CHARACTERIZATION OF STAND 1, COMPARTMENT 14

Description - The compartment is flat with a few large glacial erratics. Most of the compartment falls into V6, with a dense shrub layer, but small pockets of V4 are present. FRI label - Po_5 Bf_2 Bw_2 Sw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0.4
Loose rock and stones	0	Feathermoss	24.4
Exposed mineral soil	0	Sphagnum	0.8
Bare organic soil	0.2	Other bryophytes	1.6
Hardwood litter	44.0	Lichens	0.8
Conifer litter	11.0	Downed woody material	16.8

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	41.3	10.0	32.5	31.5	9.8
Conifer	2.5	13.8	7.5	2.3	1.8

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	57	19.5	11.4	125.02
White birch	20	14.3	4.0	28.62
Balsam fir	42	11.9	8.4	36.57
White spruce	12	16.2	2.4	15.33
Totals			26.2	205.54
Dead				
Trembling aspen	7	19.5	1.4	15.33
White birch	4	14.3	0.8	5.33
Balsam fir	40	11.9	8.0	35.62
White spruce	4	16.2	0.8	4.88
Black spruce	1	14.2	0.2	1.07
Totals			11.2	62.23

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	43.8	Acer spicatum	65.0	Linnaea borealis	4.8	Rhytidiadelphus triquestris	11.8
Abies balsamea	17.0	Corylus cornuta	6.8	Streptopus roseus	3.7	Pleurozium schreberi	9.5
Betula papyrifera	8.8	Abies balsamea	2.8	Clintonia borealis	2.8	Hylocomium splendens	2.0
Picea glauca	7.5	Lonicera canadensis	2.3	Rubus pubescens	2.3	Ptilium crista-castrensis	2.0
Picea mariana	2.5	Diervilla lonicera	2.0				

Relative abundance: woody species - 8, herbs and graminoids - 14, bryophytes and lichens - 14

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 1

Description - The compartment is flat FRI label - $Po_7\ Bf_2\ Bw_1$. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0.2	Prostrate herbs	1.0
Loose rock and stones	0	Feathermoss	31.6
Exposed mineral soil	0.8	Sphagnum	1.1
Bare organic soil	0.2	Other bryophytes	2.1
Hardwood litter	33.0	Lichens	1.0
Conifer litter	12.7	Downed woody material	16.3

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	28.8	8.8	6.3	58.0	2.0
Conifer	1.3	2.5	1.3	0.3	0.3

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	48	19.5	9.6	105.23
White birch	16	13.4	3.2	20.24
Balsam fir	11	11.1	2.2	9.26
White spruce	44	16.4	8.8	50.99
Black spruce	4	17.0	0.8	5.12
Totals			24.6	190.84
Dead				
Trembling aspen	3	19.5	0.6	6.58
White birch	7	13.4	1.4	8.76
Balsam fir	38	11.1	7.6	31.72
White spruce	21	16.4	4.2	25.93
Black spruce	4	17.0	0.8	5.12
Totals			14.6	78.11

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	31.3	Acer spicatum	40.5	Cornus canadensis	10.8	Pleurozium schreberi	9.8
Betula papyrifera	8.8	Corylus cornuta	10.0	Aralia nudicaulis	5.5	Rhytidiadelphus triquestris	4.5
Picea glauca	2.5	Diervilla lonicera	4.2	Aster macrophyllus	5.0	Hylocomium splendens	2.3
				Clintonia borealis	5.0		
				Linnaea borealis	4.8		
				Maianthemum canadense	3.6		
				Viola renifolia	3.3		

Relative abundance: woody species - 9, herbs and graminoids - 13, bryophytes and lichens - 10

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 2

Description - The compartment is mostly flat. V-types are mostly V4, V6, and V8, with moderate amounts of tall shrubs scattered across the site. FRI label - $Po_5\ Bw_2\ Sw_1\ Sb_1\ Bf_1$. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	1.0
Loose rock and stones	0	Feathermoss	18.5
Exposed mineral soil	0.1	Sphagnum	1.0
Bare organic soil	0	Other bryophytes	1.6
Hardwood litter	43.0	Lichens	1.0
Conifer litter	13.0	Downed woody material	20.7

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	47.5	16.3	21.5	37.5	0.3
Conifer	0	3.8	0	2.5	1.0

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	70	20.5	14.0	157.86
White birch	22	13.2	4.4	26.86
Balsam fir	20	12.8	4.0	19.70
White spruce	15	17.5	3.0	20.21
Black spruce	4	15.4	0.8	4.64
Totals			26.2	229.27
Dead				
Trembling aspen	1	20.5	0.2	2.31
White birch	8	13.2	1.6	9.86
Balsam fir	29	12.8	5.8	27.79
White spruce	11	17.5	2.2	14.45
Totals			9.8	54.41

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	47.5	Acer spicatum	39.8	Aster macrophylla	9.8	Pleurozium schreberi	10.0
Betula papyrifera	16.3	Corylus cornuta .	16.5	Clintonia borealis	9.3	Rhytidiadelphus triquetris	3.8
Abies balsamea	3.8	Abies balsamea	3.0	Linnaea borealis	5.7	Hylocomium splendens	2.0
				Cornus canadensis	4.5		
				Aralia nudicaulis	3.8		
				Mitella nuda	2.5		

Relative abundance: woody species - 7, herbs and graminoids - 10, bryophytes and lichens - 5

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 3

Description - The compartment is mostly flat, with a substantial depression at the rear. V-types are mostly V7 or V16, depending on the proportions of hardwoods and conifers. FRI label - Po_5 Sw_2 Bf_2 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	1.0
Loose rock and stones	0	Feathermoss	25.5
Exposed mineral soil	0	Sphagnum	1.0
Bare organic soil	0	Other bryophytes	2.0
Hardwood litter	38.5	Lichens	1.0
Conifer litter	13.0	Downed woody material	18.0

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	28.3	0.3	8.5	11.0	4.8
Conifer	20.0	1.3	0	0	0

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	58	18.4	11.6	119.82
White birch	6	13.2	1.2	7.34
Balsam fir	31	11.3	6.2	25.71
White spruce	34	15.3	6.8	43.00
Totals			25.8	195.87
Dead				
Trembling aspen	1	18.4	0.2	2.07
White birch	1	13.2	0.2	1.23
Balsam fir	23	11.3	4.6	19.53
White spruce	6	15.3	1.2	6.91
Jack pine	1	17.7	0.2	1.65
Totals			6.4	31.39

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	20.8	Diervilla lonicera	6.8	Aralia nudicaulis	5.8	Pleurozium schreberi	35.0
Picea glauca	17.5	Corylus cornuta	2.0	Cornus canadensis	4.5	Hylocomium splendens	2.3
Betula papyrifera	7.6	Vaccinium myrtilloides	2.2	Linnaea borealis	3.8	Ptilium crista-castrensis	2.0
Abies balsamea	3.8						
Picea mariana	2.5						

Relative abundance: woody species - 10, herbs and graminoids - 18, bryophytes and lichens - 12

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 4

Description - The compartment is gently rolling, falling to the rear. The vegetation is heterogeneous, with V-types V5, V6, V7, V8, V11, and V16. This compartment and Compartment 2-5 appear to have an older age structure than the rest of Stand 2. FRI label - Po_5 Sw_2 Bf_2 Bw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0
Loose rock and stones	0	Feathermoss	17.8
Exposed mineral soil	0	Sphagnum	0.9
Bare organic soil	0	Other bryophytes	1.2
Hardwood litter	48.5	Lichens	0.9
Conifer litter	13.6	Downed woody material	17.1

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	18.8	8.8	70	62.0	3.8
Conifer	8.8	10.0		1.3	2.3

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	47	19.4	9.4	102.36
White birch	12	15.2	2.4	17.18
Balsam fir	25	14.3	5.0	26.50
White spruce	26	16.7	5.2	32.13
Black spruce	3	15.2	0.6	3.43
Totals			22.6	181.60
Dead				
Trembling aspen	5	19.4	1.0	10.92
White birch	9	15.2	1.8	12.76
Balsam fir	14	14.3	2.8	15.08
White spruce	5	16.7	1.0	6.29
Jack pine	1	17.7	0.2	1.65
Totals			6.8	46.70

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	20.0	Acer spicatum	85.0	Aster macrophylla	12.8	Brachythecium salebrosum	7.0
Abies balsamea	13.8	Corylus cornuta	29.0	Clintonia borealis	9.3	Rhytidiadelphus triquetris	3.8
Betula papyrifera	7.5	Diervilla lonicera	4.0	Aralia nudicaulis	3.5	Pleurozium schreberi	3.0
Picea mariana	3.8	Abies balsamea	3.4	Mitella nuda	2.7		
				Cornus canadensis	2.0		

Relative abundance: woody species - 8 herbs and graminoids - 10, bryophytes and lichens - 9

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 5

Description - The compartment is sharply rolling, falling steeply at the rear. V-types are mostly V4, V6, and V8, with patches of moderately dense tall shrubs. This compartment and Compartment 2-4 appear to have any older age structure than the rest of Stand 2. FRI label - Po_3 Bf_3 Bw_3 Sw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0.1	Prostrate herbs	0
Loose rock and stones	0	Feathermoss	13.7
Exposed mineral soil	0.1	Sphagnum	0.7
Bare organic soil	0	Other bryophytes	0.8
Hardwood litter	49.0	Lichens	0.7
Conifer litter	15.6	Downed woody material	19.3

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	37.5	3.8	43.8	45.0	10.8
Conifer	18.8	7.5	0	1.3	0.3

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	36	19.7	7.2	80.64
White birch	21	14.1	4.2	27.96
Balsam fir	25	12.6	5.0	23.19
White spruce	14	18.5	2.8	19.28
Totals			19.2	151.07
Dead				
White birch	8	14.1	1.6	10.49
Balsam fir	5	12.6	1.0	4.75
White spruce	9	18.5	1.8	12.48
Black spruce	1	14.5	0.2	1.09
Jack pine	1	17.7	0.2	1.65
Totals			4.8	30.46

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Betula papyrifera	31.2	Acer spicatum	70.0	Clintonia borealis	16.3	Brachythecium salebrosum	3.3
Abies balsamea	16.3	Corylus cornuta	18.8	Aster macrophyllus	15.0	Mnium cuspidatum	3.3
Populus tremuloides	10.0	Diervilla lonicera	15.0	Aralia nudicaulis	8.8	Pleurozium schreberi	3.0
Picea glauca	10.0	Lonicera canadensis	9.2	Rubus pubescens	4.2	Rhytidiadelphus triquetris	3.0
		Alnus crispa	5.0	Lycopodium obscurum	2.3		

Relative abundance: woody species - 7, herbs and graminoids - 9, bryophytes and lichens - 5

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 6

Description - The compartment rises gently from the front, dropping abruptly at the rear boundary. V-types are mostly V4, V6, and V8. There are many canopy gaps and much blowdown, with often dense tall shrubs in the gaps. FRI label - Po_4 Bf_3 Bw_2 Sw_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0.8
Loose rock and stones	0	Feathermoss	17.4
Exposed mineral soil	0	Sphagnum	0.9
Bare organic soil	0.1	Other bryophytes	1.7
Hardwood litter	46.0	Lichens	1.0
Conifer litter	14.2	Downed woody material	17.9

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	22.5	17.5	26.3	57.5	1.5
Conifer	1.3	0	0	0	0.5

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	21	19.3	4.2	45.07
White birch	28	15.3	5.6	37.90
Balsam fir	32	14.3	6.4	35.34
White spruce	12	17.4	2.4	16.21
Totals			18.6	134.52
Dead				
White birch	5	15.3	1.0	7.13
Balsam fir	46	14.3	9.2	49.27
White spruce	6	17.4	1.2	7.86
Black spruce	5	14.5	1.0	5.46
Totals			12.4	69.72

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Betula papyrifera	27.5	Acer spicatum	70.0	Linnaea borealis	10.3	Pleurozium schreberi	35.0
Picea glauca	2.5	Corylus cornuta	12.8	Aster macrophyllus	9.5	Hylocomium splendens	8.8
		Diervilla lonicera	6.0	Aralia nudicaulis87.3		Brachythecium salebrosum	7.8
				Clintonia borealis	5.3	Rhytidiadelphus triquetris	3.8
				Cornus canadensis	3.8		
				Mitella nuda	3.3		

Relative abundance: woody species - 8, herbs and graminoids - 11, bryophytes and lichens - 8

PRE-HARVEST CHARACTERIZATION OF STAND 2, COMPARTMENT 7

Description - The compartment has two sharp ridges about 3-5 m in height which run across the compartment from left to right. The compartment drops off abruptly into the valley at the rear right. FRI label - Po_5 Bw_2 Bf_1 Sw_1 Pj_1. FEC Treatment Unit - B1.

Forest floor

Category	Percent ground cover	Category	Percent ground cover
Exposed bedrock	0	Prostrate herbs	0.3
Loose rock and stones	0	Feathermoss	33.7
Exposed mineral soil	0.1	Sphagnum	0.9
Bare organic soil	0.2	Other bryophytes	1.9
Hardwood litter	39.5	Lichens	1.0
Conifer litter	10.6	Downed woody material	11.8

Stand structure - Mean percent cover by canopy class

	Main canopy >10 m	Secondary canopy >10 m	2 - 10 m	0.5 - 2 m	< 0.5 m
Broadleaf	20.0	3.3	3.3	21.8	2.8
Conifer	10.0	1.3	0	0.1	0.5

Trees

Species	Relative abundance	Mean height m	Basal area m^2/ha	Volume m^3/ha
Living				
Trembling aspen	39	19.7	7.8	86.66
White birch	15	14.3	3.0	19.95
Balsam fir	25	12.7	5.0	22.75
White spruce	10	17.9	2.0	13.64
Jack pine	1	18.5	0.2	1.72
Totals			18.0	144.72
Dead				
Trembling aspen	2	19.7	0.4	4.43
White birch	7	14.3	1.4	9.35
Balsam fir	88	12.7	17.6	83.92
Totals			19.4	97.70

Vegetation cover - Mean percent cover of all species > 2% cover

Trees > 2 m		Shrubs up to 2 m		Herbs and Graminoids		Bryophytes and Lichens	
Populus tremuloides	20.0	Diervilla lonicera	11.5	Cornus canadensis	8.5	Pleurozium schreberi	35.0
Pinus banksiana	5.0	Acer spicatum	8.2	Aralia nudicaulis	6.7	Brachythecium salebrosum	5.3
Betula papyrifera	3.3	Corylus cornuta	3.3	Linnaea borealis	5.3	Ptilium crista-castrensis	4.0
Picea glauca	3.8	Vaccinium myrtilloides	2.5	Mitella nuda	5.0	Rhytidiadelphys triquetris	3.8
				Clintonia borealis	4.0	Hylocomium splendens	3.6

Relative abundance: woody species - 9, herbs and graminoids - 13, bryophytes and lichens - 11

APPENDIX 2.2

MINERAL SOIL PROPERTIES OF TREATMENT COMPARTMENTS[a]

Compart-ment	Organic matter %	pH ($CaCl_2$)	Sand[b] fragment %	Silt[b] fragment %	Clay[b] Fragment %	Total nitrogen mg/g	Available phosphorus µg/g	Exch. potassium $cmol_{(+)}/kg$	Exch. calcium $cmol_{(+)}/kg$	Exch. magnesium $cmol_{(+)}/kg$	C.E.C. $cmol_{(+)}/kg$
1-1	3.96	4.47	61.75	33.50	4.75	0.91	19.22	0.35	3.12	0.89	8.05
1-2	5.27	4.31	63.62	30.87	5.50	1.02	15.03	0.27	3.14	0.75	8.64
1-3	3.27	4.29	70.25	26.00	3.75	1.50	11.03	0.39	3.19	0.84	6.86
1-4	2.23	4.53	72.25	24.00	3.75	0.97	13.89	0.34	3.40	0.99	6.04
1-5	3.66	4.61	62.75	32.25	5.00	1.17	11.92	0.25	3.95	0.83	7.35
1-6	2.11	4.44	65.25	30.00	4.75	1.13	14.89	0.26	3.01	0.99	5.46
1-7	2.72	4.32	69.00	27.00	4.00	1.30	18.70	0.28	3.19	1.00	7.23
1-8	2.37	4.13	61.75	32.25	6.00	1.18	16.68	0.32	3.11	0.92	7.79
1-9	3.93	4.62	66.25	30.50	3.25	0.73	6.78	0.24	3.42	1.19	6.88
1-10	2.09	4.33	73.00	22.87	4.12	1.15	10.10	0.28	2.96	0.82	7.46
1-11	2.16	4.44	74.25	21.00	4.75	1.00	15.88	0.20	2.67	0.76	6.14
1-12	3.81	4.40	73.75	21.75	4.50	1.20	19.70	0.27	5.00	1.06	5.45
1-13	4.71	4.60	55.25	38.50	6.25	3.47	38.80	0.29	3.88	0.89	7.46
1-14	2.87	4.76	63.00	29.50	7.50	1.51	36.00	0.30	6.59	1.11	6.97
2-1	3.85	4.70	65.75	27.00	7.25	0.91	29.12	0.49	5.43	1.07	8.63
2-2	3.85	4.61	66.00	26.50	7.50	1.78	9.17	0.26	5.28	1.12	7.55
2-3	5.10	4.43	67.75	26.00	6.25	1.00	21.04	0.26	4.34	1.06	9.18
2-4	2.23	4.93	66.75	31.75	1.50	1.77	17.01	0.25	6.94	1.14	6.86
2-5	3.78	4.78	59.25	32.75	8.00	1.23	32.90	0.36	3.67	0.94	8.30
2-6	3.03	4.56	53.50	40.00	6.50	1.37	43.94	0.41	6.44	1.34	8.05
2-7	1.86	4.13	75.00	18.00	7.00	1.39	22.69	0.37	3.43	1.04	8.09

[a]For description of sampling and analytical procedures see introductory pages of Appendix 2.
[b]Soil fractions separated as follows: Sand - 0.05 to 2.0 mm; Silt - 0.002 to 0.05 mm; Clay - ≤0.002 mm.

APPENDIX 2.3

ORGANIC SOIL HORIZON PROPERTIES OF TREATMENT COMPARTMENTS[a]

Compart-ment	Depth of organic matter cm	Humus form[b]	Organic matter %	pH (H_2O)	pH ($CaCl_2$)	Total nitrogen mg/g	Available phosphorus µg/g	Exch. potassium $cmol_{(+)}/kg$	Exch. calcium $cmol_{(+)}/kg$	Exch. magnesium $cmol_{(+)}/kg$	C.E.C. $cmol_{(+)}/kg$
1-1	6.8	Hfb	66.2	5.24	4.92	14.12	256.60	2.52	31.63	5.21	99.99
1-2	8.1	Hfb	64.3	5.35	5.08	12.94	196.60	1.66	30.77	4.37	79.17
1-3	8.0	Shfb	60.9	5.26	5.01	13.77	250.60	2.16	28.12	4.35	104.32
1-4	7.1	Shfb	66.7	5.50	5.09	13.79	279.60	2.31	32.46	5.45	106.86
1-5	7.7	Hfb	56.3	5.95	5.41	12.18	256.69	1.49	17.50	3.17	73.94
1-6	6.1	Hfb	60.7	5.94	5.54	12.10	306.10	2.21	26.36	4.11	71.59
1-7	6.8	Hfb	61.6	5.26	4.96	12.87	250.40	1.96	25.18	4.03	79.74
1-8	6.7	Shfb	64.5	5.09	4.69	12.29	191.00	1.73	24.77	4.19	72.63
1-9	10.2	Hfb	71.1	5.25	5.02	14.29	209.20	1.46	25.38	3.76	75.45
1-10	7.5	Lfb	65.9	4.84	4.45	13.26	197.10	1.67	20.23	3.29	81.62
1-11	7.4	Lfb	63.5	5.17	4.80	13.36	213.60	1.51	22.57	3.77	81.95
1-12	6.4	Hfb	64.5	5.30	5.03	15.28	287.80	2.01	29.99	4.51	124.02
1-13	8.1	Hfb	70.7	5.67	5.28	15.88	227.80	1.72	26.37	3.93	99.51
1-14	7.9	Hfb	71.8	5.98	5.67	17.47	232.40	2.05	31.19	3.92	137.26
2-1	7.6	Hfb	63.9	5.76	5.52	14.06	176.00	1.58	24.29	4.16	124.27
2-2	5.2	Lfb	73.1	5.52	5.32	16.23	142.73	1.74	31.84	3.86	111.17
2-3	7.5	Lfb	51.5	5.03	4.56	10.48	145.63	2.08	29.31	4.30	90.05
2-4	7.4	Hfb	60.1	5.81	5.59	15.29	145.00	1.34	31.58	3.79	114.17
2-5	7.1	Hfb	64.0	5.55	5.33	16.98	148.32	2.00	38.60	6.07	94.71
2-6	6.2	Lfb	56.1	5.38	5.14	11.27	119.20	1.12	31.60	3.39	115.97
2-7	8.0	Lfb	60.0	5.14	4.80	13.38	140.59	1.35	26.55	3.45	111.32

[a]For description of sampling and analytical procedures see the introductory pages of Appendix 2.
[b]Hfb = humifibrimor; Shfb = subhumic fibrimor; Lfb = litter fibrimor (after Sims and Baldwin 1996).

APPENDIX 2.4

PRE-HARVEST FEC V-TYPE CHARACTERIZATION OF PERMANENT SAMPLE PLOTS[a]

Compart-ment	Permanent Sample Plot Number									
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
1-1	9	6	16	7	7	9	8	14	4	16
1-2	7	9	5	7	5	10	16	32	7	7
1-3	7	7	7	11	18	7	7	7	7	7
1-4	7	7	10	10	7	10	7	17	10	7
1-5	20	6	6	6	9	9	16	6	9	9
1-6	16	32	9	7	32	17	17	16	25	36
1-7	10	5	32	10	4	7	11	4	16	7
1-8	4	32	20	11	7	19	7	7	9	10
1-9	7	6	25	9	9	18	7	9	9	6
1-10	9	7	24	9	9	7	7	7	16	10
1-11	6	25	7	16	7	6	6	10	9	9
1-12	6	8	6	8	16	8	24	8	8	8
1-13	6	6	6	6	6	5	6	9	6	5
1-14	6	16	6	8	8	6	16	4	16	4
2-1	8	8	25	25	25	8	8	10	6	6
2-2	8	4	24	6	8	5	6	4	6	25
2-3	7	7	7	16	16	7	16	9	7	16
2-4	11	11	11	24	5	5	5	8	24	16
2-5	6	8	5	8	14	15	14	24	4	5
2-6	5	8	4	6	6	8	6	6	14	14
2-7	6	6	8	6	6	8	7	4	6	4

[a]Numbers in the body of the table indicate the V-type classification for each of the ten 10x10m permanent sample plots in a treatment compartment (V-types as defined by Sims *et al* 1989)

APPENDIX 3

MONTHLY CLIMATIC NORMALS FOR CAMERON FALLS, ONTARIO[a]

	Jan.	Feb.	Mar.	Apl.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature													
Daily maximum (°C)	-10.5	-7.4	-0.3	8.0	15.7	20.3	24.0	22.4	16.4	9.7	0.8	-7.3	7.6
Daily minimum (°C)	-22.4	-20.2	-13.4	-4.7	1.7	6.7	10.5	10.0	5.8	0.7	-6.9	-17.0	-4.1
Daily mean (°C)	-16.4	-13.7	-6.8	1.7	8.7	13.5	17.3	16.2	11.1	5.2	-3.0	-12.1	1.8
Degree-days													
Above 5°C	0	0	0.8	18.2	131.4	256.5	379.1	350.1	186.2	50.9	3.5	0.2	1377
Below 0°C	516.4	386.7	223.5	38.5	1.2	0	0	0	0	5.7	121.2	384.9	1678
Precipitation													
Rainfall (mm)	1.1	1.9	12.7	29.7	63.1	93.0	87.4	99.7	94.1	79.4	31.7	4.9	598.8
Snowfall (cm)	51.2	32.3	29.8	11.7	1.5	0	0	0	0.4	7.2	41.0	57.0	232.2
Total precipitation (mm)	52.3	34.2	43.0	41.4	64.7	93.0	87.4	99.7	94.5	86.6	72.7	61.9	831.4

[a]Data abstracted from Environment Canada (1993).

APPENDIX 4

POST-HARVEST COMPARTMENT INVENTORY SUMMARY, AUGUST 1994

Compartment[a]	Species	Live trees						Dead trees		Blowdown	
		Number	Mean dbh (cm)[b]	Mean ht.[b] (m)	Total ba.[b] (m^2/ha)	Total vol.[b] (m^3/ha)	Percent by vol.	Number	Total vol.[b] (m^3/ha)	Number	Total vol.[b] (m^3/ha)
1-2	Po	21	23.73	20.88	9.09	70.76	79.4	1	1.22	-	-
	Bf	4	7.55	8.21	0.19	0.82	0.9	2	0.77	-	-
	Sw	3	15.35	13.37	0.82	5.43	6.1	2	2.17	-	-
	Sb	3	16.87	14.05	0.70	4.49	5.0	-	-	1	2.94
	Pj	4	18.17	16.94	0.98	7.64	8.6	-	-	-	-
	Totals	35			11.78	89.14		4	4.15	1	2.94
1-3	Po	34	23.63	20.86	14.78	111.78	93.1	-	-	-	-
	Bw	2	14.90	14.64	0.35	2.30	1.9	-	-	-	-
	Bf	7	8.85	9.03	0.82	1.38	1.1	2	0.41	1	0.50
	Sw	1	8.70	11.17	0.06	0.30	0.2	-	-	-	-
	Pj	1	25.80	18.43	0.52	4.33	3.6	-	-	-	-
	Totals	45			16.54	120.09		2	0.41	1	0.50
1-4	Po	68	21.42	19.78	22.48	200.45	65.9	2	0.33	-	-
	Bw	8	10.05	11.92	0.91	5.85	1.9	-	-	-	-
	Bf	107	9.41	9.41	8.38	42.58	14.0	77	29.11	-	-
	Sw	6	15.91	13.56	1.14	7.19	2.4	-	-	-	-
	Sb	9	13.46	12.74	1.58	9.79	3.2	-	-	-	-
	Pj	13	16.96	15.76	4.16	38.22	12.6	4	3.08	-	-
	Totals	211			38.66	304.07		83	32.53	0	0
1-5	Po	37	17.75	18.04	9.43	69.58	72.8	5	2.27	-	-
	Bw	10	11.36	12.65	1.02	6.42	6.7	-	-	1	0.62
	Bf	31	8.85	9.03	2.03	9.6	10.1	24	8.00	-	-
	Sw	1	8.40	11.70	0.06	2.81	2.9	2	1.25	-	-
	Sb	10	11.92	9.72	1.19	7.08	7.4	5	2.15	-	-
	Pj	-	-	-	-	-	-	2	1.68	-	-
	Totals	89			13.73	95.52		38	15.35	1	0.62

[a]Excludes clearcuts and patch cuts.
[b]Abbreviations: dbh = diameter at breast height; ht = height; ba = basal area; vol = volume.

continued ....

Appendix 4 cont'd.

Compartment	Species	Live trees						Dead trees		Blowdown	
		Number	Mean dbh (cm)	Mean ht (m)	Total ba (m^2/ha)	Total vol. (m^3/ha)	Percent by vol.	Number	Total vol. (m^3/ha)	Number	Total vol. (m^3/ha)
1-6	Po	42	17.51	17.93	11.02	91.79	40.5	11	6.07	-	-
	Bw	3	13.15	13.66	0.63	4.48	2.0	-	-	-	-
	Bf	41	9.70	9.56	3.69	19.54	8.7	159	55.60	-	-
	Sw	10	14.39	13.05	2.15	14.20	6.3	3	2.57	-	-
	Sb	32	16.60	14.01	6.99	50.85	22.4	1	-	-	-
	Pj	16	21.51	17.59	5.70	45.66	20.2	8	2.75	-	-
	Totals	144			30.18	226.52		182	67.0	0	0
1-11	Po	17	19.39	18.82	5.07	43.19	64.2	1	0.38	-	-
	Bw	18	8.39	10.99	1.52	8.84	13.1	1	0.14	-	-
	Bf	30	8.69	9.25	1.89	8.78	13.0	20	8.59	4	1.06
	Sw	2	9.35	11.39	0.15	0.83	1.2	2	0.95	-	-
	Sb	2	18.80	14.79	0.74	5.66	8.4	-	-	1	0.14
	Totals	69			9.37	67.30		24	10.07	5	1.20
1-12	Po	21	18.04	18.18	5.46	45.67	50.1	1	0.24	-	-
	Bw	14	12.43	13.26	1.21	8.66	9.5	-	-	2	0.32
	Bf	2	5.85	7.14	0.05	0.20	0.2	8	2.28	-	-
	Sw	9	21.98	15.56	4.07	29.64	32.5	4	2.45	-	-
	Sb	5	15.60	13.56	1.08	6.97	7.6	-	-	-	-
	Totals	51			11.87	91.14		13	4.97	2	0.32
1-13	Po	78	21.88	20.34	25.41	230.66	72.6	11	3.70	-	-
	Bw	37	14.06	14.17	4.20	30.00	9.4	6	29.81	-	-
	Bf	54	11.85	8.26	6.57	38.52	12.1	40	23.49	-	-
	Sw	13	14.22	13.00	2.92	18.38	5.8	8	4.52	-	-
	Sb	-	-	-	-	-	-	1	0.27	-	-
	Pj	-	-	-	-	-	-	1	1.33	-	-
	Totals	182			39.10	317.56		67	63.13	0	0

continued ....

Appendix 4 conclusion.

Compartment	Species	Live trees						Dead trees		Blowdown	
		Number	Mean dbh (cm)	Mean ht (m)	Total ba (m^2/ha)	Total vol. (m^3/ha)	Percent by vol.	Number	Total vol. (m^3/ha)	Number	Total vol. (m^3/ha)
2-2	Po	21	25.65	19.70	8.79	80.31	67.2	-	-	1	1.90
	Bw	25	11.88	12.90	3.61	23.57	19.7	3	39.87	1	0.73
	Bf	11	10.49	11.11	0.91	4.97	4.2	12	21.89	-	-
	Sw	1	32.00	19.08	0.80	6.41	5.4	1	0.12	-	-
	Sb	2	19.95	14.70	0.64	4.17	3.5	-	-	-	-
	Totals	60			14.76	119.43		16	61.88	2	2.62
2-3	Po	37	17.33	16.73	10.16	66.48	72.0	1	0.28	-	-
	Bw	13	11.87	12.90	1.42	8.75	9.5	-	-	-	-
	Bf	9	7.34	9.12	0.41	1.34	1.4	26	7.97	-	-
	Sw	2	30.50	18.57	1.48	11.69	12.7	-	-	-	-
	Sb	3	15.77	13.39	0.65	4.09	4.4	-	-	-	-
	Totals	64			14.11	92.36		27	8.24	0	0
2-4	Po	14	24.54	19.72	7.07	64.65	56.0	-	-	-	-
	Bw	5	30.09	22.90	4.42	35.11	30.4	2	12.13	-	-
	Bf	2	11.50	11.75	1.60	1.25	1.1	3	0.79	-	-
	Sw	3	21.30	15.43	1.09	7.37	6.4	-	-	-	-
	Sb	3	20.13	14.75	1.02	6.97	6.0	-	-	-	-
	Totals	27			15.20	115.35		5	12.92	0	0
2-5	Po	37	20.65	18.47	11.71	100.39	34.0	4	1.13	-	-
	Bw	30	19.73	17.21	11.03	99.52	33.7	4	32.09	-	-
	Bf	32	16.91	15.16	6.49	45.34	15.4	7	7.70	-	-
	Sw	7	23.29	16.11	3.89	30.71	10.4	3	6.40	-	-
	Sb	6	23.58	15.82	2.75	19.25	6.5	-	-	-	-
	Totals	112			35.87	295.21		18	47.32	0	0

APPENDIX 5

ASSESSMENT OF DAMAGE TO RESIDUAL TREES IN PERMANENT SAMPLE PLOTS OF PARTIAL CUTS

Compartment	Species	Total trees per compartment[a]	Damaged trees					Wound frequency by position[b] (%)			Wound area by position[c] (%)		
			Number of trees	Percent trees damaged	Mean dbh (cm)	Mean wounds per tree	Mean wound area (cm^2)	0-50 cm	51-100 cm	101-200 cm	0-50 cm	51-100 cm	101-200 cm
1-2	Po	21	7	33.3	25.6	1.4	61.2	40.0	20.0	40.0	46.0	3.7	50.3
	Bf	4	0										
	Sw	3	3	100.0	15.4	1.7	193.0	20.0	60.0	20.0	94.8	4.2	1.0
	Sb	3	0										
	Pj	4	0										
	All spp.	35	10	28.6		1.5	100.7						
1-3	Po	34	7	20.6	24.4	1.6	179.9	27.3	27.3	45.4	4.4	2.3	93.3
	Bw	2	0										
	Bf	7	4	57.1	9.1	3.0	195.2	33.3	25.0	41.7	27.8	49.0	23.2
	Sw	1	1	100.0	8.7	1.0	246.1	-	100.0	-	-	100.0	-
	Pj	1	0										
	All spp.	45	12	26.7		2.0	190.5						
1-5	Po	37	0										
	Bw	10	2	20.0	7.3	2.5	22.6	-	40.0	60.0	-	42.4	57.6
	Bf	31	6	19.4	8.0	2.2	81.2	15.4	46.1	38.5	37.5	37.0	25.5
	Sw	1	1	100.0	8.4	1.0	72.2	-	-	100.0	-	-	100.0
	Sb	10	6	60.0	11.0	1.2	54.1	28.6	28.6	42.8	70.3	5.5	24.2
	All spp.	89	15	16.8		1.7	61.9						
1-11	Po	17	0										
	Bw	18	2	11.1	9.5	1.0	41.3	-	-	100.0	-	-	100.0
	Bf	30	10	33.3	8.8	1.7	76.1	-	29.4	70.6	-	7.2	92.8
	Sw	2	2	100.0	9.3	1.0	47.0	-	-	100.0	-	-	100.0
	Sb	2	0										
	Totals	69	14	20.3		1.5	66.9						

[a]Total number of trees on 10 PSPs per compartment.
[b]Mean frequency of wounds at specific heights on tree stems.
[c]Mean extent of wounding at specified heights on tree stems.

continued ....

Appendix 5 conclusion.

Compartment	Species	Total trees per compartment	Damaged trees					Wound frequency by position (%)			Wound area by position (%)		
			Number of trees	Percent trees damaged	Mean dbh (cm)	Mean wounds per tree	Mean wound area (cm^2)	0-50 cm	51-100 cm	101-200 cm	0-50 cm	51-100 cm	101-200 cm
1-12	Po	21	1	4.8	14.1	3.0	49.1	33.3	-	66.7	34.3	-	65.7
	Bw	14	1	7.1	15.4	3.0	266.8	33.3	66.7	-	71.7	28.3	-
	Bf	2	0	-	-	-	-	-	-	-	-	-	-
	Sw	9	1	11.1	20.4	1.0	29.2	100.0	-	-	100.0	-	-
	Sb	5	1	20.0	7.7	1.0	142.0	100.0	-	-	100.0	-	-
	Totals	51	4	7.8	-	2.0	121.8	-	-	-	-	-	-
2-2	Po	21	0	-	-	-	-	-	-	-	-	-	-
	Bw	25	3	12.0	8.9	2.7	66.7	-	100.0	-	-	100.0	-
	Bf	11	0	-	-	-	-	-	-	-	-	-	-
	Sw	1	0	-	-	-	-	-	-	-	-	-	-
	Sb	2	0	-	-	-	-	-	-	-	-	-	-
	Totals	60	3	5.0	-	2.7	66.7	-	-	-	-	-	-
2-3	Po	37	1	2.7	8.0	1.0	96.3	-	100.0	-	-	100.0	-
	Bw	13	3	23.1	14.4	2.7	34.4	62.5	37.5	-	38.5	61.5	-
	Bf	9	1	11.1	10.2	2.0	58.2	100.0	-	-	100.0	-	-
	Sw	2	0	-	-	-	-	-	-	-	-	-	-
	Sb	3	0	-	-	-	-	-	-	-	-	-	-
	Totals	64	5	7.8	-	2.2	51.5	-	-	-	-	-	-
2-4	Po	14	1	7.1	21.2	4.0	210.9	50.0	25.0	25.0	67.9	14.3	17.8
	Bw	5	1	20.0	12.8	3.0	271.0	66.7	33.3	-	96.3	3.7	-
	Bf	2	0	7.4	-	3.5	241.0	-	-	-	-	-	-
	Sw	3	0	-	-	-	-	-	-	-	-	-	-
	Sb	3	0	-	-	-	-	-	-	-	-	-	-
	Totals	27	2	-	-	-	-	-	-	-	-	-	-

APPENDIX 6

LIST OF STUDIES 1993-1999

In the listings that follow, addresses indicate the study leader's affiliation when the study was initiated. Where the study leader is no longer at the same address, a current e-mail address is provided where available. For information on specific studies, address enquiries to the individual designated by an asterisk (*). If no addressee is indicated, or if efforts to reach the designated individual fail, contact the Project Coordinator, Black Sturgeon Boreal Mixedwood Research Project, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5 (705-759-5740). This list was correct at the end of 1999; an up-to-date listing is maintained by the Project Coordinator.

(A) = active study. *(C)* = study completed.

HARVESTING IMPACTS COMPONENT

Impacts of harvesting practices on bird populations. (C)
Ken Abraham* (Ontario Ministry of Natural Resources, Southern Terrestrial Ecosystem Research Section, P.O. Box 5000, Maple, Ontario, L6A 1S9) (ken.abraham@mnr.gov.on.ca)

Impacts of harvesting practices on soil microarthropods. (C)
Jan Addison* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (jan.addison@royalroads.ca)

Postharvest vegetation succession and dynamics. (A)
Ken Baldwin* and Sheila Walsh (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (kbaldwin@nrcan.gc.ca)

Biomass production and carbon sequestration in second-growth boreal mixedwood forest as influenced by management and harvesting practices. (A)
Ian Morrison* and Ed Banfield (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (imorriso@nrcan.gc.ca)

Effects of harvesting on membership and structure of carabid beetle assemblages in boreal mixedwoods. (A)
Kevin Barber* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (kbarber@nrcan.gc.ca)

Postharvest site preparation and regeneration studies. (A)
Allan Cameron*, Michael Dumas, Fred Foreman, Ian Morrison, and Brad Sutherland (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (alcam@nrcan.gc.ca)

Logging damage and pathological colonization of residual trees. (A)
Michael Dumas* and John Mclaughlin (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (mdumas@nrcan.gc.ca)

Harvesting productivities and site impacts. (C)
Jean-François Gingras* (Forest Engineering Research Institute of Canada, Eastern Division, 143 Place Frontenac, Pointe Claire, Québec, H9R 4Z7) (jf-g@mtl.feric.ca)

Effects of harvest method on canopy development. (A)
Arthur Groot* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (agroot@nrcan.gc.ca)

Effects of competition and shelter on establishment of white spruce. (A)
Arthur Groot* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (agroot@nrcan.gc.ca)

Impacts of harvesting practices on the red-backed salamander. (A)
Raymond Guy* (Boreal Enterprise Centre, Collège Boréal, 21 Lasalle Blvd., Sudbury, Ontario, P3A 6B1) (rayguy@borealc.on.ca)

Logging damage and recovery of advance growth and regeneration. (A)
Jean-Denis Leblanc* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (dleblanc@nrcan.gc.ca)

Effects of silvicultural systems and harvesting methods on soil conditions and ecophysiological performance of four trees species. (A)
Hao Luu and Qinglai Dang* (Faculty of Forestry and the Forest Environment, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (M.Sc.F. thesis by Luu) (qinglai@lakeheadu.ca)

Effect of post-harvest light regime on autecology of blueberry. (C)
Faizal Moola and Azim Mallik* (Department of Biology, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (M.Sc. thesis by Moola) (amallik@gale.lakeheadu.ca)

Impacts of harvesting on distribution and cycling of organic matter and elements. (A)
Ian Morrison* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (imorriso@nrcan.gc.ca)

Seed bank dynamics, seed rain, and tree seedling recruitment. (C)
Meiqin Qi and John Scarratt* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (jscarrat@nrcan.gc.ca)

Impacts of harvesting practices on small mammal populations. (C)
Arthur Rodgers* and Carrie Hutchison (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (M.Sc. thesis by Hutchison) (art.rodgers@mnr.gov.on.ca)

Impacts of spruce budworm and budworm spraying on conifer regeneration. (C)
Chris Sanders* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (csanders@nrcan.gc.ca)
Transferred to Jean-Denis Leblanc (CFS) for monitoring of affected natural regeneration development. (A) (dleblanc@nrcan.gc.ca)

Effects of moose browsing on aspen sucker development and vegetation diversity. (A)
John Scarratt* and Bruce Canning (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (jscarrat@nrcan.gc.ca)

FIRE ECOLOGY COMPONENT

Fire behavior in budworm-killed boreal mixedwood fuel types. (C)
Terry Curran* and Bill Towill (Ontario Ministry of Natural Resources, Northwest Region Fire, 108 Saturn Road, Atikokan, Ontario, P0T 1K0) (terry.curran@mnr.gov.on.ca)

An evaluation of the fire behaviour prediction models used in predicting the fire behaviour on an experimental prescribed burn. (C)
Jason Dain and Mark Johnston (Faculty of Forestry and the Forest Environment, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (undergraduate thesis by Dain)

Impacts of burning on ecosystem structure and function. (A)
Mark Johnston and Julie Elliott* (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (julie.elliott@mnr.gov.on.ca)

Soil nutrient cycling following fire. (A)
Mark Johnston and Julie Elliott* (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (julie.elliott@mnr.gov.on.ca)

Plant succession and seedbank dynamics following fire. (A)
Mark Johnston and Julie Elliott* (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (julie.elliott@mnr.gov.on.ca)

Regeneration (A)
Brian Polhill* (Ontario Ministry of Natural Resources, Northwest Region Science and Technology, RR#1, 25th Side Road, Thunder Bay, Ontario, P7C 4T9) (brian.polhill@mnr.gov.on.ca)

Initial post-fire revegetation in a boreal mixedwood forest. (C)
Shawn Porter and Jim Kayll (Faculty of Forestry and the Forest Environment, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (undergraduate thesis by Porter) (julie.elliott@mnr.gov.on.ca)

A comparison of actual and predicted fire intensities for a prescribed burn in northwestern Ontario. (C)
Phil Temple and Mark Johnston (Faculty of Forestry and the Forest Environment, Lakehead University, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (undergraduate thesis by Temple) (julie.elliott@mnr.gov.on.ca)

Response of non-crop vegetation to prescribed fire on a former boreal mixedwood site. (A)
Bill Towill* (Ontario Ministry of Natural Resources, Northwest Region Science and Technology, RR#1, 25th Side Road, Thunder Bay, Ontario, P7C 4T9) (bill.towill@mnr.gov.on.ca)

Forest plant community response following clearcutting, fire, and simulated blowdown. (C)
Sara Wilson and Terry Carleton* (Faculty of Forestry, University of Toronto, Toronto, Ontario) (M.Sc.F. thesis by Wilson) (carleton@botany.utoronto.ca)

SITE PREPARATION COMPONENT

Impacts of site preparation method on soil fauna abundance and diversity. (C)
Jan Addison* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (jan.addison@royalroads.ca)

Impacts of site preparation method on soil microflora and the spread of root decay fungi. (A)
Michael Dumas* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (mdumas@nrcan.gc.ca)

Impacts of site preparation method on organic matter decomposition and element mobilization. (A)
Ian Morrison* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (imorriso@nrcan.gc.ca)

Impacts of site preparation method upon seedling growth and vegetation response. (A)
Brad Sutherland and Fred Foreman* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (fforeman@nrcan.gc.ca)

AQUATIC ECOSYSTEM RESPONSES COMPONENT

Aquatic insect communities as bioindicators of watershed disturbance. (A)
David Kreutzweiser* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (dkreutzw@nrcan.gc.ca)

Sediment loading, particulate matter distribution, and stream discharge monitoring. (A)
David Kreutzweiser* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (dkreutzw@nrcan.gc.ca)

Water quality monitoring and analysis. (A)
Alain Larocque (Business and Technology, Collège Boréal, 21 Lasalle Blvd., Sudbury, Ontario, P3A 6B1) (axlarocque@academe.borealc.on.ca)

Stream temperature monitoring across watersheds. (A)
Robert Mackereth (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Lakehead University Campus, 955 Oliver Road, Thunder Bay, Ontario, P7B 5E1) (rob.mackereth@mnr.gov.on.ca)

Other studies (harvesting productivity, forest vegetation response, forest regeneration, site productivity and biomass dynamics, songbird populations and activity, etc.) will be finalized when plans are completed for harvesting treatments on the watersheds. Contact David Kreutzweiser for details (dkreutzw@nrcan.gc.ca).

MISCELLANEOUS STUDIES

Effects of light, nutrients, and herbivores on early growth of transplanted spruce seedlings. (C)
Marcy Bast and Richard Reader* (Department of Botany, University of Guelph, Guelph, Ontario, N1G 2W1) (M.Sc. thesis by Bast) (rreader@uoguelph.ca)

Boreal Mixedwood Demonstration Forest. (C)
Allan Cameron* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (alcam@nrcan.gc.ca)

Effect of nitrogen deposition on mycorrhizal functioning in forests dominated by Populus tremuloides. (A)
John Neville and John Klironomos* (Department of Botany, University of Guelph, Guelph, Ontario, N1G 2W1) (Ph.D. thesis by Neville) (jklirono@uoguelph.ca)

Forest succession following spruce budworm outbreaks (re-evaluation of 1948 "Ghent" regeneration plots). (C)
Meiqin Qi and John Scarratt* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (jscarrat@nrcan.gc.ca)

Growth and yield monitoring in undisturbed control blocks. (A)
Mark Roddick* (Ontario Ministry of Natural Resources, Northwest Region Science and Technology, RR#1, 25th Side Road, Thunder Bay, Ontario, P7C 4T9) (mark.roddick@mnr.gov.on.ca)

Long-term songbird population dynamics in relation to spruce budworm populations. (A)
Chris Sanders* (Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5) (csanders@nrcan.gc.ca)

APPENDIX 7

BASELINE DATABASE FILE SUMMARY

To facilitate data sharing among project participants, pre- and post-treatment baseline information is archived in a centralized database administered by the Project Coordinator. The database includes both general data collected as part of the pre- and post-harvest characterization of the research sites, and data from specific studies that may be of interest to other researchers within the project. Those contributing data in the latter category are named in the descriptive listings that follow; anyone citing this data, or information derived therefrom, should acknowledge the appropriate contributor. All citations, including those for unattributed data, should give the source as the "Black Sturgeon Boreal Mixedwood Research Project Database". Where it is necessary to refer to a specific database file, the full path should be quoted, e.g., \\alpha\bmw\bsdata\excel\preharv\tot.xls.

The database is currently not available electronically, and copies of individual data files may be obtained from the Project Coordinator. The list of available files will be supplemented from time to time as additional data is received, and it is intended that eventually the database shall be available online. Project participants are encouraged to share descriptive datasets that may have value to future researchers, once they are prepared to release them for general use. To contribute data, contact the Project Coordinator, Black Sturgeon Boreal Mixedwood Research Project, Canadian Forest Service, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5 (705-759-5740).

A. EXCEL 97 FILES – HARVESTING IMPACTS COMPONENT

A1. Directory: \\alpha\bmw\bsdata\excel\presurv\~

Preliminary Stand Survey
Preliminary transect survey of prospective Stand 1 and Stand 2 harvesting sites to quantify stand variability prior to laying out harvest compartments. Survey conducted in May 1993.

bstally1.xls - Stand 1: individual plot vegetation data.
bstally2.xls - Stand 2: individual plot vegetation data.
bsvol1.xls - Stand 1: basal area calculations; volume estimates after Honer.
bsvol2.xls - Stand 2: basal area calculations; volume estimates after Honer.

A2. Directory: \\alpha\bmw\bsdata\excel\preharv\~

Pre-harvest Cut-block Survey

Pre-harvest inventory and vegetation surveys of 21 projected harvest compartments and uncut controls, based on 10 permanent sample plots per compartment (same PSPs as used for subsequent post-harvest surveys and inventories). Survey conducted in August 1993.

1%cover.xls - Stand 1: individual PSP vegetation data.
2%cover.xls - Stand 2: individual PSP vegetation data.
stand.xlw - Complete workbook for volume calculations, comprising the following files:-
1bstrees.xls - Stand 1: individual PSP conifer regeneration and prism sweep data.
2bstrees.xls - Stand 2: individual PSP conifer regeneration and prism sweep data.
1mortdat.xls - Stand 1: individual PSP mortality data and volume calculations.
2mortdat.xls - Stand 2: individual PSP mortality data and volume calculations.

1pltdat.xls	-	Stand 1: individual PSP volume data (living trees), derived from 1bstrees.xls
2pltdat.xls	-	Stand 2: individual PSP volume data (living trees), derived from 2bstrees.xls
1sttot.xls	-	Stand 1: individual compartment totals/averages for living and dead trees, summarized from 1pltdat.xls
2sttot.xls	-	Stand 2: individual compartment totals/averages for living and dead trees, summarized from 2pltdat.xls
tot.xls	-	Stand 1 and 2 volume totals/averages for living and dead trees, summarized from 1sttot.xls and 2sttot.xls

A3. Directory: \\alpha\bmw\excel\soils\~

Pre-harvest Soils Data

Processed and analyzed at Great Lakes Forestry Centre (GLFC); analytical methods and sampling details on hard-copy file.

min93.xls	-	Pre-harvest mineral soil analysis for samples collected July 1993. One sample from each of 10 PSPs per harvested compartment. Some missing values due to sampling errors and inadequate samples; no CEC or mechanical analysis.
min95.xls	-	Supplemental mineral soil analysis for samples collected June 1, 1995. One sample from each vegetation plot (4) in each harvested compartment. Full suite of mineral analyses, CEC, and mechanical soil analyses.
org93.xls	-	Pre-harvest organic layer analysis for samples collected July 1993. One sample from each of 10 PSPs per harvested compartment.

A4. Directory: \\alpha\bmw\bsdata\excel\harvest\~

harvrec.xls	-	Record of dates on which individual compartments were harvested in the harvesting component. (Also available as a Wordperfect 8 document — see below)
harvols.xls	-	Record of volumes removed by harvested compartment (figures supplied by Bowater Inc.). (Also available as a Wordperfect 8 document — see below).

A5. Directory: \\alpha\bmw\bsdata\excel\slash\~

slash94.xls	-	Post-harvest slash (fuel) loading determinations carried out by GLFC Fire Research Group in June 1994. Four assessment triangles per harvested compartment and two control compartments, except for cut-to-length compartments (Timberjack single-grip harvester), where two triangles were placed between the forwarder trails and two triangles within the forwarder trails. Methodology after McRae et al. (1979) [CFS Information Report O-X-287].

A6. Directory: \\alpha\bmw\bsdata\excel\structur\~

smmamhab.xls	-	Raw data from 1993 pre-harvest sampling of structural elements of small mammal habitats within all 21 compartments of the harvesting impacts component. Data collected by Drs. Abraham and Rodgers, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario. Methodology and variable names on hard-copy file.

A7. Directory: \\alpha\bmw\bsdata\excel\canopy\~

canopy93.xls	-	Pre-harvest hemispherical canopy photo data for PSPs in harvested compartments and uncut controls, with raw data from image analysis and the calculated percentage canopy cover. Methodology and variable names on hard-copy file.
canopy94.xls	-	Post-harvest (1994) hemispherical canopy photo data for same PSPs as above.
mamm94.xls	-	Post-harvest (1994) hemispherical canopy photo data for bird and small mammal monitoring stations. Methodology as above. Locations and variable names on hard-copy file.

A8. Directory: \\alpha\bmw\bsdata\excel\inventry\~

<u>Permanent Sample Plot Inventory</u>

Inventory and volume calculations for harvested compartments, based on 10 permanent sample plots per compartment. Inventory protocols and calculation formulae on hard-copy file.

i. 1994 (post-harvest) inventory.

1trees94.xls	-	Stand 1: individual tree inventory, DBH, with height and volume calculations for living, dead, and windblown trees.
2trees94.xls	-	Stand 2: individual tree inventory, DBH, with height and volume calculations for living, dead, and windblown trees.
stand1.xlw	-	Workbook of volume calculations for Stand 1, comprising the following files:-
1trees94.xls	-	Stand 1 tree inventory, as above.
1psp94.xls	-	Stand 1 inventory summary and volume calculations by individual PSP.
1block94.xls	-	Stand 1 inventory summary and volume totals by harvested compartment.
stand2.xlw	-	Workbook of volume calculations for Stand 2, comprising the following files:-
2trees.xls	-	Stand 2 tree inventory as above.
2psp94.xls	-	Stand 2 inventory summary and volume calculations by individual PSP.
2block94.xls	-	Stand 2 inventory summary and volume totals by harvested compartment.

ii. 1996 inventory.

1trees96.xls	-	Stand 1: individual tree inventory, DBH, with height and volume calculations for living, dead, and windblown trees.
2trees96.xls	-	Stand 2: individual tree inventory, DBH, with height and volume calculations for living, dead, and windblown trees.

B. EXCEL 97 FILES – FIRE ECOLOGY COMPONENT

B1. Directory: \\alpha\bmw\bsdata\excel\preburn\~

Data collected by Dr. M. Johnston and J.A. Elliott, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario.

prefuel.xls	-	Pre-burn fuel loading data for prescribed burn Compartments 1 to 8.
preveg.xls	-	Pre-harvest vegetation data for prescribed burn Compartments 1 to 16: organic layer information; FEC stand types; percent cover for trees, shrubs and herbs; tree condition; live and dead tree biomass. (Also available as a Wordperfect 8 document — see below)

B2. Directory: \\alpha\bmw\bsdata\excel\postburn\~

Data collected by Dr. M. Johnston and J.A. Elliott, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario.

ashdata.xls	-	Chemical analysis of ash samples collected immediately following the prescribed burn on 29 May, 1996, and 30 depth of burn measurements for each of the 40 fuel triangles in Compartments 1 to 8.
postfuel.xls	-	Post-burn residual fuel loading data for prescribed burn Compartments 1 to 8.
postsoil.xls	-	Post-burn chemical analysis of mineral soil and organic matter samples collected in the fall of 1996 and 1997.
postplnt.xls	-	Post-burn chemical analysis of plant samples collected in August 1996.

postveg.xls - Post-burn vegetation data for prescribed burn Compartments 1 to 8, collected in 1996, 1997, and 1998: percent cover for all tree, shrub and herb species located in 100 5x5 m plots.

seedbank.xls - Post-burn seedbank data collected in 1997.

C. MISCELLANEOUS FILES

C1. Directory: \\alpha\bmw\bsdata\wpdocs\~

Harvesting Records

harvrec.wpd - Harvesting record for harvesting impacts component (treatment record and logging dates for Stands 1 and 2). (Wordperfect 8 – also available in Excel 97, see above)

harvols.wpd - Harvested volumes, by harvested compartment for Stands 1 and 2, and prescribed burn compartments (fire ecology component). (Wordperfect 8 — also available in Excel 97, see above)

Fire Ecology Component

preveg.wpd - Pre-harvest data for prescribed burn compartments (13 tables): organic layer information; stand structure; basal area; vegetation cover; tree condition; FEC types. Data collected by OMNR, Northwest Science & Technology, Thunder Bay, Ontario. (Wordperfect 8 — also available in Excel 97, see above)

Budworm Sampling Plots

budwormplots.wpd - Sampling details and 22 tables summarizing results of vegetation, tree, shrub, and herb surveys in budworm sampling/bird monitoring plots BAA, BAB, and OBP for years 1977, 1980, 1985, 1993, and 1995. Data collected by Dr. C.J. Sanders, Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

C2. Directory: \\alpha\bmw\bsdata\sigma\budwormplots\~

Budworm Sampling Plots

Histograms of basal area in budworm sampling plots BAA and OBP by species and years (1967, 1977, 1980, 1985, 1993, and 1995) (SigmaPlot 4.0). Data collected by Dr. C.J. Sanders, Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario.

baa-ba.jnb - Basal area of trees in BAA
baasttt.jnb - Total number of trees in BAA
baabatt.jnb - Total living basal area in BAA
baababf.jnb - Basal area of balsam fir in BAA
baabaws.jnb - Basal area of white spruce in BAA
baababs.jnb - Basal area of black spruce in BAA
baabawb.jnb - Basal area of white birch in BAA
baabata.jnb - Basal area of trembling aspen in BAA
obp-ba.jnb - Basal area of trees in OBP
obpsttt.jnb - Total number of trees in OBP
obpbatt.jnb - Total living basal area in OBP
obpbabf.jnb - Basal area of balsam fir in OBP
obpbaws.jnb - Basal area of white spruce in OBP
obpbabs.jnb - Basal area of black spruce in OBP
obpbawb.jnb - Basal area of white birch in OBP
obpbata.jnb - Basal area of trembling aspen in OBP

APPENDIX 8

APPENDIX 8

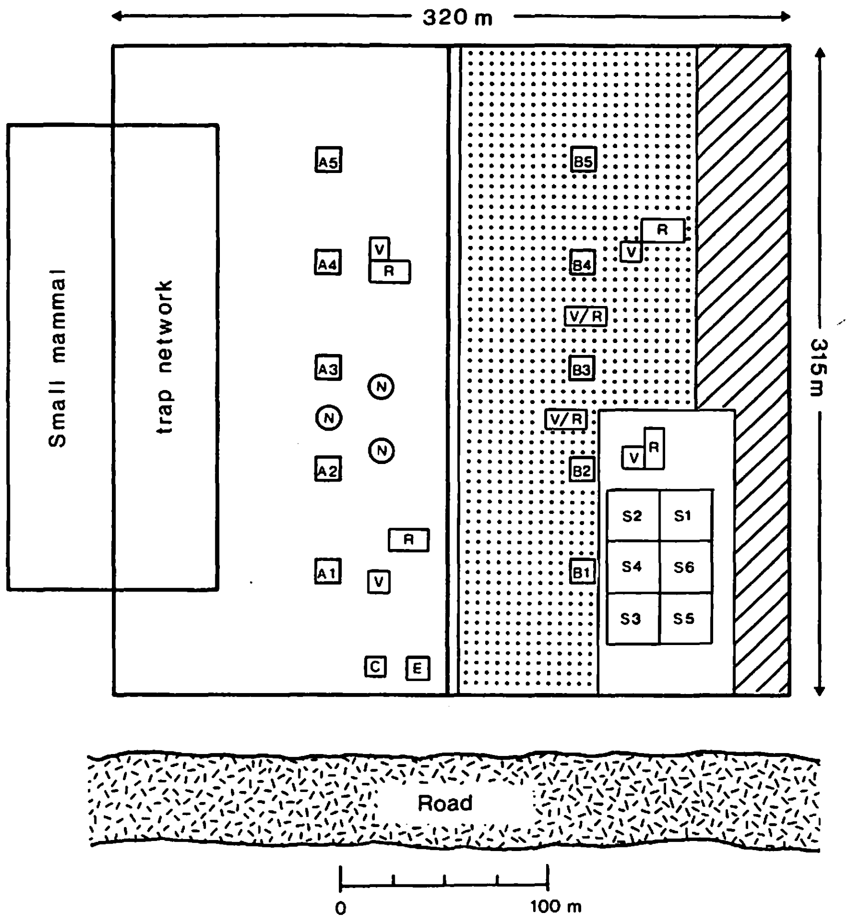
HARVESTING IMPACTS COMPONENT COMPARTMENT DIAGRAMS

All compartments except the patch-cut treatments are divided into two halves by an access path that runs from the main access road to the rear of the compartment. One half is available for future sub-treatments, while the other half will be reserved and left untreated. The small mammal trapping networks are established on the reserved (untreated) half of each compartment.

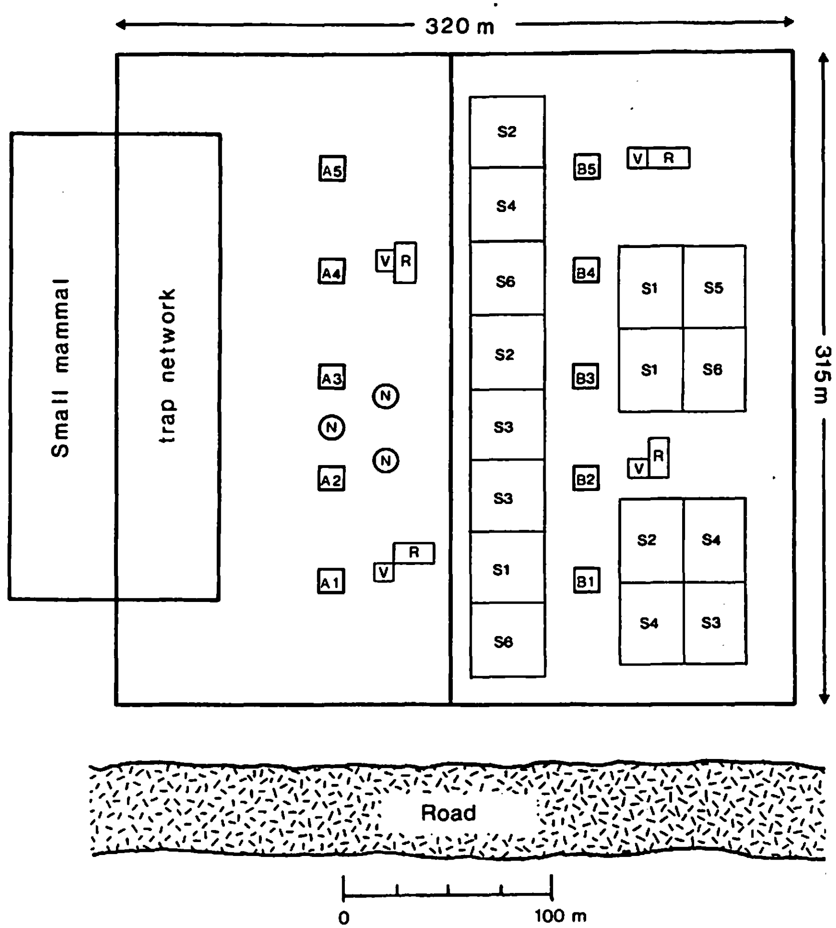
The compartment diagrams show the locations of some of the more permanent study plots. Indicated compartment boundaries and relative positions of the mammal trapping networks are conceptual only; they are neither to scale nor necessarily of the true configuration (see Figs. 3.1 and 3.2 for comparison). The positions of the permanent sample plots (PSPs) are also conceptual with respect to the compartment boundaries. The rows of PSPs are nominally aligned 100 m from the left and right compartment boundaries, respectively, with 120 m between the rows and 50m between PSPs within the rows (Fig. 3.3). The indicated positions of other research plots are accurate in relation to the closest PSPs.

Key to study plots (refer to text for details):

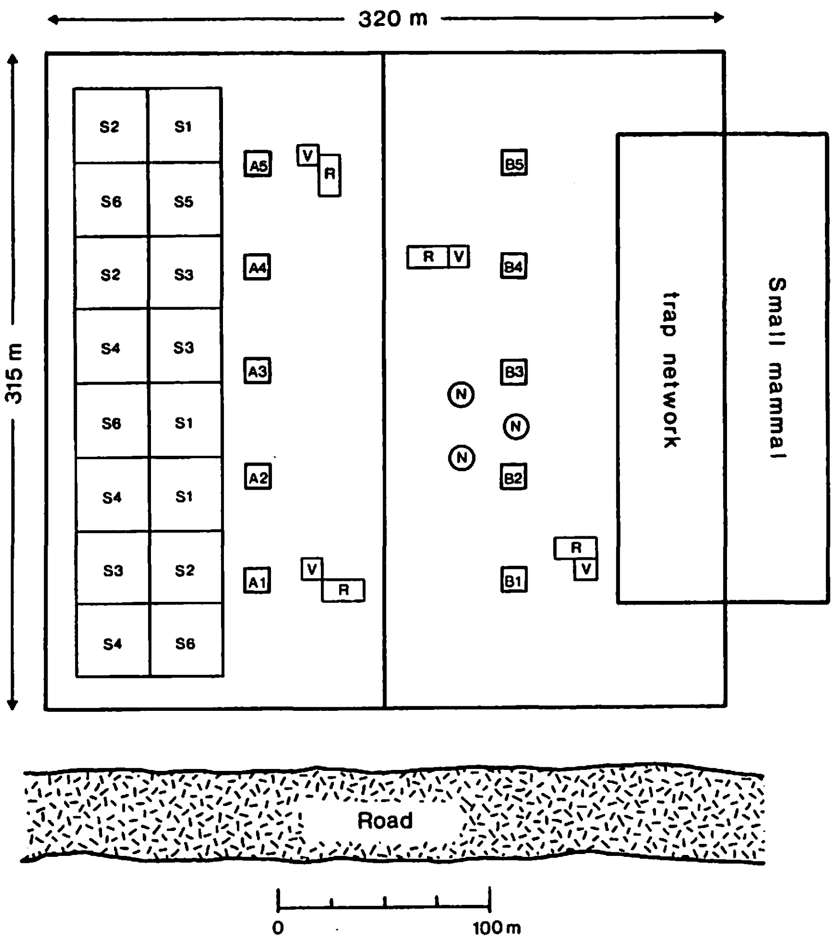
- Square plots numbered "A1" to "A5" and "B1" to "B5" indicate 10x10 m PSPs (Section 3.2.4)
- Square plots marked "V" indicate 10x10 m vegetation succession plots.
- Rectangular plots marked "R" indicate 10x20 m regeneration monitoring plots.
- Rectangular plots in the clearcuts marked "V/R" indicate 10x20 m supplementary joint vegetation and regeneration assessment plots, established after "operational" site preparation in 1995 (see Section 3.7.1).
- Circular plots marked "N" indicate nutrient and organic matter cycling study plots.
- Square plots in Compartments 1-1 and 1-14 marked "E" and "C" indicate 10x10 m fenced mammal exclosures and associated unfenced controls, respectively, for evaluation of animal browsing activity.
- Square plots marked "Sn" indicate experimental plots site-prepared in September 1995 (Section 3.7.1), and subsequently planted with spruce container stock in June 1996 (Section 3.7.2), viz:
  - S1 = Untreated control;
  - S2 = Mechanical soil mixing in strips;
  - S3 = Mechanical patch screefing;
  - S4 = Mineral mound;
  - S5 = Mixed mound;
  - S6 = Herbicide only (Vision®).
- On the clearcuts, shaded areas (dots or hatching) were operationally site prepared with a Bräcke cultivator in September 1995 (Section 3.7.1). Hatched areas received only mechanical site preparation. Areas shaded with dots received concurrent herbicide treatment (Vision®) in addition. Both site-prepared and untreated areas (unshaded) of the clearcuts were planted operationally with overwintered containerized black spruce in June 1996 (Section 3.7.2). (This applies to the non-reserved sides of the compartments only).
- Supplementary experimental plots established on the operationally site prepared areas in Compartments 1-7, 1-9, and 2-1 (Section 3.7.2) were planted with spruce container stock in June 1996, as follows:
  - S7 = Experimental planting on Bräcke scalps;
  - S8 = Experimental planting on Bräcke scalps with herbicide;
  - S9 = Experimental planting on untreated land.
- In the patch cuts (Compartments 1-8, 1-10, 2-7), areas shaded with small circles were site prepared with a Bräcke cultivator. Dots indicate Bräcke site preparation with concurrent herbicide treatment (Vision®). Areas shaded with small crosses received herbicide treatment only. (see Section 3.7.3)
- All plot markers are colour coded to indicate the type of plot and the responsible study leader. A full listing of post and flagging colour allocations is available from the Project Coordinator.



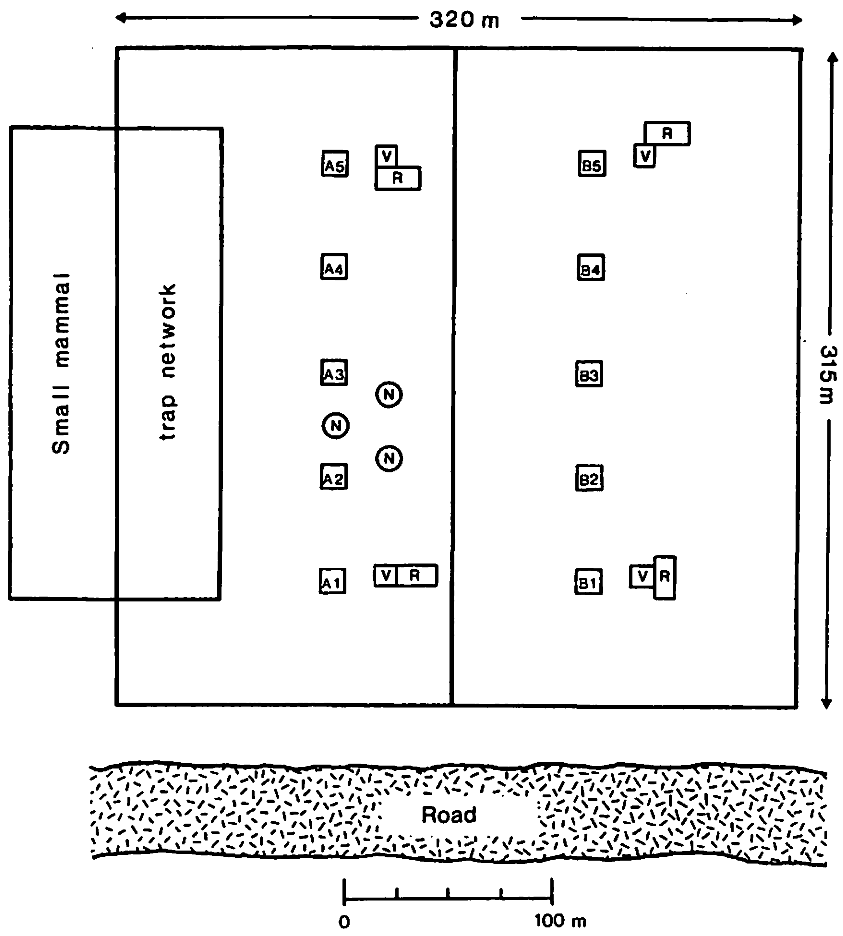
Stand 1, Compartment 1. Treatment: Clearcut 1i
Centre line bearing: 201°



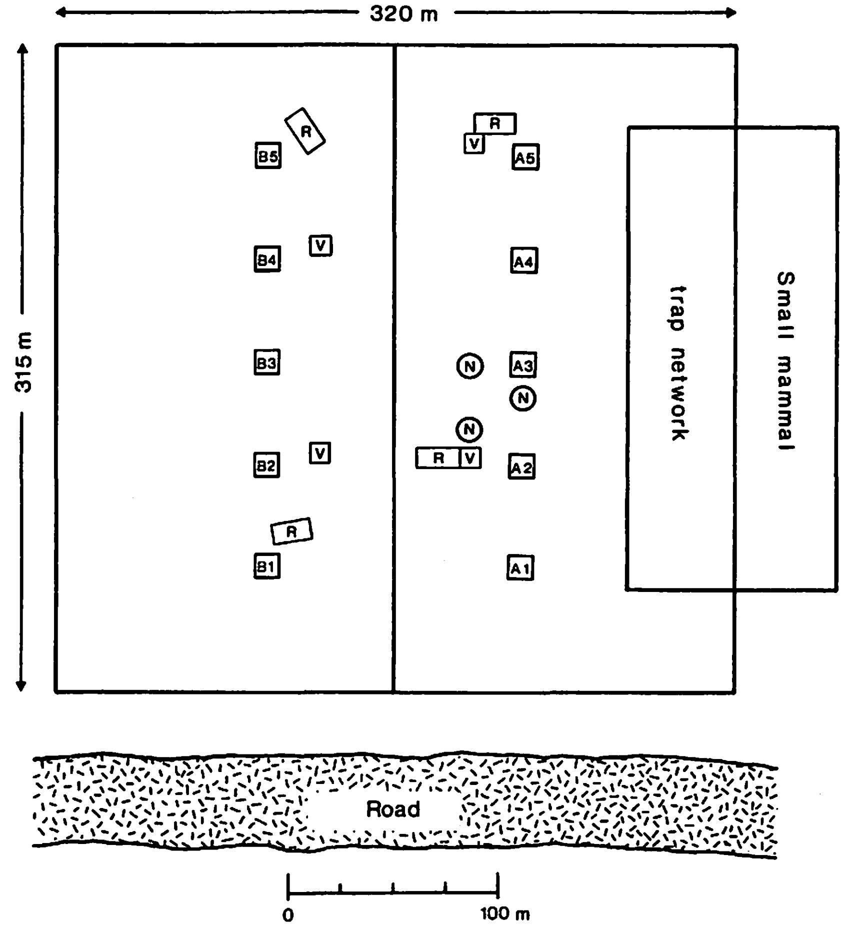
Stand 1, Compartment 2. Treatment: Partial cut 2i
Centre line bearing: 210°



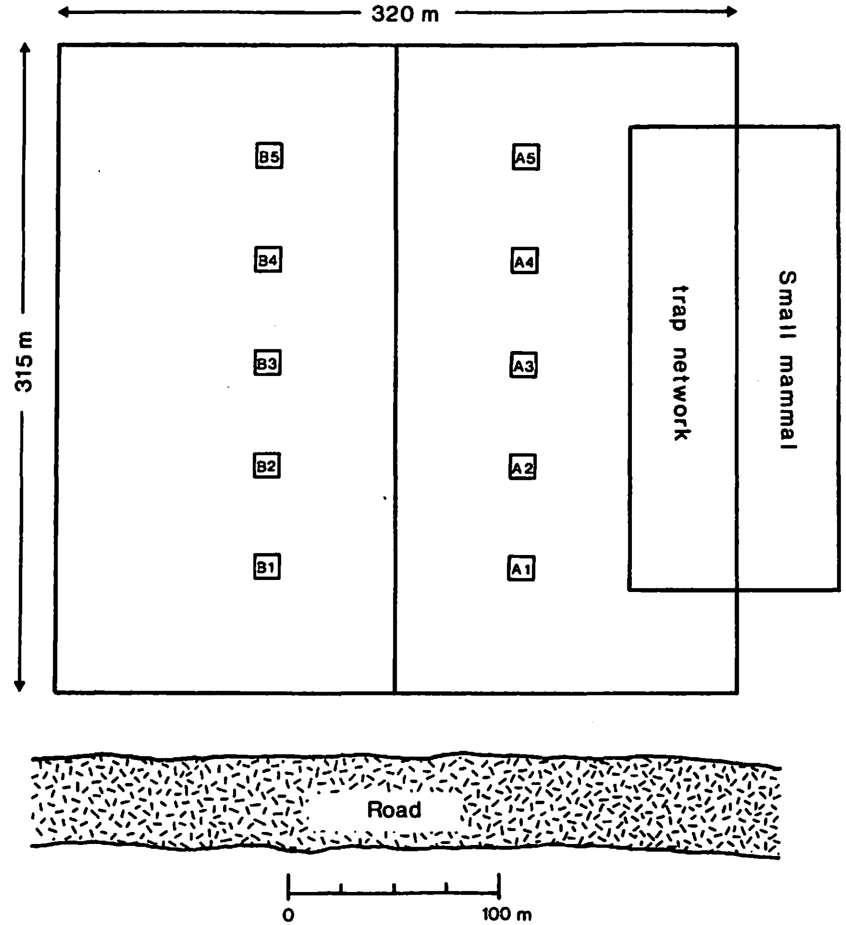
Stand 1, Compartment 3. Treatment: Partial cut 2i
Centre line bearing: 209°



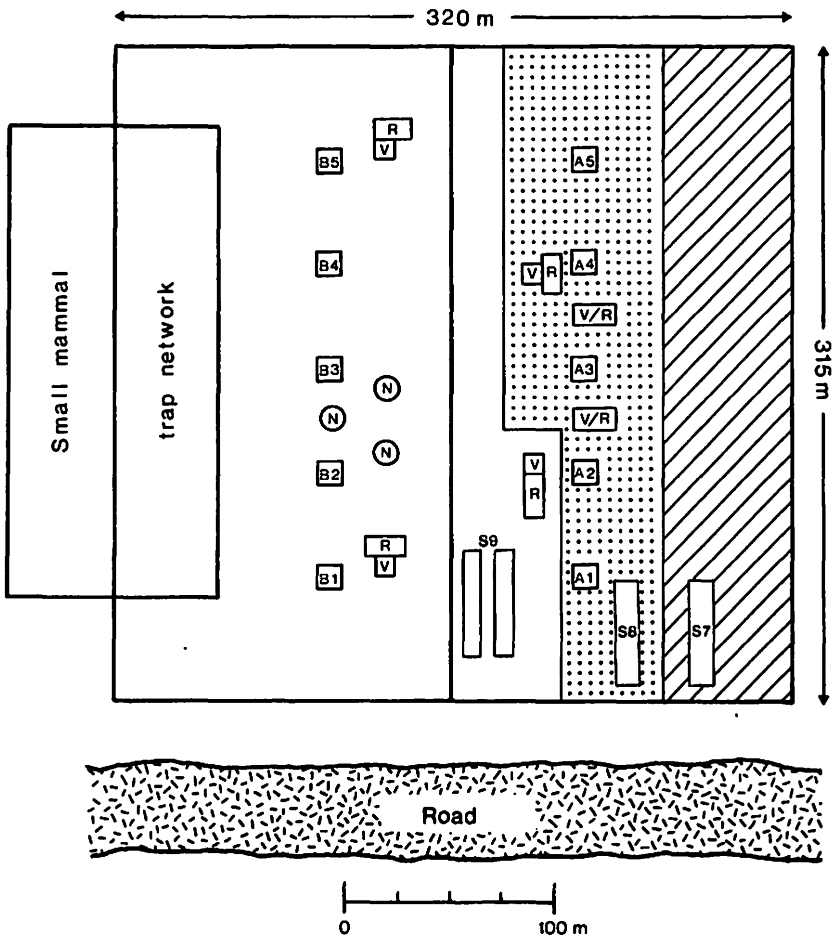
Stand 1, Compartment 4. Treatment: Uncut control
Centre line bearing: 210°



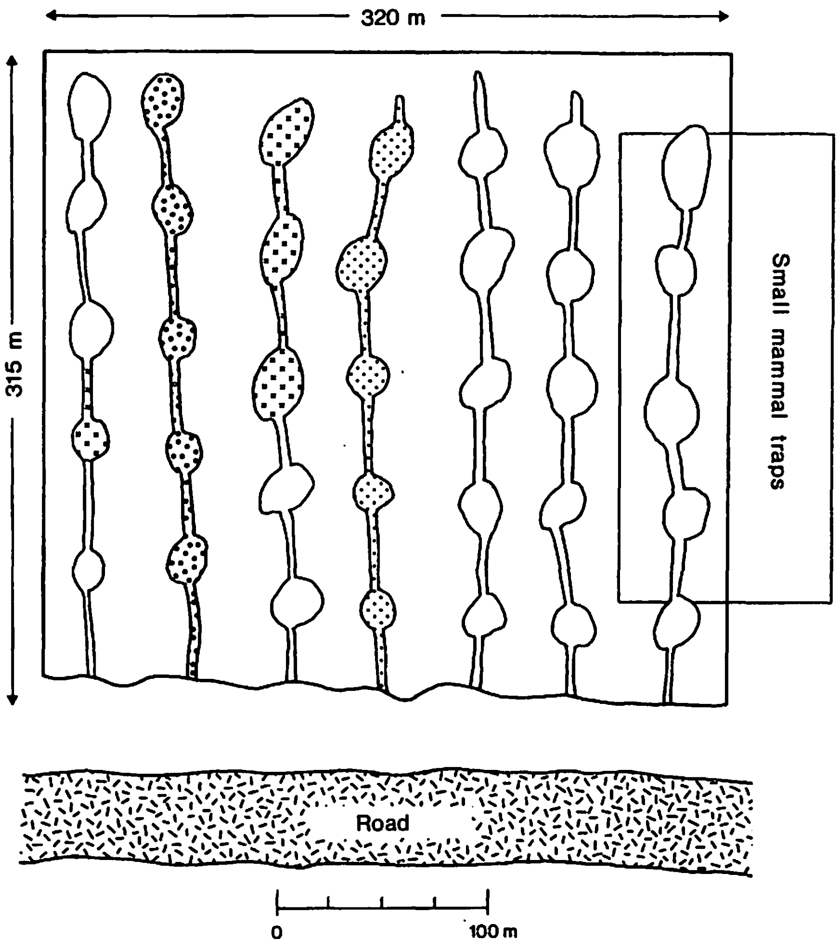
Stand 1, Compartment 5. Treatment: Partial cut 2ii
Centre line bearing: 20°



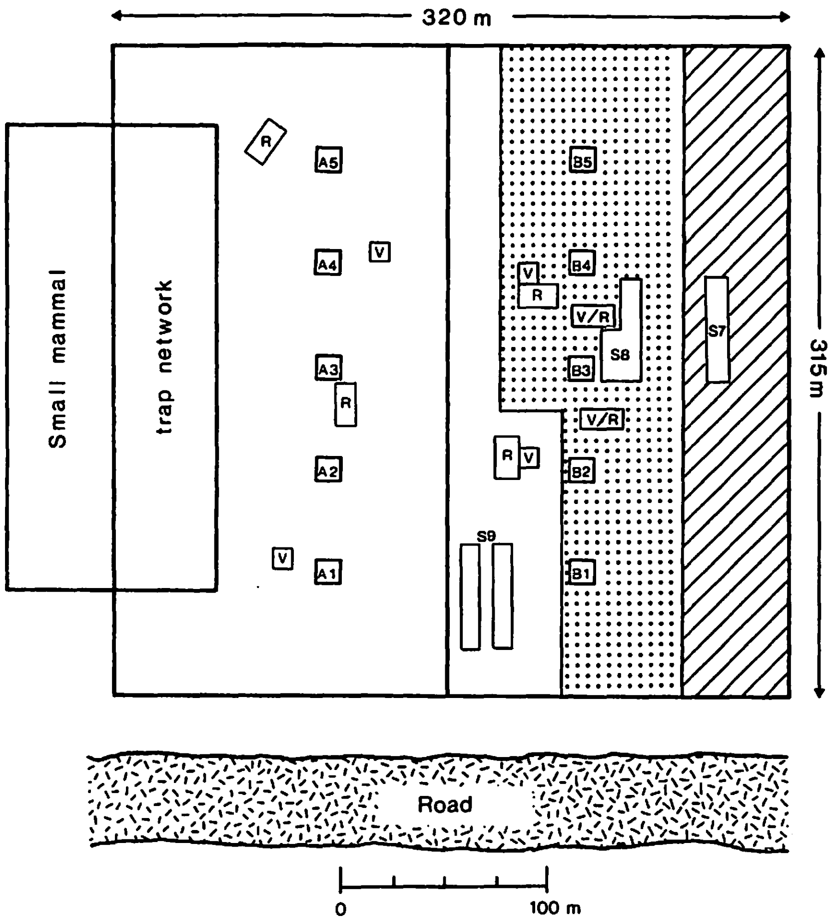
Stand 1, Compartment 6. Treatment: Uncut
Centre line bearing: 27°



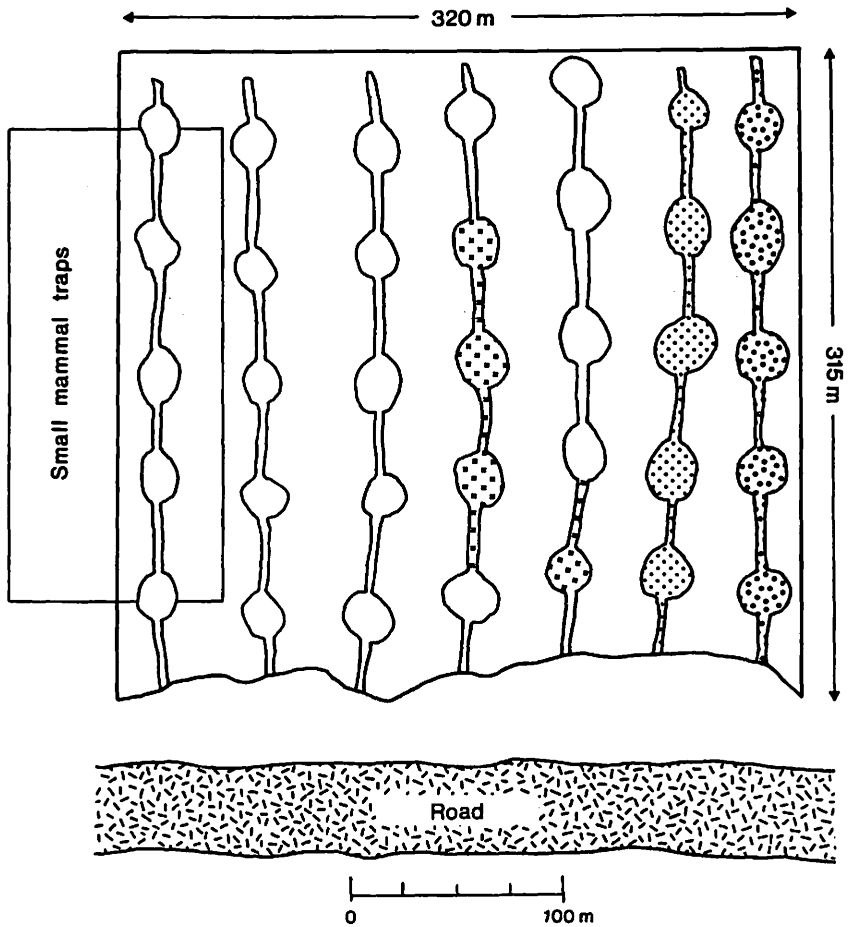
Stand 1, Compartment 7. Treatment: Clearcut 1ii
Centre line bearing: 30°



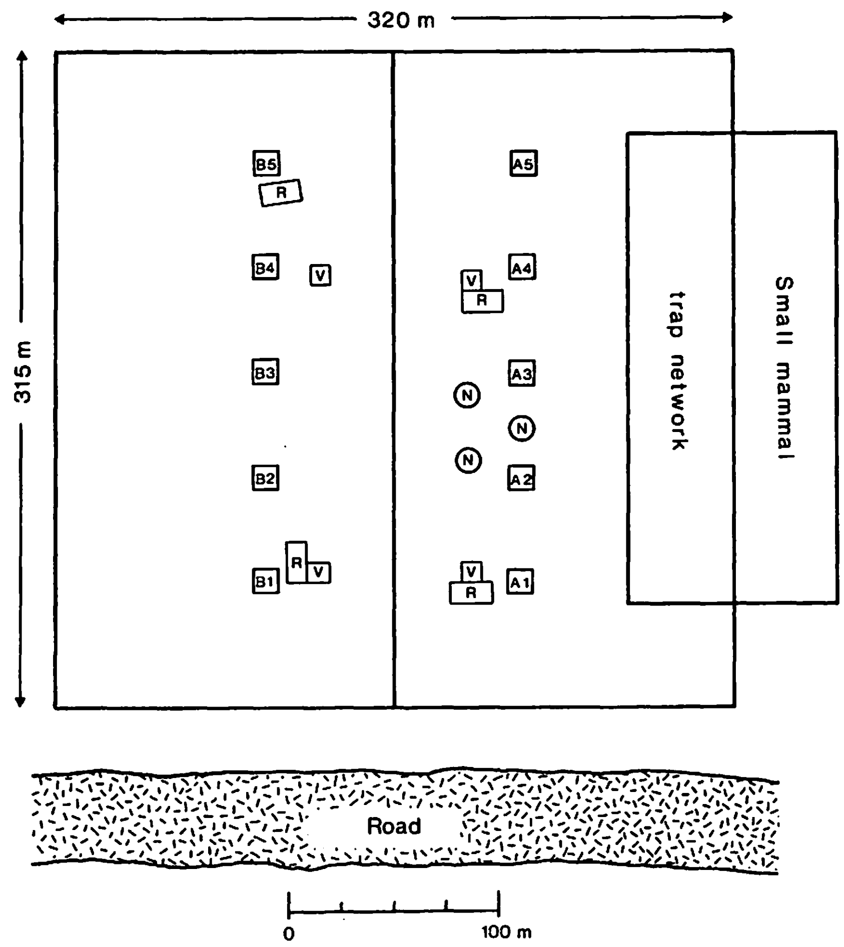
Stand 1, Compartment 8. Treatment: Patch cuts
Centre line bearing: 27°



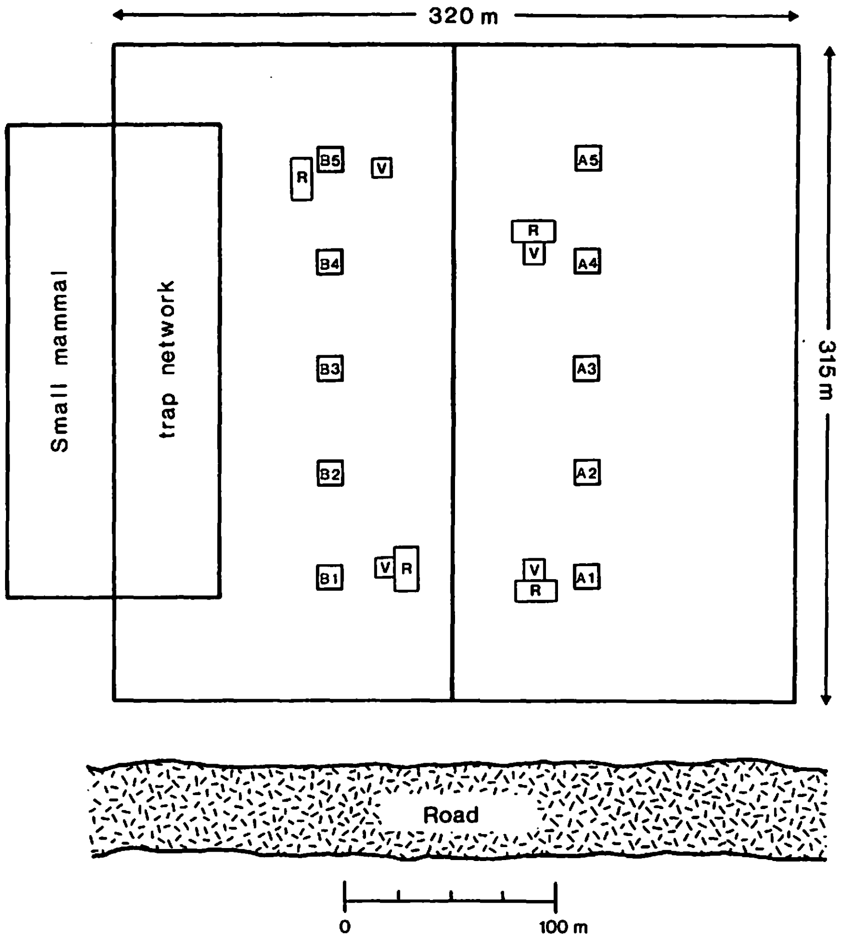
Stand 1, Compartment 9. Treatment: Patch cuts
Centre line bearing: 27°



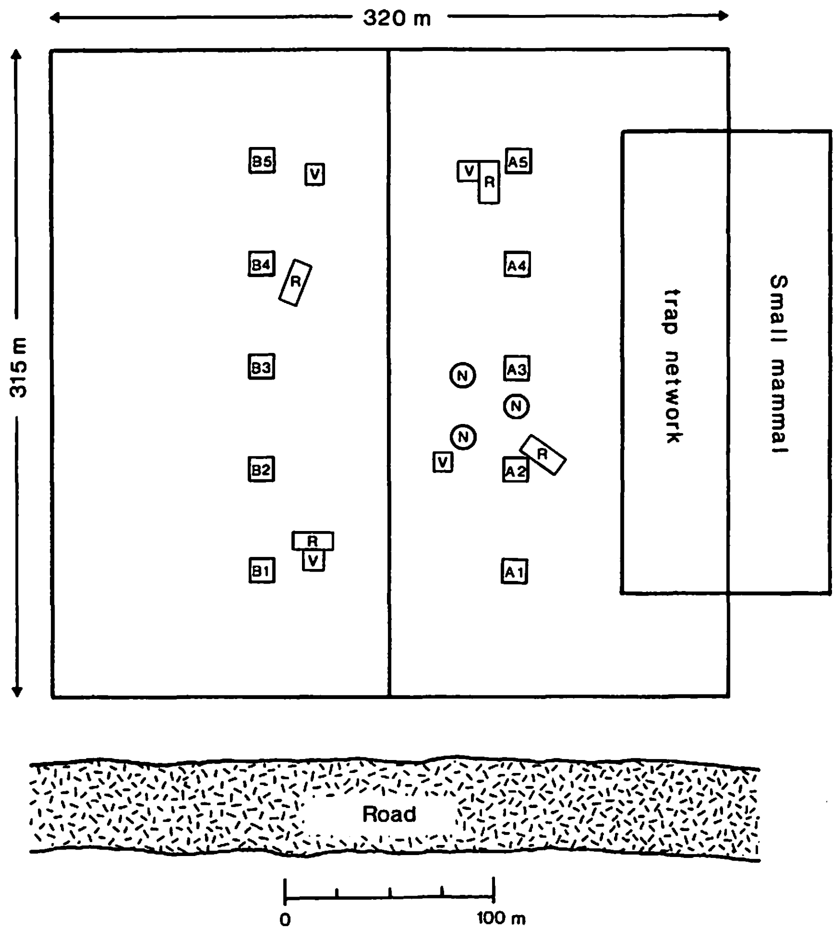
Stand 1, Compartment 10. Treatment: Patch cuts
Centre line bearing: 217°



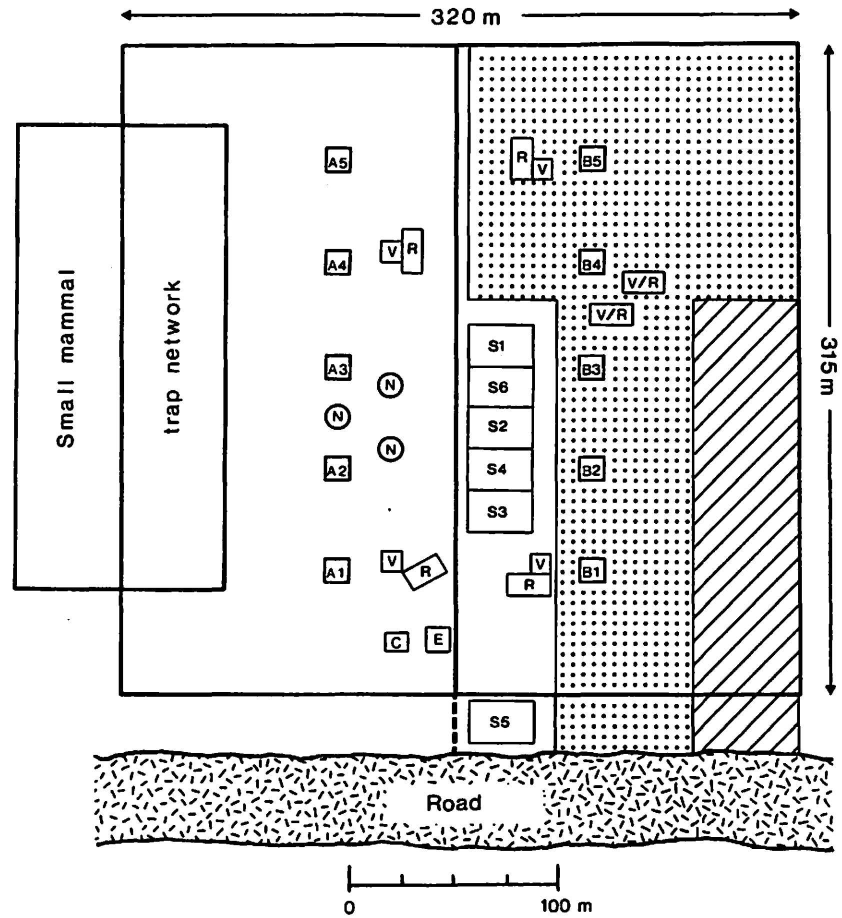
Stand 1, Compartment 11. Treatment: Partial cut 2ii
Centre line bearing: 214°



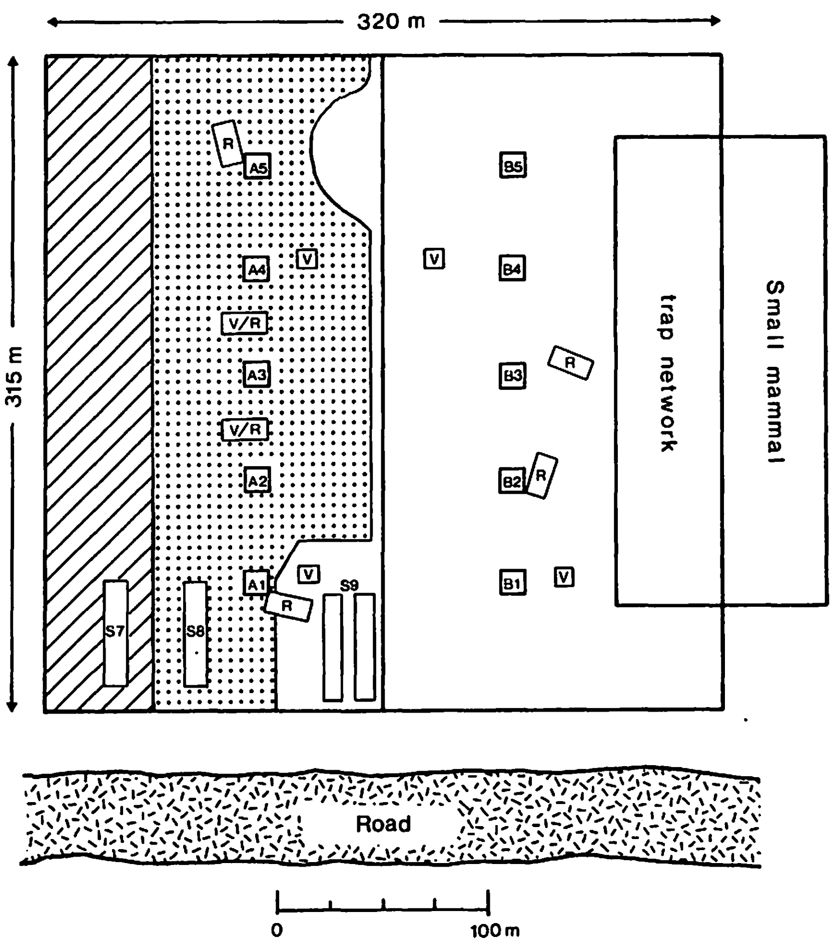
Stand 1, Compartment 12. Treatment: Partial cut 2iii
Centre line bearing: 120°



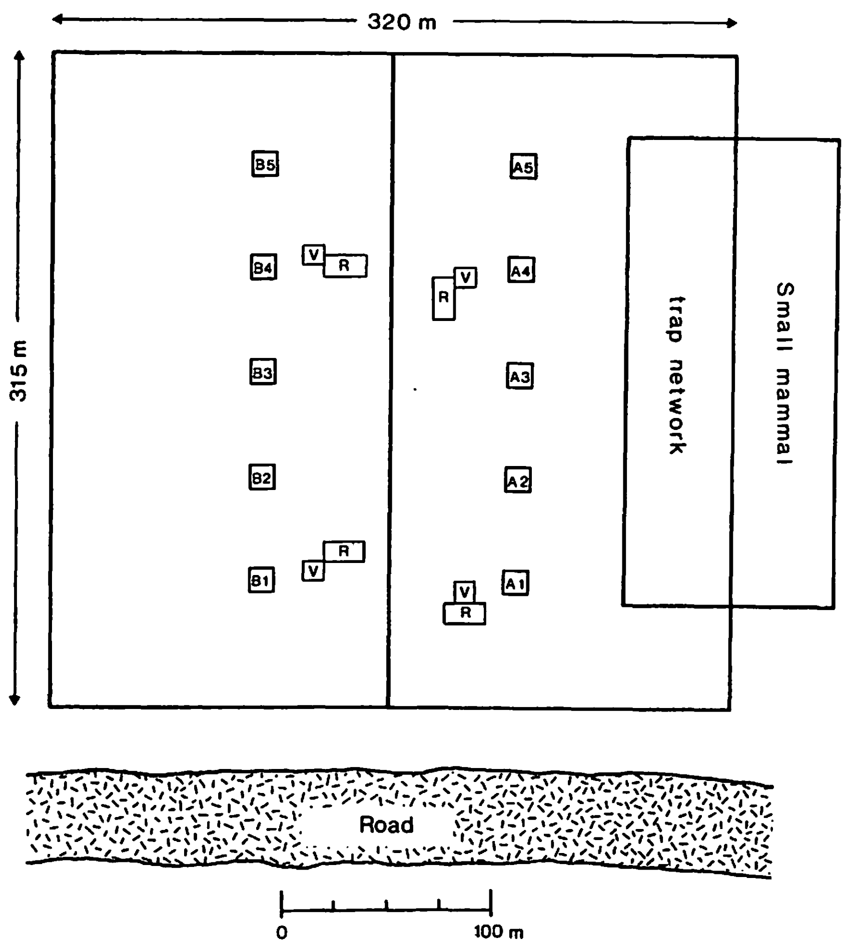
Stand 1, Compartment 13. Treatment: Uncut control
Centre line bearing: 128°



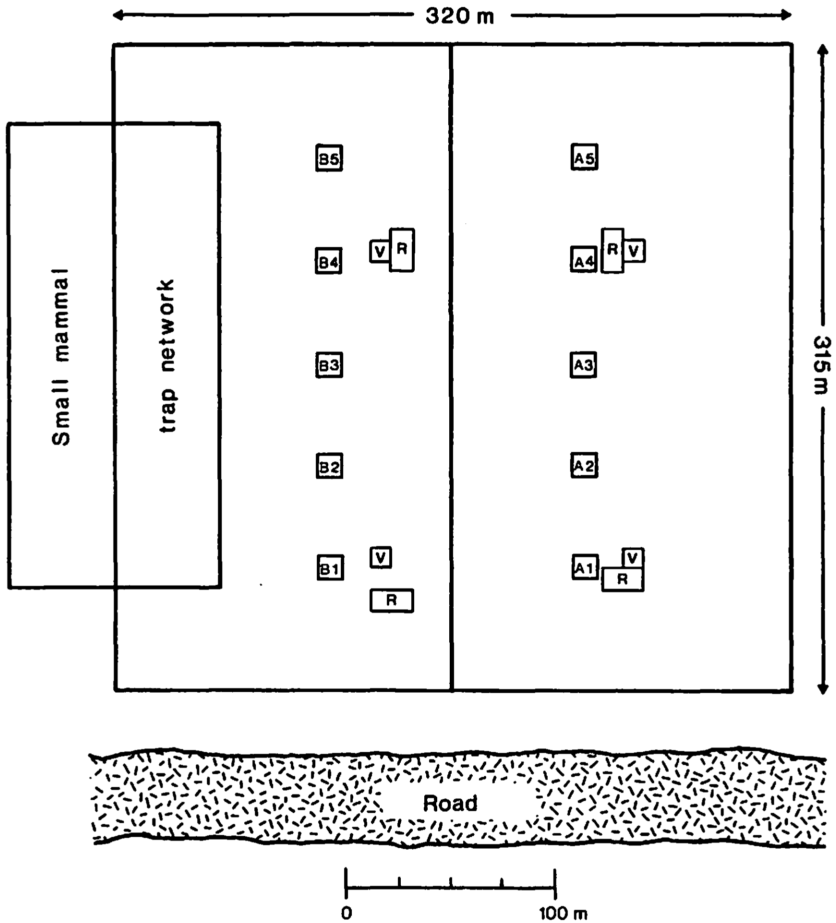
Stand 1, Compartment 14. Treatment: Clearcut 1i
Centre line bearing: 295°



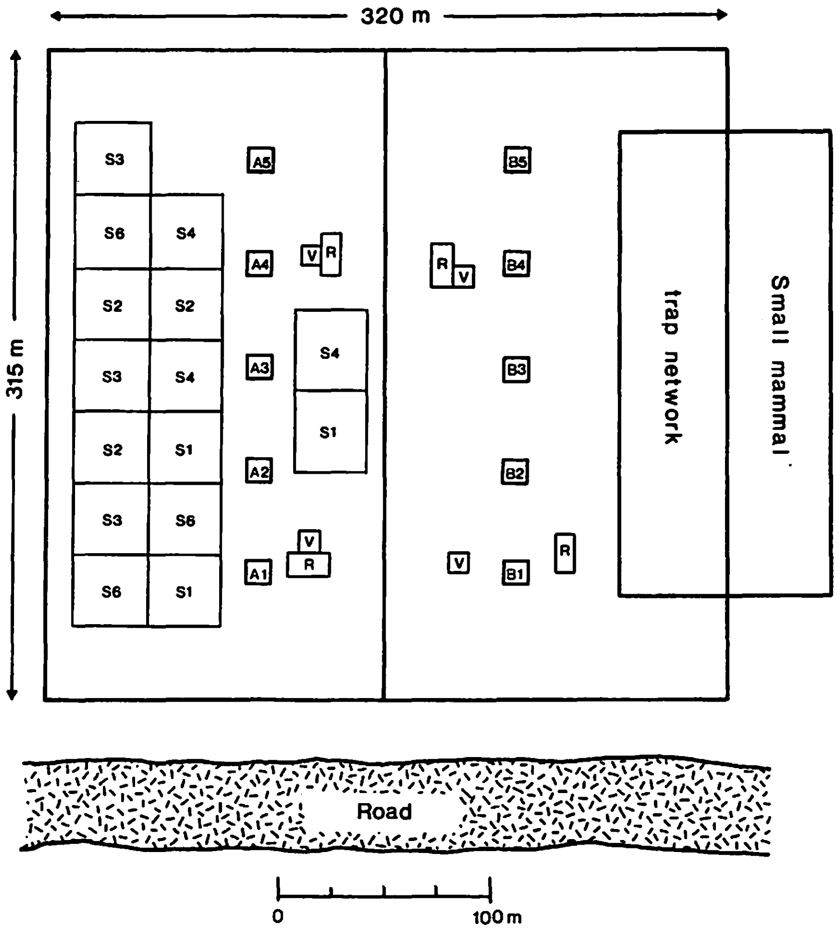
Stand 2, Compartment 1. Treatment: Clearcut 1i
Centre line bearing: 7°



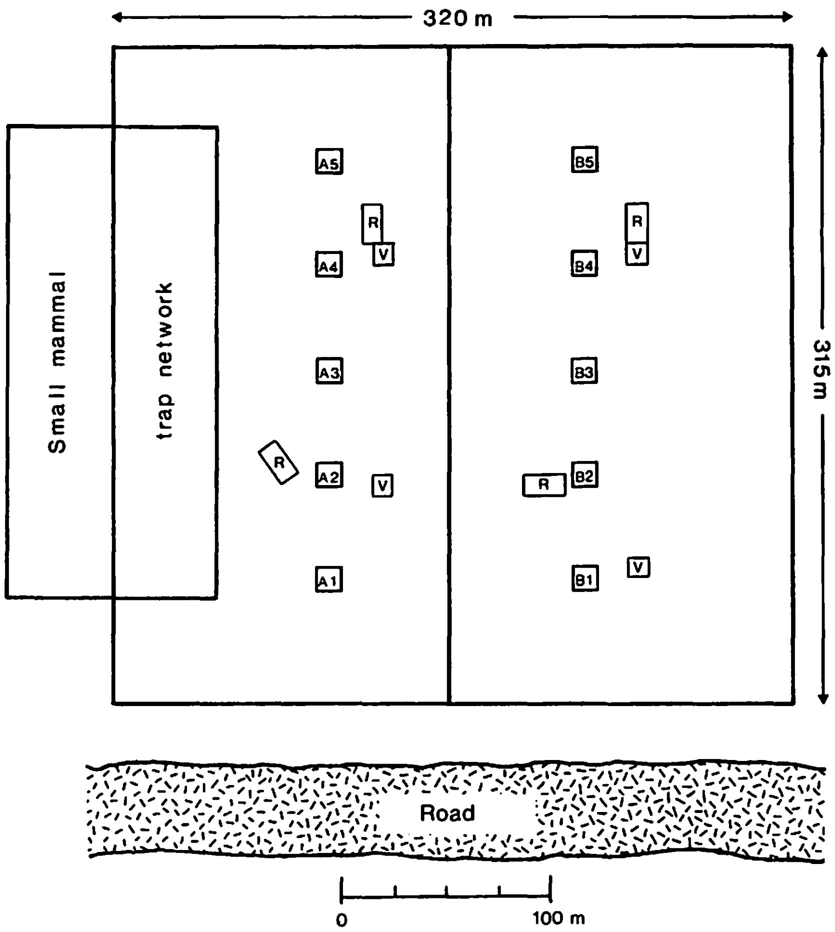
Stand 2, Compartment 2. Treatment: Partial cut 2ii
Centre line bearing: 186°



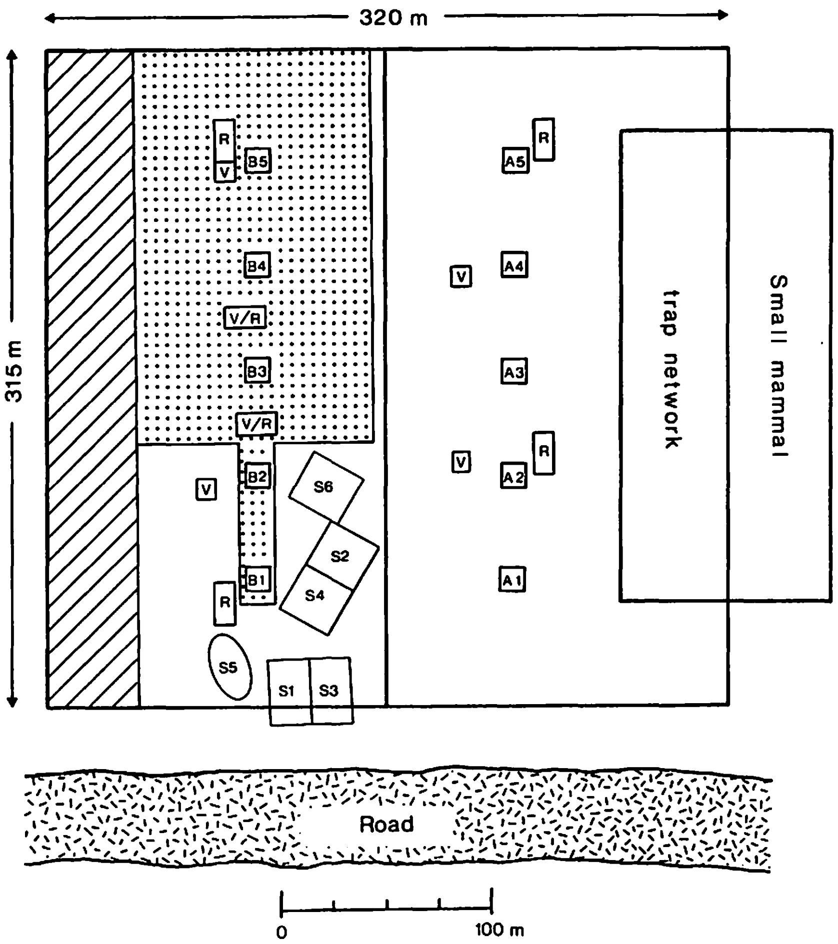
Stand 2, Compartment 3. Treatment: Parial cut 2iii
Centre line bearing: 180°



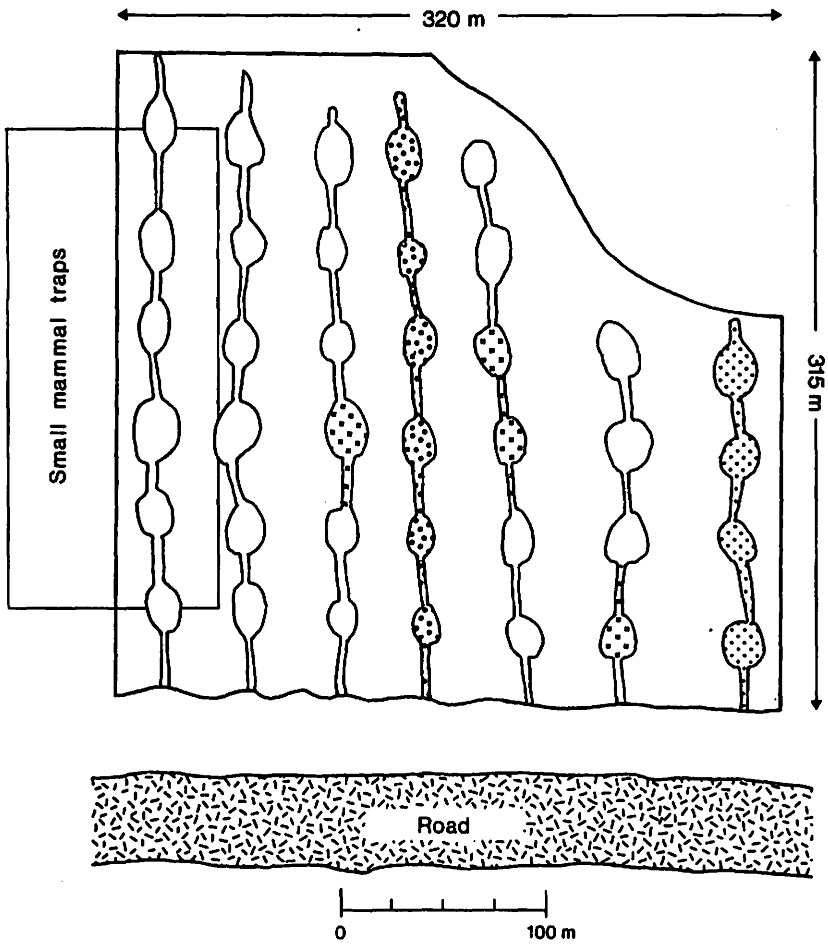
Stand 2, Compartment 4. Treatment: Parial cut 2i
Centre line bearing: 1°



Stand 2, Compartment 5. Treatment: Uncut control
Centre line bearing: 6°



Stand 2, Compartment 6. Treatment: Clearcut 1i
Centre line bearing: 88°



Stand 2, Compartment 7. Treatment: Patch cuts
Centre line bearing: 359°