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Overstory Composition of Live Residuals in Fire Affected Landscapes of Northern Alberta

by

Cheryl Lynn Smyth ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Environmental Biology and Ecology

Department of Biological Sciences

Edmonton, Alberta

Fall, 1999

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Overstory Composition of Live Residuals in Fire Affected Landscapes of Northern Alberta* submitted by *Cheryl Lynn Smyth* in partial fulfillment of the requirements for the degree of *Master of Science in Environmental Biology and Ecology*.

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Date Approved: 27 September 1999

ABSTRACT

Natural disturbance processes, such as wildfire, are influenced by pre-disturbance landscape pattern, therefore pre-disturbance landscape information can be used to explain post-disturbance landscape pattern. This study investigates the relationship between pre-fire vegetation and the distribution of unburned residuals within twenty fire affected landscapes of the boreal forest of northern Alberta. Over one-third of the residuals included in the study contained a significantly greater proportion of deciduous, mixedwood, white spruce or muskeg dominated vegetation type than would be expected from random. The influence of vegetation on residuals varied between fires, ranging from 0 to 100% of the residuals associated with one of the four vegetation types considered. The percentage of residuals with a significantly greater proportion of deciduous, mixedwood, white spruce or muskeg vegetation within a fire was positively correlated to fire size. The percentage of residuals associated with one of the four vegetation types was not correlated with annual area burned.

ACKNOWLEDGEMENTS

I wish to thank several people and organisations involved both directly and indirectly over the course of this reserach. First, thanks to my supervisory committee, Drs. Mark Dale, Peter Crown and Phil Lee, for their guidance and advice.

Primary funding for this research was provided by the Sustainable Forest Management Networks of Centres of Excellence. Aerial photographs, digital data and paper maps were provided by Alberta-Pacific Forest Industries Inc., Daishowa-Marubeni International Ltd., and Alberta Environmental Protection, Forest Resource Information Branch. Thanks to Shawn Wasel, Stan Boutin, and Bob Wynes for suggestions and discussion during project development. Research assistance was provided by a number of hard working individuals including Laura Goodchild, Debbie Mucha, Sophie Munoz, Trish Kitsco, Rena Vandenbos, and Tony Gaboury. Thanks for your efforts.

The GIS work and sampling portions of this project were performed in the Spatial Information Systems Laboratory, Department of Renewable Resources. Special thanks to Tim Martin and Rick Pelletier for your expertise and putting up with all the computer related queries.

To my family and friends, thanks for your encouragement and understanding over the past few years. I am also grateful to my officemate Rich Little, thanks for all your help and for the demented office adventures. Finally, thanks to my partner Jeff, your patience and support were remarkable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

Wildfire is recognised as the primary mechanism of natural disturbance throughout the boreal forest. Due to its importance in the structuring and dynamics of forest communities, much research has been undertaken to understand fire behaviour, frequency, and history. The scope of fire research ranges from retrospective studies describing centuries of climatic change in relation to fire frequency (Clark 1990) to empirical fire behaviour studies spanning less than an hour (Quintilio *et al.* 1991). Despite vast amounts of research on fire, few generalisations can be made regarding fire frequency and behaviour. This is due to the relative importance of numerous influences varying and interacting at a wide range of spatial and temporal scales. Some of the more common variables found to influence fire frequency and behaviour include weather (Johnson and Wowchuk 1993), landscape physiography (Bergeron 1991), and vegetation (Larsen 1997).

In a number of studies, variables related to weather conditions have been reported to influence fire frequency and behaviour. A common conclusion of studies investigating weather and fire have related years of large fires and extreme burning conditions to certain weather conditions such as drought (Turner *et al.* 1994; Foster 1983), wind (Turner *et al.* 1994) or specific atmospheric circulation conditions (Johnson and Wowchuk 1993). Other studies present contrasting evidence to the control of broad-scale weather phenomena by reporting very different fire regimes between neighbouring regions (Foster 1983). It is generally thought that during periods of favourable burning conditions, resulting from extreme weather, other influences such as vegetation and landscape physiography are relatively insignificant in affecting fire behaviour (Johnson *et al.* 1998; Dansereau and Bergeron 1993).

Different elements of landscape physiography have been found to influence fire behaviour and frequency. Many studies, particulary in areas with highly variable topography, have concluded that topographic variables such as slope, aspect and elevation influence fire regime and landscape pattern (Francis 1996; Tande 1979). The relative importance of specific topographic variables on fire behaviour may vary between physiographical regions (Kushla and Ripple 1996). Fire regimes and behaviour may also be dependent upon landscape heterogeneity. In northwestern Quebec, frequent small fires occurred in highly variable landscapes consisting of numerous lakes and rough topography, whereas larger fires were associated with homogenous landscapes (Dansereau and Bergeron 1993). Similarly, both the distance of an area to water features and the spatial distribution of water features across the landscape were influence fire frequency (Larsen 1997; Bergeron 1991).

1.2 Influence of Vegetation on Fire Behaviour and Frequency

A number of regional studies have reported an association between certain vegetation types and their propensity either to burn or to escape burning. In Yellowstone National Park, Renkin and Despain (1992) demonstrated a relationship between certain coniferous forest types and stand replacing fires. Similarly Bergeron (1991), in the southern boreal forest of Quebec, reported that fire occurrence and fire intensity was related to fuel type. The study showed that on islands dominated by pine forest, fire was more frequent but generally less lethal compared to islands dominated by spruce forest. At a regional scale, particular vegetation types exhibit distinct fire frequencies. In Wood Buffalo National Park in northeastern Alberta, Larsen (1997) reported the fire frequency in jack pine and aspen forests to be higher than black spruce or white spruce forests. In east-central Alberta however, relative burn hazard was higher in black spruce and white spruce stands than in aspen stands (Cumming 1997).

Contrary to studies described above, some research indicates that vegetation or fuel type is insignificant in explaining fire behaviour. For example, Bessie and Johnson (1995) reported that variation in weather conditions rather than variation in fuels explained forest fire behaviour to a greater degree. The range in vegetation types considered in the Bessie and Johnson study was limited to upland, subalpine, coniferous forests. During extreme burning conditions, resulting from drought and high winds, vegetation has little association with fire behaviour (Renkin and Despain 1992; Turner *et al.* 1994). The importance of vegetation to fire behaviour may therefore be dependent on the relative strength of other influences. It is generally postulated that smaller fires, not resulting from episodes of extreme weather, are more greatly influenced by local landscape elements such as vegetation (Dansereau and Bergeron 1993).

Although vegetation has been reported to influence fire regimes at a regional scale, few studies have shown a quantitative relationship at a local scale, for example at the scale of an individual fire. Based on information from laboratory and fire behaviour studies compiled in the Canadian Forest Fire Behaviour Prediction System (Alexander *et al.* 1984) specific fuel types are associated with different fire conditions and rates of spread. Therefore, local fire behaviour should vary with vegetation type.

1.3 Fire Pattern and Residuals

The combination and interaction of all factors controlling fire behaviour at a local scale are responsible for the variability of burn patterns in post-fire areas. Variable burn patterns result from a range of fire severity conditions, from areas affected by severe crown fires to areas circumvented by the fire. Post-fire pattern has important ecological consequences: the range in burn severity and post-fire pattern has consequences for plant mortality and subsequent reestablishment (Turner *et al.* 1994). For example, unburned or lightly burned areas may provide a seed source that may increase the rate of plant reestablishment (Turner *et al.* 1994). Similarly, low or moderate intensity fires may stimulate vegetatively reproducing species such as aspen (Brown and DeByle 1987).

Patches of unburned vegetation or residuals are a common feature in post-fire boreal landscapes (Eberhart and Woodard 1987; Delong and Tanner 1996). The distribution of these patches relative to landscape elements may identify factors that are important in influencing fire behaviour and subsequent landscape pattern. Due to the large number of factors influencing fire behaviour, it is often difficult to attribute burn pattern to a single variable or to a small number of variables and, therefore, the distribution of residuals may appear random (Foster 1983). A few rigorous and many observational studies have attributed the occurrence of residuals to certain landscape elements. Some landscape features observed to be associated with the occurrence of residuals include wetlands (Dansereau and Bergeron 1993; Foster 1983), certain soil conditions (Dansereau and Bergeron 1993), proximity to surface water (Kushla and Ripple 1997; Foster 1983), topographic position (Camp *et al.* 1997; Kushla and Ripple 1997) and certain vegetation types (Foster 1983).

1.4 Project Rationale

The spatial relationship of residuals to fire size and distance to unburned areas, within large fires have been described for the boreal forest by Eberhart and Woodard (1987). Few studies have been undertaken to explain the occurrence of residuals within fire boundaries for the boreal forest of northern Alberta. Although some studies of the boreal forest have shown that, on a regional scale, vegetation influences fire frequency and burn pattern (Larsen 1997; Cumming 1997), it has not been documented at a finer scale. Descriptive or observational studies have suggested that vegetation is important in the determination of burn pattern within individual fires (Foster 1983). Research undertaken by Eberhart (1986) attempted to determine if the distribution and composition of residual vegetation varied with respect to dominant pre-fire vegetation types. Results of his study indicate that composition of residual vegetation differed among preburn vegetation types but there was a trend for the dominant residual vegetation type to correspond to the dominant preburn vegetation type. Despite these general conclusions Eberhart states the importance of comparing residual vegetation to the actual preburn vegetation. If vegetation is indeed an important influence on local fire behaviour, then the resultant burn pattern should be related to the pre-fire vegetation pattern. The purpose of this research is to describe the relationship between the post-fire pattern of residuals and the vegetation composition of the pre-fire landscape.

1.5 Research Objective

The primary objective of this thesis is:

To identify pre-fire compositional variables, specifically vegetation types, that are associated with the occurrence of residuals within fire affected areas of the boreal forest region of northern Alberta.

The vegetation composition of residuals was compared with the expected composition of residuals based on random samples of the pre-fire composition within the fire area. This comparison was used to determine if certain vegetation types occur in residuals in greater proportions than expected if residuals were located randomly within the fire area. Residuals from twenty fires were examined to determine whether pre-fire vegetation composition is associated with burn pattern in the boreal forest.

2.0 METHODS

A total of 318 residuals from twenty fires in the boreal forest region of northern Alberta were analysed to determine whether their vegetation composition was different than the pre-fire vegetation composition of the fire area. For each of the fire areas, two layers of information were generated in a geographic information system (GIS) environment: a pre-fire vegetation map of the fire-affected area and a post-fire map depicting the fire boundary and interior residual boundaries. Pre-fire vegetation information was obtained from forest inventory maps. Post-fire burn patterns were interpreted from aerial photographs for each of the fire areas. The vegetation composition of the observed residuals was generated from an intersection of the post-fire coverage and the pre-fire vegetation coverage. Randomisation of each residual boundary and intersection with pre-fire vegetation information provided the expected composition of the residuals. Observed residual composition was compared with a distribution of the expected residual composition to determine if the observed residual composition was significantly different.

2.1 Study Area

The twenty fires selected for study occurred within the boreal forest region of northern Alberta (Figure 2.1). Ecological description of the boreal forest region follows that of Rowe (1972) and Strong and Leggat (1981). In the boreal forest region of northern Alberta, upland, well-drained sites are characterised by mixture of deciduous and coniferous species. Dominant deciduous species include aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*) and white birch (*Betula papyrifera*). These species occur with varying amounts of coniferous species such as white spruce (*Picea glauca*) and balsam fir (*Abies balsamifera*). Jack pine (*Pinus contorta*) and mixtures of jack pine and black spruce (*Picea mariana*), dominate on sandy soils and dry tills, respectively. Black spruce, tamarack (*Larix laricina*), and muskeg are associated with low- lying, moist areas.

2.2 Fire Selection

Preliminary fire selection involved a survey of the Fire History Database (Forest Fire Protection Centre 1996). The Fire History Database (FHD) contains a description of fires that occurred within Alberta from 1961 to present. Fire selection was based upon the following criteria: within the boreal forest region (north of Township 65), fire area greater than 100 hectares, within areas of known airphoto coverage, and occurring after 1980. The minimum fire area criterion of 100 hectares was used to increase the likelihood of selecting fires that contained residuals (Eberhart and Woodard 1987). In Alberta, large areas of forested land have been photographed since the late 1970's at a scale of 1:15,000 and 1:20,000, for timber harvest planning and forest inventory (Alberta Forestry Lands and Wildlife 1985a). These areas were included in the query because they provided a potential source of post-fire photo coverage. The further criterion of fires that occurred after 1980, was included because most of the area would have forest inventory information by the early 1980's (Alberta Forestry Lands and Wildlife 1985a). From the initial list of potential fires, fires were eliminated if post-fire photography was incomplete, poor quality, or taken within two years of the fire. Aerial photographs that were taken two or more years post-fire were selected, since mortality of some species may not be apparent until several years after the fire (Brown and DeByle 1987; Starker 1934). Further elimination of fires occurred if the fire had been salvage logged, reburned, contained no mixedwood or deciduous stands, or had no residuals. One exception to the above criteria was fire DF1-34-78, which was included in the study although a subsequent burn obscured the northern edge of the fire. Based on the selection and elimination criteria described above, twenty fires were included in the study. The selected fires are listed in Table 2.1 and shown on Figure 2.1. In Figure 2.1, the size of the fires relative to the provincial boundary is exaggerated by varying amounts to ensure visibility.

Figure 2.1: Location of Selected Fires

Table 2.1: List of Selected Fires

Fire Number	Area* (ha)	Location of Origin	Forest District
DF2-14-80	134	123-18-W5M	Footner
DA2-02-86	227	95-18-W4M	Athabasca
DP1-34-90	238	91-17-W5M	Peace River
DL2-24-80	272	80-02-W4M	Lac La Biche
DP2-13-82	276	89-04-W6M	Peace River
DL2-77-90	398	80-07-W4M	Lac La Biche
DS6-38-82	460	80-22-W4M	Slave Lake
DS6-32-82	530	78-22-W4M	Slave Lake
DS5-07-91	551	89-05-W5M	Slave Lake
DS6-19-82	559	77-26-W4M	Slave Lake
DP1-12-90	744	88-14-W5M	Peace River
DS5-09-82	917	85-06-W5M	Slave Lake
DP2-04-82	1 047	88-04-W6M	Peace River
DF1-34-78	1 053	98-11-W5M	Footner
DL2-43-82	1 069	77-12-W4M	Lac La Biche
DL2-88-90	1 292	78-04-W4M	Lac La Biche
DL3-19-82	1 403	75-23-W4M	Lac La Biche
DS6-26-82	3 400	86-02-W5M	Slave Lake
DL4-16-81	4 071	79-13-W4M	Lac La Biche
DP1-17-95	8 794	89-16-W5M	Peace River

*Area as reported in the FHD (Forest Fire Protection Centre 1996)

2.3 Pre-fire Vegetation Information

Two sources of vegetation information were used to generate pre-fire vegetation coverages for the fire areas: Phase 3 Forest Inventory (P3FI) and Alberta Vegetation Inventory (AVI).

2.3.1 Phase 3 Forest Inventory Maps

The Phase 3 Forest Inventory (P3FI) was an initiative by the province of Alberta to inventory forests on publicly owned lands (excluding provincial and national parks, wilderness areas, Indian and Metis lands and townsites) from 1970 to early 1980's

(Alberta Forestry, Lands and Wildlife 1985a). The P3FI contains forest stands or polygons interpreted from 1:15,000 aerial photographs. Polygons are delineated based on overstory species composition, crown density, height, date of stand origin, site class, and where applicable stand condition, disturbance, slope category, potential forest productivity, and understory descriptions.

P3FI maps were available for most of the fire areas and were the primary source of pre-fire vegetation information used in this study. Stand boundaries of the pre-fire vegetation within and surrounding the fire area were digitised using a Summagraphics Microgrid III digitising tablet and digitising software Digi-edit™. Polygon identification numbers and overstory composition (dominant, subdominant, and/or codominant species) from P3FI was assigned to each of the digitised vegetation polygons. Ground control points were identified on P3FI maps and UTM (Universal Transverse Mercator) coordinates for these control points were transcribed from 1:50000 National Topographic Series (NTS) maps.

2.3.2 Alberta Vegetation Inventory

Shortly after completion of the Phase 3 Forest Inventory, a new inventory, the Alberta Vegetation Inventory (AVI) was undertaken (Alberta Environmental Protection 1991). The purpose of the AVI was to provide a digital, easily updated and integrated vegetation inventory to be used in forest management plans, habitat classification and resource management. The working scale of the AVI is 1:20,000 with a minimum mapping unit of two hectares in certain vegetation types. Information on forest composition is similar to P3FI, although somewhat more detailed with respect to canopy composition and understory description. Digital AVI information for three fire areas (DP1-17-95, DP1-34-90, and DP1-12-90) was provided by Daishowa-Marubeni International Forest Products.

2.3.3 Standardisation of P3FI and AVI

Despite similarities between P3FI and AVI, there are some differences in vegetation classification of overstory and non-forested vegetation types. For example, in P3FI, vegetation is described by ranking overstory species either as dominant, codominant, or subdominant on the basis of crown closure and/or volume percentages. AVI provides slightly more detail by describing the canopy closure of each overstory species to the nearest 10%. Differences were also evident in the classification of non forested categories. P3FI classifies vegetated, non-forested areas as either treed muskeg (tree cover 11-30%), open muskeg (tree cover <10%), coniferous scrub (stunted, inferior growth of conifers), deciduous scrub (shrubs or stunted deciduous trees), or grassland. Non-forested (<6% tree cover), naturally vegetated areas from AVI are classified as either shrub (deciduous shrub sub-categorised as either open or closed), herbaceous (sub-categorised as either grass dominated or forb dominated), or bryophyte dominated areas.

For the purpose of this study, vegetation information from the pre-fire vegetation coverages was amalgamated into eleven groups: deciduous, mixedwood, white spruce, black spruce, pine, mixed coniferous, coniferous scrub, deciduous scrub/shrub, muskeg, water, and "other". The deciduous group consisted of any deciduous species: aspen, balsam poplar, or birch, alone or combined, labelled as dominant or with a canopy closure of 80% or greater. Mixedwood contained both deciduous and coniferous vegetation labeled as codominant or in combinations between 20% and 80%. Single species groups such as white spruce, black spruce, and pine were created when the associated vegetation type was dominant or greater than 80%. Mixed coniferous was defined as a mixture of two or more coniferous species with no single species greater than 80%. Muskeg included both treed muskeg and open muskeg. Additional groups included coniferous scrub, deciduous scrub/shrub, and water. The "other" group encompassed any other vegetated or non-vegetated area such as flooded, herbaceous, or cleared land.

A study completed by Joy (1995) compared AVI and P3FI information at different levels of aggregation. The conclusion of his study was that when the more detailed AVI vegetation classification was aggregated into P3FI categories, categorical differences between P3FI and AVI were not significant. One discrepancy Joy (1995) found between the P3FI and AVI datasets was the greater number of pure aspen stands in AVI compared to P3FI. The P3FI tended to classify these pure aspen stands as mixedwood. Another discrepancy between the two datasets relates to polygon size distribution. Joy also documented the higher proportion of smaller polygons (< 10 ha) mapped for AVI compared to P3FI. The difference in scale between the two inventories (1:15,000 and 1:20,000) was found to contribute a small amount of discrepancy, likely resulting from the generalisation of the larger scale P3FI.

2.3.4 Pre-fire Vegetation Coverage

Digital files of pre-fire vegetation from the P3FI maps were converted into ARC/INFO™ format using the GIS software: Idrisi for Windows™ (Version 1). Once in ARC/INFO™ format, polygon coverages were generated to represent the pre-fire vegetation for each of the fire areas. Vegetation information from the P3FI was related to each polygon.

2.4 Post-fire Burn Pattern Information

2.4.1 Aerial Photograph Interpretation

The fire boundary and residual boundaries were interpreted from post-fire aerial photographs at a scale of 1:15,000 or 1:20,000. Residuals were mapped to a minimum area of one hectare with a minimum width of 20 metres. Residuals were amalgamated if they were within 20 metres of each other. The 20 metre minimum width is consistent with AVI air photo interpretation standards and is based on the physical limitations in digitising polygon boundaries (Alberta Environmental Protection 1991). Interpretation of the fire boundary and residuals was transferred onto P3FI maps or

AVI base maps using a Bausch & Lomb Stereo Zoom Transfer Scope™. Ground control points from P3FI (measured from NTS maps) and AVI base maps were used as reference points for the post-fire, burn pattern map. The transfer of post-fire information onto existing basemaps (either P3FI or AVI) reduced the positional discrepancy that may result from georeferencing the airphotos to a "real world" coordinate/projection system. Therefore the residuals and fire boundaries may be less accurate with respect to "real world" coordinates but are relative to the pre-fire vegetation information layer.

Interpretation of the fire boundary and residuals differentiates between vegetation killed by the fire and vegetation surviving the fire. The boundaries, therefore, may not represent the maximum extent of the fire, since areas interpreted as residual or edge may have experienced fire but not at a sufficient intensity to kill the overstory vegetation. In forested areas, boundaries between burned and unburned vegetation were relatively easily distinguished based on differences in texture, colour and canopy height. Boundaries in low-lying areas and non-forested areas were more difficult to ascertain; in these instances, pre-fire aerial photographs were examined to aid interpretation.

2.4.2 Burn Pattern Coverage

Following the transfer of fire boundaries and residual boundaries onto base maps, the burn pattern was digitised (as described in subsection 2.3.1). The digital file of the burn pattern was converted into ARC/INFO™ format using Idrisi for Windows™. Once in ARC/INFO™ format, burn pattern coverages were generated and polygons were classified either as burned or unburned.

2.5 Sampling and Analysis

2.5.1 Vegetation Composition of Residuals

Within ARC/INFO™, the burn pattern coverages, for each of the twenty fires, were intersected with the associated pre-fire vegetation coverages to attain the vegetation composition of the residuals. Using a simple Quick Basic™ program, the vegetation composition of each residual was converted into proportions of each of the eleven vegetation groups described previously (subsection 2.3.3). The vegetation composition of each residual, defined by the proportion of the residual in each vegetation group, is provided in an appendix (Section 7.0).

2.5.2 Randomisation

A randomisation procedure was developed which randomly relocated residual boundaries within the pre-fire area in order to provide an expected vegetation composition of residuals. Initially, separate coverages were produced for each residual, which included a single residual boundary and the fire boundary. An Arc Macro Language™ (AML) program was written to relocate the boundary of each residual to a randomly selected position within the burn area, and to rotate it to a random orientation. This program was written by Tim Martin (Laboratory Coordinator, Spatial Information Systems Laboratory, Department of Renewable Resources) and modified by Rick Pelletier (Department of Renewable Resources). The randomly relocated boundary was then intersected with the pre-fire vegetation coverage and the vegetation composition within the random residual boundary was written to an output file. The procedure was repeated 100 times for each residual boundary. An illustration of a coverage generated from the randomisation of a residual boundary is provided in Figure 2.2. From the output files, proportions of each vegetation type were calculated for each relocated residual boundary.

Random relocation of the residual boundary occasionally resulted in the residual boundary intersecting the fire boundary (Figure 2.2). In these instances, the portion of

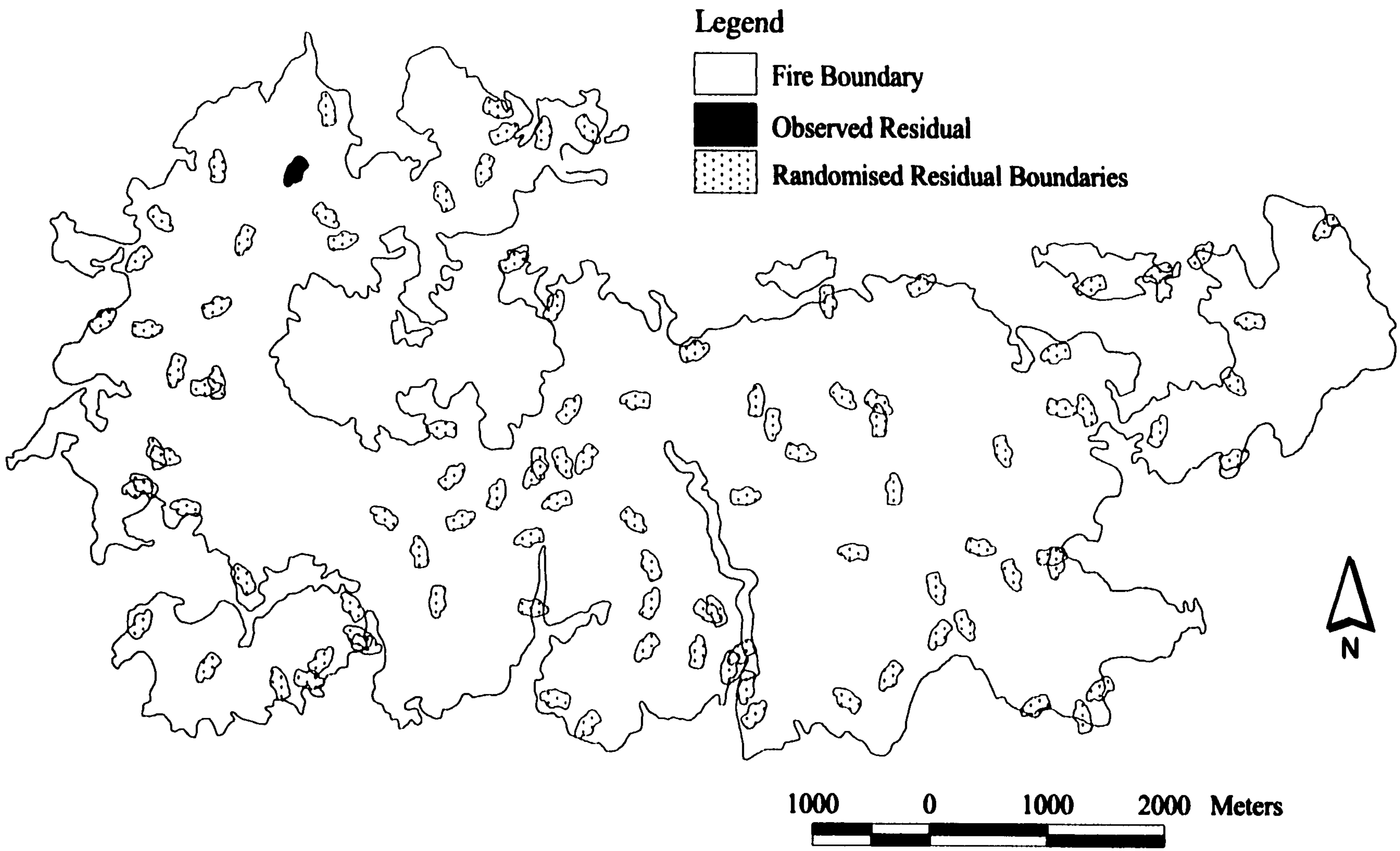


Figure 2.2: Visual Output of Randomised Residual Boundaries for DL4-16-81

the residual boundary falling outside of the fire boundary was removed and the truncated, interior portion was retained. For small residual boundaries within large fires, the probability of edge intersection was low, but for large residuals within small, irregular shaped fires the probability of edge intersection was higher. The computer time required to select residual boundaries entirely within the fire perimeter would have been prohibitive if not impossible for some fires. Therefore truncated residual boundaries were retained and used in analysis. Vegetation proportions for these truncated residual boundaries were calculated by dividing the area of each vegetation type located within the truncated residual boundary by the area of the residual boundary located within the fire boundary.

2.5.3 Comparison of Residual Composition to Random

Although vegetation composition is defined based on eleven different vegetation types, only four of the vegetation types were chosen for this analysis. Deciduous, mixedwood, white spruce, and muskeg were selected to determine whether they were associated with residuals. Deciduous, mixedwood, and muskeg vegetation types were selected since they were likely to be associated with residuals, based on the fire behaviour literature. White spruce was also selected since it is associated both spatially and compositionally with deciduous and mixedwood vegetation types. The proportion of each vegetation type in the observed residuals was compared against the proportions of vegetation types in the random residual boundaries, to determine whether the observed vegetation types were significantly different than expected from random. Significance was determined using a one-tailed test with a significance level of 0.05. A one-tailed test was used because the distributions generated from the vegetation proportions of the random boundaries were positively skewed. The positive skew of the distribution eliminated the possibility of obtaining a significantly lower proportion of the selected vegetation types than expected from random. Positive skewness was the result of the low proportion of the selected vegetation types within the fire landscape. Due to the extensive computer time required to randomise each residual boundary, only a sample of residuals from the largest fire, DP1-17-95. was processed. Forty of the 107 residuals were randomly selected and randomised as described above.

3.0 RESULTS

3.1 Fire and Residual Summary

The area encompassed by each of the twenty fires, including the area of unburned residuals, is provided in Table 3.1. This table also includes percentages of the total area that was burned and not burned (residual). The percentage of residual area ranges from 0.6% to 16.0% of the total fire area. The number of residuals within each fire range from one, in the smaller fires, to 107 residuals in the largest fire. The number of residuals per 100 hectares of fire area ranges from 0.5 to 3.8.

Table 3.1 Summary of Fire Areas

FIRE NUMBER	AREA (ha)	BURNED AREA(%)	RESIDUAL AREA (%)	NO. OF RESIDUALS	RESIDUALS PER 100 ha
DF2-14-80	76.76	95.0	5.0	1	1.3
DP2-13-82	150.78	98.1	1.9	1	0.7
DL2-24-80	174.14	96.5	3.5	3	1.7
DA2-02-86	186.58	98.1	1.9	3	1.6
DP1-34-90	213.80	99.4	0.6	1	0.5
DL2-77-90	328.45	96.3	3.7	5	1.5
DS6-19-82	379.82	97.1	2.9	5	1.3
DS6-38-82	392.21	96.2	3.8	5	1.3
DS6-32-82	475.71	97.0	3.0	7	1.5
DS5-07-91	487.95	87.3	12.7	7	1.4
DP1-12-90	707.51	95.8	4.2	13	1.8
DP2-04-82	804.13	93.9	6.1	16	2.0
DL2-43-82	834.49	97.9	2.1	7	0.8
DF1-34-78	845.18	91.0	9.0	21	2.5
DS5-09-82	916.92	89.9	10.1	35	3.8
DL2-88-90	1260.39	93.6	6.4	26	2.1
DL3-19-82	1330.79	96.4	3.6	16	1.2
DS6-26-82	2131.43	84.0	16.0	56	2.6
DL4-16-81	3259.67	92.5	7.5	49	1.5
DP1-17-95	5765.49	88.5	11.5	107	1.9

3.2 Vegetation Composition of Fire Area and Residuals

The percentage of each vegetation type within the fire area is provided in Table 3.2. Percentages of each vegetation type are based on the total vegetated area and exclude area covered by water. The vegetation composition of the residuals is provided in an appendix (Section 7.0).

Figures 3.1 to 3.4 illustrate the proportion of each vegetation type within residuals compared to its proportion within the fire area. If certain vegetation types are positively associated with residuals then the proportion should be greater in residuals than its proportion within the fire area. If a vegetation type is not positively associated with residuals then the proportions of that vegetation type within residuals would be equal to or less than its proportion within the fire area. For most fires, the proportion of deciduous vegetation in residuals is higher than the proportion within the fire area (Figure 3.1). Less than half of the fires had the proportion of mixedwood in residuals greater than the proportion within the fire area (Figure 3.2). Generalisations for white spruce and muskeg are difficult to make since these vegetation types were not common amongst all fires (Figures 3.3 and 3.4). Approximately half of the fires, which contained white spruce, had greater proportions of white spruce in residuals than in the fire area. This result is similar to the fire areas containing muskeg (Figure 3.4). Based on the information presented in Figures 3.1 to 3.4, deciduous vegetation appears to be positively associated with residuals. The association of mixedwood, white spruce and muskeg with residuals is apparent in some fire areas.

3.3 Comparison of Residual Vegetation to Expected

The proportion of each of the four vegetation types within each observed residual. was compared to the expected frequency distributions generated from the proportion of each of the four vegetation types within the randomly located residual boundaries. A p-value was generated for each vegetation type of an observed residual,

Table 3.2: Vegetation Composition (% area) of Individual Fires

FIRE NUMBER	DECIDUOUS	MIXEDWOOD	WHITE SPRUCE	BLACK SPRUCE	PINE	MIXED CONIFER	MUSKEG	CONIFER SCRUB	OTHER
DF2-14-80	0.00	3.89	0.03	87.18	0.00	8.44	0.00	0.46	0.00
DP2-13-82	5.24	8.91	51.19	0.00	0.00	10.85	0.07	20.53	3.20
DL2-24-80	20.32	14.31	5.53	26.09	0.00	11.82	6.49	15.44	0.00
DA2-02-86	15.20	2.00	0.13	48.39	9.20	1.02	2.12	21.95	0.00
DP1-34-90	92.51	0.41	0.00	5.98	0.00	0.51	0.00	0.00	0.58
DL2-77-90	4.49	5.90	0.00	57.20	0.75	3.45	10.84	17.30	0.06
DS6-19-82	3.36	6.35	12.18	12.75	0.00	16.83	0.00	45.82	2.71
DS6-38-82	9.18	11.19	3.68	0.00	2.55	0.23	0.30	72.60	0.28
DS6-32-82	4.88	0.39	0.43	1.42	0.00	0.91	0.88	91.09	0.00
DS5-07-91	36.00	3.59	0.20	2.31	0.00	2.18	0.59	55.14	0.00
DP1-12-90	4.81	0.90	1.63	3.31	0.00	3.28	0.00	0.00	86.08
DP2-04-82	4.18	13.19	39.77	0.00	0.00	10.43	5.88	24.05	2.50
DL2-43-82	2.76	15.46	0.00	40.51	6.35	4.30	2.15	28.37	0.09
DF1-34-78	1.56	9.28	10.72	33.84	0.00	43.14	0.16	1.30	0.00
DS5-09-82	23.93	16.70	0.00	1.93	5.08	5.14	1.30	43.52	2.39
DL2-88-90	6.11	21.38	5.07	39.88	9.22	11.85	0.00	4.91	1.58
DL3-19-82	10.04	6.21	0.00	57.17	2.53	4.09	2.09	15.97	1.90
DS6-26-82	13.85	24.67	5.65	0.00	14.61	0.45	1.90	37.48	1.40
DL4-16-81	2.35	12.94	0.91	49.16	1.77	7.16	3.47	22.18	0.06
DP1-17-95	29.69	7.51	1.03	50.04	0.36	8.80	0.00	0.00	2.56

Figure 3.1: Proportion of Deciduous Dominant Overstory within Residuals Relative to Porportion within Fire Area

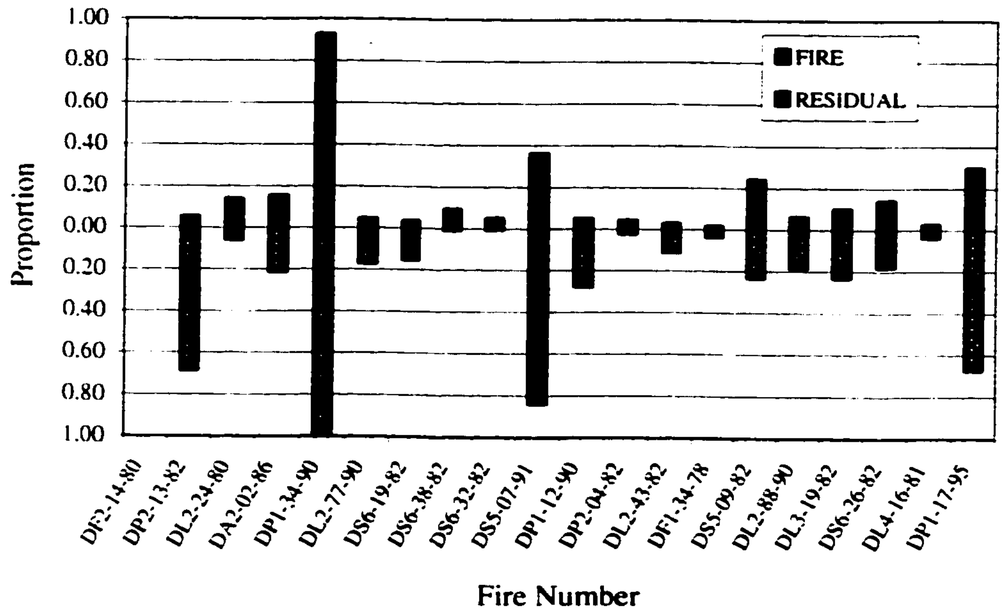


Figure 3.2: Proportion of Mixedwood Overstory Vegetation within Residuals Relative to Proportion within Fire Area

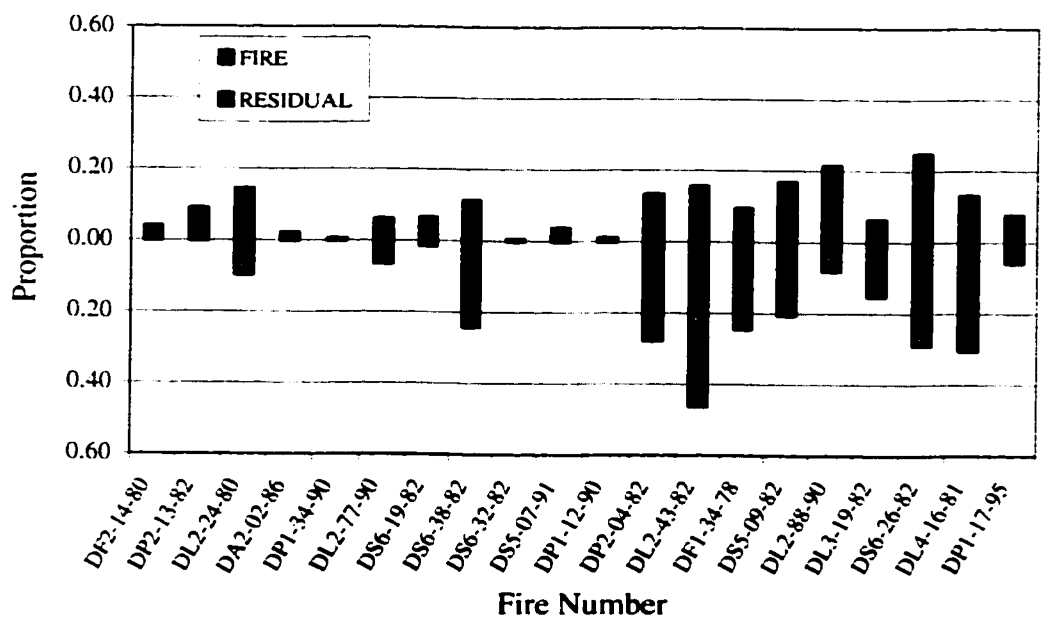


Figure 3.3: Proportion of White Spruce Dominant Overstory within Residuals Relative to Proportion within Fire Area

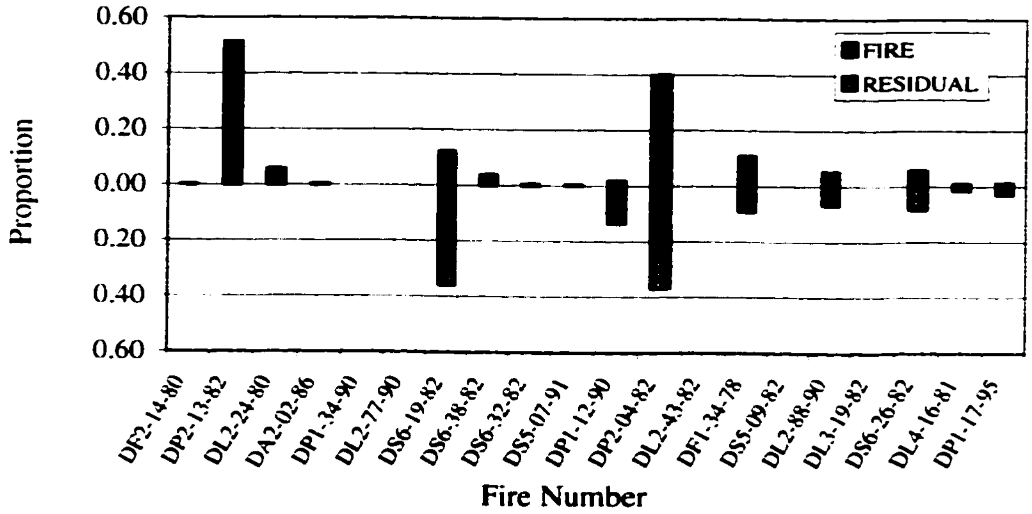
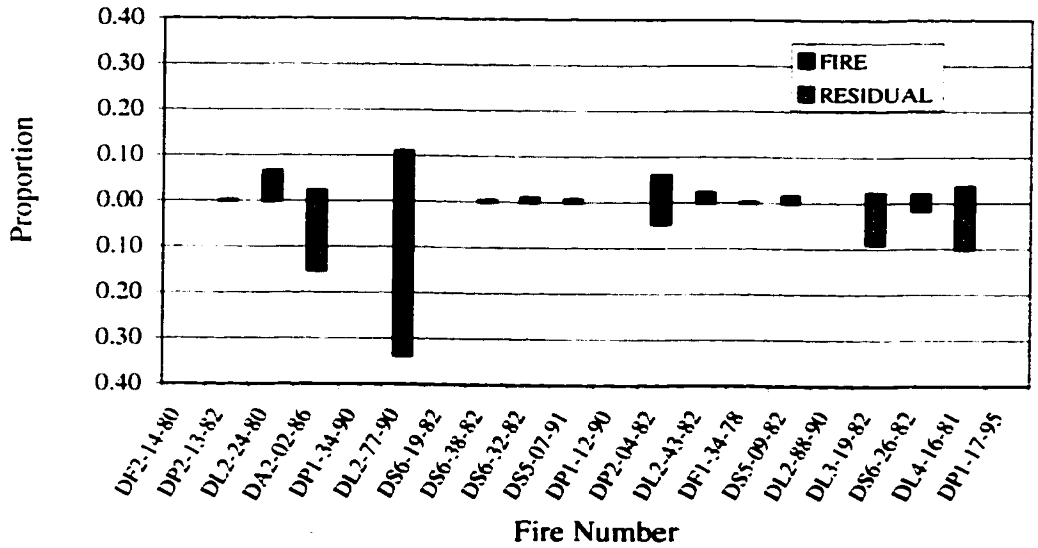


Figure 3.4: Proportion of Muskeg within Residuals Relative to Proportion within Fire Area



representing the probability that the observed proportion falls within the expected frequency distribution. For example, residuals with low p-values contain a higher proportion of deciduous than expected and residuals with high p-values contain a proportion of deciduous that is similar to expected. The frequency distribution of these p-values for deciduous, mixedwood, white spruce and muskeg vegetation types is plotted on Figures 3.5 through 3.8. These four figures illustrate the relative frequency of residuals with a certain probability of falling within an expected distribution. If the p-values for the residuals are randomly distributed you would expect a uniform frequency distribution, with equal representation of p-values (approximately 5%) within each interval. This is not the case as illustrated by Figures 3.5 through 3.8. The frequency distribution in Figure 3.5 indicates that there are a large number of observed residuals with proportions of deciduous similar to expected (represented by high p-values) and also shows that there are a number of residuals with proportions of deciduous which are much higher than expected (represented by low p-values). This trend is also evident in the frequency distributions of p-values for mixedwood (Figure 3.6), white spruce (Figure 3.7), and muskeg (Figure 3.8).

The number of residuals with significantly higher proportions of the four vegetation types than expected is provided in Table 3.3. Significance was measured from a one-tailed test at a significance level of 0.05. A one-tailed test was used because the proportions of the selected vegetation types across the landscape were usually small, resulting in positively skewed random distributions. Results of the one-tailed test are summarised in Table 3.3. The total number of residuals, and the number of residuals that contain a significantly greater proportion of any of the four vegetation types is shown for each fire. For ease of description, the term "significant residual" is used to describe an observed residual with a significantly higher proportion of a selected vegetation type compared to the expected proportion of that vegetation from the randomly relocated residual boundaries. For example, fire DL2-88-90 contains 26 residuals: three of which have a significantly greater proportion of deciduous

Figure 3.5: Frequency Distribution of *p*-values Representing the Proportion of Deciduous Within Observed Residuals

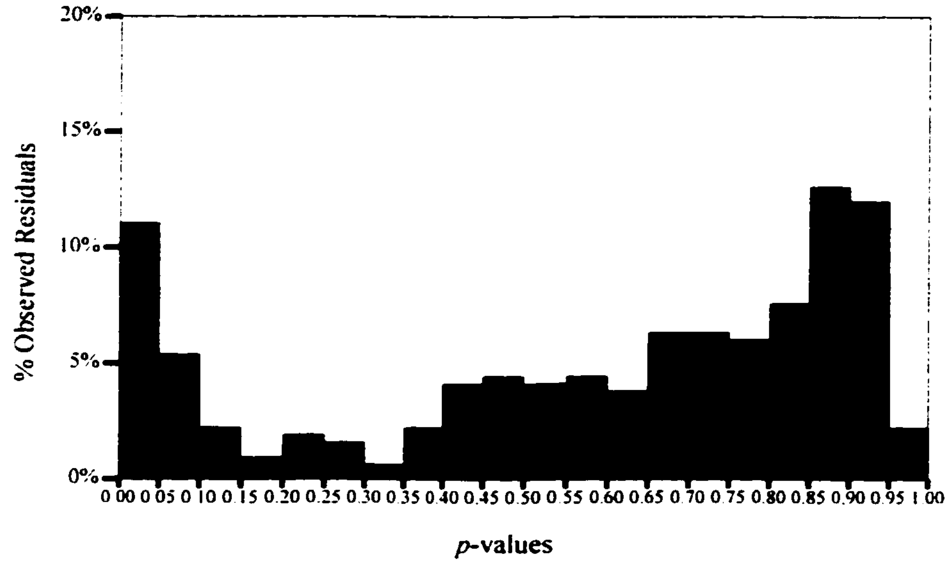


Figure 3.6: Frequency Distribution of *p*-values Representing the Proportion of Mixedwood Within Observed Residuals

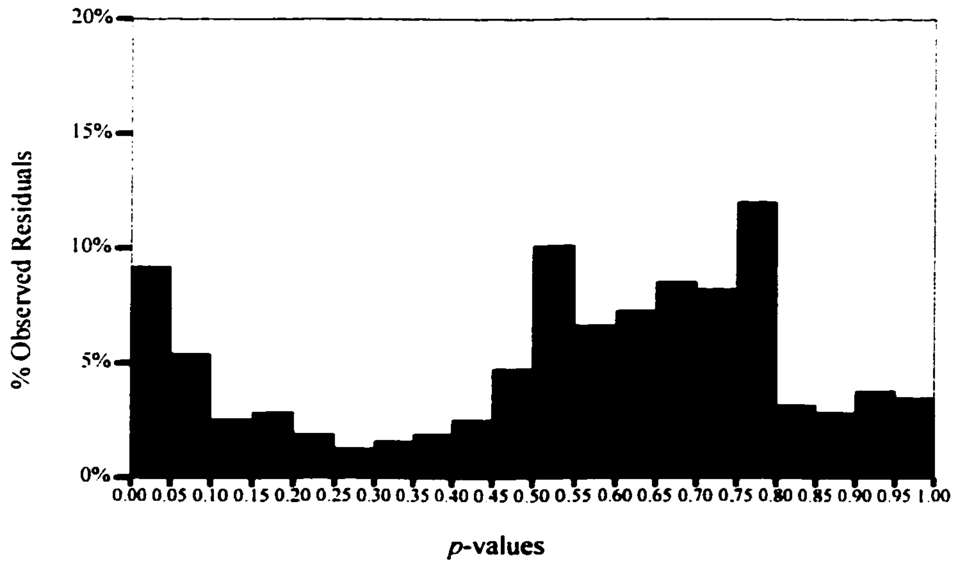


Figure 3.7: Frequency Distribution of *p*-values Representing the Proportion of White Spruce Within Observed Residuals

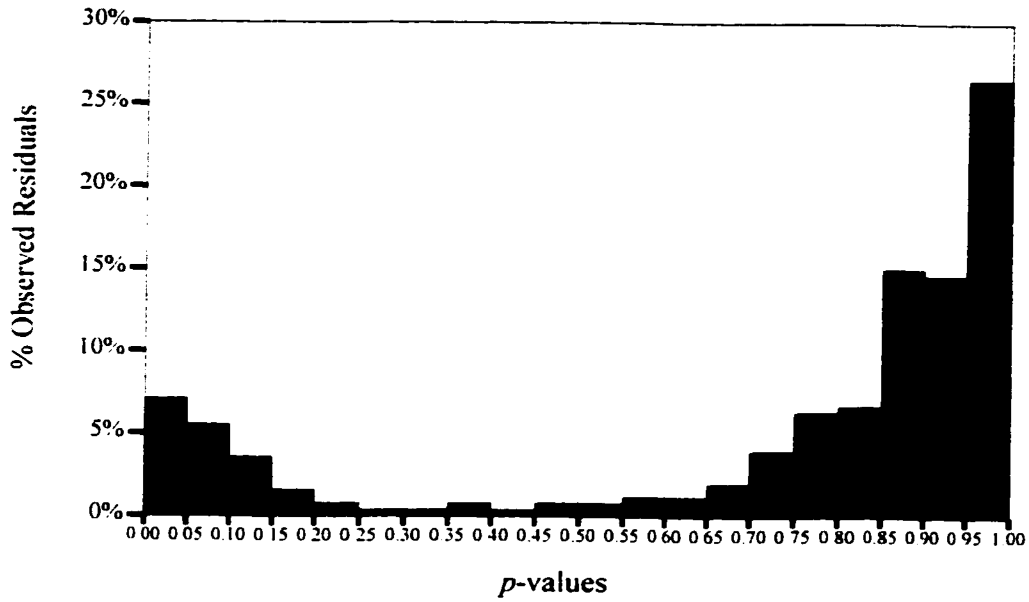


Figure 3.8: Frequency Distribution of *p*-values Representing the Proportion of Muskeg Within Observed Residuals

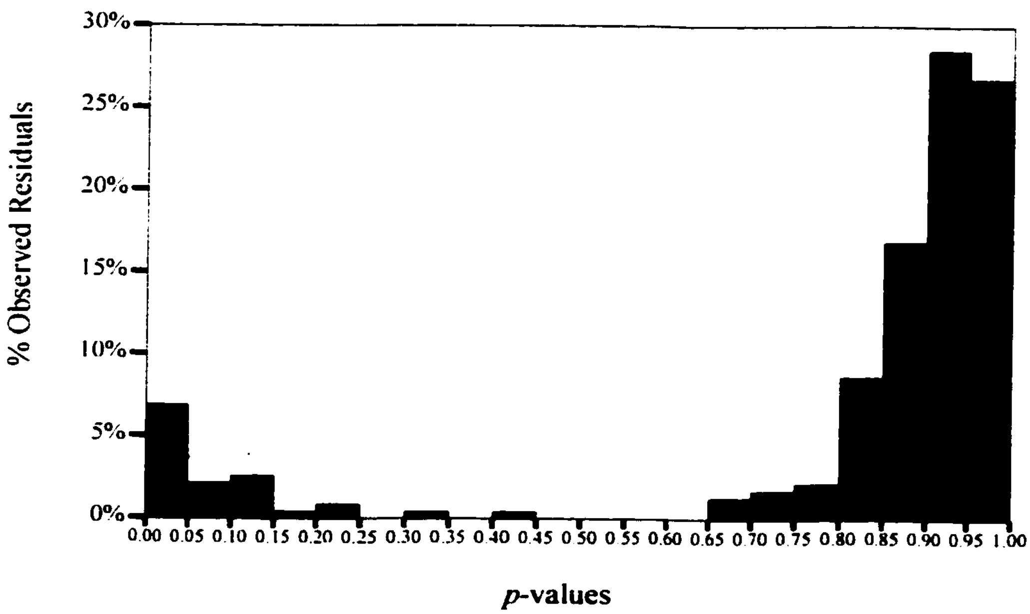


Table 3.3: Number and percentage of residuals with significantly ($p \leq 0.05$) greater proportion of selected vegetation types than expected

Fire Number	Number of Residuals	Deciduous	Mixedwood	White Spruce	Muskeg	% Signif. Residuals
DF2-14-80	1	n/a	0	0	n/a	0
DP2-13-82	1	1	0	0	0	100.0
DL2-24-80	3	0	0	0	0	0
DA2-02-86	3	1	0	0	0	33.3
DP1-34-90	1	0	0	n/a	n/a	0
DL2-77-90	5	1	0	n/a	1	40.0
DS6-19-82	5	1	0	1	n/a	40.0
DS6-38-82	5	0	1	0	0	20.0
DS6-32-82	7	0	0	0	0	0
DS5-07-91	7	0	0	0	0	0
DP1-12-90	13	1	0	0	n/a	7.7
DP2-04-82	16	1	1	1	2	31.3
DL2-43-82	8	1	3	n/a	0	50.0
DF1-34-78	21	1	6	2	0	42.9
DS5-09-82	35	3	2	n/a	3	22.9
DL2-88-90	26	3	0	1	n/a	15.4
DL3-19-82	16	5	3	n/a	1	56.3
DS6-26-82	56	1	3	5	3	21.4
DL4-16-81	49	0	6	3	6	30.6
DP1-17-95*	40	13	4	5	n/a	55.0
# Residuals Available		317	318	253	232	318
# Significant Residuals		33	29	18	16	96
% Significant Residuals		**10.4%**	**9.1%**	**7.1%**	**6.9%**	**30.2%**

n/a = no vegetation of that type within the fire area.

* Results reported for a subset of 40 residuals, randomly selected from the 107 residuals in DP1-17-95 (see subsection 2.5.3)

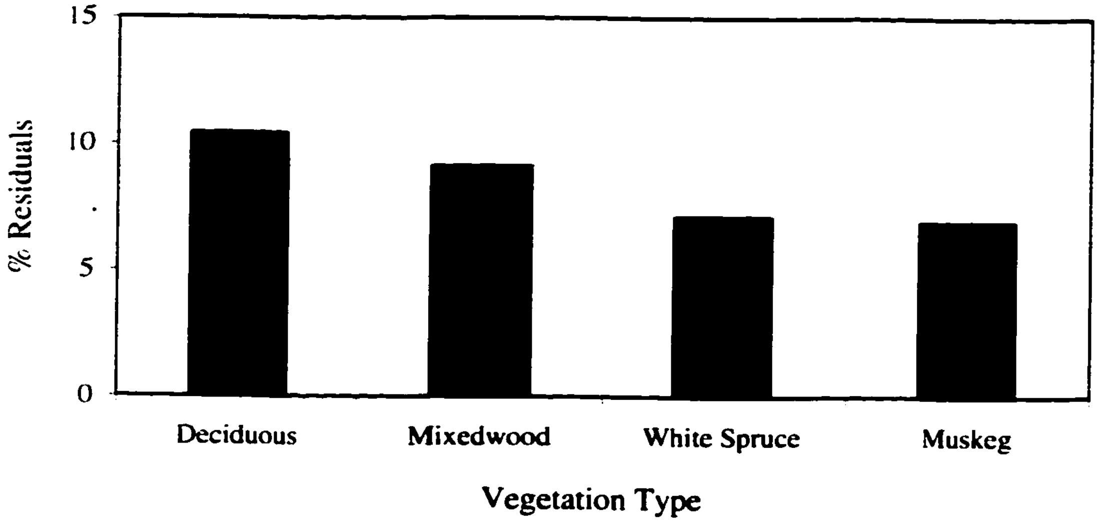
vegetation than expected and one that has a greater proportion of white spruce than expected. The proportion of mixedwood within any of DL2-88-90's residuals was not greater than expected. There was no muskeg within the fire area and it could not be expected to occur within the residuals. The percentage of significant residuals for each vegetation type is displayed in Figure 3.9. Some residuals had more than one vegetation type with a significantly higher proportion than expected, therefore the total percentage of residuals is actually a measure of the number of instances where any vegetation types occurred in significantly greater proportion than expected. Less than two percent of residuals have more than one significant vegetation type per residual.

3.4 Association of Vegetation Influence and Fire Parameters

Although there is a general trend for certain vegetation types to be associated with residuals, it varies between fires. For example, in Table 3.3, the percentages of significant residuals for individual fires range from 0% to over 50%. The percentage of significant residuals may represent the relative importance pre-fire vegetation has had with respect to influencing burn pattern. Therefore, in fires with a high proportion of significant residuals, vegetation may have been an important influence on fire behaviour and resultant burn pattern but in fires with low proportions of significant residuals, other factors may have been more important than vegetation in determining burn pattern.

An attempt was made to compare the percentage of significant residuals within each fire with two variables presumed to influence the degree to which vegetation may control fire behaviour and influence burn pattern. These variables are fire size (Dansereau and Bergeron 1993; Turner et al. 1994) and annual area burned (Bessie and Johnson 1995). Annual area burned refers to the total area burned within the province for any given year. The percentage of significant residuals for each fire was

Figure 3.9: Percentage of Residuals with Significantly ($p<0.05$) Greater Proportion of Vegetation Type than Expected



compared to the annual area burned for the same year in which the fire occurred. Correlations were done using SPSS for Windows™, version 8.0.

A scatterplot of the percentage of significant residuals for each fire and the fire size ($\log_{10}$ transformed) is provided in Figure 3.10. Fire DP2-13-82 was considered an outlier and was not included in the correlation analysis. This small fire (151 ha) contained only one residual which was significantly higher in deciduous vegetation than expected, resulting in 100 percent of residuals being reported as significant.

The Pearson correlation coefficient (r) is 0.519 and is significant at the 0.05 level (2-tailed). The results indicate that there is a positive correlation between fire size and percentage of significant residuals.

Figure 3.11 is a scatterplot of the percentage of significant residuals for each fire and the annual area burned ($\log_{10}$ transformed). The Pearson correlation coefficient (r) is 0.113 and is not significant at the 0.05 level.

Figure 3.10: Percentage of Significant Residuals vs Fire Size (ha) (Log Transformed)

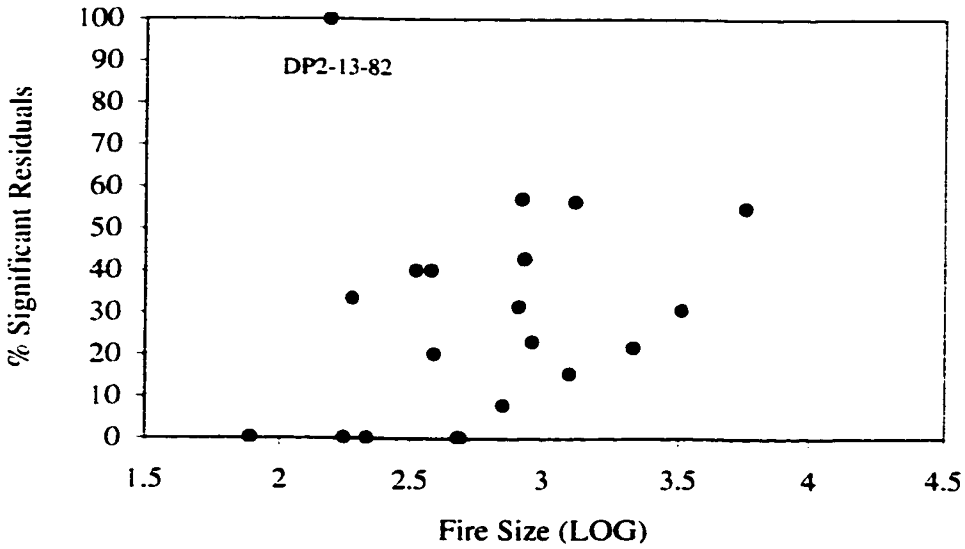
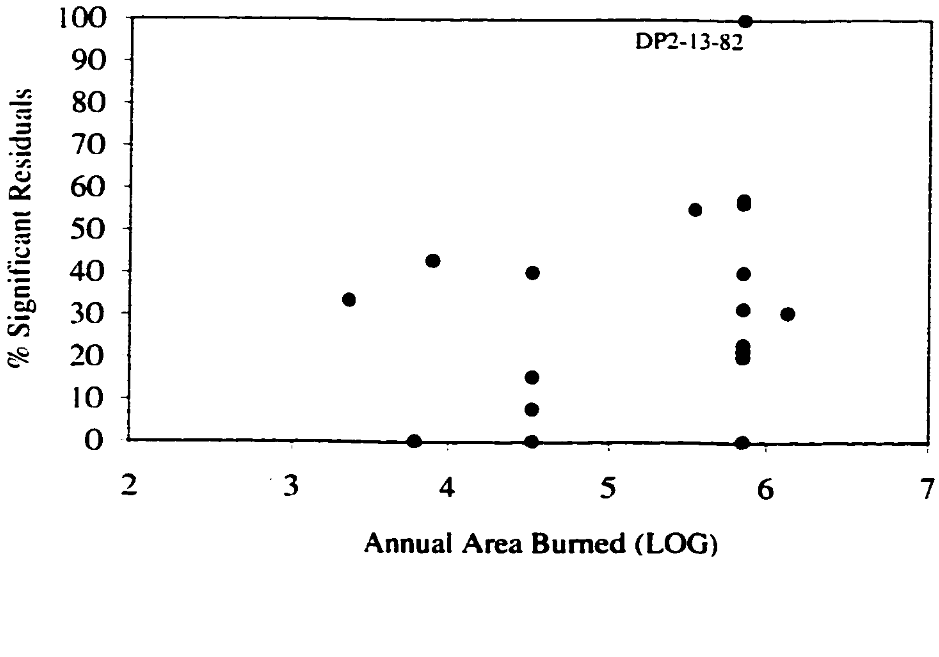


Figure 3.11 : Percentage of Significant Residuals vs Annual Area Burned (ha) (Log Transformed)



4.0 DISCUSSION

Results of the randomisation tests indicate that the pattern of residuals across the landscape is not independent of pre-fire vegetation composition. Although many of the residuals contained a proportion of deciduous, mixedwood, white spruce and muskeg similar to expected, there was a trend for a number of residuals to contain higher proportions of these four vegetation type than expected. Of the residuals randomised from the twenty fires, 10.4% had significantly higher proportions of deciduous, 9.1% had significantly higher proportions of mixedwood, 7.1% had significantly higher proportions of white spruce, and 6.9% had significantly greater proportions of muskeg than expected. In total, one-third of residuals were associated with one of the four vegetation types considered. The association between pre-fire vegetation and burn pattern is dependent upon characteristics of the specific vegetation types to reduce their susceptibility to fire damage. Despite the general association of certain vegetation types with residual distribution, the influence of vegetation was not apparent for all residuals or within all fires. The inconsistency of vegetation and residual association is likely due to variability within the vegetation types, and the influence of weather or other landscape features on fire behaviour.

4.1 Association Between Residuals and Vegetation Types

The association between certain vegetation types and residual distribution is dependent upon specific characteristics of the vegetation type either to prevent fire encroachment, avoid initiation of crown fires, or both. The four vegetation types surveyed in this study exhibit structural and stand characteristics that make them less likely to succumb to lethal fire effects.

4.1.1 Deciduous Vegetation Type

Several examples from the literature explain the association between deciduous vegetation and residual distribution. Fire intensity within aspen stands is generally low since surface fires are predominately associated with aspen stands (Quintilio *et* *al.* 1991). A decreased probability of crown fire initiation in deciduous stands may be attributed to height of crown base and foliar moisture levels (Van Wagner 1977). Deciduous tree species have relatively high crown bases, therefore requiring higher intensity surface fires for crown fire initiation (Johnson 1992). Furthermore, the relatively high foliar moisture content of deciduous tree species (Kiil and Grigel 1969) requires a greater amount of energy before ignition can occur (Van Wagner 1977). These structural features of deciduous vegetation types make them less susceptible to severe damage from crown fires. A study in southeastern Labrador attributed the survival of birch stands to their lush understory, high foliar moisture, and relatively high humidity within the stand (Foster 1983).

Despite the reduced probability of crown fires, deciduous species are relatively sensitive to fire damage due to their thin bark (Yarie 1981; Peterson and Ryan 1986). Therefore, the mechanisms associated with survival of deciduous trees are related to preventing crown fire development and limiting fire encroachment.

4.1.2 Mixedwood Vegetation Type

The behaviour of fire through a mixedwood stand is likely a combination of the behaviour through a deciduous stand and a coniferous stand. Mixedwood are less likely to support a crown fire than most coniferous fuel types but are more likely than pure deciduous fuel types (Alexander *et al.* 1984). Characteristics of deciduous vegetation that reduce crown fire initiation (height of crown and high foliar moisture) contribute to low mortality of the mixedwood vegetation type. This is supported by observations that the probability of crown fire development in mixedwood fuel types is related to the proportion of coniferous and deciduous within the stand (Alexander *et al.* 1984). The heterogeneous nature of the mixed deciduous and coniferous canopy does not facilitate the spread of crown fires, except under extreme burning conditions (Kiil and Grigel 1969).

4.1.3 White Spruce Vegetation Type

Both vegetation characteristics and stand location may contribute to the survival of white spruce forests. Compared to deciduous species, the architecture of coniferous species is more likely to facilitate and sustain crown fires. Accumulation of fine fuels (due to low decomposition rates and retention of dead branches), low crown base, conical crown shape, and low foliar moisture contribute to highly favourable conditions for crown fire intitiation and spread in coniferous stands (Kiil and Grigel 1969; Van Wagner 1977; Johnson 1992). The high probability of crown fire initiation and the relatively thin bark of white spruce, makes the species highly susceptible to fire induced mortality (Yarie 1981; Peterson and Ryan 1986). Despite these fire susceptible characteristics, results of the current study indicate that white spruce survives within residuals in greater proportions than expected. Therefore non-structural attributes of white spruce stands must reduce the probability of fire encroachment. Perhaps stand conditions for white spruce are similar to those suggested for eastern boreal, black spruce stands; where moist, drought resistance, mosses are the dominant ground cover resulting in higher humidity and lower temperatures within the stand (Foster 1983). These elements may protect the stand against burning, except in extremely dry years. Further, fire encroachment into a stand may be dependent upon the position of the stand in relation to other vegetation types. In one study, in west central Alberta, white spruce dominated communities were found to occur in moist shallow, depressions with poorly drained soils usually surrounded by aspen dominated stands (Corns 1983). The adjacent, less flammable aspen stands may help to protect the white spruce stands from fire encroachment.

4.1.4 Muskeg Vegetation Type

Other studies have also observed unburned vegetation associated with low lying areas such as peatlands (Foster 1983), wetlands (Dansereau and Bergeron 1993) and draws (DeLong and Tanner 1996). The high moisture content of these low lying areas may protect the vegetation fire, if weather conditions are not extreme. Similarly, the discontinuous shrub and tree layer found in muskeg vegetation types would not be conducive to the persistence of high intensity crown fires.

The results of the association between muskeg and residuals should be interpreted with more caution than those related to the forest vegetation types. There is a greater possibility of error associated with the delineation of residuals in non-forested vegetation types compared to forested vegetation types. It is more difficult to distinguish between burned and unburned vegetation, because the height difference between burned and unburned non-forested vegetation is negligible, compared to the height difference in the forested areas. Furthermore, regeneration of vegetation within moist areas is generally more rapid, decreasing the ability to distinguish between unburned or low burn severity areas and regeneration (White *et al.* 1996).

4.1.5 Other Vegetation Types

Only four vegetation types were tested to determine whether they were associated with residual occurrence. Other vegetation types within the boreal forest, such as pine, black spruce, and mixed coniferous probably have no positive association with residuals. Based on structural and stand conditions, most coniferous fuel types are susceptible to crown fires and experience high rates of mortality (Alexander *et al.* 1984, Johnson 1992). For example, horizontal and vertical continuity of black spruce stands renders them highly susceptible to crown fires, generally resulting in complete mortality (Kiil and Grigel 1969). Similarly black spruce fuel types also are more susceptible to crowning at lower rates of spread and initial spread indices (lower crowning threshold) compared to deciduous and mixedwood fuel types (Alexander *et al.* 1984). In general, pine stands have poor vertical but good horizontal continuity, consequently reducing the ability of crown fire to start but facilitating spread once started (Kiil and Grigel 1969). With respect to crowning thresholds, both mature and immature pine fuel types have lower crowning thresholds compared to mixedwood and deciduous (Alexander *et al.* 1984).

Although the structure of these other boreal forest vegetation types suggests that they are unlikely to be positively associated with residuals, a negative association was not tested. The relatively low proportion of pine and mixed coniferous species within each of the fire areas results in a positively skewed distribution of the random samples (Zar 1996). This makes it impractical to test for proportions of a vegetation type that may be less than expected from random, since so many of the random proportions are zero. If a vegetation type was found to occur in residuals significantly less than expected, it would imply that the vegetation type has a higher flammability or is more susceptible to fire mortality.

4.1.6 Variation Within Vegetation Types

In general, there is an association between selected vegetation types and residuals, but many areas dominated by these same vegetation types still suffered fatal affects from fire. Although weather conditions have a large influence on fire behaviour (Bessie and Johnson 1995) and short-term stand flammability (Johnson 1992), stand conditions and landscape position also may increase the flammability of an otherwise less flammable stand type. Although these factors may affect stand mortality they were not measured as part of this study; the potential influences of these factors on the selected vegetation types are briefly described.

The vegetation types chosen for this study are relatively broad, based on dominant overstory species, with potential variation in stand characteristics such as stand structure, age, and disturbance history within a single vegetation type. Variation within a vegetation type may result from differences in stand structure. The relative amounts of coniferous and deciduous within mixedwood stands influence the rate of fire spread (Alexander *et al.* 1984). Therefore mixedwood stands with higher coniferous to deciduous ratios would experience increased flammability compared to deciduous dominated mixedwood stands. Other stand characteristics such as the type of understory vegetation (Van Wagner 1974) and the height of shrub layer (Johnson 1992) have been found to affect fire intensity and mortality.

The association between flammability and stand age is debated in the literature. Numerous examples in the literature support the view that flammability either increases with stand age, decreases with stand age (Foster 1983; Alexander *et al.* 1984), or is independent of stand age (Bessie and Johnson 1995). An increase in flammability over time is generally attributed to accumulation of fuel within the stand. Of the selected vegetation types, white spruce stands are suspected to increase in flammability with age, due to accumulation of fuel within the stand (Yarie 1981). Deciduous stands are thought to experience little change in susceptibility with age (Yarie 1981). Other studies indirectly implicate age as an important influence on flammability. For example, stem diameter and bark thickness, which generally increase with age, were found to be inversely related to aspen mortality in low and moderate intensity fires (Quintilio *et al.* 1991; Brown and DeByle 1987). This relationship is also evident in coniferous species (Peterson and Ryan 1986).

In addition to variation due to stand structure and age, other stand conditions may influence fire intensity and stand mortality. The occurrence of previous disturbance such as insect infestation (Camp *et al.* 1997), disease (VanWagner 1977), and recent fire events (Quintilio 1991) may lead to an increase in the amount of fuel within the stand which results in increased fire intensity and mortality.

The position of a stand relative to landscape elements may increase the probability of burning. For example, a stand of a certain vegetation type, located near a firebreak may survive fire whereas a stand of the same vegetation type, surrounded by flammable vegetation may be more susceptible to lethal fire affects. Spatial autocorrelation, measured as a ratio of the probability of burning of neighbouring areas was found to be a significant measure in determining the probability of an area burning (Chou *et al.* 1990).

The position of the stand relative to the fire boundary may also affect the probability of burning. For example, vegetation at the periphery of a fire, where the rate of fire spread and fire intensity is lower (Johnson 1992), experience decreased rates of mortality (Brown and DeByle 1987). Similarly, Dansereau and Bergeron (1993) observed that a greater number of trees survived near the fire margins where intensity was more variable. Therefore, stands in the center and at the head of the fire, where intensity is greatest, may suffer higher mortality than stands of a similar vegetation type located near the margins or flank of the fire.

4.2 Variation Between Individual Fires

Although there is an overall positive association between residuals and certain vegetation types, the relative association between residuals and vegetation varies between fires. In some fires, over half of the residuals were associated with one of the four vegetation types, whereas other fires had no residuals associated with selected vegetation types. The importance of vegetation on burn pattern may be represented by the percentage of significant residuals occurring within each fire. The variable influence of vegetation between individual fires may be attributed to broad scale factors including weather (Bessie and Johnson 1995), season of burning (Quintilio *et al.* 1991; Peterson and Ryan 1986), fire intensity (Turner *et al.* 1994), and regional physiography (Kushla and Ripple 1996).

4.2.1 Correlation Between Fire Size and Percentage of Significant Residuals

It is generally accepted that large fires result from broad scale weather conditions such as certain atmospheric conditions (Johnson and Wowchuk 1993) and drought (Turner *et al.* 1994). Because of the extreme weather conditions the fires are generally more intense (Turner *et al.* 1994). For example, larger fires (measured as area burned per day) occurring later in the season were found to have larger patches and a higher proportion of the landscape associated with high crown fire severity compared to smaller, early fires (Turner *et al.* 1994). Similarly, the intensity within small fires is generally more variable (Dansereau and Bergeron 1993). As a result of increased fire intensity in larger fires, fire behaviour is influenced to a lesser degree by landscape pattern (Dansereau and Bergeron 1993) and vegetation (Bessie and Johnson 1995). Other studies had found no relationship between fire size and composition of vegetation within the fire area (Cumming in press). Therefore, based on the literature, it is expected that the burn pattern of large fires is less likely to be associated with vegetation types than the burn pattern of smaller fires.

Results of the correlation between fire size (log transformed) and percentage of significant residuals indicate that larger fires tend to have a higher percentage of significant residuals, suggesting that vegetation may have a greater influence on fire behaviour in larger fires than in smaller fires. This finding is contrary to what is generally thought to occur, but may be explained by the increased heterogeneity of larger fires. Since larger fires generally burn over a greater number of days, the fire encounters a wider range of burning conditions than smaller fires. Variables that fluctuate hourly, daily, or weekly such as wind speed, wind direction and fuel drying (Johnson 1992), create variable burning conditions that result in a wide range of fire intensity. During periods of low intensity, areas of less flammable vegetation, which would otherwise be burned, may survive.

4.2.2 Correlation Between Annual Area Burned and Percentage of Significant Residuals

Broad-scale weather conditions are important in controlling fire behaviour (Johnson and Wowchuk 1993). Therefore fires occurring in the same year, under the influence of similar weather conditions (Kiil and Grigel 1969), should demonstrate similar fire behaviour and burn pattern. It is predicted that fire intensity is greater during years of extreme weather conditions when large areas are burned compared to years when small areas are burned (Bessie and Johnson 1995). Furthermore, in low fire years, vegetation may influence fire behaviour but in high fire years most vegetation types reach a level of flammability that enables them to support a crown fire (Bessie and Johnson 1995).

Based on the results presented in this study. the area burned in the year of each fire was not associated with the percentage of significant residuals. This may suggest that the flammability of vegetation is independent of broad scale weather patterns. This explanation does not seem likely but perhaps the small number of fires, the low number of different fire years (N=8), and the non-stratified sample of fires with respect to annual area burned may contribute to the lack of association.

4.2.3 Further Explanation of Fire Variability

Other factors may account for the variable importance of vegetation between individual fires. Examples from the literature indicate that the season of the fire. regional landscape differences and fire suppression may contribute to varying importance of vegetation on fire behaviour.

A number of studies indicate that the flammability varies with season (Kiil and Grigel 1969; Quintilio *et al.* 1991; Van Wagner 1977; Van Wagner 1974). For aspen and mixedwood stands, an increase in fire severity is expected during leaf-off periods such as early spring and late autumn (Quintilio *et al.* 1991). Due to the increased solar radiation reaching the forest floor and drying the ground. aspen and mixedwood stands may be more susceptible to fire encroachment and experience increased mortality (Kiil and Grigel 1969). As a result, the proportion of residuals associated with deciduous or mixedwood vegetation types would be lower in spring and fall fires compared to summer fires. The probability of crown fires in conifer dominated areas may also vary depending on season. During spring and early summer, the foliar moisture content of conifers is low, which may lead to an increased susceptibility of the stand to crown fires (Van Wagner 1974). Based on this information. spring fires would likely have few residuals associated with white spruce or other coniferous vegetation types. The association between the season of burning and the percentage of significant deciduous residuals per fire was not tested in this study. Four of the twenty fires were spring fires, and three of the four spring fires had only one residual (none of which were significant). For the one spring fire that did have significant residuals, DP1-17-95, over half of the significant residuals were higher in deciduous content than expected.

The relative importance of vegetation on fire behaviour between fires may be explained in part by regional variation. For example, Kushla and Ripple (1997) found that vegetation and terrain accounted for more variation in fire behaviour within each physiographic region than over the entire study area. Similarly, the availability or proportion of fire susceptible vegetation across the landscape may explain some of the variation. Not only is the relative amount of the different vegetation types important in defining the regional fire regime (Rowe and Scotter 1973), but their spatial arrangement across the landscape is also important. Since fire spread is dependent on encountering fire susceptible areas, the spatial arrangement of these elements across the landscape may either facilitate or retard fire spread (Turner *et al.* 1989). Therefore, the heterogeneity or complexity of a landscape may account for variation in fire regimes between regions.

Suppression and fire fighting efforts are also important in determining the overall area, shape and pattern of burning. Although fire suppression information is available for most of the selected fires in Provincial Fire Reports, the level of detail between individual fire reports is variable and inconsistent and, therefore, fire suppression information was not included in this project.

4.3 Potential Error

The processes and techniques used for data capture and data processing of spatial information may introduce a certain degree of error into the dataset. Although error was not quantified as part of this study, it is important to recognise potential sources of error and consider how it may influence results.

The generation of the coverages used in this study involved a number of data capture techniques or processes including aerial photograph interpretation, data transfer, and digitising. Potential sources of error specific to this project are inherent in the use of existing information sources such as Phase 3 Forest Inventory maps, Alberta Vegetation Information, and aerial photographs. Forest inventory data were derived from aerial photograph interpretation and may be subject to inconsistencies resulting from interpretation. Possible errors associated with aerial photograph interpretation relate to drawing of boundaries between vegetation types that gradually merge into one another, transcription of three dimensional information onto a two dimensional surface, distortion at the edges of aerial photographs, and bias of different photo interpreters (Dunn *et al.* 1990; Burrough 1988; Chrisman 1982). Information from the interpretation of fire boundaries and residuals on aerial photographs was transcribed onto paper base maps. The use of paper base maps introduces another potential source of error since paper maps may become distorted with changes in humidity and folding (Burrough 1988). The width of the lines used to delineate polygons and fire boundaries represents an area of uncertainty (Burrough 1988). This area of uncertainty can be substantial if the map scale is small.

Positional errors may also be introduced during the digitising process. The magnitude of digitising errors is related to shape of lines, number points used to define a line, number and accuracy of ground control points and operator error (Burrough 1988; Warner and Carson 1991). Ground control points used to reference the map were transcribed from 1:50,000 National Topographic Series maps onto 1:15,000 base maps. This transfer of information from a small scale topographic map to a larger scale base map may introduce positional errors. The age of the topographic maps may be important. Older maps may be less accurate since standards used for the creation of maps in the past may differ from current standards (Burrough 1988). The registration of ground control points can be a large source of positional error if there is a lack of readily identified points (roads, seismic lines) on the maps (Bolstad *et al.* 1990). This was likely a source of error for fires in more remote areas.

Data manipulation and processing may also introduce error or bias. For example, during the randomisation process some randomly relocated residual boundaries intersected the fire boundary. Computer time required to relocate residual boundaries entirely within the fire boundaries would have been prohibitive if not impossible in some instances (ie. large residuals within small fires), therefore these truncated residuals were included in the analysis. Vegetation proportions for truncated residual boundaries were calculated by dividing the area of each vegetation type located within the truncated residual boundary by the total area within the original residual boundary. Therefore the vegetation proportions of these truncated residuals are biased, since the vegetation in only a portion of the residual was considered relative to the area of the entire residual. This would reduce the probability of obtaining a significantly higher proportion of a vegetation type in a truncated residual. Under these assumptions the number of residuals with significantly higher proportions of certain vegetation types may be underestimated.

Many of the possible sources of errors described above are unavoidable, due to existing data quality, availability of data, and processing techniques used. Although the accuracy of the data and the amount of error were not quantified as part of this study, it is important to acknowledge possible sources of error during each stage of data development, manipulation, and analysis.

5.0 CONCLUSIONS

The complex interaction between landscape elements and natural disturbance processes, such as wildfire, make the explanation of resultant landscape pattern difficult. Despite the difficulty in predicting burn pattern some new information regarding the relative influence of vegetation on burn pattern can be gleaned from the current study. The vegetation composition of live residuals, within twenty fire-affected areas, provides evidence that the distribution of residuals is not entirely random with respect to pre-fire vegetation pattern. There was a trend for some residuals to contain significantly higher proportion of either deciduous, mixedwood, white spruce or muskeg vegetation types than expected.

The influence of pre-fire vegetation on burn pattern varied between individual fires. An attempt was made to explain the relative influence of vegetation between fires based on individual fire characteristics. For the fires used in this study, the influence of vegetation on fire behaviour was found to be associated with fire size. Larger fires, which over a period of days may experience a broader range of burning conditions, had a greater proportion of residuals associated with one of the four vegetation types considered. No association was found between the annual area burned and the influence of vegetation on burn pattern.

Despite efforts to break down fire behaviour into a series of simple deterministic models, the large number factors influencing fire behaviour and interacting at a range of spatial and temporal scales makes prediction and explanation of burn patterns difficult. It is therefore surprising that pre-fire vegetation is associated with residuals to the degree found by this research. A better understanding of residual distribution may result from further analysis of burn pattern with respect to other landscape elements such as juxtaposition of vegetation types or proximity to water features.

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7.0 APPENDIX

VEGETATION COMPOSITION OF RESIDUALS

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DA2-2-86-2	1.2203	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DA2-2-86-7	1.0529	0.7124	0.0000	0.0000	0.1529	0.0000	0.0000	0.0000	0.1347	0.0000	0.0000
DA2-2-86-8	1.2806	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4207	0.5793	0.0000	0.0000
DF1-34-78-3	1.4238	0.0000	0.0000	0.0285	0.0000	0.0000	0.9715	0.0000	0.0000	0.0000	0.0000
DF1-34-78-7	4.4066	0.0000	0.7232	0.0000	0.0231	0.0000	0.2537	0.0000	0.0000	0.0000	0.0000
DF1-34-78-11	1.0698	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-12	15.3841	0.0000	0.3943	0.0292	0.0000	0.0000	0.5766	0.0000	0.0000	0.0000	0.0000
DF1-34-78-15	5.0301	0.0000	0.0000	0.0000	0.0000	0.0000	0.5450	0.0000	0.4550	0.0000	0.0000
DF1-34-78-16	2.6599	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-25	1.7150	0.0000	0.8737	0.0000	0.0000	0.0000	0.1263	0.0000	0.0000	0.0000	0.0000
DF1-34-78-26	1.3280	0.0000	0.9186	0.0000	0.0000	0.0000	0.0814	0.0000	0.0000	0.0000	0.0000
DF1-34-78-30	1.4199	0.0000	0.9376	0.0000	0.0000	0.0000	0.0624	0.0000	0.0000	0.0000	0.0000
DF1-34-78-32	1.8775	0.0000	0.0577	0.7954	0.0000	0.0000	0.1469	0.0000	0.0000	0.0000	0.0000
DF1-34-78-35	7.0188	0.1369	0.0000	0.1060	0.7571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-36	6.4505	0.0000	0.0000	0.6129	0.3390	0.0000	0.0481	0.0000	0.0000	0.0000	0.0000
DF1-34-78-37	1.6351	0.9952	0.0000	0.0000	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-38	1.1402	0.0000	0.0000	0.0000	0.0827	0.0000	0.9173	0.0000	0.0000	0.0000	0.0000
DF1-34-78-43	1.4411	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-46	5.8083	0.0000	0.0000	0.0000	0.2047	0.0000	0.6980	0.0000	0.0973	0.0000	0.0000
DF1-34-78-55	3.9208	0.0000	0.0000	0.0299	0.0308	0.0000	0.9351	0.0000	0.0042	0.0000	0.0000
DF1-34-78-58	5.3679	0.0000	0.7369	0.0000	0.0000	0.0000	0.2631	0.0000	0.0000	0.0000	0.0000
DF1-34-78-64	1.2131	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-34-78-68	4.1463	0.0000	0.0000	0.0000	0.7536	0.0000	0.0000	0.0000	0.2464	0.0000	0.0000
DF1-34-78-74	1.7432	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DF1-64-90-2	1.1649	0.0000	0.0000	0.0000	0.0033	0.0000	0.2089	0.0000	0.7878	0.0000	0.0000
DF1-64-90-3	8.6152	0.0000	0.0000	0.0000	0.4358	0.0000	0.0000	0.0000	0.5642	0.0000	0.0000
DF1-64-90-5	5.7166	0.0000	0.0000	0.0000	0.2278	0.0000	0.5211	0.0000	0.2511	0.0000	0.0000
DF1-64-90-7	1.3303	0.0000	0.0000	0.0000	0.9033	0.0000	0.0967	0.0000	0.0000	0.0000	0.0000
DF1-64-90-11	1.2580	0.0000	0.0000	0.0000	0.4307	0.0000	0.5693	0.0000	0.0000	0.0000	0.0000
DF2-14-80-2	3.8534	0.0000	0.0000	0.0000	0.1103	0.0000	0.8897	0.0000	0.0000	0.0000	0.0000
DL2-24-80-11	3.8454	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-24-80-9	1.0634	0.3290	0.5484	0.0000	0.0000	0.0000	0.0000	0.0000	0.1226	0.0000	0.0000
DL2-24-80-4	1.1459	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-43-82-5	1.7508	0.0000	0.9228	0.0000	0.0772	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-43-82-14	2.4847	0.0000	0.9388	0.0000	0.0612	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-43-82-16	4.2515	0.0000	0.9372	0.0000	0.0628	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-43-82-20	2.0644	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-43-82-34	2.1918	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DL2-43-82-36	1.1257	0.0000	0.0000	0.0000	0.1979	0.0000	0.0000	0.0000	0.8021	0.0000	0.0000
DL2-43-82-39	3.3106	0.0000	0.0000	0.0000	0.4743	0.0000	0.0000	0.0000	0.5257	0.0000	0.0000
DL2-77-90-7	1.8881	0.0000	0.0000	0.0000	0.4772	0.0000	0.0000	0.5228	0.0000	0.0000	0.0000
DL2-77-90-8	5.6308	0.0000	0.0000	0.0000	0.5336	0.0000	0.0000	0.2275	0.0000	0.2389	0.0000
DL2-77-90-12	1.9186	0.0000	0.0000	0.0000	0.2176	0.0000	0.0000	0.7824	0.0000	0.0000	0.0000
DL2-77-90-14	1.6915	0.4321	0.4652	0.0000	0.1027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-77-90-15	1.1444	0.0000	0.0000	0.0000	0.6805	0.0000	0.0000	0.3193	0.0000	0.0002	0.0000
DL2-88-90-3	9.0628	0.0000	0.0000	0.0000	0.4475	0.5525	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-4	6.7308	0.7870	0.0000	0.0000	0.0000	0.0000	0.2130	0.0000	0.0000	0.0000	0.0000
DL2-88-90-5	1.5686	0.0000	0.0000	0.0000	0.5290	0.4710	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-6	1.0686	0.0000	0.3948	0.0000	0.4639	0.0000	0.0000	0.0000	0.1413	0.0000	0.0000
DL2-88-90-7	5.1672	0.0001	0.0000	0.0000	0.4242	0.0000	0.5757	0.0000	0.0000	0.0000	0.0000
DL2-88-90-11	1.1530	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-15	1.8325	0.0000	0.0000	0.0000	0.2683	0.0000	0.3113	0.0000	0.0000	0.0000	0.4205

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DL2-88-90-16	1.6869	0.0000	0.9755	0.0000	0.0245	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-18	1.7936	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-20	1.2222	0.0000	0.7445	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2555
DL2-88-90-21	1.7892	0.0000	0.0000	0.0000	0.9926	0.0000	0.0000	0.0000	0.0000	0.0000	0.0074
DL2-88-90-24	9.6077	0.0000	0.0000	0.0000	0.7727	0.0000	0.0000	0.0000	0.2273	0.0000	0.0000
DL2-88-90-25	1.6592	0.0000	0.0000	0.0000	0.0000	0.8566	0.0000	0.0000	0.0000	0.1434	0.0000
DL2-88-90-26	1.2769	0.0000	0.0000	0.0000	0.8952	0.0000	0.0000	0.0000	0.1048	0.0000	0.0000
DL2-88-90-27	1.0294	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-31	1.7651	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-32	3.6133	0.0000	0.0000	0.0000	0.0000	0.2583	0.0000	0.0000	0.0000	0.4178	0.3239
DL2-88-90-33	3.8580	0.0000	0.0000	0.5533	0.4467	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-37	2.7382	0.0000	0.0000	0.9357	0.0643	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-39	1.3425	0.8803	0.0000	0.0951	0.0246	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-42	3.1054	0.0000	0.0000	0.1651	0.8344	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000
DL2-88-90-43	6.0895	0.0000	0.0000	0.0000	0.0997	0.0000	0.0000	0.0000	0.0000	0.9003	0.0000
DL2-88-90-44	8.0602	0.0000	0.4355	0.0000	0.1668	0.0000	0.3977	0.0000	0.0000	0.0000	0.0000
DL2-88-90-46	1.5598	0.0000	0.0000	0.0273	0.8826	0.0000	0.0000	0.0000	0.0000	0.0901	0.0000
DL2-88-90-49	1.0597	0.9272	0.0000	0.0565	0.0163	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL2-88-90-50	1.3503	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-3	11.7200	0.0000	0.0000	0.0000	0.1990	0.0000	0.0850	0.0000	0.0000	0.0000	0.7160
DL3-19-82-11	1.5673	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-12	1.1462	0.0000	0.0000	0.0000	0.1337	0.0000	0.0000	0.0000	0.0000	0.8663	0.0000
DL3-19-82-15	1.1904	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-17	4.5637	0.0000	0.0000	0.0000	0.2051	0.0000	0.0000	0.7949	0.0000	0.0000	0.0000
DL3-19-82-23	1.0303	0.7973	0.0000	0.0000	0.2027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-25	2.8489	0.0000	0.9877	0.0000	0.0123	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-29	9.4719	0.0000	0.0000	0.0000	0.7891	0.0000	0.0000	0.0725	0.0000	0.1384	0.0000
DL3-19-82-30	1.3152	0.9486	0.0000	0.0000	0.0514	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-31	2.4448	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-32	4.1416	0.5947	0.2209	0.0000	0.1844	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-34	1.1052	0.0168	0.9832	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-42	1.4505	0.9983	0.0000	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-43	1.2638	0.9664	0.0336	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-51	1.6843	0.9250	0.0000	0.0000	0.0750	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL3-19-82-70	1.4624	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-8	2.4509	0.0000	0.0000	0.0000	0.0429	0.0000	0.0000	0.0000	0.9571	0.0000	0.0000
DL4-16-81-14	1.2827	0.0000	0.0000	0.0000	0.6524	0.0000	0.0000	0.0000	0.3476	0.0000	0.0000
DL4-16-81-16	3.7049	0.0000	0.0000	0.0000	0.1245	0.0000	0.0000	0.0000	0.8755	0.0000	0.0000
DL4-16-81-17	5.3190	0.0000	0.0000	0.0000	0.0171	0.0000	0.0000	0.0000	0.9829	0.0000	0.0000
DL4-16-81-18	2.7673	0.0000	0.5655	0.0000	0.4169	0.0000	0.0000	0.0000	0.0176	0.0000	0.0000
DL4-16-81-20	2.4537	0.0000	0.9757	0.0000	0.0071	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
DL4-16-81-21	1.8528	0.0000	0.0000	0.0000	0.5794	0.0000	0.0000	0.0000	0.4206	0.0000	0.0000
DL4-16-81-26	14.0928	0.0000	0.0000	0.0000	0.5102	0.0000	0.0000	0.0000	0.4790	0.0108	0.0000
DL4-16-81-28	1.5412	0.0000	0.0000	0.0000	0.8098	0.0000	0.0000	0.0000	0.1902	0.0000	0.0000
DL4-16-81-34	1.3359	0.0000	0.0000	0.0000	0.7952	0.0000	0.0000	0.0000	0.2048	0.0000	0.0000
DL4-16-81-37	18.5809	0.0000	0.0000	0.0000	0.5532	0.0000	0.3689	0.0000	0.0779	0.0000	0.0000
DL4-16-81-40	1.6013	0.0000	0.0000	0.0000	0.8232	0.0000	0.0000	0.0000	0.0049	0.1719	0.0000
DL4-16-81-41	1.4343	0.0000	0.0000	0.0000	0.0568	0.0000	0.9432	0.0000	0.0000	0.0000	0.0000
DL4-16-81-42	1.0591	0.0000	0.0000	0.0000	0.4710	0.0000	0.0000	0.0016	0.5274	0.0000	0.0000
DL4-16-81-47	1.0426	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DL4-16-81-48	5.4668	0.0000	0.0000	0.0000	0.7219	0.0000	0.0684	0.0828	0.1269	0.0000	0.0000
DL4-16-81-49	35.1673	0.0000	0.9552	0.0000	0.0322	0.0000	0.0000	0.0000	0.0126	0.0000	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DL4-16-81-53	16.8493	0.0000	0.0000	0.0000	0.0864	0.0000	0.0000	0.0000	0.9136	0.0000	0.0000
DL4-16-81-57	14.3667	0.0000	0.0000	0.0000	0.2193	0.0000	0.0236	0.7278	0.0000	0.0293	0.0000
DL4-16-81-59	7.1167	0.0000	0.0000	0.0000	0.0531	0.0000	0.0000	0.0853	0.8616	0.0000	0.0000
DL4-16-81-67	2.2414	0.0000	0.6517	0.0000	0.3316	0.0000	0.0000	0.0000	0.0167	0.0000	0.0000
DL4-16-81-69	1.0980	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DL4-16-81-70	4.9101	0.0000	0.9769	0.0000	0.0231	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-71	1.7727	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DL4-16-81-72	6.3454	0.0000	0.0000	0.0000	0.2755	0.0000	0.0342	0.6515	0.0388	0.0000	0.0000
DL4-16-81-77	1.4110	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-78	1.1855	0.0000	0.0000	0.0000	0.9698	0.0000	0.0000	0.0000	0.0000	0.0302	0.0000
DL4-16-81-80	19.7554	0.0000	0.8584	0.1319	0.0097	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-81	5.0819	0.0000	0.8869	0.0123	0.1008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-82	5.0908	0.0000	0.0000	0.0000	0.1942	0.0000	0.0000	0.0000	0.3094	0.4964	0.0000
DL4-16-81-86	2.4561	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-91	2.4127	0.0000	0.9501	0.0000	0.0499	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-92	12.3192	0.0000	0.0000	0.0000	0.3083	0.0000	0.1129	0.0000	0.5788	0.0000	0.0000
DL4-16-81-93	2.1065	0.0000	0.0000	0.0000	0.2209	0.0000	0.0265	0.0000	0.1287	0.6239	0.0000
DL4-16-81-94	6.3565	0.0000	0.0000	0.0000	0.1631	0.0000	0.2011	0.0452	0.0000	0.5906	0.0000
DL4-16-81-96	1.1487	0.0000	0.0000	0.0000	0.0000	0.0000	0.4306	0.5676	0.0018	0.0000	0.0000
DL4-16-81-99	1.0381	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2468	0.7532	0.0000	0.0000
DL4-16-81-100	1.1974	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-102	3.1512	0.0000	0.9399	0.0000	0.0601	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-103	7.7942	0.0000	0.0000	0.0000	0.0287	0.0000	0.1807	0.7906	0.0000	0.0000	0.0000
DL4-16-81-104	1.1118	0.0000	0.0000	0.0000	0.0031	0.0000	0.0000	0.9969	0.0000	0.0000	0.0000
DL4-16-81-106	1.5793	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-107	1.3664	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-108	2.5695	0.0000	0.0000	0.1570	0.8430	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DL4-16-81-109	1.1362	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DL4-16-81-110	1.5282	0.0000	0.0000	0.0000	0.0261	0.0000	0.0000	0.0426	0.9313	0.0000	0.0000
DL4-16-81-114	1.6539	0.0000	0.0000	0.0000	0.4007	0.0000	0.0000	0.0000	0.5993	0.0000	0.0000
DL4-16-81-116	2.4205	0.0000	0.0000	0.0000	0.9359	0.0000	0.0000	0.0000	0.0641	0.0000	0.0000
DL4-16-81-118	2.5651	0.0000	0.0000	0.0000	0.1636	0.0000	0.0000	0.0000	0.8364	0.0000	0.0000
DP2-13-82-8	2.9303	0.6829	0.0000	0.0000	0.0000	0.0000	0.2856	0.0000	0.0315	0.0000	0.0000
DP2-4-82-2	4.9216	0.0000	0.0000	0.1220	0.0000	0.0000	0.8780	0.0000	0.0000	0.0000	0.0000
DP2-4-82-5	3.4734	0.0000	0.0000	0.2511	0.0000	0.0000	0.0000	0.0000	0.7489	0.0000	0.0000
DP2-4-82-20	4.3231	0.0000	0.6409	0.0000	0.0000	0.0000	0.3591	0.0000	0.0000	0.0000	0.0000
DP2-4-82-30	10.4940	0.0000	0.5851	0.4073	0.0000	0.0000	0.0000	0.0000	0.0076	0.0000	0.0000
DP2-4-82-32	1.7456	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP2-4-82-39	2.0158	0.0000	0.0000	0.9838	0.0000	0.0000	0.0000	0.0000	0.0162	0.0000	0.0000
DP2-4-82-40	1.0226	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP2-4-82-44	2.7924	0.0000	0.0000	0.0053	0.0000	0.0000	0.0000	0.0000	0.9947	0.0000	0.0000
DP2-4-82-47	2.3207	0.0000	0.0000	0.9266	0.0000	0.0000	0.0000	0.0700	0.0000	0.0000	0.0034
DP2-4-82-48	1.5361	0.0000	0.0000	0.0000	0.0000	0.0000	0.1103	0.0000	0.8897	0.0000	0.0000
DP2-4-82-49	1.5449	0.0000	0.0000	0.1650	0.0000	0.0000	0.0000	0.6852	0.1498	0.0000	0.0000
DP2-4-82-58	1.0047	0.0000	0.0000	0.3400	0.0000	0.0000	0.0000	0.0000	0.6600	0.0000	0.0000
DP2-4-82-59	1.8719	0.0000	0.0000	0.4667	0.0000	0.0000	0.0000	0.5333	0.0000	0.0000	0.0000
DP2-4-82-65	1.1226	0.0000	0.0000	0.9840	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0160
DP2-4-82-66	1.1164	0.9689	0.0000	0.0000	0.0000	0.0000	0.0000	0.0311	0.0000	0.0000	0.0000
DP2-4-82-78	7.6114	0.0000	0.6192	0.3686	0.0000	0.0000	0.0000	0.0000	0.0122	0.0000	0.0000
DS5-9-82-2	1.2900	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS5-9-82-7	1.7993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS5-9-82-13	2.3201	0.0000	0.0000	0.0000	0.0000	0.0150	0.0000	0.0000	0.9850	0.0000	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DS5-9-82-15	2.6393	0.0000	0.7049	0.0000	0.0000	0.0000	0.0000	0.0000	0.2863	0.0000	0.0088
DS5-9-82-19	1.4386	0.0000	0.0000	0.0000	0.0000	0.0000	0.8704	0.0000	0.1296	0.0000	0.0000
DS5-9-82-23	2.1359	0.0000	0.0000	0.0000	0.0000	0.0000	0.4789	0.0000	0.5211	0.0000	0.0000
DS5-9-82-24	1.8791	0.0000	0.5899	0.0000	0.0000	0.0000	0.0000	0.0000	0.4101	0.0000	0.0000
DS5-9-82-25	6.2707	0.0000	0.4213	0.0000	0.0000	0.0000	0.1353	0.0000	0.4434	0.0000	0.0000
DS5-9-82-27	3.5080	0.3803	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6197	0.0000	0.0000
DS5-9-82-36	2.2956	0.0000	0.1187	0.0000	0.0000	0.0000	0.0000	0.0000	0.8813	0.0000	0.0000
DS5-9-82-40	6.6170	0.0000	0.4344	0.0000	0.0000	0.0000	0.0000	0.0000	0.3925	0.1380	0.0351
DS5-9-82-41	8.7888	0.3535	0.1020	0.0000	0.0000	0.0000	0.0000	0.0000	0.5445	0.0000	0.0000
DS5-9-82-43	2.5018	0.0000	0.4541	0.0000	0.0000	0.0000	0.0000	0.0000	0.4917	0.0542	0.0000
DS5-9-82-45	1.0200	0.0348	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9652	0.0000	0.0000
DS5-9-82-51	3.5576	0.0000	0.0000	0.0000	0.0000	0.3305	0.1036	0.0000	0.5659	0.0000	0.0000
DS5-9-82-66	3.2836	0.0000	0.0000	0.0000	0.6008	0.0000	0.0000	0.0000	0.3992	0.0000	0.0000
DS5-9-82-68	1.0933	0.0000	0.0762	0.0000	0.1829	0.0000	0.0000	0.0000	0.7409	0.0000	0.0000
DS5-9-82-70	1.6962	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS5-9-82-72	1.1967	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS5-9-82-73	3.5014	0.0000	0.0000	0.0000	0.0100	0.3916	0.0000	0.0000	0.5984	0.0000	0.0000
DS5-9-82-81	2.1660	0.0000	0.6476	0.0000	0.0000	0.0000	0.0000	0.0000	0.3524	0.0000	0.0000
DS5-9-82-83	2.3271	0.6785	0.2352	0.0000	0.0000	0.0863	0.0000	0.0000	0.0000	0.0000	0.0000
DS5-9-82-86	3.8724	0.6240	0.0000	0.0000	0.0000	0.1641	0.0000	0.0000	0.0000	0.2119	0.0000
DS5-9-82-87	3.4784	0.0013	0.8179	0.0000	0.0000	0.0000	0.0000	0.0000	0.0597	0.0272	0.0939
DS5-9-82-88	2.2836	0.0000	0.0000	0.0000	0.0000	0.0251	0.0000	0.4172	0.5577	0.0000	0.0000
DS5-9-82-92	1.9995	0.0673	0.0000	0.0000	0.0000	0.5698	0.0000	0.0000	0.0000	0.2179	0.1450
DS5-9-82-96	2.9709	0.2288	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4085	0.0549	0.3078
DS5-9-82-98	1.4550	0.8576	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1424	0.0000
DS5-9-82-101	1.0534	0.0000	0.5351	0.0000	0.0000	0.0000	0.0000	0.0000	0.4649	0.0000	0.0000
DS5-9-82-102	1.1830	0.9207	0.0000	0.0000	0.0000	0.0000	0.0000	0.0793	0.0000	0.0000	0.0000
DS5-9-82-103	2.6028	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS5-9-82-108	1.8877	0.9964	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000
DS5-9-82-114	2.7799	0.1702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8298	0.0000	0.0000
DS5-9-82-119	2.2815	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS5-9-82-128	1.1767	0.5713	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2360	0.0000	0.1927
DS6-19-82-2	1.9344	0.8587	0.0780	0.0000	0.0633	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-19-82-3	1.5862	0.0000	0.0000	0.0000	0.8269	0.0000	0.0000	0.0000	0.1731	0.0000	0.0000
DS6-19-82-5	2.8690	0.0000	0.0000	0.0000	0.6347	0.0000	0.0000	0.0000	0.3653	0.0000	0.0000
DS6-19-82-6	1.5127	0.0000	0.0000	0.7008	0.0000	0.0000	0.0000	0.0000	0.2992	0.0000	0.0000
DS6-19-82-7	3.1059	0.0000	0.0000	0.9264	0.0736	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-16	1.1501	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-23	1.4970	0.0000	0.7399	0.0000	0.0000	0.0000	0.0000	0.0000	0.2601	0.0000	0.0000
DS6-26-82-25	10.8806	0.0000	0.7577	0.0000	0.0000	0.1773	0.0000	0.0000	0.0614	0.0000	0.0036
DS6-26-82-26	1.3592	0.0000	0.3199	0.0000	0.0000	0.0000	0.0000	0.0000	0.6801	0.0000	0.0000
DS6-26-82-35	1.8421	0.3966	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6034	0.0000	0.0000
DS6-26-82-36	23.4632	0.5278	0.0000	0.0000	0.0000	0.1370	0.0000	0.0000	0.3352	0.0000	0.0000
DS6-26-82-46	109.5937	0.1922	0.2136	0.0000	0.0000	0.4641	0.0000	0.0084	0.0820	0.0383	0.0014
DS6-26-82-47	2.2047	0.0000	0.0000	0.0000	0.0000	0.1906	0.0000	0.0000	0.0000	0.8094	0.0000
DS6-26-82-52	1.1013	0.0000	0.9969	0.0000	0.0000	0.0000	0.0000	0.0000	0.0031	0.0000	0.0000
DS6-26-82-54	1.4666	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-26-82-60	2.3888	0.0000	0.0000	0.0000	0.0000	0.4659	0.0000	0.0000	0.5341	0.0000	0.0000
DS6-26-82-63	1.2255	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-74	1.1918	0.0000	0.0000	0.0000	0.0000	0.1865	0.0000	0.7398	0.0737	0.0000	0.0000
DS6-26-82-75	1.2703	0.0000	0.3570	0.0000	0.0000	0.0232	0.0000	0.0000	0.6198	0.0000	0.0000
DS6-26-82-78	4.7087	0.0000	0.0000	0.0000	0.0000	0.8867	0.0000	0.0000	0.1133	0.0000	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DS6-26-82-80	1.1042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
DS6-26-82-81	1.1793	0.0000	0.0000	0.0000	0.0000	0.2529	0.0000	0.0000	0.7471	0.0000	0.0000
DS6-26-82-83	2.1837	0.7499	0.0000	0.2474	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000
DS6-26-82-86	1.4414	0.0000	0.0000	0.0000	0.0000	0.2535	0.0000	0.0000	0.7465	0.0000	0.0000
DS6-26-82-88	1.2135	0.4224	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5776	0.0000	0.0000
DS6-26-82-89	5.0019	0.0000	0.0000	0.0000	0.0000	0.6648	0.0000	0.0000	0.3352	0.0000	0.0000
DS6-26-82-90	1.0044	0.8383	0.0000	0.1617	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-91	1.2792	0.3865	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6135	0.0000	0.0000
DS6-26-82-97	1.6515	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-98	2.5600	0.0000	0.3298	0.0000	0.0000	0.0000	0.0000	0.0000	0.6702	0.0000	0.0000
DS6-26-82-100	21.5860	0.6162	0.1273	0.0000	0.0000	0.1971	0.0000	0.0000	0.0594	0.0000	0.0000
DS6-26-82-103	3.5438	0.0000	0.9191	0.0000	0.0000	0.0000	0.0000	0.0000	0.0809	0.0000	0.0000
DS6-26-82-104	1.5784	0.3304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6696	0.0000	0.0000
DS6-26-82-111	2.8149	0.0000	0.1181	0.5923	0.0000	0.0000	0.0000	0.0000	0.0000	0.1891	0.1005
DS6-26-82-112	2.3347	0.0000	0.0000	0.0000	0.0000	0.7982	0.0000	0.0000	0.0000	0.2018	0.0000
DS6-26-82-114	1.2518	0.0000	0.1167	0.4867	0.0000	0.0000	0.0000	0.0000	0.0482	0.3484	0.0000
DS6-26-82-116	3.7929	0.0000	0.0874	0.3221	0.0000	0.0000	0.0000	0.0000	0.5905	0.0000	0.0000
DS6-26-82-118	2.1090	0.0000	0.3782	0.0000	0.0000	0.1312	0.0000	0.0000	0.2301	0.2541	0.0064
DS6-26-82-122	1.8142	0.0000	0.7860	0.0498	0.0000	0.0000	0.0000	0.0000	0.1642	0.0000	0.0000
DS6-26-82-123	6.4107	0.0000	0.9631	0.0000	0.0000	0.0000	0.0000	0.0000	0.0244	0.0125	0.0000
DS6-26-82-129	1.6360	0.0000	0.0032	0.0000	0.0000	0.8228	0.0000	0.0000	0.0636	0.1104	0.0000
DS6-26-82-133	1.0220	0.0000	0.0000	0.0000	0.0000	0.9713	0.0000	0.0000	0.0287	0.0000	0.0000
DS6-26-82-134	1.3215	0.0000	0.7086	0.0000	0.0000	0.2914	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-137	5.2584	0.0000	0.2559	0.0000	0.0000	0.4721	0.0000	0.0000	0.0000	0.2720	0.0000
DS6-26-82-138	4.5517	0.0000	0.0000	0.0000	0.0000	0.8451	0.0000	0.0000	0.1373	0.0093	0.0083
DS6-26-82-139	4.0508	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-26-82-143	2.7839	0.0000	0.9334	0.0000	0.0000	0.0000	0.0000	0.0000	0.0666	0.0000	0.0000
DS6-26-82-148	15.3836	0.0000	0.6541	0.2516	0.0000	0.0000	0.0000	0.0000	0.0928	0.0015	0.0000
DS6-26-82-149	5.0571	0.0000	0.2698	0.2016	0.0000	0.0000	0.0000	0.0000	0.5286	0.0000	0.0000
DS6-26-82-154	1.0489	0.0000	0.0000	0.2678	0.0000	0.0000	0.0000	0.0000	0.7322	0.0000	0.0000
DS6-26-82-159	3.1673	0.0000	0.0000	0.7927	0.0000	0.0000	0.0000	0.0000	0.2073	0.0000	0.0000
DS6-26-82-161	4.9679	0.0000	0.0000	0.7521	0.0000	0.0000	0.0000	0.0000	0.2479	0.0000	0.0000
DS6-26-82-163	2.7043	0.0000	0.0000	0.5425	0.0000	0.0000	0.0000	0.2299	0.2276	0.0000	0.0000
DS6-26-82-168	17.2412	0.0000	0.3518	0.2504	0.0000	0.0000	0.0000	0.0000	0.3978	0.0000	0.0000
DS6-26-82-175	3.5165	0.0000	0.0000	0.9397	0.0000	0.0000	0.0000	0.0000	0.0603	0.0000	0.0000
DS6-26-82-176	2.6712	0.0000	0.0000	0.9544	0.0000	0.0000	0.0000	0.0000	0.0456	0.0000	0.0000
DS6-26-82-179	1.3697	0.0000	0.9940	0.0000	0.0000	0.0000	0.0000	0.0000	0.0060	0.0000	0.0000
DS6-26-82-181	6.4599	0.0000	0.2296	0.1153	0.0000	0.0000	0.0000	0.0000	0.6551	0.0000	0.0000
DS6-26-82-184	4.2780	0.0000	0.3413	0.0000	0.0000	0.3280	0.0000	0.0000	0.3307	0.0000	0.0000
DS6-26-82-186	20.9302	0.0000	0.7846	0.0000	0.0000	0.0000	0.0000	0.0165	0.1989	0.0000	0.0000
DS6-32-82-4	1.0699	0.0436	0.0000	0.0000	0.9564	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DS6-32-82-12	2.2743	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-32-82-14	4.8934	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-32-82-17	2.2317	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-32-82-19	1.0836	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-32-82-24	1.0646	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-32-82-27	1.6274	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-38-82-4	1.7461	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-38-82-18	1.1131	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-38-82-25	1.4603	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-38-82-32	4.2366	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS6-38-82-22	6.2785	0.0000	0.5687	0.0000	0.0000	0.0000	0.0000	0.0000	0.4184	0.0129	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DP1-12-90-4	1.0018	0.0000	0.0000	0.8055	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1945
DP1-12-90-5	6.3828	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.9306	0.0694
DP1-12-90-8	2.6130	0.0000	0.0000	0.0000	0.0000	0.0000	0.9395	0.0000	0.0000	0.0000	0.0605
DP1-12-90-9	2.3327	0.0000	0.0000	0.0000	0.0000	0.0000	0.8304	0.0000	0.0000	0.0000	0.1696
DP1-12-90-11	1.1362	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
DP1-12-90-12	1.6869	0.0000	0.0000	0.0000	0.0000	0.0000	0.8992	0.0000	0.0000	0.0000	0.1008
DP1-12-90-13	4.2827	0.0000	0.0000	0.0000	0.0000	0.0000	0.8465	0.0000	0.0000	0.0668	0.0867
DP1-12-90-15	1.7532	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
DP1-12-90-16	1.0556	0.0000	0.0000	0.7628	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2372
DP1-12-90-19	1.4766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
DP1-12-90-20	1.4525	0.0000	0.0000	0.9693	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0307
DP1-12-90-21	2.4116	0.0000	0.0000	0.4210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5790
DP1-12-90-22	2.4648	0.8289	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1711
DP1-34-90-4	1.3300	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
DS5-7-91-5	7.2595	0.7730	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2270	0.0000	0.0000
DS5-7-91-6	6.6175	0.7960	0.0000	0.0000	0.0757	0.0000	0.0000	0.0000	0.1283	0.0000	0.0000
DS5-7-91-10	42.6175	0.9134	0.0000	0.0000	0.0000	0.0000	0.0091	0.0000	0.0775	0.0000	0.0000
DS5-7-91-20	1.9499	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
DS5-7-91-21	1.3363	0.4523	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5477	0.0000	0.0000
DS5-7-91-23	1.1013	0.9306	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0694	0.0000	0.0000
DS5-7-91-29	1.0828	0.4321	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5679	0.0000	0.0000
DP1-17-95-2	1.6525	0.9377	0.0000	0.0000	0.0623	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-5	55.7801	0.6882	0.0374	0.0290	0.0354	0.0000	0.0000	0.0000	0.0000	0.1072	0.1028
DP1-17-95-10	2.5089	0.7475	0.0000	0.0000	0.1743	0.0000	0.0000	0.0000	0.0000	0.0000	0.0782
DP1-17-95-14	25.8841	0.4104	0.0000	0.0000	0.0569	0.0000	0.0000	0.0000	0.0000	0.4516	0.0811
DP1-17-95-15	3.6376	0.0000	0.0000	0.0000	0.8089	0.0000	0.0000	0.0000	0.0000	0.1911	0.0000
DP1-17-95-17	1.1368	0.6534	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3466	0.0000
DP1-17-95-18	1.2394	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-19	1.0425	0.7971	0.0000	0.0000	0.2029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-21	8.0884	0.9936	0.0000	0.0000	0.0059	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000
DP1-17-95-22	7.8011	0.8938	0.0000	0.0000	0.1062	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-25	6.6437	0.9861	0.0000	0.0000	0.0139	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-26	1.2629	0.4414	0.5586	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-27	2.4126	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-28	46.1323	0.7337	0.0000	0.0000	0.0712	0.0000	0.0000	0.0000	0.0000	0.1951	0.0000
DP1-17-95-29	2.2778	0.0000	0.0000	0.0000	0.4380	0.0000	0.0000	0.0000	0.0000	0.5620	0.0000
DP1-17-95-30	1.7999	0.4430	0.0000	0.0000	0.5570	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-31	1.3838	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-38	2.6478	0.8827	0.0000	0.0000	0.1173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-39	1.8555	0.9669	0.0000	0.0000	0.0331	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-41	2.3405	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-43	1.5967	0.9980	0.0000	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-44	1.6374	0.8435	0.0000	0.0000	0.1565	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-46	1.6418	0.9487	0.0000	0.0000	0.0513	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-47	83.7303	0.4400	0.2076	0.0662	0.1836	0.0000	0.0036	0.0000	0.0000	0.0990	0.0000
DP1-17-95-54	1.4629	0.6936	0.0000	0.0000	0.3064	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-56	1.4703	0.8192	0.0000	0.0000	0.0619	0.0000	0.0000	0.0000	0.0000	0.1189	0.0000
DP1-17-95-57	6.8531	0.9920	0.0000	0.0000	0.0080	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-58	1.5712	0.0000	0.0000	0.0646	0.9354	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-61	2.0015	0.0000	0.0000	0.8031	0.1969	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-62	1.5042	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-63	1.0003	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DP1-17-95-65	1.0472	0.0000	0.0000	0.0000	0.9912	0.0000	0.0000	0.0000	0.0000	0.0000	0.0088
DP1-17-95-67	10.8881	0.9298	0.0000	0.0000	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-68	1.7897	0.0000	0.0000	0.0000	0.9933	0.0000	0.0067	0.0000	0.0000	0.0000	0.0000
DP1-17-95-70	3.2794	0.4534	0.0000	0.0000	0.5466	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-71	4.8943	0.8084	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1916	0.0000
DP1-17-95-76	3.7469	0.8855	0.0000	0.0000	0.1145	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-79	35.9944	0.8247	0.0000	0.0087	0.0574	0.0000	0.0000	0.0000	0.0000	0.1092	0.0000
DP1-17-95-80	1.9546	0.0000	0.6587	0.3171	0.0242	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-81	1.1113	0.6236	0.0000	0.0000	0.3764	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-82	1.8936	0.0001	0.0000	0.1802	0.2062	0.0000	0.0766	0.0000	0.0000	0.5369	0.0000
DP1-17-95-83	2.7906	0.1106	0.8200	0.0000	0.0694	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-84	3.3381	0.5771	0.0000	0.0000	0.4229	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-85	31.4605	0.8874	0.0000	0.0598	0.0528	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-89	1.6099	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-91	4.8004	0.0000	0.0000	0.2995	0.2575	0.0000	0.0000	0.0000	0.0000	0.4430	0.0000
DP1-17-95-92	1.6662	0.9606	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0385
DP1-17-95-93	4.5739	0.8446	0.0000	0.0000	0.1554	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-94	5.1113	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-95	2.1402	0.5497	0.0000	0.0000	0.2489	0.0000	0.0000	0.0000	0.0000	0.2014	0.0000
DP1-17-95-97	1.9744	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-98	19.2196	0.6235	0.0157	0.0000	0.1519	0.0430	0.0000	0.0000	0.0000	0.0000	0.1659
DP1-17-95-99	1.9178	0.9135	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0865	0.0000
DP1-17-95-100	36.5670	0.0000	0.0000	0.0000	0.9594	0.0000	0.0007	0.0000	0.0000	0.0000	0.0399
DP1-17-95-101	1.9655	0.9585	0.0000	0.0000	0.0415	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-102	1.4585	0.0000	0.6782	0.0000	0.3218	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-105	4.6024	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-106	2.7041	0.0842	0.0239	0.0000	0.8919	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-107	14.1467	0.8782	0.0000	0.0000	0.1206	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000
DP1-17-95-109	8.3964	0.0327	0.0000	0.0000	0.9673	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-111	7.2444	0.4050	0.2558	0.0000	0.1583	0.1809	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-112	1.8748	0.6883	0.0000	0.0000	0.0653	0.2464	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-113	15.0380	0.6604	0.0000	0.0000	0.3396	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-115	1.1930	0.9476	0.0000	0.0432	0.0092	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-116	1.2145	0.8137	0.0000	0.0000	0.1863	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-117	1.7044	0.5307	0.0000	0.0000	0.4693	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-119	4.4964	0.7909	0.0000	0.1991	0.0100	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-120	1.0165	0.5812	0.0000	0.0000	0.4188	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-124	2.4313	0.7582	0.0000	0.2307	0.0111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-125	1.3507	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-126	3.5778	0.0094	0.1489	0.0000	0.8417	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-128	1.4318	0.7101	0.0000	0.0000	0.2899	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-131	26.6327	0.4036	0.0000	0.0805	0.0396	0.0000	0.0000	0.0000	0.0000	0.3534	0.1229
DP1-17-95-132	3.2963	0.8704	0.0000	0.0000	0.1296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-133	2.4048	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-137	2.4440	0.7751	0.0000	0.0000	0.2249	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-138	18.7645	0.7812	0.0000	0.0000	0.0068	0.0000	0.0000	0.0000	0.0000	0.2120	0.0000
DP1-17-95-141	1.0811	0.7768	0.0000	0.0000	0.2232	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-145	1.2992	0.3793	0.0000	0.0000	0.6207	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-146	1.0946	0.7911	0.0000	0.0000	0.2089	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-148	2.1056	0.9974	0.0000	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-150	1.3427	0.9488	0.0000	0.0000	0.0512	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-158	1.8674	0.8440	0.0000	0.0000	0.0127	0.0000	0.0000	0.0000	0.0000	0.1433	0.0000

APPENDIX A: VEGETATION COMPOSITION OF RESIDUALS

RESIDUAL ID	AREA(ha)	DECID	MIXED	SW	SB	PINE	CONIF	MUSK	CS	DS	OTHER
DP1-17-95-160	1.3631	0.1907	0.0000	0.0000	0.8093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-165	2.1339	0.8579	0.0000	0.0000	0.0102	0.0000	0.0004	0.0000	0.0000	0.0000	0.1315
DP1-17-95-166	2.0149	0.7471	0.0000	0.0000	0.2398	0.0131	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-167	2.2824	0.0000	0.9517	0.0000	0.0381	0.0000	0.0102	0.0000	0.0000	0.0000	0.0000
DP1-17-95-168	2.7278	0.0000	0.7407	0.0399	0.0267	0.0089	0.0000	0.0000	0.0000	0.1838	0.0000
DP1-17-95-171	1.0338	0.9387	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0613	0.0000
DP1-17-95-172	1.0377	0.9620	0.0000	0.0000	0.0020	0.0000	0.0360	0.0000	0.0000	0.0000	0.0000
DP1-17-95-173	1.2462	0.0000	0.6932	0.0000	0.3068	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-174	1.7384	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-175	1.3526	0.0000	0.9111	0.0000	0.0628	0.0000	0.0261	0.0000	0.0000	0.0000	0.0000
DP1-17-95-176	1.1685	0.0000	0.0000	0.0000	0.2477	0.7523	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-179	1.2793	0.6839	0.0000	0.0000	0.3161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-180	1.4104	0.0000	0.7377	0.0000	0.0000	0.0000	0.2623	0.0000	0.0000	0.0000	0.0000
DP1-17-95-181	1.0802	0.0000	0.0000	0.9739	0.0000	0.0261	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-183	3.8959	0.0000	0.0000	0.0000	0.9873	0.0127	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-184	2.2697	0.8557	0.0000	0.0000	0.0000	0.0000	0.1100	0.0000	0.0000	0.0343	0.0000
DP1-17-95-185	3.2713	0.0000	0.7633	0.0000	0.2367	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-187	1.5232	0.8703	0.0000	0.0000	0.1297	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-191	18.0185	0.5175	0.0249	0.0157	0.2546	0.0000	0.0046	0.0000	0.0000	0.1827	0.0000
DP1-17-95-192	1.8075	0.8417	0.0000	0.0000	0.0000	0.0000	0.1583	0.0000	0.0000	0.0000	0.0000
DP1-17-95-193	1.1565	0.8477	0.0000	0.0000	0.0250	0.0000	0.1273	0.0000	0.0000	0.0000	0.0000
DP1-17-95-194	1.9764	0.8075	0.0000	0.0000	0.0515	0.0000	0.1410	0.0000	0.0000	0.0000	0.0000
DP1-17-95-195	1.1656	0.7897	0.0000	0.0000	0.2103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DP1-17-95-196	2.1232	0.8525	0.0000	0.0000	0.1475	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DECID = Deciduous
MIXED = Mixedwood
SW = White Spruce
SB = Black Spruce
PINE = Pine
CONIF = Coniferous (mixed)
MUSK = Muskeg
CS = Coniferous Scrub
DS = Deciduous Shrub/Scrub