Climate Change and Forest Fires in Yukon Territory

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

Master of Arts

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Carleton University
Ottawa, Ontario

September 17, 2002
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“Climate Change and Forest Fires in Yukon Territory”

submitted by Vickie McCoy, B.A.
in partial fulfillment of the requirements for the degree of

Master of Arts

Chair,
Department of Geography and Environmental Studies

Thesis Supervisor

Abstract

Climate change has the potential to affect the boreal forest of Canada. Forest fires are a crucial component of the boreal ecosystem and climate change may substantially alter the fire regime. Statistical relations between climate and forest fire were obtained by regression for three fire subdistricts (Old Crow, Mayo and Watson Lake) of Yukon Territory. The relations were derived from fire and climate records, available, in general, since 1960. Summer temperature was found to be positively correlated to forest fire occurrence, area burned, the Fire Weather Index and Seasonal Severity Rating. In most cases, summer precipitation and relative humidity were negatively correlated with these variables. Climate change scenarios were applied to these relations to project future forest fire regimes under a climate with doubled CO₂. In comparison with the period of record, central Yukon may have significantly more fires, area burned and an increased fire danger in the future.

Acknowledgements

There were many people without whose assistance this thesis may not have been possible. First, a special thanks to the Village of Mayo, Yukon, for their support and encouragement of this research as well as for their warmth and kindness during the field season. I would also like to acknowledge the Northern Climate ExChange and the Community Development Fund of Yukon Territory for their support during the initial phases of research. The final stages of research were supported by the NSERC Northern Research Chair at Carleton University.

I am also grateful to David Milne, Wildfire Prevention Coordinator of Yukon Fire Management, for the fire data used in this thesis and for his advice. A similar acknowledgement to Elaine Barrow of the Canadian Institute for Climate Studies for her advice on climate change scenario selection and analysis.

A very special thanks to Chris Burn, my thesis supervisor, whose tireless support, encouragement and dedication, were greatly appreciated. I would also like to mention Mike Smith and Dave Bennett for their support as members of my thesis committee.

Finally, I am especially thankful to my Mom and Dad for all their support and encouragement.

Table of Contents

	Page
Acceptance Form	ii
Abstract	iii
Acknowledgments	iv
Table of Contents	v
List of Figures	vii
List of Tables	viii
List of Appendices	x
Chapter 1 Introduction	1
1.1 Introduction	1
1.2 General Problem	3
1.3 Research Questions	4
1.4 Thesis Structure	5
Chapter 2 Background	6
2.1 Ecological Role of Forest Fire in Boreal Forests	6
2.2 Climate and Forest Fires	7
2.3 Climate Change	9
2.4 Climate Change and Forest Fires	14
Chapter 3 Study Area and Data Description	17
3.1 Yukon Territory	17
3.2 Study Areas	21
3.3 Study Area Selection	23
3.3.1 Study Area Climate	25
3.3.2 Study Area Fire Regime	25
3.4 Data Description	28
3.4.1 Climate Data	28
3.4.2 Forest Fire Data	30
3.4.3 Climate Change Data	35

Chapter 4 Methods	43
4.1 Basic Data Organization and Calculations	43
4.2 Trends Over Time	43
4.3 Relations Between Climate Variables	44
4.4 Climate Projections	46
4.5 Problems with Methods and Data	48
4.5.1 Problems with Scale	48
4.5.2 Quality of Records	49
4.5.3 Assumptions	50
Chapter 5 Results – Trends and Relations	53
5.1 Trend Analyses	53
5.1.1 Trends in Climate Variables	54
5.1.2 Trends in Forest Fire Variables	62
5.2 Climate-Fire Relations	67
5.2.1 Climate and Forest Fire Relations	67
Chapter 6 Results – Projected Forest Fire Variables	78
6.1 Climate Projections	78
6.2 Old Crow Projections	81
6.3 Mayo Projections	83
6.4 Watson Lake Projections	85
6.5 Projected Fire Regime	87
Chapter 7 Discussion	89
7.1 Discussion	89
7.2 Conclusion	92
References	94
Appendix I – Climate Data	107
Appendix II – Forest Fire Data	133
Appendix III – Climate Model Changes	140

List of Figures

	Page
Figure 1.1. Extent of the boreal forest in North America	2
Figure 2.1. Change in global annual mean temperature for 1869-1993	12
Figure 3.1. Location of Yukon Territory, northwest Canada	18
Figure 3.2. Terrestrial ecozones of Yukon Territory	20
Figure 3.3. Forest fire subdistricts and study areas in Yukon Territory	22
Figure 3.4. Fire size distributions for the three study locations	29
Figure 3.5. Components of the Fire Weather Index	33
Figure 5.1a. Mean summer temperature at Old Crow over 48 years (1952-1999)	60
Figure 5.1b. Mean summer temperature at Mayo over 76 years (1925-2000)	60
Figure 5.2. Total summer precipitation at Old Crow over 31 years (1969-1999)	61
Figure 5.3. Fire Weather Index and Seasonal Severity values at Old Crow, Mayo and Watson Lake	65
Figure 5.4a. Cumulative probability graph of the transformed and non-transformed residuals between area burned and wind speed at Mayo	72
Figure 5.4b. Cumulative probability graph of the transformed and non-transformed residuals between area burned and relative humidity at Watson Lake	72
Figure 6.1. Projected mean summer temperature at Mayo	80

List of Tables

	Page
Table 3.1. Forest fire subdistrict fire and population characteristics	24
Table 3.2a. Mean annual and seasonal temperature (°C) and precipitation (mm) at the three study areas	26
Table 3.3. Average number of forest fires and average area burned per summer in Old Crow, Mayo and Watson Lake	27
Table 3.4. Availability of mean summer temperature, total summer precipitation, relative humidity, and wind speed at Old Crow, Mayo and Watson Lake	31
Table 3.5. Availability of summer forest fire data at Old Crow, Mayo and Watson Lake	36
Table 3.6. General circulation model characteristics	37
Table 3.7. Scenarios chosen for climate projections	41
Table 5.1. Ten warmest and coldest summers at Old Crow, Mayo and Watson Lake	55
Table 5.2. Ten driest and wettest summers at Mayo and Watson Lake	56
Table 5.3a. Summer decadal mean temperature, total precipitation, relative humidity and wind speed at Old Crow, Mayo and Watson Lake	57
Table 5.4. Yearly trend in mean summer temperature, total summer precipitation, relative humidity and wind speed	59
Table 5.5. Most and least number of forest fires at Old Crow, Mayo and Watson Lake	63
Table 5.6. Most and least area burned at Old Crow, Mayo and Watson Lake	64

Table 5.7.	Decadal summer fire occurrence, summer area burned, Fire Weather Index and Seasonal Severity Rating for Old Crow, Mayo and Watson Lake	66
Table 5.8.	Yearly trend in summer fire occurrence, area burned, Fire Weather Index and Seasonal Severity Rating over the period of record	68
Table 5.9.	Spearman rank (r_s) for climate variables and fire occurrence at Old Crow, Mayo and Watson Lake	69
Table 5.10.	Skewness and kurtosis of residuals from transformed forest fire variables	71
Table 5.11.	Pearson product-moment (r_p) correlation coefficient for climate variables and forest fire variables at Old Crow, Mayo and Watson Lake	74
Table 5.12.	Equations selected for prediction from step-wise multiple regression on transformed forest fire variables	76
Table 6.1.	Projected changes in mean summer temperature, total summer precipitation, relative humidity, and wind speed for each scenario	79
Table 6.2.	Highest, lowest and average forest fire predictions for each time period at Old Crow	82
Table 6.3.	Highest, lowest and average forest fire predictions for each time period at Mayo	84
Table 6.4.	Highest, lowest and average forest fire predictions for each time period at Watson Lake	86

List of Appendices

	Page
Appendix I - Climate Data	107
Old Crow mean temperature record	108
Old Crow total precipitation record	111
Old Crow summer relative humidity record	114
Old Crow summer wind speed record	115
Mayo mean temperature record	116
Mayo total precipitation record	120
Mayo summer relative humidity record	124
Mayo summer wind speed record	125
Watson Lake mean temperature record	126
Watson Lake total precipitation record	129
Watson Lake summer relative humidity record	132
Watson lake summer wind speed record	133
Appendix II - Forest Fire Data	134
Old Crow summer forest fire record	135
Mayo summer forest fire record	137
Watson Lake summer forest fire record	139
Appendix III - Climate Model Changes	141
Model summer change values	142

Chapter 1 Introduction

1.1 Introduction

This thesis explores relations between climate variables and the forest fire regime of selected areas in Yukon Territory. These relations are used to project potential responses of the system to climate change.

The Intergovernmental Panel on Climate Change (IPCC) accepts that the climate is now changing significantly due to human activities (IPCC, 2001), and there is concern about the potential ecological consequences of climate change throughout the world. One environment that may be altered due to changes in climate is the boreal forest of Canada, Alaska, and Russia.

The boreal forest is the largest forest region of Canada, forming a continuous belt from east to west of approximately 315 million ha (Figure 1.1) (Weber and Stocks, 1998). While there are thousands of recognized tree species in the tropics, fewer than 50 compose the boreal forest, due to several limiting factors including a relatively short growing season, low soil temperature, and extreme seasonal fluctuations in temperature and sunlight (Weber and Stocks, 1998; Bourgeau-Chavez et al., 2000). The forest is composed largely of trees that have evolved in the presence of a significant fire regime (Ward and Mawdsley, 2000). Some of the world's largest wildfires have been recorded in the boreal forests of North America (Johnson, 1992). Forest fires also play an important role in many northern communities, as fire management and protection provide both annual and seasonal employment.

Figure 1.1. Extent of the boreal forest in Canada (adapted from Hare and Ritchie, 1972)

The occurrence and severity of fires in the boreal forest are linked to the weather and climate of the region (Swetnam, 1993; Li et al., 2000), but these relations vary from region to region due to local conditions (Bergeron and Flannigan, 1995; Flannigan et al., 1998). Regionalized studies are needed to fully understand the impact of climate change on fire regimes, and, in this case, Yukon Territory is used as the study area because of the availability of relatively long and complete climate and forest fire records.

The first part of this thesis presents an analysis of climate and forest fire variables over the period of record. Next, relations between these variables are examined to investigate how changes in climate have been associated with changes to the fire regime of Yukon Territory. These relations are then used as analogues to project potential future changes to the fire regime using various climate-change model simulations. The results may be useful to communities in Yukon Territory, and to the Yukon Fire Service, for improving forest fire management and planning initiatives.

1.2 General Problem

General circulation models have projected that climate change and its associated impacts will be more pronounced in the northern high latitudes of the globe than elsewhere (Serreze et al., 2000). With these changes in climate, fire frequency and severity throughout the boreal forests may be altered, and the IPCC has proposed that these may increase (Overpeck et al., 1990; IPCC, 1995). However, on a regional scale, there is less certainty as to what may happen to the fire regime.

Regional studies have indicated both potential increases and decreases in fire occurrence and severity under a $2\times\text{CO}_2$ climate (Bergeron and Flannigan, 1995; Flannigan et al., 1998). Regional differences in potential fire behavior are attributed to differences in forest fuel type and buildup, topography and local weather conditions (Flannigan et al., 1998). In order to understand how future climatic changes may affect forest fires in one particular region of Canada, prospective changes in climate are used to infer changes in the forest fire regime at a regional scale.

1.3 Research Questions

To determine the relations between climate change and forest fires and, subsequently, the impact of potential future changes on the fire regime in Yukon, four general questions are addressed in this thesis:

1. *How has the summer climate of Yukon changed over the period of record?*

Mean summer temperature and total summer precipitation records have been analyzed for selected climate stations in Yukon using regression analyses. Average summer wind speed and relative humidity have been similarly analyzed.

2. *How has the summer forest fire record of Yukon changed over time?*

The annual number of fires and area burned during the summer have been examined for selected fire districts in Yukon. Daily Fire Weather Index and Seasonal Severity Ratings have also been assessed.

3. *To what extent are the changes in the climate and fire records related?*

Correlation methods have been used to determine how the various components of the climate and forest fire record have been related through time.

4. *Based on past relations, how might the fire regime of Yukon change under a $2\times CO_2$ climate?* Temperature, precipitation, wind speed, relative humidity and wind speed data from general circulation model predictions of future climates for Yukon have been used to project potential changes in the various components of the forest fire record based on the determined historical relations.

1.4 Thesis Structure

There are seven chapters following this introduction. Chapter Two provides the background to the study and considers forest fires and climate change issues. Chapter Three describes the study area and the data sets used. Chapter Four presents the various methods of analysis as well as an assessment of potential problems associated with the methods and data used in this thesis. Chapter Five describes the trend analyses of the climate records. This chapter also presents results from correlation analyses between various components of the climate and forest fires records. Chapter Six provides projected climate trends and potential future trends in components of the fire record. Chapter Seven interprets the results presented in chapters Five and Six presents the conclusions of the thesis.

Chapter 2 Background

2.1 Ecological Role of Forest Fires in the Boreal Forest

Fire is an important disturbance to the boreal forest as it controls the distribution of many tree species. Burning of the soil's organic layer results in an exposed mineral surface well suited to the germination of seeds of some species (Weber and Stocks, 1998; Bourgeau-Chavez et al., 2000). Fires are beneficial to seedlings as they remove the overstory shade. Many boreal forest trees germinate best on exposed mineral soils after a fire, but some species are more fire-dependent than others. Of the ten dominant tree species in the boreal forest only two, balsam fir (*Abies balsamea*) and alpine fir (*Abies lasiocarpa*), are not well adapted to fire (Bourgeau-Chavez et al., 2000). On the other hand, lodgepole pine (*Pinus contorta*) and black spruce (*Picea mariana*) depend on fire, to a certain extent, for reproduction as both species require the heat from fire to melt their serotinous cones and release seeds (Johnson, 1992). Without forest fires, lodgepole pine might eventually disappear from boreal forests (Weber and Stocks, 1998).

Forest fires are an important factor in the global carbon cycle. Boreal ecosystems contain more than 30% of all the carbon present in terrestrial ecosystems (Kasischke, 2000), with about an average of 118 tonnes of carbon contained above and below ground in one hectare of Canadian boreal forest (Bourgeau-Chavez et al., 2000). Approximately 53×10^6 tonnes of carbon are released each year from North American boreal forests through the burning of biomass (French et al., 2000). The

release of this carbon adds to the greenhouse gases in the atmosphere. However, due to reforestation and the growth of new vegetation which sequester carbon from the atmosphere, boreal ecosystems in North America may be an overall net sink for carbon (Kasischke, 2000).

As well as being a source of atmospheric carbon, the burning of the organic layer can lead to an increase in active-layer thickness for several years following a fire (Mackay, 1995; Swanson, 1996; Weber and Stocks, 1998). The soil may become warmer and drier due to temporary changes in the albedo of the surface and loss of shade from the overstory in the summer (Swanson, 1996). There may also be a deeper snow cover in winter, due to less interception of snow by the canopy. The insulating effects of a deeper snow cover warm the soil, increasing the rate of decomposition beneath the surface. An increase in the rate of decomposition leads to more CO₂ being released into the atmosphere (Kasischke, 2000).

Whether considered beneficial or not, fires are a natural and integral part of the boreal forest ecosystem. Without fire, characteristics of the boreal landscape would change dramatically.

2.2 Climate and Forest Fires

Weather plays an important role in fire occurrence and area burned. A variety of weather conditions can determine fire behavior in a given region. For instance, prolonged periods of high pressure have been linked to increased incidence of fire due to the associated warm and dry conditions (Flannigan and Wotton, 1991; Johnson and

Wowchuck, 1993; Nash and Johnson, 1996). High pressure systems may also produce dry fuel conditions in forests, subsequently increasing fire danger (Anderson et al., 2000).

Lightning is the most significant ignition source in the boreal forest (Price and Rind, 1994; Nash and Johnson, 1996), annually accounting for 38% of fires in Canada and 82% of the annual area burned (Higgins and Ramsey, 1992). The remaining fires are human caused (Higgins and Ramsey, 1992). Lightning-caused fires are initiated by cloud to ground lightning flashes, but the likelihood of lightning triggering a fire is determined by the prevailing moisture content of the fuel, as well as ambient weather conditions (Anderson et al., 2000).

Since weather conditions influence fire occurrence and area burned, it follows that climate may play a role as well. Tree-ring data and other proxy methods have allowed relations to be established between fire occurrence and behavior that extend further back in time than the observed period of record (e.g. Bonan et al., 1990; Johnson and Larsen, 1991; Johnson, 1992; Bergeron and Flannigan, 1995). Johnson et al. (1999) used a combination of fire-scar data from tree rings and written fire records for Prince Albert National Park to report that changes in timing and duration of fire season may have accompanied changes in climate over the past 160 years. They found evidence that, since 1945, the fire season has begun earlier in the year due to an earlier start to spring. They also found evidence of a longer overall fire season in the same period. Conversely, cooler and moister conditions associated with the Little Ice Age were found to coincide with longer return periods in the fire cycle throughout

western and central Canada (Johnson and Fryer, 1987; Masters, 1990; Bergeron and Archambault, 1993).

Relations between climate and fire regime have also been derived for more recent periods at many locations across Canada. Weber and Stocks (1998) determined that the annual area burned over the last three decades was related to extreme weather conditions in western and central Canada, while Balling et al. (1992) found similar relations between annual area burned and weather conditions for Yellowstone National Park for 1895 to 1989. Decreases in fire frequency have also been related to cooler and wetter climate conditions in the boreal forest of Quebec (Bergeron, 1991; Bergeron and Archambault, 1993).

A general theme emerging from these studies is that climate plays a significant role in determining the behavior of regional fire regimes. The evidence suggests that warmer and drier conditions favor an accelerated fire regime while cooler and moister conditions coincide with a reduction in the fire regime. If warmer and drier conditions increase in frequency as a result of global warming, then significant changes to the fire regime may follow.

2.3 Climate Change

The Earth's climate has varied dramatically over geological time. The mean annual temperature of the Earth has varied over the last 2 million years from 5°C above to 10°C below present-day values (Bryant, 1997). There are several possible explanations for these past changes including changes in orbital patterns of the Earth,

changes in solar output, and volcanic activity (Bryant, 1997). In the last two decades, it has been recognized that human-related activities may also explain some recent changes in climate.

The Earth's climate system is driven by energy from the sun. This energy also drives the hydrological cycle, causes the atmosphere and oceans to circulate and helps create storms (Taylor and Taylor, 1997). Several gases in the atmosphere both scatter incoming solar radiation back into space and absorb longwave radiation leaving the surface of the earth. This absorption of heat causes the Earth to be about 21°C warmer than it would be without these gases (Houghton, 1997). This is the natural greenhouse effect. Greenhouse gases include water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halocarbons, particularly chlorofluorocarbons (CFCs), and ozone (O₃). Changes in the concentration of these gases in the atmosphere can affect the flow of energy into, within, and out of the climate system, resulting in climate change (Taylor and Taylor, 1997).

Since the Industrial Revolution, humans have been extracting and burning fossil fuels which release gases, particularly CO₂, into the atmosphere. During the same period, humans have also cleared land, destroying forests that absorb and store greenhouse gases (Environment Canada, 1997). As a result, CO₂ concentrations in the atmosphere have risen by about 30% above pre-Industrial levels (Environment Canada, 1997; Houghton et al., 2001) and CH₄ concentrations by 145% (Environment Canada, 1997). Current levels of CO₂ are higher than at any other time within the last 200,000 years (Environment Canada, 1997). It is believed that the increase of CO₂

and CH₄ in the atmosphere has enhanced the natural greenhouse effect by trapping more radiation emitted from the Earth's surface. This enhanced greenhouse effect is commonly referred to as global warming because it is believed that as the atmosphere traps more heat, the Earth will warm up.

Much research has been conducted in the last two decades to determine the magnitude of global warming and it is now accepted that the climate of the Earth is warming at an unprecedented rate (IPCC, 1995; Environment Canada, 1997; Houghton et al., 2001). The global average surface temperature has increased by about 0.6°C over the last 100 years (Figure 2.1). Furthermore, 10 of the Earth's warmest years since 1861 have been in the last two decades (Environment Canada, 1997; Fung, 1997; Houghton et al., 2001). However, this warming has not been uniform across the globe. Even within Canada, regional differences in climate change have emerged. Most of the warming in Canada over the last 100 years has been in the northwest and southern parts of the country while regions in the northeast have cooled (Environment Canada, 1997).

Figure 2.1. Change in global annual mean temperature for 1860-1993 (Figure 4, Environment Canada, 1997)

Studying the climate trends exhibited over the period of record is important in advancing our understanding of the Earth's climate system and the effects that human activity may have on it. However, the ultimate purpose of climate change research is to project changes we may experience in the future.

Much of the research on future of climate change is conducted with General Circulation Models (GCMs). These models, implemented on supercomputers, are made up of complex equations used to simulate the Earth's current climate system.

By changing the concentration of greenhouse gases (most often CO₂) to reflect potential future conditions, models can be run to project the reaction of other climate variables, most commonly temperature and precipitation, to such changes.

Differences in the equations used in various GCMs as well as different initial conditions result in a wide range of projections. However, GCMs consistently indicate that with greenhouse gases continuing to be added to the atmosphere, the Earth's climate will continue to warm.

Most GCMs use a doubling of CO₂ in their scenarios to project what the Earth's climate might be like during the next century. At this rate of increase, average global surface temperatures are projected to rise by 1.4 to 5.8°C over the next 100 years (Houghton et al., 2001). Some regional projections are even greater. In higher latitude areas, such as Canada, mean annual temperatures may increase by 5 to 10°C over the next century (IPCC, 1995; Environment Canada, 1997; Houghton et al., 2001). In Yukon Territory, projected changes in mean annual temperature under a 2x CO₂ climate are between 2 and 6°C (Taylor and Taylor, 1997).

In general, larger increases in temperature are expected for Canada during the winter compared to other times of the year (Environment Canada, 1997; Taylor and Taylor, 1997) and some models suggest that spring may arrive earlier as a result (Pearce, 1996).

Variables other than average temperature have also been projected using climate models, although the perceived confidence in these projections is often not as great as for temperature. Projected changes in precipitation vary considerably between climate models, but in most regions of Canada, precipitation is projected to increase much in the form of snow (Environment Canada, 1997; Sereze et al., 2000). Fowler and Hennessy (1995) have shown that the frequency of heavy precipitation events is also likely to increase under a $2\times\text{CO}_2$ climate. Similarly, periods of extreme high temperature are projected to increase in a warmer world (Mearns et al., 1984; Katz and Brown, 1992). Without serious efforts to curb the addition of greenhouse gases to the atmosphere, the climate of the Earth is likely to continue changing, and to have a wide range of impacts on economies, communities and ecosystems.

2.4 Climate Change and Forest Fires

With the awareness that climate is changing and likely to continue to do so, much concern has arisen over what the potential impacts of climate change on natural ecosystems may be. One Canadian ecosystem that may potentially undergo significant changes is the boreal forest. The most important form of vegetation disturbance in the boreal forest is fire (Johnson, 1992). Since forest fires have been

linked to weather and climate, changes in climate could potentially alter the fire regime in boreal forests.

Recently, the fire regime in Canada's forests has changed significantly. Nationally, the number of fires per year has approximately doubled in the last three decades (Van Wagner, 1988; Stocks, 1991; Auclair and Carter, 1993; Ward and Mawdsley, 2000). With the exception of 1961, the ten years with the greatest annual area burned in Canada, since records have been kept, were in the 1980s and 1990s (Weber and Stocks, 1998). However, these increases have not been uniform across Canada. In eastern regions there has been a decline in fire frequency and fire danger (Bergeron and Flannigan, 1995). Under a $2\times\text{CO}_2$ climate, fire danger, fire occurrence and annual area burned are likely to increase further in most regions of the country (Flannigan and Van Wagner, 1991; Balling et al., 1992; Bergeron and Flannigan, 1995; Price and Rind, 1994; Kadonaga, 1997; Stocks et al., 1998).

Other indicators of potential forest fire behavior have also been examined for future changes under a $2\times\text{CO}_2$ climate. The length of the fire season is projected to increase over much of Canada (Wotton and Flannigan, 1993 and Johnson et al., 1999) and the most severe portion of the fire season may shift to later in the summer, resulting in potentially greater fire occurrence (Flannigan and Van Wagner, 1991; Anderson et al., 2000). The number of cloud-to-ground lightning strikes may also increase due to associated increases in the frequency of disturbance weather (Overpeck et al., 1990; Price and Rind, 1994). Price and Rind (1994) have estimated that lightning-caused fires could increase by as much as 44% in boreal forests.

Changes in the fire regime with the combined effect of a changing climate may alter plant and animal distributions over time (Thompson et al., 1998). Emanuel et al. (1985) have even suggested that boreal forests may eventually convert to cool temperate forests or steppe with the combined effects of increased warming and fire disturbance.

While climate changes may have a significant impact on the forest fire regime of a region, fires also play a role in changing the climate as well. When forests burn, CO₂ is released to the atmosphere, and this continues for several years afterwards due to an increase in decomposition rates of organic matter (Wein and Lanhausser, 1994). This addition of CO₂ to the atmosphere may act as a positive feedback loop to global warming.

Forest fires play a crucial role in boreal forest ecosystems, and the magnitude of this role seems to be governed, at least to some degree, by climate. Since the northern high latitudes of the globe, where boreal ecosystems dominate, are projected to undergo some of the most significant changes in climate, it is likely that the fire regimes of these areas will also change. In fact, such changes may already be detectable in some areas with relatively long climate and forest fire records.

Chapter 3 Study Area and Data Description

3.1 Yukon Territory

There are three main study areas for this thesis, all located in Yukon Territory. Yukon covers an area of 536,325 km² and is located in northwest Canada (Oswald and Senyk, 1977) (Figure 3.1). It shares its southern border with British Columbia, its western border with Alaska and eastern border with the Northwest Territories. To the north of the Territory lies the Beaufort Sea.

The physiography of the region ranges from coastal plain in the north to high mountains in the southwest (Oswald and Senyk, 1977). The Territory is composed of several mountain ranges as well as plateaus and lowlands. The St. Elias and Coast mountains cover the southwest portion of the Territory and the Kaska and Selwyn mountains cover the eastern border. The Richardson and Olgivie mountains lie in the northeast and northern portions of the Territory. The southern half of Yukon is composed largely of the Yukon Plateaus and Liard Lowland while the Eagle Lowland extends towards the north. Finally, the Yukon Coastal Plain and Arctic mountains cover the northern portion of the Territory adjacent to the Beaufort Sea.

The topography of the Territory greatly influences its climate. The climate is generally characterized as continental, with long cold winters and short but warm summers. The mountains in the southwest effectively block airflow from the Gulf of Alaska, and to a lesser degree mountains in the north block moisture from the Beaufort Sea (Wahl et al., 1987). The blocking effect of the mountains establishes the mostly

Figure 3.1. Location of Yukon Territory, northwest Canada

continental climate (Wahl et al., 1987). In general, continentality, or the difference between winter and summer temperatures increases with distance from the Pacific coast (Burn, 1994). The dissected topography of the region also influences its climate. In winter, valley bottoms are often subject to long periods of relatively cold temperature compared to areas at higher elevations. Although temperature normally decreases with height above the ground, during cold periods an inversion occurs with dense, cold air sinking to the valley floors (Wahl et al., 1987).

There are five terrestrial Ecozones that cover Yukon. However, the Tundra Cordillera in the north and east and Boreal Cordillera in the south cover the majority of the Territory (Wiken, 1986) (Figure 3.2). Other ecozones include a portion of the Pacific Maritime in the south west, and small areas in the north covered by the Taiga Plains and Southern Arctic Ecozones. The greatest diversity of tree species is found in southeast Yukon, and the dominant species are alpine fir, black spruce, white spruce (*Picea glauca*), lodgepole pine, aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and paper birch (*Betula papyrifera*) (Oswald and Senyk, 1977). At higher elevations and towards the north, stands become dispersed and trees more dwarfed. The tree line varies with elevation, climate and soil conditions, but trees can be found as far north as the valley of the Firth River, just south of the Yukon Coastal Plain (Wahl et al., 1987).

Figure 3.2. Terrestrial ecozones of Yukon Territory (after Environment Canada, 2001)

Yukon Territory, despite its remoteness, has relatively long and reliable records for both climate and forest fire variables, which makes it a suitable area for study. Climate records, including temperature and precipitation measurements, extend back to 1898 for Dawson City and to 1925 for Mayo, two communities in central Yukon. Climate records have been kept for other stations in the Yukon since the 1940s and 1950s. Prior to the 1950s and 1960s, forest fire records in Yukon Territory were generally incomplete, but in 1958 Whitehorse was threatened by a major fire in Takhini River valley (Burn, 1998). As a result, significant improvements were made to fire detection and control capabilities throughout the Territory (Barney and Stocks, 1983), and there are reliable and complete fire records for much of Yukon since 1960.

3.2 Study Areas

Three areas were chosen from the ten forest fire subdistricts of Yukon Fire Management, Indian and Northern Affairs Canada (INAC) (Figure 3.3). The first area, Old Crow, is the largest and most northern of the subdistricts. The second is the Mayo subdistrict, which covers a large portion of central Yukon. The third is the Watson Lake forest fire subdistrict in southeast Yukon. The Yukon Fire Management division of INAC keeps records of fire activity and fire danger for each of these regions. As well, daily recordings of various weather variables are taken from weather stations located at specific points within in each of the fire subdistricts for the duration

Figure 3.3. Forest fire subdistricts and study areas in Yukon Territory

of the fire season. The Old Crow climate station is located at 67.58°N, 139.83°W, Mayo at 63.62°N, 135.87°W, and Watson Lake at 60.12°N, 128.82°W.

3.3 Study Area Selection

The subdistricts chosen were required to represent contrasting climate and fire regimes within Yukon. However, the impact of human presence and activity can also greatly influence the number of fire starts and number of fires fought, reducing the influence of climate on the fire regime of an area. In order to reduce the impact of factors other than climate, selection of the three subdistricts also considered population, and the proportion of fires that were naturally ignited.

The Old Crow subdistrict had the greatest percentage of fires that have not been fought (Table 3.1). Due to the low population, this subdistrict also had the lowest percentage of human-caused fires. The subdistrict also covers the most northern and coldest area of Yukon. Mayo has the second highest percentage of lightning-caused fires and ranks third in terms of percentage of fires not fought (Table 3.1). The second ranked subdistrict in this category is Beaver Creek, one of three subdistricts where climate data are not available. Mayo, located in central Yukon, was therefore chosen as the second subdistrict for study.

In southern Yukon, Whitehorse was not considered due to its high population (Table 3.1). Of the three other subdistricts, namely Haines Junction, Teslin and Watson Lake, Watson Lake had the highest percentage of not fought and lightning-

Subdistrict	Subdistrict Size (km ²) (approximate)	Pop*	Total Number of Fires	Fires in June, July, and August (%)	Total Area Burned (ha)	Not Fought Fires (% of total)	Lightning Caused Fires (% of total)
Haines Junction	18489	800	205	69.8	16513	3.4	5.9
Whitehorse	32000	23406	1359	64.6	97044	4.2	8.5
Teslin	25885	454	188	80.9	35113	15.4	38.3
Watson Lake	61156	1690	586	80.2	503260	24.6	54.4
Ross River**	54472	397	461	84.0	536046	31.9	57.7
Carmacks**	32000	461	473	79.3	795928	13.7	55.8
Beaver Creek**	29867	109	183	82.0	142500	44.8	65.0
Dawson	76801	2057	827	91.5	920816	39.3	85.2
Mayo	83485	484	632	94.0	980869	44.6	85.0
Old Crow	97992	300	260	93.1	688516	79.2	92.7

Table 3.1. Forest fire subdistrict fire population characteristics . *1998 populations (Yukon Bureau Of Statistics, 2000). **Subdistricts with no climate data available. Values in bold are the subdistricts chosen for analysis. (fire data from Yukon Fire Management, INAC).

caused fires and was the final subdistrict included in the study (Table 3.1). Although, the population of Watson Lake is high compared to Mayo and Old Crow, it offers the best climate and fire data of the southern subdistricts.

3.3.1 Study Area Climate

The climates of each subdistrict differ considerably. In general, mean annual temperatures decrease northwards (Table 3.2). This trend occurs in winter (December, January and February) but during summer (June, July and August) the mean temperature of Watson Lake is cooler than that of Mayo despite its more southerly location (Table 3.2). This is due to the moderating effects of the Pacific ocean to the west of the Watson Lake subdistrict (Wahl et al., 1987). Similar to temperature, annual total precipitation increases southwards, with proximity to the Pacific Ocean (Table 3.2).

3.3.2 Study Area Fire Regime

Each of the study areas has a different fire regime. The Old Crow forest fire subdistrict has had an average of only six fires per summer, while the average is fifteen at Mayo, and twelve at Watson Lake (Table 3.3). The area burned each summer also varies in each of the three subdistricts. The Old Crow and Mayo subdistricts have larger fires than those reported at Watson Lake (Table 3.3). The differences in area burned are also reflected in the size distribution of fires in each of the three

	Annual	Winter	Spring	Summer	Fall
Temperature					
Old Crow	-9.2	-29.1	-10.3	12.5	-9.8
Mayo	-3.4	-22.7	-0.9	13.9	-3.7
Watson Lake	-3.0	-21.7	-1.1	13.5	-2.5
Precipitation					
Old Crow	291.4	45.3	40.3	123.5	80.4
Mayo	343.4	63.3	47.6	139.6	92.8
Watson Lake	459.6	100.4	74.5	164.0	119.3

Table 3.2. Mean annual and seasonal temperature (°C) and precipitation (mm) at the three study areas (winter includes; December of previous year, January and February, spring; March, April, and May, summer; June, July, and August, fall; September, October, and November). (Old Crow and Watson Lake climate data from the Historical Canadian Climate Database, Mayo data from Canadian Meteorological Service, Environment Canada)

Location	Number of forest fires	Area burned (hectares)
Old Crow	6	17651
Mayo	15	22831
Watson Lake	12	16394

Table 3.3. Average number of forest fires and average area burned per summer in Old Crow, Mayo and Watson Lake (data from Yukon Fire Management, INAC).

subdistricts (Figure 3.4). A greater percentage of fires at Watson Lake are smaller than at Mayo and Old Crow.

3.4 Data Description

There are three types of data set used in this thesis. The first are climate data, which include monthly, seasonal and annual mean temperature, total precipitation, average summer wind speed and average summer relative humidity for Old Crow, Mayo and Watson Lake. The second set relates to forest fire and includes the number and size of fires and the Fire Weather Index (FWI) and Seasonal Severity Ratings (SSR) for the same three stations. The third set is seven climate change scenarios for the three study areas derived from General Circulation Model output.

3.3.3 Climate Data

The data for Old Crow and Watson Lake were obtained from Environment Canada's Historical Canadian Climate Database (HCCD) (2000). These data are designed specifically for climate change analysis. The data for Mayo were obtained directly from the Meteorological Service of Canada. Relative humidity and wind speed were obtained from Yukon Fire Management, Indian and Northern Affairs Canada. For each station, the mean summer temperature (MST) and total summer precipitation (TSP) have been compiled to determine trends over time. Records for

Figure 3.4. Fire size distributions for the three study locations (data from Yukon Fire Management, INAC).

relative humidity (RH) and wind speed (U) are only available for the fire season, generally from April to October. However, since the majority of forest fires in the three study sites have occurred in summer (1 June – 31 August), the analysis has focused on summer values, calculated from average monthly data for June, July and August (Table 3.1).

Not all climate stations have equally long or complete climate records (Table 3.4). Generally, Old Crow, has the most intermittent data followed by Watson Lake. Mayo has the longest record, complete between 1925 and 2000 for temperature and between 1927 to 2000 for precipitation (Table 3.4).

3.3.4 Forest Fire Data

The forest fire records, including summer fire occurrence (SFO), summer area burned (SAB), FWI and SSR were obtained from Yukon Fire Management, Indian and Northern Affairs Canada. The fire records for the three locations include entries for the date, size, cause and action taken for each fire (i.e. whether or not they were fought). Only fires recorded during the summer months (June, July and August) were included in the analysis for consistency with the climate records. Fires that were human-caused were excluded from fire occurrence analyses since these fires were not directly attributed to climatic factors. Similarly, fires that were fought were also excluded from the area burned data, since fire suppression efforts influence the size of the area burned in each subdistrict.

	Mean Summer Temperature	Total Summer Precipitation	Relative Humidity	Wind Speed
Old Crow	1952-1999	1953-1999	1977-1998	1977-1998
Missing Years	None	1955-1968, 1970, 1974, 1975, 1977-1981	1979, 1980, 1982, 1983	1979, 1980, 1982, 1983
Mayo	1925-2000	1927-2000	1960-1998	1960-1998
Missing Years	None	None	None	None
Watson Lake	1939-1999	1939-1999	1963-1998	1963-1998
Missing Years	None	1993-1995	None	None

Table 3.4. Availability of mean summer temperature, total summer precipitation, relative humidity, and wind speed data at Old Crow, Mayo and Watson Lake.

The forest fire record also includes the daily FWI for each of the three forest fire subdistricts in this study. The Canadian Forest Fire Danger Rating System (CFFDRS) uses the FWI to calculate potential fire danger in a given area. It is important to note that the FWI is not a predictive value for fire occurrence but rather a value that predicts the potential severity of a fire should one occur.

The FWI is based on five components: three fuel moisture indexes, and two indexes that quantify the rate of spread and fuel consumption (Figure 3.5) (Canadian Forestry Service, 1987). The FWI and its components are derived from daily noon measurements of temperature, precipitation, relative humidity and wind speed. In general, as warm, dry and windy conditions persist, fuel moisture contents become lower and the FWI increases, indicating a potentially greater fire severity. The FWI is primarily designed for a standard pine fuel type but can be used as a general measure of fire danger across Canada (Canadian Forestry Service, 1987). Although each climate variable is used in specific units for the calculation, the FWI is reported as a unit-free measure of the potential fire danger for an area. In general, an FWI between 0 and 4 indicates low fire danger, 5 to 10 moderate fire danger, 11 to 18 high, 19 to 29 very high, and an FWI rating of 30 or over indicates extreme fire danger (Canadian Forestry Service, 1987). Due to the regional differences in climate, fuel type, and hours of sunlight, danger rating categories differ slightly between regions. Even the most extreme FWI ratings do not necessarily mean a forest fire will occur, although fires that occur during periods of high FWI ratings are more severe. Fires which occur

Figure 3.5. Components of the Fire Weather Index (after Canadian Forestry Service, 1987).

during periods of low to high FWI generally remain at the surface, although they become increasingly vigorous as the FWI increases (Quintilio et al., 1977). Fires during very high FWI periods may still remain surface fires but may become very intense and spread much more easily. During an extreme FWI period fires often develop into active crown fires and can spread over large areas with great ease (Quintilio et al., 1977).

The daily or mean FWI are not considered suitable for temporal analysis as they represent weather, not climate conditions (Canadian Forestry Service, 1987). Values on a given day are based upon conditions during the previous days and months due to accumulated effects of weather conditions on the forest over the season. Furthermore, the FWI can range from zero to over thirty during the course of a season. Therefore, in order to obtain a value which better represents the seasonal variation of FWI over time, the median FWI for the summer, which was lower than the mean at all three locations, was used. The median is a robust statistic, which removes some of the impact of cumulated effects over time.

The problem of using the FWI on their own may also be corrected by using the Daily Severity Rating (DSR). DSR values are calculated directly from FWI values and are purposely weighted so that they can be used for averaging over time and space (Canadian Forestry Service, 1987). From DSR values, a Seasonal Severity Rating (SSR) can also be calculated which is a measure of potential fire severity and danger for the entire season, in this case the summer.

Generally, records of forest fire occurrence and area burned began to be

collected in the 1940s but are not complete prior to 1960 (Table 3.5). The length of FWI and SSR records follow those of fire occurrence and area burned. However, the data for FWI and SSR at Old Crow are intermittent (Table 3.5).

3.3.5 Climate Change Data

General circulation models (GCMs) are the most commonly used method of projecting future climate. The Canadian Institute for Climate Studies (CICS) at the University of Victoria supplies climate projections from eight GCMs through its Canadian Climate Impacts and Scenarios project. The models include those of the Canadian Center for Climate Modeling and Analysis (CGCM1, CGCM2), the UK Hadley Center for Climate Prediction and Research (HadCM2), the German Climate Research Center (ECHAM4), the US Geophysical Fluid Dynamics Laboratory (GFDL-R15), the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO-Mk2b) and the Japanese Center for Climate System Research (CCSR-98). The GCMs used at CICS have different characteristics including the type of model, the resolution over land and ocean, number of grid boxes, number of vertical levels and flux correction (Table 3.6).

There are two types of GCM included in CICS release: the first are spectral GCMs which model the atmosphere based on vertical exchanges computed in grid point space. These models also incorporate horizontal exchanges in their calculations

	Forest Fire Occurrence	Area Burned	Fire Weather Index	Seasonal Severity Rating
Old Crow	1962-2000	1962-2000	1977-1998	1977-1998
Missing Years	None	None	1979, 1980, 1982, 1983	1979, 1980, 1982, 1983
Mayo	1960-2000	1960-2000	1960-1998	1960-1998
Missing Years	None	None	None	None
Watson Lake	1963-2000	1963-2000	1963-1998	1963-1998
Missing Years	None	None	None	None

Table 3.5. Availability of summer forest fire data at Old Crow, Mayo and Watson Lake

	CGCM1	CGCM2	HadCM2	ECHAM4	CCSR98	CSIRO-Mk2b	GFDL-R15
Model Type	Spectral	Spectral	Finite Grid	Spectral	Spectral	Spectral	Spectral
Atmospheric Resolution °lat x °long	3.75x3.75	3.75x3.75	2.5x3.75	2.8x2.8	5.6x5.6	3.2x5.6	4.5x7.5
Oceanic Resolution °lat x °long	1.8x1.8	1.8x1.8	2.5x3.75	2.8x2.8	2.8x2.8	3.2x5.6	4.5x3.7
Number of lat x long boxes in Canada	13x35	13x35	20x35	18x47	9x24	15x24	11x19
Atmospheric Vertical Levels	10	10	19	19	20	9	9
Oceanic Vertical Levels	29	29	20	11	17	21	12
Flux Correction	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3.6. General circulation model characteristics (from CICS (2002))

rather than just vertical (CICS, 2002). The second type of model has a finite grid, and divides the atmosphere into a series of vertical boxes, commonly spaced in latitude and longitude (CICS, 2002). These models do not take horizontal exchanges into account. Each model has a resolution associated with the size of boxes used in computing atmospheric exchanges over both land and ocean. Climate scenarios for each model can be derived for areas as small as the resolutions allow, which are usually defined by degrees latitude and longitude. The number of grid boxes each model contains is directly related to its resolution. The number of vertical levels in each GCM denotes the number of volumes used in modeling the atmosphere.

Due to differences in characteristics of the GCMs, each has the potential to produce different accounts of future climate. Furthermore, each model often runs a variety of different scenarios by incorporating various effects on the atmospheric regime such as the inclusion or exclusion of the effects of aerosols. Individual scenarios may also be produced by running the model under slightly different atmospheric and oceanic initial conditions (CICS, 2002). The CGCM1, CGCM2 and HadCM2 models also include an ensemble-mean scenario that reports the mean results of several individual scenarios. The eight models available at CICS provide twenty-nine different scenarios for Yukon Territory.

The results from each scenario are arranged into four general categories. Each scenario supplies an average value for the 1961-1990 simulated baseline period which is given in absolute terms. Projected values, expressed as an absolute or percent change, depending on the climate variable, are given for the 2010-2039 (referred to

here as 2020s), 2040-2069 (2050s) and 2070-2099 (2080s) periods. For each climate variable, the scenarios provide average monthly, seasonal and annual values. The climate variables available for most scenarios include mean temperature, total precipitation, wind speed and relative humidity.

The selection of climate scenarios depends on the type of analysis being conducted. CICS (2002) and the IPCC (2001) suggest that, ideally, the use of as many scenarios as possible will reveal the best range in potential results. CICS (2002) and IPCC (2001) also emphasize the use of scenarios which represent both the extreme and average range of projected changes. Another important factor that must be taken into account is the availability of climate variable outputs from each scenario. The climate variables used in this thesis are the mean temperature, total precipitation, relative humidity and wind speed, so only those scenarios which produce these climate variables in their output have been considered.

Another criterion often employed in identifying appropriate models is the ability of a model to reproduce the observed climate in a specific area. Due to discrepancies in local climatic and topographic influences, observed and simulated climates rarely correspond exactly. This is especially true for small areas, such as the three study sites. Furthermore, model output for areas of less than four to eight grid box lengths are not regarded with confidence by climate modelers (Elaine Barrow, personal communication, April 22, 2002). However, it is assumed that the difference between the observed and simulated climate will be constant throughout all projection calculations. In order to increase the validity of scenario projections, model outputs

for an area covering all three subdistricts were used. In other words, the projected climate change was the same for all subdistricts.

Based on the criteria outlined above, the twenty-nine CICS scenarios were examined for an area covering all three study sites. The areal coverage of each model varied due to differences in model grid size. Seven of the CICS scenarios did not include projections for the 2050s or 2080s, and were not considered. Of the twenty-two scenarios that remained, eight were chosen to project future climatic conditions in Yukon (Table 3.7). For each climate variable, the scenario which produced the highest and lowest projected changes for the 2050 summer period was selected. By selecting the scenarios which produced the highest and lowest extremes in climatic changes, the greatest possible range of outcomes was included in projections of future fire variables. The scenario which produced the lowest projected total summer precipitation also projected the lowest average summer wind speed. As a result, a total of seven scenarios was used for projecting changes in climate, and subsequently changes in the forest fire regime in the three study areas. The seven scenarios selected were derived from four different GCMs. Scenarios that only included the effects of greenhouse gases (denoted by GG) and those which included the effects of aerosol as well (denoted by GA) were included in this selection, adding to the variety of scenario types used. All scenarios chosen use an IS92a emission scenario to project future climate change (CICS, 2002). This scenario assumes a population rise to 11.3 billion by 2100, economic growth of 2.3% per year between 1990-2100, and no new agreements regarding the restriction

	Highest	Lowest
Temperature	CGCM1GA1	HadCM2GA1
Precipitation	HadCM2GG3	CGCM1GA3
Relative Humidity	Echam4GG1	HadCM2GAX
Wind Speed	CCSR98GA1	CGCM1GA3

Table 3.7. Scenarios chosen for climate projections

of greenhouse gas emissions (CICS, 2002). It does, however, take into account agreements regarding the reduction of emissions already in place, such as the Montreal protocol. The differences between scenarios derived from one model (e.g. CGCM1GA1 and CGCM1GA3) are due to different initial conditions.

Chapter 4 Methods

4.1 Basic Data Organization and Calculations

All the climate and forest fire data were organized in spreadsheets. Most of the calculations and analyses in this thesis were completed using one of Lotus 123, Lotus Approach Release 9 for Windows, SPSS 8.0 for Windows and Grapher 2.03. The first statistics obtained were descriptive: seasonal and annual averages, standard deviations and ranges were calculated for each of the climate and forest fire variables. Values from each data set were also ranked on an annual basis and average values for ten-year periods were calculated.

4.2 Trends Over Time

In order to determine whether significant changes have occurred in the climate and forest fire records, the data were examined for trends over time. Each value in each data set was ranked using Lotus 123 to see if there was a predominance of any decade in the highest or lowest values found. Similarly, averages for ten-year periods were calculated and compared.

Least-squares linear regression equations were developed using SPSS for all climate and forest fire variables at the three stations (Old Crow, Mayo and Watson Lake) over time. Linear regression was used since the data being examined were seasonal and comprised annual averages over relatively short periods of time. This reduces the cyclical nature of the data, particularly the climate data, and makes linear

analysis appropriate. Since June, July and August are when the majority of fires occur in northern boreal forests, the forest fire variables used in the regression equations are the number of fires per summer, area burned per summer, the median summer FWI, and summer SSR. The level of significance for the correlation coefficients of these relations was determined by testing the slope of the regression equation by two-tailed Student's t-test (Hammond and McCullagh, 1978). The level of significance chosen for the Pearson correlation coefficient, r_p , was 0.05.

4.3 Relations Between Variables

One of the primary goals of this thesis is to analyze and quantify the relations between the different climate and forest fire variables throughout the period of record. Summer temperatures, precipitation, wind speed and relative humidity were analyzed against summer fire occurrence, area burned, median FWI and SSR. Spearman's rank correlation coefficient, r_s , was the first method used to determine the strength of the relations. This method was used as a means of quantifying relations between variables that do not conform to a normal distribution (McClave and Dietrich, 1994). It also allowed for quantification of the comparisons made between the ranked fire and climate data which was a preliminary method of analysis conducted.

Similarly, the Pearson correlation coefficient, r_p , and the coefficient of determination, r^2 , were calculated by SPSS and used to determine the level of linear association between climate and fire variables. Once these relations were made,

analyses were performed in order to ensure a normal distribution of the resulting residuals since the raw data were, in most cases, positively skewed. By analyzing the skewness and kurtosis of the residuals, it was determined that positive transformations of the forest fire variables were needed. Several transformations of the data (including logarithmic, natural logarithmic, square root, cube root etc., all positive transformations) were performed and the skewness and kurtosis of the residuals were again tested. The transformed fire variables which produced residuals with skewness and kurtosis values closest to normal when correlated to climate variables were kept and used for all remaining correlation analyses. The level of confidence for these statistics was determined through the use of a two-tailed Student's t-test. Confidence levels are reported for each variable and those significant at the 95% level or higher are indicated in bold.

Another aim of this thesis is to be able to provide a statistical model for predicting forest fire variables from climate variables. This was done by bivariate and multiple regression. The significance of these models was obtained by evaluating the correlation coefficient, R , and the adjusted coefficient of multiple determination, R^2 and by testing the calculated value of F , derived from the regression coefficient, against the critical value in the F -distribution. The adjusted R^2 rather than simply the R^2 is used as it provides a more conservative estimate of how well the regression model fits the data. The standard error of the estimate was also used to estimate the

error associated with the prediction; plus or minus two standard errors provide the 95% confidence interval around individual predictions.

Due to the nature of multiple regression, the inclusion of all climate variables in the regression model to predict forest fire variables will result in the highest correlation coefficient (Hammond and McCullagh, 1978). For this reason, the strength of the relation between variables is not necessarily the best way to determine the best predictive model. In order to determine the most useful climate variables to include in the predictive model, step-wise multiple regression was performed using SPSS. This method begins by adding to the model, at the first step, the independent variable with the highest bivariate correlation. At the second step, the remaining independent variables are examined for entry and the one which has the highest partial correlation coefficient is entered. This procedure is repeated until all variables that contribute significant information to the model are included. Previously included independent variables may also be removed if it is found that their inclusion no longer contributes significantly to the model when other variables are present. All independent variables in the model must have a level of significance of at least 0.05 in order to be retained.

4.4 Climate Projections

Since the use of scenario outputs for small areas is not considered as reliable as outputs for larger grid areas, projected data from grid squares covering an area

surrounding the three study areas were downloaded for each scenario chosen. By using this method, it is assumed that all stations would undergo the same change in climate conditions. The grid area for each model used varied slightly due to differences in model resolution.

The 2020, 2050 and 2080 projected change values from the chosen grid squares were downloaded and organized into spreadsheets. The change values were then added to the 1961-1990 observed baseline climates of the three study sites separately. Although the change values added were the same for each study area, different results were obtained by adding the change values to the stations' respective baseline climates. Only summer conditions were projected so that they could be easily incorporated into regression equations produced between climate and forest fire variables. Due to differences in scenario results for each climate variable, a range in projected climate variables was obtained for each subdistrict. Projected values for each climate variable were incorporated into multiple regression equations and used to estimate the range of projected future fire occurrence, area burned, FWI values and SSR. In order to obtain statistically significant results for predictions at the 0.05 level, two standard errors were added and subtracted from the value estimated by the equation. Since the regression equations used forest fire variables that were transformed, the final results were transformed back into their original units in order to make the reporting of results more easily interpreted.

4.5 Problems With Methods and Data

As with all research, problems with methods and data often arise. Problems with scale, the quality of the data used and the assumptions that must be made in order to conduct the research have been considered.

4.5.1 Problems With Scale

One of the fundamental problems associated with the study and analysis of environmental phenomena is that data are usually gathered from one point or a series of points, but are used to estimate conditions for a region. Furthermore, when data from different components are studied together, the data are rarely gathered from the same points in space or at the same spatial scale. For example, in this thesis, the climate data were gathered at three specific points, while data regarding the occurrence of forest fires and area burned were gathered over three larger areas. As a result, the climate data used in this analysis may not reflect the variation of conditions throughout the forest fire subdistricts. This may be especially true in a region such as Yukon which is characterized by mountain ranges, valleys and tablelands which can cause significant differences in climate over small distances. Despite this, the climate and forest fire data available are used of necessity.

4.5.2 Quality of Records

The results of any statistical analysis are only as good as the quality of the data used in the analysis. The climate data used in this thesis were collected at weather stations within each of the three forest fire subdistricts in Yukon Territory and then compiled by Environment Canada. These data were compiled in a manner specifically designed for climate change analyses in Canada (Meteorological Service of Canada, 2000). The temperature data have been homogenized by the Meteorological Service of Canada to ensure that any potential discrepancies in the data due to changes in site location, exposure, instrumentation, observer, or observing program were minimized (Meteorological Service of Canada, 2000).

Similar adjustments were also taken with precipitation data. For rainfall, corrections to account for wind undercatch and evaporation have been implemented and gauge-specific wetting loss corrections have also been applied for each rainfall event (Meteorological Service of Canada, 2000). Adjustments were also made for trace amounts of precipitation, which are especially important in northern Canada where precipitation amounts are often very low. This type of adjustment allows for many trace precipitation events to be recorded where they might otherwise be ignored (Meteorological Service of Canada, 2000). Despite the measures to ensure the homogeneity of precipitation records, the data are divided into two categories, station A data and station B data. Station A data includes high quality, long term precipitation records that have very few missing years. Mayo and Watson Lake are

class A stations. Old Crow is a class B station, which has a shorter record and many missing years. For Old Crow, the precipitation record extends from 1953 to 1998, but twenty years of summer data are missing.

The relative humidity, wind speed, FWI, and subsequently SSR for each study site have been derived from climate station daily data and therefore the quality of these records depends on the quality of the climate data. The forest fire records, however, are more problematic. Although methods of detection were improved in Yukon Territory, complete records of forest fire occurrence and area burned were not available until the advent of satellite monitoring in the 1970s.

4.5.3 Assumptions

There are several assumptions that are made in this analysis. The first assumption is that no major societal changes have occurred or will occur in each of the forest fire subdistricts to affect fire occurrence, area burned or other forest fire variables. Specifically, it is assumed, that the population of each of the fire subdistricts has not changed or will not change significantly over time. This is an especially important assumption in the Watson Lake subdistrict where population is the greatest compared to the others. In the last decade there have, however, been some changes in regional populations. In Old Crow, the population has increased by close to 15% since 1991 (Yukon Bureau of Statistics, 2000). However, when put into perspective, this is only an increase of about 40 people in an area that is larger than

most of the Maritime Provinces. At Mayo and Watson Lake the population has been stable over the last decade or so.

Although in all cases the population does fluctuate, very little correlation exists between population fluctuations and fire occurrence or area burned, at least over a ten-year period. In this thesis, it has been assumed that population changes will have no effect on any of the projections for each of the fire subdistricts. In order to minimize any potential human impact on the fire regime, only "natural" fires, those that were caused by lightning and not fought, were considered.

The second assumption is that there has been no significant change in fire detection or management throughout the period of record. Although it is true that the technology involved in detecting and fire fighting has improved over the last forty years and will likely continue to do so in the future, no attempt will be made to correct for such changes.

The third assumption deals with characteristics of the fire regime. It is assumed that fires in each of the three subdistricts are not constrained by fuel supply. Once an area has burned, it is not likely to burn again for several years due to the absence of fuel at the site. Despite this, it is assumed that there is no such restriction in this thesis.

The fourth and possibly most important assumption in this thesis is that changes in climate will affect the fire regime immediately. Correlation analyses were conducted to determine if time lags of between one and six months made any

difference in the strength of fire-climate relations, but none were found. Because of this, it is assumed that changes in temperature and precipitation will have an effect on the fire regime during the same period, that is, the summer. A related assumption is that the potential cumulative effects of changes in climate are negligible. If climate does change, there are likely to be other changes in the environment that also affect the fire regime. For example, a warmer and or wetter climate could ultimately change plant species distribution, thereby changing the nature of the forest and, potentially, the fire regime. Changes in climate could also alter general weather patterns which could in turn affect the number of lightning-producing storms in a given region (Price and Rind, 1994). However, the knowledge of cumulative effects is undeveloped at present.

Chapter 5 Results – Trends and Relations

This chapter presents the results from analyses of climate and forest fire variables over the period of record. The first section considers the separate trends in climate and fire records over time. The second section addresses covariation between climate and fire variables. The examination of covariation between climate and fire variables establishes the relations needed to project future fire regime conditions for the three study areas.

5.1 Trend Analyses

In this section, temporal trends in the climate and forest fire records are discussed separately. The last two decades (1980s and 1990s) are commonly referred to as the warmest decades recorded on Earth. For this reason, the climate data were ranked and analyzed for a predominance of years from these decades at the highest and lowest extremes of the data. Average values for each decade were also examined to determine if the 1980s and 1990s differed from other decades in the climate record. Similar analyses were performed for the forest fire data in order to make comparisons with the climate data. Trend analysis was then performed with annual data for each climate and fire variable to determine if significant changes have occurred over the period of record.

5.1.1 Trends in Climate Variables

Of the warmest ten summers recorded at Old Crow between 1952 and 1999, five occurred in the 1990s, while seven of the coldest ten summers were in the 1950s and 1960s (Table 5.1). Similarly, the warmest summers at Mayo between 1925 and 1999 were dominantly in the 1990s, with seven of the warmest ten years in this decade (Table 5.1). All of the coldest ten summers at Mayo occurred before 1986 and seven of these, prior to 1960. At Watson Lake, the warmest summers between 1939 and 1999 were spread over all decades. Four of the warmest ten summers occurred in the late 1980s and 1990s, while five occurred before 1962 (Table 5.1). The coldest summers at Watson Lake generally occurred in the late 1960s and 1970s (Table 5.1). In all three study areas, most of the coldest summers on record occurred prior to the 1980s. Conversely, the majority of warmest summers on record have occurred in the last two decades.

The wettest summers at Mayo occurred mostly in the 1960s and 1970s (Table 5.2). Of the driest ten summers on record at this site, all but one occurred before 1976 (Table 5.2). Similarly, at Watson Lake, eight of the driest ten summers occurred prior to 1972 (Table 5.2).

Similar trends in temperature and precipitation were also observed when the average summer values of temperature and precipitation were for each decade examined. At all locations, the 1990s were the warmest decade (Table 5.3). The wettest decade at Old Crow was the 1990s but at Mayo and Watson Lake, the wettest

Rank	Old Crow Mean Temperature (1952-1999)		Mayo Mean Temperature (1925-1999)		Watson Lake Mean Temperature (1939-1999)	
	Warmest	Coldest	Warmest	Coldest	Warmest	Coldest
1	1958	1959	1989	1933	1989	1974
2	1979	1952	1994	1935	1994	1973
3	1994	1967	1999	1959	1958	1976
4	1999	1969	1936	1947	1998	1970
5	1998	1991	1990	1932	1971	1939
6	1989	1964	1995	1931	1957	1940
7	1990	1981	1998	1974	1953	1969
8	1977	1985	1997	1973	1961	1968
9	1957	1956	1993	1929	1990	1987
10	1993	1960	1977	1985	1948	1985

Table 5.1. Ten warmest and coldest summers at Old Crow, Mayo and Watson Lake

Rank	Mayo Total Precipitation (1926-1999)		Watson Lake Total Precipitation (1939-1999)*	
	Wettest	Driest	Wettest	Driest
1	1973	1998	1988	1957
2	1932	1957	1962	1951
3	1939	1953	1976	1965
4	1974	1928	1997	1971
5	1975	1938	1974	1967
6	1964	1955	1987	1992
7	1983	1968	1969	1985
8	1967	1940	1952	1950
9	1962	1969	1968	1958
10	1965	1977	1986	1944

Table 5.2. Ten driest and wettest summers at Mayo and Watson Lake (*1993-1995 missing)

	Mean Temperature (°C)	Total Precipitation (mm)	Relative Humidity (%)	Wind Speed (m/s)
Old Crow				
1950s	12.4			
1960s	11.9			
1970s	12.6	86.3		
1980s	12.5	130.6	57.3	9.7
1990s	13.2	147.5	58.7	8.6
Mayo				
1930s	13.2	150.3		
1940s	13.7	132.0		
1950s	14.0	110.0		
1960s	13.6	151.1	54.5	8.1
1970s	14.0	166.2	52.8	6.5
1980s	14.2	142.7	51.9	5.6
1990s	14.8	129.7	50.2	4.9
Watson Lake				
1940s	13.6	168.5		
1950s	14.1	149.4		
1960s	13.5	177.3	49.1	8.6
1970s	13.3	175.8	49.8	9.8
1980s	13.6	172.5	51.0	9.6
1990s	14.2	155.3	51.4	7.2

Table 5.3. Summer decadal mean temperature, total precipitation, relative humidity and wind speed at Old Crow, Mayo and Watson Lake

decades occurred during the 1970s and 1960s. Summers with the least precipitation occurred during the 1950s at Mayo and Watson Lake (Table 5.3).

At Mayo and Watson Lake, the decades with the highest average summer wind speed were the 1960s and 1970s (Table 5.3). Average relative humidity for each decade at Mayo has declined over the last four decades (Table 5.3). This has generally followed the decadal pattern exhibited by precipitation for the same time. However, at Watson Lake, the average relative humidity increased for the last four decades (Table 5.3). This opposes the trends shown for precipitation and temperature at Watson Lake for the same time.

Despite some variation in the ranked values and values for each decade, there is a trend towards warmer conditions in the latter part of the record. These results agree with the summer trends found when the data are analyzed on a yearly basis (Table 5.4). At all locations, the slope of the least-squares regression line indicates that temperature and precipitation have increased over the period of record. At Old Crow, mean summer temperatures as well as total summer precipitation have increased at a statistically significant rate over time (Figures 5.1a and 5.2). At Mayo, mean summer temperatures have also increased at a statistically significant rate (Figure 5.1b).

	Mean Summer Temperature (°C/yr)	Total Summer Precipitation (mm/yr)	Relative Humidity (% change/yr)	Wind Speed (% change/yr)
Old Crow	0.026	2.179	0.317	-0.126
Mayo	0.019	0.167	-0.164	-0.107
Watson Lake	0.005	0.151	0.104	-0.051

Table 5.4. Yearly trend in mean summer temperature, total summer precipitation, relative humidity and wind speed. Values in bold are statistically significant at the 95% level

Figure 5.1a. Mean summer temperature at Old Crow over 48 years (1952-1999)
With outlier removed (16.1°C in 1958)

Figure 5.1b. Mean summer temperature at Mayo over 76 years (1925-2000)

Figure 5.2. Total summer precipitation at Old Crow over 31 years (1969-1999)

5.1.2 Trends in Forest Fire Variables

When the number of forest fires recorded each summer was ranked for each location, a clear temporal division was apparent. At all locations, the most fires per summer occurred during the 1980s and 1990s, while the least were recorded in the 1960s and 1970s (Table 5.5). At Old Crow and Mayo, eight of the ten years with the most fires were in the 1980s and 1990s and at Watson Lake, seven of the ten years with the most forest fires occurred during these decades (Table 5.5). Similar discrimination was apparent when the total recorded area burned per summer was ranked. The ten summers with the largest area burned were dominated by the 1980s and 1990s, while summers with the least area burned were mostly in the 1960s and 1970s (Table 5.6).

Although these results indicate that the 1980s and 1990s had more forest fires and greater area burned per summer, the ranking of median summer FWI and summer SSR did not indicate any greater fire danger in these decades. Years with the highest and lowest median FWI and SSR were scattered throughout the record at both Mayo and Watson Lake (Figure 5.3).

The increase in forest fires per summer during the 1980s and 1990s was also shown by the average number of forest fires per decade in each of the three locations (Table 5.7). Decadal values for median FWI and SSR indicate that the 1990s had the greatest potential fire danger at Mayo, while the 1960s had the highest recorded FWI and SSR values at Watson Lake (Table 5.7).

Rank	Old Crow		Mayo		Watson Lake	
	Fire Occurrence (1962-1999)		Fire Occurrence (1960-1999)		Fire Occurrence (1963-1999)	
	Most	Least	Most	Least	Most	Least
1	1987	1981	1983	1961	1983	1979
2	1988	1968	1994	1964	1991	1970
3	1986	1970	1986	1970	1969	1987
4	1993	1997	1982	1960	1989	1964
5	1990	1967	1977	1981	1999	1963
6	1984	1978	1989	1965	1994	1988
7	1982	1974	1993	1962	1975	1993
8	1977	1965	1998	1963	1971	1973
9	1996	1964	1972	1997	1998	1977
10	1973	1991	1991	1985	1984	1962

Table 5.5. Most and least number of forest fires at Old Crow, Mayo and Watson Lake

Rank	Old Crow		Mayo		Watson Lake	
	Area Burned (1962-1999)		Area Burned (1960-1999)		Area Burned (1963-1999)	
	Most	Least	Most	Least	Most	Least
1	1977	1981	1998	1964	1982	*
2	1971	1967	1994	1961	1969	*
3	1990	1997	1989	1960	1989	*
4	1987	1968	1969	1970	1983	*
5	1993	1970	1977	1963	1994	*
6	1989	1974	1971	1973	1991	*
7	1963	1995	1976	1981	1971	*
8	1975	1969	1972	1992	1981	*
9	1986	1964	1990	1966	1961	*
10	1984	1976	1986	1988	1992	*

Table 5.6. Most and least area burned at Old Crow, Mayo and Watson Lake

* At Watson Lake the years with least area burned were not ranked, as there were more than ten such years

Figure 5.3. Fire Weather Index and Seasonal Severity rating values at Old Crow (1975-1998), Mayo (1960-1998) and Watson Lake (1963-1998).

Old Crow	Summer Fire Occurrence	Summer Area Burned (ha)	Fire Weather Index	Seasonal Severity Rating
1960s	1.6	1077		
1970s	4.7	33930		
1980s	10.2	14017	6.9	1.7
1990s	6.2	12257	4.6	1.3
Mayo				
1960s	4.3	7150	6.8	2.1
1970s	11.9	22310	6.4	1.8
1980s	19.3	16940	5.8	1.6
1990s	17.1	25023	9.4	2.6
Watson Lake				
1960s	6.7	3950	9.6	2.8
1970s	5.3	1678	7.9	2.3
1980s	9.9	21768	8.4	2.6
1990s	10.6	5820	8.0	2.0

Table 5.7. Decadal summer fire occurrence, summer area burned, Fire Weather Index and Seasonal Severity Rating for Old Crow, Mayo and Watson Lake

Since the 1980s and 1990s had more fires, the record should show an increase over time in fire occurrence. Although the slopes of the regression lines for the number of forest fires (and area burned per summer) were positive at all three locations (Table 5.8), the only statistically-significant trends, at the 0.05 level, are for the number of forest fires recorded at Old Crow and Mayo over the period of record and for area burned at Mayo.

5.2 Climate-Fire Relations

This section will examine the relations between summer climate variables (temperature, total precipitation, average relative humidity and wind speed) and summer forest fire variables (forest fire occurrence, total area burned, median FWI and SSR) over the period of record.

5.2.1 Climate and Forest Fire Relations

When the ranked data for forest fire occurrence and climate variables were compared, many of the warmest summers recorded were summers with relatively high forest fire occurrence. Similarly, some cool summers were of low fire occurrence. These relations were described by Spearman rank correlation analysis.

At Mayo, Spearman rank correlation analyses determined that mean summer temperatures are positively correlated with forest fire occurrence, area burned, FWI and SSR at a statistically significant level (Table 5.9). Positive relations between

	Summer Fire Occurrence	Summer Area Burned (ha)	Fire Weather Index	Seasonal Severity Rating
Old Crow	0.176	96.236	-0.213	-0.056
Mayo	0.371	869.577	0.107	0.021
Watson Lake	0.157	159.551	-0.057	-0.028

Table 5.8. Yearly trend in summer fire occurrence, summer area burned, Fire Weather Index and Seasonal Severity Rating over the period of record. Values in bold are statistically significant at the 95% level

Climate variables	Old Crow			Mayo			Watson Lake		
	r_s	Sig. level	n	r_s	Sig. level	n	r_s	Sig. level	n
Fire Occurrence									
MST	0.16	0.552	16	0.57	0.000	39	0.25	0.154	33
TSP	-0.01	0.970	16	-0.24	0.147	39	-0.20	0.267	33
RH	-0.08	0.774	16	-0.41	0.009	39	-0.26	0.149	33
<i>U</i>	0.16	0.560	16	-0.45	0.004	39	0.01	0.951	33
Area Burned									
MST	-0.06	0.883	16	0.67	0.000	39	0.31	0.080	33
TSP	-0.34	0.192	16	-0.34	0.037	39	-0.20	0.265	33
RH	-0.52	0.040	16	-0.55	0.000	39	-0.20	0.259	33
<i>U</i>	0.26	0.333	16	-0.30	0.061	39	-0.18	0.316	33
FWI									
MST	0.20	0.452	16	0.46	0.003	39	0.45	0.008	33
TSP	-0.72	0.002	16	-0.68	0.000	39	-0.85	0.000	33
RH	-0.58	0.018	16	-0.84	0.000	39	-0.84	0.000	33
<i>U</i>	0.07	0.796	16	-0.20	0.223	39	0.30	0.093	33
SSR									
MST	0.10	0.704	16	0.38	0.016	39	0.34	0.053	33
TSP	-0.68	0.004	16	-0.63	0.000	39	-0.79	0.000	33
RH	-0.55	0.029	16	-0.85	0.000	39	-0.83	0.000	33
<i>U</i>	0.17	0.524	16	-0.07	0.690	39	0.38	0.031	33

Table 5.9. Spearman rank (r_s) correlation coefficients for climate variables and forest fire occurrence at Old Crow, Mayo and Watson Lake

temperature and forest fire variables are to be expected since warmer air temperatures create drier fuels through increased evaporation, resulting in forests being more susceptible to fire. Although the relations between total summer precipitation and forest fire variables were not statistically significant at all locations, all relations were negative. Negative relations between fire occurrence and precipitation are also to be expected since increased moisture makes forests less likely to burn. Similar results were obtained for relative humidity. The relation between wind speed and forest fire variables is less clear. The only statistically significant relations for wind speed occur with fire occurrence at Mayo and SSR at Watson Lake (Table 5.9). At Mayo, the relation is negative, and at Watson Lake the relation is positive (Table 5.9).

When the data were subject to Pearson product-moment correlation, analyses by SPSS revealed that transformation of the forest fire variables was necessary to obtain a more normal distribution of residuals. The skewness and kurtosis of several transformations were examined and compared to the untransformed data and those with values closest to normal were used (Table 5.10). Similarly, probability plots of the transformed and non-transformed residuals were created and examined for best fit to the line of normal distribution (Figures 5.4a and b). The forest fire occurrence data were transformed by taking the square root of the raw data, area burned by the fifth root, the Fire Weather Index by the third root, and the Seasonal Severity Rating by the fifth root of the original data. These transformations produced distributions of residuals that were not statistically significantly different from a normal distribution,

Climate variables	Old Crow		Mayo		Watson Lake	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Fire Occurrence (square root)						
MST	0.135	0.684	0.319	0.257	0.333	-0.268
TSP	0.087	0.469	0.251	-0.209	0.384	-0.605
RH	0.134	0.464	0.158	0.607	0.451	-0.204
<i>U</i>	0.326	0.522	0.001	-0.628	0.233	-0.714
Area Burned (fifth root)						
MST	-0.183	-0.265	0.397	0.017	0.727	-0.093
TSP	-0.321	0.098	-0.498	-1.068	0.701	-0.388
RH	-0.075	0.141	-0.785	-0.069	0.594	-0.690
<i>U</i>	-0.015	-0.230	-0.149	-1.277	0.847	-0.209
FWI (third root)						
MST	0.844	-0.015	0.023	-0.105	-0.238	-0.255
TSP	0.762	-0.140	-0.790	2.790	-0.228	0.117
RH	0.042	-1.265	-0.082	-0.711	-1.198	1.831
<i>U</i>	0.806	-0.493	-0.034	-0.762	-0.138	-0.848
SSR (fifth root)						
MST	-0.005	-0.749	0.380	0.872	-0.236	-0.685
TSP	0.927	2.285	-0.380	1.239	0.069	0.046
RH	-0.422	-0.720	-0.411	-0.258	0.319	-0.705
<i>U</i>	0.130	-0.686	0.173	-0.250	-0.189	-0.776

Table 5.10 Skewness and kurtosis of residuals from transformed forest fire variables

Figure 5.4a. Cumulative probability graph of the transformed and non-transformed residuals between area burned and wind speed at Mayo

Figure 5.4b. Cumulative probability graph of the transformed and non-transformed residuals between area burned and relative humidity at Watson Lake

judged by the fact that the skewness indices were considerably smaller than two standard errors of skewness. Once transformations were performed, the climate and forest fire data were examined for statistically significant relations.

In general, the results from Pearson product-moment correlation were similar to the results of Spearman analysis (Table 5.11). In all cases, temperature was positively related to forest fire variables while precipitation and relative humidity were negatively related to all forest fire variables, although not all relations were statistically significant (Table 5.11). In many cases, the highest relations occurred between climate variables, particularly relative humidity, and summer FWI and SSR values (Table 5.11). These results were expected since the FWI and SSR are derived from daily measurements of temperature, precipitation, relative humidity and wind speed. However, it is important to note that FWI and SSR values are calculated daily, whereas the values used in this analysis are representative of the entire summer season.

In order to determine which climate variable, or combination of variables, would have the greatest explanatory power for predicting forest fire occurrence, area burned, FWI and SSR, step-wise multiple regression analysis was performed. Due to the nature of multiple regression modeling, as more independent variables are added to the model, the value of R^2 increases. Theoretically, a perfect relation may be obtained if the number of independent variables included in the model equals the number of data points in the dependent variable. This perfect relation may even be obtained

Climate variables	Old Crow			Mayo			Watson Lake		
	r_p	Sig. level	n	r_p	Sig. level	n	r_p	Sig. level	n
Fire Occurrence (square root)									
MST	0.12	0.665	16	0.57	0.000	39	0.30	0.093	33
TSP	-0.05	0.849	16	-0.20	0.229	39	-0.20	0.262	33
RH	-0.05	0.843	16	-0.38	0.016	39	-0.27	0.132	33
<i>U</i>	0.20	0.462	16	-0.46	0.003	39	0.10	0.585	33
Area Burned (fifth root)									
MST	-0.06	0.840	16	0.68	0.000	39	0.41	0.017	33
TSP	-0.38	0.145	16	-0.30	0.066	39	-0.24	0.175	33
RH	-0.39	0.132	16	-0.50	0.001	39	-0.27	0.135	33
<i>U</i>	0.17	0.166	16	-0.36	0.025	39	-0.08	0.647	33
FWI (third root)									
MST	0.17	0.533	16	0.48	0.002	39	0.41	0.019	33
TSP	-0.66	0.005	16	-0.64	0.000	39	-0.82	0.000	33
RH	-0.71	0.002	16	-0.85	0.000	39	-0.84	0.000	33
<i>U</i>	-0.04	0.873	16	-0.21	0.199	39	0.30	0.090	33
SSR (fifth root)									
MST	0.12	0.672	16	0.35	0.029	39	0.29	0.101	33
TSP	-0.67	0.005	16	-0.55	0.000	39	-0.78	0.000	33
RH	-0.58	0.020	16	-0.85	0.000	39	-0.86	0.000	33
<i>U</i>	-0.02	0.940	16	-0.07	0.667	39	0.39	0.024	33

Table 5.11. Pearson product-moment (r_p) correlation coefficients for climate variables and forest fire variables at Old Crow, Mayo and Watson Lake

when the independent variables added to the model are random and have no relation to the dependent variable (McClave and Dietrich, 1994). Step-wise multiple regression examines the significance level of the model (determined by the F value) as each new variable is added. Independent variables, in this case climate variables, are added to the model in different combinations, until the highest F value is reached.

In most cases, the regression equations that used only one climate variable were found to be the best predictor of fire variables (Table 5.12). When other climate variables were included in these models, the level of significance was lower. The level of correlation between the independent and dependent variables in these models were the same as the square of the Pearson's correlation coefficient (Table 5.11). Models which incorporated more than one independent variable (FWI at Old Crow and Watson Lake, and SSR at Mayo and Watson Lake) had higher adjusted R^2 values when compared to the square of the Pearson correlation coefficient for each individual variable included. For example, the square of the Pearson correlation coefficient between relative humidity and FWI at both Mayo and Watson Lake is 0.72 ($r_p = -0.85$, Table 5.11), but when wind speed is added to the prediction model, the R^2 increases to 0.89 at Mayo and 0.84 at Watson Lake (Table 5.12).

In some cases, no single climate variable, or combinations of variables resulted in a statistically significant relation for predicting forest fire variables. At Old Crow and Watson Lake, forest fire occurrence could not be predicted due to lack of

Equation	Adjusted R^2	Sig. (F)	Std. Error (Estimate)	Average (independent variable)
Old Crow				
FWI (3 rd root) = $-0.003(\text{TSP}) - 0.045(\text{RH}) + 4.748$	0.64	0.001	0.163	1.75
SSR (5 th root) = $-0.002(\text{TSP}) + 1.283$	0.41	0.005	0.078	1.07
Mayo				
Fire Occurrence (sq. root) = $1.190(\text{MST}) - 13.622$	0.30	0.000	1.472	3.18
Area Burned (5 th root) = $2.667(\text{MST}) - 32.739$	0.44	0.000	2.454	4.92
FWI (3 rd root) = $-0.074(\text{RH}) + 5.690$	0.71	0.000	0.221	1.83
SSR (5 th root) = $-0.027(\text{RH}) + 0.024(\text{U}) + 2.408$	0.89	0.000	0.064	1.12
Watson Lake				
Area Burned (5 th root) = $1.637(\text{MST}) - 13.191$	0.14	0.017	2.877	2.94
FWI (3 rd root) = $-0.003(\text{TSP}) - 0.055(\text{RH}) + 0.042(\text{U}) + 4.858$	0.80	0.000	0.179	1.97
SSR (5 th root) = $-0.032(\text{RH}) + 0.027(\text{U}) + 2.563$	0.84	0.000	0.059	1.17

Table 5.12 Equations selected for prediction from step-wise multiple regression on transformed forest fire variables.

statistically significant relations. Similarly, area burned could not be projected at Old Crow.

The standard error of the estimate associated with FWI and SSR prediction equations are small when compared to the mean of the transformed values (Table 5.12), indicating desirably narrow confidence intervals associated with the predicted value. Standard errors of the estimate for equations predicting fire occurrence and area burned were relatively higher, however, indicating wider confidence limits for the predicted value (Table 5.12). These observations suggest that conditions that influence the start and spread of forest fires, i.e., the FWI and SSR, could be predicted by these regression models more precisely than the actual incidence of fires, measured by the number of fires and area burned.

Chapter 6 Results – Projected Forest Fire Variables

This section presents results from global circulation model scenarios. Results include projections for temperature, precipitation, relative humidity and wind speed for three future time periods at Old Crow, Mayo and Watson Lake. These climate projections are then incorporated into regression equations to project future summer forest fire occurrence, area burned, FWI and SSR for the three study areas.

6.1 Climate Projections

All scenarios projected increasingly warmer summer temperatures over the next one hundred years (Table 6.1) (Figure 6.1). The CGCM1GA1 projected the greatest change in temperatures over time while all three Hadley scenarios (HadCM2GA1, GA2, and GG3) projected the lowest changes (Table 6.1). Most scenarios projected an increase in precipitation; however, two scenarios projected small decreases during the 2020s (HadCM2GA2 and CGCM1GA3) and one in the 2050s (CGCM1GA3) (Table 6.1). By the 2080s period, all scenarios projected an overall increase in precipitation for the summer. Five of the seven scenarios projected a decrease in relative humidity by the end of the century. Although precipitation is projected to increase, this is offset by the increase in summer temperatures, leading to an overall decrease in humidity (Table 6.1). The changes in wind speed were very small for all scenarios and time periods (Table 6.1). In most cases, wind speed is

	Mean Summer Temperature (°C)			Total Summer Precipitation (%)			Relative Humidity (%)			Wind Speed (%)		
	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
Had2GAI	1.0	1.3	2.2	11.5	15.8	17.3	-0.5	-2.2	-2.1	0.0	0.9	0.3
Had2GA2	1.1	1.6	2.5	-0.4	7.4	4.0	-0.4	-0.5	-1.1	-0.9	-0.4	-0.9
Had2GG3	0.7	1.5	2.4	14.4	18.4	18.4	1.0	0.2	1.9	-0.2	0.4	0.1
Cgcm1GA1	1.8	3.2	5.0	6.0	9.3	14.7	-1.0	-0.9	-7.3	0.1	0.3	0.3
Cgcm1GA3	1.7	3.1	4.7	-3.9	-1.0	7.5	-3.3	-5.8	-7.8	0.1	0.2	0.3
EchamGG1	1.4	2.6	3.8	11.5	18.0	17.1	1.4	0.3	-0.3	0.8	1.2	0.5
CSR98GA1	1.5	2.8	4.0	7.5	15.3	16.8	4.2	3.4	8.3	0.3	1.2	1.4

Table 6.1 Projected changes in mean summer temperature, total summer precipitation, relative humidity, and wind speed for each scenario

Figure 6.1. Projected mean summer temperature at Mayo

projected to increase, although the greatest increase, projected by the CSR98GA1 scenario, was only 1.4% (Table 6.1).

For each of the regression equations chosen to forecast forest fire variables, the appropriate projected climate variables (Table 5.12) from each scenario were incorporated to produce future forest fire projections. For each equation, seven different projected forest fire data sets were calculated (one for each climate change scenario, Table 3.7) for each of the three time periods (2010-2039, 2040-2069, and 2070-2099). This resulted in a total of 210 data points for each projected fire variable, for each time period (7 scenarios x 30 years). Standard errors associated with each equation used were then added and subtracted from results to ensure the projected values were statistically significant at the 0.05 level. From these results, potential highest, lowest, and average values for each time period were determined. These data were compared to the highest, lowest, and average values over the period of record.

6.2 Old Crow Projections

Due to the lack of significant relations between climate variables and fire occurrence and area burned, projections could not be made. The average projections for FWI and SSR at Old Crow suggest that these values will increase over time compared to present conditions. The highest projections for FWI and SSR exceed those encountered to date (Table 6.2). The lowest projections, are, in many cases

Old Crow		FWI		
Time Period		Highest	Lowest	Average
1960-2000		12	3	2
2020s		21	1	6
2050s		24	1	7
2080s		25	1	7
		SSR		
		Highest	Lowest	Average
1960-2000		3	1	2
2020s		5	0	5
2050s		5	0	0
2080s		5	0	2

Table 6.2 Highest, lowest and average forest fire projections for each time period at Old Crow

lower than recorded between 1962 and 1999. These results imply that not only will average conditions increase but the interannual variability will increase as well.

Although a high FWI or SSR does not necessarily mean more fires or greater area burned, high fire danger ratings such as these do have an impact on fire management teams and the community. High danger ratings require fire control teams to be on alert, and camp fires or other forest activities may also be banned.

6.3 Mayo Projections

The results for all forest fire variables at Mayo exhibit the same general pattern. Average conditions for the next hundred years are projected to increase, especially in the case of forest fire occurrence and area burned (Table 6.3). The upper range, or highest projections, are all greater than the highest value recorded for each fire variable over the period of record (Table 6.3). By the 2080s period at Mayo, some summers may experience up to four times as many fires as previously recorded. Similarly, the median FWI and summer SSR value are projected to be higher for all future time periods compared to the period of record.

Although the projections for area burned also show substantial increases in the upper range of values, these results may be somewhat misleading. The highest projected area burned per summer for the 2080s period is over twenty million hectares (Table 6.3). Although this result does suggest a substantial increase over values reported to date, it is important to note that areas that were previously burned in the

Mayo			
Fire Occurrence			
Time Period	Highest	Lowest	Average
1960-2000	50	0	15
2020s	117	0	21
2050s	156	0	34
2080s	214	1	52
Area Burned			
	Highest	Lowest	Average
1960-2000	145362	0	22832
2020s	3480893	0	34868
2050s	8106987	0	140255
2080s	20112548	44	537824
FWI			
	Highest	Lowest	Average
1960-2000	18	1	6
2020s	20	1	6
2050s	24	1	7
2080s	28	0	7
SSR			
	Highest	Lowest	Average
1960-2000	6	1	2
2020s	10	0	2
2050s	13	0	2
2080s	15	0	3

Table 6.3 Highest, lowest and average forest fire projections for each time period at Mayo

Mayo subdistrict and could therefore not be burned again for a few decades, were not taken into consideration when calculating this value. Since the area of the Mayo subdistrict is just over eight million hectares, a fire the size of the upper range of projections (twenty million hectares) would indicate that no more fires could occur in this area for several years. Nonetheless, the overall results do suggest a potential increase over the period of record. The lowest projections for forest fire variables suggest somewhat different results. The lowest projections, in most cases, are similar to the lowest values reported over the period of record (Table 6.3). These results imply that, although some summers may experience more fires, area burned, and higher FWI and SSR values, others will still likely see no fires or area burned and low FWI and SSR values. Projected changes in climate are likely to produce a more accelerated and a more variable fire regime in the Mayo subdistrict, characterized by some summers experiencing greater fire occurrence, area burned and fire danger potential, described by the FWI and SSR.

6.4 Watson Lake Projections

Due to the lack of statistically significant relations between climate variables and forest fire occurrence at Watson Lake, projections for fire occurrence could not be done. The results for area burned are similar in pattern to those projected for Mayo. The average area burned per summer is projected to increase over the next one hundred years when compared with present conditions (Table 6.4). The statistical

Watson lake	Area Burned		
Time Period	Highest	Lowest	Average
1960-2000	27590	0	4524
2020s	856094	0	3156
2050s	1719671	0	12714
2080s	3722300	0	48426
	FWI		
	Highest	Lowest	Average
1960-2000	19	1	8
2020s	28	0	7
2050s	32	0	7
2080s	35	0	7
	SSR		
	Highest	Lowest	Average
1960-2000	6	1	2
2020s	11	0	3
2050s	14	1	3
2080s	17	0	3

Table 6.4 Highest, lowest and average forest fire projections for each time period at Watson Lake

analyses indicate that by the 2080s period, Watson Lake could see some summers with over ten times the area burned than recorded to date (Table 6.4). However, as at Mayo, the results do not incorporate the fact that an area burned in the recent past is not likely to burn again. Furthermore, since Watson Lake is a more populated subdistrict, fire control and fighting is likely to be increased, especially if lives or property are at stake. Despite this, the results still suggest that some summers may experience greater area burned than at present. However, projections for the next one hundred years also show that some summers are also likely to see no area burned at all (Table 6.4). Again, this indicates a trend towards a more accelerated and variable fire regime. The projections for the FWI and SSR also suggest more variable future conditions. The highest projections for all future time periods are greater than the highest values recorded (Table 6.4). The lowest values, on the other hand, show small decreases compared to the period of record (Table 6.4). This also implies a more variable fire danger regime in the future.

6.5 Projected Fire Regime

In all cases, results indicate that the future fire regime in Yukon will continue to vary on a year-to-year basis. While some summers are still likely to have no fires, no area burned and low FWI and SSR, the significant difference occurs in the upper extremes of the projections. Mayo is likely to see summers with a substantially greater number of fires, area burned and FWI and SSR values than recorded over the last forty years or so. Similarly, Old Crow and Watson Lake are likely to see summers

with FWI and SSR values that exceed the highest values recorded. Although relations between climate variables and fire occurrence and area burned did not allow for projections of these fire regime components, the projected greater FWI and SSR suggests the potential for greater fire danger than at present.

The fact that projections did not indicate a clear shift towards an accelerated fire regime may have substantial implications for fire management. Since some summers may still have no fires and area burned it may difficult to obtain more budget support, and, subsequently, staff and equipment, to manage fires during summers with greater fires and area burned.

Although fire is a natural component of the boreal forest ecosystem, and some advocate no fire suppression, if the highest fire occurrence, area burned and FWI and SSR projections do come to pass, the boreal forest may not have time to adapt. This could mean a loss of wildlife, biodiversity and resources for the Yukon.

Chapter 7 Discussion and Conclusion

7.1 Discussion

Although the validity of climate models to project future climates, especially in mountainous regions such as Yukon, has been debated, all models project increased temperatures for the three study areas. Precipitation is also projected to increase over the next century. These projections agree with current trends at the three climate stations. Although it is difficult to tell whether the changes in climate exhibited over the period of record are a result of global warming, the decadal results in temperature and other climate variables for the 1980s and 1990s suggest it is possible.

Despite the wide range in projected future forest fire variables for the next one hundred years, most forest fire variables are projected to increase at all locations. If only the highest projections are taken into account, all fire variables are projected to increase significantly. However, it is important to note that the projected increases do not suggest a shift towards an accelerated fire regime, but rather an increase in the current upper boundaries of the fire regime. That is, the results indicate at least some summers with greater fire occurrence and area burned (in Mayo) and greater potential for fire danger, expressed by the FWI and SSR.

Although the results from the climate projections are statistically significant, it is also important to note that there are many other factors, not addressed in this study, such as an increase in length of the fire season, potential increases in lightning strikes, increases in extreme weather events, and changes in vegetation in the boreal forest due

to future climate change, which could further influence future forest fire conditions in the boreal forest.

Although the results of this study were limited to the summer season, the potential for greater fire occurrence and area burned could also be extended into the spring and fall. This would imply even more fires and area burned for Yukon fire management to contend with. Furthermore, Wotton and Flannigan (1993) have shown that the length of the fire season will increase by an average of thirty days across the Canadian Boreal Forest. A longer fire season could mean greater potential for fires and area burned.

This study has not specifically considered the occurrence of lightning. Although this omission was necessary given the constraints of the GCMs, Price and Rind (1994) report that lightning strikes will likely increase under a $2\times\text{CO}_2$ climate. This may also increase the likelihood of fire occurrence and subsequently increases in area burned.

Another important factor to consider is the impact of a $2\times\text{CO}_2$ climate on the frequency of extreme events. Although the availability of the data in this study did not allow for examination of such weather events, it has been suggested by others (Fowler and Hennessey, 1995; Groisman et al., 1999; McGuffie et al., 1999) that the projected increases in temperature could bring about an increased frequency of extreme events such as heat waves and heavy precipitation, factors that could alter the fire danger in a region.

Finally, the effects that a change in climate could have on the boreal forest ecosystem may also work to increase fire danger, particularly fire intensity. Although overstory trees may persist for decades, seedlings, particularly at the southern limits of the forest, could be dominated by a greater proportion of deciduous species, given the warmer climate. Deciduous species burn at a greater fire intensity, perhaps leading to greater area burned at the southern limits of the boreal forest (Weber and Stock, 1998).

The presence of an accelerated fire regime may have many socio-economic implications for the people who inhabit the region. Many people in Yukon's communities still partake in traditional practices such as hunting, trapping and fishing, which depend on forest resources. Also, forests are an important resource for the tourism industry in many parts of Yukon. The timber from these forests, particularly in the more southern regions, such as Watson Lake, may also become economically viable. Degradation of forests from fire could therefore have serious implications both economically and socially for residents of the Territory.

Although the degradation of the boreal forest ecosystem may mean important losses to the community, it is not economically feasible or ecologically desirable to suppress all fires. Fire management will have to be able to recognize and take into account a new fire regime when planning strategies for management. The cost of fighting or preventing more fires will also have to be considered. In small communities where resources for fire suppression are limited, this cost may perhaps have to be offset by increasing low priority fire fighting areas. No matter what fire planning and management teams decide, the accelerated fire regime projected for the

next one hundred years will undoubtedly change the boreal ecosystem and subsequently the landscape of Yukon Territory.

7.2 Conclusion

This study has shown that the climate of Old Crow, Mayo and Watson Lake is becoming warmer and wetter. This has resulted in a net increase in relative humidity at Old Crow and Watson Lake but a decrease in Mayo. These trends, exhibited over the period, are expected to continue over the next one hundred years, as projected by seven climate models.

The climate of the three study areas was, in some cases, found to be related to forest fire occurrence, area burned, and fire danger (expressed as FWI and SSR values). The relations were particularly clear in the case of temperature and fire occurrence and temperature and area burned. Precipitation and relative humidity played a greater role in determining the FWI and SSR over the period of record.

By using the relations between climate variables and forest fire variables over the period of record, forest fire occurrence is projected to increase at Mayo over the next hundred years. Also, the area expected to burn each summer at Mayo and Watson Lake will be substantially greater than experienced at present. Despite these findings, fire danger ratings at Mayo and Watson Lake are not projected to be higher than those experienced over the period of record. These results may be due to the fact that precipitation, which plays a large role in determining these values, is projected to increase by the end of the century in all scenarios chosen.

Despite the fire danger results, findings here generally indicate that Yukon Territory is likely to see an accelerated fire regime under a 2xCO₂ climate. The increased fire regime projected by this study may also be further exacerbated by other factors which may influence the boreal forest and fire regime due to climate change. Such factors include an increased length of the fire season, increase in cloud to ground lightning strikes, increases in the frequency of heat waves and droughts, as well as changes in the distribution of tree species in the boreal forest.

The results from this study, especially when coupled with other potential factors which may influence the fire regime, may lead fire management teams to reevaluate current policies. Although it will be impossible to prevent all impacts of an accelerated fire regime on the boreal forest of Yukon Territory, it will be essential to prevent the degradation of this ecosystem.

The boreal forest is the largest ecosystem in Canada and in many ways a national symbol. Although forest fire is a crucial and beneficial component of the boreal ecosystem, we must ensure the safety of the resources we derive from the forest and prevent it from degrading beyond repair.

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Appendix I
Climate Data

Old Crow Mean Temperature (degrees Celsius) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1974	-28.4	-33.6	-24.4	-14.3	2.1	9.5	14.3	12	3.4	-14.1	-22.1	-28.4	-10.3	-29.5	-12.2	11.9	-10.9
1975	-36.7	-27.3	-17.4	-12.1	3.2	11.4	14.8	10.6	0.7	-11	-28.8	-33.7	-10.5	-30.8	-8.8	12.3	-13
1976	-34.4	-35.2	-22.7	-8	2.8	10.2	13.5	12.9	6.1	-9.2	-13.3	-32.1	-9.1	-34.4	-9.3	12.2	-5.5
1977	-30.8	-22.3	-26.6	-15	3	11.5	14.2	14.7	4.6	-6.4	-25.3	-26.8	-8.8	-28.4	-12.9	13.5	-9
1978	-26.9	-27	-18.1	-10.6	-1.4	9.7	15.9	10.5	6.1	-13.7	-17.6	-25.2	-8.2	-26.9	-10	12	-8.4
1979	-24.9	-30.6	-25.5	-11.2	4.5	11.7	17.4	14.7	5	-5.3	-12.4	-28.4	-7.1	-26.9	-10.7	14.6	-4.2
1980	-32.4	-22.4	-20.8	-12.7	2.8	15	13.2	10.4	-1	-5.5	-21	-33.3	-9	-27.7	-10.2	12.9	-9.2
1981	-18.6	-27.1	-17.3	-10.2	6.2	10.9	13.1	9.2	2.1	-7.4	-20.3	-23.7	-6.9	-26.3	-7.1	11.1	-8.5
1982	-38	-27.1	-21.2	-11.7	-1.4	11.8	15.5	9.8	5.6	-12.4	-25.7	-29.3	-10.3	-29.6	-11.4	12.4	-10.8
1983	-35.2	-27.5	-24.6	-11.1	-1.9	12.6	14.7	11.4	0	-12.8	-21.7	-22.8	-9.9	-30.7	-12.5	12.9	-11.5
1984	-31.8	-30	-23	-11	2.6	13.5	13.1	8.9	3.8	-10	-26.2	-30.4	-10	-28.2	-10.5	11.8	-10.8
1985	-22.9	-31	-20.6	-17.3	2.3	11.9	12.1	10.1	3.3	-11.1	-22.7	-21.4	-8.9	-28.1	-11.9	11.4	-10.2
1986	-25.9	-24.1	-24	-17.5	-1.3	13	14.3	9.4	4	-10.4	-28.8	-21.8	-9.4	-23.8	-14.3	12.2	-11.7
1987	-24.6	-27.9	-23.6	-13.9	1.5	12.8	15	10.2	3.1	-6.6	-21	-24.5	-8.3	-24.8	-12	12.7	-8.2
1988	-28.4	-27.6	-20	-8.9	2.6	14.1	14.9	10.8	3.2	-11.2	-23.9	-22.3	-8.1	-26.8	-8.8	13.3	-10.6
1989	-36.4	-17.4	-23.7	-6.8	2.2	11.4	15.7	14.4	5.6	-9	-27.5	-24.4	-8	-25.4	-9.4	13.8	-10.3
1990	-35	-38.8	-16.6	-8	5.6	12.9	16	11.8	3.4	-8.5	-27.8	-31.8	-9.7	-32.7	-6.3	13.6	-11
1991	-27	-28.4	-21.8	-6.9	8.1	11.7	12.1	9.3	4.5	-9	-27	-31	-8.8	-29.1	-6.9	11	-10.5
1992	-26.9	-27.6	-17.5	-13.8	-0.6	13.4	14.5	11.1	-1.9	-12.9	-20.2	-30.3	-9.4	-28.5	-10.6	13	-11.7
1993	-25.6	-26.7	-17.3	-6.5	3.6	13.6	16.4	10.6	3.7	-5.6	-19.6	-22.6	-6.3	-27.5	-6.7	13.5	-7.2
1994	-32.7	-30.4	-20.9	-9.6	5.7	11.5	17.6	14.1	0.9	-6.8	-23.6	-28.5	-8.6	-28.6	-8.3	14.4	-9.8
1995	-28.1	-26.7	-23.1	-5.7	7.2	13.7	14.9	11.2	3	-9.1	-24.2	-25.8	-7.7	-27.8	-7.2	13.3	-10.1
1996	-34.9	-25	-20.8	-13.4	1.9	13.2	14.6	7.5	0	-15.4	-24	-28.8	-10.4	-30.7	-10.8	11.8	-13.1

Old Crow Mean Temperature (degrees Celsius) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1997	-33.6	-23.2	-24.9	-10.8	2.8	12.5	14.4	12.8	6.2	-10.4	-21.6	-23.5	-8.3	-28.5	-11	13.2	-8.6
1998	-31.2	-22.4	-19.6	-2.6	7.1	13.4	17.1	11.5	5.3	-8.6	-22.5	-23	-6.3	-25.7	-5	14	-8.6
1999	-31.4	-29.7	-22.1	-9.5	3.6	14.1	14.4	13.4	5.5					-28	-9.3	14	

Old Crow Total Precipitation (mm) Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1951										16.9	15.2	9					
1952	3.8		22.3	29	1.8			20.2	31.1	21.2	26.1	15			53.1		78.4
1953	11.4	2.1	7.6	0.2	4.1	20.5	20.4	23.6	3.3	2.2	0.3	14.6	110.4	28.4	11.9	64.6	5.9
1954	11.6	0.3	9.3	4.4	1.8	10.3	14.3	17.3	6.9	27.1	21.1			26.6	15.4	41.9	55
1955	9.3	16		8.9	5.5	35.5	56.3					32.6					
1956	6.4	0.8		0	29.2	162.3	20.4							39.9			
1957																	
1958																	
1959																	
1960																	
1961																	
1962																	
1963																	
1964																	
1965																	
1966																	
1967																	
1968											8.3	14.6					
1969	14.7	17.9	0.2	2	7.1	24.7	9.2	103.9	3.5	4.2	10.7	17.2	215.3	47.2	9.3	137.8	18.4
1970	4.4	9.7	11.1	4.9	6.9	2.6			36.6	25.2	19.4	12.1		31.3	22.9		81.3
1971	5.9	17.7	0.7	14.7	6.7	0.2	15.3	31.2	50.9	46.4	9.9	4.6	204.1	35.7	22.1	46.6	107.2
1972	2.9		9.7		10.2	6.8	34.2	31.2	49.4			10.8				72.3	
1973			6.8	6	0		50.4			38.5	10.9	5.4			12.7		

Old Crow Total Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1974					0.5	30.8	22.9	81.4	63.9	64.8	115.6	16.5				135.1	244.3
1975	10.5	7									9.2	14		33.9			
1976	17	4.7	8.7	1.1	45.3	22.9	5.1	57.7	44.8	27	11.6	14.8	260.8	35.8	55.1	85.6	83.5
1977	10.5	6.8				62.1	16.4		9.8		23.7			32			
1978		0.4				56.3	11.1	24.6		40	9.2	6.1				92	
1979																	
1980			43.6	19.6	30.5	26	51	70.3	44.9	23.3	34.9	23.2			93.7	147.2	103.1
1981		10.7	5.6	3.8	23.6	37.1	95.7	70.9	50.9	22.3	19.9	13.8			33	203.7	93.1
1982	2	26.1	7.9	30.6	9.1	33.8	50	44.7	25.2	24.6	20.6	15.9	290.5	42	47.6	128.5	70.4
1983	21.7	15.3	3.8	6.7	4.5	16.8	25.8	19.8	32.7	15.1	11.4			52.9	14.9	62.4	59.2
1984	23.2	16.6	19.5	20.3	18.8	69.4	90.5	53.4	3.4	16.2	9	13.2	353.4		58.5	213.3	28.5
1985	14.8	22.5	20.8	21.6	13.7	25.6	27.1	33.3	28.3	12.1	6.5	14.2	240.6	50.6	56.1	86	46.9
1986	10.4	18.3	11.4	5.7	7.2	19.6	30.4	55.3	11.9	33.9	13.4	19.2	236.8	42.9	24.3	105.4	59.2
1987	26.2	9.1	23.8	6	28.2	26.8	34.1	64.5	37.3	21.4	35.5	21.4	334.1	54.4	57.9	125.4	94.2
1988	14.4	18.4	40.2	22.4	39.4	44.7	29.1	73.8	35.8	22.2	13.5	11.2	365.2	54.3	102.1	147.5	71.6
1989	7.5	11	7.5	7	23.8	41.8	14.5	29.9	15.2	34.3	13.9	18.9	225.3	29.8	38.3	86.2	63.4
1990	19.3	15.8	16.5	3.5	4.2	33.4	23.3	22.5	25.8	23.1	32.8	16.2	236.5	54	24.3	79.2	81.7
1991	22.2	11.3	17.9	3.3	22.6	34.6	69.5	48.5	40.2	27.5	13.3	10.9	321.7	49.6	43.8	152.5	81
1992	13	23.8	10.3	11.5	7.1	25	48.7	49.1	17.2	12.1	19.9	24.2	261.8	47.6	28.9	122.8	49.2
1993	55.9	12	11.1	1.6	3.3	33.4	40.3	49.8	32	41.6	35.7	15.5	332.2	92.1	16	123.6	109.3
1994	9.3	10.2	20.5	13.5	28.3	91.6	32.7	28.5	44	18.5	22.9	20.8	340.8	35	62.3	152.8	85.4
1995	6.5	6.8	15.4	3.8	23	90	48.9	57.6	38	18.8	31.5	9.7	350.1	34.1	42.3	196.5	88.3
1996	8.8	38.1	26.5	6.5	14.5	58.8	48.8	50.7	61.6	41.6	29.5	9.5	394.9	56.6	47.5	158.4	132.7

Old Crow Total Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1997	8.5	34.9	13	5.5	27.6	43	49.5	50.3	24.4	57.5	20.8	36.6	371.6	52.9	46.2	142.7	102.7
1998	7.1	14.2	7.9	13.7	28.3	65.8	55.6	85.1	25.7	36	15.8	26.9	382.1	57.9	50	206.4	77.5
1999	24.3	10	13.9	15.9	9	38.7	39.7	62.1	41.9					61.3	38.8	140.5	

Old Crow Relative Humidity (%) Record

1977	48.7
1978	63.0
1979	
1980	
1981	45.6
1982	
1983	
1984	57.2
1985	49.9
1986	60.6
1987	58.3
1988	61.1
1989	56.9
1990	54.7
1991	57.1
1992	59.2
1993	58.3
1994	56.1
1995	62.5
1996	59.5
1997	59.0
1998	61.5

Old Crow Wind Speed (m/s) Record

1977	7.0
1978	7.9
1979	
1980	
1981	12.7
1982	
1983	
1984	13.7
1985	9.4
1986	8.4
1987	9.0
1988	8.1
1989	9.6
1990	8.0
1991	8.3
1992	8.5
1993	7.9
1994	9.4
1995	7.8
1996	10.2
1997	8.3
1998	8.9

Mayo Mean Temperature (°C) Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1925	-37.5	-28.6	-15	-2.4	8.6	14.1	14.6	11.9	6.8	-0.9	-9.8	-15.8	-4.5		-2.9	13.5	-1.3
1926	-10.6	-17.7	-3.8	2.2	8.5	13.8	14.7	12.3	6.2	-1.2	-13.7	-22.2	-1	-14.7	2.3	13.6	-2.9
1927	-29.1	-17.4	-7.4	-5.4	7.2	13.9	16.7	13.6	5.6	-3.6	-25.5	-30	-5.1	-22.9	-1.9	14.7	-7.8
1928	-20.9	-16.7	-15	-4.8	7.1	14.3	14.9	11.1	4.7	-3.8	-8.2	-15.4	-2.7	-22.5	-4.2	13.4	-2.4
1929	-22.8	-17.6	-12.8	-3	6.2	13.8	13.6	11.4	8.3	2.2	-11.1	-26.4	-3.2	-18.6	-3.2	12.9	-0.2
1930	-36.1	-23	-12.7	-1.5	8.1	12.4	15.5	13.2	6.8	-5.3	-16.2	-15.8	-4.6	-28.5	-2.0	13.7	-4.9
1931	-16.8	-11.4	-14.2	-1.2	5.3	12.7	14.1	11.2	5.9	-1.1	-16.6	-23.3	-3	-14.7	-3.4	12.7	-3.9
1932	-27.9	-32.7	-13.2	2.1	7.7	11.4	13.8	12.7	5	-2.9	-23.3	-29.5	-6.4	-28.0	-1.1	12.6	-7.1
1933	-33.4	-24.6	-12.9	-1.9	8.7	10.3	13.2	11.6	4.6	-4.6	-12.6	-42.4	-7	-29.2	-2.0	11.7	-4.2
1934	-30	-12	-12.9	1.1	7.8	12.3	15.1	12.5	5	0.2	-13.9	-22.6	-3.1	-28.1	-1.3	13.3	-2.9
1935	-31.3	-11.8	-16.6	-1.7	6.1	11.9	14.9	9.8	5.1	-7	-19.5	-20.6	-5.1	-21.9	-4.1	12.2	-7.1
1936	-27.8	-35.7	-11.7	-2.4	8.1	15.5	16.1	14.3	5.1	-0.3	-10.1	-28.9	-4.8	-28.0	-2.0	15.3	-1.8
1937	-22	-22	-7.9	1	7.7	14.8	13.1	11.1	8.3	1.3	-10.6	-25.3	-2.5	-24.3	0.3	13.0	-0.3
1938	-24.9	-25.1	-7.2	1.5	8.2	12.1	15	13.3	9.8	3.9	-12.9	-22.1	-2.4	-25.1	0.8	13.5	0.3
1939	-21.3	-24.5	-15.3	-1.1	8.1	13.5	16	11.8	4.5	-5.9	-11.4	-11.9	-3.1	-22.6	-2.8	13.8	-4.3
1940	-18.8	-16.7	-8.9	4	7.9	13.5	16.5	11.6	8.4	1.3	-16.9	-15.2	-1.1	-15.8	1.0	13.9	-2.4
1941	-23.1	-14.7	-6.2	5.8	8.7	14.7	15.1	13.9	4.9	-3.2	-17.3	-25	-2.2	-17.7	2.8	14.6	-5.2
1942	-11.8	-12	-8.6	0.9	10.4	15	16.2	12.7	7.5	1.7	-19.5	-33.1	-1.7	-16.3	0.9	14.6	-3.4
1943	-30.7	-18.2	-15	0.5	8.1	13.8	14.8	12	7.3	0	-5.1	-10.1	-1.9	-27.3	-2.1	13.5	0.7
1944	-16.9	-15.1	-11.2	-0.7	8.8	14.6	15.5	12.1	6.7	1.1	-11.8	-18.6	-1.3	-14.0	-1.0	14.1	-1.3
1945	-19.4	-14.9	-8.3	-4.7	8.1	12.5	14.4	12.3	5.3	-0.8	-22.1	-19.7	-3.1	-17.6	-1.6	13.1	-5.9
1946	-22	-16.4	-10.9	-0.4	9.9	16.1	14.9	12	6.8	-2.4	-22.1	-32.1	-3.9	-19.4	-0.5	14.3	-5.9
1947	-31	-22.4	-3.6	-0.6	8.8	11.8	16.1	9.7	6	1.4	-7.7	-13	-2	-28.5	1.5	12.5	-0.1

Mayo Mean Temperature (°C) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1948	-16.4	-25.5	-14.5	-4.7	9.2	13.4	14.5	11.1	5.6	0.7	-17.2	-30.7	-4.5	-18.3	-3.3	13.0	-3.6
1949	-24.4	-29.8	-7.6	1	5.5	11.1	14.7	13.2	8.7	-2	-7.2	-28.8	-3.8	-28.3	-0.4	13.0	-0.2
1950	-31.8	-27.6	-8.3	-1.9	8.3	16.1	15.4	12.6	8.1	-3.2	-29.8	-20.2	-5.2	-29.4	-0.6	14.7	-8.3
1951	-29.8	-26	-15.9	0.7	8.5	11.1	16.7	13.5	8.9	-8	-12.8	-28.2	-5.1	-25.3	-2.2	13.8	-4.0
1952	-34.2	-15.7	-10.5	-1	6.4	13.4	15.8	11.9	5.7	0.9	-6.4	-16.5	-2.5	-26.0	-1.7	13.7	0.1
1953	-30.4	-13.1	-11.5	2.1	9.9	15.1	15.8	12.7	6.4	-1.7	-13.8	-17.3	-2.2	-20.0	0.2	14.5	-3.0
1954	-29.7	-25	-9	-6.9	7.7	13.8	15.4	13.9	5.4	-0.2	-7.5	-23.2	-3.8	-24.0	-2.7	14.4	-0.8
1955	-16.8	-21.3	-14.4	-0.4	6.1	12.1	17	11.5	5.9	-1.3	-25.2	-29.6	-4.7	-20.4	-2.9	13.5	-6.9
1956	-28.6	-23.8	-13.6	-0.8	8	13.3	15.2	13.2	5.6	-6.1	-11.4	-31.6	-5.1	-27.3	-2.1	13.9	-4.0
1957	-28.5	-20.2	-8.2	-0.9	7.5	14.2	14.7	15.4	7.9	-2.9	-10.4	-24.5	-3	-26.8	-0.5	14.8	-1.8
1958	-14.5	-24.1	-11.3	3	7.9	14.8	15.7	12.5	5.1	-6.3	-13.7	-21.1	-2.7	-21.0	-0.1	14.3	-5.0
1959	-37.4	-19.4	-14.6	-2.9	6.7	13.6	13.5	9.8	6.3	-6.4	-15.8	-16.4	-5.3	-26.0	-3.6	12.3	-5.3
1960	-22.3	-14.6	-13.6	1.2	9.8	13	14.1	12.7	6.4	-1.3	-15.5	-14.3	-2	-17.8	-0.9	13.3	-3.5
1961	-22	-19.7	-11.3	-2.2	7.1	13.8	15.4	12.7	6.8	-3.3	-20.4	-33.4	-4.7	-18.7	-2.1	14.0	-5.6
1962	-26.1	-18.1	-14	0.6	7.1	12.6	15.4	14.5	5.2	1.3	-12.4	-20.1	-2.8	-25.9	-2.1	14.2	-2.0
1963	-24	-13.9	-14.6	-1.5	8.2	11.3	14.9	13.7	8.1	0.7	-23.4	-13.7	-2.9	-19.3	-2.6	13.3	-4.9
1964	-25.9	-14.8	-19.6	-3.4	2.9	14.1	14.3	12.3	6.1	0.8	-15.5	-35.4	-5.3	-18.1	-6.7	13.6	-2.9
1965	-30.5	-26.8	-8	-0.8	6.4	11.5	15.8	11.7	6.4	-3.8	-20.8	-23.3	-5.2	-30.9	-0.8	13.0	-6.1
1966	-42.7	-17.3	-12.5	-2	6.2	13.9	15.5	10.9	6.8	-4.5	-24.1	-26.3	-6.3	-27.8	-2.8	13.4	-7.3
1967	-28.5	-20.9	-17.1	-2.1	6.3	14	14.3	13.6	7.6	-0.7	-14.8	-20.5	-4.1	-25.2	-4.3	14.0	-2.6
1968	-29	-17.6	-4.6	-1.4	7.7	13.5	15.6	13	5.1	-2.5	-12.7	-31.2	-3.7	-22.4	0.6	14.0	-3.4
1969	-40.6	-19.6	-9.6	3.3	7.7	17.1	13.4	8.7	7.5	0.2	-15	-14.3	-3.4	-30.5	0.5	13.1	-2.4
1970	-27.5	-13.5	-3.2	0.5	7.8	12.3	15.3	11.4	4.3	-5.3	-15.7	-24.7	-3.2	-18.4	1.7	13.0	-5.6

Mayo Mean Temperature (°C) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1971	-40.2	-17.7	-12	-0.8	7.1	14.5	16.3	12.5	6	-4.1	-16.9	-29.1	-5.4	-27.5	-1.9	14.4	-5.0
1972	-35.1	-27.4	-15.1	-4.9	7.4	13.9	16	13.4	3.6	-6.1	-12	-26.8	-6.1	-30.5	-4.2	14.4	-4.8
1973	-32.4	-21.9	-8.8	2.2	7.6	12.8	14.3	11.4	6.7	-2.7	-27.1	-22	-5	-27.0	0.3	12.8	-7.7
1974	-36.6	-22.9	-14.8	0.2	6.4	12.1	14.2	11.9	6.8	-2.8	-11.1	-16.4	-4.4	-27.2	-2.7	12.7	-2.4
1975	-29.2	-21.6	-9.2	0.6	8.9	13.9	16.2	12	6.9	-3.1	-21.6	-28.8	-4.6	-22.4	0.1	14.0	-5.9
1976	-23.4	-25.2	-11.8	2.7	7.8	13.5	16.3	14.2	8.8	-1.5	-5.5	-18.9	-1.9	-25.8	-0.4	14.7	0.6
1977	-17.2	-7.3	-10.2	0.6	8.7	13.4	15.3	15.6	7.1	0.8	-21.1	-33	-2.3	-14.5	-0.3	14.8	-4.4
1978	-21.9	-14.1	-6.9	0.9	8.2	12.9	16	14.2	9.1	-2.1	-17.9	-21.1	-1.9	-23.0	0.7	14.4	-3.6
1979	-28.4	-37	-9.2	-0.2	7.7	12.8	16.3	14.6	8.6	2.1	-7.2	-24	-3.7	-28.8	-0.6	14.6	1.2
1980	-28.9	-12	-8.3	3.7	10.1	14.9	15.5	12.2	4.5	2.7	-9.2	-38.8	-2.8	-21.6	1.8	14.2	-0.7
1981	-7.6	-16.8	-3.7	-2	11.5	12.1	15	12.9	6.4	-1.2	-8.1	-21	-0.2	-21.1	1.9	13.3	-1.0
1982	-41.4	-25	-14.8	-1.5	6.5	14.2	16.7	12.8	7.5	-6.2	-17.6	-19.1	-5.7	-29.1	-3.3	14.6	-5.4
1983	-25.1	-15.6	-11.5	2.6	8.1	14.6	15.8	12.1	4.1	-3.1	-12.1	-35.9	-3.8	-19.9	-0.3	14.2	-3.7
1984	-24	-13.9	-4	3.4	8.3	14.1	14.4	12.6	6.9	-4.4	-16.8	-27.7	-2.6	-24.6	2.6	13.7	-4.8
1985	-9.4	-24.8	-9.5	-1.5	7.2	12.4	15.5	11.1	5.7	-5.4	-26.4	-12	-3.1	-20.6	-1.3	13.0	-8.7
1986	-13.7	-17.9	-10.2	-4.2	7.3	13.8	17	11.6	7.1	-1.2	-20.9	-16.5	-2.3	-14.5	-2.4	14.1	-5.0
1987	-16.7	-13.3	-12.8	1.2	8.5	14.3	16.3	12.8	6.6	1.6	-8.3	-14.9	-0.4	-15.5	-1.0	14.5	-0.0
1988	-25.1	-15.6	-5.4	3	9.9	14.4	15.8	12.9	6.1	-4.2	-15.5	-16.3	-1.7	-18.5	2.5	14.4	-4.5
1989	-29.9	-23	-16.5	3.3	10.2	14.9	17.8	16.1	6.9	-2.8	-20.5	-14.5	-3.2	-23.1	-1.0	16.3	-5.5
1990	-27.2	-29.3	-6.6	2.9	10.7	14.8	16.8	14.2	7	-3.7	-26.6	-27.6	-4.6	-23.7	2.3	15.3	-7.8
1991	-24.7	-14.2	-10.9	3.2	10	15.3	15.6	11.5	7.8	-6.1	-15.7	-19.9	-2.3	-22.2	0.8	14.1	-4.7
1992	-14.9	-17.4	-5.4	-0.7	6	13.5	16.2	12.4	0.4	-6.1	-9.1	-26.3	-2.6	-17.4	-0.0	14.0	-4.9
1993	-25.8	-18	-6.7	4.2	10.2	14.7	16.9	13.1	6.2	0.2	-14.5	-16.3	-1.3	-23.4	2.6	14.9	-2.7

Mayo Mean Temperature (°C) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1994	-26.9	-27.6	-6.3	2.7	8.7	14.1	17.3	16.5	5.9	-0.1	-18.7	-22.5	-3.1	-23.6	1.7	16.0	-4.3
1995	-21	-16.3	-12.5	6	10.6	16.1	16.5	13.2	6	-2.8	-17.6	-18.7	-1.7	-19.9	1.4	15.3	-4.8
1996	-36.5	-18.3	-12.6	1	6.9	12.7	15.9	11.5	6.1	-7.7	-23	-25.7	-5.8	-24.5	-1.6	13.4	-8.2
1997	-27.4	-12.1	-14	1.2	8.3	13.8	17.2	13.9	9.1	-6.2	-9.8	-10.9	-1.4	-21.7	-1.5	15.0	-2.3
1998	-26.2	-11.2	-7.7	3.5	11.1	15.4	17.3	12.5	6.8	-2	-14.8	-22	-1.4	-16.1	2.3	15.1	-3.3
1999	-26.8	-19.5	-6.9	1.8	7.9	16.3	15.2	15	6.9	-1.4	-13.4	-16.5	-1.8	-22.8	0.9	15.5	-2.6
2000	-25.2	-10.9	-4.3	-1.3	6.9	15.1	15.6	11.1	3.2	-3.2	-10.1	-20.9	-2	-17.5	0.4	13.9	-3.7

Mayo Total Summer Precipitation (mm) Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1925						62.2	41.1		7	25.5	12.2	15.3					
1926	7.7	36.4	3.5	47.4	17.7	8.2	66.6	12.9	21.9		4						
1927	11.6	3.8	0.2	11.9	16.8	46	17.2	63.2	39.2	12.9	11	24.1	257.8	15.4	28.9	126.4	63.1
1928	22.1	5.9	12.1	23	26.8	44.7	18	19.2	31.3	16.5	7.6	10.2	237.4	52.1	61.9	81.9	55.4
1929	22.2	18.3	13.2	2.9	22.6	25.4	71	26.9	31	16.4	34.6	35.5	320	50.7	38.7	123.3	82
1930	7.6	19.2	39.3	5	11.1	30.2	37.8	45.4	38.2	19.7	41.9	34.5	329.9	62.3	55.4	113.4	99.8
1931	21.2	30.8	12.9	9.2	15	24.4	38.3	68.4	21.1	8.1	11.8	67	328.4	86.5	37.1	131.1	41
1932	53.6	36.5	18	1.4	20.9	84.5	65.7	73.6	36.1	25.1	29.1	2.1	446.7	157.1	40.3	223.8	90.3
1933	6.5	11.7	3.7	1.2	26	61.1	42.5	7.4	42.3	22.9	24.4	4.7	254.4	20.3	30.9	111	89.6
1934	5.1	2.9	6.9	8.3	19.3	26.9	58.9	65.8	12.2	13.6	17	15.9	253	12.7	34.5	151.6	42.8
1935	6.8	11.2	13.6	10.7	35.4	49.5	25.8	53.6	29.5	67.1	25	32.9	361	33.9	59.7	128.9	121.6
1936	2.3	0.8	8.8	4.4	24.1	40.2	82.4	54	58.3	45.9	27.6	5.5	354.3	36	37.3	176.6	131.8
1937	21.3	2.9	1.7	0.4	33.2	48.1	34.7	79.7	39.1	30.9	8.1	3.4	303.7	29.7	35.3	162.5	78.1
1938	12	0.9	0.3	5.2	39.1	20.5	30.3	33.4	6.6	6.8	25.9	26.6	207.8	16.3	44.6	84.2	39.3
1939	13.7	15	34.9	2.2	46.7	55.5	57.2	106.9	28.4	50.1	37.9	12.9	461.4	55.3	83.8	219.6	116.4
1940	0.3	2.6	5.2	3.5	45	21.2	11.8	58	58.2	11.1	0.3	22.7	240	15.8	53.7	91	69.6
1941	12.5	10.9	0.4	13.4	23.6	55.6	52.8	11.7	21.4	34.7	23	3	263.1	46.1	37.4	120.1	79.1
1942	25.9	6.4	9.5	7.7	19.9	18	65.6	56.8	37.9	13.3	14	12.2	287.3	35.3	37.1	140.4	65.2
1943	31.5	8.4	3.7	9.5	36.2	21.6	60.1	81.8	42.5	38.3	15.4	27.1	376	52.1	49.4	163.5	96.2
1944	21.9	12.7	19.6	7.2	11.3	57.3	21.6	71.8	29	24.4	27.9	8.5	313.1	61.7	38.1	150.7	81.3
1945	11.6	23.4	18.2	12.3	27.9	39.5	58.5	32.7	57.2	26.2	19.6	32.8	360	43.5	58.4	130.7	103
1946	18.6	4.4	12.4	26.6	8.4	9	34.6	67.6	9.1	49.3	50.6	17.3	307.9	55.8	47.4	111.2	109
1947	42.4	17.2	28.7	8.8	8.9	14.8	43.2	46.4	63.6	21.7	26.6	12.9	335.2	76.9	46.4	104.4	111.9

Mayo Total Summer Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1948	17.2	1	1.1	1.4	17.1	38.5	59.7	63.8	28.5	14.7	15.4	7	265.4	31.1	19.6	162	58.6
1949	100.4	2.9	7.1	10	36.5	63.7	45.9	36	32.8	5.1	19.2	12.4	372.1	110.3	53.6	145.6	57.1
1950	6.4	6.7	3.8	5.4	19.5	45.6	38.2	13.9	21.2	21.6	25.8	49.3	257.5	25.5	28.7	97.7	68.6
1951	4	19.2	3.7	5.5	12.8	52.5	22.9	24.2	27.2	19.7	15.3	13.1	220	72.5	22	99.6	62.2
1952	11.8	17.4	7.5	6.2	34.5	22.1	49.1	54.4	43	8.1	13.2	13.3	280.5	42.3	48.2	125.6	64.3
1953	7.2	24.1	7.9	11.6	22.9	20.1	27.8	33.7	22.3	45.4	17.1	36.4	276.5	44.6	42.4	81.6	84.8
1954	7.4	14.6	13.6	15.9	14.9	25.9	67.5	50.9	26	5.5	15.9	29.9	288.2	58.4	44.4	144.3	47.4
1955	39.3	19.6	14.2	1.9	12.7	25.1	21	38.7	23.6	10.3	14.3	13.9	234.7	88.8	28.8	84.8	48.2
1956	11.6	10.3	1.8	3.8	16.4	38.1	70	53.5	14.1	30.6	54.2	18.6	323.1	35.8	22	161.6	98.9
1957	8.7	22.1	5.2	7.4	27.5	17.2	34.3	20.6	34.4	17	28.9	20.8	244.2	49.4	40.1	72.1	80.3
1958	29.6	5.6	3.6	2.1	22.2	28.9	36.1	60.8	1.8	68.9	21.8	31.9	313.4	56	27.9	125.8	92.5
1959	5	25.5	18.6	9.3	15.3	19.9	55.1	31.3	45.1	23.4	45.5	37.2	331.4	62.4	43.2	106.3	114
1960	21.6	17.8	15.2	8.6	21.3	36.4	95.1	45.2	33.1	47.6	44.9	22.1	409	76.6	45.1	176.7	125.6
1961	31	23.1	11.9	1.9	22.4	33.7	49.8	80.9	43.8	33.3	26	53.9	411.6	76.2	36.2	164.4	103.1
1962	35.5	16	12.9	6.1	13.4	74.3	40.5	70.9	31.1	10.4	17.1	35	363	105.4	32.4	185.7	58.6
1963	52.4	6.4	20.4	9.5	21.4	32.9	50.3	60.7	36.3	46.2	33.1	40.7	410.2	93.8	51.3	143.9	115.6
1964	27.6	27.4	12	37.4	43	47.5	113.5	31.5	13	38.5	24	33.9	449.2	95.7	92.4	192.5	75.5
1965	24.3	28.4	7.6	10.3	11.3	87.3	49.4	45.8	33.5	57.4	27.9	40.7	423.9	86.6	29.2	182.5	118.8
1966	3.3	38.6	16.8	13	21.9	14.8	47.1	36.3	18.5	30.3	50.4	16.5	307.4	82.6	51.7	98.2	99.2
1967	35.7	35.5	12.3	4	19.1	57.7	60.2	69.2	38.3	15.4	46.6	15.4	409.2	87.7	35.4	187.1	100.3
1968	31.9	11.7	4.9	13.5	42.7	27.6	25	36.3	46.8	17.3	18.3	9.3	285.2	59	61.1	88.9	82.4
1969	8.7	6.8	8.9	8.6	21	10.8	63.6	17	28.5	17.6	35.3	15.1	241.9	24.8	38.5	91.4	81.4
1970	11.2	17.8	13.4	11.9	36.2	47.3	18.2	56.3	81.6	43.9	32.5	56.6	427	44.1	61.5	121.8	158

Mayo Total Summer Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1971	10	35.7	21.9	19.9	17.6	26.7	53.3	57.8	32.7	40.7	19	28.4	363.7	102.3	59.4	137.8	92.4
1972	19.4	14	20.3	9	12.8	44.7	42	54.8	53.2	47.3	20.6	12.8	351	61.8	42.1	141.5	121.1
1973	35.1	30.9	15.5	12.9	13.3	90.2	73.3	109.5	31	32.9	22.1	33	499.7	78.8	41.7	273	86
1974	7	41.9	8.1	9.9	28.3	66.2	72.8	71.9	13.4	76.1	31.8	41.3	468.7	81.9	46.3	210.9	121.3
1975	21.8	23.2	8.5	23.9	29.4	54.4	110.1	33.5	69.3	28.4	26.5	11.9	440.9	86.3	61.8	198	124.2
1976	20.5	10.7	16.8	1.9	48.9	57.4	80.7	38.8	24.9	22.5	26.2	13.3	362.5	43.1	67.6	176.9	73.6
1977	27.2	11.9	17.2	23.2	29.4	32.6	49	14.3	38.3	13.2	32.7	11.7	300.6	52.4	69.8	95.9	84.2
1978	13.8	4.6	5.7	5.9	18.9	43.1	81.6	15.5	33.4	55	28.1	34.4	340	30.1	30.5	140.2	116.5
1979	19.5	7.3	42.6	4.6	20	19.8	114.2	32.3	41.9	30.5	25.9	31.3	389.9	61.2	67.2	166.3	98.3
1980	17.6	9.6	6	14.5	25.5	47.9	43	52.9	52.6	39.5	28.8	9.9	347.8	58.5	46	143.8	120.9
1981	4.5	18.7	6.2	4.4	12.2	69.3	50.2	20.4	57.5	51.6	27.5	8.5	331	33.1	22.8	139.9	136.6
1982	6.5	28.5	5.7	13.2	32.4	34.7	67.4	27.5	43.3	62.4	30	28.8	380.3	43.5	51.3	129.6	135.7
1983	51.7	27.4	5.7	6.1	38.1	37.2	73.6	80.2	27.1	44.2	20	17	428.1	107.9	49.9	191	91.3
1984	41.8	37.9	14.8	11.1	30.9	57.5	38.1	47.1	22.8	15.7	45.5	34.1	397.1	96.7	56.8	142.7	84
1985	38.1	32.6	16.2	14.4	8.3	51.4	69.4	35.4	38.7	49.7	23.9	31.3	409.5	104.8	38.9	156.2	112.3
1986	46	6	28.7	17.5	41.5	35.4	53.5	66.3	14	23.7	15.9	32	380.4	83.3	87.7	155.2	53.6
1987	31.5	52.6	8.8	22.8	22.1	35.7	37.3	44.2	56.6	47.3	44.6	33.8	437.3	116.1	53.7	117.2	148.5
1988	22.8	7.5	7.4	5.8	41.3	26.4	91.6	27.6	21.5	40.5	21.8	17.4	331.5	64.1	54.5	145.6	83.8
1989	33.3	4.6	3.8	10.7	30	40.8	40.4	25	31	25.3	34.3	42.4	321.6	55.3	44.5	106.2	90.6
1990	28.1	38.6	14.6	3.6	26.7	40.2	35.5	60.9	87	46.3	42	41.8	465.4	109.1	44.9	136.6	175.3
1991	28.7	27.5	28.3	12.6	6.5	27.7	48.2	53.4	32.7	33.5	49.7	45.2	393.8	98	47.4	129.3	115.9
1992	50.2	19.9	9.6	27.4	27.6	54.5	43.8	48.5	49.8	23.5	18.1	24.7	397.6	115.3	64.6	146.8	91.4
1993	36.4	31.2	15.7	5.7	20.6	38.4	37.2	48.4	20.4	21.8	26.4	28.2	330.3	92.3	42	124	68.6

Mayo Total Summer Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1994	7.2	8.3	43.4	13.7	30	48.5	28.6	21.9	39.6	25.3	34.7	12.9	314.1	43.7	87.1	99	99.6
1995			19.9										343				
1996	16.9	19.5	19.3	10.7	12.1	47.7	67.2	46.8	48.7	24.4	22.9	38	374.2	36.4	42.1	161.7	96
1997	29	13.4	14.5	29.5	44.5	55.2	66.4	47.1	44.4	48.2	27.8	35.1	455.2	80.4	88.5	168.7	120.4
1998	14.7	10.6	1.6	4.3	18.8	34	15.1	20.3	29.9	10.4	11	27.6	198.2	60.4	24.7	69.4	51.3
1999	16.6	12.9	11.6	19	39.8	30.9	55.2	45.7	35.6	45.5	21.9	25	343.1	57.1	70.4	131.8	103
2000	13.2	5.8	2.5	7.4	46.2	34.8	60.6	70.4	60.4	20.9	32.8	19.2	374.2	44	56.1	165.8	114.1

Mayo Relative Humidity (%) Record

1960	58.8
1961	53.3
1962	62.5
1963	59.3
1964	61.7
1965	55.2
1966	47.4
1967	51.6
1968	50.3
1969	45.2
1970	47.3
1971	48.4
1972	52.8
1973	60.1
1974	58.0
1975	58.0
1976	51.8
1977	48.7
1978	49.2
1979	53.2
1980	53.8
1981	49.5
1982	50.8
1983	55.1
1984	52.5
1985	57.5
1986	52.3
1987	51.0
1988	52.2
1989	43.8
1990	50.9
1991	52.2
1992	52.4
1993	46.0
1994	46.1
1995	51.2
1996	52.7
1997	55.8
1998	44.6

Mayo Wind Speed Record (m/s)

1960	7.7
1961	8.4
1962	8.9
1963	8.3
1964	7.0
1965	8.2
1966	7.3
1967	8.8
1968	7.8
1969	8.4
1970	6.7
1971	6.8
1972	7.6
1973	8.5
1974	6.5
1975	6.3
1976	4.8
1977	5.6
1978	7.0
1979	5.4
1980	6.0
1981	6.7
1982	5.5
1983	5.5
1984	8.5
1985	6.6
1986	4.4
1987	3.9
1988	4.5
1989	4.5
1990	5.3
1991	5.0
1992	3.8
1993	4.1
1994	5.1
1995	5.6
1996	5.3
1997	4.4
1998	5.4

Watson Lake Mean Temperature (° C) Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1938										1.3	-14.9	-21.3					
1939	-20.6	-21.5	-13	-0.9	6.3	12	13.8	12.1	6.2	-4.2	-14.8	-18.7	-3.6	-21.1	-2.5	12.6	-4.3
1940	-26.5	-18	-11.5	1.5	5.2	9.9	15.6	12.2	8.4	-0.8	-18.2	-22.5	-3.7	-21.1	-1.6	12.6	-3.5
1941	-27.1	-15.6	-7.6	3.8	6.4	12.7	15.2	13.6	5.4	-0.6	-15.8	-26.3	-3	-21.7	0.9	13.8	-3.7
1942	-15.6	-15.6	-9.8	1	8.7	13.7	15	14.5	8.6	1.5	-19.7	-26.1	-2	-19.2	0	14.4	-3.2
1943	-28.8	-15.9	-14.2	2	5.9	12.6	14.5	12.5	8.1	-0.2	-10.5	-12.6	-2.2	-23.6	-2.1	13.2	-0.9
1944	-20.3	-14	-7.9	1.4	7.9	13.9	16	13.2	7.8	1.6	-14.1	-18	-1	-15.6	0.5	14.4	-1.6
1945	-21	-14.5	-6.9	-4.3	7.8	11.9	13.9	14	6.7	0.3	-21.8	-25.2	-3.3	-17.8	-1.1	13.3	-4.9
1946	-23.9	-19.5	-8.9	-0.4	9.2	15.4	14.4	12.5	7.8	-0.7	-17.4	-28.2	-3.3	-22.9	0	14.1	-3.4
1947	-27.3	-22	-7.5	-0.9	7.3	12.2	15.1	11.6	7.1	0.5	-10.2	-19.5	-2.8	-25.8	-0.4	13	-0.9
1948	-23	-23.8	-16.9	-6.5	8.6	14.4	16.3	12.7	6.6	1.4	-12.6	-27.8	-4.2	-22.1	-4.9	14.5	-1.5
1949	-23.8	-26	-8.3	2.4	6.1	10.8	15	13.4	8.8	-1.5	-9.2	-28.6	-3.4	-25.9	0.1	13.1	-0.6
1950	-34.6	-22.9	-10.6	-1.8	6.6	16	15	12.4	9.2	-2.6	-22.6	-21.7	-4.8	-28.7	-1.9	14.5	-5.3
1951	-27.8	-21.7	-16	0.2	7.4	11.4	16.8	13.9	8.9	-5.9	-15.8	-27.6	-4.7	-23.7	-2.8	14	-4.3
1952	-30.7	-20	-10.9	-0.1	6.7	11.5	15.3	13	7.7	2.8	-4.4	-22.9	-2.7	-26.1	-1.4	13.3	2
1953	-30.9	-13.7	-11.6	0.8	9.2	15	15.2	13.8	7.5	0.3	-15.2	-19.1	-2.4	-22.5	-0.5	14.7	-2.5
1954	-31.8	-17.2	-9	-7.4	7.8	14.1	14.1	14.9	7.8	0.9	-9.4	-20.8	-3	-22.7	-2.9	14.4	-0.2
1955	-21.1	-18.4	-13.6	-0.9	5.6	12.3	15.7	11.8	7.5	-0.5	-23.4	-31.2	-4.7	-20.1	-3	13.3	-5.5
1956	-28.7	-20.8	-11.9	-0.6	7.6	11.9	15.4	13.8	6.8	-4	-6.6	-25.1	-3.5	-26.9	-1.6	13.7	-1.3
1957	-27.4	-19.2	-10.2	0.4	7.4	13.6	14.8	15.6	11.3	-0.2	-8.6	-24.6	-2.3	-23.9	-0.8	14.7	0.8
1958	-21.2	-22.1	-9.8	2.2	9	15.6	17.3	12.5	6.6	-0.3	-12.8	-22.2	-2.1	-22.6	0.5	15.1	-2.2
1959	-31.1	-19.6	-7.4	-0.4	6	13.4	15	10.5	7.1	-3.1	-13.4	-16	-3.3	-24.3	-0.6	13	-3.1
1960	-21.7	-15	-12.8	2.3	7.9	12.1	14.4	13.2	7.6	0.6	-13.7	-16.1	-1.8	-17.6	-0.9	13.2	-1.8

Watson Lake Mean Temperature (° C) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1961	-22.2	-18.4	-9.7	0	6.3	13.2	16.7	13.8	7.2	-1.6	-16.2	-26.3	-3.1	-18.9	-1.1	14.6	-3.5
1962	-22.5	-20.1	-13.3	0.1	5.4	11.6	15.3	13.7	7.1	2	-11.1	-19.8	-2.6	-23	-2.6	13.5	-0.7
1963	-20	-14.9	-11.5	-1.2	7.2	11	14.7	16.1	9.2	2.4	-20	-18.7	-2.1	-18.2	-1.8	13.9	-2.8
1964	-24.5	-7.7	-15	-0.7	5.6	13.9	14.4	12.5	6.3	0.7	-14.5	-26.6	-3	-17	-3.4	13.6	-2.5
1965	-24.1	-23.5	-11.2	-1.2	5.3	10.5	15.9	13.8	7.8	1.1	-16.1	-21.7	-3.6	-24.7	-2.4	13.4	-2.4
1966	-37.4	-18.7	-9.6	-1.4	6	12.8	15.7	11.4	7.9	-1.8	-20.3	-21.8	-4.8	-25.9	-1.7	13.3	-4.7
1967	-27.2	-19.2	-16.4	-1.4	6.4	14.2	13.1	13.4	8.5	-0.1	-13.4	-23.2	-3.8	-22.7	-3.8	13.6	-1.7
1968	-28.2	-18.4	-7.2	-2.5	6.9	11.9	14.6	12.3	7	-2.1	-15.5	-31.7	-4.4	-23.3	-0.9	12.9	-3.5
1969	-38	-23.1	-11.2	-0.5	7.3	14.8	13	10.2	5.9	-1.1	-13	-19.1	-4.6	-30.9	-1.5	12.7	-2.7
1970	-25.3	-14.3	-7.4	-0.4	7.1	12.5	13.3	11.7	6.5	-1.1	-16.5	-23.9	-3.2	-19.6	-0.2	12.5	-3.7
1971	-32.2	-15.7	-12.7	-1.1	6	13.3	16.7	14.2	6.7	-2.5	-16.3	-29.3	-4.4	-23.9	-2.6	14.7	-4
1972	-31.9	-25.7	-12.5	-5.5	6.7	12.5	14.3	13.5	4.9	-1.8	-11.9	-24.9	-5.2	-29	-3.8	13.4	-2.9
1973	-25	-20.5	-8.4	0.6	7.3	11.6	14.2	11.4	7.4	-0.8	-23.3	-22.7	-4	-23.5	-0.2	12.4	-5.6
1974	-31.1	-19.2	-16.2	-1.4	5	10.9	12.9	12.8	7.3	1.6	-9.2	-16	-3.6	-24.3	-4.2	12.2	-0.1
1975	-22.6	-21.1	-12.3	0.2	7.4	11.8	15.3	12.1	9.1	0	-20.1	-27	-3.9	-19.9	-1.6	13.1	-3.7
1976	-20.6	-21.9	-11.5	0.8	6.8	11.1	13.2	13.2	8.4	1.3	-9.1	-21	-2.4	-23.2	-1.3	12.5	0.2
1977	-16.8	-9.3	-9.2	2.3	7.8	12.5	14.1	15.5	7.3	0.7	-17.1	-30.9	-1.9	-15.7	0.3	14	-3
1978	-22.9	-17.2	-11.2	0.6	7.1	13.2	14.9	12.9	7.9	3.5	-14.1	-23.1	-2.4	-23.7	-1.2	13.7	-0.9
1979	-29.8	-28.5	-7.9	-1.2	5.8	11.5	16.2	15	8.9	2.6	-8.6	-21.4	-3.1	-27.1	-1.1	14.2	1
1980	-27.3	-15.8	-11.8	1.7	8.2	14.7	14.6	11.3	5.8	2.2	-8	-31.3	-3	-21.5	-0.6	13.5	0
1981	-14.8	-15.5	-5.6	-3.9	9.1	10.7	15.6	13.7	7.1	-0.3	-10.4	-25.5	-1.7	-20.5	-0.1	13.3	-1.2
1982	-35.9	-20.4	-11.6	-2.5	6.2	13.9	17.2	11.9	8.1	-0.1	-18.5	-20.6	-4.4	-27.3	-2.6	14.3	-3.5

Watson Lake Mean Temperature (° C) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1983	-23	-19.3	-13.2	1.7	7.9	14	14.9	12	5.5	-0.5	-14.2	-30.7	-3.7	-21	-1.2	13.6	-3.1
1984	-17.5	-12.2	-5.2	2.5	7.5	12	14.2	13	5.6	-2.9	-19	-27.7	-2.5	-20.1	1.6	13.1	-5.4
1985	-13.6	-21.4	-8.5	-1	6.6	11.3	15.4	11.9	7.2	-2.5	-23.3	-14.8	-2.7	-20.9	-1	12.9	-6.2
1986	-17	-19.1	-8.4	-3.8	5.8	12.3	15.6	11.8	7.4	2.6	-18.2	-16	-2.3	-17	-2.1	13.2	-2.7
1987	-18.6	-14.3	-14.4	1	6.9	11.5	15.2	12.1	7.9	3.3	-10.9	-15.6	-1.3	-16.3	-2.2	12.9	0.1
1988	-23.2	-16.4	-6	1.2	8.3	12.7	13.5	13.1	7.4	-0.9	-14.5	-19	-2	-18.4	1.2	13.1	-2.7
1989	-24.2	-21.5	-14.1	1.4	8.9	14.1	17.1	16.2	8.8	-1.6	-16.3	-16	-2.3	-21.6	-1.3	15.8	-3
1990	-23.9	-21.4	-5.8	1.3	8.3	12.7	16.4	14.4	9.5	-2.4	-21.6	-24.9	-3.1	-20.4	1.3	14.5	-4.8
1991	-25	-13.2	-8.5	2.3	9.2	14	14.2	12.3	8.1	-4.1	-16.3	-17.9	-2.1	-21	1	13.5	-4.1
1992	-17.8	-16.8	-6.4	-1.7	5.4	13.7	15.2	12.4	4.1	-3.3	-12.8	-29.7	-3.1	-17.5	-0.9	13.8	-4
1993	-24.3	-18.1	-9.5	2.7	10.3	13.5	14.3	13.4	8	1.8	-11.7	-15.6	-1.3	-24	1.2	13.7	-0.6
1994	-23.3	-27	-5.5	2.6	7.8	13.5	16.4	17	7	0.9	-18.6	-23.1	-2.7	-22	1.6	15.6	-3.6
1995	-22.3	-17.4	-13.1	2.4	10.2	14.7	15.9	12.1	10.9	0.3	-17.7	-24.1	-2.3	-20.9	-0.2	14.2	-2.2
1996	-33.8	-14.7	-10.2	-0.3	6.2	12.5	14.9	12	6.2	-3.4	-19.4	-25.9	-4.7	-24.1	-1.4	13.1	-5.5
1997	-27.4	-13.6	-12.4	0.4	7.9	13.3	15.3	14.5	9	-3.3	-13.2	-13.7	-1.9	-22.3	-1.4	14.4	-2.5
1998	-27.5	-15.6	-9.2	1.4	11.7	15.4	16.3	12.9	7.3	-0.1	-13.9			-18.9	1.3	14.9	-2.2
1999				1.1	6	13.6	15	14.5	8.3	1.3	-13.3	-14.7				14.4	-1.2

Watson Lake Total Precipitation (mm) Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1939	41.9	17	14.2	7	53.5	71.9	40.7	42.7	100.8	20.7	5.9	14.4	430.8		74.8	155.3	127.4
1940	8.5	5.8	15.5	18.7	35.1	62.9	58.2	62.5	11.3	19.2	42.6	28.3	368.6	28.7	69.3	183.6	73.1
1941	20.6	9.4	29.1	1.9	52.3	63.8	45.5	45.4	28.9	35.4	34.9	29.3	396.6	58.3	83.3	154.8	99.3
1942	10.6	6.8		30.2	8.3	96.9	65.7	38.5	49.9	33.6	36	44.1		46.6		201.2	119.5
1943	6.5	17.9	20.8	12.4	35.5	46.3	55.1	65	33.5	11.7	29.9	59.8	394.7	68.6	68.8	166.4	75.2
1944	14.2	15.4	8.5	27.5	39.6	57.8	26.8	35.7	46.5	74.6	56.5	9.3	412.4	89.5	75.6	120.4	177.5
1945	40.4	28.7	11.2	16.3	29.2	79.9	73.9	6.6	49.7	16.9	49	33.2	434.9	78.4	56.6	160.4	115.6
1946	51.4	29.7	6.4	16.3	12.4	45.7	73.4	56.7	36.8	35.4	24.4	69.3	457.9	114.3	35.1	175.8	96.6
1947	42.6	29.6	8.2	41.4	28.4	40.9	47.4	62.9	43.8	16	32.2	39.8	433.3	141.4	78.1	151.3	92
1948	53	38.1	49.8	15	14.3	40.4	40.7	78.5	69.8	12.5	41.3	32.1	485.4	130.9	79	159.6	123.6
1949	42.1	37.5	5.7	38.8	40.7	46.3	59.8	105.2	59.4	51.4	46.5	35.6	569	111.6	85.2	211.4	157.3
1950	17	48.3	6.7	18.3	5.4	18.1	47.7	43.5	27.7	32	40.6	62.3	367.6	100.9	30.4	109.3	100.3
1951	28.7	30.9	39	10.2	23.2	46.2	19.2	18.4	7.9	38.4	44.8	21.3	328.2	121.9	72.3	83.8	91.2
1952	110.1	24.4	38	19.6	10.5	92.9	63.9	74.2	58.2	50.1	21.5	23.4	586.7	155.9	68.1	231	129.8
1953	18.9	13.6	22.4	8.1	38	25.6	141.7	52.2	33.3	50.1	35.1	55.4	494.2	55.8	68.5	219.5	118.4
1954	21	25.9	21.5	10.8	34.1	40.8	61.2	19.5	58.7	37.2	43.5	61.9	436.2	102.4	66.4	121.5	139.4
1955	40	28.5	30.2	9.1	5.1	26.2	125.2	30	23.5	8.6	24.4	20.3	371	130.4	44.4	181.4	56.5
1956	15.9	42.3	43.1	14.4	15.5	111.1	49.1	36.8	16.6	54.2	69.9	64.4	533.3	78.5	72.9	197	140.8
1957	18	26.1	8.5	10.4	34.9	27.5	41.3	13.8	26.5	21	53.5	44.8	326.3	108.4	53.8	82.6	101
1958	35.8	27.9	3.1	17.3	25.1	28.3	45.8	45	66.6	53.7	32.6	42.8	424	108.5	45.5	119	152.9
1959	41.8	18.4	31.1	39.9	44.2	40.8	30.2	77.5	51.7	47.3	34.2	47.6	504.7	103	115.2	148.5	133.3
1960	26.7	29.4	53	4.4	45.8	81.6	54.2	41.9	49.8	57.4	29.1	35.3	508.5	103.6	103.2	177.7	136.3
1961	38.5	44.7	32.1	36.8	24.9	83	30.6	29.1	49.2	75.4	23.7	69.1	537.3	118.4	93.9	142.7	148.4

Watson Lake Total Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1962	61.6	12.5	36.9	30.7	45.5	107.2	58.6	95.3	69.6	28.3	28	73	647.1	143.2	113.1	261	125.9
1963	40.6	47.6	43	40.8	22	65.2	58.6	8.4	88.1	25.9	58.2	39.4	537.9	161.2	105.9	132.3	172.2
1964	31.9	19.8	46.7	21.9	67.8	42.2	71.8	91.9	45.5	39.1	28.4	47.4	554.3	91.1	136.3	205.9	113.1
1965	58	84.4	7.6	15.6	18.6	38	20	38	43.8	42.9	25.2	33.1	425.3	189.8	41.8	96	111.9
1966	41.5	34.5	27.6	19	26.3	48.9	83	63.5	59.9	40.9	58.9	71.2	575.1	109.1	72.9	195.4	159.7
1967	38.2	46.4	40.6	13.5	35.9	17.4	63.5	19.9	58.2	30.2	63.4	24.7	452	155.8	90	100.8	151.8
1968	39.1	25.5	17.7	22.2	8.2	88.9	92	42.7	70.2	39.7	44.4	29.1	519.7	89.4	48	223.6	154.3
1969	18.4	23.5	34.3	12.5	12.7	49.9	90	97.8	37	22.5	54	21	473.5	71	59.4	237.6	113.6
1970	40.7	20.7	13.4	15.9	17.7	42	46.5	73.1	102.8	47.3	24.8	47.4	492.1	82.4	47	161.5	174.9
1971	29.6	19.9	19.1	24.1	56	51.2	8.4	40.9	38.3	42.5	52.1	24.4	406.8	96.9	99.3	100.5	133
1972	35.1	39.8	35.8	46.3	28.8	48.6	54.1	62.8	42.5	50.3	24.6	37.7	506.3	99.4	110.9	165.4	117.4
1973	32	17.9	10	8.6	33	78.5	32.4	42.2	35.2	21.7	24.2	47.6	383.4	87.6	51.6	153.1	81.1
1974	42.6	15.8	30.6	14.1	85.2	51.8	133.7	53.2	35.8	75.4	20.1	30.9	589.2	106.1	129.9	238.7	131.3
1975	29.1	16.3	22.9	8.6	8.3	60.9	78	62	35.9	28.8	59.5	55.2	465.4	76.2	39.8	200.8	124.2
1976	57	47.7	15.6	21.3	46.2	82.8	104.3	62.5	42.5	20.2	13.7	52.2	565.9	159.8	83.1	249.6	76.4
1977	40.8	18.6	6.9	12.3	93	58	94.2	22.6	51.3	27	29.6	21	475.1	111.5	112.1	174.8	107.8
1978	35.1	20.5	20.2	4.8	26.1	41.1	55.5	51.9	45.5	42.2	50.8	35.6	429.3	76.6	51.1	148.5	138.5
1979	31.1	66.4	40.4	9.4	47.5	97.3	57.1	10.6	46.9			75.4		133	97.3	164.9	
1980	36.4	21	33.9	6.7	36.8	51.7	70.4	44.6	81.1	38.2	30.5	52.6	504	132.8	77.4	166.7	149.9
1981	17.3	49.6	7.9	33	34.3	57.3	24.9	42.5	43.5	54.6	34.9	23.3	423.1	119.5	75.2	124.7	133
1982	41.7	14	16.2	20.1	36.1	10.5	33.2	89.9	18.8	32	25.3	27.1	364.9	79	72.4	133.6	76
1983	39.9	19.9	14	5.1	35.5	51.6	59.9	37.3	62.2	30.4	21.2	6.8	383.8	86.9	54.6	148.7	113.8
1984	60.8	25.8	11.5	15.5	44.6	73.3	49.2	55.1	33.3	45.5	20.8	37.5	472.9	93.4	71.6	177.6	99.6

Watson Lake Total Precipitation (mm) Record Cont'd

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Win	Spr	Sum	Fall
1985	42.2	71.9	10.3	18.4	34.3	29.6	31.9	47.2	54.9	43.2	15.4	19.4	418.6	151.5	63	108.7	113.5
1986	41.1	9.9	40.6	8.4	53	35	143.8	44.6	42.8	56	40	21.2	536.4	70.4	102	223.4	138.8
1987	28.1	33.7	27.5	6.1	119	110.6	69.9	57.1	38.1	29.4	25.8	46.3	591.5	83	152.6	237.6	93.3
1988	29.1	29.6	32.3	25.6	56.1	99.2	141.6	33.5	48.3	34.5	45.4	25.2	600.4	105	113.9	274.3	128.2
1989	51.3	2.9	25.7	10.2	52.8	29.3	64.8	35.5	43.9	49.7	36.9	32.5	435.5	79.4	88.7	129.6	130.5
1990	40.4	33.8	2.3	6.9	59	77.6	50.9	21.7	41.8	41.2	41.8	49.9	467.2	106.7	68.2	150.1	124.8
1991	14.4	21.3	8.6	9.9	33.8	48.2	74	67.7	65.6	86.7	65.7	69.2	565.2	85.7	52.3	190	218
1992	30.2	28.7	8.6	27.5	14.8	18.6	37.5	50.6	60.5	29.2	28.3	29.1	363.7	128.1	51	106.8	118
1993	26.7	22.4	7.4	7.7	22.5	53.6	65.9	63.4						78.1	37.6		
1994																	
1995								48.6	23.2	35.3	46.1	23.4				104.6	
1996	20.9	47.5	21.8	7.3	13.7	23.8	37.8	60.5	44.8	37.8	17.4	23.9	357.1	91.8	42.8	122.1	99.9
1997	18.5	28.7	38.3	20	27.5	91	76.9	71	30.8	41.1	22.4	29	495.1	71	85.8	238.9	94.3
1998	20.4	17.1	12.4	35.1	36	63.4	48.8	22.6	34.9	53.1	16.2			66.4	83.6	134.9	104.3
1999				14.7	64.9	69.8	25.3	49.3	42.4	22.2	42.1	35.5				144.5	106.7

Watson Lake Relative Humidity (%) Record

1963	47.0
1964	56.4
1965	45.0
1966	47.4
1967	44.7
1968	54.4
1969	48.5
1970	46.1
1971	43.5
1972	49.5
1973	50.5
1974	52.4
1975	54.1
1976	54.7
1977	49.8
1978	47.7
1979	49.5
1980	55.5
1981	46.8
1982	46.0
1983	51.2
1984	51.0
1985	47.8
1986	50.8
1987	57.0
1988	56.5
1989	47.6
1990	48.8
1991	52.9
1992	44.8
1993	53.6
1994	51.9
1995	56.8
1996	50.1
1997	55.6
1998	48.3

Watson Lake Wind Speed (m/s) Record

1963	9.3
1964	9.4
1965	9.3
1966	7.5
1967	9.4
1968	6.7
1969	8.5
1970	9.3
1971	6.6
1972	7.6
1973	8.3
1974	10.8
1975	11.5
1976	9.6
1977	11.4
1978	10.2
1979	12.4
1980	7.2
1981	8.3
1982	11.0
1983	13.3
1984	13.4
1985	13.5
1986	9.3
1987	6.7
1988	7.4
1989	5.8
1990	8.3
1991	7.5
1992	7.2
1993	7.0
1994	6.6
1995	6.5
1996	7.4
1997	6.6
1998	7.8

Appendix II
Forest Fire Data

Old Crow Forest Fire Record	Number of forest fires	Area Burned (ha)		FWI	SSR
Year					
1962	4	1549.42	1977	11	2.9
1963	2	16169.32	1978	5.5	1.9
1964	1	20	1979		
1965	1	1183.45	1980		
1966	2	240.01	1981		
1967	0	0	1982		
1968	0	0	1983		
1969	3	12	1984	4	1.0
1970	0	0	1985	11.5	2.4
1971	9	102012.98	1986	6	1.6
1972	8	503.36	1987	4	1.3
1973	9	693.56	1988	4	0.8
1974	1	3.2	1989	8	1.7
1975	8	15640.23	1990	11	2.7
1976	5	76.12	1991	4	1.1
1977	9	214300.63	1992	5	1.6
1978	1	160	1993	5.5	1.5
1979	4	6418.53	1994	9.5	2.9
1980	5	2667.69	1995	3	0.6
1981	0	0	1996	3	1.1
1982	11	4240.71	1997	3	0.7
1983	5	863	1998	4	1.0
1984	12	7975.91			
1985	5	4265.35			
1986	14	15248.29			
1987	31	85985.82			
1988	16	3518.07			
1989	6	18650.24			
1990	12	95513.37			
1991	2	4886			
1993	14	66796.97			
1994	7	3504.62			

Old Crow Forest Fire Record	Number of forest fires	Area Burned (ha)
Year		
1995	3	9.5
1996	9	7186.36
1997	0	0
1998	4	99.87
1999	4	5399.3
2000	9	1604.69

Mayo Forest Fire Record	Number of Forest Fire	Area Burned (ha)	FWI	SSR
Year				
1960	3	0.42	3	1.21
1961	0	0	7	1.75
1962	4	3351.2	2	0.67
1963	5	60	5	0.93
1964	0	0	3	0.5
1965	3	449.5	4	0.98
1966	9	203.35	15	4.32
1967	14	35689.11	3.5	1.78
1968	11	10413.8	13	3.43
1969	10	63767.92	12	5.67
1970	1	2	7.5	2.25
1971	16	54675.4	8	3.04
1972	25	45512.46	9	2.35
1973	6	75.52	2	1.38
1974	13	2436.11	1	0.54
1975	20	2803	2	0.55
1976	11	50061.83	6.5	1.24
1977	32	62094.29	10	2.29
1978	13	6508.14	10.5	2.52
1979	7	360.53	7	1.78
1980	13	8703.04	3.5	1.25
1981	3	98.5	6	1.49
1982	35	18023.2	8	1.97
1983	50	14800.67	2	1.22
1984	11	1288.52	5.5	1.64
1985	6	243.02	3	1.23
1986	36	40520.37	4	1.34
1987	6	1124.3	8	1.93
1988	12	232.32	4	1.11

Mayo Forest Fire Record	Number of Forest Fire	Area Burned (ha)	FWI	SSR
Year				
1989	31	92963	14	3.02
1990	14	42616.35	6.5	2.33
1991	25	5244.35	5	1.74
1992	8	160.22	7	1.33
1993	29	26790.5	13	2.83
1994	41	110179.71	15	4.01
1995	12	33983.7	12.5	3.17
1996	9	30846.9	8	2.46
1997	5	2755.4	2	0.66
1998	27	145361.53	17.5	5.14
1999	18	16177.65		
2000	3	5520		

Watson Lake Fire Record	Number of forest fires	Area Burned (ha)	FWI	SSR
Year				
1961	7	7583.02	13.5	3.7
1962	2	0.01	3.5	1.1
1963	1	0	15	3.85
1964	0	0	5	0.92
1965	9	40	18.5	5.65
1966	11	4.01	3.5	1.91
1967	4	14.2	16	3.91
1968	8	0	3	0.95
1969	22	27590.15	6.5	2.71
1970	0	0	10	2.75
1971	16	16054.53	13	4.01
1972	4	0	5	1.9
1973	1	0	6	1.29
1974	7	0.03	3	0.87
1975	16	724.21	5	2.24
1976	3	0.07	4	0.79
1977	2	0	10	2.29
1978	4	0	11.5	3.67
1979	0	0	11	3.27
1980	4	2140.12	4	0.9
1981	4	12217.94	12	3.67
1982	15		15	5.9
1983	31	20833.24	7	3.36
1984	16	2978.29	8	2.13
1985	4	0	14	4.62
1986	5	84	10	2.43
1987	0	0	1	0.48
1988	1	170	3	0.82
1989	20	23293.25	9.5	1.97
1990	3	418.8	11	2.36
1991	28	20005.86	6	1.88

	Number of Area Burned forest (ha) fires		FWI	SSR
Year				
1992	8	5752.94	13.5	3.26
1993	1	0	6.5	1.27
1994	18	20755.85	7.5	1.54
1995	4	4678.29	6	2.08
1996	3	50	7	2.25
1997	5	8	3	0.73
1998	16	4322.58	11.5	2.32
1999	19	2204.33		
2000	0	0		

Appendix III
Climate Model Changes

Model Summer Change Values

Model	Scenario	Temperature (° C)	Precipitation (%)	Relative Humidity (%)	Wind Speed (%)
Hadcm2	GA1	1.258	15.825	0.873	-2.22
	GA2	1.574	7.407	-0.379	-0.506
	GA3	1.562	5.411	-0.231	-1.632
	GA4	1.56	6.408	-0.373	-1.508
	GAX	1.489	10.06	-0.383	-1.446
	GG1	1.625	14.484	0.191	0.176
	GG2	1.577	16.61	-0.287	2.242
	GG3	1.481	18.411	0.378	0.211
	GG4	1.84	11.446	0.234	1.384
	GGX	1.63	15.194	0.129	0.989
CGCM1	GA1	3.224	9.332	0.254	-0.938
	GA2	3.335	5.647	0.105	-5.679
	GA3	3.088	-1.029	0.163	-5.834
	GAX	3.216	4.422	0.155	-4.899
	GG1	4.085	14.706	0.285	-1.693
CGCM2	GA1	3.396	6.086	-0.084	-0.648
	GA2	2.941	3.606	0.131	-1.568
	GA3	3.192	7.287	0.202	-3.049
	GAX	3.176	5.534	0.086	-1.789
ECHAM4	GG1	2.613	17.997	1.23	0.341
CSR98	GA1	2.798	15.347	1.163	3.35
	GG1	3.77	11.013	0.492	1.443