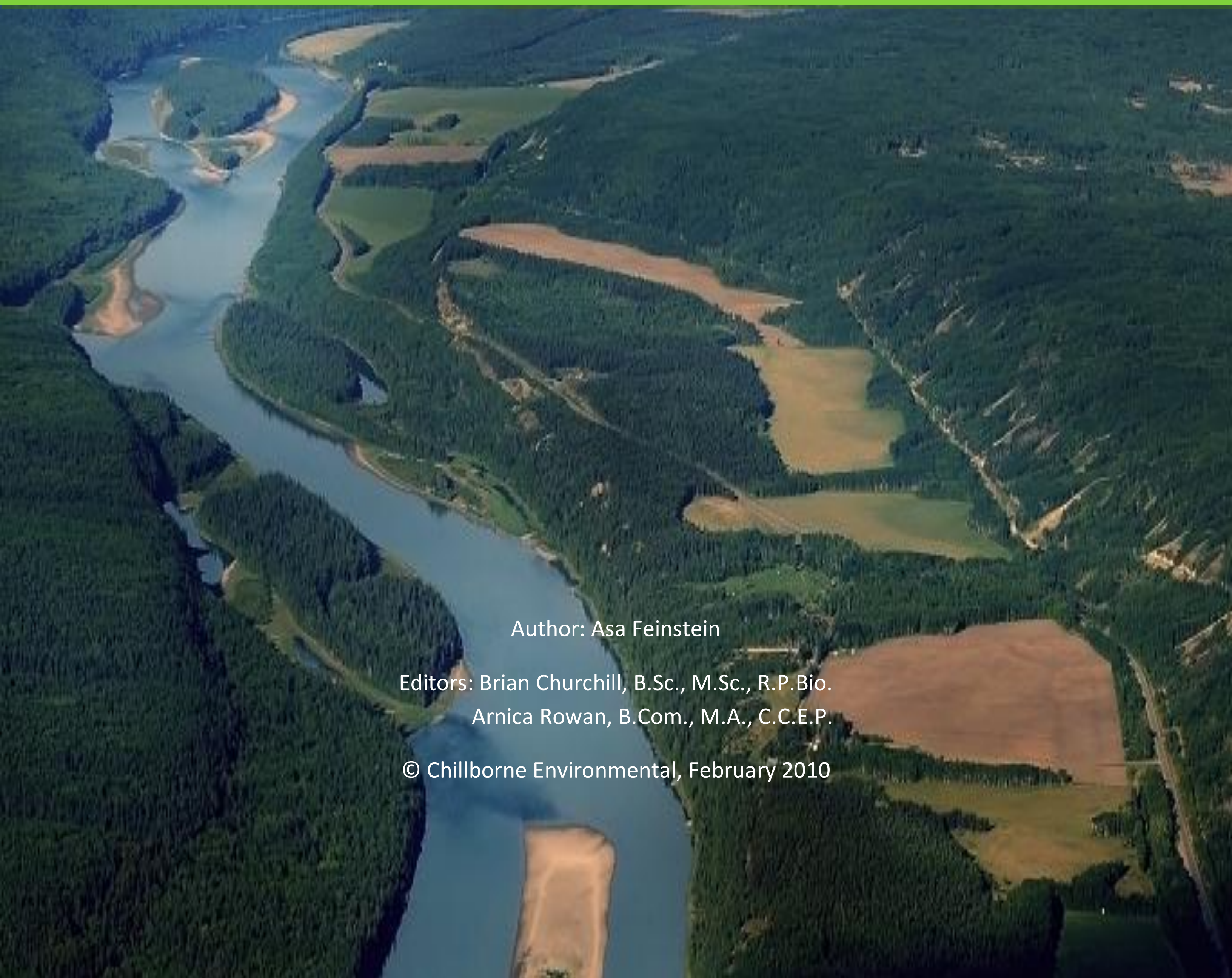
BC'S PEACE RIVER VALLEY AND CLIMATE CHANGE

THE ROLE OF THE VALLEY'S FORESTS AND AGRICULTURAL LAND IN CLIMATE CHANGE MITIGATION AND ADAPTATION



Author: Asa Feinstein

Editors: Brian Churchill, B.Sc., M.Sc., R.P.Bio.
Arnica Rowan, B.Com., M.A., C.C.E.P.

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Author Asa Feinstein, and Editors Arnica Rowan and Brian Churchill

ABSTRACT

This report discusses the importance of the Peace River Valley of Northeastern British Columbia in the context of climate change. It is argued that land-use decisions should be made with careful consideration to the value of specific landscapes in the context of climate change. The Peace River Valley plays an important role in climate change mitigation and adaptation for three major reasons: 1) the vast amounts of carbon stored in the Peace River Valley's plants and soils contribute to the mitigation of global climate change; 2) the unique biodiversity and habitat corridors of the Peace River Valley play a major role in facilitating the ability of the region's ecosystems to adapt to climate change; 3) the unique agricultural resources of the Peace River Valley have a great potential to help BC in adapting to climate change. All three of these attributes of the Peace River Valley are threatened by the potential construction of a BC Hydro hydroelectric facility known as Site C.

Keywords: Peace River, Peace River Valley, climate change, adaption, mitigation, carbon storage, intact ecosystem, habitat connectivity, agriculture, food security, local food, Site C, reservoir

EXECUTIVE SUMMARY

It is widely acknowledged that climate change is one of the greatest challenges facing our planet and our species. In order to effectively address this issue, it is becoming increasingly apparent that measures must be taken to both mitigate global climate change and enhance the ability of natural systems and human societies to adapt to climate change. It is well known that land-use decisions have a great potential in influencing these goals of climate change mitigation and adaptation. Therefore, an important way to advance these goals is by ensuring that land-use decisions are made with careful consideration to the value of specific landscapes in the context of climate change.

This report, which has been made possible by a grant from the Vancouver Foundation, discusses the importance of the Peace River Valley of Northeastern British Columbia in the context of climate change. It is argued that the Peace River Valley plays an important role in climate change mitigation and adaptation for three major reasons:

1) the vast amounts of carbon stored in the Peace River Valley's plants and soils contribute to the mitigation of global climate change;

2) the unique biodiversity and habitat corridors of the Peace River Valley play a major role in facilitating the ability of the region's ecosystems to adapt to climate change; and

3) the unique agricultural resources of the Peace River Valley have a great potential to help BC in adapting to climate change.

All three of these attributes of the Peace River Valley are threatened by the potential construction of a hydroelectric facility known as Site C.

Climate Change

Our planet's climate is currently changing due to the anthropogenic emission of greenhouse gases (GHGs). BC's climate is no exception to this phenomenon. In fact, there is widespread agreement that changes in BC's climate will exceed average global changes. Throughout BC, daily minimum and maximum temperatures are expected to increase in all seasons. Climate change is also expected to bring more annual precipitation to BC. However, this is largely accounted for by increases in winter precipitation. Growing season precipitation, a variable which is generally much more important than winter precipitation, is expected to decrease in Southern BC and increase in the North. It is also important to keep in mind that changes in BC's climate are expected to be more pronounced in the North than in the South and in the interior than on the coast.

Carbon Storage

- The Peace River Valley's lowland forests store approximately 500 tonnes of carbon per ha.
- The Peace River Valley's 4913 ha of lowland forest which could potentially be destroyed by Site C store approximately 2.5 million tonnes of carbon; an ecological service which has been valued by previous studies at over $2000 per ha per year, for a total of $9.8 million per year.

Natural ecosystems play a major role in mitigating global climate change by sequestering and storing vast amounts of carbon. Over the past century, deforestation has accounted for approximately 20% of anthropogenic CO_2 emissions. Many of BC's leading environmental organizations advocate that, in order to meaningfully reduce GHG emissions, BC must "reduce the direct emissions from land use practices and … sustain the capacity of [its] natural ecosystems to remove and store carbon (Henschel, et al., 2008)." It is clear that any approach to land use

management which includes climate change mitigation as one of its goals must carefully consider the treatment of landscapes which sequester and store large amounts of carbon. The Peace River Valley is certainly one of these landscapes.

Biodiversity and Habitat Corridors

- The Peace River Valley supports an astonishing amount of biodiversity, with over 300 wildlife species and 400 vascular plant species.
- The Peace River Valley supports a large number of rare species and ecosystems, many of which are threatened or endangered.
- The Peace River Valley provides a major habitat corridor which is critical in maintaining the biodiversity of the valley and its surrounding regions.

Natural ecosystems which exhibit high levels of biodiversity and habitat connectivity, such as the Peace River Valley, can be expected to play a major role in reducing the adverse impacts of climate change on the boreal forest ecosystem. This is because biodiversity and habitat connectivity greatly contribute to the stability (i.e. resistance and resilience) and long-term adaptation capabilities of ecosystems. The unique biodiversity of the Peace River Valley can be expected to play a major role in reducing the impact of climate change on the region's ecosystems and facilitating long-term adaptations to climate change. Much of the valley's biodiversity is exceptionally valuable when viewed in the context of climate change. This includes species which are currently threatened or endangered, species which rely on the valley's wetlands and old growth forests (because these species will experience increased habitat scarcity due to climate change), and populations which exist in the valley at the northern edge of their species ranges (because these populations are critical for allowing species ranges to shift northward in response to climate change). The Peace River Valley's role as a major habitat corridor will also become increasingly important as climate change increases the levels of stress experienced by the region's populations (e.g. by increasing habitat scarcity). Furthermore, climate change is expected to increase habitat fragmentation throughout the boreal forest ecosystem, thus increasing the value of remaining habitat corridors.

Boreal forests are expected to be one of the world's ecosystems which will be most dramatically altered by climate change. There is much concern that the fast rate at which our climate is changing, in combination with other anthropogenic influences (e.g. habitat destruction and fragmentation), may cause boreal forests to undergo rapid and catastrophic changes which could lead to mass extinctions and various hardships for human societies. The conservation of high value ecosystems, such as the Peace River Valley, would minimize the potential of these adverse changes.

Agricultural Resources

- The Peace River Valley contains a substantial amount of exceptional agricultural land, especially on its lower terraces.

  Approximately 10% of the valley is classified as premium Class 1 agricultural land, accounting for the vast majority of Class 1 land in Northern BC. Approximately 50% of the valley is classified as Class 2 land. Much of this Class 2 land would have agricultural capabilities equivalent to Class 1 land if irrigated.
- The Peace River Valley's climate is among the best in Canada for agriculture.

  Less than 1% of Canada's total land base has the Class 1 climate of the Peace River Valley. The valley contains the only Class 1 climate in Northern BC.
- The Peace River Valley's climate is exceptional in comparison to its surrounding plateaus.

  This is largely due to the valley's higher temperatures, longer frost-free periods and reduced wind speeds.

- The Peace River Valley is endowed with excellent soils, which are superior to those of its surrounding plateaus.

The agricultural capabilities of the Peace River Valley are expected to be significantly enhanced by climate change. Most significantly, warmer temperatures will likely lead to great increases in the valley's productivity and the variety of crops that can be grown there. Although climate change will likely improve agricultural capabilities throughout much of the Peace River region, the Peace River Valley will continue to maintain the enormous advantages that it has over its surrounding plateaus.

The improvement of the Peace River Valley's agricultural lands is particularly relevant since current predictions suggest that climate change will have substantial negative impacts on agriculture throughout most of North America. British Columbia, like much of the world, can be expected to experience food security related issues due to climate change. One way in which the Province can significantly increase its food security is by increasing its food self-reliance. Although a recent survey indicates that 91% of British Columbians feel it is important for BC to "produce enough food so [it doesn't] have to depend on imports from other places", BC continues to rely on imports for approximately 50% of its food supply.

The unique agricultural lands of the Peace River Valley have an enormous potential to increase BC's food self-reliance. This is particularly true with regards to vegetable consumption, which is where BC's greatest food self-reliance shortfalls exist. Although a variety of constraints currently impose significant limitations on the valley's vegetable industry, at least 42 vegetables can be commercially grown in the valley. Climate change can be expected to act as a major catalyst in the establishment of a thriving vegetable industry in the Peace River Valley. This is because climate change will make vegetable production within the valley more lucrative by improving the valley's growing conditions and by increasing the prices that the valley's farmers receive for their vegetables (due to the negative impacts that climate change is expected to have on vegetable production throughout much of North America).

It is likely that a future vegetable industry in the Peace River Valley would provide a significant source of local food for the people of Northern BC. Not only would this help satisfy increasing consumer demands for locally produced foods, but it would also lead to significant environmental, health and economic benefits which are known to be associated with local food systems.

Site C

The Peace River Valley currently faces its greatest threat from the potential construction of Site C, a massive hydroelectric facility. The development of Site C is currently being pursued through a five-stage process. At the completion of each stage, the project is reviewed and a decision is made by BC Hydro and its regulator, the BC Utilities Commission, on whether or not to advance the project to its next stage. According to a report on December 2, 2009, BC Hydro was expected to conclude the second project phase shortly thereafter (Burrows, 2009).

The construction of Site C would result in a 60 meter tall dam on the Peace River, approximately 18 km upstream of Taylor. Behind the dam, a 9310 ha reservoir would extend 83 km upstream to the Peace Canyon Dam. In 2007, BC Hydro estimated the project would cost $5.0 to $6.6 billion. Proponents of Site C justify its costs with the 4,600 GWh of electricity that the facility would annually generate (enough to power approximately 460,000 homes).

However, whether or not BC actually has a true need for this additional electricity is a matter of contentious debate, which is centered on the BC Energy Plan.

The construction of Site C would result in a number of different adverse impacts. This paper focuses on those which are especially relevant in the context of climate change.

Greenhouse Gases

Although hydroelectricity is often promoted as 'clean energy' with respect to its greenhouse gas (GHG) emissions, an emerging field of research is discovering that the reservoirs associated with hydroelectricity often have substantial GHG impacts. Reservoirs directly emit GHGs to the atmosphere as organic matter decomposes in their waters. In addition, reservoirs often replace landscapes which are GHG sinks.

BC Hydro has estimated that Site C's reservoir could result in a net GHG impact which is equivalent to approximately 147,000 tonnes of CO_2/year. This is equivalent to the annual emissions of approximately 36,000 vehicles in the Lower Mainland. BC Hydro has claimed that this is an upper bounds estimation which is only valid for the first 10 years after the reservoir is filled, and that emissions would be negligible after this time period. However, BC Hydro has provided little justification for this 10 year limit. A close examination of the methods used in obtaining BC Hydro's estimate suggests that, until a more comprehensive estimation is produced, it should be assumed that Site C's reservoir would have a net GHG impact which is equivalent to approximately 147,000 tonnes of CO_2/year over the entire life of the reservoir. Although the electricity produced by Site C would produce relatively less GHG emissions than electricity produced through certain other means (e.g. coal), this does not change the simple fact that Site C would have a significant GHG impact which is deserving of attention. This is especially true given that the BC Energy Plan requires "all new electricity generation projects [to] have zero net greenhouse gas emissions."

Microclimate Changes

The creation of Site C's reservoir would also have a substantial impact on local climatic conditions. Perhaps the most significant changes would include increases in the frequency and density of fog and increases in wind speeds. These changes could have adverse impacts on everything from air travel and road safety to wildlife habitat; although the greatest impacts would likely be inflicted upon the agricultural potential of the Peace River Valley and its surroundings.

Loss of Agricultural Land and Habitat

Some of the greatest negative impacts of Site C would directly result from the destruction of much of the valley's most ecologically and agriculturally important land. Approximately 5340 ha of the valley's land would be flooded by Site C's reservoir, over 1000 ha of additional land would be impacted by the project's construction site and transmission line, and additional lands would be marginalized due to sloughing.

At least 60% of the land which would be flooded by Site C's reservoir has an agricultural capability class rating of 1 and 2; and at least 74% has a rating of 1 to 3. Respectively, this accounts for 21% and 26% of all of the Peace River Valley's land with these ratings. The Province has recognized the importance of preserving this land by placing virtually all of it in the Agricultural Land Reserve. The loss of so much high quality land would place significant constraints on the region's agricultural industry and could potentially threaten the economic viability of certain modes of intensive agricultural production. In valuing this potential loss of high quality agricultural land, it must be taken into account that climate change is expected to substantially increase the agricultural value of this land.

The construction of Site C would destroy approximately 4900 ha of the valley's forest resources. This would result in the loss of much of the valley's highest quality habitat, including old-growth forests, riparian forests, and wetlands. The replacement of the valley's forests with a vast reservoir would also greatly hinder the valley's important role as a habitat corridor. As discussed above, the valley's unique biodiversity and habitat connectivity greatly contribute to ecosystem resistance, resilience, and long-term adaptation capabilities in the face of climate change. Therefore, the loss of these assets would decrease the valley's ability to reduce many of the adverse effects of climate change.

Conclusion

- The vast amounts of carbon stored in the Peace River Valley's plants and soils contribute to the mitigation of global climate change.
- Site C will emit substantive greenhouse gases. The construction of Site C would also counteract the valley's contribution to global climate change mitigation.
- The unique biodiversity and habitat corridors of the Peace River Valley play a major role in facilitating the ability of the North American Rocky Mountain ecosystem to adapt to climate change.
- As global climate changes, Peace River Valley agricultural resources have the unique potential to provide a significant, secure, local food source for BC residents.
- The cost of Site C's net GHG emissions resulting from the reservoir and loss of sequestering landscape substantively raise the true cost of the project.

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1. INTRODUCTION

There is no doubt that the Peace River Valley of Northern BC is one of a kind[1]. The valley, which is one of Northern BC's deepest and widest, has been formed over thousands of years by the Peace River and its tributaries. The Peace originates on the western side of the Rocky Mountains and flows east through Northeastern BC and Northern Alberta before reaching Lake Athabasca. From here, the water continues its journey to the Arctic Ocean by passing through the Great Slave Lake and the Mackenzie River.

The Peace River Valley's natural ecosystems support very high levels of biodiversity by providing critical habitat and habitat connectivity. The valley's forest cover is primarily mixed deciduous, although coniferous forests dominate the valley's north facing slopes and grasslands are common on many of the valley's south facing slopes. The valley is located within the Boreal White and Black Spruce (BWBS) biogeoclimatic zone and its most abundant tree species include trembling aspen, balsam poplar, white spruce and lodgepole pine.

The Peace River Valley is also endowed with exceptional agricultural land. This land is among the highest quality agricultural land in British Columbia and is the best agricultural land in Northern BC; a unique and valuable resource indeed. These lands currently support a thriving agricultural industry which is currently based around cereal, oilseed, pulse, alfalfa, forage grass, and livestock production. The valley's agricultural industry has a tremendous potential for growth, especially in the areas of vegetable production and production for local markets.

A diverse range of people value the valley for the recreational and aesthetic opportunities that it provides, the biodiversity it supports, and the livelihoods which it facilitates. The valley also holds special importance for many people who have experienced a close relationship with the valley for such a long time that the valley has become central to their identities. This is especially true for the First Nations of the region who hold a very special cultural and spiritual relationship with the valley (Box 1).

The Peace River Valley is currently threatened by the potential construction of the Site C hydroelectric facility. BC Hydro is currently in the process of completing the second stage of the megaproject which must still pass through at least three approval processes before construction could begin. Millions of dollars have already been spent by BC Hydro on research aimed at understanding the environmental and socio-economic impacts of the potential project. This research has indicated that some of the greatest costs of Site C (other than its $5-6.6 billion price tag) would be the loss of the valley's high quality natural ecosystems and agricultural land to Site C's 9310 ha reservoir.

It would seem almost obvious that an examination of the costs of Site C (especially on the natural environment and agriculture) would be incomplete without taking into account one of the greatest challenges which we will face over the next century, our changing climate. Unfortunately, the only research which BC Hydro has published regarding the potential impacts of Site C in the context of climate change has been a three page literature review on the potential greenhouse gas (GHG) impact of the project[2] (BC Hydro, 2005). This report provides the first extensive review of the importance of the Peace River Valley in the context of climate change and how the construction of Site C would impact the valley's contribution to climate change mitigation and adaptation.

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[1] Unless otherwise noted, all references made to the "Peace River Valley" by this paper refer to the British Columbia segment of the valley, which extends from the Peace Canyon Dam to the BC/AB boarder.

[2] A more detailed estimate of the potential GHG impact of Site C can be expected soon, at the completion of Stage 2 (BC Hydro, 2009, e). However it does not appear that the Stage 2 studies have included an investigation of the additional, more local, climate change related costs of the potential project.

Box 1: First Nations and the Peace River Valley

The Peace River Valley has held great importance to First Nations for thousands of years. The earliest evidence of human presence in the region comes from artifacts found near Charlie Lake, which have been dated to approximately 10,000 years before present. Within the Peace River Valley, a vast amount of archaeological evidence has been found which indicates that the valley was heavily used by First Nations prior to the arrival of Europeans to the region (Chillborne Environmental, 2009). Given the valley's abundance of resources (e.g. wildlife, fish, important plants, and water), it is easy to see why First Nations would have been attracted to the valley. Today, First Nations continue to value the Peace River Valley for many of the same reasons that they valued the valley, thousands of years ago.

The West Moberly and Saulteau First Nations both have communities located near the Peace River Valley and have a very close relationship with the valley. Members of the West Moberly First Nations regard themselves as Dunne Za (or "Beaver"). It has been suggested that the Dunne Za moved into the Peace River region of BC in the mid-eighteenth century after being driven out of the Athabasca River region (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006); other archeological evidence of a war between the Dunne Za and another nation at Carbon Lake approximately 400 years ago suggests habitation in that timeframe. The Dunne Za were well established within the Peace River Valley when they first encountered Europeans in 1793 (North Peace Museum). These people lived a semi-nomadic lifestyle and made use of hunting camps throughout the region, although they became less nomadic following European contact, as they stabilized around trading forts. The Dunne Za who lived near what is now Hudson's Hope eventually split into two groups in 1971, the West Moberly First Nation and the Halfway River First Nation. Combined, the nations have approximately 550 members. The Halfway River First Nation is currently based at a reserve located approximately 75 km northwest of Fort St. John, where approximately 230 people live (Treaty 8 Tribal Association, 2009). The West Moberly First Nation has a 2033 ha reserve located on the west side of Moberly Lake, where approximately 190 people live (Treaty 8 Tribal Association, 2009).

The Saulteau First Nations also have a community along Moberly Lake. The Saulteau First Nations originated in Manitoba. During the Louis Riel rebellion of the late 1800's, the Saulteau left their homelands after being on the verge of starvation due to decreases in buffalo populations. After traveling across Canada for over a decade the Saulteau eventually reached Moberly Lake in 1899 and made it their home (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). The 540 current members of the Saulteau First Nations belong to the Saulteau, Beaver and Cree Linguistic groups. The group's 3026 ha reserve, located at the east end of Moberly Lake, has a population of approximately 840 (Treaty 8 Tribal Association, 2009).

Both the West Moberly and Saulteau First Nations intensively use the land surrounding their communities and feel a strong obligation to protect this land. The West Moberly and Saulteau First Nations have identified the Peace-Moberly Tract (PMT) as an area of special interest to their communities. The PMT is approximately 1090 km^2 in size and lies between Moberly Lake and the south bank of the Peace River (stretching from the Peace Canyon Dam to approximately 20 km west of Taylor) (Figure 1). This land is in close proximity to the First Nation communities on Moberly Lake; providing easy access to hunting, trapping, fishing, gathering, and other cultural activities. The people of the West Moberly and Saulteau First Nations have retained hunting, fishing, and trapping as very important aspects of their lives and "PMT is considered to be a 'breadbasket' for 'country foods' (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006)."

The PMT is also heavily used for the collection of berries, medicinal plants, and other products that are used for crafts (e.g. hides, snowshoes, canoes, and drums) or ceremonial purposes. Unfortunately, “many areas where [the West Moberly and Saulteau First Nations] used to hunt, fish, or trap are no longer available because they have been converted to farmland or used for other kinds of development which Native trappers, hunters, and spiritual leaders are not involved in. When the people see development occur in these areas it is more than just a loss of harvesting opportunity, it is also seen as an aesthetic and spiritual loss” (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). As Kori Dokkie of the WMFN explains, this land “isn’t just a place. It’s our identity. It is us (Dokkie cited in Chillborne Environmental 2009).”

The West Moberly and Saulteau First Nations, as well many other First Nations throughout Canada, have a legal right to access culturally important resources, as stipulated by various treaty agreements. The West Moberly and Saulteau First Nations, along with 6 other First Nation bands, are signatories to Treaty 8. This treaty, which was signed in 1899, establishes a number of rights which the First Nations are entitled to. For example, under this treaty, “First Nations have a right to fish and hunt in their preferred location and in reasonable proximity to where they live (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006).” First Nations also have the right to use this land for other traditional activities (e.g. building smoke houses). Despite the fact that these rights are held by First Nations, “the Province can sell Crown land and authorize various uses of Crown land within Treaty 8 Territory even if some of these sales or authorizations have an impact on the rights of First Nations. However…the Crown’s ability to sell land and authorize incompatible uses is limited. It cannot be exercised in a manner that neuters the hunting and fishing and other rights guaranteed by Treaty 8 (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006).”

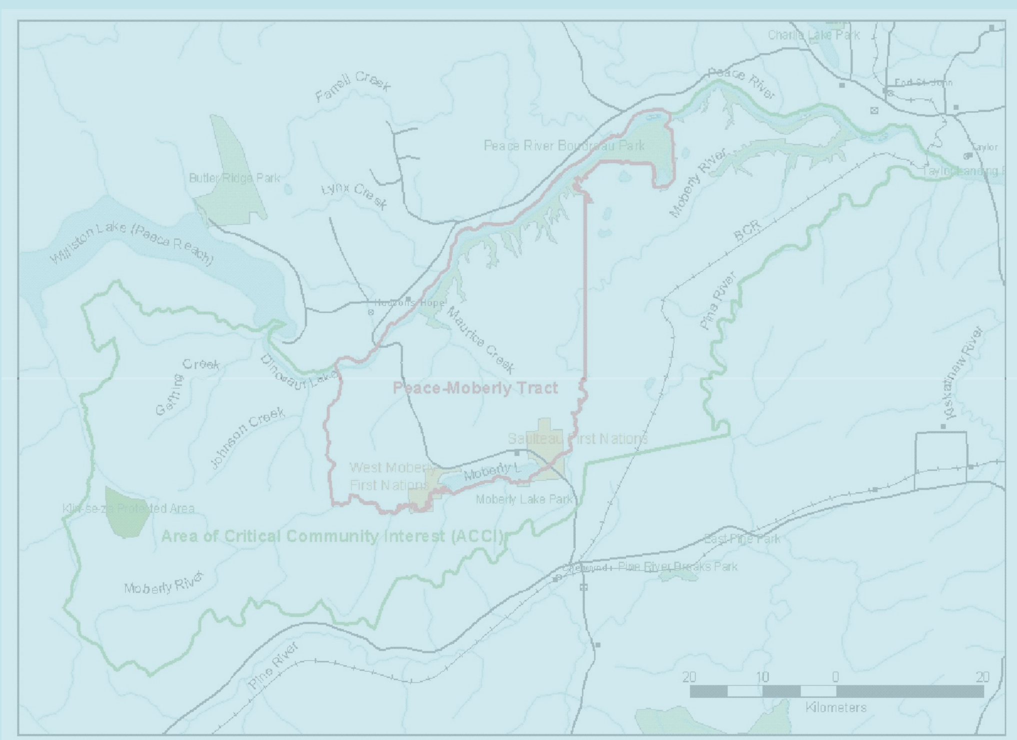

Figure 1: Location of the Peace-Moberly Tract (PMT). Source: (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006).

2. CLIMATE CHANGE

2.1. OVERVIEW OF GLOBAL CLIMATE CHANGE

It is clear that the earth's climate system is undergoing significant warming. In fact, the Intergovernmental Panel on Climate Change (IPCC), the world's most authoritative scientific body on the subject, has declared the warming of the earth's climate as being "unequivocal" (2007). The average surface temperature of the earth has warmed approximately 0.7 °C in the past 100 years. The significance of this warming is well demonstrated by the fact that the twelve years between 1995 and 2006 accounted for eleven out of the twelve warmest years between 1850 and 2006. This warming has led to "changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones." There is widespread agreement that the global climate will continue to change, and that we can expect that these changes during the 21st century to be even more substantial than the changes which occurred during the 20th century.

The IPCC (2007) has stated, with a very high level of confidence (>90%), that the currently observed increases in global average temperatures and changes in associated climatic variables (e.g. temperature extremes, wind patterns, ocean temperatures, etc.) are the result of anthropogenic increases in the atmospheric concentrations of GHGs, especially CO_2, CH_4, and N_2O (Box 2). The magnitude of these increases in GHG concentrations are well illustrated by the results of ice coring studies which have found that the atmospheric concentration of CO_2 and CH_4 are currently much higher than they have been at any point in time within the past 650,000 years. The most important source of GHG emissions over the past century has been from the burning of fossil fuels. Land use changes, especially deforestation, have been the second most important source of emissions.

Box 2: The Greenhouse Effect

The warming of the global climate is being driven by the greenhouse effect. The greenhouse effect is an extremely important component of the earth's climatic system which is caused by greenhouse gases (GHGs) in the earth's atmosphere These GHG's include water vapour, carbon dioxide, methane, nitrous oxide, and ozone (Le Treut, et al., 2007). Without the greenhouse effect, the average surface temperature of our planet could be as low as -18 °C, as opposed to the 14.5 °C average temperature which is currently observed (Lashof, 1989; Intergovernmental Pannel on Climate Change, 2007).

When solar radiation reaches the earth's surface, some of this energy is radiated back into space. Greenhouse gasses (GHGs) in the earth's atmosphere absorb some of this energy and radiate it back towards the earth, thus warming the earth's surface temperatures. Radiation which is not absorbed by GHGs exits the earth's atmosphere and is lost to space. When atmospheric GHG concentrations increase, the earth's surface temperatures can be expected to increase because a higher proportion of the heat radiated from the earth's surface is radiated back towards the earth's surface (Le Treut, et al., 2007).

2.2. BC'S CLIMATIC HISTORY

Climate change is of course not a new phenomenon. The earth's climate is known to change due to the influence of a number of different factors. Although the current climate change that the earth is experiencing is being driven by human activities that emit GHGs to the atmosphere, our planet's climate has undergone numerous changes prior to the industrialization of human societies. Some of the drivers which have caused the earth's climate to change in the past include variations in the energy output of the sun, variations in the earth's rotation around the sun, volcanism, and various complex interactions between the atmosphere and the oceans (e.g. El Niño-Southern Oscillation (ESNO) and Pacific decadal oscillation (PDO))[3].

The prehistoric climate of BC has been the focus of extensive research and the climatic history of the region over at least the past 10,000 years is well known (Walker & Sydneysmith, 2007). Towards the end of the last glaciation, approximately 12,500 years ago, the climate of BC was significantly colder and dryer than it has been in more recent history. Around that time, BC's climate began a period of rapid warming, with temperatures increasing by 5 °C within one or two centuries. From approximately 10,000 to 7,400 years before present, BC's climate was drier and 2-3 °C warmer than present. This is perhaps the most instructive interval of BC's prehistoric climatic history, as BC's climate during this period was similar to what is expected to result from current changes in climate (Walker & Sydneysmith, 2007; Wilson & Hebda, 2008). It is known that during this time period many ecosystems had different distributions than what is currently observed (e.g. lowland forests and interior grasslands reached higher elevations), bogs were less extensive, lakes and ponds were shallower, and fires were more active (Wilson & Hebda, 2008). This period was followed by a relatively warm and moist interval, which ended approximately 4400 years ago when BC's climate became roughly analogous to BC's current climate (Walker & Sydneysmith, 2007).

It is important to mention that BC's climatic history is characterized by significant short-term variability. Much of this variability can be attributed to El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), two highly complex phenomena caused by interactions between the atmosphere and the ocean (Box 3) (Walker & Sydneysmith, 2007). Although ENSO and the PDO have been relatively well studied, much uncertainty remains regarding their causes and how they will be impacted by climate change (Meehl, et al., 2007; Mantua & Hare, 2002). Given this short-term variability which characterizes BC's climate, it is important to remember that BC's climatic future will include many surprising and abrupt changes. For example, studies of BC's climatic history have found that periods of extreme drought are quite common in BC, and that the severity and frequency of droughts over the past century may have been unusually low (Walker & Sydneysmith, 2007).

2.3. OBSERVED CHANGES IN BC'S CLIMATE

BC's climate is currently undergoing substantial changes. Walker and Sydneysmith (2007) explain the recent changes in weather that the province has been experiencing. Data generated by BC's weather stations clearly indicates that BC's climate has undergone significant warming in recent decades. This warming is of course varied, both spatially and temporally. Throughout BC, there has been a general trend of increasing daily maximum temperatures. Furthermore, the number of extremely warm days and nights has been increasing, while extremely cold days and nights have become less numerous. Similarly, BC has increasingly experienced fewer frost days and longer frost-free periods. Throughout BC, daily minimum and maximum temperatures have increased in all seasons, with the greatest warming occurring in the winter and spring. Since 1900, annual mean temperatures in BC have exhibited average decadal increases of 0.05 to 0.20 °C. Throughout the past century, rain to snow ratios have increased and annual precipitation has increased 0.5 to 5.0 % per decade.

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[3] These drivers of climate change operate at various timescales and influence the earth's climate to varying degrees. For example, the aerosols and dust emitted from the eruption of Mt. Pinatubo in 1991 are believed to have cooled average global temperatures the following year by 0.4 °C (McCormic, et al., 1995). In contrast, it has been theorized that changes in the Earth's rotation around the sun, which occur on cycles of approximately 23,000, 41,000, and 100,000 years, may be responsible for causing substantial climatic changes which can even trigger ice ages and glaciation events (Hays, et al., 1976).

Box 3: El Niño - Southern Oscillation and the Pacific Decadal Oscillation

Much of the inter-annual variation of BC's climate can be attributed to El Niño-Southern Oscillation (ENSO), while the Pacific Decadal Oscillation (PDO) is responsible for much of BC's inter-decadal climatic variation. These ocean-atmosphere phenomena greatly influence temperatures, precipitation, storms, and winds in BC (Walker & Sydneysmith, 2007). ENSO is a global climatic phenomenon which occurs on a 3 to 7 year cycle and is caused by sea surface temperature anomalies across the Equatorial Pacific. The warm phase of ENSO, EL NIÑO, occurs when unusually warm sea-surface temperatures (SSTs) develop in the eastern Equatorial Pacific and may last from 6 to 18 months. During EL NIÑO, BC experiences warmer temperatures and less precipitation. Cooler and wetter conditions occur in BC during the cold phase of ENSO (La NiÑA), which also lasts 6 to 18 months, when sea-surface temperatures in the eastern equatorial Pacific are unusually cold (Walker & Sydneysmith, 2007).

The climatic impacts of the PDO on BC's climate are similar to those of ENSO, yet the PDO causes climatic variability at longer temporal scales. The PDO generally alternates phases every 20 to 30 years. The "cool" (or "negative") phases of the PDO are associated with cooler and wetter conditions in BC , while "warm" (or "positive") phases are associated with slightly warmer winter and spring temperatures and variable effects on precipitation (Walker & Sydneysmith, 2007). Like ENSO, the PDO is caused by SST anomalies across the Pacific Ocean. During the "warm" phase of the PDO, SSTs in the northwestern Pacific are relatively cool while SSTs in the northeastern Pacific are relatively warm. During the "cool" phase, the opposite pattern in SSTs is observed (Mantua & Hare, 2002). Over the past century, the PDO exhibited a "warm" phase from 1905-1945, and again from 1977 through to at least the mid-1990's. The "cool" phase prevailed from 1946-1976 (Biondi, Gershunov, & Cayan, 2001). In 2008, NASA announced that a shift to the "cool" phase of the PDO was occurring (Buis, 2008).

It is important to note that the PDO exerts a strong influence on ENSO events. During the "warm" phases of the PDO, the strength and predictability of El Niño EVENTS tends to be enhanced. Conversely, the strength and predictability of La Niña events are enhanced during the "cool" phases of the PDO (Gershunov & Barnett, 1998). Thus, some of the warmest and driest years in BC could be expected to coincide with EL Niño events which occur in the context of a "warm" phase of the PDO; while BC's wettest and coldest years could be predicted to coincide with La Niña events which occur during "cool" phases of the PDO. Both ENSO and the PDO will likely be impacted by global climate change. However, there is currently a great deal of uncertainty in predicting the precise nature of these impacts (Meehl, et al., 2007; Mantua & Hare, 2002).

Changes in BC's climate have generally been more pronounced in the interior than on the coast; and more pronounced in Northern BC than in Southern BC (Walker & Sydneysmith, 2007). Not surprisingly, changes in many of the climatic variables of BC's northern interior region have exceeded provincial averages. In this region, from 1895-2006, the annual mean temperature has increased by 1 °C, the annual extreme maximum temperature has increased by 0.4 °C, annual extreme minimum temperature has increased by 2.5 °C, and the annual precipitation has increased by 5.4% (Egginton, nd).

2.4. BC'S FUTURE CLIMATE

Creditable projections of future global climates are available from a number of different Global Climatic Models (GCMs) (Box 4). Results of these models have generally indicated that global climate change will cause BC's climate to undergo continued warming and changes in precipitation. These changes in BC's climate are expected to exceed global averages (Spittlehouse, 2008). This is not surprising, as observations of BC's recent climatic changes have indicated that they are already exceeding global averages (Mote, 2003).

Spittlehouse (2008) used the Canadian Global Climate Model version 2 (CGCM2) to project BC's future climate. The projections for BC produced by this model fall within the midrange of BC climate projections produced via other prominent models (Spittlehouse, 2008). Figure 2 and Figure 3 illustrate some of the significant increases in temperatures which BC is expected to experience in the coming decades. Winter temperatures are expected to increase the most. Warming is expected to be greater in the interior than on the coast, and greater in northern BC than in southern BC (Spittlehouse, 2008). BC is also expected to experience significant changes in precipitation regimes. For most regions of BC, mean annual precipitation is projected to significantly increase during this century (Spittlehouse, 2008). However, this may be somewhat misleading as increases in mean annual precipitation will be primarily driven by increases in winter precipitation (Figure 4), and it is the growing season precipitation which is the primary determinant of water availability throughout most of BC (Walker & Sydneysmith, 2007).

It is very important to notice that increases in growing season precipitation are expected for Northern BC, while Southern BC is expected to experience significant decreases in growing season precipitation. Decreases in growing season precipitation (Figure 5), in combination with increases in growing season temperatures (Figure 3), are expected to significantly increase growing season climatic moisture deficits throughout most of BC [4] (Spittlehouse, 2008).

[4] Climatic moisture deficits occur when the monthly evaporative demand exceeds monthly precipitation.

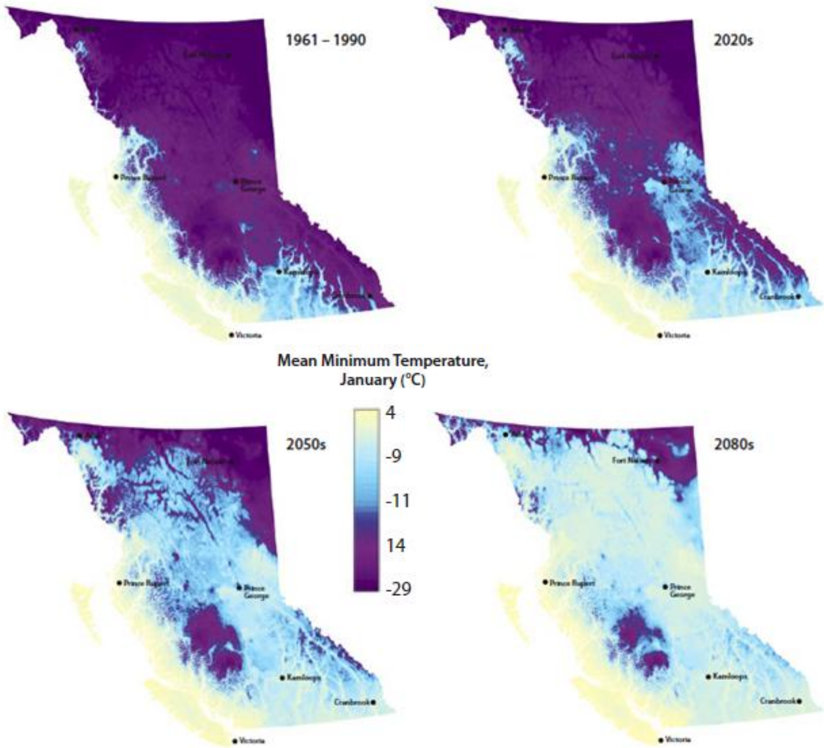

Figure 2: Mean minimum January temperatures for British Columbia. Source: (Spittlehouse, 2008).

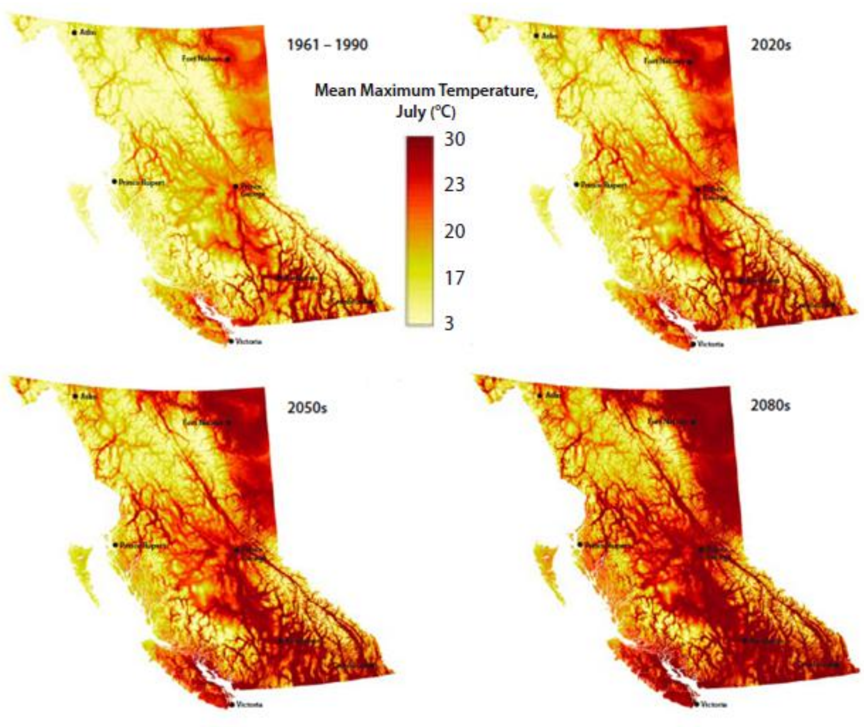

Figure 3: Mean maximum July temperatures for British Columbia. Source: (Spittlehouse, 2008).

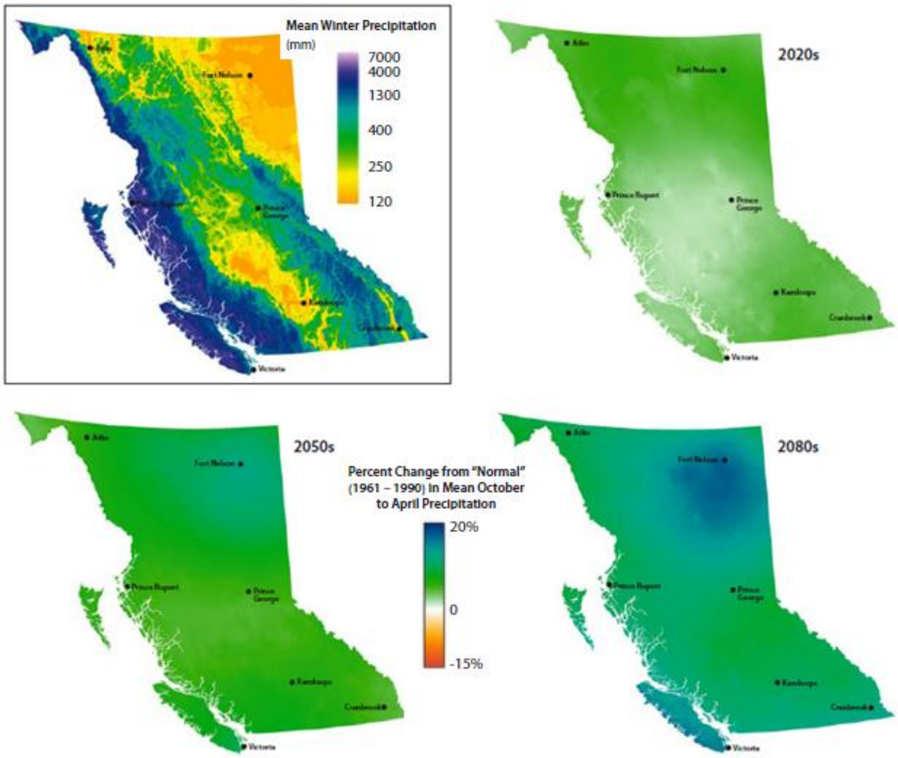

Figure 4: Mean October to April precipitation for British Columbia. Source: (Spittlehouse, 2008).

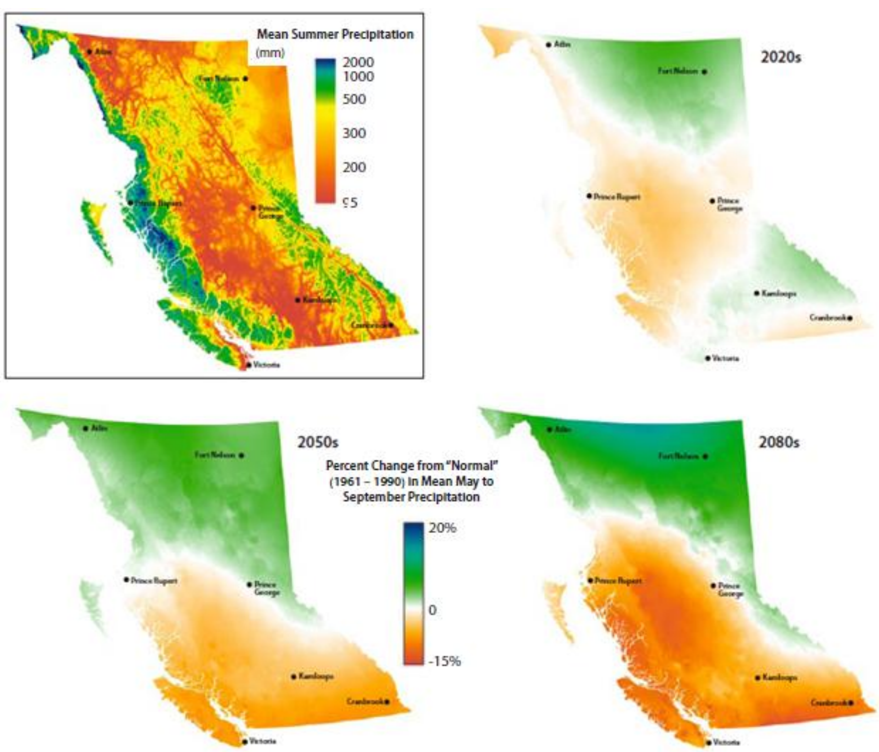

Figure 5: Mean May to September precipitation for British Columbia. Source: (Spittlehouse, 2008).

2.5. SOCIOECONOMIC IMPACT OF CLIMATE CHANGE ON BC

Climate change will undoubtedly have substantial socioeconomic impacts on BC. Some of the sectors of BC's economy which will likely face the greatest challenges due to climate change include forestry, agriculture, and hydroelectric generation (Walker & Sydneysmith, 2007). One of the greatest climate change impacts will likely affect the forestry industry, through increasingly frequent and severe natural disturbances such as fires and insect infestations (Walker & Sydneysmith, 2007; Spittlehouse, 2008). The forestry sector is already being impacted by climate change. The recent increase in fire frequencies and the severity of the current Mountain Pine Beetle epidemic have both been largely attributed to climate change (Gillett, et al., 2004; Carroll, et al., 2004). Some of the greatest challenges which will be faced by the agriculture, fisheries, and hydroelectric sectors will likely result from decreases in the availability of water during the warmer months of the year [5] (Walker & Sydneysmith, 2007). BC's infrastructure will also face massive challenges from the increase in the frequency and severity of extreme weather events which are projected by climate models (Harford, et al., 2008). It is possible that BC's infrastructure is already experiencing more damage due to climate change. From 1999-2002 extreme weather events cost BC taxpayers an annual average of $10 million for disaster financial assistance. From 2003-2005, disaster financial assistance costs increased dramatically to an average of $86 million per year, due to increases in destruction from wildfires, storm surges, heavy rains, and droughts (Whyte, 2006, cited in Walker & Sydneysmith, 2007).

Box 4: Global Climate Models

Global climate models (GCMs) are widely used to predict future climatic conditions. These models use well-established physical principles to "simulate oceanic and atmospheric processes and their interaction with the land surface for a range of future greenhouse gas emission scenarios (Spittlehouse, 2008)." GCMs have become increasingly complex in recent years and have demonstrated their high levels of reliability by reproducing observed characteristics of past climates (Randall, et al., 2007). A number of different GCMs have been produced which model climate influencing processes in different ways. The diversity of GCMs has great value because it helps address uncertainty by producing a range of possible future climates (Walker & Sydneysmith, 2007; Randall, et al., 2007). Results from different GCMs tend to be relatively similar with differences between them often being of degree rather than direction. Levels of confidence for GCM projections are generally higher for temperature than for precipitation. Confidence levels are also higher for projections of larger spatial scales and longer time averaging periods (IPCC 2007 summary report).

An important source of uncertainty in predicting future climates is derived from the difficulty in estimating future GHG emission scenarios. The future of GHG emissions is very difficult to predict, as it rests upon complex factors such as economic growth, technological development, and international co-operation (Spittlehouse, 2008). GCMs address this uncertainty by analyzing a range of different GHG emission scenarios.

[5] Climate change is expected to result in earlier spring peak flows and reduced April to September streamflows because of reduced snowpack (warming will cause increased winter melting and rain), earlier snowmelt, and higher rates of evaportranspiration (Walker & Sydneysmith, 2007).

3. CARBON AND FORESTS

3.1. OVERVIEW OF CARBON SEQUESTRATION AND STORAGE BY FORESTS

One of the most important ecological functions of forests is the role that they play in the global carbon cycle. Forests sequester carbon by absorbing atmospheric CO_2 through the process of photosynthesis. This sequestered carbon is then stored in the organic matter of forests (e.g. plant material and soil organic matter). Forests release carbon back to the atmosphere (primarily in the form of CO_2) through the respiration of autotrophs (i.e. plants), the respiration of heterotrophs (especially those which are heavily involved in the decomposition of organic matter), and the burning of biomass. Forests currently store approximately 1640 billion tonnes of carbon, which is equivalent to over twice the amount of carbon currently in our atmosphere (Sabine, et al., 2004). It has been estimated that Canada's boreal forests and peatlands store 153.5 billion tonnes of carbon, which is 20 times more carbon than what was globally emitted to the atmosphere in 2001 (Anielski & Wilson, 2009). The value of this stored carbon is estimated to be "$582 billion per year in terms of the average avoided costs of carbon emitted to the atmosphere (Anielski & Wilson, 2009)."

Over the past century, deforestation has accounted for approximately 20% of anthropogenic CO_2 emissions (Intergovernmental Pannel on Climate Change, 2007). It is important to remember that a molecule of CO_2 released to the atmosphere from the destruction of a forest is no different than a molecule of CO_2 released from the smokestack of a coal power plant. Many of BC's leading environmental organizations argue that in order to meaningfully reduce GHG emissions, BC needs to "reduce the direct emissions from land use practices and… sustain the capacity of our natural ecosystems to remove and store carbon (Henschel, et al., 2008)." It is urged that this should be achieved by adopting a "Carbon Stewardship" approach to land use management in which the "the protection and conservation of land and natural systems [is placed] at the same level of importance as the reduction of [fossil fuel] use (Wilson & Hebda, 2008)."

Box 5: Impact of Climate Change on Carbon Sequestration and Storage

Climate change is expected to have a substantial impact on the amount of carbon sequestered and stored by many of the world's forests. This impact will occur primarily through alterations in ecosystem net primary productivity, decomposition rates, and the frequency and magnitude of disturbances. For example, if decomposition rates or the frequency of stand initiating events increase without compensating increases in net primary productivity, the result will be ecosystems which store less carbon. However, it is also possible that climate change will cause some forests to store more carbon (e.g. a situation in which net primary productivity greatly increases while decomposition and disturbance rates only slightly increase). It is currently unclear what the net impact of climate change will be on carbon sequestration and storage in Canadian boreal forests (Nelson, et al., 2007). One thing which is certain is that, even if climate change does decrease the amount of carbon stored in Canadian boreal forests, these forests will nevertheless continue to store globally significant amounts of carbon.

3.2. CARBON STORED IN THE PEACE RIVER VALLEY'S TREES

To provide an illustration of the amount of carbon stored in the Peace River Valley we have produced an estimation of the amount of carbon stored in the valley's trees. This estimation was produced through the use of a well established model which was developed by the Canadian Forest Service; and which allows for the calculation of the total amount of biomass of a forest's trees (including roots, stems, branches, foliage, and standing dead trees) (Boudewyn, et al., 2007). Data required to run this model includes information regarding the leading species of each stand (i.e. the most prevalent canopy species), the volume of merchantable wood in each stand, and the region's ecozone. This data was obtained from a detailed inventory of the Peace River Valley's forest resources, which was carried out by Industrial Forestry Service Ltd. (1991)[6]. This inventory provides information on the 4913 ha of the Peace River Valley's forest resources which would be destroyed by the construction of Site C[7]. The vast majority of the forests surveyed by Industrial Forestry Service Ltd. were therefore lowland forests.

Table 1: Tree biomass and carbon storage in the Peace River Valley forests surveyed by Industrial Forestry Service Ltd. (1991).

Leading Species	Area (ha)	Tree Biomass (tonnes)	Tree Carbon (tonnes)	Tree Biomass (tonnes/ha)	Tree Carbon (tonnes/ha)
Trembling Aspen	2,071	530,915	265,458	256	128
Balsam Poplar	1,463	451,059	225,530	308	154
White Spruce	1,213	534,372	267,186	441	220.5
Lodgepole Pine	58	14,815	7,408	255	127.5
Larch	17	4,357	2,179	256	128
All Species	4,822	1,689,076	844,538	350	175

Values were calculated through the equations provided by Boudewyn et al. (2007), which allow for the calculation of the total amount of biomass of a forest's trees (including roots, stems, branches, foliage, and standing dead trees) through the use of data regarding the leading species of each stand (i.e. the most prevalent canopy species), the volume of merchantable wood in each stand, and the region's ecozone. A more detailed table, which includes volumes of merchantable timber, is provided in Appendix 1.

The results of our calculations indicate that the Peace River Valley forests surveyed by Industrial Forestry Ltd. (1991) contain an average of 350 tonnes of tree biomass per hectare. Since the carbon content of woody biomass in North American trees is approximately 50% by wet weight (Lamlom & Savidge, 2003), it is estimated that the

[6] Although this inventory was carried out almost 20 years ago it is likely that the general characteristics of the PRV's forests (e.g. species distributions and volumes of merchantable timber) have not undergone drastic changes in the past 20 years. Therefore, since more recent data was not available, we feel that it is reasonable to make a preliminary estimation of the carbon stored in the valley's trees based on the data provided by this inventory. In fact, our estimates are likely conservative, as it is likely that the forests included in the inventory have undergone net increases in biomass since 1991.

[7] This figure includes the valley's forest area which would be lost due to the reservoir (3124 ha), construction site 767 ha, transmission line widening (273 ha), and Highway 29 relocation (0.4 ha).

trees of these forests contain an average of 175 tonnes of carbon per hectare (Table 1). This value is within the upper range of what can be expected from forests within the Boreal Plains ecozone (Shaw, et al., 2005). This relatively high value is likely due to the fact that, on average, the forests surveyed by Industrial Forestry Ltd. were significantly older than most forests of the Boreal Plains ecozone[8] (Shaw, et al., 2005). Furthermore, throughout Canada, warmer and wetter climates are generally associated with greater amounts of carbon stored in living biomass (Shaw, et al., 2005). Therefore, since the Peace River Valley experiences warmer and wetter climatic conditions than most of the Boreal Plains (especially at its lower elevations), it would not be surprising for the Peace River Valley to store more carbon in its trees than the average forest of the Boreal Plains.

It is unclear as to whether or not the forests studied by Industrial Forestry Service Ltd. (1991) could be considered to be a representative sample of the entire 36596 ha of forested land contained within the Peace River Valley, with regards to the amount of carbon stored in their trees (Keystone Wildlife Research Ltd., 2009). However, if the surveyed forests could be considered to be roughly representative of all of the valley's forests, the Peace River Valley would be expected to store a total of 6.4 million tonnes of carbon in its trees[9].

3.3. CARBON STORED IN THE PEACE RIVER VALLEY'S SOILS

While trees store a substantial amount of a forest's carbon, one must also consider soil carbon to get a complete picture of an ecosystem's total carbon storage. The world's forests store approximately 1550 billion tonnes of organic carbon in their soils. This is approximately three times more carbon than is stored in all living organisms and approximately two times more carbon than is currently contained in the atmosphere (Lal, 2004).

Soil carbon develops through the following processes. When biomass dies, much of the carbon it contains is transferred to the atmosphere relatively quickly, either through burning or decomposition. However, a significant proportion of organic carbon is not immediately released to the atmosphere and is instead transferred to the soil where the biomass continues to undergo decomposition, often at a relatively slow rate. Some of this carbon will eventually become soil humus (i.e. organic matter which will not break down further under current conditions), which may persist in the soil for thousands of years if left undisturbed (Price, et al., 1997). Under most conditions, soil carbon takes a long time to develop and is relatively stable (i.e. there is little net flux of carbon into or out of soil carbon pools). However certain events (e.g. the conversion of forests to agricultural land and the draining of wetlands) can result in massive releases of soil carbon to the atmosphere (Lal, 2004).

Unfortunately we did not have sufficient data to develop a relatively precise estimate of the amount of carbon stored within the Peace River Valley's soils. However, through the use of the Forest Ecosystem Carbon Database (a compilation of carbon related data from over 700 forest plots across Canada) we were able to attain a rough understanding of the amount of organic carbon stored in the Peace River Valley's soils. The Forest Ecosystem Carbon Database provides data for three types of forests in the Boreal Plains ecozone (i.e. the ecozone, within

[8] The average stand age for 420 upland forest sites throughout the Boreal Plains was 90 years, whereas the average stand age observed by in the PRV was 116 years (Shaw, et al., 2005). Older stands are well known to contain more carbon in live biomass than younger stands.

[9] The Industrial Forestry Service Ltd. (1991) survey likely includes a disproportionately high amount of lowland and riparian forests, as the majority of the forests studied where those which would be flooded by Site C's reservoir. These forests may contain more tree biomass than the valley's upland forests. Therefore, this value of 6.4 million tonnes of carbon may overestimate the total amount of carbon stored in the PRV's trees.

which the Peace River Valley is located). These forest types include upland, transitional, and wetland10 (Shaw, et al., 2005). According to this database, the mean amount of soil carbon found at 460 different upland forest plots was approximately 130 tonnes/ha. Wetland sites (defined by an organic horizon > 1 meter in depth) contained approximately 600 tonnes of soil carbon/ha. Sites which were transitional between wetlands and uplands (organic horizon < 1 meter) contained approximately 520 tonnes of soil carbon/ha contained approximately 520 tonnes of soil carbon/ha, (n=19 and 12, respectively). The Peace River Valley likely contains only a small amount of forested area which would be classified as wetlands by the Ecosystem Carbon Database. The forests on the Peace River Valley´s upper terraces and valley walls would be best described as upland forests. The valley´s lower elevation forests (e.g. the vast majority of the forested area which would be directly impacted by Site C) would likely be classified somewhere between upland and transitional forests, Therefore, 325 tonnes of carbon/ha can serve as a very rough estimate of the amount of carbon stored in the soils of the valley´s lowland forests[11].

3.4. TOTAL CARBON STORED IN THE PEACE RIVER VALLEY'S LOWLAND FORESTS

As the discussion above has indicated, it is indisputable that the Peace River Valley's forests store a substantial amount of carbon. It is clear that different forest stands within the Peace River Valley can be expected to store very different amounts of carbon. For example, the upland forests located along the valley's slopes likely store significantly less carbon than the highly productive forests which are located at the valley´s lower elevations.

The fact that the majority of the data used in generating our tree biomass estimations comes from these lowland forests makes it difficult to accurately estimate the amount of carbon stored throughout all of the Peace River Valley´s forested land. However, our data does allow us to generate a reasonable estimate of the amount of carbon stored in the Peace River Valley´s lowland forests, the forests which face the greatest threat from the potential development of Site C. As discussed in section 3.2 and 3.3, we have estimated that Peace River Valley´s lowland forests store an average of approximately 175 tonnes of carbon per hectare in their trees and 325 tonnes of carbon per hectare in their soils. This yields a total of 500 tonnes of carbon per hectare. According to the methods of Anielski and Wilson (2009), the storage of this amount of carbon can be valued at approximately $2000/ha/yr. It is important to note that in order to obtain a more complete picture of the total amount of carbon stored in the Peace River Valley´s lowlands, one should also consider the significant amounts of carbon stored in the valley's grasslands, agricultural lands, and aquatic ecosystems.

[10] "Transitional sites were defined as those with mineral soil horizons within the top 1 m and wetlands as soils that were organic throughout the 1-m depth (Shaw, Bhatti, & Sabourin, 2005)."

[11] It is important to note that, throughout Canada, warmer and wetter climates are generally associated with greater amounts of soil organic carbon (Shaw, et al., 2005). Since the Peace River Valley experiences warmer and wetter conditions than the average for the Boreal Plains ecozone, it is likely that the Peace River Valley's soils contain more organic carbon than other sites within the Boreal Plains (excluding wetlands).

4. THE ROLE OF NATURAL ECOSYSTEMS IN CLIMATE CHANGE MITIGATION AND ADAPTATION

4.1. IMPACT OF CLIMATE CHANGE ON BOREAL FORESTS

Boreal forests are expected to be among the ecosystems which will be most dramatically impacted by climate change (Nelson, et al., 2007; Soja, et al., 2007). This is largely because the boreal ecosystem is expected to experience climatic changes which will significantly exceed global averages and because boreal forests have demonstrated great sensitivity to changes in climate. There is a general consensus that climate change will result in significantly warmer temperatures and greater amounts of precipitation in boreal regions (Soja, et al., 2007). Changes in the climatic characteristics of the boreal forests have been predicted to result in a number of different ecological responses, which could potentially lead to great changes in boreal ecosystems. Some of the most important predicted impacts include changes in disturbance regimes, productivity, and species composition.

4.1.1. Disturbance regimes

There is a general consensus that climate change will have profound impacts on the boreal forest through the alteration of fire regimes[12] (Flannigan, et al., 2009; Soja, et al., 2007). The fire regimes of boreal forests play a key role in influencing the "age structure, species composition, and floristic diversity of boreal forests" (Soja, et al., 2007). Fires are usually considered the dominant disturbance agent of boreal forests; and some researchers have argued that changes in fire regimes will likely have a greater impact on the boreal region than the direct effects of climate change on plant growth (Engelmark, 1999; Weber & Flannigan, 1999). Numerous studies have concluded that the frequency of fires in Canadian boreal forests has been increasing over the past 30 years (Nelson, et al., 2007). Gillett et al. (2004) demonstrated that anthropogenic climate change has been a significant contributor to this observed increase in fire activity. It has been estimated that, by the end of the century, the total area of forest burned in Canada each year may increase by 74 to 118%[13] (Flannigan, et al., 2005).

Insects are another key disturbances agent in boreal forests. Warmer year-round temperatures are known to enhance the population growth rates of many disturbance inducing boreal insects (Stewart et al. 1998 cited in Nelson et al. 2007). Furthermore, warmer winters are expected to increase winter survival rates of these insects. Climate change is already influencing insect disturbances in the boreal ecosystem. For example, the massive extent of the current Mountain Pine Beetle (MPB) infestation is partially attributable to climate change (Carroll, et al., 2004). Indications of the potential that climate change has in altering insect disturbance regimes also come from the boreal forests of Alaska, where several consecutive warm, dry summers led to a massive spread of spruce beetle during the 1990's (Soja, et al., 2007). There is also concern that climate change may cause increases in disturbances from other important insect pests, such as the spruce budworm[14] and the forest tent caterpillar[15] (Volney & Fleming, 2000).

[12] Climate change is expected to result in increases in the length of the fire season, the severity of fire weather, and ignition from lightning. Increases in the length of the fire season and the severity of fire weather are expected primarily due to the temperature increases in the boreal region. An increase in the ignition of fires from lightning strikes is expected because boreal forests are expected to experience more convective storms, which produce lightning (Flannigan, et al., 2009).

[13] This estimate was made assuming a 3 × CO_2 scenario (Flannigan et al. 2005).

[14] The principal hosts of the spruce budworm are white spruce and balsam fir.

[15] The principal host of the forest tent caterpillar is trembling aspen.

One of the most important effects of these expected increases in disturbance frequency and severity may be that it will cause boreal forests to have a younger age distribution (Nelson, et al., 2007). This will likely have important consequences on the function that boreal forests play in storing carbon and supporting biodiversity. More frequent and severe disturbances will likely decrease the amount of carbon stored in boreal forests, at least in the near-term (Kurz, et al., 2008). Decreases in forest ages will also have a significant impact on the biodiversity of boreal forests, since many boreal floral and faunal species depend on the unique habitats provided by mature and old-growth forests. These habitats are already limited due to anthropogenic activities (e.g. forestry, agriculture, hydroelectric development), especially in the southern boreal forests, and climate change will only decrease the availability of these critical habitats (Nelson, et al., 2007; Wilson & Hebda, 2008).

4.1.2. Productivity

Climate change associated changes in temperature and precipitation may result in a number of different responses in boreal vegetation. For example, one common prediction is that increased temperatures will cause the tree line of boreal forests to increase in elevation and latitude (Soja, et al., 2007). Similarly, since vegetation growth in the boreal is often limited by low temperatures, it has been commonly predicted that increases in temperatures may result in increased growth rates for boreal vegetation. However, recent studies have shown the relationship between temperature and vegetation growth in the boreal is not as straightforward as once thought (Soja, et al., 2007). For example, warmer temperatures have been shown to increase the susceptibility of boreal vegetation to freeze-thaw damage (Nelson, et al., 2007). Furthermore, warmer temperatures have also been shown to decrease growth rates of boreal vegetation by increasing drought stress[16] (Barber, et al., 2000).

4.1.3. Wildlife

Climate change will have a significant impact on boreal wildlife. One of the main ways in which this can be expected to occur is through changes in the availability of habitat (e.g. decreases in old-growth habitat, as discussed in section 4.4.1.). Furthermore, warmer temperatures are expected to exceed the temperature tolerances of some boreal animals, forcing these species to shift their ranges northward (Kerr & Packer, 1998). Another similar concern is that lower snowpack depths could adversely affect a number of species which have annual survival rates that are highly dependent upon this variable (e.g woodland caribou) (Nelson et al., 2007). Animals are generally able to migrate relatively quickly to track suitable environmental conditions such as climate. However, the plants and habitats which animals depend on are usually less mobile. Therefore, it is foreseeable that some animal populations will experience increased stress and mortality in situations where the vegetation and other habitat features which a particular animal species requires are not able to migrate as quickly as the animal itself, causing animal populations to experience a geographic mismatch between its climatic needs and habitat needs (Nelson et al., 2007).

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[16] In BC, increases in drought stress due to climate change are expected to change the drier Boreal White and Black Spruce (BWBS) biogeoclimatic zone into an ecosystem which is more similar to the Sub-boreal Spruce (SBS) zone (Hebda, 1997).

4.2. MITIGATING THE IMPACTS OF CLIMATE CHANGE: RESISTANCE, RESILIENCE, AND LONG-TERM ADAPTATION

As the discussion above has indicated, climate change will result in significant changes to the disturbance regimes of Canada's boreal forests. The stability of an ecosystem is largely dependent on the ecosystem's resistance and resilience to disturbances. Ecosystem resistance can be defined as the ability of an ecosystem to withstand disturbances without experiencing significant loss of function; whereas ecosystem resilience is the ability of an ecosystem to return to its pre-disturbance functional state following a disturbance[17] (Glick, et al., 2009). Ecosystem resistance and resilience varies greatly between ecosystems and is known to be influenced by a number of different factors. The most paramount of which is likely biodiversity. The relationship between biodiversity and ecosystem resistance and resilience will be discussed in section 4.2.1.

It is expected that, within the next 50 years, the impacts of climate change will likely exceed the resilience and resistance thresholds of many ecosystems (Fischlin, et al., 2007). When these thresholds are exceeded, ecosystems can be expected to undergo significant changes. Of course, ecosystems have always changed throughout time. However, there is great concern that the fast rate in which our climate is changing, in combination with other anthropogenic influences (e.g. habitat fragmentation and destruction), may cause ecosystems to undergo exceptionally rapid and catastrophic changes. It is therefore important to develop management strategies which will help enable or facilitate smoother long-term adaptations to climate change (Glick, et al., 2009).

It should be remembered that ecosystems, as a whole, do not adapt to environmental changes. Rather, it is the species which ecosystems are composed of which will be forced to adapt to climate change. Species have three possible means of adaptation. Perhaps the most obvious is adaptive evolution, in which genotypes are altered through the process of natural selection. However, for the vast majority of species, adaptive evolution will likely be too slow to keep up with the rapid pace of climate change due to genetic constraints on the speed of adaptive evolution and the restriction of gene flow caused by habitat fragmentation (Davis & Shaw, 2001). Fortunately, species can also adapt to climate change by migrating to suitable habitats. It is quite clear migration is the most common way in which species have adapted to past climate changes, and it is likely to be a very important means of adapting to current changes in climate (Noss, 2001). There will also be some species which will not have their current environmental tolerances exceeded by climate change. Therefore, these species will be able to acclimate to changes in climate due to phenotypic plasticity (Charmantier, et al., 2008).

Much of the concern regarding climate change revolves around the question of whether species will be able to adapt fast enough in order to avoid major losses in biodiversity (e.g. Visser, 2008). A study published in the journal *Nature* projected species distributions for future climatic scenarios and predicted that, given a mid-range climate-warming scenario, 15-37% of species will be "committed to extinction" by 2050 (Thomas, et al., 2004). The IPCC (2007) reported that "there is medium confidence that approximately 20-30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-

[17] "Ecosystem function" can be defined to include a wide range of land management goals. For example, it can be defined as the ability of an ecosystem to provide habitat to populations of a particular species or group of species. It can also be defined as the ability of an ecosystem to "support sustainable levels of a natural resource such as timber or provide certain ecosystem services, such as clean water. These goals are not necessarily mutually exclusive, but they may require different strategies to achieve (Glick, et al., 2009)."

1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe."

The greatest impacts of climate change on the world's natural systems will result from a combination of climate change and other anthropogenic stressors (especially habitat degradation, destruction, and fragmentation) which restrict natural adaptive processes from taking place; and which decrease ecosystem resistance and resilience (Glick, et al., 2009; Fischlin, et al., 2007; Campbell, et al., 2008). Therefore, it may come as little surprise that some of the most commonly suggested strategies for reducing the impact of climate change on the natural environment call for the reduction of non-climatic, anthropogenic stressors on the natural environment (e.g. Fischlin et al., 2007). Perhaps the most comprehensive means of achieving this goal is through the preservation of intact ecosystems. This is indeed one of the most commonly suggested strategies for mitigating the effects of climate change (e.g. Glick, et al., 2009; Nelson, et al., 2007; Wilson & Hebda, 2008; Noss, 2001). This suggestion has extensive empirical support from a wide range of studies which clearly indicate that intact ecosystems are more resistant, resilient, and capable of adapting to changes in climate (Folke, et al., 2004; Noss, 2001).

4.2.1. The Importance of Biodiversity

Biodiversity can be thought of as being akin to "natural climate insurance" (Mantua & Francis, 2004). This is because scientific evidence clearly indicates that biologically diverse ecosystems will be more capable of withstanding many of the elements of climate change (Glick, et al., 2009). A number of studies have found that the species richness of ecosystems (or, in other words, the number of different species in an ecosystem) is positively correlated with ecosystem stability and tolerance of environmental extremes. The most likely reason for this is related to the fact that, within ecosystems that have high levels of species richness, multiple species often provide the same ecosystem function (i.e. belong to the same functional group)[18] (Noss, 2001). For example, a number of different bird species may pollinate the same plant species. This diversity within functional groups is called ecological redundancy, and it is easy to see how ecosystems with high levels of species richness generally exhibit more ecological redundancy than less diverse ecosystems. Ecological redundancy contributes to ecosystem stability because "a functional group with more diverse membership can maintain its role in the ecosystem despite fluctuations in the member species", where these fluctuations may be driven by environmental changes such as climate change (Noss, 2001). For example, while one bird species that pollinates a particular plant species may be adversely impacted by climate change, another bird species that also pollinates the same plant species may exhibit a neutral or positive response to climate change. The ecological redundancy in this ecosystem would therefore be expected to decrease the impact of climate change on the plant species[19]. The importance of this can be seen when one considers that this plant species likely performs critical ecosystem functions as well (e.g. fixing nitrogen or providing wildlife habitat).

Species richness and diversity within functional groups are not the only measures of diversity that are important for ecosystem stability. Another very important aspect of biodiversity is the genetic diversity within species and populations (Glick, et al., 2009). The importance of maintaining biodiversity between populations has been well

[18] Some examples of functional groups include groups of species "that pollinate, graze, predate, fix nitrogen, spread seeds, decompose, generate soils, modify water flows, open up patches for reorganization, and contribute to the colonization of such patches (Folke, et al., 2004)." If an important ecosystem function is only provided by one species, this species is sometimes considered to be a "keystone species."

[19] It should also be noted that there is also evidence which suggests that ecosystems containing a diverse array of functional groups (as opposed to diversity within functional groups) can also be expected to be more stable than ecosystems which have a lower diversity of functional groups (Folke, et al., 2004).

illustrated by a study on the sockeye salmon of Bristol Bay, Alaska. This study found that the presence of hundreds of discrete and locally adapted salmon populations within the region enabled regional salmon populations to remain relatively stable despite major changes in climatic conditions. This stability occurred because populations "that were minor producers during one climatic regime have dominated during others, emphasizing that the biocomplexity of fish stocks is critical for maintaining their resilience to environmental change (Hilborn, et al., 2003)." Similarly, genetic diversity within populations is important because it can be expected to dampen the effects of environmental changes (Noss, 2001; Folke, et al., 2004). For example, if the trees of a particular species within a forest have a diverse array of genotypes (i.e. the population has a high level of genetic diversity), an environmental stressor (e.g. drought or high winds) would likely impact the individuals of the population in different ways, thus mitigating the net impact of the disturbance. Conversely, if the population had a lower level of genetic diversity, there is a greater likelihood that a single disturbance event could decimate the entire population.

Biodiversity not only helps maintain ecosystem stability, but it also plays an essential role in the long-term adaptation of species. This is because the adaptive evolution of species directly depends on the genetic variation (i.e. diversity) within and among populations; and high levels of this variation are well known to enhance the capacity of populations to undergo adaptive evolution (Noss, 2001). Since genetic diversity within populations is generally positively correlated with population sizes, maintaining or creating large populations is an effective and commonly suggested strategy for enhancing the ability of species to adapt to climate change (Campbell, et al., 2008).

4.3. THE IMPORTANCE OF THE PEACE RIVER VALLEY'S FORESTS IN MITIGATING THE EFFECTS OF CLIMATE CHANGE

The following sections discuss the various ways in which the forests of the PRV help mitigate the adverse effects of climate change by contributing to ecosystem resistance, resilience, and long-term adaptation capabilities.

4.3.1. The Peace River Valley's Biodiversity

The Peace River Valley contains incredible floral and faunal diversity, which undoubtedly contributes to ecosystem resistance, resilience, and long-term adaptation capabilities of the valley's ecosystems. A wildlife diversity survey from the 1970's found 311 wildlife species inhabiting the valley (Blood, 1978 cited in Chillbourne Environmental, 2009). This included 59 species of mammals, 215 species of birds, 29 species of fish, 6 species of amphibians, and 2 species of reptiles. In addition, the Peace River Valley potentially contains 21 wildlife species which the provincial government of BC considers to be *red-listed* (i.e. endangered or threatened), and 42 additional *blue-listed* species (i.e. of special concern) (BC Conservation Data Centre, 2009). Given the wide variety of wildlife species found in the Peace River Valley, as well as the large population sizes of many of these species, it is of no surprise that the Peace River Valley is known as one of the top wildlife viewing areas in BC, if not Canada.

The Peace River Valley also contains impressive floral diversity, with vegetative assemblages ranging from grasslands to old-growth riparian forests. Over 400 species of vascular plants have been observed within the valley and its immediate surroundings (Hawkes, et al., 2006). The Peace River Valley contains a very significant number of rare plants. There are 2 *red-listed* and 4 *blue-listed* plant communities that potentially occur within the Peace River Valley (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). A recent survey of the Peace River Valley found 9 *red-listed* and 9 *blue-listed* vascular plant species within the valley. Of these 18 species, 6 had never before been documented as occurring within the Peace River Valley[20] (Hawkes, et al., 2006). It should also be noted that past surveys have found an additional 6 *red-listed* species that were not observed in this most recent survey; and at least some of these 6 species are likely to still occur within the valley (Hawkes, et al., 2006). Recent surveys have reported that the number of rare plant species which were found exclusively within the valley was 3 times greater than the number of rare plant species that were found exclusively in the valley's surrounding plateaus. The valley's rare plants are particularly prevalent at the valley's lower elevations (the valley's lower terraces, riparian zones, and islands) and on the valley's breaks (Hawkes, et al., 2006).

Not only does the Peace River Valley provide habitat for a large number of species, but many of these species are represented in the valley by very large populations. As discussed in section 4.2.1., large populations are often beneficial in facilitating the adaptation of species to environmental changes such as climate change, due to the fact that large populations generally contain high levels of genetic diversity. Furthermore, in situations where adaptation depends upon migration, large populations generally hold an advantage over smaller ones because there is generally a greater probability of successful dispersal events from larger populations (Nelson, et al., 2007). The Peace River Valley's large animal populations also hold great socioeconomic importance by attracting thousands of hunters and wildlife enthusiasts to the valley each year. Among those who value the valley's rich wildlife resources are the region's First Nations who maintain a very special connection to the valley's wildlife (Box 1).

The Peace River Valley supports particularly high density ungulate populations. This is largely because snowpack depths within the valley are significantly lower than other areas of Northern BC (Blood, 1991; Simpson K. , 1991). The valley's south facing breaks are especially critical in this regard (Box 6). Moose and mule deer are traditionally the most abundant ungulates (and large mammals) of the Peace River Valley**.** Moose are attracted to the valley's riparian areas because of the thermal cover, snow interception, and high quality forage provided by these habitats (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). Moose densities within the Peace River Valley have been reported to vary from 0.7 to 3.4 individuals/km^2. Densities at the higher end of this range have generally been observed during severe winters, when moose migrate to the valley to avoid deep snow on the surrounding plateaus (Blood, 1991). Mule deer population densities in the Peace River Valley, from Fort St. John to Hudson Hope, varied between 0.6 and 2.4 individuals/km^2 during the winter months of the 1960s and 1970s. In the late 1980's deer densities in the valley increased to approximately 5.6 individuals/km^2 (Blood, 1991). Wildlife surveys

Box 6: Winter Ungulate Habitat

Snow depth is a very important factor for determining the winter ranges of ungulates. This is largely because ungulates have difficulty moving when snow depths approach chest height. Snow depth tolerance thresholds for deer (40 cm), elk (50 cm), and moose (70 cm) vary due to the size differences between these species (Simpson K. , 1991).

The lowest snow depths in the Peace River Valley can be found on the valley's south and southwest facing breaks, where steep slopes and high exposure to the sun result in lower rates of snowfall accumulation and higher rates of melting. These habitats are critical to the survival of deer and elk, due to their low snow depth tolerance. When regional deer populations are high, these breaks will support up to 10 deer per km^2 (Blood, 1991). Moose can also be expected to utilize south facing breaks during particularly severe winters (Simpson K. , 1991).

[20] A total of 24 species were recorded for the first time in the study area (i.e. the PRV and its immediate surroundings), including 2 species which had never been documented before as occuring within BC.

of the Peace River Valley have generally found the ratio of mule deer to white-tail deer to be approximately 20 to 1 (Blood, 1991; Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). The Peace River Valley also provides habitat for approximately a thousand elk, which have increasingly utilized the valley over the past few decades (Thiessen, 2009).

Ungulates are by no means the only type of animal that is highly abundant in the Peace River Valley. For example, avifauna are also very numerous within the valley. It has been estimated that 13 species of birds breed more abundantly within the PRV than any other location (Siddle, 1982). These species include the Broad-winged Hawk, Barred Owl, Blue-Jay, Philadelphia Vireo, Black and-White Warbler, Tennessee Warbler, Magnolia Warbler, Black-throated Green Warbler, Cape May Warbler, Bay-breasted Warbler, Ovenbird, Mourning Warbler, and Canada Warbler. All of these species are most abundant in the Peace River Valley's riparian forests and islands. Of these 13 species, 2 are *red-listed* (Cape May Warbler, Bay-breasted Warbler) and 3 are *blue-listed* (Broad-winged Hawk, Black-throated Green Warbler, and Canada Warbler) (Siddle, 1982; BC Ministry of Environment).

4.3.1.1. The Peace River Valley's Mature and Old-growth Forests

One important aspect of the Peace River Valley's biological diversity is that much of this diversity can be attributed to the valley's mature and old-growth stands. Older forests are often associated with high levels of biodiversity. This is largely due to the wide variety of habitats provided by the structural complexity of these forests. For example, one particularly important structural component of mature and old-growth forests is the large amount of decaying wood that they contain, which provides critical habitat to a wide variety of species. In the Boreal White and Black Spruce biogeoclimatic zone (BWBS), which includes the entire Peace River Valley, mature forests can be defined as deciduous stands over 80 years old and coniferous stands over 100 years old. Old-growth forests in the BWBS are defined as deciduous stands over 100 years old and coniferous stands over 140 years old (BC Ministry of Forests, 1995).

The Peace River Valley contains a disproportionately large amount of mature and old-growth forests compared to its surrounding regions. Approximately 70% of the Peace River Valley's forests are currently more than 80 years old (Keystone Wildlife Research Ltd., 2009). To put this figure into perspective, in the early 1990s, approximately 53% of the 1.5 million ha of forest surrounding the PRV was older than 80 years (Figure 6). It should be noted that the amount of old forests in this region is likely lower today than it was in the early 1990s, due to the mountain pine beetle outbreak and increases in fire activity (Kurz, et al., 2008; Nelson, et al., 2007). Perhaps the primary reason that the Peace River Valley's forests are, on average, older than the forests of its surrounding region is that the frequency of stand destroying fires has been lower in the Peace River Valley (Industrial Forestry Ltd., 1991). Another contributing factor is that there has been a historical lack of logging activity throughout much of the Peace River Valley (Lions Gate Consulting Inc., 2002).

Figure 6: Fort St. John and Dawson Creek Timber Supply Areas

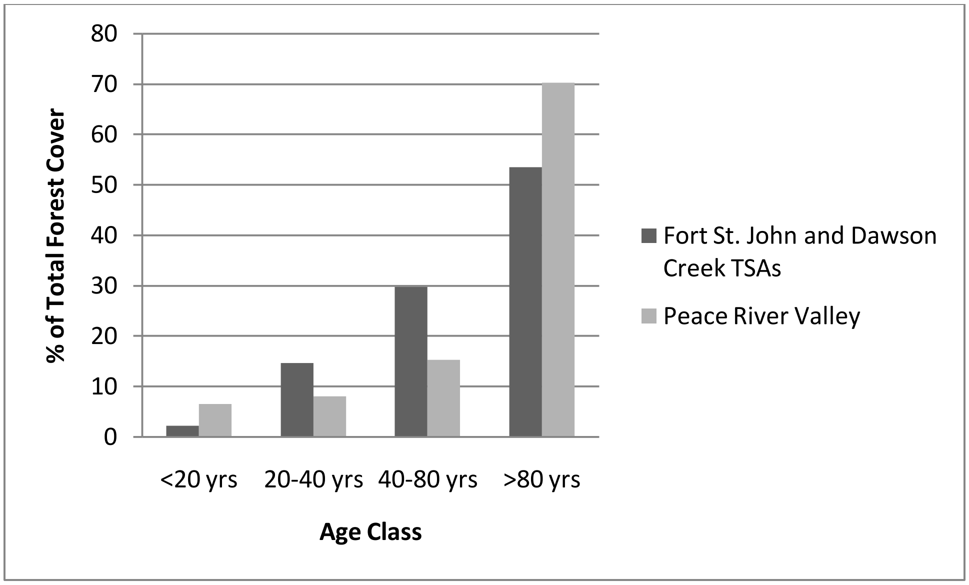

Figure 7: The age class distribution of the Peace River Valley, as well as the Fort St. John and Dawson Creek Timber Supply Areas (TSAs).[21]

A significant proportion of the Peace River Valley's biodiversity is dependent on mature and old-growth forests. For example, the valley's mature and old-growth aspen stands provide a large supply of high suitability habitat for the *red-listed* Connecticut Warbler (Simpson, et al., 2009; Hawkes, et al., 2006)**.** The six species of bats which have been confirmed to occur in the Peace River Valley, including the *blue-listed* Northern Myotis, are also highly dependent on the valley's deciduous old-growth forests for roosting habitat[22]. The bats of the Peace River Valley have been found to roost primarily within large balsam poplar trees or snags, although trembling aspen is used as well (Kellner & Simpson, 2009). The large balsam poplars found in the Peace's older riparian forests are also very important nesting sites for the Peace River Valley's large Bald Eagle population (Simpson, et al., 2009). These forests are also known to be important providers of nesting habitat for the owls which reside in the Peace River Valley. This is especially true for the Great Horned[23] and Great Gray Owls. Fishers, a *blue-listed* furbearer of high cultural and economic importance to First Nations, are also known to utilize habitat provided by the Peace River Valley's mature and old-growth riparian poplar stands (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006).

The mature and old-growth mixed-wood and coniferous stands of the Peace River Valley also hold great importance to a number of species. For example, Martens are known to prefer the mature and old-growth coniferous stands of the Peace River Valley[24] (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006). The Peace River Valley's older riparian stands which contain white spruce are important

[21] The entirety of BC's Peace River Valley is located within the boundaries of either the Fort St. John or Dawson Creek TSA, which include a combined total of over 1.5 million ha of crown owned forest available for long term timber supply. Peace River Valley data was obtained from Keystone Wildlife Research Ltd. (2009). TSA data was obtained from Industrial Forestry Ltd. (1991).

[22] These species included the little brown myotis (*Myotis lucifugus*), long-legged myotis (*M. volans*), northern myotis (*M. septentrionalis*), big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*) and hoary bat (*Lasiurus cinereus*).

[23] The Great Horned Owl holds special spiritual values to First Nations (Simpson, et al., 2009).

[24] Martens are the most commonly trapped furbearer in the region and are of great cultural and economic importance to First Nations (Saulteau First Nations; West Moberly First Nations; Government of British Columbia, 2006).

breeding habitat for the *blue-listed* Black-throated Green Warbler (Simpson, et al., 2009). The habitats which are most suitable for this species are predominantly located along segments of the Peace River Valley that are between Fort St. John and Hudson's Hope (Hawkes, et al., 2006). The *red-listed* Bay-breasted and Cape May Warblers, which are thought to be present in low numbers within the Peace River Valley, also largely rely on mature white spruce forest (Simpson, et al., 2009).

It is very likely that the Peace River Valley's old-growth forests also provide critical habitat to a variety of plant species. It has been estimated that, globally, approximately 30% of forest flora are confined to old growth forests (Ellenberg et al. cited in Honnay et al., 2002). Unfortunately, no documentation specifying the flora that are dependent on the Peace River Valley's old growth forests was found.

According to Honnay et al. (2002), old growth dependent forest species are among the species most sensitive to changes in climate[25]. Many of the old-growth dependant species of the Peace River Valley are currently threatened because of habitat loss (e.g. Warblers and Marten) (Cooper & Beauchesne, 2004; BC Government Integrated Land Management Bureau, 1999). As previously discussed, climate change is expected to result in an increase in the frequency of stand initiating disturbances (e.g. fires and insect epidemics) throughout the boreal ecosystem (Section 4.2). This will result in a general decrease in the quantity of mature and old-growth stands. Therefore, the conservation of currently existing mature and old-growth boreal forests holds even greater importance in the context of climate change (Nelson, et al., 2007).

Another important consideration regarding the mature and old-growth forests of the Peace River Valley is that these forests significantly contribute to landscape heterogeneity within the greater Peace River region. This is significant in the context of climate change because a heterogeneous distribution of forest age classes is well known to be important for dampening the effects of disturbances. This is because forests of different age classes will respond to disturbances in different ways, similarly to the way in which biological diversity dampens the effects of disturbances (Opdam & Wascher, 2004).

4.3.1.2. The Peace River Valley's Wetlands

A significant portion of the Peace River Valley's diversity can be attributed to the valley's wetlands. For example, wetlands (especially fens and backchannels) "support the majority of the [Peace River Valley's] breeding amphibian populations" (Hawkes, et al., 2006). The valley's wetland habitats also support a wide variety of other animals, including populations of **"**reptiles, marsh-nesting birds, shorebirds, waterfowl, cranes, small mammals, raptors, furbearers, large mammals, dragonflies, and bats (Hawkes, et al., 2006)". Furthermore, the Peace River Valley's wetlands are also a significant source of floral diversity (Hawkes, et al., 2006).

The Peace River Valley's wetlands hold significance in the context of climate change partially because climate change is expected to result in decreases in the extent of wetland cover in BC's central and northern interior regions (Hebda, 1997; Wilson & Hebda, 2008). Temperatures increases in the boreal ecosystem have the potential to increase evaportranspiration (i.e. water lost to the atmosphere through evaporation and transpiration), thus decreasing runoff and lowering groundwater levels, and potentially causing the drying of wetlands (Kusler, 1999)**.** Climate change has already been linked to significant decreases in wetland cover in some of Alaska's boreal regions (Klein, et al., 2005). In the particularly hot and dry year of 2006, many of the wetlands near the Peace River

[25] This is especially true when these species exist in fragmented landscapes (see section 3.2).

reportedly dried up by late August[26] (Hawkes, et al., 2006). Events such as this may become more frequent due to climate change. Many of the Peace River Valley's wetlands are likely highly to be resistant to drought because of the influence of the Peace River and the higher water tables of the valley.

4.3.1.3. The Peace River Valley at the Margin of Species Ranges

The geographic location and unique microclimate of the Peace River Valley allow the valley to support populations of a number of different species at the northern edge of their geographical distribution. For example, the Peace River Valley contains some of the most northerly habitat of the Connecticut Warbler, a *red-listed species in* BC (Cooper & Beauchesne, 2004; Simpson, et al., 2009; Cooper & Beauchesne, 2004). The Peace River Valley also supports some of the most northerly populations of the Common Garter Snake (*Thamnophis sirtalis* var. *parietalis*), Western Terrestrial Garter Snake (*T. elegans*), and Long-toed Salamander (Hawkes, et al., 2006). The valley is also known to contain some of the most northerly populations of two bat species, the Long-legged Myotis *(Myotis volans*) and the Hoary Bat *(Lasiurus cinereus)* (Kellner & Simpson, 2009). A number of plant species also have some of their most northerly populations located within the Peace River Valley (e.g. prickly pear cactus) (Chillborne Environmental, 2009).

Areas in which species exist at the edges of their geographic ranges have been identified as holding special conservation importance in the context of climate change (Thomas, et al., 2001; Hampe & Petit, 2005). At the upper latitudinal boundaries of species ranges, climate change is expected to result in increases in the colonization of populations, as new habitat becomes available due to increasing temperatures. Conversely, climate change is expected to cause populations to undergo the highest rates of extirpation at the lower latitudinal boundaries of species ranges. Differences in the ratio of colonization to extinctions at the northern and southern boundaries of species ranges, respectively, are expected to result in the pole-ward shifts for many species ranges (Honnay, et al., 2002).

The conservation of populations at the northern margins of their ranges is very important in the context of climate change since these populations can be expected to play a large role in the colonization of new habitats. Without these colonizations, climate change will result in the shrinking, rather than the shifting, of species ranges (Glick, et al., 2009). Taking measures to protect, and even enhance, the reproductive success of "isolated populations of species at the northern edges of their ranges" has been suggested as a strategy which can be used to enhance the capacity of long-term adaptation to climate change (Innes, et al., 2009). It is important to note that populations existing at the margins of their species ranges can generally be expected to be more susceptible to extirpation due to environmental disturbances (such as those which are expected to increase in severity and frequency in BC due to climate change) than populations that are more centrally located within the specie's geographic distribution[27] (Mehlman, 1997; Opdam & Wascher, 2004). Therefore, the preservation of the Peace River Valley's many populations which exist at the northern margins of their species ranges holds special significance in the context of climate change not only because many of these populations will gain increased importance due to climate change, but also because climate change will increase the vulnerability of these same populations.

[26] This may have contributed to the high levels of usage of the Peace River by waterfowl during the fall of 2006 (Hawkes et al., 2006).
[27] This is partially because less favourable climatic conditions at the edges of species distributions contribute to smaller population sizes. Another factor influencing this is that suitable habitat is generally more fragmented at the edges of species ranges (Opdam & Wascher, 2004).

4.3.2. The Peace River Valley as a Habitat Corridor

The ability of species to move between different habitats and regions is critical to both the short and long-term health of populations[28]. Most species are not able to freely move across any particular landscape. Rather they require the area through which they move to hold particular attributes. In most cases, relatively high degrees of forest cover or natural vegetation can generally be assumed to provide connectivity between habitats. Wetlands, riparian zones, and semi-natural land cover (e.g. agricultural land) can also be important sources of connectivity (Vince & Churchill, 2002). Habitat connectivity can be decreased by a number of different anthropogenic and natural factors (e.g. the development of urban areas and the destruction of forests by fire), thus limiting the movement of floral and faunal species across the landscape.

It is well known that major river valleys are often critical wildlife corridors, and the Peace River Valley is no exception. The entire Peace River Valley has been designated as being one of the most important habitat corridors within the 1.4 million hectare Peace River Survey Block, which includes all of BC's Peace Lowlands Ecosection[29] (Vince & Churchill, 2002). According to Vince and Churchill (2002), the Peace River Valley is a major part of a "natural network of major rivers with tributaries that provide not only connectivity within the Peace Lowlands but with habitats beyond. The broad Peace River Valley provides the backbone of a natural network that links habitats within the Peace Lowlands and to the Rocky Mountain ecosystems to the west" (Figure 8).

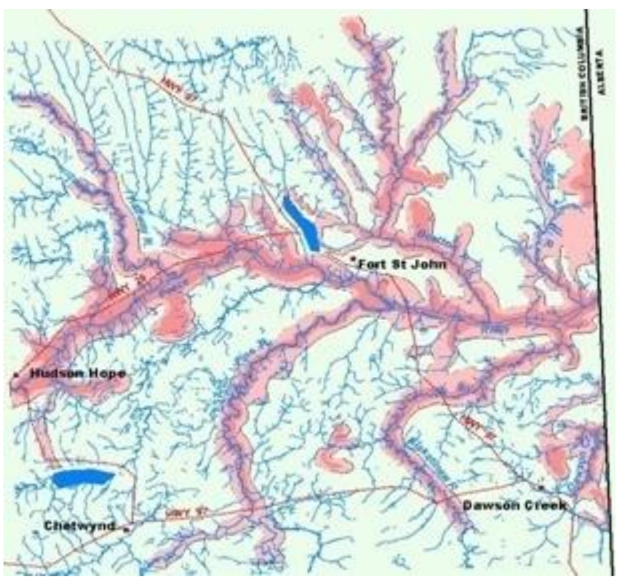

Figure 8: Critical wildlife corridors of the Peace River Valley and its surroundings. Source: (Vince & Churchill, 2002).

[28] While habitat connectivity is commonly perceived as being important to wildlife populations, studies have shown that connectivity is also of great importance to populations of forest plant species (Roy & de Blois, 2008).
[29] This survey block extends "from 60 kilometers north to 50 kilometers south of the Peace River, west from Hudson's Hope to the BC-Alberta border (Vince & Churchill, 2002)."

Not only is the Peace River Valley a vital East to West corridor, but it is also critical to the northern and southern movements of wildlife in the region. This is especially true for the area of the valley between Hudson's Hope and Fort St. John. This is because North-South habitat connectivity is limited west of Hudson's Hope all the way to the Western side of the Rocky Mountains due to the steep walls of the Peace Canyon and the wide shoreline and usually unfrozen waters of the Williston reservoir. East of Fort St. John, North-South connectivity is limited by extensive agricultural development (Figure 9).

Figure 9: Satellite image showing the critical North-South habitat connectivity provided by the Peace River Valley. The segment of the valley which is most important to the region's connectivity is east of the Peace Canyon Dam and west of Fort St. John. Image source: (Google Earth, 2009).

According to the Yellowstone to Yukon Conservation Initiative (n.d.), the Peace River Valley is located within a region of critical importance for connectivity between southern and northern grizzly bear populations. Although grizzly bear sightings in the valley are rare, they do occur. According to Clarence Willson, councillor of the West Moberly First Nations, elders of the West Moberly and Saulteau First Nations know of a family of grizzly bears that annually travels through an area which is located approximately 30 km south of the Peace River Valley (Yellowstone to Yukon Conservation Initative, 2007).

The Peace River Valley's role as a habitat corridor will become increasingly important as climate change increases the levels of stress experienced by the region's floral and faunal populations. Habitat connectivity is critical for the facilitation of migrations, interbreeding between geographically dispersed populations, and the colonization of new habitats. The roles which habitat connectivity play in facilitating seasonal migrations and interbreeding greatly contributes to the general health of populations, thus increasing resistance and resilience to climate change[30] (Millar et al. 2007). Habitat connectivity is also of importance to long-term adaptation to climate change, due to its critical role in enabling species to shift their ranges by colonizing new habitats (see section 4.2). Populations which are generally most sensitive to habitat fragmentation include those which are dependent on old-growth forests and those which are already small and isolated (Honnay, et al., 2002; Innes, et al., 2009). Recorded effects of habitat fragmentation (i.e. the loss of habitat connectivity) include population decline and extinction, loss of genetic diversity, greater impacts from environmental disturbances, and reduced recovery times following environmental disturbances (Opdam & Wascher, 2004). Given the great importance of habitat connectivity, it is of no surprise that the preservation of habitat connectivity is frequently cited as one of the most important measures which should be taken to reduce the adverse effects of climate change on the natural environment (Noss, 2001).

The forests of the Peace River Valley are a very important source of habitat connectivity and the preservation of this connectivity could be expected to play a major role in mitigating the effects of climate change, both within the valley and in surrounding regions. It is important to note that climate change is expected to increase habitat fragmentation throughout the boreal ecosystem, due to the role climate change is expected to play in increasing the frequency and severity of disturbances; thus increasing the rarity of functional habitat corridors. The impact of climate change only adds to the importance of taking measures to conserve the Peace River Valley's habitat connectivity.

[30] The facilitation of seasonal migrations can be expected to positively influence survival rates and populations sizes; whereas interbreeding holds significance due to the role it plays in increasing the genetic diversity of populations (Bond, 2003).

5. AGRICULTURE AND CLIMATE CHANGE

5.1. THE PEACE RIVER VALLEY'S AGRICULTURAL QUALITIES

5.1.1. Overview of the Peace River Valley's Agricultural Industry

Agriculture has been an important industry in the Peace River Valley, and the surrounding Peace River region, ever since the late 1800's when the first European settlers began arriving in the area. The town of Taylor in the Peace River Valley was the hub of Northeastern BC's agricultural activity until the 1940's when agriculture began to spread more broadly throughout the Peace River region (BC Integrated Land Management Bureau, 1997). Today, over 850,000 ha are farmed within the Peace River regional District (PRRD), accounting for 34% of all land that is currently farmed in BC. The region accounts for over one third of BC's Agricultural Land Reserve (ALR) (see Box 11 for a description of the ALR and the challenges that it faces). Approximately 30% of the PRRD's farmed land is used for cropping, while the majority of the remaining 70% is used as pasture. In 2001, the district's gross farm receipts totaled $119 million (BC Ministry of Agriculture and Lands, 2002). The agricultural industry provides direct employment for approximately 13% of the region's working population, and is also important as it "sustains a local pool of skilled, adaptable workers for other industries such as guide outfitting, forest harvesting, wood processing, oil and gas exploration and development, and infrastructure maintenance for roads and railways (BC Integrated Land Management Bureau, 1997)." The agricultural industry also plays a fundamental role in helping to make the region's economy among the most diverse in all of BC[31] (BC Integrated Land Management Bureau, 1997).

Box 7: Land Capability Classification for Agriculture in British Columbia

Class 1:Has no or only very slight limitations that restrict its use for the production of common agricultural crops.
Class 2: Has minor limitations that require good ongoing management practices or slightly restrict the range of crops, or both.
Class 3: Has limitations that require moderately intensive management practices or moderately restrict the range of crops, or both.
Class 4: Has limitations that require special management practices or severely restrict the range of crops, or both.
Class 5: Has limitations that restrict its capability to producing perennial forage crops or other specially adapted crops.
Class 6: Is non-arable but is capable of producing native and/or uncultivated perennial forage crops.
Class 7: Has no capability for arable culture or sustained natural grazing.

Source: (BC Ministry of Environment, 1983)

[31] The number of people direct employed in the agricultural sector in the District of Taylor grew from 240 in 1971 to 325 in 1996; accounting for 25% of the district's total employment in 1996. This growth in the number of PRV's agricultural jobs occurred due to a realization of the region's high agricultural potentials rather than national trends. This is indicated by the fact that while agricultural jobs in the PRV were increasing, the total agricultural labour force of Canada declined dramatically. Furthermore, between 1981 and 1996, average gross farm receipts per farm increased 170% in the District of Taylor and 256%

The Peace River region is very suitable for the production of a wide range of agricultural commodities. Zebrath et al. (1997) provide a good description of the region's agricultural production characteristics:

> "Agricultural production within the Peace River region is more typical of what would be found in much of Alberta or Saskatchewan than in the remainder of British Columbia and consists primarily of production of cereals and oilseeds, pulse crops, alfalfa, and forage grasses used for hay and grazing and commercial forage seed production. Animal production is in the form of both ranching operations and as part of a diversified cattle/forage/grain agricultural system. These combine to include approximately 70,000 head of livestock within the region…Crop production in this region is limited by temperature, precipitation and soil type. The cool, dry and relatively short growing season limits the varieties of crops which can be grown and the potential crop yields. Soils in the region are commonly medium to fine textured with good fertility and capable of excellent yields given good rainfall distribution (Zebarth, et al., 1997)."

Most farms within the Peace River Valley currently produce much of the same agricultural commodities which are produced throughout the greater Peace River region (i.e. cereals and oilseeds, pulse crops, alfalfa, forage grasses, and livestock). However, due to the superior soils and microclimate of the valley, yields obtained within the valley are significantly greater than those obtained from lands elsewhere in the region. In fact, the high agricultural capability of the Peace River Valley allows the valley to produce the majority of BC's grain and canola crops (Keystone Wildlife Research Ltd., 2009). Additionally, it is well known that the Peace River Valley is capable of economically growing crops which cannot be grown elsewhere in the Peace River region (see section 5.6 and Table 3).

5.1.2. The Agricultural Capability of the Peace River Valley

The Peace River Valley is endowed with a substantial quantity of Northern BC's most productive agricultural lands. The "Land Capability Classification for Agriculture in British Columbia" is a system which rates the agricultural capabilities of BC's lands according to their climatic and soil characteristics. Land rated as Class 1 has the highest capabilities for agricultural production, while Class 7 land has the lowest agricultural potential (see Box 7). Table 2 shows the amount of the Peace River Valley's land that is classified under each capability class (Lions Gate Consulting Inc., 2002). At least 75% of the valley's land area is suitable for the production of vegetable, grain, and forage crops (Class 1 to Class 4).

The Peace River Valley contains the vast majority, if not all, of the Class 1 land in Northern BC (2,564 ha, or 9.6% of the valley). The most common agricultural capability rating of lands within the Peace River Valley is Class 2 (48% of the valley). Although the 16% of the valley that is classified as Class 5 and Class 6 have limited potentials for agricultural development, these lands are often very important rangelands for livestock production.

It is important to note that the primary limitation on the majority of the Peace River Valley's agricultural lands is moisture availability (Keystone Wildlife Research Ltd., 2009). Therefore, the agricultural potential of much of the Peace River Valley's lands could be greatly enhanced through irrigation (BC Ministry of Environment, 1983). Although there is currently very little irrigation in the valley, it would be very feasible to inexpensively irrigate the valley, using readily available water from the Peace River (Harris, 1982, b).

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in the town of Hudson's Hope. While some of this increase is due to inflation, most of it is the result of land use intensification and expansion (Lions Gate Consulting Inc., 2002).

5.1.2.1. The Peace River Valley's Climate

Many might intuitively believe that the Peace River Valley has poor climate for agricultural production due to its northerly location. However, this couldn't be further from the truth. Despite the Peace River Valley's northerly location, the valley's climate is considered to be among the best in Canada for agriculture. This is very significant because climate is considered to be the greatest limiting factor for agricultural production in Canada.

Zebrath et al. (1997) describes the general characteristics of the Peace River region's climate:

> The climate in the region can be classified as cool, continental semi-arid. Mean annual temperatures generally range from approximately -1 to 1.5 °C. Mean annual precipitation ranges from 480 mm in the south to 350 mm in the north, with approximately 65% as rainfall. Growing seasons are on the order of 100 to 110 days of frost free period with moisture deficits ranging from 250 to 300 mm. To counter this, the very long days make up the equivalent of several days of growth over the growing season and the dry mid-summer period promotes rapid grain ripening and maturity.

Harris (1982, a) provides a comprehensive overview of the climatic advantages of the Peace River region in comparison to the Southern Canadian Prairies (SCP), as well as the climatic advantages of the Peace River Valley in comparison to its surrounding plateaus. Largely owing to the superior climate of the Peace River region, yields of wheat, oat, and barley are higher in the Peace River region than in the SCP, and ripening requires fewer high degree days. One of the biggest factors influencing the differences in yields between these two regions is that the Peace River region generally experiences significantly less wind than the SCP. One disadvantage of the Peace River region's climate is that its minimum and maximum temperatures during the growing season are generally lower than those of the SCP. However, this is largely compensated for by the longer growing season days of the Peace River region which result in crops being exposed to low nighttime temperatures for shorter periods of time (Harris, 1982, a).

Table 2: Peace River Valley land area by Agricultural Land Capability Classification.

Capability Class	Description	Ha.	% of Total
1	Optimum potential, full range of crops	2,564	9.6
2	Wide range of crops, some restrictions	12,502	48.7
3	Wide range under good management	1,765	6.9
4	Restricted range, several limitations	2,116	8.3
5	Perennial forage crops, severe limitations	932	3.6
6	Natural rangeland, no cultivation	3,212	12.5
7	No agricultural capability	2,656	10.4
Total		25,747	100

Adapted from Lions Gate Consulting Inc. (2002).

Another important consideration is that winter soil temperatures are generally higher in the Peace River region due to the insulation provided by the more consistent snowpack. This is significant because it means that these soils require less heat in the spring to warm up to temperatures that are suitable for germination and root development (Harris, 1982, b). Furthermore, the Peace River region generally experiences lower potential evapotranspiration and greater growing season precipitation than the SCP. This is a major reason why irrigation is usually required in the SCP but not in the Peace River region (Harris, 1982, a).

The Peace River Valley has a microclimate which is far superior to the rest of the Peace River region. The valley's climate is classified as "Class 1"; which means that its climate is among the best in all of Canada for agriculture. In fact, less than 1% of Canada's total land base has a climate which is as high quality as the PRV's (Harris, 1982 b). Class 1 climates are also very rare in BC, and the PRV contains the only Class 1 climate in Northern BC (approximately north of Quesnel, BC)[32].

One of the primary reasons for the exceptional quality of the PRV's climate is that temperatures are significantly higher in the valley than on the surrounding plateaus (Harris, 1982, a). According to a study prepared for BC Hydro, the maximum growing season temperature difference between the valley and the plateau is 2.3 °C. However, this value likely understates the temperature differences between the valley and the plateau, as it was obtained through less than ideal sampling methodologies[33] (Harris, 1982, a). The seemingly small extra amount of warmth received by the valley greatly enhances the valley's yields. One reason for this is that the warmer temperatures of the valley contribute to the valley's longer frost-free period. The valley's frost-free period is often 3 weeks longer and sometimes more than 6 weeks longer than its surrounding plateau (Harris, 1982, a). Yields can also be enhanced when warmer air temperatures lead to warmer soils. Within the valley, temperatures and frost-free periods decrease at successively higher elevations. Therefore, the lowest elevations in the valley are often able to produce the highest yields (Harris, 1982, a).

Another important attribute of the Peace River Valley's microclimate is that wind speeds within the valley can be less than half of what they are on the surrounding plateau. The lower terraces of the valley have significantly lower wind speeds than the upper terraces; which in turn have significantly lower wind speeds than the surrounding plateau. This is significant because lower wind speeds contribute to increased yields. The difference in wind speed which has been observed between the upper and lower terrace (46%) "has been shown to reduce the yield of wind pollinated crops by 30%, insect pollinated crops by 87 to 205%, and crops that do not require pollination by 87% (Harris, 1982, a)."

5.1.2.2. Soils

The majority of the Peace River Valley's soils are exceptional in comparison to the rest of the Peace River region and BC as a whole. Much of the Peace River Valley's soils have high levels of natural fertility. The soils found in the Peace River Valley also generally have a desirable loamy texture which is important for moisture retention and adequate drainage. Due to its loamy soils, the Peace River Valley has some of the best drainage conditions in the entire Peace River region (Farstat, et al., 1965). In other areas of the region, fine textured soils limit draining and

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[32] It should be noted that hours of growing season sunshine are not included in climate classifications. It has been suggested that if this element were included in climate classifications, the PRV's climate could be considered superior to many locations in the Lower Fraser Valley and southeastern Vancouver Island for the production of many crops (e.g. vegetables) (Norecol Environmental Consultants Ltd., 1991).

[33] For example, plateau sampling sites were located near the edge of the valley, where they were likely affected by warm air rising from the valley (Harris, 1982, a).

often contribute to wet soil conditions in the spring and fall which adversely impact agricultural production (Zebarth, et al., 1997).

5.2. IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Climate change will undoubtedly have a substantial impact on food production throughout the globe. Many initial predictions regarding the nature of this impact were relatively optimistic in comparison to today's scientific consensus. These initial predictions were largely based on the expected benefits of $C0_2$ fertilization (Gregory, et al., 2005). However, it is now expected that in most cases the benefits of CO_2 fertilization will be offset by adverse changes in climatic conditions (Fuhrer, 2003). These negative impacts of climate change on agriculture will largely be felt through temperature increases, decreased water availability, increased occurrence of plant pests, and increases in the frequency and intensity of extreme meteorological events.

5.2.1. CO_2 Fertilization

As discussed in section 2.1, an increase in the atmospheric concentration of CO_2 is the primary driver of climate change. Atmospheric CO_2 also has an essential role in photosynthesis, and therefore plant growth. Studies have shown that increases in the atmospheric concentration of CO_2 can have a fertilization effect on crops by causing increases in the efficiency of photosynthesis, thus resulting in significantly increased yields. It has been estimated that a doubling in the atmospheric concentration of CO_2 could result in 30% yield increases in many of the world's most important crops (Fuhrer, 2003). However, this estimation is based on the growth of crops under optimal growing conditions (e.g. optimum temperatures and a non-limiting supply of water and nutrients). It is of course very rare that crops are actually grown under these conditions. Furthermore, in most cases, the benefits of CO_2 fertilization are expected to be offset by adverse changes in climatic conditions; such as excessively warm temperatures, decreased water availability, and increases in extreme events (Fuhrer, 2003).

5.2.2. Temperature

Changes in temperature can directly impact crops by influencing growth rates, phenological development, and the timing of specific developmental phases (e.g. germination) (Fuhrer, 2003). For example, wheat is well known to have a relatively low tolerance to warm temperatures at many stages during its development. Therefore, there is concern that increases in temperatures could cause significant decreases in the yield of wheat in many regions (Porter & Gawith, 1999). Higher maximum temperatures are expected to decrease the yields of many of the world's most important crops (e.g. wheat and rice). Increases in maximum temperatures are also expected to be detrimental to many crops, especially in tropical regions. However, in temperate regions, some crops will likely exhibit increased yields in response to increases in minimum temperatures (Easterling, et al., 2007). The greatest impact of increases in temperature will likely be felt through its impact on water demand and availability (discussed below).

5.2.3. Water Availability

In many agricultural regions, the greatest threat that climate change will pose to agricultural productivity will be from decreases in water availability. Globally, climate change is expected to have a negative net impact on water resources. This will occur both through changes in the volume, variability, and seasonality of precipitation; as well as through increases in temperature which will increase evapotranspiration (i.e. water lost to the atmosphere through evaporation and transpiration) (Kundzewicz, et al., 2007). Even in regions which will experience increases in precipitation, the net benefit derived from these increases will often be reduced by the impact of increased precipitation variability and shifts in runoff regimes (Kundzewicz, et al., 2007). For example, in many watersheds which rely on snowmelt for summer stream flows, warmer temperatures will lead to decreases in spring and summer snowpack (and therefore water availability) despite increases in annual precipitation[34]. In addition to climate change driven decreases in water availability, the supply of water available for agricultural production will become increasingly stressed due to increases in demand from domestic and industrial sectors. Limited water resources are much more likely to be allocated to these sectors, as they are generally willing to pay higher prices per unit of water than the agricultural sector[35] (Kundzewicz, et al., 2007).

The agricultural sector currently accounts for 90% of global consumptive water use and is expected to be the sector which will be hardest hit by decreases in water availability (Shiklomanov & Rodda, 2003). Not only will the sector face a declining water resource base and increasing competition for this resource base from domestic and industrial sectors, but the water demanded by agriculture will also increase. Much of this increase in demand will be caused by the agricultural expansion and intensification required to meet increasing global food demands (due to projected increases in population sizes and the affluence of populations). Increases in evaportranspiration (driven by temperature increases) will also increase the water demanded by the agricultural sector. In some cases, CO_2 fertilization may increase water-use efficiency for some crops, thus mitigating some of the effects of decreased water availability. However, the impact which this complex biological phenomenon has on crop yields is highly temperature dependent and studies suggest that temperature increases may significantly offset the positive effect of increased CO_2 concentrations[36] (Porter & Perez-Soba, 2001; Amthor, 2001). The projected decreases in water supply and increases in water demand are expected to have their most severe impact on the vast quantity of agricultural lands which currently experience arid and semi-arid climatic conditions. Some of the regions which are expected to be hit the hardest by decreases in water supply and increases in demand include western USA and the Okanagan region of BC (Kundzewicz, et al., 2007).

5.2.4. Pests

Climate change is also expected to impact agriculture by increasing the prevalence of crop pests (i.e. weeds, insects, and microbial pathogens). This will have serious negative implications on the agricultural sector. Temperature is the dominant abiotic (non-living) factor affecting herbivorous insect populations and even relatively minor changes in temperature can greatly alter the development, survival, range and abundance of these insects (Bale, et al., 2002). In regions of mid- to high-latitude, it is generally expected that insect pests will become more abundant and problematic. Insect pest conditions in the tropics are expected to experience relatively fewer changes (Fuhrer, 2003). The prevalence and distribution of microbial pathogens (i.e. fungal and bacterial pests) are also highly dependent on climatic conditions. In general, it is expected that regions experiencing warmer and moister conditions will face increased challenges from microbial pathogens (Patterson, et al., 2004). Climate change will impact weeds in many of the same ways that it will impact other plants, including agricultural commodities. The important question is how climate change will alter the balance of the competitive interaction between desirable plants (e.g. crops) and problematic plants (i.e. weeds). The impact which climate change will have on weedy plants will likely be highly situation dependent. However, one notable concern regarding the

[34] For example, this could result from increases in the proportion of precipitation falling as rain, as opposed to snow; and/or increases in the rate of snowpack melting during the spring.
[35] The expected increase in water demand by these sectors is primarily due to population and economic growth.
[36] It should be noted that elevated levels of atmospheric CO_2 have been shown to result in increased water use efficiency in a number of plants. However, it is currently unclear as to what mitigating effect this may have on yields in regions experiencing water stress (Fuhrer, 2003).

future of weeds is that climate change may facilitate the range expansion of aggressive tropical and subtropical weed species into temperate regions (Easterling, et al., 2007).

5.2.5. Extreme Events

It is also important to note that climate change will result in changes in the frequency and intensity of extreme meteorological events (e.g. droughts and storms) and that these changes will greatly affect food supplies and their accessibility. In fact, the IPCC has stated that "projected changes in the frequency and severity of extreme climate events will have more serious consequences for food production, and food insecurity, than will changes in projected means of temperature and precipitation (Easterling, et al., 2007)". Temperature and precipitation extremes can directly inflict a great amount of damage on crops. In addition, , extreme meteorological events can indirectly have even further reaching impacts. For example, extreme events are well known to be a major triggering factor for insect and plant disease outbreaks (Fuhrer, 2003). In some cases extreme events can also be expected to impact food accessibility; for example, by damaging transportation routes. Unfortunately, the precise impact which changes in the frequency and intensity of extreme events will have on agricultural commodities remains difficult to predict and has therefore been excluded from most analysis of the net impact of climate change on agriculture (Easterling, et al., 2007).

5.3. IMPACT OF CLIMATE CHANGE ON THE PEACE RIVER VALLEY'S AGRICULTURAL POTENTIAL

The Peace River region is frequently cited as one of the areas of BC and of Canada where the agricultural industry is expected to benefit the most from climate change (e.g. Zebarth et al., 1997; Lemmen & Warren, 2004). The increased agricultural potential of the Peace River region holds special significance given the negative net impacts of climate change on agriculture which are expected to occur throughout much of BC and North America (see sections 5.2.1-5.2.5).

As introduced in section 2.3, climate change is expected to bring warmer temperatures and more precipitation to Northeastern BC (including the Peace River region). Mean annual temperatures in the region are expected to increase 2-3°C. In general, minimum temperatures are expected to raise more than maximum temperatures. These temperature increases will lead to increases in the frost-free period and growing temperaturedays. For example, frost free periods will likely be increased by at least 10 days (Zebarth, et al., 1997). Long before there was scientific consensus regarding the warming of the global climate, Harris (1982) stated that "increasing the length of the frost-free period and/or increasing temperature would be the most positive way of improving [the agricultural capabilities of the] Peace River environment."

It is difficult to make precise estimates of how the alteration of one climatic variable (e.g. temperature) will impact crop yields. However, studies from Beaverlodge, Alberta (approximately 150 km southeast of BC's Peace River Valley) may shed some light on the nature of the impacts which can be expected from these increases in temperature. These studies found that "increasing the maximum air temperature an average of about 1.0°C increased the yield of wheat by 23% and advanced ripening by 10 days (Harris, 1982, a)." They also found that "increasing soil temperatures by 1-2°C for 1 month in late May, and June, increased the yield of sweet corn by 54% and bush beans by 61%, and advanced harvesting of corn by 4 days and beans by 2.5 days (Harris, 1982, a)." Increases in temperature can also be expected to increase the range of crops that can be grown in Northern BC (Walker & Sydneysmith, 2007).

The increases in precipitation which are predicted for the Peace River region can also be expected to have a positive impact on the region's agricultural capabilities. Growing season precipitation is expected to increase by approximately 10%, while increases in winter precipitation are expected to be slightly higher. Despite these increases in precipitation, increases in the demand for water by plants (due to increases in temperatures) may exceed increases in growing season precipitation (i.e. there will be increases in the climatic moisture deficit[37]) (Spittlehouse, 2008). Under moderate levels of warming, preliminary models have estimated that the climatic moisture deficit of Fort St. John in 2080 will be 30% greater than its 1961-1990 average (Spittlehouse, 2008). However, it should be noted that the Peace River region will likely be impacted by increases in climatic moisture deficits to a lesser degree than other regions in BC. This is because climatic moisture deficits in the Peace River region are not expected to increase as much as in other areas of BC (e.g. 60% increases are expected near Canbrook); and because the current climatic moisture deficits of the Peace River region are currently much lower than many other areas in BC (Spittlehouse, 2008). Nevertheless, increases in climatic moisture deficits may lead farmers in the Peace River region to take adaptive measures in dealing with this impact of climate change. One way in which farmers could adapt to increases in climatic moisture deficits is by irrigating their land. Currently, very little agricultural land is irrigated in the Peace River region (only 421 ha in 2001) (BC Ministry of Agriculture and Lands, 2002). The economic viability of irrigating much of the region's agricultural lands is questionable at present. Major obstacles include the lack of infrastructure and the difficulties involved in transporting water from the deep river valleys where most of the region's surface water is found (Zebarth, et al., 1997). One of the major advantages of agricultural land within the Peace River Valley is that the cost of irrigating this land would be substantially lower than the cost of irrigating its surrounding plateaus.

In general, increases in temperature and precipitation can be expected to lead to increased yields in the Peace River region. As the region's climate changes, the agricultural commodities which can be economically produced in the region can be expected to change as well. As discussed in section 5.1.2.1., the Peace River Valley's climate is currently superior to other agricultural lands in the Peace River region because of its warmer temperatures, longer growing season, and reduced wind. These climatic advantages which the Peace River Valley has over the rest of the Peace River region can be expected to continue into the future. The superior soils of the Peace River Valley will also help the farmers of the valley reap the greatest benefits from climate change. For example, the favourable drainage characteristics of the Peace River Valley's soils will be critical in a future of increased precipitation. The valley also holds a major advantage over its surrounding region in the context of climate change due to the fact that it would be much more economically feasible to irrigate the valley's agricultural lands than the lands of its surrounding plateaus.

5.4. IMPACT OF CLIMATE CHANGE ON BRITISH COLUMBIA'S CURRENT SOURCES OF FOOD

While climate change can be expected to increase the agricultural potential of the Peace River Valley, much of BC and North America will likely experience deteriorating agricultural conditions due to climate change. This is significant because much of BC's food is currently produced in these regions where climate change is expected to have negative net impacts on agriculture. According to the B.C. Ministry of Agriculture and Lands (2006), in 2001, approximately 52% of the food consumed in BC was produced outside of the province. The greatest source of BC's food imports is the United States. BC also imports large amounts of food from other provinces in Canada (Walker

[37] "A climatic moisture deficit occurs if the monthly precipitation is less than the monthly evaporative demand (Spittlehouse, 2008)."

& Sydneysmith, 2007). It is critical to consider how climate change is expected to impact agricultural production in the regions which play a major role in feeding British Columbians.

5.4.1. Impact of Climate Change on Agriculture in British Columbia

BC's agricultural industry will be primarily impacted by climate change through increases in temperature and decreases in growing season precipitation. Increases in temperature minimums will generally have a positive impact on BC's agricultural industry and may contribute to increased yields and opportunities to grow new crops in locations which were previously too cold. However, whether or not climate change will have a positive net impact on agriculture in BC will be largely dependent on water availability. Throughout most of the province, growing season moisture deficits are expected to increase. Warmer temperatures will essentially mean that crops will demand more water and more water will be lost to the atmosphere through evapotranspiration. To compound these issues, decreases in growing season precipitation are expected throughout much of the province (Zebarth, et al., 1997).

The impact of climate change on agriculture in BC will exhibit a high degree of spatial variability. As previously discussed, the Peace River region is one of the areas of BC where climate change will have its greatest positive impact on agricultural conditions. South costal BC is another region where agriculture will likely benefit from climate change. It is expected that this region's "horticultural and forage production would be substantially enhanced by a warmer, drier growing season" which would enable increased yields and the production of a more diverse array of crops (Zebarth, et al., 1997). Another region of BC where agriculture may benefit from climate change is the northern interior. Currently, beef is the primary agricultural commodity produced in this region. It is expected that increases in temperatures will allow the region to produce a more diverse array of crops (e.g. silage corn could be grown). However, increasing water deficits will act to decrease the region's agricultural potential. Overall, "it is expected that there will be an improvement in the potential for agricultural production in the region where irrigation is available but otherwise there may be limited net effect of climate change on agriculture (Zebarth, et al., 1997)."

The southern interior, including the Okanagan Valley, will likely be one of the regions of BC where agriculture will suffer the greatest adverse impacts from climate change. Agricultural production in this region primarily consists of irrigated horticultural crops (e.g. tree fruits and grapes) and non-irrigated forage production. The southern interior is currently very arid and climate change is expected to increase the aridity of the region by decreasing growing season precipitation and increasing temperatures. It is projected that, by the later part of this century, these climatic changes will cause this region's irrigation requirements to increase by 35% (Neilson, et al., 2001). It is also important to note that significant increases in the region's population are also expected to lead to increased demand on water supplies. Overall, it is predicted that reductions in the "availability of water for irrigation could result in substantial losses in productivity (Zebarth, et al., 1997)."

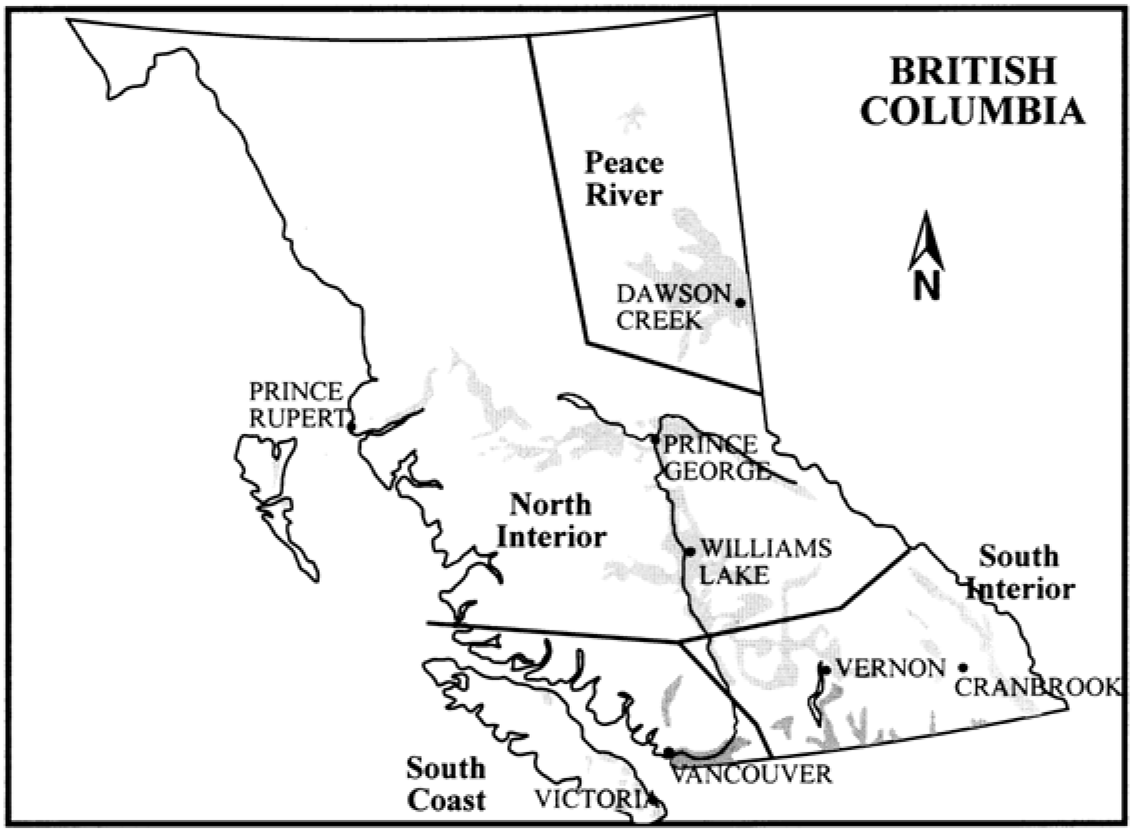

Figure 10: Agricultural production regions of BC. Source: (Zebarth, et al., 1997).

5.4.2. Impact of Climate Change on Agriculture in Canada

Climate change will impact Canada's diverse agricultural industry in a multitude of ways and the net impact that climate change will have on Canadian agriculture remains largely uncertain. It is well known that climate change will impact different regions in different ways; as the quote below from Natural Resources Canada's "Climate Change Impacts and Adaptation" report highlights.

> Although warmer temperatures, longer growing seasons and elevated CO_2 concentrations are generally expected to benefit agriculture in Canada, factors such as reduced soil moisture, increased frequency of extreme climate events, soil degradation and pests have the potential to counteract, and potentially exceed, these benefits. Some regions could experience net gains, while others may see net losses. Regional variations will result from several factors, including the nature of climate change, the characteristics of the farming system/organization, and the response of different groups (Lemmen & Warren, 2004).

Even at the regional scale, the net impact of climate change on Canadian agriculture remains largely uncertain. However, there is some consensus on what the most significant benefits and challenges from climate change will likely be in Canada's major agricultural regions. For example, although the net impact that climate change will have on the Prairies is currently unclear, there is serious concern that increases in water scarcity will cause major problems for the region's agricultural industry. This region, which primarily produces cattle, grains and oilseed, currently accounts for the vast majority of Canada's irrigated cropland and has exhibited substantial vulnerability to droughts in the past. For example, during the drought years of 2001 and 2002, the value of agricultural production on the Canadian Prairies dropped $3.6 billion (Sauchyn & Kulshreshtha, 2008). Many experts have expressed concern that droughts such as these "may be indicative of what the agriculture sector in Canada can expect more frequently in the future (Sauchyn & Kulshreshtha, 2008)." The Prairies may also experience increasingly high levels of water stress even in non-drought years due to increases in evapotranspiration (driven by temperature increases) which may exceed projected increases in growing season precipitation.

In southern Ontario, agricultural productivity will likely be reduced due to increasing moisture deficits (increases in growing season temperatures are not expected to be accompanied by increases in growing season precipitation). However, climate change may present opportunities to expand agricultural production in northern Ontario (Colombo, et al., 2007). Although warmer temperatures are expected to produce benefits for crops in Quebec and Atlantic Canada the net impact of climate change in these regions remains uncertain, largely due to concerns regarding water scarcity, pests, and extreme events (Bourque & Simonet, 2007; Vasseur & Catto, 2007). Northern agricultural regions (e.g., Peace River region of British Columbia and Alberta, and parts of northern Ontario and Quebec) are expected to reap some of the greatest benefits from climate change because low temperatures are often the primary limitation to agriculture in these regions. Temperature increases in these regions will have a greater potential for facilitating agricultural intensification rather than an expansion of production onto new lands. This is because soils throughout much of these regions are of poor quality and much of the high quality soils which are not currently being used for agriculture are located in very remote valleys (Lemmen & Warren, 2004).

5.4.3. Impact of Climate Change on Agriculture in the United States

As BC derives the vast majority of its imported agricultural commodities from the U.S., it is important to consider the impact that climate change is expected to have on agriculture south of the border. In general, it appears that climate change can be expected to have greater adverse impacts on agriculture in the U.S. than in Canada. As discussed above, climate change in Canada will produce agricultural benefits primarily due to temperature increases; largely because temperature is one of the greatest limiting factors for Canadian agriculture. However, in the U.S., temperature is much less of a limiting factor for agricultural production and increases in temperature will provide agricultural benefits in much fewer cases. In fact, in many and perhaps most cases, temperature increases will have a negative net impact on U.S. agricultural production. For example, grain, soybean and canola crops in the U.S. are expected to experience reduced yields as temperatures increase (Hatfield, et al., 2008). Other crops that will be adversely affected by increases in temperatures include short season crops (e.g. potato, lettuce, broccoli, and spinach) and crops that require long chilling periods (e.g. many apples and berries). However, it should be noted that some tropical crops (e.g. melon, okra, and sweet potato) are expected to benefit from increases in temperatures (Karl, Melillo, & Peterson, 2009). Increases in temperatures are also expected to reduce livestock productivity in the U.S. by increasing temperature related stress on animals. This is in sharp contrast to expectations for Canada where temperature increases are generally expected to benefit the livestock industry (Lemmen & Warren, 2004). Another major way in which temperature increases will adversely impact agricultural production in the U.S. is that it will facilitate the northward expansion of tropical and subtropical invasive weeds which are currently limited in range by winter temperature thresholds (Karl, et al., 2009). To illustrate the potential significance of this, it is useful to note that these extremely aggressive weeds are currently a major contributor to the fact that soybean farmers in the southern U.S. lose 64% of their crop to weeds. In the northern U.S., where these weeds are not currently prolific, only 22% of soybean crops are lost to weeds (Bridges, 1992).

The U.S. will also experience adverse impacts from climate change due to increases in the frequency and magnitude of extreme meteorological events. Like Canada, the U.S. is expected to experience increases in the frequency and intensity of droughts due to climate change. This will of course have a substantial impact on the U.S. agricultural industry (Karl, et al., 2009). The U.S. will also face substantial challenges from another type of extreme climatic event, heavy downpours of rain. The U.S. can expect more events such as the one which occurred in the spring of 2008 where heavy rains caused the Mississippi River to flood hundreds of thousands of hectares of wheat, corn, soybean, and cotton fields; resulting in $8 billion in agricultural losses (Karl, et al., 2009).

5.4.4. Impact of Climate Change on Global Agricultural Production

There are a few generalizations which may be made with confidence regarding the impact of climate change on agricultural production at a global scale. For example, the tropics are expected to experience decreases in yields, even under scenarios of minimal warming. Under moderate levels of warming, decreases in yields from the tropics are expected to be largely compensated by increases in yields from mid- to high-latitude regions. At more severe levels of warming, decreases in yields from all regions are expected (Easterling, et al., 2007). Overall, it is predicted that, under conditions of moderate temperature increases (i.e. 1 to 3°C), global food production may be enhanced. While more severe levels of warming will likely have a negative net impact on global food production (Easterling, et al., 2007). The expected impact of climate change on global food production is reflected in predictions of future food prices. For example, most studies predict that the real prices of cereals will remain relatively constant, given increases in global mean temperatures that are less than 3°C. However, at greater levels of warming, pronounced increases in the real prices of cereals are predicted (e.g. 30% increases in prices with a 5.5 °C increase in global mean temperature) (Easterling, et al., 2007).

5.5. BC'S FOOD SECURITY IN THE CONTEXT OF CLIMATE CHANGE

As the discussion above has indicated, much of BC's current food supply faces a troubling or uncertain future due to climate change. This can be seen as a serious food security issue facing the province. Food security exists "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Food and Agriculture Organization of the United Nations, 2009)." Food security "encompass components of: (i) food availability (with elements related to production, distribution and exchange); (ii) food access (with elements related to affordability, allocation and preference) and (iii) food utilization (with elements related to nutritional value, social value and food safety) (Gregory, et al., 2005)." The stresses which climate change will inflict on agricultural production (and therefore food supplies) will likely have significant impacts on food security, both in BC and throughout the world. It is important to note that, vulnerable climate change-driven food insecurity "is not determined by the nature and magnitude of environmental stress per se, but by the combination of the societal capacity to cope with, and/or recover from environmental change, coupled with the degree of exposure to stress (Gregory, et al., 2005)." Fortunately, BC has a relatively high capacity to cope with and recover from environmental changes. However, in order to prevent climate change from decreasing the food security of British Columbians, it is essential that BC takes proactive measures to help ensure that climate change does not erode the food security of its residents.

Perhaps one of the most effective ways in which BC can increase its food security is by taking measures to increase its food self-reliance[38] (Brunetti, 2009). The BC public obviously recognizes the importance of food self-reliance as

[38] It is important to note that "self-reliance does not mean100 percent self-sufficiency, but a balance between some degree of reliance on local production and products, and reliance on global agri-food trade (Brunetti, 2009)."

a recent survey concluded that 91% of BC residents "agree" and "strongly agree" that "it is important that BC produce enough food so we don't have to depend on imports from other places (Ipsos Reid Public Affairs, 2008)." The same survey indicated that 80% of BC consumers are willing to pay price premiums for food that is grown in BC.

There is currently great potential for BC to produce more of its own food; an action which could significantly increase the province's food security. It is estimated that in 2001, BC farmers produced 48% of all foods consumed in BC (BC Ministry of Agriculture and Lands, 2006, a). One indication of the potential for BC to increase its food self-reliance is that, in 2001, approximately 73% of the food that was imported into BC (and consumed in BC) was food that can be economically grown in the province. BC's largest food self-reliance shortfall is in vegetable production. In 2001, approximately 57% of the vegetables consumed in BC were imported into the province, almost all of which could have theoretically been economically grown in the province (BC Ministry of Agriculture and Lands, 2006, a). However, almost all vegetable production in BC requires high quality irrigated agricultural land. Unfortunately, BC has a very limited supply of high quality agricultural land which can be used to increase BC's vegetable production and food self-reliance (BC Ministry of Agriculture and Lands, 2006, b).

Table 3: Peace River Valley Vegetable Potential

Can be grown in the Peace River Valley and surrounding plateau	Can only be grown in the Peace River Valley
Carrot	beans
lettuce	cucumbers
onions	sweet corn
peas	tomato
rutabaga	alfalfa seed
radish	eggplant
potato	melons
rhubarb	artichoke
spinach	soybean
Chinese cabbage	sugar beet
chives	sunflower
collard	leeks
endive	sweet pepper
fennel	zucchini
parsley	marrow
parsnip	pumpkin
chicory	squash
salsify	southern pea
turnips	New Zealand spinach
Swiss chard	lima bean
horse radish	
garlic	

This table lists some of the vegetables that can be economically grown in the Peace River Valley and the surrounding plateau; and vegetables that can only be economically grown in the Peace River Valley. It does not consider the influence of climate change. Source: (Harris, 1982 b)

5.6. POTENTIAL FOR A VEGETABLE INDUSTRY IN THE PEACE RIVER VALLEY

It has been asserted that one of the most valuable attributes of the Peace River Valley is its capability to produce vegetables and other specialty crops that are currently imported into BC. Currently, at least 42 different types of vegetables could be commercially grown in the Peace River Valley. Approximately 50% of these crops, including many of the most lucrative, require the unique microclimate and soil conditions of the Peace River Valley and will not grow on the valley's surrounding plateaus (Table 3) (Harris, 1982). In 2002, only 24 ha of the entire Peace River region was being used for the commercial production of vegetables; and much of this land, if not all, was located within the Peace River Valley

(BC Ministry of Agriculture and Lands, 2002). Although commercial vegetable production within the valley is currently very limited, the Peace River Valley is known to be capable of supporting a significant horticultural industry (Harris, 1982; Canadian Resourcecon Limited, 1980). Although there has been considerable interest in the commercial production of vegetables in the PVR, the development of a vegetable industry has been slow due to "the lack of a suitable infrastructure, difficulty in gaining access to information and marketing resources, unfavorable market conditions and the placement of flood reserves…constrained development of the more intensive production options (Lions Gate Consulting Inc., 2002)." Many Peace River Valley farmers have expressed that the land tenure insecurity caused by the potential flooding of the valley for Site C has prevented them from making substantial long-term investments into their farms, such as those which would be required to initiate commercial vegetable production (Lions Gate Consulting Inc., 2002). Harris (1982 b) concisely puts the Peace River Valley's current lacking of a horticultural industry into perspective when he writes, "whether or not the establishment of a horticultural industry is economically feasible [at the present time] is not nearly as important as the question of the future need to produce commodities in which we are already deficient."

Climate change could be a major catalyst in the establishment of a thriving vegetable industry in the Peace River Valley which would bring substantial food security benefits to the people of the Peace River region and BC as a whole. The most obvious direct impact that climate change can be expected have on the Peace River Valley's potential for commercial vegetable production is through the improvement of the valley's growing conditions (section 5.3). Climatic change can be expected to both increase yields and increase the diversity of high value crops that can be grown in the valley. Furthermore, given the adverse impact that climate change is expected to have on vegetable production throughout much of BC and North America (section 5.4), BC can likely expect to experience increased vegetable prices in the near future[39]. As vegetable prices increase, there will undoubtedly be an increased incentive to produce vegetables in the Peace River Valley (BC Ministry of Agriculture and Lands, 2006, b).

5.7. POTENTIAL FOR PEACE RIVER VALLEY TO PRODUCE FOOD FOR LOCAL CONSUMPTION

In recent years, consumer demand for locally produced foods has undergone an unprecedented increase. A 2008 survey indicated that 78% of British Columbian consumers would pay more for food that was produced in their region of the province (a 5%increase from 2004). Interestingly, this willingness to pay more is greatest among people who live outside of the Lower Mainland (82% vs. 72% in the Lower Mainland). Furthermore, the study found that 88% of British Columbians "like to go out to farms and farmers markets where [they] can buy food directly from the farmer" (again, 5%increase from 2004). This preference is slightly more prevalent in Northern BC than both in the Lower Mainland and the Southern Interior (Ipsos Reid Public Affairs, 2008). The growing interest in locally produced foods "appears to be rooted in a number of underlying desired food outcomes, including control over sourcing, desire for perceived enhanced taste and nutrition outcomes, and also to outcomes related to support of ethical and environmental values (Heslop, 2007)."

Within globalized food supply chain systems, food is transported vast distances before it reaches consumers. It is estimated that North America's food supply travels an average of 2,400 kilometers from farm to plate (Brunetti,

[39] BC has already experienced significant vegetable price volatility due to the province's high dependence on imports, though it is unclear whether or not BC has yet to experience changes in vegetable prices for reasons that can be directly attributed to climate change. One instance of vegetable price increases occurred in 1998 due to decreases in the value of the Canadian dollar. In June 1998, this resulted in prices for fresh vegetables rising 15.3% from 12 months earlier, while the provincial consumer price index for all items rose only 0.4 per cent during the same period (BC Stats, 1998).

2009). Some may claim that this system currently prevails because it is the most efficient and economical. However, others argue that we pay artificially cheap prices for the food that we receive from these globalized supply chains, because when we consider "the subsidies for gasoline and roads, the effects of smog and global warming…and a range of other hidden costs, the 'efficiency' of long-distance food begins to fade away (Halweil, 2002)." One major advantage of local foods is the shorter distances that food must travel to reach consumers. Since the transport of food relies heavily on fossil fuels and produces a substantial amount of GHG emissions, the localization of food supply can contribute to decreases in fossil fuel dependency and reduced GHG emissions (Brunetti, 2009; BC Ministry of Agriculture and Lands, 2006, b).

Local food systems can also produce economic benefits beyond the elimination of significant costs associated with food transport. As Brunetti (2009) explains, "'Going local' does not mean putting communities into a state of economic isolation and eliminating international trade. Instead, increasing local food production, processing, storage and distribution means nurturing local businesses, which use local resources, employ local workers and serve primarily local consumers." Numerous studies have found that money spent on local food tends to re-circulate in the local economy to a greater degree than money spent on non-local food (Brunetti, 2009; Halweil, 2002). For example, a survey in the UK which compared a local organic food home delivery business to supermarkets found that "money spent on locally-produced food generates almost twice as much income for the local economy as the same amount spent in a typical supermarket (New Economics Foundation, 2001)."

A number of other benefits can also emerge from local food systems. For example, since these systems build closer connections between producers and consumers, consumers may be "more inclined to ask farmers how farm foods are grown or raised and thereby build demand for environmentally [and social] responsible farming practices (Brunetti, 2009)." Another benefit of localized food production is that "farmers producing for the local market tend to increase the diversity of their plantings—a shift with advantages for the diets of local people and the ecology of local landscapes (Halweil, 2002)." An additional health benefit of the localization of food supply chains is that it has the potential to address many of the issues which make food in globalized supply chains highly vulnerable to contamination from pathogenic organisms and biotoxins (e.g. *E. coli*) (Brunetti, 2009). Lastly, and simply, local food is often fresher and better tasting than food that has traveled thousands of kilometers (Halweil, 2002).

The BC provincial government has recognized the importance of local food. In 2006, the BC Ministry of Agriculture and Lands released *The British Columbia Agricultural Plan: Growing a Healthy Future for BC Families*. This plan "sets a strong foundation for the future of agriculture in [BC]. Its strategies focus on meeting and benefiting from environmental and climate challenges and ensuring innovations drive a competitive agriculture sector." The first issue addressed in the plan is the production of local foods. The plan recognizes many of the environmental and social benefits of local food and states that "all British Columbians should have access to safe, locally produced food (BC Ministry of Agriculture and Lands, 2006, b)."

Due to the Peace River Valley's exceptional agricultural characteristics, which are expected to further improve due to climate change, the valley has a unique ability to produce a wide variety of food which is currently imported into the region from great distances (section 5.6.). Given the increasing demand for local foods, it would not be surprising if the Peace River Valley became a significant source of local food for Northern BC and Alberta within the near future. This would not only help satisfy the region's consumer demands for local food, but it would also be expected to result in significant environmental, health, and economic benefits.

6. SITE C: A THREAT TO THE PEACE RIVER VALLEY

The Peace River Valley currently faces a great threat from the potential construction of a hydroelectric dam known as "Site C". The following sections discuss the proposed project, as well as the potential impacts of the project that are especially relevant in the context of climate change.

6.1. AN OVERVIEW OF SITE C'S PROPOSAL

6.1.1. The History behind Site C's Proposal

The Peace River's history of hydroelectric development began in the 1950's when British Columbia Premier W.A.C. Bennett initiated the first significant steps towards the construction of what would become one of the world's largest earthfilled dams (Loo, 2007). In 1962, the project became economically feasible when the provincial government created the British Columbia Hydro and Power Authority (BC Hydro), a crown corporation which was created through the expropriation of BC Electric (Box 2) (Loo, 2007). By 1968, the W.A.C Bennett Dam had been completed and was in operation. The energy produced by the dam contributed to significant economic benefits for the province, especially in the central interior, and also provided the BC government with significant political leverage over Ottawa (Loo, 2007). Over the past five years, the W.A.C. Bennett Dam has accounted for approximately 13 to 17% of BC Hydro's electricity supply (BC Hydro, 2009, a). Despite the benefits which this dam has delivered, it is very important to note that this dam also produced a vast amount of irreparable social and environmental damage. Whether or not the dam has produced more good or harm overall is an issue of contentious debate (Loo, 2007).

Throughout the 1960s and 1970s, BC Hydro considered the potential for another hydroelectric dam along the Peace. Five potential dam sites were initially considered. In 1967 the

Box 8: BC Hydro and the BC Utilities Commission

BC Hydro is a "commercial Crown corporation owned by the Province of British Columbia" which is primarily responsible for the generation and distribution of electricity. The stated corporate purpose of BC Hydro is to provide "reliable power, at low cost, for generations (BC Hydro, 2009, d)." BC Hydro serves approximately 95% of the province's population and annually generates 43,000 to 54,000 gigawatt hours (GWh) of electricity with the 30 hydroelectric facilities and 3 natural gas-fueled thermal power plants that it operates (BC Hydro, 2009, d).

BC Hydro is regulated by the British Columbia Utilities Commission (BCUC). Members of the BCUC are appointed by the BC Cabinet. The BCUC "is responsible for ensuring that customers receive safe, reliable and non-discriminatory energy services at fair rates from the utilities it regulates, that shareholders of these utilities are afforded a reasonable opportunity to earn a fair return on their invested capital, and that the competitive interests of B.C. businesses are not frustrated. It approves the construction of new facilities planned by utilities and their issuance of securities. The Commission's function is quasi-judicial and it has the power to make legally binding rulings (British Columbia Utilities Commission, 2009)."

list of viable sites had been narrowed down to Site C and Site E (which is located near the B.C.-Alberta border). In the mid-1970's BC Hydro began to consult with the public on Site C. At this same time, BC Hydro began to prepare for the dam's flood reserve by purchasing private land from interested owners (BC Hydro, 2007).

In 1980, the Peace Canyon Dam was completed just downstream of the W.A.C. Bennett Dam (BC Hydro, 2007). During the same year, BC Hydro applied for an Energy Project Certificate from the provincial government, in order to proceed with the construction of Site C. The application was referred to the British Columbia Utilities Commission (BCUC), which acts as the regulator of BC Hydro (Box 8). The BCUC concluded that the project was not in the interest of British Columbians and therefore rejected BC Hydro's application. The BCUC recommended "that an Energy Project Certificate for Site C should not be issued until (1) an acceptable forecast [of energy supply and demand] demonstrates that construction must begin immediately in order to avoid supply deficiencies and (2) a comparison of alternative feasible system plans demonstrates, from a social benefit-cost point of view, that Site C is the best project to meet the anticipated supply deficiency (British Columbia Utilities Commission, 1983)".

The BCUC ruling did not do much to dampen BC Hydro's interest in Site C. BC Hydro soon began to study the potential for exporting electricity generated by Site C to the U.S. (Yearwood-Lee, 2008). A 1987 report by BC Hydro concluded that there was a market for this electricity in the U.S. (BC Hydro, 1987). By 1989 BC Hydro had begun to proceed with preparatory work on the project by conducting further engineering studies and initiating some public consultation. However, in 1991, BC Hydro decided to suspend work on Site C and instead focus on promoting demand-side management (e.g. energy conservation) and natural gas-fired electricity generation (BC Hydro, 2007). In 1992, an article in the *Vancouver Sun* stated that, according to the president of BC Hydro, the Site C project was "dead" due to its unacceptable economic and environmental costs (Nutt cited in Yearwood-Lee, 2008).

6.1.2. The Currently Proposed Site C Project

BC Hydro's interest in Site C was rekindled again in the early 2000s, leading to further studies on the viability of the project (BC Hydro, 2007). In BC Hydro's 2004 Integrated Electricity Plan (IEP), it was stated that BC Hydro would proceed with the next steps of the project by "consulting with First Nations, engaging stakeholders, and pursuing licensing and environmental assessment processes (BC Hydro, 2004)." During the same year, BC Hydro proposed a five stage approach for developing the project (Figure 11) (BC Hydro, 2007). The proposed project is currently in its second stage of development. BC Hydro has the opportunity to abandon the project's development following review of the project at the completion of each of the project's three remaining preparatory stages. More importantly, the project's advancement from one stage to the next is dependent on the approval of the BC Utilities Commission (BC Hydro, 2007). Although BC Hydro (2009, c) makes it very clear that "no decision has been made to build Site C", many feel that the project's consultation process has been based on an assumption that the dam will be built.

The first stage of the project was completed in 2007 and consisted of a general review of dam's feasibility (BC Hydro, 2007). Stage 2 is well underway and is expected to be completed by the fall of 2009. This "project definition and consultation" stage involves "environmental, engineering, financial and technical studies, as well as public and stakeholder consultations (BC Hydro, 2009, b)." At the completion of this stage, BC Hydro will make a recommendation to the provincial government on whether or not to proceed to Stage 3. The provincial government will then decide whether or not BC Hydro will be allowed to proceed with Stage 3. Should Stage 3 be approved, BC Hydro would then apply for the major permits required by the project (e.g. filing environmental assessments to provincial and federal regulatory agencies). If the relevant permits are issued, and if the BCUC approves the advancement of the project to Stage 4, the project's design and construction plans would be finalized. The estimated total cost of these 4 preparatory stages is $100 million. If the proposed project were to reach the completion of Stage 4 and if the provincial government approved the initiation of Stage 5, construction of Site C would begin (BC Hydro, 2007).

If the proposed Site C project were to proceed to construction, this stage would begin no earlier than 2012. Construction would take approximately 7 years to complete and would require approximately 7,650 person-years. The construction would begin with approximately 21 months of preparatory work (e.g. building access roads, construction camps, and tunnels to divert the river). The Peace River would then be diverted for almost 4 years while the main structures of the dam and generating station would be completed. Following the completion of this stage, the reservoir would be allowed to fill with water (1 month) and the finishing touches would then be put on the project (15 months) (BC Hydro, 2007).

The project would result in the creation of a 60 meter tall earthfill dam which would be 1,120 meters long at its crest. Upstream of the dam, a 9310 ha reservoir would be created. The reservoir would flood approximately 5340 ha of land and would extend 83 km to the Peace Canyon Dam. The total generating capacity (i.e. the normal maximum output) of the dam's generating facility would be 900 MW. Average annual production is expected to be 4,600 GWh, which would be enough electricity to power approximately 460,000 homes. To put these values into perspective see Figure 12. Early estimates of the total cost of Site C range between $5.0 billion and $6.6 billion (BC Hydro, 2007).

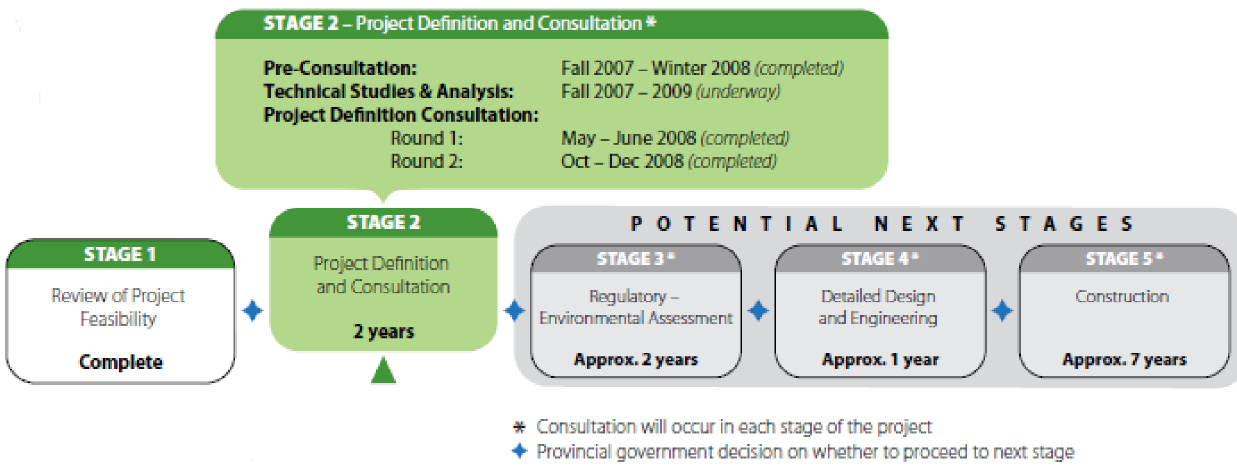

Figure 11: Potential timeline for the development of Site C. Source: (BC Hydro, 2009, c).

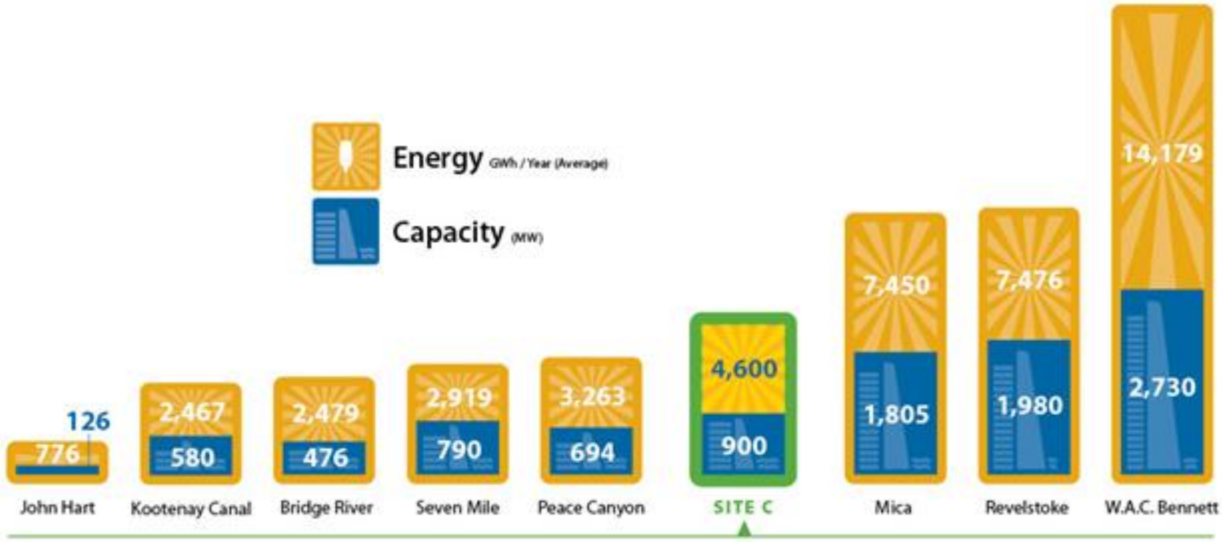

Figure 12: A comparison of the electricity generation capabilities of the proposed Site C hydroelectric facility with BC Hydro's largest hydroelectric facilities. Source: (BC Hydro, 2007).

6.1.3. The Policy Context behind Site C's Proposal: The BC Energy Plan

While this paper does not intend to present a comprehensive analysis of BC's energy policy, it is important to acknowledge that the "consideration of Site C is undertaken in the context of, and is guided by, the *BC Energy Plan* (BC Hydro, 2007)." This document, which was released by the provincial government in 2007, is a list of policy objectives and actions which address a wide range of energy related issues. The policy objectives and actions which are particularly relevant to the consideration of Site C are listed below.

- "Maintain our competitive electricity rate advantage"
- "Achieve electricity self-sufficiency by 2016" (including "insurance power")
- "Acquire 50 per cent of BC Hydro's incremental resource needs through conservation by 2020"[40]
- "All new electricity generation projects will have zero net greenhouse gas emissions"[41]
- "Ensure clean or renewable electricity generation continues to account for at least 90 per cent of total generation"

(BC Ministry of Energy, Mines and Petroleum Resources, 2007)

Through these policy guidelines, the *BC Energy Plan* creates a precedent for increasing the generation of electricity in BC, and for generating this electricity through the use technologies with low GHG emissions. Since large hydroelectric facilities generally produce large amounts of reliable electricity with what has been considered to be

[40] Although the BC Energy Plan calls this an "ambitious target", attaining this goal will only require households to reduce electricity use by approximately 10% (BC Ministry of Energy, Mines and Petroleum Resources, 2007). Furthermore, some have argued that the plan's policy of keeping electricity rates artificially low (among the lowest in all of North America) functions like an electricity subsidy program that will undermine conservation efforts (Marvin Shaffer & Associates Ltd., 2007).

[41] Presumably this allows for measures such as the purchase of carbon offsets to mitigate emissions (e.g. from construction).

relatively low GHG emissions,[42] it is not surprising that one of the actions outlined by the *BC Energy Plan* was that "BC Hydro and the Province will enter into initial discussions with First Nations, the Province of Alberta and communities to discuss Site C."

While the stated purpose of the plan, which is "to make our province energy self-sufficient while taking responsibility for our natural environment and climate (BC Ministry of Energy, Mines and Petroleum Resources, 2007)", appears relatively uncontroversial, some have suggested that the objectives and actions outlined by the plan are actually far from being environmentally friendly or economically justified. Perhaps one of the most influential critiques of the plan is a paper written by Simon Fraser University's Dr. Marvin Shaffer at the request of the Canadian Office and Professional Employees Union. One of Shaffer's major arguments is that the self-sufficiency policy of the BC Energy Plan is not in the public interest and is based on a greatly exaggerated need for new sources of domestic electricity supply. The 2007 BC Energy Plan calls for BC to have a self-sufficient electricity supply by 2016. The plan also calls for BC Hydro to acquire an additional 3000 GWh of BC generated 'insurance' electricity by 2026[43] (Province of British Columbia, 2007). The plan states that the achievement of these goals is "fundamental to our future energy security".

A major factor which led to the inclusion of this policy was that Independent Power Producer IPP lobbyists, the media, and government officials claimed that BC Hydro's net imports of electricity since 2001 were evidence that BC's electricity supply was becoming insecure (Marvin Shaffer & Associates Ltd., 2007). The BC Energy Plan states that BC is dependent on electricity from the United States and Alberta for up to 10% of the province's electricity supply (BC Ministry of Energy, Mines and Petroleum Resources, 2007). However, the true picture is more complicated than this. While BC has been importing approximately 10% of its electricity supply in recent years, the province has also been exporting a similar quantity of electricity (Figure 13). From data up to and including 2006, BC has experienced electricity trade deficits in three of the past five years; however, the total deficit over this five year period represents only 1.5% of the electricity that BC generated over the same period of time[44] (Hoberg & Mallon, 2009).

BC Hydro does not generally import electricity because domestic supplies are unavailable; rather, it imports electricity when imports are the most economical source of supply (Marvin Shaffer & Associates Ltd., 2007). BC Hydro is able to "take advantage of wholesale electricity markets without being dependent on them" largely due to the Burrard thermal plant, which BC Hydro rarely runs due to its inefficiency; but which is capable of producing a substantial amount of electricity if needed (approximately 33% more annual GWh than the proposed Site C generation facility) (Marvin Shaffer & Associates Ltd., 2007). Other critics of the BC Energy Plan also point out that BC is entitled to 1200MW of power (approximately 10% of BC Hydro's total capacity) from the U.S., due to the Columbia River Treaty. This electricity is currently does not enter British Columbia, and instead is directly sold by a BC Hydro subsidiary (Powerex) to U.S. markets. BC's electricity trade balance would look much more favourable if this electricity was accounted for as an electricity export of the province (Hoberg & Mallon, 2009).

[42] A relatively new field of research has found that hydroelectricity produces much more GHG emissions than what has been previously assumed (see section 6.2.1.).
[43] The justification for this 'insurance' supply is that BC's electricity generation varies greatly on an annual basis due to the province's high dependence on hydroelectricity.
[44] BC Hydro ran trade deficits for electricity in all years from 2001 to 2006. However, as a province, BC only ran electricity trade deficits in 2001, 2004, and 2006. This is because approximately 20% of the electricity generated in BC is not accounted for by BC Hydro (Hoberg & Mallon, 2009).

Although the preceding discussion illustrates that the need for new domestic sources of electricity may be exaggerated by the BC Energy Plan, it is of course foreseeable that in the future BC may benefit from additional sources of domestic electricity production. New sources of domestically generated electricity supply should clearly be acquired if their benefits outweigh their economic, social, and environmental costs. However, critics of the BC Energy Plan have argued that "except for the dictates of the Energy Plan, there is no urgent need to acquire new sources of supply (Marvin Shaffer & Associates Ltd., 2007)." Support for this statement comes from the fact that the policies included in the BC Energy plan are responsible for 100% of the new supply that BC Hydro is projected to require by 2016 and 70% of the new supply that BC Hydro is projected to require by 2025 (Figure 14). According to Marvin Shaffer & Associates Ltd. (2007) the BC Energy Plan "provides a solution to a problem that does not exist. It creates an urgency for new supply and it imposes artificial limitations on how that supply can be met. It will almost certainly prevent BC Hydro from meeting B.C.'s energy requirements in the most cost-effective, environmentally and socially responsible way."

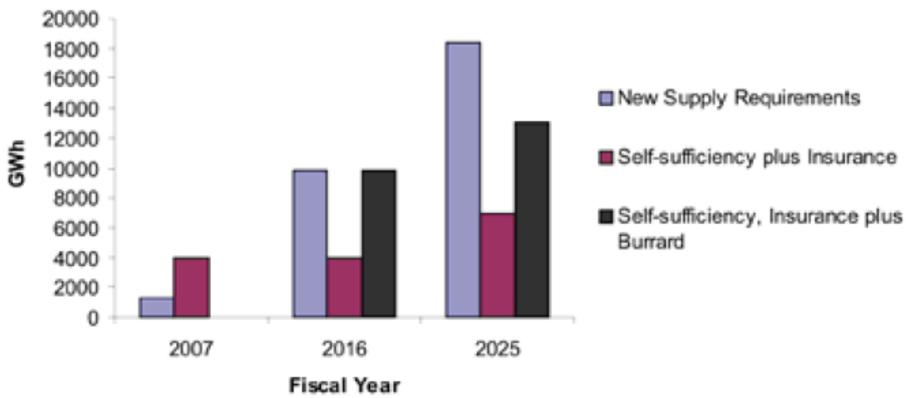

Figure 13: BC Hydro's new supply requirements for 2007, 2016, and 2025; and the contribution of stipulations in the BC Energy Plan to these requirements.[45]

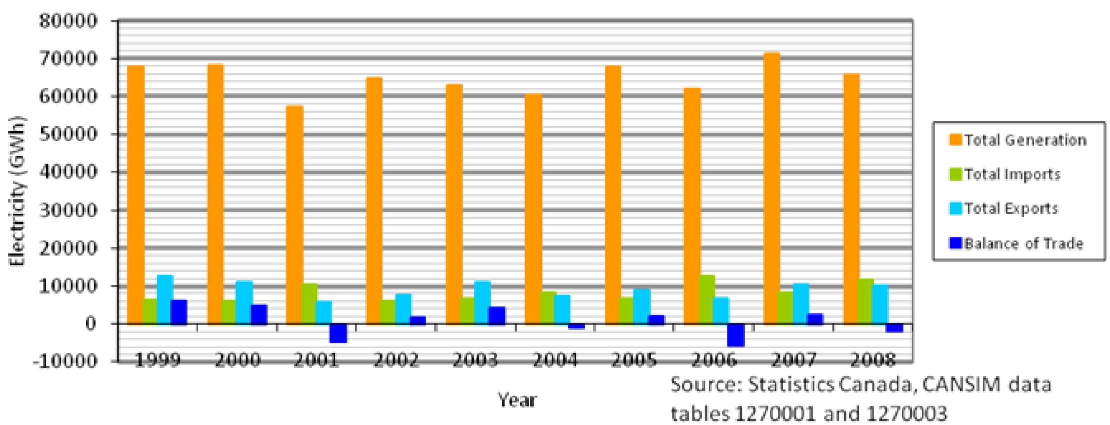

Figure 14: BC's electricity generation, imports, exports, and balance of trade from 1999 to 2008. Source: (Hoberg & Mallon, 2009)

[45] "Burrard" refers to eventual retirement of The Burrard thermal plant, an action supported by the BC Energy Plan. Source: (Marvin Shaffer & Associates Ltd., 2007)

6.2. SITE C'S POTENTIAL ADVERSE IMPACTS

6.2.1. GHG Impact of Site C

Although hydroelectricity is often perceived as clean energy, at least in terms of its GHG emissions, an emerging field of research is finding that the production of hydroelectricity can result in substantial GHG emissions. In fact, leading global researchers agree that "greenhouse gases are emitted for decades from all dam reservoirs in the boreal and tropic regions for which measurements have been made…in contrast to the widespread assumption that such emissions are negligible (World Commission on Dams, 2000)." Reservoirs produce GHGs in a number of ways (Figure 15). Some of the most significant emissions of GHGs are those which are released from vegetation and soils which are flooded by reservoirs. As this flooded organic matter decomposes, CO_2 and other GHGs are produced and are released to the atmosphere[46]. This decomposition of flooded vegetation and soil carbon causes a large initial pulse of GHG emissions. After temperate and boreal reservoirs are filled, GHG emissions tend to decline by approximately 2% per year before stabilizing approximately two decades later. Once the majority of this flooded organic matter has decomposed, GHG emissions will nevertheless continue to occur throughout the life of the reservoir. This is primarily due to the fact that "organic matter in a reservoir comes not just from flooded vegetation and soils, but also the detritus which is continuously washed in from its catchment, as well as the aquatic plants and algae which grow and die in the reservoir (International Rivers Network, 2002)." These are many of the same factors which often make natural lakes a net source of GHGs. In addition, many reservoirs receive significant quantities of organic matter from plants which grow on the seasonally exposed surfaces of reservoir drawdown zones. The decomposition of organic matter from all of these sources causes reservoirs to release GHGs to the atmosphere (International Rivers Network, 2002).

Box 9: Reservoir Methane Production

One issue of particular concern is that the underwater decomposition of organic matter has a greater tendency to produce methane gas (CH_4), a common byproduct of anaerobic decomposition. This is significant because CH_4 has a Global Warming Potential (GWP) that is estimated to be between 23 and 39 greater than that of CO_2 (International Rivers Network, 2002). This means that 1 tonne of CH_4 emissions will have an impact on the earth's climate that is comparable to the emission of 23 to 39 tonnes of CO_2. Although the GHG impact of boreal reservoirs is dominated by CO_2 emissions, while emissions of CH_4 are generally more substantial from tropical reservoirs, boreal reservoirs are known to emit significant amounts of CH_4 as well. Furthermore, emissions of CH_4 from boreal reservoirs may be presently underestimated, as significant areas of uncertainty remain in making accurate estimations of CH_4 emissions from boreal reservoirs (Duchemin, Lucotte, Canuel, & Soumis, 2006).

In order to determine the net GHG impact of a reservoir, it is not enough to only consider the amount of GHGs that the reservoir directly produces. Instead, one must also consider the flux of GHGs which would have occurred if the

[46] These GHGs are released to the atmosphere "via diffusion across the water surface and in bubbles that rise from the reservoir bottom. There can also be significant emissions, especially at dams in the tropics, from the degassing of water released through turbines and spillways (International Rivers Network, 2006)."

reservoir had not been built. Therefore, the net GHG emissions of a reservoir can be defined by the following equation (International Rivers Network, 2002):

GHGs that are directly emitted from the reservoir

(+) GHGs that would have been absorbed by the landscape if the reservoir had not been built

(–) GHGs that would have been released from the landscape if the reservoir had not been built

= Net GHG emissions from reservoir

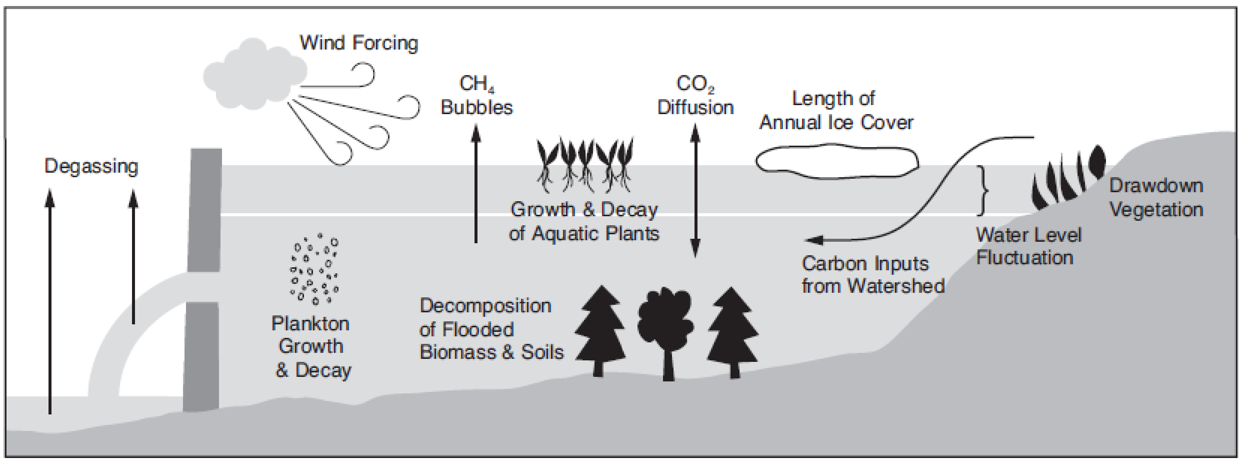

Figure 15: Some of the key factors that influence GHG emissions from reservoirs. Source: (International Rivers Network, 2006).

BC Hydro has produced a preliminary estimate of the GHG emissions which would result from Site C. This estimation is based on the following assumptions (BC Hydro, 2005):

- The total surface area of the reservoir is 9310 ha.
- The reservoir is ice-free all year.
- The total area of land flooded is 5300 ha.
- The landscape which would be flooded has a GHG capture rate (averaged throughout the entire year) of 2139 mg CO_2 eq / m^2 / day. (This figure was derived from average GHG fluxes of boreal/temperate forests, as reported by St. Louis et al. (2000).)
- The reservoir would emit 2180 mg CO_2 eq / m^2 /day. (This figure was derived from average GHG fluxes of temperate reservoirs, as reported by St. Louis et al. (2000).)

Given these assumptions, BC Hydro estimates that Site C's reservoir could result in net GHG emissions of 4,319 mg CO_2 eq / m^2 /day (BC Hydro, 2005). Since the reservoir's total surface area is 9310 ha, this would mean that Site C's reservoir would cause net emissions of 402 tonnes of CO_2 eq/day, or 146,730 tonnes of CO_2 eq/yr. To put these values into perspective, the average vehicle in the Lower Mainland produces approximately 4 tonnes of CO_2 per year (Rock, 2007). Therefore, the potential net GHG impact of Site C, as estimated by BC Hydro, can be seen as roughly equivalent to the addition of 36,000 vehicles to the Lower Mainland. Another interesting point of comparison is that the recently completed Canada Line project (a rapid transit system which links Downtown Vancouver to the Vancouver International Airport and Richmond) is expected to reduce the Lower Mainland's CO_2 emissions by 9,000 to 13,000 tonnes/yr. The approximately 500,000 tonnes of CO_2 emissions which will be avoided by 2050 due to the Canada Line is estimated to be worth between $13 and $44 million dollars (Global Change Strategies International, 2003).

BC Hydro states that their estimation of 4,319 mg CO_2 eq/m^2/day should be treated as an "upper bounds" on what the emissions from Site C's reservoir might be (BC Hydro, 2005). However, an explanation is not provided as to why this figure should be treated as an upper bounds estimation. This is especially curious since the data used in generating this estimation does not appear to contain any systemic bias which could be expected to result in a high estimation. BC Hydro also provides a lower bounds estimate of the GHG emissions that can be expected from the Site C reservoir which is approximately half of the upper bounds estimate (i.e. approximately 2,000 mg CO_2 eq/m^2/day) (BC Hydro, 2005). This lower estimation was obtained by ignoring the GHG sequestration of the land which would be flooded. However, an estimation of the net GHG impact of any reservoir would be incomplete without considering the GHG flux of the original landscape (International Rivers Network, 2002). It is unclear why BC Hydro chose to exclude this critical component in constructing their lower bounds estimation. Until detailed studies provide a more accurate estimation of the net GHG impact which could be expected from Site C's reservoir, it seems reasonable to use BC Hydro's estimation of 4,319 mg CO_2 eq/m^2/day (i.e. 146,730 tonnes of CO_2 eq/yr from the entire reservoir) for planning purposes.

In the "Site C Feasibility Review: Stage 1 Completion Report", BC Hydro makes a puzzling assertion that the GHG emission estimate which has been discussed above is only applicable "for approximately the first 10 years after the reservoir is created. Thereafter, there would be negligible greenhouse gas emissions (BC Hydro, 2007)." This statement is made despite the fact that the BC Hydro report which establishes this estimate (i.e. BC Hydro, 2005) does not state that this estimate is only valid for the first decade after the reservoir is created. In fact, given the assumptions which were used in obtaining this estimate, it seems more logical that this estimate of 146,730 tonnes of CO_2 eq emissions per year should be seen as the average annual net GHG impact of the reservoir over its entire lifespan[47].

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[47] One of the two assumptions which forms the basis of this estimate is that the reservoir would directly emit 2180 mg CO_2 eq / m^2 / day. This assumption is based on average GHG emissions which have been observed to occur from temperate reservoirs, as reported by St. Louis et al. (2000). However, this value was derived from the sampling of reservoirs of a wide variety of ages. In fact, only a very small proportion of the data used in generating this value came from reservoirs that were less than 10 years of age. This value can therefore be expected to be more representative of the average amount of GHGs which are annually emitted from temperate reservoirs over the entire life of these reservoirs rather than the amount of GHGs emitted within the first 10 years of a reservoir's life, when emissions are known to be significantly higher. The other assumption which this estimate is based on is that land which would be flooded is an emission sink of 2139 mg CO_2 eq/m^2/day. There is no reason to assume that this emission sink is only relevant for the first 10 years after the reservoir has been filled.

Another important consideration which has not been addressed above is that the process of constructing Site C will also produce a significant amount of GHG emissions (e.g. through the use of fossil fuels) which have yet to be estimated. To provide an example of the vast amount of energy consumption which would be required during the dam's 7 year construction period, building the dam would require the excavation of 400,000 to 600,000 truckloads (10 to 15 million m^3) of material from the bank slope above the dam (BC Hydro, 2007). It should also be noted that Site C would produce less GHGs than energy production through certain other means. For example, based on current estimates, a combined cycle natural gas plant which produces a similar amount of energy as Site C would have a GHG impact that is approximately 10 times greater than that of Site C (BC Hydro, 2007). However, this does not change the fact that Site C's GHG impact is significant and deserving of attention, especially given that the BC Energy Plan requires that "all new electricity generation projects will have zero net greenhouse gas emissions (BC Ministry of Energy, Mines and Petroleum Resources, 2007)".

The report which establishes BC Hydro's current estimate for the GHG impact of Site C states that, while their estimate is "rough in nature, it is felt that it will serve the purpose for a high level, long term energy planning process. However, it must be understood that further study would be needed if GHG emissions were considered an important deciding factor in the consideration of Site C (BC Hydro, 2005)." Fortunately, it appears that BC Hydro may now recognize that GHG emissions are an important deciding factor in the project's consideration. This is apparent from the fact that BC Hydro has recently commissioned a detailed study on the potential GHG impact that Site C would have. This report will be available in the fall of 2009, at the end of Stage 2 (BC Hydro, 2008; Environmental Studies: Greenhouse Gas Emissions Study Outline).

Box 10: Impact of Site C on Fog

According to BC Hydro, "the most pronounced climatic effect of the Site C reservoir would be the greater frequency and density of fog, particularly during cold weather in spring and fall (BC Hydro, 2007)." However, very little is currently known about how serious these changes could be, due to the fact that there is a severe lacking of fog and humidity data from within the valley (Tuller, 1991).

Increases in the frequency and density of fog, especially in the late summer and fall, could greatly impact agriculture in affected areas by causing problems for the drying of crops. It should be noted that the construction of the Williston Reservoir resulted in significant increases in fog which had an adverse effect on agriculture (Loo, 2007). Changes in fog patterns could also have a significant impact on transportation and road safety (Tuller, 1991). Fog increases could even impact wildlife by decreasing the amount of solar radiation reaching the valley, thus decreasing snow melt and increasing snow depths. Increases in snowpack depths could have a significant adverse impact on the valley's mule deer and elk populations. (Brian Churchill, personal communication, 2009).

6.2.2. Impact of Site C on Local Climate

There is a considerable amount of concern that Site C's reservoir could cause adverse local climatic changes. These impacts could significantly impact a wide variety of sectors; ranging from agriculture, to transportation, to wildlife. In response to these concerns, BC Hydro has commissioned studies (conducted in 1976 and 1979) on the valley's climate and the potential impact of Site C (Thurber Consultants Ltd., 1977; Thurber Consultants Ltd., 1979). BC Hydro also commissioned a review study on the subject in 1991 (Tuller, 1991). This review stated that there is "general acceptance" that the creation of Site C would result in a number of climatic changes. These predicted changes are explained in table 4.

While the general types of changes which would occur as a result of Site C's reservoir are relatively well known, there is currently a great deal of uncertainty in estimating what the magnitude and spatial extent of these changes would be. This is largely because the climate data base which has been used to estimate the potential climatic impact of Site C "is handicapped by short periods of record, limited spatial coverage, missing data, and a small number of recorded elements." BC Hydro has recently commissioned a new study on the localized climatic effects that Site C could be expected to have, which will likely be more comprehensive than previous studies. This report is expected by the spring of 2010 (BC Hydro, September 2008; Environmental Studies: Climate, Water, Temperature and Noise Study Outline).

Table 4: Estimated local climatic effects of the Site C reservoir. As reviewed by Tuller (1991).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed	+	+	+	+	+	+	+	+	+	+	+	+
Temperature (daily mean)					-	-	-	-	+	+	+	
Temperature (daily max)					+	+	+	+				
Evaporation					-	-	-	+	+	+		
Humidity (daily mean)					-	-	-	-	-	-		
Humidity (nighttime)								+	+	+	+	
Dew								+	+	+	+	
Fog Frequency				+	+	+	+	+	+	+	+	+
Fog Density					+	+	+	+	+	+	+	+

"+" represents expected increase in values and "-" represents expected decrease in values. Little is currently known about the impact that the reservoir would have on the local climate during the winter months (Tuller, 1991).

As discussed in section 5.1.2.1., the Peace River Valley's unique climate is one of the valley's most valuable resources. Throughout British Columbia (and Canada) agricultural production is primarily limited by climate. The Peace River Valley contains BC's only Class 1 climate (the highest quality of climate for agriculture) north of Quesnel. The valley's unique climate is one of the primary reasons for its substantial agricultural capabilities. Given the tremendous current importance of the valley's agricultural industry, as well as its projected future importance, it would be prudent to seriously consider the changes that Site C would have on the valley's climate. It is also important to note that climatic changes from the reservoir could extend beyond the boundaries of the valley to the surrounding plateaus, which also contain large amounts of agricultural land (British Columbia Institute of Agrologists, 1982).

Global climate change would be expected to influence the impacts of Site C on the local climate. Unfortunately, no current

Box 11: The Agricultural Land Reserve

In recognition of the fact that BC's arable land is an extremely limited resource, the BC government passed the Land Commission Act of 1973. This act established the Agricultural Land Reserve (ALR). The ALR currently covers approximately 4.8 million ha, or approximately 5% of BC's total land area (Agricultural Land Commission, 2009). The lands of the ALR are reserved for agricultural purposes; nonagricultural development of these lands is prohibited.

The Land Commission Act includes provisions which allow for the exclusion of land from the ALR for reasons of "provincial interest" or "community need." Since 1974, a total of 139,076 ha have been excluded from the ALR in order to facilitate nonagricultural development (e.g. housing projects, roads, and golf courses). During this same period, 183,263 ha of land were added to the reserve. The significance of these inclusions and exclusions of ALR land become evident when one remembers that the quality of BC's agricultural land varies greatly (Agricultural Land Commission, 2009). The land which has been excluded from the ALR has been primarily composed of the reserve's highest quality lands. This is well indicated by the fact that 72% of the land which has been excluded from the reserve has been in the southern portion of the province, where agricultural capabilities are generally the highest. Furthermore, the land which has been added to the reserve has generally been of poorer quality, as indicated by the fact that 90% of the land added to the reserve has been in Northern BC (Campbell C. , 2006). Essentially, the quantity of land reserved for agriculture in BC has remained relatively stable over the past 35 years, while the quality of this land has been steadily decreasing.

The ALR is strongly supported by British Columbians. According to a 1997 survey, "90 percent of British Columbians felt that government should limit urban development to protect farmers and farmland; 72 believed it should be difficult or very difficult to remove land from the ALR (Quayle, 1998)." In recent years, many individuals and organizations (e.g. The David Suzuki Foundation and Smart Growth BC) have expressed a great amount of discontent over the removal of high quality agricultural lands from the ALR. Site C's reservoir would destroy over 4000 ha of prime agricultural land (class ratings of 1-3) that is currently protected by the ALR. To put this into perspective, the total amount of land excluded from the ALR from 2005-2008 was 3451 ha (Agricultural Land Commission, 2009).

Table 5: Agricultural land which would be flooded by Site C reservoir.

Capability Class	Description	Ha.	% of Total
1	Optimum potential, full range of crops	192	4
2	Wide range of crops, some restrictions	2981	63
3	Wide range of crops under good management	832	17
4	Restricted range, several limitations	177	4
5	Perennial forage crops, severe limitations	428	9
6	Natural rangeland, no cultivation	4	<1
7	No agricultural capability	83	2
Total		4697	100

Source: (Lions Gate Consulting Inc., 2002).

studies have investigated this issue. As discussed in section 5.3, global climate change is generally expected to make the Peace River Valley's climate even more suitable for agricultural production. However, local changes in climate caused by Site C could negate the potential benefits of global climate change on the region's agriculture.

6.2.3. Loss of the Peace River Valley's Most Important Lands

Perhaps the greatest negative impacts of Site C would be directly related to the loss of a vast amount of the valley's highest quality land. The dam's 9310 ha reservoir would flood approximately 5340 ha of the valley's most important land (the remaining 3970 ha of the reservoir is accounted for by the flooding of the current river) (BC Hydro, 2007). Over 1000 ha of additional land would be impacted by the project's construction site and transmission line. The land which would be lost due to Site C accounts for a substantial amount of the valley's most ecologically and agriculturally important land and the potential loss of this land is particularly worrisome when viewed in the context of climate change.

6.2.3.1. Loss of Agricultural Lands

Given Northern BC's extremely limited supply of premium agricultural land, the Peace River Valley's high quality agricultural lands are undoubtedly a very valuable resource. The value of this land has been recognized by the Province, as virtually all of it is currently protected by the Agricultural Land Reserve (Box 11). Site C's reservoir would flood 5340 ha of land. At least 59% of this land has an agricultural capability class rating of 1 or 2; and at least 74% has a rating of 1 to 3. This respectively accounts for 21% and 26% of all of the Peace River Valley's land with these ratings (Canadian Bio-Resources Consultants Ltd., 1979). These numbers likely underestimate the potential losses of high quality agricultural land from Site C, as only 88% of the land which would be flooded by the reservoir has been classified for its agricultural capabilities. The loss of so much of the Peace River Valley's agricultural lands to Site C's reservoir would likely impose significant constraints on the region's agricultural industry. In fact, some have even suggested that this loss could threaten the viability of an intensive vegetable industry in the Peace River Valley by reducing the quantity of premium farmland to levels which are insufficient for the industry to be able to achieve necessary economies of scale (e.g. insufficient regional yields for the economic operation of vegetable processing facilities) (Canadian Bio-Resources Consultants Ltd., 1979; British Columbia Institute of Agrologists, 1982). As discussed in section 5, climate change is expected to increase the importance of the Peace River Valley's agricultural land. Therefore, it would be insufficient to simply consider the loss of these lands based on their current importance. One must also consider that the value of these lands will increase as climate change increases their agricultural capabilities as agricultural capabilities simultaneously decrease throughout much of BC and North America.

6.2.3.2. Loss of Forests and Habitat Connectivity

One of the most serious direct environmental impacts of Site C would likely arise from the loss of 4913 ha of the valley's forest resources, as well as through the decreased functionality of the valley as a habitat corridor[48]. Site C would destroy much of the valley's highest quality habitat, including old-growth forests, riparian forests, and wetlands. These ecosystems primarily occur at the valley's lower elevations, which is also where the construction of Site C would cause the largest losses of land. For example, approximately 10% of the forest area which would be destroyed by Site C is deciduous forest over 120 years old. These forests are among the rarest and most ecologically important forests of the entire Peace River region (Box 12).

Site C would also substantially decrease the valley's value as a habitat corridor. It is easy to see how the creation of a 9310 ha reservoir would restrict the movement of animals across (north/south) and through (east/west) the valley. As discussed in section 4.3.2, connectivity west of the Peace Canyon dam is restricted or eliminated for many species due to the wide reservoir of the Peace Canyon and W.A.C. Bennett dams and their inconsistent ice cover. The Site C reservoir would likely extend this break in connectivity eastward by some 80 km, which would be particularly detrimental to grizzly bears and small mammals whose ranges do not extent far out onto the Alberta Plateau (Brian Churchill, personal communication, 2009).

As discussed in section 4, the forests of the Peace River Valley are important in mitigating the adverse effects of climate change through their substantial contribution to ecosystem resistance, resilience, and long-term adaptation capabilities. This climate change mitigation is primarily attributable to the rich biodiversity supported by the valley's forests, as well as the valley's role as a habitat corridor. Both of these critical functions would likely be severely impeded by the construction of Site C.

Box 12: Age Class Distribution of Forests that Would Be Destroyed by Site C

As discussed in section 4.3.1.1., the Peace River Valley contains a higher percentage of mature and old-growth forests than its surrounding regions. These forests are responsible for supporting a large amount of the valley's biodiversity. Among the species which depend on these forests are at least six which are considered to be endangered by the BC Ministry of Environment. Perhaps the most significant loss of the valley's forest resources would be the loss of much of the valley's old deciduous stands. In the early 1990s, approximately 10.6 % of the forest area which would have been destroyed by Site C was deciduous forest over 120 years old (Figure 16). There is no doubt that these ecologically crucial forests are rare in the Peace River region. In fact, in the early 1990's, only 1.6% of the 1.5 million ha of forest that surrounded the PRV was of deciduous forest over 120 years old (figure 16).

The forested area that would be destroyed by Site C is actually composed of a lower percentage of mature and old-growth coniferous forests than its surrounding regions (Figure 17). However, this offers little reason for reassurance for two primary reasons. First of all, mature and old-growth coniferous forests are regionally much more common than mature and old-growth deciduous forests. Secondly, the data displayed in Figure 17 does not account for the fact that much of the mature and old-growth coniferous forests which would be destroyed by Site C are riparian forests, which are generally much more scarce and ecologically important than typical mature and old-growth coniferous forests.

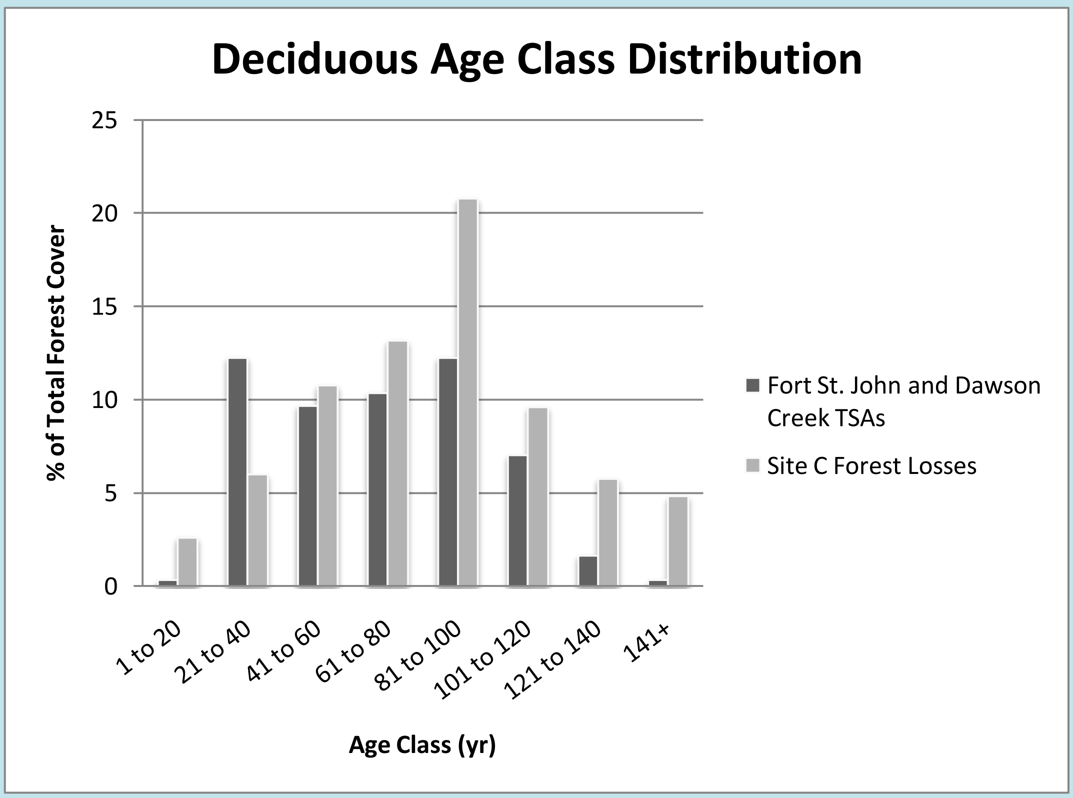

Figure 16: Age class distribution of the deciduous forests which would be destroyed by Site C and the deciduous forests which are included in the Fort St. John and Dawson Creek TSAs.

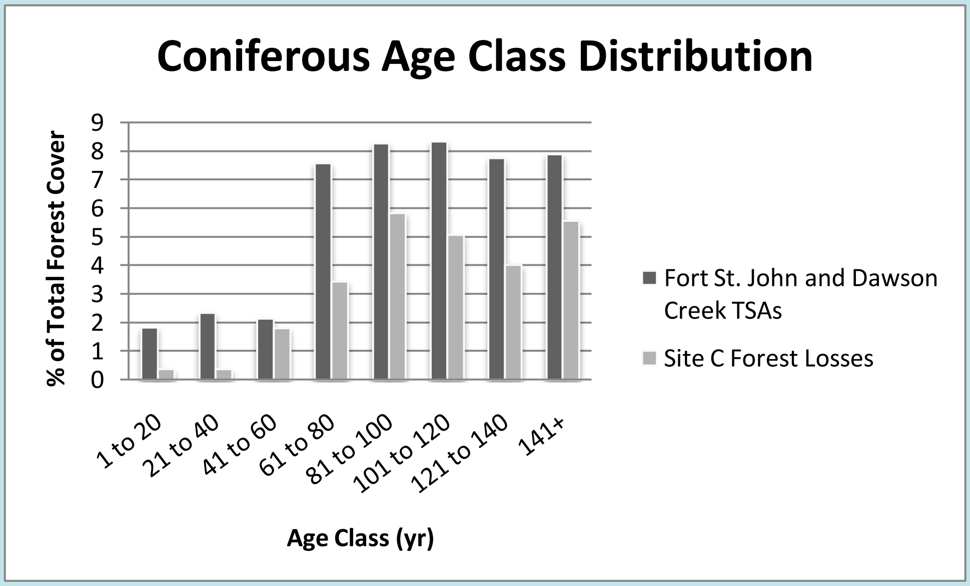

Figure 17: Age class distribution of the coniferous forests which would be destroyed by Site C and the deciduous forests which are included in the Fort St. John and Dawson Creek TSAs.

Approximately 4911 ha of forested land would be directly impacted by the proposed Site C hydroelectric project. This figure includes the forested land which would be destroyed by the reservoir (3124 ha), construction site (767 ha), transmission line widening (273 ha), and Highway 29 relocation (0.4 ha). The entirety of BC's Peace River Valley is located within the boundaries of either the Fort St. John or Dawson Creek Timber Supply Areas (TSA). Of the total gross land base that would be directly impacted by Site C (including agricultural land), 51% is located within the Dawson Creek TSA, while 49% is located within the Fort St. John TSA. The age class distributions for the Fort St. John and Dawson Creek TSAs are representative of the approximately 1.5 million ha of forests within these TSAs that are held under Crown ownership and are available for long-term timber supply. Data is derived from table VII-18, table VII-21, and page 10 of *Peace River Site C Project Forestry Studies* (Industrial Forestry Ltd., 1991).

Figure 18: FSJ and DC TSAs.

CONCLUSION

It is clear that the Peace River Valley positively contributes to climate change mitigation (by sequestering and storing carbon) and adaptation (by providing high quality habitat and agricultural land). It is equally clear that the construction of Site C would severely limit the valley's contribution to climate change mitigation and adaptation.

The vast amounts of carbon stored in the Peace River Valley's plants and soils contribute to the mitigation of global climate change. The valley's lowland forests are expected to store approximately 500 tonnes of carbon per ha; an ecological service which has been valued by previous studies at approximately $2000 per ha per year. The Peace River Valley's 4913 ha of lowland forest potentially destroyed by Site C store approximately 2.5 million tonnes of carbon, worth $9.8 million per year. It must be remembered that the CO2 released from the decomposing biomass of a disturbed forest is no different from the CO2 released from the tailpipe of a car. Likewise, climate change mitigation through the protection of natural environments can be just as important as mitigation through the reduction of fossil fuel use.

Site C will emit substantive greenhouse gases. The construction of Site C would also counteract the valley's contribution to global climate change mitigation. The construction of Site C would flood approximately 5340 ha of land which currently helps mitigate global climate change through carbon sequestration and storage. BC Hydro's own estimate is that the proposed Site C project could have a net GHG impact (including both the lost carbon sequestration as well as the direct emissions from the reservoir) equivalent to the emission of approximately 147,000 tonnes of CO_2/year, or the addition of 36,000 vehicles to the Lower Mainland. The Site C reservoir itself would generate 74,000 tonnes of CO_2 eq/yr, equivalent to the addition of 18,500 emitting vehicles, and continue to emit significant amounts of GHGs over the entire life of the reservoir.

The unique biodiversity and habitat corridors of the Peace River Valley play a major role in facilitating the ability of the North American Rocky Mountain ecosystem to adapt to climate change. Biodiversity and habitat connectivity are well known to be important in facilitating the adaptation of ecosystems to climate change, due to their contributions to ecosystem resistance, resilience, and long-term adaptation capabilities. The Peace River Valley has a high level of biodiversity, with over 300 wildlife species and over 400 vascular plant species. Furthermore, much of the valley's flora and fauna have special conservation importance in the context of climate change (e.g. threatened and endangered species; species which rely on wetlands and old-growth; and populations at the northern limit of their species range). The Peace River Valley also provides vital habit corridors within a region characterized by substantial habitat fragmentation. These habitat corridors will become increasingly important as climate change increases both habitat fragmentation and the levels of stress experienced by the region's populations. The construction of Site C would destroy approximately 4900 ha of the valley's forest resources, including much of the valley's highest quality habitat (e.g. old-growth forests, riparian forests, and wetlands). This would greatly decrease the valley's biodiversity and its function as an important habitat corridor; thus, significantly reducing the valley's contribution to climate change adaptation.

As global climate changes, Peace River Valley agricultural resources have the unique potential to provide a significant, secure, local food source for BC residents. While agriculture throughout much of BC and North America will likely experience serious adverse impacts from climate change, the Peace River Valley's agricultural potential is expected to reap some of the greatest benefits from climate change. It is very likely that climate change could help promote the establishment of a thriving vegetable industry in the Peace River Valley, which could help increase BC's food self-reliance and provide local food for the people of Northern BC. The construction of Site C would destroy the future potential of 21% of the valley's highest quality agricultural land (Class 1 and 2).

While this would not eliminate the valley's entire agricultural industry, the loss of 3173 ha of Class 1 and 2 agricultural land in Northern BC would indeed be a substantial loss. Furthermore, the loss of this land could potentially have impacts on the region's remaining land by limiting the viability of certain intensive production options which require large economies of scale. In addition, there is a significant potential that Site C's reservoir could cause local climatic changes which would adversely impact agriculture on the valley's remaining land.

The cost of Site C's net GHG emissions resulting from the reservoir and loss of sequestering landscape substantively raise the true cost of the project. The construction of Site C would severely limit the ability of the Peace River Valley to contribute to climate change mitigation (through the project's GHG impact) and adaptation (through the destruction of valuable ecosystems and agricultural land). In order to determine whether or not the construction of Site C is in the best interest of British Columbia, it is critical that an analysis of Site C's potential costs and benefits is as comprehensive as possible. Given the high level of scientific certainty regarding the substantial climatic changes which BC will experience throughout this century, it would be inexcusable to omit the influence of climate change from predictions of Site C's potential environmental and socio-economic impacts. When Site C is considered in the context of climate change, a number of very substantial costs are revealed. Unfortunately, these costs have been almost entirely ignored up to now, especially by BC Hydro.

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APPENDIX 1 – MERCHANTABLE TIMBER

Leading Species	Area (ha)	Merchantable Timber (m^3/ha)	Merchantable Timber (m^3)	Merchantable Timber (tonnes)[49]	Total Tree Biomass (tonnes/ha)	Total Tree Biomass (tonnes)
MERCHANTABLE STANDS						
Trembling Aspen	1507	205	309127		318	351502
Balsam Poplar	1324	356	471148		474	420830
White Spruce	1109	361	402209		233	525349
Lodgepole Pine	56	301	17053		259	14564
Larch	17	167	2793		261	4357
All Species	4013	300	1202330		328	1316602
NON-MERCHANTABLE STANDS[50]						
Trembling Aspen	564	34	19419		318	179413
Balsam Poplar	139	29	4049		217	30229
White Spruce	104	32	3347		87	9023
Lodgepole Pine	2	68	135		126	251
Larch	NA	NA	NA		NA	NA
All Species	809	33	26950		271	218916
ALL STANDS						
Trembling Aspen	2071	159	328546	212679	256	530915
Balsam Poplar	1463	325	475197	324149	308	451059
White Spruce	1213	334	405556	276719	441	534372
Lodgepole Pine	58	296	17188	11731	255	14815
Larch	17	167	2793	1922	256	4357
All Species	4822	255	1229280	827202	350	1689076

[49] Weight of merchantable timber was determined from the volume of merchantable timber and the following assumptions regarding the density of fresh wood (kg/m^3) for each species: Aspen=688 kg/m^3; Poplar=784 kg/m^3; Spruce=544 kg/m^3; Pine=624 kg/m^3; Larch=752 kg/m^3 (The Engineering Tool Box, 2005)

[50] Stands are considered merchantable if they have at least 80 m^3 of merchantable timber per ha.