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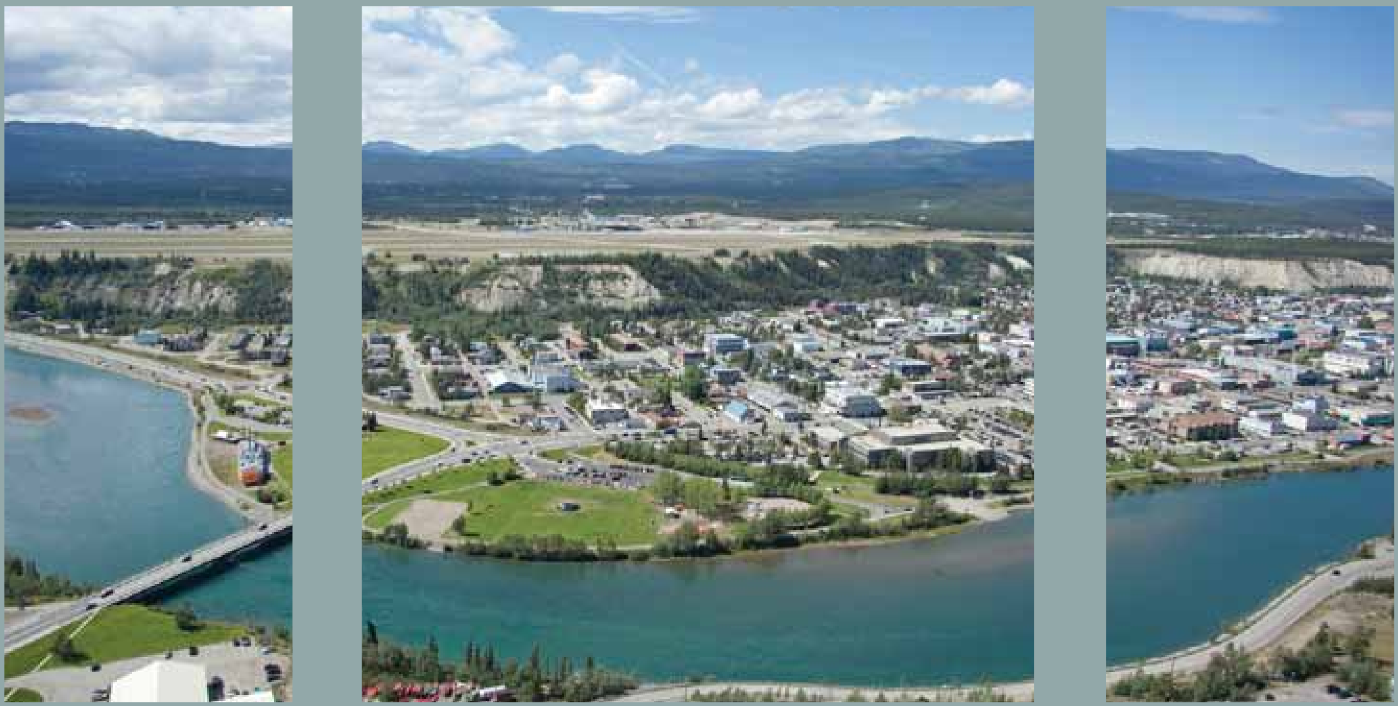


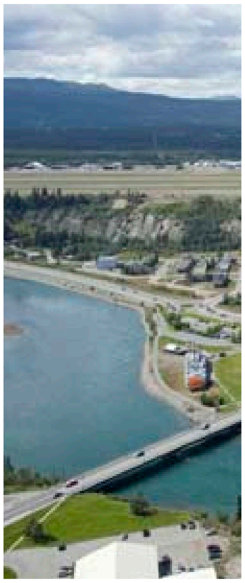
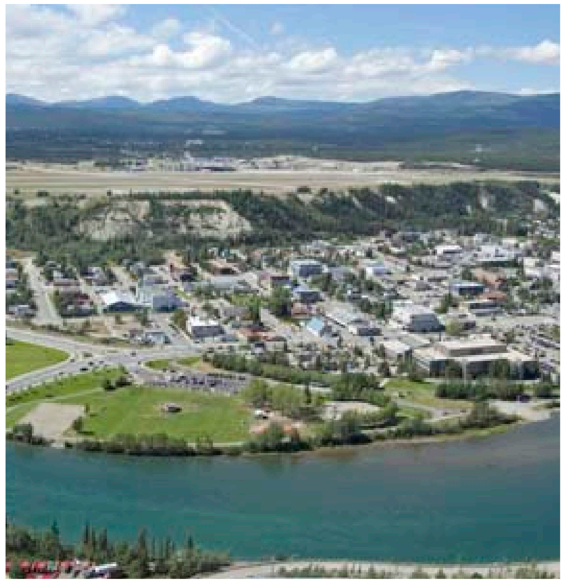
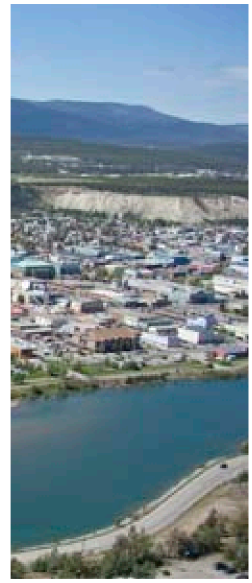
WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

June 2011

Canada
Northern Strategy Trust

Northern Climate ExChange
YUKON RESEARCH CENTRE • Yukon College

COMMUNITY ADAPTATION PROJECT

WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

June 2011

TAKING ACTION ON CLIMATE CHANGE

Yukon Government

Canada Northern Strategy Trust

UBC

Northern Climate ExChange
YUKON RESEARCH CENTRE · Yukon College

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WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

Prepared by the Whitehorse Adaptation Project Team

Northern Climate ExChange, Yukon Research Centre, Yukon College

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Office space for the Whitehorse Local Adaptation Coordinator was generously provided by the City of Whitehorse. The City of Whitehorse Planning and Development Services Department also contributed technical support to adapt the City of Whitehorse Official Community Plan maps for use in this report.

We are especially grateful to the members of the Whitehorse Local Advisory Committee and the Whitehorse Technical Advisory Committee for the commitment that they have given to this project.

Foreword from the WhiteCAP Local Advisory Committee

The main role of the Whitehorse Community Climate Change Adaptation Project Local Advisory Committee (WLAC) has been to provide a local perspective to the project and to guide the allocation of money for pilot adaptation projects. The WLAC members were chosen to balance the broad and overlapping interests/jurisdictions that co-exist in Whitehorse while striving for solutions which will be effective and widely supported.

Our goal has been to develop a community plan as a foundation in preparing Whitehorse for climate change. Our intention was that overall this work should contribute to the sustainable well-being of the community. The plan provides a broad analysis of the risks and opportunities of climate change, and makes a series of recommendations. It is now up to the decision-makers within the community - the City of Whitehorse, Government of Yukon, Ta'an Kwäch'än Council, Kwanlin Dün First Nation and other community groups to decide upon the next steps and carry the work forward.

LAC Member	Organization	Signature
Dan Boyd	Government of Yukon	Dan Boyd.
Shannon Clohosey	City of Whitehorse	Shannon Clohosey
Simon Lapointe	Ta'an Kwäch'än Council	[illegible]
John Meikle	Kwanlin Dün First Nation	[illegible]
Lewis Rifkind	Yukon Conservation Society	[illegible]
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Northern Climate ExChange
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EXECUTIVE SUMMARY

ABOUT THE WHITEHORSE COMMUNITY ADAPTATION PLAN

Climate has been changing in Whitehorse. It is clear from weather data going back to the 1940s that temperature has been warming, especially in winters. Spring break-up has been arriving earlier, freeze-up has been occurring later, and the number of frost free days have been increasing.

The Whitehorse Community Adaptation Project, or WhiteCAP, funded by the Northern Strategy Trust, begins the process of preparing Whitehorse for climate change. WhiteCAP consists of two distinct phases: planning and implementation.

The WhiteCAP plan assesses how climate change may positively or negatively affect the community over the next forty years, to 2050. The first half of the planning process focuses on exploring multiple scenarios of how the community may change by 2050. Details on the scenarios are presented in a companion document for this plan titled: *Future Histories of Whitehorse: Scenarios of Change* (Hennessey and Streicker, 2010). The second half of the planning process assesses the risks of climate change impacts and then the priorities of climate change adaptations. Parts of this plan have been implemented in the second year of the WhiteCAP project.

The first step in the WhiteCAP planning process is to project what changes are coming. We developed four scenarios describing how climate change may affect the community of Whitehorse. These futures take into consideration a range of climate change scenarios and also a range in city growth (both economic and population). Climate change is uncertain, but by bracketing the possibilities we are more likely to capture the actual future of Whitehorse.

The range of scenarios gives breadth to this complex problem. Depth is created by providing detail to the scenarios. This allows the community to evaluate its own vulnerability. Based on the scenarios, the community identified nearly 250 impacts and proposed as many adaptations to address climate change.

Community risk was assessed on a sector-by-sector basis and then on an impact-by-impact basis. Risk was determined based on the severity of anticipated impacts (or the strength of the opportunity), the likelihood of the impact occurring, and the current capacity of the community to adapt to that impact. The five priority sectors for Whitehorse are: natural hazards, infrastructure, environment, food security and energy security.

WhiteCAP is a planning process whereby the broader community was engaged through a series of open houses, focus groups and a central workshop to consider how climate change may exacerbate vulnerability in the Whitehorse region. Community members were invited to contribute to all phases of WhiteCAP, including planning, editing, and implementation. In all, four open houses and three workshops were held in the community over the two years of the adaptation project, from June 2009 to June 2011.

CLIMATE CHANGE AND WHITEHORSE

Climate change projections illustrate that Whitehorse will experience warming temperatures and shifting precipitation. Even modest changes in temperature and precipitation will have complex side effects that will intensify vulnerabilities or enhance opportunities for the community. Annual and seasonal temperatures for Whitehorse have been projected for 2030 and 2050. Warming will differ seasonally; winter is projected to warm the fastest – increasing 3°C to 5°C over the next 40 years. Mean annual precipitation is anticipated to increase 14% to 22% by 2050. Based on the projected shifts in temperature and precipitation, the number of frost-free days for Whitehorse is expected to increase, rising from 150 days to 168-175 days by 2050, an addition of 18-25 days.

ADAPTATION

Whitehorse is already being impacted by climate change and more change is projected in the near future. The key sectors being impacted are natural hazards (especially fire and flood), infrastructure, food security, environment and energy security.

Climate change is complex. Impacts will result from the recent and projected trends in climate, but also from changing intensity, frequency, variability, duration and critical thresholds. Not all impacts are negative (*e.g.*, longer, warmer growing seasons), and out of challenges, opportunities may arise.

There is enough information to make smart adaptation choices now, although there will always be some uncertainty. Uncertainty has been incorporated into the WhiteCAP research in order to understand and manage it. Where we lack enough information about the impacts or about how the community might change, then part of our response is to call for observation and the determination of baselines. Gathering knowledge, planning, and taking action (and also public education) becomes a cycle, and this in turn allows for adaptation to be evaluated in an on-going basis. This is critical as climate change is dynamic and we will need to refine our responses to it.

Adaptations (responses to the consequences of climate change), are evaluated based on how well they address impacts, how well they fit with the community, and whether they build capacity. Through the WhiteCAP project, we have identified a list of adaptation priorities for the community.

It is best to integrate climate change considerations into existing planning processes. Key areas where mainstreaming can support climate change adaptation include increasing local resilience through emergency preparedness, sustainability planning, and effective land-use planning. Throughout the planning process, it is important to understand climate projections and the associated risks of the impacts, whether there is likelihood for risk, and then determine its severity. The existing resources and capacity within the community must also be identified.

Addressing climate change is a shared responsibility for the entire community of Whitehorse. Governments, the business community, academic researchers and citizens of Whitehorse all have a role to play. Partnerships will create stronger, more lasting solutions, especially where jurisdictions overlap.

The public wants and expects that adaptation should also include a reduction of greenhouse gases; the community wants to see a response to climate change and does not differentiate between adaptation and mitigation. As part of the vision of the project, adaptations are sought which enhance the sustainable well-being of the community.

Whitehorse needs to be planning now for the long term challenges and opportunities that climate change may bring. As WhiteCAP completes its work, the lead will turn to the partners that contributed to the project, such as the City of Whitehorse and the Yukon Conservation Society.

KEY TERMS

Adaptation is a response to actual or expected climate impacts or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

Adaptive capacity is the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with consequences (IPCC, 2007).

Evapotranspiration is the amount of water returned to the atmosphere from the combination of evaporation and transpiration; the passage of moisture through the surface of plant leaves (SNAP, 2009).

Greenhouse gases are the trace gases in the atmosphere, which absorb heat radiation and cause the earth to warm. Water vapour (H_2O), carbon dioxide (CO_2) and methane (CH_4) are the primary greenhouse gases (Nebojša *et al.*, 2000).

Mitigation is an action intended to reduce the onset and severity of climate change and includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks (IPCC, 2007).

No regrets actions refer to those adaptations that provide benefits to the community even if no climate change occurs (Snover *et al.*, 2007).

Resilience is the "capability of a system to maintain its function and structure in the face of internal and external change and to degrade gracefully when it must" (Allenby and Fink, 2005, p. 1034).

Risk management is the systematic application of management policies, procedures and practices to the tasks of analyzing, evaluating, controlling and communicating the possibility of injury or loss due to an adverse effect to health, property, the environment or other things of value (CSA, 1997).

Scenarios are an internally consistent view of what the future might turn out to be (Porter, 1985).

Scenario planning is a strategic planning tool for medium to long-term planning under uncertain conditions involving the assessment of multiple futures (Lindgren and Bandhold, 2003).

Susceptibility is the degree to which a community is exposed to hazards (WHO, 1999).

Win-win actions reduce the impacts of climate change while providing other environmental, social or economic benefits (Snover *et al.*, 2007).

LIST OF ACRONYMS

CASM	Council and Senior Management (City of Whitehorse)
CCCAP	Community Climate Change Adaptation Project
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CYFN	Council of Yukon First Nations
GHG	Greenhouse Gases
GCM	Global Climate Model
IPCC	Intergovernmental Panel on Climate Change
MAT	Mean Annual Temperature
NCE	Northern Climate ExChange
SNAP	Scenarios Network for Alaska Planning
WhiteCAP	Whitehorse Community Climate Change Adaptation Project
WLAC	Whitehorse Adaptation Project Local Advisory Committee
WTAC	Whitehorse Adaptation Project Technical Advisory Committee
WPYR	White Pass and Yukon Route
YBS	Yukon Bureau of Statistics
YRC	Yukon Research Centre

INTRODUCTION

Climate change, and the host of challenges and opportunities it represents for the North, is an important matter for Yukon. Over the past fifty years, the Western Arctic and sub-Arctic region of Canada has experienced a significant increase in temperature of approximately 3°C and an increase in precipitation of roughly 8% (ACIA, 2004; Zhang *et al.*, 2000). Changes in temperature and precipitation have already resulted in subsequent shifts in landscape conditions and may increase the vulnerability of Yukon communities to environmental stresses associated with variable weather, drought, flooding, forest fire, and food and energy security. These environmental stresses in turn carry implications for northern infrastructure, the health of northern residents, and our economy. Given the far-reaching implications of climate change, the need to adapt our communities to a changing and uncertain future grows ever more clear.

The Whitehorse Community Adaptation Project, or WhiteCAP, consists of two distinct phases: planning and implementation. The WhiteCAP plan is intended to assess how climate change may positively or negatively affect the community over the next forty years, to 2050. WhiteCAP is led by the Northern Climate ExChange (NCE) Community Climate Change Adaptation Project (CCCAP). NCE is a department of the Yukon Research Centre, of Yukon College. The mandate of CCCAP is to increase the adaptive capacity of Yukon to respond to climate change through the development and implementation of adaptation plans in three communities: Dawson, Whitehorse and Mayo. WhiteCAP is funded by the Yukon Northern Strategy Trust, a federal government infrastructure development fund.

The focus of WhiteCAP is the community of Whitehorse including the people, services and facilities that fall within the city limits. Although this does not include nearby unincorporated communities, it is our expectation that the climate change risks for these nearby communities will be similar to those faced by Whitehorse. The recommendations of this plan will therefore also be applicable for neighbouring communities.

The WhiteCAP plan first documents the methodology used to assess the vulnerabilities of Whitehorse to climate change. The plan then inventories the current socio-economic and environmental characteristics of the community to provide a basis for discussions of risk later in the planning process. While some climate change impacts may be unprecedented, many represent impacts that are familiar, yet which may occur more frequently or more severely in the future. The remainder of the plan is devoted to determining priority adaptations for the community of Whitehorse.

THE WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN VISION

A Whitehorse Local Advisory Committee (WLAC) was established at the outset of WhiteCAP. The advisory committee includes representatives of Ta'an Kwäch'än Council, Kwanlin Dün First Nation, Government of Yukon, City of Whitehorse and the Yukon Conservation Society. The mandate of the WLAC was primarily to provide guidance and ensure that the planning process sufficiently reflects community concerns and capacity. As a starting point for this process, the WLAC was asked to describe their vision of a community that has successfully adapted to climate change:

> *The community of Whitehorse is preparing for climate change, including variability and uncertainty, by building capacity, knowledge, resilience and partnerships. Adaptation proactively enhances the sustainable well-being of the community.*

The community vision identifies a number of priorities, which include knowledge provision, partnership identification and capacity development. These priorities have been considered throughout the planning process and form the goals that formed the basis of the Whitehorse Adaptation Strategy (see discussion below). Other aspects of the vision, such as the well-being of the community and climate change mitigation have been factored into the planning process as special considerations.

SPECIAL CONSIDERATIONS OF THE WHITEHORSE ADAPTATION PLAN

The special considerations which emerged consistently throughout the adaptation planning process in Whitehorse are directly associated with building the adaptive capacity of the community. These special considerations include: sustainable development, climate change mitigation, and the special link between the community and the wilderness surrounding Whitehorse.

Sustainable development

In 2009, the City of Whitehorse officially adopted *The Whitehorse Strategic Sustainability Plan* (City of Whitehorse, 2009). The Sustainability Plan encompasses a wide range of values, including a sense of community, a high quality of life, nature, leadership, and the contributions of First Nations culture, the arts, and local business. The pursuit of these values further influences climate change adaptation through their contribution to the social capital of the community, and in turn the contribution of social capital to adaptive capacity (Adger, 2003). Other attributes of sustainable development, such as increases in efficiency of resource use and in the flexibility of land use, can also make a significant contribution to the capacity of the community to adapt (Fellows, 2006).

Climate change mitigation

Climate change mitigation is a priority for the community of Whitehorse. The mitigation of climate change through the control of greenhouse gas emissions is a shared responsibility, which will eventually reduce the severity of the impacts to which the community will have to adapt. As a result, a balance between mitigation and adaptation is the most effective way to respond to climate change vulnerabilities (IPCC, 2007). Often adaptations have a mitigative component which reduces greenhouse gas emissions while increasing adaptive capacity.

Several opportunities for reducing greenhouse gas emissions in Whitehorse were identified through the community consultation process. Many correlate to the Community Action Plan established by the City of Whitehorse in 2004, which suggested a number of educational, operational and policy actions that would reduce the carbon footprint of community buildings, transportation, land use, and waste management (City of Whitehorse, 2004). Where possible, the recommendations of this plan should complement mitigation efforts.

Connection between the community and the wilderness

The special connection between Whitehorse residents and the wilderness areas surrounding the city was noted on several occasions during the planning process. This connection influences recreation, culture and the sense of well-being in the community. A special mapping session was held by NCE in November, 2009 with interested participants, whereby the participants were asked to map those special aspects of Whitehorse that they valued. This connection between Whitehorse residents and the surrounding wilderness was also reported in *The Whitehorse Strategic Sustainability Plan*:

> *The Yukon River runs through Whitehorse and our city is surrounded by mountains. Our residents value the nearby access to the wilderness. Residents value the wildlife, green spaces and trails in our neighbourhoods and the connections to other neighbourhoods.*

We value clean air and water.
(City of Whitehorse, 2009, p. 8)

The urban-wilderness interface described by the City of Whitehorse makes an important contribution to the health of the urban system, which depends on a functioning, shared relationship between the built form and natural ecosystem. For example, wildfire depends on, and can be managed by, land planning and the strategic management of fuel loading (Keeten *et al.*, 2007).

WHITEHORSE ADAPTATION PLANNING PROCESS

The influence of climate and climate change on communities is complex. The Whitehorse adaptation planning process was developed to manage the uncertainty and variability associated with regional climate change. The process utilized a natural approach, which "…does not rely on any unwarranted assumptions and incorporates 'multiple everything' – strategies, scenarios, and different risk types." (Masch, 2004, p. 435).

Climate, by definition, is variable, and projecting future climate always involves uncertainty. For example, there is uncertainty in global climate models, economic growth forecasts, and population projections. Uncertainty at these broad levels is compounded at the regional scale by a lack of detailed information, and the specific responses of the landscape and the community to change[1].

Fortunately we have ways to address this uncertainty within the planning process. For WhiteCAP, a combination of scenario planning and risk management was used. Scenario planning allows for a range of probable futures to be evaluated. While it is difficult to say precisely how the climate will change, we have reasonable confidence that this change will fall within the range of scenarios. Accounting for the variability associated with change also provides a context from which to evaluate other complex relationships that influence the vulnerability of the community, such as how and where growth will occur. Risk management is a technique that allows us to make informed decisions and prioritize actions in the face of uncertainty.

SCENARIO PLANNING AND RISK MANAGEMENT

The Whitehorse adaptation plan is based on an evaluation of community vulnerability. To assess this vulnerability we developed four scenarios describing how climate change may affect the community of Whitehorse based on an increase in regional mean annual temperature of 2°C to 4°C and a population growth of 12,000 to 24,000 people by 2050.

Each scenario combines a different possibility of climate change and growth. For example, scenario 1 evaluated some climate change versus some community growth; scenario 2 evaluated some climate change against lots of growth, *etc*.

The scenarios (summarized in Appendix A) revealed a range of community-level impacts across nine broad sectors: economy, environment, socio-cultural, infrastructure, energy security,

1. Uncertainty is compounded when the coarse resolution and error in the model is refined or downscaled to a scale suitable for regional planning. Global Circulation Model (GCM) grid cells are typically 1° to 5° latitude and longitude in size. Downscaling introduces error into the climate model by interpolating the implications of climate change at a regional scale. It has also been observed that a polar amplification of the influence of greenhouse gas emissions and other variables influencing climate occurs in GCMs. This amplification varies with each GCM and some projections of climate change in northern regions are more robust. The performance of GCMs over the broader north correlates to their performance over Greenland and Alaska. Some level of error is associated with all GCM projections (Walsh *et al.*, 2008).

hazards, food security, health, and education. The full community climate change scenarios and all proposed adaptations are available in the companion document for this report: *Future Histories of Whitehorse: Scenarios of Change*[2].

During the planning process, the community identified 237 impacts and proposed 245 adaptations to address climate change. Of these, the project team anticipated only a small proportion would be of priority; therefore two levels of risk assessment were conducted to establish where vulnerability was greatest and to comprehensively manage risk to the community (Figure 1).

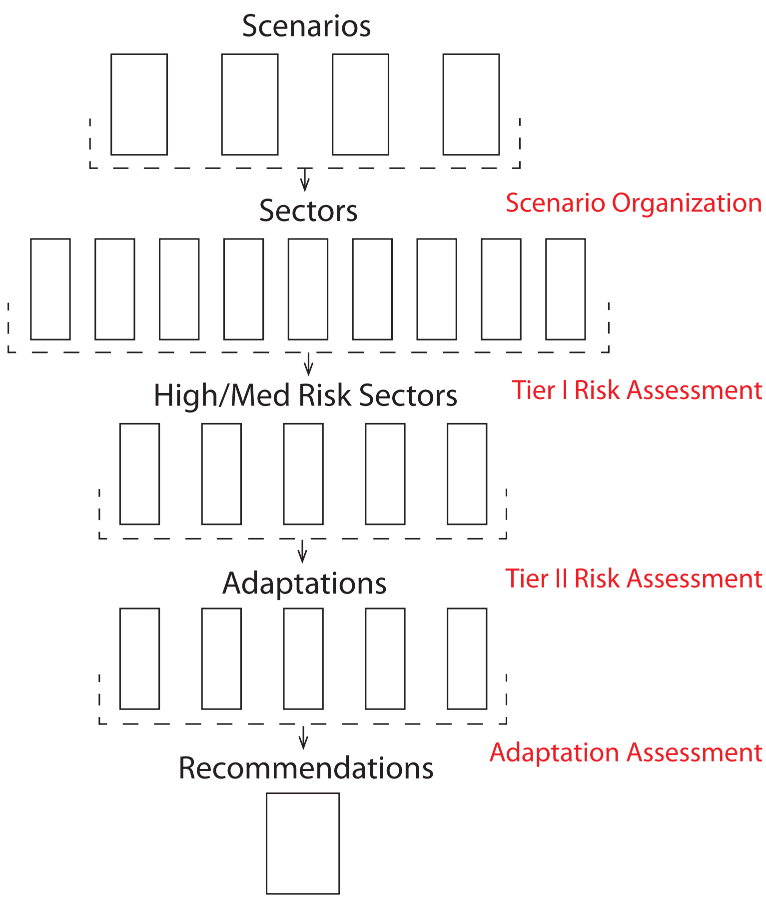


Figure 1. *Risk management process for the Whitehorse Climate Change Adaptation Plan (WhiteCAP).*

The first level of risk assessment, or tier one, prioritized the broad sectors that had emerged from the scenarios based on the severity of anticipated impacts, the likelihood of the impact occurring, and the adaptive capacity of the community to respond to that impact. The five priority sectors were determined to be natural hazards, infrastructure, environment, food security, and energy security.

In the second tier of risk assessment, the project team evaluated each specific impact from the priority sectors. The same criteria, *i.e.*, likelihood, severity and adaptive capacity, were used

2. *Future Histories of Whitehorse: Scenarios of Change* is available online at http://www.taiga.net/nce/adaptation/future-histories-of-whitehorse.pdf.

to assess risk of each impact. Opportunities were assessed in a similar fashion; however, we considered the strength of the opportunity rather than the severity of the risk.

COMMUNITY ENGAGEMENT

The community of Whitehorse was actively engaged throughout the adaptation planning process, from June 2009 to March 2011. Community engagement occurred at several levels including WLAC meetings, open houses, newsletters, technical working sessions, presentations to project partners[3] and workshops with broad community input.

As illustrated in Figure 2, the WLAC compliments the Technical Advisory Committee, a panel of professionals and academics familiar with climate change and Yukon. The combined efforts of both panels facilitated the integration of local and scientific knowledge in the planning process. Membership of both committees is documented in Appendix B.

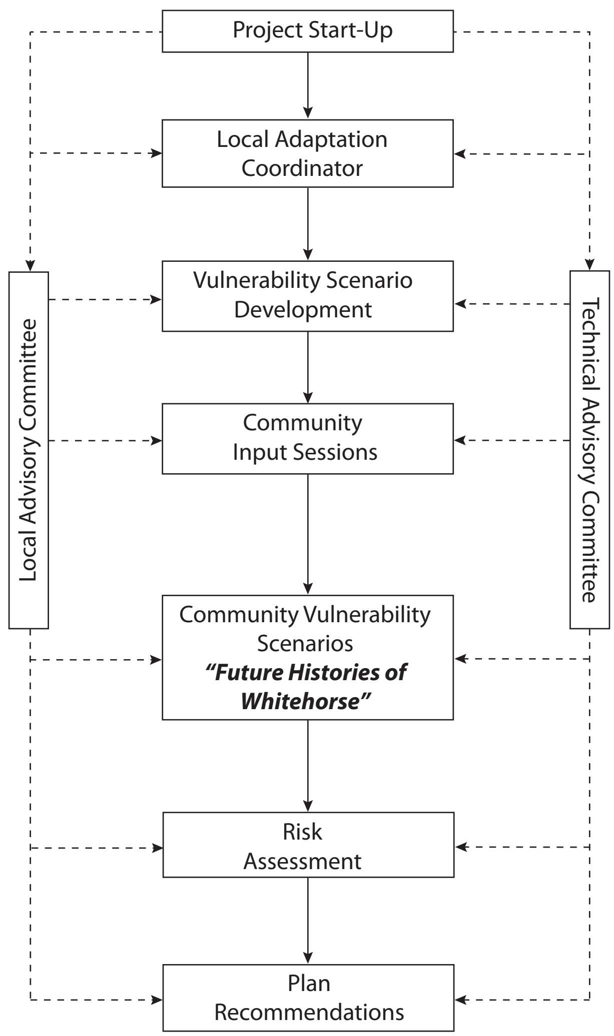


Figure 2. *Whitehorse climate change adaptation planning process.*

3. The Project Team presented at two Council and Senior Management sessions in the spring of 2009. The City of Whitehorse provided official approval for staff participation in the project at an official council meeting in the summer of 2009. A meeting with the Ta'an Kwäch'än Lands Department took place in the summer of 2010.

The broader community was engaged through a series of open houses, beginning with an introductory open house in June 2009 to promote the project. A total of four open houses and three workshops were held in the community over the course of the two-year adaptation project, from June 2009 to June 2011.

LIMITATIONS OF THE WHITEHORSE ADAPTATION PLAN

The Whitehorse adaptation plan makes recommendations to increase the resilience of Whitehorse based on the assessment of climate change vulnerability. The plan was developed through a rigorous process, which emphasized local knowledge and its integration with scientific information. However, given the broad nature of the assessment, the plan is necessarily limited by the availability and quality of data, the diversity of the community, and our emphasis on qualitative information.

Climate change will affect almost every facet of Yukon and the people who live in it. Assessing this complex system is challenging and uncertainty is a significant component of climate change research (Malone and Brenkert, 2008). While the Whitehorse adaptation planning process was designed to manage uncertainty to the greatest degree possible, data gaps do exist. Therefore, the Whitehorse adaptation plan should be revisited regularly as new information emerges and the uncertainty associated with adaptation planning is reduced.

The Whitehorse region is also remarkably complex. As will be described in the next section, the area is composed of extensive infrastructure, a number of interrelated governing bodies, and a relatively diverse population and economy. This complexity has been challenging to appraise given the broad nature of the adaptation plan. Extreme or special cases characterized by a high level of uncertainty have been especially challenging to evaluate. Such cases include a population expansion well beyond that indicated by current trends (or conversely a population decline), exceptional disaster situations, and/or regime shifts at an unprecedented rate of change. Our recommendations have been developed based on the information that could be gathered and supported by local, professional and academic technical knowledge. It should also be noted that an increase in community resilience through the timely implementation of adaptation strategies will buffer Whitehorse against some or all of the vulnerabilities associated with unprecedented and/or extreme events.

The use of spatial information in this report has been largely used to support the observations provided to us by the community and by the Local and Technical Advisory committees. Quantitative information has therefore not played a significant role in the planning process. In part, our reliance on qualitative data has arisen due to the emphasis on local and technical knowledge in the plan. Quantitative data has also been challenging to integrate due to the broad nature and suite of issues that this plan addresses. As uncertainty is addressed and additional information becomes available, it is likely that a greater emphasis can be placed on quantitative information in the adaptation planning process. It is encouraged that quantitative information is integrated into future versions of this adaptation plan as opportunity allows.

WHITEHORSE COMMUNITY PROFILE

Many factors create the unique characteristics that define Whitehorse and its vulnerability and resilience to climate change. Some of these characteristics stem from the community, such as the demographic profile of residents, their history of addressing hazards, their education, and the economy. Other characteristics emerge from the landscape (*e.g.*, biophysical profile of the community), which determines the susceptibility of the region to environmental stresses and hazards. These characteristics cumulatively determine the adaptive capacity of the community. The following profile briefly describes the current profile of the community based on the outlined characteristics of adaptive capacity and creates the context for the evaluation of climate change risk later in the plan. The Whitehorse community profile has been extensively documented elsewhere and therefore is only briefly discussed in this report (see "*2010 City of Whitehorse Official Community Plan"*, City of Whitehorse, 2010 for further reading).

Whitehorse is located within the traditional territories of Kwanlin Dün and Ta'an Kwäch'än First Nations. Given the size and diversity of the community of Whitehorse and the range of potential issues anticipated to result from climate change in the region, the study area boundary for the adaptation plan was established at the Whitehorse city limits (Figure 3). This study area boundary was used to scope some specific issues related to the population of the community as defined in the introductory section of this report, such as health, built infrastructure, and service provision. Other vulnerabilities, such as food security, emergency planning and linear infrastructure are all influenced by factors far outside of the study area boundary. As a result and by necessity, the considerations of this plan sometimes extend beyond the established boundary.

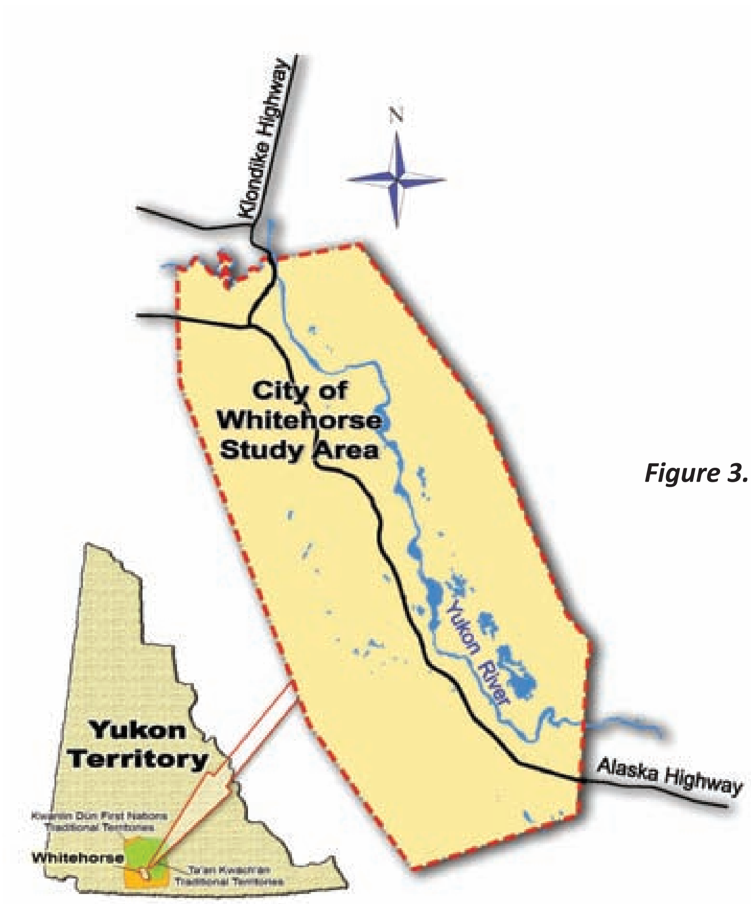


Figure 3. *Location of WhiteCAP study area.*

WHITEHORSE DEMOGRAPHIC PROFILE

Whitehorse serves as the political and commercial hub of Yukon, and has a relatively diverse economy and extensive infrastructure. As of June 2010, the community had a population of 26,418 or 75% of the total population of the Territory (YBS, 2010). This far exceeds the population of any other Yukon community. For example, in December 2009, the community with the second highest population in the Territory was Dawson City (1,873), and the majority of Yukon communities host a population of less than 1,000 residents (YBS, 2010). Many aspects of the Whitehorse community shape its adaptive capacity, including age, tradition, governance, economy, wealth, education profile, and the transience of the population. These variables define the human resources, the institutional capacity, and the expertise available for the community to respond to climate change (Engle and Lamos, 2009; Ebi and Semenza, 2008; Adger *et al.*, 2004).

Whitehorse is characterized by an aging population, and by definition, is growing most rapidly in the 55+ age group (YBS, 2007; Cameron, 2006). As of June 2010, approximately 21% of the city's population was 55 years of age or older (YBS, 2010). Moreover, in all growth projections for Yukon, the 50+ age group is anticipated to increase to more than 35% by 2018 (YBS, 2008a). The current age distribution of Whitehorse and the projected growth in the 50+ age group has significant implications for the community's adaptive capacity given that the majority of Yukon's population resides within city limits.

The economy of Whitehorse is characterized primarily by public sector employment. According to research, 26% of the population is employed by government, *i.e.*, Federal, Territorial, Municipal, or First Nation, and by institutions such as Yukon College and the Whitehorse General Hospital. Private-sector employment in Whitehorse is characterized by retail trade (11% of the total labour force), the health and social assistance sector (10%), accommodation and food services (8%), construction (7%) and education (6%). The remaining proportion of private-sector employment is provided by manufacturing, transportation and warehousing, telecommunications, finance and insurance, and other service industries. The dominance of the public sector in the employment profile has a stabilizing effect on the local economy and somewhat moderates the boom-bust influence of the mining industry (City of Whitehorse, 2010). This economic stability is important to community adaptive capacity.

The average income of Whitehorse residents is high when compared to the rest of Yukon and Canada. In addition to being relatively wealthy, the community is well educated. Within Whitehorse, 20% of residents have a university-level education, 21% have a college education, and 11% have a certificate or diploma in trades or an apprenticeship. Only 20% have no diploma or degree (compared to 26% nationally). The major fields of study reported by the community include social sciences and law, business management and public administration, architecture and engineering, and health (Statistics Canada, 2010).

The population of Whitehorse has become increasingly stable over the past few decades. Studies have shown that 78% of individuals are permanent residents who have lived in the community for over five years (Kishchuk, 2009). The decreased transience of the community increases its adaptive capacity because permanent residents tend to have a greater investment in their community and are therefore more likely to take action under adverse conditions. In addition, 19% of the Whitehorse population is self-identified as aboriginal[4] (YBS, 2008b). The proportion of indigenous peoples in the community supports a strong sense of place and connection to the region.

4. The Aboriginal identity population is composed of those persons who reported identifying with at least one Aboriginal group, that is North American Indian, Métis or Inuit, and/or those who reported being a Treaty Indian or Registered Indian, as defined by the Indian Act of Canada, and/or those who reported they were members of an Indian Band or First Nation (YBS, 2008b).

BIOPHYSICAL PROFILE OF THE WHITEHORSE REGION

Climate change vulnerability for the community arises from biophysical characteristics such as topography, hydrology, freeze-thaw activity, and local biodiversity. The City of Whitehorse is situated along the Yukon River in relatively mountainous terrain. The community is surrounded by boreal forest. The city is characterized by extensive linear infrastructure (Figure 4) and relatively secluded subdivisions (Figure 5). Country residential neighbourhoods on the periphery of the community, such as Mary Lake, Wolf Creek and Hidden Valley, are especially isolated. Much of the development within the urban core has occurred on the floodplain, including the downtown, Marwell and Riverdale areas.

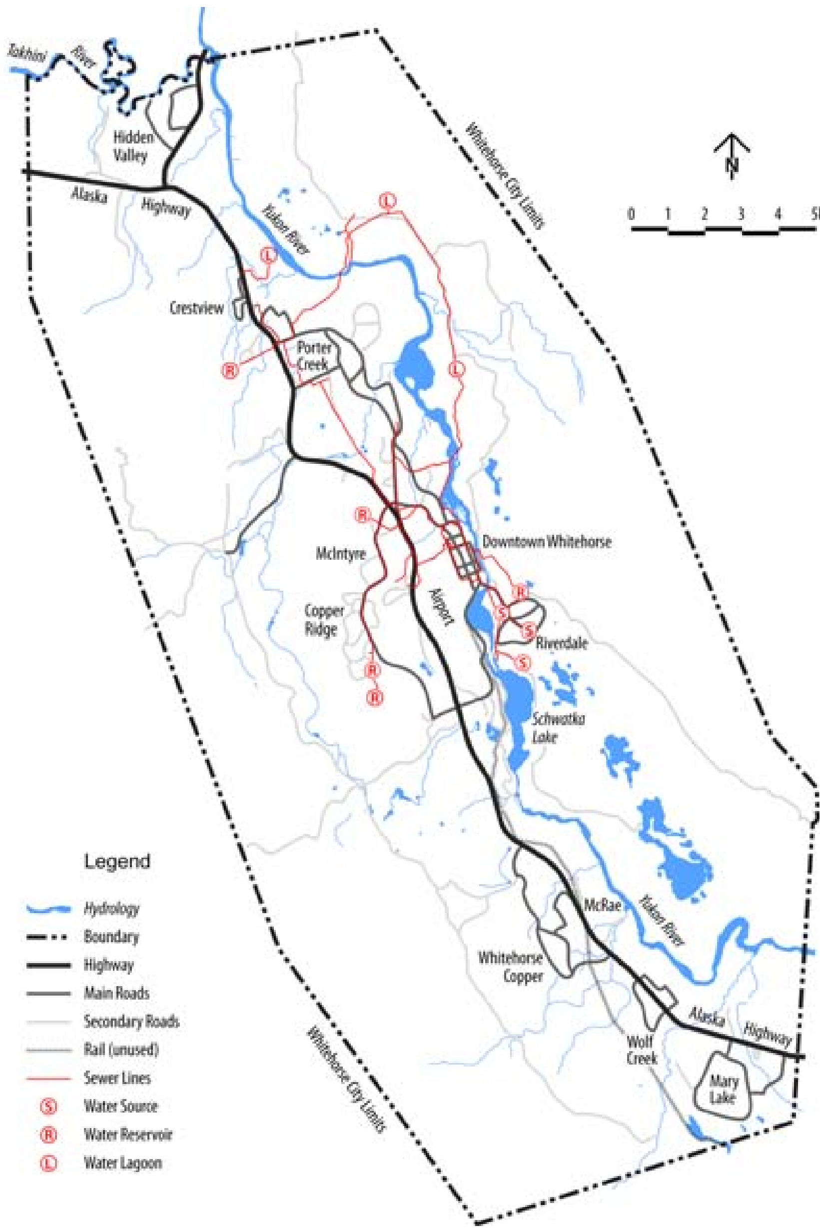


Figure 4. *Distribution of City of Whitehorse linear infrastructure (modified from the City of Whitehorse Official Community Plan; City of Whitehorse, 2010).*

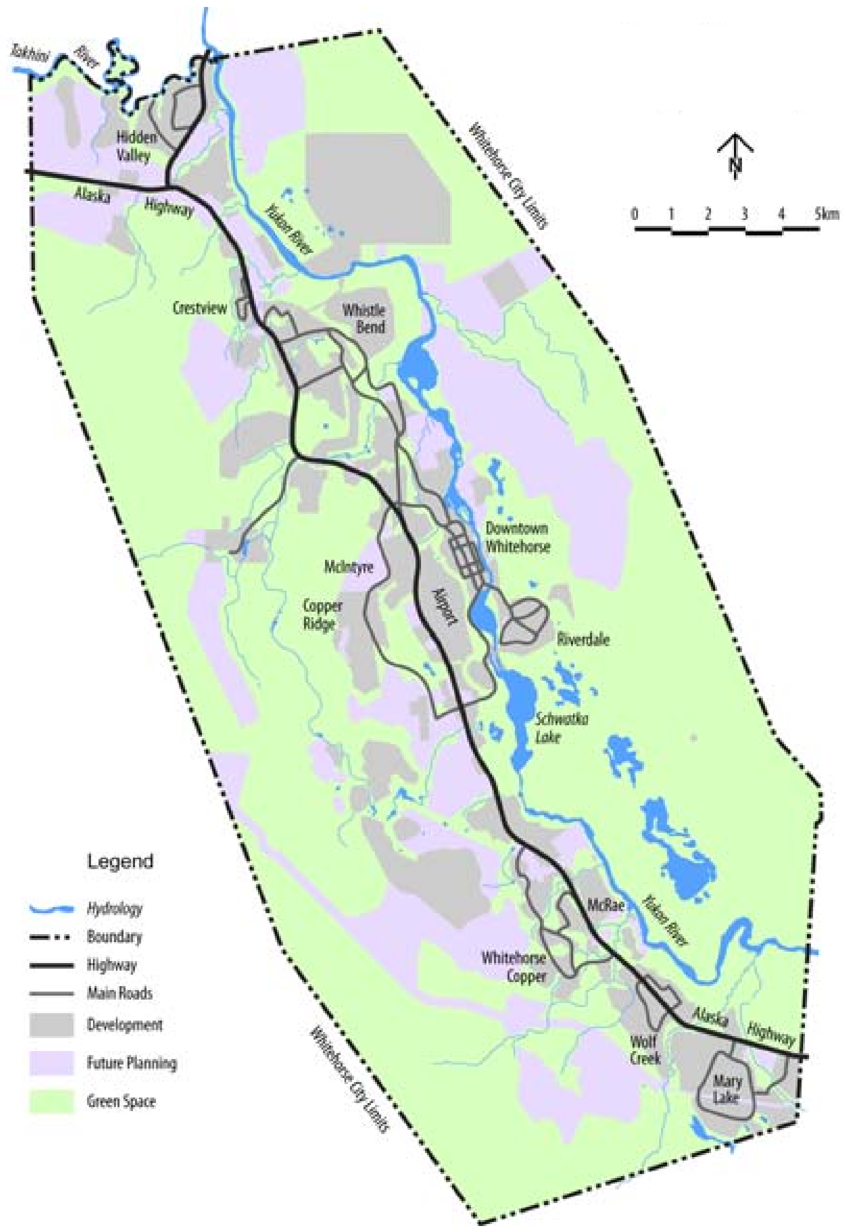


Figure 5. *Distribution of existing and planned development areas in the City of Whitehorse (modified from the City of Whitehorse Official Community Plan; City of Whitehorse, 2010).*

Whitehorse is located in the Yukon Southern Lakes Ecoregion of the Boreal Cordillera Ecozone (Yukon Ecoregions Working Group, 2004). This ecoregion is characterized by dissected plateaus and broad valleys occupied by numerous lakes and rivers. The rolling hills of the region create a profile on average of 1000-1500 m a.s.l. (above sea level), whereas downtown Whitehorse is at 650 m a.s.l. Wetlands and large lakes cover approximately 5% of the region (Yukon Ecoregions Working Group, 2004). The hydrology of the region has been influenced by the creation of the Whitehorse Dam situated on the Yukon River south, or upstream of the downtown core. In addition to creating Schwatka Lake, the dam has raised the water table in areas to the south and east of Whitehorse, resulting in higher lake levels in Hidden, Chadden and Chadburn lakes (J. Kenyon, Ducks Unlimited, pers. comm. July 2010). Within Whitehorse, some wetlands have been bisected by infrastructure such as roads, power lines, *etc.*

Open coniferous and mixed woodland vegetation dominates the Yukon Southern Lakes ecoregion and is a result of the rain-shadow and forest fire regime, which characterize the region. Pine, white spruce and mixed aspen are commonly found. Black spruce has a limited distribution (Yukon Ecoregions Working Group, 2004). Invasive species are established within the study area boundary, and while much is known about the extent of their establishment and distribution, less is known about the projected economic and environmental effects of these[5]. Little is known about the establishment, distribution, ecological effect and economic effect of invertebrates, algae and introduced plant diseases (B. Bennett, Yukon Government, pers. comm. 2011).

Approximately 50-60 Yukon mammalian species can be found around Whitehorse, including: moose, grizzly bear, wolves, coyotes, red fox, sheep, wolverine, woodland caribou, deer, lynx, beavers, and the occasional cougar (Yukon Ecoregions Working Group, 2004). The Yukon Bird Club reports 264 species of birds that can be seen in the immediate vicinity of the community, of which 129 are confirmed to breed in the region (Eckert *et al.*, 2010). Eleven species (including animals and plants) found within, near, or migrating through Whitehorse city limits have been listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). These species are listed in Table 1. Elk thistle (*Cirsium foliosum*) has not been listed by COSEWIC, but is of conservation concern (as determined by the Yukon Conservation Data Centre; R. Mulder, Environment Yukon, pers. comm. July 2010). The health and abundance of established fish and insect species will also influence the response of the ecoregion to climate change; however, a full description of these is beyond the scope of this report.

Table 1. Whitehorse regional species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Common Name	Scientific Name	Status
grizzly bear	*Ursus arctos*	special concern
woodland caribou (northern mountain population)	*Rangifer tarandus caribou*	special concern
olive-sided flycatcher	*Contopus cooperi*	threatened
common nighthawk	*Chordeiles minor*	threatened
rusty blackbird	*Euphagus carolinus*	special concern
baikal sedge	*Carex sabulosa*	threatened
wood bison	*Bison bison athabascae*	threatened
peregrine falcon	*Falco peregrinus anatum/ tundrus*	special concern
horned grebe	*Podiceps auritus*	special concern
short-eared owl	*Asio flammeus*	special concern

5. Yukon Invasive Species Council is currently investigating the distribution and potential impact of invasive species within Whitehorse with funding provided by WhiteCAP. The findings of this study will be available after June 2011.

Whitehorse is located in the zone of sporadic discontinuous permafrost (Henningbottom *et al.*, 1995). Much of the surficial geology in the Whitehorse region is characterized by glacial sediments of gravel, silt and clay, which were deposited during the most recent glacial episode (*i.e.*, the McConnell Glaciation, approximately 18,000 years ago; Bond, 2004). In and around Whitehorse, permafrost is more typically found at higher elevations on northern aspects, and is typically 2 to 3 m in thickness. Most of the developed areas of Whitehorse occur along the valley bottom (*i.e.*, lower elevations) where permafrost is rare. However, ice-rich lenses of permafrost have been found in finer grained sediments in the Marsh Lake area, Cowley Creek, Mt. Sima and Hidden Valley subdivisions, and the Takhini River valley, and may be present in other locations. The fine-grained glacial lake and alluvial sediments deposited in areas such as the Takhini River valley are prone to the development of thermokarst lakes and thaw subsidence. Ground temperature monitoring is underway at Golden Horn Elementary School and at Cowley Creek subdivision as part of the Permafrost Outreach Program, a University of Alaska Fairbanks and Yukon Geological Survey joint project (Lipovsky and Yoshikawa, 2009). Southeast of Whitehorse, less than 8% of the Alaska Highway has been constructed on permafrost. West of Whitehorse to Haines Junction, however, the incidence of permafrost increases and permafrost can be measured beneath 20% of the highway's length (Yukon Ecoregions Working Group, 2004). Regional soils were formed by glacial activity and are classified as Eutric Brunisols (Yukon Ecoregions Working Group, 2004). These soils are designated as class 5 (of 8) by the Canada Land Inventory and are suitable for forage and cold hardy vegetables (Tarnocai *et al.*, 1988).

ENVIRONMENTAL HISTORY OF THE WHITEHORSE COMMUNITY

Historic stresses can provide insight into community adaptation to climate change by showing how the community has responded to climate in the past. The frequency of historic stresses can provide a broad indication that an event can occur, while community responses demonstrate how the community gains experience when responding to challenges as they emerge. Therefore, the adaptive capacity improves with the frequency with which the community has had to respond to an environmental stress. Assuming that climate change will exacerbate current vulnerabilities, the history of environmental stresses in the City of Whitehorse can therefore be used to measure the adaptive capacity of a community. The full environmental history for Whitehorse is provided in Appendix C.

The environmental history of Whitehorse, compiled from local newspapers[6], indicates that the community has experienced stresses from forest fires, flooding and variable weather. Forest fires are the most important and common environmental stress experienced by Whitehorse. Severe fires occurred in the vicinity of Whitehorse in 1958, 1969, 1978, 1984 and 1991. These fires affected air quality and damaged infrastructure and required a significant response to control the spread of the fire (*e.g.*, the cost to the City of Whitehorse to respond to the 1984 fire outbreak was $4.6 million or $8.6 million in today's economy). Regionally, flooding has also been consistently problematic over time and can occur due to ice jams (especially during freeze-up) and precipitation. Localized flooding has occurred throughout the study area, although the downtown core and Marwell areas are more commonly affected by flooding events.

Variable weather is a normal part of the regional climate of Whitehorse and examples of the damages caused by ice, temperature and snow were noted throughout the historic record. Every year, rapidly fluctuating temperatures can first produce fog, then melting and subsequent

6. Evidence of environmental stress in the vicinity of Whitehorse was principally gathered from the archives of the two local newspapers: the *Whitehorse Star* and the *Yukon News*. About 50 articles from 1930 to 2009 were read to determine the extent, influence and repercussions of historic climate events. Other information was subsequently gathered from relevant Yukon Government or City of Whitehorse departments.

freezing, which creates icy conditions. These conditions have resulted in injury and property damage for residents. Storms and severe weather events have resulted in localized damage. Heavy snowfall has been problematic within the community, as a result of loading, or due to localized flooding from melt. Damage to buildings and linear infrastructure such as power lines has occurred. In the case of variable weather, residents have successfully coped with the negative conditions as they arose.

Over the past 80 years, city infrastructure has been significantly modified and upgraded. It is evident that the City of Whitehorse has a proven capacity to adapt and change where necessary. This capacity, and the combination of significant public sector presence and professional training in Whitehorse, emphasizes the influence of institutional experience on the adaptive capacity of the community. For example, the City of Whitehorse continues to upgrade the storm drainage system regularly, resulting in a decrease in frequency and severity of flooding across the city.

The environmental history of Whitehorse suggests that the community's adaptive capacity may be lower where behavioural-level rather than institutional-level change is required. This reinforces that residents look to their governments to take action[7].

CLIMATE AND WHITEHORSE

The city of Whitehorse is located in the Upper Yukon-Stikine Basin climate region of Yukon (Whal *et al.*, 1987). This climate region is influenced by the St. Elias/Coast Mountain ranges, which create a rain shadow. The rain shadow influences the amount of precipitation that falls in the region: typically 200-325 mm per annum (Yukon Ecoregions Working Group, 2004). Mean annual temperature for the region is -1°C to -2°C (Yukon Ecoregions Working Group, 2004). Whitehorse is the most consistently windy community in the territory due to the northwest-southeast orientation of the river valley in which it is located (Whal *et al.*, 1987).

PAST CLIMATE TRENDS IN THE WHITEHORSE AREA

The following section summarizes the climate of Whitehorse. Past trends in precipitation and temperature, as well as climate projections through to the 2050s are provided. Trends and projections are compared to climate normals from 1961-1990. Projected climate changes to the Whitehorse area were generated by the Scenarios Network for Alaska Planning (SNAP), located at the University of Alaska-Fairbanks. All climate projection maps are provided in Appendix D. Details on the projected extension of the growing season based on changes to the seasonal freeze-up and thaw dates for Whitehorse are presented in the same appendix.

Climate has been changing in Whitehorse. It is clear from meteorological data going back to the 1940s that temperature has been warming, especially in winters. Winter also has the greatest variability in temperature. Spring break-up has been arriving earlier, fall freeze-up later, and the number of frost free days has been increasing. Past climate trends give us a context from which to evaluate local climate, and also a sense of whether or not the climate has been changing. Trends can be compared against projections of future climate, such as those provided in the next section. Where the trend agrees with projections, our confidence in knowing the future climate increases; where they disagree with projections, our confidence decreases.

Whitehorse is semi-arid. While there has been a small increase in precipitation over recent decades, there is already a great deal of variability in precipitation and therefore any trend is

7. The Whitehorse Community Adaptation and Vulnerability in Arctic Regions (CAVIAR) project, funded by the International Polar Year (IPY), has extensively examined the institutional capacity of Whitehorse and its role in climate change adaptation. The results of this project are pending.

difficult to discern. Furthermore, some data from recent decades has been lost. Non-parametric trend analysis (which avoids biases associated with missing data) demonstrates that there has been a trend towards decreasing winter precipitation. The trends for temperature and precipitation are provided in Table 2.

Table 2. Climatic trends for the Whitehorse region.

Climate Variable	1961 - 1990	2000 - 2009	Rate of Change
Annual temperature (°C)	-1.1 ± 1.2	0.0 ± 0.9	0.4° C/decade
Winter temperature (°C)	-15.9 ± 4.5	-13.2 ± 2.5	0.9° C/decade
Annual precipitation (mm)	268 ± 44	276 ± 46	1.6 mm/decade
Summer precipitation (mm)	109 ± 38	121 ± 33	2.3 mm/decade
Annual average flow (m^3/s)	244 ± 31	239 ± 30	0 m^3/s per decade
Frost-free days	144 ± 9	149 ± 8	2 days per decade

Flow data is available for the Yukon River at Whitehorse. Warming trends and the melting of those glaciers which feed the Upper Yukon Basin, have increased lake levels in the drainage system above Whitehorse, but have not resulted in appreciable increase in overall annual flow of the Yukon River through Whitehorse. Seasonal variation in flow has changed, but this is most likely the result of hydrological control systems operated by Yukon Energy and not to a change in the climate system. Flooding is not typically associated with peak flow in summer, but is instead related to both freeze up (and ice damming) and spring melt (especially in heavy snow years with rapid melt onset).

Standard meteorological data show a decreasing trend for wind at Whitehorse. Conversely, more detailed research using weather balloons show a clear increase in wind. This contradiction is likely explained by changes to the horizon as trees have matured or been replaced by buildings. Both trees and buildings will break the wind and affect ground measurements of wind velocity. At a range of elevations above sea level (from 1200 m to 2000 m) wind speeds have been increasing at a rate of +0.2 m/s per decade (Pinard, 2007). At the same time, days have been getting less cloudy at a rate of 1% per decade, but there is a lot of variability with cloudiness from one year to the next.

Generally the trends show good agreement with projections (with the possible exception of winter precipitation). Some of the trends appear to be outside the range of natural fluctuation and thus relate to global climate change. However, we need to understand that natural influences are also present and are mostly driven by the relationships to large-scale ocean circulation patterns.

PROJECTED CLIMATE CONDITIONS FOR THE WHITEHORSE REGION

Climate projections for the region suggest a warmer, wetter Whitehorse. Projected climate conditions were based on two time slices (2030 and 2050) and two standard IPCC global emissions scenarios (B1 and A1B; as described in the Intergovernmental Panel on Climate Change *Special Report on Emissions Scenarios*; Nakićenović, *et al.*, 2000). The B1 scenario projects moderate to low climate change over the next century. The A1B scenario indicates medium to high climate change by 2100. These two scenarios were selected to provide a reasonable range in possible shifts in temperature and precipitation by 2050. It should be noted that while global efforts to mitigate climate change will affect how much change we are projected to receive, some change in global climate will still occur. In addition, projected climate conditions do not reflect the potential variability or extremes that could manifest in future weather.

Temperature

Annual and seasonal temperature projections are presented in Table 3. Projected increases indicate that warming will differ seasonally. Whitehorse will experience the most significant warming in winters – increasing 3.3°C to 5.4°C by 2050.

Table 3. Baseline and projected temperature changes for the Whitehorse area; changes relative to baseline are denoted in brackets. Temperatures are measured in degrees Celsius (°C).

Season	Baseline (1961-1990)	Modest Climate Change		Medium-High Climate Change	
		2030	2050	2030	2050
Annual	-5.4	-3.3 (+2.1)	-2.9 (+2.5)	-3.5 (+1.9)	-1.7 (+3.7)
Spring	-5.1	-2.9 (+2.2)	-2.9 (+2.2)	-3.4 (+1.7)	-1.7 (+3.4)
Summer	10.3	11.5 (+1.2)	11.8 (+1.5)	11.1 (+0.7)	12.3 (+1.9)
Autumn	-5.9	-3.9 (+2.0)	-3.1 (+2.8)	-4.0 (+1.9)	-2.0 (+3.9)
Winter	-20.9	-18.0 (+2.9)	-17.6 (+3.3)	-17.6 (+3.2)	-15.5 (+5.4)

Precipitation

Mean annual precipitation was also projected for the Whitehorse area based on the 1961-1990 climate normals (Table 4). Projected annual mean precipitation in the City of Whitehorse area is anticipated to increase from 268 mm to between 305 and 327 mm by 2050.

Table 4. Baseline and projected precipitation changes for the Whitehorse area. Precipitation is measured in millimetres (mm).

Season	Baseline (1961-1990)	Modest Climate Change		Medium-High Climate Change	
		2030	2050	2030	2050
Annual	268	303	305	319	327
Spring	35	40	41	43	44
Summer	109	123	123	121	125
Autumn	77	84	88	94	94
Winter	47	55	53	61	64

Seasonal precipitation is expected to increase throughout the year, and the greatest relative increase is predicted to occur in the winter. Winter precipitation is projected to increase by as much as 37%. Table 5 shows the same projected precipitation, but as a change relative to the 1961-1990 climate baseline.

Table 5. Projected changes in precipitation relative to the 1961-1990 climate baseline for the Whitehorse region.

Season	Modest Climate Change (increase from 1961-1990 baseline)				Medium-High Climate Change (increase from 1961-1990 baseline)			
	2030		2050		2030		2050	
	mm	%	mm	%	mm	%	mm	%
Annual	35	13%	37	14%	51	19%	59	22%
Spring	5	15%	6	16%	8	23%	9	26%
Summer	14	13%	14	13%	12	11%	16	15%
Autumn	7	10%	11	14%	17	22%	17	22%
Winter	8	17%	6	12%	14	30%	17	37%

FROST-FREE PERIOD

The projected growing season provided for Whitehorse corresponds to the frost-free period, *i.e.*, the number of days between spring thaw and autumn freeze-up. The dates for spring thaw and autumn freeze-up are defined by the time at which mean temperatures cross 0°C. Based on the projected shifts in temperature and precipitation, the growing season for Whitehorse is expected to increase in all projections, rising from 150 days to 168-175 days by 2050, an addition of 18-25 days per year. The date of autumn freeze-up is anticipated to occur later in all projections, moving from late September into early/mid-October. The freeze-up date in Yukon is therefore anticipated to occur 11-16 days later by 2050. Projected spring thaw dates are expected to occur earlier in the Whitehorse region. The thaw date in Yukon is projected to occur 8-12 days earlier by 2050.

CLIMATE-INDUCED VULNERABILITIES AND OPPORTUNITIES

It is evident that climate change will affect the community of Whitehorse. It is also evident that while some opportunities will emerge from climate change, the majority of the coming consequences will be negative. The four community climate change scenarios indicate that even a moderate onset of climate change will create infrastructure and environmental challenges for Whitehorse[8]. The implications of the scenario work suggest that, regardless of the rate and severity of climate change, the community must prepare to address – and therefore plan for – future challenges.

Opportunities are also evident in even the more modest of the climate change scenarios. These opportunities support sustainable development and economic diversification. As with the consequences, the presence of these opportunities indicates that the community of Whitehorse can benefit from climate change with sufficient preparation. However, given the number of consequences associated with climate change, it may be challenging to focus on any potential benefits. There is a need to ensure that the community is aware and prepared to take advantage of these potential benefits through the appropriate prioritization of vulnerabilities and opportunities.

Adaptive capacity is an integral component of an adaptation strategy. The adaptive capacity of Whitehorse is made up of the institutional capacity of the community (Burch, 2010), its physical

8. See “Scenario 1: City of Wilderness” in *Future Histories of Whitehorse: Scenarios of Change.*

resources (Kelly and Adger, 2000), the availability of skills and education (Smit and Pilifosova, 2003), and its experience in addressing consequences as interpreted within the context of an individual's perception of the risk associated with the impact (Grothmann and Patt, 2005). The institutional capacity of the community refers to the ability of the local government to coordinate responses and distribute resources (Burch, 2010). Where all of these factors are high, the community is resilient to the effects of climate change. Where one or more factors are low, the community is vulnerable to the effects of climate change and the subsequent risk for residents increases.

BROAD SECTOR LEVEL RISK: TIER I RISK ASSESSMENT RESULTS

Nine broad sectors vulnerable to climate change were apparent in the community-based scenarios. These sectors were: the local economy, environment, people and cultural resources, infrastructure, energy, natural hazards (especially fire and flood), food security (including agriculture), health, and education. The broad risk associated with each sector was prioritized by the Whitehorse Technical and Local Advisory committees at separate meetings in May and June 2010 (see section *Scenario Planning and Risk Management* for details on the risk assessment methodology used to determine priority risks for the community of Whitehorse). The intention of the first-tier risk assessment was to determine where the community was most vulnerable to climate change overall. By providing a relative ranking for likelihood, severity and adaptive capacity to each of the nine sectors identified in the community session, the sectors were prioritized into high, medium and low-risk categories. Figure 6 illustrates the relative ranking of each sector and emphasizes the range of risk associated with climate change.

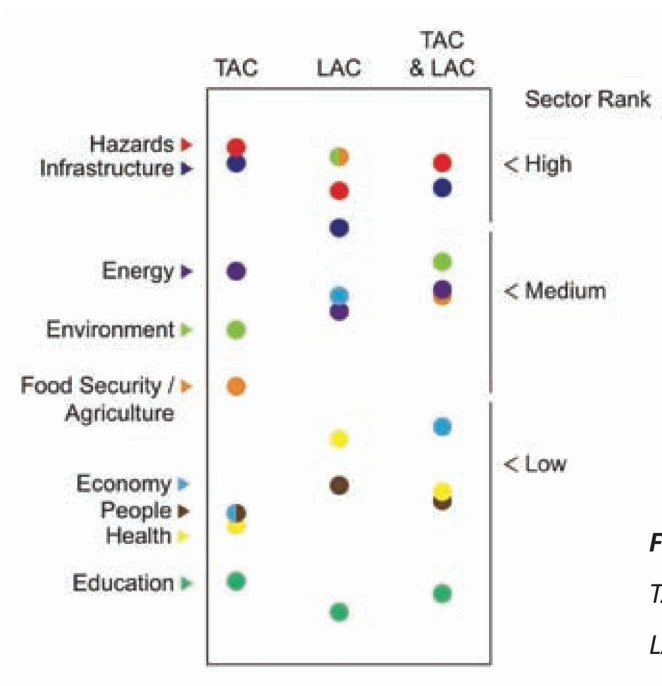


***Figure 6.** Priority scale of Tier I risks.*

TAC = Technical Advisory Committee

LAC = Local Advisory Committee.

The combined evaluation of the Whitehorse Technical and Local Advisory committees (TAC and LAC, respectively) indicates that the greatest climate change risk for the community of Whitehorse occurs within the hazards and infrastructure sectors. A more moderate risk was associated with environmental decline, energy security and food security. Economy, people and culture, health, and education sectors were removed from consideration in the Tier II assessment due to the low level of risk from climate change. A comprehensive description of all sectors is documented in the "*Future Histories of Whitehorse: Scenarios of Change"* (NCE, 2010). The remaining moderate to high-risk sectors are evaluated in the following sections and use more detailed evaluation criteria.

COMMUNITY-BASED CONSEQUENCES: TIER II RISK ASSESSMENT RESULTS

In the second stage of the vulnerability assessment the relative rankings of likelihood, level of impact and adaptive capacity were assessed, but this time on a consequence by consequence basis. Figure 7 illustrates the distribution of risk by sector and priority.

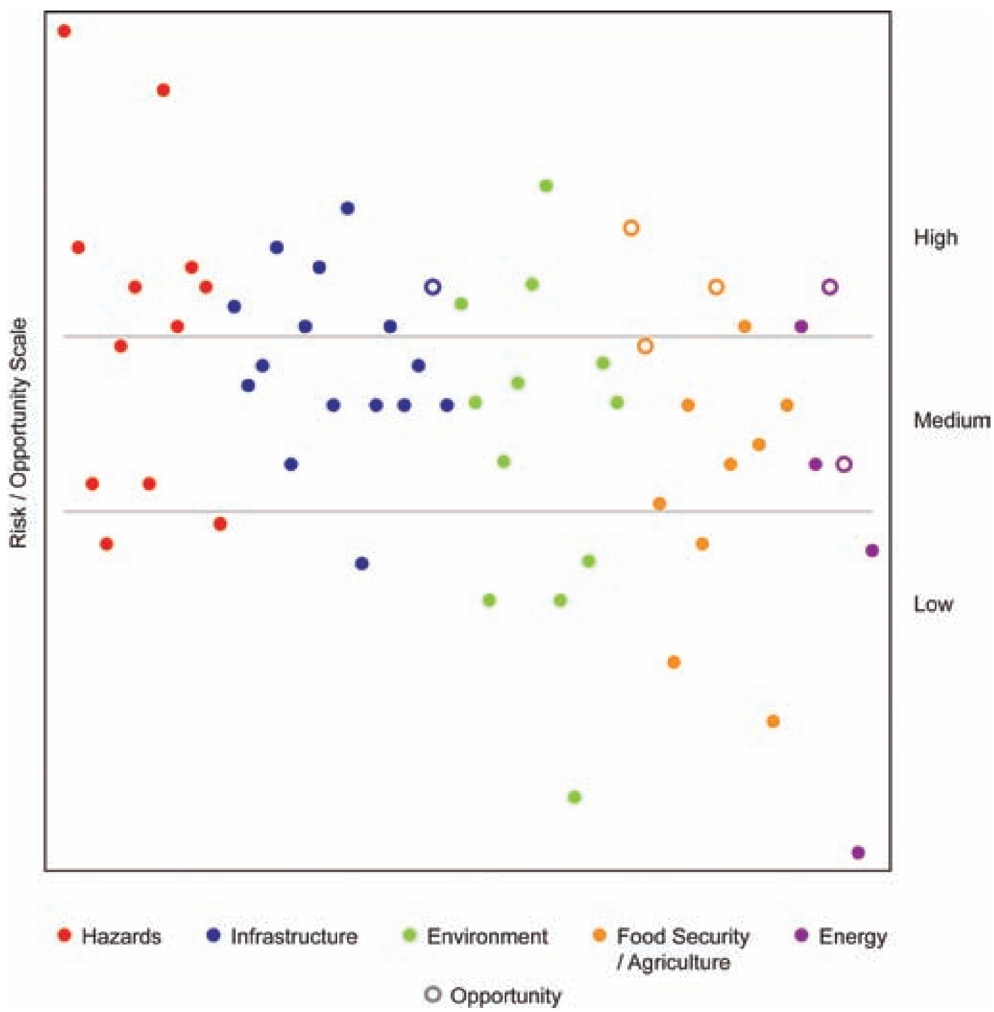


Figure 7. *Distribution and priority of climate-change consequences by sector.*

Eighteen high-priority risks were identified through the evaluation of risk documented in full in Appendix E. Priority risks are listed in Table 6. Those sectors which were prioritized as high in the Tier I risk assessment tend to have more high-ranking impacts. However, in every sector, there are impacts ranging from low to high.

Table 6. Identified high-priority risks by sector.

Sector	Consequences
Hazards	Community vulnerability to forest fire increases due to heavy fuel load, lightning, drought, wind, *etc.*
	Increased risk of catastrophic fire.
	Egress from subdivisions becomes a problem during emergency situations.
	Possibility of regional beetle infestation leading to more dead stands and increased risk of forest fire.
	FireSmart program ongoing for past decade; effectiveness is limited.
	Heavy increase in rural residential development leads to an accompanying increase in vulnerability.
	Increased risk of catastrophic flood and infrastructure failure (*e.g.*, bridge).
Infrastructure	Increased incidence of damage to power lines from wind-thrown trees, *etc.*
	Increase in multipliers - roads affect access which affects safety, *etc.*
	Increased rate of leaching from unlined dump - hazardous waste requires special consideration.
	General strain on infrastructure as the result of their age, as well as pressure from population growth and climate change.
	Increased cost to maintain roads due to shifting landscape conditions (*e.g.*, erosion).
	Integrity of spillways and dams affected by increase in variability in precipitation and flood events.
Environment	Evapotranspiration and groundwater recharge are critical and still uncertain.
	Introduction of pests/invasive species.
	Concern about change to water quality and increasing demand.
Food Security	Increased incidence of drought places more reliance on groundwater - problems with irrigation arise.
Energy Security	Energy sector increasingly vulnerable to external forces (rising energy costs, expected carbon costs).

OPPORTUNITIES

Climate-related opportunities were evident in many of the sectors evaluated in the Tier II risk assessment. These opportunities were prioritized by evaluating the benefits, the likelihood of the consequence emerging from shifting climate conditions, and how prepared the community is to profit from the consequence. Four opportunities were identified through this assessment and are listed in Table 7. The evaluation of opportunities is also documented in detail in Appendix E. Additional opportunities are evident in the sectors ranked as having a low risk in the Tier I assessment. These opportunities are reported in the *Future Histories of Whitehorse: Scenarios for Change* (NCE, 2010).

Table 7. Identified opportunities by sector.

Sector	Opportunity
Infrastructure	Increased need for Whitehorse to serve as a hub - infrastructure expansion.
Food Security	Longer growing season, likely an opportunity for agriculture.
	Whitehorse emerges as a hub, supplying food to outlying communities through local agriculture.
Energy Security	Gas pipeline mega-project may bring energy opportunity.

CLIMATE CHANGE ADAPTATION AND WHITEHORSE

The Tier II assessment of climate change risks highlights the broad nature of climate change vulnerability as perceived by the community of Whitehorse. High-priority risks exist in all of the evaluated sectors (hazards, infrastructure, environment, food security and energy security) and many of these risks are interconnected. Adapting to climate change in the Whitehorse region will therefore require the community to address sweeping concerns of an interdisciplinary nature with varying capacity.

Climate change adaptations for the community of Whitehorse were first suggested by participants at the community input session in January 2010. The list of adaptations compiled in consultation with the community is not necessarily exhaustive, and additional adaptations exist that have not been noted here. As with the identification of consequences, discussions of adaptations were rooted in local knowledge. All adaptations suggested by the community are provided in the *Future Histories of Whitehorse: Scenarios of Change* (NCE, 2010). In the following section, the project team has evaluated those adaptations suggested by the community to respond to higher-priority risks. The evaluation was intended to ensure that existing capacity in the community was enhanced.

COMMUNITY ADAPTATIONS TO HIGH-RISK CONSEQUENCES OF CLIMATE CHANGE

Leveraging adaptive capacity requires that community resources be applied to those actions that best address identified risks. A summary of the sector risk is provided at the beginning of each subsection. Only those adaptations that address high-risk consequences were evaluated. Each adaptation was assessed to determine how well it addresses the impacts (fit), how well it benefits the broader community (win-win), and whether it builds adaptive capacity. The attributes of fit, win-win and adaptive capacity development allowed for the integration of the special considerations (identified in section *Special Considerations of the Whitehorse Adaptation Plan*) associated with the community vision directly into the planning process.

Based on this assessment, priority adaptations emerged for all sectors. The number of adaptations designated with a high priority correlated to the risk associated with the sector. As illustrated in Figure 8, the bulk of priority of adaptations were associated with decreasing the susceptibility of the community of Whitehorse to landscape hazards and ensuring infrastructure remains viable. The detailed evaluation of adaptations is documented in Appendix F. Twenty-two adaptations were designated as having a high priority to respond to climate change risks. An additional six opportunities were identified to support emerging opportunities. Both sets of adaptations are listed by sector in Table 8.

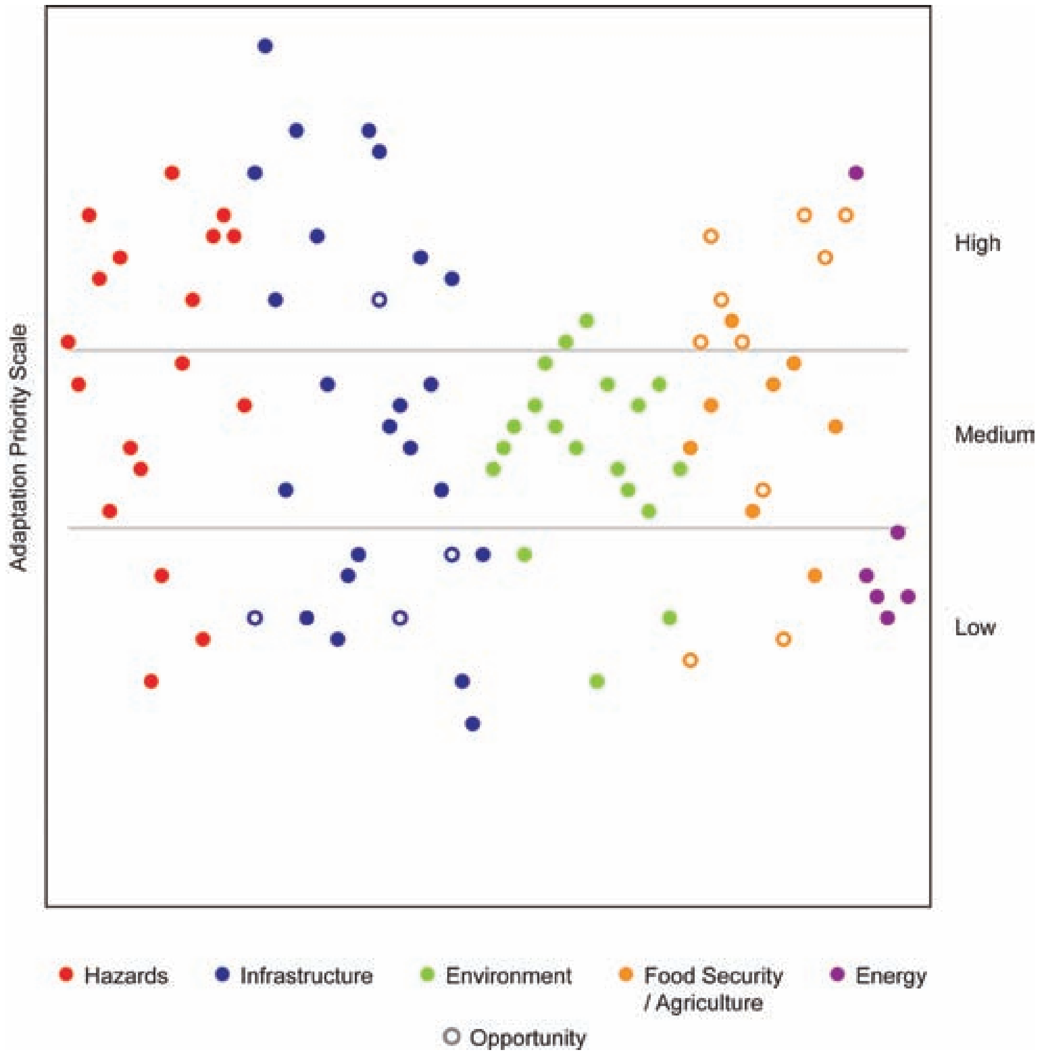


Figure 8. *Distribution and priority of climate-change adaptations by sector.*

These twenty-eight adaptations are put forward as priorities for the community of Whitehorse to adapt to climate change. These adaptations address a variety of significant consequences, provide a tangible and immediate benefit to the community, and build capacity to respond to climate change. However, for these suggested adaptations to be effective, a cohesive strategy for adaptation is required. A proposed strategy forms the basis of the final section of this plan and includes important considerations such as timing, partners, mainstreaming and implementation.

Table 8. Identified high-priority adaptations by sector.

Sector	Adaptation
Hazards	Incorporate fire considerations in all subdivision planning and zoning (*i.e.*, no dead ends, include fire breaks, plant aspens, provide access to water, and support other holistic planning issues).
	Pass consequences of climate change on to other decision-making groups involved in planning, design, engineering, and establishing standards for subdivision development, road construction and infrastructure.

Table 8. Identified high-priority adaptations by sector, *continued*.

Sector	Adaptation
Hazards	Maintain green spaces and/or strategic agriculture to reduce fire risk.
	Integrate climate-change risk and impacts into emergency planning.
	Incorporate climate into infrastructure development that is currently in the planning stages.
	Create a strategy for harvesting salvage wood (*e.g.,* beetle-kill) as both an opportunity and a control measure.
	Create zoning that reflects potential future changes in the landscape.
	Ensure critical buildings have resiliency including back-up systems (*e.g.*, power for lighting/heating).
	Investigate and assess catastrophic flood scenarios.
Infrastructure	Establish a multi-year municipal budget for dealing with climate-change variability and its effects (*e.g.*, roads and road clearing).
	Recommend development densification to allow for greater cost sharing of infrastructure.
	Educate the public to set a fair expectation for quality of service.
	Need to identify critical engineering thresholds, responsibilities and partnerships.
	Increase available warehousing (*i.e.*, links to food storage).
	Assess dependence of Whitehorse to the highway, and the vulnerability of the highway outside city limits to climate change.
	When being replaced through maintenance schedules, assess storm drainage capacity, capability and design for extremes in future climate-change projections.
	Regional and all other relevant planning needs to be revisited regularly to ensure climate change has been adequately integrated into decision-making process.
	Generate standards/best practices for subdivision development as it relates to climate change.
Environment	Create an education program around water conservation.
	Look into a strategy to enforce the protection of riparian buffers.
Food Security	Investigate new and innovative ways to grow food.
Energy Security	Create an energy plan for Whitehorse (including comprehensive energy management).
Opportunity	Learn from other circumpolar countries.
	Create a strategy to capitalize on the potential increased need for Whitehorse to serve as a hub, and incorporate the trickle-down effect to communities (*i.e.*, if Whitehorse cannot supply them, then other communities become vulnerable).
	Use agriculture to increase soil quality and quantity.
	Continue to expand on education opportunities for regional agriculture.
	Create and implement a Whitehorse/Territory-wide food security plan.
	Zone more agriculture land.

DEVELOPING A WHITEHORSE ADAPTATION STRATEGY

During the initial phase of the WhiteCAP plan development, the WLAC collaboratively developed a vision for a community that had successfully adapted to climate change (see p. 6 under *Introduction*). The key steps incorporated into this vision were:

- prepare for variability and uncertainty
- build capacity
- build knowledge
- build resilience
- build partnerships
- enhance sustainability

Many of these key steps were incorporated into the comprehensive evaluation of the risks and benefits associated with taking action to respond to climate change. These included appraising variability and uncertainty, building capacity, integrating sustainable development and the mitigation of climate change, and protecting the connection between community and wilderness. For example, we addressed variability and uncertainty by considering a range of future climate and growth scenarios. Capacity development was the foundation of our assessment of Whitehorse's vulnerability to climate change impacts. Sustainability was integrated into the ranking of adaptation priorities. Based on this comprehensive evaluation, we identified twenty-eight adaptations to reduce community vulnerability and enable residents to benefit from emerging opportunities.

This final section of the WhiteCAP plan builds a strategy from these 28 potential actions and recommends a path forward based on the vision articulated by the WLAC. Knowledge, partnerships, mainstreaming (integrating adaptation into existing decision making processes), and timing are all discussed in this section. The goal of this process is to build the resilience of the community to climate change. The plan concludes with a discussion of the implementation phase of WhiteCAP, as well as the recommendations for future steps for the community of Whitehorse for adapting to climate change.

ENHANCING KNOWLEDGE FOR ACTION

The priority actions identified form a foundation for adaptation. These adaptations respond to priority impacts, build the adaptive capacity of the community, and ensure immediate benefits to residents. However, many constraints remain that limit the feasibility of implementation, such as the availability of funds, competing policy directions, and the availability of skills and resources. Underpinning each component of the adaptation strategy is the need for sufficient knowledge to support public decisions (Burton, 2003).

Often sufficient knowledge for action already exists within the community. For instance, among the many actions that can currently be considered when adapting to climate-change risks, we have sufficient knowledge of forest composition, fire dynamics, and infrastructure vulnerability at the urban/wilderness divide to implement sound fire management strategies. However, the foundation of our knowledge of landscape responses to climate impacts can always be refined to enhance the likelihood of effective adaptation responses.

Where knowledge is incomplete or inadequate, obtaining it must be a priority. In these cases, waiting to act until sufficient knowledge is acquired is a valid option, although such a decision must be balanced against the potential risk of continued exposure to increasing vulnerability. There will always be gaps in our knowledge; however, we know enough now to begin to take action to address the effects of climate change.

It is important that knowledge and climate information be made accessible. In many cases the science to support decision-making exists, but cannot be readily found or interpreted by those who need it, hindering the development of meaningful policies. Knowledge must also be managed. The information supporting action on climate change is broad and interdisciplinary. Moreover, it is rapidly changing as we increase our understanding of the complex and related systems that determine our vulnerability to landscape and/or climate stresses. To ensure decision-makers have the necessary resources from which to develop meaningful policies and implement tangible actions, we must ensure our knowledge is succinct and relevant. Finally, knowledge must be updated. As we are affected by climate change, many of the conditions we currently have an understanding of, such as regional hydrology, will become altered. Monitoring and evaluating these changes will always be an important component of adapting to climate change.

PARTNERS

Climate change is an issue that crosses a number of boundaries and affects many facets of the community. Partnerships will be essential to making the implementation of a Whitehorse adaptation strategy successful, effective, and even feasible. While there are a number of jurisdictional overlaps present in Whitehorse, the following organizations will likely play a critical role in community adaptation.

City of Whitehorse: The City of Whitehorse is a key partner for addressing those vulnerabilities and opportunities emerging from infrastructure, hazards, land planning and energy-use sectors. The City has played a significant role in increasing the resilience of the community over time, especially with flood prevention through its storm water system. The Strategic Sustainability Plan (City of Whitehorse, 2009) commits the City to encouraging community well-being through sustainable development, while the Official Community Plan (City of Whitehorse, 2010) makes similar commitments through proactive and flexible planning and design.

Yukon government: Yukon government is a likely partner for resolving infrastructure vulnerabilities as they emerge, such as those which may potentially arise along the Alaska Highway and in the unincorporated communities on the periphery of Whitehorse (Yukon Government, 2009). Yukon government has expertise in emergency response, environment, agriculture and climate change. Many Yukon government departments and personnel may provide support for the implementation of climate change adaptation including the Departments of Community Services, Environment, Energy Mines & Resources (Agriculture Branch) and Highways & Public Works.

Ta'an Kwäch'än and Kwanlin Dün First Nations: Partnerships with the two First Nations in whose traditional territory Whitehorse is situated will be necessary for cohesive land management, emergency preparedness planning/disaster mitigation, sustainable development, and addressing food security vulnerabilities within the established interests of their citizens.

Community groups: The many residential community associations active in Whitehorse can provide assistance with the development and dissemination of knowledge within the community, ensuring community perspectives are integrated into future policy development and the implementation of adaptations. Groups like the Yukon Conservation Society provide community involvement and a level of expertise on the issue of climate change.

Private-sector groups: Private-sector groups may provide meaningful partnerships for community climate change adaptation. These groups currently house significant expertise in the community through professional services, as well as the provision of grey literature and informed/innovative input towards implementation strategies. Such informed input could provide recommendations to any potential changes to regulations and/or codes of practice, support specialized insight into conditions within the community, and provide specific knowledge related to their profession and practice.

Yukon College: Through established programs and evolving research capacity, Yukon College is a probable resource and/or research partner to assist with expanding the community knowledge base (*i.e.*, increased knowledge of invasive species shifts, changing climate conditions, *etc.*). Yukon College is also a source of innovation and can make a contribution to alternative energy technologies and environmental management.

MAINSTREAMING

Climate change impacts and the responses to those impacts are complex. One way of responding to these complex changes is to mainstream climate change adaptation. Mainstreaming adaptation means to strategically integrate climate change considerations into ongoing planning, policy and other decision-making processes at the local level (Bouwer and Aerts, 2006; Wilson, 2006). The City of Whitehorse, through their Strategic Sustainability Plan and Official Community Plan, has already developed a long-term environmental basis that influences policy development and implementation. This emphasis on sustainable development parallels adaptation, especially at the local level where conscious land-use regulations, energy management and infrastructure improvements will increase local resilience to climate change. Mainstreaming could also support Yukon government's regional commitments to the management of roads, agriculture and land-use planning in the Whitehorse area.

ESTABLISHING A TIMELINE FOR ADAPTATION

A timeline for adaptation must include elements of enhancing knowledge, planning and action. Specifically, we need to adapt to climate change now (act), but before we can act, in many instances we need to plan, and where we need to plan, we must first ensure we have sufficient knowledge. The concepts of action, planning and knowledge enhancement also encompass elements of mainstreaming, funding and institutional/organizational support. Obtaining these critical elements of implementation will require another form of knowledge enhancement: public education.

Immediate actions that should be taken to adapt the community of Whitehorse to climate change include:

- Ensuring critical buildings have emergency back-up power.
- Educating the community and decision-makers on food security risks and the opportunities associated with agriculture.
- Creating an education program about water conservation.

Immediate steps for future planning recommended by WhiteCAP are the development of a strategy to increase the energy security of the community and the mainstreaming of climate change. Specific recommendations for the mainstreaming of climate change to decision-makers and for policy development include:

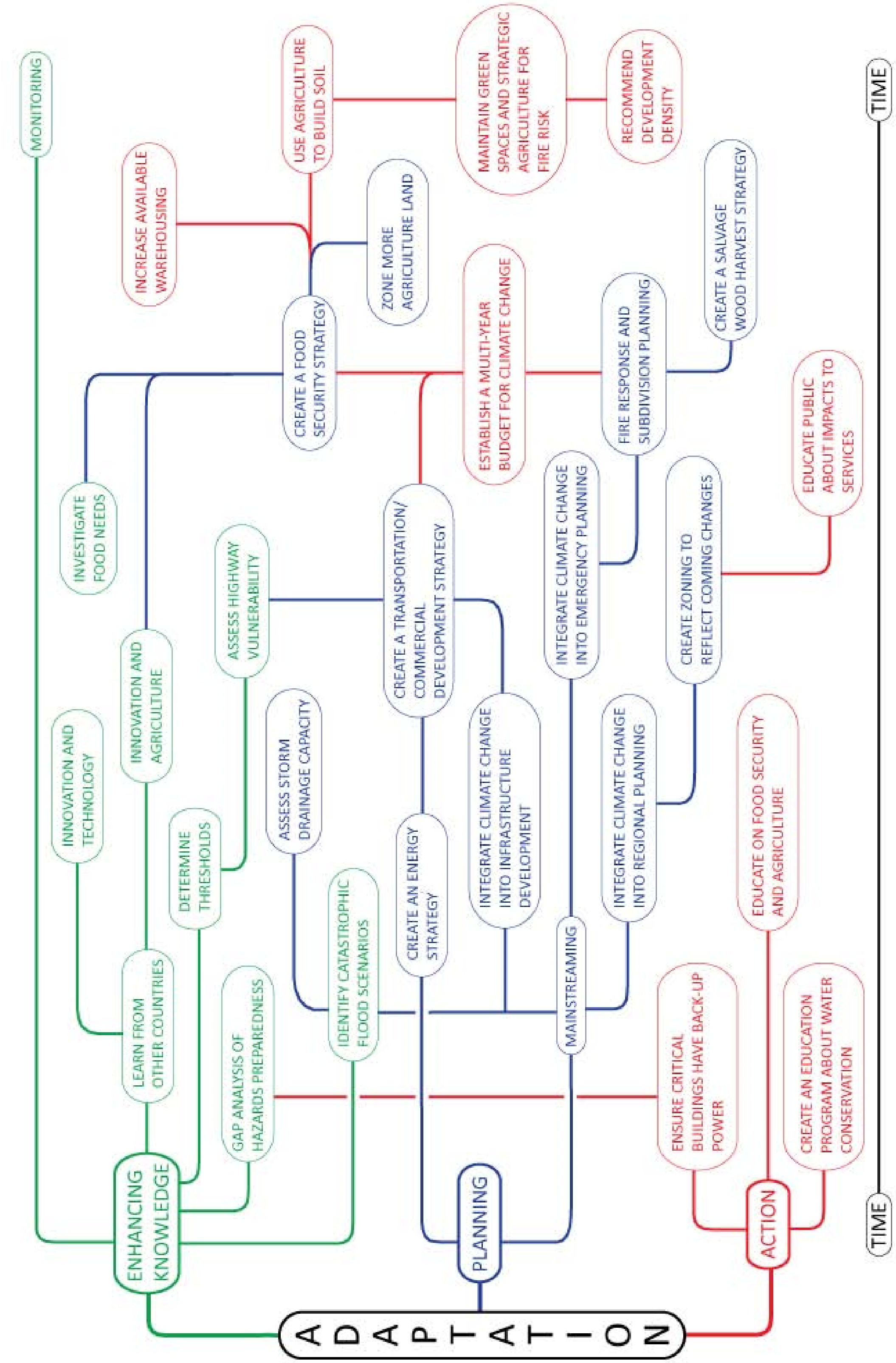
- Integrating climate change into regional planning.
- Integrating climate change into infrastructure development.
- Integrating climate change into emergency planning.

As climate change affects the Whitehorse region, many of the characteristics of the land that we understand today will begin to change. Similarly, as ecosystems and infrastructure respond to changing climate conditions, new characteristics may emerge. We must ensure our knowledge is enhanced and increased to assure that our decisions remain sound. Specific examples of how building our knowledge of the Whitehorse region can provide an immediate contribution to climate change adaptation include:

- Long-term monitoring to track changing conditions in the landscape.
- Learning from other circumpolar countries.
- Determining those thresholds that drive a shift from one ecosystem state to another.
- Completing a gap analysis of our hazard preparedness.
- Exploring catastrophic flood scenarios.

The broad number of recommendations, interconnectivity between future actions, and the number of partners involved, makes the development of a timeline challenging. There are many ways that a timeline could evolve from those adaptations recommended for immediate implementation listed above. Figure 9 illustrates one possible timeline for implementation. Many other combinations of adaptations are possible. As the suggested pathways are exhausted, additional adaptations recommended by this plan should be added to the three suggested streams (knowledge enhancement, planning and action).

Figure 9. Schematic chart of Whitehorse climate-change adaptation timeline.



WHITECAP PROJECTS

As noted in the *Introduction*, WhiteCAP is made up of two phases: planning and implementation of pilot projects. Funding of $120,000 was provided by the Yukon Northern Strategy Trust for the implementation of projects in Whitehorse that would begin the process of community adaptation to climate change. Disbursement of the $120,000 was determined by the WLAC based on a proposal uptake in September 2010. Eight projects (Table 9) were funded to respond to various food security and environmental risks identified in this plan. A full project report will be provided by the WhiteCAP Local Coordinator at the conclusion of the project in summer 2011.

Table 9. WhiteCAP Implementation Projects for 2010-2011; projects were funded by the Yukon Northern Strategy Trust.

Proponent	Project Title	Description
City of Whitehorse	Educating Through Edible Design	Design and production of educational signage for edible landscapes.
Fireweed Market	Sharing the Harvest	Yukon-made, how-to book about preserving and storing foods.
Deep Roots Permaculture	Cold Climate Permaculture Workshops	Design and delivery of workshops on permaculture in the North with a focus on food and energy resilience.
Riverdale Community Association	Edible Landscaping in Riverdale	Design and implementation of edible landscaping in Riverdale subdivision.
Takhini North Community Association	Takhini North Community Garden Project	Design and construction of a community garden in the Takhini North subdivision.
Water Resources Branch	Groundwater Data Study for the Community of Whitehorse	Collect, integrate and disseminate groundwater data and information for the community of Whitehorse.
Yukon Invasive Species Council	Invasive Species and Their Impact on Whitehorse	Complete research and reporting on the impacts of invasive species in Whitehorse.
Diane Simpson	Whitehorse Takes Action	Creation of short films highlighting Whitehorse adaptation.

These projects are intended as a modest first step in introducing adaptation to the community of Whitehorse. The priority adaptations of this plan are those recommendations put forward for the identified partners to consider.

RECOMMENDATIONS AND NEXT STEPS

Climate change is an emerging reality for the community of Whitehorse, the consequences of which will become increasingly difficult to surmount over the coming decades. The community of Whitehorse must prepare now to respond to the coming challenges of climate change. The intent of this plan is to provide a firm rational for action and to provide direction for reinforcing the resilience of the community and our surrounding environment to those stresses generated by climate change. By making smart choices and investments now, such as the mitigation of climate change, we will avoid costly responses in the future.

Broadly, the recommended adaptations identified through this community plan are:

- Mainstream climate change into planning - especially emergency, land-use and infrastructure planning - in order to reduce the exposure of the community to climate-related hazards.
- Integrate climate change into pertinent policy development.
- Implement actions to reduce the vulnerability of the community, or to benefit from emerging opportunities.
- Continue work across jurisdictions within Whitehorse to develop effective partnerships and to learn from other jurisdictions (both nationally and internationally) to assist with innovation.
- Continue to investigate how climate change will stress the natural and built environment around Whitehorse, through monitoring, threshold analysis, research and innovation.
- Explore the food needs and opportunities of agriculture of Whitehorse and Yukon.
- Work towards alternative energy production to increase our energy security and help curb greenhouse gas emissions of the community.
- Investigate avenues of adaptation through financial planning.

A cohesive strategy to adapt to climate change in Whitehorse requires actions at various scales and over many jurisdictions at the same time. Such a strategy must be based on sound planning and knowledge management. Moreover, to move forward, there will be a need for the various partners (identified above) to interpret the vision and results of this plan in order to mainstream our findings. Ultimately, however, the multi-layered nature of adaptation will require that these partners work together to build the resilience of the community of Whitehorse. For Whitehorse, the case of climate change adaptation is not necessarily one of institutional strength and responsibility, but one of exploring what we can all do together for one another.

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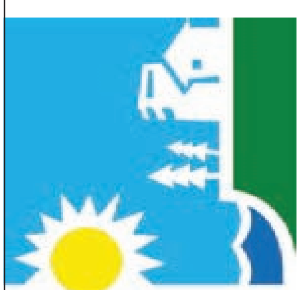
APPENDIX A - SUMMARY OF FUTURE HISTORIES OF WHITEHORSE: SCENARIOS OF CHANGE

	 Scenario 1 City of Wilderness **Some growth, some climate change**	 Scenario 2 City of People **Lots of growth, some climate change**	 Scenario 3 City of Mettle **Some growth, lots of climate change**	 Scenario 4 City of Crossroads **Lots of growth, lots of climate change**
Whitehorse	• + 6,000 people by 2030, + 12,000 people by 2050	• + 12,000 people by 2030, + 25,000 people by 2050 • growth in all areas of the city (mixed density)	• + 6,000 people by 2030, + 12,000 people by 2050 • forced densification across the city, especially in the downtown core	• + 12,000 people by 2030, + 25,000 people by 2050 • growth mostly downtown • higher turnover of population by 2050
Economy	• public sector continues to dominate • overall economic uncertainty has increased • increased taxation	• ratio of government to population normalizes • increased % of population employed by resource, service, commercial & industrial sectors • cost of living rises modestly • Whitehorse becomes even more of a hub for communities	• median income declines • private sector growth has remained sporadic and opportunistic • cost of living increases • private sector growth characterized by green industry	• mega-projects sparked growth in the private sector • increased taxation • median income decline • issues outstrip any possible benefits from an improved economy of scale
Climate	• + 1ºC by 2030 and + 2ºC by 2050 • winters will see more change with warming and variable snow	• + 1ºC by 2030 and + 2ºC by 2050 • winters will see more change with warming and an increase in snow (several cm)	• + 2ºC by 2030 and + 4ºC by 2050 • winters will see more change with warming and an increase in snow (10 cm)	• + 2ºC by 2030 and + 4ºC by 2050 • winters will see more change with warming and an increase in snow (10 cm)

APPENDIX A - SUMMARY OF FUTURE HISTORIES OF WHITEHORSE: SCENARIOS OF CHANGE, *continued.*

	Scenario 1 **City of Wilderness** **Some growth, some climate change**	**Scenario 2** **City of People** **Lots of growth, some climate change**	**Scenario 3** **City of Mettle** **Some growth, lots of climate change**	**Scenario 4** **City of Crossroads** **Lots of growth, lots of climate change**
Environment	• biodiversity pressure from development • wetlands and waterways fragmented • increased precipitation and wetter conditions • moderate increase in forest fire risk • moderate increase in flood risk	• biodiversity change due to development • water quality issues due to nitrification • increased precipitation and wetter conditions • severe fire risk due to sprawl • increased risk of landslides	• more wind initially • more extreme weather, lightening and drought • more frequent freeze-thaw events • more frequent ice-jams • run-off and increased erosion • stressed species and spread of invasive species	• more wind initially • more extreme weather, lightning and drought • more frequent freeze-thaw events • more frequent ice-jams • decreased water quality; stressed riparian systems • stressed species
Infrastructure	• public sector remains large • infrastructure strain proceeds as expected • institutional capacity is sufficient to compensate for changes	• 2nd Yukon bridge built • increase in development • increased strain on infrastructure by population • highway washouts more common	• compact development strategy • infrastructure ages normally • emphasis on green infrastructure development • increased emphasis on active transportation	• increased strain on infrastructure by climate change and population • increased influence of 'multipliers' • opportunistic renewal/ replacement of infrastructure
Energy	• increase in energy-efficient housing • moderate sustainable development	• rising oil and gas costs and continued dependency on fossil fuels • focus on biofuels to compensate for rising fuel costs	• increased demand side management of energy • high sustainable development	• rising oil and gas costs and continued dependency on fossil fuels • sustainable development strategies abandoned
Food Security	• slight increase in growing season • limited agriculture due to land use conflicts	• reliability of outside food sources declines • agriculture supported by local institutions • population increase creates stable market	• drought limits local food production • establishment of non-soil based food production program	• local agriculture develops in an ad-hoc fashion with mixed success • global food shortages affect local food security • access to country foods limited

APPENDIX B - WHITEHORSE ADAPTATION PROJECT COMMITTEE MEMBERS

Whitehorse Local Advisory Committee (LAC) Membership.

Members	Affiliation
Shannon Clohosey	Sustainability Office: City of Whitehorse
Clive Sparks	Fire Department: City of Whitehorse
Simon LaPointe	Department of Lands: Ta'an Kwäch'än
John Miekle	Department of Lands and Policy: Kwanlin Dün
Dan Boyd	Consumer Services and Infrastructure Development: Government of Yukon
Lewis Rifkind	Yukon Conservation Society
John Streicker	Whitehorse Local Adaptation Coordinator: Northern Climate ExChange

Whitehorse Technical Advisory Committee (TAC) Membership.

Members	Affiliation
Lacia Kinnear	Coordinator, Northern Climate ExChange
Robin Sydneysmith	PhD Sociology, University of British Columbia
Paul Kischuk	Principal, Vector Consulting
Frank Duerden	Professor Emeritus, Department of Geography, Ryerson University
Paul Murchison	Project Engineer, Department of Highways and Public Works, Government of Yukon
Ric Janowicz	Manager, Hydrology Section, Department of Environment, Government of Yukon
Ralph Matthews	PhD Sociology, University of British Columbia

APPENDIX C - A HISTORY OF ENVIRONMENTAL STRESSES IN WHITEHORSE: 1930-2009

INTRODUCTION

The term climate change refers to a significant change in the variability or average state of the climate (IPCC, 2007). Adaptive capacity as it relates to climate change is the ability or potential ability of a community to adjust to climate change by addressing and planning for changes, taking advantage of related opportunities, or coping with the consequences of change (IPCC, 2007). Current model predictions by the Intergovernmental Panel on Climate Change (IPCC) report greatest climate warming in the eastern arctic. However, certain regions of northwestern Canada are also predicted to continue warming at a faster-than-average-rate due to characteristic mountainous terrain and subsequent microclimates. In particular, the Yukon has warmed at an unprecedented rate (IPCC, 2007). Of particular interest is the ability of Whitehorse (the capital city of Yukon) to respond adaptively to re-occurring environmental stresses that are likely to increase in severity and frequency due to a warming climate. We define an environmental stress as an extreme, generally short-lived, natural event that tends to impact the immediate landscape. The findings of this report will assist with the evaluation of adaptive capacity during the development of the *Whitehorse Community Climate Change Adaptation Plan*. For this reason, the environmental stresses highlighted in this report are those likely to be affected by climate change. We provide an overview of how environmental stresses affected the community from 1930 to 2009, by:

- identifying the primary stresses affecting Whitehorse;
- providing historical examples of related events that illustrate how residents and the city responded; and
- gauging the community's adaptive capacity to respond to potential impacts of climate change-related events based on historical responses.

Geographically, Whitehorse is a relatively remote community located in the southern region of the Yukon Territory, at 60°43'N and 135°4'W. Whitehorse is situated in the Upper Yukon Basin, a region characterized by deep river valleys and an elevation grade of 600-1200 m above sea level (a.s.l.). Climate is continental and has a highly variable daily and seasonal temperature regime. On average, the region receives 200-300 mm of precipitation annually (Wahl *et al.*, 1987). The regional climate is influenced by teleconnections between the Pacific Decadal Oscillation, the El Niño Southern Oscillation, and the Arctic Oscillation (Werner and Murdock, 2008). The community is considered relatively urban by Northern standards. As of 2006, the population of Whitehorse was 22,114 to 23,991 residents – approximately 75% the population of Yukon (Yukon Bureau of Statistics, 2007). Because of its central location along the Alaska Highway and relatively high population density, Whitehorse functions as an economic and service hub for the territory.

METHODS

Evidence of environmental stress in Whitehorse was principally gathered from the archives of the two local newspapers: the *Whitehorse Star*, and the *Yukon News*. About 50 articles from 1930 to 2009 were examined to determine the extent, influence, and repercussions of historic extreme natural events. Additional information was gathered from relevant Yukon Government and City of Whitehorse departments.

The environmental stresses experienced in Whitehorse are classed into three categories commonly influenced by climate conditions: forest fires, flooding and weather fluctuations. This last category (weather fluctuations) was further subdivided into ice, weather variability and snow. Historic environmental stresses are therefore presented in six categories. For each category, the causes, impacts and community responses are reported for each environmental stress. Wherever possible, resulting monetary costs have been adjusted to 2009 Canadian dollar values.

WHITEHORSE ENVIRONMENTAL STRESSES 1930-2009

FOREST FIRE

Forest fires are uncontrolled fires occurring in the bush and countryside. They are the most important and common environmental stress experienced by Whitehorse residents. The behaviour and impact of a forest fire depends on a combination of factors such as available fuels, physical setting and weather.

There are many examples of forest fire incidents during the 1930-2009 time period. The most prominent fire occurred in June 1958 and burned a significant portion of the Ibex Valley. Strong winds pushed the blaze towards Whitehorse, forcing an evacuation; in part, caused by insufficient community response capacity. Some residents never returned to the area. The 400 square mile (~103 000 ha) burn was only stopped by precipitation from a timely storm. The potentially catastrophic effects of the fire continue to linger in the memory of the community. Smaller forest fires tend to cause more localized evacuations and damage. For example, in June 1969, Porter Creek and Crestview subdivisions were almost destroyed by a fire. In May 1970, Riverdale was threatened by a fire that burned 650 acres and forced residents to evacuate. Another fire threatened residents living east of Lake Laberge in 1978, burning 1359 acres. The Haeckel Hill blaze in 1991 also occurred within city limits. Another fire in 1991 affected 1500 ha, forcing the evacuation of the Echo Valley subdivision.

Causes of Forest Fires

Fires are typically started by one of two sources, those occurring naturally and those stemming from human activity. Most fires in Whitehorse are caused by human negligence (Yukon Wildland Fire Management, 2010, http://www.community.gov.yk.ca/firemanagement/index.html). Careless campers and hunters, vandalism, and industrial activities are all cited as the main causes of forest fires. In the winter, fires can be caused by electrical shorts in the wiring of houses or by chimney fires. Wood heat is also a potential source of fire, especially during cold weather when large fires are not well supervised (Yukon Wildland Fire Management, http://www.community.gov.yk.ca/firemanagement/index.html). In January 1956, sixteen phone calls were made to the fire department due to strained boilers and chimneys catching fire, causing structural damage to several homes.

The primary natural source of fire ignition is lightning, which often ignites fires during warm periods when temperatures may exceed 35°C for many consecutive days. Therefore, hot weather combined with a dry season creates a high potential for fire. Such conditions were present in the summer of 1948 when lightning sparked a local forest fire. Fires ignited by lightning strikes are reported annually and generally result in more intense fires (YourYukon, column 233, series 1, June 29, 2001, Sarah Locke).

Impacts of Forest Fires

Forest fire activity may have several consequences. In addition to the physical damage, the related financial costs can have detrimental effects on the community. For example, fire control budgets include the cost of personnel salaries, equipment maintenance, aircraft and supplies; these are based on an annual estimate of fire activity. Thus a high number of forest fires could require the hiring of additional fire fighters and the acquisition of additional equipment. Fire can also devastate vulnerable infrastructure such as roads, power lines and phone lines, adding to the total cost of the fire and leaving residents without communication and power. For example, the city's fire budget became strained in 1984, when a severe forest fire resulted in over-exertion of the fire crew and the need for additional equipment. Four WWII A-26 tankers were used to drop fire retardants, while two bird dog aircraft, two patrol planes, a DC-3 (used by smoke jumpers), 100 employees, and mountain lookouts were ultimately needed to control the fire. The effort cost approximately $4.6M ($8,600,651.47, 2009 adjusted value)[1], exceeding the fire budget for that year (*Whitehorse Star, May 24th 1984)*. The city ultimately tried to recover some of the cost of fighting the fire on Crown/Commissioners land from the federal and territorial governments.

In addition to the area burned, high wind conditions can create problems by spreading smoke to new areas. In 1998, the smoke from a nearby 3000 ha forest fire (about 1 km from Logan subdivision) drifted over Whitehorse and the surrounding area creating poor air quality for the residents.

Local infrastructure can exacerbate local vulnerability; gravel roads that are irregularly maintained can be especially problematic, creating difficult or even insurmountable problems for fire crews trying to access hinterland areas. In May 1974, a private house burned down because it was located in a slough area that the fire truck could not reach. Residences located long distances from a fire hall increase response times for fire fighters.

Forest fire is a natural process of regeneration and can be a benefit to wildlife. Generally, only small animals such as mice and voles perish in local forest fires. Large animals such as moose and bear can simply evacuate threatened regions. For example, a group of marten escaped the 1991 Haeckel Hill fire unscathed. Snowshoe hare populations generally increase in areas that have recently recovered from forest fires. This benefits lynx, coyotes and avian predators such as goshawks and great horned owls. Recently burned areas can provide improved growing conditions for certain plant species. For example, morel mushrooms grow in large quantities in the moist environment that can develop in burned areas. These mushrooms can be quite valuable if sold to an interested market.

Community Responses to Forest Fires

Only large fires near communities or residences tend to elicit a response from the community. In June 1958, the Red Cross organized a special White Pass train to evacuate residents to the Carcross Residential School. The seriousness of the 1958 forest fire also prompted authorities to upgrade the Robert Service Way to provide an alternative access route into and out of downtown Whitehorse (*2004 Wildland Fire Review, 421.34.y94*). One of the most important recent responses to forest fires in the Whitehorse area was the purchase of a new fire management system designed to detect fire in July 1983. The cost was $82,000 ($159,013.51, 2009 adjusted value).

Military firefighters, the city fire department, and the forestry division have historically worked together to control large fires threatening the city. Equipment used to fight fires included bulldozers, aircrafts and helicopters. A large fire in June 1957 required a collaborative response from fire fighters representing a number of organizations. These firemen worked collectively to make a firebreak to trap the blaze. In the past, the city has also been forced to organize head-counts of evacuees, while hotels have offered free rooms during periods of population

1. All values have been adjusted for inflation to their value in 2009 using the Bank of Canada inflation calculator, http://www.bankofcanada.ca/en/inflation_calc.html, [accessed February 2010].

relocation. The Alaska Highway was also periodically closed during historic fire seasons due to poor driving conditions.

Successful fire management depends on fire prevention, detection and suppression. In April 2003, the Protective Services Branch of the Department of Community Services (Government of Yukon) became responsible for the Fire Management Program from the federal government. Fire prevention relies both on prevention of natural and human-based ignition. Fire ratings are typically assigned to proactively manage fires. Fire bans are often issued during periods where the fire rating is moderate to high. Fire detection is possible through regular surveillance of a particular area and through reports made by members of the public via the forest fire hotline or otherwise. Finally, fire suppression depends on the capacity of fire-fighting crews and equipment made available by the Department of Community Services.

Forest Fires: Adaptive capacity and climate change

A dry climate and a close proximity to forested areas make Whitehorse vulnerable to frequent forest fires. The extent of resultant damage is dependent on the intensity, spread of the fire, and on the capacity of firefighting crews to control the blaze. The Yukon's Fire Management Plan provides the structure for implementing an adaptive response plan. However, due to the city's relative isolation, communities remain vulnerable to fires that become difficult to control due to unpredictable or changing weather patterns. A recent fuel management plan was compiled for the western Whitehorse region which highlighted that certain areas of the surrounding forest would burn particularly hot and fast[2].

Biophysical and climate research suggests that climate change may influence the frequency and intensity of forest fire activity in the northern boreal system (Duffy *et al.*, 2005; Westerling *et al.*, 2006). The area surrounding Whitehorse is characterized by a relatively arid climate, thus an increase in average temperature and changes in the intensity and frequency of precipitation events could increase the risk of forest fires. Strong communication between the government, the public, and fire managers will strengthen adaptive capacity. Overall, public education campaigns and further monetary investment in fuel management will be important preventative measures that will help to ensure that residents are aware and prepared for potential changes in the forest fire regime due to climactic changes. Effective fuel management is expensive but must be maintained. Although a FireSmart program has instigated the clearing of underbrush (potential ignition fuel) in forest surrounding certain subdivisions, such measures will not undermine the need for quick institutional response should a fire break out. Future forest fires could become bigger and more intense if periods of drought are followed by sudden thunder storms which generate lighting. Given that there are more people living in and around Whitehorse, these fires may become harder to fight. For example, there were 7.4% more residents in Whitehorse in 2006 compared to 2001 (Statistics Canada, 2006 Community Profiles, www.statcan.gc.ca). Large fires in the future may potentially threaten property and infrastructure more than ever before, especially in relatively remote areas on the periphery of the city.

FLOODING

Flooding is an important environmental stress in Whitehorse and can occur year round, regardless of seasonal conditions. Flooding can cause damage to buildings, houses, bridges, roads and sewage structures. Local vulnerability stems primarily from the Yukon River which traverses the city, one of the biggest rivers in North America. The Yukon River reacts quickly

2. Yukon News, June 11, 2010, Whitehorse ill prepared for fire, Chris Oak.

to shifting seasonal conditions because of its directional flow (flows south to north) and its many tributaries. Seasonally, river levels rise in the fall and spring, driven by increased levels of precipitation, and ebb at the end of the summer. Cold weather can cause ice-jamming and flooding as the river does not freeze completely during winter months.

Causes of Flooding

There are numerous natural and anthropogenic reasons for flooding. In the spring, the river ice breaks and moves with the current, potentially creating conditions for an ice-jam and resulting in flooding. Ice jamming can also be problematic in winter when triggered by widely fluctuating seasonal temperatures (*i.e.*, from very cold to very warm). Flooding can also result from the thawing of permafrost, which adds more water to the river drainage system. Permafrost can be melted by forest fires or by a heavy snowfall. Forest fires can melt about 3.6 m of permafrost. Heavy snowfall can trap heat from the ground, acting as an insulator to melt permafrost, especially if the snowfall occurs early in the season.

Localized flooding can happen any time through the summer due to heavy precipitation events, such as thunderstorms. According to climatologists, thunderstorms are most likely to occur in the Whitehorse area during June and July. Thunderstorms are caused by the sun heating the earth's surface and causing a large amount of warm air to rise. When the warm air is cooled by mixing with unstable atmospheric conditions at very high altitudes, a relatively sudden burst of precipitation is produced. This burst of precipitation can exceed the natural or engineered drainage capacity of a region, resulting in localized flooding. Thunderstorm activity can continue until the end of July and into August. After August, limited daylight decreases the surface area heated by the sun reducing the likelihood of a storm occurring.

Development along the Yukon River floodplain and through the river corridor has exacerbated the threat of floods. Since the installation of the new hydraulic turbines at the power dams, workers have observed flooding along the riverfront as the freezing of the river is less extensive during winter[3].

Impacts of Flooding

Flooding directly impacts residents by damaging infrastructure and property and potentially threatening the lives of residents. Damage from flooding is evident throughout the history of Whitehorse. In December 1962, about two feet of water and slush covered the streets and evacuation was necessary. High precipitation over a short period broke the record precipitation for June in 1985, resulting in localized flooding. A mudslide along Robert Service Way was created when 50.5 mm of rain fell on the area, blocking half of the road. In February 1968, there was an important flood on Sixth and Seventh avenues, particularly in the low-lying west end of the city. Flooding was caused by unseasonably warm weather which melted the snow. The resulting melt-water exceeded the coping capacity of the local sewage system. To complicate matters, the city crew did not want to increase the pressure in the sewers in case the water backed up into other basements. Another early spring thaw occurred on March 4th, 1968. The problems started when basements on Jarvis, Fifth and Sixth avenues, and beyond were flooded by melting surface water. Heavy flooding along Second Avenue in Whitehorse in 1985 submerged a vehicle in about a metre of water. That same year, heavy precipitation in the summer negatively affected the tourism season and the local economy.

The Marwell subdivision in Whitehorse has historically experienced greater issues with flooding than anywhere else. Flood levels in Marwell have measured up to about one metre of water. A flood in January 1982 reached more than 100 m into Marwell, threatening houses along Silver

3. Phone conversation with City of Whitehorse's employees, October 2009.

Road. Home owners prepared for the flood by moving furniture and vehicles and building snow dams to divert flood waters. Residents blamed the new sewer construction and historic dredging of the Yukon River. Flooding occurred again in December 1992 when water forced its way into some local basements. Water levels reached up to 125 mm, and at least one family was forced to evacuate their home. No long-term emergency shelter could be provided for the family due to the lack of available housing. Flooding occurred again in Marwell in 2000 when debris torrents and mudflows occurred downstream of the subdivision. This event caused the highest level of damage from flooding and ice-jams in twenty-five years. Fearing typhoid fever, many Marwell residents poured bleach into their wells.

In June 1997, an extreme thunderstorm hit Porter Creek and resulted in flooding and extensive damage along Jupiter and Hemlock Streets. About 20 mm of rain fell in two hours. The storm itself felled many trees, which damaged power lines and houses along the street. Yukon Electric was forced to shut down power to give employees time to clear trees from the lines. Flooding was so severe that residents were observed kayaking on Tamarack Crescent. In November 2001, localized flooding resulted in the contamination of a domestic well as flood water flushed the contents of the septic tank into well waters. Yukon government engineers have been working on similar flooding vulnerability in Copper Ridge.

Localized flooding remains an issue, especially in winter. During winter months, water does not easily flow through storm sewers and can even freeze, forming blockages. When these conditions occur, the city crew has to open the storm drains so as to melt the ice and pump up the water[4]. The director of community infrastructure was quoted saying that this was not an easy problem to resolve because they are not sure about the source of the flooding (CBC NEWS, August 11th, 2009).

Community Responses to Flooding

In 1993, city council bought a $127,000 ($163,333.33, 2009 adjusted value) drainage system in the wake of persistent spring flooding problems in country-residential developments within city limits - especially in the Hidden Valley subdivision and on Loganberry Lane. In 2009, the city continues to upgrade drainage systems where necessary. Additional measures are required to address ice build-up in the storm drains. Despite efforts to upgrade drainage systems, community level responses are still required. Residents should always check their pipes and private sewers in cold weather.

Flood relief for residents has been problematic in the past. A family was displaced by local flooding in 1992, and left without permanent shelter. Concern was expressed that there was no contingency plan in place to provide disaster relief to residents. For example, it was not known how relief would be provided if 20 families were flooded out. When a flood does result in disaster conditions, social services personnel are responsible for providing relief.

The alternative to flood relief is flood forecasting to ensure vulnerable people and property can be moved from danger. Unfortunately, flood forecasting is not very straight-forward, especially in the North. Flood forecasts are based on information collected from hydrometric stations through the winter, which are then incorporated into a computer model. Forecasting in the North is complicated by these models, the majority of which were developed for populated areas in the south and are not directly applicable to northern conditions. They do not account adequately for cold climate factors like permafrost, seasonally frozen soil, and sublimation (where snow evaporates directly into water vapour without entering a liquid state). For example, the Wolf Creek Research Basin near Whitehorse has demonstrated that up to 60% of snow can

4. Phone conversation with City of Whitehorse's employees, October 2009.

disappear through sublimation and never reach the stream channel (Yukon Flood Study, 627.42, Fe Y. Rm. 2002). The Department of Water Resource and the Division of Indian and Northern Affairs, Canada, has been working on following and understanding the northern phenomenon of flooding.

Flooding: Adaptive Capacity and Climate Change

Flooding in Whitehorse is characterized by irregular, sporadic events that are relatively difficult to predict (YourYukon, column 256, December 7, 2001). However, the city has consistently updated drainage infrastructure to accommodate local flooding, resulting in the overall decrease in damage related to flooding events. The positive effects of climate change on flooding events may include changes in freeze-up and break-up dates, increases in the number of heavy precipitation events, duration of the ice season, and ice-cover thickness (Prowse, *et al.*, 2007; Beltaos and Prowse, 2001). Flooding events depend on numerous variables driven by climate that interact through a variety of geophysical processes (*e.g.*, geo-mechanics, micro-meteorology, hydrology and hydraulics). While it is not yet clear how climate change may ultimately affect flooding, there are certain flooding events that may be more likely to be aggravated by a changing climate, such as ice-jam flooding due to large fluctuations in spring temperatures (Duffy, et al., 2005). Ice-jam flooding can be serious, even if the discharge is modest compared to open-water floods. While open-water flooding is generally predictable, ice-jam flooding is often sudden and capable of substantial bank erosion (Beltaos and Prowse, 2001). Quick, institutional responses to flooding events in the past suggest that damage induced by flooding will likely be minimized due to pre-emptive improvements to infrastructure and good communication of river conditions. Moreover, most subdivisions are located on riverbanks that are relatively elevated above normal river water levels. However, new developments should consider the possibility of sudden, unpredictable flooding and should take into consideration the historical extent of flooding in vulnerable areas, such as the Marwell subdivision.

WEATHER FLUCTUATIONS: ICE

Icy conditions are usually created by very cold weather and rapidly fluctuating temperatures, which can produce fog and flooding. Rapidly changing weather can also produce ice during seasons when residents may not be prepared for it. As a result, anticipating and accommodating ice and icy conditions is an important feature of life in Whitehorse.

Impact of Icy Conditions

Every winter accidents related to icy conditions result in tragedy. For example, on March 1957, a driver failed to accommodate icy road conditions and collided with a child on a toboggan. In January 1962, three residents were admitted to the Whitehorse General Hospital after two vehicles collided due to the icy road conditions. A major series of accidents was reported on November 25th, 1968 with the onset of winter conditions, resulting in $600 ($3,587.50, 2009 adjusted value) damage. Unsurprisingly, the majority of vehicle accidents occur in downtown Whitehorse, where the traffic is heavy. A number of accidents occurred again in November 1965 and January 1969. About $3,150.00 ($17,991.04, 2009 adjusted value) in vehicle damages occurred during this period. Heavy snowfalls occurred throughout the early winter in 1988. About 110 mm of snow fell in one day in November 1988. This anomaly was surpassed soon after when 270 mm fell in a single day in December 1988. The heavy snow and icy road conditions resulted in a three-vehicle accident on Mountainview Drive, closing the road. Accidents resulting from driving in icy conditions continue to persist today.

Accidents due to icy conditions are not limited to vehicle use. Often, simply being out in icy conditions can result in the injury of residents. In December 1964, slips and falls on icy streets resulted in injuries across the city within a mere 48 hours. Five people were admitted to the Whitehorse General Hospital during that period. In December 18th 1981, warm temperatures of 5°C resulted in about 4.2 mm of rain to fall over the course of the day. This rainfall then froze causing a rash of injuries due to slips and falls. In November 2000, mild weather was responsible for serious and non-serious injuries due to pedestrians slipping on the sidewalk. Fourteen people were treated at the Whitehorse General Hospital in one day. The warmer temperatures melted the snow, which then turned into ice, causing slippery conditions for pedestrians. As with vehicle accidents, slippery streets can still affect Whitehorse's residents. The aging population of Whitehorse is currently vulnerable to icy conditions.

Effects of Ice and Icy Conditions

Injury is the most common result of ice and icy conditions. Icy conditions in 2005 resulted in 198 admittances - 75% of the total hospital visits to the Whitehorse General Hospital Emergency room. Warmer temperatures during the same period in 2006 resulted in 113 individuals (45% of admittances to the Emergency) injured because of falls (Wendy White, Whitehorse General Hospital, pers. comm., 2009).

Icy conditions also affect infrastructure. In December 1962, electric power to Porter Creek was interrupted by heavy ice created by mild weather, sleet and rain. Ice built up on the power lines, which ultimately snapped under the load. Ice and ice fog can potentially block metal chimneys. Heat converts ice fog to water, which condenses inside the chimney and later refreezes. This ice gradually builds up until the chimney passage is completely blocked, forcing carbon monoxide levels in the building to rise. Unfortunately, this situation resulted in the death of a couple in the 1970s. Another, more fortunate family was saved in December 1977 after a public safety warning alerted them to ice blockage in their chimney. At that time, the Fire Chief had stressed the importance of checking household chimneys in cold weather after an episode of ice fog.

In addition to issues of safety and security, historic ice damage to buildings in Whitehorse can be expensive. For example, a resident who lived on Redwood Street in Porter Creek for seven years had his pipeline freeze for the first time because road improvements had lowered the road surface about 1 m. He had to pay $150,000 (~$250,000.00 in adjusted 2009 dollars) for pipe steaming. Municipal service crews have since noted that the several mild winters have put Whitehorse residents out of the habit of using frost protection devices.

Cold conditions can also create challenging conditions for city operations. On January 3, 1991, ice fog and temperatures of -45°C reduced visibility and forced the Whitehorse airport to shut down. On the same day, the record low temperatures halted work by city crews, who could not use certain equipment for fear of damage. The metal equipment became so brittle it could snap or shear when it hit curbs.

Community Responses to Icy Conditions

In 1960, Red Cross Water Safety officials stressed safety measures to ensure the security of residents engaged in winter outdoor activities. Following safety rules helps to prevent accidents and aids in rescue operations. For example, one must ensure that the ice on the rivers, sloughs and lakes is four inches thick before it is traversed.

Warnings and official messages are the standard method for creating awareness in the community of dangerous driving conditions and ensuring motorists use the proper amount of caution. In December 1981, the RCMP issued an official warning to motorists to be very careful on streets. Yukon government officials have also told residents to avoid the Yukon highways unless it was absolutely essential to make a trip. The highways around Whitehorse are sanded to increase traction and create safer driving conditions.

Historically, Whitehorse has responded well to infrastructure concerns associated with icing. In August 1989, the city made a change to their Water and Sewage bylaw, such that the city became responsible for pipes freezing on city property. However, the Municipal Services Director cautioned that residents were still responsible for their own frost protection devices (the most common being bleeders, recirculation pumps and transformers). In September 1989, the city addressed concerns about potential pipelines freezing in Porter Creek. These pipelines were fairly close to the surface and solutions were established to protect the system and prevent a freeze-up, including placing a heat trace, a bleeder and a recirculation system.

Whitehorse has been searching for a sewage treatment system that can accommodate ice since 1977. For example, sewage lagoons work best between 14°C and 30°C, and are frost free only 60 days of the year as a result. Only in the warmest summer months do the lagoons get enough light and oxygen to mix up bacteria. In 1985, the city spent a few thousand dollars to clean the sludge from the Whitehorse lagoons to meet the federal standards.

Icy Conditions: Adaptive Capacity and climate change

The city has responded consistently to episodes of icy conditions by making improvements to water and sewage infrastructure and is continually searching for new ways to improve the efficacy of sewage systems. Residents remain responsible for ensuring that the necessary precautions are taken to reduce ice build-up on housing structures and sidewalks in front of houses. However, injuries due to accidents involving icy conditions continue to occur each year, likely aggravated by the negligence of some property owners to remove ice build-up on public walkways. The enforcement of such bylaws is necessary, however this process becomes complicated when homeowners leave on vacation or are home infrequently. The importance of good communication of current weather conditions remains a key component to reducing injuries related to icy conditions. Although it is not mandatory for vehicles to have winter tires, an emphasis on the benefits of installing season-appropriate tires is an effective way to prevent accidents. Recently (2009), the province of Quebec made winter tires an obligation. Support for such a bylaw in Whitehorse would likely reduce the number of accidents related to vehicles on the road during icy conditions. Climate change-induced fluctuations in winter temperatures may increase the number of days that Whitehorse will experience icy conditions (IPCC, 2007). Potentially milder winters may lead to residents being less prepared for icy conditions on the basis that they are expecting fewer colder days. However, the combination of relatively cold nights and warmer days creates potentially good conditions for ice build-up, making communication between advisory organizations and residents all the more important.

WEATHER FLUCTUATION: WEATHER VARIABILITY

Whitehorse weather is heavily influenced by its proximity to the Pacific coast. When combined with the climatic influence of the surrounding mountains, the result is a distinct microclimate around the city (*Whitehorse Star*, October 1962). Winters are influenced by the Kuroshio Current, which is a strong western boundary current in the Western North of the Pacific Ocean. Because Whitehorse is located close to the Pacific Ocean, local weather can be affected by this current. The resulting rapid weather fluctuations can create dangerous conditions for residents, especially those engaged in outdoor activities.

Impacts and Community Responses to Weather Variability

As early as December 1938, significant variability with rapid fluctuations between warm and cold weather in late winter was reported in Whitehorse. During that period, which persisted over several years, the Yukon River froze intermittently, increasing the risk of flooding. Poor conditions were reported for outdoor sports like skiing and curling. In March 1938, an unexpected thaw made it impossible to have curling competitions. Skating on the river was dangerous. Poor winter conditions were reported again in November 1939 when a long-term resident made the 75-mile trek from Livingstone Trail to Whitehorse by dog-sled, stating it was the hardest trip of his life because of the changing weather.

Unusually warm weather also characterized the winter of 1940. The Yukon River was still open in January and remained so into February. Temperatures fluctuated again in January 1941 when temperatures rose from -51°C to 3°C in the space of three to four days, a variation of 54°C. Warm conditions continued and mild weather surprised residents again in January 1942. Interviews with community elders reported they did not remember having such warm weather. Fluctuating weather conditions occurred once more in December 1944 when warm weather conditions generated heavy snow fall and left the river unfrozen. In 1953, February temperatures reached 10°C.

Unusually warm weather occurred again in March 1967, this time leading to localized infrastructure problems. A resident from the roadhouse in Lot 19 had her house surrounded by sewage leaking from the Department of Transport line located up the hill. Variable conditions persisted for some time. The first week was relatively mild and temperatures reached 12°C. Record high temperatures occurred again in February 1968 due to a flow of warm air that persisted for four days. Whitehorse recorded 9°C, six degrees higher than the previous record in 1949.

Weather conditions also vary in summer. Temperatures three degrees lower than normal were reported in July 1962. Lower than normal precipitation (61.7 mm below normal) accompanied low temperatures. At one point in the month, 101.6 mm of snow fell - the highest record of snow precipitation for July at that time. The summer of 1994 was also cooler than the accepted norm, until it warmed significantly in August. After August, summer temperatures soared to record highs. Summer temperatures over 30°C have only been recorded three times over the past 53 years. These periods of have additionally been characterized by below-average precipitation. Moreover, during the record highs recorded in 1994, Whitehorse received only 29.4 mm of precipitation - 76% of the July norm. In October 1998, unseasonably warm fall temperatures prevented the normal freezing of roots undermining the anchorage of trees. When a severe storm inevitably struck, wind-thrown trees fell onto power lines cutting power to the community.

A combination of hot weather and low precipitation can create dust devils. Dust devils form due to a combination of high temperatures and unstable air over hot surfaces such as pavement and/or dusty and sandy surfaces; this combination causes updrafts that lift dust, rocks and other surface debris off the ground. Dust devils also occur when the relative humidity drops dramatically. Environment Canada Whitehorse reports that dust devils are a common local phenomenon, although they are very hard to predict. It should be noted that the City of Whitehorse has increased the total paved surface area over the last 10 years because of new developments. For example, 178 new residences were constructed in 2007 and another 212 in 2008 in addition to the construction of new commercial developments across the City[5]. The increase in paved surface area has increased the vulnerability of city areas to the incidence of dust devils.

Dust devils often die down less than a minute after forming and generally do not have wind speeds higher than 70 km/h, thus they usually do little damage. However, dust devils can be hazardous when the heavy dust obscures vision. This scenario occurred in July 1951 when two vehicles collided due to poor visibility, injuring 8 people at McCrae. Another dust devil hurled

5. Housing Market information, CHML, Whitehorse.

dust and debris several thousand feet into the air in May, 1978. Again, in May 1989, a giant dust devil struck the Lobird trailer park, ripping a quilt off of a clothesline and carrying it 300 m. Paper and garbage bags were reported to have flown 1000 ft into the air. Serious damage occurred when the roof of a mobile home was peeled off and folded back on top of itself. Another strong dust devil occurred in June 1996. This dust devil ripped through a short stretch of downtown Whitehorse and was observed throwing 4’ x 8‘ sheets of plywood up in the air. A carpenter for Cardinal Contracting Ltd. renovating the roof of the Whitehorse Elementary School subsequently reported missing 20 sheets of plywood. Injuries did not occur because the school was closed for the summer. One piece of plywood was reported to have caused about $2000 damage ($2,559.64, 2009 adjusted value) to a Norcan Leasing pickup truck parked nearby.

Weather Variability: Adaptive Capacity and Climate Change

Climate change may increase weather variability and thus the frequency of related environmental stresses. Incidences of drastic weather have become more frequent and scattered over the last 20 years. Potential impacts of increased weather variability include an increased uncertainty in lake and river ice stability and decreased reliability in predicting weather conditions. Quick changes in temperatures can rapidly create potentially dangerous conditions such as heavy rain, snow, ice, high winds, and/or very warm or very cold weather. Increasingly variable weather could also affect ground integrity, as it may take longer for soil to freeze. Falling trees may therefore become more common if there is an associated high wind during the fall, increasing the chance of power line damage and subsequent power failure. Damages or injuries can be minimized by maintaining appropriate infrastructure that is built to withstand a wide range of conditions; ensuring a quick response time for clearing transportation routes; and emphasizing public advisory warnings. Government services are responsible for dealing with most public infrastructure damage that result from ice and snow build-up due to rapid temperature fluctuations. However, prevention of injuries, vehicle accidents, and damage to private property are strongly dependent on the awareness and conscientiousness of residents. While such events are sometimes predictable, being prepared with the proper equipment and knowledge is necessary to reduce injuries and further damage. Government programs related to public awareness will be important assets in spreading information and building adaptive capacity in this regard.

WEATHER FLUCTUATIONS: SNOW

The 1990s were marked by a considerable change in the timing and amount of snow fall. Over the past few decades, the first snowfall of the season has been observed to occur earlier. Annual snowfall is reportedly thicker and heavier.

Source of Winter Precipitation

Heavy winter precipitation is caused by the collision of the cold Arctic air mass and the warm, humid pacific coastal air mass which combines to create an Arctic front. The warm, wet coastal air slides above the cold arctic air, condenses and falls as snow. The Arctic front frequently stalls along the Ogilvie Mountains and jumps directly to Prince George, BC - skipping Whitehorse as a result. Snowfall in Whitehorse is also influenced by the St. Elias Mountains and The Coast Range, which can act as a barrier to the warm and wet weather coming from the south.

Regardless, communities in Southern Yukon - including Whitehorse - generally receive more snow than the rest of the Territory. Large lakes like Lake Laberge, Lake Bennett, Marsh Lake and Tagish Lake also influence snowfall in Whitehorse, contributing to increased amounts of snowfall in the area.

IMPACTS AND COMMUNITY RESPONSES TO PROBLEMATIC SNOWFALL

Snow generally impacts the community in two ways: directly through the amount of snow that falls or through the amount of water released when it melts. One example of problematic snowmelt occurred in April 1952 when heavy snowmelt created flooding in city streets, causing damage to basements and furnaces and decompressing wells. Other examples of the damage caused by problematic snowmelt can be found under the section *Impacts of Flooding*. The remainder of this section describes the impacts of snow itself.

Structural damage due to heavy snow loads occurred in April 1954 when a large snow-slide off the roof of the Civic Center damaged a part of the building. The heavy snow load also forced the walls out of line and destroyed the windows. The cost of the damage was about $3,000 ($24,425.53, 2009 adjusted value). In October 1968, newly fallen snow caused a number of motor vehicle accidents. The same conditions occurred again in November 1968, which was the first time that the airport runways were closed due to heavily falling snow. In December 1980, Whitehorse missed a record snowfall by only two inches (the record was set in 1967 with a snowfall of 272 mm). Snow clearing crews worked non-stop on Christmas day to clear the road to the hospital and the priority streets in the downtown area. Nine minor accidents occurred regardless.

The late 1980s and 1990s are seemingly marked by a considerable change in the amount of snowfall in the Whitehorse area. The record for snowfall was broken several times over this period, causing localized damage around the city. For example, a significant amount of snow fell on Whitehorse in September 1986, which far surpassed the normal monthly total snow water equivalent for that month. The mix of snow and freezing rain created dangerous driving conditions, compounded by driver error. In at least one case, a resident failed to properly clear their vehicle windows and accidentally backed into another vehicle. In the case of this storm, public warnings constituted the community response. City crews were unable to keep up with the snow clearance levels that the storm demanded, which resulted in poor driving conditions on the highway. City crews subsequently warned residents against using the highway unless necessary. At this time, the highway to Carcross was still under construction which further increased the infrastructure stress. The 1986 storm set a record for precipitation and 67.2 mm of snow and rain accumulated. About 53.9 mm of precipitation fell in 4 days, 2.2 mm fell as rain, and another 31.4 mm fell as snow.

In December 1991, the 1986 snowfall record was broken and 677 mm of snow accumulated. The city experienced high snow fall again in 1992; the warm wet snowfall caused an afternoon blackout for 1000 people living between McCrae and Teslin. Moist snow had fallen onto an insulator, which then broke off an electrical pole near Miles Canyon, resulting in a short. A diesel generator was used to provide power for the Teslin area until the damage could be repaired. Three megawatts of power were lost in the blackout. In the same storm, the weight of 300 mm of snow caved in the roof of a vehicle.

In February 1996, a combination of mild weather and high winds resulted in a heavy snowfall that caused trees to snap and fall on power lines. Problems reportedly began at the Robinson subdivision and then expanded to include Annie Lake, Cowley Creek and Horse Creek. Residents became frustrated as they lost power. The damage was so extensive that ultimately the electric company opted to wait for temperatures to rise to 5°C and melt the ice and snow along power lines. As a result of this incident, Yukon Electrical installed a breaker that would allow isolation of a particular subdivision in the event that repairs would have to be made. Breakers are standard across the territory such that power outages due to repairs are limited to localized areas.

Snow: Adaptive Capacity and Climate change

Climate change models for the Yukon predict that winters will warm more than summers; however, predictions related to precipitation changes are more uncertain (IPCC, 2007). In general, models predict increased winter precipitation with more pronounced changes towards the north. Models also suggest that the Yukon will experience more extreme precipitation events, and large amounts of precipitation will fall in a short time period (IPCC, 2007). The ability of Whitehorse institutions to cope with the hazards induced by heavy snowfall is primarily dependent on equipment and personnel capacity, and budget allowance. Currently, the Public Works Department is responsible for snow and ice control on municipal roads and approximately 300 km of highway within the municipal boundaries (excluding the Alaska Highway which is maintained by Yukon government). Due to a limited budget, the city prioritizes snow removal based on traffic levels on the roadway (City of Whitehorse, Public Works Department). In the event of a snowstorm, only certain roadways will be continuously cleared and the frequency of clearance of secondary roadways is dependent on the time available and the snow removal budget. A flexible and potentially larger snow-removal budget may be necessary if snowfall events increase in frequency and intensity. The resistance of buildings and other structures to heavy, dense snow is currently being studied in hopes of improving structure resistance to future snowfall events. Individual capacity to respond to large snowfall events or substantial snow accumulation depends on both the awareness of individuals to the potential related hazards and the potential for taking preventative measures if given appropriate warning. Thus government monitoring of weather and incidental reporting of predictions is an important variable in preventing accidents related to adverse weather conditions.

CONCLUSION

This report identifies common environmental stressors in Whitehorse likely to be influenced by climate change and describes historical events in an attempt to consider adaptive capacity on an institutional and individual level. Climate change in Yukon is predicted to enhance and/or change the frequency of occurrence of the environmental stresses identified (forest fires, flooding and weather fluctuations).

Overall, institutional responses to environmental stresses provide evidence of adaptive capacity and are defined as improvements to infrastructure, upgrading personnel capacity, improving quality/quantity of equipment, and initiating education and awareness programs. However, a rapid rate of change may outstrip the adaptive capacity of the city to keep up with climate change given the limited tax base and potential increases associated with maintaining extensive response units.

Adaptive capacity at the individual level was also considered. This report provides some evidence to suggest that individual capacity is consistently weaker than institutional capacity. This conclusion is not unexpected considering that individuals tend to be more reactive rather than proactive when responding to a particular stress. Institutions often promote proactive responses to potential hazards as they rely on logical planning processes to consider how best to respond to a future or immanent stress; however, clear, complete planning is necessary for successful implementation. For example, individuals tend to heed evacuation warnings concerning potential forest fire or flooding risks, but also require institutional support for knowing where to find shelter and safety. Individuals that are accustomed to relying on institutional direction for proper risk response are not only less likely to be injured or severely impacted by an environmental stressor, but may also facilitate institutional attempts to control and neutralize the source of danger by staying out of the way and following directions. Thus, an effective response requires the institution to provide residents with enough information to dissuade them from taking action themselves and thus potentially complicating efforts to lessen a particular threat. It is important to note that despite a noticeable effort by Whitehorse's institutional departments to improve responses to environmental stresses, there is persistence in individual injuries and private property damage that result from a particular stress, despite a lessening of overall impact. For example, heavy snowfalls or icy conditions tend to consistently result in accidents and injuries despite advanced warnings about the potential hazards. Thus, the community's adaptive capacity is low where behavioural, rather than institutional-level change, is required. This will likely affect future climate change adaptations as they are implemented. Environmental stresses such as flooding and forest fires are more easily mitigated with institutional support, as their impacts tend to be more localized and they often require access to specialized equipment. Educational programs and ensuring the community is aware of the benefits associated with city programs such as FireSmart will likely be pivotal for future adaptation programs, especially on an individual level.

While climate change may result in new environmental stresses that carry unknown risks, it will also exacerbate known stresses and the hazards. For example, structural issues arising from snowfall that exceeds the loading capacity of buildings may become increasingly common. Ice on roadways may become more frequent due to unseasonable rain and changing weather, and could be of major concern given that there are more drivers and pedestrians in Whitehorse than ever before. Accidents due to poor driving conditions or icy walking conditions are therefore also likely to increase. Finally, the risks associated with a potential increase in the number of forest fires and flooding events will test both the adaptive capacity of the institution and the individual. The environmental stresses documented in this report provide a basis for evaluating how climate change may affect the community of Whitehorse. This report indicates which of these historic hazards has proven problematic for residents, and which hazards continue to result in the damage of property and the injury of residents. The impacts and responses to these stresses are something that we should consider and evaluate for years to come. As a result, these stresses should be considered in the development of the Community of Whitehorse Climate Change Adaptation Plan.

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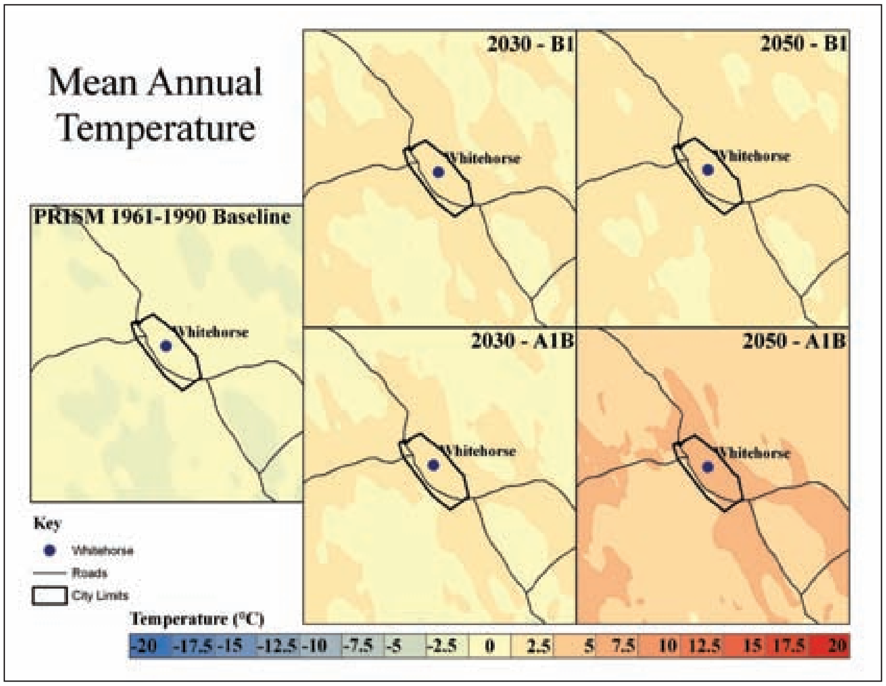
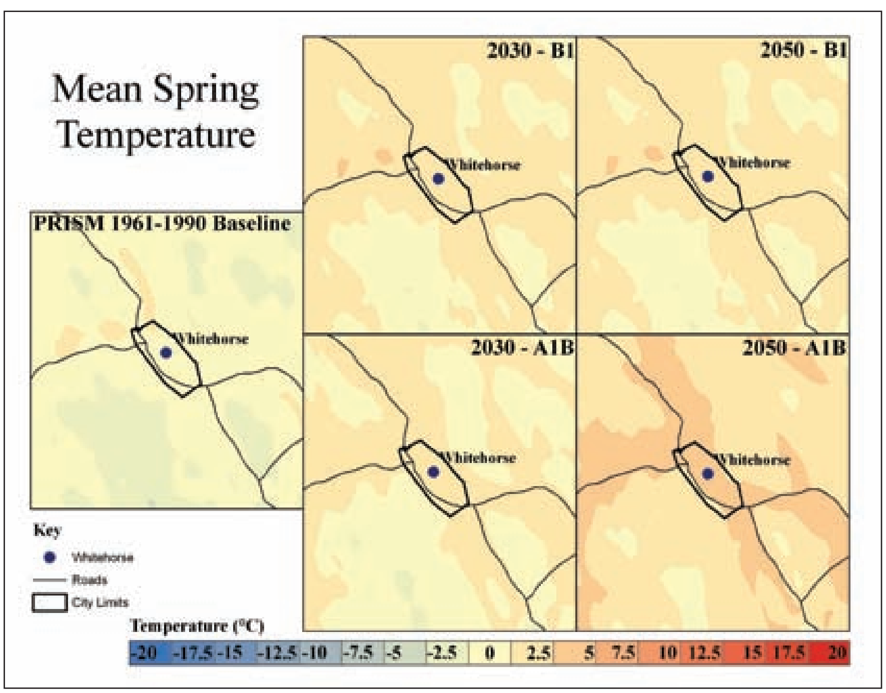
APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS

Projected changes in mean annual temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

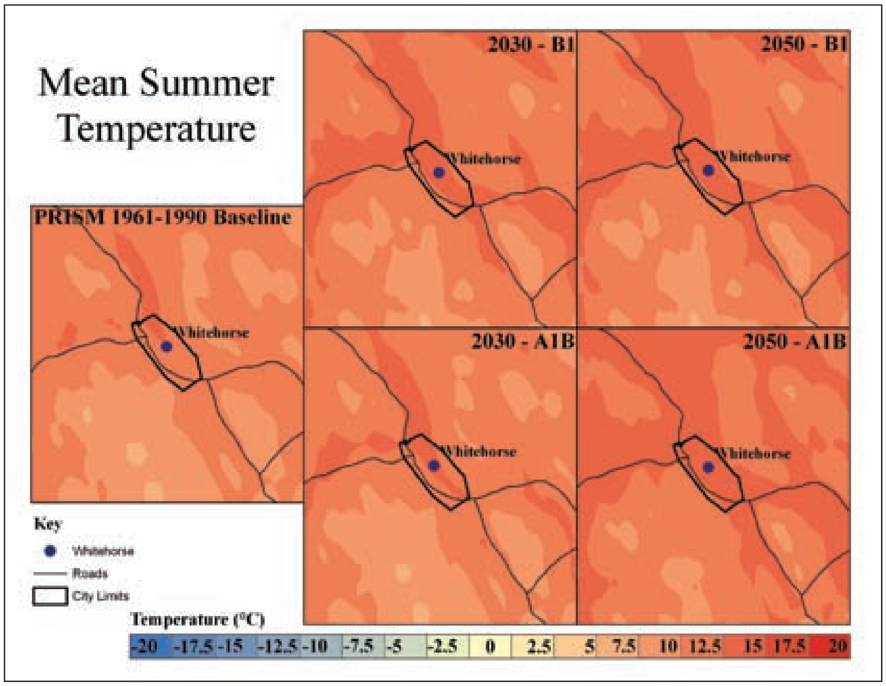


Projected changes in mean spring temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

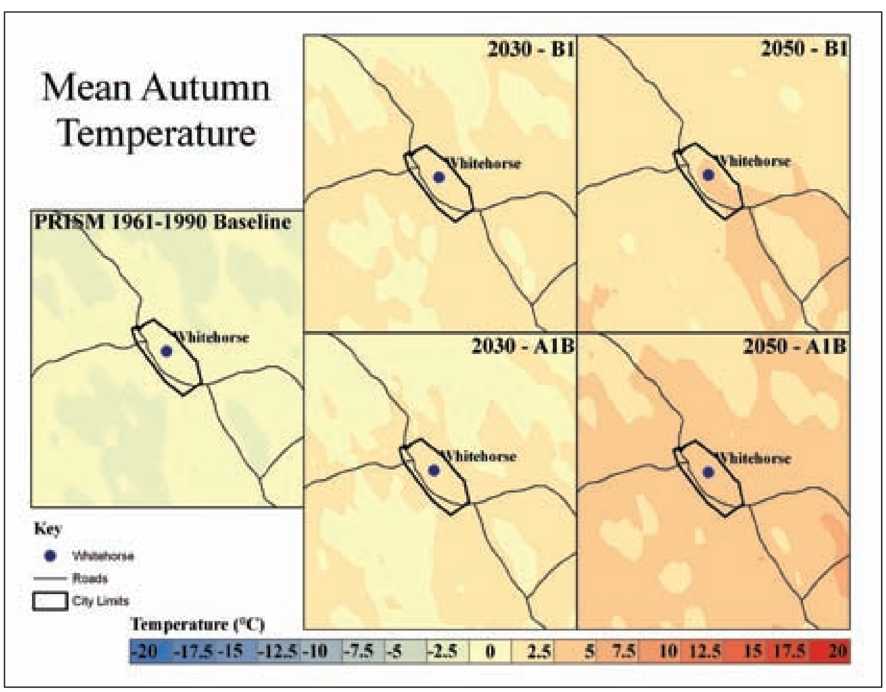


APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in mean summer temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

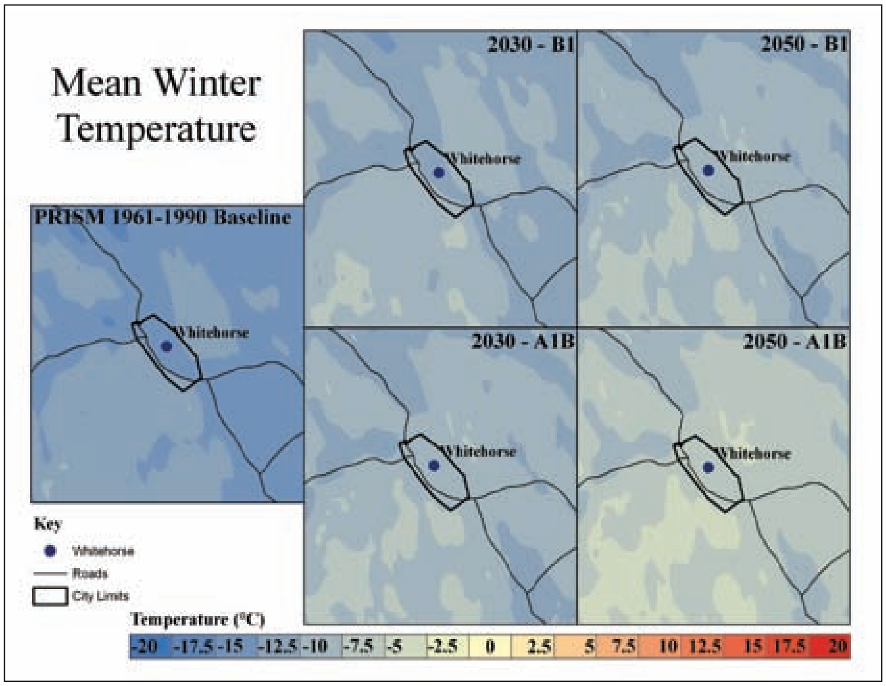


Projected changes in mean autumn temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

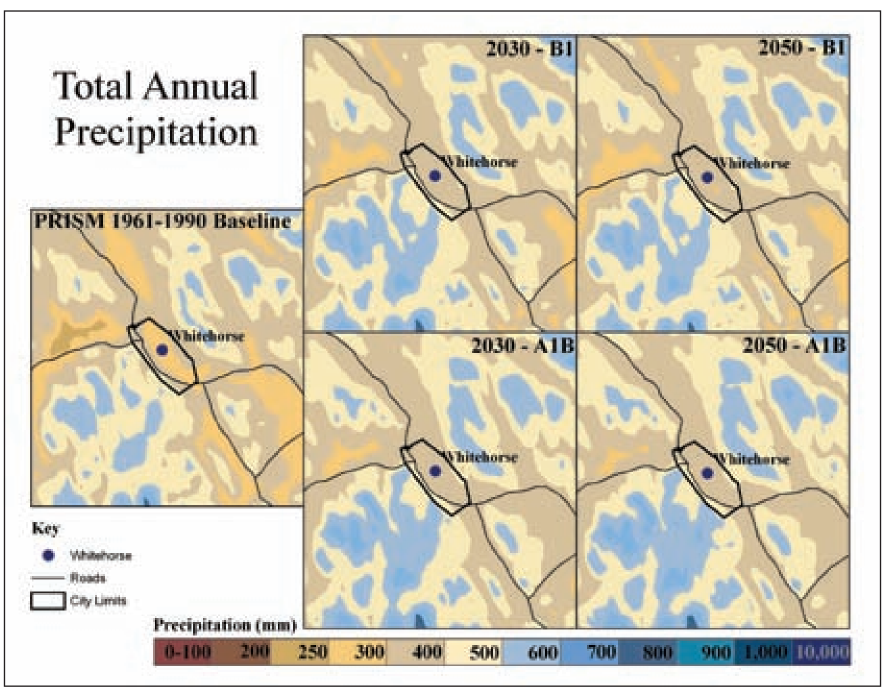


APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in mean winter temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

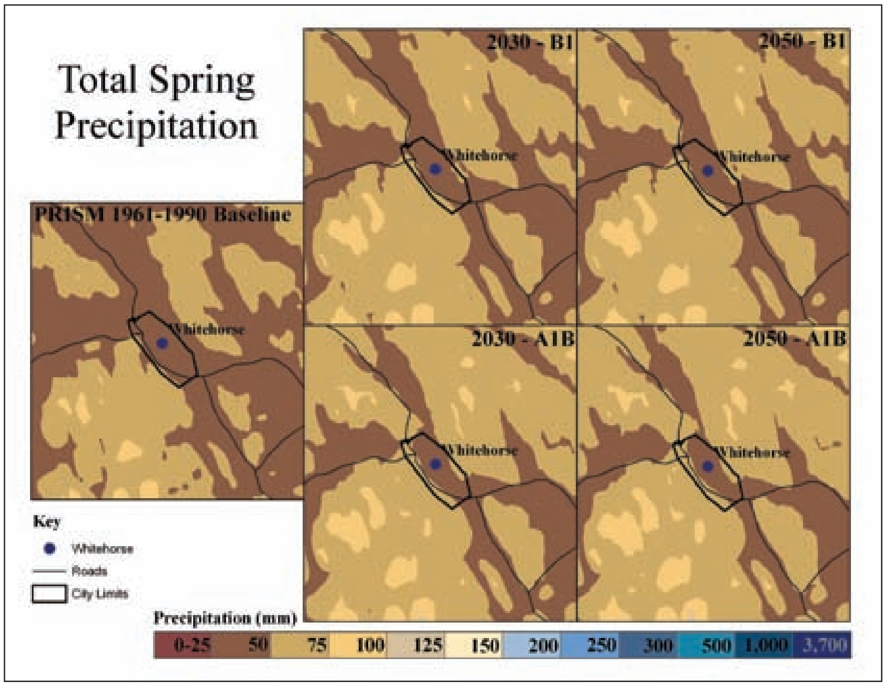


Projected changes in total annual precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

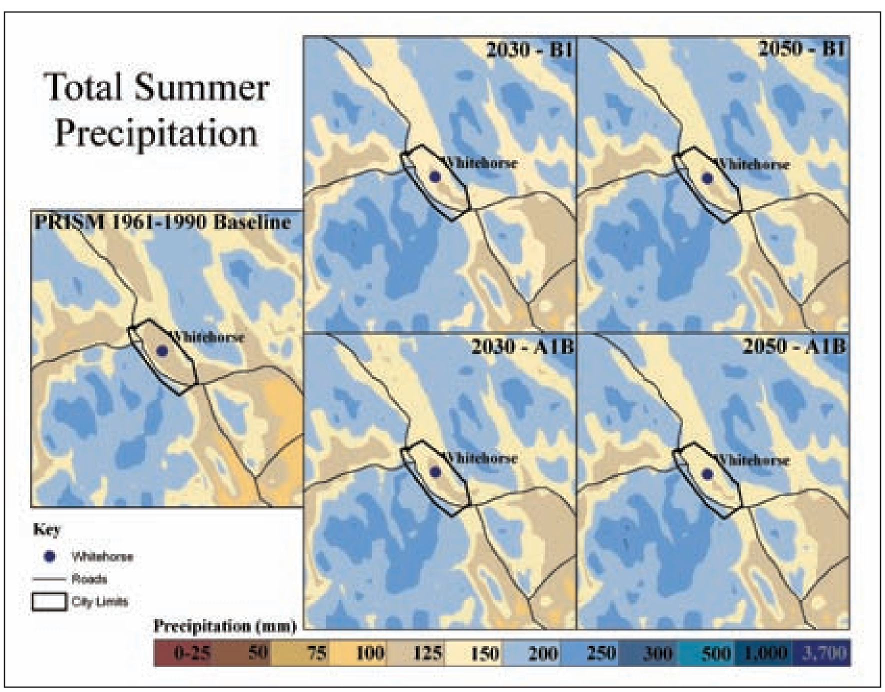


APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in total spring precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

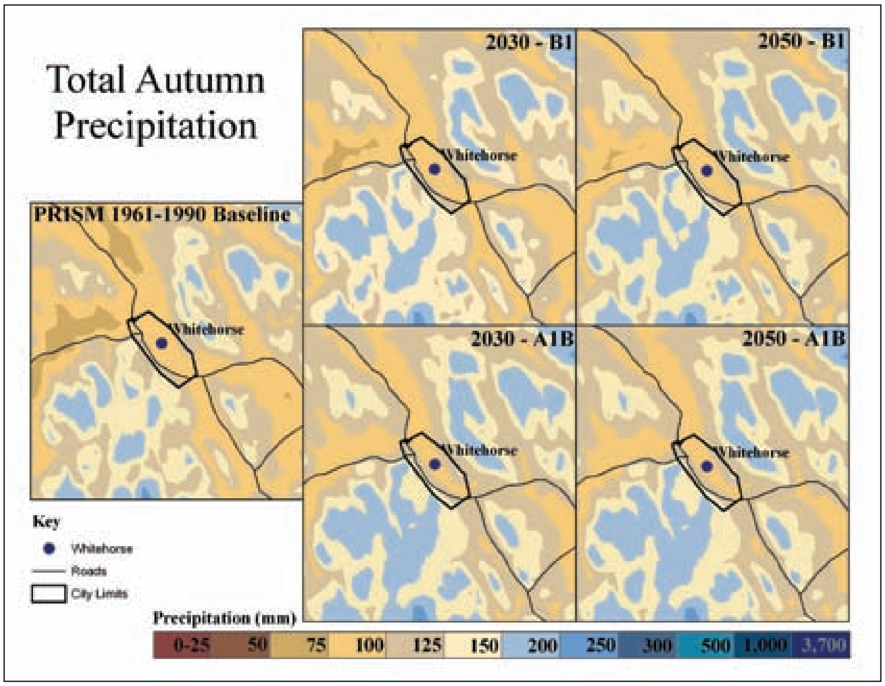


Projected changes in total summer precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

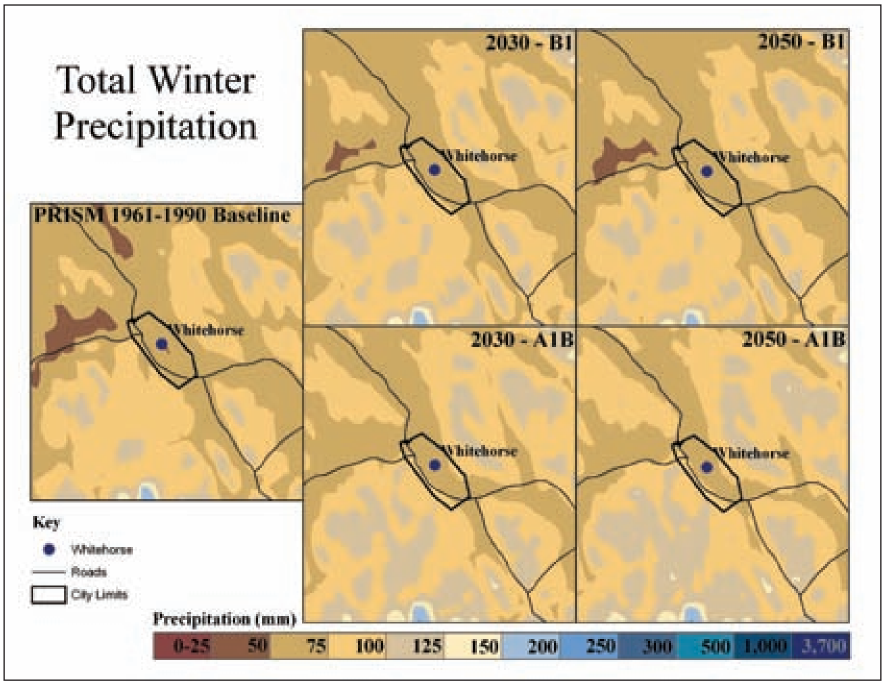


APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in total autumn precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

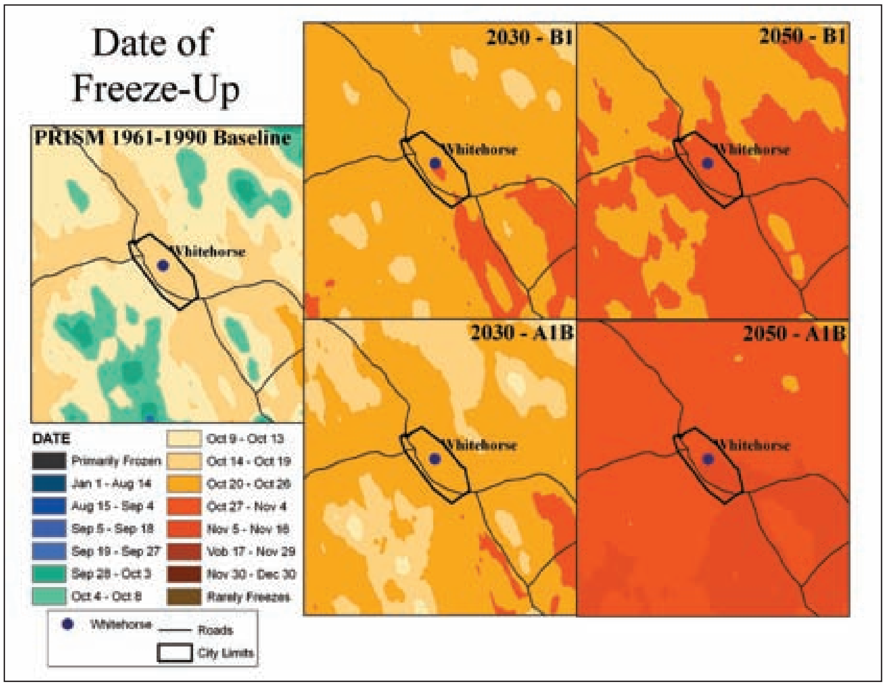


Projected changes in total winter precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

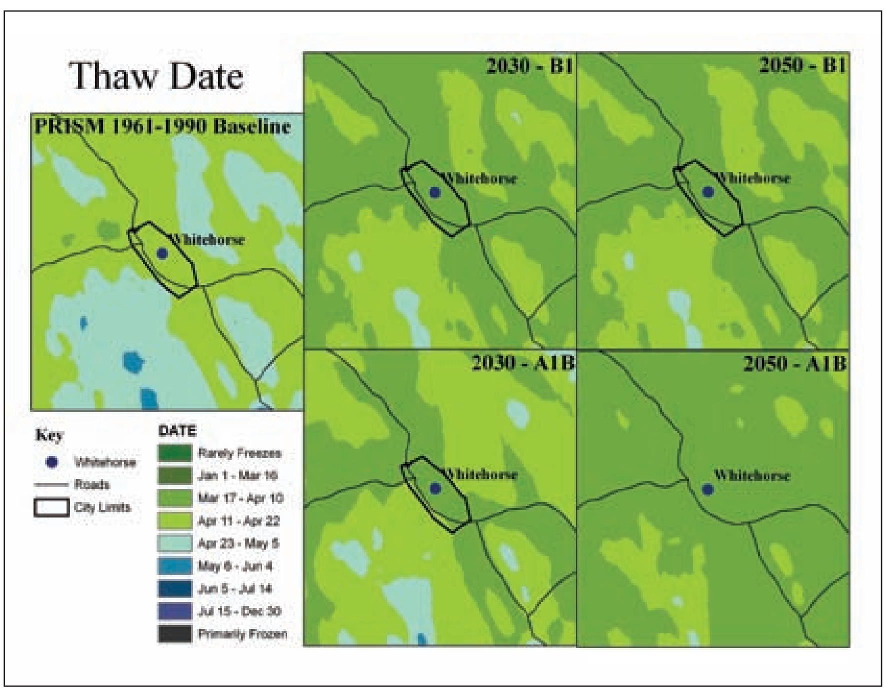


APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in date of freeze-up for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

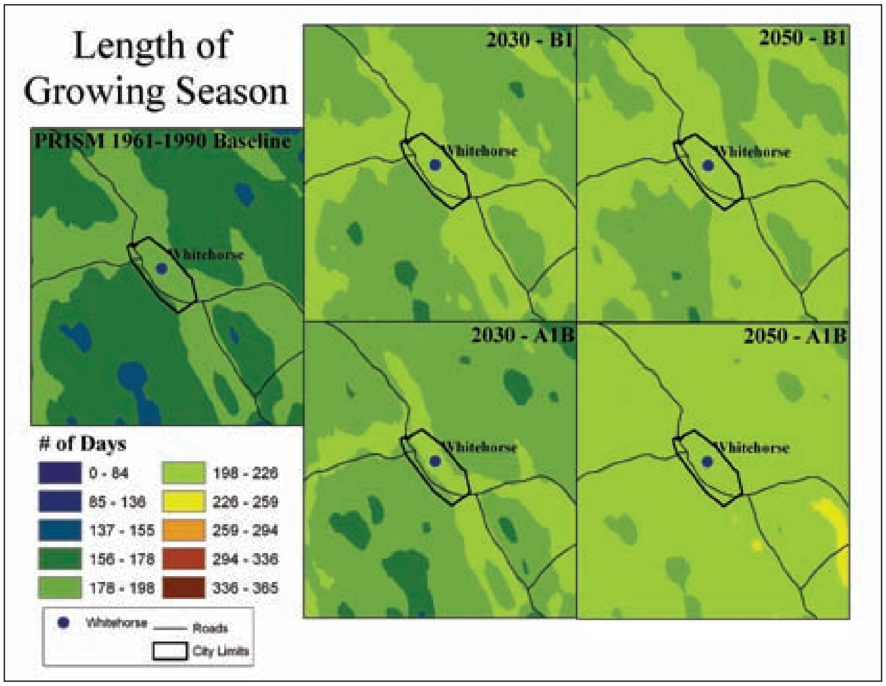


Projected changes in the thaw date for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.



APPENDIX D - WHITEHORSE CLIMATE-CHANGE PROJECTIONS, *continued.*

Projected changes in the length of growing season for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.



APPENDIX E - COMMUNITY OF WHITEHORSE RISK ASSESSMENT

TIER II ASSESSMENT OF RISK: CLIMATE-CHANGE VULNERABILITY AND THE COMMUNITY OF WHITEHORSE

Risk assessment is a common method for identifying priority vulnerability where there is a required community adaptation to climate change. Risk assessments are normally based on the analysis of the uncertainty and severity of a potential vulnerability. The assessment of risk completed for the WhiteCAP plan incorporated an additional variable that influences vulnerability: adaptive capacity. Adaptive capacity was integrated into the risk assessment as a measure of community preparedness under the assumption that if the community is prepared for a climate-related event, the vulnerability would be reduced. Priority risks are therefore characterized by high likelihood, high severity and low adaptive capacity. The characteristics assigned to vulnerabilities by the WhiteCAP planning team are provided below. The Tier II risk assessment also evaluated climate-related opportunities. These opportunities were prioritized by evaluating the benefits, the likelihood of the consequence emerging from shifting climate conditions, and how prepared the community is to profit from the consequence. Each sector of vulnerability is characterized at the opening of each section.

Uncertainty and variability were two characteristics of climate change that were challenging to evaluate. These characteristics were assessed using a multiple environmental scenario methodology through which four possible scenarios of growth and climate change were created by the WhiteCAP planning team. The four scenarios allowed for the expression of climate change variability, such as declining or increasing water availability in the region, to 2050. Uncertainty was evaluated by the emergence of vulnerabilities across the range of scenarios. For example, an increase in the incidence of forest fire was common to all scenarios which made this vulnerability more likely to occur than one which only emerged in a single scenario, such as the emergence of significant health risks. A summary of the scenarios is provided in Appendix A.

HAZARDS

Hazards are characterized by climate-influenced disturbances at the landscape scale such as landslides, forest fires, floods, *etc.* Increasing winter temperatures, increased variability in water availability, as well as the more frequent occurrence of extreme weather events all increase the hazard risk for the community of Whitehorse.

Community Consequences of Hazards

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
H.1	Community vulnerability to forest fire increases due to heavy fuel load, lighting, drought, wind, *etc.*	H	H	L	High
H.2	Increased risk of catastrophic fire.	H	M	L	High
H.3	Egress from subdivisions becomes a problem during emergency situations.	H	M	L	High
H.4	Possibility of regional beetle infestation leading to more dead stands and increased risk of forest fire.	H	H	L	High

Community Consequences of Hazards, *continued.*

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
H.5	Community continues to not buy into FireSmart program.	M	H	M	High
H.6	Heavy increase in rural residential leads to an accompanying increase in vulnerability.	M	H	M	High
H.7	Increased risk of catastrophic flood and infrastructure failure (*e.g.*, bridge).	H	L	M	High
H.8	Variable and/or increased snow, ice and wind compromises infrastructure.	M	M	M	Med
H.9	Concerns about freeze-thaw and road icing.	L	H	H	Med
H.10	Frequent fires outside city limits leads to health issues and problems with air quality.	L	L	M	Med
H.11	Slope instability as a result of rain and warming (*e.g.*, escarpment).	M	L	M	Low
H.12	The combination of increased and variable rain and urban growth lead to issues of leaching and seepage.	M	L	H	Low

INFRASTRUCTURE

Climate change increases the risk to linear and non-linear infrastructure in Whitehorse. Non-linear infrastructure includes buildings, foundations and other structures, while linear infrastructure is the community's power lines, roadways, storm and sewer systems, *etc.* Climate-induced vulnerability is generated by an increased risk of hazards, as well as increased temperature fluctuations, frost heaves, windthrow, and severe weather.

Community Consequences Associated with Infrastructure

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
I.1	Increased incidence of damage to power lines from windthrown trees, *etc.*	H	H	H	High
I.2	Increase in multipliers - roads affect access which affects safety, *etc.*	H	M	M	High
I.3	Increased rate of leaching from unlined dump - hazardous waste requires special consideration.	M	M	L	High
I.4	General strain on infrastructure as a result of age and pressure from growth and climate change.	M	H	M	High
I.5	Increased cost to maintain roads due to shifting landscape conditions (*i.e.*, erosion).	M	H	M	High

Community Consequences Associated with Infrastructure, *continued.*

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
I.6	Integrity of spillways and dams declines.	H	L	L	High
I.7	Stormwater requires treatment; levels exceed current capacity.	M	M	M	Med
I.8	Climate change (freeze-thaw, erosion, *etc.*) affects road safety and infrastructure.	L	H	M	Med
I.9	Highway washouts related to increased storms and flooding (threatens food security).	M	L	M	Med
I.10	Variable/increasing snow load impacts roofs, roads and other linear structures.	M	H	H	Med
I.11	Sewage lagoon system may be stressed due to population and precipitation increases.	M	M	M	Med
I.12	Growth of green infrastructure not possible.	M	L	L	Med
I.13	Structural strain on bridge abutments as glacial flow increases river levels.	H	L	M	Med
I.14	Changes in energy type and use will likely require new and/or upgraded infrastructure.	L	M	M	Med
I.15	Increased stress on culverts due to precipitation.	L	M	H	Low

ENVIRONMENT

Community vulnerability from climate-induced environmental stresses in the Whitehorse region stems from an increasing presence of damaging invasive species, changes to the quality/productivity of the environment, and increasing pressure on local wildlife. The resulting risk to the community is characterized by declining water quality, shifting landscape conditions, and a changing community relationship to the environment.

Community Consequences of Environmental Decline

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
EV.1	Evapotranspiration and groundwater recharge are critical and still uncertain.	H	H	L	High
EV.2	Introduction of pests/invasive species.	M	H	L	High
EV.3	Concern about change to water quality and increasing demand.	H	M	M	High
EV.4	Warming water combined with decreased groundwater leads to loss of fish habitat.	M	M	M	Med
EV.5	Wildlife pressures from climate change, fragmentation, hunting and competing land use.	M	H	H	Med

Community Consequences of Environmental Decline, *continued.*

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
EV.6	Ecosystem stability declines; habitat shift occurs.	M	L	L	Med
EV.7	Watersheds, forests, wetlands will experience change as we grow at the same time.	M	M	L	Med
EV.8	Information cannot be generated/communicated fast enough to keep pace with changes – compounded by the pace of policy generation and implementation.	L	H	L	Med
EV.9	Increased nutrification of water with warming - affecting water quality (pressure from agriculture).	L	L	M	Low
EV.10	Increased commodification and increase in the value of water.	L	L	H	Low
EV.11	Increased population stresses river and lakes from increased recreation pressure and development.	L	M	H	Low
EV.12	Concern about air quality if we increase industry, wood fires, and if inversions should occur.	L	L	H	Low

FOOD SECURITY

Food security refers to a community's access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy lifestyle (Paci *et al.*, 2004). While food security encompasses economic access, the risks associated with food security in Whitehorse are tied to a reduction in the physical presence of sufficient healthy food within the community due to negative climate-induced impacts along the supply chain and in food producing areas.

Community Consequences of Decreased Food Security

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
F.1	Increased incidence of drought places more reliance on groundwater; problems with irrigation arise.	H	H	M	High
F.2	Decrease in First Nations' ability to harvest traditional foods, leading to loss of culture and health issues.	M	M	M	Med
F.3	The cultivation of food leads to introduction of invasive species and disease.	M	M	L	Med
F.4	Endemic pest and diseases affects food security and health.	M	M	H	Med
F.5	External food supply is diminished as transportation becomes less reliable.	H	L	H	Med
F.6	Conflict emerges over the balance of land use, water use, water availability and soil suitability.	L	H	M	Med

Community Consequences of Decreased Food Security, *continued.*

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
F.7	Contamination increases due to increased use of fertilizers and other pollutants.	M	L	H	Low
F.8	Concerns of historic land dispositions for agriculture arise.	L	M	H	Low
F.9	Supermarkets compete with local producers as a by-product of scaling issues.	L	L	H	Low

ENERGY SECURITY

Energy security is indicative of the community's access to reliable sources of energy sufficient to meet its needs. The energy security of the Whitehorse community may be negatively affected by climate impacts which reduce the efficiency of existing sources of energy or the feasibility of future (renewable or sustainable) sources of energy.

Community Consequences of Decreased Energy Security

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
F.1	Increased incidence of drought places more reliance on groundwater; problems with irrigation arise.	H	H	M	High
F.2	Decrease in First Nations' ability to harvest traditional foods, leading to loss of culture and health issues.	M	M	M	Med
F.3	The cultivation of food leads to introduction of invasive species and disease.	M	M	L	Med
F.4	Endemic pest and diseases affects food security and health.	M	M	H	Med
F.5	External food supply is diminished as transportation becomes less reliable.	H	L	H	Med
F.6	Conflict emerges over the balance of land use, water use, water availability and soil suitability.	L	H	M	Med
F.7	Contamination increases due to increased use of fertilizers and other pollutants.	M	L	H	Low
F.8	Concerns of historic land dispositions for agriculture arise.	L	M	H	Low
F.9	Supermarkets compete with local producers as a by-product of scaling issues.	L	L	H	Low

OPPORTUNITIES

Climate-related opportunities were evident in many of the sectors evaluated in the Tier II risk assessment. These opportunities were prioritized by evaluating the benefits, the likelihood of the consequence emerging from shifting climate conditions, and how prepared the community is to profit from the consequence. Additional opportunities are evident in the sectors ranked as having a low risk in the Tier I assessment. These opportunities are reported in "*Future Histories of Whitehorse: Scenarios for Change" (Hennessey and Streicker, 2010).*

Community Climate Change Opportunities

	Sector/Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
O.1	**Food Security**				
	Longer growing season; likely an opportunity for agriculture.	H	M	M	High
O.2	**Infrastructure**				
	Increased need for Whitehorse to serve as a hub due to infrastructure expansion.	H	M	M	High
O.3	**Food Security**				
	Whitehorse emerges as a hub, supplying food to outlying communities through local agriculture.	H	L	L	High
O.4	**Energy Security**				
	Gas pipeline mega-project may bring energy opportunity.	H	L	L	High
O.5	**Food Security**				
	Increased yields, but concerns about variable precipitation.	M	M	M	Med
O.6	**Energy Security**				
	Warmer winters reduce heating load (*e.g.*, +2°C in winter = 5-10% reduction in heating costs).	L	H	H	Med

APPENDIX F - COMMUNITY OF WHITEHORSE ADAPTATION ASSESSMENT

ASSESSMENT OF ADAPTATIONS: IDENTIFYING PRIORITY ACTIONS FOR THE COMMUNITY OF WHITEHORSE

Just as vulnerabilities were evaluated to determine priorities, the WhiteCAP team evaluated proposed adaptations to identify actions suitable for immediate implementation. This assessment was undertaken to ensure that the adaptive capacity of the community was invested in those actions that best address identified risks. A summary of the sector risk is provided at the opening of each section. Each adaptation was assessed to determine how well it addresses the impacts (fit), how well it benefits the broader community (win-win), and whether it builds adaptive capacity. The attributes of fit, win-win and adaptive capacity development allowed for the special considerations associated with the community vision (identified in Special Considerations of the Whitehorse Adaptation Plan) to be directly integrated into the planning process.

Fit is a measure of how well an adaptation responds to climate change impacts, both in number and priority. To evaluate if an adaptation has a good fit, the project team considered the following questions:

- How many impacts does the adaptation improve, and what is their priority?
- How well does the adaptation address the range of impacts?
- How well does the adaptation integrate with other adaptation strategies?
- Is the cost of the adaptation acceptable?

Win-win actions are those adaptations that provide other benefits to the community in addition to climate change (Snover et al., 2007). To assess if an adaptation was win-win, the project team considered the following questions:

- Is the adaptation also mitigative?
- How well does the adaptation integrate with other existing planning processes?
- Will the action decrease the risk of losing unique environmental or cultural resources?
- Will the adaptation increase scientific confidence?

The project team also determined the extent to which the adaptation would develop community adaptive capacity. To ensure that a positive contribution was made to capacity development, the team addressed the following questions:

- Is the adaptation equitable?
- Does the adaptation enhance the resources (financial, physical, knowledge) available for action?
- Does the adaptation enhance or build partnerships?
- Does the action increase the community's resilience?

HAZARDS

Hazards are expected to be exacerbated by climate change in the Whitehorse region. Challenges for which the community is currently poorly prepared include increases to local forest fire risk, flood risk, and the impact of snow, ice and wind on vulnerable infrastructure. Even a modest increase in forest fire risk is anticipated to negatively affect the community.

Suggested Adaptations for Hazards

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Incorporate fire considerations in all subdivision planning and zoning *i.e.*, no dead ends, add fire breaks, aspen plantings, access to water, and other holistic planning issues).	H1-3,5,6	H	M	L	High
Increase densification of City to reduce vulnerability to hazards.	I4	M	M	L	Med
Pass consequences of climate change on to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure.	H1,2	H	M	M	High
Integrate climate change risk and impacts into emergency planning.	EV3,5, 7,11	H	M	M	High
Allow fire department greater latitude for proactive responses.	I2,4,5	M	L	L	Med
Incorporate climate into infrastructure development that is currently in its planning stages.	H1-12	H	M	M	High
Consider fuel abatement and fuel mitigation (*i.e.*, produces biomass).	I1-15	M	M	L	Med
Recommend a second strategy for community-based disaster response, *i.e.*, equates to a residential fire strategy	H1-12	M	L	L	Med
Enhance building codes, *i.e.*, consider biomass heating to maintain air quality and reduce the risk of structural fire.	I1,9,13	L	L	L	Low
Continue education around responsible fire safety.	H1-6	H	L	L	Low
Create a strategy for harvesting salvage wood, such as from insect damage, as both an opportunity and a control measure.	H1-3, 6-8	H	H	M	High
FireSmart around vulnerable infrastructure.	I1-15 EV3, 5,7,11-12	H	L	L	Med
Create zoning that reflects potential future changes in the landscape.	H1,2,4	H	M	L	High
Introduce climate-change education and training for safety sector.	ES1,2	L	L	L	Low
Ensure critical buildings have back-up power for lighting/ heating in case of emergencies.	H1-6	H	M	M	High
Maintain green spaces and/or strategic agriculture to reduce fire risk.	H8	H	H	M	High
Investigate and assess catastrophic flood scenarios.	H1-3,5,6	H	H	M	High
Encourage/support redundant emergency systems on both sides of the river (to prepare against potential loss of bridge).	H1-2,4-6	M	M	L	Med

INFRASTRUCTURE

Even a modest onset of climate change is anticipated to negatively affect the linear infrastructure of Whitehorse, such as roads and power lines. Risks to linear infrastructure stem from variable weather and wind (affecting power lines and roads), or erosion and landslides (affecting roads). Risks to linear infrastructure from climate change are anticipated to compound existing stresses, exacerbating the cost of maintenance and creating secondary risks for the community as the influence of multipliers increases. Climate change is also anticipated to increase the risk of leaching from the Whitehorse dump. Spillways and dams are also perceived to be at a slightly higher risk from a catastrophic flood.

Suggested Adaptations for Infrastructure

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Establish a multi-year municipal budget for dealing with climate change variability, *e.g.*, roads and road clearing.	I2, 4, 5, H9	H	M	M	High
Recommend development densification to allow for greater cost sharing of infrastructure.	I2, 4, 5; H1, EV7; F6; ES3	H	H	H	High
Educate the public to set a fair expectation for quality of service.	14, 5	M	H	L	High
Reduce downtown vehicle traffic (*e.g.*, through better transit).	I1-15	L	L	L	Med
Need to identify critical engineering thresholds, responsibilities and partnerships.	I2, 4, 5, H7-9, 12; EV3	H	M	H	High
Look into feasibility of micro-hydro.	I1-15	L	L	L	Low
Increase available warehousing (links to food storage).	I6; F5, 9; O1,3,5	H	L	H	High
Expand active road monitoring stations in problem areas (roads and infrastructure).	14; H9, 11	H	L	M	Med
Explore feasibility of automatic de-icing at problem intersections.	15; H9	L	L	L	Low
Separate untreatable garbage to reduce leaching, *e.g.*, source-separation, hazardous materials transfer station, *etc.*	I2; EV3	L	L	L	Low
Increase storm water retention within the city – allow for natural recharge (*e.g.*, create porous parking lots.)	I3; EV1, 4	L	L	L	Low
Assess dependence of Whitehorse to highway, as well as vulnerability of highway to climate change outside city limits.	I6; H1, 2, 7, 11	H	M	H	High
Assess storm drainage capacity/capability and design for extremes in future climate change projections when being replaced through maintenance schedules.	I4	H	M	H	High

Suggested Adaptations for Infrastructure, *continued.*

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Ensure standards and regulations are "living" so they are changed as we acquire more information.	I6, H8	H	M	L	Med
Have flexible zoning (beyond the downtown core) to allow for densification increases in areas of the City.	I1-11, 13, 15; EV3, 5, 7, 11	M	M	L	Med
Design neighbourhoods outside the downtown core to have services.	I2, 4, 5	M	L	L	Med
Regional planning and all relevant planning needs to be revisited regularly.	I2, 4, 5; H1-3, 6; EV6-8; F8; ES3	H	M	L	High
Redesign buildings if there are problems in the future, such as retrofitting insulation, *etc.*	I2, 4; H8	L	M	M	Med
Use buildings as carbon sinks and/or use waste materials for insulation.	I4	L	L	L	Med
Generate standards/best practices for subdivision development for climate change.	I4, 14; H3; EV3, 5, 7, 11-12	H	M	M	High
Promote education and training to compensate for increased snow loads.	I1-5, 7; H8	L	L	L	Low
Create a strategy to move forward as demand for waste management constrains flexibility.	I4, 5	L	L	L	Low
Create a strategy to compensate for capacity issues as people and expertise are strained by changing climate conditions.	I3, 11	L	L	L	Low

ENVIRONMENT

Risk to the environment of Whitehorse from climate change is characterized by shifts in the rate of evapotranspiration, the introduction of invasive species, and pressure on water quality. Impacts on local water quality due to infrastructure decline were a risk identified by the community. These infrastructure risks do overlap with environmental risks to water quality (see section *Community Adaptations to High Risk Consequences of Climate Change*). It is important to note the cross-sector nature of some adaptations.

Suggested Adaptations for Environment

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Enhance greenspaces plan (build resilience to climate change).	EV1	L	L	M	Med
Need to reassess situation and values over time while planning for change now.	all EVs	L	M	L	Med
Evapotranspiration and groundwater recharge are critical and uncertain, therefore we need to retain capacity and expertise in these areas.	EV5-7	M	M	L	Med
Integrate life-cycle management into decisions, *e.g.*, water life-cycle includes how water passes through the human-built world.	EV1-12	L	L	L	Low
Create and implement a groundwater management plan.	EV1	H	L	L	Med
Monitor water quality and quantity through the careful examination of fish, wildlife and other indicators.	EV1-12	H	M	L	Med
Increase our use of grey water for other purposes (toilets, plants, *etc.*).	EV1, 3; F1, 6	M	M	L	Med
Create an education program around water conservation.	EV1-12	H	M	M	High
Continue to look at water conservation – avoid shipping water out of the Territory.	EV3	M	M	L	Med
Look into a strategy to enforce the protection of riparian buffers.	EV3	H	L	H	High
Make any sale of water taxable so the community benefits.	EV3	L	L	L	Low
Gather and collect local observations/data conclusions, both scientific and traditional.	EV3, 5, 7, 9, 11; F2, 6	M	M	L	Med
Restore weather stations.	EV3, 10	H	L	L	Med
Set aside funding to monitor fish, wildlife and the environment.	EV1-9	M	L	L	Med
Divert additional environmental protection funds to Territorial and First Nations governments.	EV8; F2	M	L	M	Med
Train (and pay) local people for monitoring.	EV5-7	M	L	L	Med
Take advantage of digital technologies to gather, store, and share information – this information hub must consider the abilities of the people who need access to it.	EV1-12	M	M	L	Med
Look at other areas with similar biophysical characteristics to predict what changes may occur and how to address them.	EV1-12	L	L	L	Low
Aquifer monitoring.	EV1-12	M	L	M	Med

FOOD SECURITY

Priority climate-change risks to food security were associated with an over reliance on groundwater due to an increased incidence of drought.

Suggested Adaptations for Food Security

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Choose crops that conserve water or are not water intensive.	F1, 6; EV1, 3, 10; O5	H	L	L	Med
Encourage small community plots.	F5, 6, 8; O1	L	M	M	Med
Investigate new and innovative ways to grow food.	F1, 2, 5-9; O1, 3	H	M	M	High
Increase animal husbandry in the region.	F2, 5, 9; O3	L	M	L	Med
Create policies to encourage the use of greywater for agriculture purposes.	F1, 6; EV1, 10; O5	H	L	L	Med
Increase irrigation infrastructure in the region.	F5, 9; O5	L	M	M	Med
Create food security plans that address poverty and the sharing of food.	F2, 5	L	L	L	Low
Make a portable abattoir available in the Whitehorse area.	F2, 5, 9	L	M	L	Med

ENERGY SECURITY

The energy sector may be increasingly vulnerable to external forces including rising energy costs and a future cost tied to carbon emissions. These risks may limit the availability of energy to the Whitehorse community over time.

Suggested Adaptations for Energy Security

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Create an energy plan for Whitehorse (including comprehensive energy management).	ES1-3; I12, 14; O2, 3	H	H	M	High
Respond to the need for energy storage (even in homes).	ES2, 4	L	L	L	Low

Suggested Adaptations for Energy Security, *continued.*

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Promote seasonal energy uses, *e.g.*, greenhouses.	ES1, 2	L	L	L	Low
Continue to investigate the feasibility of district heating.	ES1, 2; I12	L	L	L	Low
Push for super-green construction of homes to reduce heat demands.	ES1, 2; I12	L	L	M	Low
Take advantage of benefits if pipeline comes. (Note: will not be cost effective at our current economy of scale.)	ES1, 2; O4	L	L	L	Low

OPPORTUNITIES

Climate change adaptation is also necessary to ensure that the community of Whitehorse is strategically prepared to benefit from climate change opportunities. The following adaptations were suggested by the community to support opportunities as they arise.

Suggested Adaptations to Support Opportunities

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Re-open the railway corridor and repair the old link into the downtown.	O2; I2, 4, 9, 10, 12	M	L	L	Low
Install communication infrastructure to facilitate people working from home.	O2; I4	L	L	L	Low
Revisit Skagway as a transportation node.	02, 3; F5; I9	L	L	L	Low
Learn from other circumpolar countries.	O2; I3	H	L	M	High
Support recycling as a growth industry.	O2-4; F5, 9	L	L	L	Low
Create a strategy to capitalize on the potential increased need for Whitehorse to serve as a hub – incorporate trickle-down effect to communities (if Whitehorse cannot supply them, then they become vulnerable).	O1, 3, 5; F5, 6, 8, 9	M	L	M	High
Use agriculture to build soil.	O3; I4; F5, 9	H	L	H	High
Continue to expand on education opportunities for regional agriculture.	O1, 3; F9	H	L	M	High

Suggested Adaptations to Support Opportunities, *continued.*

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Investigate improving efficiency of food transportation.	O1-3; F2, 5, 8, 9	M	L	L	Med
Place a moratorium on subdividing agricultural land.	O1-3; F5, 8, 9	L	L	L	Low
Create and implement a Whitehorse/Territory-wide food security plan.	O1-3, 5; F5, 9	H	M	M	High
Zone more agricultural land.	O1, 3; EV2, 8; F2-4, 6-8	H	M	M	High
Build processing facilities and cold storage.	O1,3,5 EV2,9 F1-9	H	M	H	High
Share knowledge of food growth between First Nations and the research and development sector.	O1-6	H	M	M	High