COMMUNITY ADAPTATION PROJECT

MAYO REGION CLIMATE CHANGE ADAPTATION PLAN

April 2012

Canada
Northern Strategy Trust

Northern Climate ExChange
YUKON RESEARCH CENTRE • Yukon College

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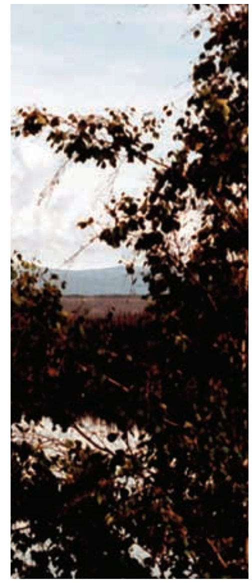

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TAKING ACTION ON CLIMATE CHANGE

Yukon Government

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MAYO REGION CLIMATE CHANGE ADAPTATION PLAN

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FOREWORD

The people of the Mayo Region have been watching and remarking upon changes to the landscape and the weather for well over 20 years. Climate-change workshops and workshops with Elders to specifically discuss changes have been held in Mayo since 2001. The time was right, therefore, to start talking and planning for continued changes. Hence, the Mayo Region Climate Change Adaptation Project began.

The Local Advisory Committee for the Adaptation Project was a group of volunteers who shared a common vision and goal. The vision was that the communities of Keno City, Mayo, and Stewart Crossing, and the region in which they are situated, could adapt to changing climatic conditions in a way that benefits the region and its inhabitants – human and non-human alike. The goal is that the region would adapt in this way and that negative effects of climate change would be minimized.

The Mayo Region Climate Change Adaptation Plan should be used as a living document – used and modified as we live through climatic changes. The adaptations we suggest come from discussions with community residents. The adaptations are broad, such as ‘explore agriculture and horticulture potential’ rather than telling everyone they should plant gardens. Broad adaptations allow us to use them in ways that fit our needs rather than pushing us to conform to a blueprint. This allows us to adapt with intelligence.

Use this plan and revisit it as the human population, the environment, and the climate changes. Use it to benefit our communities and our region.

Susan Stuart

Susan Stuart

Mayo Region Local Adaptation Coordinator, Northern Climate ExChange, Yukon Research Centre

Chair, Mayo Region Local Advisory Committee

EXECUTIVE SUMMARY

BACKGROUND

Climate-change projections indicate that over the next forty years the average annual temperature of the Mayo Region will increase by up to 3.6°C. This report examines possible impacts on the Region and its communities, subsequently identifying measures that would assist in adapting to a changing climate. The Region, encompassing some 15 000 km^2 of largely mountainous terrain, is drained by the lower Stewart River and its tributaries. The Region is located in the discontinuous permafrost zone, i.e., more than half, but less than 90% of the landscape is underlain by permafrost. The current climate is characterized by winter extremes and warm summers. For the last several thousand years, it has been the home of the First Nation of Na-Cho Nyäk Dun, and contemporary populations are dispersed between three communities, Keno City, Stewart Crossing and Mayo. Traditionally, the region's economy was based on wildlife harvesting, and while traditional food harvesting is still important, over the past century, mining has become a dominant component of the wage economy. Because of the mining industry's dependence on global markets, the economy has been characterized by marked boom-bust cycles.

APPROACH

The Region's communities partnered with the Northern Climate ExChange to produce this assessment, which is predicated on the argument that the ability to adapt to the impact of a changing climate is partly a reflection of the magnitude of the anticipated change and the ability of a community to adjust to stress. A Local Advisory Committee, made up by members of the three participating communities, articulated the desire to develop a regional adaptation plan that would "enhance regional well-being, economy, and conserve the health of the environment" and worked with the research team to identify emerging regional vulnerabilities. The assessment of the adaptive capacity of the Region to deal with stress was accomplished through a review of available resources, and an analysis of the region's historical exposure to environmental stresses. Projections based on climate-change models were used to forecast ways in which the regional climate would probably change over the next fifty years. Two forecasts were generated (i.e., low change and high change) and combined with projected future regional population growth trends (i.e., no growth and high growth) to produce scenarios that depict ways in which human activity would be impacted over the next forty years if no ameliorative measures were taken.

PROJECTED IMPACTS

It was evident that the population is already cognizant of a changing local climate, and analysis revealed that even under a low-change scenario, permafrost thaw and local ecosystem shifts would impact infrastructure integrity and wildlife harvesting. This scenario would bring about the greatest stress to the more disadvantaged members of society and negatively affect housing quality and food security. With the high-change scenario, these pressures are considerable and societal impacts potentially more widespread, causing transportation and mining to be negatively affected and challenging the capacity of the region to adapt.

RECOMMENDATIONS

Emerging from the analysis were five broad goals and a series of objectives that should be accomplished if climate-change impacts are to be minimized: ensuring the integrity of traditional foods, ensuring the integrity of the regional highway system, preventing deleterious impacts on human health, minimizing any negative impacts from mining, and exploiting the

beneficial aspects of climate change. Each goal is accompanied by a series of required actions or adaptations. A total of 33 actions were identified for implementation by 2030. Of these, five actions are viewed of priority because they will most effectively assist with adaptation in the Mayo Region. These priority actions are:

- Integrate climate change into all land and resource planning.
- Ensure appropriate climate-change projections are integrated into new infrastructure planning.
- Upgrade the dike along the Mayo River.
- Evaluate the health needs and capacity of each community in the region to provide health services to its residents.
- Review anticipated demands for water in the region from the mining industry, as well as possible 'down-stream' impacts from mining in a changing climate.

Given the Region's small population and the reality that, when dealing with current stresses, resources are already limited, it is clear that the three communities cannot act in isolation, and the development and maintenance of strong partnerships with (for example) the Government of Yukon and the mining sectors will be key to successful adaptation.

KEY TERMS

Adaptation is an action that responds to actual or expected climate impacts or their effects, either moderating harm or exploiting beneficial opportunities (IPCC, 2007).

Adaptive capacity is the ability of a community to adjust to climate change, either by taking advantage of opportunities or by coping with consequences (IPCC, 2007).

Mitigation is an action intended to reduce the onset and severity of climate change by reducing greenhouse gases such as carbon dioxide (IPCC, 2007).

Potential evapotranspiration is the likely amount of water that is returned to the atmosphere through the combination of evaporation and transpiration (Scenarios Network for Alaska Planning (SNAP), 2010).

Resilience is the ability of a community to either stay the same during a period of change or to slow down the rate of change so that it is acceptable to residents (Allenby and Fink, 2005).

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

Transpiration is the evaporation of water into the air from the leaves and stems of plants (University of Illinois, 2010).

Vulnerability is the degree to which a community is susceptible to, and unable to cope with, the consequences of climate change (IPCC, 2007).

LIST OF ACRONYMS

GCM	Global Climate Models
IPCC	Intergovernmental Panel on Climate Change
MRCAP	Mayo Region Climate Change Adaptation Project
MRLAC	Mayo Region Local Advisory Committee
NCE	Northern Climate ExChange
NND	First Nation of Na-Cho Nyäk Dun
PET	Potential Evapotranspiration
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SNAP	Scenarios Network for Alaska Planning
VOM	Village of Mayo

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INTRODUCTION

Climate change is already having tangible effects in the Mayo Region. Community Elders have reported a wide range of changes, including increased weather variability, increased wind, shifting seasonal temperatures (warmer winters and summers), thawing permafrost, and changes in wildlife diversity (Williams and O'Donoghue, 2005). Given these changes, the Mayo Region Community Climate Change Adaptation Project (MRCAP) was originally undertaken in cooperation with the First Nation of Na-Cho Nyäk Dun (NND) and the Village of Mayo in the summer of 2010 to evaluate and address community vulnerability to climate change. The communities of Stewart Crossing and Keno City were approached shortly after the planning process began because of their close proximity to Mayo and their shared concerns associated with climate change. The three communities agreed to participate in MRCAP in the summer of 2010. Their participation in the planning process was led by the Mayo Region Local Advisory Committee (MRLAC), which provided direction to the planning team and determined the priorities of MRCAP. While all three communities participated in plan development, the capacity, resources, and available information for the Region were concentrated in Mayo. As a result, there is a strong emphasis on the community of Mayo in the adaptation plan.

Adaptation planning provides an opportunity to evaluate the effects of climate change and determine how to minimize the negative effects of changing landscape conditions (Adger et al., 2005). The Mayo adaptation plan is intended to contribute to sound decision-making processes and policy development in the Mayo Region and the plan's recommendations provide a road map for reducing community vulnerability to climate change. Ideally the recommendations of this plan will be implemented in tandem with actions to reduce the severity of climate change, such as a reduction of greenhouse gases (climate-change mitigation), or enhancing the use of geothermal energy or biomass production as an alternative source of heat and energy.

WHY SHOULD WE BE PLANNING FOR CLIMATE CHANGE IN THE MAYO REGION?

Global warming has been taking place for some time. The average annual temperature has risen 1.5°C to 2.0°C over the past fifty years (1950-1998) across the Western Arctic, including Yukon (Furgal and Prowse, 2008). Over the next 100 years, and based on measured and projected changes, the Intergovernmental Panel on Climate Change (IPCC) is predicting an increase in the average global temperature of 1.8°C to 4.0°C, and some of the most marked shifts are anticipated to occur in northern regions (IPCC, 2007). The anticipated consequences of climate warming in the Territory include increasingly variable temperature and precipitation, and unpredictable and extreme weather events (Government of Yukon, 2009). Changing climate conditions will lead to subsequent landscape changes, including the destabilization of permafrost, increased forest fires, and changes in the distribution of wildlife, which will have subsequent impacts on the lives of northern residents (Arctic Climate Impacts Assessment (ACIA), 2004).

A first reaction on viewing these projections is to perhaps panic, and the way the climate change message has been communicated to many communities has indeed induced a sense of alarm. Global newscasts reporting on climate disasters have reinforced this sense of panic and resulted in the perception that even the slightest shifts in weather or the local environment is evidence of an approaching cataclysm. In their effort to present balanced reporting, the media has also given ample air time to the poorly supported views of sceptics who refute the severity of climate projections and suggest that humans are having no influence on climate at all. The end result is confusion. But the reality is that global climate change is occurring, and over the next several years, its impact will be felt everywhere and most markedly in polar regions, where landscapes are highly sensitive to shifts in temperature. However, while scientists have successfully communicated the potential future effects of climate change, they have fallen somewhat short of translating what the long-term trends mean to the average person (questions such as: How will climate change be experienced? What will it feel like?).

Put simply, climate change will bring significant alterations to the daily life of the resident in the Mayo Region. Based on the changes reported by the Mayo community since 2001 (McCoy and Burn, 2001; Northern Climate ExChange, 2001; Williams and O'Donoghue, 2005), there will be noticeable changes in the region's landscapes and a greater frequency of unexpected or extreme weather events over the long term. These changes will likely impact the region's ecosystems and wildlife populations, and may ultimately impact community life. At a larger scale, global events, such as drought or storms that affect agricultural centres far from the Yukon, could affect food security in the Mayo Region. However, the full impact of a changing climate will not be felt for some time, and this provides a window of opportunity to prepare and plan for change accordingly. It is fair, therefore, to say that adaptation is something to be thought about and planned for, but it should not be a preoccupation giving rise to over-stated alarmism, which can detract from everyday life.

SO WHY ARE WE PLANNING NOW FOR A CHANGING CLIMATE IN MAYO?

We are planning now for a changing climate for a very simple reason: the costs of adapting now will be much less than the costs of adapting later, both within Yukon (Government of Yukon, 2011), and globally (United Nations Framework Convention on Climate Change (UNFCCC), 2009). By focusing resources where they should be invested, adaptation planning becomes an important cost-saving exercise. Furthermore, through the prioritization of adaptations, the ability of the community to respond to climate change is increased by making the most of its limited resources. For example, any significant infrastructure projects with a long life cycle (dams, bridges, highways) will be built in an environment that is changing, and the assumption that variables such as temperature and precipitation that dictate engineering standards will stay the same, are no longer valid. Equally, and particularly relevant in the Mayo region, are mines, which will have to factor in the new reality of a changing climate and its effects on run-off, freeze-thaw action, and a shifting distribution of permafrost into site design and, in the longer term, decommissioning of the mine site. It is therefore important for communities to take action now to ensure they are adequately prepared to face the challenges of climate change later (Adger et al., 2005). Given the widespread nature of the consequences of climate change (such as affecting the landscape, infrastructure, food and water), and the complexities of adaptation (which can occur individually, regionally, territorially, nationally or even globally), the challenge for decision-makers in the community is to decide how and when to act (Adger, 2003). It is for these reasons that we are planning now for a changing climate in the Mayo Region.

Another issue that adaptation planning addresses is the speed with which communities will have to respond to changing climate conditions. Adaptation has always been a component of life in the north. First Nations people have, over millennia, adapted to long-term climate trends and to short-term shifts in the availability of wildlife. Over the past century, northern populations have coped with a range of social and economic stresses and the dislocations of communities with changing transportation technologies. So the notion of "adapting" is nothing new to Northerners. However, the projected changes to the climate and landscape of the Mayo region will yield an unprecedented rate of change with increasing magnitude and levels of interaction among stresses that may leave Northerners vulnerable and struggling to keep up (ACIA, 2004). The purpose of community-based planning for climate change is to enable individuals and institutions to anticipate future trends and prioritize strategies for adapting. Unlike past events which have impacted northern society, ample scientific evidence provides us with plenty of warning about impending change, allowing some breathing room when considering what to do about climate change within the constraints of resource limitations.

There are limitations to adaptation planning. While there is strong scientific evidence to support climate change, it is challenging (if not impossible) to know with certainty what the future will look like. However, we can reduce uncertainty and attempt to remove the sense of fear by rationally evaluating the available data to identify those things which will most likely happen, and those things that probably will not. This evaluation provides the necessary foundation for adapting to changing events and is essential in providing the impetus for action.

Vision of the Mayo Region Community Climate Change Adaptation Plan

At the start of MRCAP, members of the Mayo Region Local Advisory Committee were asked to envision their ideal outcome of this planning process and provide a basis for determining what is important for adaptation in the Mayo Region from the perspective of residents. The vision provides a foundation for evaluating vulnerability, establishing the actions necessary to address that vulnerability, and making recommendations that will increase the ability of residents to respond to climate change. This vision is:

> ***The communities and residents of Mayo, Stewart Crossing, Keno City and the surrounding region will have information, knowledge and resources to be proactive and resilient to climate change. The adaptations we make will enhance our region's well-being, economy, and conserve the health of our environment.***

Based on this vision, we have evaluated the capacity of the communities to respond to climate change. In essence, the remainder of this plan flows from this vision, which provides a framework for proposing and evaluating possible climate-change adaptations.

Developing the Plan: Our Approach

The planning process has two components: 1) the assessment of the implications of a changing climate for the region, and 2) the development of the adaptation plan based on these implications. A series of scenarios depicting how conditions in the Mayo Region may be vulnerable to changing climatic conditions in the future provides the basis for determining the implications for community adaptation. The adaptation plan then proposes adaptive responses to address these vulnerabilities. Recommendations and a timeline for implementation conclude the plan.

Part 1: Assessing Implications of a Changing Climate for the Mayo Region

Determining Vulnerability

The starting point in developing the plan was an assessment of the current vulnerability of the Mayo Region to environmental stresses. Assessment of vulnerability was based on review of the historic exposure of residents to environmental stresses, examination of the current distribution of infrastructure and vulnerable landscape features, assessment of community resources, and community input into the planning process. This information is provided in a brief history of environmental stresses in the Mayo Region, which was compiled in 2010 from research and interviews with residents (Appendix A). Research was also conducted in 2010 to determine the implications of climate change for the mining industry in the Region (Appendix B). A third and independent study also completed through the Northern Climate ExChange (NCE) in 2011 examined the implications of climate change on surficial geology, permafrost and hydrology in order to provide an assessment of geological hazards in the Mayo townsite (NCE, 2011).

Development of Possible Community Climate Change Vulnerability Scenarios

The implications of a changing climate depend on the magnitude of the physical changes and the level of human activity. Rapid landscape changes will have a greater impact if populations are growing and the footprint of economic activity expands. In such situations, the feedback from human activity would exacerbate stresses created by a changing climate. For example, the combination of increased transport pressure on rapidly degrading highways underlain by thawing permafrost will speed the deterioration of the highway infrastructure faster than if either increased use of the highway, or thawing permafrost were to occur in isolation. Four scenarios were generated by the project team through a scenario planning process to determine the future vulnerability of the Mayo Region to climate change. These vulnerability scenarios are based on climate projections provided by Scenarios Network for Alaska Planning (SNAP, 2010; see Appendix C) and information available on potential human activity within the region over the next 40 years. Community input provided during a workshop held in the community in April 2011 (Community Input Session), was important to the scenario planning process. Each scenario explores the evolution of community vulnerability by examining the following:

1. *Possible implications of a changing climate for the landscape of the Mayo region*. How will a changing climate affect permafrost, hydrology, forest fires, flora and fauna?

2. *Possible implications of climate change for human activity.* How will the implications of climate change on the landscape affect infrastructure, food security, health, and other aspects of human activity in the region?

3. *Implications of climate change for community vulnerability.* How will the implications of climate change on human activity result in vulnerability for residents?

While modeling future climate trends is relatively straightforward, predicting future population and activity trends is not. It is evident from even the most cursory examination of growth trends in northern Canada that long-term trends are difficult to predict and it is impossible to portray growth scenarios with any sort of confidence. The history of the Mayo Region, characterized by rapid growth early in the twentieth century with an economy largely linked to the fortunes of the global mineral industry, is testament to this. Thus, in developing scenarios depicting future implications of a changing climate for the region's population, the only thing we can do with confidence is identify some of the possible implications for vulnerability that may emerge from specific sectors of activity over time. Rather than attempting to predict what the future economy or population may be with any precision, the scenarios are characterized by conditional statements, such as, "If there were to be rapid growth, townsite expansion may be limited because of permafrost degradation", or "Marked growth in the pace of mining may increase the potential for environmental degradation as precipitation and freeze-thaw patterns change". Such anticipation of events then leads to prescriptive adaptive measures to reduce anticipated stresses.

PART 2: DEVELOPMENT OF THE MAYO REGION CLIMATE CHANGE ADAPTATION PLAN

The intent of the Mayo adaptation plan is to improve the Region's capacity to respond to climate change impacts as depicted in the scenarios. The plan does this by first providing a summary of possible stresses associated with a changing climate. An action planning approach was then utilized to identify adaptations to address identified vulnerabilities. Starting with the local vision of a successfully adapted community articulated by the Mayo Region Local Advisory Committee in the spring of 2011, the plan proposes a series of goals and objectives to address vulnerability. Adaptations, or actions, are subsequently proposed as solutions meet the suggested objectives.

The adaptations are then organized by the time anticipated to complete the action. We have also identified a number of priority adaptations to provide focus to the implementation process under the assumption that this plan will be implemented opportunistically. These priority actions are expected by the project team to be most effective for building community resilience. We conclude the plan with a discussion of governance in the Mayo Region and the policy implications of climate-change adaptation for future planning.

THE MAYO REGION

The Mayo Region, covering 15 592 km^2, encompasses the lower the Stewart River and its northern tributaries, the Mayo and McQuesten rivers (Figure 1). The region is also situated within the NND Traditional Territory. Throughout the twentieth century, central Yukon (including the study area) was periodically a significant mining region and the landscape has an abundance of abandoned mines and derelict mining camps. Today, the three small communities of Mayo, Keno City and Stewart Crossing remain. These communities and their surrounding environment have been well documented in numerous publications (for example, Bleiler et al., 2006; Mayo Historical Society, 1990; Aho, 2006). This section is therefore intended to provide a brief overview of the study area to support a discussion of adaptive capacity (the ability of residents to adapt to environmental change), which depends on the extent of future changes, the manner in which these changes impact on the Region's landscapes, the resources of the communities within it, and the magnitude of pre-existing stresses.

THE LANDSCAPE OF THE MAYO REGION

Relief and Drainage

The study area is located within the Yukon Plateau-North ecoregion (Yukon Ecoregions Working Group (YEWG), 2004) and encompasses components of the Stewart Plateau and the Stewart River valley. The topography of the region is characterized by rolling uplands and steep-sided, U-shaped valleys carved by glaciers.

Peak river flows typically occur in the spring (May and June) in response to warming temperatures and snow melt (Bleiler et al., 2006). While snowmelt is a significant component to Stewart River discharge, rainfall also enhances the river volume in summer and fall. Low flows typically occur in the late winter when the only significant input to river discharge is from unfrozen groundwater (Janowicz, 2008). Data compiled for the Village of Mayo suggests that ground water is quite close to the surface (EBA Engineering Consultants Ltd. (EBA), 2010).

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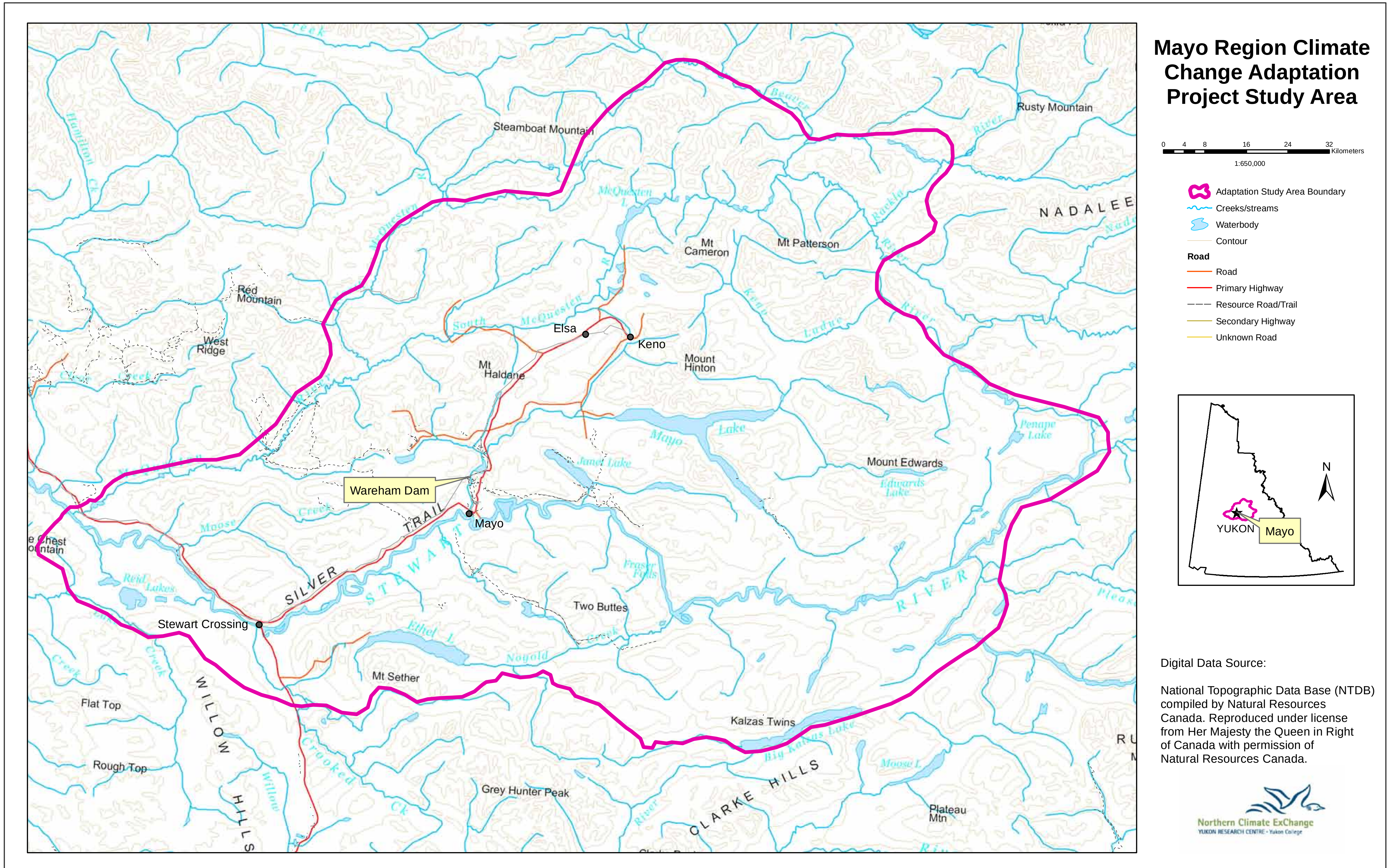
Figure 1. *Map of Mayo Region Climate Change Adaptation Plan project study area.*



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Permafrost

The Mayo Region is located in Yukon's discontinuous permafrost zone, where the landscape is underlain by more than 50% and less than 90% of ground that is frozen for two or more years (Bleiler et al., 2006). The characteristics of permafrost within the study area are variable and are mainly controlled by the topography in the region, vegetation cover, and snow depth in winter (Bleiler et al., 2006). In Mayo, the thickness of permafrost is variable and has been measured from 5-7 m (NCE, 2011), to a maximum thickness of 30-40 m (Bleiler et al., 2006). Thin permafrost (5-7 m) is presumed to be relatively warm and thus is susceptible to thaw (NCE, 2011). Permafrost around Keno is much thicker and was documented at a depth of 135 m (Bleiler et al., 2006). Near Mayo, the thickness of the active layer (the top layer of soil that thaws and re-freezes annually) has been measured to a depth between 65 cm and 1 m (Bleiler et al., 2006). Ground temperatures near Mayo also vary considerably. For example, average ground temperatures at a depth of 5 m vary between -2°C in forested areas, to 2.6°C in dry gravel near the local cemetery, a difference of 4.6°C (Bleiler et al., 2006).

Flora and Fauna

A wide variety of flora and fauna inhabit the Mayo region in complex assemblages and varies with topography, geology and fire regime (Bleiler et al., 2006). A total of 533 plant species have been recorded and colonize the region's wetlands, forests and subalpine habitats. Forty of these species are considered rare in Yukon (Bleiler et al., 2006). Wetlands, including marshes, swamps and peat-forming wetlands, are found at varied elevations. They are most extensive in lowlands and along major river and creek corridors. Forests may grow in elevations as high as 1500 m (Bleiler et al., 2006). These forests are primarily comprised of white and black spruce (*Picea glauca and P. mariana*) and aspen (*Populus tremuloides*) in lowland areas, and by subalpine fir (*Abies lasiocarpa*) at higher elevations. Subalpine vegetation is dominated by dwarf birch and willows (*Betula glandulosa* and *Salix* spp.).

Many of the plants, berries, trees and lichens found in the area play an important role in the diet of Northern Tutchone and local people. Not only do they have nutritional and medicinal value, but they are generally free of contaminants, easily accessible, less expensive than store-bought food, and maintain a vital link to the land and culture. The diet of many Mayo people is comprised of a wide variety of species of berries as they are eaten raw, or made into preserves, tonics or juices.

Bleiler et al. (2006) provide a comprehensive description of the vertebrate fauna of the Mayo region, which includes 15 species of fish, 1 species of amphibian, 160 bird species and 45 species of mammals. Of the fish, 5 species migrate out of the area for part of their life cycles and the others are more sedentary. Chinook salmon (*Oncorhynchus tshawytscha*) runs have sustained Northern Tutchone people for millennia and have great cultural importance; lake whitefish (*Coregonus clupeaformis*), arctic grayling (*Thymallus arcticus*), lake trout (*Salvelinus namaycush*), and northern pike (*Esox lucius*) are the main freshwater fish used for food by the community (J. Hogan, Heritage Manager, First Nation of Na-Cho Nyäk Dun, pers. comm., November 2011). The rich variety of birds includes species from 36 families; 26 species are year-round residents and the rest migrate south for the winter—some of these return to breed in the summer while others just pass over the Mayo area on their way to and from their arctic breeding grounds. Ducks (22 species), geese (4 species, but mostly Canada Geese, *Branta canadensis*) and grouse (7 species) are the main birds hunted for food. The mammals living in the Mayo area range in size from tiny shrews to moose more than 10,000 times their size. Other large mammals include species like caribou that have been here since the last ice age, as well as recent arrivals like coyotes and deer. All total, there are 6 species of shrews, 1 bat, 13 carnivores (wild dogs, cats, bears, and weasels), 5 ungulates (hoofed animals), 18 rodents, and 2 rabbit family species. Moose (*Alces alces*) and salmon are by far the most important subsistence food sources for residents of the Mayo Region. Caribou (*Rangifer tarandus*), sheep (*Ovis dalli*), snowshoe hares (*Lepus americanus*), porcupines (*Erethizon dorsatum*), and beavers (*Castor canadensis*) are also harvested for food. Most carnivores besides bears are trapped for their fur, but lynx (*Lynx canadensis*) and marten (*Martes americana*) are the mainstays in the fur industry for the Mayo area.

In Mayo, the knowledge of hunters, berry pickers, and other harvesters, which has been gained from years of observations on the land and from knowledge passed on to them, has formed the basis of community monitoring programs. The Community Ecological Monitoring Project (Elsa Remediation) is one example of this type of program. This baseline information will help detect changes in the environment over time, whether from natural or human causes. People are already noticing changes to the land. As stewards of the land, local people play an important role in monitoring the changes on the land, as well as changes to wildlife and plants.

The Elders tell many stories about picking plants, berries, and making medicines when they were young – about the places they would go, and how they would use these traditional foods and medicines. People who harvest from the land are familiar with their surroundings and have gained an intimate knowledge of the land, which has been passed down from Elders. This knowledge continues to develop each year as they spend more time on the land and learn from others.

The harvest, sharing and consumption of traditional foods and medicines are important socially and culturally for First Nations and local people. Harvesting traditional foods and medicines provides opportunities for individuals and families to spend time on the land learning and passing on traditional ways. Many people have knowledge about traditional harvesting despite the fact that they may not be presently practicing these techniques. They have gained the knowledge from time spent on the land as a child, from family members, and from Elders.

THE MAYO REGION: POPULATION AND ECONOMY

Of the three participating communities, Mayo, Keno City and Stewart Crossing, detailed demographic and economic information was only available for Mayo. The population of Mayo, including residents living in the surrounding area, is estimated to be 457 by the Yukon Bureau of Statistics (YBS) as of December 2011 (YBS, 2012). The 2006 Federal census estimates that 52% of Mayo residents were aboriginal[1]; this estimate may be low however, given the census boundary used by the Government of Canada. This estimate also does not include First Nation citizens living in Stewart Crossing or Keno City, or in remote areas of the Region. The estimated populations of Keno City and Stewart Crossing, as reported by residents in the spring of 2011, were approximately 20 and 25 respectively. The population of the region is also made up of an uncertain number of transient workers in mine camps. The 2006 census data also indicate that turn-over rates in the permanent population are relatively low, and 83% of residents were reported to have been living in the community for 5 years or more. As with the rest of Canada, the population of Mayo is aging. Approximately 30% of the population was over the age of 55 at

1. The Aboriginal identity population is composed of those persons who reported identifying with at least one Aboriginal group, that is North American Indian, Metis, 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 for First Nations (http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-594/Index.cfm?Lang=E).

the time of writing, and an additional 23% of the population will enter the 55+ cohort within the next decade.

The economy of the Region is based on public sector employment (approximately one third of the labour force), mining and mineral exploration, wildlife harvesting, and tourism (Bleiler et al., 2006; First Nation of Na-Cho Nyäk Dun (NND), 2008). Many of these employment opportunities are seasonal (NND, 2008). Mining in the region is constituted by either hard rock or placer mining. Placer mining, while producing a significant amount of gold, is characterized by small operations working the same creeks they have for about a century. Placer mining is not considered problematic by residents. Conversely, hard rock mining is characterized by large-scale operations with a considerably larger footprint and resource needs. While hard rock mine operations have long been integral to the growth and development of the Mayo Region (Blieler et al., 2006), residents are concerned about the future impacts of growth in this mining sector on the Region. Mining in this report therefore refers exclusively to hard rock mines and those activities associated with their operation. A map of the quartz (hard rock) and placer claims in good standing as of May 2011 is provided in the accompanying map *"Mayo Region Climate Change Adaptation Project Including Claims in Good Standing as of May 2011"*.

Diversification and the stabilization of the economy are considered important to the long-term interests of residents (VOM, 2006a; NND, 2008; VOM, 2006b). Most employment is centered in Mayo where the municipal, First Nation and territorial government offices are located, and which serves as the retail and service hub for the region.

Three institutions provide public services to residents of the region: The Village of Mayo, NND and the Government of Yukon. The Village of Mayo supplies the community with a range of services including water and sewer, recreation, recycling, management of the landfill, volunteer fire fighting, land planning and administration, tourism planning and the management of heritage resources. NND provides a broad range of services to its citizens including: health and social services, capital and housing development, and the management of heritage and natural resources within the NND Traditional Territory. Both organizations have limited staff, and as a result, their institutional capacity is also limited. The Government of Yukon provides additional services in the community, including health care, infrastructure maintenance and renewal (through Yukon Highways), ambulance service (staffed by community volunteers), environmental monitoring and management, justice, regulatory services for the monitoring and enforcement of conservation and mining in the region, and a suite of social services. The distribution of NND settlement lands and major infrastructure is provided in the accompanying map *"Mayo Region Climate Change Adaptation Project Including NNDFN Settlement Lands and Protected Areas"*.

Education is provided to the community through the Yukon Department of Education at the JV Clark School (K-12) and a community campus of Yukon College. The 2006 Federal census suggests that 26% of the population over the age of 24 has no high-school certificate, diploma or degree. This number is higher than the rest of the Territory, which reported 15% of residents over the age of 24 with no educational certifications.

THE MAYO REGION: EXPERIENCE IN ADAPTING TO STRESS

The manner in which a community will be impacted by a changing climate is dependent on the duration of the changes it faces (exposure) and the extent to which the community is able to respond to changing circumstances (sensitivity) (Turner et al., 2003). The likelihood that a community could be harmed by events associated with a changing climate is determined largely by its ability to respond to changing circumstances. The ability to respond is a reflection of its location, the extent to which various aspects of community life are exposed to stressful events, its historic experience in dealing with stress, and the ability of residents, businesses, institutions and agencies in the community to cope with emerging events. Overall, the capacity to cope can be seen as a reflection of resources, organization and experience (Yohe and Tol, 2002).

To better assess the region's experience in dealing with environmental stress, the project team commissioned an environmental history which examined how the community has responded to severe weather events from 1920 to 2010 (see Appendix A). The major climate-induced stresses the community has confronted have been wildfire and flooding.

Wildfire is a natural component of the boreal forest and a familiar environmental stress to the residents of Mayo, Keno City and Stewart Crossing. A total of 630 wildfires have burned in the region over the past 50 years and 58 fires have burned within 30 km of the Silver Trail since 1940. Of these 58 fires, the most significant have been the 1971 Janet Lake and McQuesten Valley fires, the 1990 Janet Lake fire, the 1998 Stewart Crossing fire, and the 1998 Ethel Lake fire. In recent years, the implementation of FireSmart by the Village of Mayo and NND has decreased the risk to community infrastructure from forest fire. Wildfire management from the local office in Mayo and from Whitehorse has also played a pivotal role in reducing community risk to wildfire.

Flooding has played a less pervasive role in the environmental history of the Mayo Region. The only massive flood on record occurred in 1936, which inundated much of the Mayo townsite. Another significant flood occurred in 1964. Institutional responses led to the construction of a flood defense system along the Stewart River which now controls seasonal flooding. Flooding now occurs in the community as seepage events either from the relatively high water table or through the Mayo River dike, which is permeable, having been constructed from organic debris. Flooding of this type occurred in Mayo in 2011.

Responses from the community to fire and floods during the period from 1920 to 2010 suggest that institutional responses are important to community adaptive capacity. When combined with the available skill set and experience of residents, the emergent 'picture' of adaptive capacity is one of a resilient community threatened by significant landscape vulnerability from historic and new sources. Future adaptive capacity will be dependent on the continued effectiveness of the institutions governing the community and the ability to retain critical skills as the population ages, or skilled individuals seek more lucrative employment elsewhere.

Community Attitudes Towards Stress

It is evident from community meetings and interviews that residents are aware of climate change and the potential for negative impacts. Equally, they identified a variety of concerns about current stresses in the region, including flooding, mining and development, the vulnerability of heritage resources, and declining quality of housing in some areas of the community. While climate change will exacerbate these issues, it was not apparent from community input that the effects of climate change were well understood. Stresses unrelated to climate change, such as aging of a significant part of the population, will likely impact the adaptive capacity of the community. Similarly, the relatively limited nature of the economy and limited educational opportunities beyond the secondary school level also challenge community capacity. However, the Integrated Community Sustainability Plans of both NND and the Village of Mayo call for economic diversification and increased education, which may in turn address the capacity limitations evident in this overview.

Community Resources

Access to resources is integral to a community's ability to respond to environmental stresses (Yohe and Tol, 2002). The distribution of resources within the community, especially for emergency response, is dictated through planning by the Village of Mayo and NND. In Mayo these plans are complete and sufficient to address the distribution of resources in such a small community. As time and climate change progress however, these plans must be updated to keep pace with changing conditions in the community, which will require sufficient economic capital within the territorial, municipal and First Nation governments. With adequate foresight and budgeting, such funding is not anticipated to be problematic and no concerns have been raised by residents.

Given the relative isolation of the Mayo Region, access to transportation infrastructure is also important to local adaptive capacity. Transportation infrastructure determines residents' access to health resources, food, and other outside resources. Participating communities in the Mayo Region Adaptation Plan (Stewart Crossing, Mayo and Keno City) are linked by the Silver Trail, or Highway #11, which is surfaced with a bituminous surface treatment (BST) from Stewart Crossing to Mayo, and gravel from Mayo to Keno City. A second access road, the Duncan Creek Road, also links Keno City to the Silver Trail. Based on feedback from the community, the Region's transportation infrastructure currently detracts from the adaptive capacity of the communities. Access to the Region, via the Silver Trail, is reportedly in poor condition and expected to worsen as traffic increases due to mining activity (Government of Yukon, 2009).

While it is apparent that the Region has the capacity to deal with most contemporary events in the coming decades, the aging of the community and limited economy, combined with the impacts of a changing climate, will challenge capacity. However, the stability of the population, relative experience of residents, and the observed capacity of community institutions in Mayo (First Nation of Na-Cho Nyäk Dun, Village of Mayo, Government of Yukon) suggest that resources will be available to address capacity gaps as they emerge. Local knowledge and experience, especially as it historically relates to subsistence harvesting, illustrates a high adaptive capacity from a resource perspective. However, current vulnerability to the consequences of environmental stress does exist for the community and this vulnerability will be exacerbated as the climate changes.

CLIMATE OF THE MAYO REGION

The Mayo Region is characterized as having the most variable climate in Canada (Bleiler et al., 2006). This variability is a product of the complex topography of the region, combined with the effects of latitude and the movements of atmospheric pressure systems, which allows for the regionalization of climate within the Yukon Territory. The Mayo Region falls within two of these climate regions: the Central Yukon Basin and the Ogilvie Mackenzie Mountain regions (as defined by Whal et al., 1987). Both regions are generally characterized by a relatively dry continental climate (Whal et al., 1987). In this section, we determine the extent to which the climate of the Mayo Region may shift in the coming decades to provide a basis for deliberating how community vulnerability may increase.

CURRENT CLIMATE

Temperature and precipitation in the Mayo region can vary widely with seasons and with elevation. While mountain regions can be cold, thermal inversions or the pooling of cold air at low elevations for extended periods of time during winter, ensure that valleys also experience periods of intense cold (Bleiler et al., 2006). Interestingly, and perhaps counter-intuitively, these thermal inversions result in warmer temperatures in the mountains relative to the valleys during the winter. Mayo currently holds the record for the greatest temperature range in Canada with a 98.3°C difference between the extreme high and low temperatures recorded in that community (the measured extreme low, -62.2°C was recorded in February 1947; the extreme high, 36.1°C, was recorded in June 1969; Bleiler et al., 2006). The baseline average annual temperature (also known as Mean Annual Temperature or MAT) established for the study area for the period of 1961-1990 is -4.8°C (SNAP, 2010). Seasonal baseline (1961-1990) temperatures are provided in Table 1 below.

Table 1. Baseline and projected temperatures for the Mayo Region (°C). The relative difference between baseline temperatures (1961-1990) and projected temperatures is signified by the symbol "Δ".

Season	Baseline (1961-1990)	Modest climate change				Medium-high climate change			
		2030		2050		2030		2050	
		Temp	Δ	Temp	Δ	Temp	Δ	Temp	Δ
Annual	-4.8	-2.7	+2.1	-2.3	+2.5	-2.9	+1.9	-1.2	+3.6
Spring	-4.0	-2.3	+1.7	-1.7	+2.3	-2.3	+1.7	-0.4	+3.6
Summer	10.9	12.0	+1.1	12.4	+1.5	11.7	+0.8	12.8	+1.9
Autumn	-5.6	-3.8	+1.8	-3.1	+2.5	-3.8	+1.8	-2.1	+3.5
Winter	-20.3	-17.4	+2.9	-17.0	+3.3	-17.0	+3.3	-15.1	+5.2

Precipitation in the region is also influenced by topography, and is usually higher in the mountains than in the valleys. Elevation dictates the amount of precipitation received as snow. For example, in Mayo, 42% of precipitation is in the form of snow, compared to Keno City (located at a higher elevation) which receives 62% of its precipitation as snow (Bleiler et al, 2006). In general, precipitation in Central Yukon is considered moderate (Whal et al., 1987). However, in summer, the long days result in relatively high rates of evapotranspiration yielding higher levels of precipitation than in the southern areas of the Yukon Territory (Bleiler et al., 2006). Total annual precipitation for the study area for the period 1961-1990 was 524 mm per year (SNAP, 2010). Precipitation varies seasonally and spring is typically the driest season (Bleiler et al., 2006). For example, the average seasonal precipitation for summer (June to August) measured for the period 1961-1990 was 202 mm. An average of 97.7 mm fell during the winter months (November, December and January) over the same period (SNAP, 2010). Seasonal baseline (1961-1990) precipitation is provided in Table 2 below.

Table 2. Baseline and projected precipitation for the Mayo Region (mm). The relative difference between baseline precipitation (1961-1990) and projected precipitation is signified by the symbol "Δ".

Season	Baseline (1961-1990)	Modest climate change						Medium-high climate change					
		2030			2050			2030			2050		
		mm	Δ mm	Δ %	mm	Δ mm	Δ %	mm	Δ mm	Δ %	mm	Δ mm	Δ %
Annual	524.2	551.1	26.9	5	577.3	53.2	10	571.3	47.2	9	595.9	71.7	14
Spring	78.8	87.9	9.1	12	89.5	10.7	14	90.5	11.7	15	91.2	12.4	16
Summer	201.7	212.3	10.6	5	225.0	23.3	12	219.0	17.3	9	225.4	23.7	12
Autumn	145.9	147.3	1.4	1	157.2	11.3	8	157.7	11.8	8	164.8	18.9	13
Winter	97.7	103.7	6.0	6	105.6	7.9	8	104.2	6.5	7	114.6	16.9	17

CURRENT CLIMATE TRENDS

Trends for regional temperature and precipitation demonstrate that the climate for the study area has already changed. These trends are derived from recorded Environment Canada and Yukon Forest Service data from 1925 to 2009 (Purves, 2010). The bulk of the data was recorded by the Mayo weather station (#2100700). Gaps or inconsistencies in the record, for example the relocation of the weather station in 1969, were compensated for through additional calculations when determining trends (Purves, 2010). It should be noted that insufficient data exist to determine trends in the region beyond those derived from the Mayo weather station. It is our assumption that these trends hold true for the entire region.

Temperature

Average annual temperature in the Mayo Region has increased at a rate of 0.28°C/decade. The record, spanning approximately 80 years, first declined for the period between 1947 and 1977, then increased to 2009 at a rate of 0.33°C/decade. Summer and winter temperatures reflect the pattern apparent in the annual trends. Daily summer temperatures first cooled from 1941 to 1964 at a rate of 0.49°C/decade, then warmed at a rate of 0.41°C/decade for an overall warming trend of 0.16°C/decade for the entire period. Similarly, daily winter temperatures declined from 1943 to 1975 at a rate of 1.6°C/decade, then warmed at a rate of 0.71°C/decade for an overall warming trend of 0.22°C/decade (Purves, 2010).

Precipitation

There is a strong relationship between temperature and precipitation (IPCC, 2007). As a result, precipitation trends reflect those determined for temperature in the Mayo Region over the same 80-year period. Total annual precipitation has increased by 5.9 mm/decade or 21% per century. This rate of increase is higher for the past thirty years, rising at a rate of 19 mm/decade or 67% per century. As with temperature, the trend for precipitation varies seasonally. Total summer precipitation has increased 3.7 mm/decade (28% per century), and over the last thirty years, the trend has increased to 6.4 mm/decade (44% per century). Total winter precipitation has varied significantly from decade to decade over the past 80 years, decreasing 2% per century over the entire period. Snow depth (measured on February 28th of each year) has also decreased at a rate of 69 mm/decade (105% per century; Purves, 2010).

Frost-Free Period

The frost-free period for Mayo has increased over the past 85 years, rising from approximately 55 days recorded in 1925 to approximately 90 days in 2009, increasing at a rate of 4.5 days/decade (Purves, 2010).

PROJECTED CLIMATE CONDITIONS

It is evident from the recorded trends that temperature, precipitation, and the frost-free period in Mayo are increasing, supporting the conclusion that the climate of the region is changing and will continue to change in a manner consistent with the forecasting of global climate models (GCMs). The following discussion of future climate change for the Mayo Region is based on projected changes in the region's annual average temperature and total annual precipitation. These trends are consistently increasing indicating that the climate in the region, subject to the influence of increasing variability, will most likely become warmer and wetter. Projection maps for the Mayo Region are provided in Appendix C (SNAP, 2010).

Average Annual Temperature

The Mayo Region will most likely continue to warm, with average annual temperatures rising by approximately 2.5°C to 3.6°C by 2050. The warming of the local climate will be seasonal, however, and winters will warm more than summers. By 2050, winter temperatures are projected to rise from 3°C to 5°C, while summers are only projected to warm by approximately 2°C (SNAP, 2010). The projected temperatures for all seasons are provided in Table 1.

Total Precipitation

Total annual precipitation is also projected to increase, rising from 524 mm/year to 577-596 mm/year by 2050, a difference of 53-72 mm/year, or an increase of 10-14%. As with temperature, the increase in precipitation will vary by season. In the modest climate-change scenario, the greatest increases in precipitation are projected for the spring months. In the medium to high climate-change scenario, seasonal precipitation is again highest in the spring to 2030, but by 2050, this shifts to the winter months (SNAP, 2010). See Table 2 for projected changes in precipitation.

Frost-Free Period

For the purposes of these projections, the frost-free period is defined as the period between the date that the daily average temperature drops below 0°C and the date when it rises above 0°C. The frost-free period is expected to lengthen because of warming seasonal temperatures. By 2050, the frost-free period is expected to be 16 to 23 days longer, rising from a baseline (1961-1990) frost-free period of 153 days, to a period of 169 to 176 days.

Climatic Variability

As noted previously, climatic variability in the Mayo Region is significant (Bleiler et al., 2006). Long-time residents report that over the past 50-80 years this variability has been increasing, resulting in stronger, more Chinook-type winds, and less persistent cold snaps in winter. While an assessment of the influence climate change will have on weather variability in the Mayo Region was not explicitly completed as a component of this study, there is evidence to suggest that climatic variability in the region will increase (Werner et al., 2009). The Mayo Region is influenced by three large-scale atmospheric systems: The Pacific Decadal Oscillation (PDO), the El-Niño Southern Oscillation (ENSO) and the Arctic Oscillation (AO). These large-scale atmospheric systems regularly cycle through warm and cool phases which can last a few years (ENSO) to decades (PDO). The interaction of these systems influences climate variability resulting in temperatures that are warmer or colder, and wetter or drier, depending on which system is in a warm or cool phase and how it is relating to the other systems. These systems will continue to affect local weather, adding to the effects of climate change. In addition, the atmospheric systems themselves may change in a changing climate. Climate variability will increase as a result, and the region may experience an even greater range of warm or cold, wet or dry conditions, and even an increase in extreme events as a result.

VULNERABILITY AND THE MAYO REGION

The extent of community vulnerability to climate change will largely depend on the magnitude of climate change, the size of the Region’s population, and level of economic activity. While a changing climate alone will modify landscapes and affect people’s lives, growth within the Region would lead to greater exposure to impacts, and have a damaging effect, for example, by placing increasing traffic on highways underlain by thawing permafrost, or by placing additional pressure on wildlife already stressed by changing habitats. Scenarios depicting the way the Mayo

Region may be vulnerable to a changing climate over the next forty years serve to identify how these types of challenges may affect the community.

There are two basic climate scenarios, one depicting the situation if the rate of change follows the trend observed since 1960, and one depicting change if green-house gas emissions are not brought under control. Similarly there are two growth scenarios, one where growth follows the same general pattern it has over the past fifty years, and one where economic activity and local population growth increases considerably as the global population grows and demand for minerals increases. It is difficult to quantify future population changes because experience tells us that the north tends to be an unpredictable place, and the boom-bust economic cycles such as those seen in Yukon often characterize growth.

For the purpose of this study, growth based on current trends is seen to lead to no more than a doubling of the population over the next forty years. Rapid growth is manifested through a marked increase in mining activity throughout the region and the revitalization of Mayo as a regional service hub. Each scenario describes climate conditions, landscape changes, implications for human activity, and implications for community vulnerability if no action is taken to remedy the situation. The assumptions underlying these scenarios are provided along with full scenarios and citations in Appendix D.

SCENARIO 1: FUTURE CLIMATE FOLLOWS TRENDS OBSERVED OVER THE PAST SIXTY YEARS

Climate Scenario

By 2050, the average annual temperature in Mayo has risen from -4.8°C to -2.6°C, while total annual precipitation has risen from 524.2 mm to 571.4 mm. While this is a low rate of change relative to trends depicted in Scenario 2 below, the implications for change in the Mayo Region could be significant. Change has accelerated over the past eighty years (1925-2009), and climate change in this scenario is based on that trend. Even a relatively slowly changing climate would have a cumulative impact on the region's complex ecosystems, and seasonal weather patterns would be modified, notably in the critical 'shoulder seasons' with an earlier onset of spring and a longer fall season.

Scenario 1a: Limited Climate Change and Low Regional Growth

Impacts

- Permafrost thaw will continue in the region, resulting in localized groundwater flooding within the Mayo townsite, especially in areas where the ground surface is disturbed, such as housing developments and along highways.
- Water level fluctuations and seasonal weather variability result in periodic flooding along the Mayo River.
- Moderate increases to temperature, combined with increases in precipitation, keep overall trends in wilderness fires within the range observed between 1961 and 1991. Wildfire activity remains variable and large fires continue to occur. During the period of 1961 to 1991, 0.4 fires occurred per year, burning 870 ha in the region. Wildfire continues to be manageable near inhabited areas.

- Initially, the Region's complex assemblages of flora and fauna continue to fluctuate within the range historically experienced by residents, but over the long term, there are changes in the distribution and populations of species. Some new species enter the region.

Implications for human activity

- Permafrost degradation, continued ground water flooding, and sporadic flooding along the Mayo River would result in a decay of building integrity and decline in housing quality. A decline in the quality of houses and larger buildings will be hastened by the aging of buildings, and perhaps result in their abandonment.
- Degradation of the local highway system would occur as a result of frost heaves, permafrost thaw, and traffic volumes that reflect current use.
- Over the long term, traditional food harvests, which currently fluctuate from year to year, would become increasingly unpredictable and in some years there would be a relative scarcity of country foods.

Implications for community vulnerability

The more disadvantaged individuals in the community would most likely be vulnerable to changes in the region's climate. With low growth, the population would continue to age, creating a predisposition to harm from climate-related events (for example, health issues associated with a decline in housing standards such as dampness and mould growth resulting from increased precipitation and permafrost thaw) and diluting the human resource capacity of the Region. Vulnerability evident in Scenario 1a includes:

- Declining housing stock may lead to economically marginalized individuals and families inhabiting substandard housing. Excess moisture within housing (already reported in the NND subdivision east of the Mayo townsite) would become more problematic and detrimental to health.
- Increasingly significant health issues associated with increased dampness and mould growth.
- Local food security and increased dependence on commercial foods would become a more significant issue as wildlife patterns change. Local people would need to change their harvest range and the species in their harvest.
- Continued permafrost thaw may enhance landscape degradation and increase the potential for contamination from abandoned mine sites.

Scenario 1b: Limited Climate Change and Significant Growth

If significant population growth takes place, the vulnerabilities identified in Scenario 1a would be compounded. Such growth may result from a marked increase in mining activity and the revival of Mayo's fortunes as a regional hub. Population growth and economic development increase the capacity of the Region by revitalizing skills and increasing the range of human resources. An increase in capacity enables the community to address some issues, such as substandard housing.

Impacts

Growth would potentially stress the Region's infrastructure and landscape by increasing the demand for local resources such as land and water and placing pressure on already vulnerable ecosystems. Settlement expansion, expanded mining activity and increased use of highways and local access roads and trails would potentially further compound permafrost disturbance.

- Thawing permafrost could create some localized changes in the distribution and quality of water. Stress on regional hydrology could also arise from the increased demand for hydro power from mines.
- Water quality may also be impacted by the increased presence of toxic materials associated with mining, increasing the risk of water contamination.
- A broad increase in land-use activities (mining, tourism and recreation) would increase pressure on wildlife.

Implications for human activity

- Population growth pressures combined with the decline in housing quality outlined in Scenario 1a would possibly lead to the need to seek new sites for housing outside of the 65 housing units scheduled for development in the NND C6 subdivision by 2030 (as scheduled in VOM (2006a).
- Increased population and expansion of the mining industry would result in deterioration of the regional road system as a result of interaction between increased traffic volumes and thawing permafrost.
- Traditional food harvests already affected by climate-change events would become increasingly stressed by conflicts resulting from increased population pressure and expanded land-uses with additional habitat disturbance resulting from settlement expansion, mining, or increased recreational land-uses.

Implications for community vulnerability

Community vulnerability will largely encompass economically disadvantaged members of the community. However, with an increase in population, the ability of the Region's communities to care for these disadvantaged members will improve. Vulnerability in this scenario results from:

- Increased difficulty in procuring quality traditional foods as a result of land-use pressures. A decline in the availability of traditional foods also leads to negative effects on the cultural values of the Region's communities.
- The quality of housing may deteriorate outside of Mayo. For example, the presence of asbestos and lead paint has been documented in the housing at Elsa, the nearby, abandoned mining community (Access Consulting Group, 2010). If that community is resettled, or if resettlement in Keno increases, new residents may be (unknowingly) exposed to a number of contaminants if they rely on old housing stock.

Ideally, growth brings increased prosperity, a wider human resource base, and a range of services, and these may have the potential to address some of the stresses associated with a changing climate by enhancing community capacity as new populations expand and the range of skills increase. Growth also has the potential to increase capital for infrastructure renewal. Thus, paradoxically, while placing pressure on environment and community infrastructure, an increased population may enhance community capacity by broadening the suite of skills available.

SCENARIO 2: THE RATE OF CLIMATE CHANGE INCREASES SIGNIFICANTLY

Scenario 2 explores how the extent of community vulnerability described in Scenario 1 may be compounded with increased climate-induced stress on the region. The medium-high climate change scenario described above (see *Projected Climate Conditions, p. 15)* was selected as the counter-point to the constant climate scenario in order to characterize the best possible range of potential climate impacts.

CLIMATE SCENARIO

The average annual temperature of the Mayo Region rises from -4.8°C to -1.2°C by 2050. Precipitation increases over the same period. By 2030, total annual precipitation has increased from 524.2 mm to 571.3 mm (a 9% rise over the average for the 1961-1990 climate period). By 2050, total annual precipitation has increased to 595.9 mm (a 14% increase over the 1961-1990 climate period). Seasonal precipitation increases. By 2030, the most significant increases occur in the spring months (March, April and May). By 2050, the most significant increases occur over the winter months (December, January and February).

Over the next forty years, rising temperatures and the increase in precipitation, especially annual snowfall, would lead to the thawing of permafrost in river valleys and along north-facing slopes. In wilderness areas, the thawing of permafrost leads to subsidence, landslides, and increased erosion. Increasing temperature and precipitation result in greater variability in river ice conditions, including a greater likelihood of ice jam events on the Mayo and (potentially) Stewart rivers with the potential to increase the incidence of flooding. Flooding events will increase erosion, affecting water quality in the spring.

Hot, dry conditions occur in late summer with greater frequency, leading to an increase in surface water temperatures and subsequent impacts on fish populations. Warmer water temperatures may also lead to an increase in the frequency and severity of pests, parasites and bacterial outbreaks. Changing ecological conditions would also provide the opportunity for invasive alien species to proliferate. The risk of wildfire in the region becomes increasingly unpredictable and, when combined with shifting precipitation patterns and increased stress to forest ecosystems, leads to more severe wildfire conditions and subsequent effects on the region's environment. For example, as the half century closes, the distribution of forest species begins to change, contributing to the overall increase in fire risk despite increasing precipitation. Cumulatively these physical changes would affect the character, location and availability of wildlife.

SCENARIO 2A: SIGNIFICANT CLIMATE CHANGE AND LOW REGIONAL GROWTH

Impacts

- Warmer conditions and changing precipitation leads to increased permafrost thaw. In wilderness areas, the thawing of permafrost leads to subsidence, landslides and increased erosion.
- Seasonal weather variability results in increased flooding along the Mayo River in late winter.
- The incidence of forest fire becomes increasingly variable; no fires will occur in some summers, while other years will be characterized by burns of greater frequency, larger burn area, and a greater fire danger potential than that recorded in the 1961-1991 time period.

- The distribution of wildlife populations changes in response to climate-induced changes in vegetation and hydrology. Fluctuations in the abundance, character and location of wildlife fall outside the recall or experience of local residents.

Implications for human activity

Permafrost thaw along highway corridors, at mine sites and within established housing developments would have significant impacts in the Region.

- Permafrost thaw would compromise the regional highway system especially the connection between Mayo and Keno City, which is underlain by a significant amount of permafrost and reported by the community to already be unstable.
- Abandoned mine infrastructure would be vulnerable to shifting landscape conditions as permafrost underlying relict sites deteriorates leading to possible contamination of the surrounding environment.
- Existing and new mines would face challenges presented by permafrost degradation as it may impact infrastructure such as water-storage ponds, mine roads, waste-rock piles and tailings ponds. The 30-year climate trends and environmental forecasts used for determining development thresholds and engineering standards for the mining industry fail to accurately anticipate highly variable climate (and therefore landscape) conditions.
- Government infrastructure in Mayo (such as the administration building or hospital) would be severely compromised by permafrost thaw.
- The quality of housing in the Mayo townsite would be further threatened if fluctuations in groundwater levels are associated with permafrost thaw.
- The increased incidence of flooding along the Mayo River, and possibly the Stewart River, continues to create problems for residents.

Changes in aquatic regimes, seasonal patterns and ecosystems would affect wildlife populations leading to shifts in the availability of traditional foods.

- Shifts in traditional foods would affect the distribution and densities of valued species, making their harvest more difficult.
- Deteriorating travel conditions on the land (because of avalanches, landslides, and travel difficulties brought about by increased winter snowfall and earlier onset of spring), water quality issues (timing and volume of peak flow), pests and pathogens, and problem animal encounters may also limit the community's access to traditional foods.

Implications for community vulnerability

Addressing the effects of permafrost will become increasingly difficult as permafrost under the Mayo townsite and the NND subdivision to the east of the downtown continues to thaw as average annual temperatures increase by 3.6°C. As a result:

- The incidence of housing concerns noted in Scenario 1 will likely increase, especially if flooding events continue to increase along the Mayo River.
- Increasing health issues associated with living in substandard housing, as well as a greater dependency on commercial rather than traditional foods may adversely impact health.
- Towards the end of the study period (2050), local food security issues may be compounded as global foods are endangered by climate change.

- Health issues associated with an aging population would increase pressure on local health facilities. The more economically marginalized members of the community will be increasingly stressed and lack the household resources to adequately cope with change.
- The risk of wildfire in the region would increase. Standard emergency response policies continue to reduce the direct risks of wildlife for the community.

Scenario 2b: Significant Climate Change and High Regional Growth

Impacts

- Landscape instability resulting from accelerated permafrost thaw will be exacerbated by increased human activity in highway corridors.
- Pressure on the region's hydrology will increase as reduced summer flows coincide with increased demand for hydro power from the mining industry.
- Seasonal weather variability results in increased flooding along the Mayo River in late winter combined with a greater incidence of groundwater flooding associated with permafrost thaw; this will render areas of the Mayo townsite inhospitable at the same time that the population is expanding.
- The incidence of forest fire increases in response to variable climate conditions during the summer, ecosystem stress, and an increased potential for human-induced fires.
- The distribution of wildlife populations shifts in response to changes in vegetation and hydrology. Wildlife populations are also stressed by increased development and other human activity resulting from settlement and infrastructure expansion, and increased harvesting associated with a growing regional population.

Implications for human activity

Population growth and economic development exacerbate landscape change and lead to an increased incidence of land-use conflicts as the community expands and demand increases for residential construction outside current residential areas (within municipal boundaries and the NND C6 subdivision). Additionally, mining activity and associated camps or communities proliferate throughout the region.

- Thawing of permafrost and subsequent subsidence, landslides, and accelerated erosion increase the potential for contamination from mining activity. This risk increases as mining activity expands and if proper mitigative measures are not taken (for instance, if the mining industry does not integrate climate change into mine life-cycle planning).
- Additional pressure is placed on the region's water by landscape change, increased consumption and use from mines (processing and hydro-power) and a growing population.
- The increase in traffic from an expanding population hastens the deterioration of the regional road system, resulting in increased demand for infrastructure upgrades.
- The fire risk to communities increases with growth and expanded human activity in the Region. Changes in hydrology and/or water quality and proliferation of invasive species would stress the region's ecosystems. These stresses would be compounded by pressures from community expansion, proliferation of mining activity, and increased recreational land use. The availability of traditional foods would subsequently decline significantly.

- Increased snowfall and shifts in shoulder seasons may make travel on the land more difficult.
- Trapping is negatively affected by a decline in, or redistribution of, marketable species and increased winter precipitation.

Implications for community vulnerability

- The projected decline of permafrost in the community in combination with population growth and expansion leads to an increase in vulnerable infrastructure in this Scenario.
- Housing quality and the health of residents would be affected in the Region. With increasing population placing pressure on housing stock, some residents would likely live in older, sub-standard housing vulnerable to dampness and mould growth. Given the projected housing shortfall and population increase, exposure is not limited to a single demographic, and the exposed population will grow with the community.
- Dietary-related health problems would increase as traditional foods become more difficult to obtain. The procurement of high-quality food becomes increasingly problematic. The cost of transportation and declining availability of traditional foods could make obtaining nutritious food challenging for some in the community.
- Wildlife stress may also carry economic implications for outfitters and trappers.
- A decline in the availability of traditional foods and reduced opportunity for pursuing traditional activities, such as trapping, leads to subsequent effects on local culture.

The scenarios suggest that trade-offs exist between community growth and climate change. Rapid development can lead to increased landscape stress and community vulnerability, but can also enhance adaptive capacity. Ideally, growth brings increased prosperity, a wider human resource base, and a range of services that might build capacity and capital for infrastructure renewal. Increased capacity, in turn, may have the potential to address some of the stresses associated with a changing climate. However, this is only true if the scope of vulnerability remains within the capacity of the Region's communities to address it. It is therefore in the interests of residents to take action to address their vulnerability regardless of growth and on the assumption that climate change will increase their sensitivity and exposure to environmental stresses. The remainder of this report suggests a framework for taking these steps to increase the capacity of the Mayo Region to respond to environmental stresses.

ADAPTATION PLANNING TO REDUCE COMMUNITY VULNERABILITY TO CLIMATE CHANGE IN THE MAYO REGION

It is evident from the scenarios provided in the preceding section that vulnerability to environmental stress will increase over the next four decades. The scenarios also demonstrate that, even with minimal change to the region, the vulnerability of the Region's communities to environmental stress will increase. Broadly, vulnerability stems from the negative effects climate change has on the natural environment of the region and from the implications of a changing climate for infrastructure maintenance and replacement.

While the consequences of climate change for the Mayo Region are expected to be widespread and negative, climate change may also offer some beneficial opportunities for residents. A component of effective adaptation is enhancing the ability of residents to support actions that enable them to benefit from climate change (IPCC, 2007). The recommendations of the Mayo

Region adaptation plan therefore provide guidance for how residents may take action through adaptation to exploit opportunities emerging from changing climate conditions.

The remainder of this report completes the Mayo Region adaptation plan by identifying goals and objectives for community adaptation and proposes a pathway for implementation of the plans recommendations. This pathway includes a suggested timeline and discussion of the policy implications of adaptation for development within the Region.

GOAL 1: ENSURE THE INTEGRITY OF THE REGION'S ENVIRONMENT AND THE AVAILABILITY OF TRADITIONAL FOODS

Changes to the ecosystem of the Mayo region have been reported by Mayo residents for some time (Williams and O'Donoghue, 2005). These observations of change were reiterated by residents throughout the planning process and would appear to be ongoing and significant. The vulnerability scenarios demonstrate that these changes will continue over the next 40 years and impact access to traditional foods, viewed by residents as integral to community well-being. For example, it has been reported that "Hunting, fishing, berry-picking, hiking, snowmobiling and 'the great outdoors' are more than just pastimes." (Village of Mayo, 2006a, p. 3), while the First Nation of Na-Cho Nyäk Dun (2008, p. 5) states that "traditional hunting, fishing and gathering are still a significant part of community life". Three objectives have therefore been proposed to ensure the participating communities have continued access to a healthy ecosystem and to traditional foods and reduce vulnerability resulting from changing landscape conditions.

Objective 1.1: Anticipate and accommodate shifts in the environment and implications for wildlife health

Increased temperature and precipitation accompanied by shifting water availability, an increased forest fire regime, and thawing permafrost will likely alter the abundance and distribution of the Region's flora and fauna. Depending on the magnitude of landscape disturbance resulting from climate change, the abundance of some species may dwindle and the availability of some traditional foods may decline. To understand how climate change is affecting ecosystems and to manage wildlife and development appropriately by accommodating shifts in the environment, research and monitoring of ongoing changes will be required. It will be necessary to communicate the results of monitoring to policy-makers and managers.

Proposed adaptations:

1.1A Continue to monitor the health of valued species (see *The Landscape of the Mayo Region, p. 5* above) and their response to changing conditions in the region.

1.1B: Integrate climate change into all land and resource planning.

1.1C: Maintain communication between regulatory agencies, residents and hunters.

1.1D: Compile detailed assessments of landscape and wildlife health based on local and traditional knowledge.

1.1E: Continue to monitor water quality.

Objective 1.2: Minimize the effects of land-use conflicts on traditional foods

The vulnerability scenarios illustrate that the impacts of climate change on the region's ecosystems will be compounded by growth. It is therefore important to manage the impacts of growth in order to bolster the health of these ecosystems.

Proposed adaptation:

1.2A: Integrate climate change into the Yukon Environmental and Socio-economic Assessment Act (YESAA) review process.

Objective 1.3: Acknowledge change as a component of obtaining traditional foods

As the regional ecosystem responds to changing climate conditions the landscape may irreversibly change. It is important that the residents remain flexible and accepting of these changes. New sources of food may emerge and restraint may be required in gathering more traditional food sources that have become stressed. While the traditions and culture of the First Nation of Na-Cho Nyäk Dun will provide guidance on the sensitive treatment of traditional foods, additional actions may be taken to help residents reliant on the land to adjust to new landscape conditions.

Proposed adaptations:

1.3A: Consider the importance of modern technologies, such as remote sensing, for a more comprehensive monitoring of landscape changes.

1.3B: Ensure that the population of the region is cognizant of possible ecological and wildlife shifts associated with a changing climate and maintains flexibility in hunting and harvest strategies.

1.3C: Encourage the diversification of local food sources through the support of hot-house development and local horticulture.

GOAL 2: ENSURE THE INTEGRITY OF THE REGION'S HIGHWAYS, UTILITY SYSTEMS AND BUILDINGS

Aging infrastructure in the region can affect the health and well-being of residents. For example, increased precipitation and ongoing changes to the water table of Mayo are anticipated to result in increased mould growth and water damage in the community's buildings that will affect the health of residents. While health is explicitly addressed in Goal 3 (below), policy development associated with infrastructure maintenance and renewal can directly reduce vulnerability. The Region's highway system is critical for access to resources, ensuring the ability of residents to respond to hazard events, and to support economic growth. Three objectives are proposed to address vulnerability resulting from the Region's infrastructure.

Objective 2.1: Complete a comprehensive assessment of the highway system's vulnerability to permafrost degradation

Given the isolated location of Keno City and the vital role the highway plays in providing employment and resources to the communities in the region (Mayo, Keno City and Stewart Crossing), it is imperative that an assessment of the vulnerability of the highway system to permafrost thaw be completed. This assessment will enhance the ability of the relevant authorities (such as the Government of Yukon) to allocate resources in a timely manner. For example, additional information will be required by decision-makers to allocate resources for highway maintenance. Additional information on the vulnerability of the highway system to permafrost thaw can also inform policy development in response to growth within the region.

Proposed adaptations:

2.1A: Inventory the state of permafrost within the highway corridor, including along adjacent slopes, to determine the potential for subsidence or slumping.

2.1B: Maintain transportation corridors servicing the region (#2 North Klondike Highway and #11 Silver Trail Highway) to a standard sufficient to reduce pressure on the highway system and reduce the potential for isolation.

2.1C: Investigate the feasibility of upgrading the Duncan Creek road to reduce transportation pressures on the Silver Trail.

Objective 2.2: Identify sites in the community suitable for future development

Current municipal planning for community growth in Mayo recommends constructing new houses and buildings within the municipal boundary (Village of Mayo, 2006a). This recommendation carries a number of advantages for residents, including a sustainable footprint for infrastructure and improved revenue generation for the municipal government. However, recent work in the community (NCE, 2011) suggests that much of the land within the municipal boundary is moderately susceptible to permafrost thaw, which may limit infill development. Demand for lots outside the municipal boundary is also likely, regardless of the availability of land in the village, and within the nearby First Nation subdivision (C-6). Growth in Keno City and Stewart Crossing is not currently planned for. The identification of suitable areas for residential development in the region will therefore be advantageous in offsetting the influence of climate change on future growth.

Proposed adaptations:

2.2A: Identify where land is available for housing development outside current areas of development (complete local-area planning).

2.2B: Ensure appropriate climate-change projections are integrated into new infrastructure planning.

Objective 2.3: Ensure the provision of quality housing to residents

Climate change may alter the water table within Mayo and increase the already present local flood risk. While the condition and maintenance of buildings within the Village of Mayo is the responsibility of the owner and adaptation may be at the discretion of the individual, action can still be taken at the community level to offset the potential consequences of climate change on homes.

Proposed adaptation:

2.3A: Ensure building codes, zoning and by-laws are adequate for use in a changing climate.

Objective 2.4: Mitigate flood risk to the community of Mayo

Residents of Mayo are concerned about existing and future flood risk to the community from the Stewart and Mayo rivers. The flood defense system along the Mayo River is not sufficient and flooding has occurred in the community recently. The community is also concerned about recent flood levels on the Stewart River. Regardless of how climate change will affect the hydrology of the region, the following actions are recommended to address these concerns.

Proposed adaptations:

2.4A: Upgrade the dike along the Mayo River.

2.4B: Determine if and how climate change will alter flood conditions on the Stewart River.

2.4C: Ensure the flood defense network in Mayo meets the standard required to protect the community from flooding.

GOAL 3: PREVENT DELETERIOUS IMPACTS OF CLIMATE CHANGE ON HEALTH

Climate change will compound existing health risks for the residents of the Mayo Region. For example, variable weather conditions resulting from a changing climate may increase health risks for the elderly. The health of the community may also be negatively affected by aging infrastructure (residential homes and administrative buildings) in the region. In addition to those actions that indirectly reduce health risks impacted by climate change (such as ensuring the provision of quality housing – Objective 2.3 above) adaptations need to be taken that explicitly improve the ability of residents to safeguard their health. These adaptations should support ongoing health programs in the Mayo Region.

Objective 3.1: Mitigate the health risks of problem buildings

Health risks may emerge if the condition and quality of housing declines in the Region due to the aging of buildings or an increase of damp conditions. In addition to the adaptations proposed above, the incidence of health issues associated with sub-standard housing needs to be monitored to inform residents if and when housing problems pose a serious health risk to the community.

Proposed adaptation:

3.1A: Monitor health issues associated with substandard housing in the Mayo Region.

3.1B: Ensure new buildings are constructed to a standard that minimizes health issues.

Objective 3.2: Educate residents on the implications of climate change for community health

Many of the climate impacts on regional health will require action at the individual or family level to mitigate risks exacerbated by climate change. For these actions to be effective, residents must be informed of the risks and how to address them. Providing this information to residents will require continued support to the various health organizations within the communities so that they may provide meaningful health information.

Proposed adaptations:

3.2A: Complete an injury-prevention campaign to address the increased risk of injuries resulting from variable climate conditions.

3.2B: Increase the awareness of residents with regard to the possible health risks associated with substandard housing conditions.

3.2C: Integrate the potential impacts of climate change on traditional foods into ongoing education programs emphasizing the importance of healthy food choices.

Objective 3:3: Assess the capacity of health providers to continue ongoing programs and provide additional resources if needed

If climate change will exacerbate existing health risks in the Mayo Region, then sufficient resources need to be allocated to ensure that the capacity of health care agencies is sufficient to meet future challenges.

Proposed adaptations:

3.3A: Evaluate the health needs and capacity of each community in the region to provide health services to its residents.

3.3B: Evaluate the capacity of the nursing station based on the potential future needs of residents.

3.3C: Support the community market initiative to ensure a local base for supplying healthy foods.

GOAL 4: MINIMIZE THE NEGATIVE IMPACTS OF MINING

Mining is intimately linked to the history of the Mayo region. Both the communities of Mayo and Keno City were founded by prospectors early in the 20th century (Bleiler et al., 2006). Mining remains an integral component of the region's economy and culture. Mining can also have a negative effect on the regional landscape, especially water quality. These effects, particularly for abandoned mines and mines reaching the end of the operational life within 20 years, will be compounded by changing climate conditions (Mining Association of Canada (MEND), 2011). For example, permafrost thaw may affect the stability of infrastructure on current and abandoned mine sites. Increased precipitation may also increase the impact of mining on the landscape by exacerbating the leaching of contaminants from containment structures. The problem of leaching may be especially problematic in the case of abandoned or derelict mine sites where monitoring is not ongoing and infrastructure may become unsuited to changing climate conditions (MEND, 2011). The implications of climate change for the mining industry in the Mayo region, compiled as a part of this planning process, are documented in full in Appendix B.

Objective 4.1: Integrate climate change into the design and life cycle of mines

The mining industry is vulnerable to changing climate conditions; however this vulnerability is viewed by many in the industry as negligible and of low concern (Pearce et al., 2009). Continued support for the integration of climate change (or mainstreaming) into the design and life cycle of mines is recommended to ensure these engineering solutions remain effective.

Proposed adaptations:

4.1A: Integrate climate-change projections into all aspects of mine life-cycle planning.

4.1B: Complete land-use planning to minimize conflicts with, and to buffer, ecologically sensitive areas.

4.1C: Review anticipated demands for water from the mining industry in the Region as well as possible 'down-stream' impacts of mining in a changing climate.

Objective 4.2: Evaluate the implications of climate change on relict mine sites

While climate change may result in significant consequences for the mining industry (Pearce et al., 2009), the industry is rigorously monitored. This is not the case with relict mine sites, which will be impacted by climate change, and the effects of which are not well understood.

Proposed adaptation:

4.2A: Explore the vulnerability of abandoned mine sites in the region to disturbance occurring as a consequence of climate change.

GOAL 5: EXPLOIT BENEFICIAL ASPECTS OF CLIMATE CHANGE IN THE REGION

A changing climate may enhance some economic opportunities in the Region and community discussions yielded a range of suggestions as to how this may occur, including potential opportunities in tourism, local agriculture and horticulture, in addition to the exploitation of renewable energy. Investment within the community to ensure that sufficient capacity exists to take advantage of emerging opportunities will be required, along with sound assessment of viability.

Objective 5.1: Investigate the feasibility of opportunities to diversify the economy of the Mayo Region

Several economic sectors active in the Mayo Region may benefit from improved climate conditions to expand their activities and diversify the Region's economy. These sectors include, but are not limited to, tourism, forestry agriculture and energy. Some of these sectors, such as tourism, are established and in a position to expand as needed and at the discretion of the operators. Other sectors will need feasibility assessments to support establishment and start-up costs. For example, little interest in agriculture exists in the community (as reported by residents during the planning process) despite the presence of unusually deep soils in some parts of the region and a good growing climate (Bleiler et al., 2006). Investigation into the benefits of expanded agriculture or horticulture in the region may therefore be required before the community is willing to invest their limited resources or time in this sector.

Proposed adaptations:

5.1A: Complete a regional forest resource management plan to identify sustainable harvest levels for local forests in a changing climate.

5.1B: Examine the possibilities of improved climate conditions for agriculture or horticulture in the Region.

IMPLEMENTATION OF THE MAYO REGION CLIMATE CHANGE ADAPTATION PLAN

The changing climate that the Mayo Region is currently experiencing, when combined with future changes anticipated in even the most modest of our projections, suggest that the Mayo adaptation plan should be implemented by no later than 2030. While the 32 adaptations proposed above compose the recommendations of the Mayo Region Climate Change Adaptation Plan, the reality of implementation is that some actions are more effective than others, and some are easier to implement than others. We therefore first establish a timeline for implementation based on our appraisal of each action, its importance to community adaptation, and the time horizon for the execution of the action. We then proceed to identify priority adaptations to provide a focus for the implementation process. The plan concludes with a brief discussion of other important considerations that must accompany the implementation process: the need for continued partnership development and the policy implications of planning.

ACTION TIMELINE

The action timeline (Table 3) establishes a strategy for implementing this plan. Each horizon, short (0-5 year), medium (5-10), or long-term (10+), reflects the period anticipated to complete the adaptation. In some instances, residents of the Mayo Region were found to be already adapting, and these adaptations are noted in a column labeled “established”. These adaptations provide a tangible starting point for the implementation of the broader adaptation plan and continued support for them will be an important component of building community resilience to climate change.

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Table 3. Timeline for adaptation for the Mayo Region.

Goal	Established	Short-term (0-5 years)	Medium-term (5-10 years)	Long-term (10+ years)
Goal 1: Ensure the integrity of the Region's environment and the availability of traditional foods.	• Continue to monitor the health of valued species (see *The Landscape of the Mayo Region* p. 6 above) and their response to changing conditions in the region (1.1A). • Maintain communication between regulatory agencies, residents and hunters (1.1C). • Compile detailed assessments of landscape and wildlife health based on local and traditional knowledge (1.1D). • Continue to monitor water quality (1.1E). • Ensure that the population of the region is cognizant of possible ecological and wildlife shifts associated with a changing climate and maintains flexible hunting and harvest strategies (1.3B).	• Integrate climate change into all land and resource planning (1.1B). • Integrate climate change into the Yukon Environmental and Socio-economic Assessment review process (1.2A).	• Consider the importance of modern technologies, such as remote sensing, for a more comprehensive monitoring of landscape change (1.3A). • Encourage the diversification of local food sources through the support of hot-house development and local horticulture (1.3C).	
Goal 2: Ensure the integrity of the Region's highways, utility systems and buildings.		• Inventory the state of permafrost within the highway corridor, including adjacent slopes, to determine the potential for subsidence or slumping (2.1A). • Maintain transportation corridors servicing the region to a standard sufficient to reduce pressure on the highway system and reduce the potential for isolation (2.1B). • Ensure appropriate climate-change projections are integrated into new infrastructure planning (2.2B). • Ensure building codes, zoning, and by-laws are adequate for use in a changing climate (2.3A). • Upgrade the dike along the Mayo River (2.4A).	• Investigate the feasibility of upgrading the Duncan Creek road to reduce transportation pressures on the Silver Trail (2.1C). • Identify where land is available for housing development outside current areas of development (2.2A). • Determine if/how climate change will alter flood conditions on the Stewart River (2.4B). • Ensure the flood defense network in Mayo meets the standard required to protect the community from flooding (2.4C).	

Table 3. Timeline for adaptation for the Mayo Region, *continued*.

Goal	Established	Short-term (0-5 years)	Medium-term (5-10 years)	Long-term (10+ years)
Goal 3: Prevent deleterious impacts of climate change on health.	• Support the community market initiative to ensure a local base for supplying healthy foods (3.3C).	• Monitor health issues associated with substandard housing in the Mayo Region (3.1A). • Ensure new buildings are constructed to a standard that minimizes health issues (3.1B). • Increase the awareness of residents with regard to the possible health risks associated with substandard housing conditions (3.2B). • Integrate the potential impacts of climate change on traditional foods into ongoing education programs emphasizing the importance of healthy food choices (3.2C). • Evaluate the health needs and capacity of each community in the region to provide health services to its residents (3.3A).	• Complete an injury prevention campaign to address the increased risk of injuries resulting from variable climate conditions (3.2A). • Evaluate the capacity of the nursing station based on the potential future needs of residents (3.3B).	
Goal 4: Minimize the negative impacts of hard-rock mining.		• Review anticipated demands for water from the mining industry in the Region as well as possible 'down-stream' impacts of mining in a changing climate (4.1C). • Explore the vulnerability of abandoned mine sites in the region to disturbance occurring as a consequence of climate change (4.2A).	• Integrate climate change projections into all aspects of mine life-cycle planning (4.1A). • Complete land-use planning to minimize conflicts with, and to buffer, ecologically sensitive areas (4.1B).	
Goal 5: Exploit beneficial aspects of climate change in the region.			• Examine the possibilities of improved climate conditions for agriculture or horticulture in the Region (5.1B).	• Complete a regional forest resource management plan to identify sustainable harvest levels for local forests in a changing climate (5.1A).

PRIORITY ADAPTATIONS RECOMMENDED BY THE MAYO ADAPTATION PLAN

Implementation of the adaptations in the order established in the timeline will enhance community resilience to climate change. Many of these adaptations are inter-related and will reinforce each other. For example, ongoing monitoring programs will provide the information necessary to ensure appropriate land and resource planning, awareness of changing conditions in the landscape within the region, and ensure timely infrastructure upgrades.

Currently, few resources have been allocated to the implementation of the plan and it is realistically anticipated that the broad suite of actions identified above will be implemented only as opportunities arise. To support a targeted implementation of adaptation actions we have identified five priority actions which will be most effective for achieving the goals set out above. These priority adaptations are:

- Integrate climate change into all land and resource planning (1.1B).
- Ensure appropriate climate-change projections are integrated into new infrastructure planning (2.2B).
- Upgrade the dike along the Mayo River (2.4A).
- Evaluate the health needs and capacity of each community in the region in order to provide any necessary health services to residents deemed necessary in a changing climate (3.3A).
- Review anticipated demands for water in the region from the mining industry as well as possible ‘down-stream’ impacts of mining in a changing climate (4.1C).

The implementation of these priority recommendations will contribute to regional resilience by enhancing the adaptive capacity of all participating communities. The exception is recommendation 2.4A, which is included here because of the recent impact flooding has had in Mayo, and the resulting concerns expressed by residents. In addition to the sufficient funding and staff that will be required to implement this plan, two other considerations have been identified by the project team as necessary to support adaptation in the Mayo Region. These considerations are the need for continued partnerships and the implications to policy development related to this adaptation plan.

THE NEED FOR CONTINUED PARTNERSHIP DEVELOPMENT FOR REGIONAL ADAPTATION

Many of the identified adaptations, such as regional land-use planning or infrastructure renewal, will require the collaborative participation of more than one organization or institution. Many of these partners are aware of the implications of a changing climate and are already undertaking adaptive initiatives in the region. However, in the long term, the measures required to adapt to a changing climate will exceed the capacity of any one partner. Adaptation is an end that can only be achieved through partnership between groups working to address emerging issues through the coordination of multiple jurisdictions and specializations. The following organizations could play a vital role in the implementation of this plan.

First Nation of Na-Cho Nyäk Dun: As a self-governing First Nation, NND will be a key partner for climate-change adaptation. The entire study region falls within their Traditional Territory and they are responsible for delivering a broad range of services to their citizens, especially with regard to traditional foods, health and resource management.

Village of Mayo: The Village of Mayo has an essential role to play in adaptation strategies involving land management, zoning and infrastructure renewal within municipal boundaries.

Government of Yukon: The Government of Yukon is responsible for the delivery of services and infrastructure to the region, and thus will be a necessary partner for community adaptation, especially where infrastructure renewal and highway maintenance, education, potential contamination issues, health care, resource management (including fire control, environmental monitoring, mine regulation, etc.), and land-use conflicts are concerned. The Yukon government may also play a significant role in supporting emerging opportunities for forestry and agriculture.

Community Representation: Community representation, especially in Stewart Crossing and Keno City which do not have municipal status, will play an important part in ensuring partners are aware of changing conditions in the Region. Community organizations such as the Mayo District Renewable Resources Council, the Keno City Community Club, the Stewart Valley Community Market and many other organizations are already playing a role in economic diversification, ecosystem health, and agriculture. These types of organizations will need to continue with their activities as the climate changes.

Private Sector: The private sector, notably the mining industry, has a significant role to play in assisting the Mayo Region's communities to adapt to climate change. By regulating themselves, ensuring infrastructure is robust and disturbance is limited, these organizations can reduce vulnerability simply by ensuring problems do not arise. The private sector can also play a meaningful partnership role by providing access to their store of skills, resources and information which may make a difference in preparing for climate change.

Academic Institutions: Academic institutions have been active in the region for some time, have accumulated a significant amount of information, and have developed skills important to adaptation. By sharing data, information, or other resources at their disposal, academic institutions will reduce the workload of the other partners and increase the resilience of the region.

Federal Government: The Government of Canada has some regulatory responsibility in the Region and access to resources and capacity not readily available to the other partners noted above. However, these resources are subject to the conditions of the devolution agreement with the Government of Yukon and the First Nation of Na-Cho Nyäk Dun Self-Government Agreement. Federal support in the region will be important to partners that are active in reducing vulnerability, as well as for adaptation.

BROADER POLICY IMPLICATIONS OF ADAPTATION

Development of policy to support adaptation will be integral to the implementation of this plan. As conditions change within the Yukon Territory, policy will have to continually evolve to support the following:

- increased maintenance and renewal of transportation corridors in the region;
- changing landscape conditions within, and outside the participating communities that are relevant to building renewal, zoning and development standards;
- regional land use, including (rapidly) changing landscape conditions, shifting water needs and demands, shifting resource demands, and changing thresholds determining ecosystem health;

- cultural/heritage protection as landscape conditions change; and
- changing health needs.

Maintaining policies to support adaptation in a changing climate will require the cooperation of the partners noted above, the collaboration of relevant departments within those institutions providing governance, and the public. The broader implications of adaptation for policy cannot be underestimated.

Adaptation in the Mayo Region is considerably more than community-based action. Increasing the ability of the region's population to respond to climate change includes a combination of the implementation of this plan, partnership development, and policy based on open communication with residents of the Mayo Region. The various partners identified to support adaptation in the region must remain flexible and open to changing landscape conditions and to the needs of residents. The collaboration of these partners and the public will ensure that the Region's communities can move towards full plan implementation, minimizing negative effects of climate change and possibly benefitting from opportunities that may arise from a warmer climate. Ultimately, however, the negative effects outnumber the positive, and the residents of the Mayo Region are vulnerable to a wide range of events that may threaten their way of life. It is imperative that members of the three communities lead the process of climate change adaptation. The leadership and detailed knowledge that these champions will provide will be important to partnership development, meaningful policy development, and the full implementation of this plan.

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APPENDIX A - A HISTORY OF ENVIRONMENTAL STRESSES ALONG THE SILVER TRAIL

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INTRODUCTION

PURPOSE OF STUDY

A History of Environmental Stresses Along the Silver Trail was drafted as a component of the Mayo Community Climate Change Adaptation Project. It combines a comprehensive environmental history of the region with an assessment of Silver Trail communities' adaptive capacities, and includes an emphasis on the community of Mayo. The environmental history will focus specifically on climate effects and the impact of these environmental stresses on the study area. It will evaluate the most notable of these occurrences, as well as the reactions of the communities (i.e., Stewart Crossing, Mayo, Elsa and Keno City) to each instance.

By examining historical environmental stresses and the manner in which communities have reacted to these in the past, adaptation strategies for the future may be developed. This historical component of the Mayo Climate Change Adaptation Project is a tool that may provide direction for discussions about regional climate-change implications.

REPORT STRUCTURE

Following an overview section about the climate and geography of the region, the report is organized by category of environmental stress: wildland fires, floods, temperature and precipitation. The most notable events for each category were identified and then examined for severity, impact, and community response. While fires and floods stand out as the most important environmental stresses in the region, seasonal temperature extremes and heavy precipitation are important to the area's historical and future climate regime. The prospect of widespread permafrost thawing is also addressed. Finally, this study concludes with a brief discussion on environmental stresses and socio-economic implications with respect to the energy and mining sectors. A bibliography and appendices are also included.

RESEARCH METHODS AND SOURCES

Research for this report relied heavily on newspaper articles and government records, and some primary data was generated through oral interviews. Sources for the study were compiled mostly through research at the Yukon Archives, Department of Tourism and Culture, Government of Yukon. By searching through back issues of newspaper articles and available archival sources, a comprehensive data set eventually emerged, despite the relative scarcity of information. Newspapers used in this study include *The Yukon News, The Whitehorse Star, The Stewart Valley Voice, The Dawson Weekly News* and *The Northern Times*. Diaries, as well as private and public sector materials and publications were also examined. Other materials and information were incorporated from Yukon government sources, through email, telephone correspondences or pursuant to meetings with government officials. In addition, oral interviews were conducted with First Nation of Na-Cho Nyäk Dun citizens and Silver Trail area residents. These proved to be valuable in assessing where to prioritize research efforts. It also illustrated which past environmental stresses stand out in the collective memory of residents living in the area.

GEOGRAPHIC SCOPE OF THE STUDY AREA

The geographic parameters for the study area were limited to the length of the Silver Trail Highway (Stewart Crossing to Keno – a distance of 110 km – encompassing the communities of Stewart Crossing, Mayo, Elsa and Keno City), and included a 30-km buffer north and south of the highway. The study area covers a region that is roughly 170 km east-west by 60 km north-south. The 30-km buffer along the Silver Trail was chosen as a boundary to delineate forest fire activity that occurred within close proximity to communities and infrastructure since the 1940s, a point in time when reliable fire data started to be compiled. The area of study comprises a good stretch of the Stewart River valley, and some of the First Nation of Na-Cho Nyäk Dun's territory. Please see Appendix 1 to view historical wildland fire distribution of the study area.

SILVER TRAIL OVERVIEW

GEOGRAPHY

The Silver Trail is situated in a relatively isolated region located between the Wernecke Ranges and the Stewart Plateau, which is an extension of the Canadian Cordillera. The Wernecke Ranges are characterized by "rugged terrain", whereas the Stewart Plateau, located south of Mayo Lake, is populated by "rounded and flattish hills" (Bleiler, et al., 2006, p. 3). Mayo, the largest community in this region, is located at the confluence of the Stewart and Mayo rivers.

The St. Elias Mountains are southwest of the study area and include some of the highest peaks in Canada (e.g., Mt. Logan at 19,541 ft). This massive mountain range generally keeps Pacific Ocean air masses, which consist of humidity and moderate temperatures, out of continental Yukon. A continental climate regime dominates, and is regionally modified by local microclimates created by hills, mountains, plateaus and valleys. The range of elevations from valley floors to mountain peaks and the orientation of hill slopes greatly influence the types of ecosystems present and the plant and animal life that flourish within them.

CLIMATE

Mayo proudly declares that it is the "hottest and coldest" place in Yukon. Temperature variations are extreme – one of the highest in Canada, and one of the greatest on the planet due to its continental climate. Most years, the temperature range is 80°C or more (e.g., +30°C in the summer and -50°C in the winter). The hottest temperature recorded was +36.1°C on June 14, 1969, and the coldest recorded temperature was -62.2°C on February 2, 1947 – a range of 98.3°C (Bleiler et al., 2006, p. 19).

The variability in temperature is great in any season, particularly for the town of Mayo. Temperature variations within the study area are the greatest in winter (e.g., temperatures can reach -60°C); however, thaws may also occur in January, which is typically the coldest month of the year. In the summer, frost may occur on any given night, although the south-facing slopes along the Stewart River valley often bake in the summer sun and temperatures of +30°C are not uncommon. The Stewart River valley is arguably the warmest region in Yukon during the summer and has been the site of successful agricultural endeavours and recreational gardening despite its high northern latitude (Bleiler et al., 2006).

In winter, temperature inversions sometimes cause cold air masses to drop, settling in low-lying areas, such as the Stewart River valley. When there is little solar radiation, valley floors become concentration areas for cold air and as a result, higher elevations may be warmer. Keno, though higher in elevation, is often warmer and clearer than Mayo, which might be blanketed in shallow ice fog, containing colder pockets of air (Bleiler et al., 2006).

In terms of precipitation, 62% of Keno's annual total comes from snow, whereas 58% of Mayo's annual precipitation is from rain. More precipitation tends to fall at higher elevations in the central Yukon. In Mayo, April is the driest month, whereas Keno's driest month is May. The region is generally a moderately dry place; however, there have been greater snowfall accumulations during the winter months in recent years (Bleiler et al., 2006).

Rain is obviously critical to plant growth and agricultural activities. Rain has some effect on wildland fire control, and lots of rain seems to encourage the reproduction of mosquitoes. Snow is important for winter travel and recreational activities such as snowmobiling, dog sledding, skiing and snowshoeing. Snow is important for hibernating animals, providing shelter and thermal barriers. Snow's thermal blanketing effect can also be helpful in preventing the freezing of pipes, and sewers (Bleiler et al., 2006).

CURRENT POPULATION ESTIMATES

Roughly 500 people live full-time within the study area and about 65% of residents belong to the First Nation of Na-Cho Nyäk Dun. Mayo's population is around 400 people, whereas about 50 people live in Stewart Crossing. Population estimates for Keno and Elsa are approximately 20 and 30, respectively. Elsa and Keno's populations may swell at different times in the near future as mines in these areas are set to reopen.

WILDLAND FIRES

INTRODUCTION

Overview

Wildland fires have been a persistent environmental threat to the communities along the Silver Trail since the Gold and Silver rushes, and surely for hundreds of years before that for the First Nation of Na-Cho Nyäk Dun and other pre-colonial peoples who have lived in the Stewart River valley. Unfortunately, reliable data for the region does not exist prior to the 1940s.

Since wildland fires are likely the region's biggest perennial environmental threat, it will receive the most attention in this study. Three notable fire years - 1971, 1990 and 1998 - have greatly affected the evolution of the area's response to this threat. Over the past 40 years, response to forest fire has evolved. In the 1970s responses to fires were largely a corporate and/or a private/federal government endeavour characterized by a lack of coordination or *ad hoc* intervention, and a heavy reliance on resources from the mining industry. Over time, responses to wildland fires have become much more multi-organizational, whereby institutional bodies provide well-defined, coordinated roles pre-determined by an integrated emergency response plan. While wildfire management and response is still evolving in the region today, it has nevertheless developed into a relatively coordinated and comprehensive program.

A cut-off date of 1940 was chosen for this study and coincides with the onset of fairly reliable wildfire data collection. Since the 1960s wildland fire data has become more comprehensive (Bleiler et al., 2006, p. 40). Fire detection, monitoring technologies, and fire data collection have gradually improved over time (Don Hutton, Northern Tutchone Zone Manager, pers. comm., 2010).

Silver Trail Wildland Fire Statistics

The incidence of wildfire has varied from decade to decade. From 1940 to present, 58 wildland fires burned within 30 km of the communities along the Silver Trail Highway, from Stewart Crossing to Keno.[1] Over the past 50 years, there have been 630 fires in the Mayo fire district (McCoy and Burn, 2001, p. 111). The peak of wildland fires occurred between 1980 and 1999, an era with many fires, including the 1983 record year of 50 fires (McCoy and Burn, 2001, p. 111). There has been a downward trend in the number of Silver Trail-area forest fires from 2000 to 2009. Eight of the top ten fire seasons occurred during the last 20 years of the twentieth century.

Lightning has played a dominant role in the fire regime throughout the recorded history of wildfires in the Mayo region. From 1960 to 1999, 85% of wildland fires in the Mayo district were ignited by lightning strikes. Throughout the 1980s and 1990s, only 8% of wildland fires were human-induced. A concerted effort to lessen environmental impacts and minimize human-caused ignitions during this period may explain why lightning accounts for such a high percentage of wildland fires (McCoy and Burn, 2001, p. 40).

Mitigating Factors and Impacts

Whether a fire is human-caused or lightning-generated, mitigating factors come into focus once a blaze is underway. Winds, droughts, topography, bodies of water, humidity levels and barometric pressure are considerations in wildland fire severity, however none are pivotal. The number and severity of fires within a given fire season are mildly correlated with hot temperatures and dry conditions. Furthermore, rain can abate or even extinguish a wildland fire, but high amounts of precipitation do not necessarily correspond to fewer fires (McCoy and Burn, 2001, p. 41). What can be safely stated is that more lightning strikes will most likely result in more wildland fires, regardless of how hot, cool, dry or wet a given summer is.

Wildland fires bring both negative and positive consequences to the surrounding environment and nearby communities. While fires are a naturally occurring and necessary phenomenon that is vital for soil regeneration, they may exacerbate permafrost thaw, as they heat up the ground and leave the forest floor more exposed to snow accumulation and direct sunlight for several years following a fire. Furthermore, fires may alter wildlife habitats. Moose and caribou populations increase and decrease respectively in burn areas during summer months, as they provide open space for moose, yet remove the lichen that is an important food source for caribou. Nearby streams may also heat up possibly altering the patterns and life cycles of fish inhabiting those waters (Don Hutton, Northern Tutchone Zone Manager, pers. comm., 2010). These possible changes to both land and water-based wildlife affect trappers, hunters and fishermen.

Wildland fires sometimes generate smoke that will settle in nearby communities, threatening the health and safety of residents. Smoke or fire, if in close proximity to a major road or highway, poses a direct threat to travellers by reducing visibility and may delay transportation or block it altogether. Not only does this prevent delivery of important goods and services to communities dependent on road transport, it can also negatively impact tourism in the area and beyond. A decrease in tourism can threaten an economy already burdened by the financial costs of fighting the fires. This can lead to a strain on manpower, equipment and other resources.

However, wildland fires may sometimes create a welcome economic boost to a local community. As public resources and money are brought into a community with a nearby fire, outside

1. Fire data provided by Whitehorse Wildland Fire Management office, October 2010. See Appendix #2 for detailed fire data of all 58 fires.

manpower can fuel the local economy. Furthermore, wildland fires have fostered the development of community preparedness and response capacities towards emergencies.

Evolving Wildland Fire Policies

Since the 1940s, evolving policies, strategies and fire-fighting capacities have sometimes affected how many hectares a fire would ultimately consume. Wildland fires that have been fought in recent decades are necessarily near population bases, infrastructure or other significant property of value. Consequently, some remote fires have burned longer and over a greater area. Fires burning closer to areas deemed important are often fought with greater vigour.

As a result of the further entrenchment of the Yukon Government's Wildland Fire Management office in Whitehorse, this policy shift has made responses to fires more automatic. Some members of the community of Mayo and the First Nation of Na-Cho Nyäk Dun are not supportive of the let-it-burn approach to far-flung fires, particularly when intervention could extinguish a fire; however, others are content to have the rules of engagement clearly defined.[2]

HISTORIC RESPONSES TO WILDFIRE

Overview

Three important, well-documented fires were identified and studied for the purpose of this report. The manner in which these fires were addressed show how responses to fires have changed over the last several decades. An investigation of each highlights both the impact of forest fires and the evolution of community response and emergency preparedness.

When forest fires broke out in the Silver Trail area in the 1970s, responses depended on the availability of individuals, contractors and equipment. Today, the amount and diversity of equipment available to fight forest fires far exceeds what was available then due to the dramatic advancement in technology.

In the 1970s, planes were fewer, capable of only short flights, and unable to carry significant water loads or deliver fire retardant chemicals with precision. Heavy loads of equipment could not be airlifted safely into any location by powerful helicopters as they are today, and there were fewer trained pilots available. On an organizational level, coordinated responses to wildland fires were not clearly laid out in advance, and public bodies were smaller. For example, in the early 1970s, the absence of a territorial government and a self-governing First Nation meant that businesses and the federal government were the main bodies capable of contributing equipment and personnel to combat a fire. This reality determined both the responses to, and the available resources for, fighting fires in the area.

The 1971 McQuesten Valley/ Janet Lake Fire

Fires broke out near Janet Lake and the McQuesten River valley in 1971, within close proximity to the Elsa mine, owned and operated by United Keno Hill Mines Ltd. (UKHM). This enterprise provided much of the economic and labour activity along the Silver Trail. The federal government presence in the area was relatively limited, and while decisions made in Whitehorse were relevant, they were not as significant as efforts that could be undertaken within close proximity to the fire activity. Instead, in an era of relatively strong corporate power and fewer governmental bodies, emergency responses were of an *ad hoc* nature, and characterized by tension between the mining industry and government. Coordinated, cooperative procedures

2. "DIAND Fire Action Zone," *The Stewart Valley Voice*, vol. 13, no. 4, March 7, 2003. In the past, both NND and the Village of Mayo have opposed government decisions to reduce the area around the communities in which a fire would be automatically and actively fought.

had yet to be agreed upon by the two bodies, and therefore much disagreement and confusion existed around the response to the 1971 fire season.

A record of acrimonious correspondence exists between representatives of United Keno Hill Mines Ltd. (UKHM) and those of the Department of Indian Affairs and Northern Development (see Appendix #3). From the federal government's perspective, UKHM provided a strong presence in the region in terms of manpower and heavy equipment and was a primary supplier of firefighting resources in the area; however, there were jurisdictional disagreements. The government expected the mining industry would provide many resources necessary to fight the blaze. It buttressed its claim with the argument that mining was indebted to the government because it used forest resources. UKHM, on the other hand, complained that the government was misusing – and in fact, abusing – both the men and equipment of UKHM, and that it lacked a comprehensive plan of operations to make the firefighting endeavour efficient (Yukon Archives, 1971; see Appendix 2).

The 1990 Janet Lake Blaze

When the memorable Janet Lake blaze (MA 05 fire, see Appendix 3) was ignited by lightning on July 3rd, 1990 the dynamic between private and administrative bodies in the region had changed significantly (Woods, 1990a). For instance, UKHM, having closed its mines in the late 1980s, no longer had a strong presence in the area, a reality that affected the regional response to wildland fires. By 1990, responses to wildland fires were no longer characterized by the same tensions that existed in the early 1970s. The response to the Janet Lake fire demonstrates an access to resources and a level of planning that was non-existent twenty years earlier.

Human effort, dollar expenditures and media coverage are all influenced by the location of the fire and the degree of risk it poses to nearby communities. Over 100 firefighters battled the blaze; half were brought up from Alberta. Heavy equipment, including three bulldozers and water bombers, were also brought in (Woods, 1990a). Close proximity to the town of Mayo and concerns that the fire would "cross power lines, reach the Mayo dam, or possibly make its way to Mayo" governed the intensity with which the fire was fought (Woods, 1990b). Potential impacts to infrastructure and communities were unprecedented, and have not been seen since.

Significant adaptation (suppression) strategies were attempted early on with the MA 05 fire. Machines and firefighters were working the land base adjacent to the fire within a couple days of its ignition (Woods, 1990b). Land-based suppression strategies were coupled with aerial ones. The media reported "[t]he Yukon's water bombers were set to begin fighting the fire at noon today. They will be joined by two Fire cats from British Columbia that are dropping 'long-term retardant' chemicals on areas in front of the fire" (Woods, 1990b). All available resources were implemented for this fire from the outset. A week later, more direct intervention put people and equipment in peril: "The crew working the northern fire-line were forced back by the fire, leaving about 300 metres of hose behind in the blaze. Invisible to helicopter pilots because of the smoke, they had to hike back to Janet Lake … to be airlifted to safety" (Woods, 1990c).

Mitigating factors became just as dangerous as the fire itself as winds began to howl (Woods, 1990c). The local residents found themselves in a precarious state, as the spread and direction of the blaze were very much dependent upon the wind (Woods, 1990b).

The costs associated with fighting the fire were extensive. A week into the blaze $850,000 were already spent. Factoring in the gas taken to fuel the seven helicopters, the federal government was spending about $86,000 a day (Woods, 1990d). In the end, an estimated $3,000,000 was spent on the fire.

Not all impacts of the fire were negative. Never has more money been spent to fight a forest fire in the region as the MA 05 fire, which burned throughout the month of July 1990. Although it cost a lot to fight the fire, what resulted locally was nothing short of an economic stimulus package. According to some, "[w]hat's bad for the forest, can be good for the pocketbook. And when what's bad for the forest is able to pump more than $100,000 a day into this village of 470, the economy lights on fire" (Woods, 1990d).

Spin-offs from wildland fires that burn within close range to communities and valuable infrastructure have fuelled the Yukon's economy in Mayo and elsewhere. "[T]he crew members have to be fed and taken care of in their bush camp. That means a large increase in sales for the area grocer" (Woods, 1990d). There are even opportunities for lasting economic benefits from wildland fires: "[Mayor Hutton]'s hoping that a lot of the money spent by the federal government on the fire during the summer will still be stimulating the village economy in the winter" (Woods, 1990d).

The 1998 Stewart Crossing Fire

The 1998 fire season was a memorable one, both on a local and territorial level. Territorially, it was one of the biggest fire seasons of the century.

On July 2, 1998, lightning sparked a large forest fire (MA 08, see Appendix 1) that came perilously close to the tiny community of Stewart Crossing, and forced residents to evacuate to the village of Mayo. By July 23, a "35,000 hectare fire was raging 8 km southwest from [where] Stewart Crossing [residents lived]," threatening the entire community's property, "suspending transportation through kms 463-580 of the N Klondike highway," and ultimately sending community members out of the area while the fire was most volatile (McNeely, 1998a). High temperatures and strong southerly winds compounded the extent of the danger (McNeely, 1998a). The proximity of the fire to the North Klondike Highway and the small community of Stewart Crossing ultimately led to the evacuation of about "50 residents and 25 recreation vehicle travelers" to the community of Mayo (McNeely, 1998a).

Emergency coordination and preparedness were effective on a local level. Many residents from Stewart Crossing were put up in an emergency shelter at the community hall in Mayo. Mayo Emergency Measures Organization coordinator Margrit Wozniak stated, "if necessary the hall could house up to 50 guests. And if conditions worsened, they could always open up the local school gym" (McNeely, 1998a). Wozniak asked that Stewart Crossing residents "check into the reception areas when they arrive in Mayo so that we know of their whereabouts," illustrating the kind of coordination that went into accommodating Stewart Crossing residents (McNeely, 1998a).

The 1998 Ethel Lake Fire

On July 17 of the same year, a fire began to burn near Ethel Lake, forcing the closure of the territorial campground and threatening First Nation of Na-Cho Nyäk Dun resources. Although the fire size was modest at 800 hectares, it was burning "five kilometres northeast of the Na-Cho Nyak Dun's First Nation outpost" (McNeely, 1998d). This fire led to 20 firefighters being flown up from British Columbia as Yukon emergency firefighters were already working at capacity. Their strategy was to suppress the southern front of the fire to keep it away from the campground and First Nation assets that were located in proximity to the blaze.

The 1998 Fox Lake Fire

The human-caused Fox Lake fire forced delays and closures at different times throughout July 1998, leading to negative impacts on Silver Trail tourism. The three major fires burning on

July 3, 1998 in the territory – Primrose Lake, Haines Junction and Fox Lake – "were all human-caused … so people should use extra caution when camping" (McNeely, 1998b), warned INAC representatives. The Fox Lake fire was "started in a gravel pit, likely by careless campers", according to fire officials (McNeely, 1998b).

The North Klondike Highway was either completely shut down, or restricted by way of pilot car accompaniment, periodically in early July between kilometres 254 to 270 of the highway. "The thickening, acrid smoke proved too risky for public travel" (McNeely, 1998b); this lasted for extensive periods, bringing traffic movement to a complete halt. The long delays in traffic created, among other things, often conflicting reports on the status of the road's navigability. "There was mass confusion about the highway's status all weekend…. [R]adio reports suggested the highway was closed, [but] a highway flagman at the MacPherson subdivision (at the most southern point of the North Klondike Highway) assured motorists the highway ahead was actually open" (McNeely, 1998c).

So unpredictable was the status of the highway, that even crews from the Department of Community Services directing convoys of vehicles through the smoke were unsure of the road's safety. "A pocket of smoke had settled in front of the road so thick, reduced visibility had turned into no visibility…. The convoy made its way back, and drivers were forced to return to their [original] place in line, as they did an hour earlier" (McNeely, 1998c).

The Summer of Yukon Wildland Fires: 1998

By the end of the fire season, the Mayo fire district witnessed "28 fires, 26 … [of which] were lightning caused.… The impact on the landscape was significant. In 1998, 142,375 ha burned in the district."[3] People's movements were affected significantly in light of the Fox Lake burn, keeping travellers from heading north intermittently throughout the month of June. Likewise, the July 22nd Stewart Valley fire greatly delayed movement on the North Klondike Highway and temporarily forced people to evacuate from their homes. All told, 94 persons fought forest fires in the area; 15 fires were fought, while 13 were left to extinguish naturally.[4]

CONCLUSION

An investigation into three notable fire years – 1971, 1990 and 1998 – in the Silver Trail region highlights both the impacts of, and responses to, wildland fires in proximity to communities. The development of a coherent and comprehensive community response plan is ongoing today, and there is significant cooperation between different proponents in the region, including the Village of Mayo, First Nation of Na-Cho Nyäk Dun, and the territorial and federal governments.

The Village of Mayo and First Nation of Na-Cho Nyäk Dun have received funding for local FireSmart programs, having been awarded over $700,000 since the inception of the territorial government funding initiative. Effective planning and coordination between these two bodies characterize both FireSmart programs (Margrit Wozniak, Village of Mayo, pers. comm., 2010).[5] The Mayo district averages 16 fires annually, and most occur during the months of June and July. However, fires have started as early as March and as late as October (McCoy and Burn, 2001).

Wildland fires are a natural part of the landscape, and will remain ever-present during the summer months and shoulder seasons (Don Hutton, Northern Tutchone Zone Manager, pers. comm., 2010). Fires impact the region in numerous and diverse ways, including sending smoke

3. "Mayo Fires," *The Stewart Valley Voice*, December 11, 1998, p. 14.
4. *Ibid.*, p. 14.
5. See Appendix 4 for the breakdown of the Village of Mayo and NND FireSmart funding.

and its related dangers into nearby communities, impeding transportation and blocking roads, affecting regional tourism and impacting financial resources, straining manpower and machinery, possibly catalyzing permafrost thaw, and affecting wildlife habitat. However, fires are also a natural, necessary occurrence for soil regeneration. They can also spur a welcomed boost to a community's economy, and over time, have led to more rigorous development of emergency preparedness and community response.

Some of the questions for those contemplating the impacts climate change may have on forest fires will be: how much hotter will mean temperatures get; how much permafrost will thaw and how will that impact forest health, and communities; and will there likely be more lightning-generating storms in the region over time?

FLOODS

INTRODUCTION

Overview

Peak river flows resulting in spring flooding are a very infrequent occurrence, but nevertheless pose a potential threat to the Mayo townsite on an annual basis. Mayo is situated at the confluence of the Stewart and Mayo rivers, and the main development of the townsite occurs on the floodplain of the Stewart River. The Stewart River, which can be quite menacing during peak flow, has left its mark on the Mayo townsite on several occasions in the past. The townsite of Mayo is currently located on a former delta of the Mayo River, which has also been known to cause flooding of the community. Furthermore, the town of Mayo is downstream from the Mayo River's earthen Wareham Dam. The Mayo B power project, a current initiative by Yukon Energy, will affect the behaviour of the Mayo River and the manner in which flooding may occur downstream from the dam in the future due to the altered river flows.

Regional Mitigations to Flooding

The construction of flood control infrastructure has had a tangible influence in shaping the hydrology of the Mayo region. Some examples of these include large dykes built along the Stewart River, as well as tall dykes, some as high as town buildings, along the last few hundred metres of the Mayo River before it spills into the Stewart River. In short, one cannot help but immediately notice how adaptation to the persistent environmental threat of flooding has given shape to the town's contours.

In June of most years, residents of the Stewart River valley actively monitor the river levels. In July 1992, there was a level of alertness in Mayo: "This year the flood potential is fairly great given the large snowpack that still remains. If the weather gets warm rapidly, the river may rise quickly, with a risk of flooding."[6] A year earlier, *The Stewart Valley Voice* alerted residents about the possibility of flooding. Indian and Northern Affairs Canada's 1991 Yukon Territory Snow Survey Bulletin & Water Supply Forecast was apparently released because of certain warning factors: "Yukon-wide weather for the month of march [*sic*] was warmer than average, snowpack conditions were higher than average, and stream flow is higher than average for almost all major Yukon Rivers." (MacGregor, 1991).

Community responses to flooding are influenced by past experiences and the pervasiveness of flooding potential. For example, the dyke protecting the townsite from the Stewart River was built after the 1936 flood, and upgraded with a couple of additions in height since the original

6. "Flood a Possibility," *The Stewart Valley Voice,* vol. 2, no. 12, June 5, 1992, p. 1.

construction. The latest addition was in 1987, increasing the height of the dyke to a total of 11.2 m (Rick Janowicz, pers. comm., October 2010). Some residents have debated whether the dyke can withstand great volumes of Stewart River water flowing past the higher elevations in town, although some people were relieved to hear the statement made by INAC's Water Resources Division that "the Mayo dike is capable of handling about 200% of average peak volumes" (MacGregor, 1991).

However, the most persistent threat to minor flooding in the community is dependent upon water table levels. "If the river [Stewart or Mayo] level comes up high enough, it will start flooding [the town of] Mayo by raising the water table and flooding low lying areas and basements, even if the water does not come over the dike."[7] In fact, yearly basement flooding is a common occurrence in spring, regardless of whether the dike is breached or not (Bill Leary and Susan Stuart, pers. comm., September 2010).

Stewart River Basin: Snowpack a Major Factor in the River's Peak Flow

There is a relatively strong correlation between the snow depth in the Calumet region (northeast of Mayo, between the towns of Elsa and Keno) in March and April and the water flow of the Stewart River (McCoy and Burn, 2001, p. 36). If unseasonably warm temperatures occur during these months, the risk of flooding is further increased. Large volumes of water from a quickly melting snowpack will affect watersheds and possibly result in higher-than-average peak discharge in the associated rivers and streams. Peak flow periods are normally around the first week of June (MacGregor, 1991).

Ice-Jams

Ice-jams are an issue in the study area. Where and when they may occur in a river system is quite random, and can wreak havoc regardless of temperature or snowpack. Dams on the Mayo River upstream of the townsite are of particular concern. The volume of water flowing by the town is quite dependent on the regulation of discharge at the dams, i.e., if water is released in the winter, it might flow above the ice surface causing irregular flows and breaches of river embankments.

Potential Flooding Impacts: General

The potential impacts from flooding are many and varied. In severe cases, residents have had to abandon their property and rush to higher ground. Loss of life and livelihoods are possible. If homes are spared, often sewage systems are impacted and contamination to properties results. If water systems become contaminated, sicknesses of various types can ensue. Diseases and the prevention of diseases in the form of inoculations often follow. Other infrastructure may also be affected, such as power lines and roads. School closures or damage to buildings are common. Riverbanks erode and shorelines can be left in conditions drastically different than before the flood, leading to costly fortifications in order to prevent further damage to riparian zones. Economic life is likely to change at least in the short term, often resulting in income losses in the private sector as businesses are forced to close due to damages or disruptions in transportation or goods.

According to the Government of Yukon's Emergency Measures Organization's website, "[i]n addition to endangering lives and damaging property, flooding will contaminate drinking water sources, disable septic systems and disrupt power and heating sources" (http://www.community.gov.yk.ca/emo/floodprep.html).

7. "Flood a Possibility," *The Stewart Valley Voice,* vol. 2, no. 12, June 5, 1992, p. 1.

HISTORIC RESPONSES TO FLOODING

OVERVIEW

The biggest flood in the region occurred in 1936. In June, the Stewart River brimmed, marking arguably the single-most severe climate event in the region in the 20th century. Heavy winter snowfalls, coupled with an unseasonably warm period in late spring, brought the worst flood in Mayo's history "[which rose to] ... 16 feet above the usual high water mark" (Aho, 2006, p. 181; Tempelman-Kluit, 2001). The Stewart River flowed freely, flooding the entire town. Though nobody was injured, the extent of property damage was severe. The flood mitigation that has taken place since the event is an indication of the town's dedication to never relive the same disaster. Mayo's town history is inextricably tied to the event, and the dyke that has been constructed and expanded over time is a testament to the danger that flooding poses to the region.

Since the 1936 disaster, a far-less serious flood occurred in 1964. This inundation was the result of classic spring conditions that gave rise to water-level changes: "continuing hot weather caused a rapid runoff of snow-water from the hills."[8] The 1964 flood was the second largest in Mayo's history, though not nearly as severe as the 1936 flood. Nevertheless, various impacts were felt in the region as a consequence.

THE GREAT FLOOD OF 1936

The impacts of the 1936 Mayo flood are well documented. They include interruption of communication with areas outside the community, damaged and/or destroyed infrastructure, blocked transportation, riverbank damage, and loss of important supplies and materials. The flood greatly affected the region's economic state in terms of loss and damage to infrastructure, and some believe the community morale and spiritual state was also greatly affected.

The town sustained a great deal of infrastructure damage from the 1936 flood. "[M]any buildings were knocked off their foundations, floated away or were simply ruined."[9] Almost every building suffered from some degree of damage. "[T]he whole town [was] practically under water. The two churches and the liquor store were the only places on dry land."[10] Communications were cut-off in the flood's aftermath, as the radio station was flooded and out of commission along with most homes and businesses in the town. "Mayo's contact with the world was severed."[11] This put residents in a precarious state, and impeded both the speed and degree to which outside help could reach the community.

All places of business were disrupted or forced to close.[12] "The N.C. and Taylor & Drury stores lost heavily. Reports have it that water came up so rapidly that many barely had time to flee to the hills, leaving behind all their worldly belongings, which were destroyed by water. The total damages are expected to run into staggering figures."[13] Important medical supplies were either lost or destroyed, further exacerbating the emergency situation. Transportation was impeded, and "[t]here was nowhere safe for incoming planes [to land] to bring help or goods."[14] Later,

8. "Flood Waters Hit Dawson, Mayo," *The Whitehorse Star*, vol. 64, no. 45, June 8, 1964, p. 1.

9. *Ibid*., p. 1.

10. "White Pass Plane Delivers Hospital Supplies to Mayo," *The Dawson Weekly News,* vol. 37, no. 135, June 9, 1936.

11. "Mayo Flooded as Stewart River Rises Over an Inch an Hour, Many Homeless," *The Whitehorse Star*, vol. 4, no. 23, June 5, 1936, p. 1.

12. "Town of Mayo Now Covered with Water," *The Dawson Weekly News,* vol. 37, no. 134, June 6, 1936, p. 1.

13. "White Pass Plane Delivers Hospital Supplies to Mayo," *The Dawson Weekly News,* vol. 37, no. 135, June 9, 1936.

14. "Mayo Flooded as Stewart River Rises Over an Inch an Hour, Many Homeless," *The Whitehorse Star*, vol. 4, no. 23, June 5, 1936, p. 1.

after the water receded, it was reported that "roads [were] ruined and out of commission."[15] Because of the lack of communication capabilities immediately following the flood, these supplies were not replaced until after the White Pass plane brought the first news of the flood to the outside world.[16]

The Mayo 'Indian Village' was also hard hit by the flood disaster.

> *All the residents of the Village had to flee to the high hill across the river from which point they watched the flood current cut away 25 feet of the bank, wash away houses and damage property. There was very little that could be done.... The Church at the Village suffered the greatest damage.... The residents of the Village did everything possible to get their possessions on top of cabin roofs or to places of safety…. Every house in the Village was flooded save for a few situated back of the main site.... The Indians are greatly concerned now as to where to build a new village.*[17]

Initial responses by residents in the 'Old Indian Village' involved carrying on without many of their buildings in the short term. "The Indians have been busy since the flood cleaning their homes, fixing them up, salvaging goods and collecting scattered artefacts."[18] Both the church and school were destroyed, forcing church and educational services to move outdoors in the short-term.[19] In addition, the First Nation of Na-Cho Nyäk Dun (NND) traditional clothing was lost in the flood, and along with it, a significant symbol of tradition and memory.[20] The traditional NND clothing was never replaced, and the Old Village never rebuilt. Instead, a new site was built closer to the village of Mayo (Bleiler et al., 2006, p. 87-88).

Conflicting reports exist, however, about the kind of help received in Mayo from outside the community. According to Dr. Aaro E. Aho, "the only outside help was a shipment of chloride of lime to sprinkle on the stagnant pools of water" (Aho, 2006, p. 183). Aho writes about the resiliency and the indomitable spirit in the community in *Hills of Silver*. Medical supplies did eventually arrive, but not in a timely fashion according to Aho.

The resilience of the community was also reported in Dawson media sources. This resilience boosted the "sourdough spirit.... The spirit of the north is again exemplified" by their efforts to "carry on undaunted" after the flood.[21] The Mayo region was praised for its resilience in such trying times.

The reconstruction of infrastructure began almost immediately after the waters had receded. A government crew, under the supervision of the government road foreman for the Mayo district, was called upon to repair or replace damaged and destroyed buildings, build stronger foundations under important structures and rebuild damaged roads. Much heavy equipment was used, including a grader from Keno and government road repair equipment.[22] The 'Old Indian Village' was relocated and moved onto better land, i.e., further away from the riverbanks and the direct threat of future floods.

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15. "Mayo Fire Hall Has Been Repaired," *The Dawson Weekly News,* vol. 37, no. 149, 1936, p. 1.
16. "White Pass Plane Delivers Hospital Supplies to Mayo," *The Dawson Weekly News,* vol. 37, no. 135, June 9, 1936.
17. "Mayo Indian Village is Heavily Damaged by the Recent Flood Disaster," *The Whitehorse Star*, vol. 4, no. 27, July 3, 1936, p. 1.
18. *Ibid*., p. 1.
19. *Ibid*., p. 1.
20. "Mayo Flooded by High Water from the Stewart," *The Dawson Weekly News,* vol. 37, no. 133, June 4, 1936, p. 1.
21. "Dawson and Mayo Show Sourdough Spirit," *The Dawson Weekly News,* vol. 37, no. 148, July 11, 1936, p. 1.
22. "Mayo Fire Hall Has Been Repaired," *The Dawson Weekly News,* vol. 37, no. 149, 1936, p. 1.

The 1964 Flood

A similar suite of issues affected the community during the 1964 flood. For example, road washouts once again impeded the transportation of goods to the community. Bringing food into Mayo during the flood meant that freight trucks were required to make "quick runs into the area whenever the roads [were] open"; goods were also flown in by air during the active phases of flooding.[23] The townsite's homes, the school and other buildings were affected, including basement flooding and sewer lines "backing up into basements."[24] In fact, the school year ended early in 1964 due to health concerns over the basement of the school filling up with contaminated water from sewage run-off. Cleaning up and decontaminating the town was a serious task (Don Hutton, pers. comm., October 2010). Indeed, Dr. Dave Kinloch, a medical health officer noted "the prime concern is not so much high water as is the problem of sanitation once the rivers drop. Raw sewage is backing up in sewers behind the dykes."[25]

In contrast to the 1936 flood, the response to the 1964 flood suggests a good level of preparedness and a certain degree of coordination, indicative of the developing emergency planning already in motion. Rivers throughout the territory were on high water alert in 1964. Residents of Dawson and Mayo were on flood watch during the spring of 1964. Mayo ordered 5,000 sandbags from Dawson in preparation.[26] By June 8th, 85% of Mayo had been evacuated "to higher ground at the airport" as hot weather caused a sudden melt, and the highlands drained quickly. Volunteers from Mayo and Elsa attended to the dykes, sandbagging and undertaking repairs.[27] Other preparations for the flood were evident at various jurisdictional levels throughout the community:

> *The Mayo Flood Control Officer Gordon McIntyre said Yukon Forest Service has pumps and hoses operating.... The community hall is readied for use if necessary for persons that might have to leave their homes. The hall is on higher ground at Mayo and out of immediate danger of becoming surrounded by water.... Workmen have been busy building up the dyke along Front St. and are connecting it with the old dyke along the Mayo River. Seven trucks, a grader and a D8 bulldozer were operating Saturday night tamping down gravel for the dykes.*[28]

Furthermore, goods such as bread and potatoes were being flown in by Canadian Pacific Airlines, and freight trucks continued with deliveries whenever possible.[29] One thousand shots of typhoid inoculations were flown into Mayo from Toronto.[30] The flood response of 1964 received praise from Ottawa, and federal officials who toured the flooded areas stated: "[w]e are very much impressed with the high morale of the people and in the fine way in which Commissioner Gordon Cameron and his staff are handling the situation."[31]

23. "Mayo Fire Hall Has Been Repaired," *The Dawson Weekly News,* vol. 37, no. 149, 1936, p. 1.
24. *Ibid*., p. 1.
25. "Yukon Morale Good in Flooding Areas," *The Whitehorse Star,* vol. 64, no. 47, June 15, 1964, p. 1-2.
26. "River H_2O Rising," *The Whitehorse Star,* vol. 64, no. 44, June 4, 1964, p. 1.
27. "Flood Waters Hit Dawson, Mayo," *The Whitehorse Star*, vol. 64, no. 45, June 8, 1964, p. 1.
28. *Ibid.*, p. 1.
29. *Ibid*., p. 1.
30. "Yukon Morale Good in Flooding Areas," *The Whitehorse Star,* vol. 64, no. 47, June 15, 1964, p. 1-2.
31. *Ibid*., p.1-2.

CONCLUSION

Less than three decades after the 1964 flood, the First Nation of Na-Cho Nyäk Dun became a self-governing First Nation and now co-coordinates with the Village of Mayo in community emergency planning and preparedness for flooding (Margrit Wozniak, pers. comm., September 2010).

Communication resources have obviously improved dramatically since the time of the Great Flood. For example, flood threats are now regularly monitored and data is publicly available through INAC's Yukon Territory Snow Survey Bulletin & Water Supply Forecast. Flood watch in the community is also ongoing. In April of 1991, this monitoring was detailed in the *Stewart Valley Voice*. The article explained the threshold for flooding on the Stewart River, and concluded that Mayo would not likely flood that particular year (Wozniak, 2004, p. 3). Emergency planning for the region was also established in a comprehensive manner in 1992. At that time there was a level of alertness related to flooding during peak discharge of the Stewart River. The Emergency Measures Organization coordinated meetings in Mayo that resulted in the various local authorities committing to specific roles and responsibilities in the event of an emergency.[32] Roles were given out to specific individuals under the hypothetical scenario of a flood:

> *If the water level should continue to rise and appear in danger of breaching the dike, an evacuation would be performed before the town flooded. The Rangers will be responsible for a dike watch to monitor the water level around the clock. If relocation is necessary, Dennis Heasley will coordinate this with people being transferred from J.V. Clark School and Na-Cho Nyak Dun band office to the YTG garage.*[33]

This degree of monitoring and preparedness is in sharp contrast to previous decades, as is evident with the flood of 1936.

The Mayo region has had to contend with two serious floods in its history. Both had similar impacts, but with varying degrees of severity. The top five water levels for peak flow events in Mayo are the following: 1957: 9.9 m; 1961: 9.9 m; 1964: 10.6 m; 1975: 9.1 m; and 1983: 9.5 m (Rick Janowicz, pers. comm., October 2010).

The emergence of coordinated emergency responses to flooding in 1964 ensured that the community was much more prepared in the event of a flood compared to their response in 1936. As a result of these past experiences, a flood preparedness plan has evolved over the decades, especially throughout the 1990s, and is rather comprehensive. In addition, the Mayo dike presently measures 11.2 m, and it would require a much greater volume of water than was seen in 1964, or in the high water-level year of 1983, to breach it. However, annual flooding still occurs, as the water table rises in places, affecting low-lying areas and basements every spring.

PRECIPITATION

INTRODUCTION

Snow and rain are facts of life anywhere in Canada. In the central Yukon, the climate is greatly affected by its many hills and valleys. Bounded by the Wernecke Ranges, the St. Elias and Coast mountains, and the Tintina Trench, the high degree of elevation change from valley floors to mountain peaks, as well as topographic aspect "mainly control the amount of rainfall and snowfall at a site"; this is due to factors such as sunlight and the settling of cold air (Bleiler et al.,

32. "Flood a Possibility," *The Stewart Valley Voice,* vol. 2, no. 12, June 5, 1992, p. 1.
33. *Ibid.*, p. 1. See complete breakdown of roles and emergency plan in Appendix 5.

2006, p. 4-5). As a result, the amount of precipitation can be highly variable within this region. For example, Keno Hill, situated roughly 60 km east of Mayo and at a higher elevation, receives a larger proportion of its precipitation as snow compared to Mayo, at 62% and 42%, respectively (Bleiler et al., 2006, p. 19). However, throughout the entire region, there has been an overall increase in winter precipitation over the last century. In fact, precipitation as snowfall has experienced an average decadal increase of 10.4 cm since 1927 (McCoy and Burn, 2001, p. vii). This has resulted in a deeper snowpack during the spring season (McCoy and Burn, 2001, p. vii). A continuing increase in snowfall would have various impacts on the region, and is thus an important environmental stress to investigate.

Snow accumulation plays an important role in the Silver Trail area, and is "as important as rainfall for the boreal ecosystem. Snow cover is also important for winter travel, the survival of hibernating animals, and the protection of town pipes and sewers from freezing" (Bleiler et al., 2006, p. 19).

However, increased snow is not without its negative consequences. Deep snow accumulation throughout the winter, resulting in a deep snowpack come spring, can signal an increased threat of flooding, since the "snowmelt from the high ground is the source of floodwater in the major rivers in late May and June" (Bleiler et al., 2006, p. 19). Therefore, snow accumulation has been a perennial concern for the region, as it "could very easily cause flood conditions after the breakup [in] spring."[34] Snow can lead to power shortages, which can be dangerous during the long, cold winters. While ice in ditches is often the main culprit of the area's somewhat frequent blackouts, snowdrifts have also played a role in the past.[35]

HISTORIC RESPONSES TO PRECIPITATION

Heavy snowfall can tax financial and human resources, "caus[ing] plenty of extra work for the government road crews and for ... the ... streets foreman."[36] Furthermore, the livelihood of many in the area is affected by climate and weather, and heavy snowfall has historically proven to be "a drawback for woodchoppers, trappers, hunters and transportation men in the district," as experienced in the winter of 1948-1949 when snowfall had already been recorded at 41 inches by January.[37]

Decreased mobility and highway interruptions are additional consequences of heavy snowfall and accumulation. Travelling around town is often restricted in deep snow conditions, yet it has even greater implications for those living outside of the communities, who may not be able to drive to work or school, or into town for supplies.[38] The highways throughout the region may also be blocked or closed for extended periods of time, especially if high winds are coupled with snow to produce dangerous snowdrifts and whiteouts. Indeed, this created much concern in 1952, as delivery trucks were unable to enter residential areas. One newspaper noted that "[l]ocal stores are without fresh produce of any description, yeast is not procurable and is starting to cause a shortage of bakery bread. One store has beefsteaks only. Cigarettes and tobacco are limited to a very few brands and very little of them."[39]

34. "41 Inches of Snow Recorded this Winter," *The Dawson Weekly News*, vol. 50, no. 23, January 13, 1949, p. 1.
35. "Power Shortage," *The Dawson Weekly News*, vol. 55, no. 12, October 29, 1953, p. 1.
36. "Stormy Weather Brings Mild Weather Yukon," *The Dawson Weekly News*, vol. 40, no. 23, January 13, 1949, p. 1.
37. "41 Inches of Snow Recorded this Winter," *The Dawson Weekly News*, vol. 50, no. 23, January 13, 1949, p. 1.
38. "Heavy Snowfall Ushers in 1947," *The Dawson Weekly News,* vol. 48, no. 24, January 9, 1947, p. 1.
39. "Winter Roads Blocked by Heavy Drifts," *The Dawson Weekly News*, vol. 53, no. 36, January 24, 1952, p. 1.

CONCLUSION

Despite the increasing snowfall throughout the 20th century in the Silver Trail region, residents are accustomed to variable and often trying winter conditions, and are adaptable to future changes as long as they continue to have access to proper resources and equipment for snow removal. With high spring temperatures and much remaining snow on the ground, the streets are often “ploughed hurriedly when they threaten to become quagmires from the fast melting snow. All over town, there are small ditches on the street and in yards to drain off water.”[40] The community in Mayo works “very hard to keep its roads, driveways and roofs cleared,” and many volunteers help clear and shovel the deep snow (Wozniak, 2004). This will become increasingly important if the trend of increased precipitation as snow continues in the coming years.

Volunteerism and a sense of communal benevolence have played a role in the community’s response to increased snowfall and accumulation. A woman was trapped in her remote cabin and subsequently rescued by her Mayo campus classmates in the winter of 2004. They cut through the snow in a Hummer and shovelled her out, allowing her to get to school (Williams et al., 2004).

TEMPERATURE

INTRODUCTION

The central Yukon boasts the largest climate variability in Canada, and Mayo rightfully claims to be the hottest and coldest place – recording the greatest temperature range (98.3°C) in the country. The many hills and valleys that characterize the landscape control much of the climate, and the “settling of cold air in the valley bottoms leads to the coldest temperatures regularly recorded in North America” (McCoy and Burn, 2001, p. vii). Thus, residents of the Silver Trail region are accustomed to extreme cold, sweltering heat, and sudden dramatic shifts in temperatures.

Changes in temperature patterns have been two-fold in this area: a general gradual increase in temperature, and more extreme temperature variability. First, comparative temperature measurements between weather stations in northwest Canada indicate “a consistent pattern of climate warming during the latter years of the twentieth century” in this area (McCoy and Burn, 2001, p. 12). While this warming is most apparent in spring, there are indications of statistically significant temperature increases in summer and/or winter as well (McCoy and Burn, 2001, p. 12). Second, “[t]here has been noticeable climate variability in ... [recent decades], with, for example, and unusually warm winter in 2000-2001, a wet summer in 2000, and little snow in winter 1998-1999” (McCoy and Burn, 2001, p. vii). Although variability characterizes all seasons in this region, this is most extreme during the winter season (McCoy and Burn, 2001, p. viii).

HISTORIC RESPONSES TO TEMPERATURE

Northern winters consistently bring extreme cold to its residents. Winter conditions are a perennial subject in local newspapers, and often the same concerns over wood supplies, fuel consumption, and reduced mobility and outdoor activities appear in media articles. Cold is an environmental stress that occurs every winter season, and one in which residents can rely on each year.

40. “Spring Suddenly Sprung at Mayo,” *The Whitehorse Star*, April 18, 1963, p. 8.

However, there have been times when severe cold has become a more serious threat to residents and communities. In February 1947, the region experienced its coldest temperature on record of - 62.2°C in Mayo, and legitimate concerns were raised during this "bitter cold wave" that lasted three weeks.[41] Schools and businesses were closed, "partly owing to the extreme cold, partly to conserve fuel supplies." The area experienced a shortage of wood, a dangerous situation since everyone at that time relied on wood as their main source of heat. One newspaper article warned, "[w]ood dealers have completely sold out every available surplus on hand while in this weather it is impractical for cat and trucks to go out to wood camps to bring in additional supplies."[42] Still today, elders remember their experiences of 1947, including being stuck indoors in a hunting cabin in isolation with a dwindling supply of firewood, waiting for warmer weather to return and allow for safe travel (NND Elder, Pat Van Bibber, pers. comm., September 2010). Most in the region, in fact, "remain[ed] in complete isolation as long as the cold spell persist[ed]."[43]

The following year, in 1948, a severe cold spell blew across the Silver Trail region, due to "a large mass of cold air from the Aleutians meeting a similar cold air mass" and blanketing the area.[44] Although temperatures did not reach the severity of the previous winter, the cold did "curtail activities around town," and "cut most activities to a minimum and kept householders and business people busy stoking their fires."[45] Perhaps due to the experiences of 1947, however, the communities were well stocked with wood, and there were no shortages throughout the cold wave.[46]

In October 1982, the cold spell came early to central Yukon, surprising unprepared residents and raising some concerns. The "frigid weather penetrated everything from gas tanks to water reservoirs, leaving a trail of frozen pipes and frozen planes behind it."[47] While residents expect cold winters, plumbing and towing companies state that people are usually not ready for it, and 1982 was extreme due to its early arrival.[48]

Extreme cold is a reliable norm in this area, although the winters have become milder over time. Under severe winter conditions and extreme cold temperatures, the community response is that "[p]eople are doing the best they can – one helping the other to the best of his or her ability."[49] However, seldom today are schools and business closed due to temperature extremes, and frozen pipes, oil or gas problems, or periods of complete isolation are infrequent.

CONCLUSION

In the future, the residents of this area are more likely to face problems brought on by weather variability, and already they are beginning to notice this pattern. One local article noted in 2007 "[t]he cold mornings during the past week have been breaking records set back in the 1930s for

41. "Wood Situation Acute in Dawson as Temperatures Drop to Record Breaking New Levels for Yukon," *The Dawson Weekly News,* February 6, 1947, p. 1.
42. *Ibid.*, p. 1.
43. "Wood Situation Acute in Dawson as Temperatures Drop to Record Breaking New Levels for Yukon," *The Dawson Weekly News,* February 6, 1947, p. 1.
44. "Break Foreseen in Prolonged Cold Wave," *The Dawson Weekly News*, vol. 50, no. 19, Dec 9, 1948.
45. *Ibid.*
46. *Ibid.*
47. "Temperature Drop Shock," *The Whitehorse Star,* October 28, 1982, p. 3.
48. *Ibid.*, p.3.
49. "Wood Situation Acute in Dawson as Temperatures Drop to Record Breaking New Levels for Yukon," *The Dawson Weekly News,* February 6, 1947, p. 1.

these dates. The extremes we've been getting – a record cold November followed by very warm average temperatures from December through mid-February and now record low temperatures again – are…. predicted by climate change models. Not only is an overall warming trend predicted, but we're supposed to get more extreme swings in weather as well" (O'Donoghue, 2007).

PERMAFROST

INTRODUCTION

Discussions about permafrost will likely be more pertinent in upcoming community meetings about climate change adaptation. Permafrost thaw, while a potentially insidious environmental threat, is characterized by subtle, gradual changes over time, and is in contrast to more palpable and dramatic events such as wildland fires or floods. Thus, there is little reference to permafrost in historical sources, and even less in terms of documented environmental events. However, any changes to permafrost in the region are very significant, and it is imperative that it be monitored and included in any discussion related to climate change.

Central Yukon is located in a discontinuous permafrost zone, where permafrost underlies 50-90% of the landscape. Permafrost, or perennially frozen ground, gives stability to the soil, slopes, and riverbanks. Many landforms in central Yukon have underlying permafrost with an active layer that thaws in the summer and freezes in the winter, creating seasonal ground shifts. Unusually warm summer temperatures can deepen the active layer causing ground subsidence. Climate change may exacerbate this phenomenon, as "[a] continual warming of the active layer destabilizes the ground and any infrastructure it supports" (Beacom, 2006). Landslides become more probable if permafrost thaw occurs on slopes. "The climatic control is governed by the mountains in the region, while the important surface conditions are mainly the dryness and shading of the site in summer and the snow depth in winter" (Bleiler, et al., 2006, p.22).

The subject of permafrost thaw has come up most in the context of wildland fires. When fires burn large swaths of land, the groundcover is no longer shaded by any kind of canopy, thereby allowing proportionately more solar radiation to reach the ground surface. Burns also affect large mammal populations; e.g., caribou are driven out as their food source of lichen is destroyed by fire and the dramatic increase in sun exposure prevents regrowth. However, moose are likely to move into the area to feed in the newly opened spaces. The effects of forest fires on permafrost are complex and can have significant impacts for fish and wildlife, and thus are also a concern for people.

PERMAFROST AND RESEARCH

An example of permafrost thaw and subsequent ground subsidence is a 'drunken forest', which occurs along the North Klondike Highway between Pelly and Stewart Crossing. This tract of trees is rooted in shifty ground, and trees protrude every which way except towards the sky (Don Hutton, pers. comm., October 22, 2010). Areas like these may multiply as climate change affects permafrost in the region.

In the winter, the snowpack insulates the ground below, retaining heat collected from the summer sun. According to Chris Burn, permafrost specialist, this effect is magnified if there is a heavy snowpack (Beacom, 2006). Therefore, snowfall and accumulation must be monitored and assessed in relation to its impact on permafrost thaw.

In discussions with Mayo residents, it was mentioned that large sections of riverbank have fallen into the Stewart River, potentially due to unprecedented levels of permafrost thaw (Bill Leary, pers. comm., September 2010).

As mean annual temperatures continue to rise, impacts to the ground surface eventually penetrate downward through the active layer and to the underlying permafrost. When this occurs, thawing permafrost may release carbon dioxide and water trapped in the form of ice. The thawing of ice-rich permafrost could potentially increase the odds of flooding and the risks associated with it, such as damaging sewage systems and resulting in basements filling up with contaminated water. Other types of infrastructure, particularly subterranean systems, are likely to be affected as the ground shifts and twists, and damages whatever is in the vicinity.

Dr. Chris Burn, Professor and NSERC Northern Research Chair, Carleton University, has been studying permafrost in central Yukon for over 20 years. His work has brought a level of awareness to the region that might not have otherwise been there. Burn meets regularly with local officials and writes newsletters for the *Stewart Valley Voice* about his studies and about how permafrost is behaving in the area. Burn writes: “This year we obtained the first data from Canada’s western Arctic which shows that the permafrost is indeed warming up…. Over the last 30 years while the air temperature of the region has warmed by about 2.5°C, the permafrost has warmed by about 1.5°C” (Chris Burn, pers. comm., 2011). Burn believes denser snowpacks provide part of the explanation, as they insulate the ground from cold winter temperatures (Bleiler et al., 2006).

CONCLUSION

The prospect of permafrost thawing in the area is one that residents are likely not prepared for, and such a thing is difficult to undertake preventative measures against. It is difficult to gauge at what moment in time thawing permafrost will affect infrastructure such as buildings, schools or the town’s protective dike. Shifting ground due to thawing permafrost could occur under the Mayo River delta or under the airport. Landslides related to permafrost thaw due to wildland fires are well documented in Yukon (Burn, 1998; Huscroft et al., 2004; Lipovsky and Huscroft, 2007; Lipovsky et al., 2008). However, unless dramatic changes occur in mean annual temperature trends, it is not a question of if, but rather of when, the Stewart River valley, particularly the townsite of Mayo, will be impacted. There is a critical need to continue discussions with permafrost specialists such as Dr. Chris Burn, while further advancing our baseline knowledge on the characteristics of permafrost as it relates to climate change.

ENVIRONMENTAL STRESSES AND IMPACTS TO STEWART VALLEY ASSETS

INTRODUCTION

Residents, governments and the private sector living and working in the region may face new challenges if climate-change impacts are significant. Permafrost thaw or loss, especially in areas that are heavily developed, could have serious consequences. Climate change is predicted to cause greater weather variability almost everywhere. If mean annual temperatures rise, how will the wild spaces in the study area be affected? Will there be more wildland fires? Perhaps the Silver Trail will see more lightning strikes in the future, resulting in more fires that could potentially threaten the mines that are set to become economic drivers locally and territorially. If permafrost does start thawing under large tracts of land, how will today’s infrastructure be affected and how will planning for future developments change?

INCREASED POTENTIAL FOR WILDLAND FIRES, EXTREME WEATHER AND THAWING PERMAFROST IN THE CONTEXT OF REGIONAL HYDROELECTRIC PROJECTS, TRANSMISSION LINES AND MINING ACTIVITIES

Flooding Risks

As previously suggested, the persistent threat to Mayo residents of flooding in the town are increased by the presence of the upstream Wareham Dam and Mayo B projects. The Wareham structure was built in 1951 at a cost of $500,000 and was intended to be in use for only 15 years (see http://www.yukonenergy.ca/services/facilities/hydro/). Wareham Dam was originally constructed to supply the mining sector in Elsa and Keno with electricity. Now it mostly serves the needs of the town of Mayo. Some town residents question the structural integrity of the Wareham Dam over the long term. If the dam should fail, the town of Mayo would be greatly impacted. How might changes to permafrost affect this infrastructure and future development in these project areas? The Mayo B project, situated only 3 km downstream from Wareham Dam, will only compound the worries expressed by some residents who do not feel comfortable living downstream from a dam (see http://www.yukonenergy.ca/about/projects/mayob/).

Transmission-Line Risks

In 2003, a Mayo-Dawson transmission line was built, covering 232 km at a cost of more than $35 million, to supply energy to Dawson.[50] The transmission line runs through areas that are prone to wildland fires. Although the type of threats to the line are the same at any given time, could an increase in lightning strikes in the future, coupled with higher average summer temperatures, put the line at increased risk?

Increased Potential for Blackouts

Blackouts can be the result of lightning strikes and other weather factors. Sometimes, however, equipment failure is the reason. While Mayo residents have experienced many blackouts throughout its history, 2007 was an exceptionally striking year, due to “[t]he heavy snow in the winter and the high number of lightning strikes in the summer ... around Mayo.” In 2008, there were another 23 unplanned outages, “some of which were due to lightning strikes in the summer.”[51] The impacts from blackouts can be especially challenging in cold weather if hydro is relied upon for essentials such as heating. Businesses often have to suspend activities, potentially hurting revenues.[52] Mitigation takes time and money, and many residents do not have backup power. Years like 2007 could become more typical if mean annual temperatures rise, winter snowpack increases, and summer storms become more frequent and severe.

Return of Mining Activity in the Region Coincides with Changing Climate

Mining and exploration has been the most significant economic driver in the region over the last century, particularly when there is an operational mine. It has provided benefits such as employment opportunities, created new infrastructure, and shaped the communities along the Silver Trail that we know today.

However, impacts on adjacent environments from mining have at times been deleterious. Perhaps the most extreme example of mining’s impact in creating environmental stresses in the area was a documented effluent spill at Elsa. In the late 1970s, United Keno Hill Mines was taken to court when a “20-30 foot hole [opened] in the retaining dike allowing the partially treated

50. “Energy Corporation Should Follow Rules,” *The Yukon News*, October 12, 2007.

51. “Why is the Yukon Often Left in the Dark? Asks Critics,” *The Yukon News*, August 27, 2007.

52. *Ibid*.

effluent to spill out into Flat Creek, the South McQuesten River and eventually, the Stewart River."[53] This may have been due to "shifting soil as the result of melting permafrost."[54] When the incident occurred, salmon were "just completing spawning in the McQuesten River, and grayling were also to be found in the river."[55] How will effluent from mines in the region be contained? Are mines in the region part of the discussion about potential impacts brought on by a changing climate?

The Yukon Conservation Society, based in Whitehorse and created in 1968, has acted as a watchdog for the mining sector. Among some of the work this organization does, it has historically lobbied the Yukon Water Board to "take [mining] compan[ies] to court to force [them] to clean up the toxic tailing and other mines wastes [they] left behind. The fear is that heavy metals from the mine site could leach into the river and poison fish and other wildlife."[56]

Many fires occurred at the Elsa and Keno mines throughout their operation. Impacts from these are varied and include emissions from the fire, as well as extra transportation costs and use of fuel associated with the repair of collateral damages. Rebuilding damaged infrastructure at the mine would also require shipment of materials which has associated transportation impacts to the environment – from site of origin to destination.

Finally, forest resources surrounding the mine sites were often abused. Wood is used for construction, heating, and is cleared anytime a land use is designated where 'overburden' exists.

CONCLUSION

Can stakeholders be assured that the mining sector will plan for changes that are likely to affect the land and water resources of the region? Cleared land means increased summer insolation. A denser snowpack is predicted to accumulate in these areas in the winter, thereby insulating the ground and retaining the increased summer heat. This may result in permafrost thaw and subsidence, which would have negative consequences for adjacent infrastructure. The likelihood of warmer temperatures, more lightning strikes and more wildland fires highlights the need to carry on with emergency response planning in the area, and to develop new projects with a heightened level of awareness for the surrounding environment.

OVERALL CONCLUSIONS

Local guide and elder Jimmy Johnny has noted some significant changes in central Yukon throughout his lifetime of being out on the land. Johnny said that he has noticed "the trails and hillsides in the region melting, lichen – a primary food source for caribou – turning grey, Bonnet Plume and Snake rivers drying up and beavers leaving the area" (Keevil, 2007).

Permafrost and climate change expert Dr. Chris Burn, along with the researchers that have accompanied him to Mayo, have generated dialogue and awareness in the area (Beacom, 2006).

While forest fires and floods constitute the two main threats in the region, a discussion of the area's environmental history must also consider the impacts that temperature and precipitation have had in the past. All of these stresses have affected the communities in different ways, and have led to the development of varying responses. Furthermore, since permafrost underlies

53. "Elsa Spill Test Results Beginning to Come Back," *The Northern Times*, September 14, 1978.

54. "Keno Hill in Court," *The Whitehorse* Star, vol. 79, no. 199, October 16, 1979. "Keno Spill Bigger than Announced," *The Northern Times*, August 31, 1978. (quote taken from the latter article)

55. "Elsa Spill Test Results Beginning to Come Back," *The Northern Times*, September 14, 1978.

56. "Clean Up Abandoned Mine Site, says Society," *The Yukon News,* June 8, 1990.

more than 50% of the region, and is essential to the stability of vegetation and infrastructure, it will most likely become a more important component of future discussions on climate change.

The Silver Trail's economic and institutional reality has changed considerably in the last twenty years, greatly affecting how communities in the region respond to environmental stresses. Presently, there are several highly functioning institutional/governmental bodies in the area that coordinate efforts collaboratively. In the past, independents, the private sector, and a relatively removed federal government were the players responding to emergencies in the region. The establishment of the self-governing First Nation of Na-Cho Nyäk Dun in the area has greatly added to the institutional capacity of the area, and along with it, the ability to deliver emergency response as a body, working in concert with municipal, territorial and some federal bodies, all with their respective roles and resources.

A key to the future success of emergency response and preparedness will be the ability of these organizations to include and integrate private interests into regional considerations. Mining activity will most likely be affected by changes to the land base, and may create new environmental stresses due to their impact on surrounding forest resources, fish and wildlife, air and water.

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Pat Van Bibber, First Nation of Na-Cho Nyäk Dun Elder, September 2010.

Margrit Wozniak, Chief Administrator of the Village of Mayo, September 2010.

Don Hutton, Northern Tutchone Zone Manager, Wildland Fire Management, October 2010.

Richard Janowicz, Manager, Hydrology, Water Resources Branch, Department of Environment, Government of Yukon, October 2010.

Bill Leary, Senior Natural Resources Officer for Mayo Mining Inspections Office, Energy, Mines and Resources, Government of Yukon, September 2010.

Susan Stuart, Local Coordinator for the Northern Climate ExChange's Mayo Climate Change Adaptation Project, September 2010.

A HISTORY OF ENVIRONMENTAL STRESSES: APPENDIX 1 - WILFIRES OF MAYO

Number	Fire Year	Fire ID#	Hectares Burned
1	2009	MA 01	52
2	2009	MA 02	184
3	2006	MA 10	62
4	2005	MA 01	5496
5	2004	MA 37	3025
6	2004	MA 09	3025
7	2001	MA 02	34
8	1999	MA 07	4042
9	1998	MA 08	74 529
10	1998	MA 07	7070
11	1998	MA 11	9028
12	1998	MA 23	1101
13	1997	MA 04	168
14	1995	MA 04	723
15	1995	MA 07	763
16	1994	MA 09	1001
17	1994	MA 36	663
18	1994	MA 23	5192
19	1994	MA 15	2179
20	1994	MA 07	1326
21	1993	MA 07	979
22	1993	MA 05	735
23	1990	MA 05	18 342
24	1989	MA 18	3776
25	1989	MA 17	667
26	1989	MA 14	1866
27	1986	MA 04	3369
28	1983	MA 41	147
29	1983	MA 03	852

Number	Fire Year	Fire ID#	Hectares Burned
30	1982	MA 18	4855
31	1982	MA 17	18 276
32	1972	MA 06	11 010
33	1972	MA 08	4826
34	1972	MA 20	974
35	1972	MA 15	3505
36	1972	MA 05	676
37	1971	MA 03	707
38	1971	MA 05	364
39	1971	MA 12	9710
40	1969	MA 10	2801
41	1968	MA 09	275
42	1967	MA 09	15 183
43	1967	MA 10	6056
44	1965	MA 03	513
45	1958	YT 28	2201
46	1957	YT 43	4178
47	1955	YT 60	11 388
48	1955	YT 49	899
49	1955	YT 12	2435
50	1955	YT 34	20 284
51	1954	YT 12	134
52	1952	YT 11	234
53	1952	YT 10	24 749
54	1951	YT 39	3879
55	1951	YT 51	40 178
56	1951	YT 14	41
57	1950	YT 26	262
58	1950	YT 21	25 897

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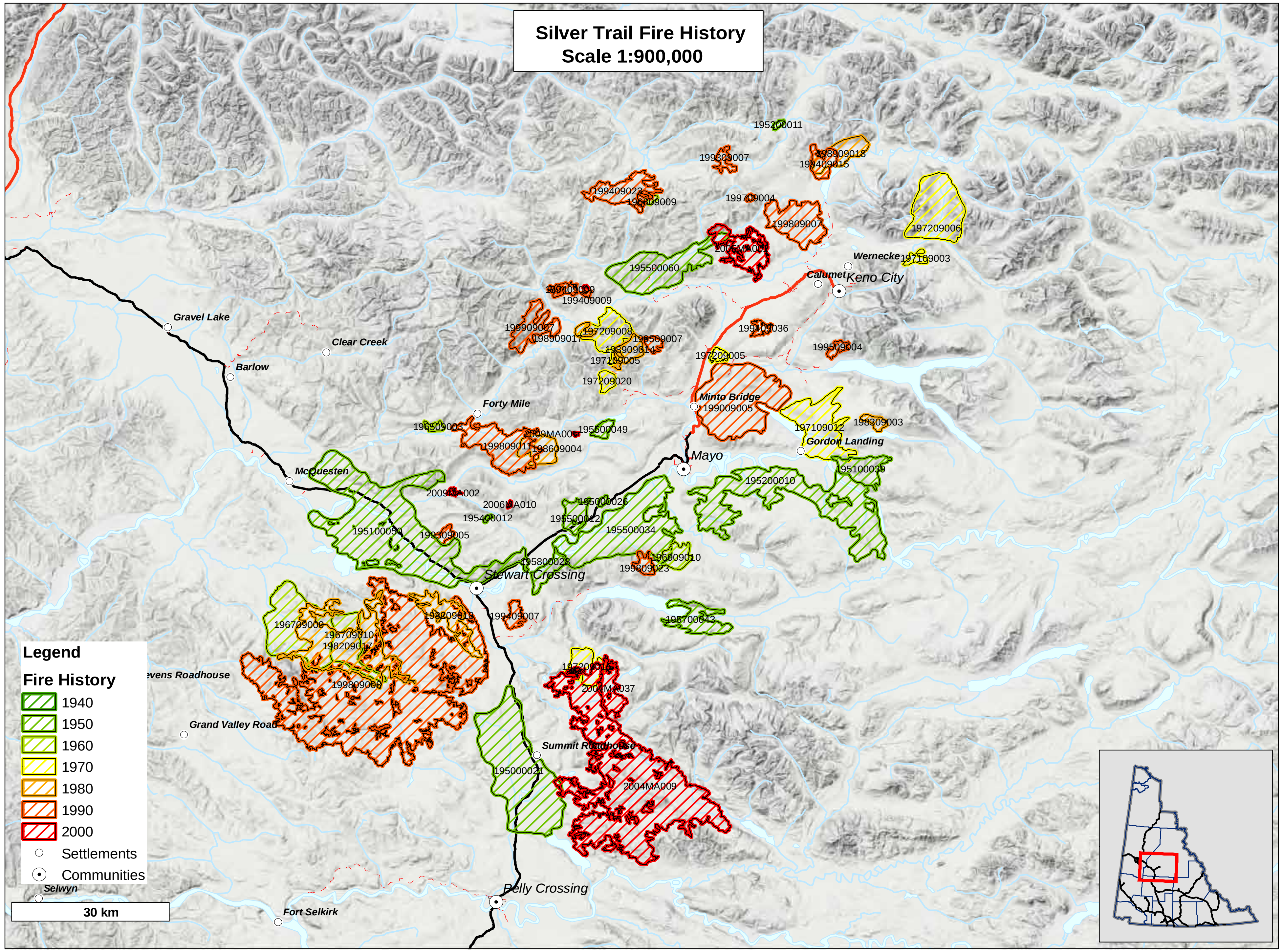
A History of Environmental Stresses: Appendix 2 - Silver Trail Fire History Map



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A History of Environmental Stresses: Appendix 3 - Northern Affairs - United Keno Hill Mines Correspondence, 1971

Department of Indian Affairs and Northern Development

CANADA

Ministère des Affaires indiennes et du Nord canadien

Yukon Forest Service
Box 100,
Mayo, Y.T.

Mine Manager, J.E. Ashton,
United Keno Hill Mines,
Elsa, Yukon

July 13, 1971

1-1-1

Dear Sir:

The Mayo District is experiencing a severe (and normal) fire season which is necessitating the services of numerous fire-fighting personnel. The source of manpower in the district is limited, with the exception of the Keno Hill Mine. We have been using several of your employees whom we consider valuable to our efforts, but to date have not deliberately requested the services of additional mine personnel. Also, we recently requested and reluctantly received the use of several catapillars, which proved to be very helpful to us. In both instances we have received a negative feedback from you.

Although we realized that you are running a mining operation we feel that it is necessary to point out once again that your operation depends a great deal upon the forest resource. Also, your community like many others in the Yukon , is vulnerable to damage in one form or another by wild fires.

It is our opinion that your company should play a more active role in the fighting of forest fires, especially those in the vicinity of Elsa. To this end we appreciate your co-operation in the following:

A History of Environmental Stresses: Appendix 3 - Northern Affairs - United Keno Hill Mines Correspondence, 1971, *continued*.

1) Organizing several fire-fighting crews who would be available upon request - of great importance is the ~~txin~~ training of reliable personnel at the crew-boss and straw-boss level.

2) Establishing an equipment cache which can be used by your employees in emergency fire-fighting situations.

3) Making company equipment available under emergency conditions.

4) Discussing our policy regarding conscription of mine personnel.

With a program of this sort, we feel many of the recent misunderstandings can be avoided. Of equal importance would be a letter to headquatters in Whitehorse, outling your feelings toward fores fire-fighting. The more feedback we get from individuals or companies regarding the protection of forests and communities, the more opportunity we may have to increase fire-fighting potential. We assume, of course, that your company is more than willing to accept a larger and more effective government fire-fighting agency.

Yours truly,

Ranger, J.B. Klassen

J.B.K: em

A History of Environmental Stresses: Appendix 3 - Northern Affairs - United Keno Hill Mines Correspondence, 1971, *continued*.

fires - resources.

United Keno Hill Mines Limited
ELSA, YUKON

Executive Offices
21st Floor, 7 King Street East
Toronto 1, Ontario

Mine Office
Elsa, Yukon

16th July, 1971

Mr. J. B. Klassen, Ranger
Yukon Forest Service
P. O. Box 100
Mayo, Y. T.

Dear Mr. Klassen:

This will acknowledge your letter dated July 13th.

To clear up several areas in your letter I will list the events which took place during the last three weeks involving your District Office and the United Keno Hill Mines.

Sunday, June 20th
Mr. B. Mills, the Elsa Fire Chief, phoned to tell you that a forest fire had broken out in the McQuesten valley. You requested, and Mr. Mills gathered a group of ten men to fight the fire. A helicopter was sent out to assist in fighting the fire but unfortunately it crashed. The pilot and the two passengers, who were employees of ours, were not seriously hurt. The fire pump you sent out would not work. You have since told me it had a grounded ignition system caused by a faulty stop button and that you have now repaired it. A rain storm came up and extinguished the fire and you released the men with the exception of an assayer who had no previous experience in fighting forest-fires, whom you took with you to Mayo.

Wednesday, June 23rd
At 2:00 pm you phoned the Mine and asked for a Cat to be used for fighting a forest-fire at Janet Lake. The Cat was brought in from the McQuesten valley where it was on exploration work, was serviced, loaded onto a low-boy and delivered to the rendezvous point designated by you on the Mayo Lake road complete with fuel and crews for round-the-clock operation. All this within one hour of your phone call.

... 2

A HISTORY OF ENVIRONMENTAL STRESSES: APPENDIX 3 - NORTHERN AFFAIRS - UNITED KENO HILL MINES CORRESPONDENCE, 1971, *continued*.

2.

It has never been explained why you let this Cat sit for seven hours before directing it to where you wanted it to work.

At 10:30 pm you again called and asked for a second Cat. Again, within an hour, the second Cat was brought in, serviced, loaded on a low-boy, provided with around-the-clock operators, and was on its way to the fire. This second Cat does not belong to us and is on a rental agreement which limits the use and the operating hours for the unit.

The two United Keno Hill Cats were the only ones that operated continuously during the Janet Lake fire. Part of their operating time was spent in getting the Forestry Cat and the Dressen Cat out of difficulties and with our operators repairing breakdowns on the other Cats.

Saturday, July 26th 6:00 pm
The first United Keno Hill Cat released and returned to the mine.

Monday, July 28th
The second Cat which was on rental to U. K. H. M. was released and returned to the Mine.

During the time the United Keno Hill crews and Cats were out fighting the Janet Lake fire they only received one meal from the Forestry Service. Had it not been for the back-up of the United Keno Hill men with our pick-up trucks the crews would have been in bad shape.

As shown above, you have received the men and equipment in the earliest possible time after you have asked for them. Writing letters such as you have done is a peculiar way of enlisting cooperation from anyone.

Reviewing your proposals for improving your fire fighting we will deal with each one in turn.

.... 3

A History of Environmental Stresses: Appendix 3 - Northern Affairs - United Keno Hill Mines Correspondence, 1971, *continued*.

3.

1 Organizing fire-fighting crews.
This is the first you have mentioned this proposal. We would like to see what you have done along these lines in Mayo and if this looks suitable it could be used as a model for a similar program in Elsa.

2 Establishing an equipment cache.
This could be done at the mine during the fire season and it would ensure that the equipment would be servicable and ready for use in an emergency.

3 Making Company equipment available in an emergency.
After using two of our Cats, a low-boy and tractor and several pick-up trucks it is obvious that this equipment is available with our drivers under conditions of emergency.

4 Discussing your policy on company personnel.
When you formulate a policy on this matter, we will be ready to discuss it with you.

The suggestion that this be referred to whitehorse is well taken and to that end I am sending copies of your letter along with copies of my reply to you to Commissioner James Smith and to Mr. Taylor the Chief Ranger.

Yours very truly

United Keno Hill Mines Limited

J E Ashton

J. E. Ashton
Mine Manager

A HISTORY OF ENVIRONMENTAL STRESSES: APPENDIX 4 - FIRESMART FUNDING, VILLAGE OF MAYO AND FIRST NATION OF NA-CHO NYÄK DUN, 2006-2010

Project Name	Funding Requested	Funding Approved
2006 Mayo FireSmart Plan	$56,384	$38,038
Village Prescription	$47,500	$47,500
Na-Cho Nyak Dun FireSmart Project	$52,500	$50,000
NND FireSmart	$58,813	$30,000
Na-Cho Nyak Dun First Nation	$35,570	$30,000
Na-Cho Nyak Dun FireSmart 2010	$48,178	$30,400
Village FireSmart Project	$27,795	$26,600
Village of Mayo	$27,065	$28,817
NND Community Fire Action Plan	$45,439	$45,439
Village of Mayo	$55,584	$45,450
Na-Cho Nyak Dun FireSmart 2009	$50,093	$41,600
Mayo 2007 FireSmart	$40,216	$29,200
Village of Mayo FireSmart 2008	$36,178	$30,000
Village of Mayo FireSmart 2009	$36,899	$41,600
Village of Mayo FireSmart 2010	$42,189	$30,400
NND	$60,000	$50,198
Na-Cho Nyak Dun FireSmart Project	$30,323	$30,232
NND	$35,569	$29,200
Village of Mayo FireSmart, Phase 3	$65,089	$60,000
Totals	$851,384	$714,674

APPENDIX B - MINING AND CLIMATE CHANGE IN THE MAYO REGION

Based extensively on Pearce, T., Ford, J., Prno, J. and Duerden, F., 2009. Climate Change and Canadian Mining: Opportunities for Adaptation. Prepared by ArcticNorth Consulting for The David Suzuki Foundation, Ottawa, ON, 150 p.

INTRODUCTION AND BACKGROUND

Mining has been a feature of the Mayo region landscape for over a century. Along with wildlife harvesting, government and tourism, the mining industry is an essential component of the regional economy, and is strongly associated with regional identity. Placer mining has been active on the creeks north of Mayo since the early twentieth century, but by 1920, after the discovery of silver-lead-zinc deposits in the Keno Hill area, hardrock mining predominated and Keno, Elsa and the mining camp at Wernecke emerged as mining communities. The well being of the mining industry reflected the vagaries of the global economy and the associated fluctuations in mineral prices. Mining in a region with high transport costs and a sensitive climate was, and is, highly influenced by such fluctuations, and the boom-bust cycles affecting the region are reflected in the contemporary landscape which contains some sixteen extant underground mines and several open pits along the detritus of abandoned mining operations. The most recent increase in metal and mineral prices and the demand from emerging markets have resulted in a thriving industry for both the placer and hard rock mining sectors. Placer mining occurs on creeks leading away from Keno, and in the McQuesten Lakes region. Hard rock mining currently occurs in the Keno Hill Silver District which encompasses the region in and around Keno City and the town of Elsa (e.g., the Bellekeno Mine, owned and operated by Alexco Resource Corp.). There is advanced hard-rock mining activity at Dublin Gulch, approximately 40 km north of Mayo (i.e., Victoria Gold Corp.'s Eagle Gold Deposit) and there is the potential for the Rackla Gold Project (including the Rau and Nadaleen trends) to be developed, located 55 km northeast of Keno City (owned by ATAC Resources Ltd.). All-season access roads serve the Bellekeno Mine and the Dublin Gulch property; 40 km of an existing winter road (Wind River Trail) provides access to the Rackla/Rau property. Most, but not all, placer mines have some form of summer road/trail access. Some are only accessible by water in the summer, and heavy equipment is brought in during winter on ice bridges/roads. Given the renewed mining (Bellekeno) and advanced-stage development in the area (Dublin Gulch and Rackla Project), trends in global mineral demands, and a recent upswing in exploration activity, it is anticipated that mining in the region will expand in the foreseeable future.

In essence, factors impacting the viability of mining in the Mayo region typify mining environments throughout the north. There exists a higher cost of operation for mines in the north due to the following: high labor costs due to isolation; high transport costs in inhospitable terrain and a greater distance to markets; high operations costs associated with working in inhospitable terrain characterized by climate extremes; and less annual revenue due to climatically enforced seasonality of operations. The question of the vulnerabilities associated with the industry's exposure to a changing climate in the region is a complex one, involving not only the vulnerability of the mining industry to economic and environmental factors, but also the implications of mining impacts for other land uses. For example, increased precipitation or accelerated freeze-thaw action due to climate change may introduce toxic materials from relict mines into local waterways, in turn impacting vegetation and wildlife. Equally, permafrost degradation could compromise highways and back country mining roads, which are also used for local travel, access to harvest areas, and recreation.

MINING AND CLIMATE

The mining industry, as a matter of necessity, has always been highly cognizant of the relationship between climate and mining, and climate is a central consideration in mine design. Mine drainage, tailings and holding ponds, seasonality of operations, power generation (hydro), and transport are all highly climate sensitive. However, mine planning and design in Canada has essentially assumed a "steady state", based historically on the not unreasonable notion that climate does not change significantly; however, recently the mining industry has become proactive in recognizing the need to accommodate future climate trends in project design.

Mine sites in central Yukon are underlain by discontinuous permafrost, which may be especially sensitive to thawing as the climate warms. Additionally, changes in precipitation are anticipated, notably an increase in summer rainfall. It is anticipated that weather events will become both more unpredictable and extreme, with increased precipitation in some areas, but water deficits in others. There is already some evidence of this trend and the Yukon government's Department of Environment has noted that changes to precipitation in Yukon could require costly upgrades and redesign of tailings dams and water diversion structures in the Yukon's mining industry. (http://environmentyukon.gov.yk.ca/pdf/ccp1whatisclimatechange.pdf).

Permafrost degradation will have implications for transportation and for stability of mining infrastructure. Waste-rock piles, tailings and water retention ponds rely on the impervious nature of permafrost to retain environmentally hazardous materials that are of particular concern.

SPECIFIC RISKS

It is anticipated that shoulder seasons will lengthen, due to winter freeze-up arriving later and spring break-up occurring sooner. As far as transport is concerned, this is perhaps not as great a problem as it was before the advent of the all-weather road system. However, the Mayo Mining District is connected to the port of Skagway by an 800-km highway that traverses areas of discontinuous permafrost and crosses numerous rivers and creeks. It is thus potentially exposed to permafrost degradation and erosion associated with accelerated spring run-off. Most mines are connected to the main highway system by unsurfaced access roads that are built to less exacting standards than highways. Generally, this makes them more susceptible to erosion and washouts, and may prove to be an increasing problem if climate change results in more precipitation as is anticipated. While lower engineering standards may possibly make local mining access roads more vulnerable to the impacts of a changing climate, the manner in which they are constructed makes them relatively easy to repair by using readily available materials and equipment (e.g., a backhoe).

Climate change may be beneficial for the placer mining industry. Because most of their operations are based on thawing out frozen ground to release the gold, permafrost thaw could potentially improve their operations. Additionally, the on-site infrastructure of placer mining is small and all equipment is transportable. Should ground conditions become unstable, equipment can easily be moved and infrastructure such as water settling ponds can easily be rebuilt.

Weather conditions in the Mayo region have always had environmental implications for abandoned mines. Freeze-thaw action and precipitation variously interact with relict spoil and waste heaps and abandoned engineering works such as retaining walls, dykes, etc. The detritus from mining is generally a permanent feature of the landscape and in the future will be subject to changing climate conditions that probably lie outside the design tolerances of abandoned mines. Permafrost degradation along with freeze-thaw action and increased run-off will potentially affect ground stability, causing increased erosion and potential leaching of hazardous materials. There are sixteen relict mines and several open pits in the Mayo region. While we can postulate on the impacts of a changing climate, the extent to which abandoned mine sites would be adversely impacted by climate change is largely unknown.

Mines in the Mayo region depend increasingly on hydro power, and if mining expands, as is anticipated, so will the demand for power. Power generation would be sensitive to climate change in that summer drought conditions are predicted to increase; furthermore, winter snowpack is anticipated to decrease in the long term.

CONCLUSION

The changing climate is an important consideration for the mining industry in the Mayo Region because it may bring additional costs to industry operations, and those costs will increase as climate change becomes more marked. It is also important because mining in the region will place increased stress on the regional environment as warming brings about permafrost degradation and changes in precipitation. Increased pressure on local roads, slope instability, and erosion at relict mine sites are all potential problems, and these problems are likely to increase concomitant with a marked growth in mining activity. The worst case scenario would involve a combination of high growth and a high degree of climate change. Sound planning by the mining industry, incorporation of good quality contemporary data into forecasting models, and realistic mine life cycle planning would all contribute to minimizing risks potentially associated with mining in an environment where the climate is changing.

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APPENDIX C - CLIMATE-CHANGE PROJECTIONS TO SUPPORT THE MAYO REGION CLIMATE CHANGE ADAPTATION PLAN

INTRODUCTION

Climate-change projections are an important tool for adaptation planning. While the observations of residents, especially those of Elders in the First Nation of Na-Cho Nyäk Dun, can tell us how the climate of the Mayo Region is changing, projections provide an idea of how the Region will continue to change climatically. Climate-change projections therefore provide meaningful insight into the circumstances for which the community must prepare through adaptation. Sixty-five maps that illustrate changes to the climate of the Mayo region were provided by the Scenarios Network for Alaska Planning (SNAP) in 2010.

DESCRIPTION OF THE MODELLING PROCESS

These projection maps are based on the outputs of General Circulation Models (GCM), which model the complex variables that lead to climate change, such as land-surface processes, albedo (how much heat is reflected off the surface of the Earth) and cloud cover, and the responses by the atmospheric gases that have been found to cause climate change. Given the global nature of climate change and the complex systems being analyzed, GCMs project changes to temperature or precipitation over a large spatial scale, usually over a grid between 1° to 5° latitude and longitude. This coarse scale makes interpreting the influences of local topography, which is important for determining the regional effects of climate change, difficult. The climate projections provided by SNAP are downscaled using climate data from PRISM (Parameter-elevation Regressions on Independent Slopes Model) which creates a very fine scale of 2 km. For more of the regression process, please refer to online resources provided by SNAP: http://www.snap.uaf.edu/resources.php.

The GCM projections are based on standard emissions scenarios provided by the International Panel on Climate Change (IPCC). These emissions scenarios account for the various ways that global population, economic development, the evolution of technology, and land-use can influence the global release of the greenhouse gases that cause climate change - such as carbon dioxide. Two emissions scenarios were selected for use in the Mayo Region adaptation plan: the B1 and A1B scenarios. The B1 scenario represents a future where global greenhouse gases are brought under control by 2050 and represents the low range of the climate projections presented in this plan. The A1B scenario was used to determine the high end of the projected range of climate conditions. Under this scenario, rapid development and emissions peak at 2050, and subsequently decline. While other emissions scenarios do illustrate a more severe onset of climate change by 2100, the peak in emissions at 2050 depicted in the A1B scenario results in the most significant onset of climate change within the period considered in this planning process (Nakićenović et al., 2000). The B1 and A1B emissions scenarios were therefore selected as the basis for climate-change projections because they create the greatest possible range in warming to 2050. For more on these emissions scenarios, please consult Nakićenović et al. (2000).

LIMITATIONS OF CLIMATE-CHANGE PROJECTIONS

The primary limitation of climate-change projections is uncertainty. Uncertainty in the models results from the way in which the complex variables influencing climate change interact, which is not well understood. Uncertainty also results from the weighting of these variables and which variables are represented in the model. The number of variables and their weighting vary between models. The projections provided by SNAP are based on the five GCMs that perform best over Alaska to reduce error in Arctic projections. These five GCMs have been averaged to further reduce variation between the models and through the ground-truthing of historical data. For more on the methodology used by SNAP, please refer to Walsh et al. (2008) and information available on the SNAP website (provided above).

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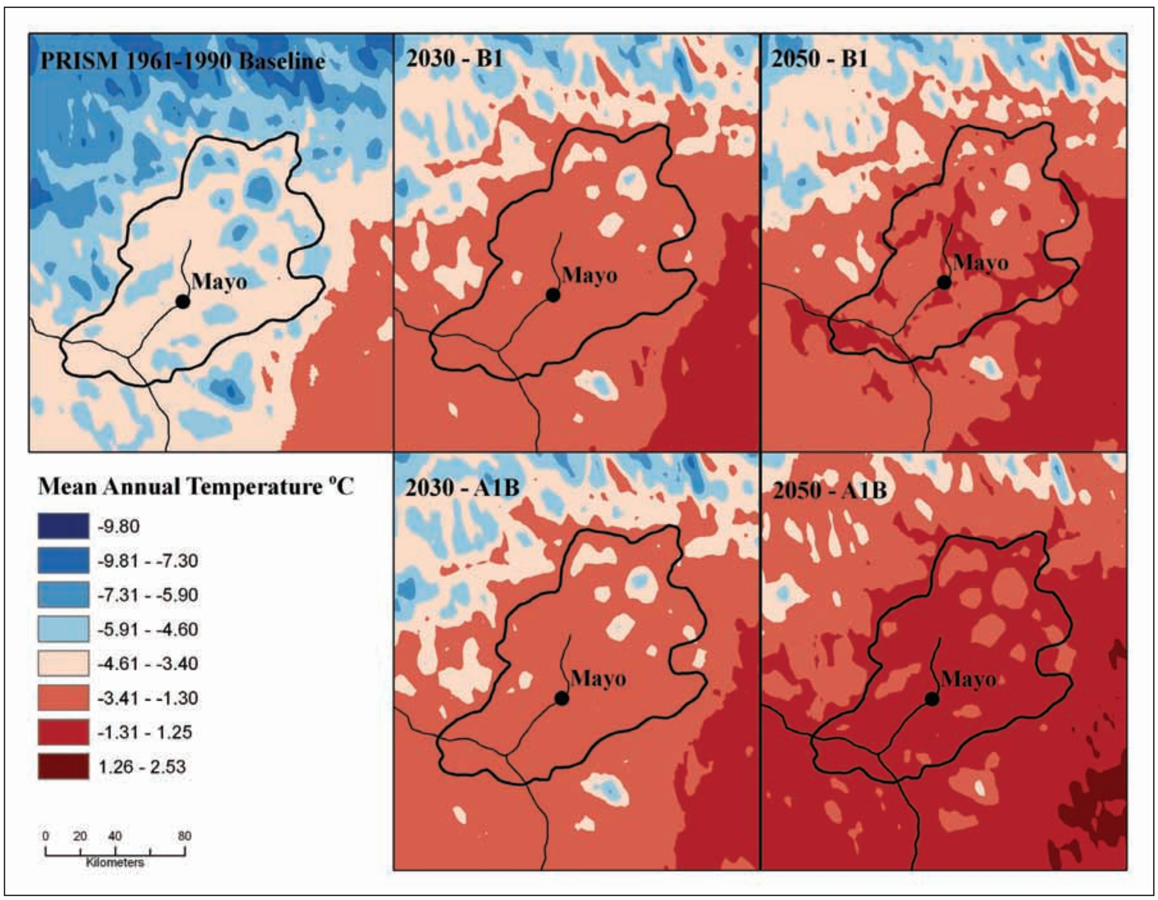
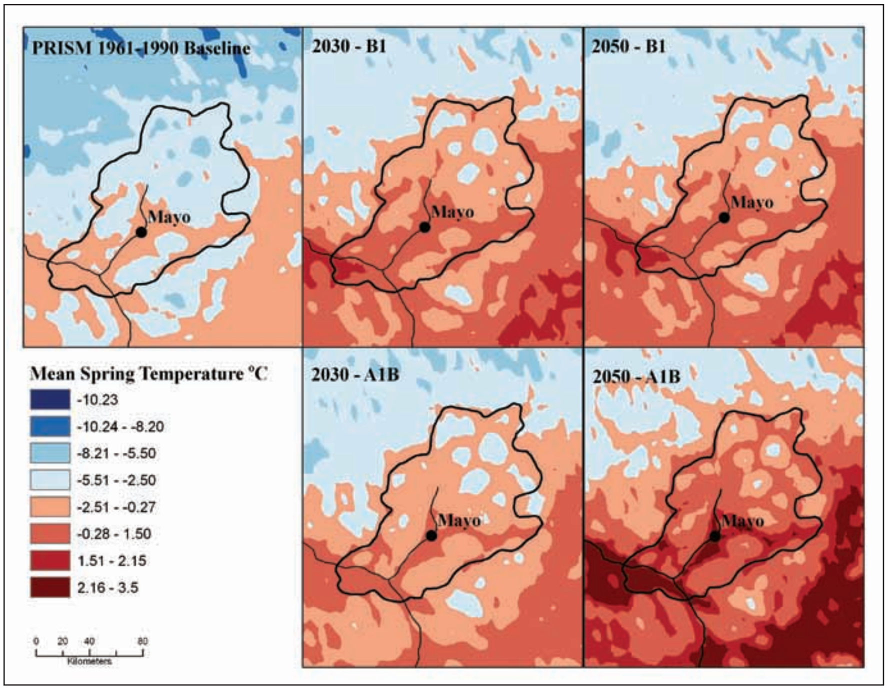
Walsh, J., Chapman, W., Romanovsky, V., Christensen, J. and Stendel, M., 2008. Global climate performance over Alaska and Greenland. Journal of Climate, vol. 21, p. 6156-6174. http://www.snap.uaf.edu/attachments/Walsh2008.pdf

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.

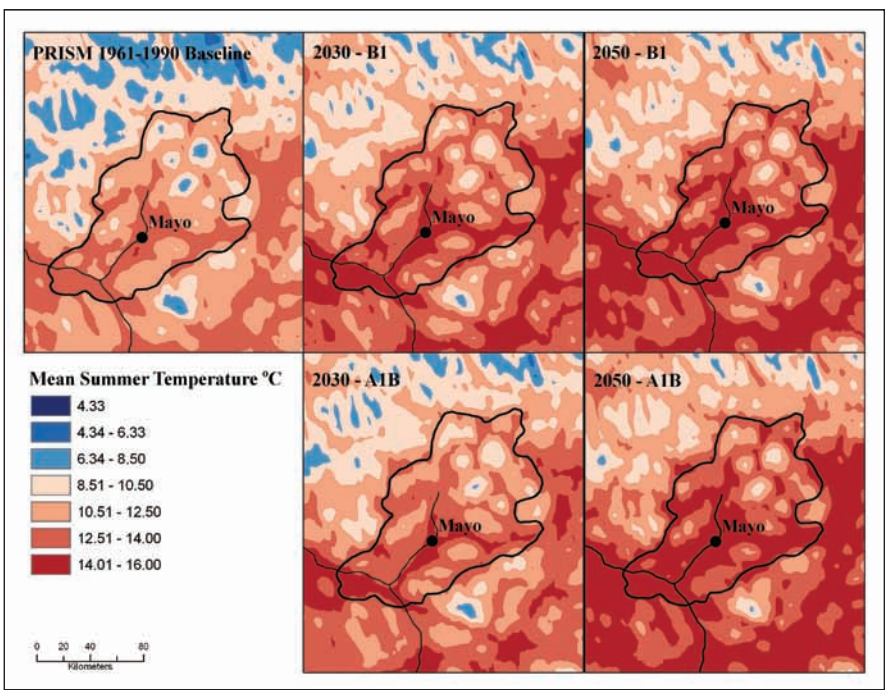


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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.

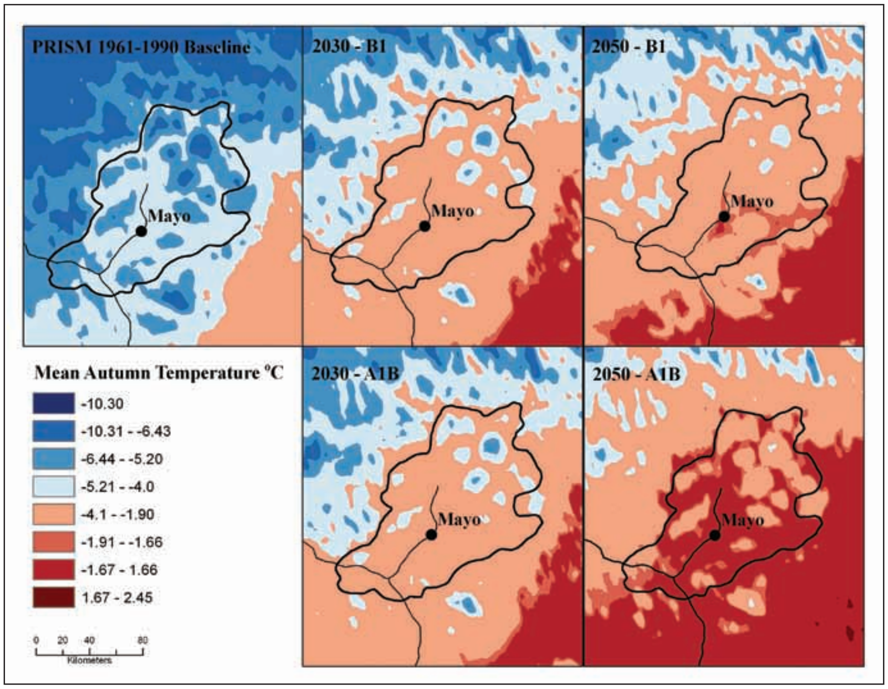


Projected changes in mean summer temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

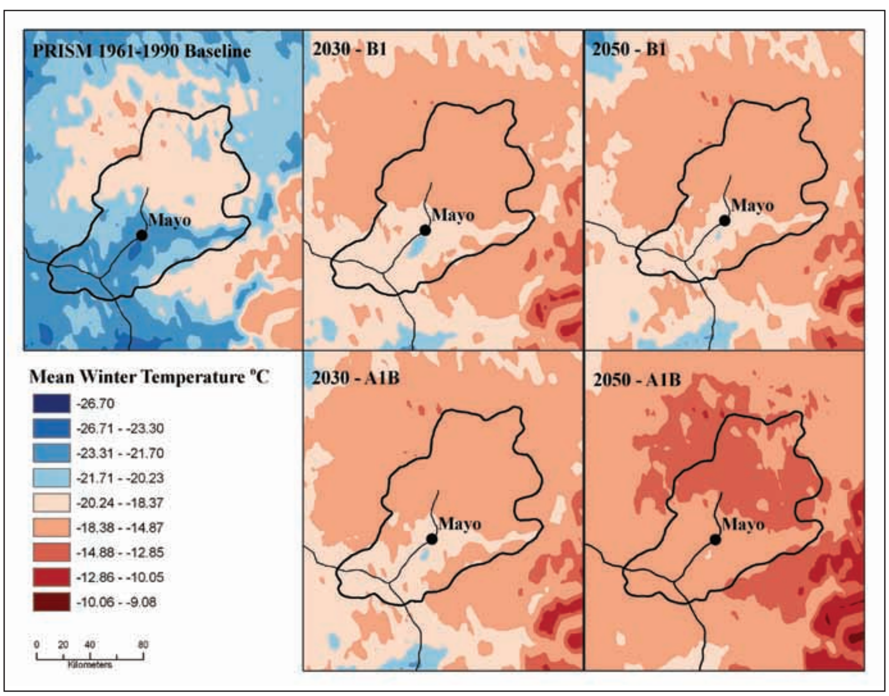


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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.

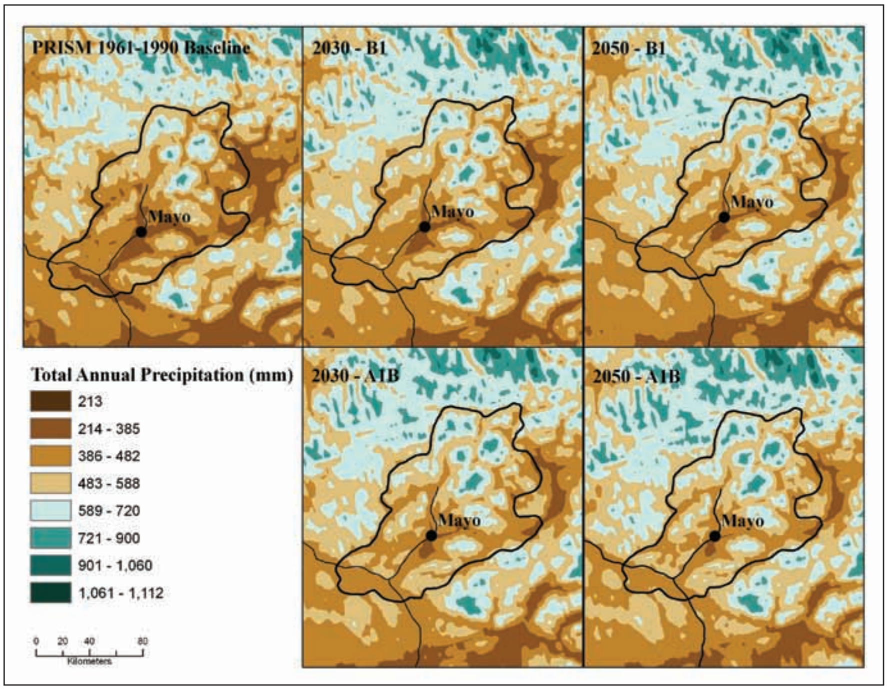


Projected changes in mean winter temperature for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

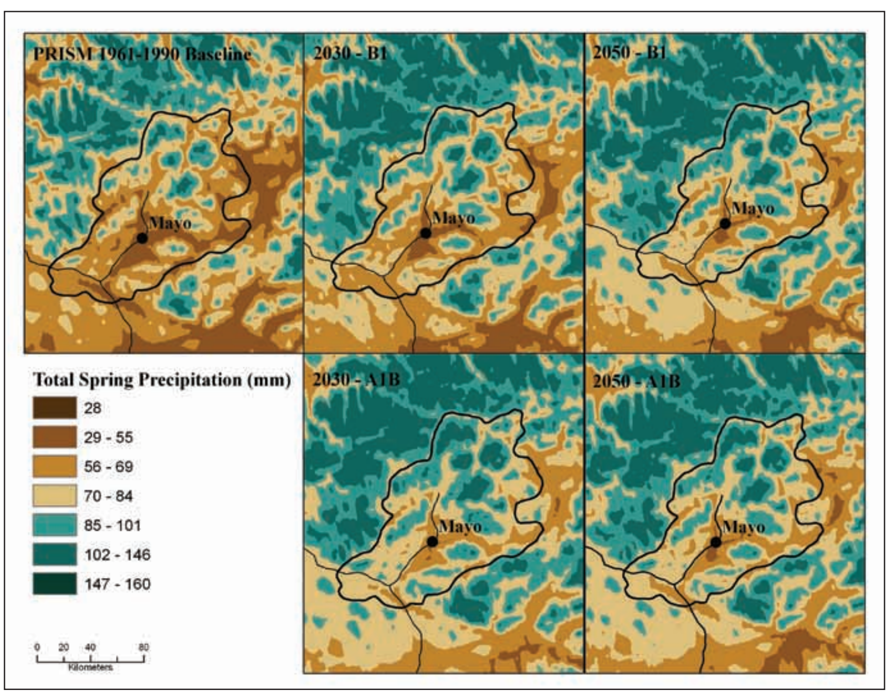


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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.

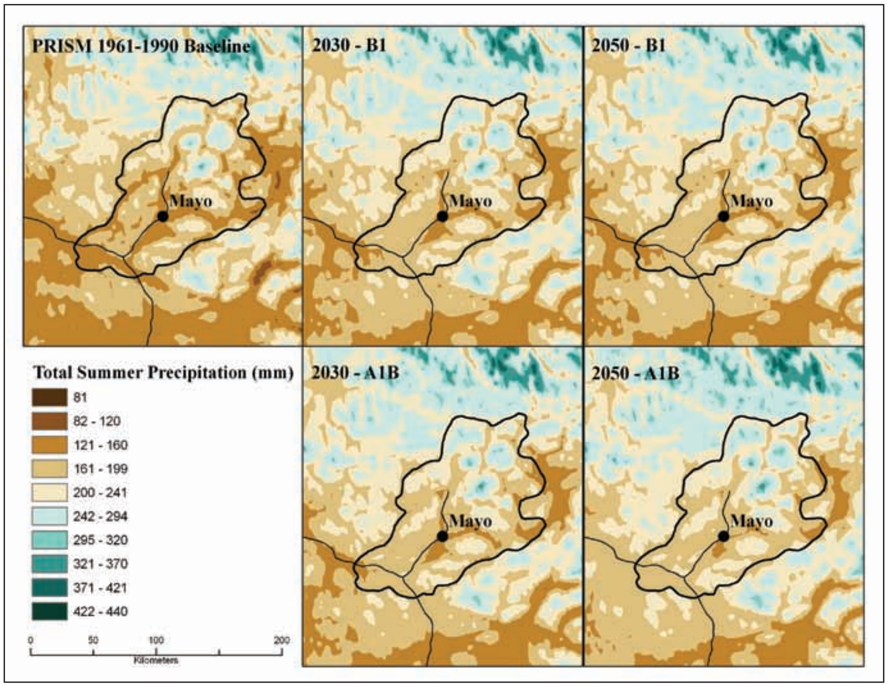


Projected changes in total spring precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

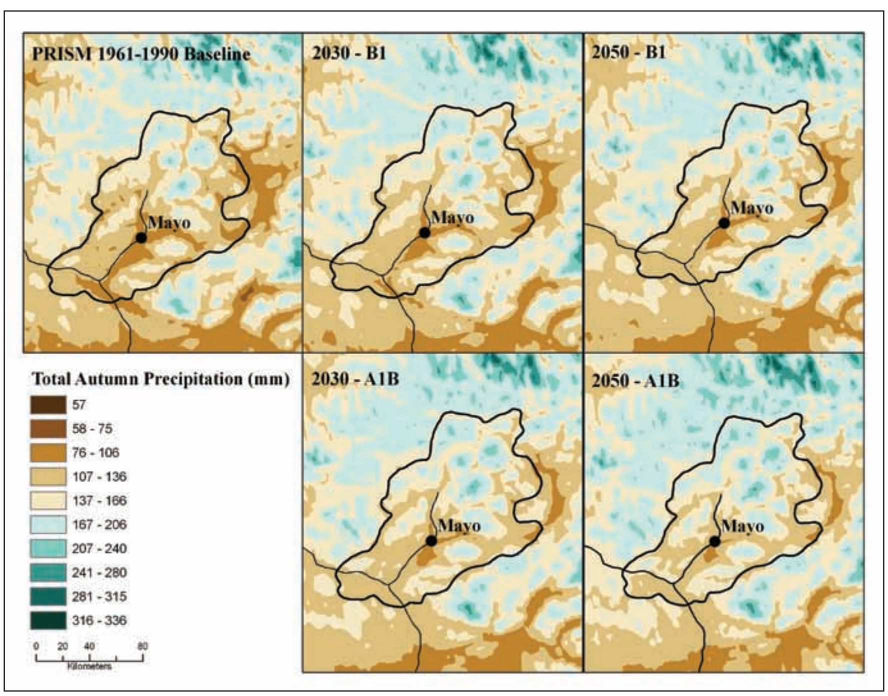


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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.

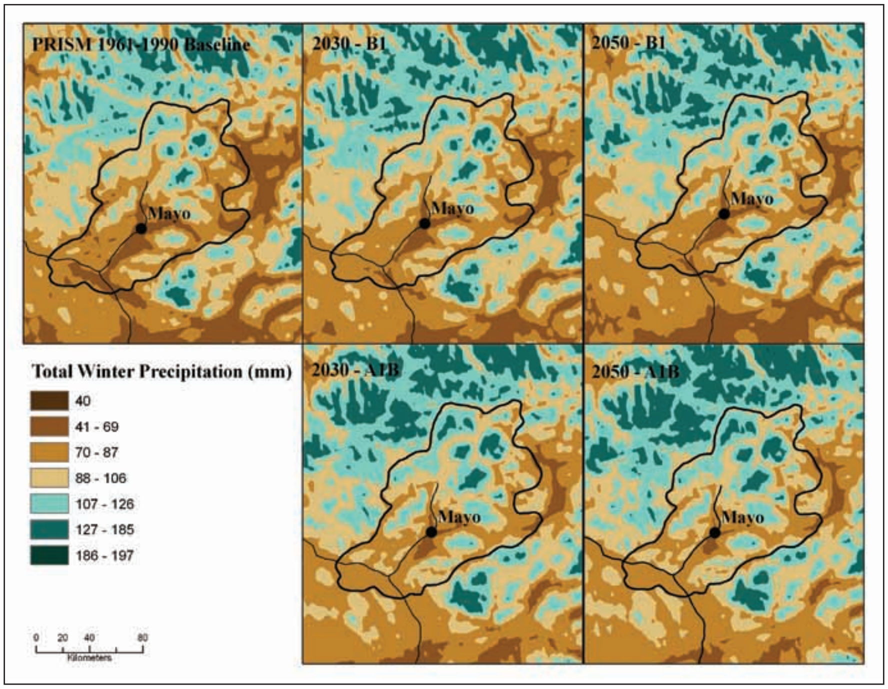


Projected changes in total autumn precipitation for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

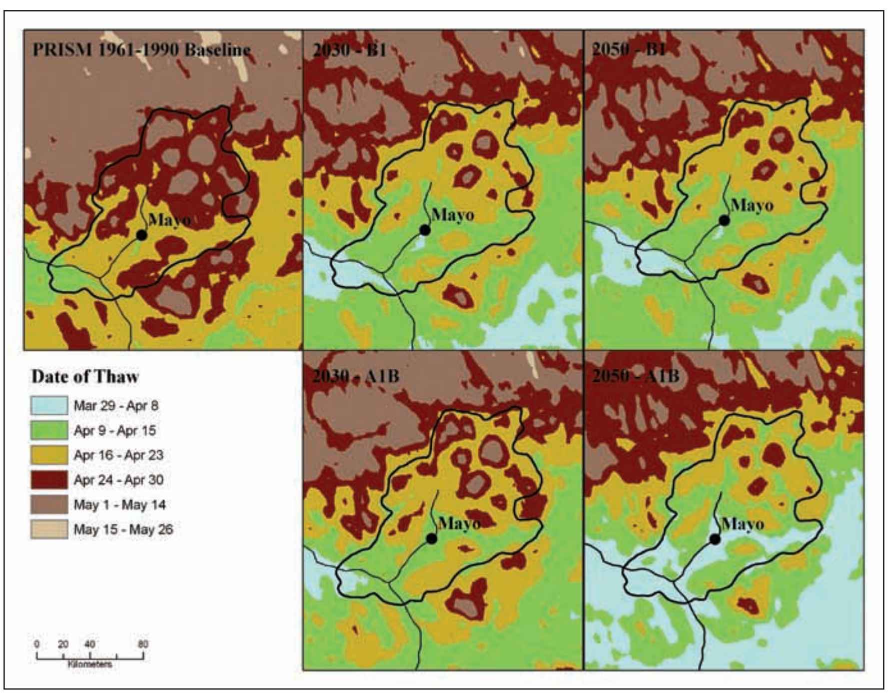


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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.

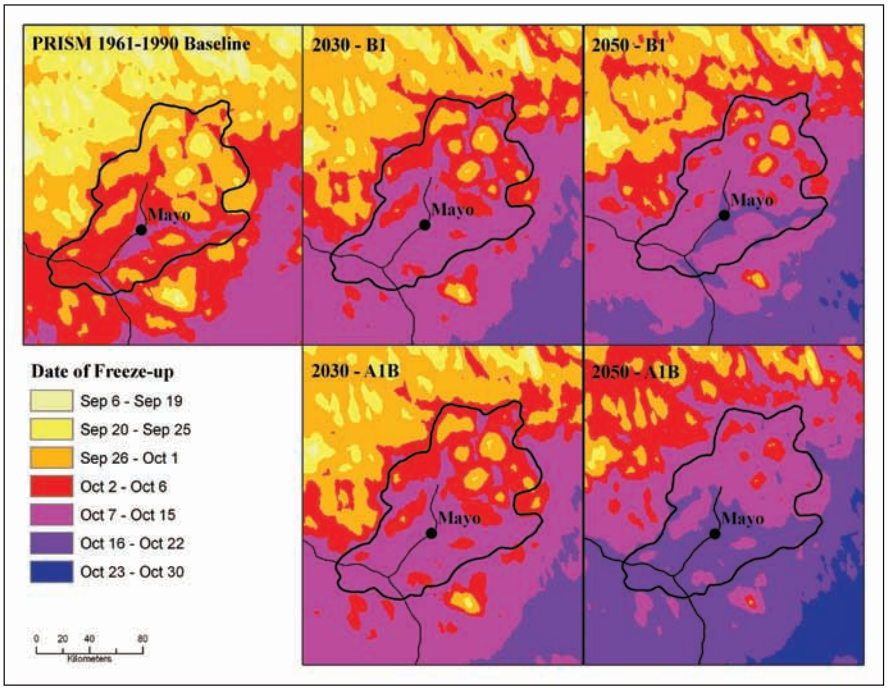


Projected changes in date of thaw for 2030 and 2050, based on the B1 and A1B scenarios, respectively. Baseline (1961-1990 climate normal) conditions are provided.

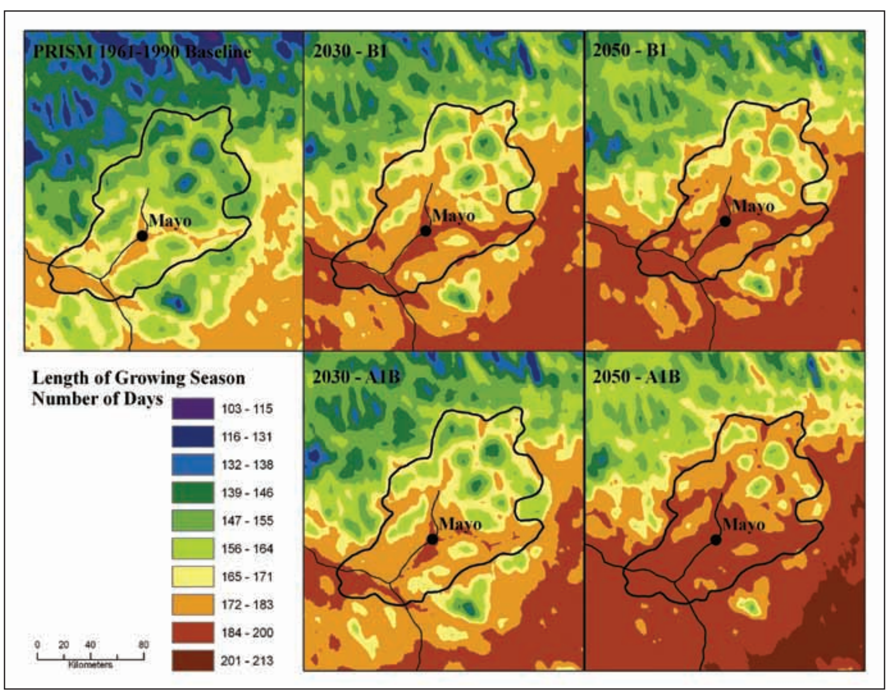


APPENDIX C - MAYO REGION CLIMATE-CHANGE PROJECTIONS, *continued.*

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 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 D - MAYO REGION CLIMATE CHANGE VULNERABILITY SCENARIOS

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INTRODUCTION

Four vulnerability scenarios were developed in order to better depict how the Mayo region (including the communities of Mayo, Keno City and Stewart Crossing, Yukon) may be vulnerable to a changing climate. The vulnerability scenarios were compiled as a foundation for the *Mayo Region Climate Change Adaptation Plan*. The scenarios are intended to characterize community vulnerability if no action is taken to reduce the susceptibility (the degree to which the community is exposed to a hazard event) of regional residents to environmental stresses exacerbated by climate change. Each scenario describes climate conditions, landscape change, and implications for human activity and for community vulnerability. Each scenario differs in terms of the degree of population growth and the rate of climate change as follows:

Scenario 1: Climate continues to change at the present rate.

Scenario 2: Climate continues to change at the present rate and the community grows rapidly.

Scenario 3: Climate changes faster than the present-day rates.

Scenario 4: Climate changes faster than present-day rates while the community grows rapidly.

The scenarios have been developed with input from the communities within the Mayo region, namely residents of Stewart Crossing, Mayo and Keno City. The scenarios are based on the changes observed by community residents within the study area (*see Figure 1, Mayo Region Climate Adaptation Plan, p. 7*). The technical expertise of professional planners, engineers, economists and other experts in the field of community adaptation, in addition to available resources examining the possible impacts of climate change in the region, have been drawn upon in order to integrate science with the local knowledge. Important resources that recorded local knowledge and regional conditions used in preparation for this report are: McCoy and Burn, 2001; Northern Climate ExChange, 2001; McCoy and Burn, 2005; Williams and O'Donoghue, 2005; Bleiler et al., 2006; and Northern Climate ExChange, 2011.

Each scenario examines community vulnerability to climate change. Vulnerability is founded on current (Scenarios 1 and 2) and projected (Scenarios 3 and 4) climate conditions in the Mayo region at 2030 and 2050. Each scenario then examines how elements of the region's physical environment (e.g., hydrology, permafrost and ecology) may be affected by climate conditions. The scenarios then proceed to look at the implications of physical changes (i.e., a changing landscape) on human activity, by examining:

- infrastructure (housing and roads);

- economy (mining, agriculture, and forestry); and
- traditional activities (gathering food and trapping).

Each scenario concludes with a summary of community vulnerability extending from the consequences of climate change for human activity. Each summary describes the community's capacity (or lack thereof) and challenges that residents may face as the climate changes. While the scenarios offer alternative depictions of how the future may unfold, it is highly uncertain that the future will occur exactly in the manner described in any one scenario. No judgement is therefore offered in this report as to which scenario is most likely to occur, nor do we suggest that anyone interpret them as such. Instead, the scenarios offer insight into the pathways common to each scenario through which climate change may influence vulnerability in the Mayo Region. The scenarios, in particular the mid-range scenario (Scenario 2), also suggest possible methods for enhancing the adaptive capacity of participating communities and provide some guidance for policy and decision-makers by describing the best possible future.

ASSUMPTIONS SUPPORTING THE MAYO REGION VULNERABILITY SCENARIOS

A number of assumptions about regional landscape conditions and economic development were required for the purpose of completing vulnerability scenarios for the Mayo region. These assumptions are necessary because of the significant range and rate of change possible in the Mayo region over the course of the next 40 years and the complex interrelationships between variables. The assumptions have been divided into two groups: those related to human activity and those related to landscape change.

Unprecedented vulnerability

Climate change may generate unprecedented vulnerability, especially if greenhouse gas (GHG) emissions result in a rapid and severe onset by 2100. Possible events such as a massive climate-induced ecosystem shift (i.e., a shift from a forest to grassland ecosystem), a massive shift in the region's hydrology due to significant changes to precipitation and/or reduced glacial melt, or the occurrence of a global economic disaster (such as the breakdown of global food security), have not been considered in this plan. While these events are among the possible long-term effects of climate change, they lie outside the timeline of this plan.

Assumptions underlying projected human activity in the Mayo region

Human activity was identified as a factor that will create change in the Mayo region, as determined by the Local Advisory Committee for the Mayo Region Climate Change Adaptation Project (the community-based steering committee guiding the project). The following assumptions about population growth, economic growth, mining activity, and infrastructure development have been adopted to determine how regional growth will contribute to future community vulnerability.

Population growth in the region has been extrapolated from the linear rate of increase for the Yukon between 2000 and 2010, and between 2005 and 2010. The total population from the Mayo Region has been estimated based on the population count completed by Yukon Bureau of Statistics (YBS) (December 2011), which includes residents living in the Yukon Unincorporated census region outside the Village of Mayo, and the approximate populations of Keno City and Stewart Crossing provided by those residents in the spring of 2011. These population counts are as follows: 457 residents in Mayo, 20 residents in Keno City, and 25 residents in Stewart Crossing. The total population for the Mayo region used as a basis for estimating population growth in these scenarios is 502 residents.

The rate of population increase in the Territory was higher between 2005 and 2010 reflecting increased growth in Yukon over the latter part of the decade. The projected population of the region was calculated based on the proportion of the Mayo population against the whole territory (35,667) in 2010, which is 1.4% of the territorial population (YBS, 2010). In other words, the assumption here is that the population of Mayo will continue to be 1.4% of the territorial population. This method for projecting the population of the region is very simple, and does not account for migration, birth or death rates, or the structure of the population outside the municipal boundary. For these reasons, assumptions of population growth have been very simply expressed in the scenarios as the following: 1) a stable population (i.e., no growth to marginal growth: *no growth* based on the stability of the Mayo population reported in the 2006 federal census, and *slow growth* reported by the Yukon Bureau of Statistics and the current economic activity experienced in the region); and 2) a doubling of the population (high growth) based on anticipated economic growth (see *Economic growth* below) projected to support the influx of a (presumably younger) population and bolstered by a young demographic cohort within the First Nation of Na-Cho Nyäk Dun (Fred, 2008).

Economic growth for the region was based on forecasts for the Yukon Territory to 2025. The sectors expected to experience growth in the region are culture and wilderness tourism, resource (primarily minerals) exploration and extraction, technological innovation related to energy generation, and business opportunities driven directly by the First Nation of Na-Cho Nyäk Dun (Government of Yukon, 2006). Cycles of economic growth and decline are expected to continue as the economy responds to those global forces that dictate tourism and resource extraction (Global Business Network, 2008). Given the buffering influence of mining in the region (see *Future mining activity* below) the cycles of growth and decline in the region are expressed in the scenarios as stable to high economic growth.

Mining activity in the region was based on a linear estimate of active and planned mines based on the anticipated rate of start-up in 2011. At the time of completion of these vulnerability scenarios, one mine was active in the region (Alexco Resource Corp.'s Bellekeno silver-lead-zinc mine) and 2 additional mines are at an advanced stage of development (Victoria Gold Corp.'s Eagle Gold Project and Atac Resources Ltd. Rackla Gold Project). The activity of the mining industry in the region for each scenario was then tailored based on surveyed perceptions of deterrents from 2010 to 2011, such as transparent or fair legal processes, regulatory duplication and inconsistencies, or taxation regime, which indicate that Yukon is considered a 'safe' place for investment (McMahon and Cervantes, 2011). At least 2 mines are therefore expected to be operating in the Region over the next 40 years, which represents the low end of anticipated mining activity and 'low' economic growth. The start-up of additional mines in the region supports the high end of anticipated mining activity in the region.

Infrastructure development within the Mayo region may change significantly over the next forty years. For the purpose of developing future environmental scenarios, it has been assumed that existing infrastructure in the region, such as the dike along the Stewart River in the Village of Mayo, will remain in use. We have also assumed that the construction of new infrastructure will occur in accordance with current (2005-2011) planning. While some speculation for the development of new infrastructure was required if circumstances within the scenario suggested the necessity, we have not considered some of the more radical (and unlikely) potential changes to transportation technologies within the territory, such as the construction of a river transportation corridor between Whitehorse and Mayo.

Assumptions underlying future landscape conditions in the Mayo region

In addition to those assumptions about global population growth, technological innovation, global land-use trends, and emissions of greenhouse gases (the drivers of climate change) that determine the severity of climate change in the future, additional assumptions about landscape conditions in the region were required to determine community vulnerability. These assumptions characterize those stresses in the region that will be affected by climate change and will ultimately increase community vulnerability. These stresses are already well known to residents: permafrost thaw, flooding, forest fire and drought.

***Permafrost thaw**,* or the extent that permafrost may thaw in the region and lead to subsequent community vulnerability stemming from changing landscape conditions, was determined from thresholds established by Northern Climate ExChange (NCE), 2011. The dynamics of permafrost thaw in a changing climate is a complex area of study and it is challenging to evaluate how permafrost will respond to increases in average annual temperatures. NCE (2011) examined the impact of atmospheric warming on the probable distribution of permafrost if the average annual temperature increased by 1°C and 2°C. Based on this work, and for the purposes of these scenarios, we assume that if average annual temperature increases by 1°C, there will be some thawing of permafrost in disturbed areas. At 2°C, our assumption is that permafrost may altogether be eliminated in disturbed areas, i.e., those areas where permafrost becomes vulnerable to thaw if vegetation cover is removed due to development or forest fire. An increase of 3°C or more (as predicted by SNAP; SNAP, 2010) will affect the distribution of permafrost in disturbed as well as undisturbed areas, and the response rate to thaw will occur more rapidly. Disturbance associated with the redistribution of permafrost will range from no change to substantial change, which may manifest as a thickening of the active layer, ground subsidence, increased erosion, and some localized retrogressive thaw flows.

Flooding and its contribution to community vulnerability will primarily result from changes to the spring freshet, i.e., the seasonal melt of the accumulated snowpack. Peak water flows accompany the seasonal melt of snow and ice in the Mayo region (Bleiler et al., 2006). Projected climate conditions suggest a shorter winter period characterized by increased precipitation (up to 16%) including some falling as rain, increased infiltration of snowmelt, and more frequent mid-winter/early spring thaws; all of these phenomena will increase the variability and timing of regional flood risk (Scenarios Network for Alaska & Arctic Planning (SNAP), 2011; Government of Yukon, 2011). However, regional trends show that currently, winter precipitation is falling at a rate of 2% per century and the snowpack has been reduced at a rate of 69 mm/decade (Purves, 2011), which may result in a reduced flood risk. The literature on climate change impacts on flooding is also inconclusive (NCE, 2011). For example, Walsh (2005) concludes that the effects of increased warming and precipitation could result in either an increase or decrease in the incidence of ice-jamming depending on a number of variable conditions. Elders from the First Nation of Na-Cho Nyäk Dun report that such changes in winter conditions are already occurring (Williams and O'Donoghue, 2005) and shifts in water levels on the Mayo and Stewart rivers have been observed. Despite the trends of declining precipitation and snowpack, flooding occurred along the Mayo River in 2011. Residents attribute this flooding to rising water levels on the Stewart River, resulting in flooding at its confluence with the Mayo River. To balance this discussion of climate change and its impact on the flood risk of Mayo, it is assumed that climate change will not sufficiently alter water levels on the Stewart River enough to breach the Stewart River dike. However, given that the Mayo River dike does not provide complete protection from flooding, it is assumed that the flood risk for the community of Mayo will increase as a result of changes to the Mayo River. Other factors that will increase the flood risk for Mayo include the flooding and its associated effects at the confluence of the Stewart and Mayo rivers (as reported by residents), recent changes to the Wareham dam and anticipated shifts in the regulation of water levels on the Mayo River, and the increased and variable winter precipitation projected by climate change. More research on the hydrology of Mayo is strongly recommended.

Forest fires will be affected by climate change in a number of ways, but mainly due to increased variability in total summer precipitation and average summer relative humidity (McCoy and Burn, 2005). These changes will prolong the fire season and shift the severe part of the fire season to later in the summer (McCoy, 2002). Trends for the Mayo region (1961 to 1991) suggest that 0.4 fires occurred per year, burning 869.6 ha. As climate changes, the fire regime in the Mayo region will become increasingly variable, and some summers will be characterized by no fires at all, while others will experience “greater fire occurrence, area burned and fire danger potential” (McCoy, 2002, p. 85).

Drought conditions, or decreased water availability resulting from drying conditions in the landscape, may potentially occur as a result of climate change. Water availability in the Mayo region is influenced by a number of factors including relative humidity (water vapour in the air), water removed from the region by evaporation and by plants (called evapotranspiration), vegetation change, fire activity, and permafrost thaw (SNAP, 2011). Relative humidity in the Mayo region is projected to drop (McCoy, 2002) at the same time that temperatures are expected to rise. When combined with a longer growing period (during which time plants will remove water from the system), reduced water entering the system in the spring (see *Flooding* above), increased forest fire activity (see *Forest Fire* above), and shifting drainage due to permafrost thaw. As a result, while drought is not currently an anticipated problem in the Mayo Region (Bleiler et al., 2006), the availability of water may decline slightly (SNAP, 2011). The frequency of drought conditions is therefore assumed in this report to increase with the severity of climate change.

Ground water is quite shallow in the Village of Mayo townsite. Residents report frequent, and possibly annual, basement flooding, likely associated with fluctuating groundwater levels. It is assumed in this report that with a shifting precipitation regime and alterations to regional hydrology (possibly influenced by permafrost thaw) that the water table will rise and the groundwater activity observed by residents will continue. Rising groundwater will not affect drinking water. Wells in the Village of Mayo are relatively shallow and currently drilled to a depth of approximately 6-7.5 m (M. Wozniak, Chief Administrative Officer, Village of Mayo, pers. comm., 2011). The aquifer is connected to the Mayo River. The capacity of these wells will improve if the groundwater rises. While the quality of drinking water from these wells may be affected by increased turbidity in the Mayo River, the possibility of contamination is not known, and is considered unlikely (R. Savage, Quest Engineering, pers. comm., 2011).

Flora and fauna are already changing in the Mayo Region. Elders from the First Nation of Na-Cho Nyäk Dun report fewer salmon and new species entering the region, including plants, moths, birds and insects. Other changes reported by Elders include smaller fish of reduced quality for consumption (soft meat, less fat and containing more parasites) and changing natural cycles for animal species (Williams and O’Donoghue, 2005). It is assumed that these changes will continue with climate change and become more persistent and severe as average annual temperatures rise. For example, there has been a heavy infestation of aspen leafminer in the Mayo Region for the past 15 years (M. O’Donoghue, Northern Tutchone Regional Biologist, pers. comm., 2011). While not currently problematic, these populations and other forest insects like spruce bark beetles may thrive in a changing climate, and may cause extensive damage in the future.

SCENARIO 1: FUTURE VULNERABILITY IF CLIMATE TRENDS OBSERVED OVER THE PAST CENTURY CONTINUE AND THERE IS LITTLE COMMUNITY OR REGIONAL GROWTH

Climate scenario

By 2050, the climate in Mayo has continued on the same trend that was observed between 1929 and 2009. Average annual temperature for the region has risen from -4.8°C (SNAP, 2011) to -2.6°C at a rate of 0.28 degrees/decade (Purves, 2010). Based on precipitation trends reported for Mayo by Purves (2010), total annual precipitation has risen from 524.2 mm (SNAP, 2011) to 571.4 mm, a linear increase of 5.9 mm/decade.

Impacts

In this scenario, the landscape will continue to experience change in keeping with the reported observations of residents. Winter conditions will continue to change, resulting in increased precipitation characterized by variable snowfall and increased rain. Mid-winter and early spring thaws will continue to affect ice conditions, snow pack and spring freshet.

Permafrost thaw will continue to occur in the region, and this continued thaw will result in localized groundwater flooding within the townsite of Mayo. Thaw would occur in disturbed areas such as housing developments and along highways. Variable water levels and seasonal weather variability leads to sporadic flooding along the Mayo River.

The incidence of forest fires continues to decline near inhabited areas of the region and overall trends in wilderness fires stay within the range observed from 1961 to 1991. Wildlife populations continue to fluctuate as ecosystem changes occur, with increasing variability over time, but there are no major redistributions or local extinctions of species.

Implications for human activity

The quality of housing in affected areas within Mayo would decline over the projected time period due to the following: the normal aging of infrastructure, continued groundwater flooding, and sporadic flooding along the Mayo River. All of these factors would result in mould growth and structural decay. Some of these houses are eventually abandoned. A combination of changing landscape conditions and traffic volume continues to affect the Silver Trail (Highway #2) by producing seasonal frost heaves that would affect the connection between Stewart Crossing and Mayo. There would be continued degradation of that part of the Silver Trail which connects Mayo and Keno City due to permafrost thaw along the highway corridor where it was disturbed during road construction.

Economically, the region will continue to grow along current trends. Continued mining exploration and development will be moderately affected by transportation issues due to permafrost thaw, but not enough to significantly affect their progress in development. Hotter summers and increased seasonal precipitation may promote increased forestry or agriculture in the region, but only if sufficient interest in expansion is acted upon and supported by the Region’s residents.

Variable winter conditions will affect the ability of residents to travel on the land. Residents have already reported challenges with back-country travel, such as a heavy snowpack and variable ice conditions, which have made trapping difficult. Variable ice conditions have also made ice fishing challenging. Variable conditions in winter will likely persist, and will continue to effect traditional activities. Climate change will also create variable landscape conditions in summer, resulting from varying water availability and warmer average temperatures (continuing the trends reported by residents). These changing conditions will also affect the reliability of traditional food harvests, and in some years, there is a relative scarcity of traditional foods.

Consequences for community vulnerability

In this scenario, the capacity of the community would be stressed along the same lines currently experienced by the community. Capacity will remain high for the most part, but will be increasingly strained by infrastructure decline, the aging of residents, and a relatively narrow economy. In this scenario, it is the disadvantaged individuals in the community who would most likely be vulnerable to changes in the region's climate.

The aging of the community may expose residents to harmful situations as a result of climate-related events (e.g., declining housing stock may lead to marginalized individuals and families inhabiting substandard housing with problematic levels of mould). Excess moisture, which has already been reported in houses located in the NND subdivision east of the Mayo townsite, would become increasingly problematic. Subsidence and slumping along highway corridors, currently associated with permafrost thaw, would continue. Changing hydrology, increased precipitation, and thawing permafrost would create problematic conditions for infrastructure at abandoned mine sites, potentially leading to contamination of soil and water and increased health risks for residents.

SCENARIO 2: FUTURE VULNERABILITY IF THE COMMUNITY GROWS RAPIDLY

The picture of community vulnerability emerging from Scenario 1 suggests extensive landscape impacts and mild consequences for the community. If population and economic growth occur, the vulnerabilities identified in Scenario 1 would be compounded. Such growth may result from a marked increase in mining activity and the revival of Mayo's fortunes, making it a regional economic hub.

Climate scenario

By 2050, the climate in Mayo has continued on the same trend observed between 1929 and 2009. Mean annual temperature for the region has risen from -4.8°C (SNAP, 2011) to -2.6°C at a rate of 0.28 degrees/decade (Purves, 2010). Based on precipitation trends reported for Mayo by Purves (2010), total annual precipitation has risen from 524.2 mm (SNAP, 2011) to 571.4 mm, a linear increase of 5.9 mm/decade.

Impacts

Hydrologic change in the region resulting from shifting winter conditions (described in Scenario 1) will exacerbate the current stress on regional hydrology arising from the increased demand for hydro power from mines. Water quality may also be impacted by the increased presence of toxic materials associated with mining, increasing the risk of water contamination.

Population growth resulting in settlement expansion around any of the three communities, coupled with increased pressure on the highway system from mine activity and permafrost thaw would lead to further deterioration of the Silver Trail. Thawing permafrost could create some localized changes in the flow and quality of water.

Population growth and the increased activity produced by the larger number of residents may further stress regional ecosystems.

All other climate-related impacts remain the same as those identified in Scenario 1.

Implications for human activity

As in scenario 1, the quality of housing stock declines in parts of the Mayo townsite, and this, combined with the population increase, would possibly lead to changes to the current Village of Mayo Official Community Plan. For example, new residents may choose to seek housing construction sites outside of the 65 housing units scheduled for development in the NND C6 subdivision by 2030 (as scheduled in the plan; VOM, 2006). Growth of the mining industry could potentially have a detrimental impact on the physical environment and also compound the need for effective management of highway corridors.

Population growth in the region, in combination with added wealth from economic prosperity, increases the capacity of the region. This increased capacity leads to economic diversification. Hotter summers and increased seasonal precipitation may lead to increased forestry or agriculture in the region, but only if sufficient interest in expansion is supported and acted upon by residents. The capacity of the First Nation of Nacho Nyäk Dun increases with a favourable economy, enabling the First Nation to address observed issues with housing stock (a priority noted in their current strategic plan). Mining remains the dominant economic driver in the region. Continued mining exploration and development will be moderately affected by transportation issues due to permafrost thaw, but not enough to significantly affect their progress in development.

Traditional food harvests are increasingly stressed as a result of competition and conflicts resulting from increased population pressure. These conflicts are compounded by the growth in other land uses in the region (i.e., mining, tourism and recreation) that stress the Region's ecosystems. Trapping is similarly affected by an increased human presence in the region, as well as by ecosystem stresses associated with a changing climate.

Consequences for community vulnerability

Community capacity would likely grow in this scenario. New residents would contribute to the skillset available to the community. New members of the community would also likely be younger, addressing the capacity impacts that aging has on the community as was suggested in Scenario 1. While vulnerability will largely encompass disadvantaged members of the community in this scenario, the ability of the community to care for these marginalized members will improve with increased wealth and population.

Anticipated improvements to the housing stock in the Region that is expected to occur in this scenario will reduce the likelihood of health issues in Mayo; however, the possibility exists that rapid development may result in the accelerated growth of areas outside of the three settlements. For example, the presence of asbestos has been reported in the housing stock in Elsa (Access Consulting Group, 2010). If that community is resettled, or if resettlement in Keno increases, new residents may be (unknowingly) exposed to a number of contaminants if they rely on old housing stock.

The possibility of significant water contamination may increase, but bolstered by improved economic conditions and capacity, mitigative measures such as water monitoring and treatment remain sufficient to address escalating risks for the human population. However, increased stress is placed on ecosystems already struggling to respond to changing climate conditions. Quality country food becomes increasingly challenging to procure as a result of land-use pressures, while at the same time (if global economic trends continue), commercial food will become more costly. Other traditional activities, such as trapping, may become equally challenging to pursue. Given that the majority of new residents anticipated in this scenario will not be members of the First Nation of Nacho Nyäk Dun (NND), the loss of traditional activities will have a negative impact on its citizens. If the prominence of the First Nation in the community is reduced, this will result in subsequent negative impacts to the culture and mental health of its citizens.

SCENARIO 3: FUTURE VULNERABILITY IF THE CLIMATE CHANGES

This scenario explores how community vulnerability, as described in Scenario 1, may be compounded with increased climate-induced stress on the region. The severity of climate change is based on the Intergovernmental Panel on Climate Change A1B emissions scenario (Nakićenović et al., 2000). The A1B emissions scenario, in which climate change is moderate to severe by 2050, was selected as the counterpoint to the modest onset of climate change (described in Scenarios 1 and 2) in order to provide the best possible range of potential climate impacts.

Climate Scenario

The average annual temperature of the Mayo Region rises from -4.8°C to -2.9°C by 2030, and to -1.2°C by 2050. Precipitation increases over the same period. By 2030, total annual precipitation has risen from 524.2 mm to 571.3 mm (a 9% rise from the 1961-1990 normal). By 2050, total annual precipitation has increased to 595.9 mm (a 13.7% increase from the 1961-1990 normal). Seasonal precipitation increases. By 2030, seasonal precipitation has increased annually, and most significantly (15%) during the spring months (March, April and May). By 2050, the most significant increase in precipitation, 16%, occurs over the winter months (December, January and February).

Impacts

Increasing temperature and precipitation result in greater variability in river ice conditions, including a greater likelihood of ice-jam events on the Stewart and Mayo rivers. Ice jams have the potential to increase the incidence of flooding resulting in increased erosion, which may possibly affect water quality in the spring. The snowpack continues to decline due to intermittent thaws throughout the winter, reducing the spring freshet, and changing regional hydrology. Increased precipitation falling as rain in late winter/early spring makes up for the reduced freshet to some extent, but drier conditions become the norm in late summer.

Warmer conditions and changing precipitation leads to increased permafrost thaw. In wilderness areas, the thawing of permafrost leads to subsidence, retrogressive thaw flows, and increased erosion.

Hot, dry conditions in late summer lead to an increase in water temperatures and subsequent impacts on fish populations. These impacts are compounded by increased sedimentation in water resulting from higher levels of erosion. Suspended sediment affects spawning habitat, and has a negative impact on fish and invertebrate communities. Warmer water temperatures may also lead to an increase in the potential frequency and severity of pests, parasites and bacterial outbreaks. Increased weather variability, including hot and dry conditions, as well as increased storm intensity, increases the variability of the fire regime. Over time, the area burned increases substantially, possibly up to seven times the area seen in the late 20th Century (McCoy and Burn, 2005). Increased variability in the fire regime and area burned has subsequent effects on the landscape of the Mayo Region. For example, the distribution of forest species begins to change favouring deciduous species that burn with greater fire intensity (Weber and Stock, 1998), which contributes to an overall increase in fire risk despite increasing precipitation. Cumulatively, these physical changes affect the character, location, and availability of traditional foods, as temperature-sensitive forest species are displaced by warming temperatures, shifting hydrology and a changing fire regime. Changing ecological conditions would also provide the opportunity for invasive alien species to proliferate.

IMPLICATIONS FOR HUMAN ACTIVITY

Permafrost degradation in the region along highway corridors, at mine sites, and within established housing developments would have significant impacts on the Region's infrastructure. For example, the quality of housing in the townsite of Mayo would be threatened if observed fluctuations in groundwater levels are associated with permafrost thaw. An increased incidence of flooding along the Mayo River and possibly the Stewart River may also create problems for residents. Abandoned mine infrastructure would be vulnerable to shifting landscape conditions and may result in possible contamination of the environment resulting from shifts in rock dumps, head wall failures in open pits/quarries, and water diversions. Existing and proposed mines would face challenges associated with variable precipitation and the subsequent strains on water-storage ponds. The fire risk to communities and infrastructure also increases.

The region will see few, if any, economic opportunities emerge with changing climate conditions. Changing landscape conditions would have a negative impact on tourism, especially for outfitters, as ecosystems are stressed by climate change. Trappers will be similarly affected by increased snowfall, challenges travelling on the land, and reduced harvests. Infrastructure renewal challenges, ecosystem stress, and subsequent effects on the community limit the extent of capacity that can be leveraged toward emerging opportunities. These capacity limitations subsequently prevent residents from capitalizing on agriculture or biofuel opportunities without external support from Yukon/Federal governments.

Changes in aquatic regimes, seasonal patterns and ecosystems (such as the proliferation of established or new parasites) would affect wildlife populations, leading to shifts in the density and distribution of traditional foods. Gathering traditional foods may also become challenging because of: deteriorating travel conditions on the land (because of variable and less favourable ice conditions, avalanches, and landslides), water quality issues (higher temperatures, increased sediment loads in streams and rivers, and problematic/variable flow speeds and timing), pests and pathogens, and problematic animal encounters.

CONSEQUENCES FOR COMMUNITY VULNERABILITY

Community capacity is stressed from a number of sources. As permafrost thaw compromises infrastructure, the relative isolation of some residents, particularly in the Keno area and in the McQuesten Valley, may increase. The cost of providing services to these areas, such as maintaining reliable access routes, could be high if infrastructure renewal is left too long. While climate change will extend the potential tourism season in Mayo, reduced wilderness opportunities due to ecosystem stress may reduce tourist interest in the region, resulting in economic shortfalls. Such shortfalls will further reduce community capacity. The challenges with infrastructure renewal may be compounded by deteriorating housing quality in the Village of Mayo if groundwater flooding is not addressed. Abandonment of even small areas of the village in response to substandard housing conditions will reduce the income of the municipality, creating a subsequent and negative impact to community capacity. The aging of a significant component of the region (in Keno and in Mayo) will also exacerbate capacity limitations.

Health concerns also arise from a number of sources. Scarcity of traditional foods may lead to an increased reliance on store-bought foods. The availability of these foods, which is already limited, may be further reduced by an increased demand and/or an increased cost if transportation is hampered by infrastructure problems. Poor quality food choices may result in the switch to store-bought foods. This may bring about subsequent and negative impacts to community health, or affect community culture and/or mental health. Compounding these concerns may be an enhanced risk for residents and tourists if they choose to consume untreated water while travelling in hinterland areas as climate warming may reduce water quality.

SCENARIO 4: FUTURE VULNERABILITY IF THE COMMUNITY GROWS RAPIDLY AND THE CLIMATE CHANGES

In this scenario, the community and the region experiences marked growth with climate change as is envisaged in the A1B emissions scenario (Nakićenović et al., 2000). In addition to those impacts projected in Scenario 3, the following stresses will carry implications for human activity in the Mayo region, and have subsequent consequences for community vulnerability.

CLIMATE SCENARIO

The mean annual temperature of the Mayo Region rises from -4.8°C to -2.9°C by 2030 and to -1.2°C by 2050. Precipitation increases over the same period. By 2030, total annual precipitation has risen from 524.2 mm to 571.3 mm (a 9% rise from the 1961-1990 normal). By 2050, total annual precipitation has increased to 595.9 mm (a 13.7% increase from the 1961-1990 normal). Seasonal precipitation increases. By 2030, seasonal precipitation has increased annually, and most significantly (15%) during the spring months (March, April and May). By 2050, the most significant increase in precipitation, 16%, occurs over the winter months (December, January and February).

IMPACTS

The hydrology of the region is further changed as water consumption increases to meet the demands for hydro power generation, and the demands by a growing community and the mining industry.

Thawing permafrost, in addition to the increasing challenges observed in Scenario 3, results in widespread infrastructure stress. The section of the Silver Trail connecting Mayo and Keno is particularly affected given the number of operating mines in around Keno Hill.

Population growth and increased activity on the land, when combined with ecosystems stress resulting from climate change, leads to an increased risk of human-induced forest fires, the spread of invasive species, and the further displacement of endemic species.

IMPLICATIONS FOR HUMAN ACTIVITY

Infrastructure renewal becomes a paramount concern in the Mayo region as environmental stresses impact housing, mines and roads throughout the region. In some areas, such as Mayo, the increasing need for housing combined with deteriorating housing stock forces some to live in substandard housing. The use of substandard housing may increase if thawing permafrost reaches a degree at which it begins to limit the area available for development. Permafrost thaw, changing hydrology, and other landscape changes may have a negative effect on travel conditions throughout the Region if they occur along traditional travel routes. Transport challenges result in an increased demand for infrastructure upgrades. Fire risk to community infrastructure increases with the growth of the community, requiring regular fire control treatments along highway corridors and nearby to community developments. The 30-year climate trends and environmental forecasts used for determining development thresholds and engineering standards for the mining industry fail to accurately anticipate highly variable climate (and therefore landscape) conditions. Mining infrastructure begins to fail with increasing regularity and has subsequent impacts on the environment. Abandoned mine infrastructure is also undermined by changing landscape conditions, possibly resulting in subsequent contamination of the environment.

Economic growth offsets some of the challenges observed in Scenario 3. Rising populations in the region create local demand for forest and agricultural goods. The economy diversifies, making up for losses to trapping and outfitting. While infrastructure stress and relative isolation in some areas reduces the extent to which residents are able to diversify the Mayo regional economy, capacity in the region does improve overall. This increased capacity leads to improvements to infrastructure, especially housing.

Traditional activities are negatively affected. Water quality decreases, subsequently raising the possibility that contamination issues will arise despite the continued monitoring and treatment of domestic water. Traditional foods such as fish would be impacted with the changes to water quality. Changes in hydrology and/or water quality would compound those stresses on the Region's ecosystems that are associated with warming conditions such as proliferation of invasive species and the pressures from increased human activity. The availability of traditional foods declines significantly as a result. Trapping is negatively affected by a decline in, or the displacement of marketable species, as well as the increased challenges experienced when travelling on the land.

Consequences for community vulnerability

The implications for community capacity in this scenario are not as severe as those discussed in Scenario 3. While the regional capacity to respond to stresses will no doubt decrease, the benefits of a larger population will limit the extent to which capacity may be reduced. Regional capacity will be stretched by a number of sources, including the effects of infrastructure decline, the impacts of climate change on local culture, and the pace with which new skills will be required (i.e., the new skills required for expanding the agriculture or forest industries as opposed to trapping, an industry that may begin to decline). Regional capacity will also be stretched by the dynamics of the mining industry as it relates to the Region and will be determined by how the industry chooses to respond to the impacts of climate change. For example, the continued reliance of the mining industry on labour and materials procured outside the community will not improve capacity within the Region. On the other hand, capacity may be improved if the mining industry opts to invest directly in the Region, improving infrastructure and enhancing the range of skills available in the three communities.

The procurement of high-quality food becomes increasingly problematic. The cost of transportation and declining availability of traditional foods could make obtaining nutritious food challenging for some in the community. Local agriculture, if supported by population growth and climate change, may address some of these challenges. Increased consumption of food by those employed by the growing mining industry will create further demands on local food sources and may result in decreased food availability even if local food production increases. A reduction in the availability of traditional foods will also have an impact on local culture.

Health concerns arise from a number of sources. With increasing population placing pressure on housing stock, a segment of the population would likely live in older, sub-standard housing vulnerable to dampness and mould. This is different when compared to Scenario 2, in which sub-standard housing stock was replaced, given the reductions to community capacity by the severity of emerging challenges. The projected housing shortfall, when combined with a rapid increase in the regional population, suggests that exposure to negative consequences such as health risks due to sub-standard housing, will not be limited to a single demographic. Health issues such as obesity also increase, largely from the need for nutritious food. Food security would become an increasing concern, and current dietary-related health issues would be increasingly exacerbated as traditional foods become more difficult to obtain.

CONCLUSIONS

The scenarios discussed in this report demonstrate that even relatively minimal changes to the Mayo region (i.e., climate change and population growth) will exacerbate the pre-existing vulnerabilities in the community. Challenges influencing vulnerability in all scenarios are associated with continued pressures placed on infrastructure and regional health. More acute climate change compounds these stresses while at the same time introducing new ones, having subsequent impacts on community health and capacity.

Similarly, while capacity limitations were observed in all scenarios, it is interesting to note that capacity was decreased by climate change (e.g., scenarios 1, 3, and 4), while improved by community growth (Scenario 2). This suggests that any policy or planning that supports economic growth in the region will assist the community in adapting to climate change. This capacity is reduced, however, by the rapid and severe onset of climate change that is projected via the A1B SRES emissions scenario. Capacity is stretched the most in scenarios where the community does not grow, resulting in the significant issues discussed in Scenario 3 where the local population remains constant at the same time that a moderate to severe change in climate occurs. The scenarios therefore suggest that, in addition to economic development, adaptation must improve the capacity of residents to anticipate and address the effects of climate change as they emerge, with a focus on addressing contamination concerns, sub-standard housing, and food procurement.

The scenarios also imply that the traditional activities of the community, such as hunting and trapping, are vulnerable to climate change. In all scenarios, the trade-offs between changing population and changing climate conditions lead to a reduction in traditional activities. These trade-offs occur in all scenarios, even Scenario 2, where community capacity improves over time. Residents report that a decline in traditional activities will result in subsequent and correlated impacts to community culture and the mental health of some residents. Adaptations that preserve and protect traditional activities are therefore important to ensuring community resilience.

The picture of community capacity that emerges from these scenarios, which depicts a Region facing increasing and variable challenges from a number of sources, demonstrates that planning is required to determine how the residents can act now to prepare for a changing tomorrow. The adaptation plan currently being prepared for the Mayo Region should address vulnerability emerging from declining infrastructure, impacts to traditional activities, emerging health concerns, and the potential impacts stemming from mining in the region (for example, contamination and infrastructure concerns associated with relict mine sites in the Region).
In addition to adaptations recommended specifically to increase the ability of the Region's communities (Stewart Crossing, Mayo and Keno City) to respond to increasing vulnerability or emerging opportunities, the plan should explore the implications of policy relating to those sectors influenced by climate change. Specific areas of policy that may be relevant to improving community resilience, as observed in the scenarios, include natural resource management (to ensure healthy ecosystems), infrastructure renewal (to ensure dependable access to the region), economic development (to support growth) and the protection of First Nation's culture.

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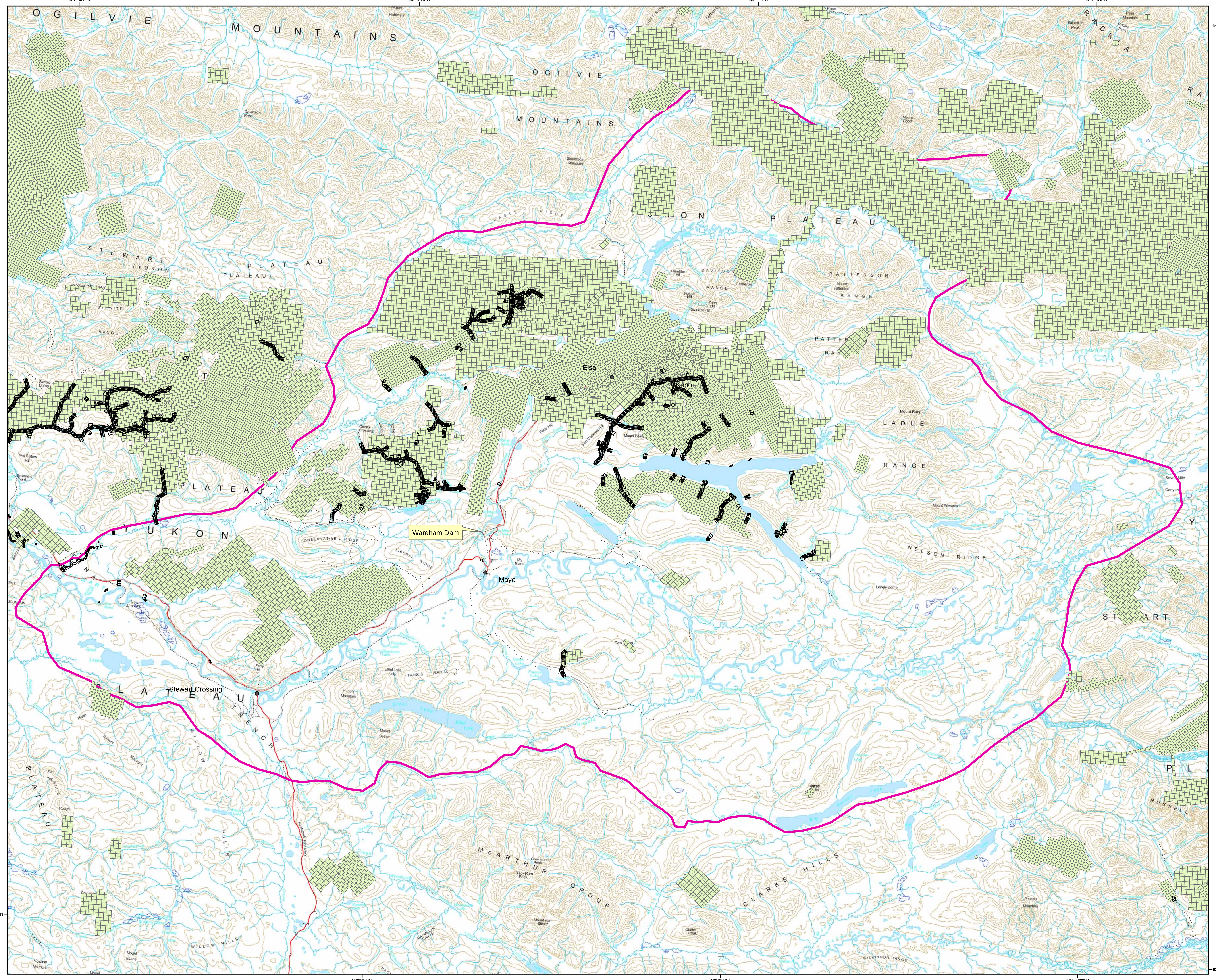
Mayo Region Climate Change Adaptation Project Including Claims in Good Standing as of May 2011



1:350,000

0 5 10 20 30 40 Kilometers

Yukon Albers Area Projection

Adaptation Study Area Boundary

Quartz Claims

Placer Claims

Creeks/streams

Contour

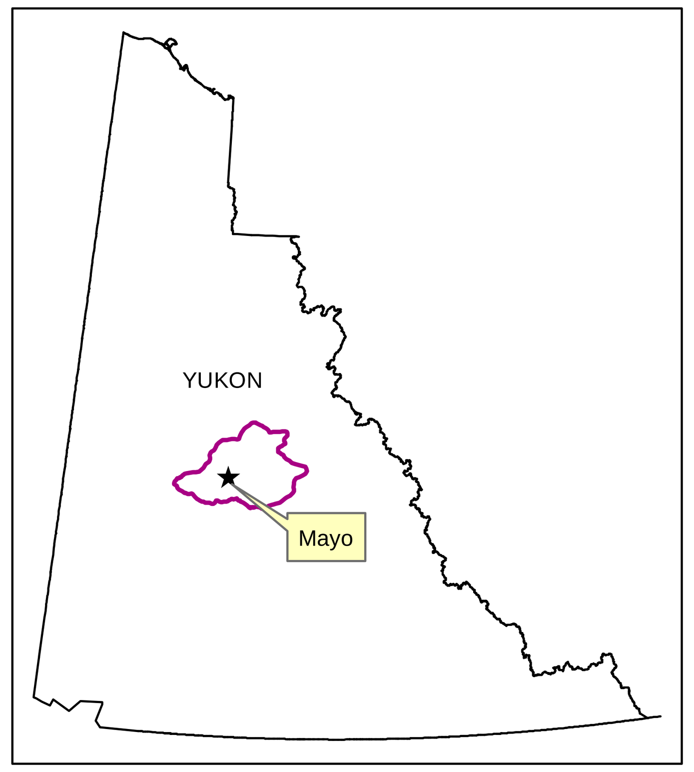
Waterbody

Roads

Main Road

Limited-use road

Trail



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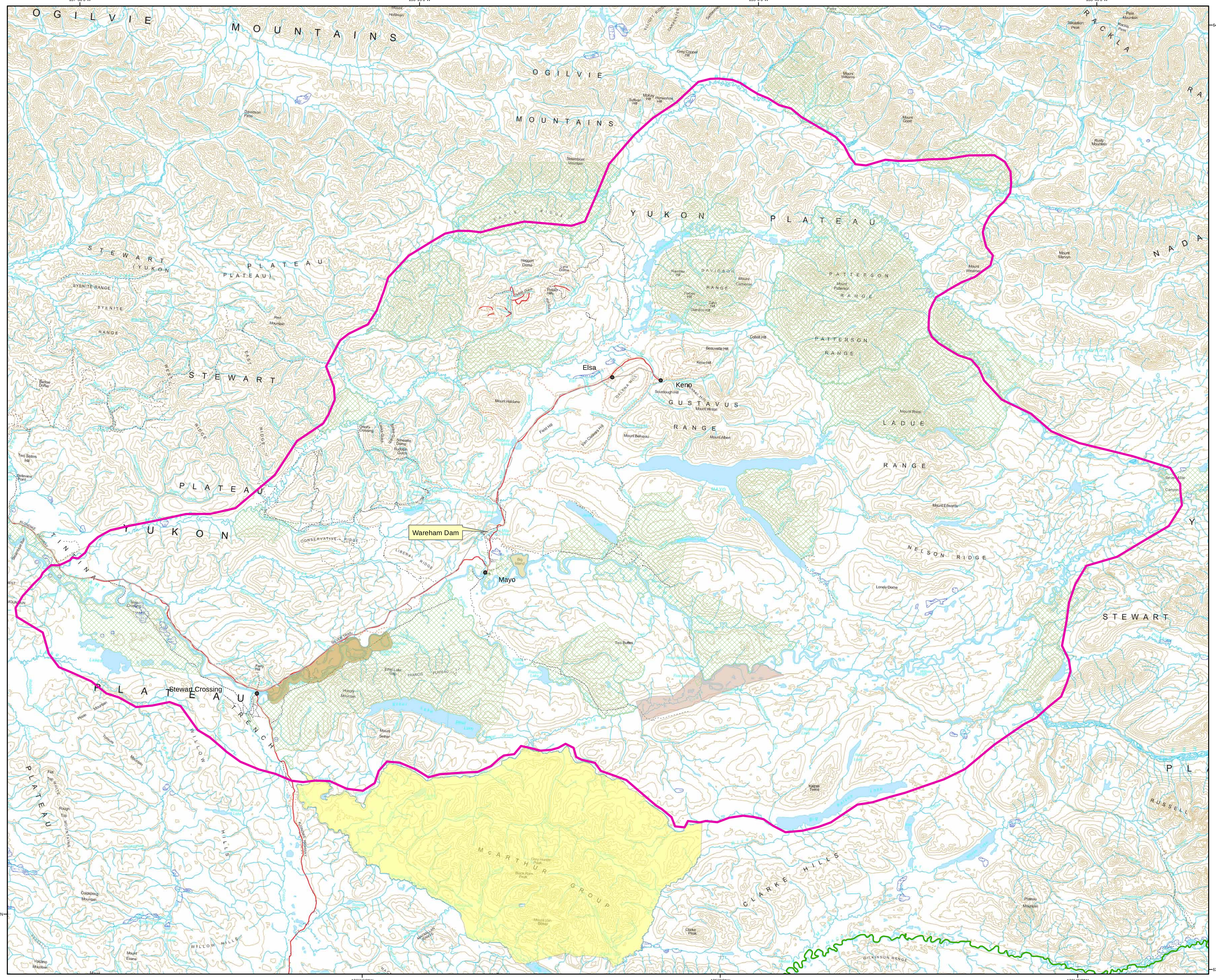
Mayo Region Climate Change Adaptation Project Including NNDFN Settlement Lands and Protected Areas



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Yukon Albers Area Projection

Adaptation Study Area Boundary

NNDFN Settlement Lands

Habitat Protection Areas

Big Island

Ddhaw Ghro

Devil's Elbow

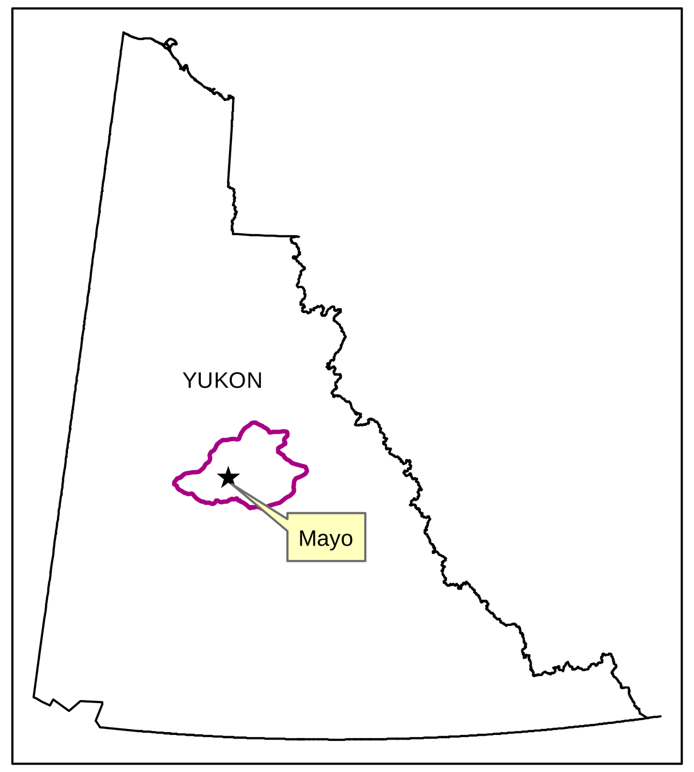
Horseshoe Slough

Roads

Main Road

Limited-use road

Trail



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