CARCROSS DRINKING WATER SUPPLY – SOURCE WATER PROTECTION PLAN

PREPARED FOR:

YUKON GOVERNMENT COMMUNITY SERVICES

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EXECUTIVE SUMMARY

The objective of this source water protection plan is to identify hazards and vulnerabilities that may threaten the safety and sustainability of the water supply in the community of Carcross and to recommend risk management actions to address them. The plan includes a delineation and characterization of the drinking water source; an inventory of potential contaminants; a characterization of drinking water source risks; and recommendations to protect the water source.

The municipal drinking water source for the community of Carcross is surface water from Bennett Lake. The assessment area for this report consists of the Bennett Lake watershed area upstream of the water intake. Several possible weaknesses of the source were identified:

- The source water experiences high levels of turbidity as result of sediment transport in the Watson River during spring freshet and when Bennett Lake turns in spring and fall. Other spikes in turbidity occur, possibly due to a build-up of sediment in the intake system.
- The water intake is currently susceptible (no protection around the intake) to vandalism.
- While water-based recreation is not believed to occur at a level that would pose a measurable risk to source water, no precautions have been made to minimize this risk through management actions.

We recommend four risk management actions to improve the safety and sustainability of the water source. These management actions are listed in order of priority.

1. Increase the level of security at the water intake by constructing a cage around the water intake. The cage should be removable, but with limited access so it can't be opened accidentally. This action will abate the risk of damage to the structure and/or contamination due to vandalism or accidents from recreational activities.
2. Institute a regular maintenance schedule for the water intake (at least twice a year). This involves removing sediment build-up around and in the intake structure.
3. Continue regular monitoring of the raw water quality. Correlate this information with any other activities to the water intake system to determine what causes turbidity spikes outside of the expected seasonal peaks.
4. There is a lack of regular water quality and hydrology monitoring information that would allow rapid response to changes in the water system that may be occurring due to mining drainage, fuel and fecal contamination, or climate change. While monitoring responsibilities may lie with other governments or departments, we point out their importance:
   a. Monitoring the precipitation and hydrology (i.e. lake levels and flow) of the watershed to plan for any trends associated with climate change.
   b. Monitoring tributaries to Bennett Lake that are affected by mining drainage, such as acid rock drainage, to ensure quality standards for drinking water are met.
   c. Monitoring water quality within the vicinity of the water intake in Bennett Lake and Nares River for fecal coliform, hydrocarbons, and other possible contaminants in the area.

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1 INTRODUCTION

The Government of Yukon, Department of Community Services is proposing to upgrade the drinking water system in Carcross, Yukon. As part of this project EDI has prepared a source water protection plan to provide guidance for safeguarding the existing surface water source.

1.1 OBJECTIVE

The objective of this source water protection plan is to identify hazards and vulnerabilities that may threaten the safety and sustainability of the water supply and to recommend risk management actions to address them. This plan focuses on source protection: we delineate and characterize the drinking water source, provide a potential contaminant source inventory, characterize the drinking water risks, and recommend action to improve drinking water protection.

Elements of the drinking water supply that involve drinking water treatment, system maintenance, monitoring, operations and emergency response are not part of this plan, but are described and incorporated in the design plans to upgrade the Carcross Drinking Water System (design in progress by Dayton & Knight for Yukon Government).

1.2 SCOPE

Since 1990, the municipal drinking water source for the community of Carcross has been surface water from Bennett Lake. Prior, the water came from groundwater wells, but due to elevated arsenic levels in the groundwater, this option is no longer used. The geographic focus of this source water protection plan is therefore the Bennett Lake watershed. In this we focused on aspects of the watershed located upstream of the water intake and that relate to drinking water (Figure 1).

1.3 OUTLINE

The report has been laid out in a manner that is consistent with the key components of the Comprehensive Drinking Water Source to Tap Assessment Guideline (B.C. Government, 2010) as it relates to an assessment of raw source water.

Section 2 describes the methods of this guide document and how they were applied in this assessment.

Section 3 provides the results of the assessment. In this section, we delineate and characterize the watershed; provide a detailed outline of potential sources of contamination; describe the current source water protection measures in place; and provide a risk evaluation for the potential contaminant sources.

Section 4, provides a list of recommended actions that will abate some of the risks of contamination to raw water for drinking water supply for the community of Carcross.

2 METHODS

As there is no Yukon guidelines for source water protection, the assessment was conducted using the methods outlined in the Comprehensive Drinking Water Source to Tap Assessment Guideline (2010), published by the BC Ministry of Healthy Living and Sport. We used the guideline modules that apply to developing a protection plan for source water and did not use the modules relating to other elements of the drinking water system, including treatment, system maintenance, monitoring, operations and emergency response.

The assessment used Module 1: Delineation and Characterization of the Drinking Water Sources; Module 2: Inventory of Potential Contaminants; and the relevant parts of Module 7: Characterization of Risks and Module 8: Recommendation of Actions to Improve Drinking Water Protection. Module 1 and 2 were completed using existing information only. Descriptions of the methods followed are provided below.

The watershed and the water intake system were characterized based on available documentation. The background information was analyzed, potential hazards to the source water were identified, and the risks of these hazards were assessed, following the methods suggested in the draft guideline. A prioritized list of recommended actions of a drinking water risk management strategy for the Bennett Lake watershed was then developed.

3 ASSESSMENT RESULTS

3.1 DELINEATION AND CHARACTERIZATION OF THE DRINKING WATER SOURCE

This section includes the delineation of the contributing watershed, definition of the assessment area, characterization of the watershed, and evaluation of the integrity and location of the water intake.

3.1.1 WATERSHED AND ASSESSMENT AREA BOUNDARY

The boundary of the Bennett Lake watershed was delineated as the entire catchment area for Bennett Lake. Geographically, the watershed covers 3,525 km^2, extending from Yukon Territory into the northwest corner of British Columbia and a small section of Southeast Alaska. Bennett Lake is the most prominent waterbody in the catchment area. Watson River and Wheaton River are the largest rivers in the watershed.

The source water is primarily affected by upstream events and activities, but flow reversals can occur during spring freshet and other high water events (e.g. flooding; EBA, 2009). Therefore, downstream activities could affect the water intake and the source water. The assessment area for this report corresponds therefore with the Bennett Lake watershed and the area downstream of the water intake including Nares River to Nares Lake. The watershed boundary is shown in Figure 1 and the water intake location in Figure 2.

3.1.2 CHARACTERIZATION OF THE WATERSHED

The characteristics of the watershed have been documented through various existing sources. These sources include, but are not limited to, federal and territorial government studies, biophysical classification literature, private industry assessments, and government summary records on contaminated sites and climate data.

3.1.2.1 PHYSIOGRAPHY

The study area is located on the transition between two major landscape features: the South Yukon Plateau to the east and the Boundary Range of the Coast Mountains to the west. The mountains are most rugged and have the highest elevations in the eastern portion of the study area. A number of peaks have elevations over 2,000 m, including Mt. Skukum (2,347 m) and Mt. McNeil (2,300 m). Most of the mountain ranges in the region drain via the Wheaton and Watson rivers. Bennett Lake is the largest lake in the watershed. Other smaller lakes include Lindemann, Homan and Alligator lakes.

The Bennett Lake watershed lies primarily within the geologic terrain known as Stikinia, which spans the area between Carcross and the Primrose River. Three volcanic cauldron complexes are found within Stikinia: underlying the highlands of Montana Mountain, around the West Arm of Bennett Lake, and Mount Skukum (Smith *et al.*, 2004). According to Smith *et al.* (2004), each complex "…contains cliff bands and pinnacles of dark, fine-grained andesite, dacite flows and breccia. Steep faults separate the volcanics from sandstone conglomerate of the Laberge Group, and augite porphyritic basalt and limestone of the Lewes River Group, which define Stikinia."

This area has significant mineral potential and has a history of mining and exploration. Gold, silver and antimony mineralization have been mined at Mount Skukum (Taylor, 2007) and Montana Mountain (Roots, 1981). The Wheaton River area also contains many metallic mineral showings that are detailed by Hart and Radloff (1990).

3.1.2.2 BIOLOGICAL FEATURES

The town of Carcross is located at the convergence of three ecoregions, although only two of the ecoregions are found within the catchment area. The Bennett Lake watershed is bisected by the Yukon Stikine Highlands Ecoregion, which roughly covers the southern two thirds of the catchment area, and the Yukon Southern Lakes Ecoregion, which spans the northern third of the catchment. The Boreal Mountains and Plateau Ecoregion is found immediately to the east of Carcross but is located outside of the catchment area.

The vegetation reflects the great variation in elevation and precipitation of the catchment area. Vegetation in the Yukon Stikine Highlands Ecoregion is influenced by large snowfalls at the high elevations and high moisture in the valley bottoms (Smith *et al*., 2004). Because of the coastal influence, vegetation is not limited by moisture, as are the ecoregions found further toward the interior (Smith *et al*., 2004). Valley bottoms are typically dominated by coniferous and some mixed forests, while subalpine is dominated by shrubs, and tundra above 1,350 m in elevation is dominated by dwarf shrubs and lichens. The dominant tree species is white spruce in the lowlands, with lodgepole pine being common in burned areas. In the subalpine, white spruce and sometimes subalpine fir are found mixed with shrub birch and willow.

The Yukon Southern Lakes Ecoregion which predominates through the northern half of the catchment area is typified by a much drier and cooler climate (Smith *et al*., 2004). The ecoregion is set largely in the rain shadow of the St. Elias Mountains, resulting in lower rainfall than is found in the Yukon Stikine Highlands Ecoregion. The vegetation of the Yukon Southern Lakes Ecoregion is typified by largely open coniferous and mixed woodland (Smith *et al,* 2004). Lodgepole pine is the dominant tree species, reflecting the lower precipitation of this area and the frequency of forest fires. Areas that have higher moisture, such as in flood plains, and that have not experienced a forest fire in the previous 100 years are typified by white spruce forests. Subalpine fir is dominant in higher elevation forests. In these high elevation forests, feathermoss has high cover where the canopy is dense, and scrub-birch and lichen have high cover where the canopy is open (Smith *et al.,* 2004).

The catchment basin is rich in wildlife diversity. The eastern section of the Yukon Stikine Highlands Ecoregion is inhabited by the Ibex woodland caribou herd (Smith *et al*., 2004). It is small and fragmented herd, numbering about 450. Other mammals are common in the catchment area. These include mountain goat, moose, Dall sheep, wolves, wolverine and black bear. Amongst amphibians, the Columbia spotted frog has been observed at two locations along the West Arm of Bennett Lake and is at its known northern limit (Smith *et al.,* 2004).

Many bird species take advantage of the expansive lakes and high elevation streams. As noted by Smith *et al.* (2004), in early spring, open water at the outlet of Bennett Lake provides a staging area for swans, diving ducks, and some dabbling ducks. Bennett Lake provides breeding and staging habitat for a host of other birds, including Pacific and Common Loons, Common Merganser, Bonaparte's, Mew, Herring Gulls, and Arctic Tern. Fast-flowing mountain streams provide habitat for Harlequin Duck and American Dipper while the Wandering Tattler breeds at the headwaters. Other species known to occur in the Yukon Stikine Highland Ecoregion include Bald Eagle, Northern Goshawk, Spruce Grouse, Great Horned Owl, Northern Hawk Owl, Three-toed Woodpecker, Gray Jay, Common Raven, and Boreal Chickadee (Smith *et al.,* 2004).

Fish species found in Lake Bennett include lake trout, lake whitefish, northern pike, round whitefish, longnose sucker, burbot, least cisco and Arctic grayling (de Graff, 1992).

3.1.2.3 CLIMATE

The climate of the project area is strongly influenced by the catchment area's position on the transition from the Coast Range to the drier interior. The temperature regime of the southwest Yukon is typically continental, with great daily, seasonal and regional variability (Ogden, 2006). Carcross itself lies within the Cordilleran climatic region, which is characterized by long cold winters and warm and dry summers (Mann, 1998). Because the region lies in the rain shadow of the Coast Mountains, this area is one of the driest parts of the Yukon. Approximately half the annual precipitation falls as snow (Smith *et al.*, 2004). Carcross receives a mean total precipitation of 211.4 mm, 56.1% as rain and 43.9% as snow. The mean monthly temperature at Carcross ranges from a low of about -20 ºC in January to a high of about 12 ºC in July (Mann, 1998).

The climate for much of the catchment area is different than what is experienced at Carcross due to increased elevation and a reduced rain shadow effect. The climate of the Yukon Stikine Highlands ecoregion, which spans the majority of the catchment area, is near enough to the Pacific Ocean to receive somewhat higher amounts of precipitation with annual amounts of 300 to 500 mm (Smith *et al.*, 2004). Precipitation is the lowest from February through May and the greatest in the fall and early winter. Precipitation generally falls as snow from October to May, as well as at elevations above 2,000 m throughout most of the year. In the mountainous areas of the catchment, temperatures range dramatically with elevation (Smith *et al.*, 2004). During January, the mean temperatures are near -25 °C in the lower valley floors compared to nearly –18 °C at higher elevations. In July, the lower valleys have mean temperatures similar to Carcross, although this decreases to 5 °C over the higher terrain.

3.1.2.4 HYDROLOGY

The catchment area receives water from the eastern-facing slopes of the Boundary Ranges, and is part of the Yukon River drainage. Most of the Bennett Lake watershed finds its sources in the Yukon Stikine Highlands ecoregion which encompasses the mountains of the Boundary Range. Because the watershed is a high altitude source region, and because of its relatively small size, there are no large representative streams within its boundaries. The major intermediate streams in the watershed are the Wheaton and Watson rivers (Smith *et al.*, 2004).

Hydrologic response is typical of a glacial system even though the total area of glacier coverage is generally low (Smith *et al.,* 2004). As described by Smith *et al.* (2004), annual stream flow within these systems is characterized by a rapid increase in discharge in May due to snowmelt in the valleys, and a peak discharge in July or August due to high elevation snowfield and glacier melt. Both the Watson and Wheaton rivers have glacial sources. Systems in the catchment area that are not glacier-fed typically peak in June (Smith *et al.*, 2004). Stream flow response tends to be quick and flashy as a result of the steep and relatively short stream channels. Intense summer rain events result in approximately 40% of the annual maximum flows on the smaller streams. Some of these smaller streams are also susceptible to mudflows as a result of these summer storms (Smith *et al.*, 2004).

Smith *et al.* (2004) also provides a thorough overview of hydrological runoff within the Yukon Stikine Highlands Ecoregion. As described in Smith *et al.* (2004), "…mean annual runoff is moderately high and variable with values ranging from 130 mm in some non-glaciated basins to 500 mm in glaciated basins with an ecosystem mean of 317 mm. Mean seasonal and summer flows are moderately high with values of 21×10^{-3} and 17×10^{-3} $m^3/s/km^2$, respectively. The mean annual flood and mean maximum summer flow are moderately low and moderate with values of 63×10^{-3} and 42×10^{-3} $m^3/s/km^2$, respectively. Minimum stream flow generally occurs during March or earlier."

3.1.2.5 WATER QUALITY

Current and relevant water quality data is limited for Bennett Lake and the watershed. Much of the available information comes from older studies (e.g. Baker, 1979), from contaminant studies with highly constrained scope regarding water quality reporting (e.g. Roach, 1999) and from secondary locations associated with mine sites and other disturbed areas (e.g. Mann, 1998). Overall, all water quality studies that were reviewed specific to Bennett Lake have found that the water quality has met all applicable standards at the time the studies were conducted. Table 1 lists the contaminated sites (as defined by YG Environment) within 10 km of Carcross. In addition, records were searched for recent spills, but none were reported. In cases without referenced literature, the information provided here comes from YG Environment Contaminated Sites file summaries (Yukon Government 2010).

The most complete account of water quality for Bennett Lake comes from a 1977 study which reviewed water quality of selected Yukon River headwater lakes potentially impacted by communities (Baker, 1979). While this study is based on only one year of data, the study utilizes numerous sampling points in Bennett and Nares lakes to characterize water quality using a full spectrum of water quality variables. Turbidity was found to exceed the acceptable limit at a number of sample locations during the July sampling period, although all of these sample sites were located downstream of the current water intake. Elevated turbidity is likely related to spring run-off and wind-related mixing (Baker, 1978). The monitoring results from 1977 demonstrate that the quality of raw water in Bennett Lake appears to be acceptable year-round. All water chemistry measurements taken upstream from the Nares River in Bennett Lake were either below detectable limits, or below the acceptable limits as recommended by the Working Group on Water Quality Objectives in 1977 (Baker, 1978). Water chemistry variables that were examined during this study included pH, nitrite, nitrate, ammonia, turbidity, total organic and inorganic carbon, extractable metals, dissolved heavy metals, hardness and total coliform. All sites upstream of the Nares River, including the current location of the Carcross water intake, were within the objectives (Baker, 1979).

More recently, a study was conducted in Carcross targeting specific water quality concerns of possible off-site contamination in the Nares River and the surrounding lakes. An investigation into potential organochlorine contamination of local water resources was prompted in response to the detection of high levels of PCP and other contaminants on site at a railway tie treatment plant in Carcross (Roach, 1999), which was located on the waterfront of the Nares River. The investigation revealed that higher levels of chlorophenols and anisols were present in Bennett Lake than would be expected from normal atmospheric airborne deposition. The higher concentration of volatile chlorophenols in Bennett Lake was determined to be possibly a result of short-range airborne transport from the tie treatment plant. The levels of contamination in Nares Lake were over double that of Bennett Lake with the contaminants assumed to have been transported by surface flows. However, all chlorophenol levels were well below the 1999 Yukon Aquatic Life Standard of 20,000 ppt for soils (Roach, 1999).

There are several sites in Carcross where reportable amounts of fuel have been spilled or leaked (Table 1), however it is not clear if any of this contamination has reached Nares River. All sites are located downstream from the water intake.

In addition, several spills have been reported over time from the operation of the Skagway-Whitehorse pipeline as well as the White Pass Yukon Route Railroad (WP&YR). The pipeline paralleled most of the WP&YR; both were operated by the same company. Some may have been near Bennett Lake. Resulting contamination of the source water is difficult to determine due to the historical nature of the spills (pipeline ceased operation in 1992; spill reports data back well before that), limited reporting as well as limited delineation efforts. For instance, although some contamination with poly-aromatic hydrocarbons and metals (above 2002 CCME guidelines) was found in sediment of a creek that flows into the south end of Bennett Lake near the Bennett Lake Railyard, the scope of the study was limited, and neither the source nor the extent of contamination in the Bennett Lake could be verified (EBA 2002).

Water quality concerns arising from mine site drainage have been summarized by Mann (1998) and Roach and Cunningham (2000). These documents examine water contamination related to mining activities in the Montana Mountain area, particularly arsenic and acid rock drainage (ARD). A number of mine sites in the Montana Mountain area, past and present, are within the Bennett Lake watershed. Mann (1998) concludes that water quality from the mine sites met the Canadian Council of Ministers of Environment (CCME) Freshwater Aquatic Life remediation criteria at that time (i.e. 1998), with the exception of the water flowing from the Venus and Arctic mines and associated tailings pond. While some of the Arctic mine site is within the Bennett Lake watershed, the creeks adjacent to the Arctic Mine (Arctic Caribou/Big Thing and Peerless Mines) show little or no impact from the poor quality mine waters. Similarly, runoff from the Arctic Gold and Silver tailings pond has no measurable impact on the water quality of Tank Creek, which meets Freshwater Aquatic Life criteria (Mann, 1998). Further investigation on the Arctic Gold and Silver tailings site revealed that no measurable environmental effect was found on the water quality of the beaver pond and Tank Creek, a direct tributary of Bennett Lake. While the tailings on site were found to contain metal concentrations that could have been hazardous, the drainage was not large enough to have a measurable effect on the water quality downstream (Roach and Cunningham, 2000).

Table 1: Listing of known contaminated sites (as defined by YG Environment) within 10 km of Carcross.

Site ID	Location	Contaminant of Concern	Status
Carcross Hydrometric Station	Southwest edge of Carcross town site, west of the railroad bridge. 60° 09' 50"/134° 42' 27"	Mercury, resulting from gauging station activities	Roach and Cunningham 1997 – site is contaminated. No info in YG Environment files
Carcross Waterfront (former railroad tie plant)	Waterfront on the north side of Nares River, west of the South Klondike Hwy	Pentachlorophenol (PCP), petroleum hydrocarbons, metals, resulting from tie processing	Various cleanup and restoration activities completed since 1997, but no final closure report available
Carcross Pump Station	North side of Carcross near railroad, Block 50, CLSR 67253	Petroleum hydrocarbons, resulting from historic pipeline pumping activities	Contaminated soil removed , but some residual contamination left at the site.
Carcross Housing Unit	Unit 1005 Tagish Avenue, Carcross	Petroleum hydrocarbons due to 200L heating oil spill	Site cleanup and remediated in 1998, but no final closure report available.
Carcross CTFN lot along Klondike Hwy	Lot 1006 (1&2), Carcross	Petroleum hydrocarbons due to fill up spills and leakage of underground storage tanks	Site was delineated, and contamination likely migrated off-site. Some remediation was completed, but no information on cleanup status available.
RCMP Detachment	Just west of the Klondike Hwy, north of the Nares River, Lot 1022, CLSR 70266	Petroleum hydrocarbons spill (appr. 4,000L)	Site has been delineated. Cleanup plan is being developed (2009).
Old Choutla School	Lot 1143, CTFN C 17	Petroleum hydrocarbons from a fuel oil spill.	30 m^3 of contaminated soil removed, but no final cleanup report available.
Carcross Airport	East of the Klondike Hwy, disposition 2009-1040	Pentachlorophenol (PCP), petroleum hydrocarbons in drums on site	Drums removed, but unsure if any leakage occurred because no record of soil sample present. Current site status is unknown.
Old Dump/Sewage Lagoon	North of the Carcross Airport	Metals, petroleum hydrocarbons	Contamination likely due to sewage lagoon rather than dump leachate. Sludge removed in 2005. Site contamination remains
Arctic Gold and Silver Mine, Tailings Impoundment	4 km south of Carcross on Montana Mountain	Petroleum hydrocarbons, metals; tailings are acid generating	Unclear if the site has been remediated since 1998 investigation.
Arctic Gold and Silver Mine	4 km south of Carcross on Montana Mountain	Arsenic dust from mining activities	Historic mine operation now shut down. Tailings are acid generating and are discharging low pH seepage with high metal content into small adjacent lake.
Arctic Caribou	8 km south of Carcross on Montana Mountain	Petroleum hydrocarbons, metals	Most recent (2006) monitoring shows no contaminated soils or groundwater on site

Site ID	Location	Contaminant of Concern	Status
Big Thing	9 km south of Carcross on Montana Mountain	Hydrocarbons; tailings are acid generating	Cleanup low priority as waste rock is not impacting significant receptors, as per notes from 2008.
Bennett Lake Railyard	Tributary at south end of Bennett Lake	Hydrocarbons, metals in sediment in creek	This site is located in B.C. No cleanup records.

3.1.2.6 LAND USE

Historical land use of the Bennett Lake watershed has been dominated by mining. During the time of the Klondike Gold Rush (1896-1898), the lakes and rivers of the watershed were used primarily as a transportation corridor by stampeders in their migration to and from the gold fields of Dawson City. Stampeders traveled from Skagway, over the Chilkoot Pass, following the watercourse all the way to Bennett Lake, Carcross and beyond (Parks Canada, 2004). Interest in mining within the area occurred shortly after, in 1899, when silver and gold were first discovered in the Windy Arm area of Tagish Lake. This discovery sparked an intensive mining era in the region, with attention focused on Montana Mountain district. The Montana Mountain ridgeline has been actively explored and intermittently mined for 100 years (Mann, 1998). Most of the activity in this area was focused in two periods, from 1905 to 1921, and 1965 to 1971.

Other mining activities have focused upon the Wheaton River District, including Mount Skukum and the lands around the Wheaton and Watson rivers. The Wheaton River District first gained attention in the early 1890's when gold-bearing veins were discovered. Early exploration continued to discover occurrences of gold and silver throughout the area into the 1920s (Deklerk and Burke, 2008). The district was explored intermittently for precious metals, then for other metals such as copper and molybdenum in the late 1970's. In 1981, exploration activity peaked in the Wheaton River district due to an increase in the price of gold and the discovery of gold in the Mount Skukum volcanic complex. From 1986 to 1988, this site was subsequently mined for gold. Exploration is ongoing throughout the Wheaton River district and actions are being by companies, such as the Tagish Lake Gold Corp., to begin mine production again (Deklerk and Burke, 2008).

Tourism and recreation are also prominent land uses within the watershed area. According to Yukon Community Profiles (Yukon Government, 2004), recreational uses in the region include hiking, camping, skiing, recreational boating, fishing, hunting, horseback riding and snowmobiling. The Chilkoot Trail National Historic Site is likely the most popular recreation area in the catchment area, located at the headwaters of the watershed in the northeastern corner of British Columbia. This protected area, managed by Parks Canada, covers 135 km^2 of land at the southern-most point of the Bennett Lake watershed. The park attracted an average of 3,039 hikers per year between 1995 and 2005 (Parks Canada, 2004). Because of the wealth of outdoor recreation opportunities and access to tourist market, tourism is identified as being the primary area with potential for economic growth for Carcross. Plans for a multi-million-dollar First Nation resort complex near Carcross were in discussion as recent as 2004.

Residential land use is centered on the town of Carcross, although a number of small properties are scattered in very low density along the shores of Bennett Lake and across the watershed. Most survey land parcels outside of the Carcross area are located along the Klondike Highway. A few small agricultural properties are also accessible from the Klondike Highway, largely situated along the Watson River. Agriculture is very limited in the catchment area.

The presence of the White Pass and Yukon Railway and the fuel pipeline paralleling it have also been an influential land use throughout the catchment area. The railway runs largely parallel to the Klondike Highway, traditionally running from Skagway to as far as Whitehorse. At present, trains are only operated for sight-seeing purposes, bringing tourists from Skagway as far as Carcross. From Carcross, the train crosses the Nares River and runs for about 45 km along the shore of Lake Bennett until it crosses over the pass toward Fraser before heading down the toward the coast to Skagway.

3.1.2.7 WATER USE

The community of Carcross currently uses surface water from Bennett Lake as its potable water source. The water intake in the lake is located 380 m from shore and 2 m below the seasonal low water mark. From there the water is piped (pipe is buried 1.7 m for most of its length) to a treatment plant located at the corner of 4th Street and Bennett Avenue. The potable water is distributed to the residents of Carcross through water truck delivery to individual users, as required, to meet demand.

3.1.2.8 CLIMATE CHANGE

Evaluations of recent and projected changes in precipitation and temperature due to climatic variations have been completed for the western cordillera of Canada including Southern Yukon using computer modeling (Bonsal *et al.*., 2003). Overall, the network for monitoring climate in the southwest Yukon is very sparse and covers only a very short period. Therefore, the ability of to use historical weather observations as evidence of climate change is limited. Comparisons of climate normals for 1951-1980 and 1971-2000 show Whitehorse experienced an increase in mean annual temperature (0.5 ºC) and mean January temperature (3.0 ºC), but change in the mean July temperature; and increase in total annual precipitation (6.2 mm) between these two time periods (Ogden, 2006).

While there is no analysis is available specific to the Carcross region, broader modeling has been completed for southwest Yukon. Climate modeling projects that temperatures are expected to warm by 2.9 to 7.1 ºC in the southwest Yukon by 2080 (Ogden, 2006). Winters are anticipated to experience a greater degree of warming. Annual precipitation is predicted to increase by 10-30%, with the greatest increase being during the winter (Table 2).

One of the large uncertainties facing the southwest Yukon is whether the increase in precipitation will keep pace with the predicted warming. This is particularly a concern during the summer months. As temperatures increase, the rate of evaporation also increases. If temperature increases outstrip increases in precipitation, land areas will dry out and introduce the risk of drought conditions (Ogden, 2006). However, the snow cap melts faster too and could lead to flooding but also more moisture in the system.

Changes in temperature and precipitation will likely affect hydrologic flows in the regime, particularly for those systems that are glacier-fed, such as the Wheaton and Watson rivers (Church and Clague, 2009). Historic changes in precipitation and temperature have been correlated to recent deglaciation of the upper Wheaton River watershed. Observations collected from the National Climate Data and Information Archive for the Carcross weather station have shown an increase in mean atmospheric temperature, as well as an increase in average winter snowfall from 1907 to 2005. Despite increasing winter snowfall, changes in temperature continue to be the main cause of the persistent negative mass balance of the Wheaton glacier. Church and Clague (2009) predict that if air temperatures continue to rise and glaciers disappear, discharges and timing of peak flow events of these glacier-fed systems will be affected.

Table 2: Annual temperature and precipitation projections for Southern Yukon (adapted from Ogden, 2006)

Range of Predictions	Annual Temperature Projection (°C Change from 1961-1990 baseline)			Annual Precipitation Projections (% Change from 1961-1990 baseline)		
	2020	2050	2080	2020	2050	2080
Low	0.9	2.0	2.9	2.1	4.3	8.8
Medium	1.1	2.5	4.3	6.9	13.0	20.1
High	1.8	4.0	7.1	9.6	17.8	30.1

3.1.2.9 RECENT EXTREME WEATHER

The Southern Lakes region, including Carcross experienced flooding in August of 2007. This was a result of rapid snowmelt in the mountain at the headwaters of the Yukon River near Atlin, after higher than normal snowfall earlier that winter. The water level in Nares Lake was so high that it back flowed through Nares River into Bennett Lake (EBA 2009).

3.2 INVENTORY OF POTENTIAL CONTAMINANTS

Our inventory of potential contaminants was based on the review of historical and existing land uses or activities in the watershed, and those planned for the foreseeable future. It also includes possible contamination of the source water due to natural events. Potential contaminants are summarized in Table 3.

Based on the information reviewed, historical land uses that may have left persistent sources of residual contamination in the watershed include:

1. Historical mine sites;
2. Historical industrial land uses in and near of Carcross (i.e. railroad, tie plant); and
3. Historical residential use.

Mining operations on Montana Mountain, including the Venus Mine area, Arctic Mine area and Arctic Gold and Silver tailings and mill site, have potential to contaminate the system via direct water drainage and by wind-transport. While Bennett Lake may also be susceptible to wind-borne contaminants, particularly arsenic, water quality testing found that that all extractable metals were below detection limits (Baker 1978, Road 1999).

Within the town site, historical industrial sites including a railway tie treatment plant, a pipeline pump station and an old hydrometric station are also known to be contaminated. Residential septic fields and leach pits could potentially have contaminated land and water, however none have been measured.

Despite the presence of contaminated sites in and nearby the watershed, there is no measurable impact on water quality as a result from site discharge (Roach, 1997). The potential contamination to the Bennett Lake water supply due to residual effects of past mining activities and industrial land uses within the town site is therefore considered negligible.

<u>Existing sources</u> of potential contamination in the source water were identified to include:

1. Recreational use of Bennett Lake and watershed;
2. Historical mine sites;
3. Historical industrial land uses within the community of Carcross;
4. Current town land uses (i.e. residential/buildings/storage);
5. Vandalism; and
6. Sedimentation.

As described for historical sources of potential contaminants, the available documentation supports the assessment that potential contamination due to historical mine sites and industrial land uses within the community of Carcross are negligible at the present.

Based on available documentation and literature review, potential sources of contamination due to current recreational use of the lake and interior areas of the watershed are negligible. The key concern surrounding potential contaminants due to upland recreation would be fecal contamination. Potential contamination as a result of upland recreation is considered negligible as the primary inland recreation area in the watershed, Chilkoot Trail National Historic Site, has an effective human waste management system (Parks Canada, 2004). Human waste from train passengers on the WhitePass railroad that runs from Skagway to Carcross is held in holding tanks (Whitepass, pers. comm. 2010), so it is not a concern as a potential contaminant of the water source either. Water contamination resulting from water-based recreation is also expected to be negligible. Although boat usage can result in turbidity, shore erosion, introduction of invasive species and chemical contamination from fuels (Mosisch and Arthington, 2004), the size of the lake and the low density of motorized boat users in comparison to other studies suggests that potential contamination resulting from water-based recreation is expected to be low.

Current urban land uses within Carcross, such as homes, commercial buildings and storage sites, have introduced contaminants (i.e. microbial pathogens, hydrocarbons) to the soils and water at various locations in the community. While these contaminated soils have potential to affect water quality of groundwater wells in the town site (EBA Engineering Consultants Ltd., 2006), their potential to contaminate the source waters of Bennett Lake has not been identified.

Carcross is located near an area with high seismic activity, however, the peak ground acceleration (PGA) number is 0.128 which is considered low. The PGA helps designers determine how severely the ground/building will move. Therefore, the potential of structural damage to the water intake or increased sedimentation of the lake due to an earthquake is low.

Potential future sources of contamination were identified to include:

1. Recreational use of Bennett Lake and watershed
2. Future mine sites
3. Future industrial land uses within the community of Carcross
4. Future urban land uses within the community of Carcross (i.e. Residential/buildings/storage)
5. Vandalism
6. Sedimentation
7. Future mining
8. Earthquake
9. Climate change
10. Flooding events
11. Railroad activities

Again, based on the available documentation and a general understanding of the region, the potential sources of future contamination due to recreational use of Bennett Lake and the watershed, historical mine sites and historical industrial land uses, and earthquakes within the community of Carcross are considered negligible.

Mineral tenures and exploration activity for a variety of metals, particularly gold, exist throughout the watershed, including in the Montana Mountain and Wheaton River districts. Work is being undertaken to begin mine production in the Mount Skukum and Wheaton River area (Deklerk and Burke, 2008). Any proposed mining would be subject to prior review and approval/rejection under Yukon Environmental and Socio-economic Assessment Act (YESAA). A YESAA approval would be conditional upon ensuring that risks of contamination entering the watershed are mitigated. .

Sedimentation is and will continue to be a potential source of contamination. The primary source of incoming sediment is the Watson River, which drains into Bennett Lake relatively close to the water intake. High turbidity occurs during lake turn-over in late winter and early spring, during spring freshet and heavy precipitation (Baker, 1979). Wind conditions can also contribute to increased turbidity. It is conceivable that rising temperatures with more rapid snow melt or extreme weather events could contribute to increased run-off and sedimentation in the long term.

Table 3: Description of potential contaminant sources identified in the Bennett Lake watershed.

Contaminant Source & Description	Owner/ Jurisdiction	Distance/ direction from water intake	Possible Contaminants of Concern	Contaminant Transport Mechanism	Comments
Recreational use of lake	Yukon Government, Canada	0 m or more	Microbial pathogens, organic matter, hydrocarbons, etc.	Direct deposition	Ongoing but low intensity
Recreational use of uplands	Yukon Government, CTFN, Parks Canada	>500 m	Microbial pathogens, organic matter, hydrocarbons, etc.	Overland flow	Ongoing but low intensity
Residential/Buildings /Storage	Private, Government (YG, Canada, CTFN)	>100 m	Septic fields and tanks, fuel storage tanks, drums, gas station, cemetery	Leaching and overland flow	Potential for Fecal Coliform near shore. Contaminants affect well water but no indication of affects the source (lake) water
Historical industrial site contamination	Private	>500 m	Organochlorines and mercury	Leaching and overland flow	Contaminants present in soils and under buildings.
Vandalism	Yukon Government	0 m	Sediment, unknown substances	Sediment suspension; direct deposition	Likelihood of significant disturbance is considered low
Historical mining activities	Claim/Leaseholder, Yukon Government	10-50 km	Sediment, metals, nutrients, etc.	Wind, sediment suspension, direct deposition	Arsenic contaminated dust
Future mining	Claim/Leaseholder, Yukon Government	10-50 km	Sediment, metals, nutrients, etc	Wind, sediment suspension, direct deposition	Production is being sought in catchment area and is likely to proceed.
Sedimentation	Canada	Watson River	Sediment	Water flow	High turbidity during spring freshet
Earthquake	Yukon Government, CTFN	Entire watershed	Sediment, organic matter, nutrients, trace metals	Overland flow, sediment suspension, direct deposition	Potential structural damage to intake; no damage observed in 20 years of use.
Flooding	Yukon Government, CTFN	Entire watershed	Sediment, pathogens	Sediment suspension, overland flow	
Naturally occurring sources	Yukon Government	Entire watershed	Arsenic, radionucleides, pathogens	Ground water, overland water, direct deposition	Present regardless of level of protection
Railroad activities	White Pass & Yukon Route (private)	200 m or more	Derailment, railroad washouts	Water	Ongoing, and possibly increased activity

3.3 CURRENT SOURCE WATER PROTECTION

The water intake pipeline runs under the beach, drawing water from deep in the water column 380 m offshore from the town site. The current source water protection measures are limited. While no contaminants have entered the system due to failure of the system, we have identified several weaknesses:

- Presently, the source water experiences high levels of turbidity which are a challenge for proper treatment of the drinking water. To deal with turbidity and other contaminants, the water treatment system has a sand filter, a 10 micron filter, and a 1 micron absolute filter. During periods of high turbidity the system is not capable of filtering to the required 1 NTU. In order to adapt to this situation, filters are changed frequently. The raw water turbidity levels are between 1 and 7 NTUs most of the time (Dayton & Knight, 2010). This means that the water intake is actually outside of the Watson River sediment plume, otherwise the levels would be much higher (more like 40 to 80 NTUs). However, these levels are considered too high for regular filters to deal with. The problem is that the particle size is quite small, thus the particles stays in suspension and are difficult for the current water treatment system to filter out. Most of the sediment goes by the larger filters and plugs the small 1 micron filter. (Dayton & Knight/Jeff Boehmer 2010). In addition, spikes in the turbidity were reported in winter this year besides the seasonal lake turn-over sediment peaks. Dayton & Knights suspect that is a result of sediment being stirred up during startup of the pumps and consequently taken into the water supply system (water is not pumped 24/7).
- While water-based recreation is not believed to occur at a level that would pose a measurable risk to source water, no precautions have been made to minimize this risk through management actions. Access to the area immediately surrounding the water intake is unrestricted to all lake users.
- Although damage to the water intake has not been reported nor has security been identified as an explicit concern in any of the documentation reviewed, the water intake is currently susceptible to vandalism and no precautions have been taken to prevent any from happening. For instance, there is no protective structure around the water intake that is located in the lake.

3.4 RISK ASSESSMENT

The risks associated with the hazards and vulnerabilities identified in the preceding section are assessed qualitatively and outlined in

Table 4. The magnitude and/or the likelihood associated with a contamination event are understood for those potential sources that are of foremost concern, including contamination associated with sedimentation, past and future mining, and contaminated sites within the community. Risk has been managed for these potential hazards through management practices at the source of potential contamination (e.g. water management at mining sites) or within the water system itself (e.g. treatment

of sediment at Carcross Water Treatment Station). The assessment used qualitative methods, drawing inferences from existing site-specific documentation and scientific literature.

Table 4: Hazards associated with potential contaminant sources identified in the Bennett Lake watershed

Drinking Water Hazard Type	Possible effects	Existing Preventative Measures	Barriers for Drinking Water Protection[1]
Recreational use of lake	Contamination from boaters, fishers and swimmers	Disinfection by chlorination	Treatment, monitor
Recreational use of uplands	Contamination from hikers, campers, road vehicles, snowmobiles, horses and ATVs	Disinfection by chlorination; human waste management	Treatment, monitor
Residential/Buildings/Storage	Contamination from leachates, biological pathogens, fuels	Position and distance of water intake upstream.	Source protection, monitor
Historical industrial site contamination	Contamination from leachates	Historical sites have been remediated	Monitor
Vandalism	Damage to the intake affecting water quality and/or availability	Restricted access	Source protection, system maintenance
Historical mining activities	Contamination from sediments and leachates	Waste water management systems; water quality monitoring	Source protection; monitor
Future mining	Contamination from sediments and leachates	Regulatory review processes; waste water management systems; water quality monitoring	Source protection, monitor
Sedimentation	Contamination from sediments associated to spring run-off and lake turn-over	Disinfection by filtration	Treatment; system maintenance, operator training
Earthquake	Sediment contamination from landslides in watershed; damage to intake.	None.	System maintenance, monitor
Climate Change	Changes in water quantity or quality	None	Monitor
Flooding	Sediment and contaminants	Monitoring; emergency shutoff	Monitor, emergency response planning
Naturally occurring sources	Contamination by naturally occurring pathogens, natural leachates	None	Treatment, monitor
Railroad activities	Contamination from fuel (derailment) or sediment (track washouts)	Railroad company maintains their infrastructure	Monitor

[1] Barriers for drinking water protection are based on the six barriers (source protection, treatment, water system maintenance, water monitoring, operator training, emergency response planning) described in the multi-barrier system evaluation in the Comprehensive Drinking Water Source to Tap Assessment Guideline (2005). Barriers represent a collection of preventative strategies to protect drinking water.

The vulnerabilities are described below in further detail with respect to each of the hazards' potential to affect the water source, and summarized in Table 5. Risk abatement is achieved through the implementation of measures that reduce the vulnerability of the system to the hazards that are present.

<u>Recreation</u>

Water-based and upland recreation are identified as being potential sources of contaminants. Recreational properties are present in small numbers along the shores of Bennett Lake. The condition and method of waste management at these locations is unknown but are infrequent enough to assume a low risk; however, the level of certainty is also low. Water-based recreation innately poses slightly more risk due to possibility of contaminants being introduced closer to the intake. At the present, boaters and other water recreationists are not restricted in their use around the intake by barriers or dissuaded by signage. The presence of motorized water-based recreation around the water intake poses a vulnerability to the source water as a result of potential inadvertent damage of the intake or stirring up of sediment near it. Such events are highly unlikely and the magnitude would be very low.

Land Uses in Community of Carcross

Numerous potential contaminant sources exist within the community itself, including a cemetery, fuel tanks, septic tanks and fields, storage lots and gas stations. While these land uses are likely sources of contamination to some of the groundwater wells within the community, their influence on the source waters at the water intake is unlikely. The distance of the water intake from the community and its location upstream from the town site minimizes this influence. The vulnerability of the system to contaminants from residential and commercial land uses is considered low.

Industrial Site Contamination

Two sites within the community of Carcross were identified as being the source of contamination to soils: a hydrometric station and the former White Pass and Yukon Railway tie treatment plant site. The hydrometric station was contaminated with mercury. In 1999 the tie plant was implicated as the source of organochlorine found in Bennett Lake. Various cleanup efforts have been completed at the tie (and hydrometric station) since, and the contamination is likely removed (no final cleanup records were available at YG Environment). The vulnerability of the source water quality due to this hazard is considered low.

Historic Mine Sites

The mine sites located in the Montana Mountain district, including the Venus Mine area, Arctic Mine area and Arctic Gold and Silver tailings and mill site, all have contaminated water flowing from the sites and within the associated tailings ponds. However, the creeks that drain these areas show little or no impact from the poor quality mine waters. The only creek that drains into the Bennett Lake from these sites, Tank Creek from the Arctic Gold and Silver tailings site, has no measureable contamination (Mann, 1998). Contamination from these sites is unlikely and would have an insignificant consequence. The vulnerability of source water to contamination from historic mine sites is low.

Mining Exploration and Production

Mining exploration is currently underway and production is likely in the future within the Bennett Lake watershed. In particular, much focus has been given to mine developments in Watson River and

Mount Skukum. Contamination from these operations is monitored through review and regulatory restrictions that are placed on such operations. Mining operations would not proceed if there is any risk of contamination to the source water.

Vandalism

The security of water supplies and related system infrastructure is frequently highlighted as a growing concern. However, damage to the water intake has not been reported nor has security been identified as an explicit concern in any of the documentation reviewed. Existing security measures at the intake are limited. For instance, there is no cage structure around the water intake or is there signage to warn boaters they are near a water intake. Although the likelihood of vandalism that would result in serious consequences is low, the vulnerability of the water intake is high.

Sedimentation

Sedimentation introduced to Bennett Lake from the Watson River is a natural hazard to the source water. Contamination of source water with sediment is a common occurrence, typically occurring during spring run-off and lake turn-over. The magnitude of sedimentation is high enough to challenge the water treatment system, resulting in costly filter replacements. Although the consequence of sedimentation is considered to have a minor consequence, the high likelihood of occurrence and medium-high magnitude result in a moderate vulnerability to sediment contamination.

Severe Earthquake

Carcross it is located relatively close to the St. Elias region (150 - 200 km), which is one of the most seismically active areas in Canada (Natural Resources Canada, 2005). A strong earthquake could happen at any time in the watershed. Although such an event is rare in Carcross, the magnitude of the event is moderate to high. Noteworthy is that Carcross has a low peak ground acceleration rating of 0.128. This is a low rating and means that little structural damage would be expected as result of an earthquake. The most likely consequence of a severe earthquake would be contamination of the source water by sediment introduced by landslides. In addition, the water intake infrastructure would also be vulnerable to damage. The overall vulnerability of the source water to contamination or disruption is moderate.

Climate Change and Extreme Weather Events.

Based on the projections for increased precipitation and higher temperatures for this region, it is hard to predict what the affect would be on the drinking water source. Extreme precipitation events, like heavy rain or snowfall, will likely result in flooding with increased chance of sedimentation and possible contamination from surface runoff. This may be of minor consequence as the water intake can be protected, the high likelihood of occurrence and medium-high magnitude result in a moderate vulnerability to contamination.

Railroad

The railroad has resumed tourist travel between Skagway and Carcross. In future the White Pass & Yukon Route company may increase travel as well as restart cargo shipments. We assume that current-day safety standards mandate regular maintenance of the trains and tracks, so the overall vulnerability of the source water to contamination is low due to possible derailments or wash-outs.

Table 5: Qualitative risk assessment of safety and reliability of source water obtained Bennett Lake.

Hazard (rank)	Description of Potential effect	Magnitude	Likelihood	Consequence	Risk	Assumptions
Human-made Hazards						
Recreational use of lake	Contamination from boaters, fishers and swimmers due to discharge of hydrocarbons and fuels	Low	Rare	Insignificant to minor	Low	Assumes no restrictions on water-based recreation
Recreational use of uplands	Contamination from hikers, campers, vehicles, horses, snowmobiles and ATVs	Low	Unlikely	Insignificant	Low	Assumes minimal management of upland recreational activities.
Residential/ Buildings/ Storage	Contamination from leachates, biological pathogens, fuels	Low	Unlikely	Minor	Low	Assumes existing site conditions and management actions prevent transport of contaminants from town site to source water intake.
Historical industrial site contamination	Contamination from leachates	Low	Unlikely	Insignificant	Low	Assumes no further remediation has been completed. Wind-transported contamination is well below actionable limits.
Historic mine sites	Contamination from leachates	Low	Unlikely	Insignificant	Low	Assumes decommissioning is effective and any residual contaminants in drainage are diluted in the lake water.
Future mining production	Contamination from sediments and leachates	Low	Unlikely	Insignificant	Low	Assumes regulatory requirements and standard Best Management Practices are employed.
Vandalism	Damage to the intake affecting water quality and/or availability	Low	Rare	Major	High	Assumes no additional security measures are implemented.
Railroad activities	Fuel and sediment contamination	Medium-high	Rare	Minor	Low	Assumes regular maintenance of the railroad trains and tracks.
Natural Hazards						
Sedimentation	Contamination from sediment from spring run-off and lake turn-over	Medium-High	Likely	Minor	Moderate	Assumes water intake is outside of the Watson River sediment plume.
Severe Earthquake	Sediment contamination from landslides in watershed	Medium-High	Rare	Minor	Moderate	Focus is on sedimentation. Assumes no physical impacts on intake structure.

Hazard (rank)	Description of Potential effect	Magnitude	Likelihood	Consequence	Risk	Assumptions
Flooding	Sediment contamination, contamination from surface runoff	Medium-High	Rare	Minor	Moderate	Assumes emergency shutoff of the water intake system will be in effect.
Climate Change						
Higher average temperature	Unknown; may include changes in water quantity and quality	Low	Possible (longer term)	Insignificant	Low	Assumes that this is a gradual change, with the effects not being significant within 10 years.
Change in precipitation	Unknown; may include changes in water quantity and quality	Low	Possible (longer term)	Insignificant	Low	Assumes that this is a gradual change, with the effects not being significant within 10 years.

4 SOURCE WATER RISK MANAGEMENT STRATEGY

The following risk management actions are recommended to improve the safety and sustainability of the water source. These management actions are listed in order of priority.

1. Increase the level of security at the water intake by constructing a cage around the water intake. The cage should be removable, but with limited access so it cannot be opened accidentally. This action will abate the risk of damage to the structure and/or contamination due to vandalism or accidents from recreational activities.
2. Institute regular maintenance for the water intake (at least twice a year). This involves removing sediment build-up around and in the intake structure.
3. Continue regular monitoring of the raw water quality. Correlate this information with any other activities to the water intake system to determine what causes turbidity spikes outside of the expected seasonal peaks.
4. There is a lack of regular water quality and hydrology monitoring information that would allow a response to changes in the water system that may be occurring due to mining drainage, fuel and fecal contamination or climate change. While monitoring responsibilities may lie with other governments or departments, there are a number of parameters that are of interest:
    a. Monitoring waterbodies into Bennett Lake affected by mining drainage, such as acid rock drainage, to ensure quality standards for drinking water are met.
    b. Monitoring water quality within the vicinity of the water intake in Bennett Lake and Nares River for fecal coliform, hydrocarbons, and other known contaminants in the area.
    c. Monitoring the precipitation and hydrology (i.e. lake levels and flow) of the watershed to plan for any trends associated with climate change.

    Community Services has a responsibility as a public institution to work with other groups within government or other governments to ensure short-comings in monitoring are addressed.

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6 FIGURES

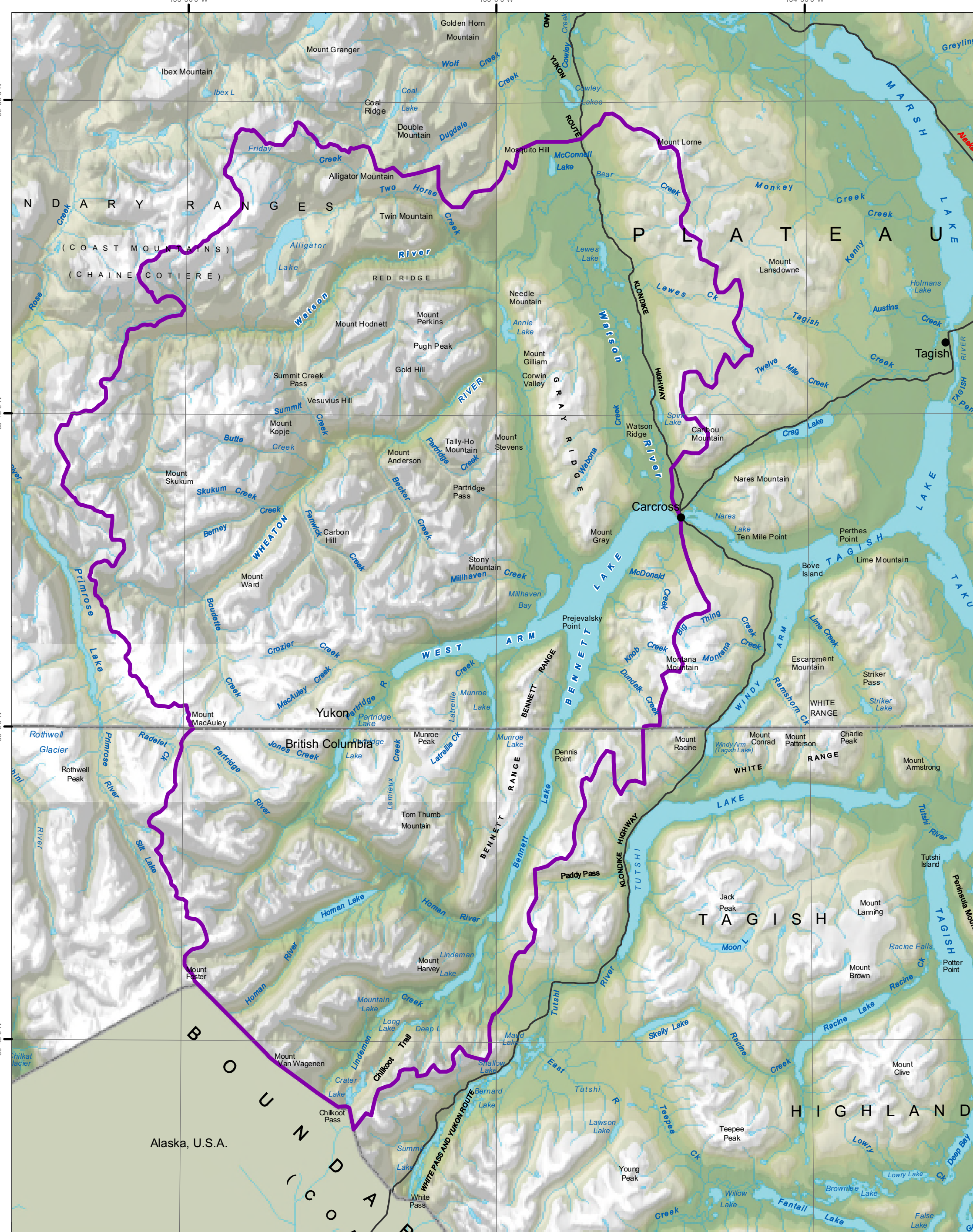


Figure 1. Watershed Boundary - Bennett Lake and Project Assessment Area.

Drawn By: M. Power / Laura Grieve
Checked By: P. Tobler
Date: 25 November 2010
Projection: NAD 1983 UTM Zone 8
EDI Project #: 10-YC-0002

Legend

- Bennett Lake Watershed Area
- Waterbody (lakes and rivers)
- Watercourse (streams) & Project Assessment Area

1:250,000 Topographic Spatial Data: Canvec and National Topographic Database (NTDB). Used under license courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Bennett Lake Watershed Boundary derived from the National Hydrological Network provided courtesy of Natural Resources Canada. The southwest corner was digitized by EDI using height of land and watercourse layers.

This document is not an official land survey and is presented without prejudice. The spatial data presented is subject to change without any notice.

0 5 10 15 20
Kilometers

Figure 2. Location of water intake and water treatment facility in the community of Carcross.

Drawn By:	M. Power / L. Grieve
Checked By:	P. Tobler
Date:	24 Nov 2010
Projection:	NAD 1983 UTM Zone 8
EDI Project #:	10-YC-0002

Legend

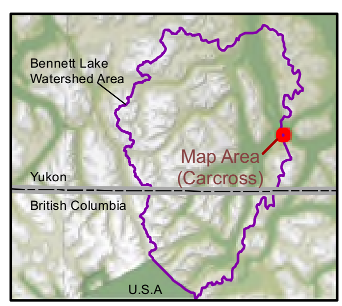
- Water line (Approximate)
- Direction of water flow

Bennett Lake Watershed Boundary derived from the National Hydrological Network provided courtesy of Natural Resources Canada. The southwest corner was digitized by EDI using height of land and watercourse layers.

Disclaimer

This document is not an official land survey and is presented without prejudice. The spatial data presented is subject to change without any notice.

0 50 100 150 200 250 300
Meters



Prepared by:

EDI