

## **Parkaeology and Climate Change: Assessing the Vulnerability of Archaeological Resources at Klondike Gold Rush National Historical Park, Alaska**

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### **Introduction: United States National Park Service and Climate Change Adaptation**

The United States National Park Service (NPS) is a federal land management agency concerned with the preservation of natural and cultural resources for the enjoyment, education and inspiration of current and future generations. Cultural resources, which include archaeological sites, cultural landscapes, ethnographic resources, historic structures and museum collections, have distinct considerations with respect to climate change. Because each resource is unique and derives much of its significance from the place in which it was created, the capacity of cultural resources to adapt to changing environmental conditions is limited (NPS 2010). To address the threat of climate change impacts on cultural resources, the NPS developed a four-pillar model for cultural resource management that includes science, adaptation, mitigation and communication (NPS 2010; Rockman et al. 2016). The science pillar identifies and tracks impacts of climate change on cultural heritage, the adaptation pillar develops management strategies for the threats identified in the science pillar, the mitigation pillar incorporates cultural heritage into energy-efficient planning and the communication pillar develops multiple communication pathways concerning information from the other

three pillars (Rockman 2015; Rockman et al. 2016). Although the NPS developed a thorough strategy for cultural resource adaptation to climate change, it is ultimately up to the discretion of individual parks to assess, develop and implement these strategies. This article presents the climate change response strategy for archaeological resources at Klondike Gold Rush National Historical Park (KLG0) as a case study for the broader implementation of the NPS adaptive framework for cultural resources.

The archaeological resources at KLG0 provide outstanding opportunities for visitors to learn about a significant historical event that transformed the landscape between Alaska and the Yukon. As the most visited national park in Alaska, with nearly one million visitors a year, KLG0 is uniquely positioned to tell the story of climate change impacts on our nation's cultural legacy (NPS 2013). Alaska is experiencing the impacts of climate change at twice the rate of the lower 48 states in the US (SNAP 2009), making the effects of climate change an immediate concern to KLG0 land managers. During the summer of 2016, the archaeology division of KLG0 developed a more effective climate change response to threatened cultural resources within park borders of the international Chilkoot Trail. The work of 2016 was primarily driven by the loss of archaeological sites to changing fluvial dynamics of the glacier-fed Taiya River. Archaeological resources at KLG0 are highly vulnerable to climate change-driven landscape changes, including glacial outburst floods, earlier snow melt, melting ice patches and increased glacial melt and spring runoff volumes.

### **Northern Exposure: Background of KLG0 Natural and Cultural Environments**

KLG0, in southeast Alaska, is a three-unit land management area (fig. 1) established in 1976 to commemorate the Klondike Gold Rush of 1897–1899 (NPS 2009). In this case study, we examine climate change threats to archaeological resources within the Chilkoot Trail Unit at KLG0. The Chilkoot Trail was one of the main travel corridors to the Yukon gold fields in Canada, with 20,000 to 30,000 gold seekers transporting their one-ton outfits across the Chilkoot Trail during the first year of the gold rush (Norris 1986).

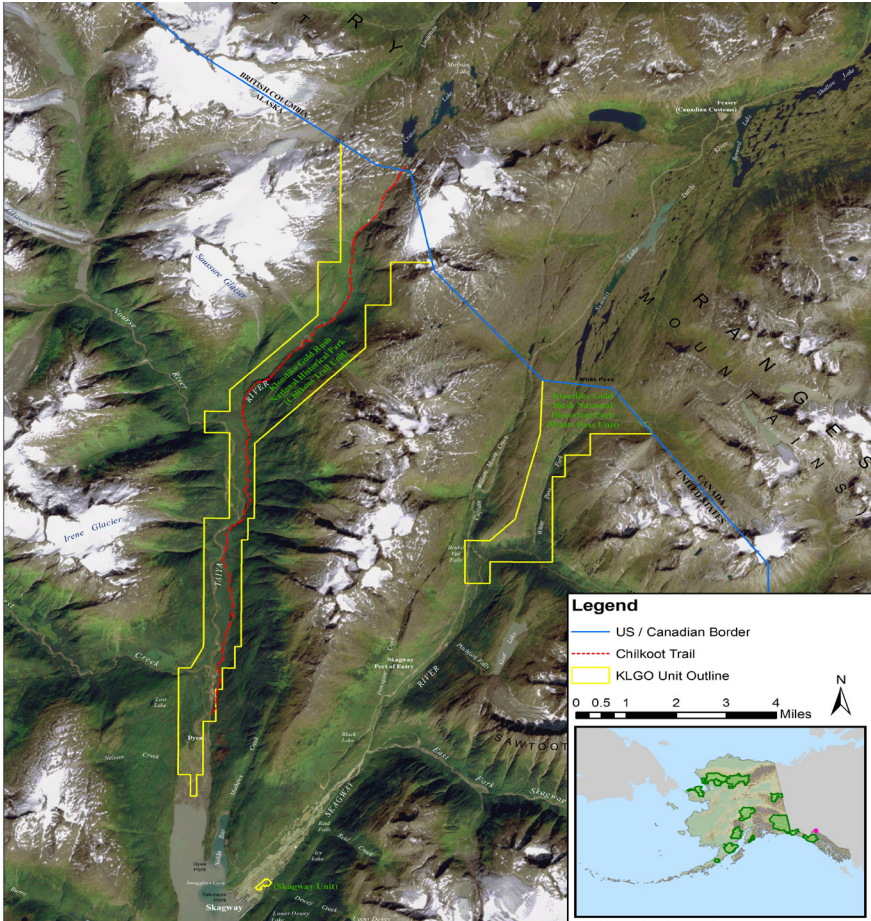


Fig. 1. Klondike Gold Rush National Historical Park, southeast Alaska, is comprised of three units. This case study focuses solely on archaeological resources in the Chilkoot Trail Unit (NPS photograph).

*Environmental Setting and Projected Climate Change Scenarios*

The Chilkoot Trail Unit begins at the historic townsite of Dyea, Alaska, where the glacier-fed Taiya River flows into the Inside Passage of the Pacific Ocean (Bernatz et al. 2011; Ferreira 2010). From Dyea, the US portion of the Chilkoot Trail follows the Taiya River into the Coast



Fig. 2. Gold Rush archaeological resources in the Chilkoot Trail Unit. A) Wood remains of structures along the historic Dyea interpretative trail. B) Steam boiler along the interpretative loop trail at Canyon City. C) Glass, ceramic and metal artefacts in excavations at the Kinney Bridge Complex. D) Leather shoes and metal artefacts abandoned near the Scales (NPS photographs).

Mountains through 24km of coastal rainforest and then two kilometres of Alpine environment. The US land management area terminates at Chilkoot Pass (elevation at 1067m). The remaining 27km of the Chilkoot Trail transverses boreal forest that is maintained in British Columbia by Parks Canada (Bernatz et al. 2011; Ferreira 2010).

The Chilkoot Trail Unit is dominated by a maritime climatic regime. No published data sets of long-term meteorological information exist for the Chilkoot Trail Unit; however, averages for the 30 years between 1970 and 2000 are available from the neighbouring town of Skagway, Alaska. Mean maximum winter temperature is  $-2.8^{\circ}\text{C}$ , and mean maximum summer temperature is  $19.5^{\circ}\text{C}$ , while mean minimum winter

temperature is  $-7.7^{\circ}\text{C}$ , and mean minimum summer temperature is  $10^{\circ}\text{C}$ . Mean total precipitation at Skagway is 66.6cm per year, with precipitation generally lowest in April (2.7cm) and highest in October (11.68cm). The greatest amount of snowfall normally occurs during December and January. The maritime climatic regime, in addition to its moderating effect on temperatures, tends to provide more moisture from which precipitation can form (Bernatz et al. 2011; Capps 2004).

Climate change scenarios predict that mean annual temperature will rise by as much as  $4^{\circ}\text{C}$  by 2080, with annual winter temperatures rising  $4^{\circ}\text{C}$  and summer temperatures rising  $2.5^{\circ}\text{C}$ . Winter precipitation is expected to increase by 16 per cent, and summer temperature is expected to increase 13 per cent by 2080. As mean winter temperatures are expected to rise above the freezing point (to  $1.11^{\circ}\text{C}$  by 2080), it is likely that much winter precipitation will be in the form of rain and ice. Higher summer precipitation is expected to be offset by higher evapotranspiration, caused by warmer temperatures (SNAP 2009).

#### *Archaeological Resources in the Chilkoot Trail Unit*

The Chilkoot Trail began as a trading route between Chilkoot Tlingit and Athapaskan Tagish peoples of southeastern Alaska (Griffin and Gurcke 2011). Pre-contact use of the trail includes commodity exchange between the coastal Tlingit and interior Athabaskans (Mog 2017). Very few pre-contact archaeological resources have been discovered. The archaeological resources along the Chilkoot Trail primarily include historic Gold Rush era (1897–1899) features and artefacts. These archaeological resources were deposited during the trail's use as a travel route from Dyea, Alaska, to the gold fields near Dawson City, Yukon. Historical cultural resources threatened by climate change on the Chilkoot Trail include abandoned and collapsed structure features from townsites along the trail, structural depression features, abandoned wagon roads and abandoned supplies (fig. 2) (Griffin and Gurcke 2011). Two rock shelters currently comprise all the pre-contact sites at KLGO, and neither is threatened by climate change impacts (Rankin 2016). The Chilkoot Trail is currently used as a recreational backcountry trail that accommodates approximately 3,000 hikers per year (NPS 2013).

During the Klondike Gold Rush, several towns were established along the Chilkoot Trail to assist prospectors on their trek to the Klondike gold fields, including Dyea, Kinney Bridge, Finnegan's Point, Canyon City and Sheep Camp (Norris 1986). Before the Klondike Gold Rush, Chilkoot Tlingit occupied the Dyea area. Dyea was originally established as a seasonal Tlingit fishing camp, but the influx of prospectors in 1897 turned Dyea into a gold rush boomtown, including a large wharf for unloading imported goods (Bears 1970). At its peak, Dyea boasted over 150 businesses that supported up to 15,000 gold seekers (Norris 1986). The archaeological remains of Dyea include wood pilings from the wharf, wood remains of structures, depression features of structures and various metal and glass artefacts related to daily life in a Gold Rush boomtown (fig. 2). After leaving Dyea, gold seekers would travel on a wagon road that followed the Taiya River. The Kinney Bridge Complex assisted prospectors in crossing the Taiya River (Norris 1986). Today, the Kinney Bridge Complex consists of structural depression features and various ceramic, metal and glass artefacts (fig. 2) (Richards et al. 2016). Continuing north on the Chilkoot Trail, the site of Finnegan's Point consisted of a toll bridge and was a small layover point for gold prospectors (Norris 1986). Today, two features are all that remain of Finnegan's Point. Further north is Canyon City, the third largest townsite along the Chilkoot Trail (Gurcke 1986). The wagon road from Dyea ended at Canyon City, and gold prospectors had the opportunity to transport their outfit via tram (Norris 1986). The archaeological remains of Canyon City include those of the wagon road, various structure basins, a large steam boiler from the tram system and various metal and ceramic artefacts (fig. 2) (Laven 1988). After Canyon City, Sheep Camp was the last stop on the trail before prospectors could cross the Chilkoot Pass into Canada. Sheep Camp was the second largest townsite along the Chilkoot Trail, hosting dozens of businesses and up to 7,000 gold seekers at its peak (Norris 1986). Today, the original location of the Sheep Camp townsite is bisected by the Taiya River. From Sheep Camp, gold prospectors would have to transport their one-ton outfit over the "Golden Stairs" of the Chilkoot Pass. The Golden Stairs were 1,500 steps carved into the snow and ice covering the Chilkoot Pass. At the base of the Golden Stairs were the "Scales", where gold prospectors would re-weigh their outfit to determine how much it would cost to transport their supplies over the

| Assessment                         | Description  | Score |
|------------------------------------|--|-------|
| <b>Probability</b>                 |  |       |
| Possible                           | The risk is present; however, there is no indicator that it will occur in the future             | 1     |
| Likely                             | There are indicators that the risk will occur in the future                                      | 2     |
| Certain                            | Risk is already damaging resource, or future damage is enviable in current conditions            | 3     |
| <b>Time Frame</b>                  |  |       |
| Long Term                          | Risk will slowly damage resource through time  | 1     |
| Intermediate                       | Risk will slowly damage resource through time, but may have punctuated moments of immediate risk | 2     |
| Short Term                         | Risk is or will be immediate   | 3     |
| <b>Severity</b>                    |  |       |
| Marginal                           | Risk will only impact a small portion of the resource  | 1     |
| Critical                           | Risk will impact a large portion of the resource   | 2     |
| Catastrophic                       | Risk will destroy the entire resource  | 3     |
| <b>Inventory</b>                   |  |       |
| Low                                | No or only some level of documentation   | 3     |
| Moderate                           | Complete documentation   | 2     |
| High                               | Complete documentation and some excavations  | 1     |
| <b>Archaeological Significance</b> |  |       |
| Low                                | Many out of context artefacts, no features   | 1     |
| Moderate                           | Few out of context artefacts, few features   | 2     |
| High                               | Many in-situ artefacts and features  | 3     |
| <b>Interpretative Significance</b> |  |       |
| Low                                | Inaccessible to visitors or lack of resources to interpret                                       | 1     |
| Moderate                           | Partially inaccessible to visitors   | 2     |
| High                               | Accessible to visitors, many resources for interpretation  | 3     |

Lowest Possible Score = 6

Highest Possible Score = 18

Table 1. Vulnerability assessment criteria and scoring system.

pass via tramway or pay others to assist with transport (Norris 1986). Because of the high cost to transport goods over the Chilkoot Pass, many unnecessary items were abandoned to reduce costs (fig. 2) (Higgs 2008).

## **Methods: The NPS Climate Change Response Strategy in Action**

The science pillar of the NPS response strategy focuses on data collection to determine how climate change affects cultural resources. Thus, data collection under the science pillar is fundamentally the first step in the climate change response strategy. Regular inventory of cultural resources along the Chilkoot Trail has occurred since KLGO's establishment in 1976. Many of these resources were already incorporated into a geographic information system prior to the conception and completion of this project; as such, the project relied completely on the established inventory system to determine which resources could be impacted by climate change threats. Climate change threats to known cultural resources in the Chilkoot Trail Unit were identified by reviewing previous research on environmental hazards, landscape change, climate change projections, state of the park reports, trail and resource condition assessments and environmental assessments conducted by KLGO and other US Department of the Interior agencies. Additionally, annual river bank monitoring data collected over the past 40 years in a geographic information system were examined, new river bank data were collected and formal surveys of snow and ice patches were conducted. Relying on previous research and new data collected during the 2016 season, the vulnerability of each individual resource was calculated based on the probability that the climate change threat will occur, the time frame and severity of the threat, the completeness of resource inventory, the archaeological significance of the resource and the interpretative significance of the resource. Each of these assessment categories was given a qualitative description and a corresponding quantitative score (table 1). Quantitative scores for each of the assessment categories were totaled to determine an overall vulnerability score, with a lowest possible score of six and a highest of 18.

The adaptation pillar of the NPS response strategy involves determining what is to be done about the specific situations defined in the science pillar. Adaptation options include offsetting stress, improving resilience, managing change, relocation, monitoring, documenting and preparing for loss, interpreting the change or no active intervention. Offsetting stress, improving resilience and managing change were not considered as adaptation options for KLGO because they were too expensive and/





Fig. 3. Three of the four climate change threats to archaeological resources at KLGO. A) This Gold Rush-era stove was discovered eroding into the Taiya River in 2011 and is an example of the threat of fluvial channel instability to archaeological resources. B) One of the twelve ice patches examined near the Chilkoot Pass in 2016 Ice Patch Survey, melting ice patches have revealed new Gold Rush sites and possible one new pre-Gold Rush site. C) An example of organic Gold Rush artefacts that have been well preserved in the cold conditions of the high alpine environment near the Chilkoot Pass (NPS photographs).

or detrimental to natural resource management; additionally, relocation of resources was not considered as an adaptation option because it does not align with KLGO's long-term management strategies. The remaining adaptation options—no action, monitoring, documentation and interpretation—were selected using a structured decision-making model based on inventory completeness and public accessibility of the resource, as well as the severity and time frame of the climate change threat. Prioritization of adaptation options for specific resources was determined based on overall vulnerability scores, with the most vulnerable resources given highest priority and the least vulnerable resource given lowest priority.

The communication pillar involves the development of multiple communication pathways concerning climate change threats to cultural

resources. In this case study, communication between researchers and KLG0 management directly informed adaptation options and decision-making models for prioritization. During the data collection phase of this project, NPS blogs and local news reports kept the public updated about park activities regarding climate change impact research. After the completion of this project, presentations through the North Pacific Landscape Conservation Cooperative and the Alaska Centennial Science and Stewardship Symposium disseminated research to various federal and state agencies, Tribes/First Nations, consulting agencies and universities in the North Pacific and Alaska region.

## **Climate Change Impacts on Archaeological Resources at KLG0**

### *Fluvial Channel Instability*

Fluvial channel instability is the most continuous climate change threat to cultural resources because most of the cultural resources in the Chilkoot Trail Unit are located along the Taiya River (fig. 3). Streams are naturally dynamic and adjust their form to changes in sediment load, discharge and other geomorphic processes. Channel instability is normal in most fluvial systems, but it is especially marked in glacially-fed streams due to their high sediment loads and flashy seasonal discharge. Disturbances to a fluvial system, such as lowering of base level, changing average discharge and changing sediment influx, can initiate channel instability until new dynamic metastable equilibrium conditions are established. The Taiya watershed naturally has many such disturbances; however, the increased glacial melt projected in future climate scenarios will increase the threat posed by channel instability to cultural resources (Furbish and Curran 2001).

The watershed is located between the latitudes of 59.48° and 59.80° and longitudes of -135.2° and -135.6°. The Taiya watershed has four sub-watersheds: Nourse River (205km<sup>2</sup>), West Creek (115km<sup>2</sup>), Lower Taiya (111km<sup>2</sup>) and Upper Taiya (59km<sup>2</sup>) (Hood et al. 2006). The Upper Taiya subwatershed is especially vulnerable to channel instability from Sheep Camp to Pleasant Camp. This segment is particularly unstable because the gradient of the valley floor transitions from 10 per cent to one per cent here, allowing for large-scale sediment deposition and poor channeliza-

tion (Capps 2004). As glaciers continue to melt at more rapid rates, discharge and sediment influx will increase, making the channel system near Sheep Camp more unstable and increasing the occurrence and hazard of floods (Capps 2004; Furnish and Curran 2001). Lower Taiya subwatershed is very different from the Upper Taiya subwatershed. Its valley slope is continuously less than one per cent and has net deposition of sediment. The reach from Canyon City to Finnegan's Point has shown very little channel migration throughout recent history. Repeat photography shows the modern morphology of this reach to be almost identical to that of 1894 (Hocker and Carstensen 2005). It appears that this reach is currently unable to rework the relatively large-sized sediments deposited from glacial outburst floods and is not expected to experience much channel instability in the future (Bearss 1970; Capps 2004; Streveler 1995). The Nourse River and West Creek subwatersheds contain lakes that capture the majority of transported sediment. The numerous lakes in the Nourse River and West Creek valleys will fill in with glacial sediment as glaciers continue to recede. Once these lakes are infilled, more sediment will be available for transportation through the system than is currently available, causing increased fluvial instability. Areas closer to the coast, such as Dyea, are more complicated. All of the above processes apply, plus the effect of isostatic rebound. Isostatic rebound refers to the rise of land masses following the melt of large ice sheets. Current evidence, such as high cutbanks on the river near the historic Dyea Townsite, suggests that rebound is a more dominant control of channel instability than either changing sediment influx or discharge related to increased glacial melt (Capps 2004; Rankin 2016). Rebound rates at Dyea are extremely high (1.8cm/yr) and are expected to remain the dominant control on channel processes at the Dyea segment of the Lower Taiya (Bosworth 2000; Hood et al. 2006).

### *Early Snow Melt*

Many organic artefacts—wood, cloth and leather—deposited from the “Scales” to the summit have been well preserved since the Klondike Gold Rush because they are covered by snow for 10 months of the year (fig. 3). Climate change scenarios estimate that both winter and summer temperatures will rise. As mentioned above, the average annual winter temperature is expected to rise above freezing point by 2080

(SNAP 2009). This increase in temperature will decrease the artefact preservation period. With increasingly warm climates, KLGO can expect its organic artefacts to start decomposing more rapidly than in the past (Blackholm 2009; Hudson et al. 2012; Rockman 2011).

### *Melting Ice Patches*

Unlike glaciers, ice patches have not accumulated enough mass to flow downhill. Glaciers are not well suited to preserve archeological material because the movement of ice destroys any artefact deposits. Artefacts deposited in ice patches are preserved due to the stable nature of the ice. The spatial extents of ice patches are determined by a balance of winter snow accumulation and summer melting. The trend of decreased winter snow accumulation and increased summer melting has resulted in irregular ice patch shrinkage and loss in alpine environments (Feierabend and Schirokauer 2008). As these ice patches disappear, atmospheric elements can rapidly destroy and degrade newly exposed artefacts. The cultural resources preserved in ice patches are unknowable until the ice patch begins to melt and reveal the resources long-preserved and hidden in the ice. Archaeologists must quickly access these melting ice patches before the resources are destroyed and there is nothing left to document (Vanderhoeh et al. 2012).

There are 277 identified ice patches within the boundaries of KLGO (Rankin 2016). Out of these, the 2016 archaeology crew selected an ice patch survey area within the vicinity of the Chilkoot Pass based on its likelihood to yield historic and pre-Gold Rush remains, as well as on accessibility to the area (fig. 3), and 12 ice patches were surveyed in the summer of 2016. The results from the survey yielded 18 new historic artefacts. In addition to surveying for artefacts, ice patch extent was mapped with a handheld Trimble GeoExplorer 6000 with a Zephyr antenna. Yearly re-survey will be conducted to identify new resources and document rates of ice-patch melt.

### *Glacial Lake Outburst Floods*

Glacial Lake Outburst Floods (GLOF) are catastrophic events that occur when a dam confining a pro-glacial lake fails. The Chilkoot Trail Unit has already experienced three datable GLOFs (Capps 2004). Two GLOFs occurred during the Klondike Gold Rush from the Nourse subwatershed

| Archaeological Site          | Taiya Channel Instability | Glacial Outburst Floods | Early Snow Melt | Melting Ice Patch |
|------------------------------|---------------------------|-------------------------|-----------------|-------------------|
| Dyea                         | X                         | X                       |                 |                   |
| Kinney Bridge                | X                         | X                       |                 |                   |
| Finnegan's Point Canyon City |                           | X                       |                 |                   |
| Sheep Camp                   | X                         | X                       |                 |                   |
| Scales to Summit             |                           |                         | X               | X                 |

Table 2. Climate change threats to individual archaeological resources in the Chilkoot Trail Unit.

(Bearss 1970; Capps 2004; Streveler 1995), and the most recent occurred in July 2002 from the West Creek subwatershed (Capps 2004). In an area already prone to GLOFs, climate change is elevating both the frequency and hazard of GLOFs by increasing the water volume in pro-glacial lakes and creating an environment that is more likely to overwhelm the pro-glacial lake dam (Khanal et al. 2015). If a GLOF were to occur in the Nourse Valley, the flood could have catastrophic consequences for cultural resources on the Taiya River. Nourse Lake is currently the only pro-glacial lake with the capacity to significantly damage cultural resources along the Taiya River (Capps 2004; Denton 2005; Denton et al. 2005).

Nourse Lake is a large moraine-dammed lake at the toe of the Nourse Glacier. Nourse Lake appeared sometime between 1948 and 1979 (Capps 2004). It has a surface area of 69km<sup>2</sup> and a deepest depth of 29.5m, with a height-to-width ratio of approximately 1:17 (Denton 2005; Denton et al. 2005). Moraine-dammed lakes such as Nourse Lake can have a variety of failure mechanisms. Dam overtopping by mass movement-generated waves is the most common; these waves can be generated by avalanches, land/mud slides and very large discharge events. The western flanks of the lake have an average slope of 76 per cent from the glacier to the top of the mountain, and the eastern flanks have an average slope of 58 per cent (Fisk 2005). While these average slopes are too steep to form avalanches under normal conditions, abundant breaks in slope may allow significant slabs of snow to form. Therefore, times of unusual avalanche activity could be very dangerous for the stability of the Nourse Lake dam. A large landslide into the lake could also compromise the stability

of the dam. Two potential sources for landslide material are bedrock and unconsolidated debris mantling the slopes. Failure of a moraine dam can also result from unusual runoff circumstances, such as periods of rapid glacial retreat, heavy rainfall or rapid snowmelt (Capps 2004). However, such an event here would have to be extraordinary because the moraine has been stable since the lake formed over 25 years ago (Fisk 2005).

Based on the size and depth estimates for Nourse Lake, a GLOF would yield a discharge of  $1,600\text{m}^3/\text{s}$ . This discharge is twice that of the predicted 500-year flood for the Taiya River and three times the discharge of the flood of 2002 (Capps 2004). A flood of this magnitude would inundate and probably destroy most cultural resources in the floodplain and on fluvial terraces. Nourse Lake represents a very serious local and distant hazard: all cultural resources in low-lying areas below the lake are at risk from a catastrophic flood. Because of its location near the confluence of the Nourse and Taiya Rivers, Canyon City would have the most impacted cultural resources (Capps 2004).

### **KLGO Prioritization and Management Strategies**

There is no single climate change threat that will impact all cultural resources in the Chilkoot Trail Unit (table 2). As such, climate change response strategies for cultural resource management must be specific to each resource.

The Dyea townsite is the largest, most significant cultural resource in the Chilkoot Trail Unit. Channel migration and bank erosion near the Dyea townsite has been an issue since KLGO was established as a National Park in 1976. Long-term bank monitoring shows that the Taiya River has extensively migrated, destroying half of the eastern portion of the Dyea townsite. The river channel appears to have stabilized since the 1990s to an average rate of 25cm loss per year (Inglis 2002). The landscape change driving channel migration at Dyea is lowering base level due to isostatic rebound. The Dyea segment of the Lower Taiya used to be a more anastomosing system, but the lowering of base level due to high rebound rates has caused the Taiya river to become more of a meandering system. The extreme channel migration observed in the early twentieth century represented development of the meandering channel. Now that the channel meander

| Site             | Risk              | Probability | Time Frame   | Severity     | Inventory | Archaeological Significance | Interpretative Significance | Vulnerability Score | Recommendation                   |
|------------------|-------------------|-------------|--------------|--------------|-----------|-----------------------------|-----------------------------|---------------------|----------------------------------|
| Dyea             | Channel Migration | Likely      | Intermediate | Marginal     | High      | High                        | High                        | 12                  | Continue monitoring              |
| Kinney Bridge    | Channel Migration | Certain     | Short term   | Catastrophic | High      | High                        | Low                         | 14                  | Continue monitoring              |
| Finnegan's Point | Outburst Flood    | Possible    | Short term   | Catastrophic | Moderate  | Low                         | Low                         | 11                  | No Action                        |
| Canyon City      | Outburst Flood    | Possible    | Short term   | Catastrophic | Moderate  | High                        | High                        | 15                  | Documentation                    |
| Sheep Camp       | Channel Migration | Certain     | Intermediate | Critical     | Low       | High                        | Moderate                    | 15                  | Documentation of western site    |
| Scales to Summit | Snow/Ice Melt     | Certain     | Long term    | Marginal     | Moderate  | Moderate                    | High                        | 13                  | Documentation and Interpretation |

Table 3. Vulnerability assessment, total vulnerability score and recommendation for each archaeological resource. Only the primary climate change threat is listed under "risk". Prioritization is ranked by total vulnerability score. Canyon City and Sheep Camp have the highest priority; Finnegan's Point has the lowest priority.

is established, the Taiya should stop migrating and start incising its current channel (Capps 2004; Rankin 2016). The only cultural resource currently threatened is a historic cemetery that is within a metre of the river's current cut bank. Because the overall severity of risk is marginal and the time frame for the risk is not immediate, Dyea has a low vulnerability score and is ranked five out of six for priority (table 3). Recommended management strategies include ongoing yearly monitoring of the historic cemetery to ensure channel erosion does not become an immediate threat in the future.

The river crossing complex at the Kinney Toll Bridge contains 17 features dating from the Klondike Gold Rush (Richards et al. 2015). Kinney Bridge is the only archaeological site along the Chilkoot Trail that does not have interpretative information for backpackers along the trail (Rankin 2016). In 2011, a Gold Rush-era stove was discovered eroding by the river (fig. 3) (Cremer 2011). Upon discovering the erosion taking place at Kinney Bridge, KLGO park archaeologists excavated and documented the majority of the site (Jones 2014a). The results of ongoing bank monitoring since 2011 show that 3–4m of bank loss are occurring at the Kinney Bridge complex per year (Jones 2014b; Richards et al. 2015). The most recent 2016 bank measures show that two archaeological features are within five metres of the 2016 bank, and the furthest feature is 13m from the 2016 bank. If bank erosion continues at its current rate, the two features closest to the bank will be in immediate threat in 2017, and the entire site is expected to be destroyed within the next four years (Rankin 2016). The Kinney Bridge Complex ranks three out of six for priority because it is immediately threatened and the severity of that threat will be catastrophic. However, because the site has already been fully documented and its interpretive value is low, only continued monitoring is recommended (table 3).

Unlike Dyea and Kinney Bridge, archaeological resources at Finnegan's Point and Canyon City are not under threat from fluvial channel instability. Finnegan's Point is not a significant archaeological resource. During its use in the Klondike Gold Rush, Finnegan's Point served as a minor tent site along the trail; as such, only two archaeological features exist at Finnegan's Point (Gurcke 1986). Because of the lack of cultural resources at Finnegan's Point, it ranks lowest (six out of six) for management priority (table 3). No further action is recommended at the site. Canyon City, the



third largest townsite along the Chilkoot Trail, is a significant resource, not only because of its archaeological richness, but because of its interpretative value (Laven 1998). An interpretive trail through the historic Canyon City townsite allows visitors to experience and learn from an outdoor museum. Although Canyon City is not threatened by fluvial channel instability, the site is under catastrophic threat should a GLOF occur from Nourse Lake. A GLOF from Nourse Lake would damage all cultural resources along the lower Taiya; though, as stated above, Canyon City would be the most impacted due to its location. A GLOF from Nourse Lake would completely destroy the site and its interpretative infrastructure (Capps 2004). Because Canyon City has not been fully inventoried and the risk is catastrophic, this resource is ranked as highest priority (table 3). As a GLOF is impossible to predict, the only way to ensure that the resources from Canyon City are not lost, should this catastrophic event occur, is to ensure that the Canyon City site is thoroughly documented.

Sheep Camp is the second largest townsite along the Chilkoot Trail, after Dyea. The majority of the main townsite is hard to access because it is not on the trail side of the Taiya River. Initial pedestrian surveys at Sheep Camp are incomplete, and no archaeologist has been to western Sheep Camp since the early 1990s (Fenicle 1992; Hoffman 1990). Currently, the inventory of cultural resources at Sheep Camp is not complete enough to determine what is being impacted by climate change threats. Sheep Camp shares the highest priority with Canyon City because the inventory is incomplete and the risk is certain and high (table 3). Full documentation of western Sheep Camp is recommended.

The preservation of long-exposed organic materials, such as leather, cloth and wood, is the main concern at the “Scales” and summit. The historic artefacts on the summit are currently accessible to visitors and serve more value being left in place to decompose than they would if removed and preserved in curation. Although the risk to these objects is certain and the interpretative value is high, these objects are ranked at a lower priority of three out of six because the time frame of early snowmelt risk is long-term (table 3). Future work to document the decomposition of these objects should be done with an interpretative product in mind. Further, the 2016 ice patch surveys revealed new historic sites. Thus, yearly survey of tar-

ged ice patches is recommended to ensure documentation of newly exposed resources. Additionally, melting ice patches are likely to expose pre-Gold Rush era materials, which are severely lacking in the KLG0 archaeological record; because these have much higher archaeological value than interpretive value, collection of this material is recommended.

### **Future Work and Recommendations for Resource Managers**

While the National Park Service is in the development phase of producing climate change response actions, KLG0 has proactively developed a Climate Response Program to effectively manage current issues affecting cultural heritage. KLG0 has designed a response programme that involves compilation of KLG0 archaeologists' original research on the project areas, project survey methodology and development of a repeatable survey plan to be carried out over the next 10 years, specifically focusing on Taiya River erosion and ice patch surveys. Future work will include ongoing annual bank monitoring of the Taiya River at Dyea and Kinney Bridge, a complete inventory of western Sheep Camp and further archaeological investigations at Canyon City. The 12 permanent ice patches near the Chilkoot pass will be annually re-surveyed to account for continued melt. Other ice patch survey areas are being explored and could potentially be included in future surveys, while drainage views of ice patches will be considered to expand the survey area. Climate change is the heritage of the future: it is our duty to ensure full documentation of the effects of climate change on cultural resources for the education of future generations.

For resource managers with the intention of developing a climate change response programme in their land management area, we strongly recommend active, ongoing engagement with various stakeholders to develop prioritization schemes and management strategies. At KLG0, the resources ranked as highly significant for archaeological value often ranked as less significant for interpretative value. As an archaeological division, we had originally only considered the archaeological value of resources for prioritization. Meetings with stakeholders made us aware that the park community placed higher value on interpretation and education than on preservation. We adjusted our prioritization scheme to consider the interpretative value of resources and developed management strategies

that will provide information for future interpretative and educational materials. If stakeholders' desires are not addressed, the implementation of climate change response programmes will likely prove difficult.

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