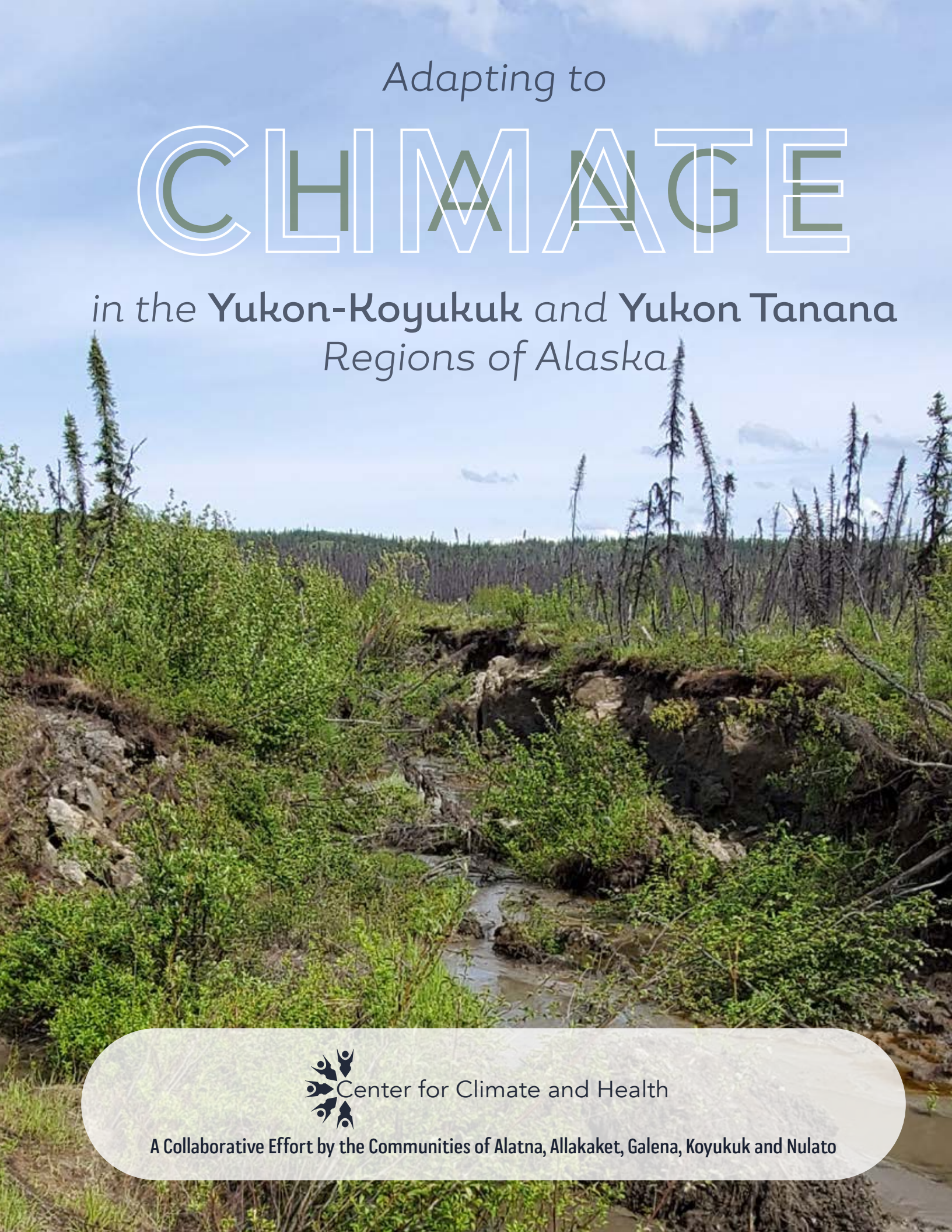

Adapting to CHMATE

in the **Yukon-Koyukuk** and **Yukon Tanana** Regions of Alaska

Center for Climate and Health

A Collaborative Effort by the Communities of Alatna, Allakaket, Galena, Koyukuk and Nulato

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Tanana Chiefs Conference
USGS science for a changing world
ALASKA NATIVE TRIBAL HEALTH CONSORTIUM
LEO NETWORK

Cover photo: Erosion near Nulato.
Photo courtesy of Martha Turner

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River boat near Koyokuk.
Photo courtesy of Laurie Lolnitz

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Lowbush cranberries.
Photo courtesy of Richard Drake

INTRODUCTION

The Yukon-Koyukuk and Yukon Tanana region is experiencing environmental change that affects the ability of people to maintain infrastructure, travel safely, access clean water and harvest healthy foods. Alaska Native People are very concerned about the rate of change and the impacts touching every aspect of life. They are also innovating and finding ways to adapt to the many challenges and in some cases, opportunities.

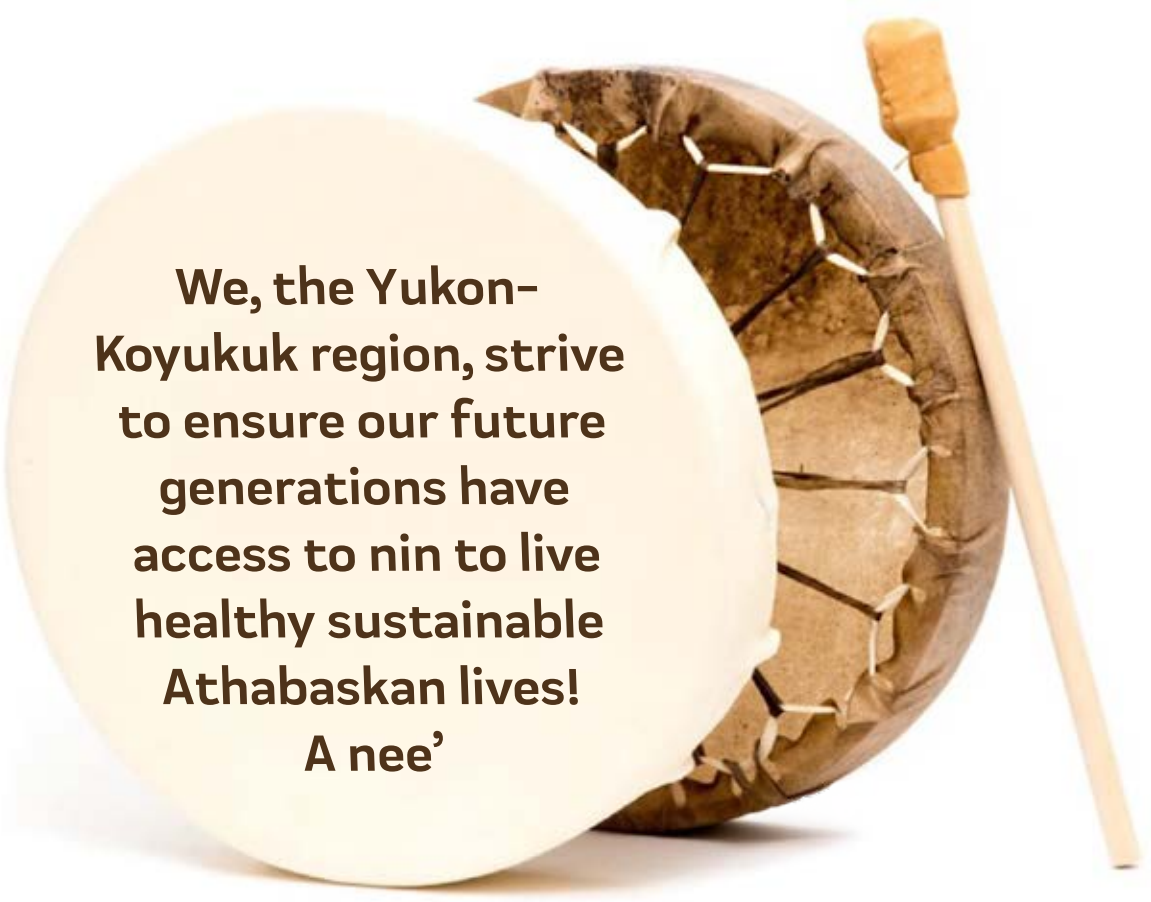
In late 2019, the Alaska Native Tribal Health Consortium (ANTHC) received funding from the Bureau of Indian Affairs (BIA) Tribal Resilience Program for the development of a regional adaptation plan. ANTHC partnered with Tribes from five communities: Evansville, Allakaket, Alatna, Galena, Koyukuk and Nulato to participate in the project. Other partners included Tanana Chiefs Conference (TCC) and the United States Geologic Survey (USGS). The goal of this project was to record observations and concerns of local residents, to share what we have learned from traditional knowledge and the available science, and to explore adaptation strategies as possible responses across the region. This process followed the 7 Generations Climate Adaptation Planning Process, developed by the ANTHC Tribal Capacity and Training Program. The steps in this process include:

- Creating a planning team;
- Collecting community information;
- Collecting observations and Traditional Knowledge about environmental change;
- Collecting scientific information about environmental change;
- Creating a prioritized list of impacts to address through adaptation and;
- Identifying potential responses and solutions

Figure 1: 7-Generations Climate Adaptation Planning Steps (ANTHC 2021)

During 2020, the planning team comprised of ANTHC staff, project leaders from each community and partners at TCC came together to discuss the goals of the project and to begin collecting community demographic information. In March of 2021, we met virtually to discuss how the environment in the region is changing and how those changes are impacting communities. Later that year in August, the planning team met in-person in Fairbanks to create a prioritized list of impacts and brainstorm possible adaptation strategies.

The outcome is this report. It provides local observations, a summary of the available science, and a description of response actions that emerged through these meetings and discussions. The report authors recognize that global warming is a complex and emerging driver for environmental change in Alaska. We do not assume to include or understand all that is being experienced in the Yukon-Koyukuk and Yukon Tanana region. We recognize the importance of the knowledge shared and the value for better understanding what is being experienced today, so we can begin to learn how these changes are occurring and how to respond. We hope the process with help us in finding healthy ways to adapt. This process has been guided by a vision statement created by participating regional residents. It reads:



REGION

The Koyukuk River flows southwest for 425 miles from its headwaters in the Endicott Mountains in the Brooks Range and joins the Yukon River before ending at the Bering Sea. The river moves from the mountains down into boreal forest, where it meets the Yukon River, before the landscape transitions to lowland marsh near the mouth of the river. Traditionally, Koyukon Athabascans, Inupiaq and Nunamiut people traveled across the region hunting, fishing and utilizing their extensive trade networks.

Today, the people of the region continue traditional practices, and in thirty-seven communities continue to build and develop a diversity of infrastructure, economies, and services. Communities along the Koyukuk and the central portion of the Yukon River receive services from the Tanana Chiefs Conference (TCC), the regional non-profit health corporation. TCC provides healthcare and natural resource management as well as tribal development, public safety, and transportation services to thirty-seven communities divided in to six sub-regions. They are also part of Doyon Limited, the for-profit Alaska Native Corporation with a portfolio including oil fields services, construction, information technology, tourism, and real estate.

Communities participating in the climate adaptation plan are located in both the Yukon Koyukuk and the upper Yukon Tanana sub regions of the TCC service area. This area is largely covered by boreal forest, partially within the boundaries of the Koyukuk National Wildlife Refuge and the Kanuti National Wildlife Refuge. Boreal forest is characterized by black spruce, white spruce, balsam, paper birch, aspen and willow, which cover the floodplains and other areas with well-draining soil. Undergrowth is made up of dense shrub, including alder, willow, rose, dogwood, Labrador tea, and a variety of berry plants. Ferns, grasses, horsetail, wildflower, lichen and moss cover the forest floor. An extensive network of rivers and streams feed lakes and ponds underlain in many areas by permafrost.

Communities in the region practice subsistence, hunting moose and occasionally caribou from the Western Arctic caribou herd. Residents fish burbot, pike, sheefish and whitefish year round and fish all five salmon species over the course of the spring, summer and early fall. Each year, countless migratory birds including tundra and trumpeter swans, white fronted and Canada geese, sandhill cranes, loons, gulls, terns, shorebirds, mark the start of spring with their arrival.

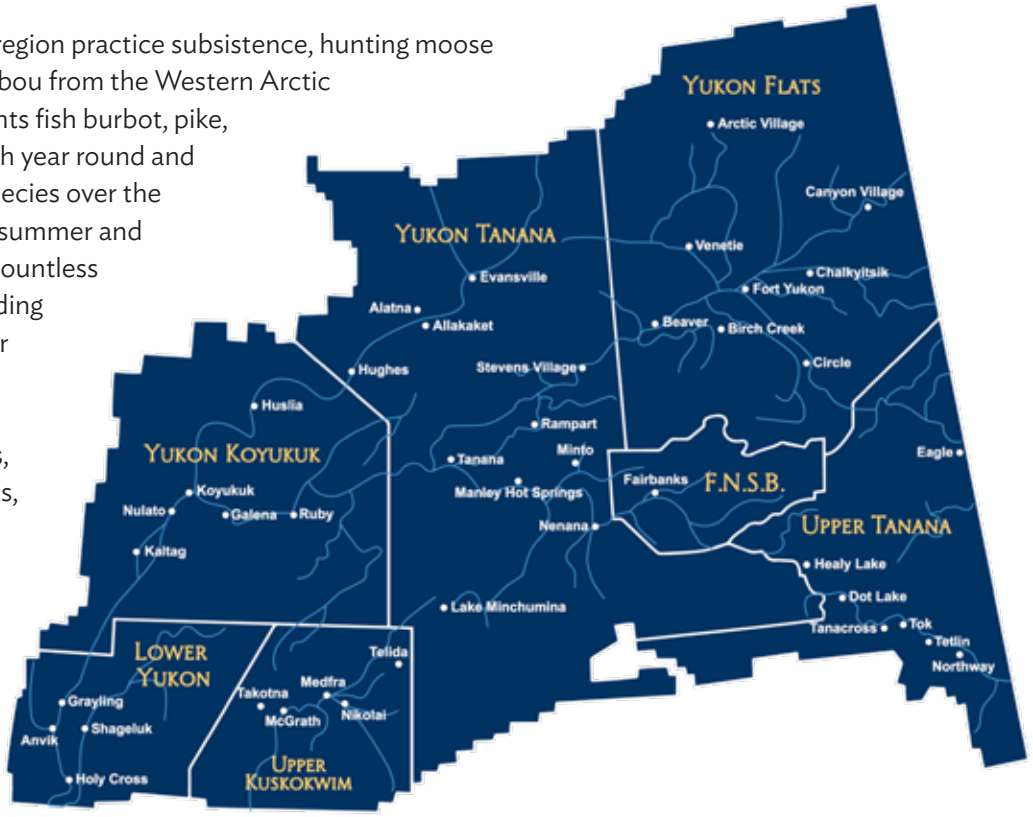


Figure 2: Tanana Chiefs Conference Service Area (TCC 2021)


Chukchi Sea
Evansville
Alatna
Allakaket
Koyukuk
Nulato
Galena
Fairbanks
Norton Sound
Anchorage
Bristol Bay

YUKON-TANANA SUB-REGION

Evansville

Evansville sits on the east bank of the Koyukuk River next to the community of Bettles, 180 air miles from Fairbanks. In 1948, the Federal Aviation Administration constructed an airfield and communications facility near Bettles as a stopover between Fairbanks and Utqiagvik. Shortly after the airfield was constructed, Evansville was settled by trading company operator Wilfred Evans, Sr. and his brother-in-law Frank Tobuk, who moved from Alatna/Allakaket to take advantage of growing economic opportunities at the airfield. In 1950, a post office was established, followed by a school in 1956 and a health clinic in 1980. In 2003, the Evansville school closed due to low enrollment. Today the community is governed by the Evansville Village Tribe. The US census estimates that there are 15 people currently living in Evansville. Healthcare is available at the Frank Tobuk Sr. Health Center, administered by TCC. Diesel generated electricity is supplied by Alaska Power and Telephone. No homes are plumbed, and residents haul water. In the summer, the community can be accessed by plane via the state-owned airport in Bettles, or by boat up the Koyukuk River. During the winter, residents follow the 30-mile Hickel Trail to the Dalton Highway (a) DCRA 2021).

Koyukuk River at Evansville.
Photo courtesy of Charlotte Mayo

"Since I was a little kid, a big part of the land has been caving, caving and caving. Some houses caved over. The whole front of Evansville kinda caved over. There used to be rocks when you were walking up the bank, now the bank is all cut-off."

— Charlotte Mayo

Aalaa Kkaakk'et (Koyukon) – Allakaket

Allakaket is located on the south bank of the Koyukuk River. In 1906, Episcopal Church missionaries built the St. John's-in-the-Wilderness mission followed by a post office in 1925. In 1938, the mission community changed its name to Allakaket, and an Inupiaq community across the river became the current community of Alatna. In 1957 the first public school was constructed in Allakaket, but was damaged in 1964 when an ice-jam flooded 85% of the community. In 1975, Allakaket and Alatna incorporated as one city to share services. A clinic was built in 1978, followed by a new school and roads in 1979. In 1994, another flood damaged nearly all infrastructure in Alatna and Allakaket. Residents have rebuilt their communities, although they no longer share a formal incorporated city boundary.

Allakaket is currently home to an estimated 164 people, currently co-governed by the City of Allakaket and Allakaket Village. Individual homes are not plumbed and residents haul water from a community well. Diesel generated electricity is provided by the Alaska Power Company. Healthcare is available in the community at the Allakaket Clinic, administered by TCC. The community is accessible year-round by airplane, by boat in the summer, and by snowmachine in the winter ((b) DCRA 2021).

Allakaket

Photo Credit: Department of Commerce, Community and Economic Development; Division of Community and Regional Affairs' Community Photo Library.

"I think the biggest change I've seen has been with moose – we have to go really far when hunting"

— Crystal Bergman

Alaasuq (Iñupiaq) – Alatna

The community of Alatna sits on the north bank of the Koyukuk River, directly across from Allakaket, at the site of a traditional trading center where Athabascan and Iñupiat peoples exchanged goods. Traditionally, people moved across the land following seasonal hunting, fishing and gathering, but in 1851, settlements were established that later became Alatna and Allakaket. Alatna adopted the community name in 1938 after the former St. John's-in-the-Wilderness mission community across the river changed its name to Allakaket. In 1975, both Alatna and Allakaket incorporated as a single city, and a new clinic and airport was built shortly after in 1978 followed by a new school and road system in 1979. However, in 1995, a severe flood damaged almost all of Alatna's community infrastructure. Residents relocated Alatna a mile away, outside of the Koyukuk River flood plain, but fell approximately two miles outside the incorporated city boundary. Alatna is currently unincorporated, and governed by the Alatna Village.

As of 2010, the US Census estimates that 37 people live in Alatna. Bulk fuel and electricity are provided by Alaska Power Company. Health care is administered by TCC at the Alatna Clinic. Alatna can be accessed by plane or snow machine in the winter, and by boat in the summer ((c) DCRA 2021).

Koyukuk river at Alatna.
Photo courtesy of Dawn David

"Growing up as a child we used to cross the river to the neighboring village of Allakaket every year by snow machine for Halloween. Now the timeframe for freeze up is later and later. Last year was very late resulting in us having to cross by boat. This year it was still risky crossing the river in November and early December."

— Jonathan Henzie

YUKON KOYUKUK SUB-REGION

Notaalee Denh (Koyukon) – Galena

East of Koyukuk and Nulato, on the north bank of the Yukon River, sits Galena. Traditionally, Koyukon Athabascan tribes floated down the river in summer to fish between the Koyukuk and Nowitna Rivers. In 1918, Galena was established near one fish camp known as Henry's Point, and became a supply point for nearby lead ore mines. The community grew in 1920 as Louden tribal members moved to Galena to sell steamboats and haul freight for the mines. As the population grew, a school was built in 1920 and a post office opened in 1932. In 1941, the US Air Force constructed a military air field, increasing the population and driving the construction of more new infrastructure. The Air Force station was closed in 1993 following the end of the Cold War, leaving significant soil contamination.

Galena became an incorporated city in 1971, and is currently governed by the City of Galena and Louden Tribe. The community is larger than most surrounding villages and acts as a regional hub. Among many of the estimated 470 residents, traditional subsistence hunting, gathering and fishing practices are fundamental to community life. Galena is accessible year-round by airplane. In the summer, travelers boat up and down the rivers and a barge delivers heavy materials such as vehicles and building supplies. Packaged foods and other goods arrive by air and by barge. During winter, residents mostly travel by plane or on frozen sections of the Yukon River when weather allows. Most of the homes in Galena are plumbed, and either receive water delivery or are connected to a city well. Drinking water is purchased separately. Electricity is generated from diesel fuel delivered by barge in the summer and is distributed by the City of Galena ((d) DCRA 2021).

Fish Shipments in Galena.
Photo courtesy of Brooke Sanderson

"The weather this fall and winter has been warmer than average and river ice on the Yukon at Galena did not stop moving until very late (among the latest dates on record). Continued warm weather and snowfall have made travel away from the villages very difficult and dangerous due to open holes in the river ice and large amounts of overflow on lakes and sloughs."

— LEO Network Post by Karin Bodony in Galena, 2017

Meneelghaadze T'oh (Koyukon) – Koyukuk

On the Yukon River, approximately 30 miles west of Galena, is the village of Koyukuk. Historically, Koyukon Athabascan people traveled through the area following seasonal animal migrations. Koyukuk Station became established as a year-round settlement following the construction of a Western Union telegraph station in 1867, followed by a trading post in 1880. The community grew as the gold rush era brought prospectors and other new residents to the area. In 1890, a measles epidemic, followed by food shortages, devastated residents. Although gold prospectors began leaving the area in 1906, other mining operations remained, and in 1937 a new school was built. The school drew additional permanent residents to Koyukuk and in 1973, Koyukuk became incorporated as a second-class municipal city. Today, the community is co-governed by the City of Koyukuk and the Koyukuk Tribal Council.

Today, the village is home to approximately 96 people, and is accessible by boat and plane in the summer, and by plane-only in the winter. ANTHC is in the process of installing running water and sanitary services to each home. Electricity is diesel generated, and provided by the City of Koyukuk. Healthcare is available at the Koyukuk Clinic, administered by TCC ((e) DCRA 2021).

Warm summer day in Koyukuk.
Photo courtesy of Laurie Lolnitz

"Climate change in Koyukuk, AK as it is today. There are very high winds both during the summer and fall time, much higher than 30 MPH. In 2019, we had over 100 days of sunshine during the summer months here in Koyukuk. The Middle Yukon River freezes later in the fall than ever, late November and early December. The summer king salmon all but disappeared from the Yukon River. We have not seen silver salmon for two consecutive summers and fall now."

—Loretta Lolnitz, Koyukuk lifelong resident

Noolaaghe Doh (Koyukon) – Nulato

Five miles downriver from Koyukuk, Nulato is on the west bank of the Yukon River. The settled community began as a series of seasonal fish camps used by Koyukuk Athabascan tribes. In 1839, a Russian fur trader known as Malakov established a trading post, taking advantage of existing trade activity in the area. Gold rush explorers flooded the region in the early 1880s, bringing heavy river traffic and devastating epidemics. In 1887, the Roman Catholic Our Lady of Snows Mission was built at Nulato, followed by a post office in 1897. In 1970, the community decided to relocate to a new town site in the hills, outside the observed floodplain.

Today, Nulato is home to an estimated 264 residents, co-governed by the City of Nulato and Nulato Village. Some homes are piped with running water and sewer services, using water drawn and treated from a community well, while other households haul water. Fuel is delivered by barge during the summer, although many homes are heated using wood. Electricity is diesel generated, although the community has plans to install solar panels on community buildings to help offset the high cost. The community is accessible year-round by plane, in the winter by snowmachine, and in the summer by boat ((f) DCRA 2021).

Nulato.
Photo courtesy of Martha Turner

"Lots of changes in the environment from climate change. Permafrost thaw, lakes are forming from small ponds near family cabins in Kaiyuh, our banks are eroding causing us to make new trails to get to our cabins. Strange weather, its taking longer for our river to freeze, it use to freeze solid in October, nowadays the river is still running and people are still driving boats into November". Its becoming normal for it to rain in December, our raining season is usually from May to September, now it rains in December and sometimes January. In 2012 it was -65 on new years day, in 2013 it was -25, in 2014 it was 25 above, now its been averaging from zero degree's to -20 on New Years day."

—Nulato community member

CHANGING CLIMATE

The Yukon-Koyukuk and Yukon-Tanana sub-regions experience a continental climate, characterized by weather patterns and storm tracks that are influenced by geographic features, such as mountains and lowlands, and less influenced by the ocean. For residents of the region, these influences often lead to extreme temperature differences between seasons (Brabets et al 2000).

The Alaska Climate Adaptation Science Center prepared projections for six indicators of climate change and climate-driven ecosystem change, which include changes in temperature, precipitation, snowpack, ground temperature, vegetation distribution and wildfire frequency. These projections are dependent on future emissions scenarios called Representative Concentration Pathways (RCPs). These scenarios demonstrate what the future climate may look like if emissions of carbon dioxide and other greenhouse gases were reduced on a global scale and result in less warming (RCP 4.5 referred to as a lower emissions scenario), and the current emissions scenario resulting in more warming (RCP 8.5 referred to as a higher emissions scenario).

For temperature, precipitation, and snowpack, the historical and projected climate used to develop the mapped changes came from the University of Alaska Fairbanks Scenarios Network for Alaska and Arctic Planning (SNAP) archive. These use statistically downscaled bias-corrected climate model output for five climate models shown to have skill in the Arctic (CGCM3, GFDL CM3, GISS E2R, IPSL CM5A LR, and CCSM4). Mapped averages are the average of these five climate models and are presented for Representative Concentration Pathways (RCP) 4.5 and 8.5 to describe the range of likely warming given atmospheric greenhouse gas concentrations. The mapping for these variables also focuses on two different thirty-year time windows: the 2050s (2040-2069) and the 2080s (2070-2099). Changes are compared to downscaled data collected from the period 1970 to 1999, which represent the historical average. Using two RCPs addresses the uncertainty in the rate of future greenhouse gas emissions. Using thirty-year averages decreases the role of natural climate variability in the timing and size of projected changes.

Erosion on the Koyukuk river.
Photo courtesy of Jonathan Henzie

Projections for permafrost, vegetation distribution and fire frequency took slightly different approaches. Permafrost projections (mean annual ground temperature) were available for two climate models (ECHAM5 and CCMA) run under the older A1B greenhouse gas emissions scenario, which is in between RCP 4.5 and RCP 8.5 by the late 21st century. Ecosystem (vegetation and fire) projections were available for two climate models (CGCM3 and CCSM4) used to drive the ALFRESCO landscape fire model under the RCP 8.5 scenario.

Annual temperatures are projected to increase under all climate scenarios. Under a lower emissions scenario (RCP 4.5), annual temperatures are projected to rise an estimated 5.7°F above average between 2040 and 2069 across the region. Between 2070 and 2099, annual temperatures are projected to rise an average of 7.0°F. Under a high emissions scenario (RCP 8.5), annual temperatures are projected to rise 7.0°F above average during the years 2040 to 2069. Between 2070 and 2099, annual temperatures are projected to rise an average of 11.4°F.

Overall, annual precipitation is also expected to increase in the region. However, each year is different and there will be some years with wetter seasons, and some with drier seasons. Overall, the increase in precipitation is not enough to offset the increase in temperature, and will leave some areas drier than they have been historically. Under a low emissions scenario, annual precipitation is projected to increase by 21% during the period 2040-2069 and increase 25% during the period 2070 and 2099. Under a higher emissions scenario, precipitation is projected to increase by 26% for the period 2040 and 2069 and by 41% for the period 2070 and 2099.

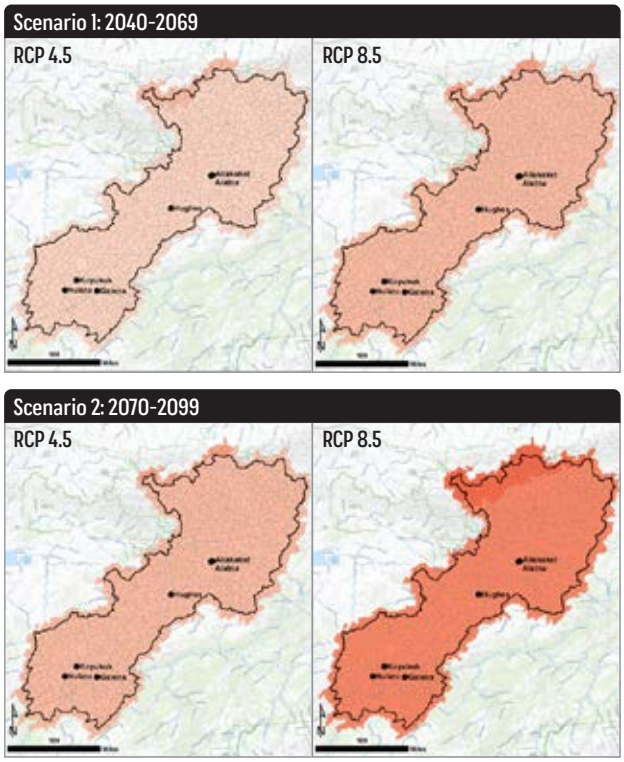


Figure 3: Annual Temperature Change (°F), Relative to 1970-1999

4-6 6-8 8-10 10-12 12-14

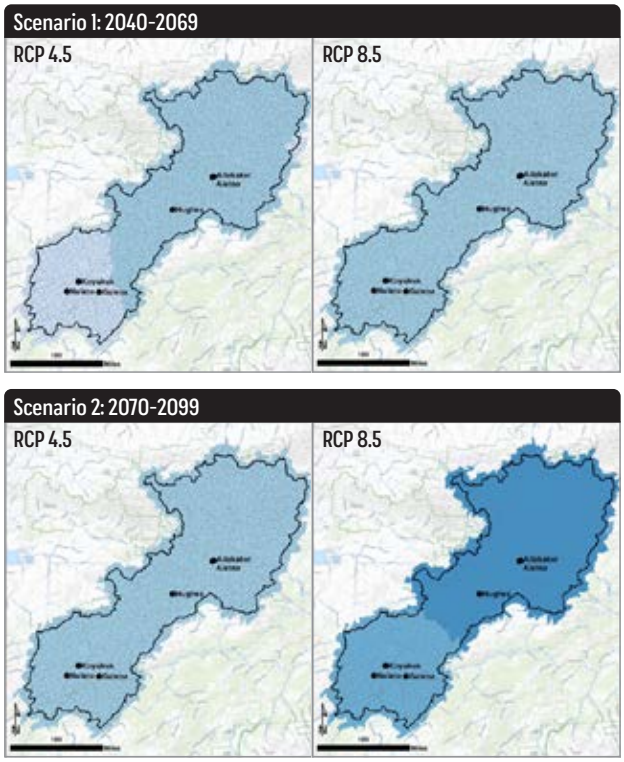


Figure 4: Change in Annual Precipitation, Relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70

ENVIRONMENTAL CHANGE IMPACTS: TRAVEL

Winter Travel Summary Points:

- Winter temperatures are warmer, causing the river to freeze later. Ice conditions throughout winter are becoming more variable.
- Under a high emissions scenario, winter temperatures are expected to increase 10.6°F during the 2050s (2040-2069) and 16.2°F during the 2080s (2070-2099).
- Under a high emissions scenario, winter snowfall recorded between October and March is also expected to increase by 9% during the 2050s (2040-2069) and by 3% during the 2080s (2070-2099)

Snow and ice are crucial to winter travel in the Yukon Koyukuk and Yukon Tanana sub-regions. Communities are not connected by a road system, and depend on snow conditions to support overland travel by snowmachine, as well as consistent ice quality to travel on frozen rivers. Safe winter travel-ways allow residents to travel between communities for events and religious services, as well as for groceries when supplies run low. The region is tight-knit, with many family members living in neighboring communities. In-person travel is an important way to maintain connections between friends and family.

In community memory, the autumn temperatures used to get cold enough for the rivers to freeze in October, allowing travel on the ice soon after. Recently, winter temperatures have been inconsistent and have changed usual patterns of ice freeze. Today, residents wait until December for the river to begin freezing, and do not usually begin travel on the ice until January or February. Evansville residents are especially reliant on the ice road that connects the

Winter travel from Koyukuk to Huslia.
Photo courtesy of Laurie Lolnitz

"Usually this time of year, the temperatures would be 50 to 60 below, with about 7 feet of snow. This year we have maybe about 2 to 3 inches of snow on the ground. On the Yukon River from Koyukuk, maybe about 24 miles below Galena, there is Bishop Mountain summer camp. There's a strong eddy there and it's open. We can't go up river anymore on the ice because of the open water. We can't even go up to Galena through the portage. The river channels have changed. Three miles above Koyukuk it's open, and still open about 3 miles below. That's the first part that used to freeze up back in the early days. We started seeing all these open holes on the Yukon in maybe 1981. We started seeing changes, but it was still cold. In 1981, the last

community with the Dalton Highway, built over frozen rivers and creeks. Warm winter temperatures make the ice less stable, which increases the danger of cars falling through the ice. When travel on the ice is not possible, residents must travel by air at a higher cost. However, when temperatures are warm enough for snow to fall as rain during the winter, runways may accumulate too much ice for planes to safely land.

Changes in winter conditions are also making travel more unpredictable. Periods of heavy snow cause trees to fall and block marked overland trails, while warm temperatures will cause localized flooding. In 2020, adults and youth on snowmachines went out to the Koyukuk Flats using a known trail. When they got to the river crossing, they found the ice was thawing and there was open water. They had to re-route 50 miles, causing a delay by 7-8 hours. When trails are flooded, travelers run a higher risk of getting wet and becoming hypothermic. High winds that are common in the area will blow snow into large drifts, complicating travel by snowmachine.

Winter temperatures are projected to increase under all climate scenarios. Under a lower emissions scenario (RCP 4.5), winter temperatures are projected to rise 7.7°F above average during the period

Iron Dog Checkpoint - Yukon River Galena.
Photo courtesy of Brooke Sanderson

place to freeze on the Yukon was maybe one place above Koyukuk before Thanksgiving. But it was still thin ice. That's when we started losing people in the river because in the past we were just used to going up and down the river- it used to be frozen. They didn't know this place was open. Then we started communicating to Search and Rescue between Galena and Nulato and telling people what direction to take. The last time it was safe to go on the Yukon was 1980. After that there were holes. And now there's more open holes. This last week it was open 12 miles down to Nulato. Right now it finally freezing, but it's thin ice."

— LEO Network Post by Marilyn Roberts in Koyukuk, 2018

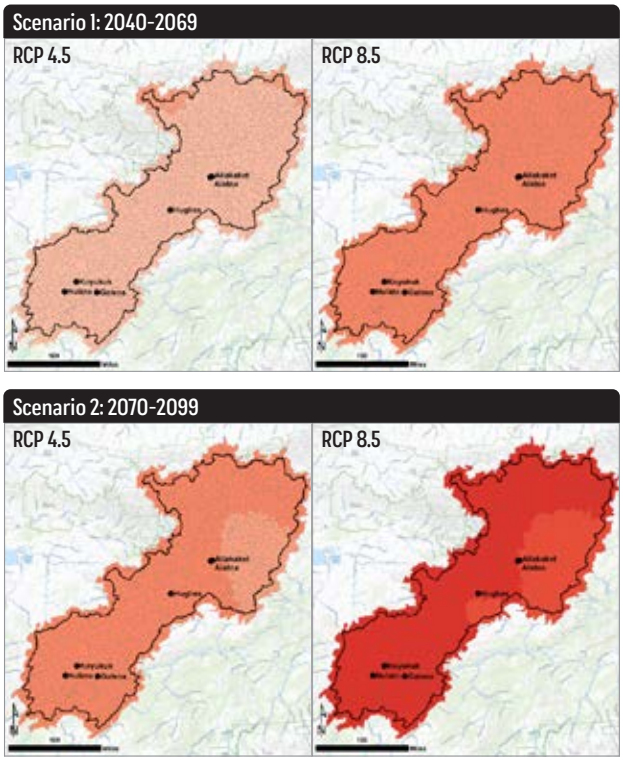


Figure 5: Winter (DEC-FEB) Temperature Change, Relative to 1970-1999

6-8 8-10 10-12 12-14 14-16 16-18

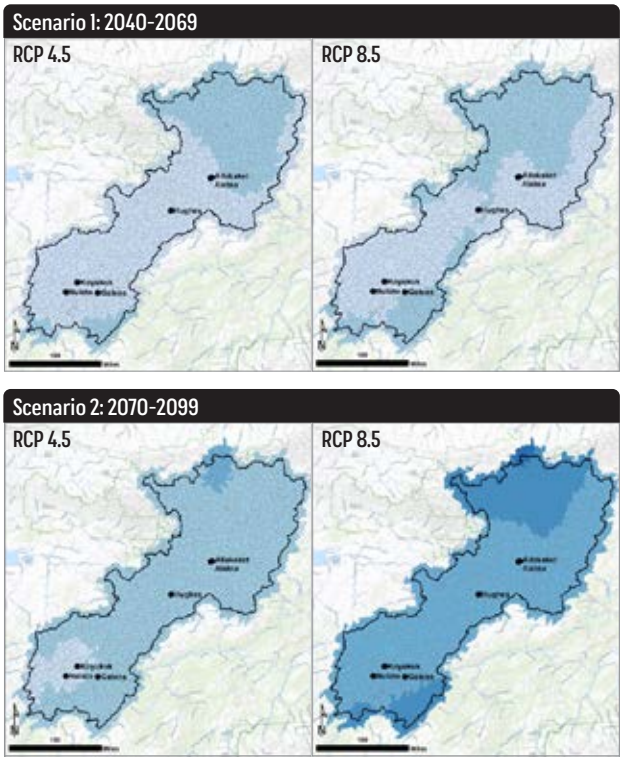


Figure 6: Change in Winter (DEC-FEB) Precipitation, Relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70

2040-2069. During the period 2070-2099, annual temperatures are projected to rise 10.2°F. Under a high emissions scenario (RCP 8.5), winter temperatures are projected to rise 10.6°F above average during the 2050s. During the 2080s, annual temperatures are projected to rise 16.2°F.

Winter precipitation, measured between December and February, is also expected to increase, bringing more snow to the region in the cooler months and more rain in the warmer months. Under a low emissions scenario (RCP 4.5), precipitation is projected to increase by 20% during the period 2040-2069 and increase by 25% during the period 2070-2099. Under a high emissions scenario (RCP 8.5), precipitation is projected to increase by 20% during 2040-2069 and by 39% during 2070-2099.

Although there will be variation between years, on average, the majority of winter precipitation between October and March is projected fall as snow rather than as rain across the region. However, residents may see a change in the number of months with reliable snow cover, defined as 70% or more of the monthly precipitation arriving as snow. Months with reliable snow cover are not expected to change much in the northern part of the region, but the southern part of the region may see a decrease up to 2 months, suggesting that some precipitation may fall as rain.

Figure 6: Change in reliable snow (months)

-6 -5 -4 -3 -2 -1 0

Koyukuk river near Alatna.
Photo courtesy of Dawn David

ENVIRONMENTAL CHANGE IMPACTS: TRAVEL

Summer Travel Summary Points:

- The Yukon River has recently experienced higher than normal water levels, which affect the rate of river bank erosion
- Winter precipitation is projected to increase with the majority of precipitation still expected to fall as snow rather than rain. An increase in snowfall at high elevations may increase spring runoff.
- Boaters and barge captains have to carefully navigate the river to avoid personal injury or damage to the boat.

In recent years, residents have watched the water levels rise on the Koyukuk and Yukon. Many people boat up and down the rivers, traveling out on the land or going to visit other communities. In some cases, the high water helps barges as they travel upriver to deliver food, fuel, mail and other purchases. However, as river discharge has increased, so has the rate of riverbank erosion. The water will move sediment in to the river creating sandbars that are dangerous for boaters.

Boaters have to read the water carefully and watch for sandbars. The river changes every year, and even experienced boaters can be caught off guard by small changes. However, some changes are more substantial. Boaters must carefully navigate the rivers to avoid injury or damage to their boat.

Barges provide a more cost-effective method of transporting freight than air transport. Barge service is provided by Ruby Marine out of Nenana, and regularly delivers to Tanana, Ruby, Galena, Koyukuk, Huslia, Nulato, Kaltag, Grayling, Anvik, Holy Cross, Shageluk, Russian Mission, Marshall, Pilot Station,

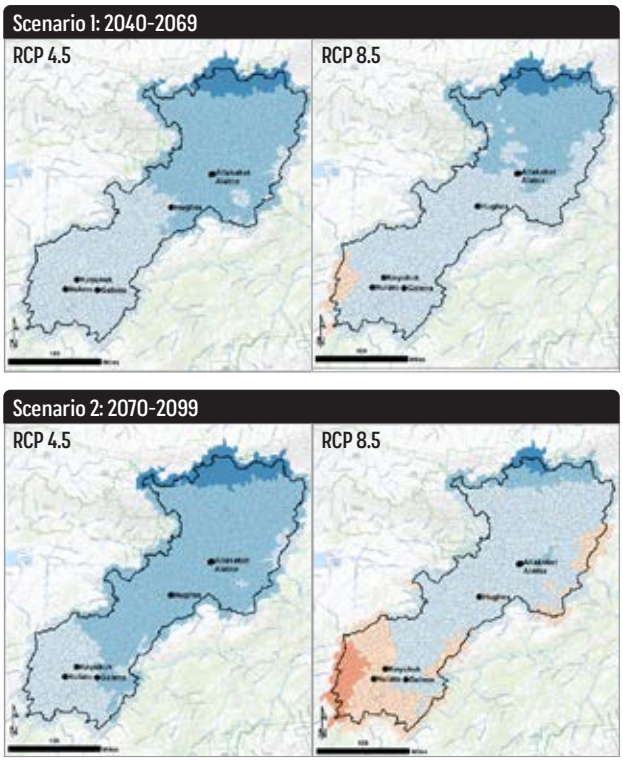


Fig. 7: Change in OCT- MAR Snowfall Water Equivalent, Relative to 1970-1999

"There's sooo much snow – tall as homes! If it slowly melts this spring, it will be good, but if it just gets hot all of a sudden, there's a higher chance there might be a flood."

— Charlotte Mayo

St. Mary's, Mountain Village, Emmonak, Alakanuk, and Nunam Iqua. When the water is high, the barge can reach Allakaket. Barges usually deliver heating fuel, gas, large-item orders, bulk orders of groceries for community stores and families, and then transport backhaul out of the communities. Moving sandbars, driven by the energy of moving water, present a risk for barges. In the past, barges have gone high-and-dry on sandbars. If a barge stranded with a crack, residents worry that it could leak fuel in to the water.

Winter snowfall is an important factor in spring river runoff. Under a low emissions scenario (RCP 4.5), winter snowfall recorded from October to March is projected to increase by 11% during the period 2040-2069 and by 13% during the period 2070-2099. Under high emissions scenario (RCP 8.5), winter snowfall is projected to increase by 9% during the period 2040-2069 and by 3% during the period 2070-2099. These increases are projected to be concentrated in the northern part of the region, contributing to river discharge.

Barge on Yukon near Galena.
Photo courtesy of Brooke Sanderson

ENVIRONMENTAL CHANGE IMPACTS: INFRASTRUCTURE

Infrastructure Summary Points:

- Communities frequently experience some degree of seasonal flooding, however increasing spring temperatures and winter snowfall may increase the risk of ice jam flooding during breakup
- High water is contributing to riverbank erosion that is threatening some structures and campsites
- Permafrost thaw is destabilizing some structures, causing them to tilt
- Temperature change, among other factors, may lead to a water deficit and make vegetation more vulnerable to wildfire that affect community health and safety

Flooding and Erosion

Communities in the Yukon-Koyukuk and Yukon-Tanana sub-regions are at risk of seasonal flooding due to ice jams and heavy rainfall. Ice jam flooding occurs when ice restricts water flow. This can happen when different areas of the river freeze at a different rate or during spring breakup, when ice chunks clog an area downstream. The risk of ice jam flooding can increase during years when warm spring temperatures at high elevations melt the snow more quickly than the river ice can melt. Communities can flood when water backs up behind the ice jam, or flood during the surge of water when the ice jam breaks and the water is released (USACE 2001). As described by Jenny Bryant, "Later spring break-up dates are indicative of major flooding events, particularly when the temps suddenly rise and the lower elevation meltwater backs up, but the river ice is solid and jams up. Higher elevation melt doesn't occur until later in the summer (mid-June usually) when the water will come back up after breakup (such as from Brooks Range runoff on the Koyukuk River)." Ice jam flooding is difficult to predict and often happens quickly. For this reason, the Alaska Pacific River Forecast Center and the Alaska Division of Emergency Services coordinate spring aerial reconnaissance to identify potential river hazards, integrating information from observers on the ground (Rundquist 2021).

For many river communities, seasonal flooding is expected and many have plans in place to evacuate and protect homes and belongings. However, some floods in the region have been unusually severe. Prior to 1994, the community of Alatna was located near the Koyukuk River bank and incorporated in the Allakaket city boundary. In 1964, 85% of Alatna was inundated by floodwater from an ice jam. In 1994, heavy rainfall caused both Allakaket and Alatna to flood, damaging nearly all community infrastructure and food supplies in Alatna, and severely eroding the riverbank. The Federal Emergency Management Agency (FEMA) and the State of Alaska helped Alatna residents relocate to higher ground, but outside of the city boundary shared with Allakaket ((a) USACE 2008). Galena residents have experienced three major floods. The first occurred in 1945, and a dyke was

"There is actually less seasonal flooding occurring now then 40-50 years ago. Minor flooding was a regular occurrence and it was the odd year when water did not flow into the grass lakes and oxbow lakes along the rivers. Now it is the opposite, it is the odd year when water flows into Alexander's Lake from the Yukon and the major flooding events are less frequent. Flooding on the Koyukuk River is also less frequent during breakup, but higher water in mid-summer and sometimes throughout the summer is more common today."

— Comment by Jenny Bryant, 2021

constructed to help control floodwaters in the future. The community experienced another major flood shortly after becoming an incorporated city in 1971. The damage to community infrastructure was extensive, and prompted residents to move the community 1.5 miles east to Alexander Lake. Over 150 homes were constructed at the new town site, along with a health clinic, a school, a washeteria, and a store. In May of 2013, Galena experienced severe flooding from an ice jam that inundated 90% of community infrastructure, including homes, businesses, transportation infrastructure and government buildings with up to 9 feet of water. Nearly all residents were evacuated by air to Fairbanks and Anchorage (Galena 2010).

Even for communities who have not experienced large scale flooding, repeated seasonal flooding will increase the rate of riverbank erosion, presenting another risk to infrastructure. Those traveling by boat frequently see caving along the banks, causing trees and old homes and important historical and cultural sites to fall in to the river. Looking ahead, boaters have to beware any new sandbars where soil is moving in to the water. In addition to the risk of losing community infrastructure, residents are also grappling with losing important personal campsites that have significant meaning to each family. For generations, these areas have hosted families as they fished, picked berries, hunted, and gathered wild plants.

The riverbanks near Koyukuk have experienced flooding and erosion since the 1920s. More erosion occurs during high water, or when waves from the south and southwest are directed at the banks. In 2008, the US Army Corps of Engineers assessed the impact of erosion to Koyukuk, noting that the riverbanks were 10-15 feet high and had a slope of 60 degrees or greater ((b) USACE 2008). Today, the upper east area of the bank, where the barge lands, has become very steep. People have to use ladders to reach their boats. Near Evansville and Nulato, some of the houses have caved over, and sloping banks have turned in to abrupt cutoffs.

2013 flood in Galena.
Photo courtesy of Brooke Sanderson

Erosion monitoring has become a focus in the region. The Yukon River Inter-Tribal Watershed Council is currently working with affected communities in the Yukon River watershed to establish protocols for using drones to monitor erosion extents from the air. This data collection would allow communities and researchers to better understand what factors are contributing to increased erosion and how much land is being lost (Fidel et al 2020). This will be important work for the area, since several climatic factors that affect flooding and erosion, such as permafrost thaw, as well as temperature and precipitation, are projected to change.

Annual precipitation is projected to increase by some percentage under each climate scenario. Projected increases in precipitation are concentrated in the northern, mountainous part of the region near Evansville, Alatna and Allakaket.

As discussed in the section on travel, winter precipitation is projected to still fall as mostly snow. Under both high and low climate scenarios, the amount of snow that will fall across the central and northern part of the region, near Allakaket, Alatna and Evansville, is projected to increase by 0-20%. Under a high emission scenario (RCP 8.5) southern areas near Koyukuk, Nulato and Galena, are projected to see 0-20% decreases in the amount of snowfall during the period 2070-2099. Under the same high emissions scenario, a projected 51-80% of winter precipitation is projected to fall as snow, while the rest falls as rain.

However, the length of the snow season will decrease on average in both parts of the region. Spring temperatures are projected to increase throughout the region, possibly increasing the rate at which the snow melts. Under a low emissions scenario, spring temperatures are projected to increase 4.2° F during the period 2040-2069 and 5.6° F during the period 2070-2099. Under high emission scenario (RCP 8.5), spring temperatures are projected to rise 3.7° F for the period 2040 – 2069 and 6.8° F for the period 2070 -2099.

Precipitation, snowmelt and temperature also contribute to surface runoff, or the amount of water that runs over the surface of the land and into streams. Surface runoff is projected to increase during April in the area around Alatna and Allakaket, as well as the area north of Hughes, and can contribute to river discharge.

Nulato road to subsistence grounds.
Photo courtesy of Martha Turner

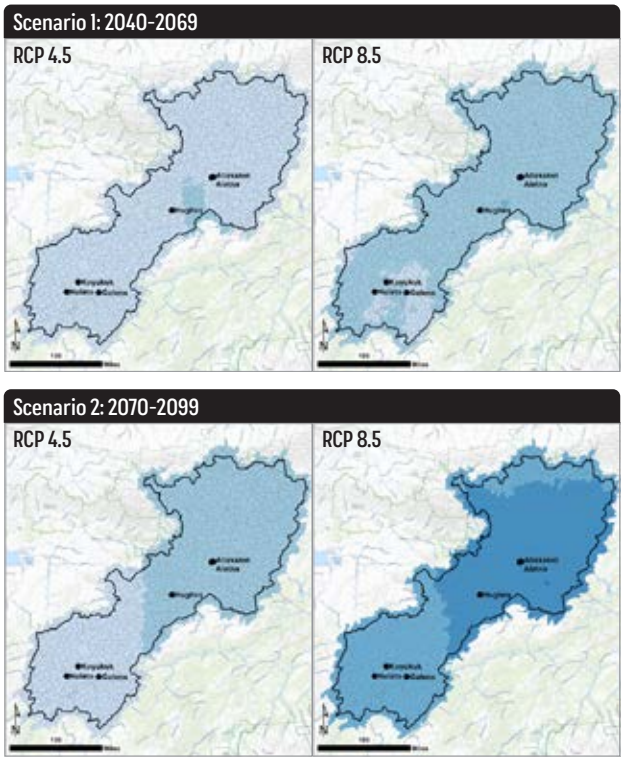


Figure 8: Projected Change in Precipitation (%) MAR-MAY, relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70

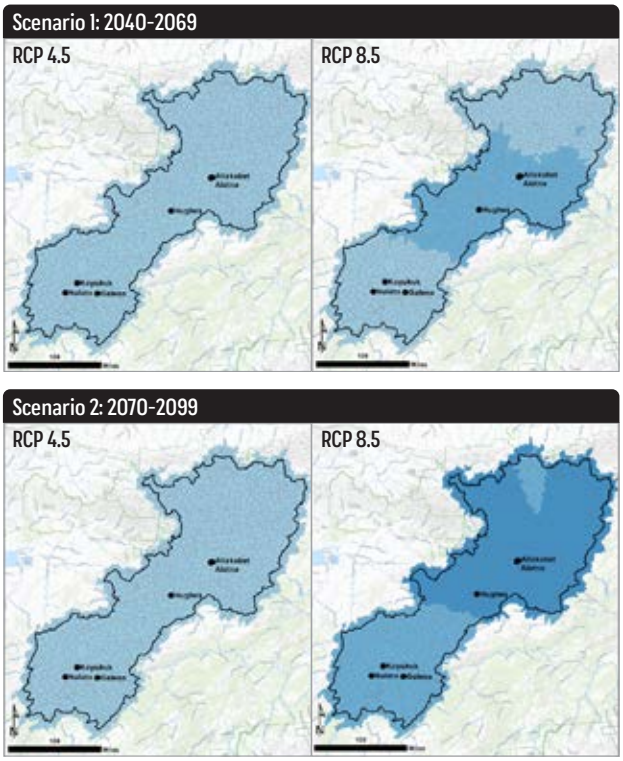


Figure 8: Projected Change in Precipitation (%) JUN-AUG, relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70

Foundation remediation in Alatna due to erosion.
Photo courtesy of Jonathan Henzie

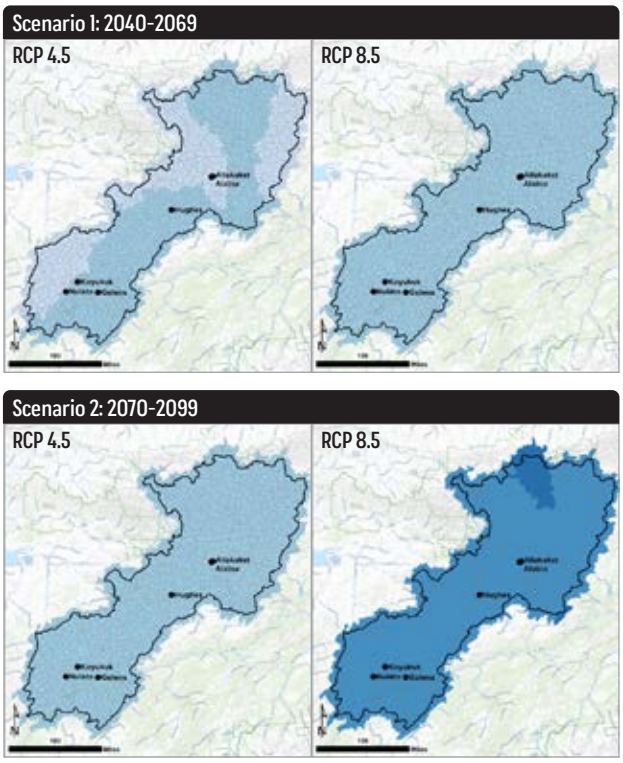


Figure 8: Projected Change in Precipitation (%) SEP-NOV, relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70

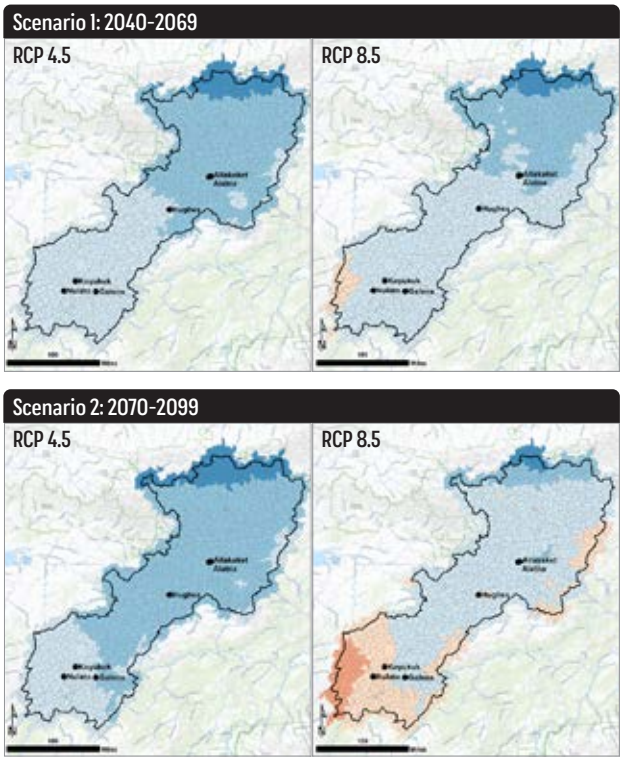


Figure 9: Change in OCT-MAR Snowfall Water Equivalent, relative to 1970-1999

-60-40 -20-10 0-10 10-20 20-40
-40--20 -10-0 10-20 40-60

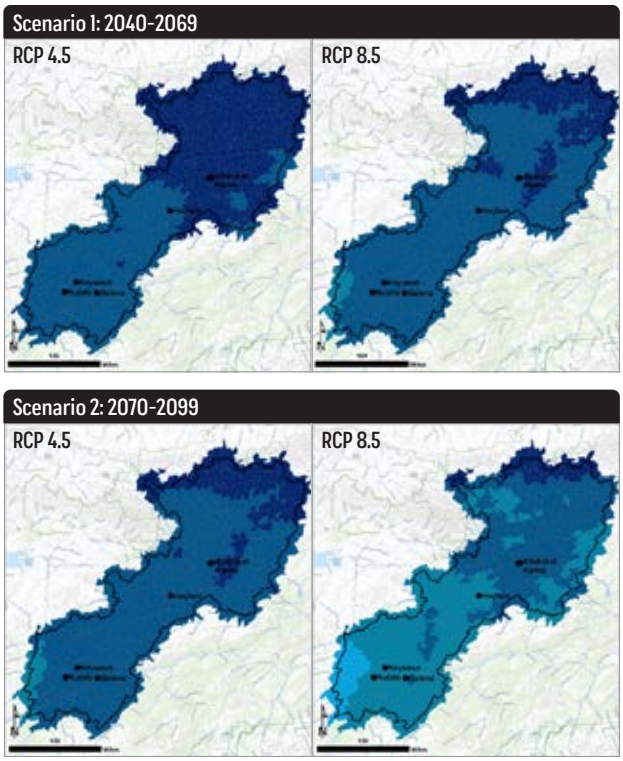


Figure 9: Snow Index, OCT-MAR % of Precipitation in April 1st Snow, relative to 1970-1999

0-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100

Permafrost Thaw

According to the Alaska Climate Adaptation Science Center, there is a high probability that permafrost underlies most of the region. As temperatures increase, ground temperatures are also projected to rise above freezing.

Permafrost thaw has a variety of impacts in the region. In some areas, lakes and ponds have dried as the melting permafrost lets water drain down in to the soil. In communities, some buildings with pilings driven down in to permafrost are beginning to tilt. As the ground conditions change, residents find water pooling around structures, and often have to add gravel to manage localized flooding. Power lines are also at risk, and can cause widespread outages if damaged. Alatna receives power from Allakaket, where poles are beginning to lean. If they fall, two communities are at risk for an outage.

Trees also lean when the ground thaws and may be more likely to fall on homes and other buildings. Near Nulato, large sinkholes are appearing in frequently traveled areas where residents used to gather vegetation or pick berries. Some holes are obscured by vegetation and may not be easy to see. For this reason, some people are reluctant to travel across those areas because of the risk or an accident.

Drunken forest from permafrost thaw.

Wildfire

Increased temperatures, earlier snowmelt, later winters and more lightning strikes are significant influences on the frequency of wildland fires. Across the state, tundra and boreal forest areas are experiencing larger and more frequent fires. Some fires are surviving over winter and re-burning in the same locations (UAF IARC 2021).

Some impacts from wildfire are unique to areas underlain by permafrost. Residents note that the active permafrost layer, ground that thaws during the summer and refreezes in winter, tend to sink more rapidly following wildfire events. According to wildland fire researchers at the University of Alaska Fairbanks, wildfires burn away the duff and soil layers that help insulate permafrost, increasing the rate of thaw. In turn, thawing permafrost allows more water to drain away from the surface, which dries out the vegetation and leaves it more prone to burning (UAF IARC 2021).

Increases in temperature will likely offset the increases in precipitation, leading to a decrease in water availability. Less water may increase the likelihood of wildfire and lead to changes in vegetation distribution. Currently, central parts of the region are dominated by deciduous forest, with patches of black and white spruce, while heath and grass and shrub tundra dominate the uplands.

The number of fires per century is projected to increase over much of the historically forested parts of the region under both the CGCM3 and CCSM4 climate models, though the CGCM3 model projects less area with increased fire frequency than CCSM4.

The increase in fire activity may cause vegetation distribution to change at a slightly higher rate, and contribute to a gradual transition from spruce to deciduous forest in the central part of the region. However, models also project that spruce will establish in what has been historically deciduous forest in areas north of Allakaket. Historically, communities have utilized spruce for building homes and other structures, but deciduous trees rebound

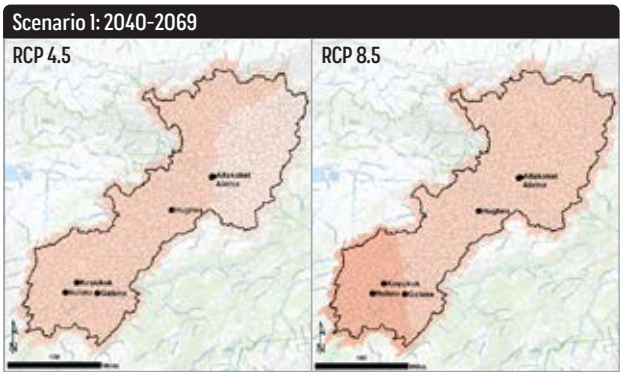


Figure 10: APR & MAY Runoff - Change in temperature (°F)

2-4 4-6 6-8 8-10 10-12

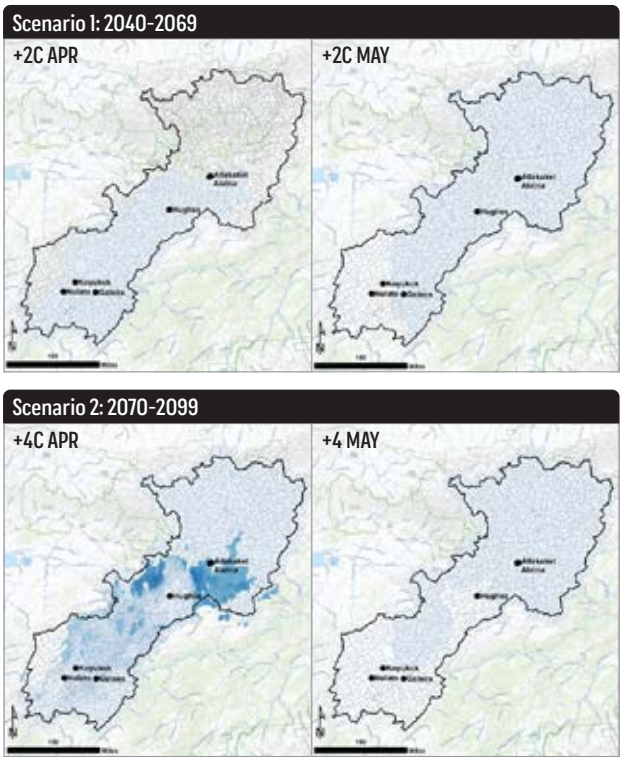


Figure 10: APR & MAY Runoff - Change in surface runoff (mm)

-50-0 50-100 200-250 400-450 500-550

0-50 100-150 250-350 450-500 550-600

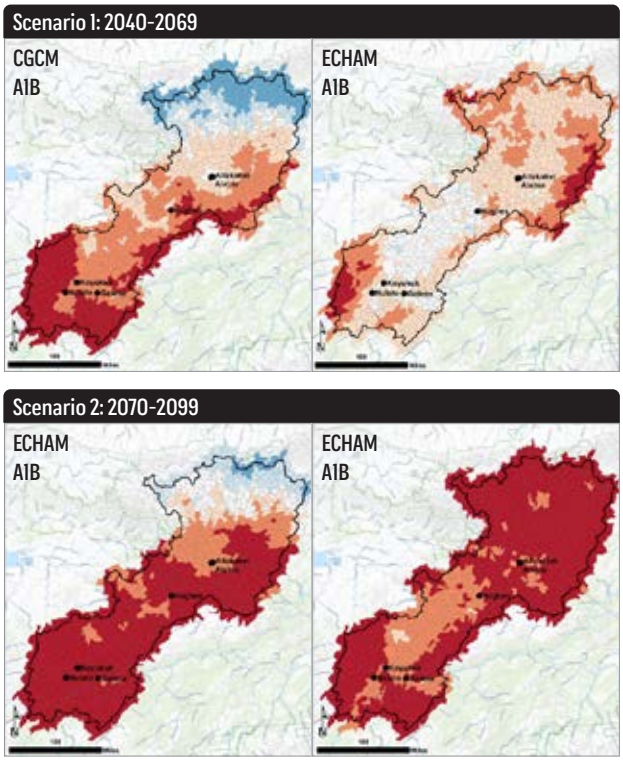


Figure 12: Ground Temperature at 1 Meter Depth

-4-2 -2-1 -1-0 0-1 1-2 2-12

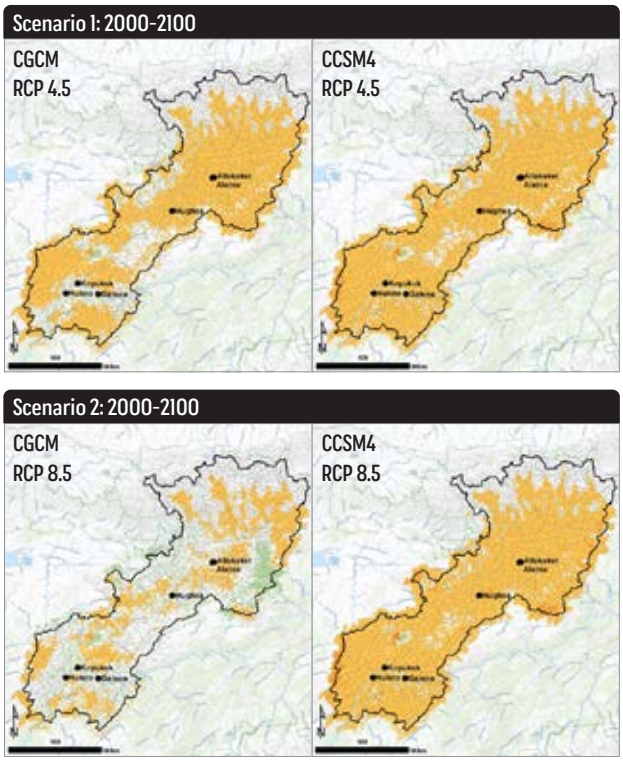


Figure 14: Change in Fire per Century

-1.5-1 0-0.1 1.1-2 3.1-4

-0.9-0.1 0.2-1 2.1-3 4.1-5

more quickly following a fire. Residents also note that spruce bark beetles are moving north and damaging spruce trees, contributing to vegetation change and increasing fire risk.

Residents recall instances of wildland fires in the past that have inspired current fire safety protocols in communities. In 2015, a fire broke out around Nulato, where residents were evacuated by boat when the airstrip closed due to smoke coverage. The Alaska Division of Forestry is working with Alatna, Allakaket and Koyukuk to remove burnable vegetation according to each Community Wildfire Protection Plan (ADNR 2021).

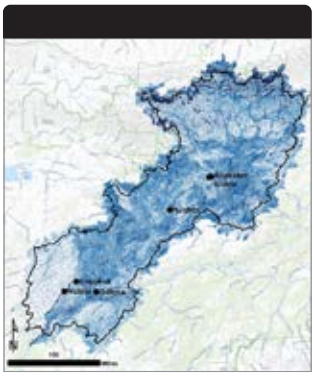


Figure 11: Probability of Permafrost (%)

0-10 21-30 41-50 61-70 81-90

11-20 31-40 51-60 71-80 91-100+

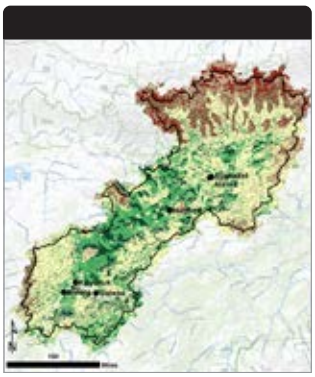


Figure 13: Current Vegetation

Not Modeled Lichen/Moss/barren

Black Spruce Heath

White Spruce Maritime Upland Forest

Deciduous Forest Maritime Forested Wetland

Shrub Tundra Maritime Fen

Grass Tundra Maritime Alder Shrubland

Wetland Tundra

2015 Nulato fire.
Photo courtesy of Martha Turner

2015 Nulato fire.
Photo courtesy of Martha Turner

ENVIRONMENTAL CHANGE IMPACTS: FOOD SECURITY

Food Security Summary Points:

- Moose do not move around as much in warm weather, and are more difficult to find during hunting season
- Salmon are becoming smaller in size and the runs less abundant
- High water complicates salmon fishing, especially when combined with high winds
- Temperature and precipitation are projected to increase, contributing to high water

Seasonal harvest of fish, plants, animals and birds is a vital part of the regions cultures as well as fundamental to food security and economics. Communities are not connected to the road system, and depend on air and boat travel for mail, food, fuel, and other supply deliveries.

Warm trending summers are good for gardens in the region. Some residents in each of the communities maintain home gardens and share produce when the garden harvest is abundant. However, the complexities of a warming climate can be seen on the landscape, affecting food in other ways. Residents have noticed that berries are sensitive to changes in temperature and precipitation. If the weather is too hot, the blueberries will dry out. If the winters are too cold, the blueberry plants will not produce, or will produce small berries. Abundance of a variety of berries might also be related to recent fire activity, although residents are unsure whether it is safe to eat the berries after fire retardants have been dropped on an area.

Observations shared during project meetings of birds and insects may provide clues to important but subtle changes. Residents notice spiders emerging in the spring when there is still snow on the ground, perhaps because the air temperatures are warming. Black hornets and yellow jackets are becoming more abundant in some areas, and are a nuisance to people cleaning fish or processing meat. Koyukuk is not usually

Cloudberries in Nulato.
Photo courtesy of Martha Turner

"This past year going out hunting and fishing with my husband and father I have noticed an increase in bear activity. There have been a number of bear sightings here in Koyukuk. A Grizzly bear was killed in town and also a couple of black bears. We see tracks all over the beaches on the Koyukuk River. Maybe they are looking for food. The Grizzly that was killed here was going to a smoke house here in town every night for a week at the same time 11:30 pm. There is also an increase in wolves. My 8 year old daughter and I ran into a wolf while out chicken hunting (we were walking) behind Koyukuk! It wasn't scary until I got home

a migratory destination for robins, but the birds have started arriving in the spring. Galena residents reported seeing new species of birds around the community, and wonder what impact the new arrivals have on resident birds.

Moose

Moose make a significant contribution to food security in the Yukon-Koyukuk and Yukon-Tanana region, where 92% of households consume moose (Brown et al 2004), but are a relatively new addition to the dinner table. Before the first moose was seen in the region during the 1940s, residents hunted caribou that crossed above Ruby. However, as conditions change, residents have noticed change with populations declining in some areas (McNeeley 2012) and increasing in others.

Changes in seasonal temperatures may be reducing chances of encountering moose during harvest times. In some areas, residents shared that warmer August temperatures have resulted in moose not moving in to lower elevations at the same time of year, making it more difficult to harvest one during the subsistence-hunting period before the general permit hunt opens or before the hunting season closes altogether.

Are temperature, leaf drop and water level affecting moose harvest success in Nulato?

Arnold Demoski and Tessa Hasbrouck

Is climate change affecting moose harvest success? Tessa Hasbrouck, with Arnold Demoski and the Nulato Tribal Council, are exploring this question by examining two environmental factors, leaf fall and water levels, that affect moose harvest success. This information is important for the Nulato Tribal Council in developing Board of Game proposals that advocate for considering climate impacts in harvest regulations.

Arnold Demoski discussing the importance of moose hunting in Nulato.

Supporting or example of these positive changes:	Responding to these challenges:
• Cooperation and collaboration foundational to an Indigenous governance framework. • Increasing capacity in tribal management, advocacy, and better science.	• By researching effects of an unpredictable environment from climate change. • By researching effects of regulations and hunter conflicts.

Figure 15: Community-Identified Research Project Exploring Impacts of Climate Change on Moose. *(Heeringa et al 2018)*

and realized if I didn't have my daughter with me I probably would have went running after it. I wasn't too sure what it was at first and my cousin told me it sounded like it could have been a wolf. Sure enough the place where we saw the wolf there are fresh wolf tracks and we hear them howling behind town almost every night. This year was the first time I had seen a live bear in years. So yes I think we are seeing an increase in bear population. I am 33 years old and have never seen a live wolf before and this year I have seen three live wolves!!"

LEO Network Observation by April Williams and Hazel Lolnitz in Koyukuk, 2012

People are also reluctant to travel long distances to hunt when the weather is warm, not only because the chances of a successful hunt decrease, but the meat might spoil in the heat as they travel home. Traditional practices of hanging meat may be impaired by high seasonal temperatures. If hunters wait for the temperatures to cool, they run the risk of getting a moose that is in rut, which changes the quality of the meat. They also risk hunting out of regulatory compliance. Each hunting trip can cost as much as $1,000 per boat for food, fuel, and supplies, so hunters must weigh their chances of success against high cost or risk not having meat over the winter (McNeeley 2012). Harvesting a moose later in the season also overlaps with the time that residents are usually harvesting and preserving silver salmon.

Residents also identified predation and illness as two other factors that might affect moose populations. Residents notice that the bear and wolf populations are growing. In Evansville, bears will walk in to the community without fear. Other residents reported that wolves will chase people on snowmachines when they travel on the river. In other cases, harvested moose showed some signs of illness. Residents do feel like any concerns they have about the health of an animal are adequately addressed by Fish and Game, although there is little understanding about the impacts of illness to moose populations as a whole.

Local and non-local moose harvest in the Koyukuk River

Tessa Hasbrouck

How does non-local hunting pressure affect hunting success of local residents? Tessa Hasbrouck, with guidance from the Koyukuk Tribal Council is documenting when and where moose hunting season overlaps occur between local and non-local hunters in the Middle Yukon area, particularly the Koyukuk River. Moose is an important food resource to rural interior communities and competition from outside hunters is often implicated as placing a strain on a local community's capacity to harvest what they need.

Tessa Hasbrouck presenting on preliminary results of her research.

Supporting or example of these positive changes:	Responding to these challenges:
• Cultural value of sharing. • Importance of protecting a way of life. • Cooperation/collaboration from an Indigenous	• Constrained access because of competition from outside hunters. • Regulations affecting harvest.

Figure 16: Community-Identified Research Project Exploring the Regulatory Pressure on Moose hunts. *(Heeringa et al 2018)*

"My husband and I caught this fish on August 19, 2015. We thought it was funky looking, we took pictures of it and released it back into the Yukon. Someone said it could already have started spawning, I thought it was too early for spawning... Also a couple of days later my husband caught another salmon which was covered in spots completely all over its body from head to toe. We dried it but didn't eat it or take any pictures, we dried it for our dog."

LEO Network Observation by April Williams in Koyukuk, 2015

When communities have not gotten enough moose, residents have requested special hunts from regulatory authorities. These hunts have been contested in courts, and regulatory agencies do not always recognize community members' traditional and familiar hunting areas. Institutional responses from the Board of Game and Federal Subsistence Board, who dually regulate hunting and fishing in Alaska, have not allowed residents the flexibility needed to adapt in years where annual variation affects moose behavior (McNeeley 2012).

Residents are noticing that moose are moving farther south, but the impacts of temperature, vegetation change and water level are not yet well understood. These questions are now a focus of a community-identified research project in Nulato. Members of the Nulato Tribal Council are advocating for this research to inform Board of Game proposals that account for the impacts of climate change in harvest regulations (Heeringa et al 2018). The Koyukuk Tribal Council is also supporting another community-identified research project exploring the hunting pressure on moose when local and non-local hunting seasons overlap in the Middle Yukon (Heeringa et al 2018).

Hunting in the fall.
Photo courtesy of Laurie Lolnitz

Fish

Since time immemorial, Native People across Alaska have depended on salmon. In recent years, this important traditional food has not been adequately available resulting in harvest closures and disaster declarations. Chinook salmon (Oncorhynchus tshawytscha), usually a staple food, has been declining for years. Residents have instead turned to abundant Coho (Oncorhynchus kisutch) and chum salmon (Oncorhynchus keta) as substitutes. However, in 2019, water temperatures across much of western Alaska were too high for migrating salmon to survive as they migrated up the Yukon and Koyukuk Rivers. In one survey, researchers counted 1,364 chum salmon that were dead along 275km of riverbed (Westley 2020). Although the true number of salmon that died is unknown, the impact that these deaths will have on salmon returns is undeniable, and prompted a disaster declaration request from Alaska Governor Dunleavy to US Secretary of Commerce

Processing the Harvest.
Photo courtesy of Charlotte Mayo

Gina Raimondo. At the time of this report, in September 2021, the Lower Yukon chum fishery has all but collapsed (Hughes 2021), leaving smokehouses empty and commercial fishers' pockets bare.

While the range of reasons behind the astoundingly low salmon returns are still being investigated, Yukon Koyukuk and Yukon Tanana regional residents have long grappled with slow moving ecological changes that have affected fishing. Over the years, residents have noticed that salmon are becoming smaller in size, and their flesh is becoming unusually pale. Local fish habitats are changing as well. River water levels are higher than they have in the past, largely due to more runoff from the mountains, but also from increasing precipitation. Spring snowmelt always contributes to the highest river flow of the year, but as more snow accumulates at higher elevations, even spring runoff is higher than normal. The river is especially high and swift as the snowfall comes off the mountains during spring.

Residents have used driftnet seines to catch salmon since the 1980s and 1990s, but persistently high water and strong winds can complicate fishing. High water keeps people from seining in their usual spots. In some cases, protected areas are eroded away by wave and wind energy. When people cannot go to their usual spots because of high water, other areas within regulatory boundaries become crowded. Residents also note that winds have become stronger over the past few years. In some instances, residents have not been able to fish during regulatory openers because the water is too rough.

Warm summer weather will increase the river water temperatures. When this happens, the fish swim closer to the bottom of the river where the water is cooler. When the water is high and warm, the regulation fishing nets (6" mesh and 150 feet) do not reach deep enough to catch Chinook salmon. Residents are leery of proposing regulation changes that would allow them to fish deeper waters, because the risk of snagging a net on the bottom of the river is too high. Eroding banks have caused many trees to fall in to the river, presenting a risk to the fisher if the net snags.

Variations in summer weather have reduced the ability of residents to reliably preserve fish. When summer temperatures are warm, fish laid out on drying racks will dry quickly. However, when the summer is wet, residents will put a woodstove in the smokehouse to increase the heat and prevent fish from molding. Residents will also put rocks in the bottom of smokehouses because the ground is too wet. Changes in the abundance of salmon and access to fishing areas has changed the amount of time that resident need to get enough salmon for the year. Depending on increasing variability of water levels and weather, fishing activities that used to take a couple of days now takes a couple weeks.

Changes to precipitation and temperature will likely increase river water flow and contribute to high river water levels that affect fishing. As referenced in the section describing flooding and erosion, annual precipitation is projected to increase by some percentage under each climate scenario. Projected increases in precipitation are concentrated in the northern, mountainous part of the region near Evansville, Alatna and Allakaket. In the winter, this precipitation will still likely fall as snow rather than rain. Under both high and low climate scenarios, the amount of snow that will fall across the central and northern part of the region, near Allakaket, Alatna and Evansville, is projected to increase by 0-20%. When large amounts of snow melt in the headwaters, river water levels will increase in the spring and can stay high depending on the amount of precipitation that falls over the summer and fall.

Drying salmon on the Yukon.
Photo courtesy of Dr. John Cloud

ENVIRONMENTAL CHANGE IMPACTS: COMMUNITY HEALTH

Variations in summer weather have the potential to produce different outcomes for regional community health. Residents identified road dust and excessive heat as two negative impacts to community health during the summer, but also saw potential for increased rain to become a possible source of clean water.

Road Dust

Many communities across Alaska do not have paved roads, and are experiencing increasingly dusty roads in summers without precipitation. Road dust irritates residents' respiratory systems and increases the frequency of allergy-like symptoms that may keep people from engaging in normal summer activities. The region often experiences extreme windstorms, which in addition to regular vehicle traffic, will kick dust up in to the air.

Excessive Heat

Warming summer temperatures are becoming too hot for residents to feel comfortable. Many residents live in prefabricated homes provided by the US Department of Housing and Urban Development (HUD). Residents notice that the HUD homes have a tendency to trap more heat than homes built with a traditional log design. Portable air conditioners are available for check out in Hughes during periods of high heat, although some residents dislike the change in air quality and humidity.

Drinking Water

Some communities in the region are plumbed with access to a community well, while others continue to haul water. A potential increase in rainfall may open up the possibility of utilizing rainwater catchment as a secondary water source with appropriate treatment and filtration or for applications such as watering gardens and pets. Alternatively, it may be used as a water source for community gardens in communities where residents must pay for water.

Catching rainwater at a house in Koyukuk.
Photo Credit: Department of Commerce, Community and Economic Development; Division of Community and Regional Affairs' Community Photo Library.

"So So Hot, in the direct sun thermometers, are reading between 111 - 113 degrees Fahrenheit!! It has been hot like this for a while. Too hot to work outside, houses are too hot to use propane stoves, can't work on gardens or in the yard."

LEO Network post by April Williams in Koyukuk, 2013

Four wheeler road dust in Nulato.
Photo courtesy of Martha Turner

ADAPTING TO CHANGE

Variations in summer weather have the potential to produce different outcomes for regional community health. Residents identified road dust and excessive heat as two negative impacts to community health during the summer, but also saw potential for increased rain to become a possible source of clean water.

The adaptation planning process in the Yukon-Koyukuk and Yukon-Tanana regions has gone through two stages. Residents first met virtually in March of 2021 to share observation of environmental change and discuss the impact those changes have had on community travel, infrastructure, food security and community health. Residents met again, this time in-person, in Fairbanks during August 2021, to identify priority adaptation areas and develop adaptation goals and project ideas.

Discussions about the types of environmental changes occurring in the area resulted in 29 statements of change, categorized by topic and impact. Topic areas included changes to weather and temperature, river characteristics, landscape characteristics and wildlife. Impact categories included food security, community health, air quality, travel and safety, activities and relationships, and infrastructure.

During the in-person workshop in August, a group a residents, topic experts and facilitators discussed how the projected changes may affect current observations of environmental change. Following these discussions, residents reviewed and revised the statements of change, topic areas, and impacts, then prioritized each statement of change as "high," "medium," or "low" priority for adaptation.

IMPACT PRIORITIZATION	
HIGH	A critical activity that should be the focus of energy and resources
MEDIUM	Makes a substantial contribution to adaptation goals; lower priority for resources
LOW	Makes a contribution to adaptation goals, and should be developed as resources or opportunities become available

"Due to the flood (2018), it created so much mud and there's a lot of road dust now. Last summer me and my assistant picked up that type of oil that goes on airport runways for dust and we drove around town spilling it out on the roads to try to reduce road dust."

— Crystal Bergman, Allakaket Environmental Program

From the 29 statements, residents identified 12 as priority areas for adaptation:

PRIORITY AREAS FOR ADAPTATION	
WINTER TRAVEL CHALLENGES	Warm spring weather melts river ice earlier in the season, allowing river travel earlier in the year.
	Fluctuating winter temperatures are making winter travel times, and routes, unpredictable. Leads in the river ice will appear at unusual times during the year, and prevent people from traveling between communities. When the river does not freeze until January, the ice is not good quality, increasing the risk of accidents.
	When travel is not possible due to poor ice conditions, it is depressing to go so long without seeing friends and family.
FOOD SECURITY CHALLENGES	Moose populations and availability. They do not move around in warm temperatures, causing hunters to travel farther to find them. More moose are showing signs of illness.
	High water keeps people from seining in their usual spots. When the water is high and warm, the regulation fishing nets (6" mesh and 150 feet) do not reach deep enough to catch king salmon. Overall fish are smaller and less abundant. More fish have pale flesh.
	Predatory animals are changing in abundance and may not be getting enough to eat. They are seen in or near communities more often than usual.
	Warm summers increase the amount of vegetables in community gardens.
COMMUNITY HEALTH CHALLENGES	During warm summers, it is difficult to keep cool, even with the windows and doors open.
	Lots of rain provides opportunities for use of rainwater.
INFRASTRUCTURE CHALLENGES	Permafrost is thawing in Allakaket, Koyukuk and Galena. In Galena, causing buildings and other infrastructure to sink and water to pool around the pilings.
	Campsites are being lost to permafrost thaw and erosion.
	Warm spring temperatures causes the snow to melt quickly, sometimes more quickly than the river ice can melt, increasing the risk of ice jam flooding.

"I've been gardening most of my life – about 20 years – and have seen a lot of change. Last year there was a lack of soil so I had to haul it from the riverbank to make richer soil and I got a lot more root vegetables. It did real good and I shared my crop with others. There wasn't much rain so I had to haul water from the river."

— Marilyn Roberts, Koyukukm

ADAPTATION PRIORITY AREAS AND PROJECT IDEAS

IMPACTS TO WINTER TRAVEL

Impact Summary: Warm spring weather melts river ice earlier in the season. Earlier river breakup allows people to travel between communities earlier, but spring ice is variable and dangerous. Earlier access may also not be in line with the activity for the season.

Fluctuating winter temperatures are making winter travel times, and routes, unpredictable. On the river, leads in the river ice will appear at unusual times during the year, and prevent people from traveling between communities. When the river does not freeze until January, the ice is not good quality, increasing the risk of accidents. Further complicating travel, winter rain will keep planes from landing, and wind-blown snowdrifts make travel by snowmachine difficult. When travel is not possible due to poor winter conditions, it is depressing to go so long without seeing friends and family. Communities may also run short on groceries during extended periods of poor weather.

Nulato winter travel.
Photo courtesy of Martha Turner

Climate Projection Information: Temperatures are projected to increase in all seasons. Under current levels of global emissions (RCP 8.5), climate models project that winter temperatures from December to February are projected to increase by 7.7° F for the period 2040 -2069 and 10.6° F for the period 2070 – 2099. Similarly, spring temperatures in the Yukon-Koyukuk region are projected to increase 4.8° F for the period 2040 – 2069 (19-48 years from now), and 9.1° F for the period 2070 -2099 (49-78 years from now).

The amount of precipitation that falls between December and February is also projected to increase by 20% for the period 2040-2069 and by 39% for the period 2070 – 2099.

Snowfall during the months of October through March is projected to increase. Under current emissions levels, snowfall is expected to increase by 9% for the period 2040 -2069 and by 3% for the period 2070 – 2099.

Potential Adaptation Strategies:

- **Coordinate between communities to monitor weather conditions**
  - Local guides can hunt with each other
  - River Rats Facebook page lets people know the locations of snags and holes
  - Provide daily updates of river and ice conditions over the radio with a scheduled time for people to tune in
- **Create safety plans and provide safety equipment**
  - Koyukuk tribe bought CB radios for homes, and provide handheld radios and InReach devices for check out
  - Encourage people to share a travel plan and take extra supplies
  - Support Search and Rescue coordination between communities
- **Support weather related communication**
  - Share information on how to find and interpret information about weather and ice conditions from the National Weather Service before travel
  - Hire someone in the community as a local weather observer. This person will correspond with weather forecasters to get more specific information for individual communities, and can share info from forecasters with search and rescue
  - Local bulletin board with travel updates and alerts
- **Improve safety infrastructure**
  - Place trail markers between communities
  - Build shelter cabins and create a map of shelter areas
  - Alatna is working on improving cell service
  - Build a bridge between Alatna and Allakaket for emergencies
  - Make sure air transportation is available in all communities
- **Create community emergency food supplies**
- **Schedule spring carnivals and other community events based on weather and travel conditions**

IMPACTS TO INFRASTRUCTURE

Impact summary: Permafrost is thawing across the region, causing buildings and other infrastructure to sink and water to pool around the pilings. Along the rivers, homes and campsites are being lost to permafrost thaw and erosion.

Warm spring temperatures causes the snow to melt quickly, sometimes more quickly than the river ice can melt, increasing the risk of ice jam flooding.

Climate Projection Information: As temperatures increase in the region, ground temperatures will also increase. Between 2044 and 2099, ground temperatures are projected to increase between 1 -12° F around much of the area near communities, increasing the likelihood of permafrost thaw. Temperatures are projected to increase during all seasons.

Affecting the timing of spring breakup, under current levels of global emissions (RCP 8.5), climate models project that spring temperatures in the Yukon-Koyukuk region may increase 4.8° F for the period 2040 – 2069, and 9.1° F for the period 2070 -2099.

2013 Galena flood.
Photo credit: Alaska Department of Transportation and Public Facilities

In spring, summer, and winter, projected increases in precipitation are concentrated in the northern, mountainous part of the region near Evansville, Alatna and Allakaket. In the winter, this precipitation is projected to still fall as mostly snow. In the northern, mountainous part of the region, the amount of water in the snowpack is projected to increase between 20% and 60% compared to historical. In the southern part of the region near Koyukuk, Nulato, and Galena, the snowpack is expected to hold 20% - 40% less water than it did historically. However, the length of the snow season will decrease on average in both parts of the region.

Surface runoff, or the amount of water that runs over the surface of the land and into streams, is projected to increase during April in the area around Alatna and Allakaket, as well as the area north of Hughes. This surface water runoff will contribute to increased river discharge, which contributes to river bank erosion.

Potential adaptation strategies:

- Creating community flood plans
  - Encourage households to pack important belongings in the spring and secure anything outside
  - Create evacuation and emergency response plans
    - Designate spaces for camping and parking vehicles
    - Identify who will help manage which parts of the emergency plan
  - Identifying high risk potential damages – such as housing insulation – and stocking supplies to make repairs during the season
  - Hold regular meetings during breakup season to make sure every household has the resources they need
  - Build rafts to move large items
  - Identify emergency best practices, such as filling water containers before breakup in case utilities are affected, storing emergency food supplies, and storing backup generators and fuel
  - Create emergency plans for utilities and clinics
    - Make sure a health aid is available during potential emergencies
  - Have a plan for disposing of damaged goods and designate a community group to help clean up
  - Issue a regional reminder to update community response plans
  - Extend planning process between communities to help evacuate and provide disaster assistance
- Coordinate communication about river conditions
  - Schedule weekly radio updates on river conditions, including River Watch updates, starting a month before breakup
- Pursue funding for community river monitoring projects
  - TCC Hunting and Fishing Task Force has a NASA grant to start a pilot citizen science program to identify what river monitoring or safety improvement projects Tribes would like to pursue
- Improve infrastructure to reduce damages from flooding and permafrost
  - Build and maintain dykes for protection from floods
  - Explore building practices that are more resilient to flood and thaw hazards and create building codes based on flood and permafrost thaw projections
  - Remove unstable trees that might fall on buildings
- Monitor permafrost thaw affecting infrastructure
  - Document permafrost change for FEMA funding that can support infrastructure repair
  - Create plans for building repair, relocation, or rebuilds based on permafrost projections

IMPACTS TO FOOD SECURITY

Impact Summary: Temperatures are warmer than usual during hunting season, and moose stay at higher elevations later in the season. Those who go out have to travel farther, spending more money in fuel. Some moose are showing signs of illness, but residents feel like there is good communication with Alaska Department of Fish and Game when there are concerns about food safety. In general, people feel like the animals are safe to eat, however ticks may become something to worry about in the future.

High water keeps people from seining for salmon in their usual spots. When the water is high and warm, the regulation fishing nets (6" mesh and 150 feet) do not reach deep enough to catch king salmon. Overall fish are smaller and less abundant. More fish have pale flesh. Predatory animals may be eating salmon at the mouth of the river.

Increasingly warm summers increase the amount of vegetables in community gardens.

Climate Projection Information: Summer and autumn temperatures are projected to increase. Under current emissions levels (RCP 8.5), temperatures from June to August are projected to rise 3.7° F for the period 2040 – 2069 and by 6.8° F for the period 2070 and 2099. Autumn temperatures from September to November are projected to increase 9.2° F for the period 2040 – 2069 and by 13.5° F for the period 2070 – 2099.

Annual precipitation is projected to increase by some percentage under each climate scenario. In spring, summer, and winter, projected increases in precipitation are concentrated in the northern, mountainous part of the region near Evansville, Alatna and Allakaket. In the winter, this precipitation is projected to still fall as mostly snow rather than as rain.

Moose cow and calf in Galena.
Photo courtesy of Brooke Sanderson

In the northern, mountainous part of the region, the amount of water in the snowpack is projected to increase between 20% and 60% compared to historical. In the southern part of the region near Koyukuk, Nulato, and Galena, the snowpack is expected to hold 20% - 40% less water than it did historically. However, the length of the snow season will decrease on average in both parts of the region. Contributing to high river water levels, spring temperatures are also projected to increase throughout the region, possibly increasing the rate at which the snow melts. Under current emission levels (RCP 8.5), spring temperatures are projected to rise 3.7° F for the period 2040 – 2069 and 6.8° F for the period 2070 -2099. Surface runoff, or the amount of water that runs over the surface of the land and into streams, is projected to increase during April in the area around Alatna and Allakaket, as well as the area north of Hughes.

Potential adaptation strategies:

- Increase local representation at state and federal regulatory meetings to advance community-supported regulation changes
    - Write resolutions for AFN and NCAI as a collective, including tribes and large organizations such as Doyon, to advocate for community interests
    - Provide training on public comment and resolution development
    - Provide community education on what the roles of each regulatory board are, and how Tribes can influence the process
- Partner with Intertribal Watershed Councils and other researchers to increase local contributions to research about changing salmon abundance and health
    - Some community research questions include:
        - Impact of ocean trawlers on salmon
        - Impact of river boats on salmon
- Improve communication between coastal and river communities to ensure that shutdowns are equitable between user groups across the state
- Ensure community food security
    - Designate local hunters to provide for elders and others
    - Designate someone in the community to check on everyone to see if they have food
    - Work with sport hunting guides to coordinate meat donation, ensuring no meat is wasted
        - Build a community shed for preparing and storing meat for the community
    - Create a communal fund to provide fuel and other supplies to those who need help
- Build community gardens to donate food
    - Coordinate with the UAF Cooperative Extension to share information across communities about gardening practices such as how to build soil, add nutrients back in to the soil, make use of peat moss and biochar as fertilizers, build raised beds, and utilize waste streams such as fish carcasses and moose blood
    - Create a venue for sharing gardening tips, seeds, and recipes such as the Alaska Tribal Conference on Environmental Management (ATCEM), social media, radio, zoom
    - Offer garden tools for check out by the Tribe

Impact Summary: Predatory animals are changing in abundance and may not be getting enough to eat. They are seen in or near communities more often than usual.

Potential adaptation strategies:

- Pursue funding to install street lights in communities
- Make whistles/noisemakers/fog horns easily available

IMPACTS TO COMMUNITY HEALTH AND SAFETY

Impact Summary: Rainwater provides an opportunity to increase quantity of water available to households, improve water security and reduce costs, especially in communities where drinking water has to be purchased.

Climate Projection Information: Annual precipitation is projected to increase under all climate scenarios, but the amount that it increases is likely to vary by season. Under current emission levels (RCP 8.5), spring precipitation from March to May is projected to increase by 24% from 2040 – 2069 and by 40% for the period 2070 – 2099. Summer precipitation from June to August is projected to increase by 29% for the period 2040 – 2069 and 39% for the period 2070 and 2099. Autumn and winter precipitation is also expected to increase, but will likely fall as snow rather than rain.

Potential adaptation strategies:

- Build rain catchment system with filtration and purification as emergency or extra water supply

Impact summary: During warm summers, it is difficult to keep cool, even with the windows and doors open.

Climate Projection Information: Summer and autumn temperatures are projected to increase. Under current emissions levels (RCP 8.5), temperatures from June to August are projected to rise 3.7° F for the period 2040 – 2069 and by 6.8° F for the period 2070 and 2099. Autumn temperatures from September to November are projected to increase 9.2° F for the period 2040 – 2069 and by 13.5° F for the period 2070 – 2099.

Potential adaptation strategies:

- Make homes easier to cool
  - Pursue grants to provide portable AC for homes and businesses
  - Make air conditioning units available for checkout from the Tribe
  - Install reflective sheeting, such as Panda Film, to keep buildings cool
- Create cooling centers in community buildings
- Designate someone to check in on people during periods of high heat
- Go back to a traditional log home design which are cooler than the prefabricated homes

Workshop caption.
Photo courtesy of ??

Solar panels.
Photo courtesy of Michael Brubaker

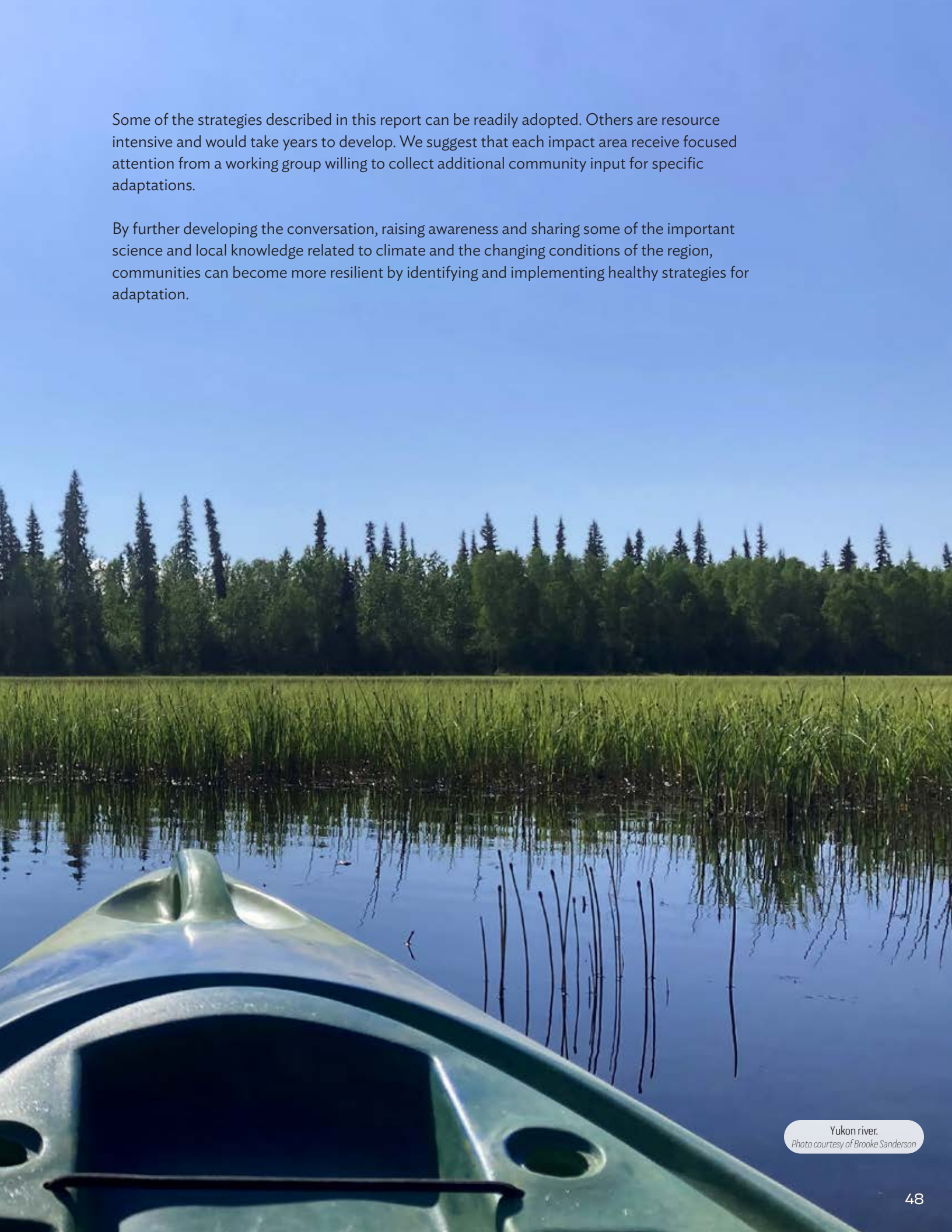
CONCLUSION

According to the United Nations, Climate Adaptation refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Climate adaptation is a continuous process of learning to live in harmony with the environment as it changes. One plan is unlikely to cover all the changes that a community or region may experience, but each is a building block in addressing the impacts of change to a community.

This plan is intended to be that first building block, by documenting some of the local knowledge and available climate science about communities in the Yukon Koyukuk and Yukon Tanana regions. Over the course of the planning process, we learned about impacts to travel, infrastructure, food and water security and community health that come as the result of changes to air temperature and precipitation as well as other climate-driven ecosystem changes.

Some of the strategies described in this report can be readily adopted. Others are resource intensive and would take years to develop. We suggest that each impact area receive focused attention from a working group willing to collect additional community input for specific adaptations.

By further developing the conversation, raising awareness and sharing some of the important science and local knowledge related to climate and the changing conditions of the region, communities can become more resilient by identifying and implementing healthy strategies for adaptation.



Yukon river.
Photo courtesy of Brooke Sanderson

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Riverboat on the Yukon.
Photo courtesy of Brooke Sanderson

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