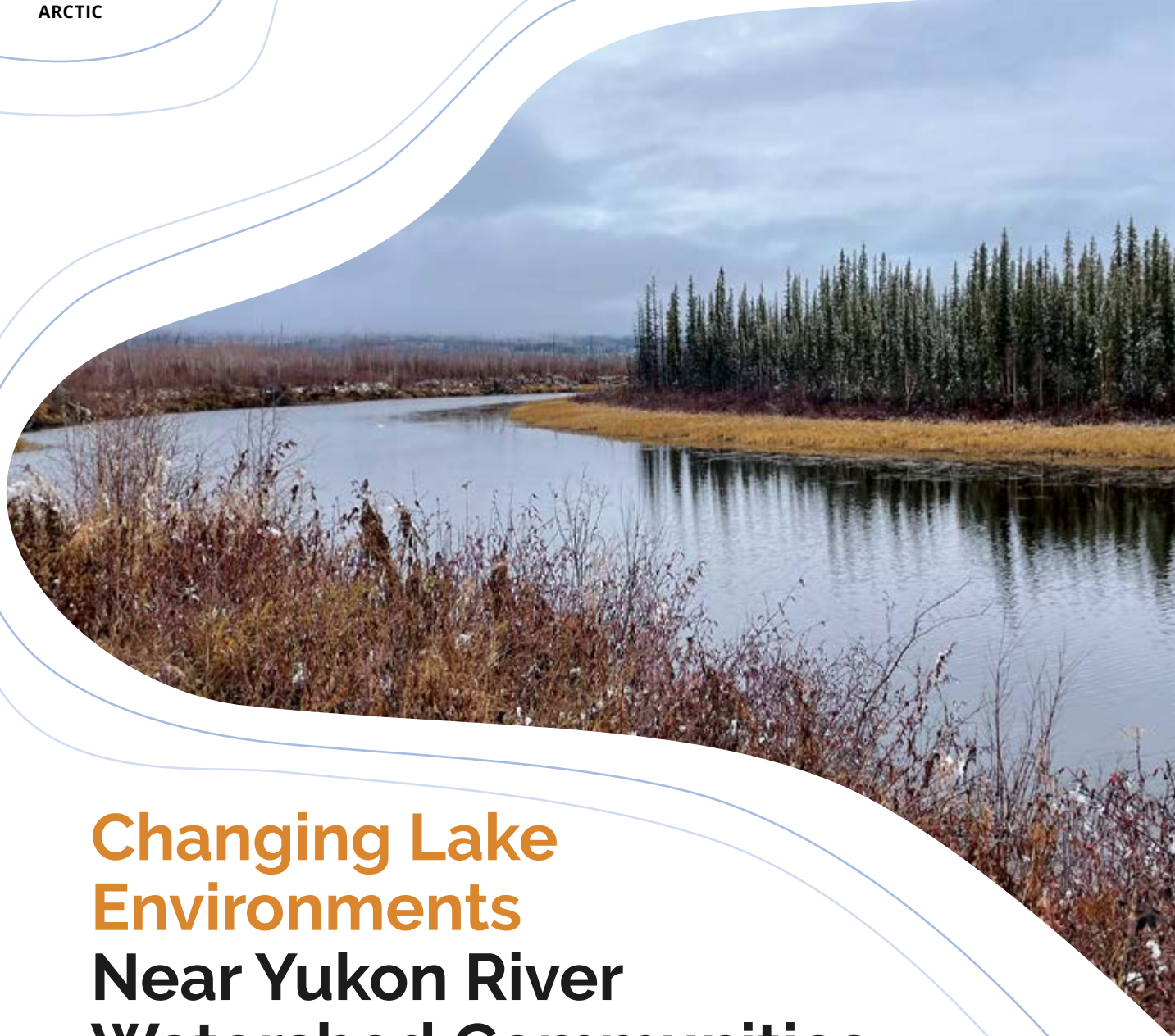




NAVIGATING
THE NEW
ARCTIC



Changing Lake Environments Near Yukon River Watershed Communities



University
of Colorado
Boulder





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Funding for this study was provided by the National Science Foundation, Navigating the New Arctic Award #2022561.

This study was performed with the support of the Council of Athabascan Tribal Governments (CATG). See signed resolution (Appendix 33).

Near Circle, Alaska - Tracie Curry



ABOUT

CHANGING LAKES AND WHAT WE CAN LEARN FROM THEM

The Arctic is currently warming nearly four times faster than the rest of the planet, based on the latest reports from the 2025/2026 Arctic Report Cards and the Copernicus Climate Change Service. This warming will result in significant permafrost thaw and changes to the landscape in Alaskan communities.

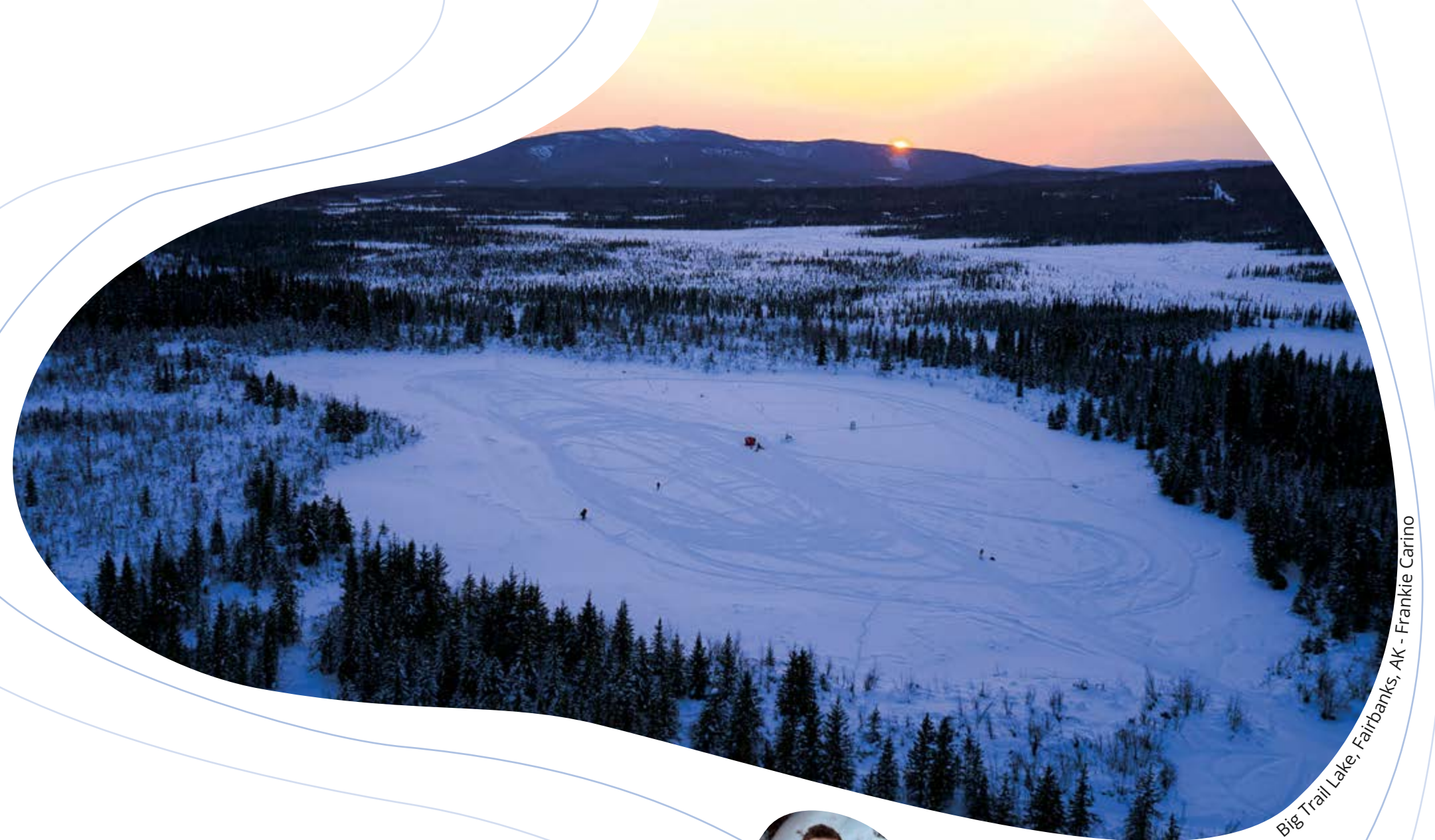
Due to this thaw, the amount of methane emitted from permafrost is soon expected to increase substantially. One source of methane is abrupt thaw lakes, which are also known as thermokarst lakes. However, there is scientific disagreement about how much methane the lakes release.

An abrupt thaw lake is a body of water formed when ice-rich permafrost thaws rapidly, causing the ground to collapse and form a basin that fills with water.

Abrupt thaw lakes emit methane because the overlying water prevents the ground below from refreezing in the winter. This can create a permanently thawed layer of soil beneath the lake, allowing microbes to remain metabolically active year-round as they “eat” newly thawed organic matter.

Microbial activity results in methane emissions within the soil, some of which can bubble up through the lake and escape into the atmosphere.

Methane mixes quickly into the atmosphere and then spreads across the globe. Because methane is a greenhouse gas, it traps more heat in the atmosphere, which leads to further warming—a positive feedback loop.



Big Trail Lake, Fairbanks, AK - Frankie Carino



Tyler Jones is an Assistant Research Professor at INSTAAR, University of Colorado. His research focuses on polar abrupt climate change, both past and present. His research occurs in Greenland and Alaska, studying ice sheets and permafrost.

“Our research team is studying methane emissions from abrupt thaw lakes in Alaska to better understand what might happen in the future and to develop techniques to improve our ability to measure methane escape.”



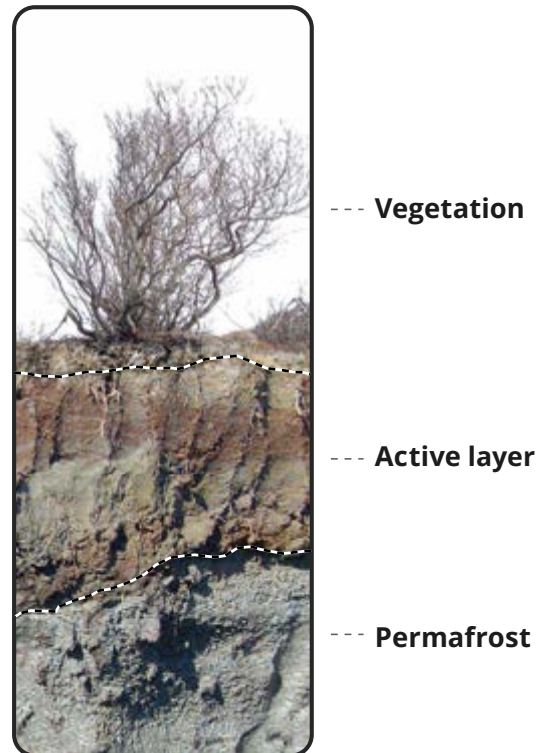
KEY TERMS

ACTIVE LAYER

Active Layer: The active layer is the soil above the permanently frozen ground that thaws in summer and refreezes in autumn. By measuring active-layer depth in late summer, during peak thaw, over multiple years, we gain insight into how a warming climate affects permafrost.

PERMAFROST

Permafrost is ground consisting of soil, organic matter, rock, and ice that remains frozen for at least two consecutive years. The active layer above permafrost freezes and thaws every year. As permafrost thaws, the active layer gets deeper, making it possible for more trees and shrubs to grow.



Permafrost Diagram – Tracie Curry



Photo by Allison Woodard (PolarTREC 2018),
Courtesy of ARCUS



Photo by Bruce Taterka (PolarTREC 2013),
Courtesy of ARCUS

METHANE

When people encounter certain lakes, especially those that are bubbling, they may be walking or boating through an area with elevated methane concentrations. Methane is invisible and poses no immediate harm to people, but it plays an important role in a larger story. Once methane is released into the atmosphere, it disperses globally and acts as a potent greenhouse gas that traps heat. While temperature is the trigger for permafrost thaw, the duration of thaw is what drives methane release. The longer the soil remains thawed, the more methanogens increase their population and the more methane they collectively produce.

METHANOGENS

Methanogens are microorganisms that are active in environments that lack oxygen, such as waterlogged wetlands, peatlands, and lake sediments. Methanogens are inactive while frozen, but as the ground warms above freezing, they become active and begin metabolizing the organic matter. Though invisible to the naked eye, methanogens collectively produce large quantities of methane through their metabolism.

THERMOKARST

Thermokarst is terrain formed when permafrost thaws. The landscape is characterized by thaw lakes and unlevel ground including marshy areas, hummocks, and depressions such as sinkholes.



Photo by Katie Gavenus (PolarTREC 2019)
courtesy of ARCUS



Photo by Robin Ellewood
(PolarTREC 2008),
Courtesy of ARCUS

Kid's Activity!

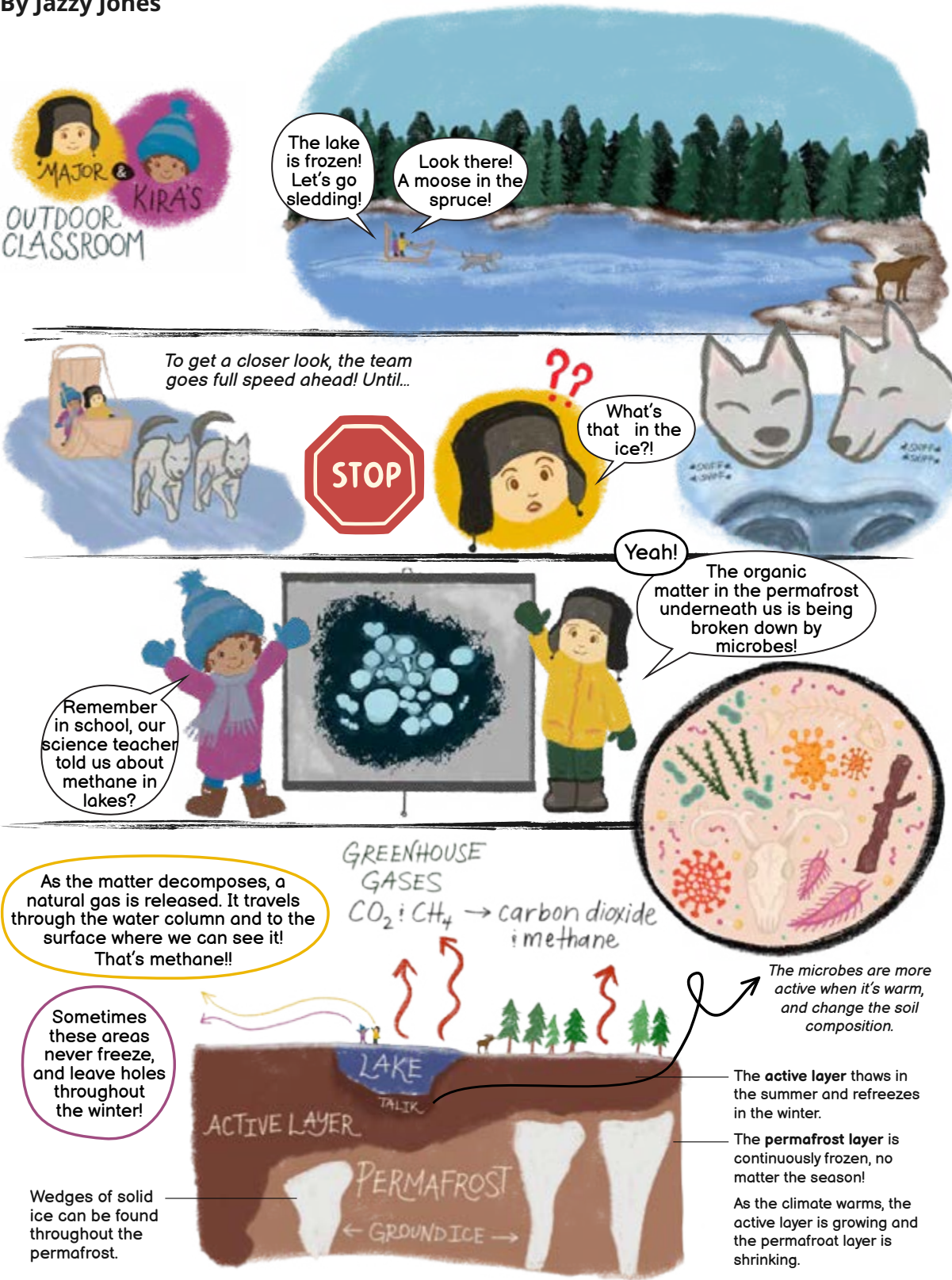
Learn more about these amazing microbes in *Major and Kira's Outdoor Classroom* (pg. 8)



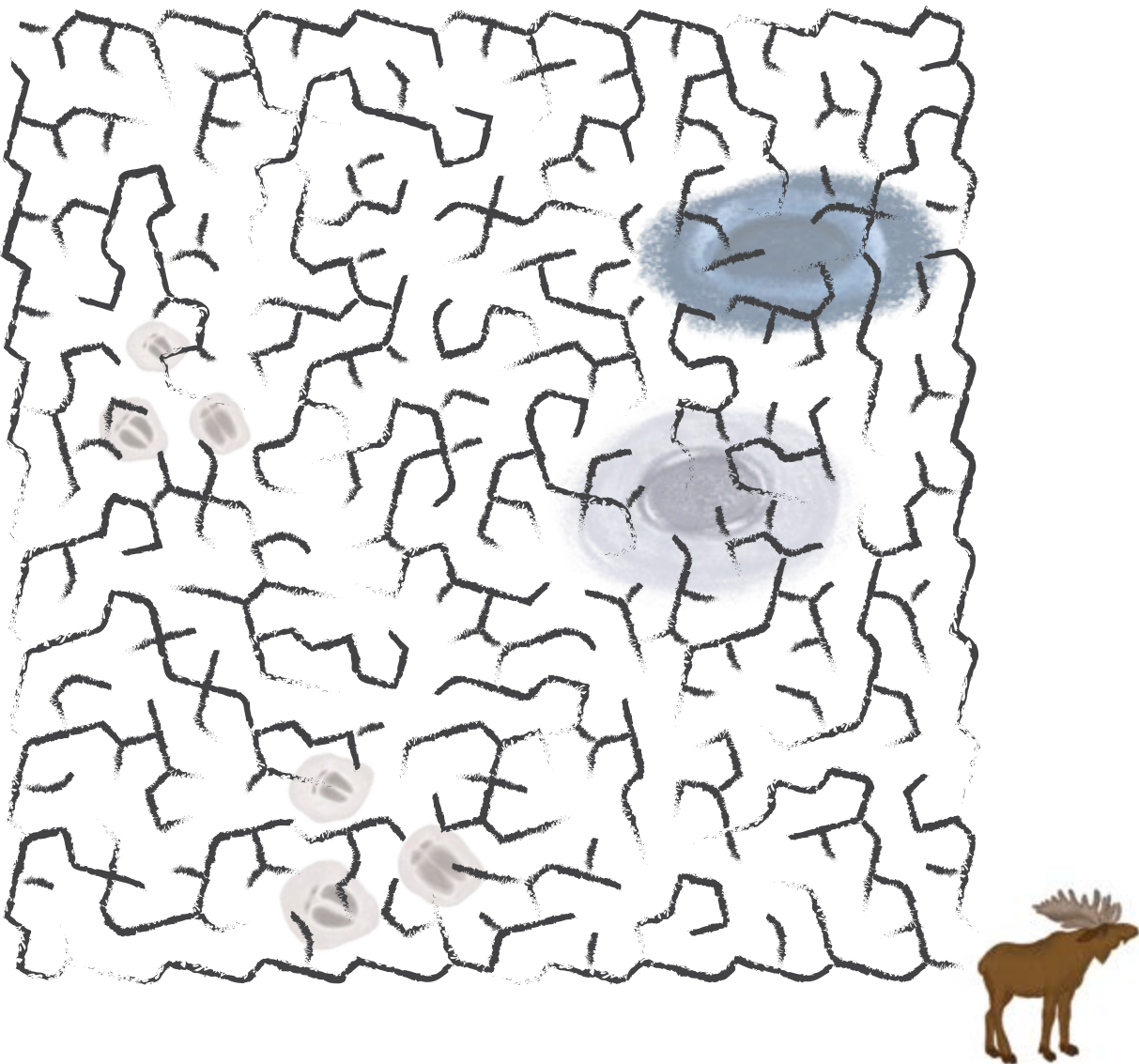
BUBBLES UP FROM DOWN BELOW

METHANE IN A CHANGING LAKE ENVIRONMENT

By Jazzy Jones



They proceed with caution, sticking to the solid ice that is safe to travel on. Can you help Major and Kira find their way to the moose and avoid any methane holes?





GUIDED BY LOCAL KNOWLEDGE

CIRCLE, ALASKA

These are times of change, and the residents of the Yukon River Watershed are daily witnesses to this fact. It can be seen in the changing waterbodies, shorelines, vegetation, animals, and communities themselves. Local observations of landscape change were an important starting place for this study. We asked local knowledge holders what they were seeing and where, so that we would know where to look for evidence of methane seeps and other signs of permafrost thaw. In addition to helping focus our research, these interviews also provided valuable information to help our team better understand the communities they would be working in, including how residents are impacted by

the changing environment and their concerns. In this section, we are sharing back the information that was shared with us.

We interviewed five Circle Knowledge-holders in four interviews (two participants preferred to be interviewed together). The interviews took place September to October, 2022. To protect participants' privacy, we identify them only by a unique number (7-10). Multiple participants are cited when there was broad agreement on a topic. When multiple numbers are noted, for example (7,9), means that participants 7, and 9 independently made statements that were in agreement on the same topic.



Tracie Curry is a social scientist with Northern Social-Environmental Research in Fairbanks, Alaska. She documents local stories and observations to better understand how people experience and shape the environments they call home.

THANK YOU!

Dennis Carroll
Larry Nathaniel
Sam Nathaniel
Amanda Pope
Jormah Pope



FIVE PARTICIPANTS REPORTED SEEING HOLES IN THE ICE OR BUBBLING WATER CONSISTENT WITH METHANE SEEPS

These observations were made at ten different locations near Circle. Four out of the ten locations were known to multiple people (mentioned by at least three participants). Two participants (jointly interviewed) noted the danger that these features present for winter travel given they are often hidden by a layer of snow and difficult to see.

"It seems like there's spots in the lake that don't freeze and somebody told me that's from the methane that kind of builds up under there. And even though you got snow over it, you can't see it until you go through it. I know I fell through a few lakes because, you know, you're walking on the lake and it's, you know, it feels pretty solid. Well then all of a sudden you hit this rotten spot and either your snow machine goes through or you go through (7)."

Holes in ice can be hard to see but sometimes there are clues:

"You just never know where those spots are until you hit 'em. And sometimes you'll see some red in the snow where the water is, because it's kind of irony, I guess. And it seeps up into the snow and you kind of see it and you avoid it (7)."

ENVIRONMENTAL CHALLENGES

- Contaminants in the environment related to permafrost thaw
- Dropping water levels in lakes
- Forest fire management- too much acreage allowed to burn
- Outside hunters poaching



TRAVEL IS BECOMING MORE DIFFICULT AS THE ENVIRONMENT AND LOCAL PRACTICES CHANGE

Three participants highlighted **increasing brushiness** as a major barrier to getting around on the land in all seasons.

"I've talked to some of the elders who trapped out there before. They would tell me how it used to be very open, you know, just the black spruce flats and stuff where it was pretty open. You didn't really have to cut as much trail, like we do today. All the black spruces kind of filled in with willow and alders and all kinds of brush and it's really thick. (7)."

In addition to increasing vegetation, trail surfaces have become rougher for travel. One participant observed a prime wood cutting trail become nearly unusable over a span of 20 years, possibly as a result of permafrost thaw.

"There's a road that runs up that hill and we used to drive equipment up there for wood cutting. But now I walked up there not long ago and it was real bumpy and up and down. There's gouges in the road and I think the ice melted or something and it sank down (9)."

Another participant suggested that disuse is a major factor for why the trails are getting bad. Instead of

accessing remote trails from the river as was previously common, people are now using the highway to access spots for wood cutting and hunting.

"... we hardly use them anymore. We have other means of getting wood. We mostly go out the highway now and harvest. We used to go up and down along the river and harvest, that's when we keep these trails open. Since we don't do that along the river, the trails are hardly ever being used, so they're just going back to nature (10)."

Warming temperatures and increasingly delayed freeze-up is another major factor impacting transportation. Periods of 'deep cold' are important for safe winter travel over ice.

"It seems to fluctuate pretty wildly, which can, you know, be difficult. Cause you're sitting around waiting sometimes just for cold weather... we need that cold weather, because it's scary when you haven't gotten that and you know, you're out there trying to travel. Falling through the ice isn't fun. Sinking your snow machine isn't fun. It's frustrating when we don't get that deep cold that we need. It definitely affects our travel (7)."



ENVIRONMENTAL SHIFTS HAVE CONSEQUENCES FOR SUBSISTENCE

The landscape is becoming increasingly wet in some areas and dryer in others. Increasing wetness has made it hard to reach traditional hunting areas at key times in the season.

"We used to hunt ducks and geese here all the time, but now, it's pretty hard to get into there. Before we'd go around probably the 27th of April to about the first part of May, we go and hunt. But now when we get to the lake, there's just water (8)."

At the same time, lakes across the region are drying up which reduces the available habitat for key subsistence species.

"We used to go out there fishing in the winter but mostly in the springtime for pike. And that's the only fish that's in there now is pike fishing. And we used that lake to go black

duck hunting in the springtime. We don't do that anymore since the lake is low and very few black ducks go in there anymore. You know, they bypass this part of the world. There's some, but not in any great numbers anymore (10)."

Additionally, as people's traditional hunting and fishing spots become less desirable, it is increasingly difficult to find alternative places to go because of growing competition from outsiders.

"We'll never get rid of all the hunters. It's harder to hunt with a lot of people around. There's, even now, there's three times where we went in and there's people there. We have to kick them the heck outta here because it's private. This is our hunting area (8)."

Hills alongside the Steese Highway
Tracie Curry

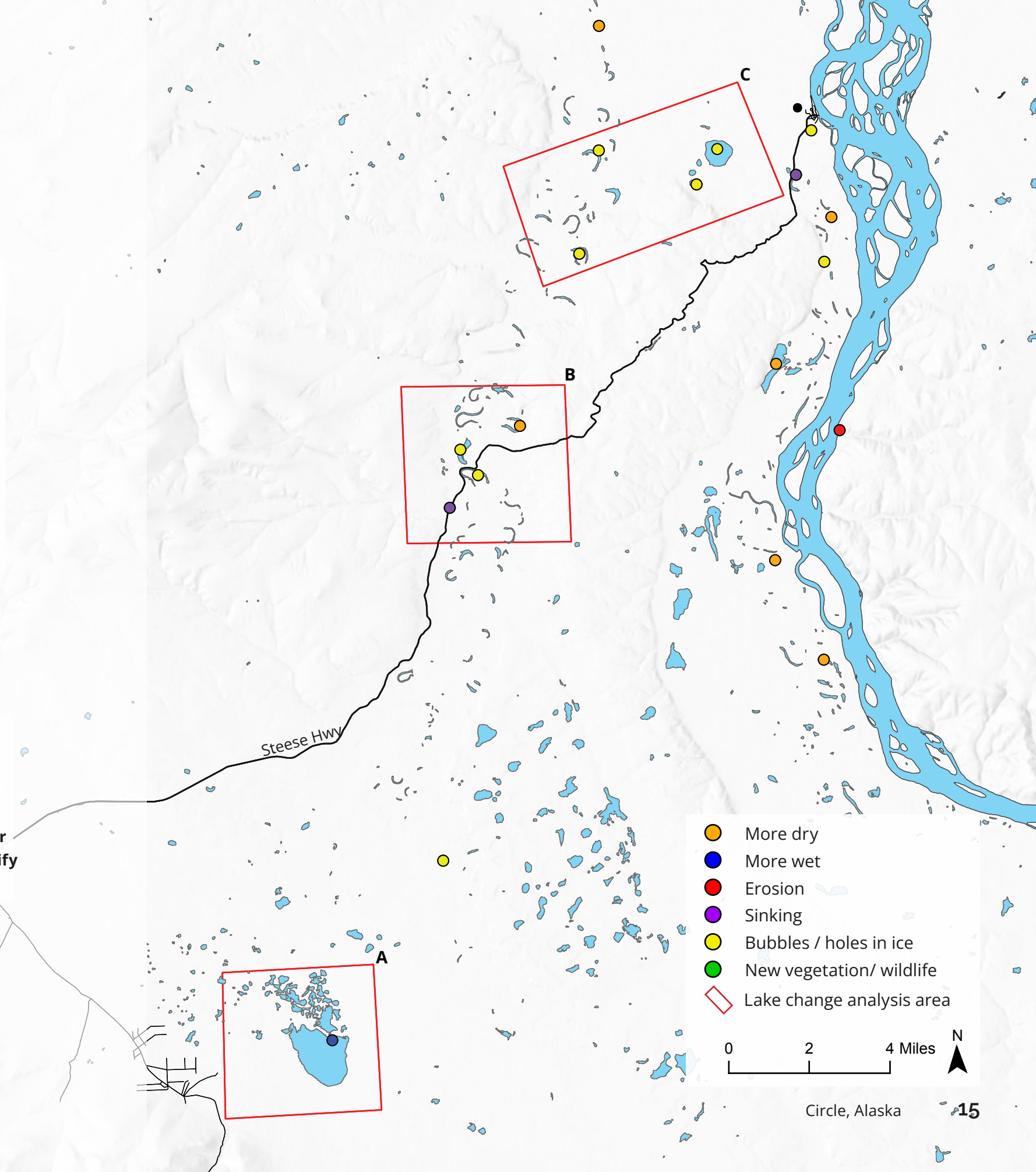
CIRCLE

MAPPING CHANGE

We conducted interviews with 5 Circle residents, all of whom were recommended to us for their in-depth knowledge of the local environment. Interview questions asked participants about the environmental changes they have observed over the years and how their ways of life are being impacted. Additionally, we provided printed maps and asked participants to identify the locations where changes are happening. Participants discussed observations in four main categories; 1) places that are getting more wet or more dry, 2) erosion, 3) bubbling water or holes in ice (these are indications of methane), 4) new vegetation or wildlife, and 5) sinking. The locations of observed changes across all categories in Circle are shown in Figure 1.

Figure 1: Observed Changes - Circle, 2022

Seeing everyone's observations in one shared map can help the community plan and spark discussion. Residents can see whether others are noticing the same changes, compare familiar places with reports from other areas, and identify new locations to add through conversation.

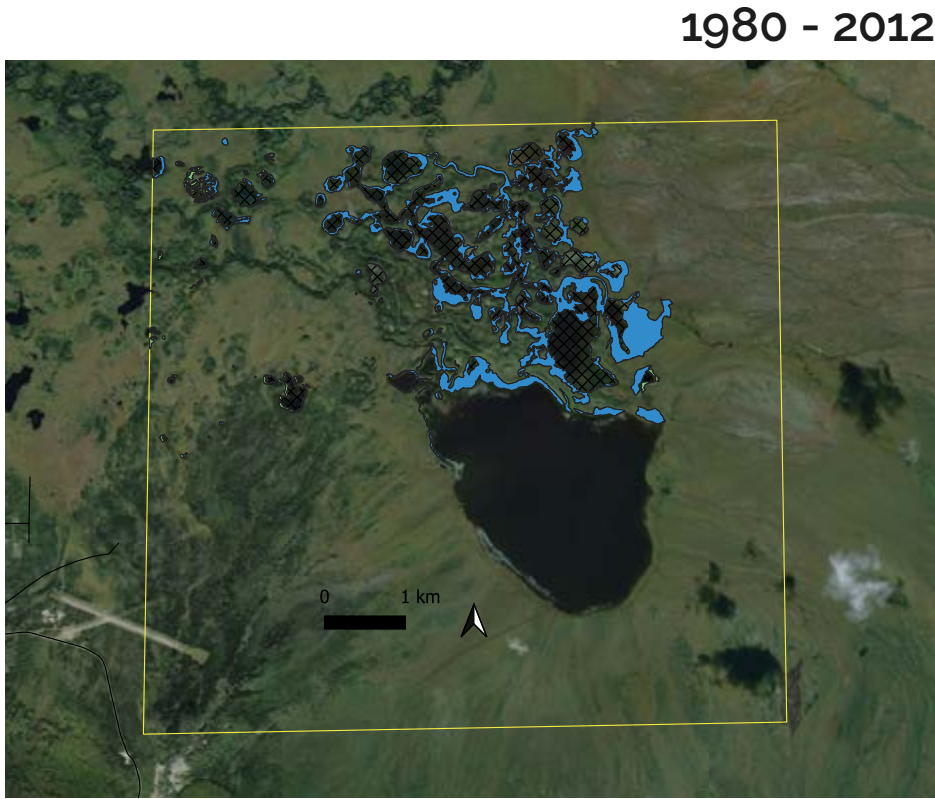


LAKE CHANGE ANALYSIS - CIRCLE, AK

AREA A: MEDICINE LAKE AREA

The following analysis focuses on key areas from the larger map, selected because of their importance to subsistence and recreation, and due to the significant changes observed in these locations. Zooming in on these areas allows for a closer examination of reported lake changes in relation to places of ongoing local use and significance.

We chose two time slices for the analysis based on the availability of historic imagery; 1980-2012 and 2012-2022.



Note: Southern edge of Medicine Lake has unrectified terrain issues in 1980 that do not overlap correctly with 2012 lake margin. Therefore, this area has been excluded in the lake change map

Circle, Medicine Lake - Area Change (1980 - 2009/12) EXCLUDES MEDICINE LAKE

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss Water to Land/Veg	70,604	4.20%	4.20% of WATER in 1980 is LAND/VEG in 2009
	New Lake Area Land/Veg to Water	1,598,340	53.83%	53.83% of WATER in 2009/12 is new

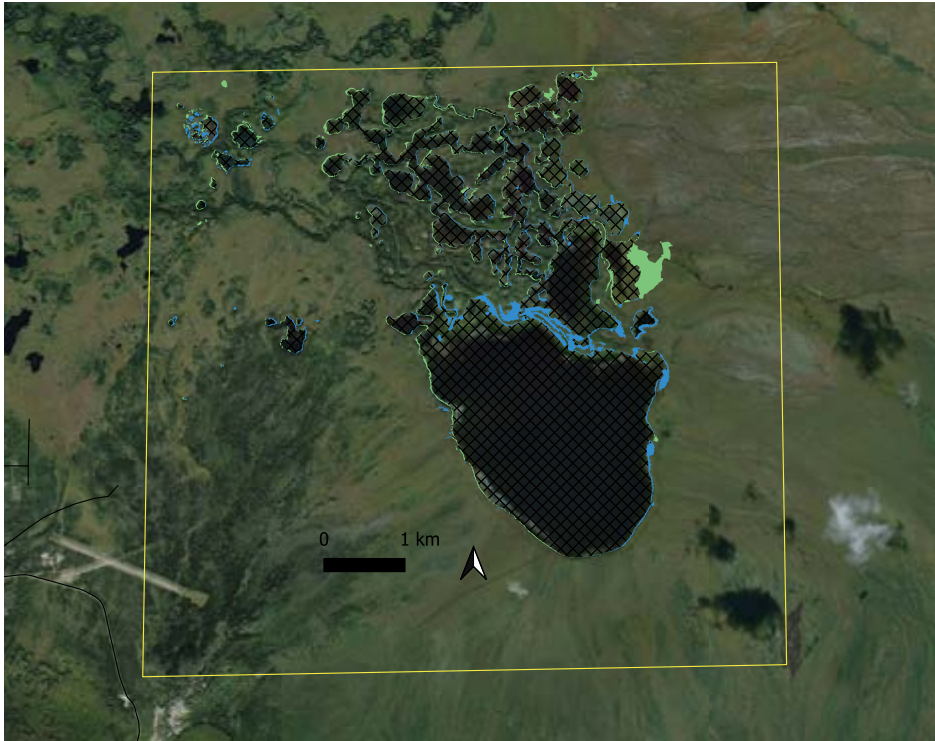


Credit to Prajna Regmi Lindgren, Ph.D. for this lake change analysis

2012 - 2022

Also note the significant increased water and increased lake connections immediately north of Medicine Lake

Western lake edges are more dry while the eastern lake edges are more wet. This may indicate draining.



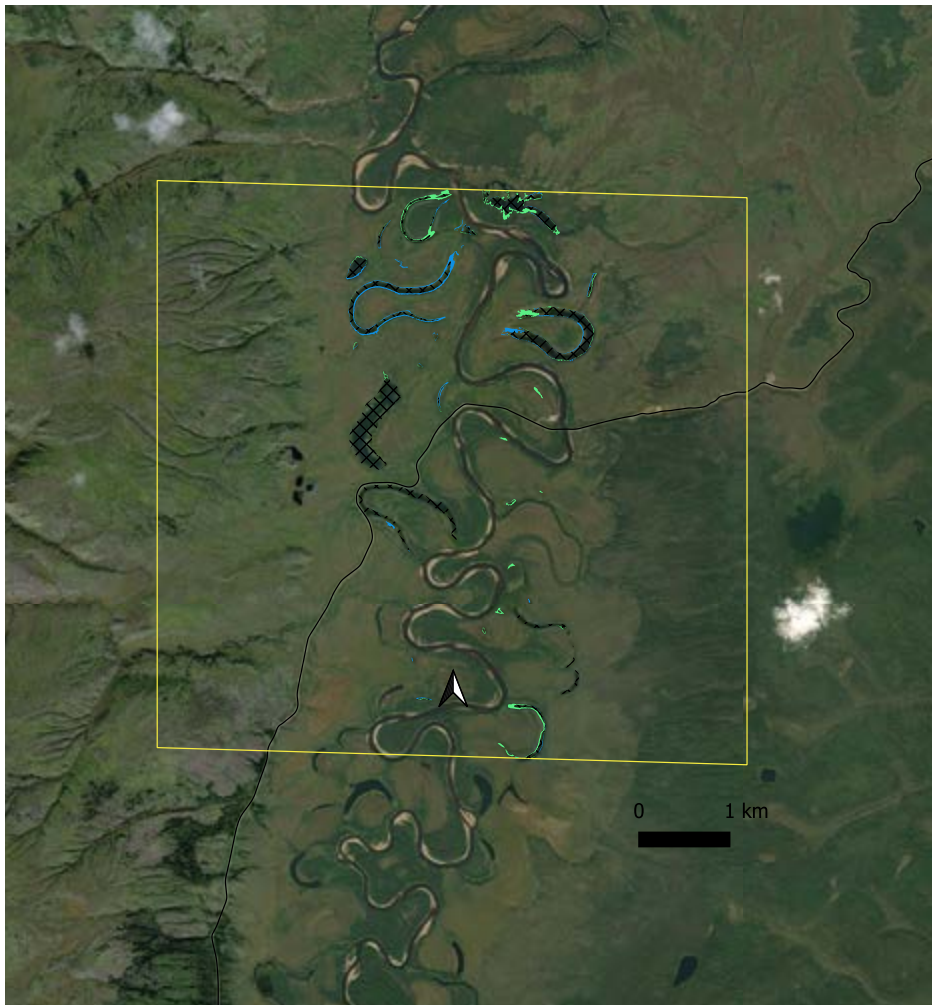
Circle, Medicine Lake - Area Change (2009/12 - 2022) INCLUDES MEDICINE LAKE

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss Water to Land/Veg	359,664	5.27%	5.27% of WATER in 2009/12 is LAND/VEG in 2022
	New Lake Area Land/Veg to Water	369,572	5.42%	5.42% of WATER in 2022 is new

LAKE CHANGE ANALYSIS - CIRCLE, AK

AREA B: STEESE HWY. MILEPOST 144

1980 - 2012



Circle Area B - Lake Area Change (1980 - 2012)

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss Water to Land/Veg	98,327	10.3%	10.3% of WATER in 1980 is LAND/VEG in 2012
	Lake Area Stable	860,420	89.7%	89.7% of WATER in 1980 is still WATER in 2012
	New Lake Area Land/Veg to Water	107,025	11.1%	11.1% of WATER in 2012 is new

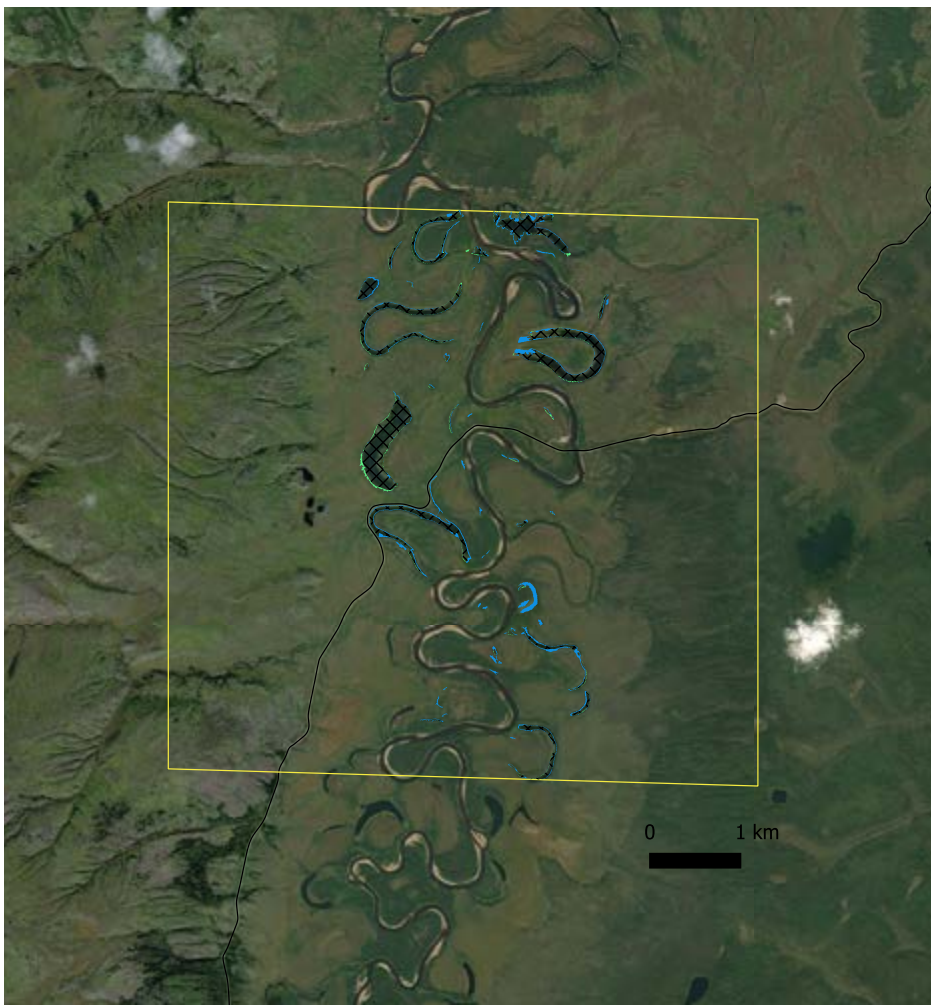


2012 - 2022

Not much overall change between 1980 and 2012.

It got more wet between 2012 and 2022, mostly south of the highway.

Note that lakes are in the vicinity of Birch Creek. Lakes near flowing water tend to be more dynamic.



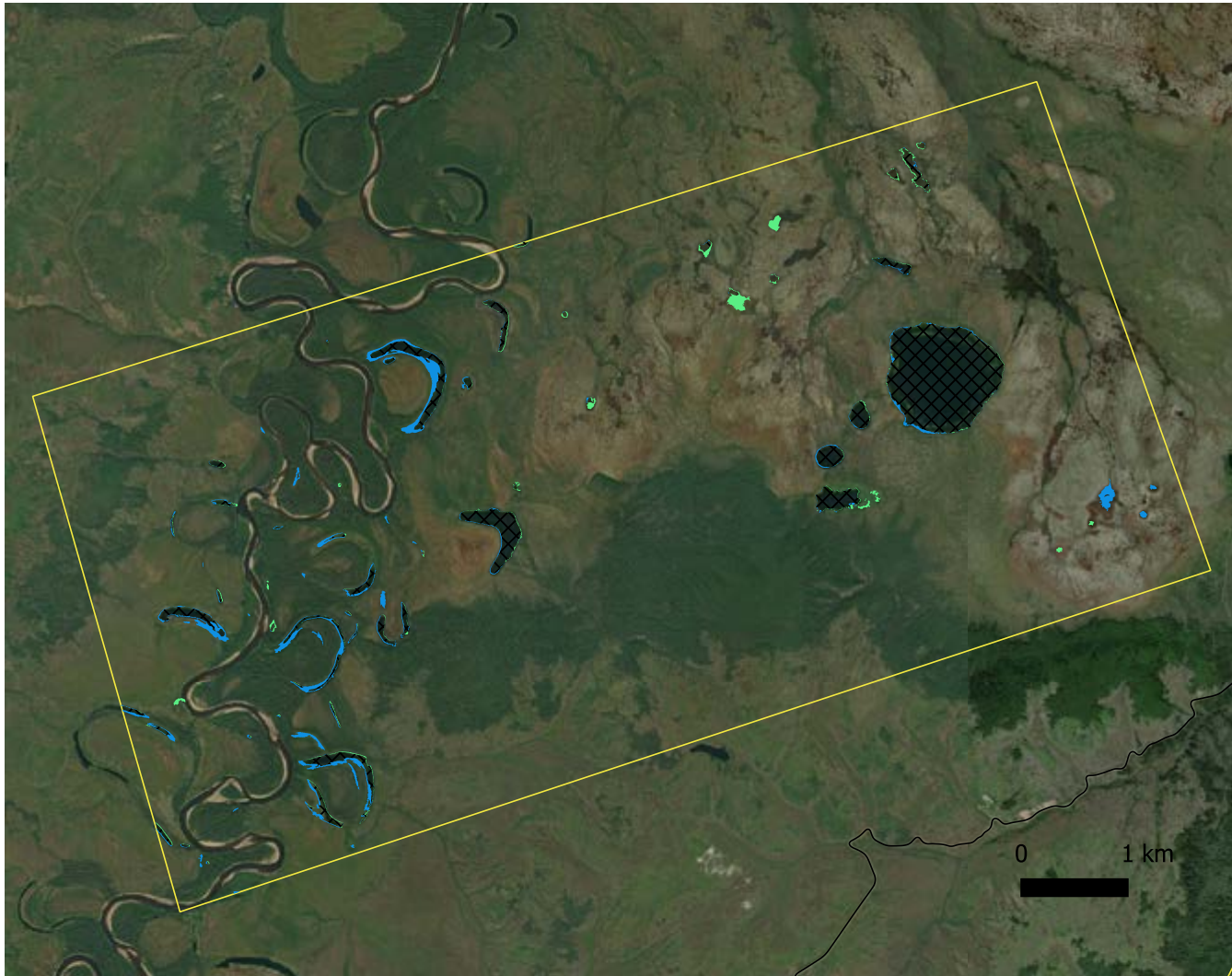
Circle Area B - Lake Area Change (2012 - 2022)

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss Water to Land/Veg	35,661	3.7%	3.7% of WATER in 2012 is LAND/VEG in 2022
	Lake Area Stable	931,786	96.3%	96.3% of WATER in 2012 is still WATER in 2022
	New Lake Area Land/Veg to Water	213,257	18.6%	18.6% of WATER in 2022 is new

LAKE CHANGE ANALYSIS - CIRCLE, AK

AREA C: BIG LAKE (FIASCO LAKE) AREA

1980 - 2012

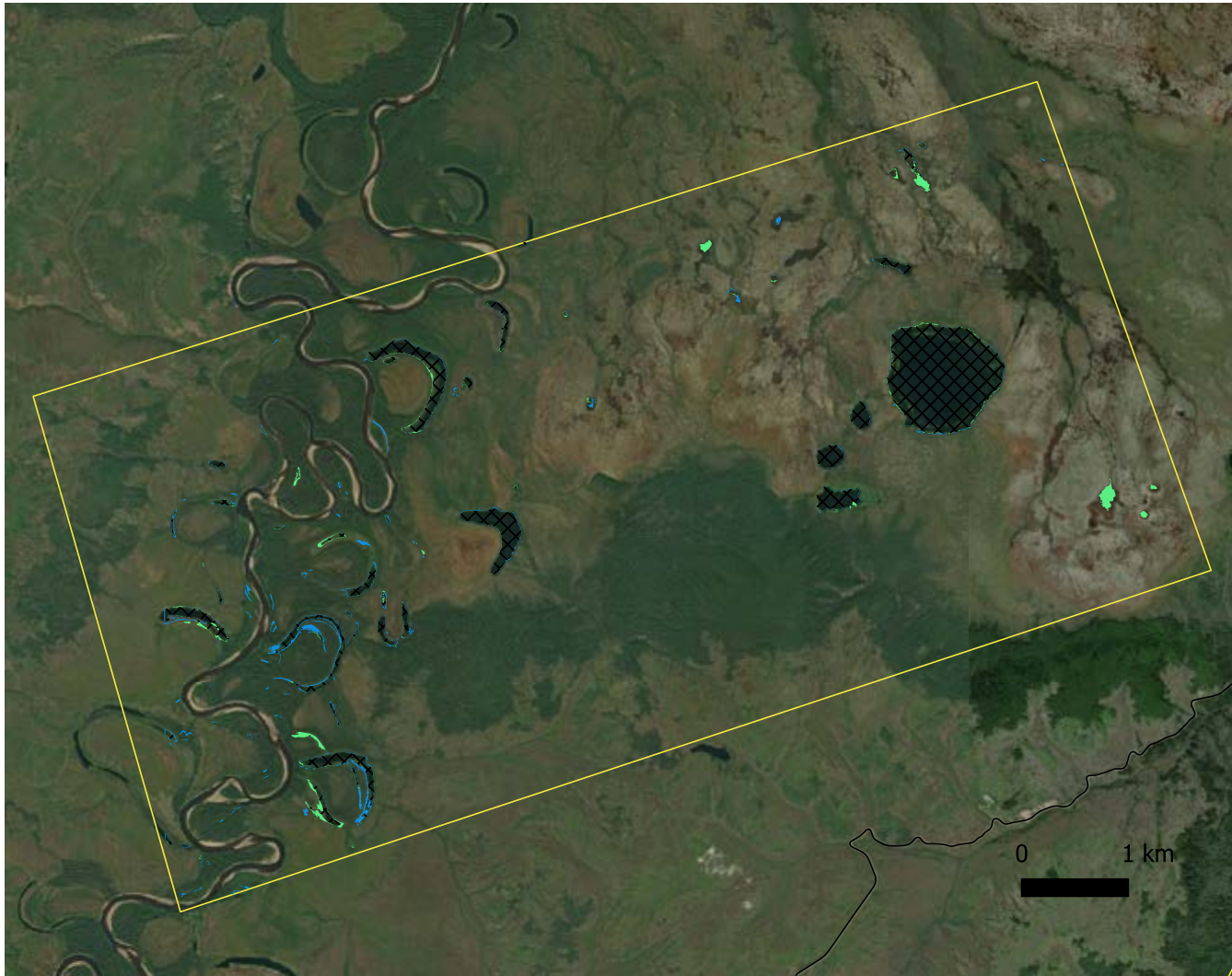


Circle Area C - Lake Area Change (1980 - 2012)

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss I Water to Land/Veg	104,646	6.2%	6.2% of WATER in 1980 is LAND/VEG in 2012
	Lake Area Stable	1,585,330	93.8%	93.8% of WATER in 1980 is still WATER in 2012
	New Lake Area I Land/Veg to Water	312,774	16.5%	16.5% of WATER in 2012 is new

Significant change between 1980 and 2012, but less between 2012 and 2022. Note that most of the change is in the vicinity of Birch Creek. Lakes near moving water tend to be more dynamic.

2012 - 2022



Circle Area C- Lake Area Change (2012 - 2022)

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss I Water to Land/Veg	121,973	6.5%	6.5% of WATER in 2012 is LAND/VEG in 2022
	Lake Area Stable	1,746,100	93.5%	93.5% of WATER in 2012 is still WATER in 2022
	New Lake Area I Land/Veg to Water	145,338	7.7%	7.7% of WATER in 2022 is new

AIR TEMPERATURE AND THE ACTIVE LAYER:

THE YUKON RIVER INTER-TRIBAL WATERSHED COUNCIL

The Yukon River Inter-Tribal Watershed Council (YRITWC) established a science program to support the signatory Alaska Tribes' and First Nations' efforts toward clean water and to protect and preserve the Yukon River Watershed. This includes two projects focused on water quality and active layer dynamics to address concerns about past and current changes to the landscape and hydrology.

Warming air temperatures heat the ground and gradually affect permafrost temperatures from the surface downward, leading to deeper seasonal thaw, warmer soil temperatures, and mineral leaching. Permafrost thawing in the Yukon Flats has caused wetlands and lakes to drain, shrink, or expand as underground ice melts. This alters hydrology by shifting water

movement from surface overland flow to deeper groundwater pathways, releasing thawing organic matter, such as methane, into the atmosphere, and mobilizing stored elements, such as metals and nutrients, from wetland soils into river and stream systems.

Circle Tribal Council staff have supported the Yukon River Inter-Tribal Watershed Council's effort to collect water quality data to evaluate changes in active layer depth, soil moisture, and water chemistry since 2008. To track these changes, YRITWC staff have collected water samples from the Yukon River and Birch Creek and have set up an active layer site. The following sections provide graphs and an explanation of the collected data and how it connects to the lake analysis, hydrology, and water quality in Circle.

Edda Mutter, an environmental scientist with the Yukon River Inter-Tribal Watershed Council, organized and led drone training sessions to track environmental changes and collected active layer and water quality data as part of Indigenous Observation Network's initiatives throughout the Yukon Basin.

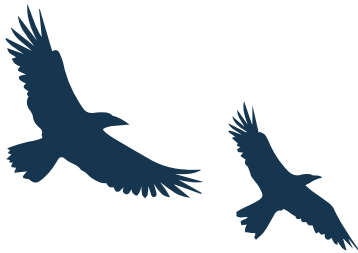


Figure 1 presents air temperature records from 2009 to 2024. No air temperature data were recorded between September 2012 and December 2016, but based on sensor measurements, the warmest annual average temperatures were recorded in 2018-2019.

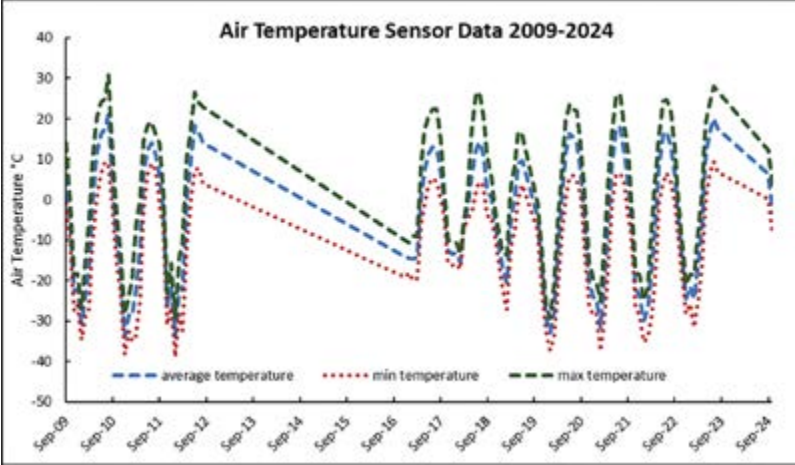


Figure 2 illustrates the relationship between air temperature and shallow and deep soil temperatures, which penetrate the ground and deepen the active layer. Physical measurements from 2009 to 2024 showed a 2 cm/year increase in active layer depth.

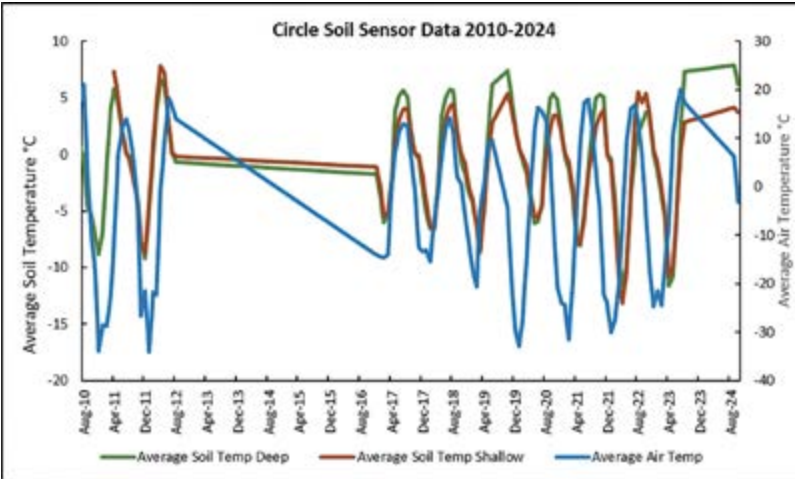
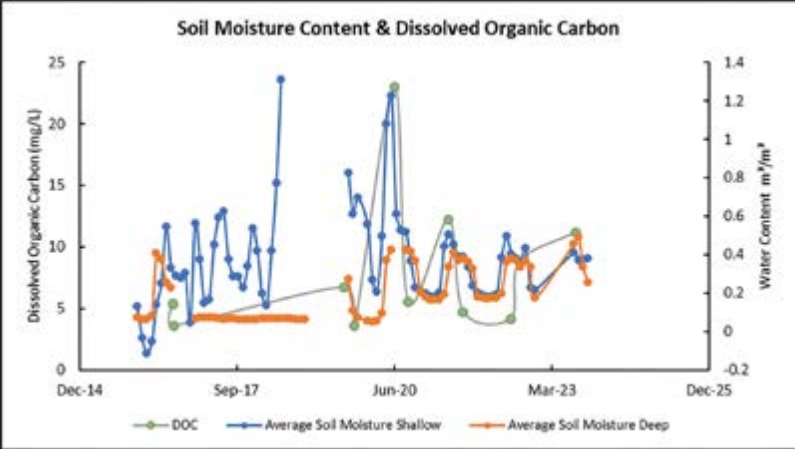


Figure 3 is a great example to illustrate the interconnection between soil moisture content and the mobility of Dissolved Organic Carbon (DOC). Higher soil moisture content at the Active Layer site directly correlates with higher DOC concentrations detected in the Yukon River. The same relationship has also been observed with trace metal concentrations being mobilized from the wetlands into the river and stream systems across the Yukon River watershed. More detailed water quality and active layer data will be provided with the next Indigenous Observation Network community report this fall.



FORT YUKON

GUIDED BY LOCAL KNOWLEDGE

FORT YUKON, ALASKA

These are times of change, and the residents of the Yukon River Watershed are daily witnesses to this fact. It can be seen in the changing water bodies, shorelines, vegetation, animals, and communities themselves. Local observations of landscape change were an important starting place for this study. We asked local knowledge holders what they were seeing and where, so that we would know where to look for evidence of methane seeps and other signs of permafrost thaw. In addition to helping focus our research, these interviews also provided valuable information to help our team better understand

the communities they would be working in, **including how residents are navigating the changing environment and their concerns.**

We interviewed six Knowledge-holders in Fort Yukon in April 2022. To protect participants' privacy, we identify them only by a unique number (1-6). Multiple participants are cited when there was broad agreement on a topic. **When multiple numbers are noted, for example (1,5), it means that participants 1, and 5 independently made statements that were in agreement on the same topic.**

THANK YOU!

Robert Solomon, advisor.
Julie Mahler, advisor
Dr. Stanley Edwin
Dwayne James
Alfred Peter
Walter Peter

Credit to Tracie Curry
for contributions to this
Fort Yukon section



NO REPORTS OF METHANE SEEPS, LARGE HOLES IN THE ICE, NEAR TOWN.

Many people have observed holes in lake ice in the Yukon Flats when traveling by plane to/from Fort Yukon. One participant noted seeing smaller ice holes near town, which they believe are muskrat push ups (1). Two participants have observed bubbling water in the summer, on the Black River (1) and at Emil Lake (3) .



PEOPLE ARE HAVING TO WORK HARDER TO TRAVEL BY RIVER.

As the riverbanks erode, gravel bars are getting bigger and river channels are changing (1,3,4). This requires people to relearn the water and find different, often less direct, routes which requires more time and resources. **Low water levels** are also a problem (3,4,6).

"Last year we weren't getting the runoff from the mountains and the river was low. Even in Old Crow they could walk across. Never been that bad until the last couple years. People used to come down from old crow by boat but they couldn't. That's how dry the water got (3)."

"The rivers are drying up. The Yukon, Porcupine, all the rivers are getting low. You have to know how to read rivers good (4)."

ENVIRONMENTAL CHALLENGES

- Low water levels in rivers and sloughs
- Riverbank erosion
- Increased number of snags in the river
- Flooding

Lakes in the Yukon Flats area observed from airplane - Tracie Curry



...TRAVELING CONTINUED

Winter snow and freeze-up now take longer, delaying the ability to travel anywhere (1).

"Ice thickness is a big factor, especially in the fall. When I'm trapping I used to go a little early, like around November or end of November. In recent years, I haven't been able to do that because the ice doesn't freeze so good (6)."

Warmer spring temperatures contribute to faster snowmelt, impacting late season snow machine travel on the river because there is more water to navigate. This has impacted people's ability to hunt geese in the spring.

"They had to come back early from geese hunting upriver because there was way too much water... it's harder, more difficult to get on that frozen pack, and that frozen pack is becoming more dangerous. So the hunting up there is less than before (5)."

On the other hand, **faster snow machines** make it so people can travel over open water for short stretches.

"You don't even worry about open spots anymore because if the snow machine is 600 or above in terms of horsepower it basically runs on top of the water it's so fast. Most people travel the river like a bat outta heck (5)."

High water on the Yukon is good for traveling but not for fishing.

Low water is also not good for fishing.

"The Sucker River at the mouth of the Porcupine is drying up. [Last year] there was hardly any water to where you could walk across. We're usually able to pull lots of fish but last year it was dried up. That's not normal... Fished the Sucker River spot for about 40 years before it started getting dry (3)."

Formerly reliable fishing spots are also changing due to erosion from riverbanks (1).

"Sand bars are not where they used to be and the fish aren't where they used to be. It's a big difference. I'm lucky to come back with two or three. (3)"

Robert Solomon, Fort Yukon resident and coordinator for the Environmental Protection Agency, Indian General Assistance Program, served as a project advisor and local liaison.



LAND TRAVEL IS COMPLICATED BY INCREASING BRUSH AND WILDFIRE

Taller, faster growing shrubs impact land travel in all seasons by creating increasingly brushy conditions.1,3, 5).

"In some places, willows grow like crazy and we have to cut trail there to get to where we want to go (1)."

"It's hard to go through [in the summer] if the brush is so thick, you never know when you're nose to nose with a 'big-headed mean guy' [a bear] (5)."

Wildfire also impacts the ability to travel on land. According to

one participant, the old trap line trails north and west of Fort Yukon are "burnt out" and people now must rely more on rivers to access those locations (3).

Wildfire impacts subsistence as well. If it burns, it takes a long time for the animals to come back (1).

"The land trails all got burnt out so now we use the river. Fire has impacted the ability to travel on the trap line trails to the north and west of town (3)."

Fort Yukon, AK tripod. A new tripod is set up on the river each spring. When the tripod tips, river breakup has arrived. Tracie Curry



Drying lake beds as seen from an airplane above Fort Yukon. Tracie Curry



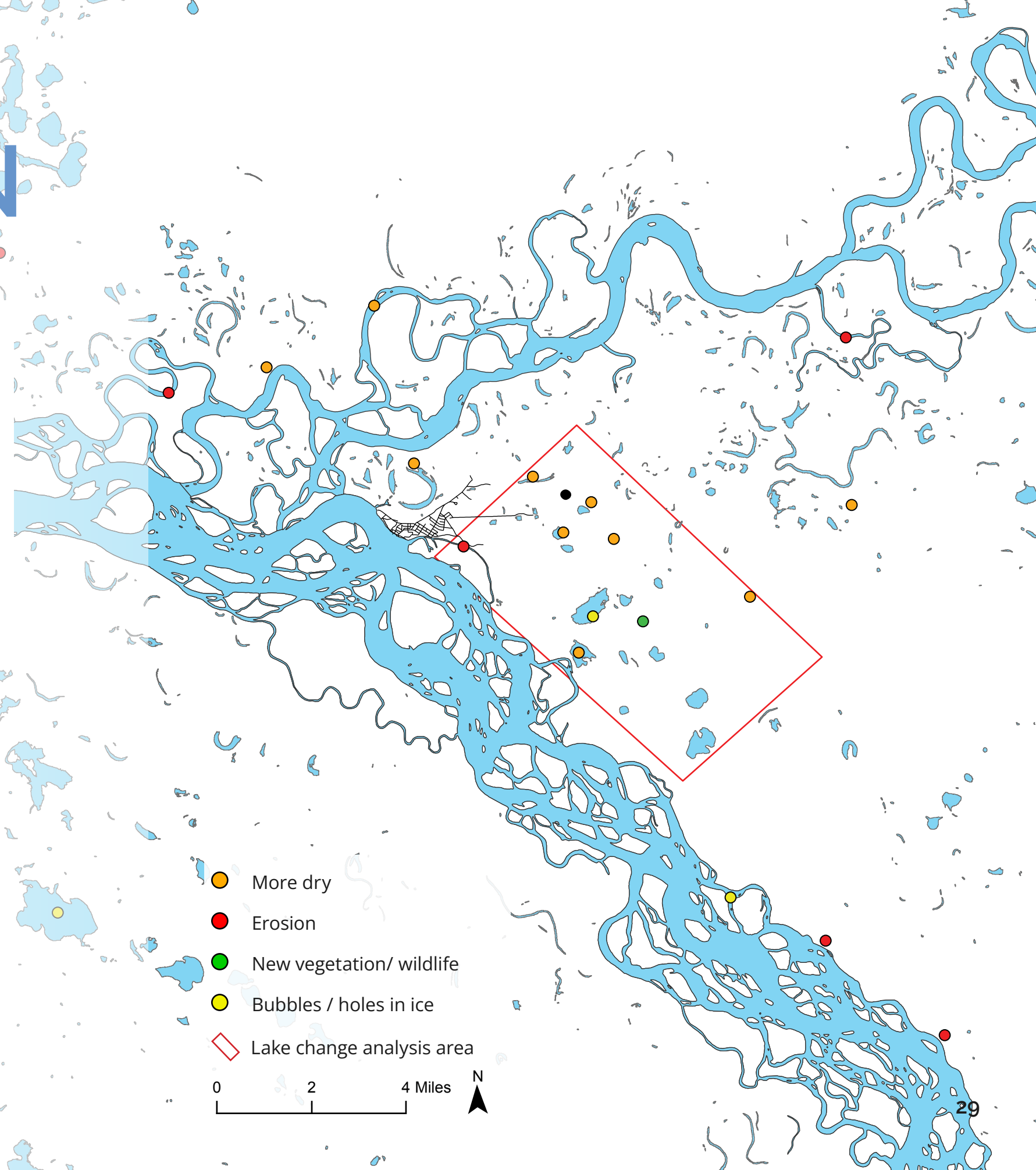
FORT YUKON

Observed Changes

We conducted interviews with 6 Fort Yukon residents, all of whom were recommended to us for their in-depth knowledge of the local environment. Interview questions asked participants about the environmental changes they have observed over the years and how their ways of life are being impacted. Additionally, we provided printed maps and asked participants to identify the locations where changes are happening. Participants discussed observations in four main categories; 1) places that are getting more wet or more dry, 2) erosion, 3) bubbling water or holes in ice (these are indications of methane), and 4) new vegetation or wildlife. The locations of observed changes across all categories in Fort Yukon are shown in Figure 1.

Figure 1: Observed Changes - Fort Yukon, 2022

Seeing everyone's observations in one shared map can help the community plan and spark discussion. Residents can see whether others are noticing the same changes, compare familiar places with reports from other areas, and identify new locations to add through conversation.



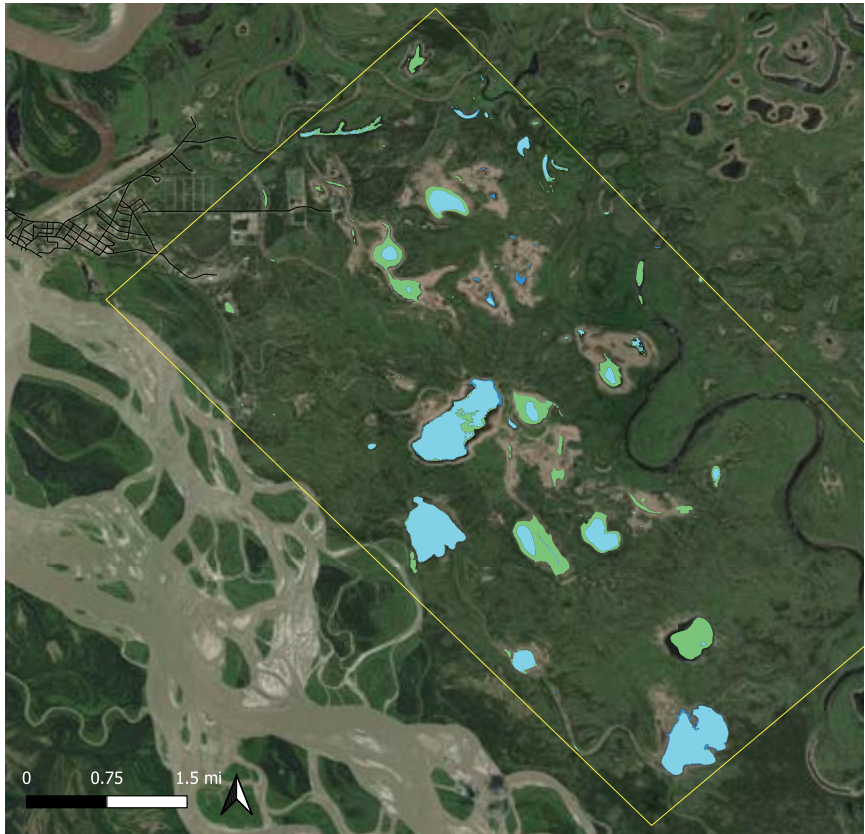
LAKE CHANGE ANALYSIS - FORT YUKON

The following analysis focuses on a key area from the larger map, selected because of its importance to subsistence and recreation, and due to the significant changes observed there. Zooming in on this area allows for a closer examination of

reported lake changes in relation to places of ongoing local use and significance.

We chose two time slices for the analysis based on the availability of historic imagery; 1978-2010 and 2010-2023.

1978-2010



Lake change around Fort Yukon between 1978/1980 and 2010 overlaid on Alaska Statewide High Resolution Imagery_2020_rgb_cache.

Lake Area Change Statistics Between 1978 and 2010

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss I Water to Land/Veg	1,550,580	38.28%	38.28% of WATER in 1978 is LAND/VEG in 2010
	Lake Area Stable	2,500,210	61.72%	61.72% of WATER in 1978 is still WATER in 2010
	New Lake Area I Land/Veg to Water	130,273	4.95%	4.95% of WATER in 2010 is new

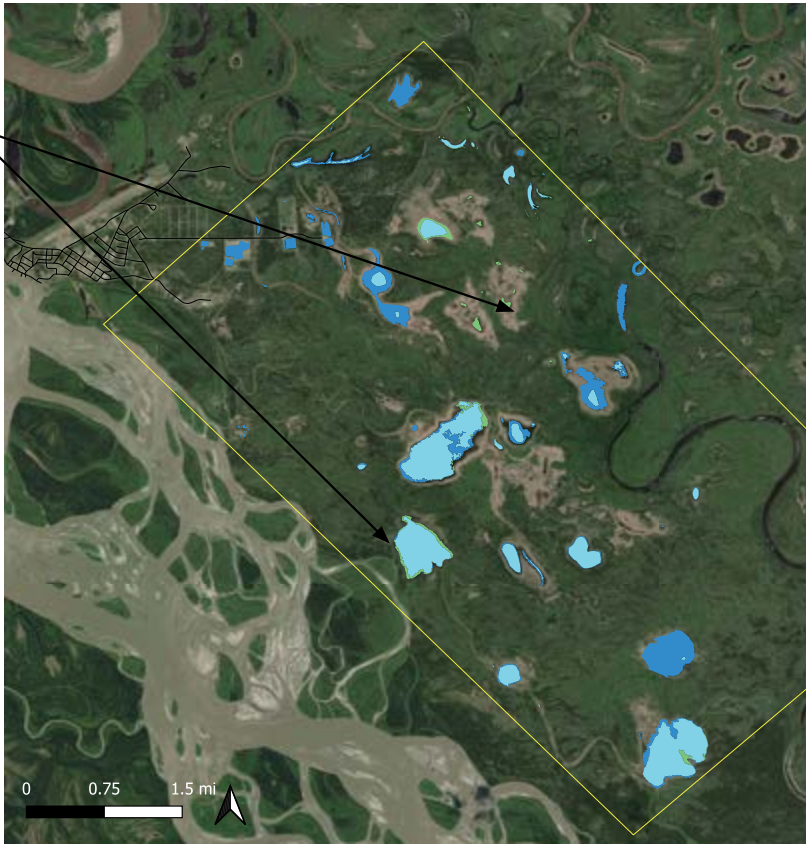
Credit to Prajna Regmi Lindgren, Ph.D. for this lake change analysis

Fort Yukon experienced a substantial flood in May 2023, which likely explains the large increase in water during that year. The flood reached the community and damaged several buildings, including homes.

2010-2023

While there was an overall gain in lake area between 2010 and 2023, some localized drying can also be observed.

Lake change around Fort Yukon between 2010 and 2023 overlaid on Alaska Statewide High Resolution Imagery_2020_rgb_cache.



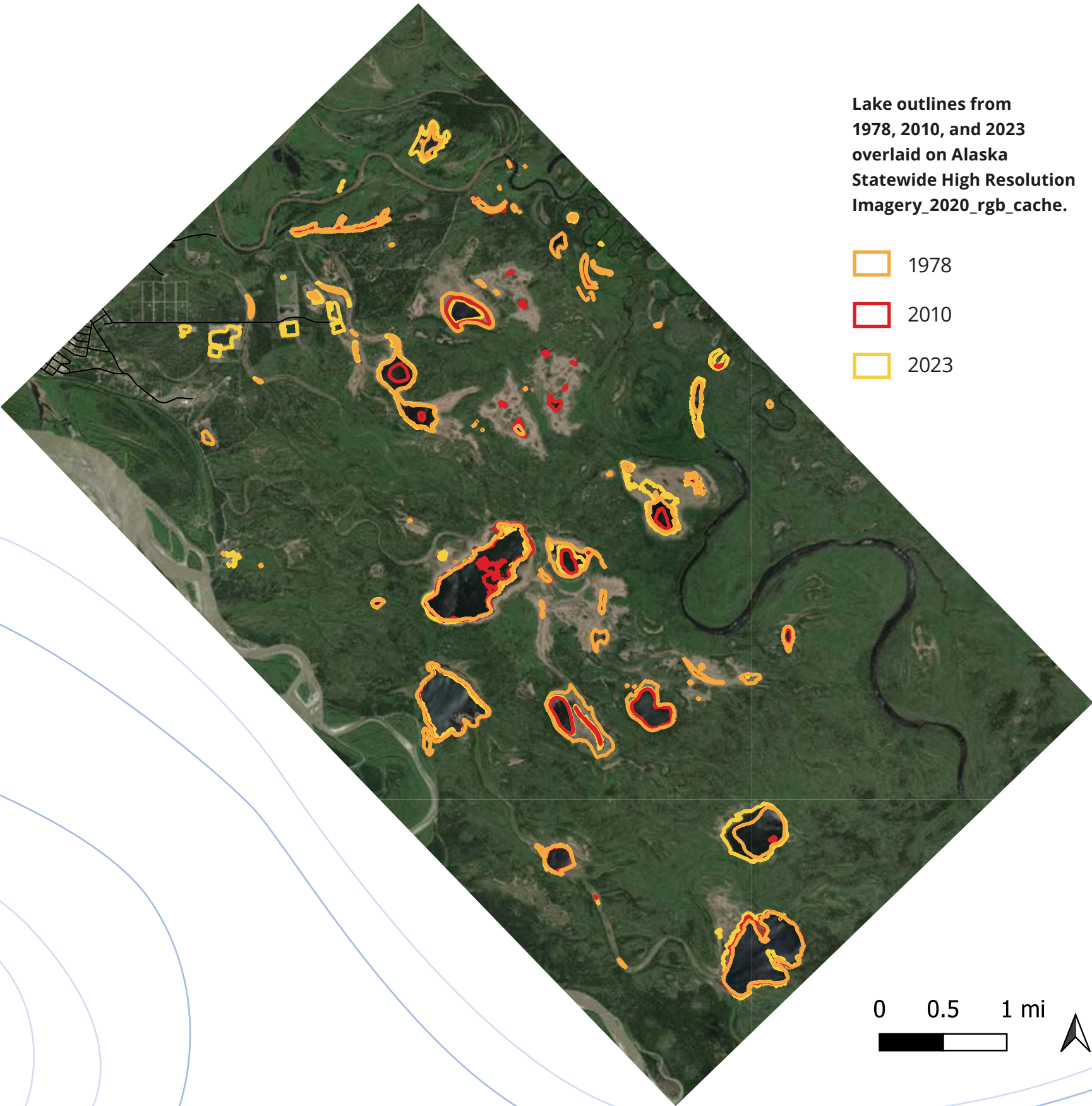
Lake Area Change Statistics Between 2010 and 2023

	Lake Status	Lake Area Change (m2)	Lake Area Change (%)	Interpretation
	Lake Area Loss I Water to Land/Veg	227,508	8.65%	8.65% of WATER in 2010 is LAND/VEG in 2023.
	Lake Area Stable	2,402,720	91.35%	91.35% of WATER in 2010 did not change and is WATER in 2023
	New Lake Area I Land/Veg to Water	1,634,250	40.48%	40% of WATER in 2023 is new

LAKE CHANGE ANALYSIS - FORT YUKON

Participants noted that lakes in the Yukon Flats go dry and then fill up again as part of the natural cycle, but that the land is more dry overall. The satellite historic satellite imagery analysis (1978-2023) provides evidence of this trend.

While we see some fluctuation over the years (more dry from 1978 to 2010 and more wet from 2010 to 2023), there is an overall loss in lake area (0.34%) between 1978 and 2023.



Lake outlines from
1978, 2010, and 2023
overlaid on Alaska
Statewide High Resolution
Imagery_2020_rgb_cache.

- 1978
- 2010
- 2023

0 0.5 1 mi

AIR TEMPERATURE AND THE ACTIVE LAYER:

THE YUKON RIVER INTER-TRIBAL WATERSHED COUNCIL

The Yukon River Inter-Tribal Watershed Council (YRITWC) established a science program to support the signatory Alaska Tribes’ and First Nations’ efforts toward clean water and to protect and preserve the Yukon River Watershed. This includes two projects focused on water quality and active layer dynamics to address concerns about past and current changes to the landscape and hydrology.

Warming air temperatures heat the ground and gradually affect permafrost temperatures from the surface downward, leading to deeper seasonal thaw, warmer soil temperatures, and mineral leaching. Permafrost thawing in the Yukon Flats has caused wetlands and lakes to drain, shrink, or expand as underground ice melts. This alters hydrology by shifting water movement from surface overland

flow to deeper groundwater pathways, releasing thawing organic matter, such as methane, into the atmosphere, and mobilizing stored elements, such as metals and nutrients, from wetland soils into river and stream systems.

The Council of Athabascan Tribal Governments Fort Yukon Natural Resource Staff have supported the Yukon River Inter-Tribal Watershed Council’s effort to collect water quality data to evaluate changes in active layer depth, soil moisture, and water chemistry since 2009. Fort Yukon residents collect water samples from the Porcupine and Yukon Rivers and support the setup of an active layer site. The following sections provide graphs and an explanation of the collected data and how it connects to the lake analysis, hydrology, and water quality in Fort Yukon.

Credit to Edda Mutter for contributions on the active layer

Figure 1 presents air temperature records from 2009 to 2025. The warmest annual average temperatures were recorded in 2015–2016 and 2018–2019, whereas the coldest years were 2010–2011 and 2012–2013.

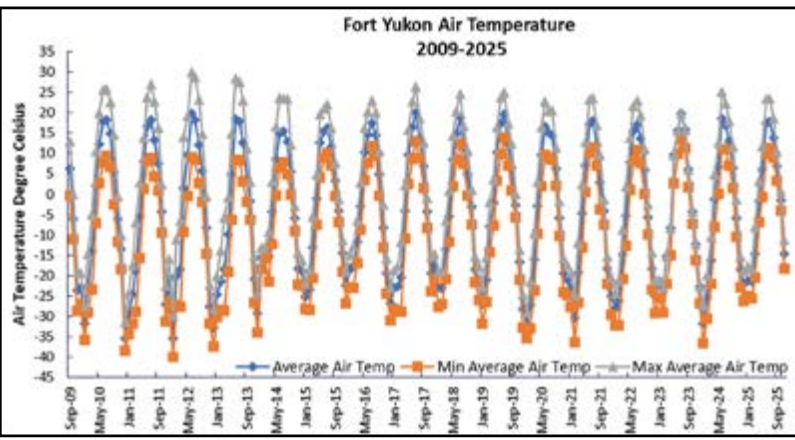


Figure 2 illustrates the relationship between air temperature and shallow and deep soil temperatures, which penetrate the ground and deepen the active layer. Physical measurements from 2009 to 2014 showed a 2.4 cm/year increase in active layer depth, and measurements from 2021 to 2024 showed a 2 cm/year increase.

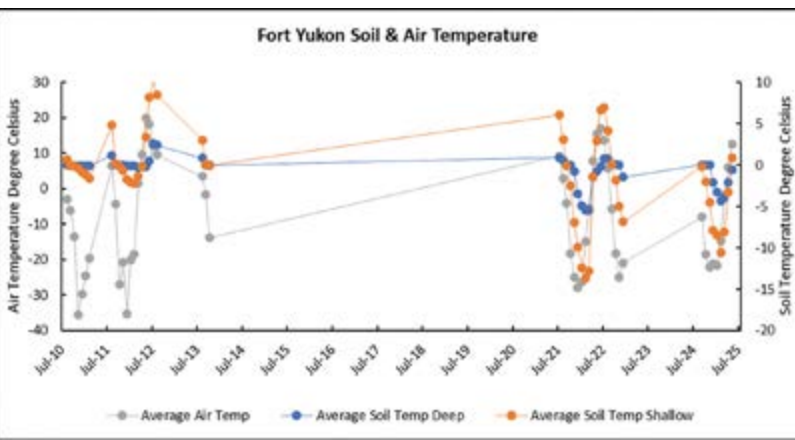
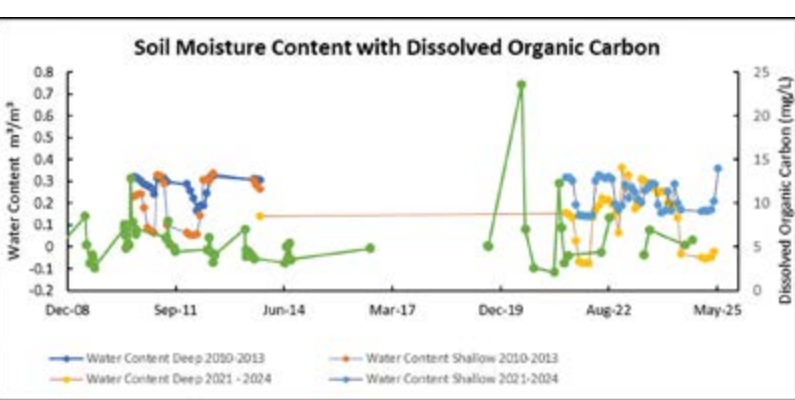


Figure 3 is a great example to illustrate the interconnection between soil moisture content and the mobility of Dissolved Organic Carbon (DOC). Higher soil moisture content at the Active Layer site directly correlates with higher DOC concentrations detected in the Yukon River. The same relationship has also been observed with trace metal concentrations being mobilized from the wetlands into the river and stream systems across the Yukon River watershed. More detailed water quality and active layer data will be provided with the next Indigenous Observation community report this fall.





STUDY SITE: BIG TRAIL LAKE

Our research team focused on Big Trail Lake in the Goldstream Valley near Fairbanks, which emits more methane than most lakes in the Arctic. One of the major scientific goals of this study was to measure methane emissions from Big Trail Lake at different distances: from up close on the ground, to valley wide using a laser, to high in the atmosphere using a drone.

We found very large methane gradients within the lowest few meters of the atmosphere—sometimes 6 times as much methane as the normal atmospheric amount. From our research, we gained two main takeaways.

The first finding is that there is a lot of methane being released in wintertime. This is surprising because though the landscape seems dormant and frozen, the bottom of Big Trail Lake remains above freezing, allowing methanogens (microscopic, single-celled organisms) to continue

producing methane through the wintertime. The methane then bubbles up to the surface ice layer on the lake and escapes through small ice holes or other pathways through the ice and snow. Scientific models currently include little to no wintertime methane emissions, but this is clearly the wrong assumption.



Kevin Rozmiarek recently obtained his PhD through the Earth Science Department at the University of Colorado. His research focuses on understanding methane release from permafrost, especially from abrupt thaw lakes.



Big Trail Lake, Fairbanks, AK - Frankie Carino

Second, there is a high concentration of methane in the lowest two meters of the atmosphere, which prompted us to consider that the trees and plants help to trap methane near the surface, inhibiting the mixing of methane into the higher atmosphere. This is a theory that still needs to be proven, but similar results have been found in agricultural contexts. If this theory is true, we also need to determine where all the methane in the lowest 2 meters of the atmosphere ends up.



Big Trail Lake, Fairbanks, AK - Frankie Carino



DRONE WORKSHOPS

Over the course of the project, three two-day drone workshops were conducted: Fairbanks, AK (2024), Akiachak, AK (2025), and Fort Yukon, AK (2025). All workshops were taught by two certified UAS (Uncrewed Aerial System) flight instructors from the University of Colorado.

The sessions in Fairbanks and Fort Yukon were open to all community members, while the Akiachak workshop was offered to invited participants and community members, including some who were flown in from nearby villages.

In addition to workshop instruction, we identified several opportunities to enhance the use of existing drone platforms already owned by tribal communities.

We found that many Alaskan educational programs include drones that communities are not fully prepared to operate. In several cases, drones had never been flown, were in disrepair, or knowledge of their operation had been lost over time.

Our team restored several of these drones to full operability, returning a combined estimated value of \$34,000 to the communities.

Coursework was modeled after the University of Colorado Division of Public Safety's UAS Ground School,

with additional content adapted to community requests. Topics included:

1. How to operate a multirotor drone. Every community member involved was able to fly on both days.
2. Applications for the use of UAS including:
3. Search and Rescue
4. Community science
5. Infrastructure surveys
6. Pathways to legal flying for community members:
7. Hobbyist
8. Commercial
9. Public (uniquely suited for tribal governments)
10. Interfacing with the Federal Aviation Administration
11. Understanding airspace classification

a-b. Outdoor instruction led by Kevin Rozmiarek and Chase Rupprecht during Fairbanks workshop

c. Akiachak school teachers dig out unused equipment from the school's storage

d. Kevin Rozmiarek leads outdoor instruction during Akiachak workshop

e. Participants pilot drones during Fort Yukon workshop

f. Alex Rudick leads classroom instruction in Fort Yukon



a



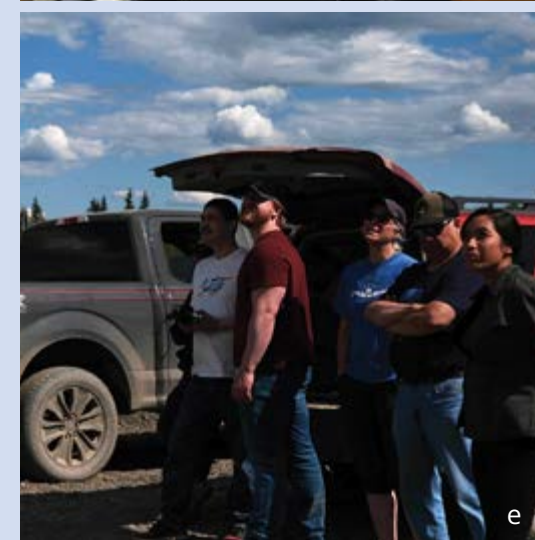
b



c



d



e



f



FINDING THE RIGHT TOOL FOR THE JOB

Since methane is an invisible gas, we measured it with specialized equipment. Up close, we used chambers (small buckets) or bubble traps within Big Trail Lake to capture methane as it enters the atmosphere. We also used an eddy covariance tower in the middle of the lake to measure methane emitted from an area roughly the size of the lake.

We also used two new technologies to measure methane, including drones and open-path dual-comb spectroscopy. The goal was to determine if all these measurement techniques agreed in their measurements of methane, and if they did not, at what distances we struggle to get reliable information.



Eddy covariance tower
Frankie Carino

PRECISE MEASUREMENTS FIXED-WING DRONE

We used a fixed-wing drone to collect air samples in glass flasks over Big Trail Lake and then measured methane concentration in a laboratory setting. We also directly measured methane concentration in the atmosphere using an onboard laser spectrometer, which was a less precise method.

We learned that there are small detectable changes in the amount of methane in the air at altitudes greater than 50 meters in the atmosphere above the ground, but we can only detect them using the more precise method. This method is more time intensive and only produces limited amounts of data, which is not useful for improving our simulations of the abrupt thaw lake.

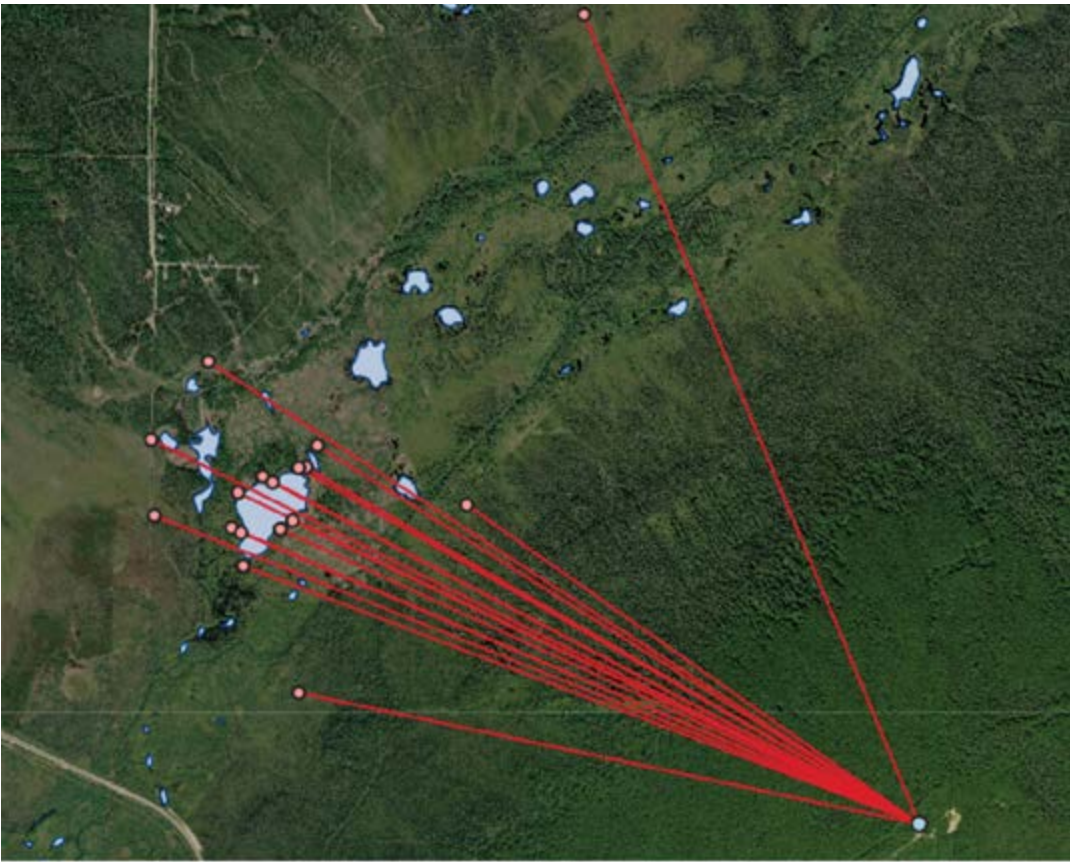
Using the less precise method, we could not get a good enough reading of methane due to lower instrument precision and other uncertainties. We had hoped the less precise method would have worked to detect methane plumes in the atmosphere over Big Trail Lake, because this method provides more data, which would have been helpful for improving models of methane release from abrupt thaw lakes.

With the knowledge that very small methane gradients existed in the atmosphere over Big Trail Lake, we used a laser spectrometer to measure methane emissions around the perimeter of the lake in wintertime.

Fixed wing drone aloft in Goldstream Valley - Frankie Carino



Dual-comb spectrometer beam paths



Goldstream Valley

Fairbanks, Alaska

0 250 500 750 m

Laser System
Tower
Reflector
Laser Paths
Study Features
Lakes and Ponds



Dual-comb spectrometer



BROAD MEASUREMENTS DUAL-COMB SPECTROMETER

A dual-comb spectrometer utilizes lasers to detect molecules in the air. If a standard laser is a single musical note, then a comb laser is a grand piano; it plays thousands of notes all at the same time, perfectly spaced apart. While the laser is invisible to the human eye, it is specifically tuned to interact with the methane molecules.

Methane molecules absorb very specific “colors” (or in our example, musical notes) of the laser light. When the light returns to a detector, if methane was present along the path, certain “musical notes” in the pattern will be softer or missing.

By measuring how much light was lost over that specific path length, the system calculates how much methane is in the air. The value of the dual-comb system is that it allows us to send out lasers to scan across an entire valley.

This is the first dual comb system that has been used in the far north so we are continuing to make improvements. Eventually, we may use the system in a number of Arctic locations, including as a potential early warning system of increases in methane emissions due to thawing permafrost.



“We hope our research leads to better estimates of future methane release from the Arctic, as well as better methods of measuring methane escaping from lakes.”

Eli Miller is a Ph.D. student in the Mechanical Engineering Department at the University of Colorado. His research focuses on the use of dual-comb spectrometers for detecting methane emissions from boreal lakes/wetlands and from landfills.





KEY TAKEAWAYS



The observations shared by knowledge holders from Circle and Fort Yukon show that environmental change is affecting how people navigate the river, hunt, trap, fish, gather wood, and use familiar places on the land. In Circle, participants described changing lake levels and shorelines, wetter and drier ground, thicker brush, rougher trails, delayed freeze-up, and holes in lake ice or bubbling water that can create hazards for winter travel. In Fort Yukon, participants described low water levels in rivers and sloughs, and drying lakes. They also described eroding shorelines, changing river channels, thicker brush, and delayed freeze-up that can hinder

winter travel. These observations are valuable both for the current study (helping to identify key study features) and for planning future work (helping to identify research topics that address local priorities).

The lake-change analysis for Circle and Fort Yukon shows that waterbodies in both areas examined are dynamic. In Circle, some lake edges have become drier or transitioned to vegetation, while other areas have become newly inundated. Changes were especially apparent near Birch Creek and around Medicine Lake, where lake margins shifted over time.

While water levels in Fort Yukon have increased in some years, the overall trend since 1978 has been toward drying. Other factors, such as hydrology and weather, affect lake trends in addition to permafrost conditions. For this reason it is important to note that these patterns are not evidence of a single cause and should be interpreted alongside long-term data, including local and Indigenous knowledge.

Even with advanced technology, we are not currently able to capture the full picture of what is happening with

methane release at Big Trail Lake. However, we gained knowledge that might make drone and dual-comb laser measurements more useful in the future. For instance, we've learned how to evaluate drone-based sensors for future work and practiced operating aircraft in challenging landscapes. We have deployed and operated a laser over a permafrost landscape for nearly three years and continued to refine these very sophisticated and sensitive instruments for future outdoor work.





APPENDIX

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Rainclouds over hills with a distant rainbow as seen from Murphy Dome
Tracie Curry



COUNCIL OF ATHABASCAN TRIBAL GOVERNMENTS
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RESOLUTION 2021-10

IN SUPPORT OF A PARTNERSHIP BETWEEN THE COUNCIL OF ATHABASCAN TRIBAL GOVERNMENTS AND THE YUKON RIVER INTER-TRIBAL WATERSHED COUNCIL

WHEREAS: The Council of Athabascan Tribal Governments (CATG) is a tribal consortium composed of Arctic Village Council, Beaver Village Council, Birch Creek Village Council, Canyon Village Council, Chalkyitsik Village Council, Circle Village Council, Gwichyaa Zhee Gwich'in Tribal Council, Rampart Village Council, Stevens Village Council and Venetie Village Council; and

WHEREAS: The purpose of CATG is to conserve and protect tribal lands and other resources; to encourage and support the exercise of tribal powers of self-government; to aid and support economic development; to promote the general welfare of each member tribe and its respective individual members; and to preserve and maintain the cultural and spiritual values of the Tribe and its Tribal members; and

WHEREAS: The CATG Council of Chiefs is the legal governing body of the CATG by the authority of the Constitution and the By-Laws of the CATG; and

WHEREAS: The CATG are founded on the principles of tribal self-governance, working to empower and build capacity of local member Tribal Governments to assume management responsibility of programs within their villages; and

WHEREAS: The CATG Natural Resource Department goal is to empower the people of the Yukon Flats with skills and tools to execute self-governance over the resources that sustain the Traditional and Customary Use; and

WHEREAS: The Yukon Flats landscape is changing due to a warmer climate that is resulting in increasing permafrost thawing, altering hydrological pathways that is impacting tundra ponds and lakes/wetland areas; and

WHEREAS: The Yukon River Inter-Tribal Watershed Council's Indigenous Observation Network seeks out funding sources from government and foundations for conducting and providing environmental science, research, education, trainings, and technical assistance to tribes and communities within the Yukon River Watershed

WHEREAS: The Yukon River Inter-Tribal Watershed Council's Indigenous Observation Network and research partners from the University of Alaska Fairbanks, University of Colorado Boulder and Northern Social-Environmental Research received funding from the National Science Foundation to address the Council of Athabascan Tribal Governments needs for improving monitoring capacity of forecast landscape changes and water quality changes; and

WHEREAS: The Yukon River Inter-Tribal Watershed Council's Indigenous Observation Network and research partners seek CATG's support to produce information that allows to predict landscape changes; provides scenarios of future landscape changes, and to increase water quality monitoring capacity;

NOW THEREFORE BE IT RESOLVED That the Council of Athabascan Tribal Governments approves and supports a partnership between the Yukon River Inter-Tribal Watershed Council's Indigenous Observation Network program, the University of Alaska Fairbanks, University of Colorado Boulder, Northern Social-Environmental Research; and

BE IT FURTHER RESOLVED That the Council of Athabascan Tribal Governments support the research project entitled "Collaborative Research on Changing Lake Environments near Yukon River Watershed Communities"; and

BE IT FURTHER RESOLVED That the Council of Athabascan Tribal Governments urges and encourages member tribes to participate in a landscape change and water quality research project.

CERTIFICATION

Resolution 2021-10 was adopted by the Council of Athabascan Tribal Governments Council of Chiefs on the 24th day of June 2021.

ATTESTATION OF RESOLUTION 2021-10

Roll Call Vote:

YES

Chief Robert Sam, Arctic Village

Chief Rhonda Pitka, Beaver

Chief Jacqueline Baalam, Birch Creek

Chief Delma Fields, Canyon Village

Chief Stephanie Herbert, Chalkyitsik

Chief Dennis Carroll, Circle

Voice vote via phone

Chief Michael Peter, GZ Tribal Government

Chief Michael Wiehl, Rampart

Chief David Kriska, Stevens Village

Chief Paul Tritt Jr., Venetie

Attest:
Kelly Fields, Executive Assistant

Date: 4/30/21

Collaborative Research: NNA Track 1: Global impacts and social implications of changing thermokarst lake environments near Yukon River Watershed communities

Intro:

Interior Alaska landscapes are changing. Through this research we want to better understand the nature of these changes, how they compare to changes observed in the past, and how they are impacting your way of life today. Our team includes scientists who use different methods to study frozen ground (permafrost), lake ice, methane released from the environment, and water quality. The information you share today will help us collect information about the changing landscape that is useful for addressing your community’s needs.

Personal info:

Name:

DOB:

Years lived in community:

How do you spend time out on the land?

How long have you been doing these activities in the area?

Subsistence and transportation:

What are the most important parts of the landscape for your subsistence?

What landscape features or types of terrain are desirable for subsistence and transportation (summer, fall, spring, winter)?

What landscape features or types of terrain create difficulties for subsistence and transportation (summer, fall, spring, winter)?

Examples of landscape change:

Erosion:



Credit: Ground Truth Trekking

Slumping:



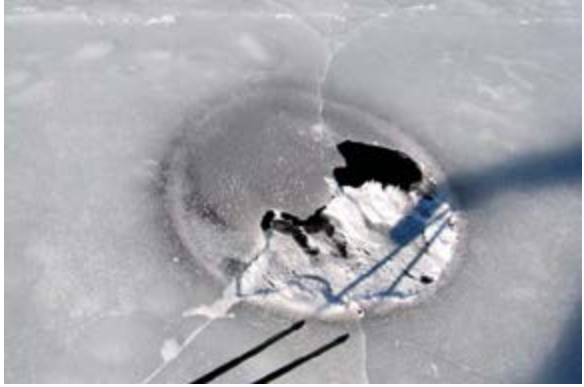
Credit: Katey Walter

Sink hole:



Credit: Ground Truth Trekking

Hole in ice:



Credit: Lakeice.org

Have landscape changes impacted your subsistence?

How?

Where? Map

When (timing)? For each map location

What do you think is the **cause** of these changes?

Have landscape changes impacted transportation (car, boat, 4-wheeler, snow machine)?

How?

Where? Map

When (timing)? For each map location

What ground transportation routes do you use most?

Where? Map

Have you noticed any changes along these routes that you haven’t already told us about?

Where? Map

Since when? For each map location

How do recent landscape changes compare to changes from the past?

Frozen ground/ lake ice:

Have you noticed any changes related to the timing of freeze-up and thaw?
How does this compare to the recent past (last few years)?
How does this compare to the distant past?

Have you seen any open ice holes in the winter?
Where? Map
What size?
Are there bubbles?
When did each form?
Do any return from winter to winter?

Have you noticed any [other] changes related to frozen ground or lake ice?
Where? Map
When (timing)? For each map location
Cause?

Additional prompts (if not previously answered):
Timing of freeze-up and thaw
Bubbles in ice
Ice thickness

Do you know if similar frozen ground/lake ice changes have occurred in the past?

How do recent changes compare?

Lake area change and Landscape change:

Have you noticed any changes in the lakes near here?
What?
Where? Map
Since when?

Have you noticed any [other] new or growing lakes?
Where? Map

Have any lakes or ponds disappeared?
Where? Map
When?

Have you noticed any places where water is bubbling in the summer?
Where? Map

Have you noticed any changes in the soil?
What?
Where? Map
Since when?

Are there any areas where the soil has become more wet and soggy? Or areas where the soil has become dryer?

Where? Map

Have you noticed any changes related to the timing of soil thaw and soil freeze-up?
How does this compare to the recent past (last few years)?
How does this compare to the distant past?

Have you noticed any changes in the types of plants around?
What type?
Where? Map
Since when?

Have you noticed any changes in the height of the vegetation?
What?
Where? Map
Since when?

Have you noticed any changes in snow cover?
What?
Timing (first snow, duration of snow cover)?
Quality (thickness, feel)?
Where? Map

Water quality:

Where does your drinking water come from? Map

Do you have any concerns about the quality of water you use for drinking?
What?
Since when?
Cause?

Do you have any other concerns about the quality of water in your area?
What?
Where? Map
Since when?
Cause?

Are there any places where the water used to be good, but that you no longer trust?
Where? Map
Since when?
Cause?

Are there specific water sources you think we should look into?
Where? Map
Why?
Level of importance?

Have you or your community experienced water quality changes before these recent changes?

How do recent water quality changes compare past changes?

Wrap-up:

Of the changes you shared, which are the most important or the most cause for concern?

In what locations would you suggest we focus our research efforts? Point out on map

Why?

Level of importance?

Do you have any questions about landscape changes and possible impacts on subsistence that we haven't already discussed?

What kind of information related to the changes you describe would be most useful to you (maps, aerial images, website etc.)?

Anything else that we should know?

Anyone else that we should talk to?

Is it okay if we contact you for follow-up questions?

Phone number _____

Email _____

Would you like to review a copy of your interview responses after we process this audio recording?

YUKON RIVER INTER-TRIBAL WATERSHED COUNCIL AND CIRCLE AND FORT YUKON WATER QUALITY AND ACTIVE LAYER

The Yukon River Inter-Tribal Watershed Council established the science program to support the signatory Alaska Tribes and First Nations' efforts toward clean water and to protect and preserve the Yukon River Watershed. In 2006, in partnership with the Alaska Tribes and First Nations, the USGS and YRITWC launched the Indigenous Observation Network (ION), a community-based program that combines Traditional Knowledge and modern science. The network has developed two projects focused on water quality and active layer dynamics to address concerns about past and current changes to the landscape and hydrology. Since then,

the network has collected water quality data to evaluate changes in active layer depth, soil moisture and temperature, and water chemistry.

Permafrost thawing in the Yukon Flats has caused wetlands and lakes to drain, shrink, or expand as underground ice melts. This alters hydrology by shifting water movement from surface overland flow to deeper groundwater pathways, releasing thawing organic matter, such as methane, into the atmosphere, and mobilizing stored elements, such as metals and nutrients, from wetland soils into river and stream systems.

SITE DESCRIPTION: ACTIVE LAYER NETWORK CIRCLE

Circle's active layer site was established in 2008 and is located at Longitude -144.08° and Latitude 65.83°, with an elevation of 185 meters. The 50 m² grid at the Circle site is in an imperfectly drained area of open, flat tundra. Vegetation consists of low tussocks, low bush berries, and sparsely scattered black spruce. The topsoil is peat, with soft clay at greater depths. The soil profile consists of 5 cm of sphagnum moss, 6 cm of organic material, 17 cm of dark organic material, and 63 cm of silty clay to permafrost at 91 cm depth. A 50 m² grid is established, with sensors for air temperature, soil moisture, and soil temperature that record data every 30 minutes,

CONTINUED: ACTIVE LAYER NETWORK CIRCLE

following the protocols of the Circumpolar Active Layer Monitoring (CALM) Program. Continuous soil temperature and moisture sensors are located above permafrost and just below the surface. The depth of the active layer is measured each year at each grid location. Measurements are taken every 5 meters for a total of 100 measurements. Measurements are made with a calibrated 2.1-meter steel rod with a blunt tip and a T-handle grip.



Picture of the Active Layer site in 2019

SITE DESCRIPTION: ACTIVE LAYER NETWORK FORT YUKON

Fort Yukon's first active layer site was established in 2009 and was located approximately 8 miles up the Porcupine River on the South bank at Longitude -145.18° and Latitude 66.59°, with an elevation of 140 meters. The site was an imperfectly drained open grassy space surrounded by willows and black spruce. The ground level slants slightly inward toward the center and



Picture of the Active Layer site in 2009

CONTINUED: ACTIVE LAYER NETWORK FORT YUKON

is marshy throughout the area. At each site, a 50 m² grid is established, with sensors for air temperature, soil moisture, and soil temperature that record data every 30 minutes, following the protocols of the Circumpolar Active Layer Monitoring (CALM) Program. Continuous soil temperature and moisture sensors are located above permafrost and just below the surface. The depth of the active layer is measured each year at each grid location. Measurements are taken every 5 meters for a total of 100 measurements. Measurements are made with a calibrated 2.1-meter steel rod with a blunt tip and a T-handle grip. The active layer site became too wet for maintaining the sensors and was removed in 2014.

A new site was established in 2021, located approximately 2.8 miles northeast of Fort Yukon at longitude -145.14° and latitude 66.57°, with an elevation of 137 meters. Sensors were installed below the top mossy soil at 15 cm, with the following 45 cm as dense organic soil. The layer just above permafrost was sandy-loam soil and scattered gravel. Sensor above the permafrost was installed at 85 cm.



Picture of the Active Layer site in 2021

