

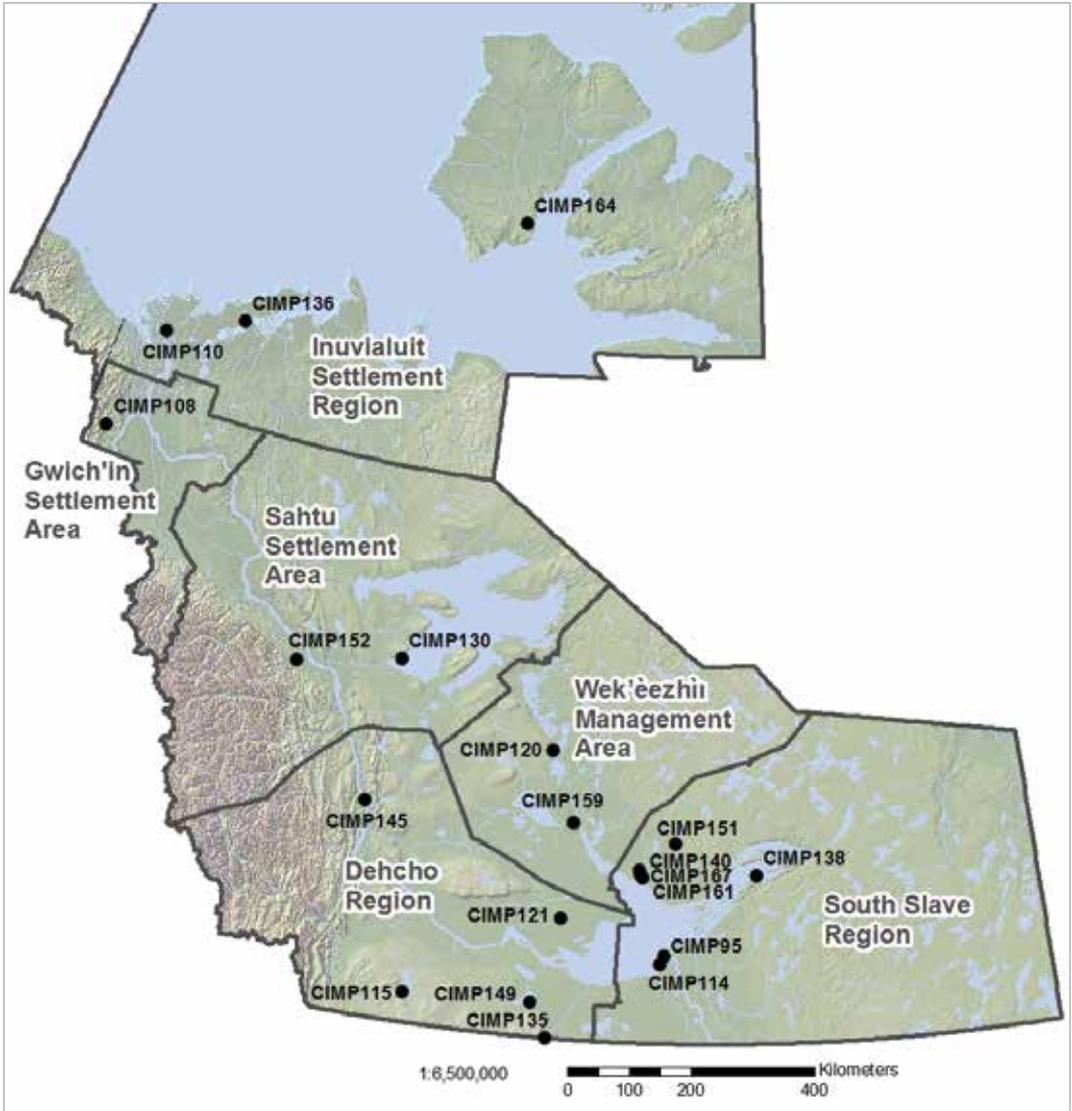
Monitoring and Research Results 2010-2015

NWT Cumulative Impact
Monitoring Program
(NWT CIMP)

WATER



NWT CIMP-funded water projects in the NWT



Cover illustration by Trey Madsen

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October 2016

About the Northwest Territories Cumulative Impact Monitoring Program (NWT CIMP)

The Northwest Territories Cumulative Impact Monitoring Program (NWT CIMP) coordinates, conducts and funds the collection, analysis and reporting of information related to environmental conditions in the NWT. Its main purpose is to support better resource management decision-making and sustainable development in the territory by furthering our understanding of cumulative impacts. Based on the priorities of environmental regulators, co-management boards and Aboriginal organizations, the program has focused on caribou, water and fish since 2011.

NWT CIMP strives to place research and monitoring results in the hands of those who need it to make decisions. As such, the program focuses on reporting back to communities and to environmental regulators who can use the information to manage the land and water. This booklet of water monitoring and research is one way in which the program shares results. Other means include community presentations by researchers, regional results workshops, peer-reviewed publications and online through the NWT Discovery Portal.

NWT CIMP annually funds approximately 30 projects, providing \$1.5 million to research and monitoring of cumulative impacts in the Northwest Territories. This publication provides high level summaries of the results from the water research and monitoring projects that were funded in 2010-2015 (see map on previous page).

For more information on the program, visit www.nwtcimp.ca. For NWT CIMP project results, visit nwt.discoveryportal.enr.gov.nt.ca or email the principal investigator directly.

Contents

Inuvialuit Settlement Region

- CIMP110** Using Inuvialuit observations to monitor change in the Mackenzie Delta Region..... 2
- CIMP136** Environmental conditions and beluga whale entrapment events in the Husky Lakes..... 4

Gwich'in Settlement Area

- CIMP108** Mega-scale permafrost disturbances and their effects on terrestrial and aquatic systems in the Richardson Mountains, NWT..... 6

Sahtú Settlement Area

- CIMP130** Community-based water quality monitoring in Great Bear Lake..... 8
- CIMP152** Establishing a watershed framework for assessing cumulative impacts of development..... 10

Dehcho Region

- CIMP121** Landscape scale flooding in the Great Slave Lake Plain: Expansion of lakes, flooding of wetlands and implications to bison habitat and local land users..... 12
- CIMP135** Transboundary Monitoring Program – Hay River water and suspended sediment quality 14
- CIMP149** Investigating the cumulative impacts of environmental change and human activity in the Tathlina watershed..... 16

Wek'èezhì Management Area

- CIMP120** Tłıchǫ aquatic ecosystem monitoring program..... 18
- CIMP159** Marian watershed community-based Aquatic Effects Monitoring Program..... 20

South Slave Region

- CIMP95** Community monitoring of the Great Slave Lake ecosystem 22
- CIMP114** Slave River and Delta Partnership project vulnerability assessment for the Slave River and Slave River Delta, and sediment core sampling to assess contaminant deposition to the Slave River Delta over time..... 24
- CIMP138** Cumulative impact monitoring in Thaidene Nëné – Ni Hat'ni Dene Program 26
- CIMP140** Changing hydrology in the Taiga Shield: Geochemical and resource management implications 28
- CIMP151** Establishing a water quality dataset for cumulative effects assessment in the North Slave..... 30
- CIMP161** Cumulative impact monitoring of aquatic ecosystem health of Yellowknife Bay, Great Slave Lake..... 32

Multi-Regional

- CIMP115** Water monitoring capacity building..... 34
- CIMP145** Implementing collaborative cross-NWT water quality monitoring to address the needs of water partners, focusing on cumulative impacts and community concerns 36
- CIMP164** Mapping permafrost disturbance and impacts to aquatic systems across the northern NWT..... 38
- CIMP167** Changes in dissolved organic carbon quality and quantity: Implications for aquatic ecosystems and drinking water quality for northern communities 40

Years Funded: 5

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Using Inuvialuit observations to monitor change in the Mackenzie Delta Region

Purpose

In this research project we used participatory multimedia mapping (PMM) to record Inuvialuit environmental observations. PMM combines 'on-the-land' interviews with videos and photographs captured by program monitors. Observations recorded by local experts focused on a range of topics, including disturbances (drained lakes, thaw slumps, storm surges), threats to infrastructure (winter icings, coastal erosion, failed culverts), local changes in weather, the locations of fish and wildlife habitat, and areas of cultural significance. Participant observations were combined with photo, video and audio recordings that were organized in a web-based map called the Inuvialuit Knowledge Keeper (<http://inuvialuit.kwusen.com>) maintained by the University of Victoria. Ultimately, this project provides a regional atlas describing the dynamic state of the environment in the Inuvialuit Settlement Region.

Key Findings

- The PMM protocol was used to record local observations at 179 sites identified by 46 Inuvialuit monitors and the project steering committee.
- Several monitoring themes relating to water emerged from the field and the results of 72 interviews conducted with regional experts.
- Water-related themes included changes in hydrology (drained lakes, sedimentation) near Aklavik affecting muskrat habitat and travel, changing ice conditions in the delta lowlands, and increased sedimentation of rivers important for travel.

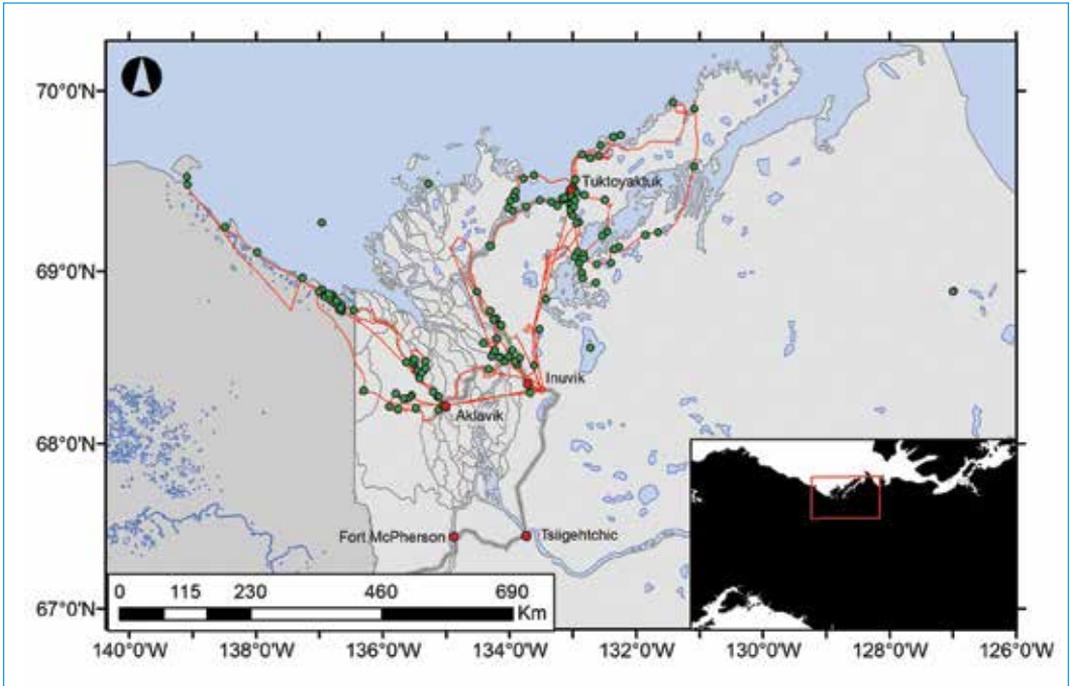


Figure 1: Map of study region with Delta communities (red points) showing terrain covered by program monitors (red lines) and sites monitored (green points). Inset at the bottom right shows the position of the study area in western North America. This map includes sites discussed in interviews conducted between 2012 and 2014.

How does this project help in understanding cumulative impacts?

This protocol provides a flexible and effective way to document environmental observations as well as traditional ecological knowledge and is intended to be used by any group or organization interested in monitoring in the NWT (with permissions). A Master's student at the University of Victoria is currently working on a project that integrates PMM, ecological field sampling and remote sensing to investigate local observations suggesting that regional changes in hydrology are linked to declining muskrat populations.

Years Funded: 1

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Environmental conditions and beluga whale entrapment events in the Husky Lakes

Purpose

To compile archived environmental data to analyze beluga whale entrapment events in Husky Lakes and Liverpool Bay near Tuktoyaktuk, NWT.

Key Findings

- Beluga whales use Liverpool Bay in summer and some occasionally go into the Husky Lakes, where they can become trapped if they do not depart prior to freeze-up. We built a database of entrapment events using a variety of literature sources, documenting seven entrapments since the 1960s (1-2 events per decade).
- We built databases for sea ice (thickness, concentration and seasonal cycle) and air temperature using archived data. Risk of entrapment may be related to sea ice conditions in the southern Beaufort Sea. Heavy spring ice conditions could result in delayed access to important feeding opportunities in Liverpool Bay and the lake system, and late arrival could subsequently result in delayed departure and increased entrapment risk.
- Entrapment years are characterized by heavy ice cover (> 80%) early in the ice season, with > 60% cover extending into mid-June. Ice cover conditions were also similar, however, for many years in which an entrapment did not occur. No entrapments have occurred in the years with lowest May-June ice concentrations. The data suggest that entrapments do not occur in low ice years, but these low ice years have also rarely occurred in the past. Ice thickness and air temperature data showed no obvious relationships to entrapment occurrence.

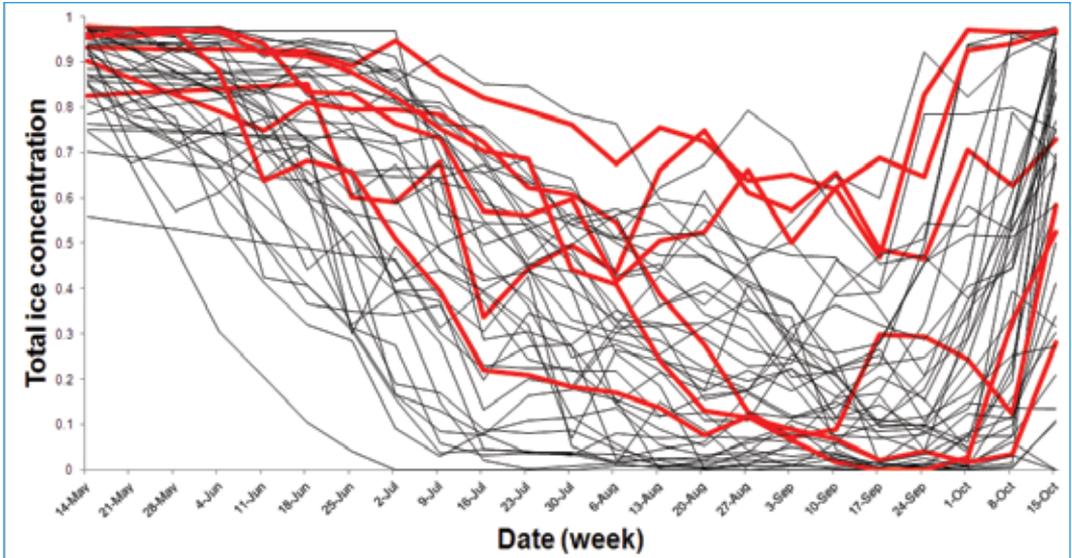


Figure 2: Annual time series of May-October ice cover for 1968-2011 in the Mackenzie subregion (as defined by the Canadian Ice Service). The red lines are years in which a beluga whale entrapment in the Husky Lakes did occur ($n = 6$) and the black lines are non-entrapment years.

How does this project help in understanding cumulative impacts?

The project synthesized available information into a database of beluga entrapment events, which co-managers can use as a baseline for future monitoring, data collection and reporting. The project also collated sea ice and weather data from a variety of sources and produced time series datasets that can be used for additional research and monitoring.



Beluga whales entrapped in Husky Lakes. Photo: J Orr, DFO, November 2006.

Years Funded: 5

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Mega-scale permafrost disturbances and their effects on terrestrial and aquatic systems in the Richardson Mountains, NWT

Purpose

To examine the impacts of permafrost degradation (i.e. thaw slumps) on aquatic life in streams by monitoring bugs known as benthic macroinvertebrates. Benthic macroinvertebrates are an important food source for aquatic animals, including fish.

Key Findings

- Permafrost thaw, in the form of large thaw slumps, is a major stressor on aquatic ecosystems in the Richardson Mountains.
- Total suspended solids (TSS) concentration, which is the cloudiness of the water, was significantly different near all disturbances, with TSS increasing with increasing disturbance levels.
- Highly disturbed sites, impacted by more than two slumps, had significantly fewer (an order of magnitude lower) macroinvertebrates than undisturbed sites. Conversely, there was a significant positive relationship between abundance and distance from a disturbance.
- In general, high concentrations of TSS related to permafrost thaw leads to a reduction of all invertebrates. It does not appear to affect only certain types of macroinvertebrates.
- With respect to community composition (types of bugs found at site), increases in both TSS and nutrient concentrations appear to be the cause of community differences between highly disturbed and undisturbed sites. Highly disturbed sites were more similar compared to other levels of disturbance. Similarly, undisturbed sites were more similar to each other compared to other levels of disturbance.

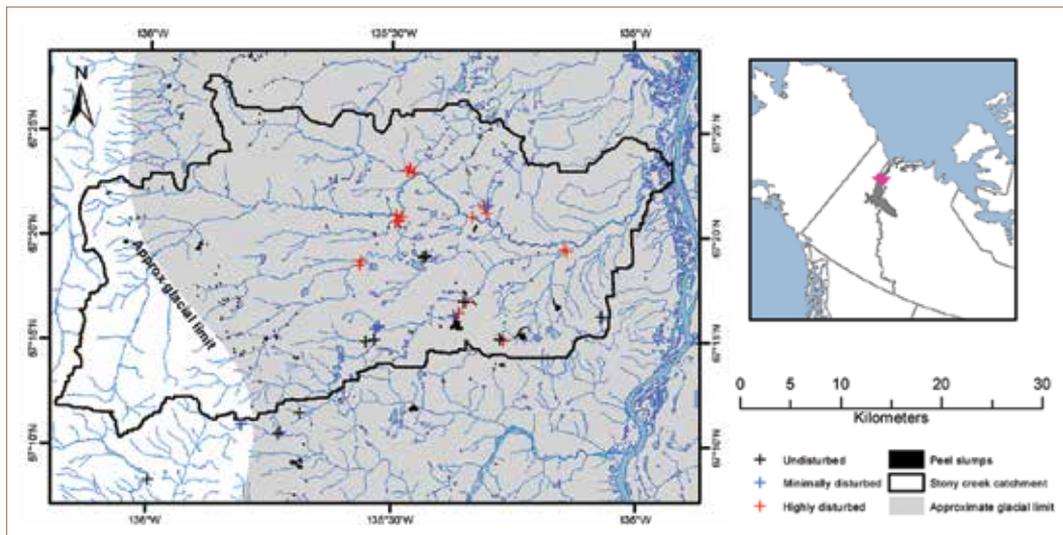


Figure 3: Map showing the Peel Plateau, the Stony Creek watershed and study sites. Inset shows the location of the study area within Canada.

How does this project help in understanding cumulative impacts?

This research gives insight on how large-scale permafrost disturbances influence stream macroinvertebrates, which can then have cumulative impacts on other aspects of the food web, such as fish. The work also defines current baseline conditions in the Richardson Mountains, which is important when discerning between natural versus anthropogenic changes of water quality indicators.



Thaw slump in the Richardson Mountains.

Years Funded: 1

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*This project has now
been incorporated into
an ecosystem study
(CIMP127) conducted
by the Department of
Fisheries and Oceans
(2012-present).*

Community-based water quality monitoring in Great Bear Lake

Purpose

To implement a long-term water quality monitoring program of Great Bear Lake (GBL) that collects scientifically robust baseline data, incorporates traditional knowledge and builds local capacity to better understand the cumulative impacts of climate change.

Key Findings

- Integration of scientific and traditional ecological knowledge occurred through scientific sampling and community workshops. Scientific and traditional ecological knowledge together informed the design of the water quality monitoring program.
- Developed local capacity by administering the monitoring program through the DRRC and by training local water quality monitors.
- Results indicate that arms of GBL are becoming either completely or partially stratified (changing temperature at different depths due to the change in water density with temperature). This represents a fundamental shift from the historically reported isothermal conditions. These findings are consistent with traditional and local knowledge provided by community members regarding changing ice conditions and climate change impacts.



Russell Kenny and Chris Yukon collecting samples. Photo: L. Nesbitt.



Figure 4: Initial Great Bear Lake water quality monitoring sampling sites.

How does this project help in understanding cumulative impacts?

This project has been incorporated into other local research that involves continued sampling by community monitors to better inform good management decisions. This monitoring helps to understand current baseline water quality at several locations in GBL and may assist in detecting and understanding future changes in the aquatic ecosystems.

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Establishing a watershed framework for assessing cumulative impacts of development

Purpose

To develop an understanding of the cumulative impact of various disturbances on aquatic systems in an area of significant oil and gas exploration in the Sahtú Region, in particular, for watersheds draining the eastern foothills of the Mackenzie Mountains.

Key Findings

- Preliminary findings from 2013 and 2014 macroinvertebrate data demonstrated that there were no obvious trends/patterns in invertebrate abundance or composition with respect to a rudimentary classification of disturbances in the watersheds.
- 2015 data will be used along with a more refined system of measuring disturbances on the landscape to analyze invertebrate abundance and community structure.
- The study has expanded to include coring work to determine historical hydrocarbon concentrations in the area of potential development using lake sediments.
- The project has helped to support two successful eight-day cross-cultural camps with researchers and traditional knowledge holders, and environmental monitors-in-training.
- A video describing aquatic sampling activities in the Sahtú is available at www.enr.gov.nt.ca/programs/nwt-cimp.



Local community monitors-in-training learning aquatic data collection methods.

How does this project help in understanding cumulative impacts?

The project provides baseline information on aquatic health, which is critical to assessing cumulative impacts. Disturbances on the landscape have been and are currently being mapped and measured as part of the analysis to determine how they are or are not impacting the aquatic environment. Analyses of the benthic invertebrate data will lead to the development of statistical models that will describe important variables that influence aquatic health. Analysis of the remote sensing data will help determine parts of the landscape most susceptible to terrain disturbances.

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Landscape scale flooding in the Great Slave Lake Plain: Expansion of lakes, flooding of wetlands and implications to bison habitat and local land users

Purpose

To use scientific and traditional knowledge to track and understand causes of abrupt landscape scale flooding and ecosystem change in the Great Slave Lake Plain area, assess the cumulative effects of environmental stressors driving this change and determine the implications for wildlife management, particularly bison and moose, as well as local land use activities.

Key Findings

- Tree ring records suggest the Mackenzie Bison Sanctuary (MBS) region has been wetter than average over the last century.
- The proportion of the MBS occupied by water doubled between 1986 and 2007, and low-lying meadows, which provide most of the grazing habitat for bison, experienced the greatest amount of flooding.
- Between-year changes in lake size from 1986 to 2011 was correlated with the July to October Pacific/North American pattern, a large-scale pattern of weather anomalies that is correlated with warmer and wetter winters in Great Slave Lake region. Between-year changes in lake size were also correlated with local temperature and precipitation records.
- Analysis of lake sediment cores revealed the scale of recent lake expansion exceeded others within the past 300 years.
- The Palmer Drought Severity Index (PDSI) is a climate index that incorporates aspects of both temperature and precipitation, and is designed to measure the intensity, duration and spatial extent of drought. The PDSI reconstruction indicates that, on average, climate conditions in the MBS have remained stable between 1915 and 2011; however, variability has increased.

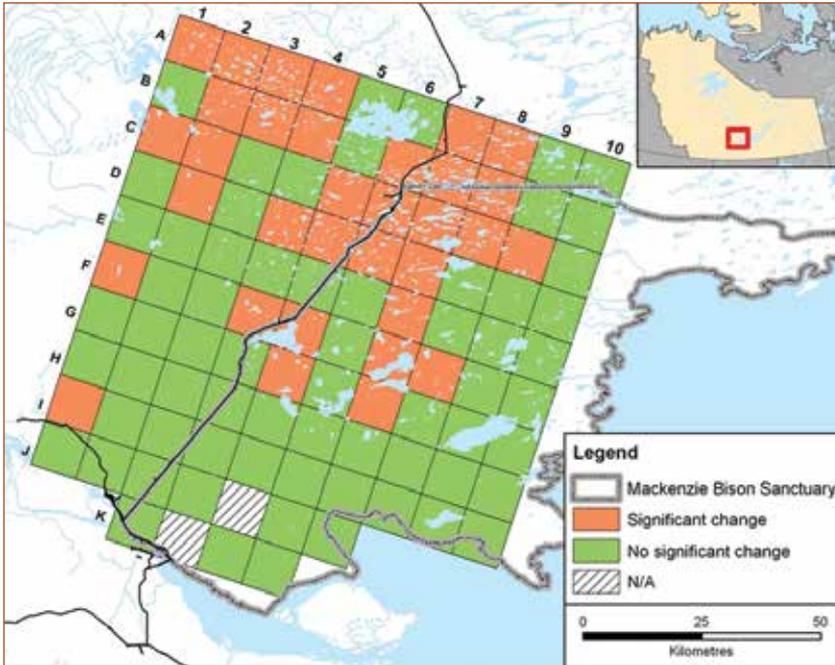


Figure 5. Grid map of the study area, highlighting areas of significant change (red) and non-significant change (green). N/A = Not Applicable, meaning no lakes are present within these grid cells.

How does this project help in understanding cumulative impacts?

This project provides important information on the potential cyclicity and cause(s) behind recent lake expansion, which will also be applicable to other regions undergoing lake expansion as a result of recent environmental changes. Project results will also provide essential information required for wildlife and ecosystem management and planning in the region from the Horn Plateau to Great Slave Lake.



Recently expanded lake that has expanded into bison habitat.

Years Funded: 1

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Transboundary Monitoring Program – Hay River water and suspended sediment quality

Purpose

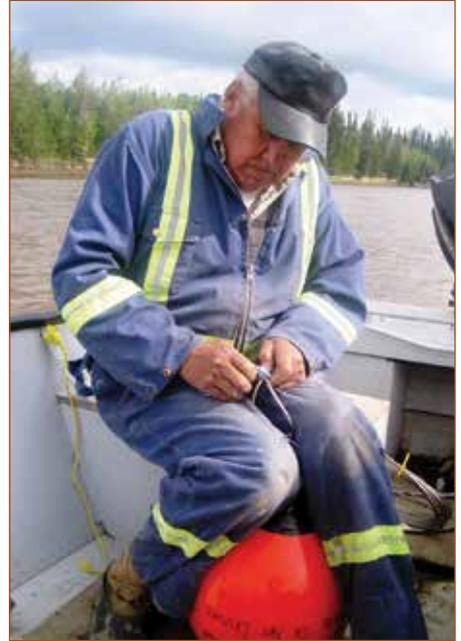
Building on the Environment Canada Hay River water quality monitoring program, the GNWT Transboundary (TB) Monitoring Program involves the collection of water and suspended sediment samples. These samples are analyzed for routine substances, such as nutrients and metals, but also for organic substances, such as hydrocarbons, pesticides and polychlorinated biphenyls (PCBs). The data generated from both the Environment Canada and TB Monitoring Programs were used to develop a summary report entitled Water Monitoring Activities in the Hay River Region (2014).

Key Findings

- While amounts vary from year to year, and were particularly low in the fall of 2012, the volume of water in the Hay River has generally remained relatively stable since monitoring began in 1963. Only a slight increasing trend in winter flow was revealed.
- Some changes in water quality were also found, such as increasing trends in phosphorus and decreasing trends in calcium, magnesium and sulphate. This means that the levels of these substances have changed since sampling began in 1988. Further work is needed to understand the ecological significance of these trends.
- Levels of organic substances in the water and suspended sediment samples collected from the Hay River are low and below the Canadian Environmental Quality Guidelines (CCME) guidelines for the protection of aquatic life (where guidelines exist).
- Overall, the water quality and quantity of the Hay River is good. Continued monitoring activities will increase our knowledge of this important river and help to identify changes.



The Hay River at Enterprise.



Robert Lamalice of the K'at'odeeche First Nation. Robert has contributed to the program since 2011.

How does this project help in understanding cumulative impacts?

Working cooperatively with members of the K'at'odeeche First Nation provides learning opportunities for everyone. Continued water and suspended sediment quality sampling on the river will help to identify trends in water and/or suspended sediment quality due to climate variability and/or upstream resource development. Potential impacts of climate change will be difficult to quantify without an understanding of baseline water chemistry.



Centrifuge equipment mounted on boat anchored in the river. Centrifuge runs for up to 24 hours and collects the suspended sediment from the river. Both the suspended sediment and water are analyzed for many different substances, including metals and hydrocarbons.

Years Funded: 4

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Investigating the cumulative impacts of environmental change and human activity in the Tathlina watershed

Purpose

The central objective of this project was to develop a better understanding of how upstream industrial development and regional environmental change may be influencing the lakes and rivers of the Tathlina watershed. Indicators of ecosystem health were monitored in the Cameron River and in Tathlina Lake. To assess present and past contaminant loading in the watershed we analyzed polycyclic aromatic hydrocarbons (PAH) burdens in benthic invertebrates from the Cameron River and paleorecords from lakes adjacent to oil and gas development areas. In partnership with the Ka'a'gee Tu First Nation, a regional community-based monitoring (CBM) program was developed to monitor future environmental change in the Tathlina watershed. Regional water quality monitoring continues as part of the GNWT territory-wide Community-based Water Quality Monitoring Program supported by Environment and Natural Resources (see CIMP145).

Key Findings

- Changes related to climate warming are ubiquitous in the lakes of the Tathlina watershed. In contrast, there was very little indication of impact from local oil and gas development in the lakes and rivers of the watershed.
- Drainage patterns, terrestrial carbon and mercury transport to aquatic ecosystems are being altered by peat subsidence in the lowlands region around Tathlina Lake, resulting in increased dissolved organic carbon and sedimentary mercury concentrations in lakes.
- Hydrocarbon pollution (PAHs) in stream invertebrates are not elevated in sites downstream of the Cameron Hills oil and gas development.
- Tathlina Lake is a large and very shallow lake, consequently, by mid-winter under ice dissolved oxygen concentrations are low (~3mg/L). Paleorecords indicate that primary production has increased in Tathlina Lake in the recent past and may exacerbate low levels of dissolved oxygen in the lake during the winter, which can negatively impact fish populations.

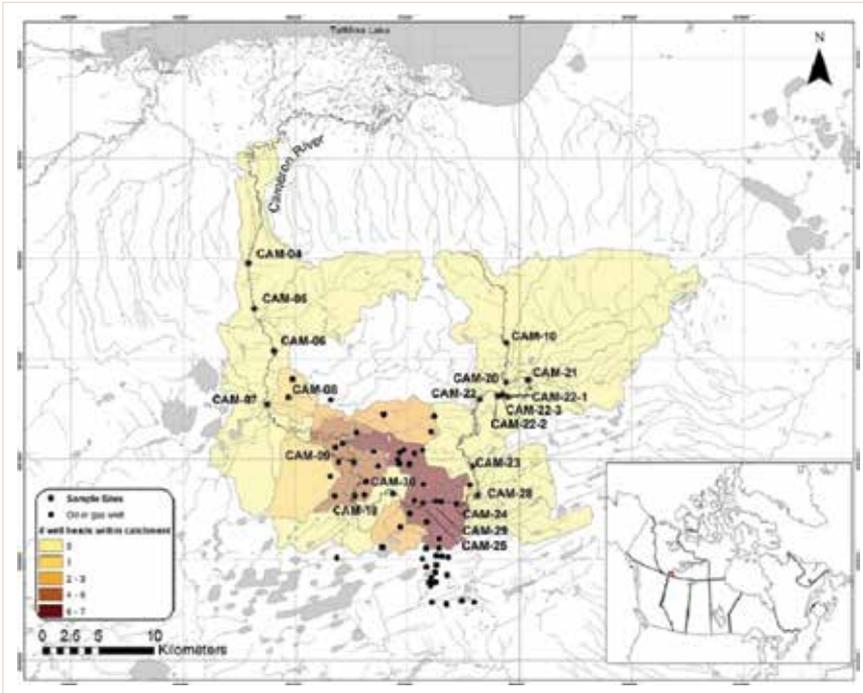


Figure 6: Map of the Cameron Hills showing the locations of sampling sites along the Cameron River and the locations of oil and gas wells (both active and shut-in). The coloured polygons represent the amount of cumulative oil and gas wells in the subcatchments that influenced each of the sampling points in the Cameron River. Inset shows the location of the Cameron Hills within Canada.

How does this project help in understanding cumulative impacts?

This project monitored the impacts of development and landscape change in the Tathlina watershed. A new methodology was developed to monitor indicators of ecosystem health when assessing the impacts of oil and gas development on receiving aquatic systems. This methodology is now being applied in the Central Mackenzie Valley to help establish baseline PAH levels in benthic invertebrates of streams in the region prior to increased oil exploration. Baseline information can be used for cumulative impact assessment and future cumulative impact monitoring initiatives.



George and Melaine Simba (Ka'á'gee Tu First Nation) participating in the Tathlina Watershed Community-based Monitoring Program.

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Tłı̨chų aquatic ecosystem monitoring program

Purpose

To determine fish health, water and sediment quality near Tłı̨chų communities, using Tłı̨chų and scientific knowledge. Tłı̨chų community members, including elders and youth, are directly involved in the monitoring and exchange of information with research scientists in communities and on-the-land settings. Samples were collected from lakes near each of the four Tłı̨chų communities (Behchokò, Wekweètì, Gamètì and Whatì).

Key Findings

- Results suggest that fish, water and sediment quality are considered to be good – that is, not abnormal.
- Results were presented in all Tłı̨chų communities to assist with the interpretation and understanding of results.



Youth participating in hands-on learning by collecting sediment samples, Behchokò.
Photo: M. Schnurr.

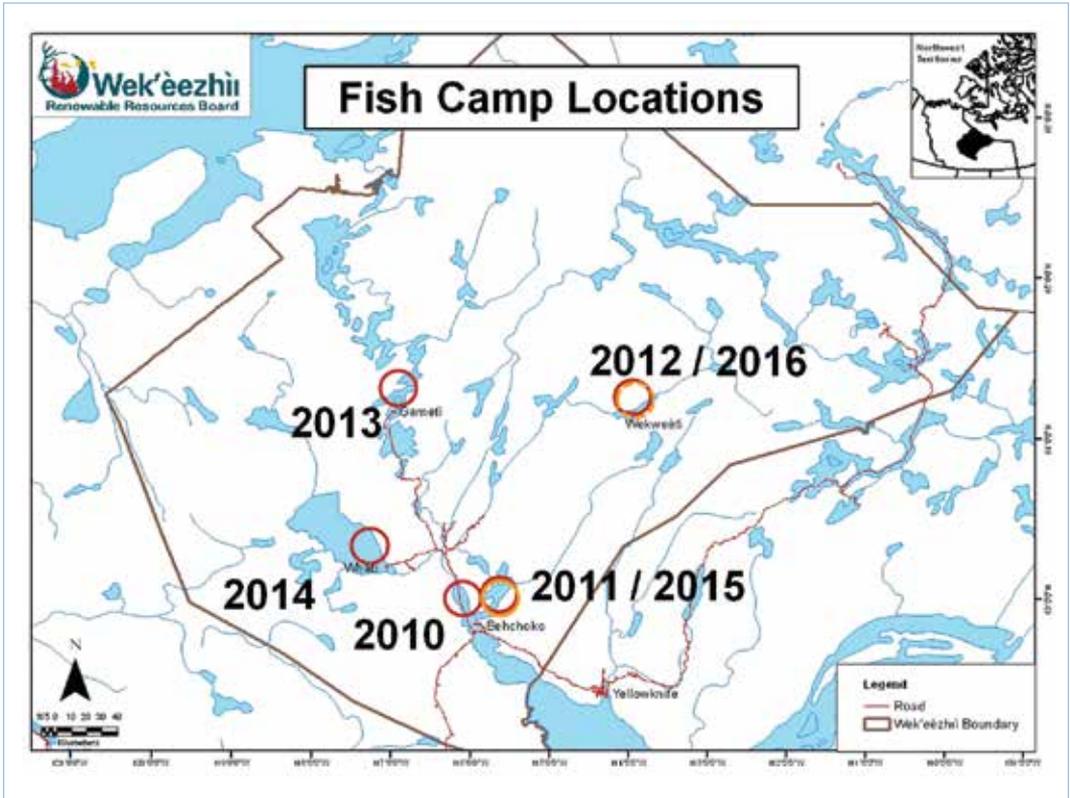


Figure 7: TAEMP fish camp and water sampling locations 2010 to 2015. Solid orange line shows location of camp/sampling activities near Behchokò 2011 to 2015, and the dotted orange is where the camp will occur in September 2016 near Wekwèètì. Red = baseline sampling phase, orange = comparative sampling phase.

How does this project help in understanding cumulative impacts?

This project helps to establish ecological baseline conditions for fish health, water and sediment quality. Establishing baseline datasets will enable the monitoring of temporal and spatial trends over time.



Paul Vecsei demonstrating how to extract the ear bone (otolith) so that the fish can be aged. Gamètì. Photo: S. Elsasser.

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Marian watershed community-based Aquatic Effects Monitoring Program

Purpose

The Tłıchǫ community-based Aquatic Effects Monitoring Program (AEMP) was designed to link industry and community monitoring by using the same methodology and analyses. It was built and is operated by the Tłıchǫ Government and Tłıchǫ citizens. The purpose of the program is to implement a long-term, community-based Tłıchǫ AEMP to monitor water, fish and sediment quality in the Marian Watershed near the NICO – Gold-Cobalt-Bismuth-Copper Project, and other past and future developments. Analyzed sediment cores provide results for a suite of parameters to reconstruct past hydro-ecological conditions and to identify the range of natural variations in metal concentrations.

Key Findings

- 22 Tłıchǫ community members have been trained in water sampling and fish collection.
- The Tłıchǫ Government has adopted monitoring protocols for monitoring on Tłıchǫ lands.
- Scientific baseline data is being collected in places that are important to Tłıchǫ community members.
- Sampled fish were good to eat. Mercury levels in fish were low.
- Water and sediments samples were normal.
- Communities trust the program.



Nicole Dion demonstrates handling of water quality samples. Photo: Nicole Dion (GNWT ENR).

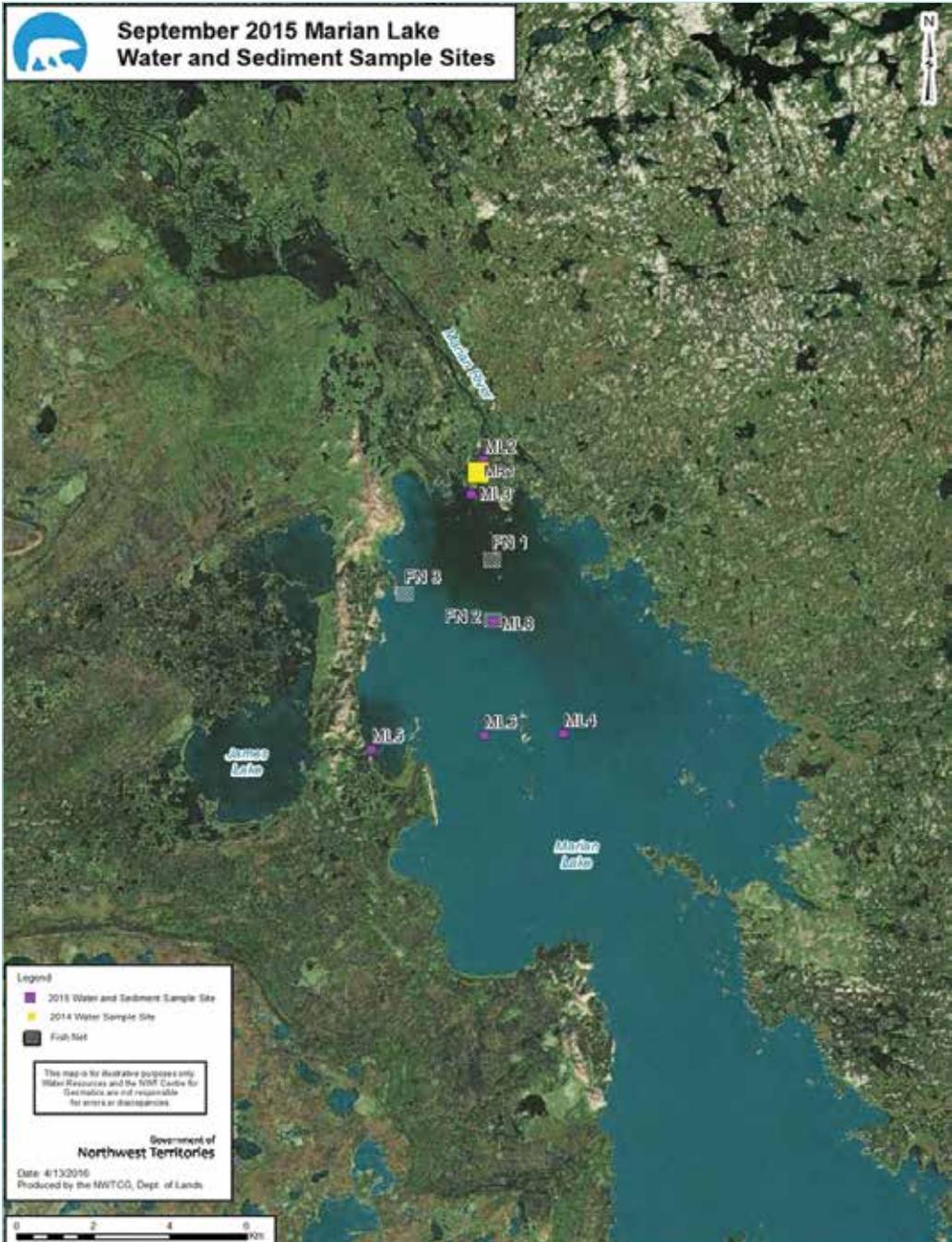


Figure 8: Map of net and water sampling locations.

How does this project help in understanding cumulative impacts?

This project establishes baseline information in order to monitor cumulative effects of development, land disturbance and climate change. Results are shared back to communities by community members. The program ensures further monitoring of Tłıchǫ waters by Tłıchǫ people.

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Community monitoring of the Great Slave Lake ecosystem

Purpose

To develop community capacity by developing a water quality study at the domestic water intake at Fort Resolution located on the Slave River Delta and at several sites within Resolution Bay. The water quality data provides insight into productivity cycles in Resolution Bay, factors affecting mercury trends in fish and addresses concerns about metal levels in drinking water from upstream influences.

Key Findings

- Turbidity varied markedly through the year, increasing in June and remaining high through November, but was always below Canadian Council of Ministers of the Environment (CCME) guidelines. Variations in turbidity were related to Slave River inflow, but also to winds, which re-suspended sediments in this shallow bay, which has a long fetch. Climate variability may affect differences in turbidity patterns between years; water circulation also is affected.
- Metal concentrations of, for example, arsenic, were below CCME drinking water quality guidelines. Total phosphorus and total nitrogen concentrations often were high, with seasonal patterns correlating with turbidity and reflecting the strong influence of the Slave River in bringing nutrients into the West Basin.
- Chlorophyll concentrations generally were low, peaking in spring and fall; the beginning of the spring phytoplankton bloom was detected while the Bay was still ice covered.



Figure 9: Location of water sampling sites near Fort Resolution, NT.

How does this project help in understanding cumulative impacts?

Primarily a capacity-building project, hands-on training to community members in sample collection, data entry, graphing and interpretation occurred. This intake monitoring project presently continues with a decreased number of parameters being measured.



Elizabeth Giroux filtering water for chlorophyll analysis. Photo: M. Evans.

Years Funded: 1

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SRDP vulnerability assessment for the Slave River and Slave River Delta, and sediment core sampling to assess contaminant deposition to the Slave River Delta over time

Purpose

The Slave River and Delta Partnership (SRDP) was formed in 2010 to support communities along the Slave River and Delta develop community-based monitoring and research programs to address concerns and questions raised by local residents about the water and the aquatic ecosystem from a whole watershed perspective.

The SRDP worked together on:

1. A State of the Knowledge of the Slave River and Slave River Delta Report, which consolidated a large amount of information (including both scientific information and available traditional and local knowledge) on the Slave River and Delta (e.g. 'what do we know');
2. A Vulnerability Assessment of the Slave River and Delta to identify and prioritize monitoring and research activities (e.g. 'what do we need to know' and 'what do we want to know first'); and
3. Sediment core sampling to assess contaminant deposition to the Slave River Delta over time.

Key Findings

- Some of the top priorities from the vulnerability assessment included: determining why flow is reduced and why seasonal patterns have changed; assessing fish tissue for changes in texture, taste and contaminant exposure; and monitoring muskrat and beaver populations as important fur species and potential indicators of water quality and quantity.
- Water quality was rated as the highest monitoring priority, particularly monitoring of hydrocarbons and metals due to community concerns related to potential downstream effects of oil sands development. Wildlife and hydrology were the next highest ranked indicators, respectively.
- Sediment cores were taken from a flood-prone lake (SD2) in the Slave River Delta, which provided a record of organic contaminants and metals deposited before and after development of Alberta's oil sands.

- Results from analysis of the sediment cores showed that the proportion and concentration of river-transported bitumen-associated polycyclic aromatic compounds carried by the Slave River into Lake SD2 during flood stages has not changed substantially between pre- (1967) and post- (1980s and 90s) oil sands development. However, due to lower water levels, flooding of delta lakes has been less frequent in recent decades. Infrequently flooded lakes may not be subjected to the same proportion and concentration of contaminants as river channels.
- Average concentrations of the river-transported bitumen-associated polycyclic aromatic compounds (PACs) at Lake SD2 are less than half compared to a flood-prone lake in the Athabasca Delta (PAD31).
- Potential changes in concentration and proportion of river-transported bitumen-associated polycyclic aromatic compounds could not be assessed during the past decade because Lake SD2 was not frequently flooded by the Slave River.
- Post-1967 concentrations of metals of concern – for example, vanadium, arsenic – normalized to lithium concentration, are within ranges of expected natural variations.
- Concentrations of some metals – arsenic, strontium and calcium – exceeded background levels during the 1950s, which may be associated with Giant Mine production because they coincide with peak emissions from gold smelting.

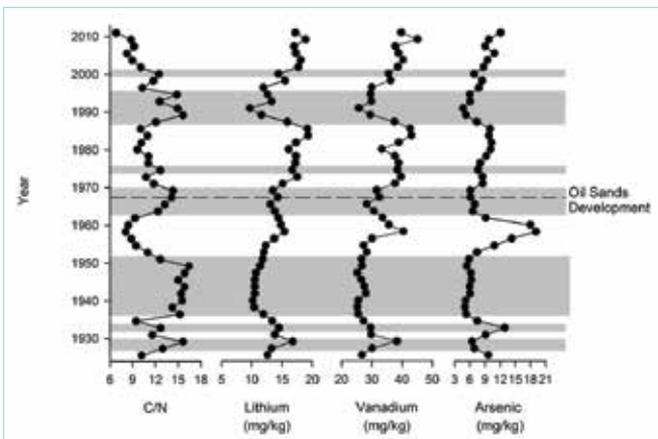


Figure 9: Changes in time of three metals in the sediment core from Lake SD2, Slave River Delta, in relation to past flooding. Grey shading identifies periods of strong flood influence from the Slave River, as recorded by increases in carbon/nitrogen weight ratios reflecting delivery of terrestrial-derived organic matter to the coring site. Lithium is a common metal in natural rocks, is associated with clay-sized minerals and is not influenced by human activities. Vanadium is a naturally occurring metal, but can also serve as an indicator of oil contamination. Notably, the lithium and vanadium profiles co-vary – that is, show the same pattern – suggesting the vanadium is largely natural. While there is generally the same trend with arsenic, notably high concentrations occurred during the 1950s attributed to emissions from Giant Mine [MacDonald et al. 2016, *Science of the Total Environment* 544: 811-823].

How does this project help in understanding cumulative impacts?

The three phases of this project brought together partners to identify monitoring priorities based on concerns about changes in aquatic ecosystem health and potential cumulative impacts of multiple stressors. The project drew on traditional and local knowledge and science together to assess the state of Slave River and Delta and to identify key question and priorities. The SRDP continues its work to address community-identified concerns, the results of which will support ongoing cumulative impact monitoring and decision-making. The results of the sediment core study are also relevant to northern decision-makers.

Years Funded: 3

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Cumulative impact monitoring in Thaidene Nënë – Ni Hat'ni Dene Program

Purpose

To broadly promote stewardship of Thaidene Nënë by conducting environmental monitoring to add to the baseline understanding of local ecosystems as well as monitor how water quality and fish parameters are changing over time in relation to this baseline. Ni hat'ni Dene Program was initiated and implemented by the Łutsel K'e Dene First Nation based upon its own concerns and priorities. Key among these concerns is monitoring whether Great Slave Lake is impacted by the cumulative impacts of industrial development and contaminants.

Key Findings

- Better baseline understanding of East Arm of Great Slave Lake water quality and fish condition and abundance.
- Standardized protocols for water and fish monitoring were implemented at consistent sampling sites, feeding data directly into long-term baseline studies conducted by Environment Canada and fishery assessment work conducted by the Department of Fisheries and Oceans.



Monitors Dillon Enzoe, Morningstar Silas and Dawn Catholique collect water samples near Łutsel K'e, NT.
Photo: J. Morse.

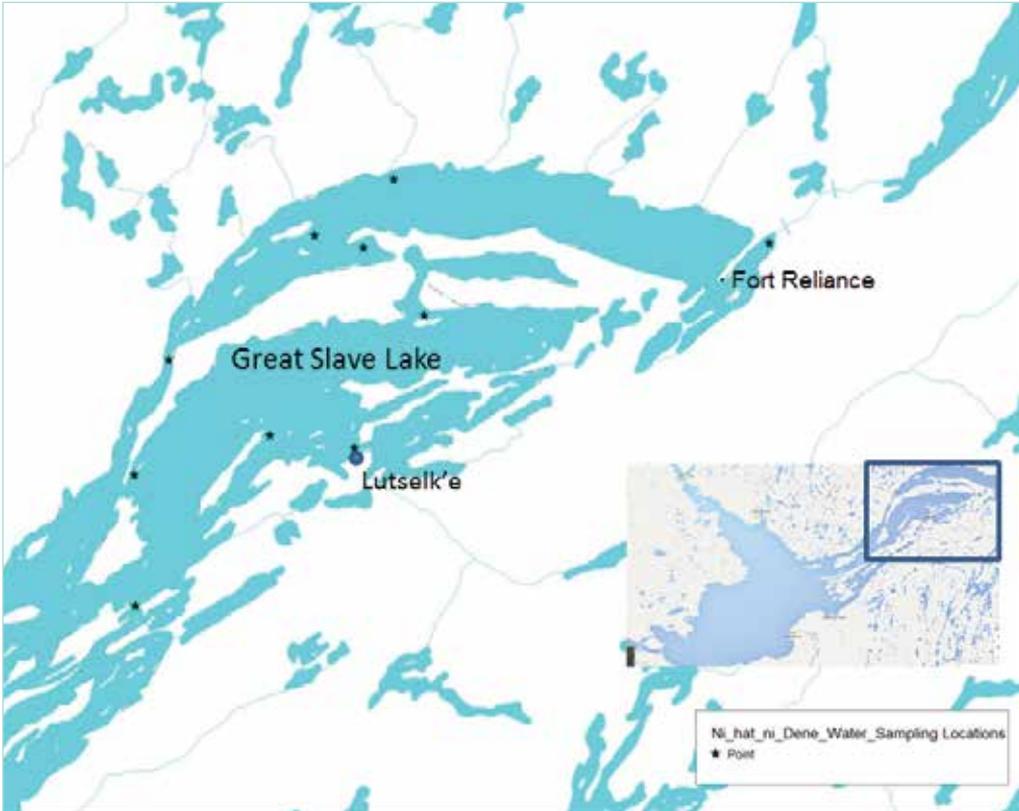


Figure 10: Map of water sampling sites.

How does this project help in understanding cumulative impacts?

This project provides baseline water quality and fish data at locations relevant to the community of Łutsel K'e. Standardized data from multiple years and locations provides important baseline information for a variety of uses, such as integrated fisheries management plans, that can be used to manage cumulative impacts.

Years Funded: 3

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Changing hydrology in the Taiga Shield: Geochemical and resource management implications

Purpose

To describe and understand the consequences of recent changes in streamflow and geochemical regimes in the North Slave Taiga Shield.

Key Findings

- The North Slave Taiga Shield region is experiencing greater autumn rainfalls, which are causing wetlands and headwater lakes to fill with water, resulting in more runoff in the fall and through the winter. The consequences of these changes include higher chemical loads, particularly metals and nutrients, and increasing ice development in stream channels.
- In May 2011, the development of anchor ice in Baker Creek, which flows through the Giant Mine site, forced water into the flood plain causing a spill of contaminated tailings downstream.
- Changes in winter streamflow will continue to pose water management challenges at the Giant Mine site. Baker Creek has the potential to flood the underground workings and release arsenic trioxide to surface waters. The project team continues to address this current risk via any required mitigative measures until the final remediation plan is implemented.



Large icing development in Baker Creek during May 2011 at the Giant Mine, North Slave Region, Northwest Territories. Photo: P. Vecsei.

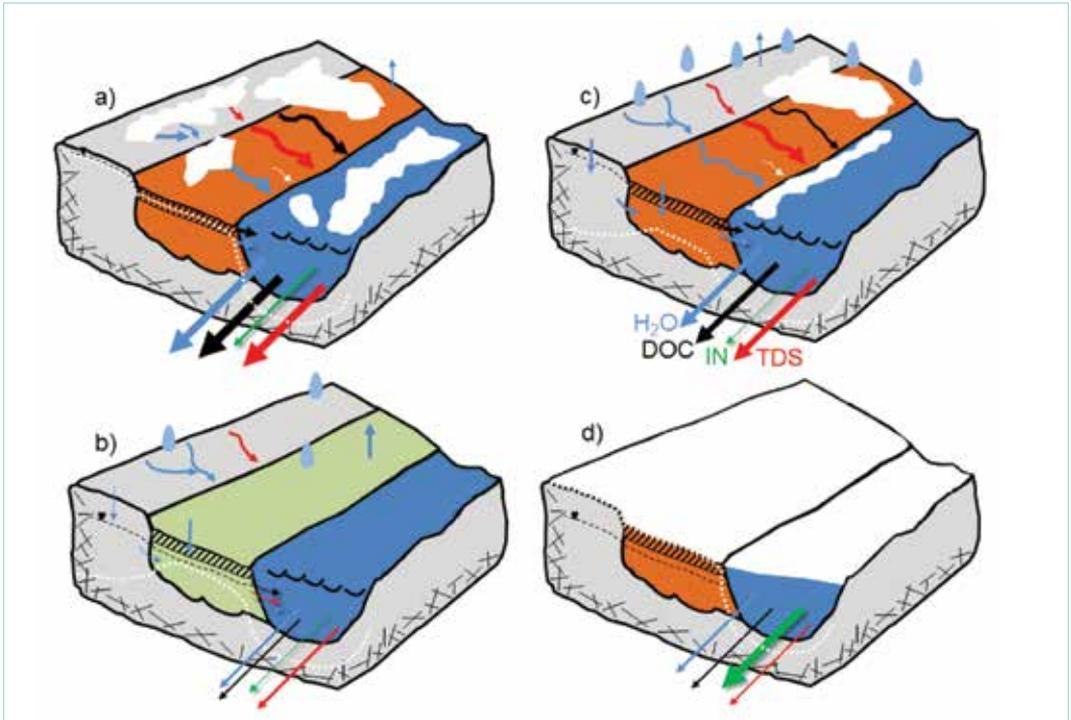


Figure 11: Conceptual model of seasonal water, carbon, nitrogen and TDS flux from northern Precambrian Shield catchments. The grey represents upper hillslope Precambrian bedrock. The orange and green denote conditions of dormant and active vegetation, respectively, in soil-filled areas. The blue represents ponds and lakes along a discontinuous stream network. The hatched area in the soil filled area refers to the zone of high hydraulic conductivity close to the topographic surface. The frost and water tables are denoted by the white dotted and black dashed lines, respectively. Ice and snow are represented by white patches, rain by droplets. The fluxes of water, DOC, TDS, inorganic nitrogen are shown with blue, black, red and green arrows, respectively. The thickness of the arrows denotes the relative flux. The different seasons are represented in: a) spring freshet, b) late summer, c) a wet autumn, and d) winter with enhanced streamflow.

How does this project help in understanding cumulative impacts?

The data provides valuable information for streamflow and chemistry. As baseline conditions change, water management will need to be adapted to address persistent streamflow throughout winter and icing development. Monitoring results of this project suggest there will continually be changes in aquatic chemistry, particularly increased metals and nutrients in Baker Creek. As a consequence, water license limits may need to be re-evaluated by northern decision-makers.

Years Funded: 3

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Establishing a water quality dataset for cumulative effects assessment in the North Slave

Purpose

To compile and consolidate existing water quality information collected from lakes in the North Slave Region in a common database; understand predominant drivers of regional variation; and examine the influence of ice-road construction and operation on water quality of lakes along Tibbitt-Contwoyto winter road corridor.

Key Findings

- A database of existing water quality information from lakes collected by various agencies in the North Slave Region since the early 1990s is now available from NWT CIMP.
- Concentrations of arsenic are elevated in lakes within 17.5 km of Giant Mine relative to lakes beyond this distance. Arsenic concentrations were highest in small lakes (< 100 ha) that were downwind and proximal to the historic stacks, suggesting a gradient in impact from historic roaster operations at Giant Mine consistent with predominant wind direction in the region. Arsenic concentrations were not related to underlying regional geology.
- Concentrations of arsenic are low in popular recreational lakes, such as Walsh Lake and Prosperous Lake, as these lakes tend to be larger and connected to stream networks.
- This project also provided new knowledge about metal and polycyclic aromatic compound (PAC) concentrations in water, sediments and snow of northern remote and developed areas.
- Concentrations of PACs, including those associated with diesel emissions, were variable in water, sediment and snow across all sites sampled along the Tibbitt to Contwoyto Winter Road and around Yellowknife.
- The highest concentrations of PACs in snow were reported in winter road lakes located in the subarctic boreal forest, where forest fires are common. No compositional differences were observed for PACs in sediment and water samples between Yellowknife and winter road lakes.
- We did not observe any evidence of metal contamination in snow collected along the winter road, and metal concentrations in snow from winter road sites were consistently lower than Yellowknife sites.
- Our results show that a high contribution of PACs from natural sources can obscure potential contributions from diesel traffic emissions along the winter road.

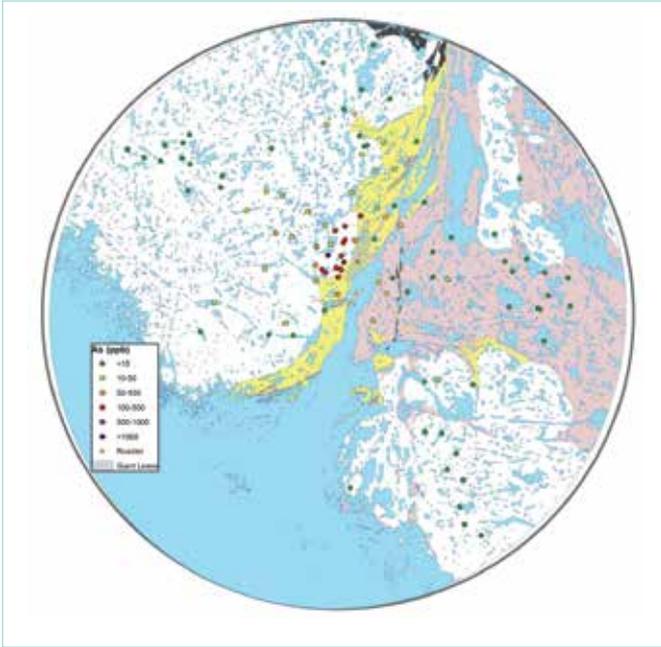


Figure 12: Dissolved arsenic concentrations in surface water samples from 100 lakes in the Yellowknife area. The yellow shaded area in the figure indicates the Yellowknife Greenstone Belt, pink areas are metasedimentary units and the white are granitoids.

How does this project help in understanding cumulative impacts?

Information on elemental and polycyclic aromatic hydrocarbons (PAH) concentrations in the snow pack along the ice road and near Yellowknife provide an important baseline of information to be considered when undertaking cumulative effects research. Our new understanding of arsenic and antimony concentrations near Giant Mine is important in our understanding of cumulative effects of legacy mining activities on local water bodies. This project can also inform good management decisions, so that stakeholders can differentiate between natural variation and anthropogenic influences.

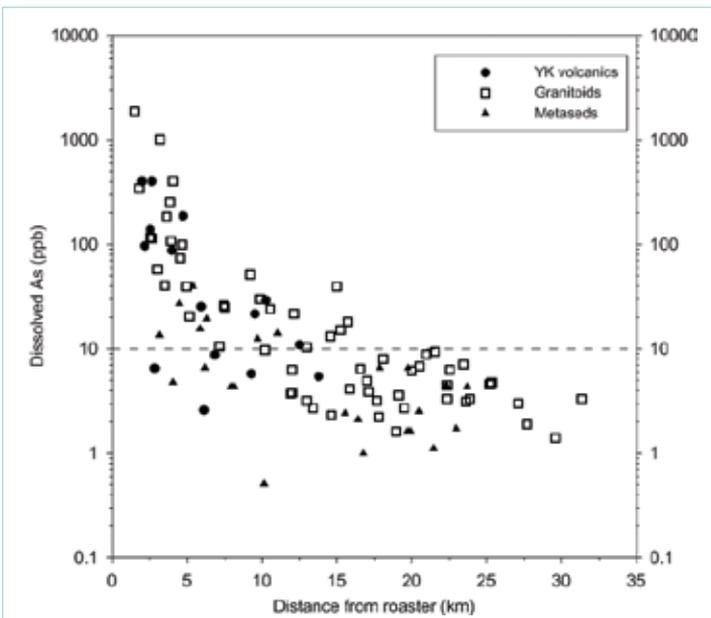


Figure 13: Concentration of dissolved arsenic in lakes with distance from the historic Giant roaster. Sites are symbolized according to underlying generalized bedrock geology. As observed in the figure, lakes on the Yellowknife Greenstone Belt (YK volcanics) are not elevated in arsenic with respect to lakes overlying other bedrock geology units.

Years Funded: 2

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Cumulative impact monitoring of aquatic ecosystem health of Yellowknife Bay, Great Slave Lake

Purpose

To better understand the transport and fate of metals from Giant and Con mines in the water column and lake bed sediments, and to develop new tools for monitoring the aquatic ecosystem's response to the cumulative impact of metal contamination and climate change.

Key Findings

- Total concentrations of arsenic in water were relatively low in Yellowknife Bay (<3ug/L) and Back Bay, although total concentrations were four times higher at Back Bay than at the mouth of Yellowknife Bay and the main body of Great Slave Lake.
- The form of arsenic is important for understanding its toxicity and movement in the environment. Arsenate (a less toxic form) was the dominant inorganic type of arsenic in water at the majority of the sample sites.
- Sunlight oxidizes Arsenite (more toxic) to form Arsenate (less toxic) in nutrient poor northern surface waters. Oxidation occurs more quickly when dissolved organic matter is present.
- Lead isotopes were used to determine the relative importance of watershed versus direct atmospheric loadings of metals. Lead isotope ratios show that the greatest sediment accumulation of lead from mine emissions to Yellowknife Bay occurred in the late 1940s and 1950s.
- Lead isotope ratios have returned to background near Dettah and 20 km south from Giant Mine. Back Bay and Yellowknife Bay continue to accumulate lead released from historical mining activities.
- Historic arsenic pollution contained in Back Bay and Yellowknife Bay is not being fully buried by younger, less contaminated sediment; a significant pool of sediment arsenic has diffused towards the sediment-water interface.
- The presence of cyanobacteria has increased recently and the cyanobacterial community structure has changed significantly over the last 100 years, likely representing a shift in environmental conditions in Great Slave Lake.

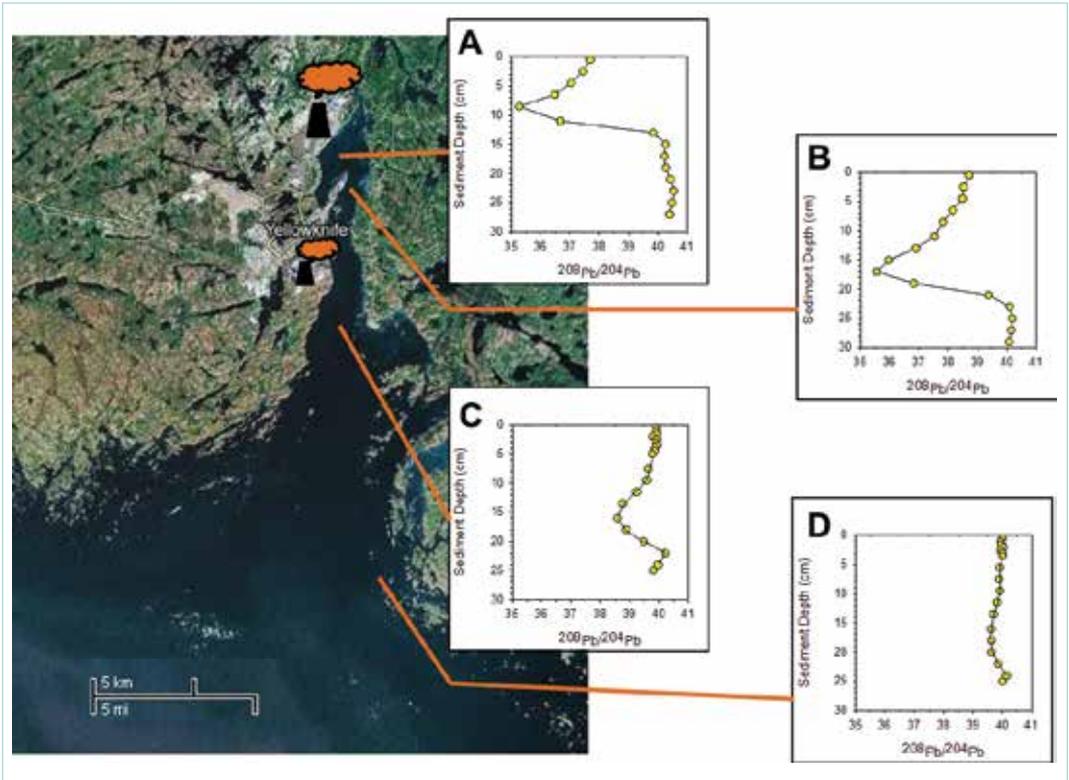


Figure 14: Profiles of lead isotope ratios ($^{208}\text{Pb}/^{204}\text{Pb}$) in four sediment cores collected with increasing distance from the Giant Mine. Changes in lead isotope ratios in the cores reflect inputs from a lead source that is different from background (i.e. mine emissions, likely via atmospheric deposition), with greater shifts in cores A and B resulting from larger inputs of lead pollution. The profiles show historical change (during the 50 years of mine operations) in contributions of background and mine sources of lead by comparison of older, deep sediments with younger, surface sediments. Giant and Con mines are represented by the smokestacks.

How does this project help in understanding cumulative impacts?

This project establishes spatial and temporal levels of metal contamination, provides better understanding of the fate and transport of metal contamination in the aquatic ecosystem, and has established temporal changes in the aquatic ecosystem that may be due to climate change.

Years Funded: 1

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Water monitoring capacity building

Purpose

To communicate the role of water licenses in guiding municipal wastewater management and to build confidence in water monitoring with the community broadly.

Key Findings

Łutsel K'e

- Collaborative wastewater monitoring was completed twice in Łutsel K'e with the participation of hamlet public works staff and with the active observation of high school students. The project leveraged additional partner support to continue collaborative sampling once during each of the subsequent two years.
- There was no indication that pathogens from Łutsel K'e wastewater were entering Great Slave Lake.
- A lesson plan was developed tying in to NWT curriculum outcomes and facilitating students to examine their own community's context to explore concepts of sustainability and source water protection.
- Results were subsequently used by Łutsel K'e Hamlet Council and their retained consultants to make decisions about future planning of the community's wastewater lagoon. The results confirmed that improvements could be made to the wastewater lagoon in place, rather than building a new lagoon at a new location.

Sambaa K'e

- Baseline water quality sampling was achieved in Sambaa K'e and a plan established for subsequent sampling during decant of the wastewater lagoon.
- Water sampling was conducted in collaboration with Sambaa K'e First Nation's (SKFN) public works staff to build an understanding of sampling methods and an awareness of the value of a water license and corresponding Surveillance Network Protocol in monitoring wastewater and ensuring source water protection.
- The project provided a basis for subsequent partnerships between Ecology North, SKFN and ENR. Together, the partners have since developed a source water protection plan, completed a first year of the plan's implementation and attained funding for a second year of plan implementation.



SKFN's public works foreman, Ron Kotchea, explains how the wastewater lagoon functions. Photo: C. Wenman.

How does this project help in understanding cumulative impacts?

This initiative aimed to provide more data to inform decision-making about Łutsel K'e and Smbaa K'e sewage lagoons, specifically during spring and fall months. This project also sought to communicate among all decision-makers to ensure accuracy and consistency of wastewater information being communicated. The project developed lesson plans to complement the NWT Experiential 30: Freshwater Systems curriculum. The lesson plans guide students to access and understand available community water quality data, and to understand concepts of watershed management and to contextualize water quality data.

Years Funded: 4

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Implementing collaborative cross-NWT water quality monitoring to address the needs of water partners, focusing on cumulative impacts and community concerns

Purpose

To collect, analyze and report on water quality while increasing community capacity to contribute to decision-making processes in the NWT and enhance understanding of cumulative effects on water.

Key Findings

- Used a standardized protocol to collect data in 22 communities. Results are available on Mackenzie DataStream <http://www.mackenziedatastream.org/>.
- At each site, as expected, seasonal differences in water quality existed. For example, in 2012 on the Slave River, there were three peaks in turbidity: in June from spring melt and in July and August when rain or high flows moved soil into the river causing it to become more turbid.
- On a particular river, upstream to downstream trends can be identified and are often related to rain events.
- Parameters which have exceeded guidelines and/or measures of natural variability are often associated with periods of high turbidity (e.g. during heavy rains).
- Analysis of long-term data from other sources indicates that many substances showed no trend (e.g. arsenic, mercury, silver), while some substances increased (molybdenum, total dissolved solids, turbidity) or decreased (e.g. nickel, cadmium, lead) over time.
- For some substances, guidelines were exceeded, but they had also exceeded in the past. For these substances, increasing trends were not found.
- Most of the dissolved hydrocarbon concentrations were below the background levels for northern rivers (15ng/L). All of the dissolved hydrocarbon results were well below concentrations that can affect aquatic life (400ng/L).

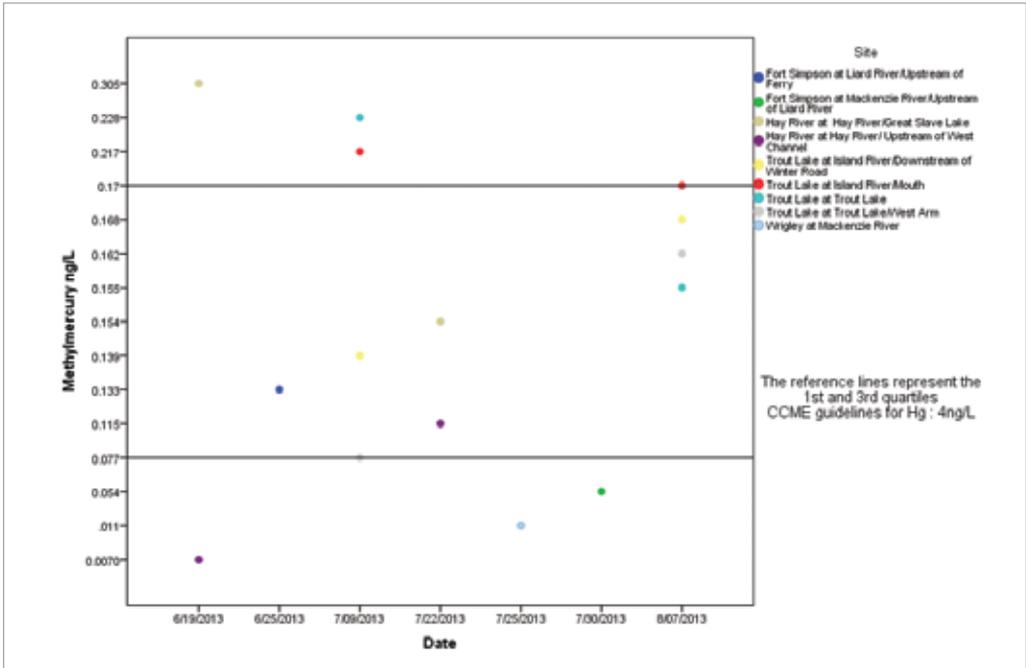


Figure 15: Methyl mercury in 2013 using the Dissolved Thin Film Gradient (DGT) passive samplers in the Dehcho Region.

How does this project help in understanding cumulative impacts?

This project provided up-to-date baseline water quality data. Data collected through this program can be compared to data collected at a particular site over time or among sites (e.g. the whole NWT, regions or rivers) during a particular month. The CBM program is important because we are learning about water quality in more places across the NWT. Before the CBM program, long-term monitoring existed at nine of the 42 sites. As regular sampling continues in the future, the data could be used to analyze for environmental trends and to detect or understand cumulative effects.



Sampling near San Sault Rapids (between Norman Wells and Fort Good Hope), 2012.

Years Funded: 2

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Mapping permafrost disturbance and impacts to aquatic systems across the northern NWT

Purpose

To map the distribution and density of major permafrost slope disturbances and areas impacted by lake drainage within the continuous permafrost zone of the NWT, and to refine remote sensing techniques to monitor changing landscape conditions (slumping and lake drainage) at local and regional scales. Thaw slumps mobilize large volumes of sediment and soluble materials, and are amongst the strongest drivers of changing water quality in north-western NWT. Lake drainage completely alters the structure and function of a lake ecosystem. Mapping of these disturbance types provides valuable baseline information on the spatial patterns of changing aquatic ecosystems.

Key Findings

- Developed a method to identify the presence and level of activity of thaw slumps using remotely sensed data.
- Mapped the areas with stream, lake and coastal environments impacted by thaw slumping and evaluated change over time.
- Evaluated the stream scales most prone to impacts by thaw slumps.
- Mapped the distribution of thaw slumps throughout the continuous permafrost zone in the NWT and assessed landscape factors that control their distribution and growth rates.
- Used disturbance maps to assess potential risk to Gwich'in cultural heritage resources.
- Provided new insight on the sensitivity of permafrost terrain in north-western Canada by illustrating the relationship between glacial terrain and thaw slumping; the study has also shown that extensive areas of north-western Canada are underlain by relict Laurentide ground ice.

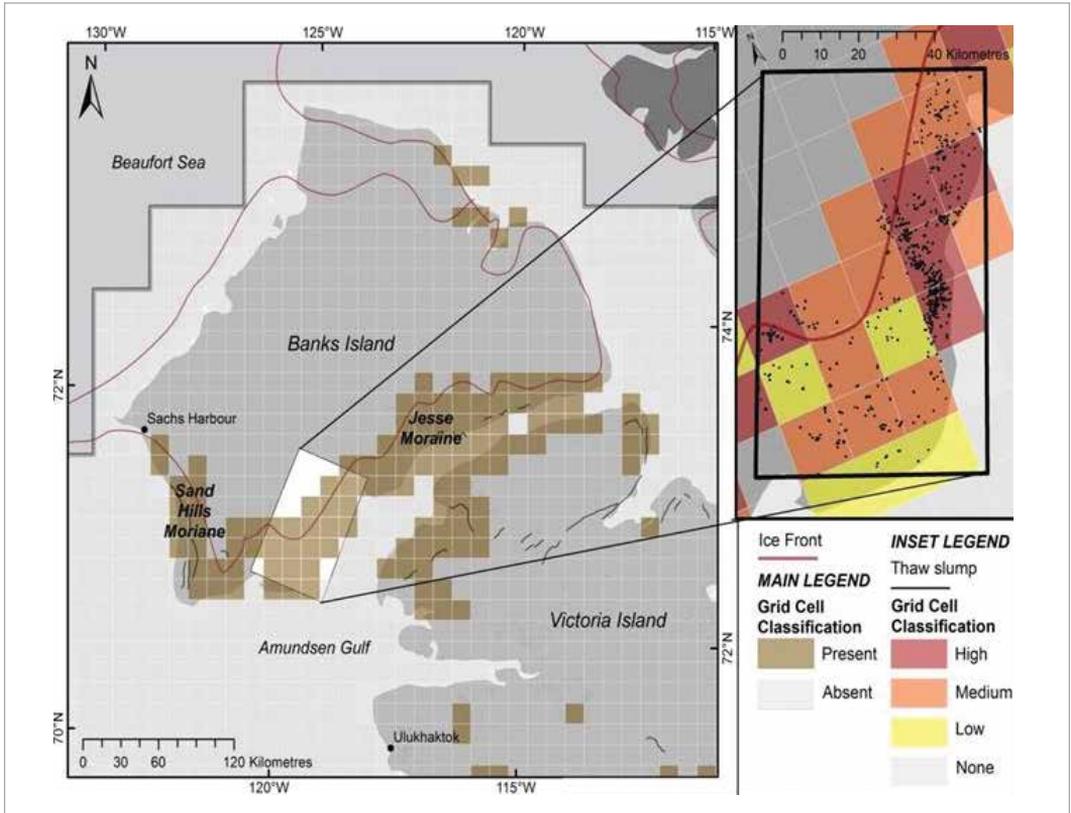


Figure 16: Broad-scale slump mapping results for Banks Island and adjacent Victoria Island. The inset on the right shows an area of south-eastern Banks Island. The shaded grid cells indicate disturbance intensity and the detailed assessment of thaw slump distribution delineated using a combination of air photographs and SPOT imagery (solid black areas). (Kokelj et al., 2015, GeoQuebec).

How does this project help in understanding cumulative impacts?

This research program provides both broad and fine-scaled data on terrain disturbance that can be used as baseline layers in project planning, assessing ecosystem health and cumulative impacts. The map products can also show areas where rivers, lakes or coastal zones are most likely to experience water quality impacts resulting from slumping. The mapping also shows areas where lake drainage is affecting aquatic ecosystems. In addition to providing new information, the study is developing methods that will both lead to protocols to measure and report permafrost disturbance on the landscape and the potential downstream areas impacted. The project will make available spatial data that can be used by territorial and local organizations to inform water-related decision-making.

Years Funded: 2

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Changes in dissolved organic carbon quality and quantity: Implications for aquatic ecosystems and drinking water quality for northern communities

Purpose

This research looks to determine the quantity and quality of dissolved organic carbon (DOC) and the main processes that dictate its fate within NWT surface waters. DOC is a critical determinant of aquatic ecosystem health and drinking water quality. Key objectives are to understand links between quality and fate of DOC, implications for aquatic systems and how this may change with natural and anthropogenic disturbances.

Key Findings

- DOC concentrations and composition in the NWT vary significantly within a small spatial scale.
 - NWT environments contain high concentrations of DOC when compared to similar hydrologic sites around Ontario.
 - Differences in DOC concentration can be up to an order of magnitude between subsurface waters, rivers and lakes.
 - DOC composition differs with hydrologic environment.
 - Terrestrial subsurface contains different mixtures of DOC molecules than small ponds or downstream rivers and lakes.
- DOC degradation varies with type of degradation (microbial or photolytic) and the source of water (subsurface, pond and creek).
 - More DOC is lost from photolytic (sunlight) than microbial degradation across different sources of water.
 - Peat plateaus around Yellowknife contain a high concentration of easily altered DOC in subsurface (up to 20 mg/L lost).
 - DOC decomposition end-products of photolytic degradation differ from microbial decomposition.
- Photolysis of both subsurface and Yellowknife River water results in decreased amount of total chlorine needed to be added to maintain residual chlorine concentration.

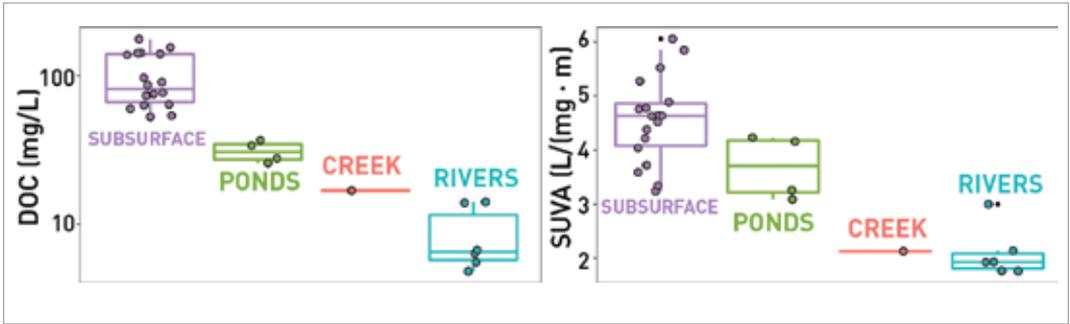


Figure 18: Dissolved organic carbon concentration (DOC; left column) and specific ultra-violet absorbance (SUVA; right column) for samples collected from different hydrological environments around Yellowknife. SUVA represents the ability of certain DOC molecules to absorb ultra-violet light and is one measure of the type of molecules (or quality) found within DOC. Higher SUVA values correlate with more aromatic (or ‘ring’ like) molecules. These figures illustrate that DOC is not all the same; quality and quantity can differ on such a small spatial scale within a NWT watershed.

How does this project help in understanding cumulative impacts?

This project contributes baseline information on both nutrients and DOC quantity and quality from different spatial and temporal scales. DOC is increasing in northern waters with increased temperatures, resulting in permafrost melt. As such, understanding these baseline levels of DOC is important for planning purposes such as water treatment and permitting development.



Dr. Michael English carrying samples for dissolved organic carbon from two lakes near Wekweëti, NWT. The “tea” colour of these samples indicates a high concentration of dissolved organic carbon typical in this area. Photo: P. Aukes.



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