Annual reporting for GNWT Environmental Studies Research Fund – 2019/20

Title: Assessing terrain sensitivity to permafrost thaw and fire to understand and predict boreal caribou habitat and forage quality in the Sahtú

Investigators: Drs. Jennifer Baltzer (jbaltzer@wlu.ca) and Merritt Turetsky (mrt@uoguelph.ca)

Collaborators: Drs. Steve Kokelj, Sharon Smith, Andrew Spring, Dave Rudolph and Derek Gray

Project Description: The proposed research will address how fire and permafrost conditions interact to determine caribou habitat responses to climate change and human activity in the Sahtú, a resource-rich region poised for substantial oil and gas development. Using a combination of field measurements and remotely sensed land cover change, we will improve predictions about the sensitivity of permafrost to fire and human activity in the Sahtú and how this relates to caribou forage availability and quality and caribou habitat use. This will be accomplished by quantifying key metrics of land cover change, terrain stability, and vegetation across a range of permafrost conditions and disturbance gradients.

Progress during 2019/20 Funding Year

Research team: We have an excellent team of researchers to support this work as outlined in Table 1 below. For 2018 field work we directly collaborated with HQP from the research groups of Drs. Rudolph and Gray to promote integration of hydrologic (Rudolph), aquatic ecosystem (Gray) and terrestrial measurements (Baltzer/Turetsky) measurements in the region.

Name	Position	Funding
Carolyn Gibson	PhD student	University of Guelph
Kirsten Bill	MSc student	ESRF
Ana Sniderhan	Research Associate	Global Water Futures
Emily Ogden	MSc Student	Northern Water Futures
Alexis Jorgensen	MSc Student	ESRF
Jessica McCuaig	MSc Student	NSERC SPG
Cathal Doherty	Field Assistant	NSERC SPG
Jason Paul	Research Technician	Wilfrid Laurier University

2) Community consultation

Thermokarst and wildfire were both identified as key community concerns at the Sahtú Environmental Monitoring Research Forum meeting in Tulita that our team attended in February 2018. During our field sampling in 2019, we were fortunate to have Jeffrey Jackson and Roger Odgaard join our team as environmental monitors for the entirety of our field sampling periods in both the summer and fall.

To enhance our capacity for community consultation and engagement, in collaboration with the Sahtú Renewable Resources Board, Leon Andrew and Jennifer Baltzer are co-leading a Global Water Futures project to support on the land camps that will lead to improve knowledge sharing between researchers and community members. The first of these camps took place on the Bear River in August 2019 and involved members of our ESRF team (Ogden, Gibson, and collaborator Grey).

***Figure 1**. Thermokarst and fire site reconnaissance with Elder Leon Andrew during the summer of 2018. Photos courtesy of Carolyn Gibson.*

Research progress

Below, we provide updates on three distinct though interconnected components of this project:

1) Thermokarst vulnerability assessments
2) Vulnerability of lichen peatlands to fire and thaw
3) Post-fire forage lichen forage recovery

Thermokarst vulnerability assessments

We are employing the framework presented in our 2017/18 and 2018/19 reports to evaluate thermokarst vulnerability in the Sahtú region.

***Figure 2**. Examples of thermokarst features in the Sahtú region. Photos courtesy of Carolyn Gibson.*

Over the last year, we have made considerable progress toward this goal. The first steps of this framework involve the detection of thermokarst (Fig. 3). Gibson has completed the mapping of lowland thermokarst vulnerability for the entire Taiga Plains, including the Sahtú region as part of the NWT Thermokarst Collective initiative. Using the broad-scale thermokarst inventory techniques of Kokelj et al. 2017, Fraser et al. 2018 and the methodologies of Segal et al. 2016, permafrost peatlands were mapped using a 15 by 15 km grid system within the Taiga Plains ecozone of the NWT (Fig. 3). Each 15 by 15 km grid were broken in smaller grid cells where presence/absence of a permafrost peat plateau and thermokarst features were recorded. Percent coverage of permafrost peatland in each cell were be calculated as (*number of 'present'/total number of tiles*)**100.* These results are presented in Figs. 4 & 5.

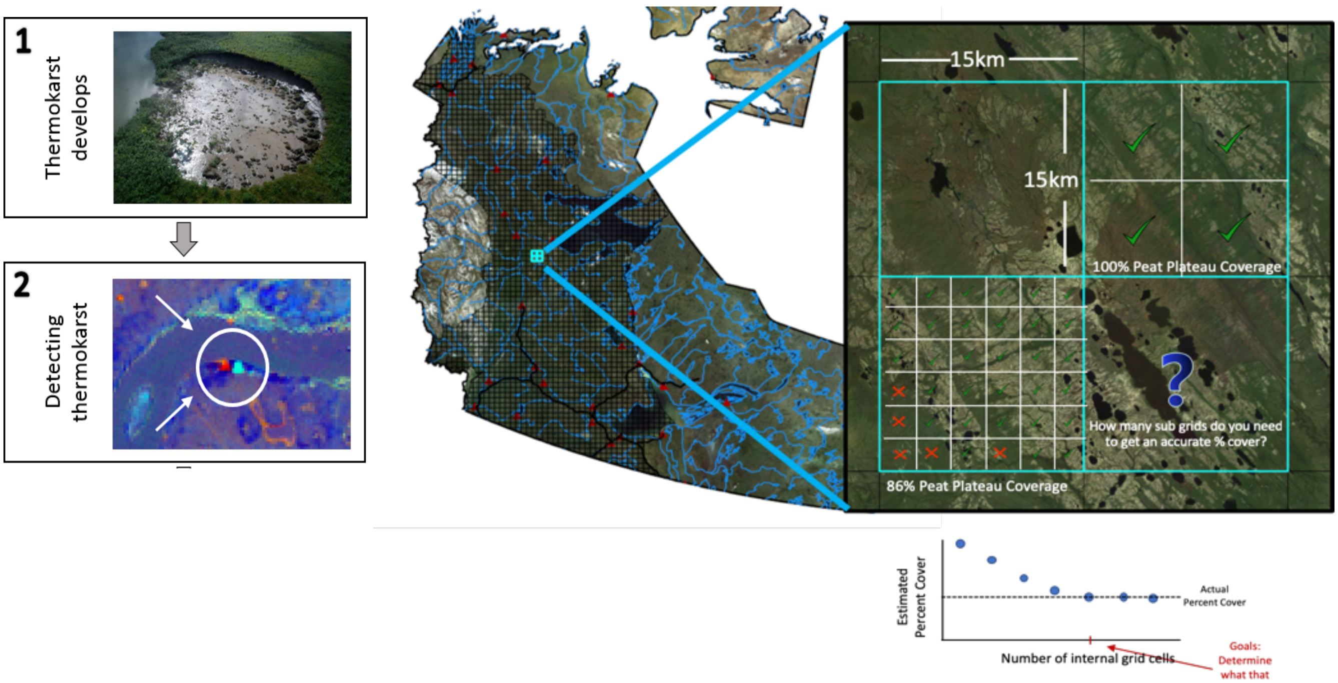


Figure 3. Steps 1 and 2 of thermokarst vulnerability framework and the process used to quantify peatland distribution and lowland thermokarst density each Sentinel gridcell.

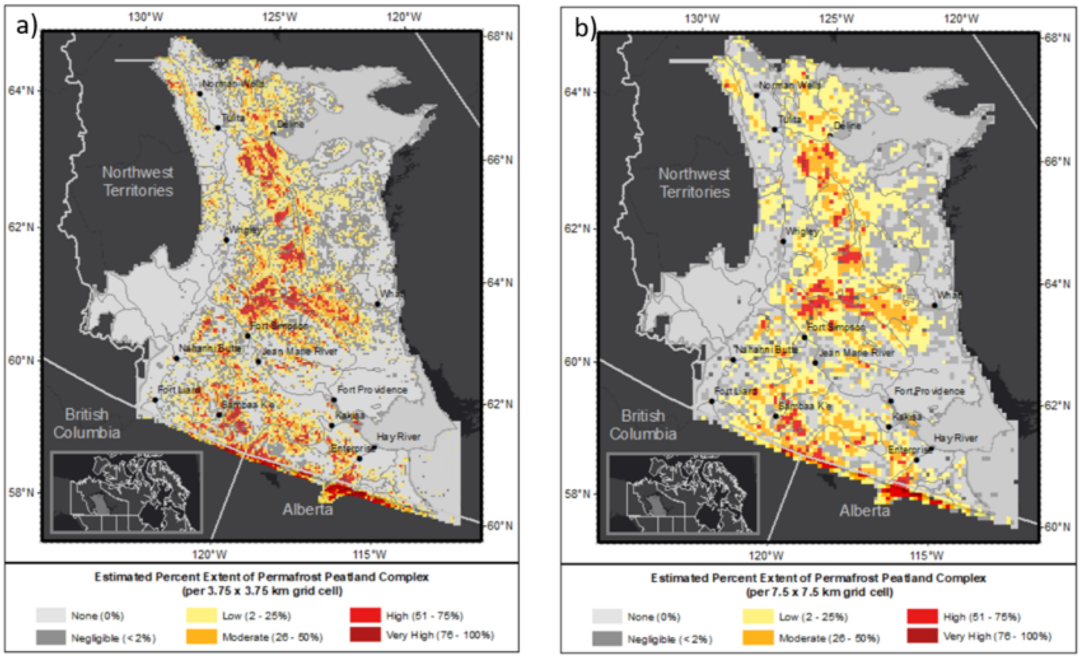


Figure 4. Maps showing the density distribution of peat plateau complexes in the discontinuous permafrost zone of the Taiga Plains. Data are shown according to both a) sub-grid cell (3.75 × 3.75 km) and b) grid cell size (7.5 × 7.5 km). These data give us an indication of the areas in the Taiga Plains vulnerable to lowland thermokarst.

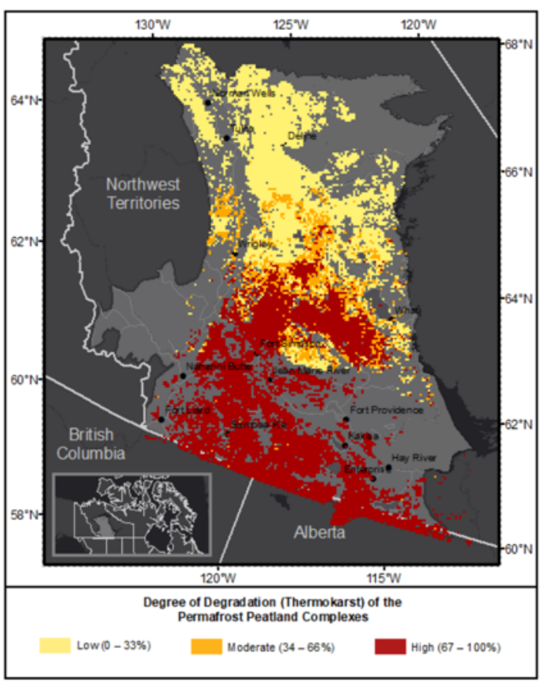
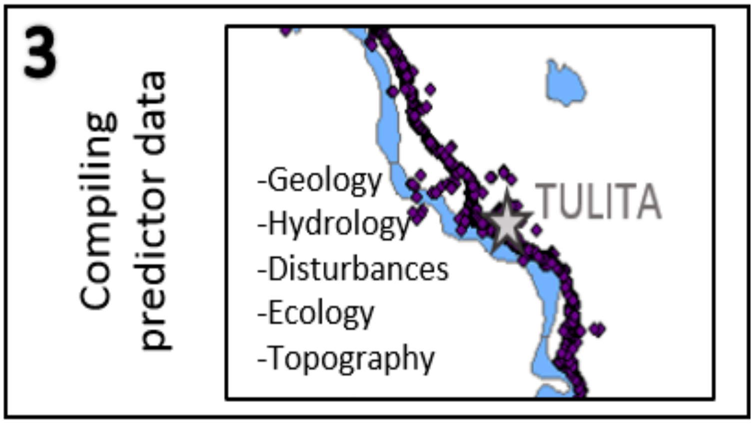


Figure 5: Degree of degradation (thermokarst) of the permafrost peatland complexes presented in Figure 5. Visually estimated as low (0 – 33%), moderate (34 – 67%), or High (67 – 100%).

The next steps in our framework involve the determination of predictors of thermokarst vulnerability (Fig. 6). We are in the process of compiling these spatial data layers, most notably ground ice content. Paul has been compiling existing ground ice data and during the summer of 2019 he led efforts to characterize ground ice contents for the lichen peatlands that were the focus of the summer 2019 field campaign (see below).



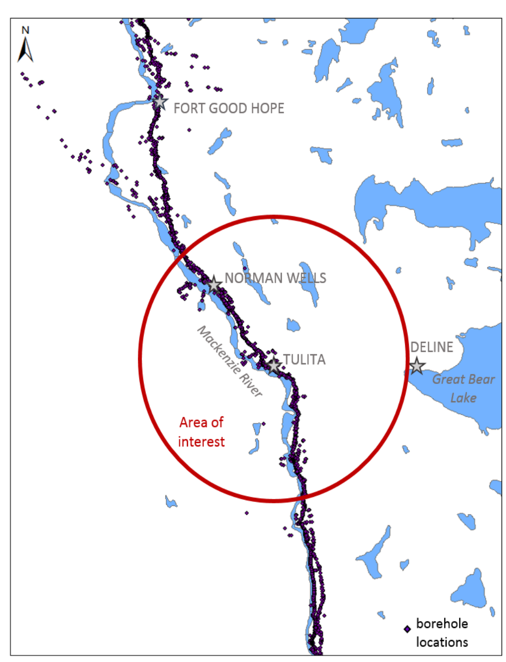


Figure 6. Step 3 of our thermokarst vulnerability framework and locations of borehole data being compiled.

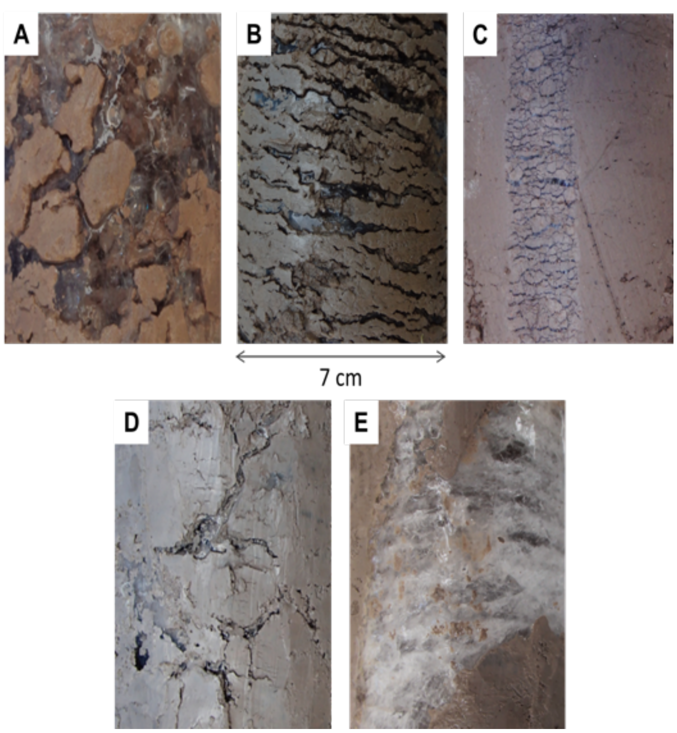


Figure 7. Examples of different cryostratigraphy and ground ice contents from permafrost cores (from Paul et al. 2020) and an image of Jason Paul logging a permafrost core in the field.

The next steps for this effort is to use these predictors to develop a lowland thermokarst vulnerability assessment as exemplified in Fig. 8.

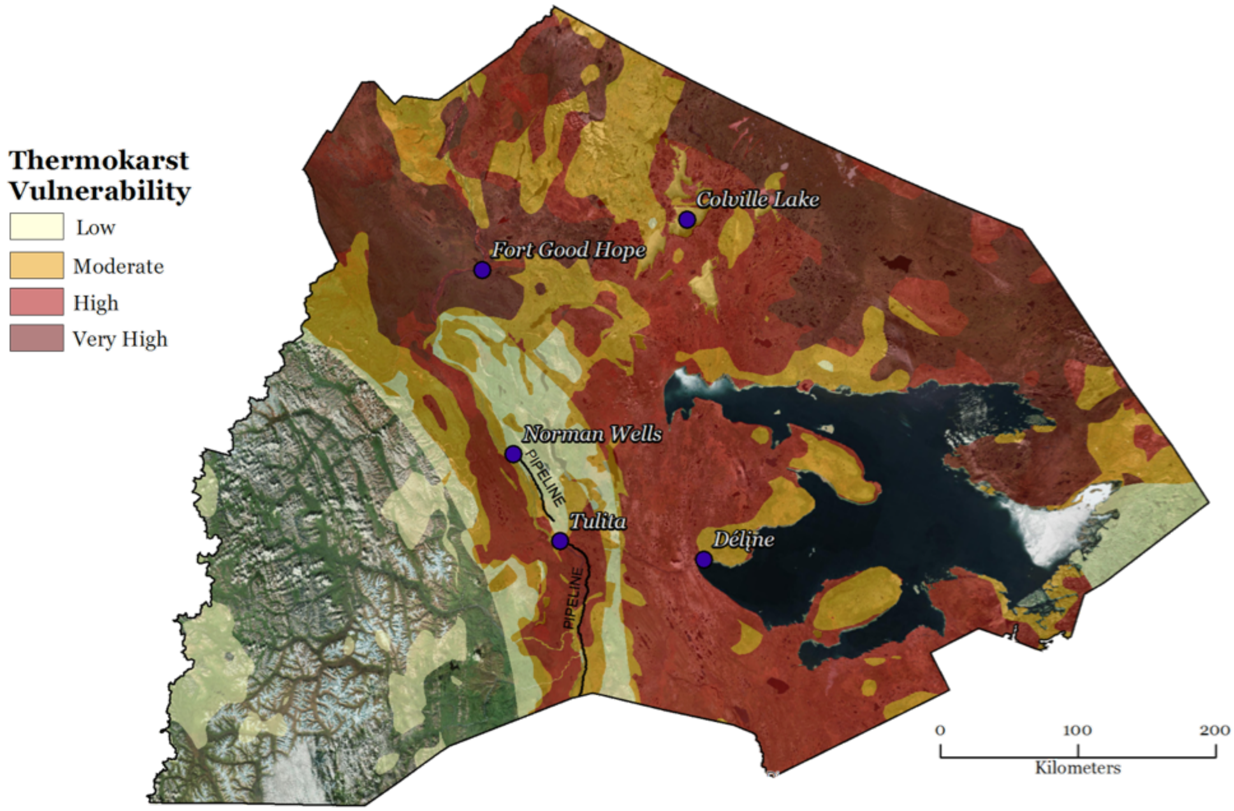


***Figure 8**. Thermokarst vulnerability map based on Olefeldt et al. 2016. The data we are collecting and analysis we are conducting will produce a finer scale and more accurate vulnerability map for this region.*

Vulnerability of lichen and peatlands to fire and thaw in the Sahtú

In addition to these remote sensing-based efforts, in 2019, we conducted new field sampling in lowland permafrost environments in the Sahtú region. These efforts were focused on permafrost peatlands dominated by reindeer lichen cover (Fig. 9). Our sample design involved characterizing vegetation communities and soil carbon stocks for peatlands ranging in fire-free interval (from sites that burned in 2014 to those that have not burned since 1969). Within each location, we sampled thermokarst bogs (Fig. 10) that were stable and those showing evidence of rapid permafrost thaw, permafrost plateau locations, and surrounding forest environments (Fig. 9). These sample efforts included:

1) measurement of soil organic layer thickness and carbon content and collection of permafrost cores for characterization of ground ice and permafrost carbon (Fig. 11)
2) Measurement of carbon stocks in thaw features (Fig. 12).
3) Stand structure and composition (where relevant) and ground vegetation characterization (Fig. 12) in all sampled features

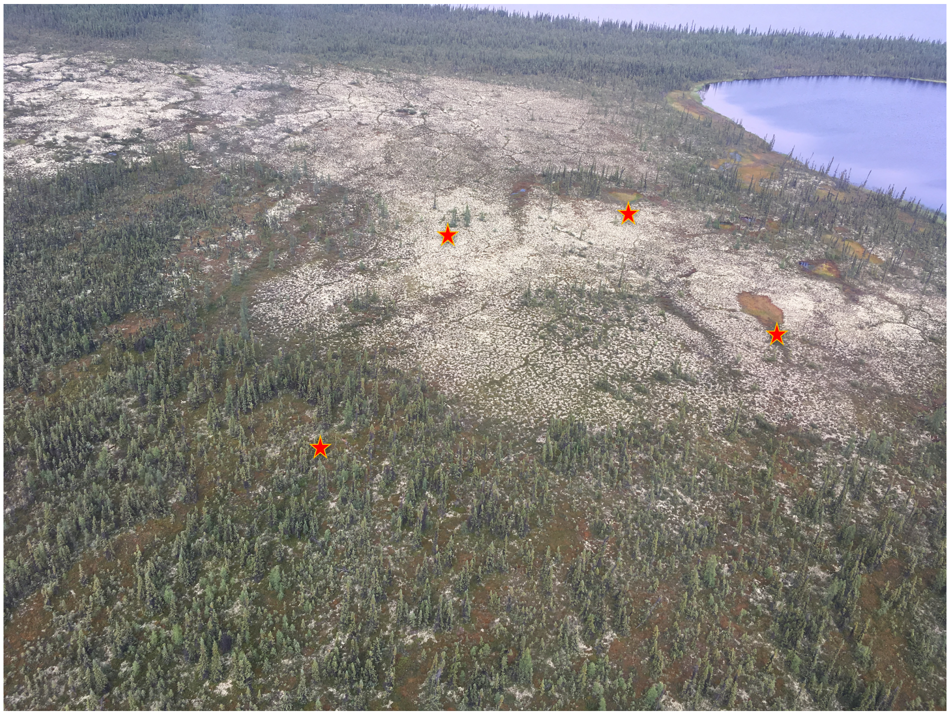


Figure 9. Sampling locations within each sampled lichen peatland including stable and unstable thermokarst bogs, permafrost plateau and forest interior. This sampling included sites that burned in 2014, 2007, 1993, 1969, and "unburned controls" for which we will assess burn date based on stand age.

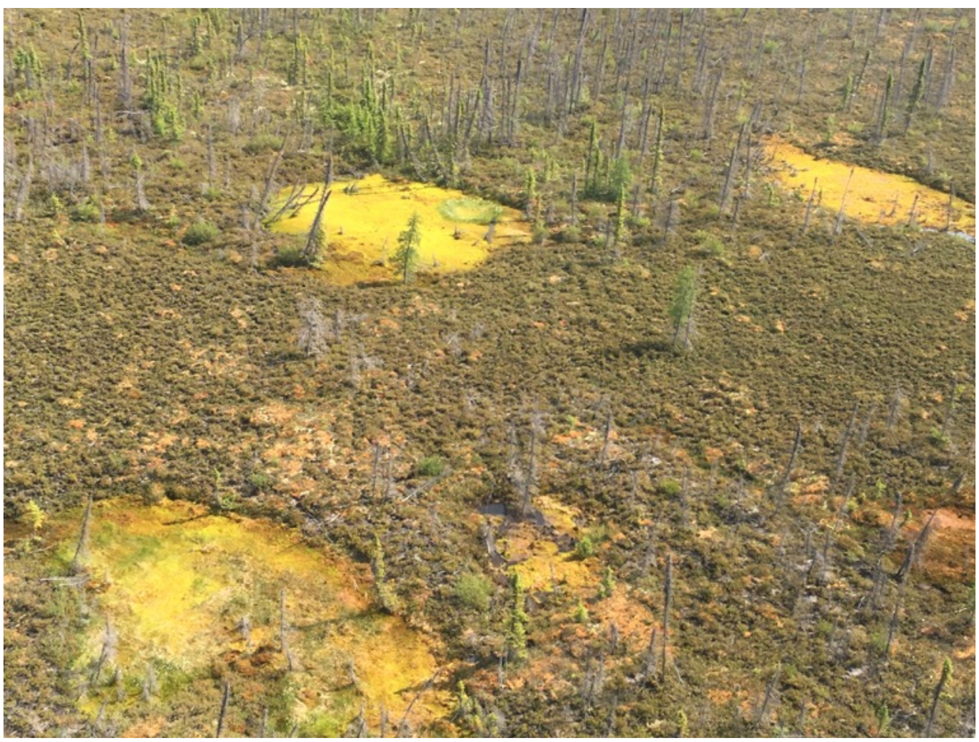


Figure 10. Thermokarst bogs in a recently burned lichen permafrost peatland. Brighter green areas indicate regions of active thaw.

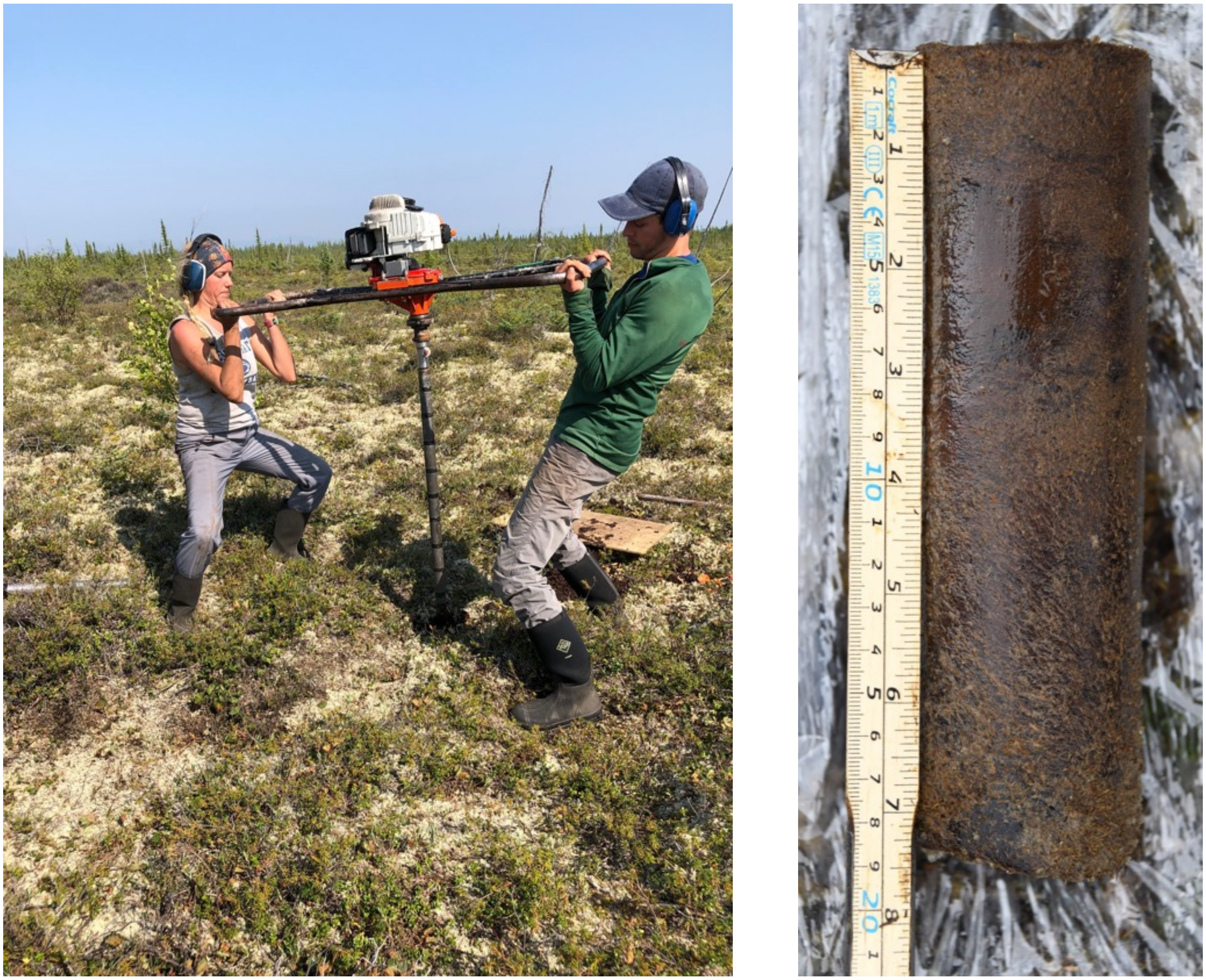


Figure 11. McCuaig and Paul coring permafrost in a lichen peatland (left) and peat-rich permafrost core segment (right).

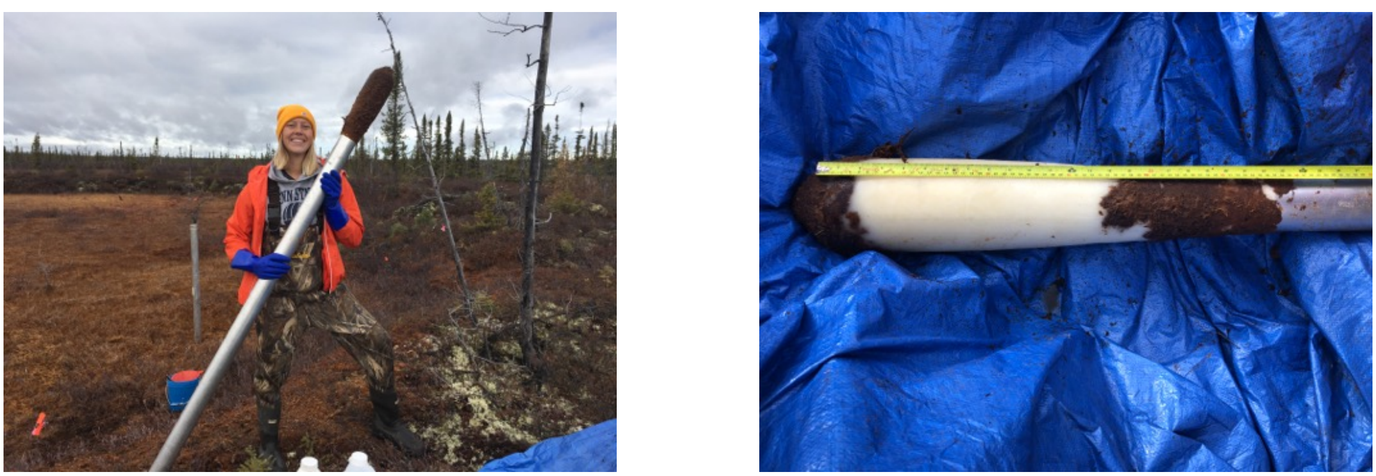
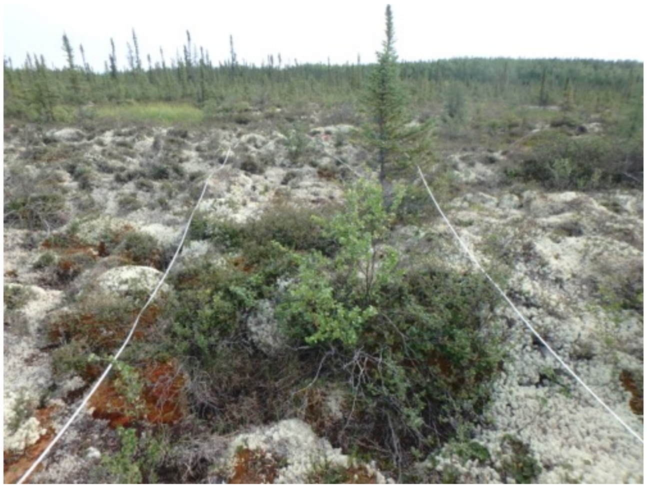


Figure 12. Frozen finger sampling in thermokarst bog features. McCuaig with frozen finger sampler (right) and a sample with water (frozen due to the sampling technique) between peat layers.



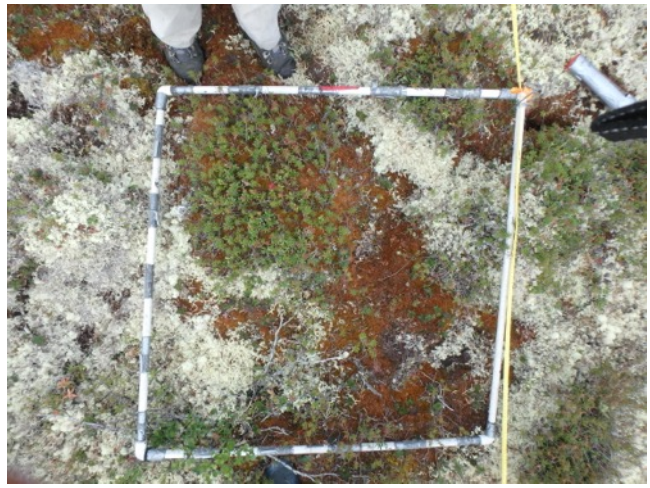
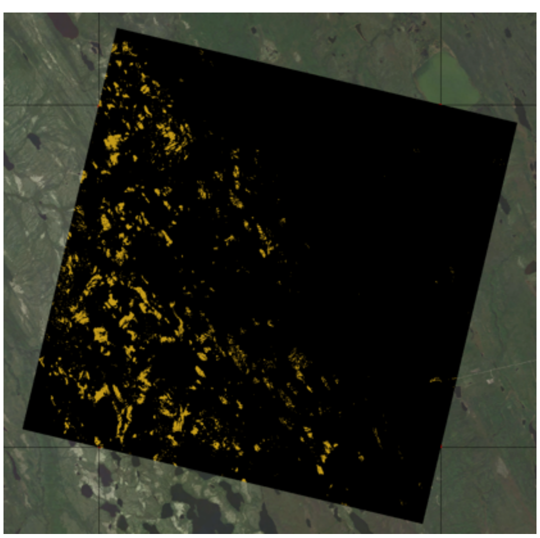


Figure 13. Vegetation sampling transect (left) and quadrat (right) in a lichen permafrost peatland.

These field-based sampling efforts will be combined with fine scale thermokarst mapping that will also support the broad-scale thermokarst mapping described above. This work will be conducted in a 70 x 70 km grid around Norman Wells and Tuilta. During this process, peat plateaus will be manually digitized peat plateau within the area of interest. This will provide an 'true' estimate of peat plateau area around these communities. Using this 'true' area, Gibson will then determine the area the number of sub grid cells to get an accurate estimate of the true are using presence/absence. She will start by creating the initial grid cell into four 7.5 by 7.5 grid cells, doing presence/absence, and continually break the grid cell into smaller and smaller sub-cells, doing presence/absence, until I can accurately represent the true permafrost peatland area using presence/absence grid cells (Figure 5).

The final product will provide a spatial distribution of permafrost peatlands, and will be coupled with work described above to make statements about the fate of permafrost peatlands within the NWT in the next 50 – 100 years. Progress to date:
Manual delineation of permafrost peat plateaus has begun around Norman Wells using supervised classification (Figure 14).



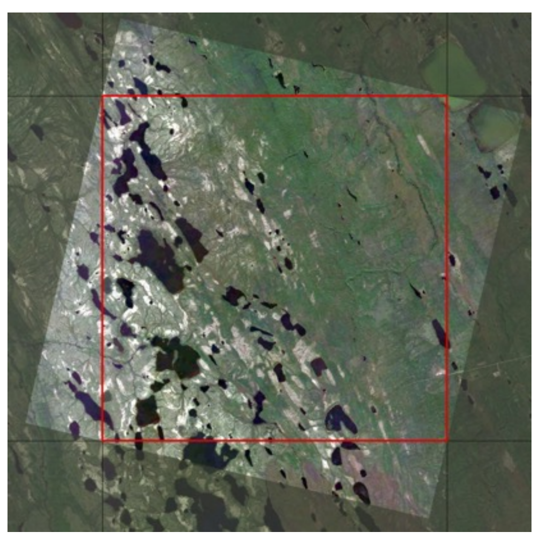


Figure 14. *Example supervised classification of permafrost peat plateaus 50 km east of Norman Wells. Yellow represents permafrost peatlands susceptible to wetland thermokarst formation.*

Post-fire forage lichen recovery

In 2018, we established 12 sites in which we sampled stand age, ground vegetation, soils development and forage lichen biomass recovery (points in the Sahtú region in Figure 15). We used methods identical to an ongoing study in the southern NWT, allowing us to compare these processes in the Sahtú, Tlicho and Dehcho regions. Further, for the lichen biomass sampling, a collaborator had comparable data from northern Saskatchewan facilitating a regional comparison of lichen biomass accumulation rates in northwestern Canada. This combined dataset has supported the first comprehensive evaluation of forage lichen recovery times following fire for the NWT and provides Sahtú-specific estimates as well. The resulting manuscript was developed by Degré-Timmons and has been submitted to the scientific journal Ecological Applications. The next steps for this dataset is to develop ecological forecasting tools to provide managers the ability to evaluate changes in forage lichens under different wildfire scenarios. Our current work on the interaction between fire and permafrost thaw will allow that to be extended to include scenarios of fire and thaw. Some of the key results from the paper are included in Figs 16 & 17.

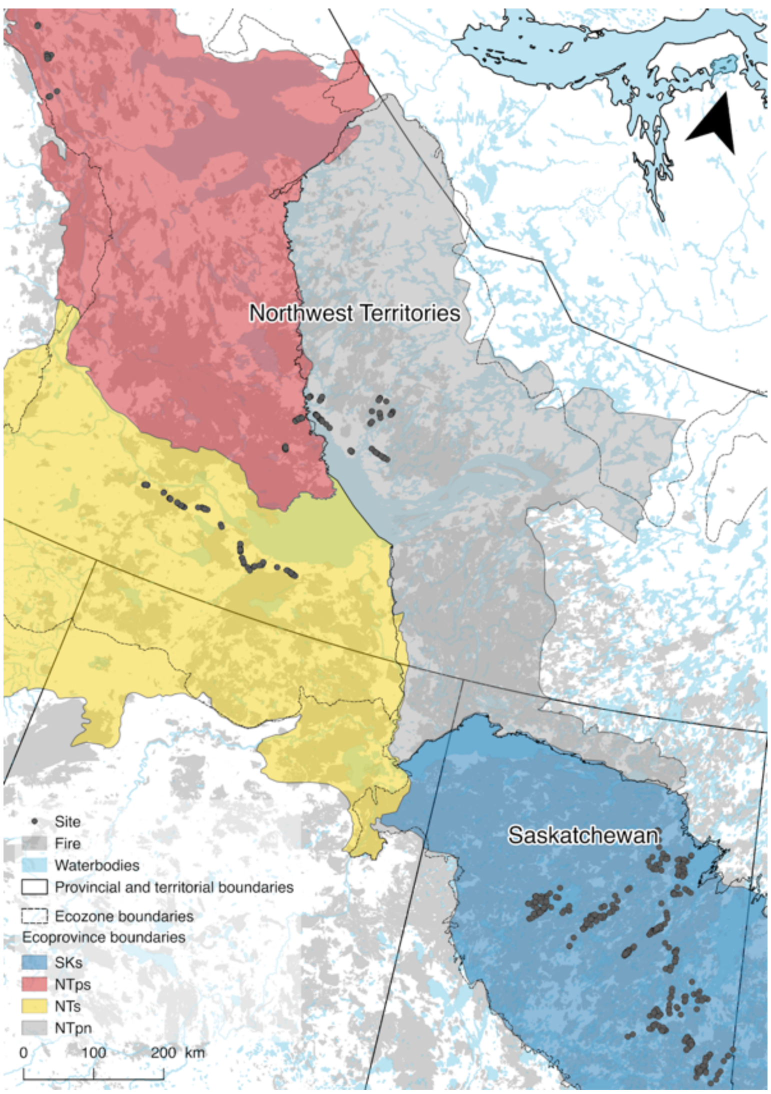


Figure 15. *Locations of all sampling locations used to evaluate post-fire recovery of lichen and its generalizability across northwestern Canada. Included in this broader analysis are our sampling efforts to date in the Sahtú region. Characteristics of NWT-based sites are provided in Table 1.*

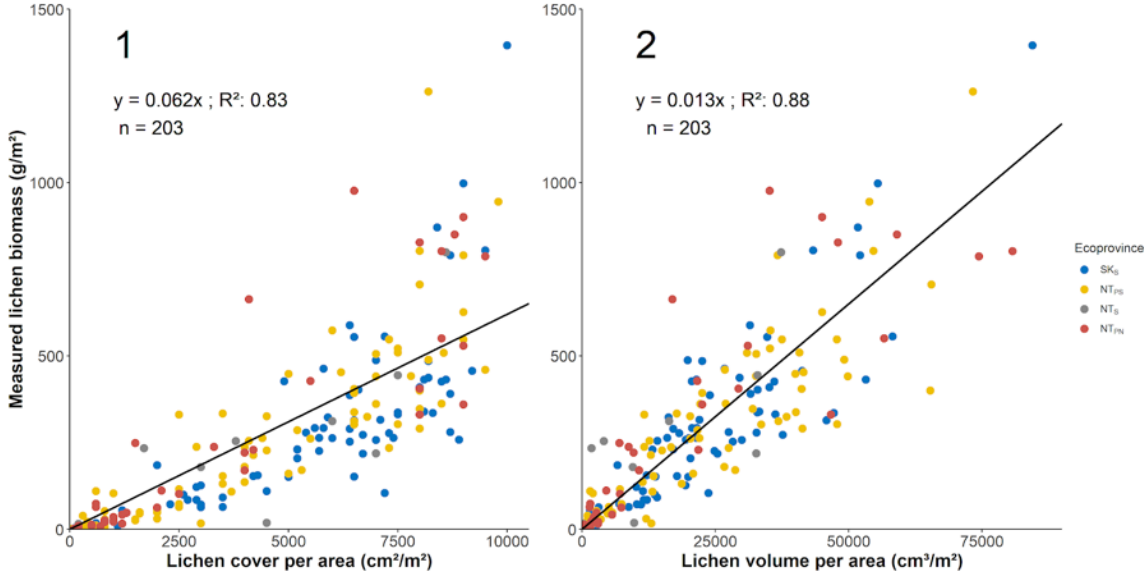


Figure 16. *Allometry for a forage lichen (Cladonia sp.) across ecozones depicted in Fig. 15. The relationship between in situ lichen volume (area x depth) measured in field plots vs. true lichen biomass measurements (mass-based) show a strong positive relationship and no difference between ecozones allowing us to apply this allometry to all field samples regardless of location.* Ecoprovince: SK_S = Saskatchewan Shield, NT_{PS} = Northwest Territories Plains South, NT_S = Northwest Territories Shield, NT_{PN} = Northwest Territories Plains North. *Gruel, Degre-Timmons et al. in review.*

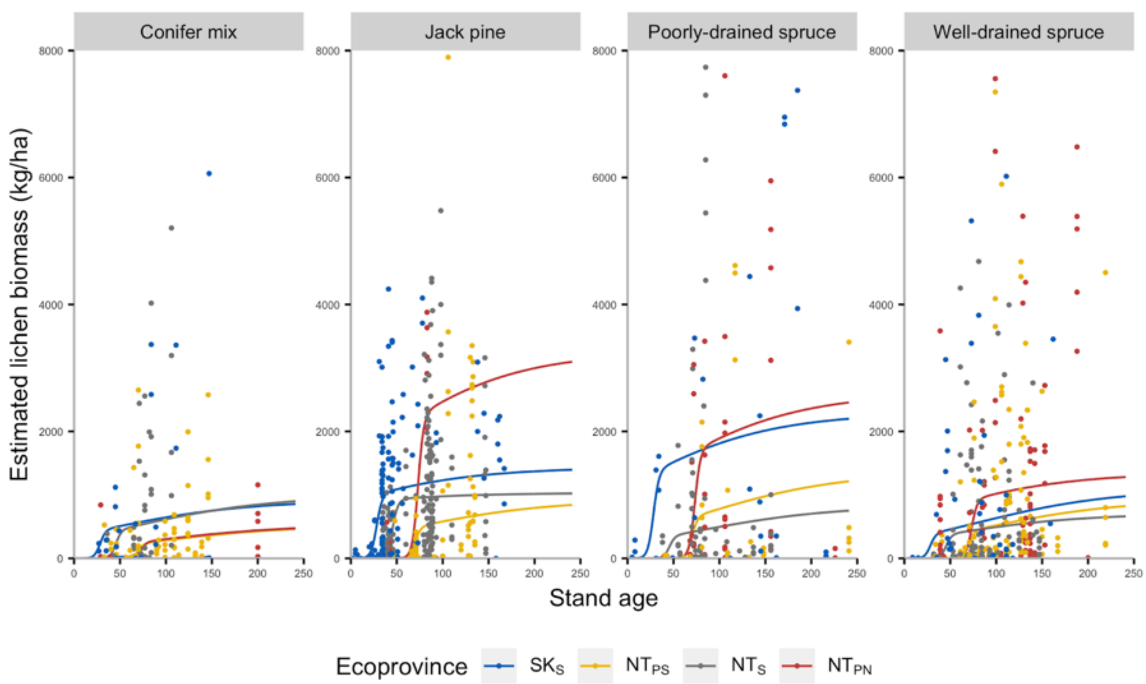


Figure 9. *Lichen biomass accumulation through time (stand age in years) in each ecoprovince for each stand type. Ecoprovince: SK_S = Saskatchewan Shield, NT_{PS} = Northwest Territories Plains South, NT_S = Northwest Territories Shield, NT_{PN} = Northwest Territories Plains North. We see the importance of poorly drained spruce in supporting high maximum lichen biomass accumulation across all regions. Gruel, Degre-Timmons et al. in review.*

Next steps:

Unfortunately, the COVID-19 situation is preventing our final field season scheduled for this summer and a one-year extension on the project has been approved. In the coming summer, Caitlyn Lyons (incoming PhD) will be using air photo analysis evaluating landcover change for areas of known ground-ice content (Collaborator Smith borehole and permafrost monitoring sites established between 2002-2004; Fig. 6). This will allow us to pre-select sampling locations at which we will conduct detailed ecological evalutions during the summer of 2021. This will allow us to assess how changes in permafrost conditions over the last 20 years have affected land cover and associated caribou forage availability.

Our planned on the land activities involving the community of Fort Good Hope have also been postponed for a year but Kristen Bill (incoming PhD) will be continuing to engage this community to enhance our planning for that event which will now occur in 2021.

Thermokarst vulnerability mapping and modelling efforts will continue through this and partner projects including Northern Water Futures and a recently funded NSERC Strategic Project Grant (see additional funding sources).

Progress toward proposed project deliverables
As evidence, we are making substantial progress toward the stated project deliverables:
1) Yrs 1-4: Collaborative community workshops in Tulít'a to identify areas important for caribou on the landscape
- Completed for 2017/18, 2019, postponed for 2020 due to COVID-19.
2) Yr 1: Research team involvement in the Sahtú Environmental Monitoring Research Forum meeting in Tulita to engage the community further in the proposed research
- Completed; it is noteworthy that our extended project also supported a Forum call in 2019.
3) Yr 1: Review and synthesis of literature, data, and images on permafrost, fire, and caribou habitat in the Sahtú
- In progress – This forms part of MSc Alexis Jorgensen's thesis project.
4) Yr 1-3: Field surveys and analysis of data to establish relationships between fire, permafrost, and vegetation
- Successful field seasons in 2018 and 2019. 2020 field campaign delayed to 2021 due to COVID-19.
5) Yr 2-3: Point based photointerpretation of change characteristics
- In progress – PhD Carolyn Gibson's work
6) Yr 3-4: Develop maps and related decision-aids for predicting and detecting areas with a high potential for thermokarst and land subsidence post-thaw
- In progress as part of PhD Carolyn Gibson's work
7) Yr 3-4: Produce spatially explicit information on post-thaw landscape change and subsidence in critical caribou habitat
- In progress. 2019 and 2021 fieldwork will produce the data to finalize this goal.

Leveraged funding to date
ESRF funds are being heavily leveraged against other funding sources as outlined below making the proposed research feasible.

1) Global Water Futures (~$20,000/year)

  - The salary of Dr. Ana Sniderhan is being supported by core funding to Wilfrid Laurier University from Global Water Futures. Dr. Sniderhan will lead the vegetation sampling in the Sahtú over the course of this project. During 2018, I anticipate that Ana will spend ~25% of her time on this project.
  - Travel support for Sniderhan
2) Northern Water Futures (~$50,000 per year)
  - The salary of Dr. Anna Coles was supported through Northern Water Futures until November 2018 at which point Anna took a position with the GNWT. Anna was dedicating roughly 50% of her time to this project.
  - Support for community outreach and engagement is available (during 2017, $10,000 was provided to support the Nę K’ə Dene Ts'ıl̨ ı ̨ Forum workshop; during 2019, a similar amount will help to support the on-the-land camps that comprise the Water Knowledge Camps program)
  - Field expenses for the teams
  - Northern Water Futures has been renewed for another 3-year period, providing additional support for this work.
3) Water Knowledge Camps ($100,000/year for 3 years)
  - This Global Water Futures funded program will help to ensure community engagement and knowledge exchange between our teams and the community members on whose lands we are working.
  - There will be one camp per year in Tulita (2019), Fort Good Hope (2020), and Deline (2021)
4) Polar Continental Shelf Program ($45,438 for 2018 field work; $64,428 for 2019 field work)
5) University of Guelph – Carolyn Gibson’s salary is supported through a prestigious scholarship at the University of Guelph.
6) Government of the Northwest Territories ($150,000 in 2018, $75,000 in 2019)
  - These year-end contributions are helping to support the establishment of this field program and those of Drs. Rudolph and Gray. These resources are helping to support helicopter time to access disturbance features on the landscape. The inaccessible nature of much of the landscape makes this sampling particularly challenging and costly.
7) Wilfrid Laurier University ($15,000) – Jason Paul led the gorund ice sampling in the Sahtú in 2019 and his predecessor Genevieve Degre-Timmons led the effort to understand changes post-fire in forage lichen biomass. They both spent ~25% of their time on this work and their salaries are funded through Baltzer’s Canada Research Chair funding provided through Laurier.

Spending to date

2017/18 funding - $50,000
2017/18 expenditures - $11,557 Husky site visit and Kristen Bill salary)

2018/19 funding - $50,000 + 2017/18 fund balance forward of $33,443 (total funds available = 83,443)
2018/19 expenditures - $59,841 (Field costs and Kristen Bill salary)
2019/20 expenditures – Total expenditures: $49,273: $808 (Materials and Supplies); $42,038 (Helicopter charters to support 2019 field sampling campaign; $6426 (Overhead)

The Contribution Agreement for this project began in July 2017, too late to start a 2017 field season. As agreed upon, we were underspent on these ESRF funds in 2017 and 2018. We are now largely on track for spending but we will not spend any ESRF funs in 2020/21 due to COVID-19. We will save our remaining allocation for the 2021 field season described above.

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