Annual reporting for GNWT Environmental Studies Research Fund – 2017/18

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

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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 2017/18 Funding Year

1) Assembly of research team: We have recruited an excellent team of researchers to support this work as outlined in Table 1 below. For 2018 field work we will be directly collaborating 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	Activities during 2017/18
Anna Coles	Postdoctoral Fellow	Northern Water Futures	- Compile necessary datasets for change detection, subsurface conditions, and surface conditions - Derive relationships between the degree of surface surface changes (thermokarst formations; subsidence) and the associated subsurface conditions (What are the subsurface conditions that drive the development of thermokarst landscapes and, conversely, what conditions help maintain a stable landscape? - Determine the hierarchy of importance of different drivers of permafrost thaw and the interactions between them
Carolyn Gibson	PhD student	University of Guelph	- Synthesise current understanding of factors governing permafrost stability, identify knowledge gaps (e.g. importance of geology) and presently data-poor areas - identify areas of thermokarst development (i.e. thaw slumps, lake expansion/drainage, wetland expansion) and subsidence that will serve to target sampling efforts in summer 2018
Kirsten Bill	MSc student	ESRF	- Develop field methods for assessing soils development following disturbance - Support change detection analysis necessary for field sampling efforts
Ana Sniderhan	Research Associate	Global Water Futures	- Develop vegetation sampling plan for 2018 field sampling campaign

2) Community consultation – For this project some of our main deliverables for the 2017/18 year focused on community consultation to ensure that the research was addressing community concerns and priorities. During 2017/18 our team made two trips to the Sahtú to support consultation with the community regarding research priorities and community involvement in the research program. Outcomes of these visits are described briefly below.

July 2017 Husky Site visit

In July 2017, Jennifer Baltzer and Dave Rudolph travelled to Norman Wells to meet with community members and visit the Husky lease site to assess research opportunities at that site. ESRF funds supported the travel of community members from Tulita to participate in the site visit. Participants included Andrew Applejohn (GNWT), Jenny Vandermeer (GNWT; community of Deline), Joe Hanlon (SRRB, community of Tulí t'a), Ken Hansen (ESRF), Jenica Vonkuster (Husky), and Frank Pope (Norman Wells RRC; hired as bear monitor). The goals of this trip were to explore the lease to assess the feasibility of this as a research hub for this work and the groundwater project being led by Dr. Rudolph. The site was determined to be a promising location for integration of different parts of the ESRF and Northern Water Futures projects given the access to different landcover types along the all-weather road and the range of disturbances on site (seismic, fire, well pad clearings). For the purpose of the present project, this landscape has been characterized as being vulnerable to thermokarst and will likely serve as a sampling location in summer 2018.

January 2018 participation in the Nę K'ə Dene Ts'ıl ı˛(Living on the Land) Forum meeting in Tulí t'a
Northern Water Futures (NWF)/ESRF researchers, Jennifer Baltzer, Dave Rudolph, Anna Coles, and Carolyn Gibson travelled to the community of Tulí t'a for the Nę K'ə Dene Ts'ıl ı˛Forum, a workshop aimed at connecting communities within the Sahtú region with researchers to discuss research priorities in the region and for researchers to provide updates from existing projects. The Dene people of the Sahtú region have expressed deep concern about the impacts of climate change on their lands and waters. One of the major goals of the Nę K'ə Dene Ts'ıl ı˛Forum is to ensure co-development of research in the region and support the incorporation of both western and traditional knowledge into research planning, thereby ensuring that researchers and community members work side by side. As our team is initiating new

research activities in the Sahtú region in the coming summer and Nę K’ə Dene Ts'ıl̨ ı˛Forum workshop provided an ideal opportunity to develop these plans with the community.

Over the three-day workshop, researchers listened to stories about landscape change and its effects on ecosystems, livelihoods and safety. Through the Forum, the researchers gained a better understanding of the region and the effects climate-warming driven landscape change as experienced by the community. The researchers heard concerns about the impacts of wildfires on vital boreal caribou (tǫdzı) habitat, the impact of warming water on fish populations, and how permafrost thaw changing how much water is on the land. There was concern about how fire impacts the frozen ground below it with stories of slumping hillslopes and riverbanks following fire. Community members have observed decreasing lake and river water levels. Changes are happening fast in the Sahtú and community members want to have a better understanding of what their lands will look like in the future; data from this region is sparse making such predictions very difficult. The ESRF/NWF team saw great potential for our proposed permafrost and vegetation measurements to contribute to key community concerns that emerged at this meeting.

The need to work together to understand changes happening on the land was emphasized. The meeting involved both elders and youth and discussions revolved around two main priorities for community involvement in NWF research: 1) Working with elders to incorporate knowledge of changes on the land into sampling design; and 2) Building research capacity in the youth through direct involvement in sampling, support for on-the-land training and bringing research into the classroom. NWF has been successful in accessing additional NSERC funding to support on-the-land learning opportunities for high school age children. We plan to work with the SRRB to explore this opportunity as part of this project.

The Nę K’ə Dene Ts'ıl̨ ı˛Forum provided an excellent opportunity for dialogue between researchers and community members to ensure that research generated in the region is of shared value. The information gathered at the forum is helping the team to finalize research plans for the coming summer and shape new research questions moving forward.

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Progress update on subsurface data compilation and remotely sensed image analysis

Remote sensing data and methodologies

There exist several methods for detecting thermokarst on the landscape that utilise a variety of spatial data and tools. Supervised classification can be used to identify areas that have undergone an ecological succession from a forested peat plateau to a *Sphagnum* dominated thermokarst bog (Fig 1). This method takes advantage of the spectral differences in these land cover types and relies on the use of high resolution satellite imagery.

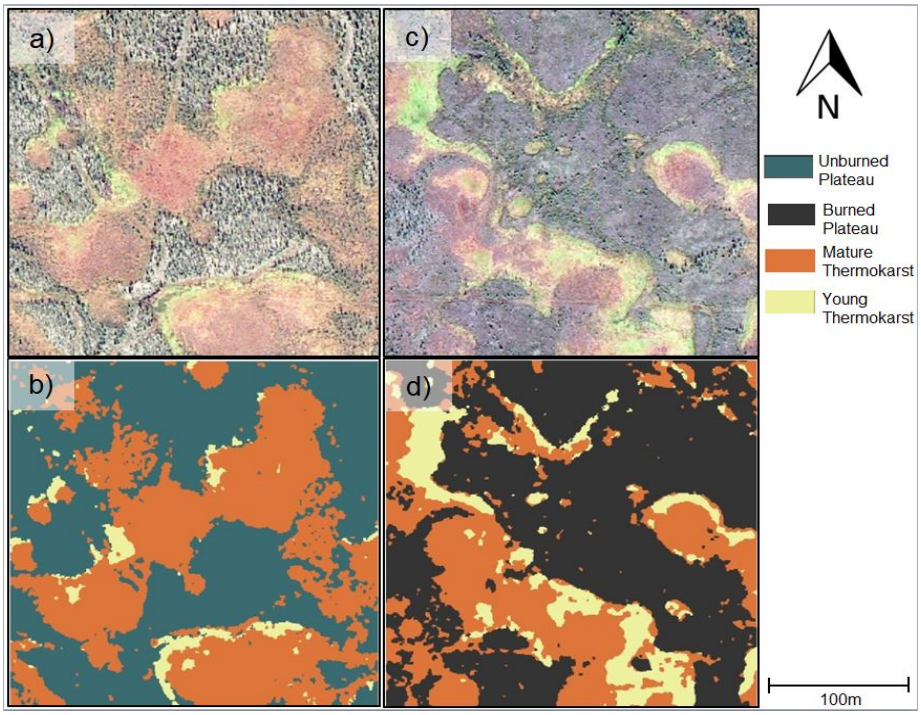

Figure 1. Example of images before and after supervised classification. Gibson et al., in review.

Historical aerial photos can be used to interpret landscape change by manually digitizing permafrost areas in historical images and present-day satellite images and overlaying them to identify areas of change (Fig 2).

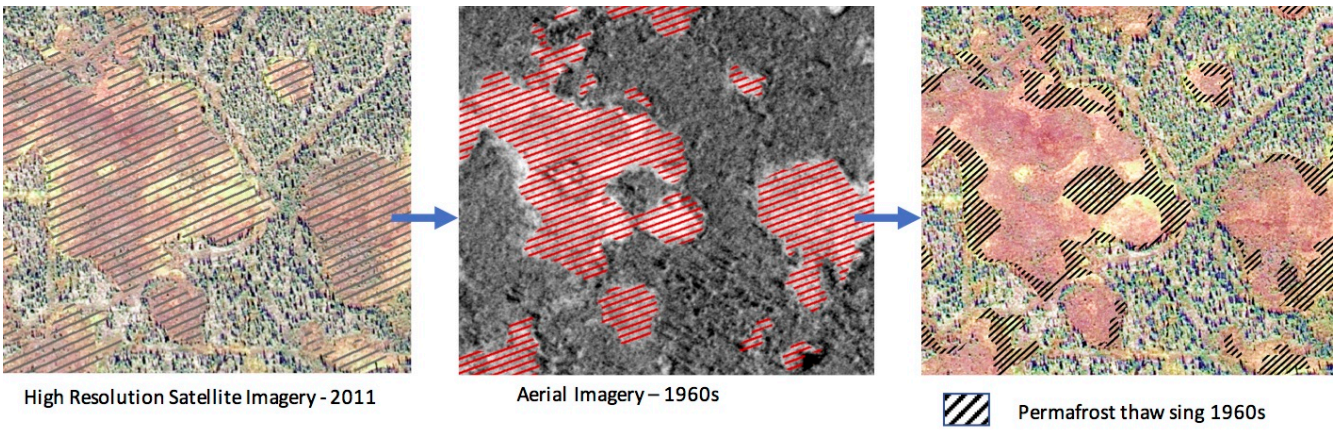

Figure 2. Example of air photo time series used to assess land cover changes.

The Tassle Cap trend analysis can be used to monitor/identify temporal changes in vegetation across larges areas by using a dense stack of Landsat images (Fig. 3). This approach calculated trends in the change over time for greenness, brightness, and wetness. These are then combined into a single stacked image so that the linear trend for each transformation can be interpreted. Each of these approaches provides pros and cons based on data availability, costs, and resolution. Therefore, a combination of all three approaches will be used for thermokarst detection in this project.

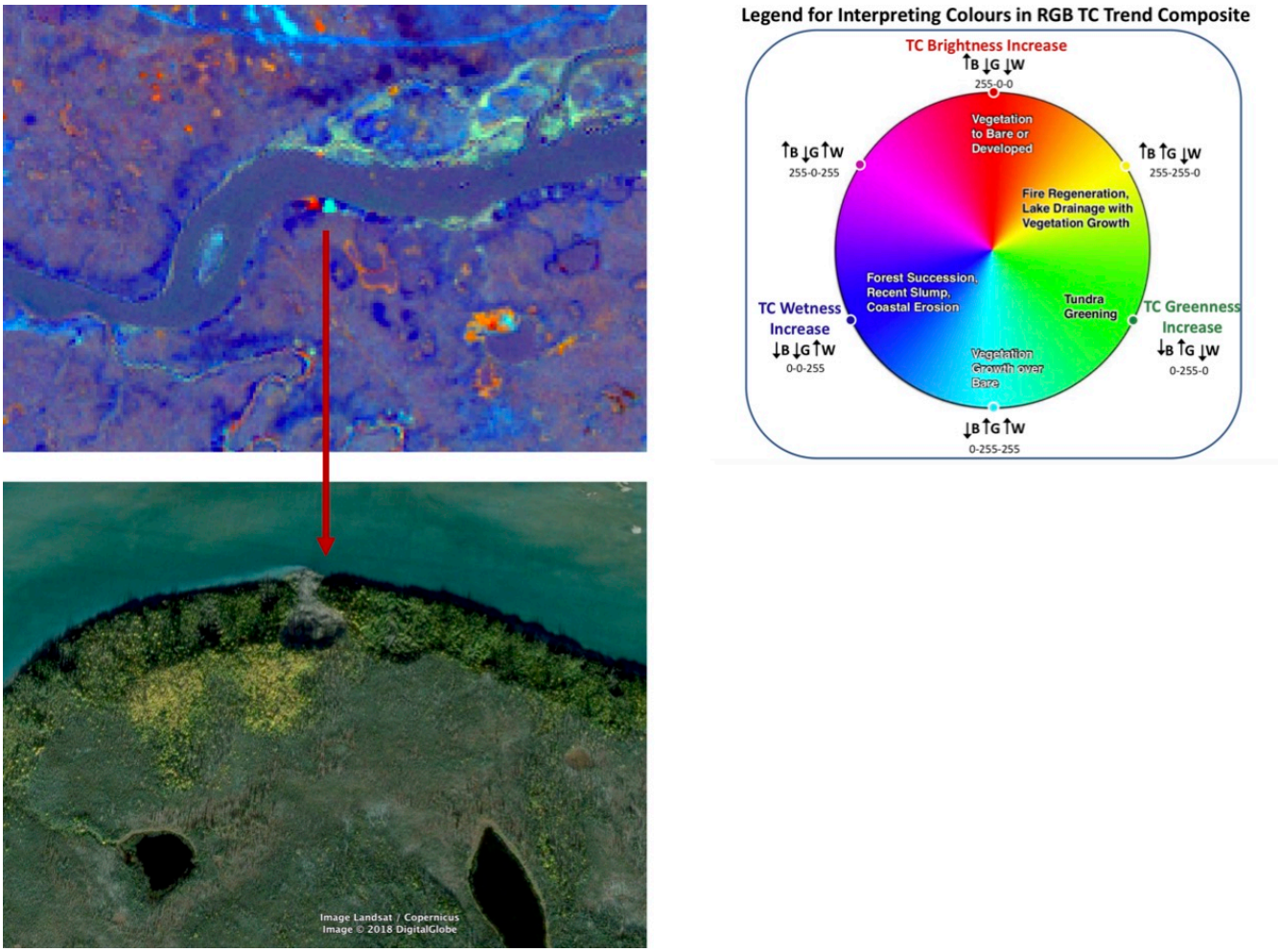

Figure 3. False color Tassle Cap product with color key. Photo at the bottom of the figure shows the thaw feature in captured in red on the false color image.

During 2017/18 we have been compiling the datasets necessary to proceed with these analyses. Table 2 contains information on the remote sensing data that have been compiled to date.

Table 2. Datasets to be used for landscape surface change detection and the sources of this information

Surface datasets for change detection	Data source
Landsat Tasselled Cap trend imagery	Robert Fraser (Natural Resources Canada) and Jurjen van der Sluijs (NWT Centre for Geomatics)
Ecological Land and Classification (ELC) oblique air photos	NWT Department of Environment and Natural Resources
CCAdapt InSAR surface elevation change imagery	NWT Centre for Geomatics
Google Earth imagery	Google Earth
Peel Plateau active thaw slumps inventory	Northwest Territories Geological Survey
National Hydro Network	Natural Resources Canada
NWT fire history	NWT Department of Environment and Natural Resources
Aerial photography	Natural Resources Canada National Air Photo Library
NWT Seismic Lines	National Energy Board
NWT Spatial Data Warehouse – spatial data on mining, road and community development	NWT Spatial Data Warehouse

We have also been working with Dr. Smith at the Geologic Survey of Canada and a range of consulting firms in the NWT to compile geotechnical borehole data the locations of which are depicted in Figure 4.

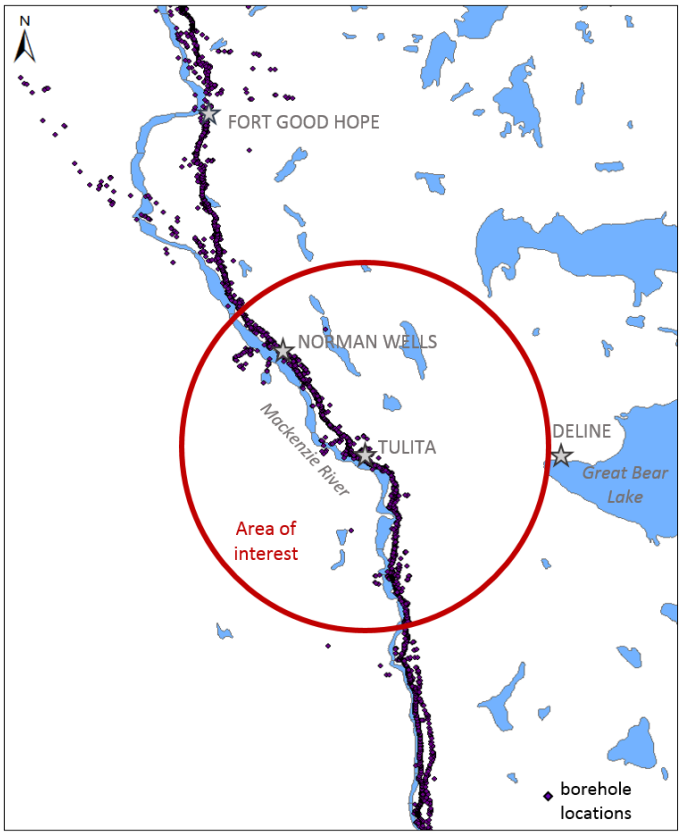

Figure 4. Locations of geotechnical boreholes in the Sahtu, so far compiled (c. 7000 boreholes). Data sources include Geological Survey of Canada Open Files 4924, 3912, 6041 and 6677. Soon to incorporate data collected as part of consultancies' projects for the GNWT (c. 3000 boreholes). Red circle shows a 100 km radius around one community of interest – Tulita. This delimited area is where we will focus our surface change detection work.

We have compiled a range of other data types to support the proposed analyses. Table 3 provides an overview of the type of information provided by each type of data. Figure 5 provides an overview of the how these different types of data will lead to the development of improved understanding of terrain sensitivity.

Table 3. Predictor variables to be used in the decision tree analysis to understand landscape surface changes.

Category	Predictor variables	Data source
Hydrology	Soil moisture / ground ice content	Geotechnical borehole dataset compiled from Geological Survey of Canada Open Files & GNWT consultancies
	Distance to water course	National Hydro Network (Natural Resources Canada)
	Surficial geology	Northwest Territories Geological Survey & Geological Survey of Canada
Substrate	Soil type	Geotechnical borehole dataset
	Organic layer depth	Geotechnical borehole dataset
	Geomorphology	Northwest Territories Geological Survey
Topography	Slope	Digital Elevation Models (DEMs) (e.g. Mackenzie Valley 30m Digital Elevation Models – UTM Zone 8. 9 & 10 from NWT Centre for Geomatics)
	Aspect	
Ecology	Vegetation cover	NWT Centre for Geomatics
	Time since wildfire (if applicable)	NWT Fire History (NWT Department of Environment and Natural Resources, 1965-present fire polygons)
Disturbance	Distance to seismic line	NWT Seismic Lines (Historical seismic line database from National Energy Board)
	Distance to development (mining, road, community)	NWT Spatial Data Warehouse – various data sets on road networks, mineral, oil and gas developments, and communities.

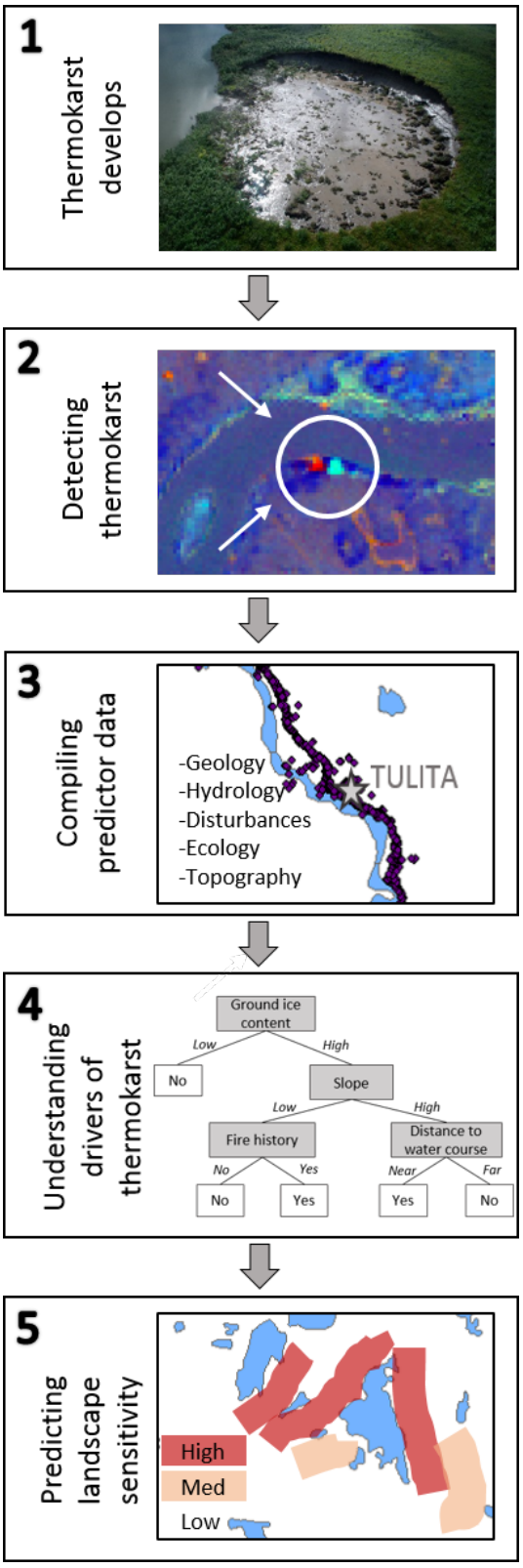

Figure 5. Work plan connecting remote sensing tools (Figs 1-3 and Table 1) with geotechnical (Fig 4, Table 2) and new field-based data collected during this project. Panel 4 demonstrates the decision tool that will be used to assess vulnerability to changing permafrost conditions.

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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

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

3) Yr 1: Review and synthesis of literature, data, and images on permafrost, fire, and caribou habitat in the Sahtú

- In progress

4) Yr 1-3: Field surveys and analysis of data to establish relationships between fire, permafrost, and vegetation

- Will be initiated in 2018 as agreed upon

- We will establish a network of field plots in the Sahtú region across a range of disturbance features. In each plot, we will make intensive measurements of stand age and structure, plant composition, foliar nutrient content, active layer depth, and ground ice content. Plots will capitalize on the location of any existing permafrost boreholes, which will allow us to relate terrain and vegetation characteristics to historical ground thermal data. These data will support the procedure in Figure 5 but also allow us to assess plant community changes associated with a range of disturbances supporting prediction of potential impacts to caribou habitat.

5) Yr 2-3: Point based photointerpretation of change characteristics

- In progress

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

7) Yr 3-4: Produce spatially explicit information on post-thaw landscape change and subsidence in critical

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)
    a. 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 Sahtu over the course of this project. During 2018, I anticipate that Ana will spend ~25% of her time on this project.
    b. Travel support for Sniderhan
2) Northern Water Futures (~$50,000 per year)
    a. The salary of Dr. Anna Coles is being supported through Northern Water Futures. Anna is dedicating roughly 50% of her time to this project.
    b. 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)
    c. Field expenses for the teams
3) University of Guelph – Carolyn Gibson's salary is supported through a prestigious scholarship at the University of Guelph.
4) Government of the Northwest Territories ($150,000 for 2018 field work)

   a. This is a one-time contribution to help support the establishment of this field program during 2018. This will be particularly important for supporting helicopter time to access disturbance features on the landscape. The inaccessible nature of much of the landscape makes this sampling particularly challenging and costly.

5) In addition, we are coordinating field logistics with the teams of Drs. Rudolph and Gray to ensure maximum output and efficiency from all sampling efforts and the integration of these different teams to promote interdisciplinarity in the research program and results.

Spending to date

2017/18 funding - $50,000
2017/18 expenditures - $11,557 ($6220 of travel for Husky site visit; $5338 in salary for Kristen Bill)

The Contribution Agreement for this project began in July 2017, too late to start a 2017 field season. As agreed upon, we are underspent on these ESRF funds. There are two main reasons for this:

1) Many of the HQP recruited to conduct the research are funded from other sources meaning we have only had to pay salary for Kristen Bill's first year of her MSc
2) In order to support a full first field season, we decided it necessary to reserve some funds from the 2017/18 fiscal year to support that work. This will help ensure that we have the resources necessary to appropriately support the cost of conducting research in this remote region.