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**Community workshop on permafrost and landscape change,
Rankin Inlet, Nunavut**

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SUMMARY

A community workshop on permafrost and landscape change was held in Rankin Inlet, Nunavut February 1–3, 2016. The workshop was organized by the Geological Survey of Canada in collaboration with the Canada Nunavut Geoscience Office and the Government of Nunavut Climate Change Section. The workshop consisted of an open house on permafrost research at Natural Resources Canada, educational outreach activities on climate change and permafrost, and a participatory mapping exercise for gathering local and traditional knowledge on permafrost and landscape change in the Rankin Inlet region. The mapping exercise involved GSC scientists interacting with participants to record observations of landscape features and landscape change that may be related to permafrost and permafrost processes. In addition to general observations, participants were specifically asked to consider observations of frozen ground or ice, changes in drainage or surface waters, patterned ground, and erosion or slope movement. On-the-table mapping was performed in small groups using topographic maps with supplementary optical satellite imagery and aerial photographs. Participants interacted with a facilitator over the maps while a recorder transcribed the observations. Observations shared during the participatory mapping exercise are presented as a series of maps keyed to a table of descriptions. The observations include many different landscape features and possible permafrost phenomena. As well as documenting observations of landscape change, the mapping exercise provided an opportunity for participants to consider how permafrost-related landscape changes might be important to them. Information gathered from the participatory mapping exercise will be interpreted in terms of permafrost conditions in the Rankin Inlet region and workshop results will be used to design and develop research activities and field operations within Natural Resources Canada.

INTRODUCTION

Permafrost is ground that remains at or below 0°C for at least two consecutive years (French, 2007). Permafrost and associated ground ice can significantly affect the landscape and land-based infrastructure through its influence on ground stability and drainage patterns. Knowledge of permafrost conditions is required to characterize climate change impacts, reduce risks and aid in adaptation solutions for Northern Canada. To improve regional characterization of continuous permafrost and to increase basic permafrost information for the Kivalliq region of Nunavut, a collaborative project between the Geological Survey of Canada (GSC) and the Canada-Nunavut Geoscience Office (CNGO) was initiated to study permafrost conditions for the western coast of Hudson Bay (Tremblay et al., 2016). As part of the planning process, a community workshop was held in Rankin Inlet from February 1–3, 2016 to inform development of permafrost research activities in the region. The workshop consisted of an "open house" presentation on permafrost research at Natural Resources Canada, educational outreach activities on climate change and permafrost organized by the Government of Nunavut Climate Change Section (CCS), and a participatory mapping exercise for gathering local and traditional knowledge (LTK) on permafrost and landscape change in the Rankin Inlet region.

The Government of Nunavut has a history of collecting and documenting LTK and Inuit Qaujimagatuqangit on a range of topics including climate change (Government of Nunavut, 2005a; 2005b). Community meetings and workshops on climate change have been conducted in the three Inuit regions, including a 2007 climate change workshop in Rankin Inlet (Government of Nunavut, 2011; Mate and Reinhart, 2011). These initiatives contributed to the development of the Nunavut Climate Change Partnership between the Government of Nunavut, the Canadian Institute of Planners, Natural Resources Canada, and Indian and Northern Affairs Canada. From 2008 to 2011, this collaboration resulted in the development of various climate change adaptation resources including land hazard maps, permafrost monitoring stations, community climate change adaptation plans and a climate change adaptation toolkit for Nunavut communities (Nunavut Climate Change Partnership, 2010a; 2010b; 2011). In 2014 and 2015, the CCS hosted permafrost and community infrastructure workshops in Arviat and Cape Dorset to support Government of Nunavut hazard mapping work. In conjunction with these workshops, ArcticNet partners from Memorial University and Université Laval installed permafrost monitoring stations in Arviat and Cape Dorset (Nunavut Climate Change Centre, 2014) that complement installations in other Nunavut communities (Ednie and Smith, 2011; 2015).

In a similar spirit of community involvement, this workshop on permafrost and landscape change in Rankin Inlet represents an initial step towards establishing communication with the community, gathering local and traditional knowledge, and stimulating interest in permafrost science activities (e.g., Nickels et al., 2007). This report describes the components of the community workshop on permafrost and landscape change in Rankin Inlet and presents the results of the participatory mapping exercise.

STUDY AREA

Permafrost underlies almost half of Canada's landmass and all of Nunavut (Heginbottom et al., 1995). Rankin Inlet and the western coast of Hudson Bay are within the continuous permafrost zone where 90% to 100% of the land area is underlain by permafrost (Figure 1). Within the continuous permafrost zone, unfrozen zones termed taliks may exist under large water bodies (French, 2007; Golder Associates, 2014). Permafrost thickness in the Rankin Inlet region has been estimated to be 200–300 m and active layer thickness may vary from 0.3–4 m depending on location (Brown, 1978; Smith and Burgess, 2002). Little information exists on ground ice occurrence in the region, although it is likely variable and related to surficial geology and hydrology.

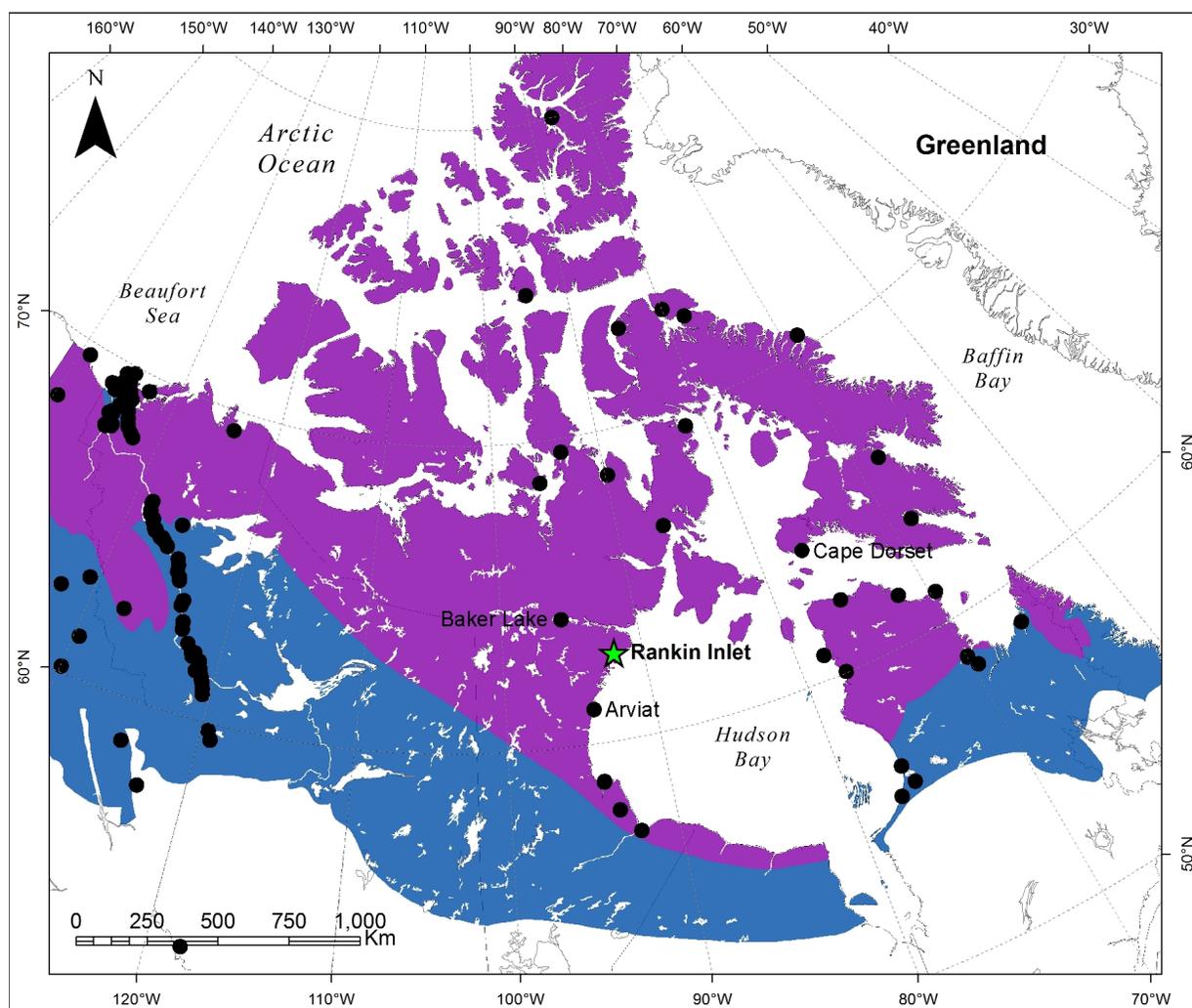


Figure 1. Map of permafrost monitoring stations in the Canadian Permafrost Monitoring Network (updated from Smith et al., 2010). The Baker Lake station has been inactive since 2008. Purple is the continuous permafrost zone; blue is the discontinuous permafrost zone (after Heginbottom et al., 1995).

Mean annual air temperature for 1981–2014 calculated using Environment Canada climate station data is -10.3°C for Rankin Inlet. During the same time period, mean annual air temperature has risen by 2.2°C . Similar trends are recorded for Arviat, Chesterfield Inlet and Whale Cove climate stations and significant changes in permafrost conditions, hydrology, ecology and infrastructure sustainability may be in store for the western coast of Hudson Bay in response to climate warming (Zhang, 2013; Tam, 2014). However, there is limited historical or contemporary permafrost data along the western coast of Hudson Bay (Smith and Burgess, 2000). The majority of Canadian permafrost monitoring sites are located in the Yukon and NWT (Smith et al., 2010). At the same time, the Kivalliq region of Nunavut is undergoing significant infrastructure developments associated with natural resources, shipping and community sustainability. Ground temperature data are often collected as part of natural resource projects such as Meadowbank and Meliadine; while useful, these data are often limited in recording period or are not publically accessible beyond data released in environmental assessment reports (e.g., Smith et al., 2013). Without fundamental knowledge of past and current permafrost conditions, any response of permafrost or landscape change to climate warming is difficult to establish.

ACTIVITIES

Open House

The workshop was initiated with an "open house" style event on the evening of February 1st that included a presentation on permafrost research conducted by the GSC and Natural Resources Canada. Posters and visual aids provided examples of permafrost research performed in other Nunavut communities. Various permafrost fieldwork activities were described along with some of the resulting products such as maps and reports. Discussion was focused on permafrost and climate change, and the benefit of earth science information for climate change adaptation, infrastructure planning and maintenance, and northern resource development. The discussion included comments from the audience about permafrost, air and water temperature, wind direction, and water level changes.

Outreach Activities

During the workshop, the CCS organized several educational and outreach activities related to climate change and permafrost designed to encourage open conversation and the sharing of information. In conjunction with the open house on February 1, the CCS presented the 2010 Inuktitut language documentary film *Inuit Knowledge and Climate Change* by co-directors Zacharias Kunuk and Ian Mauro. The film includes a series of interviews with Nunavummiut that explore the social and ecological impacts of climate warming in the Arctic

(<http://www.isuma.tv/inuit-knowledge-and-climate-change>). After the screening, there was a general discussion around climate change impacts in Nunavut and the effects on the community of Rankin Inlet and the surrounding landscape.

The CCS also organized and conducted youth engagement events on February 1–3. These events included drop-in outreach sessions for elementary and high school students of all ages, and also in-class activities for the Grade 5/6 students at Simon Alaittuq School. The drop-in outreach sessions included a presentation on climate change and permafrost, and a climate change art exhibit featuring the students' original art. Students had a chance to interact with the CCS in an informal session and discuss how climate change is impacting their community and what they can do to adapt. In-class activities involved a short presentation on climate change and permafrost followed by a hands-on activity in which students built model houses on thawing blocks of "permafrost" to investigate how the houses responded to changing ground (Figure 2). Both teachers and students were enthusiastic about the activity and it generated discussion on methods of keeping houses stable over thawing permafrost (e.g., Government of Nunavut, 2013).

In addition to school activities, the CCS hosted a local radio show on climate change on the evening of February 3. Listeners were encouraged to call in and share observations on climate change and permafrost, or to ask questions. Approximately 15 callers participated in the show both with questions about climate change and permafrost, as well as their own observations of the changing landscape. Call topics included observations of ground subsidence in the community, observations of changes in the seasons, and discussion of the role of traditional clothing in living on the land.



Figure 2. Activities at Simon Alaittuq School including an introduction to climate change and permafrost (left) and model house construction on "permafrost" blocks (right).

Mapping Exercise

The participatory mapping exercise was designed to gather local and traditional knowledge on permafrost conditions and landscape changes in and around Rankin Inlet, and to stimulate community engagement in permafrost science activities. The objective of the mapping exercise was for GSC scientists to interact with participants to identify 1) areas that have undergone or are undergoing landscape change potentially related to permafrost degradation, 2) areas that are sensitive or critical to traditional land-use or ways of life such as culturally significant areas, wildlife zones, or areas where access may become limited due to permafrost and climate change, and 3) areas that may have high ground-ice occurrence. Participants included community members, representatives from the Kivalliq Inuit Association, the Rankin Inlet Hunters and Trappers Association, employees of the Hamlet of Rankin Inlet, and employees of the Government of Nunavut (Appendix A). Interpreters from the community also participated in the mapping exercise.

The mapping exercise was preceded by a short presentation that introduced participants to permafrost landscape features using photographs and diagrams. In addition to general observations of the landscape, participants were asked to specifically consider the following:

- any observations of frozen ground, such as ice in the ground or ice exposed in river banks (Figure 3)
- any observations of thawing, such as settlement
- any observations of changes in drainage patterns, changes in rivers or lakes, or appearance/disappearance of lakes that might indicate thermokarst processes (Figure 4)
- any observations of patterned ground or changes in patterned ground (Figure 5)
- any observations of erosion or slope disturbance (Figure 6)
- any changes in perennial snow patches, icing, or vegetation.

At the same time, participants were asked to consider how permafrost-related landscape changes might be important to them. For example, in Arviat, concern was expressed that early thawing of the active layer is affecting caribou migration and that it is getting harder to travel to hunting sites in the summer (Government of Nunavut, 2010a). In Whale Cove, it was observed that the graves at the graveyard were sinking as the ground thawed (Government of Nunavut, 2010b).

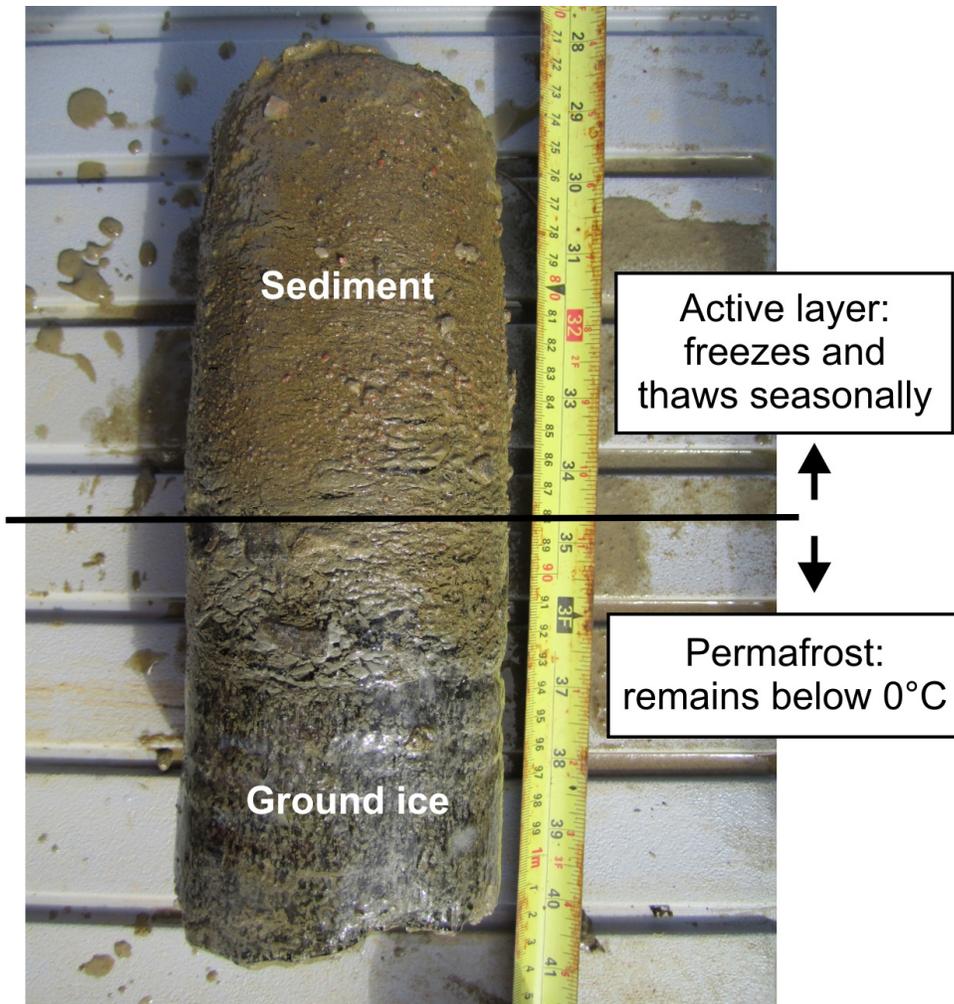


Figure 3. Example drill core from permafrost terrain exhibiting the active layer and ground ice. Active layer depth may respond to changes in climate or the land surface.



Figure 4. Examples of small lakes in permafrost terrain in the vicinity of Rankin Inlet (photos courtesy of S. Wolfe, Geological Survey of Canada). Lakes and ponds may form, grow, shrink or disappear due to changes in permafrost.

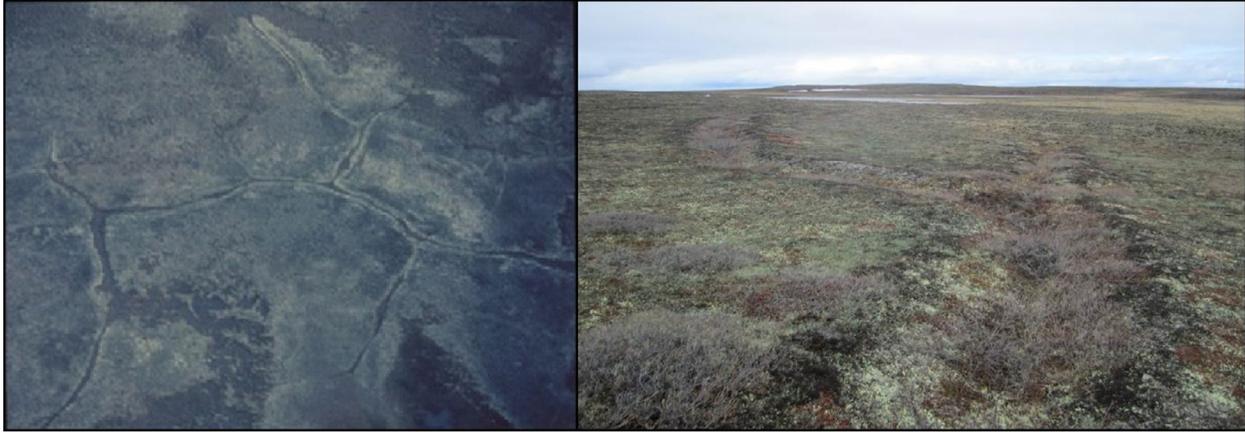


Figure 5. Examples of patterned ground associated with ice-wedge polygons in the vicinity of Rankin Inlet (left photo courtesy of S. Wolfe, Geological Survey of Canada). Furrows may deepen or fill with water and form drainage patterns.



Figure 6. Different types of slope movement can occur in permafrost terrain. Triggers include thawing of ice-rich material and saturation with water. Left: downslope flow of unfrozen ground over permafrost (gelifluction lobes) in the vicinity of Rankin Inlet (photos courtesy of S. Wolfe, Geological Survey of Canada). Right: Active layer detachment landslide near Pond Inlet (photo courtesy of J. Shirley, Nunavut Research Institute).

The presentation was followed by on-the-table mapping where, in small sessions, participants were asked to share their observations of permafrost and the landscape in the Rankin Inlet region (Figure 7). Mapping was performed using CanVec topographic map data from Natural Resources Canada (1:50,000 and 1:250,000) scaled and plotted at 1:35,389 for the Rankin Inlet region and 1:200,000 for the region from Whale Cove to Chesterfield Inlet. The topographic maps were supplemented by optical satellite imagery and aerial photographs where available. For each mapping session, participants interacted with one facilitator. The facilitator guided the discussion in a sort of semi-directed interview fashion. Participants were encouraged to draw on the map while describing their observations to provide the geospatial information. The facilitator then grouped similar observations where applicable and assigned a reference number. If the participant(s) did not draw directly on the map, the facilitator would draw on the map and get confirmation from the participant(s) that the location was in accordance with the observation(s).



Figure 7. Mapping exercise participants sharing observations of permafrost landforms and landscape change in the Rankin Inlet region.

During mapping, one or two scientist recorders transcribed the observations of the participant(s) as true-to-word as possible, paraphrasing when necessary. When two recorders were available, a comparison of the recordings allowed for troubleshooting and some assessment

of the accuracy of the recording process. The scientific recorder keyed each observation to its map reference number assigned by the facilitator and assigned attribution for the source of each observation such as "participant's name" or "group consensus." The scientific recorders also made note of any geoscientific interpretation of participant observations, or of any hypothesis that might explain participant observations. In several instances, the scientific recorder provided notes to the facilitator to obtain further information or detail on particular observations. Any interpretation of observations either from the scientific recorders or the participants was clearly identified and separated from the participant observations to be used in further analysis of the data collected.

RESULTS

During the mapping exercise, participants described landscape features, landscape change, and land use in the Rankin Inlet region and identified the locations of observations. Participants also noted several changes to the landscape within the municipal boundary, often involving infrastructure construction. Input from participants provided a perspective on current landscape conditions and landscape change over past generations. Observations shared during the mapping exercise are presented as a series of maps keyed to a table of descriptions in Appendix B. Observations from all mapping sessions and from all participants have been reported in aggregate. The following general comments summarize participant observations directly or indirectly related to permafrost.

- Most observations could be categorized as being related to water, slope movement, erosion, ground ice and vegetation.
- Observations of water level changes in rivers, lakes, ponds and streams were identified in every mapping session. Specific observations included receding shorelines, dried ponds, low river levels and seasonal flooding.
- Subsidence, water pooling and building damage were observed in developed areas of the Hamlet.
- Observations of permafrost features and landscape changes were shared for other areas in the Kivalliq region (Coral Harbour, Whale Cove, Chesterfield Inlet, Ukkusiksalik National Park) which are not included herein.
- Although there is recognition that the landscape is changing every year, specific changes were most often identified as occurring within the last 5–10 years. This timeframe coincides with increased land use and development, including the lengthening and maintenance of access trails.

In addition to gathering LTK, workshop activities were intended to establish open communication with the community and to stimulate interest in permafrost science. Workshop

attendees, students, radio show listeners and mapping exercise participants were all encouraged to ask questions of the presenters and facilitators. The following is a list of questions asked by community members during the workshop activities that may be of interest to the public.

- Q: What is the reason for studying permafrost? *A: To better understand permafrost along the western coast of Hudson Bay and to understand how the landscape may respond to climate warming and/or infrastructure development.*
- Q: Why is it important to study landscape changes or to know where landscape changes occur? *A: Changes in the landscape may be an indicator of the presence of ground ice and the sensitivity of permafrost to climate change or infrastructure construction.*
- Q: How is permafrost measured and monitored? *A: At the GSC, we use a variety of methods including geological mapping, airphoto analysis, ground temperature measurements, shallow drilling, satellite remote sensing and geophysical methods.*
- Q: What is the current level of knowledge of permafrost in the Kivalliq Region? *A: There are some ground temperature data (Figure 1) and some theoretical modelling studies have been carried out, but the state of knowledge is less mature than in other regions of Canada.*
- Q: Will Natural Resources Canada install a monitoring station in/near Rankin Inlet? *A: This is not known at the moment, but installation of a ground temperature monitoring station would be a logical first step for any research activity in the region.*
- Q: If a monitoring station is established, would permafrost monitoring data be publicly available? *A: All data collected by the GSC are publically available. A permafrost monitoring station installed by the GSC would be added to the Nunavut Permafrost Monitoring Network which is a collection of stations that measure ground temperature across the territory.*
- Q: What is the drilling depth required for a monitoring stations? *A: Drilling depth is location-dependant but is usually between 3–15 m.*
- Q: Would the drilling activity or monitoring activity disturb wildlife such as caribou migration? *A: Disturbance to the landscape is minimal and does not involve permanent infrastructure. Actual drilling activities would be conducted away from sensitive wildlife areas.*
- Q: Is permafrost change linked directly to climate change? *A: The temperature and stability of permafrost is strongly dependant on air temperature, but other environmental and human factors can also affect the stability of permafrost.*
- Q: Is there a difference in permafrost between natural landscapes and man-made landscapes? *A: Permafrost is ground that remains below 0°C and this condition can*

- exist in both natural and man-made landscapes; both natural and man-made changes to the land surface can affect permafrost.*
- Q: Will permafrost change in the Rankin Inlet area impact infrastructure such as the airstrip? *A: The answer to this question depends on many factors such as the surficial geology, the hydrology, the presence of ground ice, and the engineering design of the infrastructure.*
 - Q: Do changing water levels in rivers and lakes have an impact on permafrost? *A: The presence or absence of permafrost and ground ice can be related to surface water (lakes, streams and rivers).*
 - Q: Is methane released when permafrost melts? *A: Yes, but mostly in areas where there is significant organic material such as peatlands.*
 - Q: Does post-glacial rebound in the Hudson Bay region have an impact on permafrost? *A: After glaciation, most of the Hudson Bay coastal region was overlain by seawater to 150–190 m elevation. Permafrost formation in the region occurred as uplift exposed the land.*
 - Q: Is Natural Resources Canada planning to visit the area in summer or early fall when the landscape can be observed? *A: Site visits in all seasons would be a likely component of any research activity in the region.*
 - Q: Are all changes observed in our landscape related to permafrost change? *A: No, but permafrost is an important component of a complicated and dynamic collection of physical phenomenon that shape the landscape.*
 - Q: Are the DInSAR maps depicting satellite remote sensing measurements of land subsidence available for Rankin Inlet? *A: Maps will be publically available in the near future.*
 - Q: Would a permafrost monitoring station or permafrost research activity be undertaken in partnership with other organizations such as Environment Canada? *A: GSC research often utilizes data from other federal departments and enters into collaboration with other organizations when possible and beneficial.*
 - Q: How will scientific data and Inuit Qaujimaqatuqangit [LTK] be used together to develop a comprehensive understanding of permafrost in the region? *A: This is a subject of ongoing discussion and research.*
 - Q: Are the cracks in my house from permafrost thaw? *A: Cracks in housing or other buildings maybe caused by normal seasonal freeze/thaw processes (frost heave) or longer-term permafrost degradation.*
 - Q: The bottom of my house is covered in plywood. Is this a good thing? *A: Skirting on buildings can trap heat and increase ground temperature. To help preserve permafrost, skirting can be removed or wire mesh skirting can be used.*

- Q: My house is on piles but they don't seem to be working. Why? A: *Piles are subject to downward creeping as permafrost deforms under load and upward heaving due to freeze/thaw processes. To be most stable, piles can be anchored in bedrock. In the absence of bedrock, adjustable foundations may be suitable such as screw jacks, pad and wedge designs, or space frames.*

CONCLUDING DISCUSSION

A community workshop on permafrost and landscape change was held in Rankin Inlet, Nunavut from February 1–3, 2016 as a first step in developing permafrost research activities in the region. Central to the workshop was a participatory mapping exercise designed to gather local and traditional knowledge on permafrost and landscape change in the Rankin Inlet region. This Open File presents a compilation of observations shared by participants during the mapping exercise that cover many different landscape features and possible permafrost phenomena.

The information gathered from the participatory mapping exercise will be interpreted in terms of permafrost conditions in the Rankin Inlet region. Participant observations will be combined with other types of information such as surficial geology, air photo analysis and satellite images to provide some idea of permafrost history, insight to present day permafrost processes, and an integrated understanding of permafrost conditions in the region. The topic of integration of contemporary science and LTK is a topic of ongoing research and the workshop results will be used in method development for integrating LTK and permafrost science at the GSC.

Workshop results will be used to design and develop research activities and field operations within Natural Resources Canada and to establish research partnerships with communities. For example, sites identified during the mapping exercise may provide a suite of potential locations for installation of ground temperature monitoring stations. Participants recommended a summer visit by GSC scientists to travel to sites identified during the mapping exercise and also commented that a research project involving permafrost and ground temperature monitoring within the Hamlet in both developed and undeveloped areas would provide valuable information for the region and all levels of government. It is the hope that any future research activity will benefit from further community input to address local needs and interests, as well as providing useful information for the community and territorial governments.

ACKNOWLEDGMENTS

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REFERENCES

- Brown R.J.E., 1978. Influence of climate and terrain on ground temperatures in the continuous permafrost zone of northern Manitoba and Keewatin district, Canada. Third International Conference on Permafrost, 15–22.
- Dyke A.S. and Dredge L.A., 1989. Quaternary geology of the northwestern Canadian Shield. In: *Quaternary Geology of Canada and Greenland*, Fulton R.J. (Ed.), Geological Survey of Canada, 189–214.
- Ednie M. and Smith S.L., 2011. Establishment of community-based permafrost monitoring sites and initial ground thermal data, Baffin region, Nunavut. Geological Survey of Canada, Open File 6727.
- Ednie M. and Smith S.L., 2015. Permafrost temperature data 2008–2014 from community based monitoring sites in Nunavut. Geological Survey of Canada, Open File 7784.
- French H.M., 2007. *The Periglacial Environment*, 3rd ed., John Wiley and Sons.
- Golder Associates, 2014. Final Environmental Impact Statement – Meliadine Gold Project, Nunavut, Volume 6.0: Terrestrial environment and impact assessment, Project number 288-1314280007 Ver.0.
- Government of Nunavut, 2005a. Inuit Qaujimajatuqangit of Climate Change in Nunavut, A Sample of Inuit Experiences of Recent Climate and Environmental Changes in Pangnirtung and Iqaluit, Nunavut. Government of Nunavut Department of Environment.
- Government of Nunavut, 2005b. Inuit Qaujimajatuqangit of Climate Change in Nunavut, A Sample of Inuit Experiences of Climate Change in Nunavut, Baker Lake and Arviat, Nunavut. Government of Nunavut Department of Environment.
- Government of Nunavut, 2011. Upagiaqtavut, Setting the Course, Climate Change Impacts and Adaptation in Nunavut. Government of Nunavut Department of Environment.
- Government of Nunavut, 2013. A Homeowner's Guide to Permafrost in Nunavut. Government of Nunavut Department of Environment.
- Heginbottom J.A., Dubreuil M.H. and Harker P.T., 1995. Canada, Permafrost. In: *National Atlas of Canada*, 5th ed., Plate 2.1, MCR 4177.
- Nickels S., Shirley J. and Laidler G., 2007. Negotiating Research Relationships with Inuit Communities: A Guide for Researchers. Inuit Tapiriit Kanatami and Nunavut Research Institute.
- Nunavut Climate Change Centre, 2014. Arviat Climate Change Community Engagement. Climate Change Section, Department of Environment, Government of Nunavut. <http://climatechangenunavut.ca/en/project/arviat-climate-change-community-engagement>
- Nunavut Climate Change Partnership, 2010a. Climate Change Adaptation Action Plan for Hamlet of Arviat. Government of Nunavut Department of Environment.
- Nunavut Climate Change Partnership, 2010b. Climate Change Adaptation Action Plan for Whale Cove (Tikirarjuaq). Government of Nunavut Department of Environment.

- Nunavut Climate Change Partnership, 2011. Climate Change Adaptation Planning: A Nunavut Toolkit. Government of Nunavut Department of Environment.
- Mate D. and Reinhart F., 2011. Nunavut Climate Change Partnership Workshop, February 15–16, 2011. Geological Survey of Canada, Open File 6867.
- Smith S. and Burgess M.M., 2000. Ground temperature database for northern Canada. Geological Survey of Canada, Open File 3954.
- Smith S. and Burgess M.M., 2002. A digital database of permafrost thickness in Canada. Geological Survey of Canada, Open File 4173.
- Smith S.L., Romanovsky V.E., Lewkowicz A.G., Burn C.R., Allard M., Clow G.D., Yoshikawa K., Throop J., 2010. Thermal state of permafrost in North America: A contribution to the international polar year. *Permafrost and Periglacial Processes* 21, 117–135.
- Smith S.L., Riseborough D.W., Ednie M. and Chartrand J., 2013. A Map and Summary Database of Permafrost Temperatures in Nunavut, Canada. GSC Open File 7393.
- Tam A., 2014. The impacts of climate change on potential permafrost distributions from the subarctic to the high arctic regions in Canada. PhD Thesis, University of Toronto.
- Tremblay T., Kendall M.S., LeBlanc A.-M., Short N., Bellehumeur-Génier O., Oldenborger G.A., Budkewitsch P. and Mate D.J., 2016. Overview of the surficial geology map compilation, RapidEye land-cover mapping and permafrost studies for infrastructure in the western Hudson Bay area, Nunavut. Canada-Nunavut Geoscience Office, Summary of Activities 2015, 145–160.
- Zhang Y., 2013. Spatio-Temporal features of permafrost thaw projected from long-term high-resolution modeling for a region in the Hudson Bay Lowlands in Canada. *Journal of Geophysical Research* 118, 542–552.

APPENDIX A

Mapping Exercise Participants

Table A1. List of mapping exercise participants, excluding three anonymous participants.

Name	Organization
Jerome Tautuinee	Resident
Andy Aliyak	Resident
Patrick Karlik	Resident
Nigel Kubluitok	Rankin Inlet Hunters and Trappers Association
Ashley Ymana	Hamlet of Rankin Inlet
Maria Serra	Kivalliq Inuit Association
Veronica Connelly	Kivalliq Inuit Association
Craig Beardsall	Kivalliq Inuit Association
Robert Connelly	Government of Nunavut, Economic Development and Transportation
Theresie Tungilik	Government of Nunavut, Economic Development and Transportation
Tommy Bruce	Government of Nunavut, Economic Development and Transportation
Brian Duguay	Government of Nunavut, Community and Government Services
Jakub Garbarczyk	Government of Nunavut, Community and Government Services
Manasie Oingonn	Government of Nunavut, Community and Government Services
Ronald Ooloyuk	Government of Nunavut, Community and Government Services
David Beamer	Government of Nunavut, Department of Environment
Mary Rose Angoshadluk	Interpreter
Johnny Ayaruaq	Interpreter

APPENDIX B

Mapping Exercise Compilation of Results

The following maps represent a compilation of observations shared during the participatory mapping exercise. Observations from all mapping sessions and from all participants have been reported in aggregate without attribution to specific individuals. Observations that were described by participants at a particular location are generally reported as point features. Observations that were described by participants over a particular region or multiple nearby locations are reported as encompassing areas. If an observation applied to an entire lake, it is generally reported as a point feature, but if an observation applied to a particular section of a waterway, it is reported as an area or line. In some cases, the regions described by participants were mapped by the facilitator and thus involve some degree of subjectivity, influence or error in terms of boundaries. In other cases, the regions described were mapped by the participants themselves and thus, the reported areas directly reflect the observation of the participants. The regions described during the mapping exercise (mapped by either the participant or the facilitator) were often imprecise and thus, the reported areas are imprecise. The Inuit Owned Land boundaries have been modified to fit the scale of the base data and should be considered only as an approximate representation.

Descriptions of participant observations are provided in Table B1 and are keyed to the maps. Observations and descriptions are also included as Google Earth™ files. Recorders transcribed the observations of the participants as true-to-word as possible. Although the descriptions of observations inevitably involve paraphrasing of the dialogue between the participants and the facilitator, an effort was made to report an accurate representation of the observations that avoids the introduction of interpretation or bias. No attempt has been made to establish the veracity of observations. When possible, the facilitator attempted to get group consensus on an observation, or confirmation of an observation from multiple participants either during the same mapping session or during a subsequent mapping session. This was a dynamic process that was not explicitly recorded, but is sometimes reflected as repeated similar observations. All observations are presented as equal-valued.

Table B1. LTK Observations.

Number	Location	Map	Observation
1	Josephine River	A	Low water level and fish death
2	Josephine River	A	Low water level; river bank erosion
3	Rankin Inlet Area #5	B	Buildings need levelling to adjust to ground movement
4	Rankin Inlet Area #6	B	Ground movement causing the houses to shift shortly after construction (during the last 5 years)
5	Rankin Inlet	B	Historical lakes within the Hamlet limits; drained/filled prior to infrastructure construction
6	Rankin Inlet (cemetery)	B	Subsidence of graves in the cemetery in the last 10–15 years
7	Rankin Inlet (quarry)	B	Coarse gravel underlain by fine sand; water table 2 m below ground surface, level with top of sand
8	Rankin Inlet	B	Shifting of residential pile structure
9	Rankin Inlet	B	Ground movement causing damage to municipal pipe system
10	Rankin Inlet (Williamson Lake)	B	Lake size reduced
11	Nipissar Lake	B	Low water levels in recent years
12	Landing lake	B	The lake is not totally frozen during winter; bubbles present at the lake surface in the open water
13	Sandy Lake	B	Low water levels, especially during the last 5 years; past shorelines exposed; adjacent esker stable
14	Rankin area (Sandy Lake)	B	Ponds west of Sandy Lake are drying out
15	Territorial Park	B	Numerous ice wedge polygons; stable
16	Rankin area (esker)	B	Landslide
17	Meliadine River	B	Unusual ice build-up on the river during winter months that raised the surface up to 3.7 m; occurred only twice in the last 30 years, both times in the last 5 years
18	Meliadine River	B	Warmer water temperature
19	Little Meliadine Lake	B	Exposed visible ice in the ground
20	Little Meliadine Lake	B	Ground ice exposed along creeks
21	Little Meliadine Lake	B	Increased exposure of island; water level decrease
22	Little Meliadine Lake	B	River crossing earlier in spring
23	Little Meliadine Lake	B	Landslide; mud
24	Little Meliadine Lake	B	Relocation of ATV trail from north to south side of lake due to muddy conditions in the last 10–15 years
25	Meliadine Lake	B	Low water level
26	Meliadine Lake area	B	Landslide
27	Diane River	B	Low water level in the last 5 years; adjacent creek now dry

28	Diane River	B	At least one event of flowing water on top of river ice in winter months that flooded an important area adjacent to the river
29	Diane River	B	Historical food cache site not cold enough; last 7–8 years
30	Diane River	B	Low water level in recent years; still areas of strong current and deep water
31	Rankin area (Diane River access trail)	B	Access trail to Diane River washed away during summer 2015
32	Char River	B	Bridge damaged by flooding
33	Barrier Island	B	Low sea water level; more land exposed in the last 10 years
34	Barrier Island	B	Exposed visible ice
36	Thompson Island	B	Landslide; wet gentle slope
37	Rankin area (East)	B	The summer vegetation has changed colour from green to brown making it harder to predict change of season
38	Rankin area (East)	B	The land has become muddy during recent years
39	Rankin area (East)	B	Exposed visible ice in mounds surrounded by sediment
40	Rankin area (East)	B	Perennial snow
41	Rankin area (East)	B	Lakeshore erosion, shrinking ponds, increased snow thickness, change of predominant wind to NE
42	Rankin area (East)	B	Landslide
43	Rankin area (East)	B	Landslide; exposed visible ice
44	Rankin area (East)	B	Landslide
45	Rankin area (East)	B	Landslide; muddy area
46	Rankin area (East)	B	Slope movement
47	Rankin area (Northeast)	B	Increased difficulty travelling over land by ATV
48	Rankin area (Northeast)	B	Shrinking of perennial snow patch
49	Rankin area (Northeast)	B	Landslide, muddy area and ice wedge polygons
50	Rankin area (West, Caribou Valley)	B	Ice wedge polygons; change in drainage following construction of access trail
51	Rankin area (West)	B	Increase in willow height from 0.3 m in the past to 1.2 m currently
52	Rankin area (Southwest)	B	Ground subsidence along ATV trail; furrows filled with rocks need to be re-filled as rocks sink
53	Southwest	C	Landslide
54	Southwest	C	Low water level
55	Southwest	C	Low water level in ponds; dryer conditions in last 10 years
56	Southwest	C	Exposed visible ice with soil cover; feature dimensions are approximately 1.8 m by 2.4 m by 0.6 m high

