Assessing and Monitoring Permafrost along the Dempster Highway: Paving the Way for an Adaptation Strategy

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Dempster Highway, Yukon

- Only all-season road connection to the western Arctic.
- 740 KM (460 miles) hard packed gravel road.
- About 90% built on permafrost.

$ $22k to $36k of additional costs / km/ year

$ Permafrost sections: 5 times more expensive to maintain.

Climate is changing: +2.5 to 4.0°C in 2050

+ Increase in precipitations

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Various geohazards

Landslide

Sinkhole

Erosion

Subsidence

Thermal erosion

Thermokarst

An holistic functional plan

Develop a function plan that considers climate change and incorporates climate resiliency into short, medium and long term planning and cost estimates.

- Review and compile existing project data
- Contribute knowledge of permafrost conditions
- Carry out intensive field program focusing on priority sites

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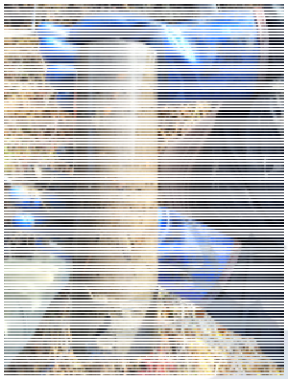
Field and Laboratory assessment

Drilling

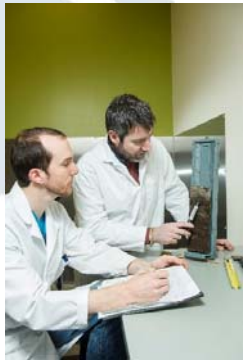




Geophysics


Monitoring


Geotechnical analysis

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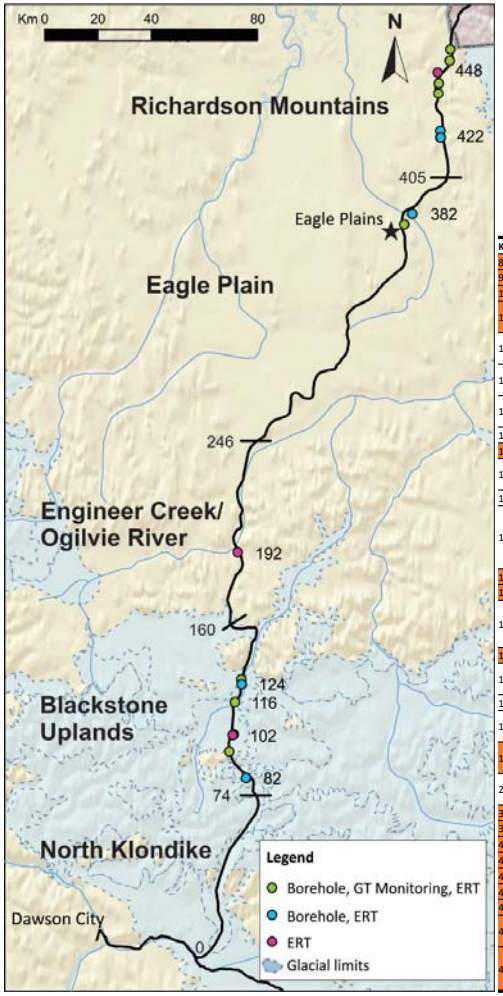
Site selection

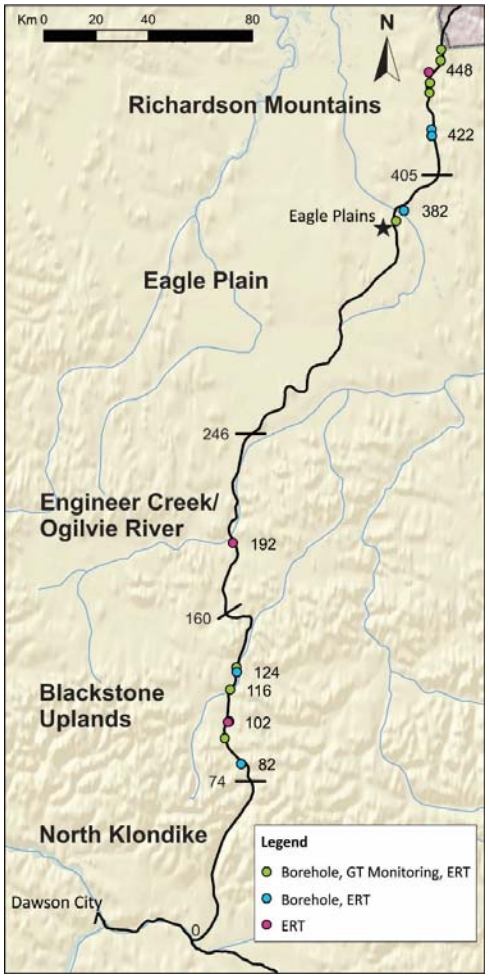


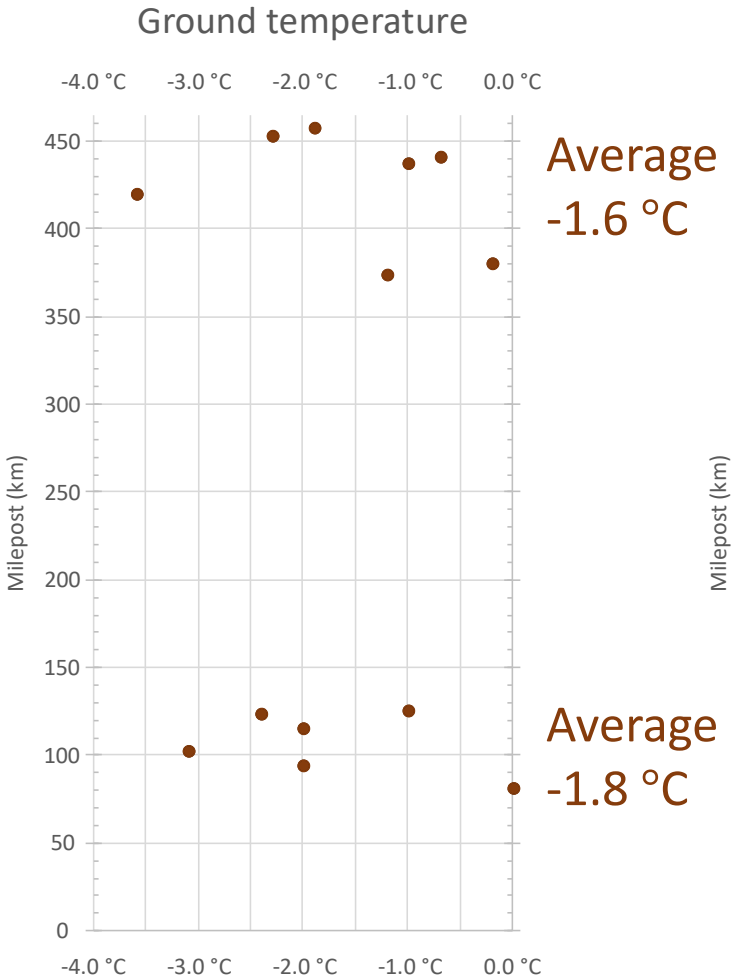
17 sites (out of 30):

- **Recurring, long-term issues**
- **Requiring intensive maintenance**
- **Representative (geomorphology, environment, …)**

Km post	Longitude	Latitude	Degradation type	Comments	Survey	Monitoring
82	-138.277208	64.586202	Sinkhole		ERT	HPW Borehole
95	-138.398027	64.677519	Ground movement	Failure 20 m long at RHS	ERT, Drilling	NCE borehole in field
102.5	-138.361639	64.732985			ERT, Drilling	NCE borehole in field
103	-138.360546	64.736358	Subsidence	Sagging at Two Moose Lake, Refill one week ago (at time of photo)	ERT	
103.5	-138.365217	64.740842	Thermokarst lake - Ice wedges - thaw lakes	The lake is expanding at north side		
104.5	-138.373087	64.749559	Erosion	The river is eroding the embankment at RHS		
109.4	-138.350782	64.789328	Slide	Slide at LHS on hill slope - new from this year		
109.6	-138.350733	64.791175	Slide	Debris flow at LHS		
116.5	-138.336849	64.843072	Major subsidence - deep excavation		ERT, Drilling	NCE borehole in field
117	-138.323624	64.845332	Water ponding	Standing water at RHS, smaller at LHS - new of this year (2016)		
119.5	-138.296320	64.864069	Water ponding			
121.5	-138.286917	64.882431	Water ponding	Water gaining on road, level higher on LHS, the Blackstone is flowing on RHS, culvert in between does not seem flowing.		
123.8	-138.277402	64.901459	Channel forming	Repairs crossing airstrip	ERT	
124	-138.277826	64.903173	Major depression - transversal		ERT	Met Station
125	-138.280323	64.908234	General subsidence	HPW continues to build up the embankment and the road is becoming narrower		
126	-138.277803	64.918621	Sinkhole (filled)		ERT, Drilling	NCE borehole in field
129	-138.270686	64.94307	Cracking	Cracking RHS at Culvert, thick embankment (high grade)		
135	-138.201989	64.98399	Washout	Repaired - debris flow?		
166	-138.336622	65.142857	General subsidence	The road is sinking, bern at both side, peat deposit at LHS		
192	-138.256425	65.3466	General subsidence - Sinkhole	The road is sinking. Presence of a hole in the middle of the road	ERT	
264	-137.773054	65.826508	Sinkhole	Cones at LHS, water ponding, water disappearing in holes at LHS		
375	-136.719994	66.418483	Thermokarst ponds - Slide		ERT, Drilling	NCE borehole in field
381	-136.664156	66.446562			ERT	NCE borehole in field
421	-136.358622	66.700926			ERT	HPW Met Station
424	-136.357464	66.722663	Slope movement and thermal erosion		ERT, Drilling	
438	-136.346322	66.852419	Degradation	Degradation in the field, 500 m at LHS	ERT, Drilling	NCE borehole in field
442	-136.338391	66.883582	Subsidence	Located in field at RHS	ERT, Drilling	NCE borehole in field
447	-136.337862	66.920699	Sinkhole	Material keeps disappearing	ERT	
454	-136.229042	66.956397	Ice wedge degradation - thaw lake - subsidence		ERT, Drilling	NCE borehole in field
458	-136.215026	66.994515	Sinkhole - thaw lake - subsidence	Disappearing water at RHS, large depression at LHS - Patch of snow on LHS	ERT	NCE borehole in field

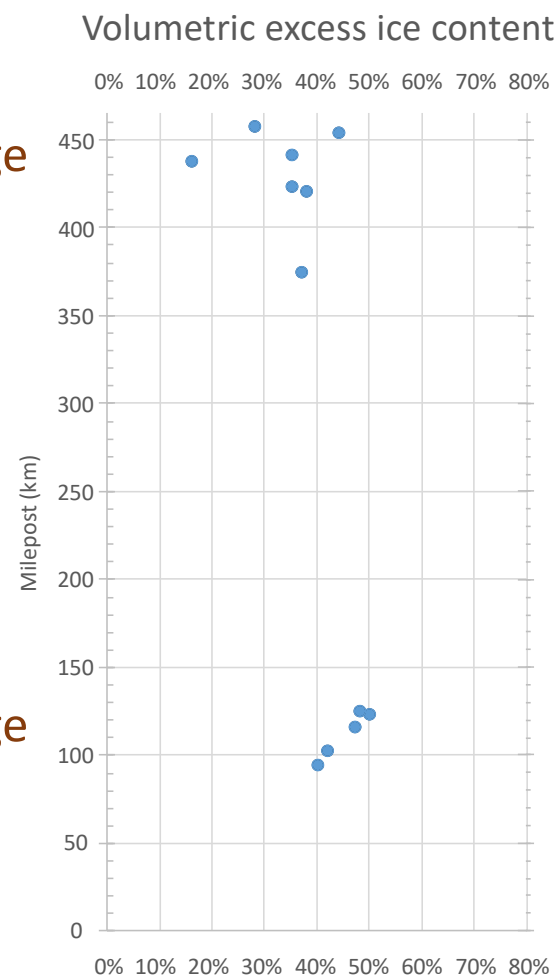
Ground temperature & Excess ice content





Average
-1.6 °C

Average
-1.8 °C



Average
33%

Average
45%

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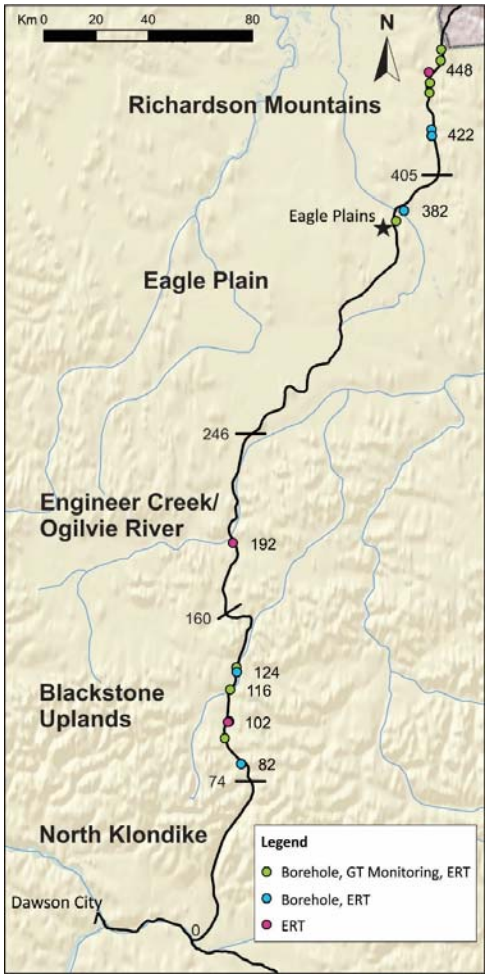
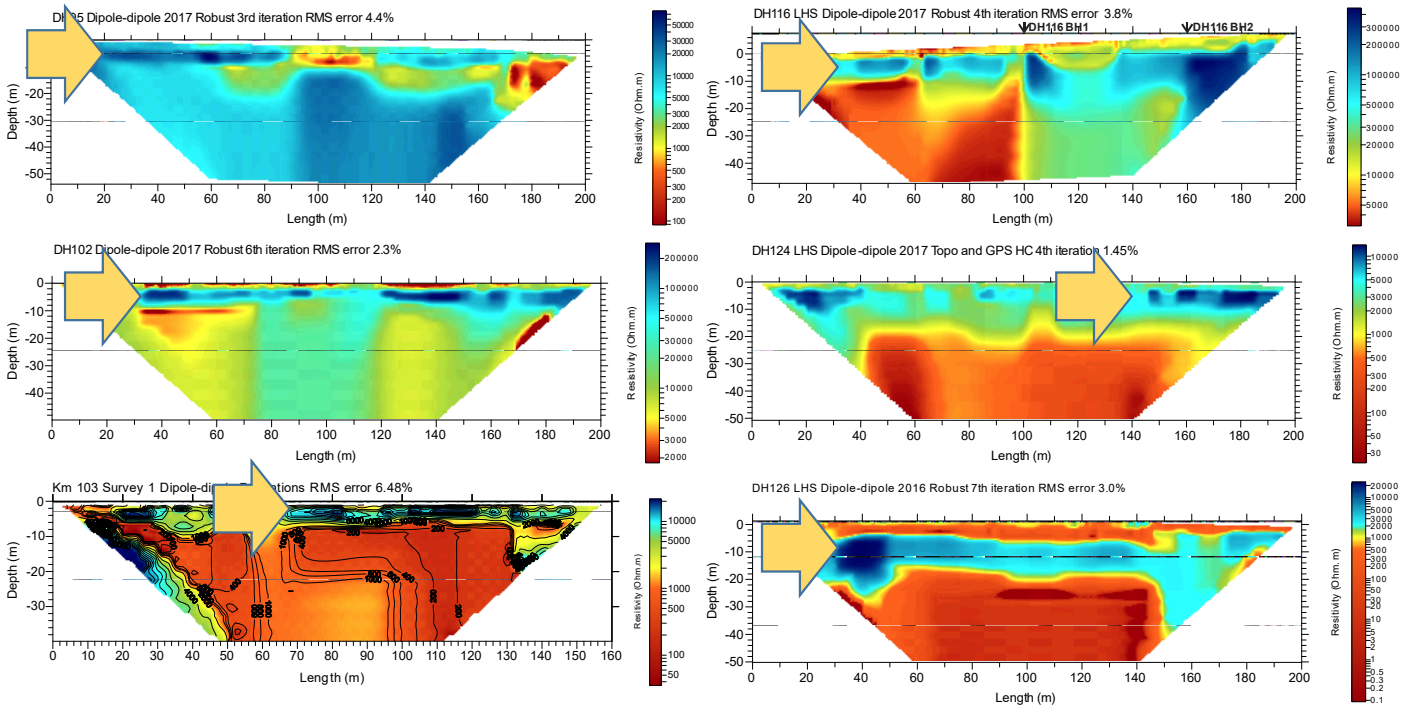
Ground Ice : nature and extent - South





- **Ice Wedge (several meters)**

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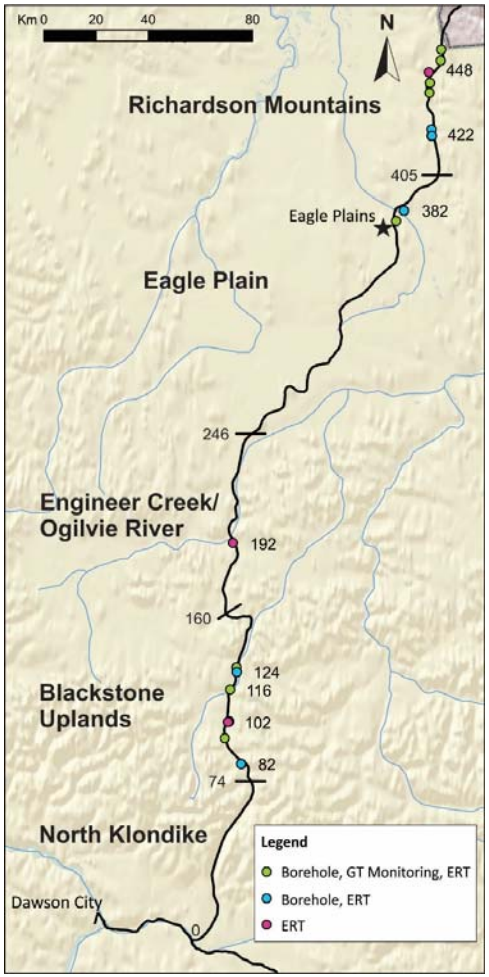
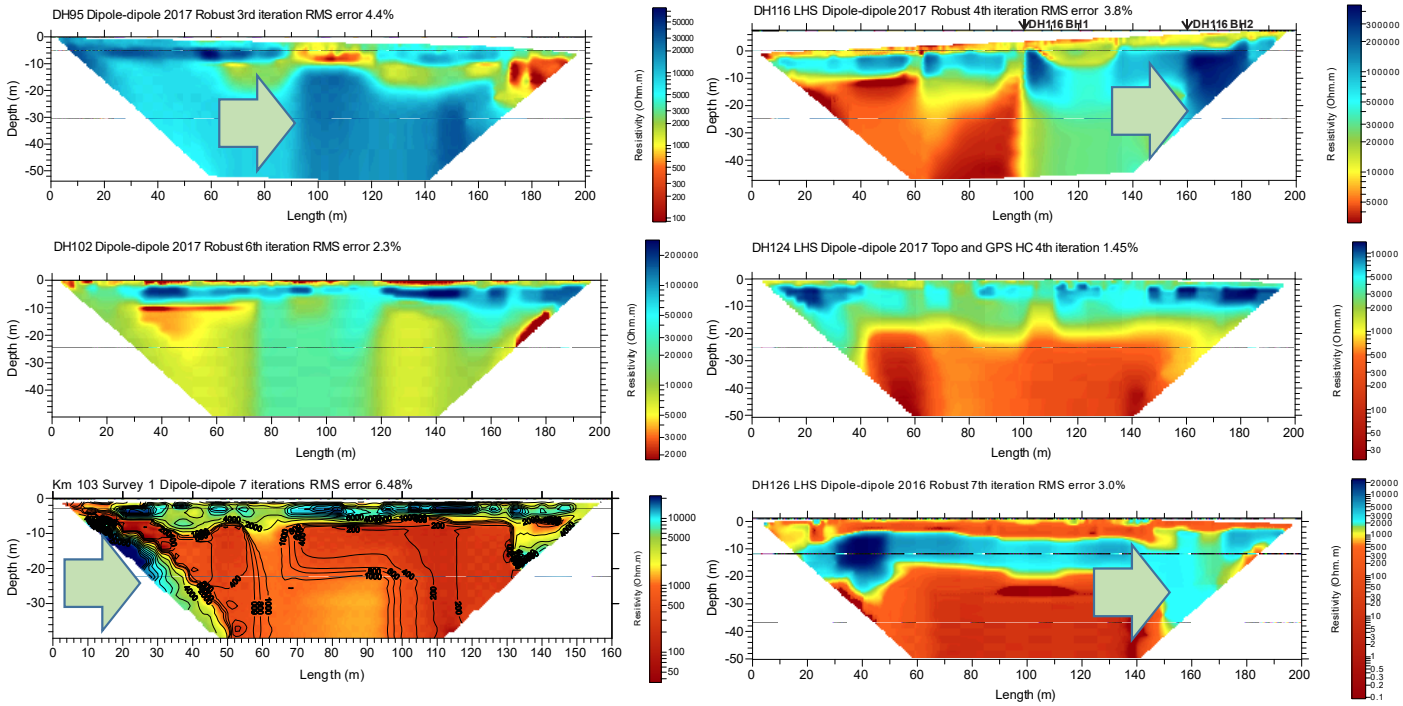
Ground Ice : nature and extent - South





- **Buried Ice (?)**

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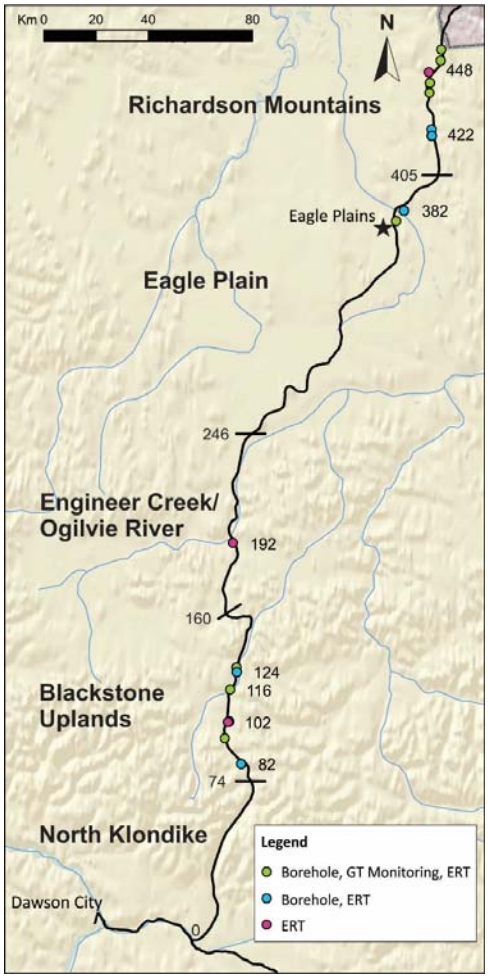
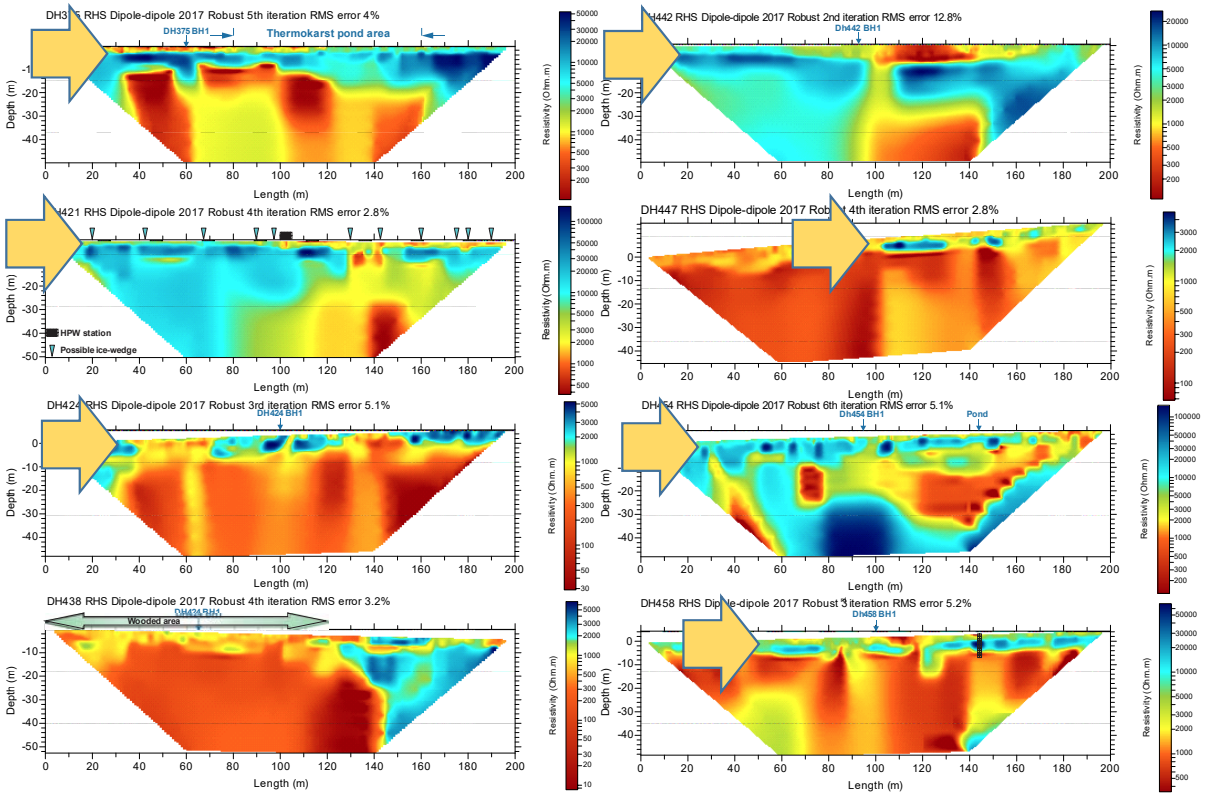
Ground Ice : nature and extent - North





- **Ice wedge (shallow)**

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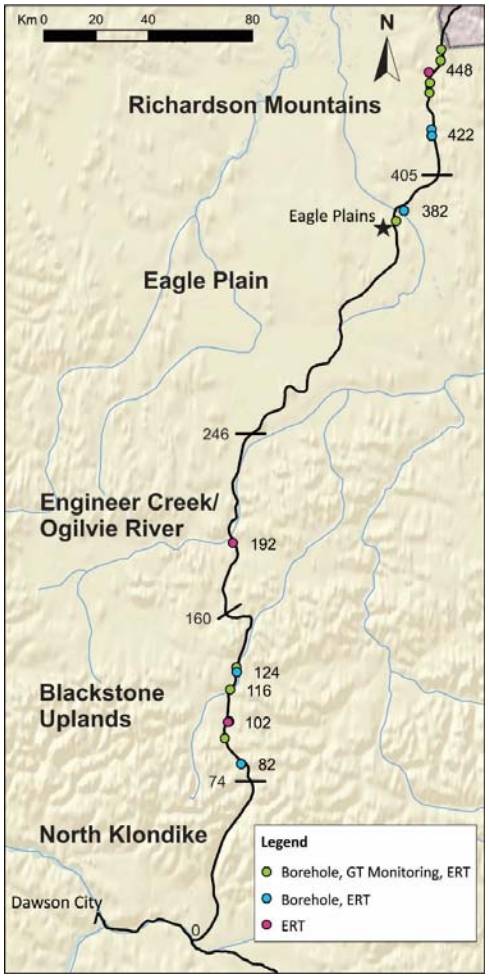
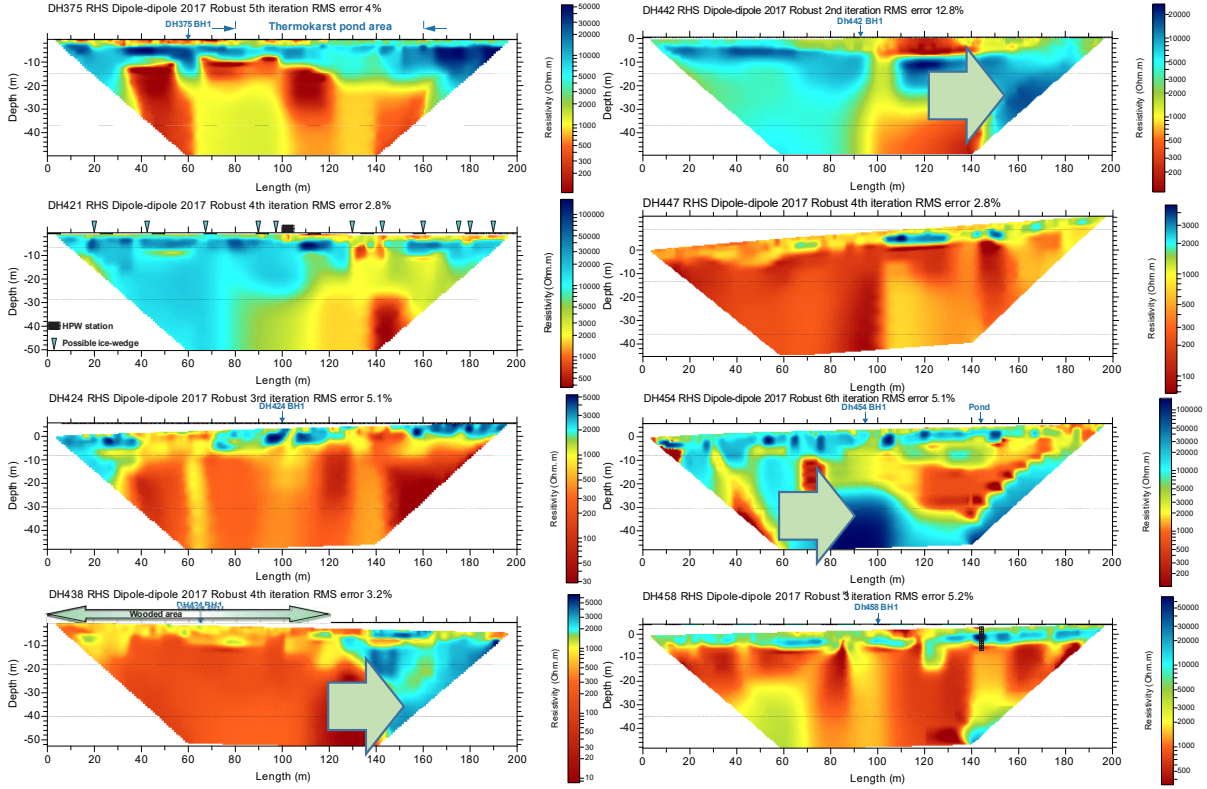
Ground Ice : nature and extent - North





- **Deeper ice?**

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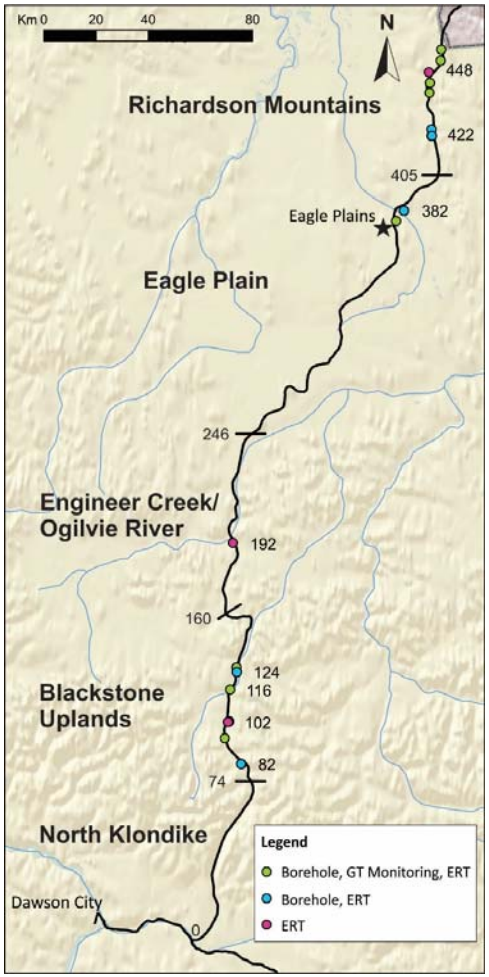
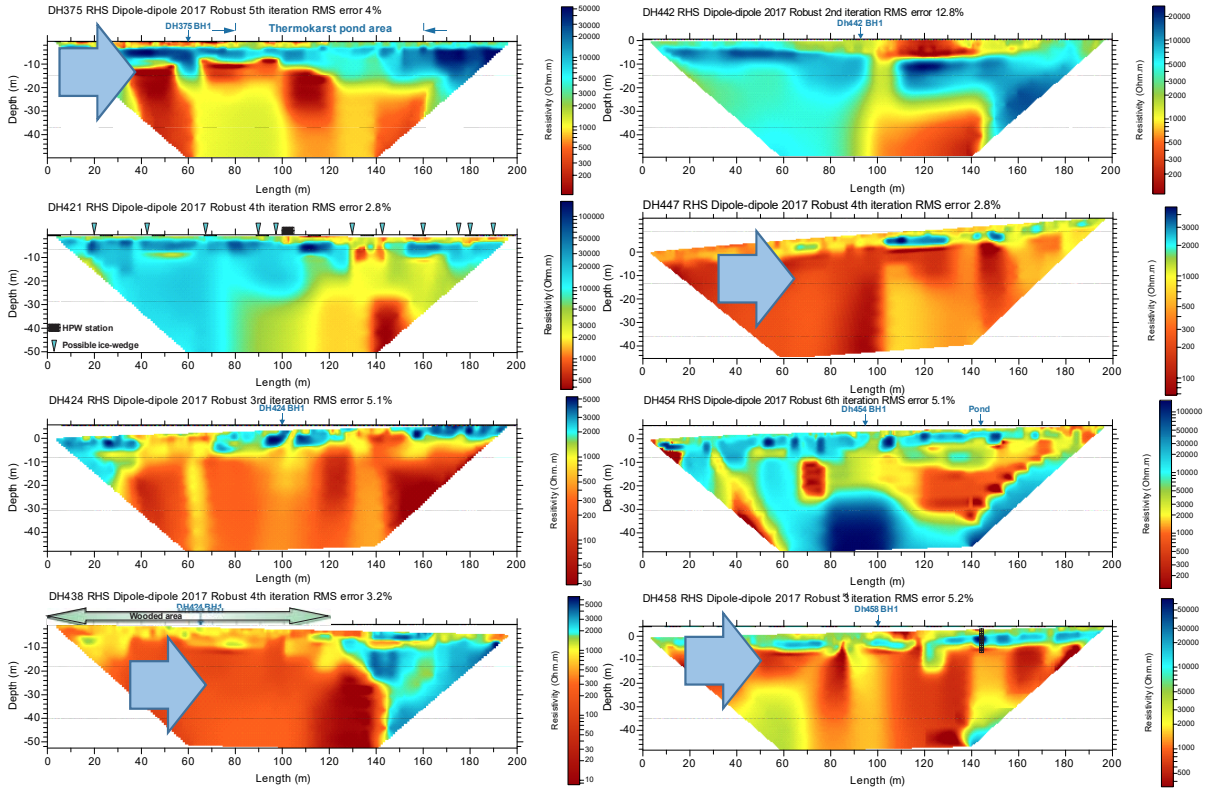
Ground Ice : nature and extent - North





- **Water / unfrozen**

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Ground water – km 82 - Sinkholes

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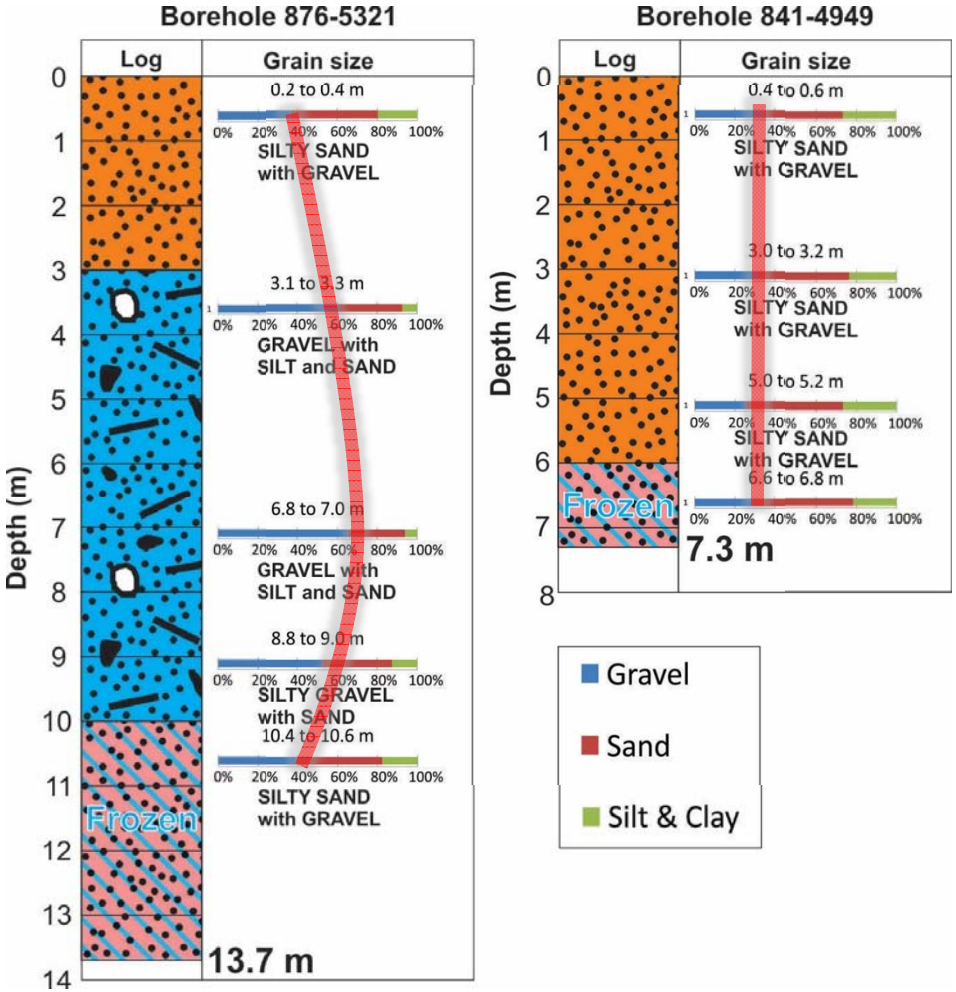
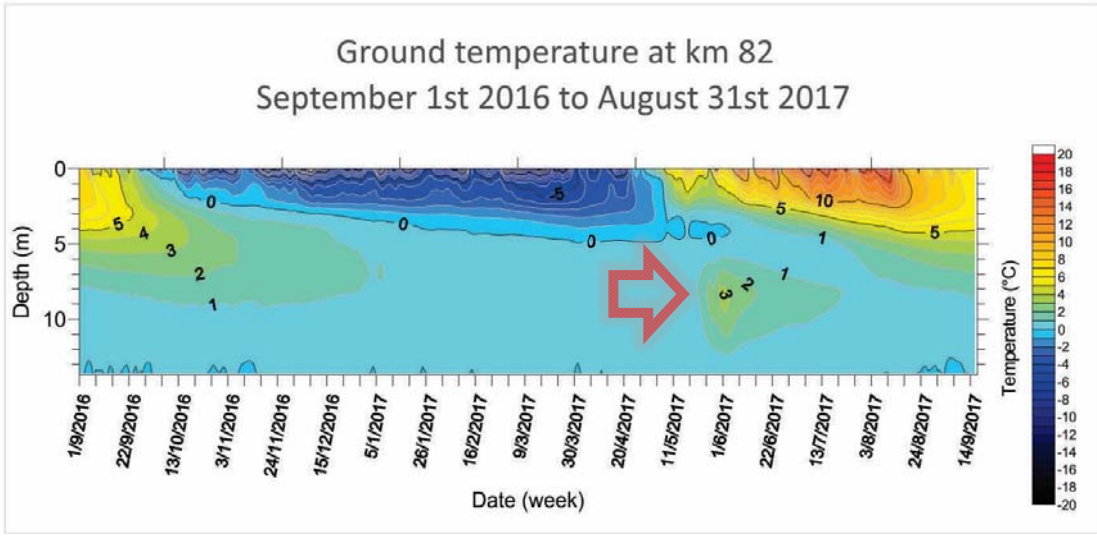
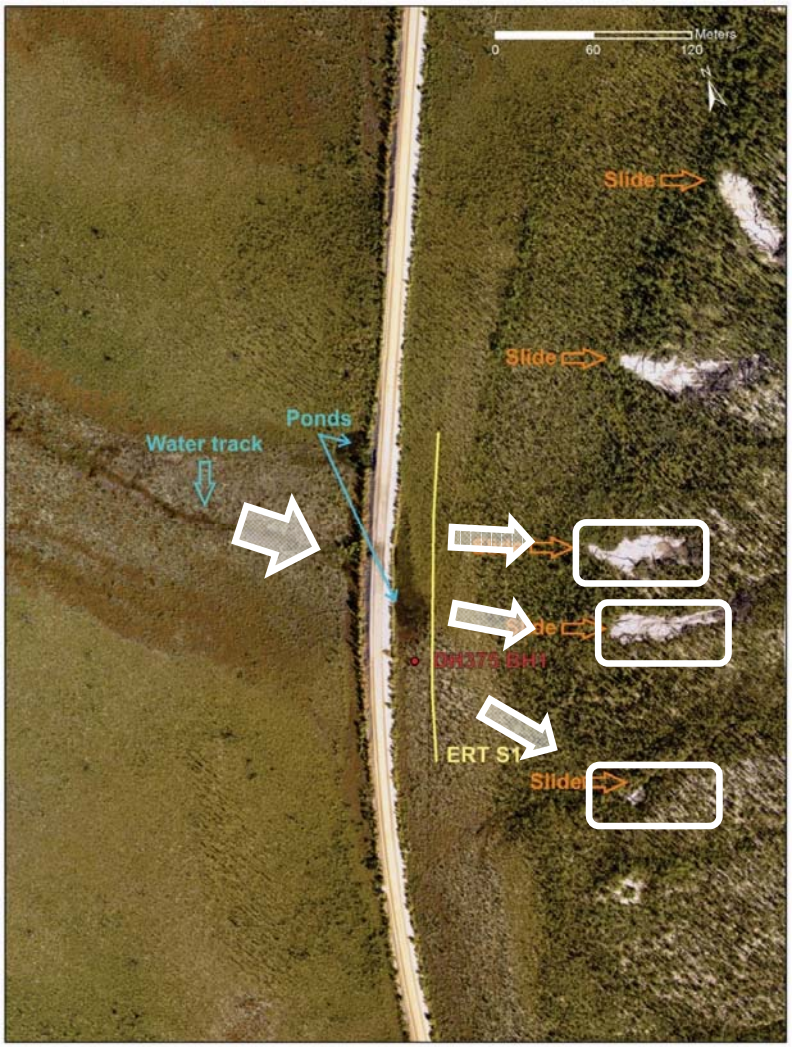
Ground water – km 82 - Sinkholes



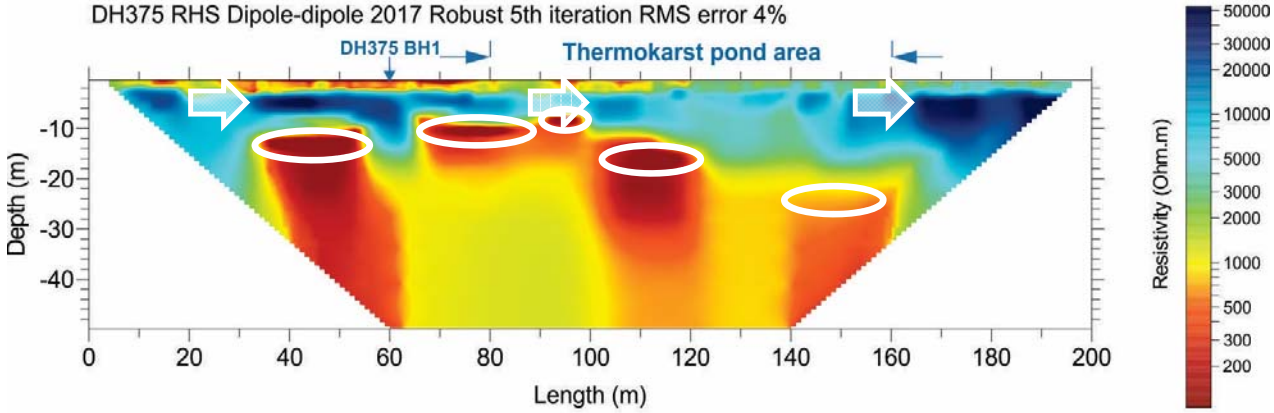
- No massive ice observed
- Depleted in fine material
- Thermal impact at freshet



Ground water – km 375 – Thermokarst & Slide



- Ice-rich Ground
- Ground water flow?
- Slides?



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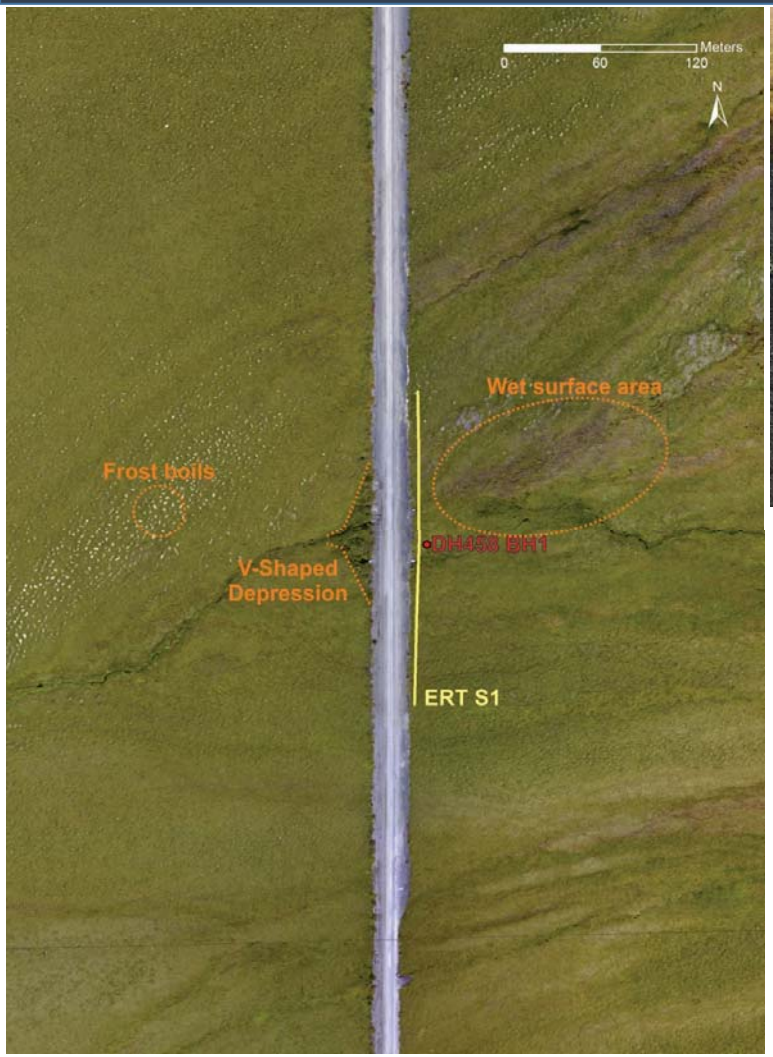
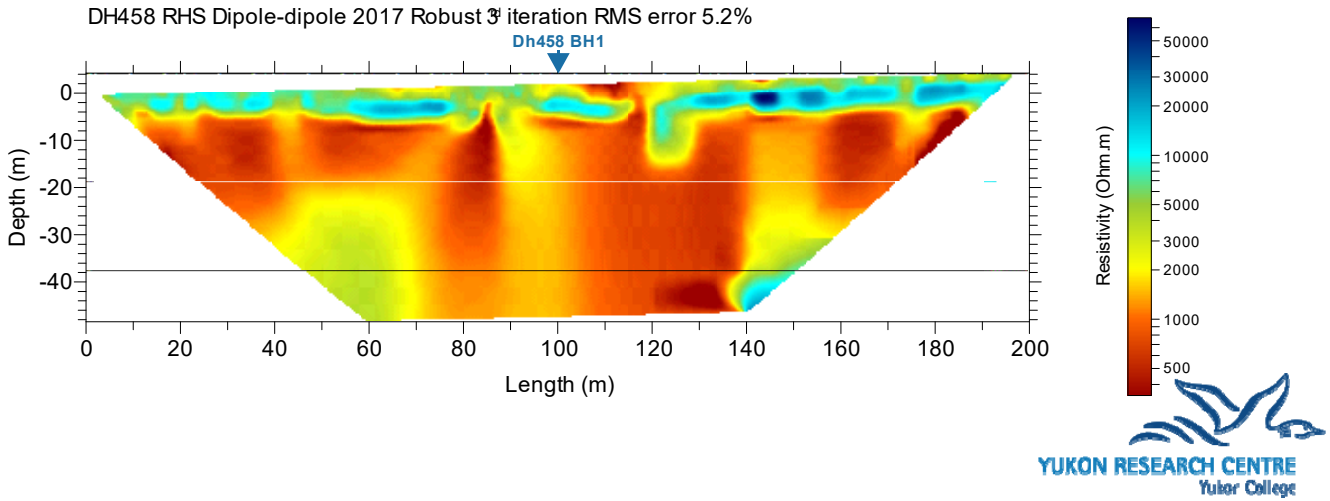
Snow accumulation – km 458 - Subsidence



August 2016

September 2016



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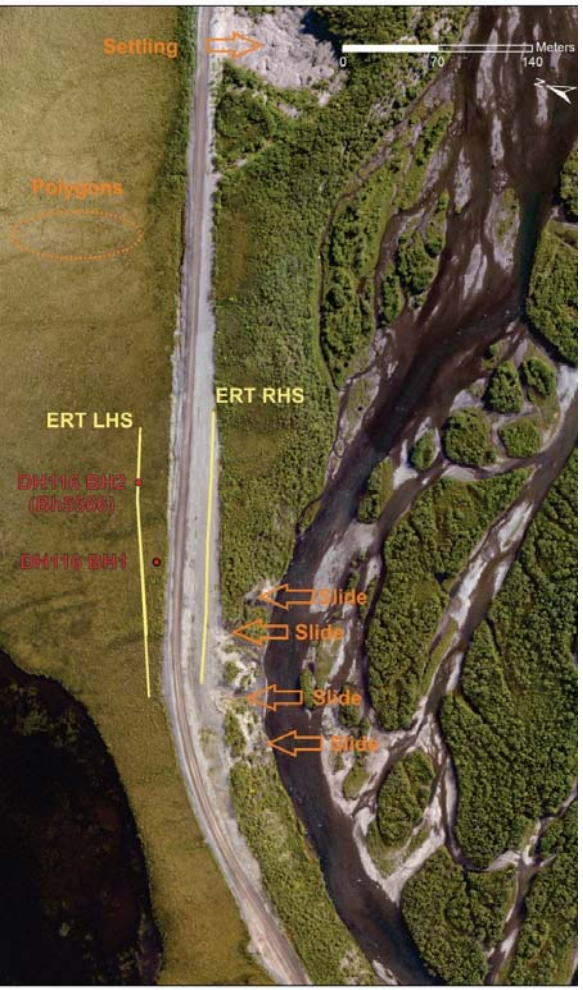
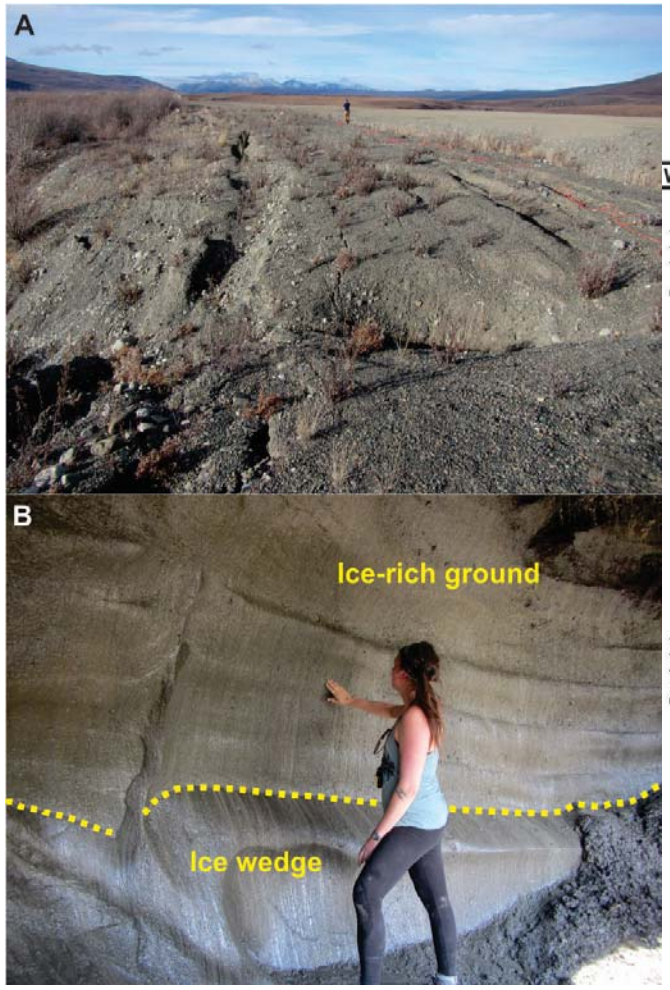
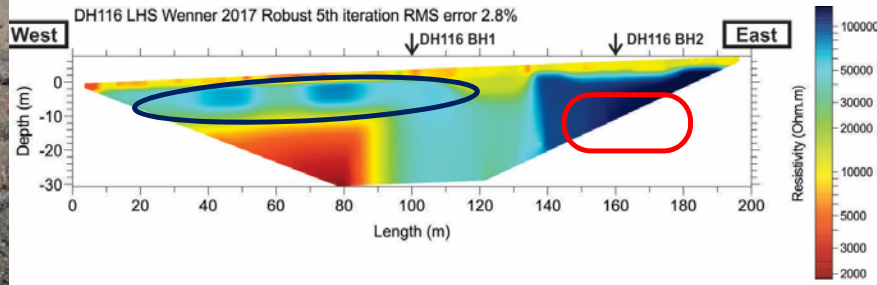
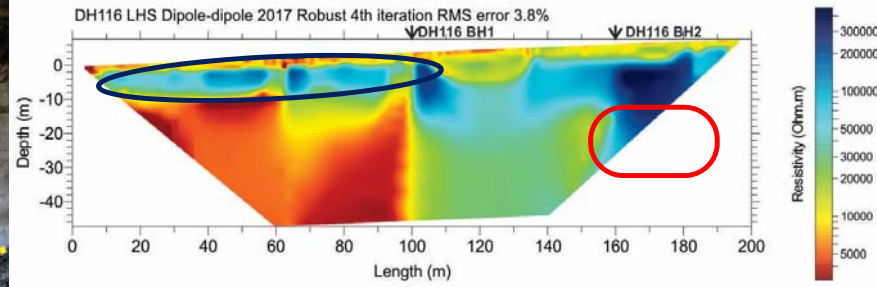
Ground ice – km 116 – Tutti Frutti









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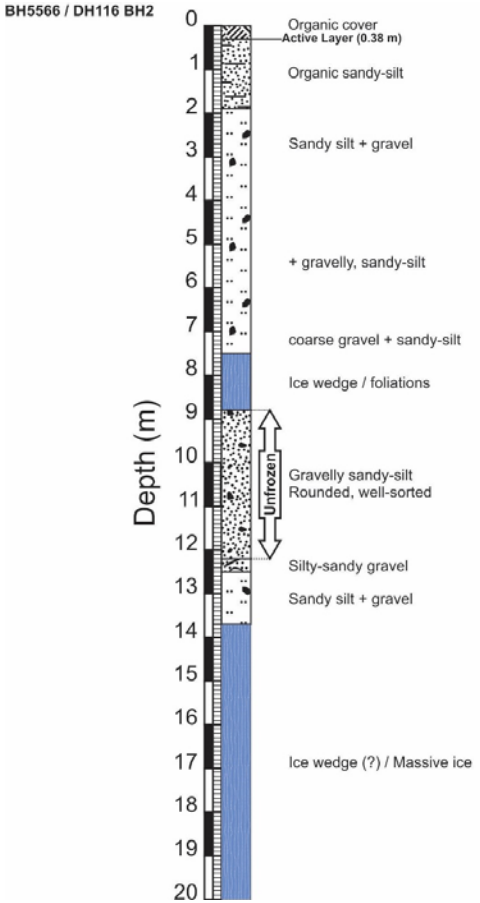
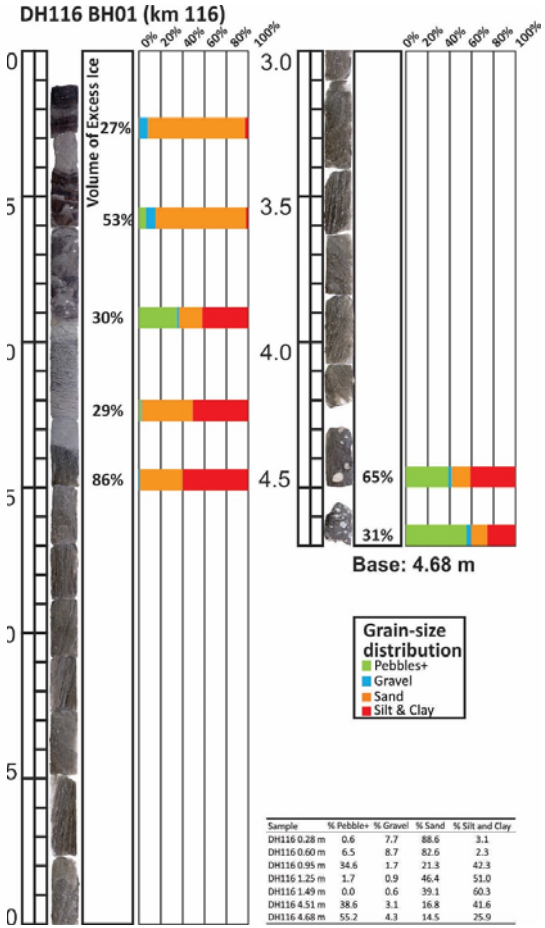
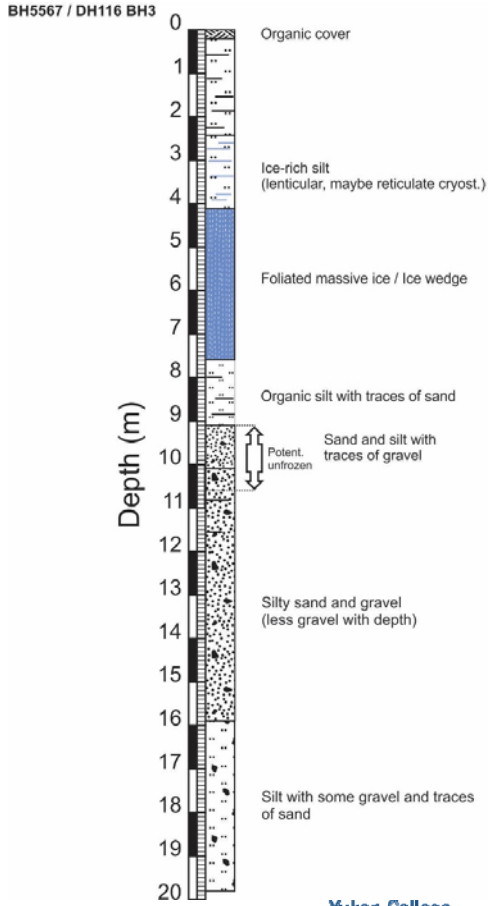
Ground ice – km 116





Sample	% Pebble+	% Gravel	% Sand	% Silt and Clay
DH116 0.28 m	0.6	7.7	88.6	3.1
DH116 0.60 m	6.5	8.7	82.6	2.3
DH116 0.95 m	34.6	1.7	21.3	42.3
DH116 1.25 m	1.7	0.9	46.4	51.0
DH116 1.49 m	0.0	0.6	39.1	60.3
DH116 4.51 m	38.6	3.1	16.8	41.6
DH116 4.68 m	55.2	4.3	14.5	25.9



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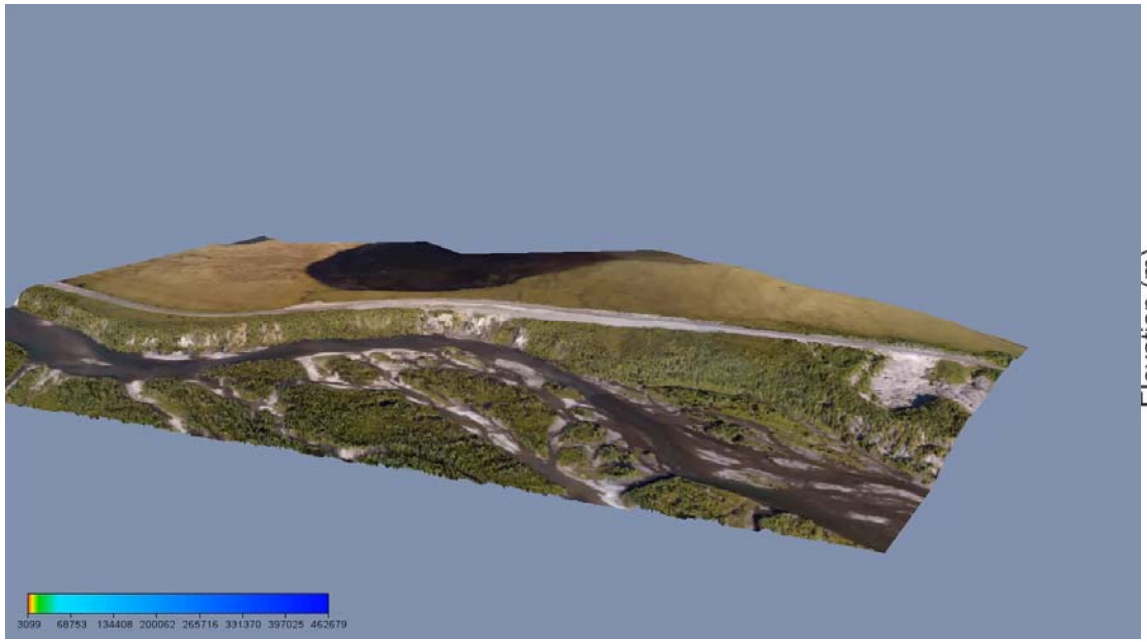
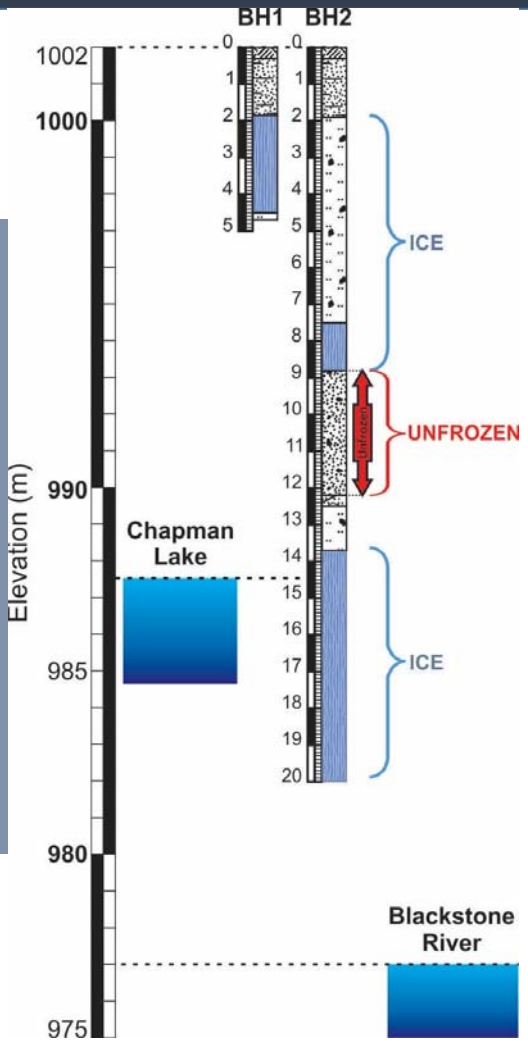
Ground ice – km 116



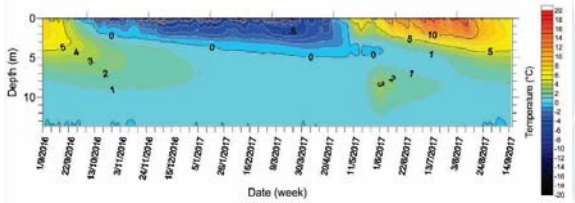


Impacts on maintenance costs

Excess Ice → Volume of Granulate (ice wedge distribution and dimension…)

Ground ice distribution → timing of the degradation, type of mitigation…

Water → more slides, more seepage, thermal erosion and impacts...



Snow → more clearing, more thermal effect…

Impacts on maintenance costs

Maintenance

not affected by climate changes

Maintenance

decreases with time

Ex. No more ground ice

Maintenance

Increases with climate changes

Ex. More slides, more subsidence

Adaptation

stabilize/mitigate the situation

Next Steps:

- Establish a better model between biophysics and economics to chose the best strategy

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