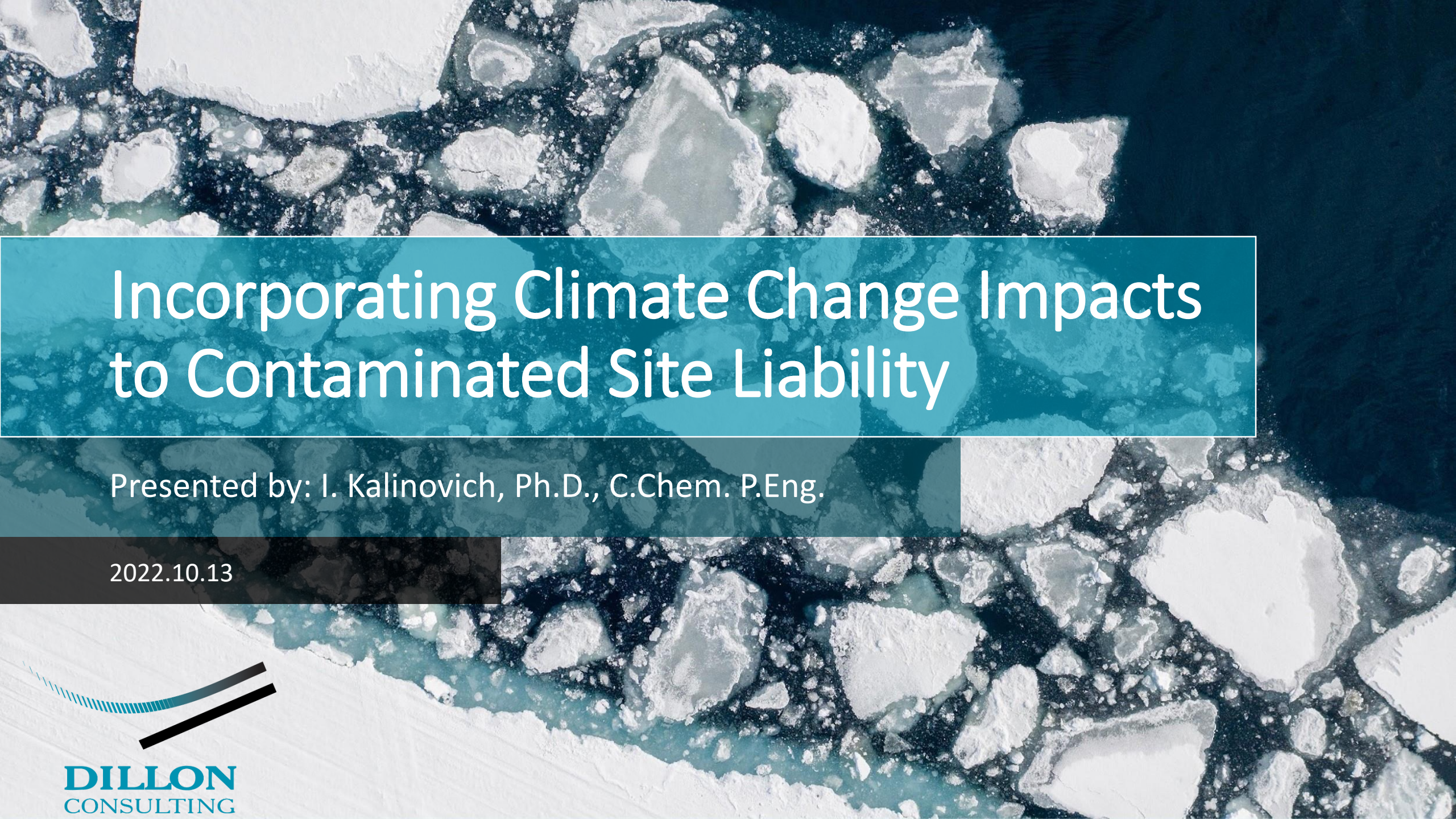

Incorporating Climate Change Impacts to Contaminated Site Liability

Presented by: I. Kalinovich, Ph.D., C.Chem. P.Eng.

2022.10.13

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Implications of Climate Change in the North

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The Impact of Climate Change in the North

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Arctic stronghold of world's seeds flooded after permafrost melts

No seeds were lost but the ability of the rock vault to provide failsafe protection against all disasters is now threatened by climate change

▲ The Svalbard 'doomsday' seed vault was built to protect millions of food crops from climate change, wars and natural disasters. Photograph: John Mcconnico/AP

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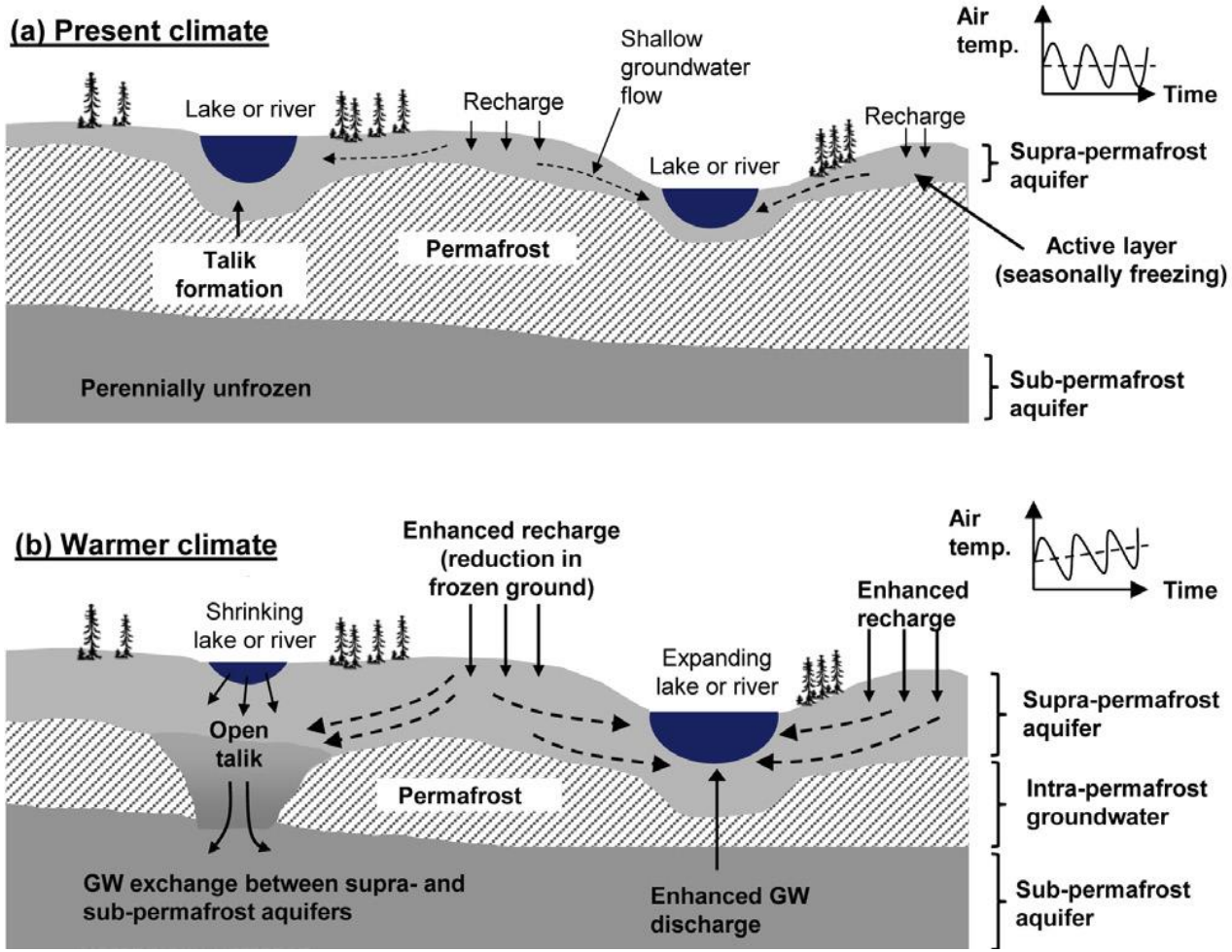
Permafrost is Not Always an Impermeable Barrier



Example of Climate Change Effects on Permafrost Hydrogeology (Walvoord and Kurylyk 2016)

- **A warming climate will:**
  - **Deepen the transition boundary between the active layer and permafrost;**
  - **Increase freeze-thaw cycles;**
  - **Increase surface run-off;**
  - ***Change precipitation patterns;***
  - ***Could decrease snow pack cover;***
  - **Increase groundwater infiltration;**
  - **Sea level rise;**
  - **Exacerbate ice scouring and wave action; and,**
  - **Change surface water/groundwater interactions (migration pathways).**

Permafrost thaw can permit the opening of previously blocked flow paths.

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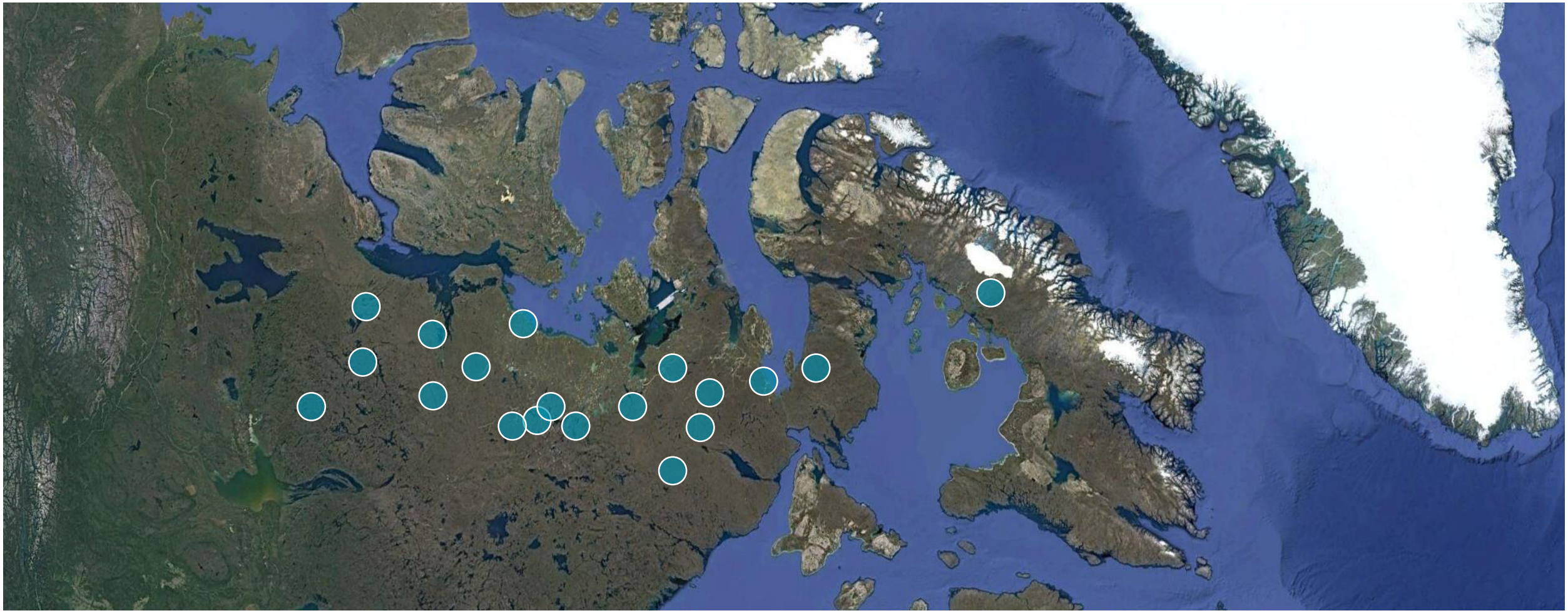
Triaging “Inherited” Historical Contaminated Site Files



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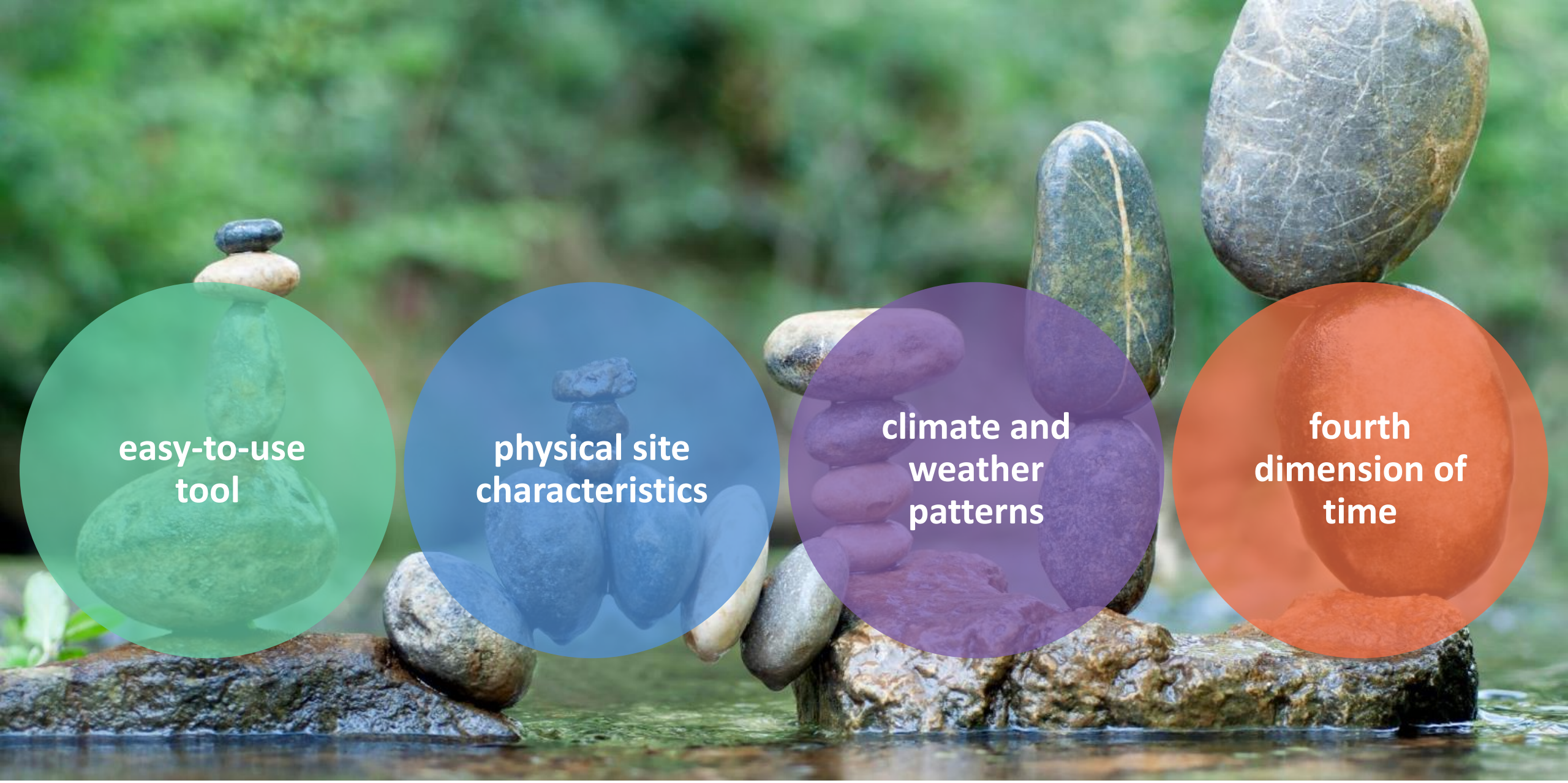

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MOVIECLIPS.com

Environmental Contamination

Environmental Contamination/ Geology

GIS

Climate Change

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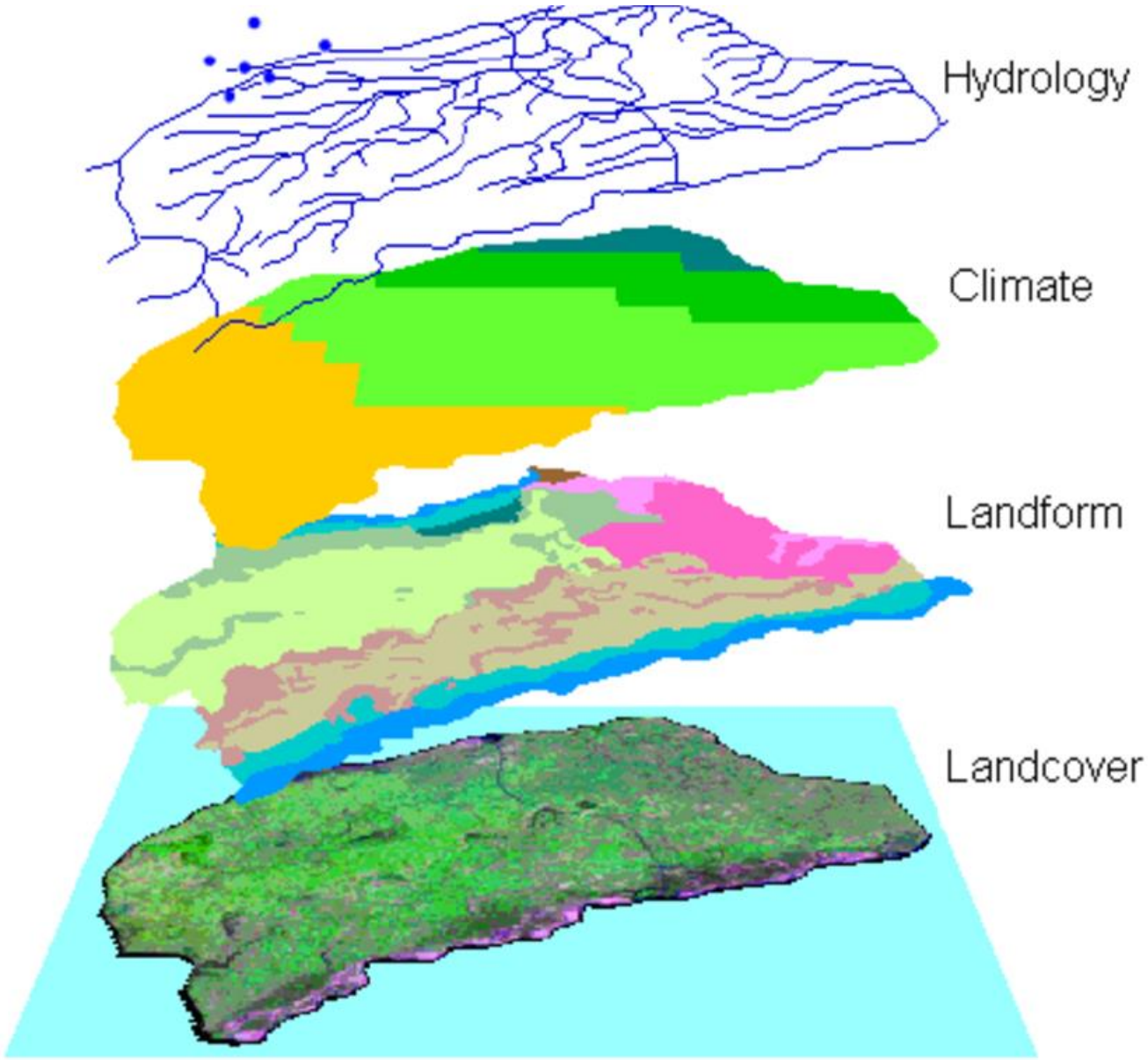

- Interactive map
- Current physical characteristics
- Potential effects of climate change
- Modified risk score
- Holistic risk profile

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ArcGIS Survey123

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Is the site near a lake (distance in metres)? *

301

Is the site near a wetland (distance in metres)? *

301

Is a potential drinking water source within 100 m (either groundwater, or surface water body used locally)? *

- ○ Yes
- ○ No
- ● Unknown

Geology

Permafrost

Vegetation

Contaminant Source

PHCs

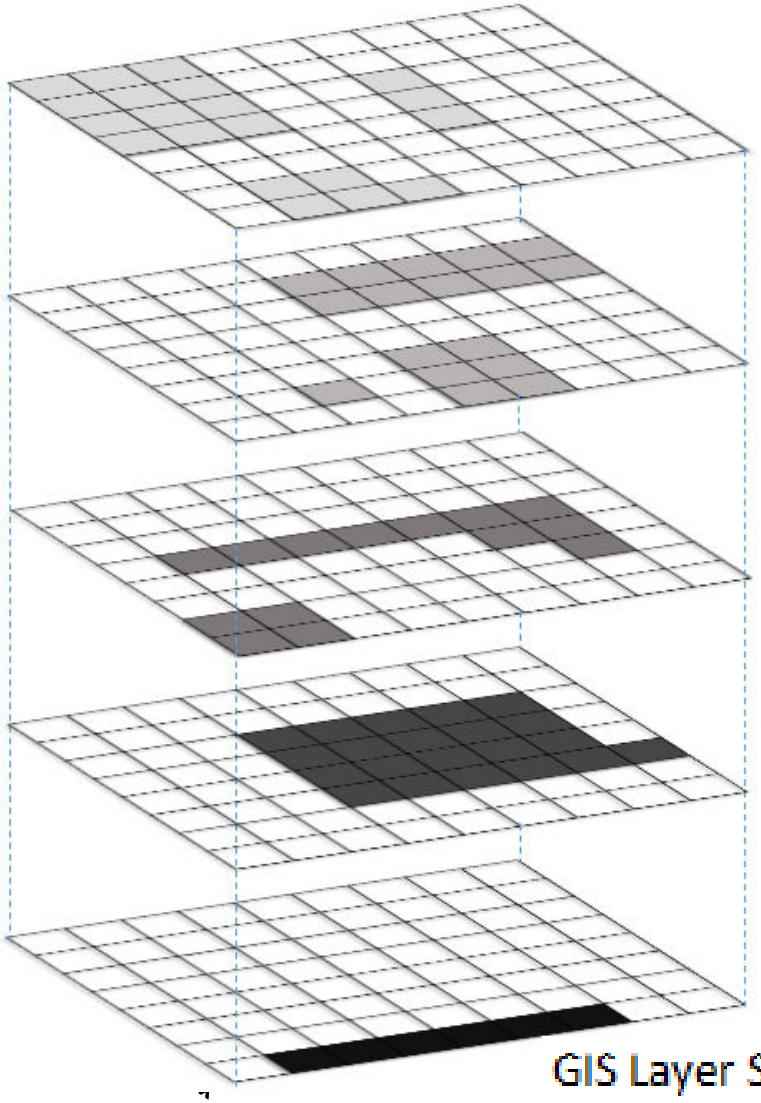
PAHs

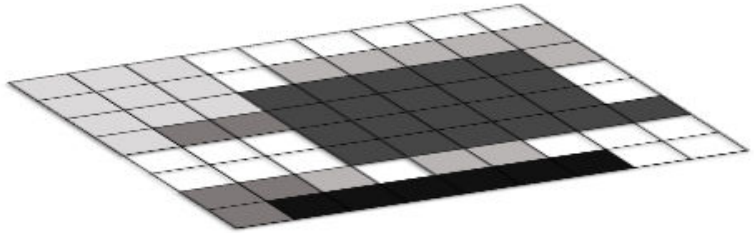
PCBs

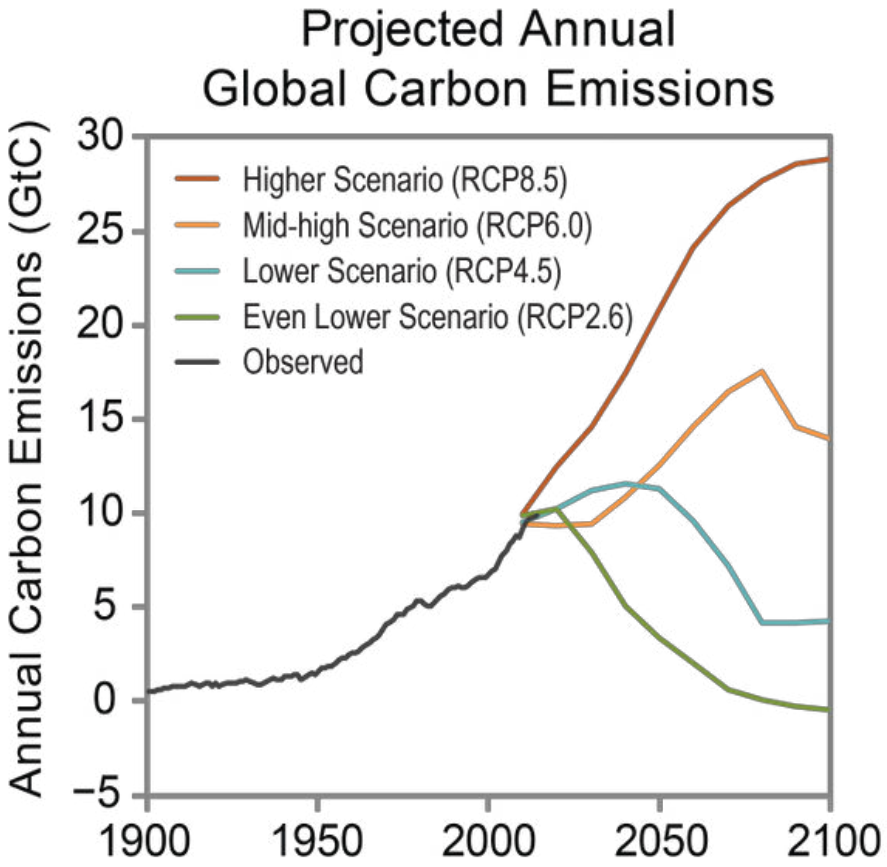
Metals

Other Contaminants

Climate Hazard Indicator	Contaminated Sites Relationship
Mean Annual Air Temperature (MAAT)	Strong correlation between MAAT and permafrost zero amplitude temperature (Throop et al., 2012). Distinguishes whether very cold to warm permafrost (with potential to become discontinuous permafrost)
Thawing Index – Degree Days above 0C (TDD)	Anomalously high values indicate “hot” summers, which can be related to rapid subsidence, talik formation risk and permafrost thaw (Farquharson et al., 2019) If medium or high, measurements indicate permafrost subsidence of 1 m can occur within the next 10-30 years (Farquharson et al., 2019)
Snowfall Total (spring flooding risk)	Indicator for potential spring flooding (and soil thermal buffering) The High and Low Climate Hazard Thresholds can consider regionally differing upward/downward trends in precipitation (and 2050s projections)
Summer Rainfall Excess	Cumulative value that is indicative of permafrost thaw and flooding potential (Douglas et al., 2020). Used to score permafrost degradation and flooding risks. Above average summer rainfall amounts, indicate additional permafrost thaw and flood risks Index is sensitive to heavy rainfall events (erosion), increasing rainfall trends and as well as years with frequent rainfall events
Coastal Sensitivity Index (CanCoast2.0)	Index is calibrated for all Canadian coasts, integrates coastal materials, tides, backshore slope, ground ice in permafrost, wave height and sea ice cover, and storm surge







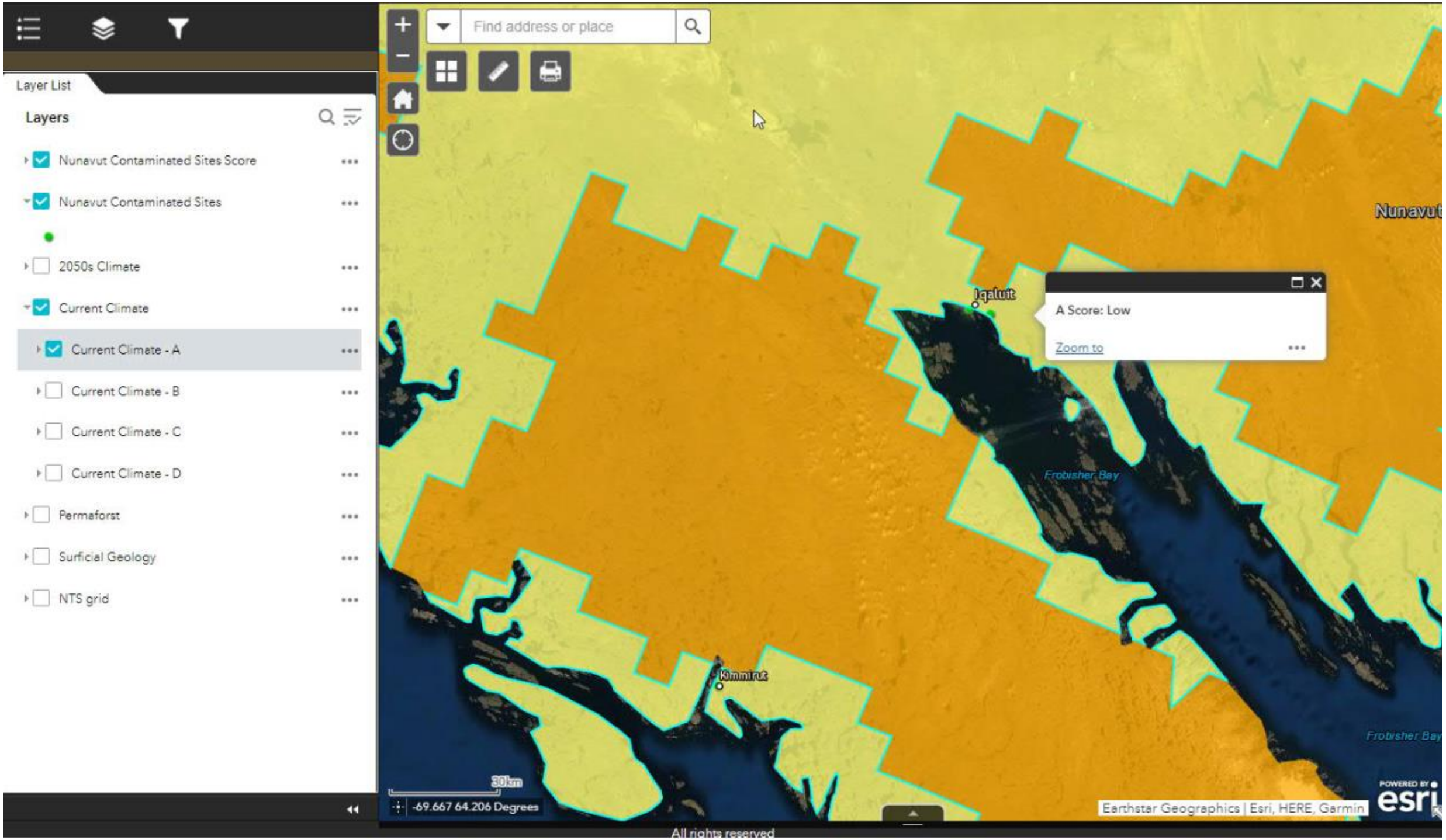
GIS Layer Selection		Exposed Bedrock?		
		Yes	No	Unsure
Coastal Proximity (m)	<100	A	C	C
	100-300	A	C	C
	>300	B	D	D

Climate Indices

1 MAAT
2 TDD
3 Snowfall
4 Summer Precip
5 CanCoast2.0

Combination Layers

A 3+4+5
B 3+4
C 1+2+3+3+4+5
D 1+2+3+3+4



Local Questions that Affect the Climate Change Scoring

Climate Concern	Question	Response Scoring	
Melting/Thawing Permafrost	Is the soil bare or covered with occasional low vegetation?	If 3 or more responses are Yes, then permafrost degradation may be a significant concern and the total climate score can be bumped up to High. If 2 responses are Yes, the total GIS-based climate score can remain as Medium (requiring further investigation) and if 1 or no responses are Yes, then the score can remain as Low.	
	Is there evidence of permafrost degradation lately e.g. soil slumping, water ponding in summer?		
	Is the soil ice-rich?		
	Is the depth/thickness of the active layer greater than 1.5m?		
	Have anomalously (very) warm summers become more frequent over past 30 years?		
Drainage (Migration Pathways)	Have snowfall amounts increased over the past 30 years?	Yes = Medium Risk	Both responses are Yes = High Risk
	Have rainfall amounts or heavy rainfall events increased over the past 30 years?	Yes = Medium Risk	
Coastal Impact (Erosion)	Is the shore ice-free season longer than 3 months?	Yes = Medium Risk	
	Is the shore ice-free season longer than 7 months? OR Has coastal erosion increased significantly over the past 30 years?	Yes = High Risk	

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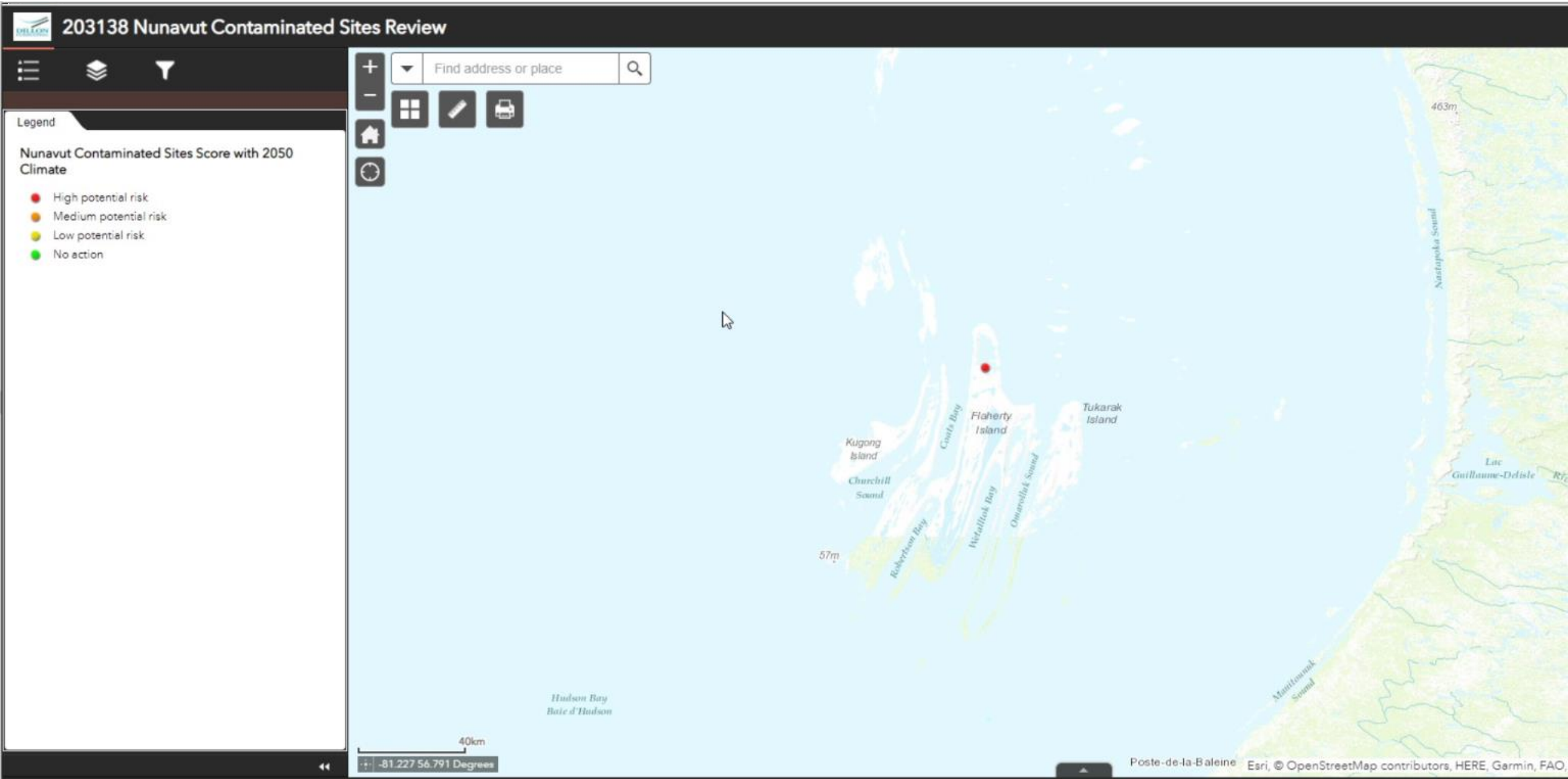
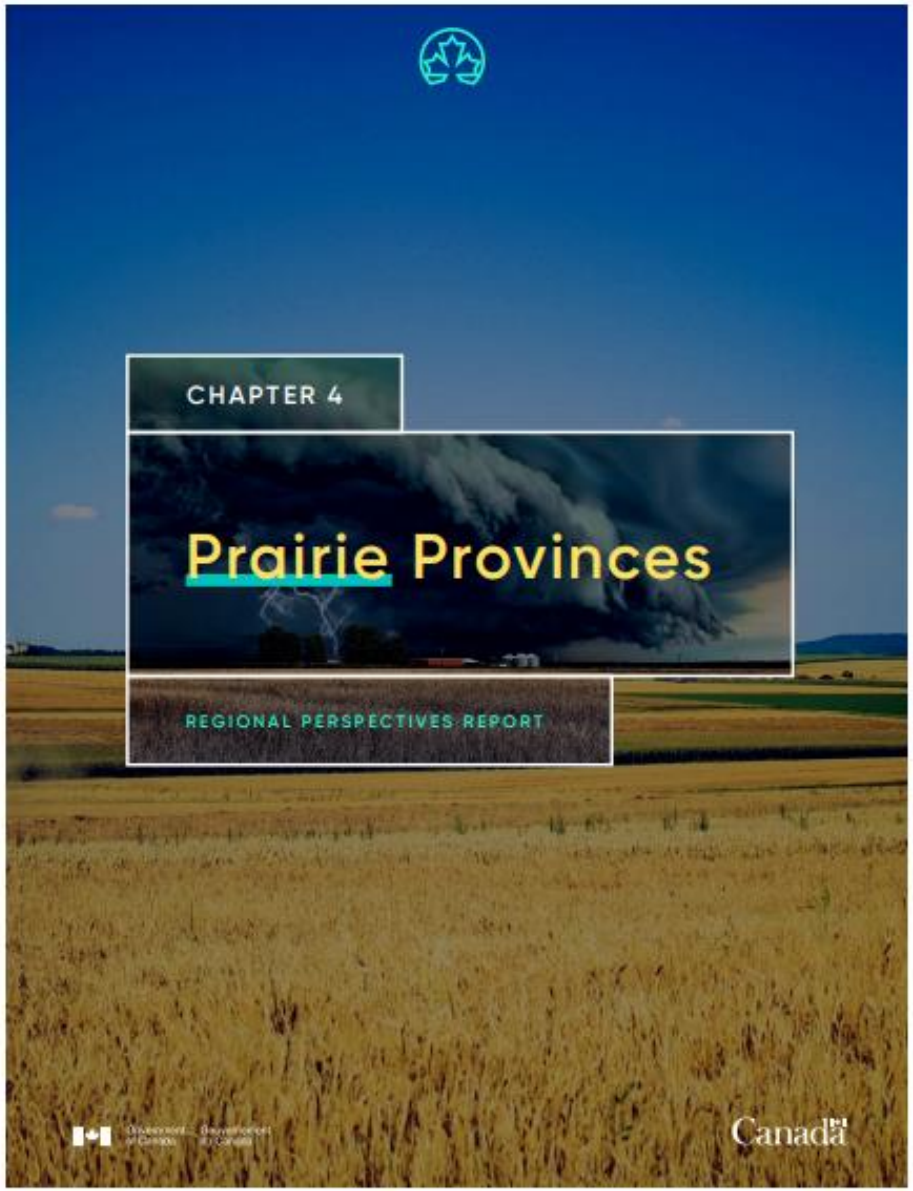


Climate Change Doesn't Start/Stop at the 60th Parallel



The Prairies, and western Canada generally, have had the strongest warming to date across southern Canada, especially in winter.

Prairie ecosystems will shift and transform as the climate warms.

Floods, drought and wildfires are getting worse.

Sauchyn, D., Davidson, D., and Johnston, M. (2020): Prairie Provinces; Chapter 4 in Canada in a Changing Climate: Regional Perspectives Report, (ed.) F.J. Warren, N. Lulham and D.S. Lemmen; Government of Canada, Ottawa, Ontario

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Thank You for Listening!

Further questions?
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