NWT Highway 3 - Climate Change Vulnerability Assessment

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Presentations Overview

- Highway 3 – Overview
- Highway 3 – Challenges
- PIEVC Climate Change Vulnerability Assessment
- Initial Observations
- Summary and Conclusion

Highway 3 Case Study

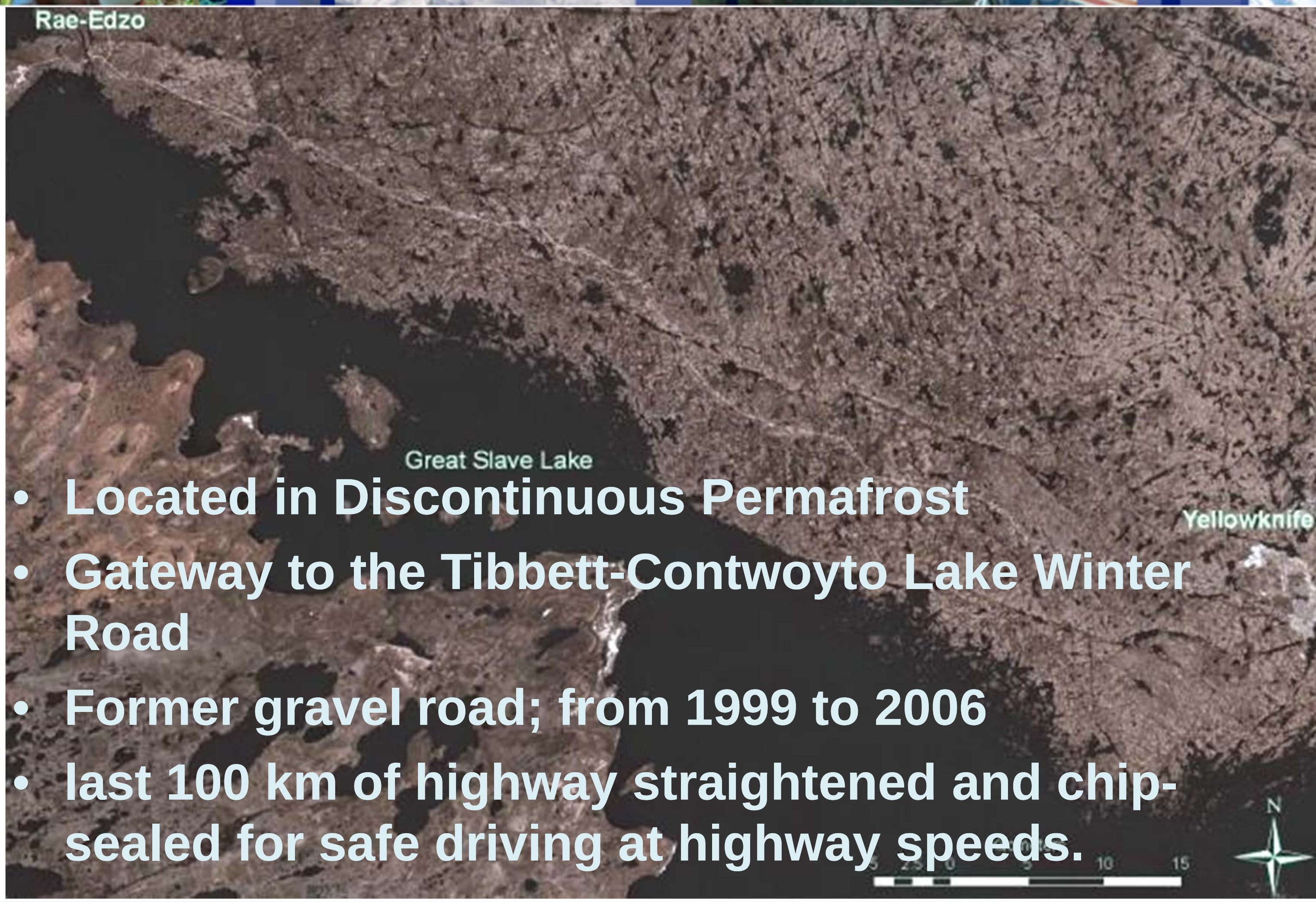
- Host: Department of Transportation – Government of the Northwest Territories
- Partner: Engineers Canada
- Consultant: BGC Engineering Inc.

Yellowknife Highway (Hwy 3)

Yellowknife Highway (Hwy 3)

- Highway is the only all-weather road connecting the City of Yellowknife to southern Canada
- Gateway to the Tibbett-Contwoyto Lake Winter Road
- Formerly gravel road constructed in the 1960's.
- Segment (~100 km) of highway reconstructed from 1999 to 2006
- 640 vehicles per day (Average Annual Daily Traffic, 2008)
- Design speed of 110 km/hr (RAU 100)
- Located in Discontinuous Permafrost

Yellowknife Highway (Hwy 3)

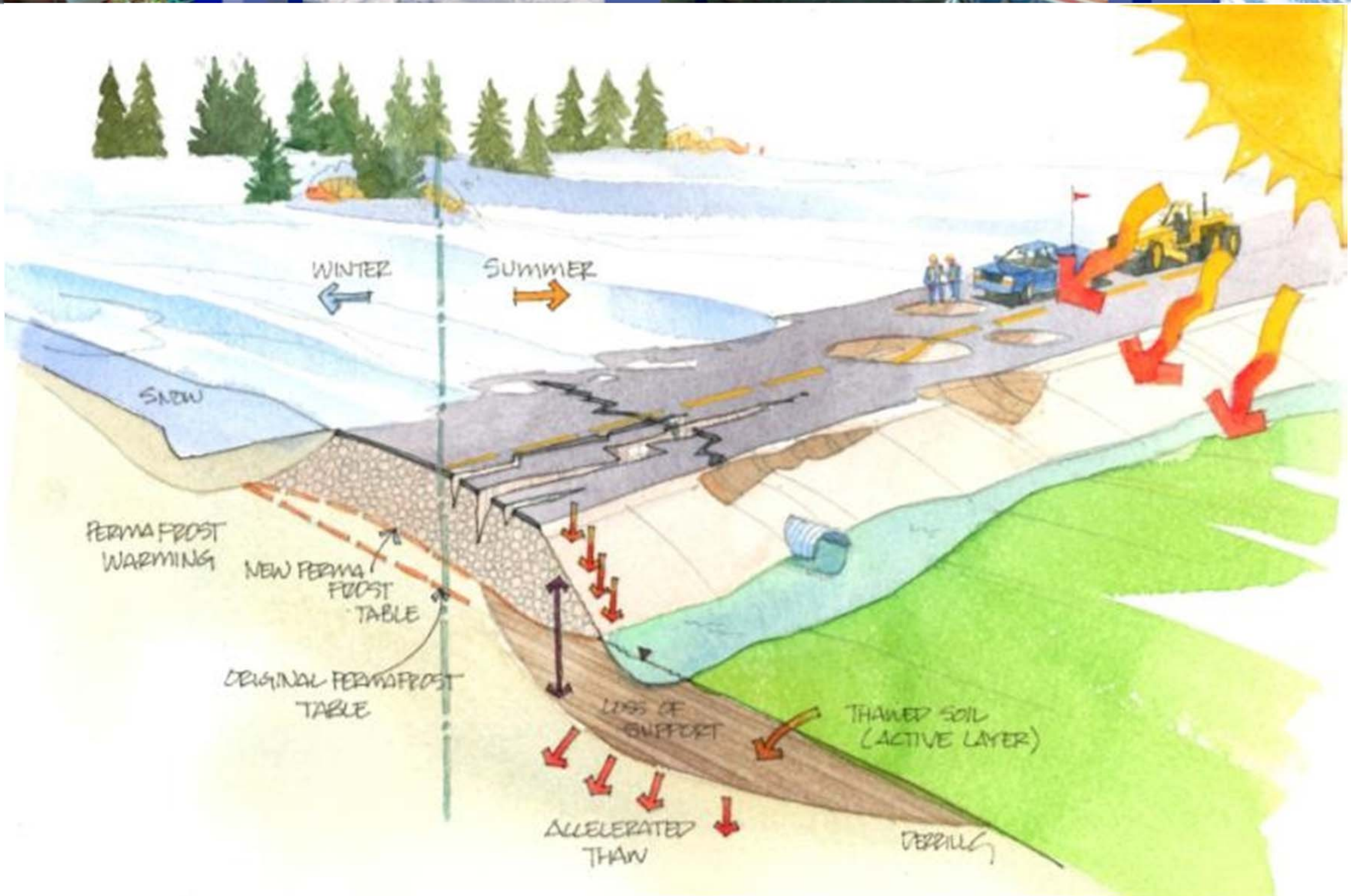


- Located in Discontinuous Permafrost
- Gateway to the Tibbett-Contwoyto Lake Winter Road
- Former gravel road; from 1999 to 2006
- last 100 km of highway straightened and chip-sealed for safe driving at highway speeds.

Highway Performance since Reconstruction

- The reconstructed highway has been designed in anticipation that the **permafrost will be sustained to the greatest extent possible** in order to minimize long-term settlement of the embankment over a 20-year timeframe.
- The Department of Transportation has reported substantial ongoing **maintenance and repairs much higher than expected**
- Such performance is **no different** to roads, railways, and airfields constructed on warm permafrost in other jurisdictions (e.g., **Alaska**, **Yukon**)

Problems


WINTER
SUMMER
SNOW
PERMAFROST WARMING
NEW PERMAFROST TABLE
ORIGINAL PERMAFROST TABLE
LOSS OF SUPPORT
THAWED SOIL (ACTIVE LAYER)
ACCELERATED THAW

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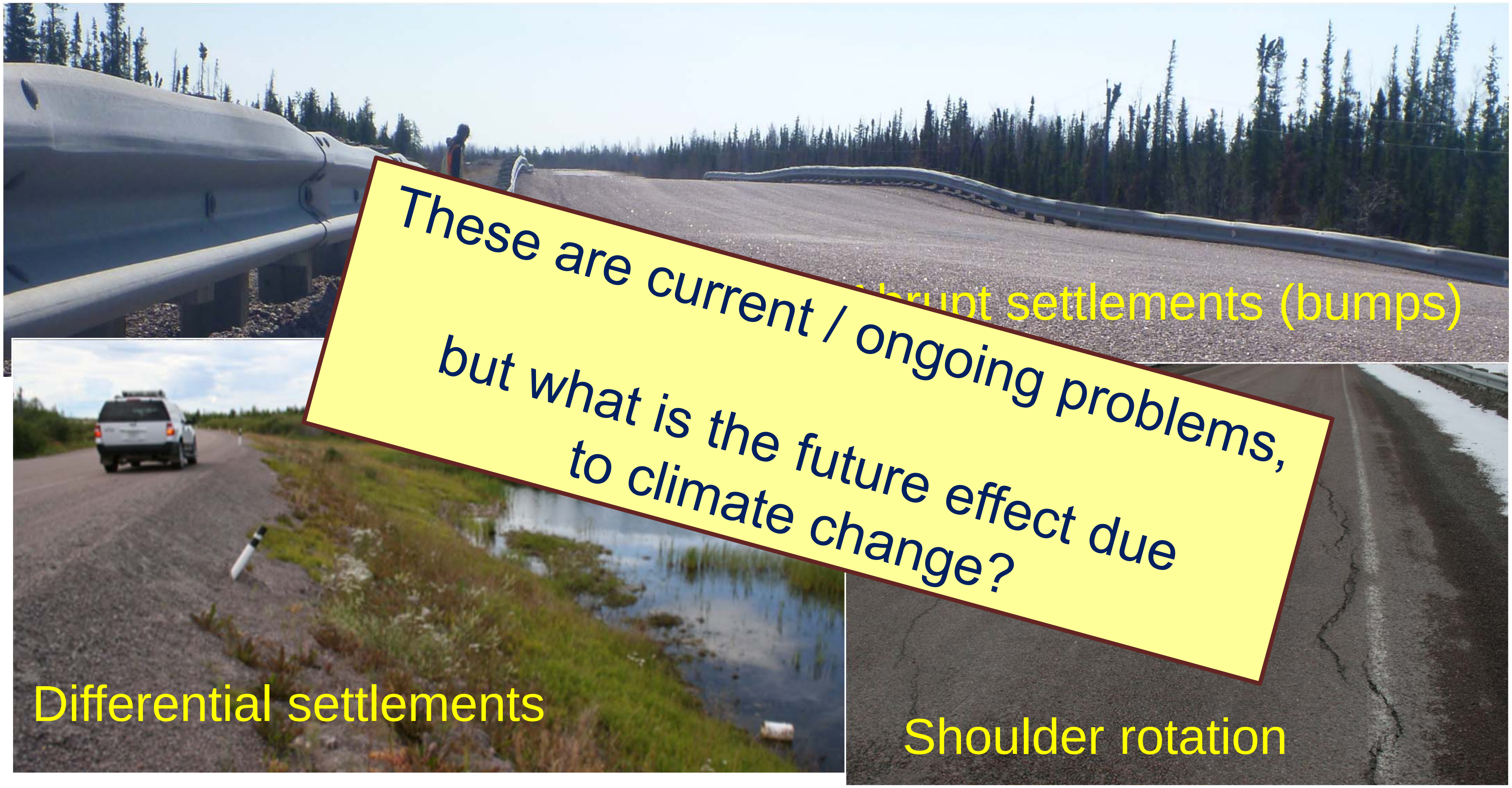
Hwy 3 Road Instabilities

Northwest Territories Transportation



Summary of Historical Climate Trends

- Over the past thirty years, there is a clear **warming trend.**
- There is also trend of **increasing precipitation** (both rainfall and snowfall).
- Snow depth changes are more cyclical, but show a trend of **increasing snow depth**.
- The combined increase in both snowmelt and rainfall during the last decade has led to **more surface water available** for infiltration and runoff.

Trends are consistent with those reported from other regions in the arctic

Climate Change and Road Performance

- Mean Annual Air Temperature (current: -4.3°C):
  -3.2°C (2020) **-2.1°C** (2050)
- Increase in Precipitation:
  9 – 29% (2020) **15 – 46%** (2050)

Significant increase in frequency of high intensity rainfalls expected

= Ground Warming ➡ Permafrost Degradation ➡ Unstable Foundation

Public Infrastructure Engineering Vulnerability Committee (PIEVC)

- Oversee a national engineering assessment of the vulnerability of public infrastructure to climate change in Canada
- Facilitate the development of best engineering practices that adapt to climate change impacts
- Recommend reviews of infrastructure codes and standards
- Partnership between Engineers Canada and Natural Resources Canada

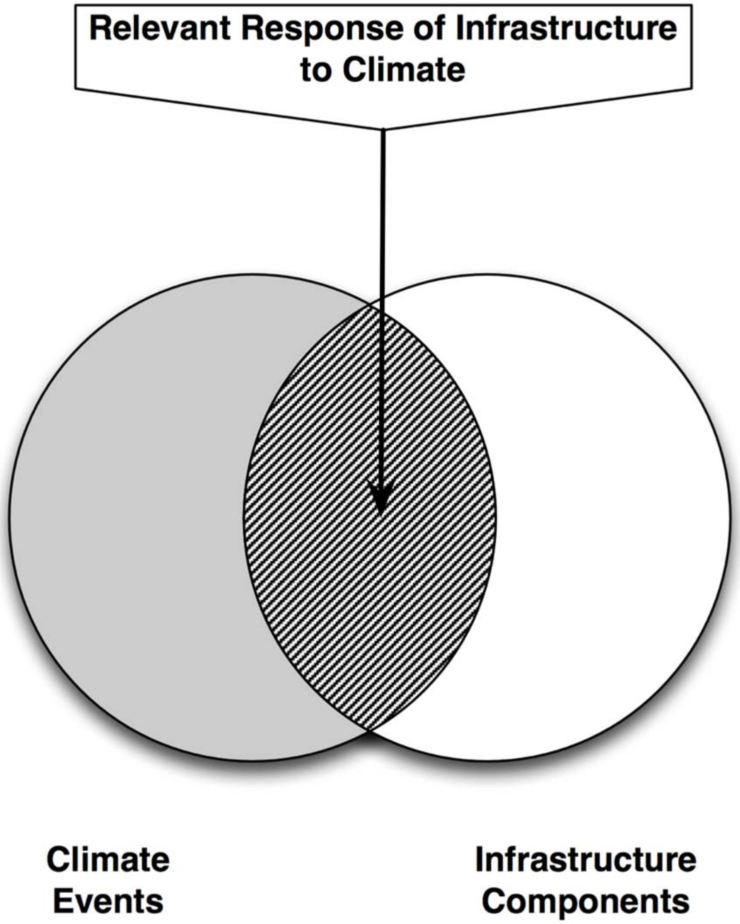
PIEVC CVIIP

Infrastructure Climate Risk Protocol Principles

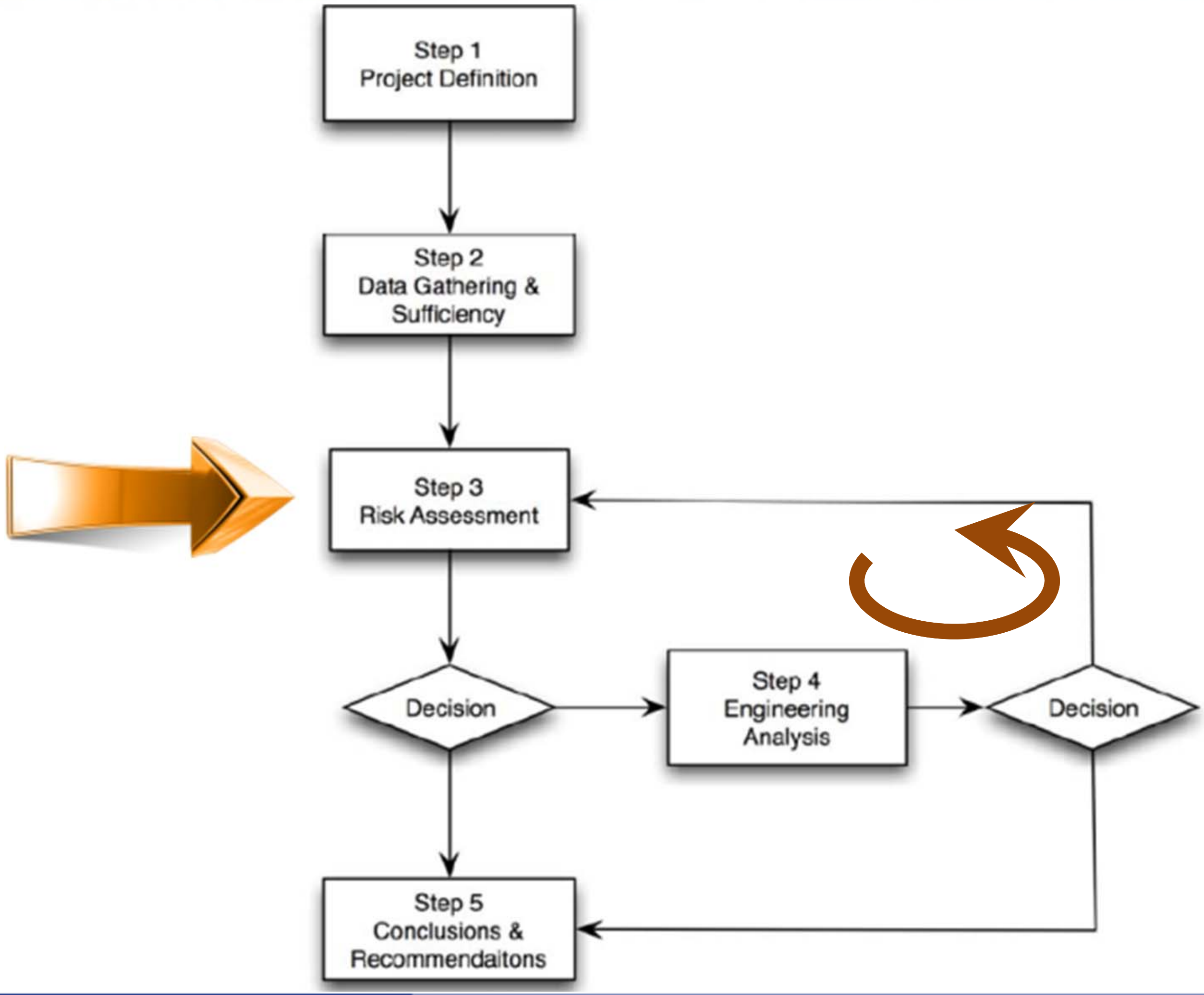
The Protocol is a step by step process to assess impacts of climate change on infrastructure

Goal:

Assist infrastructure owners and operators to effectively incorporate climate change adaptation into design, development, asset management and decision-making



5 Step Protocol



Climate Events and Performance Response Considerations

Climate Events	Performance Response Considerations
• Air Temperature	• Structural Design
• R	
• S	ter, Ground
• W	
• F	e and
• Ic	
• H	
• Frost	• Insurance Considerations
• Ice Accretion	• Policy Considerations
	• Social Effects

Qualitatively assess Probability of Climate Event (***P***) against Severity of Consequences and Effects (***S***) to Compute Risk (***R***) where

$$R = P \times S$$

Probability, P and Severity, S

Scale[10]	Probability*		
	Method A	Method B	Method C
0	negligible or not applicable	<0.1 % 0.1 / 20	negligible or not applicable
1	improbable / highly unlikely	5 % 1 / 20	improbable 1:1 000 000
2	remote	20 % 4 / 20	remote 1:100 000
3	occasional	35 % 7 / 20	occasional 1:10 000
4	moderate / possible	50 % 10 / 20	moderate 1:1 000
5	often	65 % 13 / 20	probable 1:100
6	probable	80 % 16 / 20	frequent 1:10
7	certain / highly probable	>95 % >19 / 20	continuous 1:1

*

a) Choose Method A, Method B or Method C to select the probability.
b) Record in project documentation the Method that was used.
c) Use the same Method for all probabilities used in the evaluation.

Scale	Magnitude	Severity of Consequences and Effects
	Method D	Method E
0	no effect	negligible or not applicable
1	measurable 0.0125	very low / unlikely / rare / measurable change
2	minor 0.025	low / seldom / marginal / change in serviceability
3	moderate 0.050	occasional loss of some capability
4	major 0.100	moderate loss of some capacity
5	serious 0.200	likely regular / loss of capacity and loss of some function
6	hazardous 0.400	major / likely / critical / loss of function
7	catastrophic 0.800	extreme/ frequent/ continuous / loss of asset

*

a) Choose Method D or Method E to select the severity.
b) Record in project documentation the Method that was used.
c) Use the same Method for all severities used in the evaluation.

Vulnerability Assessment Workshop
(Yellowknife, July 26-27, 2010)

- 1.5 Day Workshop
    - ~15 Participants from Operations and Maintenance, Planners, Engineers, Scientists
- Included ½ day highway drive with stops

Initially, **420** risk combinations expanded to **1457** before being whittled down to **1107**

Engineering Challenges

- Linear infrastructure
- Variable foundation conditions
- Variable embankment configurations
- Difficult to manage surface water
- No real as-built information available
- No maintenance records available
- Unclear causes for instability even under no climate change conditions (e.g. Beaver activity)

Infrastructure Component	Performance Response (✓ if yes)										Average Daily Air Temperature				Freezing Index			
	Structural Integrity	Serviceability	Functionality	Operations & Maintenance	Emergency Response Risk	Insurance Considerations	Policies & Procedures	Economics	Public Health & Safety	Environmental Effects	Y/N	P	S	R	Y/N	P	S	R
Infrastructure System																		
Physical Infrastructure																		
Culvert (on ground ice)	✓		✓	✓						✓	N				Y	2	3	6
Culvert (not on ground ice)	✓		✓	✓						✓	N				Y	2	3	6
Rock Drains (on ground ice)	✓		✓							✓	N				Y	2	3	6
Rock Drains (not on ground ice)	✓		✓							✓	N				Y	2	3	6
Bridges	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	3	3	9	Y	3	4	12
Standard Embankment Height (<=2m)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	N				Y	2	2	4
High Embankments	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	N				Y	2	2	4
Subgrade I, ice-rich soil	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	7	6	42	Y	6	6	36
Subgrade II, ice-poor soil	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	5	6	30	Y	4	6	24
Subgrade III, soil, no ice	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	3	5	15	Y	3	5	15
Subgrade IV, surface water/ponds	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	5	5	25	Y	4	5	20
Subgrade V, rock	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	2	3	6	Y	2	3	6
Road Surface		✓	✓	✓	✓	✓	✓	✓			Y	5	5	25	Y	5	6	30
Road Base	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Y	5	4	20	Y	5	4	20
Ditches and Flow Channels			✓						✓	✓	Y	3	3	9	Y	3	3	9

Risk Assessment Summary

- PIEVC Protocol helped **identify critical elements** and **data gaps**
- Independent on the actual infrastructure, **ice-rich foundation** conditions pose highest risks
- **Increase in ground temperatures**, which is considered to be **highly probable**, considered the **cause** for most high risk scenarios
- Road embankment **stability** is relatively **unsusceptible** to climate change
- **Increase in maintenance** and repair efforts and costs is expected
- **No immediate remedial action** is warranted, but collection of baseline information and documentation of future maintenance and repair activities are recommended

Observations 1: Workshop

- Very helpful in identifying **new elements**
- Mixing of the groups during different **break-out sessions** worked well
- **Mix of professionals** was very good
- **Time** was an issue
- **No pre-selection** of crucial combination was carried out
- A 100 km highway is a **challenging infrastructure** to be assessed in a 2D matrix

Observations 2: Vulnerability Assessment

- Was the assessment helpful?

  YES!

  – It allowed to identify critical elements

  – It showed data gaps

Initial Recommendations on Assessment

- Organize **two one-day workshops** allowing participants to digest initial ideas
- **Focus** on the most **critical elements** identified before the workshop
- Including a **3rd dimension** in the risk matrix **for linear infrastructure** on heterogeneous conditions to identify critical sections

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Test Sections

Northwest Territories Transportation

Questions

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