

Climate Change Impacts to BC Resource Roads: Update on Research

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Ministry of
Forests, Lands, Natural
Resource Operations
and Rural Development



climate change assessments team



- Mark Partington, RPF, M.Sc.
- Al Bradley, RPF, P.Eng.
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- Francis Bober, EIT

Poll: slido.com (fpi is event code)

Outline

- **1. Background**

 - **Poll:** applying climate change in professional practice

 - **Basics:** central climate change language and ideas

- **2. Progression of climate change impact assessment methods**

 - **FSR-scale:** (3 BC locations) – risk methods, extensive workshops

 - **District-scale:** (Eastern Canada) – simpler risk methods, workshops

 - **Province-scale:** (BC) – regional vulnerability methods, short workshops

- **3. BC regional assessments**

 - **Overview:** method and results from workshops, climate data summaries

 - **Tool development:** purpose and components

- **4. Discussion (~20 min)**

 - **Feedback:** poll, questions, comments, ideas...

Poll: slido.com (fpi is event code)

Poll: check-in on professional practices

Poll: slido.com
event code: [fpi](#)



1. Background

Basics: climate change terms

1. Standard projection reporting: 2030s, 2050s, 2080s

- 2010-2039 (or 2030s)
- 2040-2069 (or 2050s)
- 2070-2099 (or 2080s)

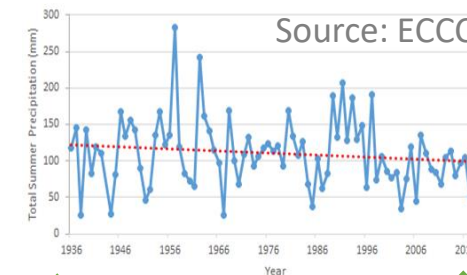
Poll: slido.com (fpi is event code)

Basics: climate change terms

1. Standard projection reporting: 2030s, 2050s, 2080s

2. Types of climate change impacts: averages and extremes

1. Changes in average conditions over long time
 - Eg: average rainfall total per year
2. Changes in extreme events' intensity and frequency
 - Eg: number of heavy rain days



Both are linked



Poll: [slido.com](https://www.slido.com) (fpi is event code)

Basics: climate change terms

- 1. Standard projection reporting: 2030s, 2050s, 2080s**
- 2. Types of climate change impacts: averages and extremes**
- 3. Quantification of climate change: climate indices**
 - Statistical summaries of climate, for example:
 - maximum consecutive days with no rain
 - daily maximum precipitation
 - average number of days/year that reach 20 degrees
 - 5-day daily antecedent rain >15mm
 - 1 in 10-year extreme rainfall amount within 48 hours.....

Poll: slido.com (fpi is event code)

Basics: climate change terms

1. Standard projection reporting: 2030s, 2050s, 2080s

2. Types of climate change impacts: averages and extremes

3. Quantification of climate change: climate indices

- Can be on the spectrum of specific to general:
 - 3-day rainfall of at least 10mm, followed by day with freezing temperatures
 - 3-day sustained rainfall with each day at least 40mm
 - 1-day extreme rainfall
 - monthly average rainfall

Poll: slido.com (fpi is event code)

Basics: climate change terms

- 1. Standard projection reporting: 2030s, 2050s, 2080s**
- 2. Types of climate change impacts: averages and extremes**
- 3. Quantification of climate change: climate indices**
 - Different levels of certainty
 - The higher temporal resolution of the event → more uncertain
 - Extremes compared to averages → more uncertain
 - Those that mix more than 1 variable → more uncertain

Poll: slido.com (fpi is event code)

Poll: check-in

**Poll: [slido.com](https://www.slido.com)
event code: [fpi](#)**

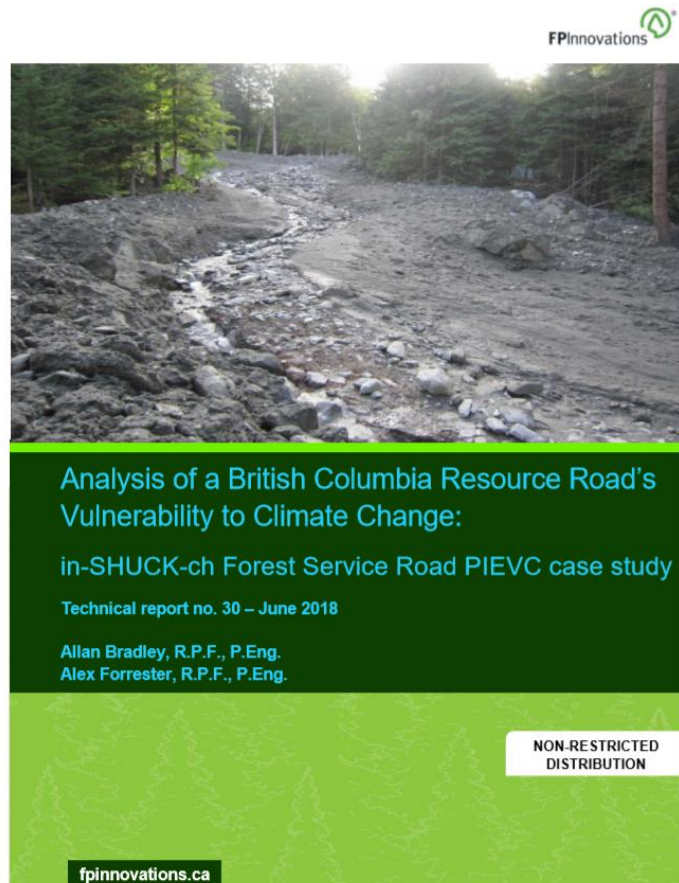
?

2. Progression of climate change impact assessment methods

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR



Public Infrastructure Engineering Vulnerability Committee Protocol

- Built upon ISO 31000 risk management process that is specific to infrastructure
- Requires intensive workshop to consider each interaction between climate events and infrastructure elements
- Uses **PROBABILITY** (of a climate event likelihood) and **SEVERITY** (consequence)
- **PROBABILITY x SEVERITY = RISK**

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Climate indices



Analysis of a British Columbia Resource Road's Vulnerability to Climate Change:
in-SHUCK-ch Forest Service Road PIEVC case study
Technical report no. 30 – June 2018

Allan Bradley, R.P.F., P.Eng.
Alex Forrester, R.P.F., P.Eng.

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Resource road elements

Road Infrastructure Components	Precipitation as Rain																
	7 Total Annual Precipitation			8 Extreme High Rainfall in 24 hour period			9 Sustained Rainfall			10 Antecedent rain followed by significant rain event		11 Low Rainfall		13 Snow Frequency		14 Snow Accumulation	
IF R < 16, the influence of climate change is anticipated to be minor on the element in question and no further consideration is needed. IF 16 < R < 30, further consideration might be needed. IF R > 30, climate change is anticipated to strongly impact the element and detailed engineering analysis by experts familiar with its design is recommended.	1000 mm (North) and 1515 mm (South)			>20-year return period, 80 mm & 80 mm rain in 24 hour period in north & south			≥ 3 consecutive days with 100 & 150 mm rain/day in north & south (20 year return period) Not on snow			Antecedent: 14 consecutive days cumulative amount >150 mm rain followed by 24 hr rainfall exceeding 50 mm		≥ 10 consecutive days with precipitation < 0.2 mm		Snow frequency: days with snowfall < 10cm (Tavg < 1°C) Currently 5 days/yr		Snow accumulation: 5 or more consecutive days with a snow depth >50cm 87 cm per year now	
	Y/N/P	S	R	Y/N/P	S	R	Y/N/P	S	R	Y/N/P	S	R	Y/N/P	S	R	Y/N/P	S
Structures that cross streams:				Y 6 5 30			Y 6 5 30			Y 3 5 15		N		N 6 0		N 5	
§ Bridges § Major (>1800mm dia; >6m3s) § Other culverts (<2000mm) Culvert cross drains Ditches Road surfacing Embankment/Fill Slopes Cut Slopes - Other Material (OM) Cut Slopes - rock Upslope hillslopes beyond road prism - managed Upslope hillslopes beyond road prism - unmanaged Dnslope hillslopes beyond road prism - managed Dnslope hillslopes beyond road prism - unmanaged River training works Retaining walls (rock block, rock stack, log, etc) § MSE/GRS walls/fills Signage Third party utilities: § Hydro poles/towers § Hydro lines § Communication/utility towers § water lines Archeological sites (Grave sites; FN sites) Environmental Features: River hydraulics Flood plain migration Lake level flooding Alluvial fan features Landslide initiation Debris flow initiation Snow avalanche zones Riparian habitat/Fish sensitive streams Miscellaneous: Administration/personnel & engineering Winter maintenance Summer maintenance Gravel/rock pits/spoil sites																	

Sustained Rainfall

≥ 3 consecutive days with 100 & 150 mm rain/day in north & south (20 year return period) Not on snow

Predicted to increase frequency to 8 yr rtn period in 2040 to 2070. Relevance = culvert and bridge design, road surface, safety

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Climate indices



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Resource road elements

	Precipitation as Rain																
	7			8			9			10		11		13		14	
Road Infrastructure Components	Total Annual Precipitation			Extreme High Rainfall in 24 hour period			Sustained Rainfall			Antecedent rain followed by significant rain event		Low Rainfall		Snow Frequency		Snow Accumulation	
	Y	N	P	Y	N	P	Y	N	P	Y	N	Y	N	Y	N	Y	N
1000 mm (North) and 1915 mm (South)																	
Relevance = water management. Based on observed 30 year average total annual rainfall.																	
>20-year return period, 80 mm & 80 mm rain in 24 hour period in north & south																	
predicted to increase frequency to 10-year period. Relevance = culvert and bridge design, road surface, safety. Adjust to consider dry/wet zone as appropriate																	
≥ 3 consecutive days with 100 & 150 mm rainfall in north & south (20 year return period) Not on snow																	
Antecedent: 14 consecutive days cumulative amount >150 mm rain followed by 24 hr rainfall exceeding 50 mm																	
Mathias reference 2 wks impacts to outfill slopes, landslides refer Bill Floyd																	
≥ 10 consecutive days with precipitation < 0.2 mm																	
no info from models (relevance for fire hazard)																	
Snow frequency: days with snowfall < 10cm (Avg < 1 Currently 5 days/ yr)																	
Predicted to be 3 days/ yr Relevance = when need to plough road																	
Snow accumulation: 5 or more consecutive days with a snow depth >50cm @ on per year now																	
measure of how much snow accumulates on road edges due to snowfall and from snow plowing. Snow on hills above road. Predicted to drop to 40 cm per year 2011 to 2040																	
Structures that cross streams:																	
6 Bridges	N																
6 Major (>1800mm dia; >6m3/s)	N																
6 Other culverts (<2000mm)	N																
Culvert cross drains	Y																
Ditches	Y																
Road surfacing	Y																
Embankment/Fill Slopes	Y																
Cut Slopes - Other Material (DM)	N																
Cut Slopes - rock	N																
Upslope hillslopes beyond road prism - managed	N																
Upslope hillslopes beyond road prism - unmanaged	N																
Downslope hillslopes beyond road prism - managed	N																
Downslope hillslopes beyond road prism - unmanaged	N																
River training works	N																
Retaining walls (rock block, rock stack, log, etc)	N																
6 MSE/GRS walls/fills	N																
Signage	N																
Third party utilities:																	
6 Hydro poles/towers	N																
6 Hydro lines	N																
6 Communication/utility towers	N																
6 water lines	N																
Archeological sites (Grave sites; FN sites)	N																
Environmental Features:																	
River hydraulics	Y																
Flood plain migration	Y																
Lake level flooding	Y																
Alluvial fan features	Y																
Landslide initiation	N																
Debris flow initiation	Y																
Snow avalanche zones	Y																
Riparian habitat/Fish sensitive streams	Y																
Miscellaneous:																	
Administration/personnel & engineering	Y																
Winter maintenance	Y																
Summer maintenance	N																
Gravel/rock pits/spoil sites	N																

Climate index * element = risk scores

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR



FPinnovations

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Technical report no. 30 – June 2018

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fpinnovations.ca

Probability

Road Infrastructure Components	Precipitation as Rain																							
	7			8			9			10			11			13			14					
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	Y	N	P	Y	N	P	Y	N	P	Y	N	P	Y	N	P	Y	N	P	Y	N	P	Y	N	P
1000 mm (North) and 1915 mm (South)																								
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Snow accumulation: 5 or more consecutive days with a snow depth >50cm @ 87 cm per year now																								
measure of how much snow accumulates on road edges due to snowfall and from snow plowing. Snow on hills above road. Predicted to drop to 40 cm per year 2011 to 2040																								

Severity

	Y	N	P
6 Bridges	6	5	30
6 Major (>1800mm dia; >6m3/s)	6	7	42
6 Other culverts (<2000mm)	6	7	42
Culvert cross drains	6	7	42
Ditches	6	7	42
Road surfacing	6	7	42
Embankment/Fill Slopes	6	7	42
Cut Slopes - Other Material (DM)	6	7	42
Cut Slopes - rock	6	7	42
Upslope hillslopes beyond road prism - managed	6	7	42
Upslope hillslopes beyond road prism - unmanaged	6	7	42
Downslope hillslopes beyond road prism - managed	6	7	42
Downslope hillslopes beyond road prism - unmanaged	6	7	42
River training works	6	7	42
Retaining walls (rock block, rock stack, log, etc)	6	7	42
6 MSE/GRS walls/fills	6	7	42
6 Signage	6	7	42
Third party utilities:			
6 Hydro poles/towers	6	6	36
6 Hydro lines	6	6	36
6 Communication/utility towers	6	6	36
6 water lines	6	6	36
Archeological sites (Grave sites; FN sites)	6	4	24
Environmental Features:			
River hydraulics	6	4	24
Flood plain migration	6	4	24
Lake level flooding	6	4	24
Alluvial fan features	6	4	24
Landslide initiation	6	5	30
Debris flow initiation	6	5	30
Snow avalanche zones	6	5	30
Riparian habitat/Fish sensitive streams	6	5	30
Miscellaneous:			
Administration/personnel & engineering	6	3	18
Winter maintenance	6	3	18
Summer maintenance	6	3	18
Gravel/rock pits/spoil sites	6	3	18

Probability * severity = risk scores

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Score	Probability	
	Method A	Method B
0	Negligible	< 0.1 %
	Not applicable	< 1 in 1,000
1	Highly unlikely	1 %
	Improbable	1 in 100
2	Remotely possible	5 %
		1 in 20
3	Possible	10 %
	Occasional	1 in 10
4	Somewhat likely	20 %
	Normal	1 in 5
5	Likely	40 %
	Frequent	1 in 2.5
6	Probable	70 %
	Very frequent	1 in 1.4
7	Highly probable	> 99 %

Probability

Road Infrastructure Components	Precipitation as Rain																	
	7			8			9			10		11		13		14		
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	Y	N	P	Y	N	P	Y	N	P	Y	N	Y	N	Y	N	Y	N	
Structures that cross streams:																		
6 Bridges	N	6																
6 Major (>1800mm dia; >6m3/s)	N	6																
6 Other culverts (<2000mm)	N	6																
Culvert cross drains	Y	6																
Ditches	Y	6																
Road surfacing	Y	6																
Embankment/Fill Slopes	Y	6																
Cut Slopes - Other Material (DM)	N	6																
Cut Slopes - rock	N	6																
Upslope hill/slopes beyond road prism - managed	N	6																
Upslope hill/slopes beyond road prism - unmanaged	N	6																
Upslope hill/slopes beyond road prism - unmanaged	N	6																
Upslope hill/slopes beyond road prism - unmanaged	N	6																
River training works	N	6																
Retaining walls (lock block, rock stack, log, etc)	N	6																
6 MSE/GRS walls/fills	N	6																
Signage	N	6																
Third party utilities:																		
6 Hydro poles/towers	N	6																
6 Hydro lines	N	6																
6 Communication/utility towers	N	6																
6 water lines	N	6																
Archeological sites (Grave sites; FN sites)	N	6																
Environmental Features:																		
River hydraulics	Y	6																
Flood plain migration	Y	6																
Lake level flooding	Y	6																
Alluvial fan features	Y	6																
Landslide initiation	N	6																
Debris flow initiation	Y	6																
Snow avalanche zones	Y	6																
Riparian habitat/Fish sensitive streams	Y	6																
Miscellaneous:																		
Administration/personnel & engineering	Y	6																
Winter maintenance	Y	6																
Summer maintenance	N	6																
Gravel/rock pits/spill sites	N	6																

Severity

	Y	N	P	S	R
6 Bridges					
6 Major (>1800mm dia; >6m3/s)					
6 Other culverts (<2000mm)					
Culvert cross drains	Y	6	5	30	
Ditches	Y	6	7	42	
Road surfacing	Y	6	7	42	
Embankment/Fill Slopes	Y	6	7	42	
Cut Slopes - Other Material (DM)	Y	6	7	42	
Cut Slopes - rock	Y	6	6	36	
Upslope hill/slopes beyond road prism - managed	Y	6	4	24	
Upslope hill/slopes beyond road prism - unmanaged	Y	6	4	24	
Upslope hill/slopes beyond road prism - unmanaged	Y	6	3	18	
Upslope hill/slopes beyond road prism - unmanaged	Y	6	3	18	
River training works	Y	6	3	18	
Retaining walls (lock block, rock stack, log, etc)	Y	6	3	18	
6 MSE/GRS walls/fills	Y	6	3	18	
Signage	Y	6	3	18	
Third party utilities:					
6 Hydro poles/towers	Y	6	3	18	
6 Hydro lines	Y	6	3	18	
6 Communication/utility towers	Y	6	3	18	
6 water lines	Y	6	3	18	
Archeological sites (Grave sites; FN sites)	Y	6	3	18	
Environmental Features:					
River hydraulics	Y	6	3	18	
Flood plain migration	Y	6	3	18	
Lake level flooding	Y	6	3	18	
Alluvial fan features	Y	6	3	18	
Landslide initiation	Y	6	3	18	
Debris flow initiation	Y	6	3	18	
Snow avalanche zones	Y	6	3	18	
Riparian habitat/Fish sensitive streams	Y	6	3	18	
Miscellaneous:					
Administration/personnel & engineering	Y	6	3	18	
Winter maintenance	Y	6	3	18	
Summer maintenance	Y	6	3	18	
Gravel/rock pits/spill sites	Y	6	3	18	

Probability * severity = risk scores

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Score	Severity of consequences and effects	
	Method D	Method E
0	No effect	Negligible Not applicable
1	Measurable	Very Low Some measurable change
2	Minor	Low Slight loss of serviceability
3	Moderate	Moderate loss of serviceability
4	Major	Major loss of serviceability Some loss of capacity
5	Serious	Loss of capacity Some loss of function
6	Hazardous	Major Loss of function
7	Catastrophic	Extreme Loss of asset

Probability

	Precipitation as Rain																													
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	Y	N	P	S	R	Y	N	P	S	R	Y	N	P	S	R	Y	N	P	S	R	Y	N	P	S	R	Y	N	P	S	R
Structures that cross streams:																														
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Ditches	Y	6																												
Road surfacing	Y	6																												
Embankment/Fill Slopes	Y	6																												
Cut Slopes - Other Material (DM)	N	6																												
Cut Slopes - rock	N	6																												
Upslope hillslopes beyond road prism - managed	N	6				Y	6	5	30																					
Upslope hillslopes beyond road prism - unmanaged	N	6				Y	6	3	18		Y	3	2	6		Y	6	3	18		N	6	0			N	5			
Downslope hillslopes beyond road prism - managed	N	6				Y	6	7	42		Y	3	1	3		Y	6	3	18		Y	6	3	18		N	5			
Downslope hillslopes beyond road prism - unmanaged	N	6				Y	6	7	42		Y	3	1	3		Y	6	3	18		N	6	0			N	5			
River training works	N	6				Y	6	7	42		Y	3	2	6		N	6	0			N	6	0			N	5			
Retaining walls (lock block, rock stack, log, etc)	N	6				Y	6	3	18		Y	3	3	9		N	6	0			N	6	0			N	5			
MSE/GRS walls/fills	N	6				Y	6	7	42		Y	3	1	3		N	6	0			N	6	0			N	5			
Signage	N	6				Y	6	7	42		N					Y	6	2	12		Y	5	3	15		Y	5	3	15	
Third party utilities:																														
Hydro poles/towers	N	6				Y	6	6	36		N					N	6	0			N	6	0			Y	5	2	10	
Hydro lines	N	6				Y	6	6	36		N					N	6	0			N	6	0			N	5			
Communication/utility towers	N	6				Y	6	6	36		N					N	6	0			N	6	0			N	5			
Water lines	N	6				Y	6	4	24		N					N	6	0			Y	5	3	15		Y	5	3	15	
Archeological sites (Grave sites; FN sites)	N	6				Y	6	4	24		N					N	6	0			N	6	0			N	5			
Environmental Features:																														
River hydraulics	Y	6				Y	6	3	18		Y	3	2	6		N	6	0			N	6	0			N	5	0		
Flood plain migration	Y	6				Y	6	3	18		Y	3	2	6		N	6	0			N	6	0			N	5	0		
Lake level flooding	Y	6				N					Y	3	1	3		N	6	0			N	6	0			N	5	0		
Alluvial fan features	Y	6				Y	6	3	18		Y	3	2	6		N	6	0			N	6	0			N	5	0		
Landslide initiation	N					Y	6	6	36		Y	3	5	15		N	6	0			N	6	0			N	5	0		
Debris flow initiation	Y	6				Y	6	5	30		Y	3	4	12		N	6	0			N	6	0			N	5	0		
Snow avalanche zones	Y	6				Y	6	5	30		Y	3	1	3		N	6	0			N	6	0			Y	5	4	20	
Riparian habitat/Fish sensitive streams	Y	6				N					N					Y	6	3	18		N	6	0			N	5	0		
Miscellaneous:																														
Administration/personnel & engineering	Y	6				Y	6	5	30		Y	3	3	9		N					Y	6	2	12		Y	5	3	15	
Winter maintenance	Y	6				Y	6	4	24		Y	3	4	12		N					Y	5	4	20		Y	5	5	25	
Summer maintenance	N	6				Y	6	4	24		Y	3	4	12		Y	6	2	12		N	5	0			N	5	0		
Gravel/rock pits/spoil sites	N	6				Y	6	3	18		Y	3	1	3		N					N	5	0			N	5	0		

Severity

Probability * severity = risk scores

FSR-scale: 2016-19

2017-18

- Simplified approach for Tum Tum FSR

Climate indices



Analysis of a British Columbia resource road's vulnerability to climate change:

Tum Tum Forest Service Road PIEVC case study

Technical report no. 35 - June 2018

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Resource road elements

Table 10. Summary of risk scores for baseline (B = 2011 to 2040) and future (F = 2041 to 2070) periods

Infrastructure components	Drought		Daily temp. variation		Freeze/thaw		Cold spells		Spring thaw		Extreme rainfall		Sustained rainfall		Ante. rain		Rapid snow melt		Ice / ice jams		Snow freq.		Snow accum.	
	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Road prism																								
Road surface	12	12	5	5	7	7	5	5	28	28	12	15	9	12	18	18	6	6	6	6	10	10	14	12
Cut fill and slope	6	6	5	5	7	7	5	5	7	7	12	15	9	12	18	18	6	6	0	0	10	10	14	12
Ditches	0	0	5	5	21	21	5	5	7	7	12	15	9	12	18	18	12	12	4	4	5	5	7	6
Catch basins	0	0	5	5	14	14	15	15	7	7	8	10	6	8	12	12	12	12	0	0	5	5	7	6
Cross drains																								
Stream crossings																								
Major culverts																								
Other culverts																								
Bridges																								
Upslope/downslope beyond road prism																								
Managed																								
Unmanaged																								
Operational considerations																								
Commercial access																								
Emergency response	18	18	0	0	14	14	5	5	7	7	20	25	15	20	30	30	6	6	6	6	5	5	7	6
Winter maintenance	N	N	0	0	21	21	15	15	7	7	N	N	N	N	N	N	12	12	6	6	10	10	14	12
Summer maintenance	12	12	0	0	N	N	N	N	N	N	12	15	9	12	18	18	N	N	N	N	N	N	N	N
Personnel	18	18	0	0	14	14	0	0	0	0	12	15	9	12	18	18	6	6	6	6	5	5	7	6


Threshold	Risk range	Response
Low	< 13	No action required
Low-Medium	13 - 25	Remedial actions may be required
High-Medium	26 - 36	Remedial actions may be required
High	>36	Immediate action required

1. A risk score of "N" indicates that the infrastructure component was not assessed for risk to the corresponding climate factor.

FSR-scale: 2016-19

2018-19

- Simplified again for Willow FSR



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ANALYSIS OF A BRITISH COLUMBIA RESOURCE ROAD'S VULNERABILITY TO CLIMATE CHANGE: WILLOW FOREST SERVICE ROAD PIEVC CASE STUDY

Mark Partington, R.P.F., M.Sc., Senior Researcher
Allan Bradley, R.P.F., P.Eng., Lead Researcher

November 2019 Non-restricted distribution

Resource Road Elements

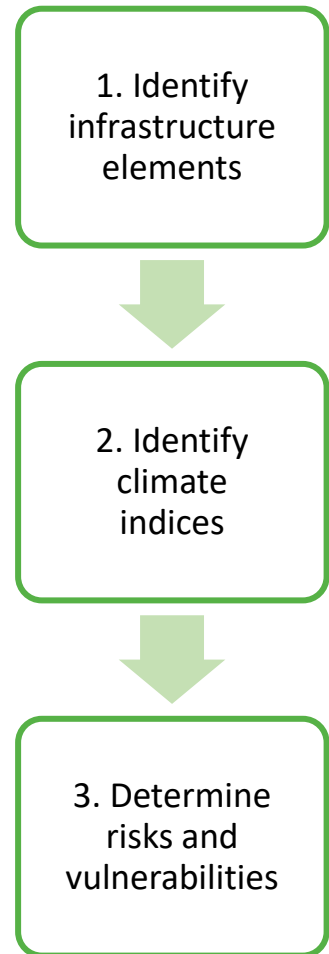
Climate indices

Table 10. Summary of risk scores for baseline (B = 2011 to 2040) and future (F = 2041 to 2070) periods.

Infrastructure components	Drought		Extreme high rainfall in 24 hr period		High rainfall in 24 hr period		Sustained rainfall		Antecedent rain followed by significant rain event		Freeze-thaw cycling		Freeze / thaw 2		Spring thaw		Rain on snow		Rapid snow melt		Snow frequency	
	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Road features																						
Road prism	6	6	12	15	4	6	6	9	5	5	21	21	24	36	42	42	20	25	10	10	3	2
Cut fill and slope	4	4	12	15	4	6	6	9	5	5	14	14	8	12	7	7	20	25	10	10	3	2
Ditches	0	0	16	20	6	9	6	9	5	5	35	35	12	18	7	7	24	30	12	12	3	2
Cross drains	2	2	16	20	4	6	6	9	5	5	35	35	20	30	7	7	24	30	12	12	3	2
Stream crossings																						
Major culverts >2.0m	2	2	8	10	2	3	4	6	3	3	7	7	4	6	7	7	8	10	4	4	3	2
Other culverts <2.0m	2	2	16	20	4	6	8	12	5	5	28	28	12	18	7	7	20	25	10	10	3	2
Bridges	12	12	8	10	2	3	4	6	3	3	7	7	4	6	7	7	8	10	4	4	3	2
Operational considerations																						
Commercial, recreational, residential access	8	8	12	15	2	3	6	9	5	5	42	42	24	36	35	35	20	25	10	6	9	6
Emergency response	12	12	12	15	2	3	6	9	5	5	28	28	24	36	35	35	20	25	10	10	9	6
Winter maintenance & construction	na	na	na	na	na	na	na	na	na	na	21	21	24	36	28	28	24	30	12	12	9	6
Summer maintenance & construction	12	12	12	15	2	3	6	9	5	5	na	na	na	na	na	na	na	na	na	na	na	na
Safety	10	10	8	10	4	6	6	9	5	5	35	35	24	36	28	35	24	30	12	12	12	8

District-scale: 2020

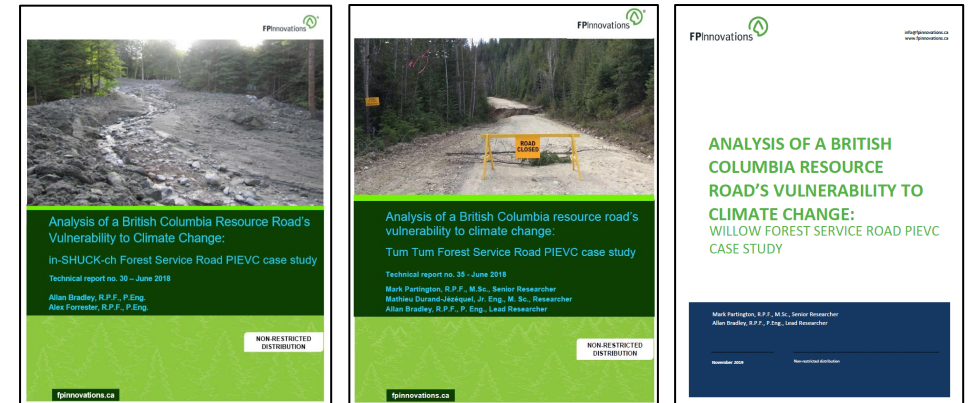
Latest simplified risk assessment:



Used FSR experience to simplify selection of elements for a road network

Used FSR experience to simplify climate index selection + public climate projection data to get percent change, estimate probabilities

Used FSR experience to simplify ranking system + streamlined workshops to assign severities



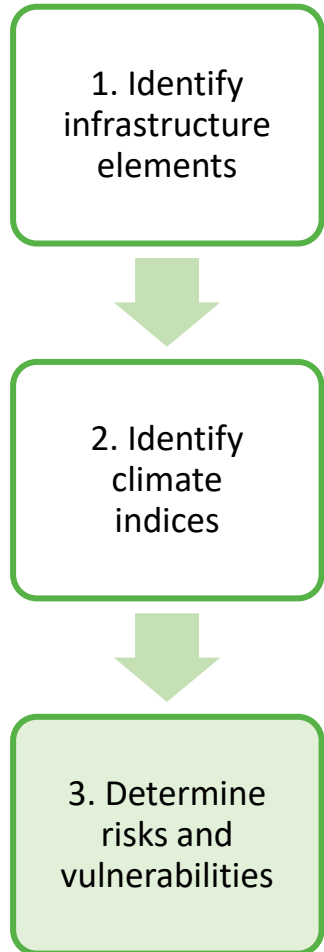
Many publicly accessible climate projection data now available through various web interfaces/applications

		Probability				
		1	2	3	4	5
Severity	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

District-scale: 2020

Latest simplified risk assessment:

Resource road elements



Climate indices

Climate Vulnerability Event	Infrastructure elements and considerations													
	Road prism (surface/subgrade)		Water control structures		Water crossings - Culverts		Water crossings - Bridges		Maintenance & construction (Summer)		Maintenance (Winter)		Roads in high value areas	
	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future
Sustained rainfall	4	6	6	12	4	6	4	6	4	6	N/A	N/A	6	9
High Rainfall	8	8	12	12	8	8	8	8	8	8	N/A	N/A	12	12
Extreme high rainfall	6	12	8	16	8	16	4	8	6	12	N/A	N/A	8	16
Rain on snow (winter)	6	10	12	20	6	10	6	10	N/A	N/A	9	15	6	10
Freeze thaw days (winter)	12	16	9	12	9	12	6	8	N/A	N/A	12	16	6	8
Rapid snow melt (spring)	8	12	8	12	6	9	8	12	N/A	N/A	8	12	8	12
Freeze thaw days (spring)	12	20	6	10	6	10	6	10	N/A	N/A	9	15	6	10
Drought / extended dry days (summer)	9	15	3	5	3	5	3	5	9	15	N/A	N/A	3	10

Provincial-scale: 2020-21

recent climate vulnerability assessment

- Need: economical assessment for entire BC

Surveyed professionals in region about climate vulnerabilities beforehand, then reviewed results/discussed in workshops

Used public climate tools, experience from 3 FSRs as a starting point, along with expertise from PCIC

Presented climate index projections with survey results about historic observations to help interpretation during workshops

1. Identify vulnerable forest operations activities

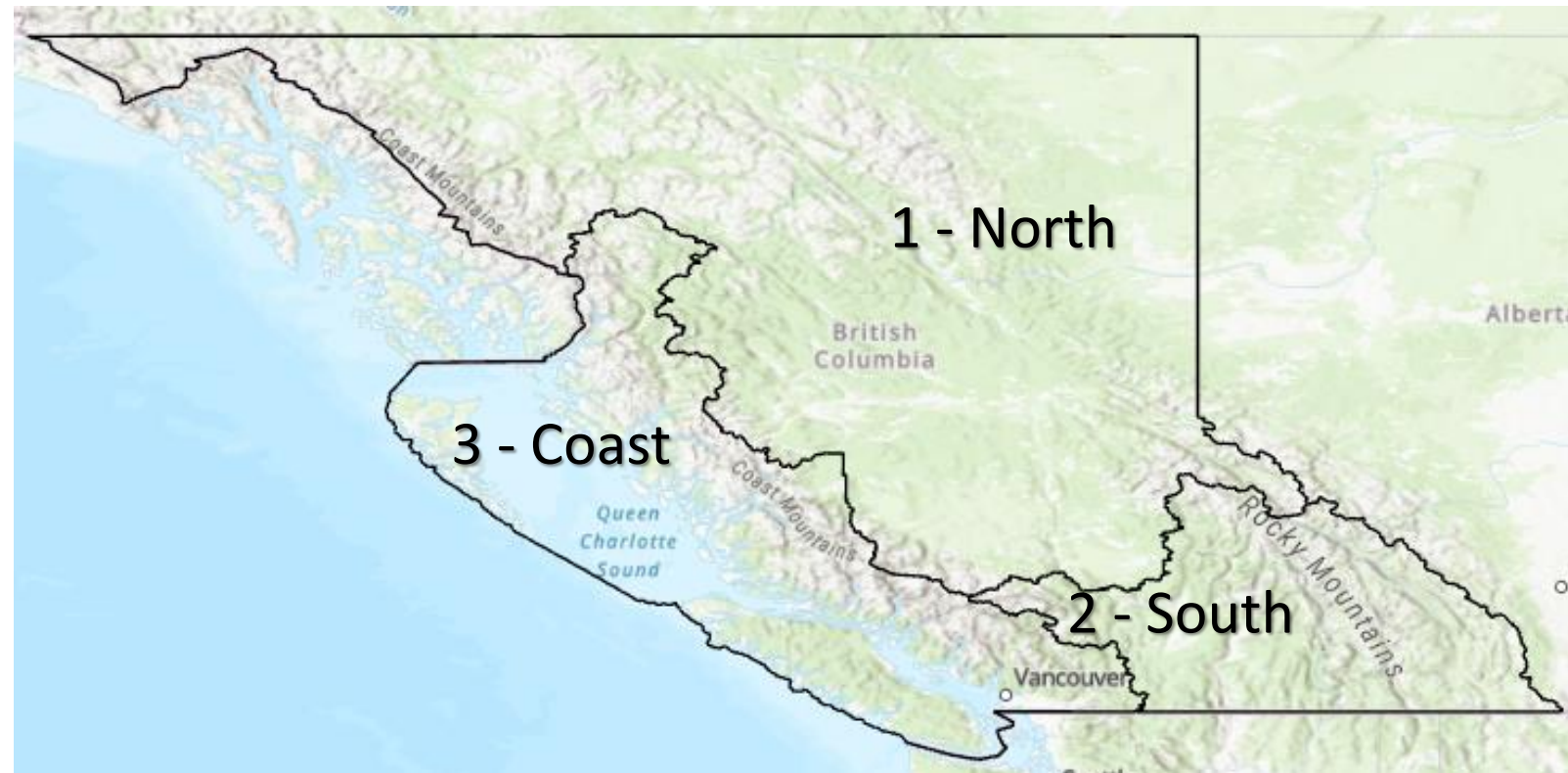
2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

3. BC regional assessments

Overview: BC regional assessments - method

- Three workshops: 6-10 participants (private & government forestry professionals)
- Participants received surveys prior to a 2 h workshop asking about past climate vulnerabilities of forest operations



Overview: BC regional assessments - method

Surveys re: forest operations activities previously vulnerable to climate events

Harvesting and Silviculture

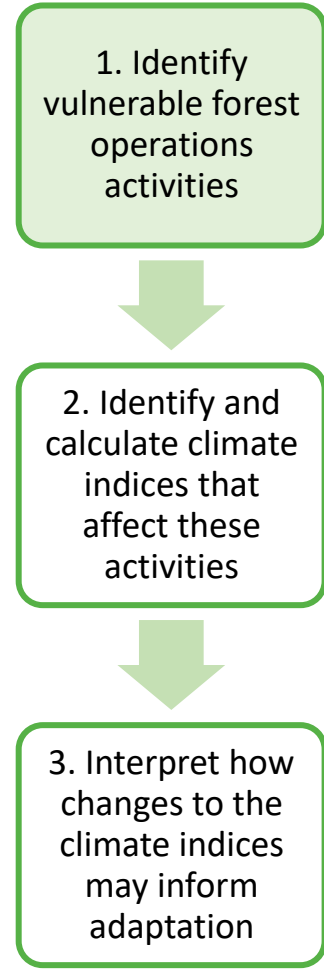
1. Shutdown/disruption – due to dry conditions	9. Need to perform salvage operations
2. Shutdown/disruption – due to rain	10. Slash pile burning – scheduling window
3. Shutdown/disruption – frequency – due to milder winters	11. Herbicide spray – scheduling window
4. Spring shutdown start date (earlier =decrease)	12. Herbicide spray – start
5. Safety concerns	13. Challenges in meeting soil disturbance requirements
6. Planting failures	14. Overall harvesting and silviculture activity costs
7. Planting season – length	
8. Planting season – start	

Roads and Infrastructure

1. Shutdown/disruption – due to dry conditions	8. Water crossing structure maintenance or replacement
2. Shutdown/disruption – due to rain	9. Bridge scouring / embankment erosion
3. Shutdown/disruption – due to milder winters	10. Usability of winter roads
4. Spring shutdown start date (earlier =decrease)	11. Summer road maintenance
5. Safety concerns	12. Winter road maintenance
6. Shutdowns/disruption frequency – due to landslides/mass wasting	13. Overall road and infrastructure costs
7. Road washouts and repairs	

Transportation

1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Transportation scheduling challenges
7. Vehicle traction challenges /getting stuck
8. Overall transport costs



■ substantial decrease
 ■ decrease
 ■ no change
 ■ increase
 ■ substantial increase
 ■ not sure

Overview: BC regional assessments - method

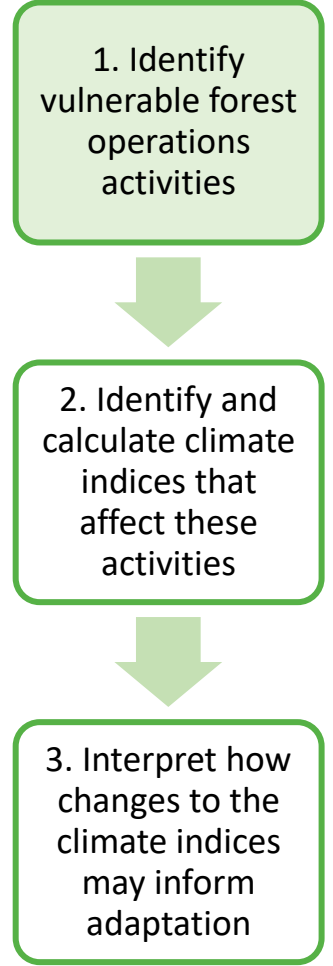
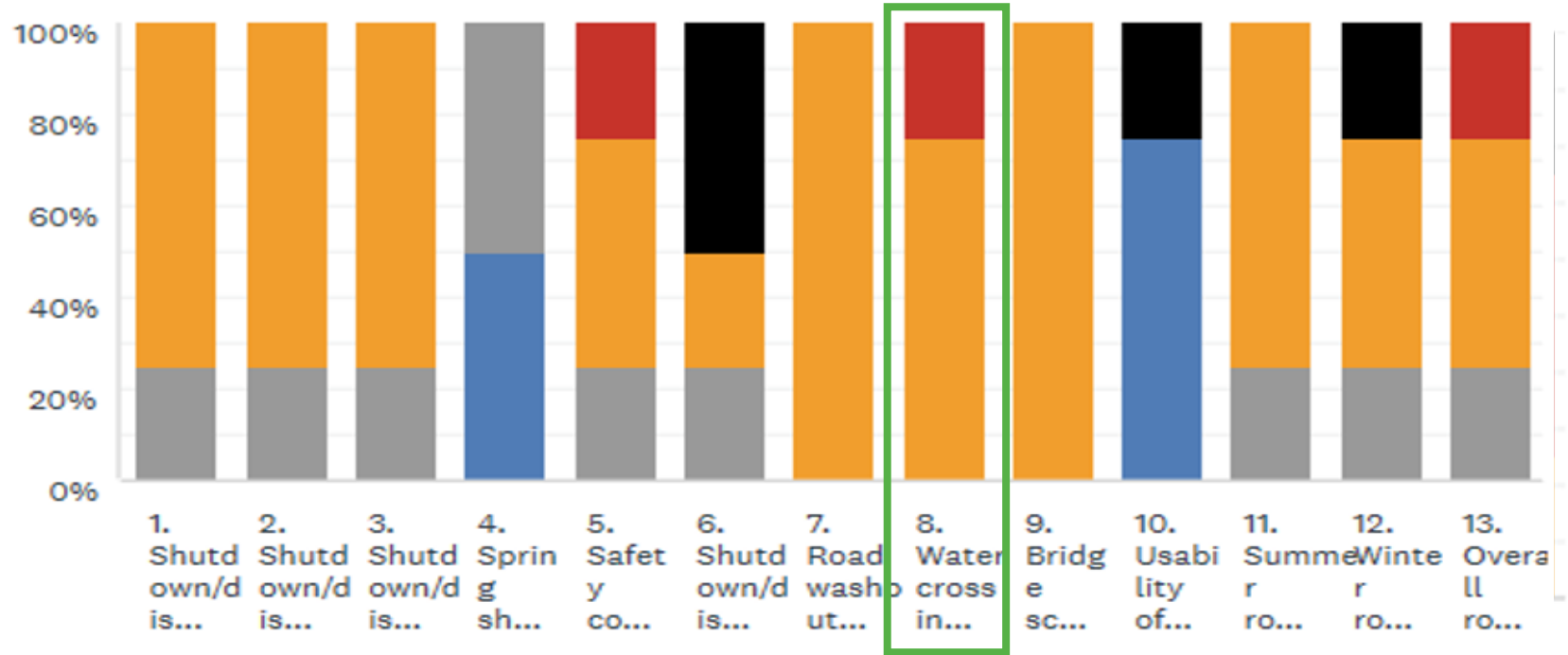
Surveys re: forest operations activities previously vulnerable to climate events

Example from southern BC region

“In your experience, how has climate change affected the vulnerabilities of the following forest ops activities? (past 10-15 years)”

8. Water crossing structure maintenance or replacement

Roads and Infrastructure

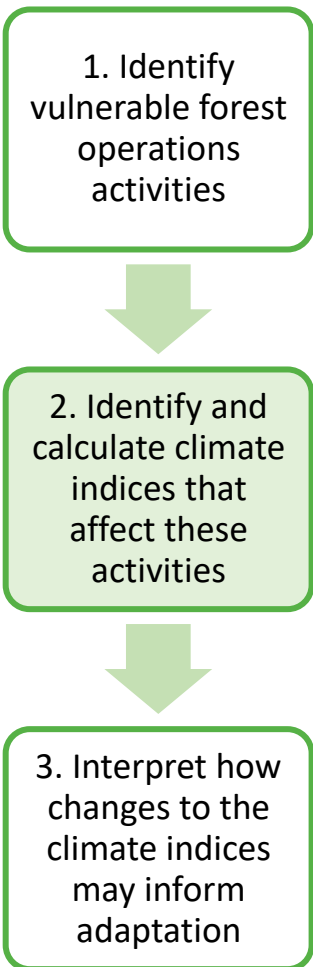


■ substantial decrease
 ■ decrease
 ■ no change
 ■ increase
 ■ substantial increase
 ■ not sure

Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)
1. Drought	Max. daily temp (Summer)
2. Spring Thaw	Freezing degree-days (Winter)
3. Freeze/Thaw cycling	Freeze-thaw days (Year)
4. Short intense storms	20-year return period daily precipitation
5. Sustained rainfall	Max 1-day storm (Year)
6. Snowfall	Precipitation as snow (Winter)

- Experience from FSR assessments
- Literature review: other work in fields related to forestry
- Consultations with climate experts: how well do available climate indices work as proxies?
- How does each of these climate vulnerabilities affect activities from step 1?

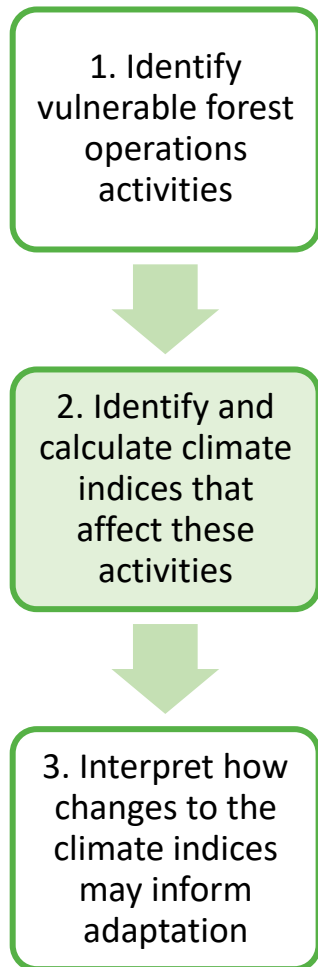


Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)	West Coast		South Coast	
1. Drought	Max. daily temp (Summer)	16.9	18 % 20 %	18.2	29 % 33 %
2. Spring Thaw	Freezing degree-days (Winter)	202	-43 % -64 %	351	-42 % -66 %
3. Freeze/Thaw cycling	Freeze-thaw days (Year)	74	-39 % -28 %	98	-29 % -32 %
4. Short intense storms	20-year return period daily precipitation	91	15 % 25 %	69	14 % 26 %
5. Sustained rainfall	Max 1-day storm (Year)	61	23 % 35 %	47	19 % 36 %
6. Snowfall	Precipitation as snow (Winter)	?	-55 % -65 %	?	-42 % -53 %

Baseline value (1971-2000) % change from baseline:
 2040-2069
 2070-2099

- Data sources: PCIC Climate Explorer (#1,2,4,5) Climatedata.ca (#3) & Plan2Adapt (#6)



Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)	West Coast		South Coast	
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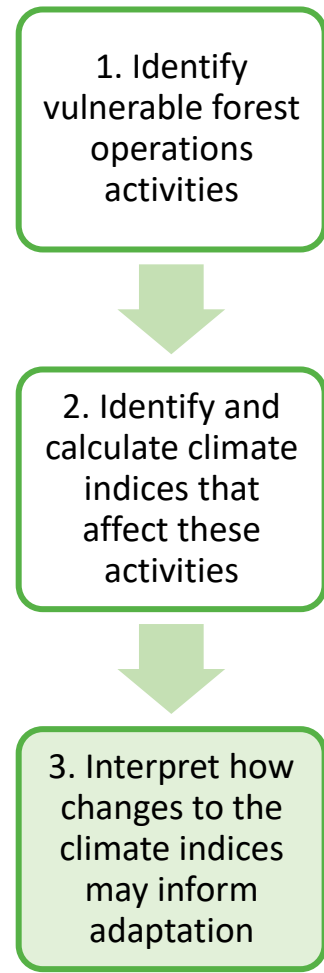
Baseline value (1971-2000) % change from baseline:
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Error sources:

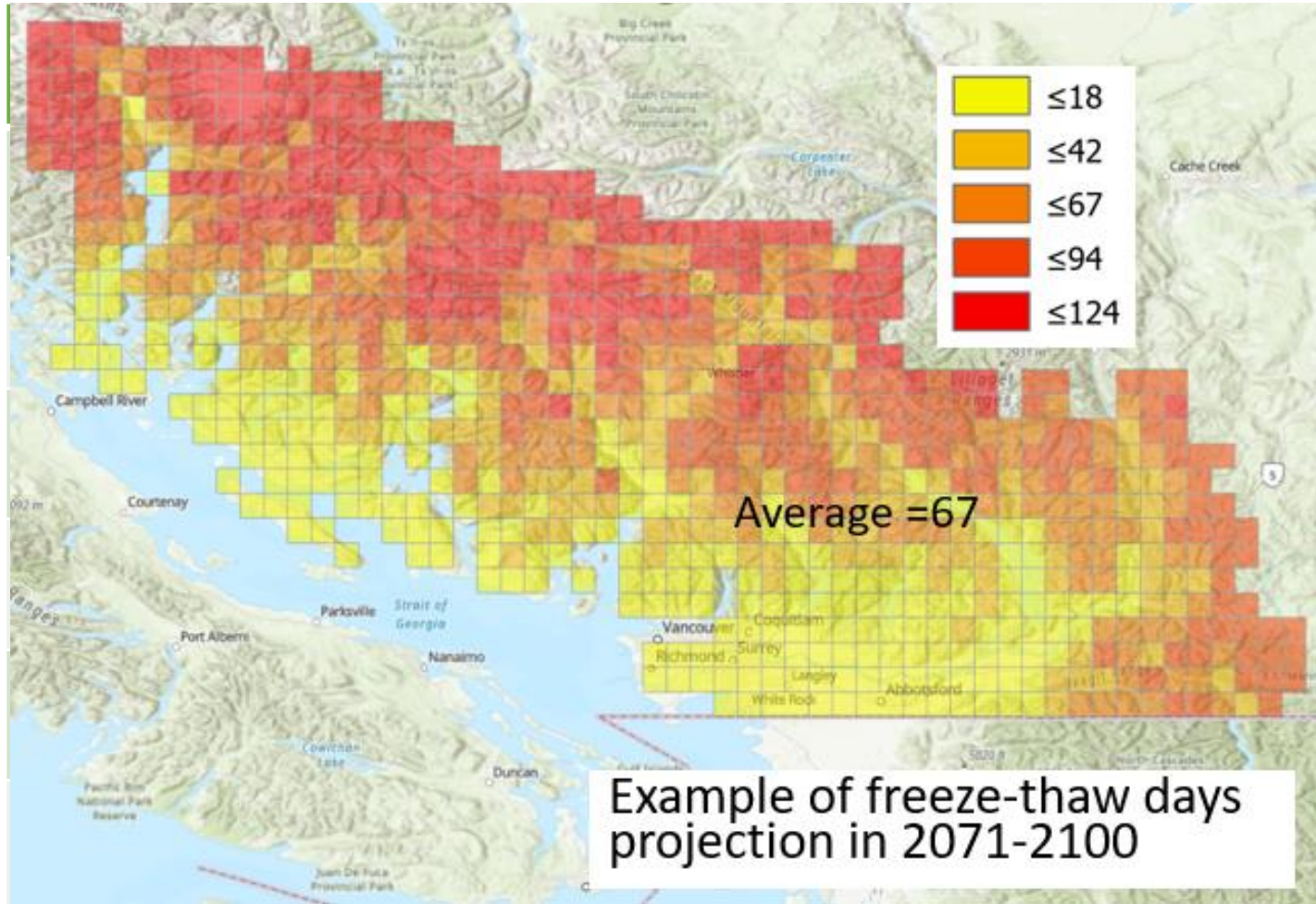
- Historic values
- Baseline selection
- Ensemble variance
- Spatial error
- Temporal error

Link to activities:

- A need to think of past in new terms



Overview: BC regional assessments - method



Baseline value (1971-2000) % change from baseline:
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Link to activities:

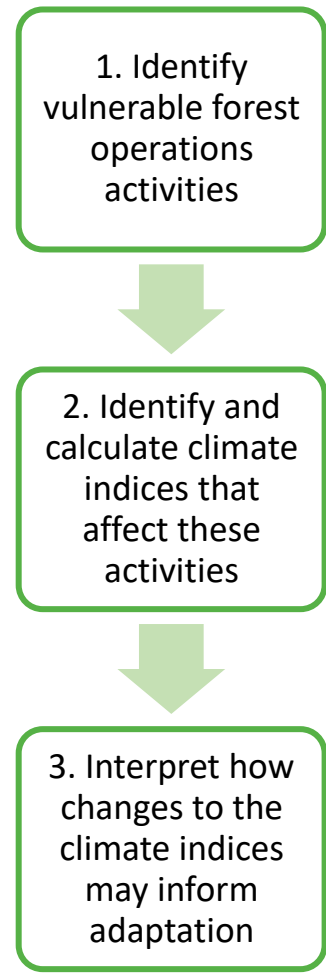
- A need to think of past in new terms

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - results



Overview: BC regional assessments - results

North – a sample of observations on past climate interactions with resource roads

Winter roads tough to establish

Culverts being blocked by ice build-up due to rain on snow events, mid-winter thaws and fluctuations in transition from winter to spring

Decrease in frost in the ground in the northeast possibly as a result of more moisture in the fall.

Snow insulates the from frost penetration observed (Freeze-up used to occur by end of October)

The spring break-up period appears to be longer.

Road bans coming off later. MOTI. With fire watch.

More maintenance, more failures observed old FSRs and to a lesser degree, new FSRs; more saturated road conditions especially in mountainous areas

More rain occurring in January, creating unsafe road conditions with icy roads.

Lots of unpredictability to forest operations planning due to so many variables.

Safety concerns increasing due freeze-thaw and winter rain events. Icy roads more common with thaw occurring on top of the ice. More rutted roads being created.

Costs have increased due to building roads out of mud/Not a lot of good road builders in tough wet ground

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - results

Climate vulnerability event

1. Drought risk
2. Spring Thaw
3. Freeze/Thaw action
4. Short intense storms
5. Sustained rainfall
6. Snowfall

Many-to-many relationship

Roads and Infrastructure vulnerabilities

1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Shutdowns/disruption frequency – landslides
7. Road washouts and repairs
8. Water crossing structure maintenance or replacement
9. Bridge scouring / embankment erosion
10. Usability of winter roads
11. Summer road maintenance
12. Winter road maintenance
13. Overall road and infrastructure costs

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

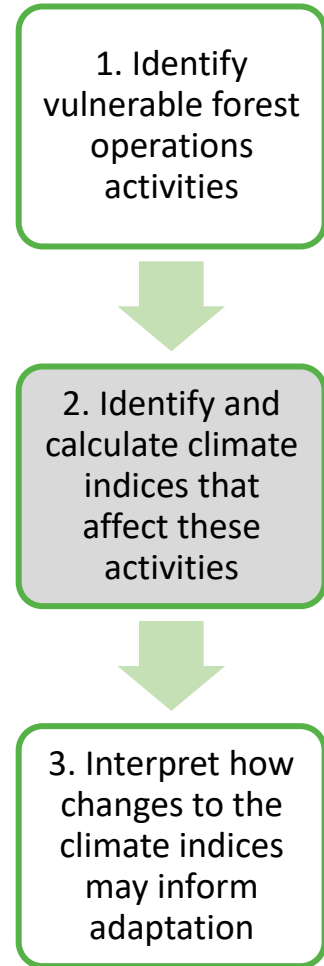
3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - results

Climate vulnerability	South Coast	
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Many-to-many relationship

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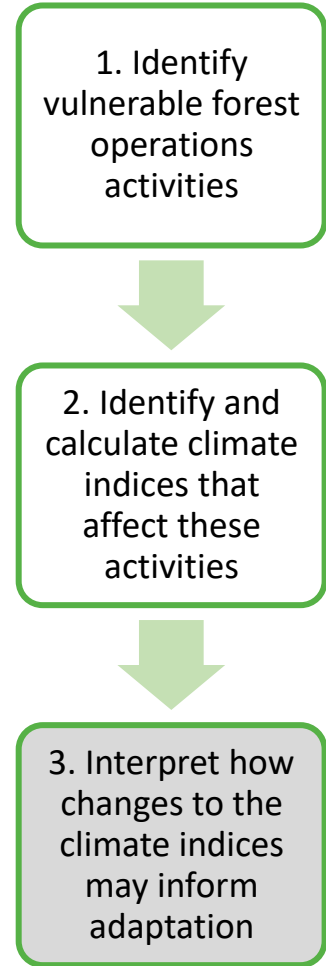
Overview: BC regional assessments - results

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Observation:

All workshops requested historical trends for each climate vulnerability to help interpret meaning of % change

Roads and Infrastructure vulnerabilities	
1. Shutdown/disruption – due to dry conditions	
	nters
	crease)
	lides
	r replacement
12. Winter road maintenance	
13. Overall road and infrastructure costs	



Overview: BC regional assessments - results

North – a sample of climate change adaptations /need for adaptations

Washouts/deteriorating conditions require more machine movements for suitable work; more mobilization/demobilization for grinders

Road and infrastructure maintenance and repairs have been reactive to events for the most part

Increased efforts to steam culverts out during spring breakup (more now than 20 years ago)

There have been upgrades on older roads as an adaptation measure

Starting to use rig mats in very saturated roads (many blocks accessed by rig mats)

1. Identify vulnerable forest operations activities

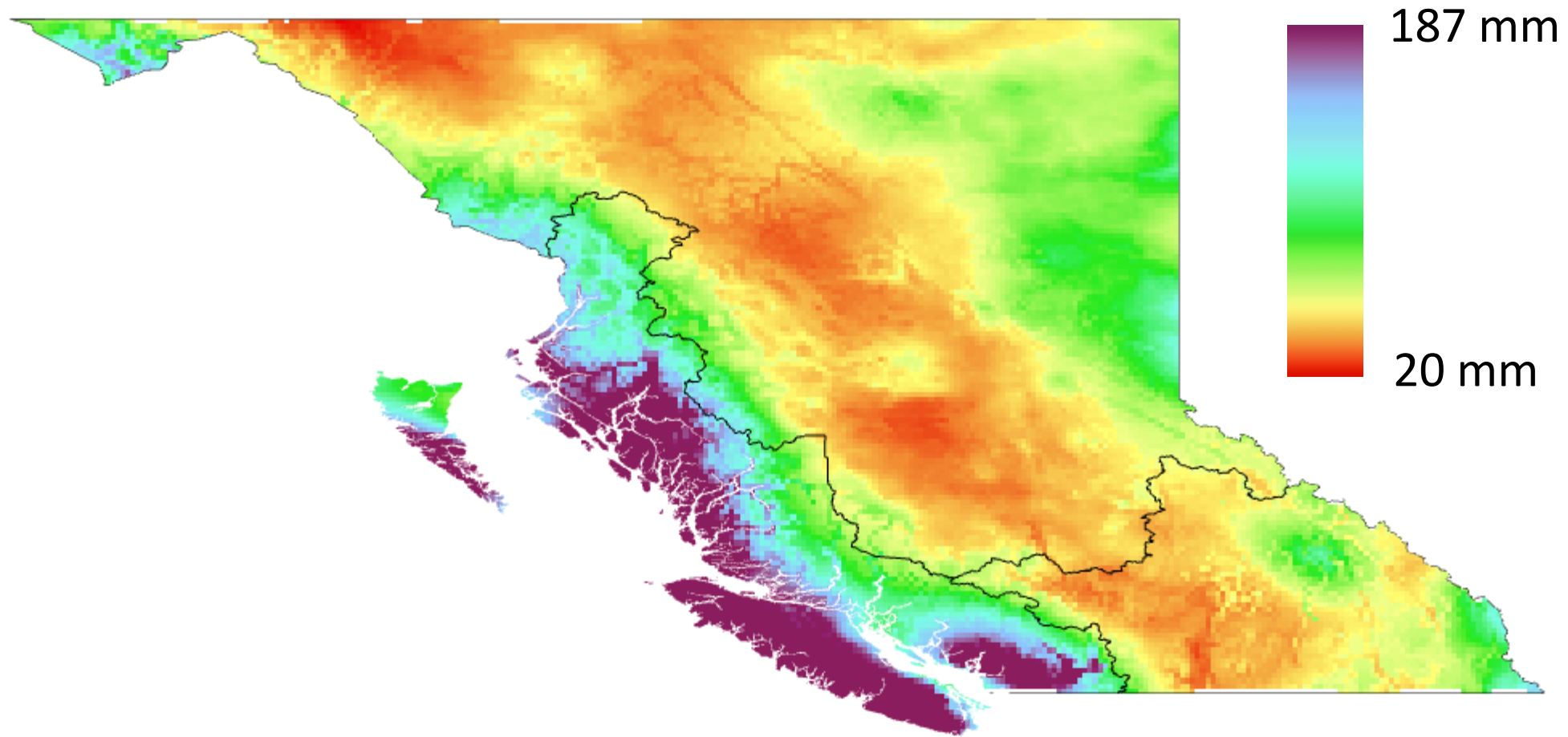
2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Tool development: how it all applies

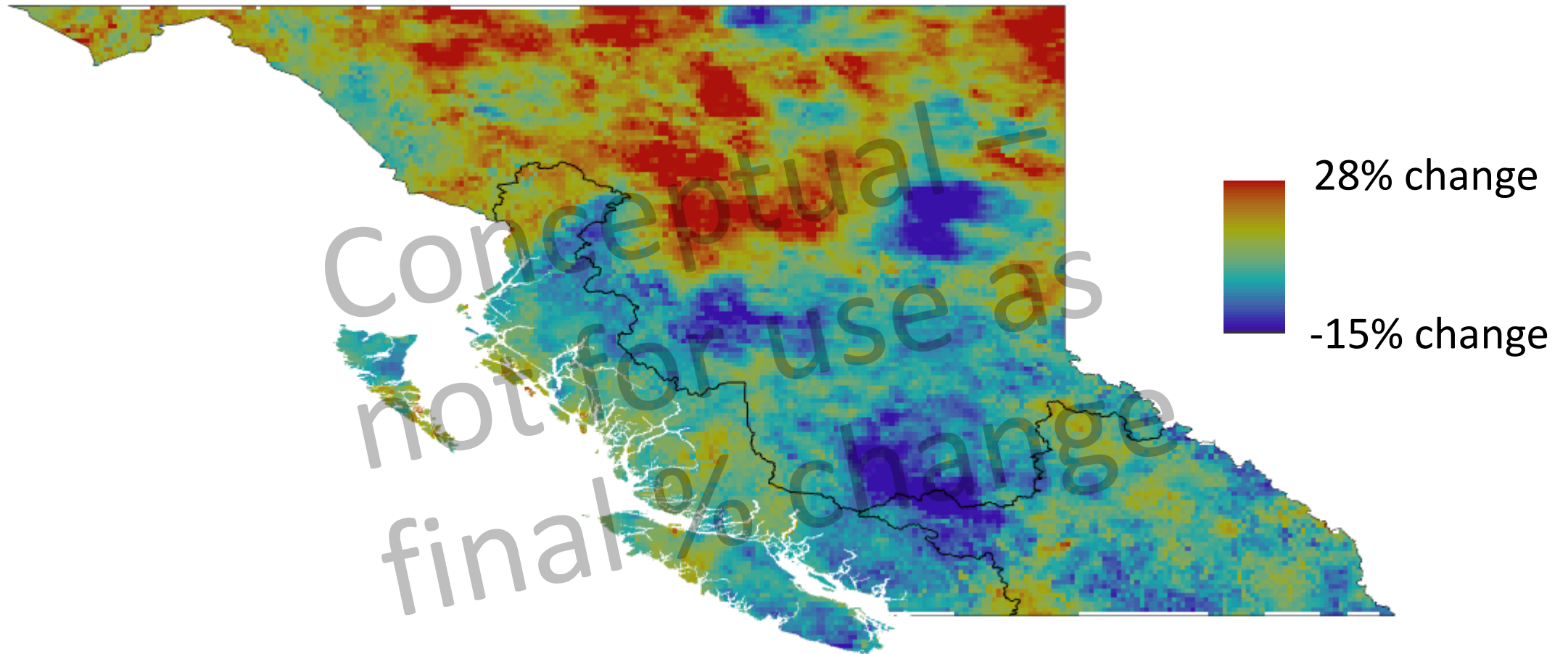
- A story map will summarize the 6 climate vulnerabilities in regions by:
 - Showing maps/values for each through cartography/interaction
 - Including options to summarize different options for RCPs, future periods, and percentiles
 - Explaining the limitations and characteristics of each climate index
 - Final proxy climate indices will be defined with PCIC input
 - Summarizing trends for forest operations vulnerabilities identified in workshops
 - To highlight relevant/different forest operations between regions (local knowledge/experience)
 - Including historic trend information
 - In response to workshop feedback; PCIC will prepare the data
- Data availability:
 - Downloading the data will be an option
 - All raster climate projections files from PCIC post-processed into shp file with all change calculations in the attributes

Tool development: how it all applies



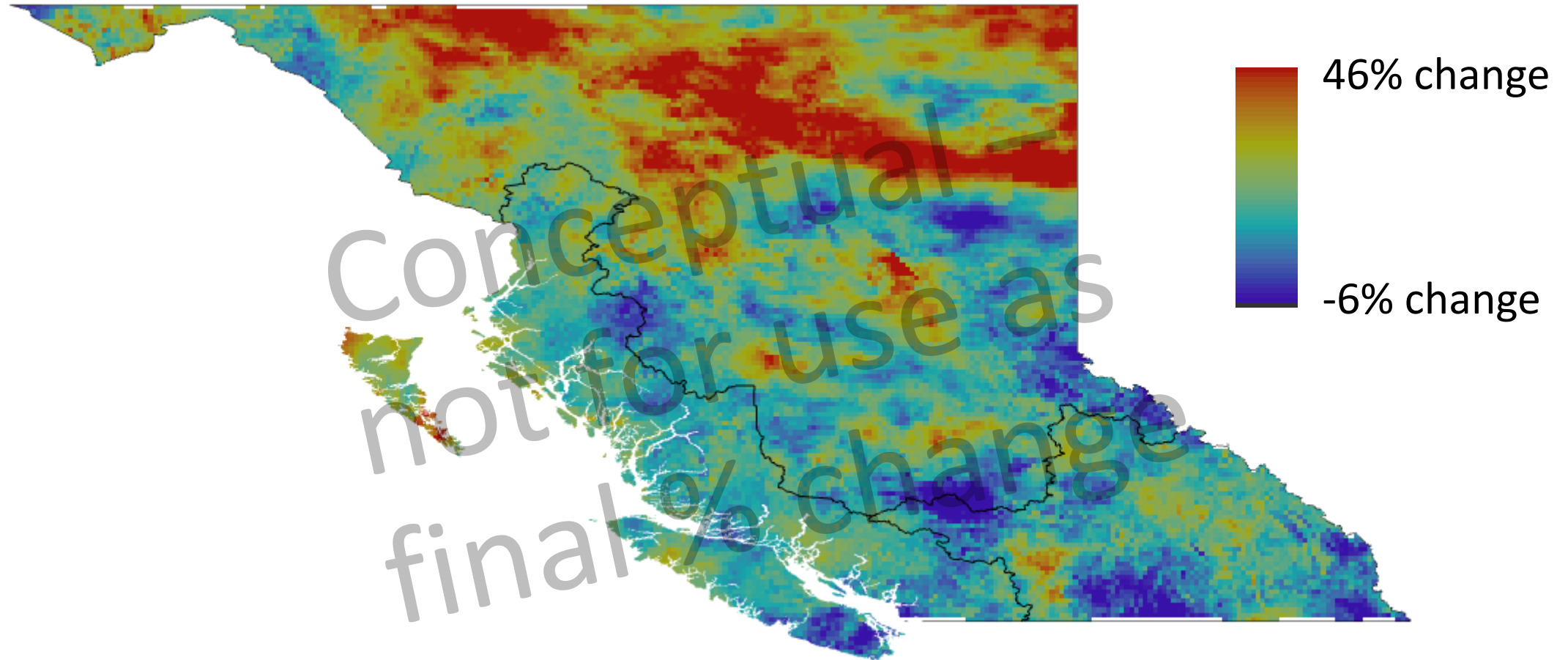
20-year return period daily storm (mm) baseline (1971-2000)

Tool development: how it all applies



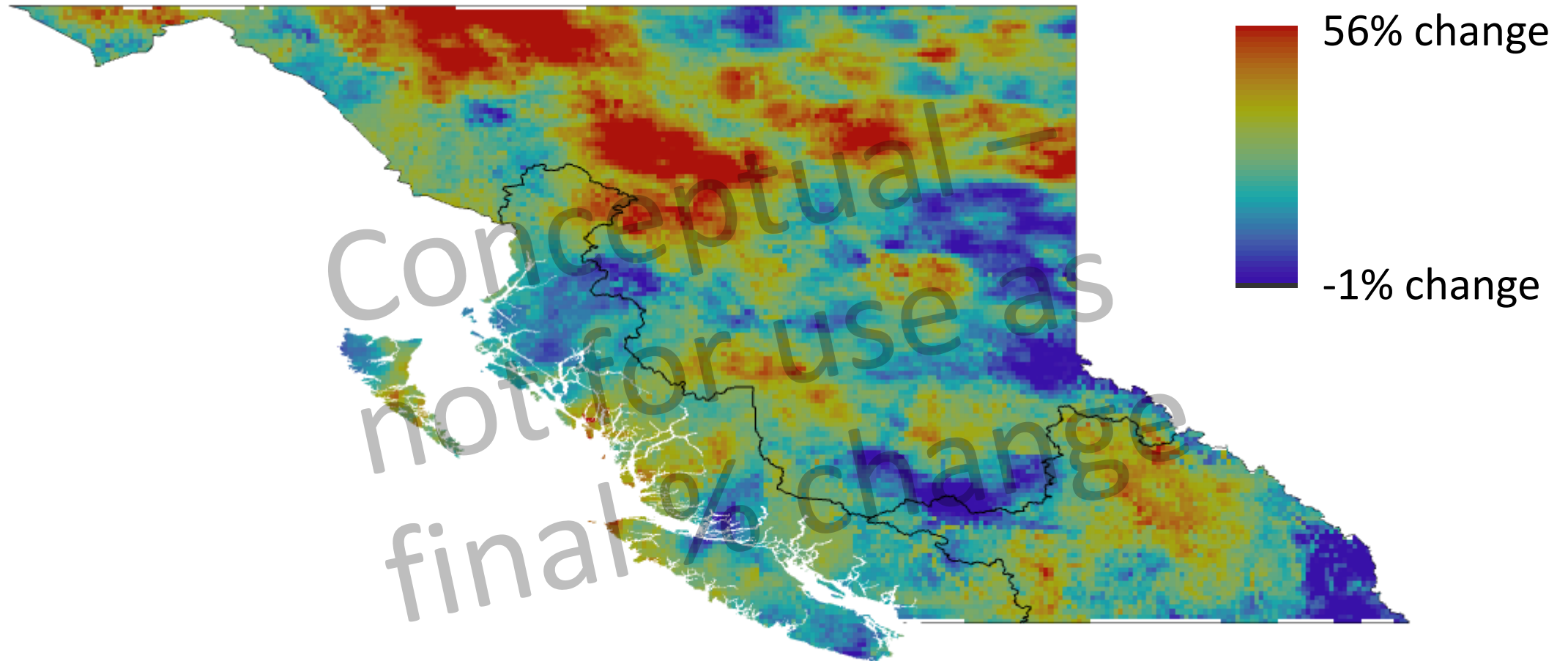
20-year return period daily storm – RCP 8.5 **2030s** p50 (% change from baseline)

Tool development: how it all applies



20-year return period daily storm – RCP 8.5 **2050s** p50 (% change from baseline)

Tool development: how it all applies



20-year return period daily storm – RCP 8.5 **2080s** p50 (% change from baseline)

Tool development: how it all applies

- Example conclusions that could come from vulnerability assessment
 - Importance of road maintenance/implementing practices/budgets
 - Reviewing culvert sizing requirements to projected peak flows
 - Adapting transportation to spring thaws/weight restriction periods
 - Decision-making about road seasoning and seasonal access
 - Better estimates for lifecycle costs
- Ongoing related research at FPInnovations - adaptation
 - Optimizing adaptation solutions for climate change
 - Current experiments on techniques to
 - 1) keep a road frozen 2) keep road dry during spring

4. Discussion

Poll 2: check-in after presentation

Poll: slido.com
event code: [fpi](#)



Further reading: resources

- The 3 FSR climate change risk assessments are available at:
 - [Climate change adaptation for resource roads - Province of British Columbia \(gov.bc.ca\)](https://www2.gov.bc.ca/gov/content/spe/spe_topic/spe_topic_040000/spe_topic_040000_000000/spe_topic_040000_000000_000000.htm)
- Partington, M. (2019). ***Creating climate resilient resource roads: Adapting to climate change***. (InfoNote 1 through 5). Pointe-Claire, Quebec: FPInnovations.
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