Climate Change and Engineering Adaptation

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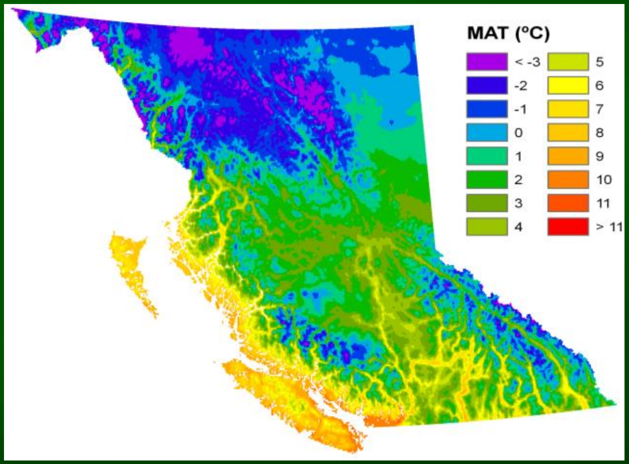
The Road to Resilience:
MoTI-FLNR Engineering and Climate Adaptation
February 20, 2015

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

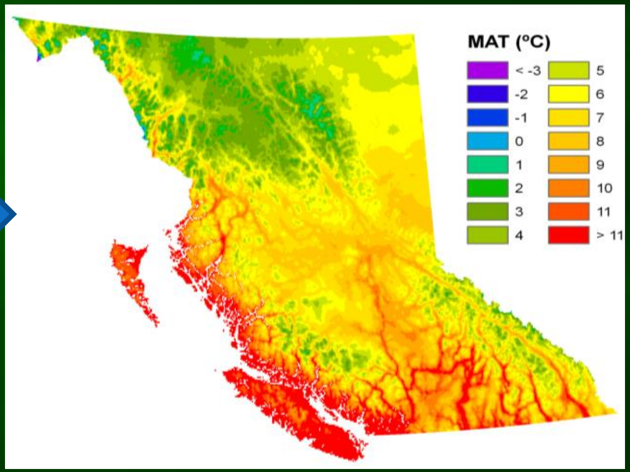
Climate Risk & Adaptation Context

- Climate change impacts regardless of emission reductions
- Examine future climate risk and historical patterns
- Developing adaptation strategies for climate risk include economic, social and environmental implications

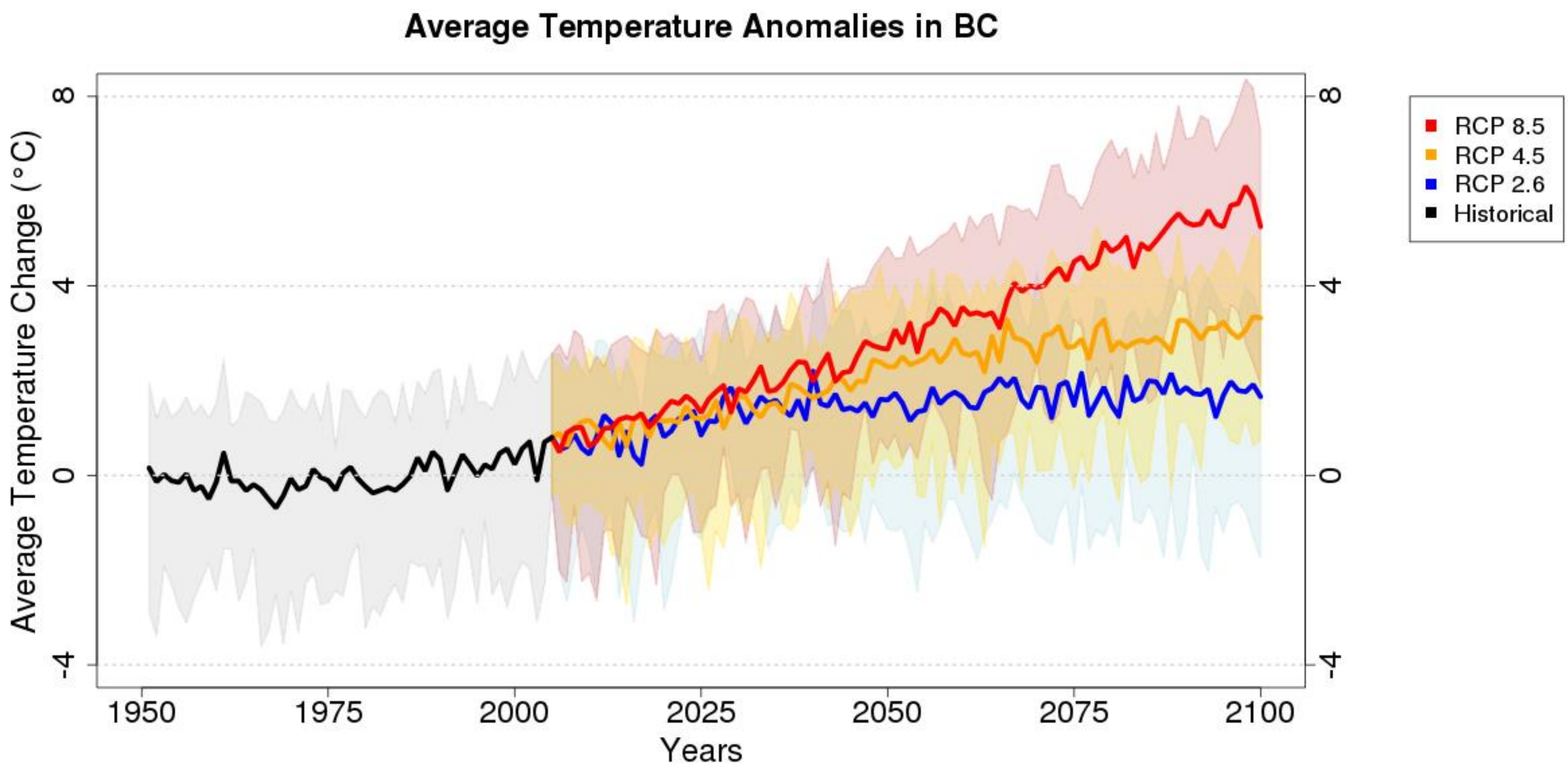
1961-1990 Mean Annual Temperature BC



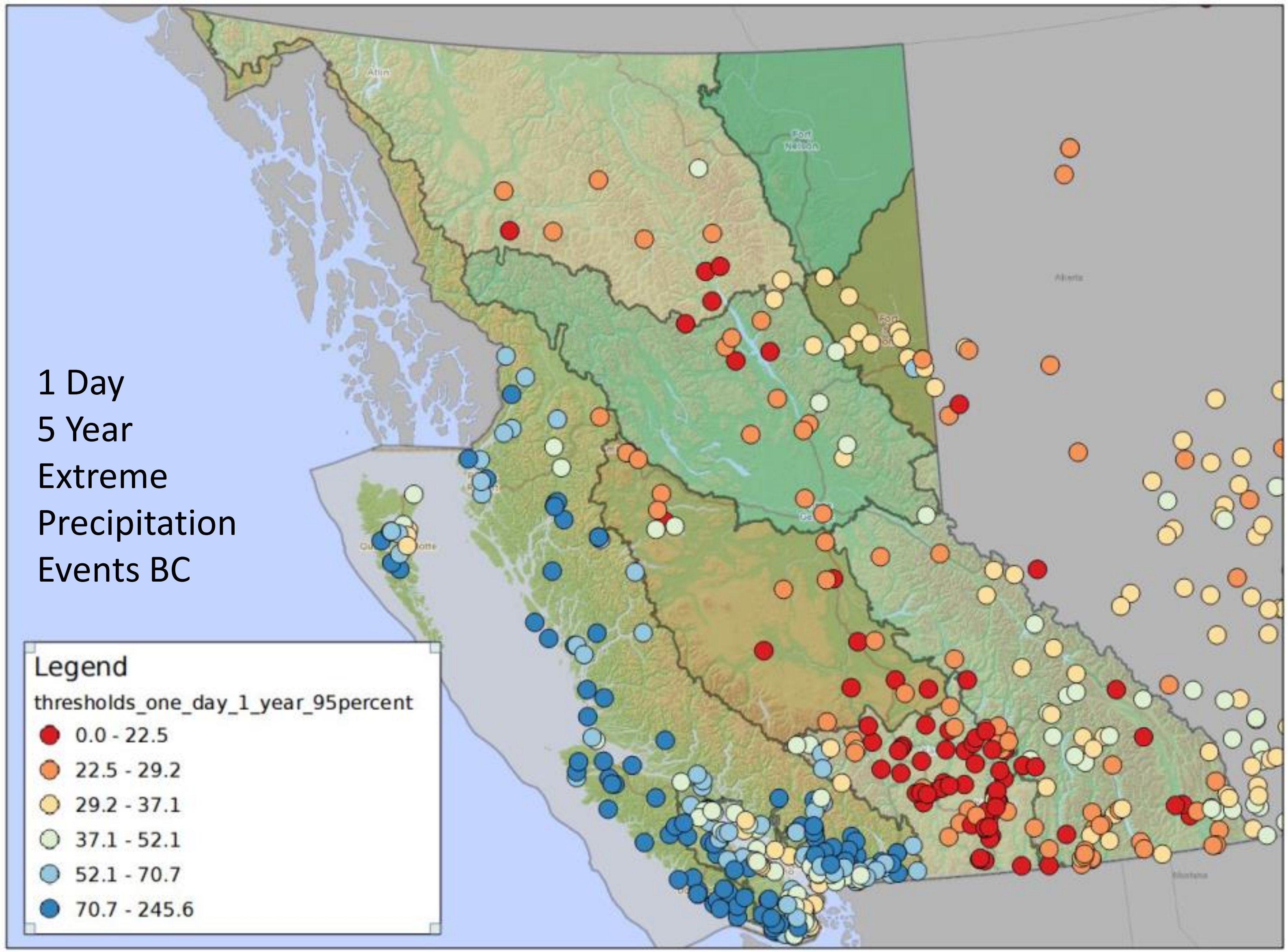
2080s Mean Annual Temperature BC



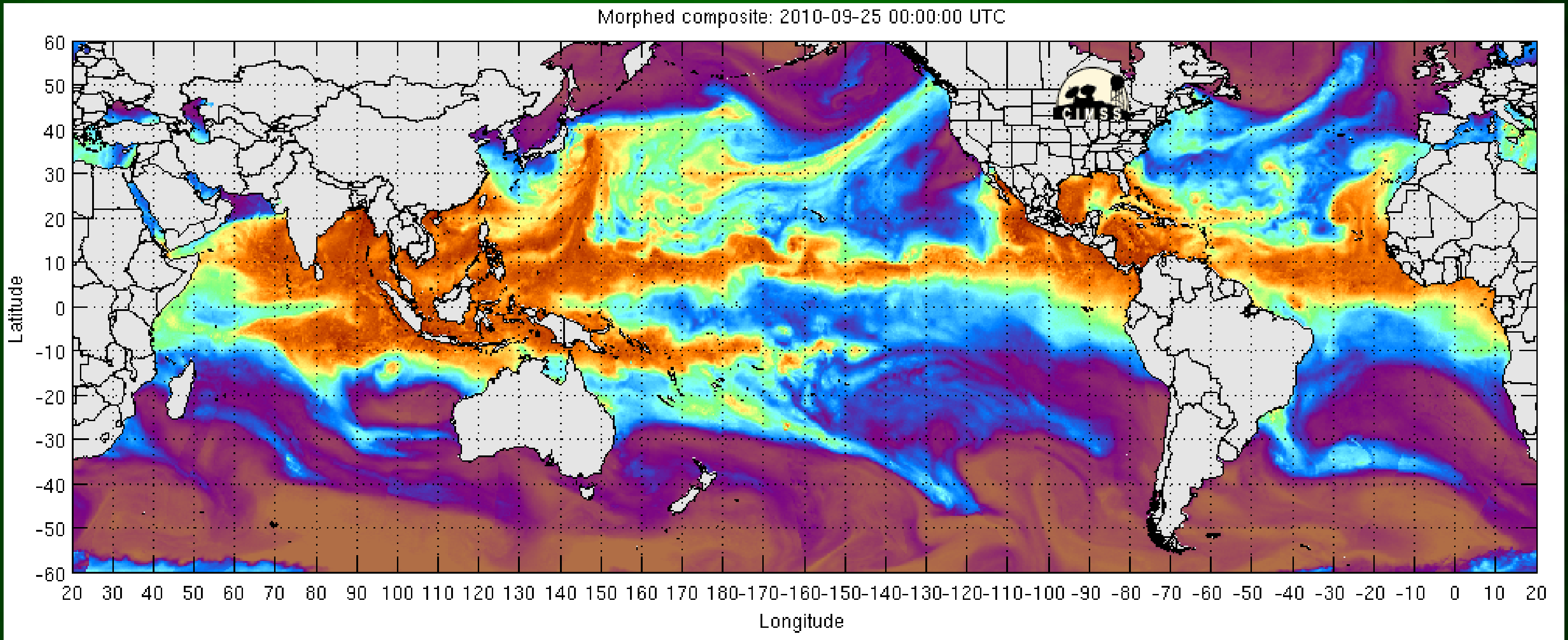
Climate Change in BC - Projected Warming



Extreme Precipitation Events



Atmospheric River - Bella Coola Event
(September 25, 2010)



Extreme Weather Events & Infrastructure
(Risk with Climate Change)

Extreme Weather Events at BC Locations

Site	Watershed Size km^2	Rainfall Intensity mm/24hrs*	Return Period Rainfall Yr [estimated]	Return Period Streamflow Yr [estimated]
Bitter Creek (Stewart) Sept 2011	276	120	20	20
Medby Creek (Bella Coola) Sept 2010	2	192	>100	25
Fisher Creek (Pine Pass) June-July 2011	44.8	103	100	25-40
Fur Thief Creek (Pine Pass) June 2011	9.3	103	100	20-30

Extreme Weather Events, Risk Analysis & Adaptation

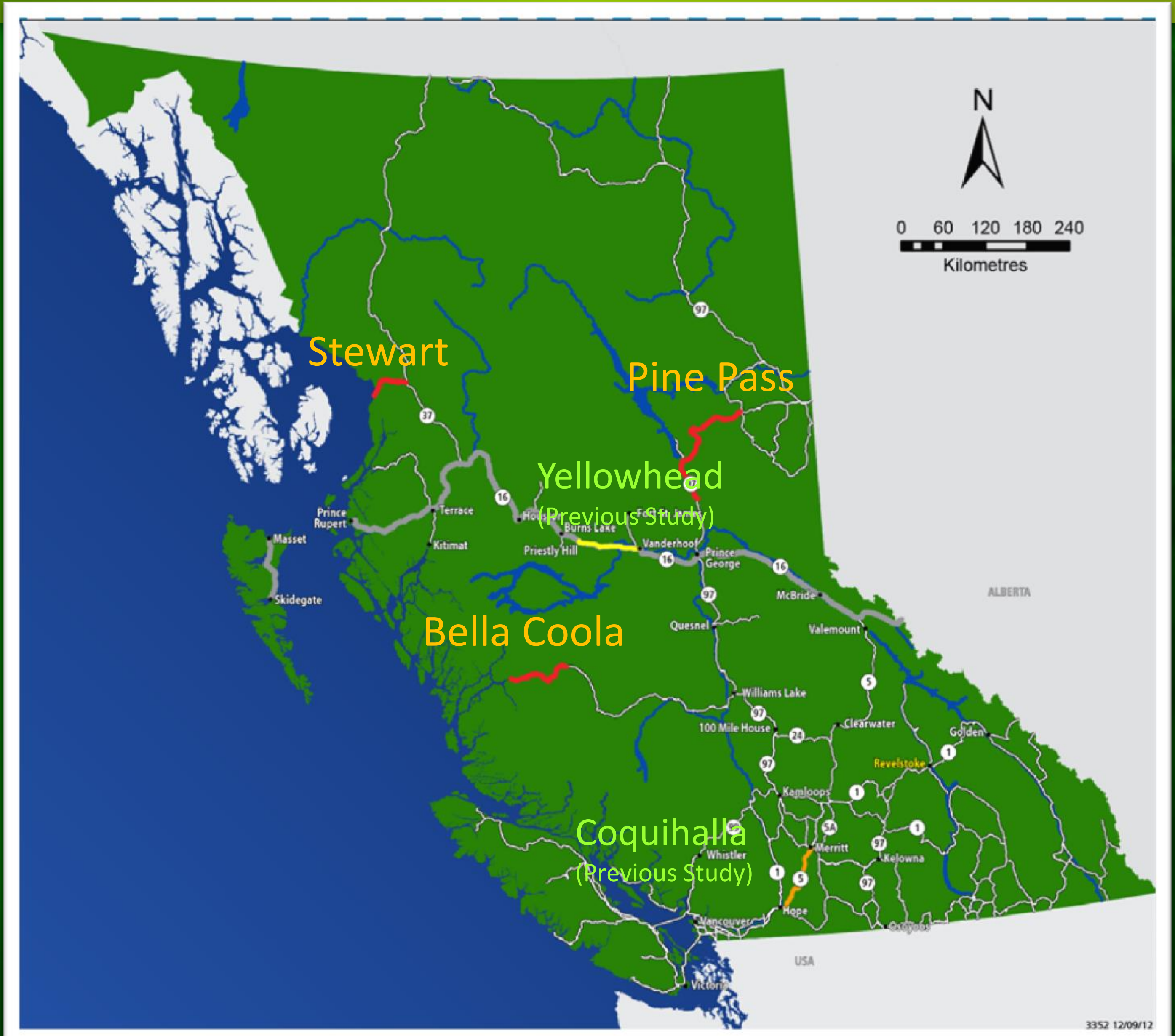
- Recent extreme weather events affecting BC Transportation:
  - Coastal: Bella Coola -- $45M damage to transportation infrastructure (Sept 2010), Stewart (Sept 2011);
  - Interior: Pine Pass -- $70M damage to transportation infrastructure (June-July 2011)*
- Risk analysis – for future climate change and extreme weather events
- Climate adaptation implications from risk analysis – Impacts on transportation (management, planning, engineering design, operations and maintenance)

BCMoTI and PIEVC Risk Tool

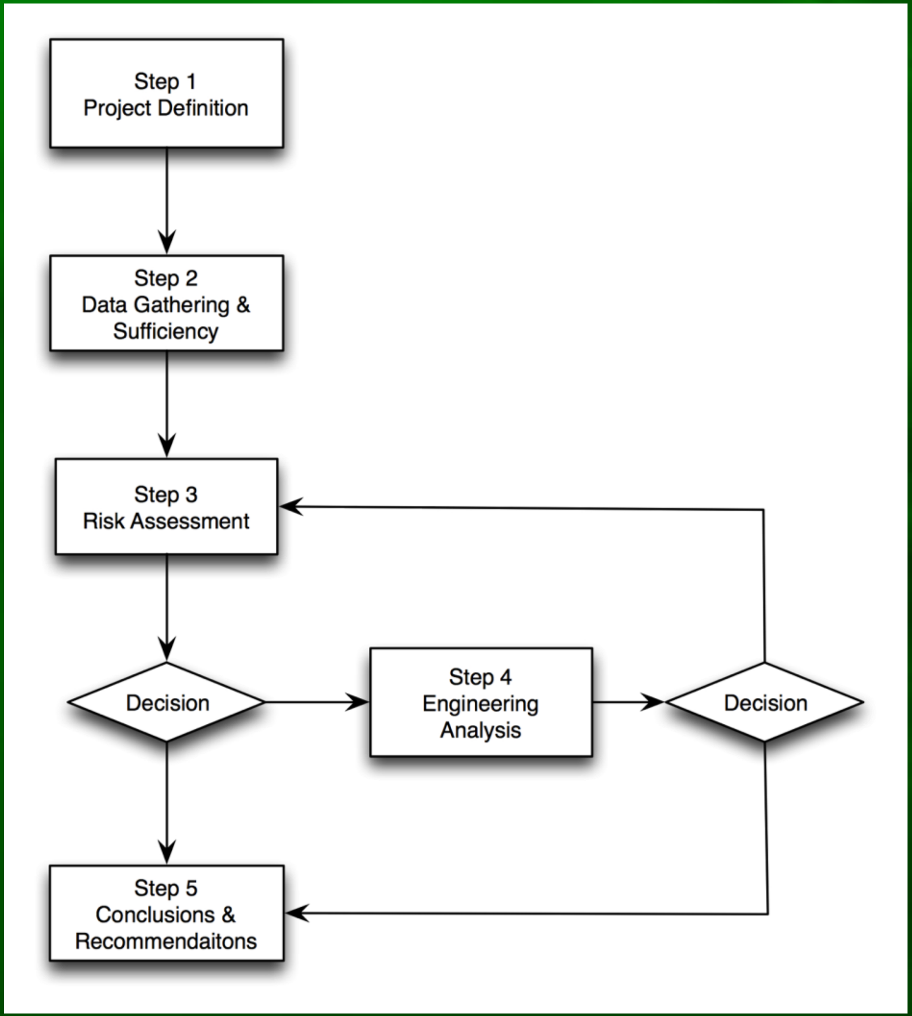
Shifts in climate and extreme weather events may affect reliability of infrastructure

- Require Civil Engineering risk assessment tool
- BCMoTI involved in the development of PIEVC Protocol (Public Infrastructure Engineering Vulnerability Committee)

BC Highway Risk Study Locations



PIEVC Protocol: A Five Step Process



Data Gathering
Infrastructure Components

- Examples of infrastructure components in BCMoTI risk studies (up to 40)

- Surface asphalt
- Bridges
- Ditches
- Catch basins
- Culverts
- Third-party utilities


Yellowhead


Coquihalla

FLNR Component List

Road Infrastructure Components	**Environmental Features**
Road surfacing	River hydraulics and flood plain migration
Structures that cross streams	Landslide features
• Bridges	Avalanche Zones
• Major culverts	Flood Zone
• Other culverts	Riparian habitat/Fish sensitive streams
Culvert cross drains	
Signage	**Miscellaneous**
Ditches	Administration/Personnel & Engineering
Road Prism - Embankments/Cuts	Winter Maintenance
Natural hillslopes	Summer Maintenance
River training works	Ancillary buildings and utilities and yards
Retaining walls	Gravel/rock pits
• MSE/GRS walls/fills	
Third party utilities	
• Hydro poles/towers	
• Hydro lines	
• Communication/utility towers	
Invasive plants & pests	
Archeological sites	

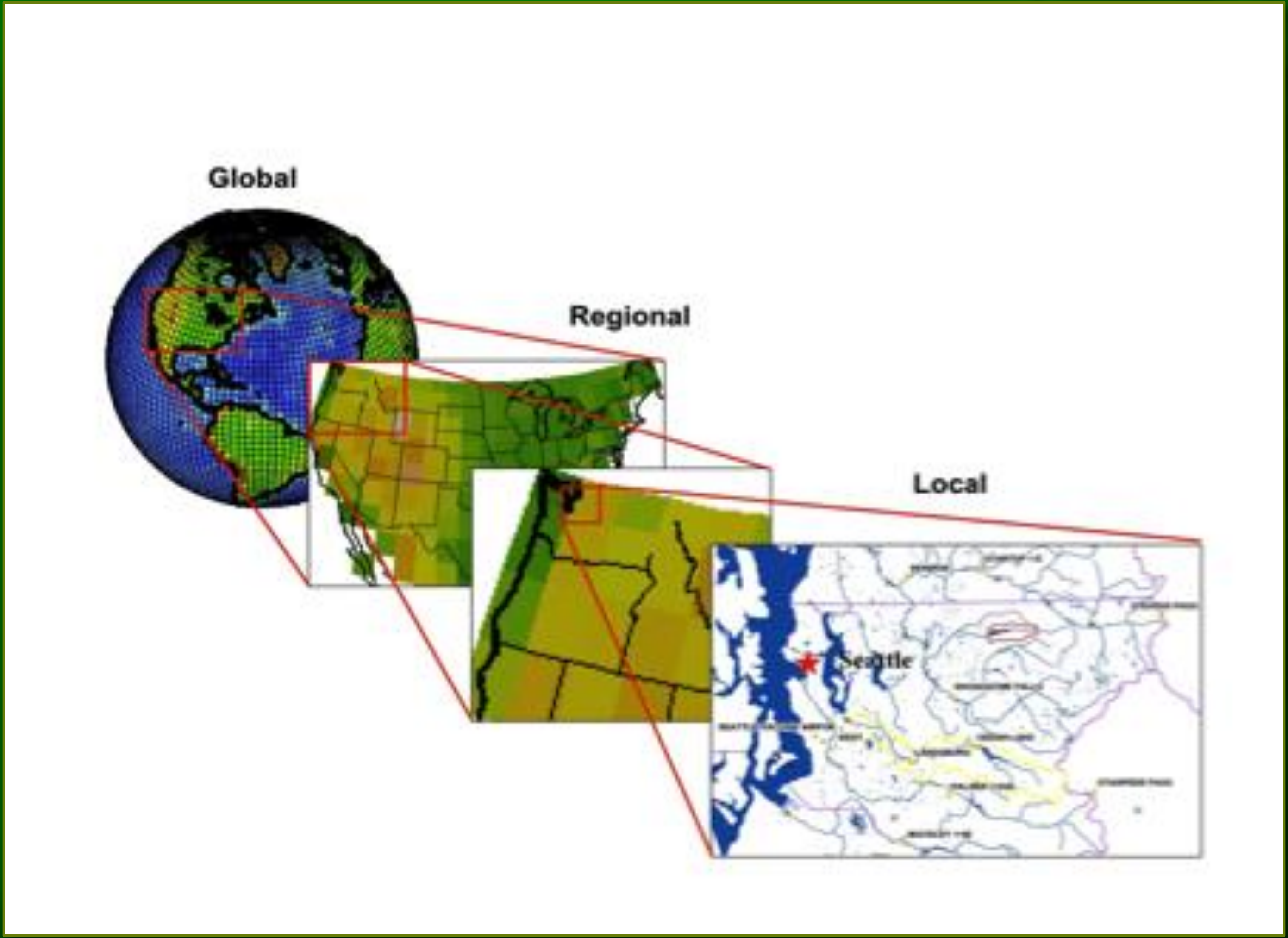
Climate Factors

- Climate parameters based on design considerations and location
- Relevance:
    - Climate or weather effects on infrastructure component
    - Combinations of events
    - Climate or weather effects related to design specifications, operations and maintenance
- Availability of data

Climate Parameters

#	Climate Parameter	Infrastructure Indicator
1	High Temperature	Number of Days with max. temp. exceeding 30ºC
2	Low Temperature	Days with min. temp. below -24ºC
3	Temperature Variability	Daily temperature variation of more than 24ºC
4	Freeze / Thaw	17 or more days where max. temp. > 0ºC and min. temp < 0ºC
5	Frost Penetration	Assessed through empirical analysis of forecast climate conditions
6	Frost	47 or more days where min. temp <0ºC
7	Extreme Rainfall Intensity Over One Day	Determined empirically. PCIC used . 76mm over 24 hrs.
8	Magnitude of Severe Storm Driven Peak Flows	Determined empirically. PCIC used directional wind speed, temperature and precipitation all > median values.
9	Frequency of Severe Storm Driven Peak Flow Events	Determined empirically. PCIC used directional wind speed, temperature and precipitation all>. median value for three consecutive days in autumn.
10	Rain on Snow	10 or more days where rain falls on snow
11	Freezing Rain	1 or more days with rain that falls as liquid and freezes on contact
12	Snow Storm / Blizzard	8 or more days with blowing snow
13	Snow (Frequency)	Days with snowfall > 10 cm
14	Snow Accumulation	5 or more days with a snow depth > 20 cm
15	High Wind / Downburst	Wind speed > 80.5 km/hr
16	Visibility due to Fog	Decrease in stopping sight distance < 245 m

Climate Models & Downscaling

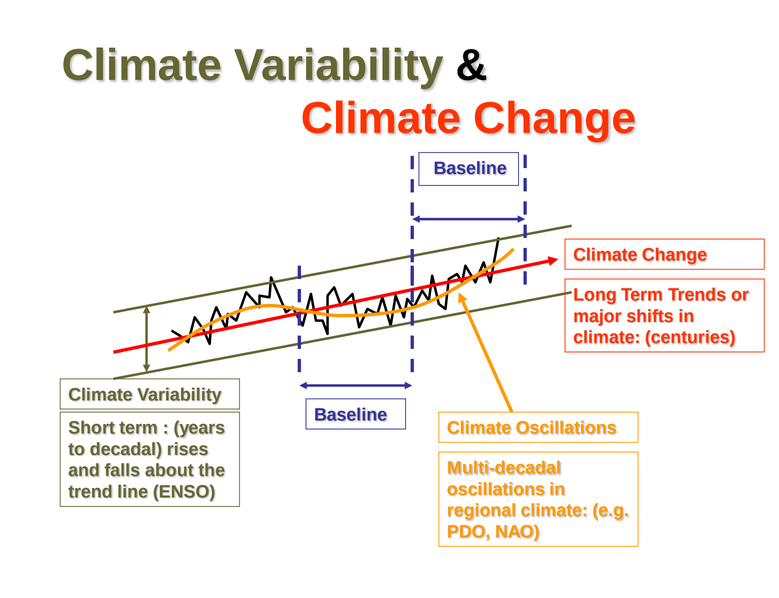


Climate Projections - PCIC at UVic
(Pacific Climate Impacts Consortium)

- Yellowhead - six climate models A2 scenario (Coquihalla three models)
- Example of model:

Climate Change Scenario A2

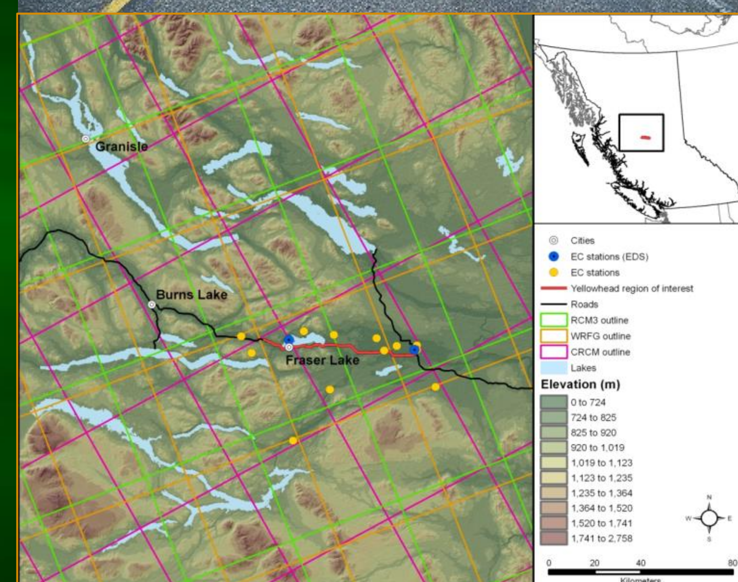
  - Independently operating, self-reliant nations;
  - Continuously increasing population;
  - Regionally oriented economic development; and
  - Slower and more fragmented technological changes and improvements to per capita income



- Sensitivity analysis

Yellowhead Climate Projection Example (2050, 2100)

- Warmer conditions
  - decreasing strong frost periods (very likely)
  - increasing hot extremes (very likely)
  - decreasing diurnal temperature range (very likely)
- Wetter conditions
  - total precipitation increasing (likely)
  - heavier and more sustained precipitation (likely)
- More extreme conditions
  - moderate (10y) to extreme (>100y) events increasing



Model Past and Projected Precipitation

Location	Indicator	Past (1971-2000) from Model	Future (2041-2070) from Model	% Change
Stewart	Annual mm	1290	1477	14
	25Yr mm/24hr	75	96	28
Bella Coola	Annual mm	673	744	11
	25Yr mm/24hr	44	60	36
Pine Pass	Annual mm	653	734	12
	25Yr mm/24hr	41	51	24

PIEVC Engineering Analysis Vulnerability Evaluation

Infrastructure Component	Design Standard	Total Load	Total Capacity	Vulnerability
	Return period Max-min temp	L_T	C_T	$V_{R+} = L_T / C_T$
Road Surfaces & 24-hrs Duration Extreme Precipitation (mm/24hrs)	1:5			
Coquihalla 2050s		101	88	1.15
Median & Roadway Drainage Appliances & 24-hrs Duration Extreme Precipitation (mm/24hrs)	1:10 to 1:25 (use 1:25)			
Coquihalla 2050s		153	121	1.26
Catch Basins & 24-hrs Duration Extreme Precipitation (mm/24hrs)				
Coquihalla (Storm Sewers) 2050s	1:10 to 1:25 (use 1:25)	139	117	1.19
Yellowhead (Stormwater Inlets) 2050s	1:5	33.8	27.8	1.21
Yellowhead (Stormwater Inlets) 2010s	1:5	41.4	27.8	1.49
Culverts < 3 m & 24-hour Duration Extreme Precipitation (mm/24hrs)	1:100			
Yellowhead 2050s		56.6	42.8	1.32
Yellowhead 2100s		73.8	42.8	1.73
Concrete Bridges & Extreme High Temperature (°C)	Max-min temp (Forecast event 1:50)			
Yellowhead 2050s		35.7	34.4	1.04
Yellowhead 2100s		37.5	34.4	1.09
Concrete Bridges & Extreme Low Temperature (°C)	Max-min temp (Forecast event 1:50)			
Yellowhead 2050s		-48.8	-45.0	1.08
Yellowhead 2100s		-53.4	-45.0	1.19

Vulnerability Assessment Conclusions

- Based on the risk assessments, BC Highways are generally resilient to climate change
- Extreme precipitation events could overload drainage infrastructure
- Extreme temperature effects on highway components require further analysis
- Review engineering design guidelines for highway infrastructure for future climate data parameters to achieve a robust and reliable highway system

PIEVC Risk Studies in Canada
(5 MoTI + 20 others)

- Extreme precipitation risks (atmospheric rivers etc.)
- Terrain and combination events
- Quality climate data (recent, local, past events)
- Ensemble of climate models
- Data + expert judgement

Lessons Learned

- Develop awareness of climate and extreme weather changes and implications
- Include adaptation in organizational practice
- Use multidisciplinary teams for projects
- Use qualified professionals with local knowledge (climate, meteorological, hydrologic, hydrotechnical)
- Investigation of future climate/weather parameters: including visibility (fog) and high wind/downburst
- Adaptation education for professionals, consultants, staff & students

Best Practices

- Monitor **data** used in codes and standards
- Use quantitative data and/or professional judgement
- Review guidance (professional associations, etc.)
- Understand risks and uncertainties
- Apply sensitivity analysis
- Adaptation for lifespan and location over time (maintenance programs etc.)

Technical Circular

BCMoTI guidance for ensuring transportation engineering design is resilient and adapted to climate change

- Climate change analysis - project, design, lifespan
- Location specific climate data and projections
- Climate information from recognized source (e.g. PCIC web portal)
- Design sheet with climate information consulted

Technical-Circular Development

- Members:
  - BCMoTI; PCIC (climate scientists)
  - ACEC-BC Reps – consultants from various disciplines
  - APEG-BC
- Screening process – modified risk analysis
- At functional and/or detail design stage
- Climate data sources and cost
- How much prescriptive and initial info does MoTI provide?
- Draft T-Circular - end of January

PCIC Portal – Plan2Adapt

PACIFIC CLIMATE IMPACTS CONSORTIUM

PLAN2ADAPT

PCIC Home | Contact Us

- Summary
- Region & Time
- Temperature
- Precipitation
- Snowfall
- Growing DD
- Heating DD
- Frost-Free Days
- Impacts
- Notes
- References

Summary of Climate Change for British Columbia in the 2050s

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Mean Temperature (°C)	Annual	+1.8 °C	+1.3 °C to +2.7 °C
Precipitation (%)	Annual	+6%	+2% to +13%
	Summer	-1%	-8% to +7%
	Winter	+8%	-2% to +15%
Snowfall* (%)	Winter	-10%	-17% to +2%
	Spring	-58%	-71% to -11%
Growing Degree Days* (degree days)	Annual	+283 degree days	+177 to +429 degree days
Heating Degree Days* (degree days)	Annual	-648 degree days	-955 to -454 degree days
Frost-Free Days* (days)	Annual	+20 days	+12 to +29 days

The table above shows projected changes in average (mean) temperature, precipitation and several derived climate variables from the baseline historical period (1961-1990) to the **2050s** for the **British Columbia** region. The ensemble median is a mid-point value, chosen from a PCIC standard set of Global Climate Model (GCM) projections (see the 'Notes' tab for more information). The range values represent the lowest and highest results within the set. Please note that this summary table does not reflect the 'Season' choice made under the 'Region & Time' tab. However, this setting does affect results obtained under each variable tab.

* These values are derived from temperature and precipitation. Please select the appropriate variable tab for more information.

Climate Resources

- IPCC (Intergovernmental Panel on Climate Change)

http://www.ipcc.ch/

- PCIC (Climate Data)

http://www.pacificclimate.org/

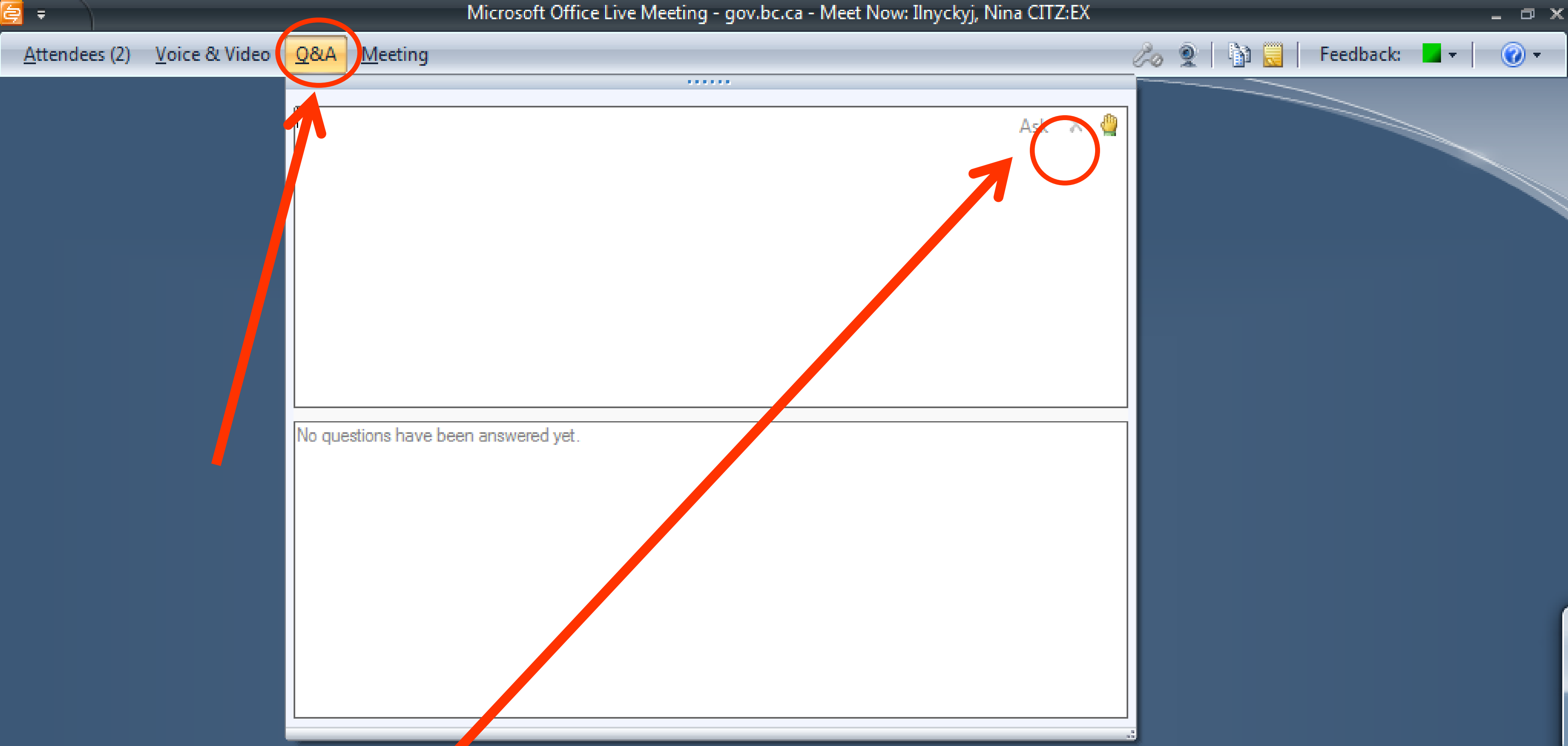
Climate Change & Adaptation

Thank You

BCMoTI Study Links:

http://www.th.gov.bc.ca/climate_action/adaptation.html

http://www.pievc.ca/e/index_.cfm



Q & A

- If you have a question for our presenter, type it into the Q&A panel, then hit "ASK"

FLNR Engineering, Roads and Bridges Climate Adaptation PIEVC Pilot Project

Part 2
Climate Change and Projections for In-SHUCK ch FSR

February 24, 2015 – 1:00 to 3:00pm