THIS ROAD TO AN ADAPTATION POLICY WAS PAVED THROUGH COMPLEX TERRAIN

T. Q. Murdock*, D. Nyland, S. Sobie, and J. Wolf

*Corresponding Author E-mail: tmurdock@uvic.ca

PACIFIC CLIMATE IMPACTS CONSORTIUM

Top: Bella Coola 200-year event ~260 mm over 3 days in September 2010 (triple normal September precipitation)

Middle: Pine Pass > 100-year event ~115 mm over 3 days in June 2011

Bottom: Stewart ~50-year one day event in September 2011 with lawet antecedent previous season

Photo credit: BC Min of Transportation & Infrastructure

OVERVIEW

Large scale infrastructure projects have long lifespans so planning them considers the long term.

Highways in British Columbia are already experiencing extreme events beyond design capacity (see: photos at left).

In 2008, the BC MOTI identified a pair of adaptation case studies, the results of which informed four streams of subsequent work (see timeline and other text boxes).

A best practices summary of four years of adaptation work recommended MOTI produce a policy document. Following stakeholder and expert review, a "Technical Circular" was published in 2015, requiring all projects for MOTI to consider climate. To assist with implementation, the Association of Professional Engineers and Geoscientists of BC is developing comprehensive guidelines for engineers to mainstream adaptation into their practice.

Climate Information User:
British Columbia (**BC**) Ministry of Transportation and Infrastructure (**MOTI**)
www.th.gov.bc.ca/climate_action/adaptation.html

Regional Climate Service Provider:
Pacific Climate Impacts Consortium (**PCIC**)
www.PacificClimate.org

Climate Risk Assessment Process:
Engineers Canada's **"PIEVC** Protocol"
www.PIEVC.ca

PILOT STUDIES IN TWO CLIMATE ZONES

In fall1976, early construction on the Coquihalla highway was underway when an extreme precipitation event washed out roads that should have been safe according to design standards. At the time, an ad hoc practice of doubling culvert sizes was used, and it has been clear since then that design standards needed to be updated.

When a risk assessment process ("PIEVC protocol") was developed for infrastructure, MOTI saw it as a route to new explicit design standards adapted to climate change: a clear opportunity to draw from the Coquihalla experience.

A case study was also carried out for the Yellowhead Highway include a part of the Province with a different climate zone. Case study locations are shown on the map at right.

Each project resulted in about a dozen recommendations. The top one in both Coquihalla and Yellowhead was to assess if reserve capacities are sufficient to handle changing hydrology associated with extreme precipitation events.

Case study locations

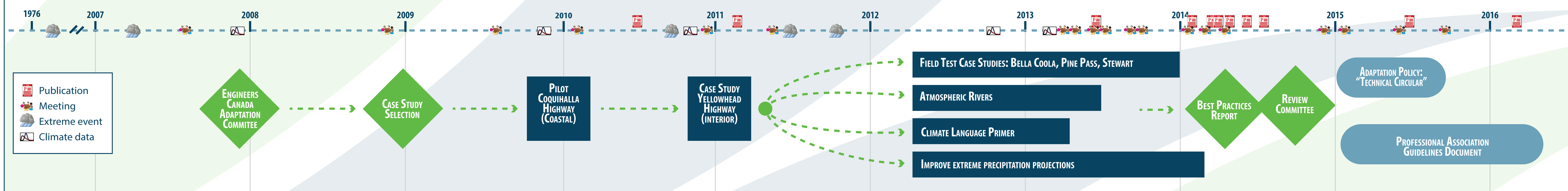
FIELD TEST CASE STUDIES

A set of three additional PIEVC case studies were later carried out at locations that had experienced damage from recent events (see map at left, photos at far left, and table at bottom center).

Tying these case studies with recent extreme events allowed for a "field test" of the PIEVC protocol. If the risk assessment process had been carried out in these locations before the events, would the infrastructure have fared better?[3c] The result was positive in all three cases, including Pine Pass where the event had no previous historical analogue (due to the time of year in which it occurred).

These case studies reinforced the findings of the pilot studies that BC highways infrastructure is already maladapted to current climate variability and change.[3b]

While the pilot case studies provided a rationale for incorporating climate change into design standards, this set of field test case studies moved one step closer to adjusting and adapting design.



Projected percent change by 2050s compared to 1971-2000 for Bella Coola. Relative change is larger for more extreme events. This pattern holds for several other indices at different parts of the distribution of extreme precipitation. This general result can be used by engineers interested in, for example, the 100-year retrurn event as an indication of a likely minimum bound of expeceted relative change.

Indicator	2050s Change
Annual Total	11%
10-year event	31%
25-year event	36%

Infrastructure Components	Total Annual Rainfall	Extreme High Rainfall	Light Sustained Rainfall	Heavier Sustained Rainfall	Snow (Frequency)	Snow Accumulation	Rain on Snow	Rain on Frozen Ground	Rapid Snow Melt	Snowmelt Driven Peak Flow Events	Magnitude of Storm Driven Peak Flow Events	Frequency of Storm Driven Peak Flow Events	Ice / Ice Jams
Above Ground													
Shoulders (Including Gravel)		24	7	20	3	12					24		
Ditches		12	7	10	3	12	15		0	18	18	15	
Embankments / Cuts	8	18	7	15		12	5		0	12	36	30	
Natural Hillside/Slope Stability	10	24	7	20		12	5		0	12	36	30	
Protection Works / Armoring	6	30	7	25		12	20		0	30	42	35	1
Engineered Stabilization Works	4					12			0	6	6	5	
Structures that Cross Streams		24					20		0	24	18	15	1
Below Ground													
Road Sub-Base											36	30	
Culverts < 3 meters		24	7	20			15	4	0	24	36	30	1
Culverts >3 meters		30	7	25			15	4	0	18	18	15	1
Bridge End Fill		36		30			25		0	36	42	35	

Example of Public Infrastructure Engineering Vulnerability Committee (PIEVC) risk assessment protocol of Engineers Canada for climate events in Bella Coola Low risk, less than 12, indicates no immediate action is necessary. Medium risk, 12-36, is shaded yellow and suggests that action or more in depth engineering analysis may be required. High risk, greater than 36, indicates that immediate action is needed. Numerical values are assigned using expert opinion in a workshop setting to estimate vulnerability to projected climate change.

ATMOSPHERIC RIVERS

» Several extreme events that caused damage to highways in BC were "Atmospheric Rivers": an intense and relatively narrow flow of moisture-laden air
» Climate scientists and researchers met in 2013 to review and summarize the state of the knowledge
» Analysis of historical trends and future projections was conducted using a small ensemble of Global Climate Models (high resolution required to resolve narrow flow characteristic of these events)
» Preliminary findings: events projected to roughly double across BC by 2050s from current annual occurences of 5-10 events in the interior and 10-20 events on the coast
» Regional climate service providers met with users in 2014 to review risks to extreme precpitation in the Province

DATA TO MEET USER NEEDS

» Climate data provision evolved due to new data sources, downscaling methods, and understanding of user needs[4]
» Spatial resolution advanced from ~100 km to 50 km to 10 km
» Scale improved in time from seasonal to daily; investigating feasibility of sub-daily precipitation intensity projections
» General climate variables to indices of extremes and return periods[7]
» Testing robustness of precipitation extremes for engineers' use
» Consider custom online tool for engineers

LESSONS LEARNED

Good Practices in Communication

» Develop and document common vocabulary across disciplines[3a] 33 terms were identified in the climate language primer that are used differently by engineers and climate scientists
» Understand decision context by listening before explaining[2]
» Ongoing dialogue essential to overcoming mismatch between expected and available climate information[4,6,7]

Managing the Process

» Risk/vulnerability assessments can deliver new insights
» Focus on understanding and meeting user needs[3a]
» Genuinely motivated champion critical to follow-through[2]
» Iterative engagement between users and scientists[4]
» Incorporate learning on both sides[3a]

Overcoming Limitations of Data

» Engineers identified a need to understand more about details of climate information, assumptions, and caveats - not just a new source of information that can be looked up
» Different data needs at different stages of design
» Seek out best sources of information, which will evolve with time, but accept and use imperfect information[2]
» Attempting to meet specific needs for highways infrastructure led to methodology improvement used in all downscaling conducted by PCIC[1]

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