Applying the Climate Lens Resilience Assessment in a BC Context

FBC Presentation
Dirk Nyland, P.Eng., IRP,
Chief Engineer, BCMoTI

December 4, 2018
There has been a substantial increase in the intensity of heavy-precipitation events over large parts of the Northern Hemisphere due to greenhouse gases. (Storms with over 100 millimetres of precipitation in 24 hours.)

Goal is to reduce damage from extreme weather events and climate changes by adapting engineering design and practices for resilient, reliable, efficient and effective transportation infrastructure.

**COST OF INFRASTRUCTURE**

- Design
- Construction
- Maintenance

(resilience = lower maintenance)
BCMoTI involved developing PIEVC tool to assess infrastructure vulnerability to projected extreme weather and climate change. Using multi-disciplinary/stakeholder and local knowledge/experience inputs.

Commotion Creek Hwy 97 2016

Peace Region Flooding 2016
BC Assessment Sites

- 2010 Coquihalla Highway
- 2011 Yellowhead Highway
- 2013 Bella Coola, Stewart, Pine Pass
- Sites have different geographic and climatic conditions
Highways are generally resilient to climate change except for extreme precipitation events; further research is required for events such as rain on snow, fog and wind, avalanche, landslides, sea level rise, etc.

Yellowhead Hwy

Bitter Creek Bridge, Stewart, Sept 2011
Lessons Learned to Date

• Develop awareness of climate change/extreme weather and implications (primarily water related events)
• Include climate adaptation in organizational practice
• Use multidisciplinary teams for projects
• Use qualified professionals with local knowledge (climate, meteorological, hydrotechnical)
• Adaptation education for professionals, consultants, staff and students
Best Practices

- Monitor data used in current codes and standards and develop climate resilience specific codes
- Use data and/or professional judgement
- Apply sensitivity analysis
- Understand risks and uncertainties
- Review association guidance

Bella Coola, Sept 2010

- Use information from ensemble of climate models
- Determine best models and data to use
In 2014-15, ACECBC consultants, EGBC, PCIC and BCMOTI partnered in developing a technical circular considering climate adapted design for highway reliability.
Technical Circular Requirements

• Design for climate change and extreme weather event from model projections
• Vulnerability screening analysis for the design life of structures and components including data sources
• Development of practical and affordable design criteria
• Design Criteria Sheet to summarize climate parameter changes
**BC MoTI Design Criteria Sheet for Climate Change Resilience**

Highway Infrastructure Design Engineering and Climate Change Resilience

Ministry of Transportation and Infrastructure

<table>
<thead>
<tr>
<th>Project:</th>
<th>Project No. 12573 Highway 1 at Mountain Highway Interchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Work:</td>
<td>Interchange Improvement</td>
</tr>
<tr>
<td>Location:</td>
<td>Highway 1 at Mountain Highway Interchange, North Vancouver, BC</td>
</tr>
<tr>
<td></td>
<td>LKI Segment 0515 km 6.18</td>
</tr>
<tr>
<td>Discipline:</td>
<td>Drainage</td>
</tr>
</tbody>
</table>

### Design Component

<table>
<thead>
<tr>
<th>Design Component</th>
<th>Design Life or Return Period</th>
<th>Design Criteria + (Units)</th>
<th>Design Value Without Climate Change</th>
<th>Change in Design Value From Future Climate</th>
<th>Design Value Including Climate Change</th>
<th>Comments / Notes / Deviations / Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Drainage System</td>
<td>50 yr 100 yr</td>
<td>Flow Rate [m³/s]</td>
<td>18.1</td>
<td>+20%</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Culvert &gt; 3000 mm</td>
<td>50 yr 100 yr</td>
<td>Flow Rate [m³/s]</td>
<td>18.1</td>
<td>+20%</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Keith Creek</td>
<td>100 yr</td>
<td>Flow Rate [m³/s]</td>
<td>18.1</td>
<td>+20%</td>
<td>21.7</td>
<td></td>
</tr>
<tr>
<td>Minor Drainage System</td>
<td>25 yr</td>
<td>Intensity [mm/hr]</td>
<td>Varies</td>
<td>+20%</td>
<td>Varies</td>
<td></td>
</tr>
<tr>
<td>Storm Sewer – MoTI</td>
<td>10 yr</td>
<td>Intensity [mm/hr]</td>
<td>Varies</td>
<td>+20%</td>
<td>Varies</td>
<td></td>
</tr>
<tr>
<td>Storm Sewer – CNV / ONV</td>
<td>10 yr</td>
<td>Intensity [mm/hr]</td>
<td>Varies</td>
<td>+20%</td>
<td>Varies</td>
<td></td>
</tr>
<tr>
<td>Catchbasin – All</td>
<td>10 yr</td>
<td>Intensity [mm/hr]</td>
<td>Varies</td>
<td>+20%</td>
<td>Varies</td>
<td></td>
</tr>
</tbody>
</table>

**Explanatory Notes / Discussion:**

1. Plan2Adapt Tool (PCIC Website)
   a. Annual Precipitation estimated to increase by ~7% (Mean) ~10.5% (75\% Percentile) ~ 17.5% (50\% Percentile), for year 2065.
2. APEGBC Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC
   a. If no historical trend is detectable, apply a 10% increase (to year 2100)
   b. If there is a significantly detectable trend, apply a 20% increase (to year 2100)
3. IDF-CC Tool (Western University / Canadian Water Network)
   a. Ensemble mean estimates approximately a 18% / 18% / 23% increase in rainfall to the year 2065 (assumes RCP 8.5 climate change scenario), for Environment Canada rain gauges North Vancouver Lynn Creek / Vancouver Harbour CS / North Vancouver Sonora Drive.

**Recommended by:** Engineer of Record:
(Print Name / Provide Seal & Signature)

**Date:** 2016-01-29

**Engineering Firm:**

Accepted by BC MoTI Consultant Liaison:

Deviations and Variances Approved by the Chief Engineer:

Program Contact: Dirk Nyland, Chief Engineer BC MoTI

Rev. 0
EGBC Practice Guidelines

Request for Proposal (2.2.1.1)

Define Highway Infrastructure project (3.2)

Conduct screening-level, climate change risk assessment (3.3)

Identify and incorporate climate adaptation options (3.4)

Documents (3.5)
- Climate change risk assessment
- Hwy resilient design report
- Assurance statement
- BCMoTI Design Criteria Sheet
The Concessionaire shall comply with Technical Circular T-06/15

Consider at a minimum, temperature, rain, snow, ice, fog, hail, frost, humidity, ice accretion, wind, floods, extreme temperatures and precipitation, and storms of various intensities

Rely on current climatological modelling analysis relevant to Greater Vancouver area of BC

Assess how vulnerability risks are anticipated to change over the Design Life

Assess potential impacts and identify proposed actions
Vulnerability Screening - PIEVC

1. **Step 1** Project Definition
2. **Step 2** Data Gathering & Sufficiency
3. **Step 3** Risk Assessment
   - Engineering Analysis?
     - Yes → **Step 4** Engineering Analysis
     - No → **Step 5** Conclusions & Recommendations
4. **Step 4** Engineering Analysis
5. **Step 5** Conclusions & Recommendations

**TRIPLE BOTTOM LINE MODULE**

6. **Step 6** Adaptation Scenarios
7. **Step 7** Multi-Factor Analysis
8. **Step 8** Recommendations & Follow-Up
   - Reporting

**Reporting**
- Yes → Yes
- No → Yes
Types of Data for Vulnerability Assessment

- Infrastructure Components
- Infrastructure Age
- Availability of Infrastructure Data
- Geotechnical Indicators
- Variety of Terrain
- Traffic Volumes
- Strategic Importance of Route
- Occurrence of Extreme Environmental Events
- Historic Weather Data Available
- Current Weather Data Available
- Expected Climatic Change – Temperature
- Expected Climatic Change – Precipitation
- Climatic Regions
- Sea Level Rise
Infrastructure Components

- Surface asphalt
- Bridges
- Ditches

- Catch basins
- Culverts
- Third-party utilities

Kootenay Pass 2018

Salmon Arm 2018
Climate Projections – Design for Extremes

- Extreme rainfall in one or more days (e.g. >76 mm/24 hrs)
- Atmospheric River-Pineapple Express (e.g. >150 mm/24 hrs)
- High Temperature (e.g. number of days over 30°C)
- Temperature variability (e.g. freeze-thaw)
- Sea level rise
Design implications for higher temperature and precipitation over lifecycle of components, i.e. pavement (15-20 years), culverts (75 years), bridges (50-100 years)
### Hydrotechnical Design – Scour

| Current Standards | Maximum instantaneous discharge (Q200)  
|                  | Clearance between design water surface and bridge soffit (ie. 1.5 m) |
| Climatic Inputs  | Historic streamflow from hydrometric gauges  
|                  | Historic precipitation from weather stations |
| Climate Change Risk Issues | Changes in streamflow (Q200)  
|                        | Changes at watershed scale (land use & vegetation)  
|                        | Changes in channel scale (stability, sediment transport) |
| Potential Adaptation Measurer | Estimate and use future streamflow (Q200)  
|                            | Structure clearance, size, clear span  
|                            | Construction quality (riprap)  
|                            | Debris control  
<p>|                            | Maintenance for debris and sediment |</p>
<table>
<thead>
<tr>
<th>Bridges and Structures</th>
<th>Thermal Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Standards</strong></td>
<td>Canadian Highway Bridge Design Code</td>
</tr>
<tr>
<td><strong>Climatic Inputs</strong></td>
<td>Temperature allowance in excess of max and min mean daily temperature</td>
</tr>
</tbody>
</table>
| **Risk Issues**        | • Increase in temperature  
                        | • Temperature extremes  
                        | • (Note: for general bridge design – risk may be low. Temperature changes may be small relative to accuracy of bridge code values) |
| **Adaptation Values**  | NRC incorporate projected future temperature maps in code |
## Geotechnical

### Slope Stability

<table>
<thead>
<tr>
<th>Current Standards</th>
<th>Safety factor 1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climatic Inputs</td>
<td>Current conditions and moisture changes</td>
</tr>
</tbody>
</table>
| Risk Issues       | • Increased precipitation  
                   | • Groundwater changes  
                   | • Changes in land use and vegetation  
<pre><code>               | • Higher flow volumes and velocities |
</code></pre>
<p>| Adaptation Values | Compare recent conditions and future climate projections |</p>
<table>
<thead>
<tr>
<th>Geotechnical</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pavement Grade - Asphalt Cement Mix</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Current Standards</strong></td>
<td>Standard Specification 952</td>
</tr>
<tr>
<td><strong>Climatic Inputs</strong></td>
<td>Pavement Grade values based on historic temperature and use</td>
</tr>
<tr>
<td><strong>Risk Issues</strong></td>
<td>Increased temperatures</td>
</tr>
<tr>
<td><strong>Adaptation Values</strong></td>
<td>Modify PG rating based on future temperature and use</td>
</tr>
</tbody>
</table>
Change in Projected Flows  
(Model Averages)

<table>
<thead>
<tr>
<th>Model Output</th>
<th>Location</th>
<th>Average Change Relative to Historic 2040-2069</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-year Hourly Peak Flow (m$^3$/s) (% change to historic)</td>
<td>Bitter Creek (Stewart)</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Medby Creek (Bella Coola)</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Fisher Creek (Pine Pass)</td>
<td>39</td>
</tr>
</tbody>
</table>
Adapted Bridge Designs - Flow

<table>
<thead>
<tr>
<th>Region</th>
<th>Return periods from sheets vary</th>
<th>% ↑ Design Value for Climate Change</th>
<th>Climate Data</th>
</tr>
</thead>
</table>
| NR     | 100-200yr                       | +9% to +30%                         | -MoTI practices  
-EGBC recommendations*  
-PCIC regional reports  
-IDFCC  
-Consultant Reports |
| SIR    | 100-200yr                       | +10% to +20%                        | -MoTI practices  
-EGBC recommendations*  
-PCIC  
-Consultant Reports |
| SCR    | 200yr                           | +11% to +15%                        | -MoE coastal guidelines  
-EGBC recommendations*  
-Consultant Reports |
## Adapted Culvert Designs - Flow

<table>
<thead>
<tr>
<th>Region</th>
<th>Return periods from sheets vary</th>
<th>% ↑ Design Value for Climate Change</th>
<th>Climate Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>50-200yr</td>
<td>+10% to +25%</td>
<td>- IDFCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Consultant reports</td>
</tr>
<tr>
<td>SIR</td>
<td>25-200yr</td>
<td>+10%</td>
<td>- MoTI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- EGBBC recommendations*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Consultant Reports</td>
</tr>
<tr>
<td>SCR</td>
<td>5-200yr</td>
<td>+3.6% to +25%</td>
<td>- EGBBC recommendations*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- PCIC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- IDFCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Consultant Reports</td>
</tr>
</tbody>
</table>
Zonnebeke Creek – Culvert Replacement
(Design $1 million / Construction $10 million)

| Zonnebeke Creek Culvert Replacement Hwy 29S | Culvert (6,470 mm SPCSP) | Return 200yr | Flow Rate (m³/s) 61.6 | Climate Change +25% | New Flow Rate (M³/S) 77 | NHC IDFCC Report on the 2016 Flood Event and Regional Hydrology – NHC, 2017 |
McKenzie Interchange
(Critical Sewer Segment 2 of 10)

<table>
<thead>
<tr>
<th>Admirals-McKenzie Interchange Hwy 1</th>
<th>Critical Sewer Segment #2</th>
<th>200yr</th>
<th>Flow Rate (l/s)</th>
<th>Climate Change</th>
<th>Flow Rate (l/s)</th>
<th>Urban Systems Future IDF curves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>711</td>
<td>+18.4%</td>
<td>842</td>
<td></td>
</tr>
</tbody>
</table>
### Mtn Hwy Interchange

<table>
<thead>
<tr>
<th>Mountain Hwy Interchange</th>
<th>Major Drainage systems</th>
<th>Flow Rate (m³/s)</th>
<th>Climate Change</th>
<th>Flow Rate (M³/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hwy 1</td>
<td>Keith Creek Culverts</td>
<td>18.1</td>
<td>+20%</td>
<td>21.7</td>
</tr>
</tbody>
</table>

Associated Engineering:
- PCIC (Plan2Adapt 90th% 17.5%↑)
- APEGBC (10%, 20%↑)
- IDFCC (18-23%↑)
BCMoTI Continuing Work

• NRCan Project – interdependencies and adaptation economic analysis
• PCIC Climate Explorer
Climate Resources

PCIC Climate data portal and support

- Plan2Adapt
- Downscaled climate data - projections
- Hydrologic model output – projections
- Engineering specific tool – projections (in development)
- Support from climate scientists
### Summary of Climate Change for British Columbia in the 2050s

<table>
<thead>
<tr>
<th>Climate Variable</th>
<th>Season</th>
<th>Projected Change from 1961-1990 Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ensemble Median</td>
</tr>
<tr>
<td>Mean Temperature (°C)</td>
<td>Annual</td>
<td>+1.8 °C</td>
</tr>
<tr>
<td>Precipitation (%)</td>
<td>Annual</td>
<td>+6%</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>-1%</td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td>+6%</td>
</tr>
<tr>
<td>Snowfall* (%)</td>
<td>Winter</td>
<td>-10%</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>-58%</td>
</tr>
<tr>
<td>Growing Degree Days* (degree days)</td>
<td>Annual</td>
<td>+283 degree days</td>
</tr>
<tr>
<td>Heating Degree Days* (degree days)</td>
<td>Annual</td>
<td>-648 degree days</td>
</tr>
<tr>
<td>Frost-Free Days* (days)</td>
<td>Annual</td>
<td>+20 days</td>
</tr>
</tbody>
</table>

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.
PCIC Climate Explorer
BCMoTI Adaptation Site

BCMoTI Adaptation site: https://www2.gov.bc.ca/gov/content/transportation/transportation-environment/climate-action/adaptation

Sportsman Bowl Rd 2018
Old Kamloops Rd Hwy 5A 2018
Recap

Adapt highway infrastructure for resilience to extreme events and climate change using vulnerability assessment and climate projection tools
Thank you. Questions?

Grizzly Creek Culvert
Trash Rack – Flying V (2013)