Technical Circular T-04/19
Date: March 27, 2019

To: All TRAN Staff

Subject: Resilient Infrastructure Engineering Design - Adaptation to the Impacts of Climate Change and Weather Extremes

Requirements:

- Provide engineering design adaptation to climate change and weather extremes using climate projections and risk analysis
- Submit a Design Criteria Sheet for Climate Change Resilience (Appendix 1) to the Chief Engineer's Office

Purpose:
This technical circular supersedes Technical Circular T-06/15 – Climate Change and Extreme Weather Event Preparedness and Resilience in Engineering Infrastructure Design.

Given the potential for climate change to impact transportation infrastructure in BC, it is prudent to develop directives and guidance for incorporating climate adaptation into engineering designs provided to the BC Ministry of Transportation and Infrastructure.

Thus, the Ministry requires engineering design work to evaluate risk and include adaptation measures to the impacts of future climate change, weather extremes and climate-related events, as well as changes in average climate conditions. This policy applies to all new projects, as well as rehabilitation and maintenance projects.

Supporting resources for this policy, such as practice guidance, adaptation project examples and risk assessment methods, can be obtained from sources such as professional associations. Climate information can be obtained from climate resource providers. Some of these resources are found on the BCMOTI Climate Change and Adaptation website.

This policy aligns with the BC Climate Action Plan - in developing strategies to help BC adapt to the effects of climate changes. And therefore, the Ministry will continue to provide a provincial transportation system that is resilient, reliable and efficient regardless of unfolding impacts of climate change,

Background:
Climate change impacts are being felt in communities across the province with more frequent and intense weather extremes and climate-related events causing damage to infrastructure, property, and ecosystems. Therefore, climate change adds additional challenges to environmental risks of flood, wildfire, landslide, geologic subsidence, rock falls, avalanche, snow, ice, temperature extremes and variability, extreme precipitation, and storms of various intensities.

Furthermore, the design life of transportation infrastructure is inherently long, thus service requirements for roads, bridges, tunnels, railways, ports and runways may be required for decades, while rights-of-way and specific facilities may continue to be used for transportation purposes for much longer. Thus, climate change presents added risks to the long-term reliability of interconnected systems that are already exposed to a range of stressors such as aging and deteriorating infrastructure, environmental risks, land-use changes, and population growth.

Consequently, infrastructure designers and operators must consider the magnitude of potential stress that any project will be expected to withstand over its design life. While transportation infrastructure is currently designed to handle a broad range of impacts based on historic climate, preparing for future climate change and weather extremes and other climate related events as well as changes in average climate conditions is also to be considered.

Thus, preparing for implications regarding the design, construction, operation, and maintenance of transportation systems to future conditions is critical to protecting its integrity and current and future investment of taxpayer dollars and will result in wise use of resources.

Timeline: Effective immediately for all new engineering design assignments

Expectations:

1. Reasonable consideration of the impacts of future climate change and weather extremes appropriate to the scale of the project (including new, rehabilitation and maintenance projects)
2. Using risk assessment methods and climate information for design work from sources such as those providers listed in Appendix 4 (and on the BCMOTI Climate Change and Adaptation website)
3. At the concept stages, the project designer will identify the design components at risk from the impacts of future climate change and weather extremes over the expected project design life
4. At the concept stages, the project designer will summarize changes in temperature, precipitation and other climatic variables over the expected project design life
5. The project designer will identify the risks to project design components from these projected climate changes and summarize the risks in the *BCMOTI Climate Change Design Criteria Sheet for Climate Resilience* (Appendix 1)
6. The project designer will develop adaptation design strategies to address climate change risks for the project
7. Based on evaluation of future climate change effects and impacts, the project designer will develop a project-appropriate set of design criteria for event preparedness and resiliency
8. Engineering design parameter evaluation and modification for adaptation to climate change will be summarized and listed on *BCMOTI Climate Change Design Criteria Sheet for Climate Resilience* (Appendix 1)
9. The design team will implement the developed design criteria into the project

Documentation:

Design Criteria Sheet for Climate Change Resilience (included below):

This document summarizes the impacts of future climate change and weather extremes and the implications to engineering project infrastructure components. Thus, this sheet will include a list of infrastructure components at risk of being impacted by future climate change events and detail adaptation measures and costs included in the infrastructure design. Please list the climate risks encountered for project components. Adaptation costs are the estimated costs of climate adaptation for the components of the project (such as increasing the size of culvert pipes, etc.). One criteria sheet is required per discipline involved in design work. All Design Criteria Sheets are to be submitted to the Chief Engineer's Office at: BCMoTI-ChiefEngineersOffice@gov.bc.ca.

(BCMoTI Design Criteria Sheet for Climate Change Resilience – Explanatory Notes/Discussion Example - included below)

This example provides guidance on the types of information to include in the Explanatory Notes/Discussion section of the BCMOTI Design Criteria Sheet for Climate Change Resilience.

Appendix 1: BCMOTI Design Criteria Sheet for Climate Change Resilience
Appendix 2: BCMOTI Design Criteria Sheet for Climate Change Resilience – Explanatory Notes/Discussion Example
Appendix 3: Scope of guidance and resources
Appendix 4: Climate adaptation and vulnerability analysis sources
Appendix 5: What definitions are used in this directive?

<u>Contact:</u>

Chief Engineer
BCMOTI-ChiefEngineersOffice@gov.bc.ca

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Chief Engineer

Design Criteria Sheet for Climate Change Resilience

Highway Infrastructure Engineering Design and Climate Change Adaptation
BC Ministry of Transportation and Infrastructure
(Separate Criteria Sheet per Discipline)
(Submit all sheets to the Chief Engineers Office at:
BCMOTI-ChiefEngineersOffice@gov.bc.ca)

Project:	*(i.e. Project Name and Number)*
Type of work:	*(i.e. Capital/Rehab/Reconstruction, Bridge Structures, Culverts, Interchange/Intersection/Access Improvement, Corridor Improvement, etc.)*
Location:	*(i.e. Road Names (Major/Minor), Closest City, Municipality, Cardinal Directions, Electoral District, GPS, LKI Segment and km reference, etc.)*
Discipline:	

Design Component	Design Life or Return Period	Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value from Future Climate	Design Value Including Climate Change	Adaptation Cost Estimate ($)	Comments / Notes / Deviations / Variances
Example Only: Culvert <3m	75 yr DL 100 yr RP	Rainfall Intensity (mm/h)	51.9	+40%	72.7	$X	- See work including climate projections
Example Only: Culvert <3m	100 yr RP	Flow Rate (m^3/s)	20	+10%	22	$X	- See work including climate projections
Example Only: Bridge	200 yr RP	Flow Rate (m^3/s)	82.8	+20%	99.3	$X	- See work including climate projections

Explanatory Notes / Discussion:

(Provide brief scope statement, purpose of project and what is being achieved. Enter comments for clarification where appropriate and provide justification and evidence of engineering judgment used for items where deviations are noted in the design parameters listed above or any other deviations which are not noted in the table above.)

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

Date: ______________________________

Engineering Firm: ______________________________

Accepted by BCMOTI Consultant Liaison: ______________________________
(For External Design)

Deviations and Variances Approved by the Chief Engineer: ______________________________
Program Contact: Chief Engineer BCMOTI

Design Criteria Sheet for Climate Change Resilience

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(Separate Criteria Sheet per Discipline)
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(Design Criteria Sheet - Explanatory Notes/Discussion example)

Design Criteria

The drainage design criteria for the project are based on the principals outlined in the BCMoTI Supplement to TAC Geometrics Design Guide – 1000 Hydraulics Chapter. This drainage assessment is limited to evaluating a single culvert. No pavement drainage, roadside ditches, or catch basin design is included in this scope of work. The design criteria noted below provide a summary of the key design items.

Hydrology

- Flow rates to be calculated using the Rational Method
- Rainfall Intensity Duration Frequency (IDF) Data to be based on Environment Canada's rain gauge, with 25 years of data from 1980– 2007
- Time of concentration to be calculated using the Kirpich Formula and/or the Hathaway formula
- The runoff coefficient to be calculated using values from Table 1020.A in the Supplement to TAC

Culverts

- Culverts with spans less than 3000 mm are to be sized for the 100-year return period design flow rate
- Outlet-controlled culverts are to be sized to limit the head loss across the culvert to 300 mm
- Inlet-controlled culverts are to be sized to limit the headwater-to-diameter (HW/D) ratio to 1.0
- Minimum culvert diameter under a highway or main road is 600 mm

Design Life

As outlined in the BCMoTI Supplement to TAC Geometric Design Guide Hydraulics Chapter, the structural design life for culverts less than 3000 mm span shall be 75 years.

Climate Change Risk (Please include this section in all Design Criteria Sheet submissions)

In accordance with BCMoTI Climate Change Technical Circular (previously T-06/15), the potential impacts of future climate change need to be considered on all Ministry projects. For the drainage design components of this project, future climate change is anticipated to increase the amount of rainfall.

Climate Change Estimates

Climate Explorer - PCIC (Pacific Climate Impacts Consortium)

IDFCC (Western University Ontario)

Using the IDFCC tool to estimate increases to rainfall intensities for Environment Canada's rain gauge to the year 2067. Using the ensemble median of appropriate GCMs, and assuming a Representative Concentration Pathway (RCP) 8.5 climate change scenario, looked at the estimated increases to rainfall rates for a variety of return periods and storm durations. Looking at storm durations from 30 minutes to 2 hours for the 100-year return period, the estimated increase in rainfall intensity varies from 30% to 39%.

Flow Estimate

Estimated the 100-year peak flow rate for the culvert using the Rational Method. The peak flow is a function of the catchment area, runoff coefficient, and rainfall intensity. To account for climate change, applied an increase of 40%, resulting in a design rainfall intensity of 72.7 mm/h. Using these values, estimated a peak 100-year design flow rate of 0.11 m3/s.

Results - Culvert Hydraulics

The existing culvert crossing under the highway is a corrugated steel pipe (CSP) and has a diameter of 800 mm. Estimated length of the culvert is approximately 30 m. At the design flow rate of 0.11 m3/s, the culvert has a head loss of less than 0.1 m under outlet control conditions; therefore, the culvert appears to have sufficient capacity.

Appendix 3

What is the scope and application of this guidance?

This directive pertains to transportation infrastructure engineering design work by BCMOTI staff and consultants and others working on projects for BCMOTI. Many parameters, such as type, location, traffic volume, and design life of transportation infrastructure will determine the scope and scale of climate change related analysis required.

In general, for transportation engineering design projects BCMOTI will require:

- Consideration of impacts of future climate change and weather extremes and climate-related events and changes in average climate conditions
- Assessment of Infrastructure and climate risk for the design life of components, indicating relevant information and sources
- Design that incorporates information, analyses and projections of the impact of future climate change and weather extremes
- Development of practical and affordable project design criteria which takes adaptation to climate change into account
- *BCMOTI Design Criteria Sheet for Climate Change Resilience* to summarize engineering design parameter evaluation and modification for adaptation to climate change

Where can I obtain guidance, climate resources and vulnerability analysis tools?
For more information and links to resources and tools related to the impacts of future climate change, weather extremes and adaptation to these, please see Appendix 4 (and the BCMOTI website on climate adaptation). These contain links to climate information providers such as the Pacific Climate Impacts Consortium and risk analysis tools such as the Public Infrastructure Engineering Vulnerability Committee Protocol.

Appendix 4

Climate Adaptation and Vulnerability Analysis Sources

BCMOTI Climate Adaptation Site

BCFOR Climate Change Adaptation for Resource Roads

EGBC - Climate Change Information Portal
- **Professional Practice Guidelines**

Pacific Climate Impacts Consortium
- **Climate Explorer**

ClimateBC

Canadian Centre for Climate Services (CCCS)
- **ClimateData.ca**

Public Infrastructure Engineering Vulnerability Committee (PIEVC)

IDF_CC Tool (Western University Ontario)

Federal Highway Administration – Climate Adaptation (USA)
- **U.S. Climate Resilience Toolkit**
- **Climate Change Adaptation Tools**

AASHTO – Center for Environmental Excellence (USA)

Intergovernmental Panel on Climate Change (IPCC)

Appendix 5

What definitions are used in this directive?

1. **Climate Change.** Climate change refers to any significant change in the measures of climate lasting for an extended period of time. Climate change includes major variations in temperature, precipitation, or wind patterns, among other environmental conditions, that occur over several decades or longer. Changes in climate may manifest as a rise in sea level, as well as increase the frequency and magnitude of extreme weather events now and in the future

2. **Extreme Weather Events.** Extreme weather events can include significant anomalies in temperature, precipitation and winds and can manifest as heavy precipitation and flooding, heatwaves, drought, wildfires and windstorms. Consequences of extreme weather events can include reliability concerns, damage, destruction, and/or economic loss. Climate change can also cause or influence extreme weather events

3. **Extreme Events.** For the purposes of this directive, the term "extreme events" refers to risks posed by climate change and extreme weather events. The definition does not apply to other uses of the term nor include consideration of risks to the transportation system from other natural hazards, accidents, or other human induced disruptions

4. **Preparedness.** Preparedness means actions taken to plan, organize, equip, train, and exercise to build, apply, and sustain the capabilities necessary to prevent, protect against, ameliorate the effects of, respond to, and recover from climate change related damages to life, health, property, livelihoods, ecosystems, and national security

5. **Resilience.** Resilience or resiliency is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions

6. **Adaptation.** Adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects

7. **PIEVC**. Public Infrastructure Engineering Vulnerability Committee

8. **PCIC**. Pacific Climate Impacts Consortium