

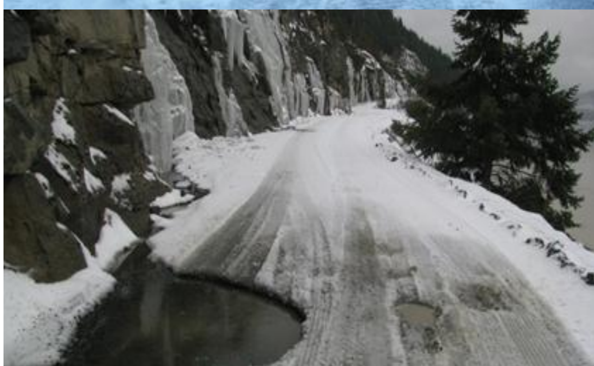


# Applying the PIEVC process to forest service roads in B.C.: Summary of 2015 training and In-SHUCK-ch FSR case study

**DRAFT REPORT**

**Date: May 2015**

**By: Allan Bradley, P.Eng., Associate Research Leader, Resource Roads**

fpinnovations.ca

FPInnovations is a not-for-profit world-leading R&D institute that specializes in the creation of scientific solutions in support of the Canadian forest sector's global competitiveness and responds to the priority needs of its industry members and government partners. It is ideally positioned to perform research, innovate, and deliver state-of-the-art solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. FPInnovations' staff numbers more than 525. Its R&D laboratories are located in Québec City, Montréal and Vancouver, and it has technology transfer offices across Canada. For more information about FPInnovations, visit: www.fpinnovations.ca.

Follow us on:

30100XXXX: Project name
Technical Report – Report number

## ACKNOWLEDGEMENTS

This project was financially supported by B.C. Ministry of Forests, Lands and Natural Resource Operations, Engineering Branch.

## REVIEWERS

Brian Chow, P.Eng. Chief Engineer, Engineering Branch, FLNRO

## COVER PHOTOS

The cover images illustrate weather impacts to the In-SHUCK-ch FSR. Photos, clockwise from top left, are heavy snowfall narrows roadway, road flooding due to high water levels in Lillooett Lake, new bridge replaced undercapacity culvert battery, and ice build up on cut face and road surface.

## CONTACT

Allan Bradley, P.Eng.
Associate Research Leader
Resource Roads
(604) 222-5667
allan.bradley@fpinnovations.ca

## Table of contents



## List of tables



## List of figures

# 1. INTRODUCTION

**Comment [AB1]:** Needs Executive Summary to tie together workshop outcomes, participant survey, results from engineering analyses of high risk elemetns, and recommended storm proofing measures,

Climate changes and more extreme weather are affecting the safety and performance of transportation infrastructure in diverse and unplanned for ways. In some cases, the result has been reduced safety for road users, accelerated degradation or increased failure rates for structures, and increased maintenance. Those responsible for this infrastructure are obliged to identify and respond to structures, including roadways, for which safety or performance has already, or may in the future, reach unacceptable levels.

In collaboration with the Sea-to-Sky District, FLNRO Engineering Branch is piloting an engineering infrastructure vulnerability assessment protocol of an FSR; the protocol was developed by the Public Infrastructure Engineering Vulnerability Committee (PIEVC). The protocol provides a structured methodology for assessing infrastructure for climate change vulnerability so that modifications to processes and procedures can be identified in planning, design, construction, maintenance and rehabilitation.

The B.C. Ministry of Transportation and Infrstructure (MOTI) has piloted the PIEVC protocol on five highway corridors and is assisting FLNRO with this pilot study project of the In-SHUCK-ch Forest Service Road, located south east of Pemberton. A two-part training webinar was held to introduce participants to the PIEVC protocol, to define climate change, and to discuss how climate change was modeled for the In-SHUCK-ch Forest Service Road.

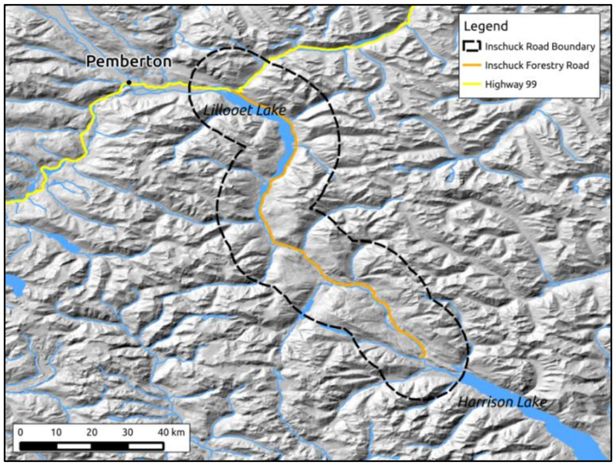


**Figure 1. In-SHUCK-ch FSR pilot PIEVC case study area**

A FLNRO case study workshop followed these webinars, was led by MOTI PIEVC experts Dirk Nyland and Jim Barnes, and had invited participants from FLNRO and consultants familiar with the subject road. With this training, the PIEVC pilot outcomes and this summary document it is hoped that FLNRO Engineering Branch will be empowered to help define steps to better address climate change adaptation considerations for resource roads going forward.

## 2. PIEVC CLIMATE CHANGE VULNERABILITY ASSESSMENT PROTOCOL

The protocol is a 5 step process to analyze the engineering vulnerability of an engineered structure (e.g., a building or a road infrastructure) to current and future climate parameters such as prolonged dry periods or extreme rainfall. The 5 steps of the protocol are: project definition; data gathering and sufficiency check; risk assessment; engineering analysis, if judged necessary; conclusions and recommendations (Figure 2). Version 10 of the protocol is currently in use.

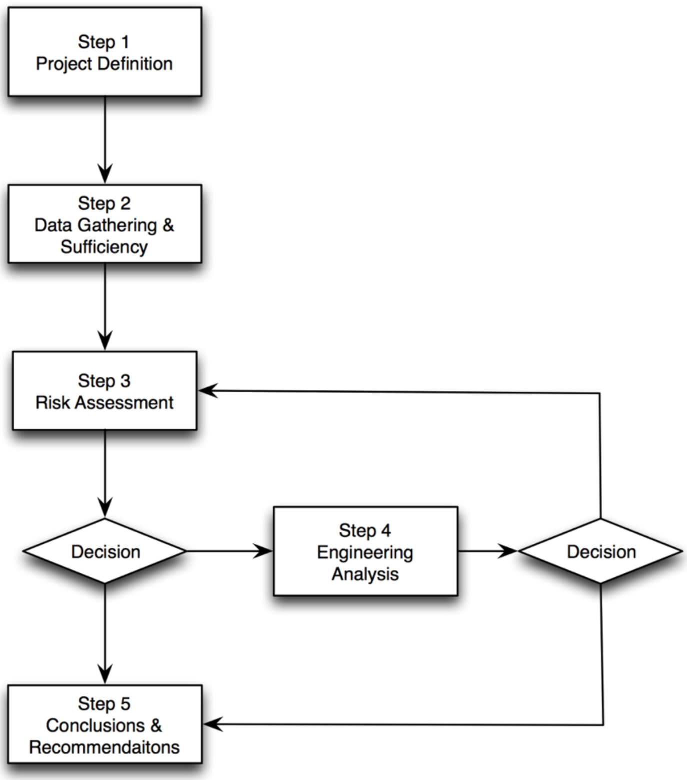


**Figure 2. PIEVC process steps**

In the data gathering and sufficiency step, it is important to consider what infrastructure elements to gather data on (e.g., bridges, road surfacing, cut slopes), which climate parameters are important, and how these climate parameters are likely to influence the infrastructure elements. Table 1 lists the structural elements proposed by FLNRO Engineering Branch for use in this pilot case study.

In the risk assessment step, climate factors for the resource road are developed based on the watershed, location, temperatures, etc. Climatologists input these factors, with assumptions for various climate change scenarios, into climate prediction models to make both regional and down-scaled climatic predictions. These predictions are then used to identify trends and general results.

A high level risk assessment is made for each infrastructure element identifying which, and by how much, climate parameters are likely to influence the performance of each infrastructure element. For any element judged to be at higher risk, an engineering analysis by experts familiar with its design, may be indicated.

The engineering analysis step has various components, including refining the climatic predictions, and assessing load capacity vulnerability. Those familiar with the design of the infrastructure elements review the design assumptions, material properties, etc. to assess the anticipated changes in performance given the climate changes predicted. If design changes are warranted to ensure safety or reliability, then these are recommended. The anticipated changes are often reviewed by maintenance contractors.

**Table 1. Road corridor elements for consideration in the In-SHUCK-ch FSR vulnerability analysis**

| Structures that cross streams: | Third party utilities: |
|---|---|
| Bridges | Hydro poles / towers |
| Major (>1800 mm dia; >6m$^3$ /sec) | Hydro lines |
| Other culverts (<2000 mm) | Communication / utility towers |
| Culvert cross drains | Water lines |
| Ditches | Archeological sites (grave sites; First Nation sites) |
| Road surfacing | Environmental Features |
| Embankment / fill slopes | River hydraulics |
| Cut Slopes - rock | Flood plain migration |
| Cut Slopes - other material | Lake level flooding |
| Upslope hillslopes beyond road prism - managed | Alluvial fan features |
| Upslope hill slopes beyond road prism - unmanaged | Landslide initiation |
| Downslope hill slopes beyond road prism - managed | Debris flow initiation |
| Downslope hillslopes beyond road prism - unmanaged | Snow avalanche zones |
| River training works | Riparian habitat / fish sensitive streams |
| Retaining walls (lock block, rock stack, log, etc) | Miscellaneous |
| MSE / GRS walls or fills | Administration / personnel & engineering |
| Signage | Winter maintenance |
| | Summer maintenance |
| | Gravel / rock pits and spoil sites |

## 3. IN-SHUCK-CH FSR OPERATING CONDITIONS

**Comment [AB2]:** Could try to add some examples of local experience about weather when infrastructure damage occurred. This could lead to a recommendation that data collection format be developed that links weather indices to damaging events

The In-SHUCK-ch FSR is approximately 70 km long with KM numbering starting from the north end at the FSR intersection with Highway 99 (Figure 3). The terrain is mountainous and drops in elevation from north to south. Due to the steep terrain, the FSR closely follows the eastern shore of Lillooet Lake, and the western side of Lillooet River. Originally built as a powerline route to the lower mainland, the FSR provides access for a number of first nations and public communities, managed forests, recreational areas and independent power projects (near Port Douglas).

Climate-related issues on the In-SHUCK-ch FSR have included flooding near KM 24 at the outlet from Lillooet Lake; ice flows and ice falls onto the road near KM 1; culvert washouts and bridge undercutting by high stream flows; rock and water falls onto the road; debris torrents; and, narrow road width due to fill slope failures. Wild fires in the surrounding area are also a concern as they may increase flash flooding and woody debris in streams.

The FSR is currently the subject of an upgrade project to improve the reliability of access to the First Nations communities. Construction operations are underway to raise the road in areas subject to flooding, widen the roadway and improve alignment, where needed.

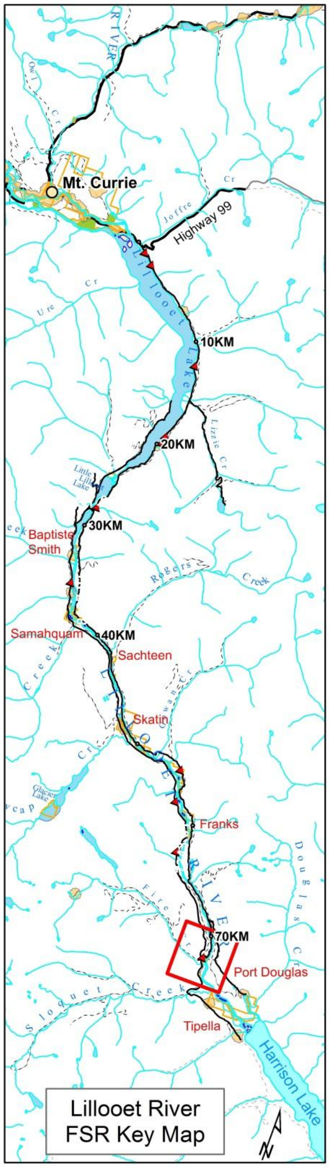


**Figure 3. Detail of In-SHUCK-ch FSR road corridor**

## 4. CLIMATE CHANGE AND THE IN-SHUCK-CH FSR

Weather data was accessed from four weather stations near the In-SHUCK-ch FSR, however, only one of these provided detailed, accurate, longer term records. Seasonal means, daily extremes, and return periods of temperature and precipitation were analysed and used in climate models to predict short term and long term climate changes for the area. Various climate change scenarios were modeled and the predicted trends from these compared.

Table 2 provides a summary of predicted peak precipitation changes. From these predictions it can be anticipated that stream flows will grow with time and that structures intended to last over 60 years (e.g., bridges) will be most impacted.

Peak temperature for the area averaged 34° C from 1971 to 2000. Peak temperature (i.e., 20-year return period maximum temperature) is predicted to increase by 2° C in the short term but by as much as 7° C in the longer term. Other predictions for the area include wetter winters, with les snowfall, and much drier summers.

Temperature and precipitation-based climatic metrics used in the B.C. MOTI PIEVC case studies were considered and the 16 relevant ones were selected for use in the In-SHUCK-ch FSR risk assessment. Based on field experience, threshold values were picked that were likely to be associated with road-related issues. Table 3 lists the climatic metrics and local threshold values used for this analysis as well as comments to highlight how each is expected to impact roada corridor features.

**Table 2. Predicted change in 20-year return period 1-day maximum precipitation from the 1971 to 2000-period average (≈100 mm). In-SHUCK-ch FSR road corridor**

| Model scenario | 2011 to 2040 | 2041 to 2070 | 2071 to 2100 |
|---|---|---|---|
| Scenario rcp4.5 | 20% | 30% | 30% |
| Scenario rcp8.5 | 20% | 30% | 50% |

**Table 3. Climatic metrics used to assess climate change risk to the In-SHUCK-ch FSR**

| Climatic metric | Comments |
|---|---|
| Temperature metric | |
| <u>High temperature</u>: days with maximum temperature exceeding 35° C | Max. mean daily temp. = 24°C for area.<br>(Design max. temperature from 34° to 49° C depending on bridge structure: concrete or steel) |
| <u>Prolonged dry period</u>: > 30 consecutive days with maximum temperature >15° C and < 0.2 mm ppt | Implications of dryness: need for dust control, cut slope ravelling, rockfall, and wildfire effects (increased runoff, debris flow potential). |
| <u>Temperature Range</u>: daily temperature variation of more than 25° C | Range for bridge could be either 104° C or -79° C depending on structure type. |
| <u>Freeze - thaw</u>: number of days where maximum temperature >0° C and minimum temperature <0° C<br>Not consecutive days. | 110 ± 30 days.<br>Concern is total number of events.<br>This parameter affects how much frost growth will occur in subsoils, below foundations, etc. Rock fall is related to freeze / thaw (as seen as KM 1 In-Shuck-ch). Also generates fog. |

| | |
|---|---|
| Rock face ice build-up: 7 days temperature max < -5° C | Ice build-up on rock faces resulting in rock and ice fall onto road prism.<br>Helps capture ditch and culvert ice buildup. |
| Frost / frost penetration: XX degree days temp. < 0° C | Road: mainly affects how thick the road gravels need to be to prevent frost heaving in the subsoil.<br>Local frost > 0.6 m depth (frost probe data available).<br>(Use frost degree days.) |
| Precipitation metric | |
| Total Annual Rainfall: 1500 mm | Based on observed 30 year-average total annual rainfall. Affects only riparian habitat / fish sensitive streams. |
| Extreme high rainfall in 24-hour period: > 125 mm rain in 24-hour period | Adjust to consider dry / wet zone, as appropriate. |
| Sustained rainfall: ≥ 3 consecutive days with > 75 mm rain/day<br>Not rain on snow | |
| Antecedent rain followed by significant rain event: ≥ 21 consecutive days cumulative amount > XX mm rain additive with 24 hr rainfall exceeding XX | Matthias reference suggests 14+ days of antecendent rain is a concern.<br>Impacts cut / fill slopes, landslides. |
| Snow frequency: days with snowfall > 10 cm | |
| Snow accumulation: 5 or more consecutive days with a snow depth >60 cm | A useful measure of how much snow accumulates on road edges due to snowfall and from snow plowing. |
| Rain on snow: Rain (100 mm in 24 hours) on >60 cm of "ripe" saturated snow pack; freezing > ridge tops. | |
| Rain on frozen ground: ppt > 25 mm/day & surface Temperature <0° C. No snowfall | Rain on frozen ground results in surface icing - traction and runoff issues. |
| Freezing rain: number of days with rain that falls as liquid and freezes on contact | Road surface icing - traction issue; visibility; iced tree debris & power line icing. |
| Rapid snow melt: snow melt > 30 mm / day | A driver for rising lake level (and flooding). |

## 5. ASSESSMENT OF THE VULNERABILITY OF FEATURES IN THE IN-SHUCK-CH FSR CORRIDOR

A variety of infrastructure, environmental features and miscellaneous other elements are found along the In-SHUCK-ch FSR. The PIEVC process (step 3) involves a high level assessment of the risk posed by the predicted climate changes on each of these elements. This assessment involves estimating whether the predicted climate changes are expected to influence the behaviour or performance of each road corridor element (Table 1). If a negative outcome is expected, evaluators assess the probability of this occurring (P) on a scale of 1 to 10, and the anticipated severity of the damage (S) on a scale of 1 to 10. The result (R) = P x S. If R is less than 16, the influence of climate change is anticipated to be minor on the element in question and no further consideration is needed. If R is between 16 and 30, further consideration might be needed. If R is over 30, climate change is anticipated to strongly impact the element and detailed engineering analysis by experts familiar with its design is recommended (step 4). A spreadsheet was used to organize this analysis, with climatic metrics and associated risk comments along the horizontal axis and corridor features along the vertical axis.

**Comment [AB3]:** Could list what the higher risk items were.

**Comment [AB4]:** Could add a section called 'storm proofing roads'. In it I could put details about the engineering analyses of the high risk structures that was done to confirm their vulnerability. Could also list recommended design changes and how best to implement these. Finally, also list recommended maintenance changes.

## 6. WORKSHOP OUTCOMES

Infrastructure owners have learned that they mustn't ignore climate change. And that they must think about adaptation.

Local knowledge teams help find knowledge gaps and make plans work.

Climatologist's models have trouble predicting fog and wind and snow (e.g., whether dry snow and wet snow avalanches are changing).

Climate parameters in design codes and design guides aren't that up-to-date. Therefore, it is important to get good data and assess risk of loss. APEGBC is developing climate change practice guidelines. MOTI will publish a Technical Circular by May 2015 which stresses the importance of accounting for climate change in designs in a formal consistent manner.

Those structural elements with long design lives (e.g., bridges) are more at risk to climate changes than short lived elements; designs for these structures are typically more conservative and able to handle some climate change.

It is anticipated that there will be a lack of weather data to describe the climate history of some resource roads.

Generally highways have been found to be resilient to climate change. Extreme precipitation may overload drainage structures, and lead to bridge loss by shifting large amounts of bed load to under the bridge. Extreme temperature effects are less well known and may influence pavement and bridge component life. Frost heave may also become a problem. Resource roads experience the same extreme storms as highways and terrain is anticipated to contribute to loading; therefore, these same problems are anticipated to be a concern for resource roads.

Table 1 illustrates the infrastructure elements considered in the PIEVC pilot of the In-SHUCK-ch FSR. Based on a similar list used by MOTI, this list is specific to resource roads. Changes to the list may be needed to address specific features and unique concerns for other FSRs.

# 7. PARTICIPANT SURVEY

A participant survey of the workshop attendees was distributed and 5 responses were received (2 from government employees and 3 from consultants or others external to government). The survey results provided insight into the effectiveness and completeness of the webinars and workshop presentations, the suitability of the PIEVC protocol for assessing FSR climate change vulnerability, the importance of the topic, and how the process might be better tailored to FSRs. Table 4 summarises the participant responses to survey statements; in some cases, responses were aggregated when statements were similar.

**Table 4. Summary of survey responses from participants of the PIEVC protocol training and In-SHUCK-ch FSR case study**

| Survey statement | Average Agreement Rating (on a scale of 1 to 5) |
|---|---|
| The webinars were valuable preparation for the PIEVC protocol workshop. | 4.0 (moderate agreement) |
| The PIEVC protocol is suitable for assessing resource road climate change vulnerability. | 4.4 (moderate to strong agreement) |
| The training provided enough information to apply the PIEVC protocol to a resource road. | 4.2 (moderate to strong agreement) |
| The training adequately highlighted that the PIEVC process must be founded on local knowledge, weather data and climate change predictions for the resource road corridor. | 4.2 (moderate to strong agreement) |
| The training was well presented, and provided adequate time for questions and explanations. | 4.6 (moderately strong agreement) |
| The PIEVC protocol is useful and needed for assessing climate change-induced risk on B.C. resource roads. | 4.0 (moderate agreement) |

When asked how the risk evaluation could be improved, participants offered the following comments:

1. Include more case histories, including exploring the effects of climate change on fans in B.C..
2. Include more information about the design criteria for FSRs and how these might be affected by climate threshold values.

FPInnovations®

## Head Office

**Pointe-Claire**
570, Saint-Jean Blvd
Pointe-Claire, QC
Canada H9R 3J9
T 514 630-4100

**Vancouver**
2665 East Mall
Vancouver, BC.
Canada V6T 1Z4
T 604 224-3221

**Québec**
319, rue Franquet
Québec, QC
Canada G1P 4R4
T 418 659-2647

OUR NAME IS INNOVATION