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Project name:
BC MoTT - Highway 8 Reinstatement

Project ref:
Project E - Drainage Design Memorandum Project
E: Sites 16-19, MoTT Project No. 26355

From:
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Date:
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Memo

Subject: Drainage Design Memorandum Project E: Sites 16-19

1. Introduction

During the design phase of Project E, AECOM completed a drainage assessment and preliminary culvert sizing to support the design submission. This memorandum provides an overview of the hydrologic and hydraulic analysis completed for Project E, sites 16 to 19 along Highway 8. It addresses catchment areas, drainage basin hydrology, flow calculation methodology, precipitation data, peak flows, climate change-adjusted flows, and culvert sizing. AECOM is also proposing a drainage design variance with an outline included in this memorandum for the culvert analysis and design.

2. Hydrologic and Hydraulic Analysis

2.1. Guidance and Available Data

The criteria and background information used in preparation of this study include

- Terrain Resource Information Management (TRIM) 1:20,000 scale format digital positional map sheet in Digital Elevation Model (DEM) type prepared by GeoBC, Ministry of Forests, Lands and Natural Resource Operations.
- Additional DEM data from the Geospatial Data Extraction Tool by the Government of Canada.
- Section 1000 of the Supplement to TAC Geometric Design Guide, BC Ministry of Transportation and Transit, 2019.
- Resilient Infrastructure Engineering Design – Adaptation to the Impacts of Climate Change and Weather Extremes, Technical Circular T-04/19, BC Ministry of Transportation and Transit, March 27, 2019.
- Topographic survey provided by the Ministry of Transportation and Transit, May 2024 for Site 16-17, July 2024 for Site 18, and September 2024 for Site 19.
- Soil Map with Textural Classification, BC Ministry of Environment and Parks.

2.2. Catchment Areas and Existing Conditions

A catchment analysis was completed using ArcGIS and the ArcHydro tools. The topographic ground surface data used for catchment delineation combined the DEM from TRIM, the DEM from the Geospatial Data Extraction Tool by the Government of Canada, the survey data from MoTT, and the proposed road design surface. Catchments are presented in Figure 2.1.

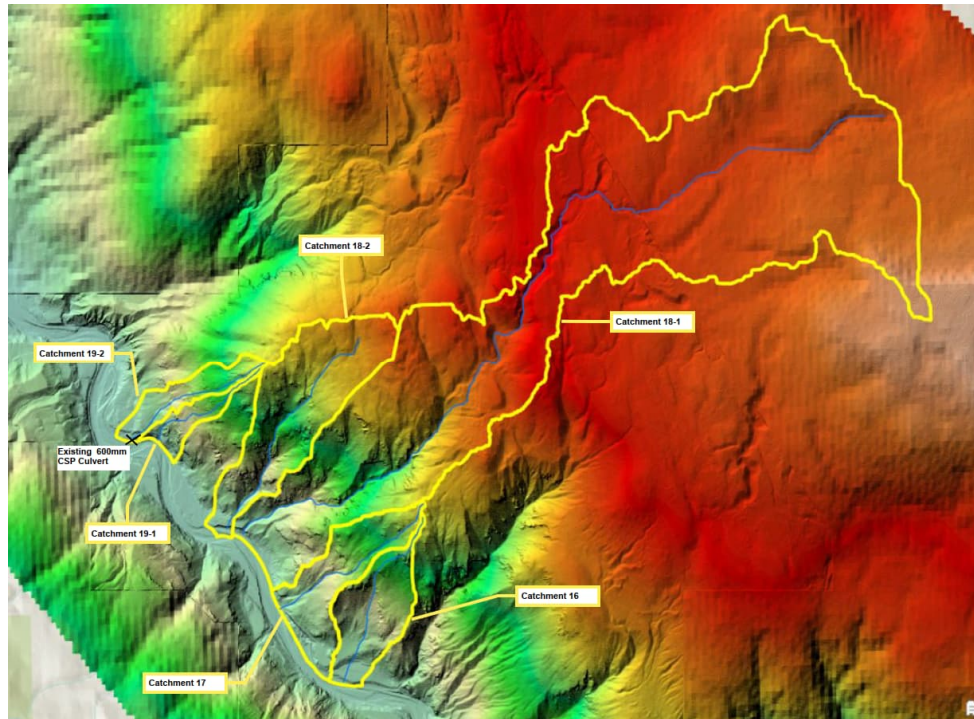


Figure 2.1 Project E Drainage Catchment Map

The effective area of the contributing catchments (including sub-catchments) ranged from 0.11 to 4.83 km². According to the British Columbia Ministry of Transportation and Transit (BC MoTT) Supplement to TAC Geometric Design Guide, Section 1020.06, the Rational Method is generally applied to catchments less than 10 km² for rural catchments. Therefore, the design flows of all the catchments are calculated using the Rational Method. Table 2-1 summarizes the four catchments within Project E (Site 16 to Site 19).

Table 2-1 Summary of Catchment Information

| Catchment ID | Catchment Area (km ²) | Stream Length (km) | Average Channel Slope (%) |
|------------------------------|--------------------------------------|-----------------------|------------------------------|
| Catchment - 16 | 0.35 | 1.309 | 42.9 |
| Catchment - 17 | 0.41 | 1.271 | 46.7 |
| Catchment – 18-1 East | 4.83 | 7.039 | 14.6 |
| Catchment – 18-2 West | 0.74 | 1.675 | 40.9 |
| Catchment – 19-1 East | 0.11 | 0.949 | 62.1 |
| Catchment – 19-2 West | 0.18 | 1.085 | 53.9 |

Existing Conditions

The catchments reporting to all four sites are situated within the Nicola River basin, primarily located north of Highway 8. Each catchment originates in steep, mountainous terrain where snow accumulates at higher elevations. Overland flow and runoff are guided by the natural topography, draining through a network of valleys, gullies, and natural depressions before ultimately discharging to the Nicola River.

The upper portions of the catchments are characterized by forested, alpine environments. The vegetation and root structures in these areas promote infiltration and reduce runoff velocities. As the drainage systems approach the highway and the Nicola River, the terrain generally flattens, and soils transition to sandy materials. These lower elevations tend to have slightly higher infiltration capacity.

Highway 8 and its adjacent features interact with natural drainage in several ways. In some areas—especially within the largest catchment (Catchment 18)—roadside ditches intercept and convey stormwater to the existing culverts. Banks along the river and culvert outlets are often protected with riprap to reduce erosion.

Catchment-Specific Notes:

Catchment - 16:

This smaller catchment originates in rugged, steep terrain, with elevations ranging from about 840.9 m at the top to 279.1 m near the highway. Rainfall flows downhill along natural channels, ultimately reaching the Nicola River. Most of the highway in this area appears to be superelevated toward the mountainside, indicating that runoff from the roadway surface is directed toward the hillside. According to the site survey (2024), a shallow roadside ditch exists along this highway segment and ends at the west of this segment. However, the survey found no existing culvert to discharge the stormwater from the roadside ditch.

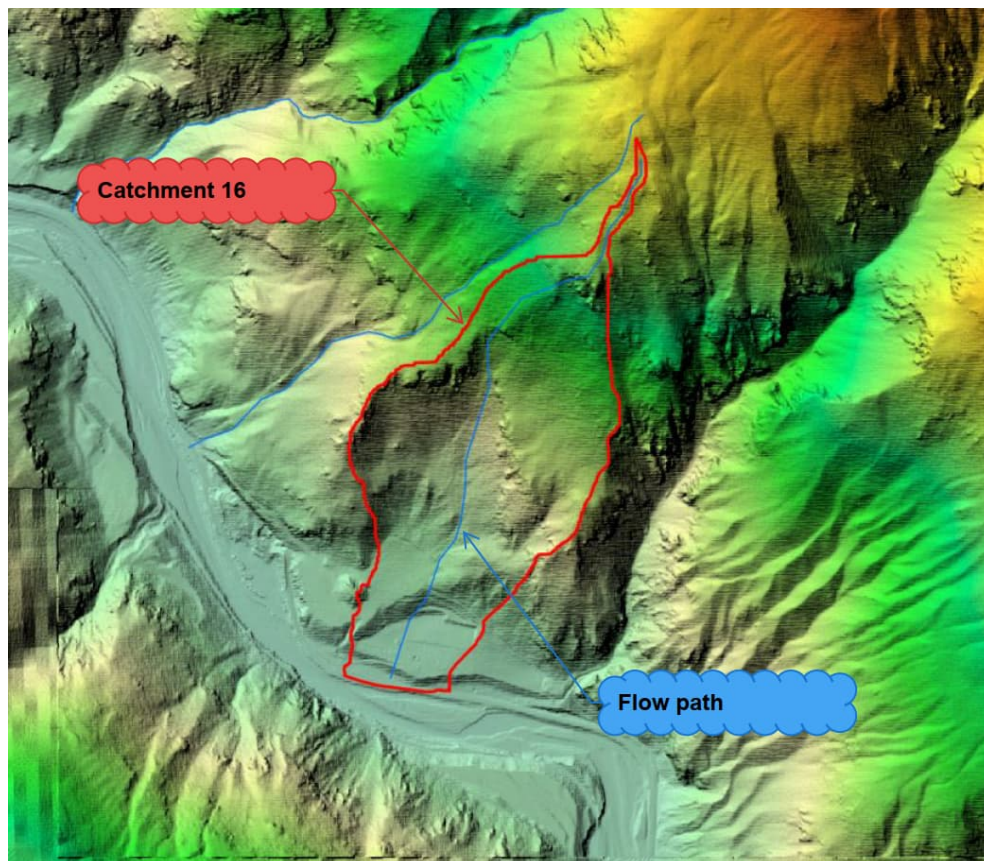


Figure 2.2: Catchment - 16

Catchment - 17:

Similar in area and morphology to Catchment - 16, this catchment features steep slopes and natural drainage paths with the highest elevation of 858.9m and lowest elevation of 265.1m. Forested vegetation moderates runoff and supports infiltration, with flows ultimately reaching the Nicola River. The site survey (2024) shows no existing culverts within this highway segment. Based on the communications with the Ministry, it is assumed that the primary drainage mechanisms for this catchment are that the sheet flow from uphill is directed to the low area and infiltrates through the soil underneath the highway to the river.

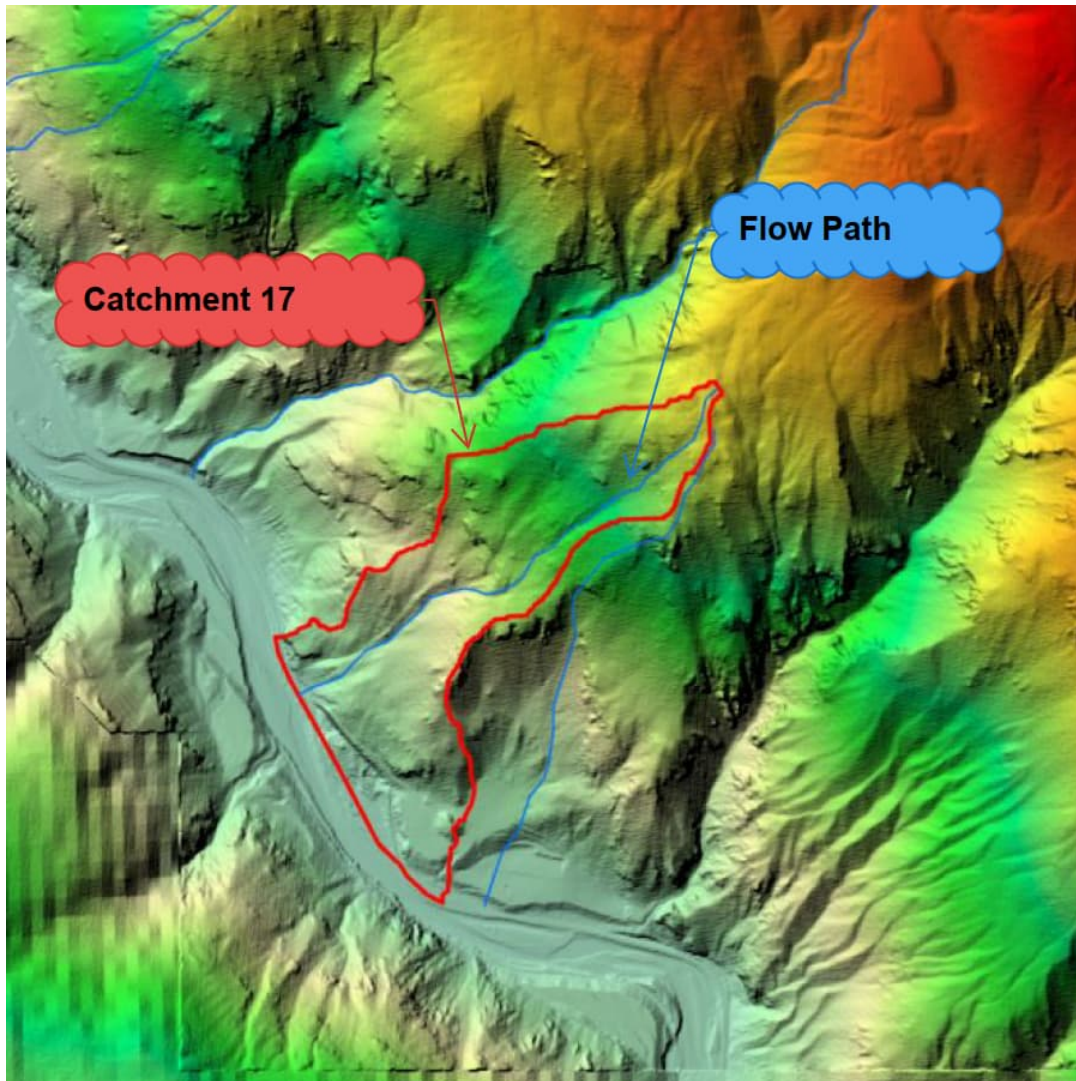


Figure 2.3: Catchment - 17

Catchment - 18:

Catchment - 18 covers the largest area and features a comparatively gentler average slope, collecting the greatest runoff volume. The upper reaches remain forested with flat terrain that helps regulate flow, while lower sections near the highway are steep with high infiltration due to rapidly drained sandy terrain. Geotechnical investigations and the BC Soils Map confirmed that the surrounding area primarily consists of sandy soils with high infiltration capacity.

The flow path for this catchment is evident from terrain features observed in Google Earth Imagery. The channel appears to follow a natural drainage pattern with a network of converging valleys and gullies. The super-elevated highway sections of Site 18 direct sheet flow toward the Nicola River corridor. Riprap armouring is present along the riverbank to protect against erosion.

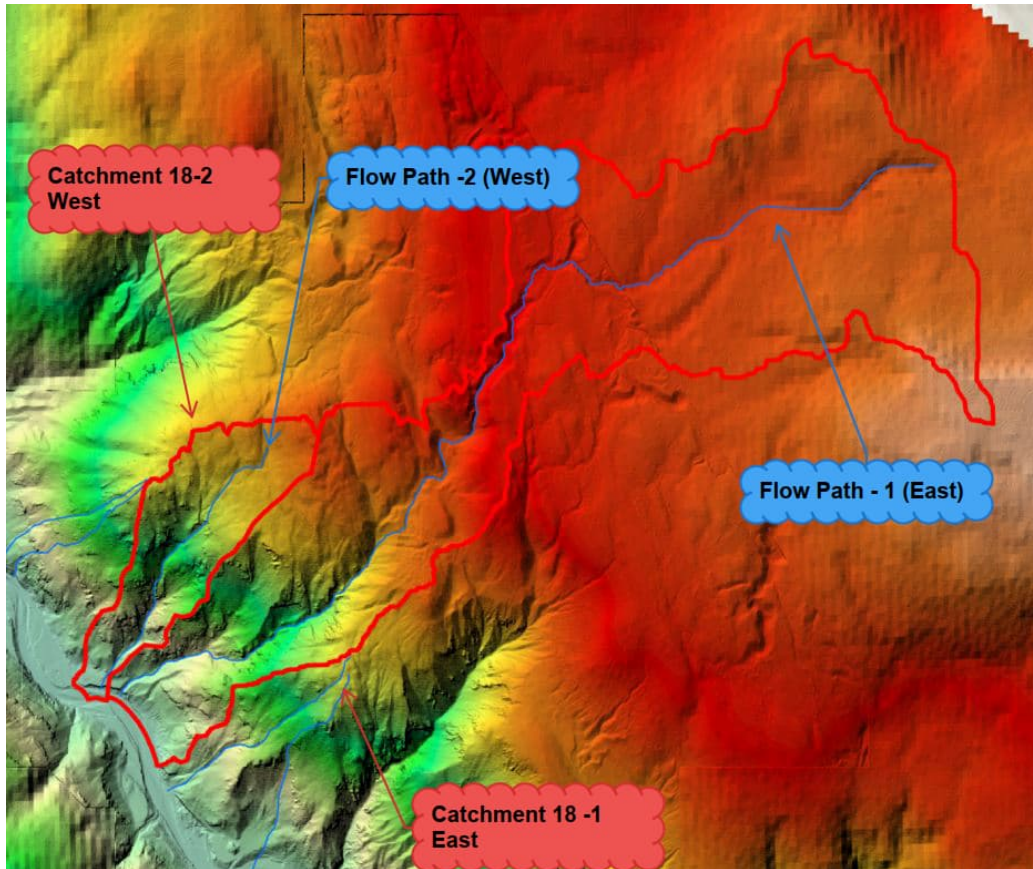


Figure 2.4: Catchment - 18

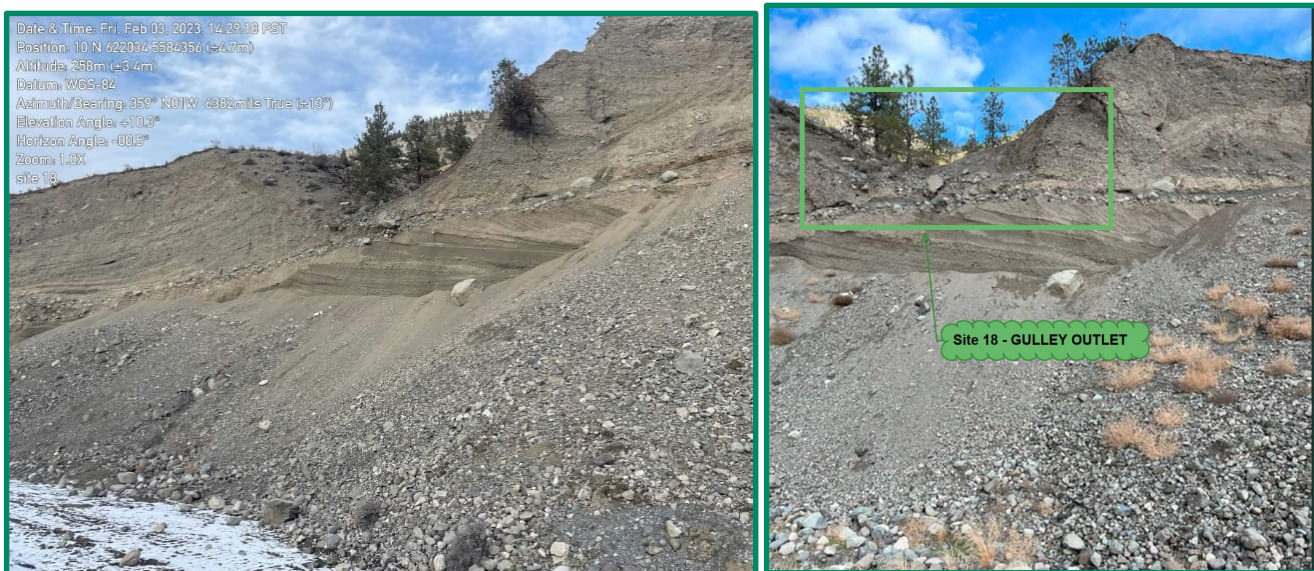


Figure 2.5: Site 18 Gully Outlet Immediately Upstream of Highway -8

Catchment - 19:

This small, steep catchment directs its flow toward the highway corridor. The east part of the catchment is captured as a small detention storage area with rapidly drained sandy soils indicating high infiltration. On the West side, an existing 600 mm CSP culvert with a 20 m length crossing located at a low point conveys storm runoff flows from uphill to the river. The highway has a mix of crowned and superelevated pavement, directing runoff both to the roadside ditch and across the roadway.

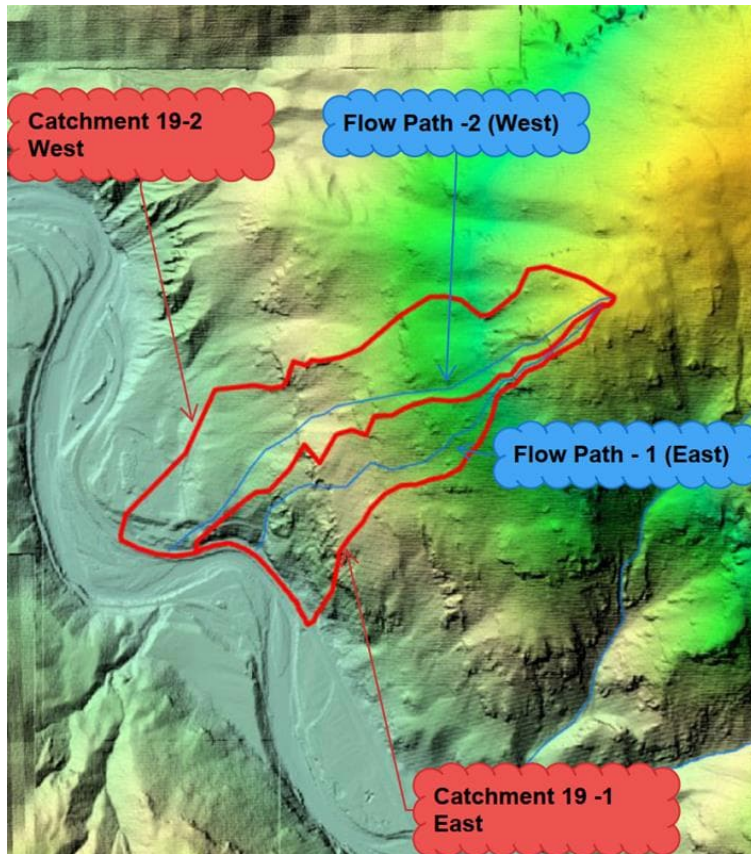


Figure 2.6: Catchment - 19



Figure 2.7 Site 19 Existing 600mm CSP culvert



Figure 2.8 Site 19 Downstream topography

2.3. Project Hydrology Design Criteria

For the culvert design in this project, AECOM followed the 2019 BC Supplement to TAC—Geometric Design Guide. The design criteria used are presented in this section.

2.3.1. Design Return Period

Per Table 1010. A in Section 1010.02 of the BC Supplement to TAC, a 1 in 100-year return period for maximum instantaneous discharge is appropriate for the culvert designs in this project. Highway 8 is classified as an Arterial Road with no natural watercourse. Additionally, given the sizes of the existing culverts along the corridor, it is not expected that the proposed culverts will have a span greater than 3 m.

2.3.2. Runoff Coefficients (C)

The runoff coefficients for peak flow calculations were calculated based on the Transportation Association of Canada (TAC) Drainage Manual Volume 1 (1982), Table 2.4.1-2.4.3¹.

The runoff coefficients from the TAC Drainage Manual are based on two parameters: soil description and land use. According to the BC soil map, the soil within Project E is well-drained loamy sand, and the land use selected for the calculations is pasture. Table 2-2 summarizes the runoff coefficients calculated based on the TAC Drainage Manual.

Table 2-2 Runoff Coefficients Per TAC Drainage Manual

| Catchment ID | Soil Description | Land Use ¹ | Runoff Coefficient less than 25-year | Runoff Coefficient for 25-year | Runoff Coefficient for 50-year | Runoff Coefficient for 100-year ² |
|----------------|------------------|-----------------------|--------------------------------------|--------------------------------|--------------------------------|--|
| Catchment - 16 | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |
| Catchment - 17 | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |

¹ RTAC Drainage Manual Volume 1 (1982), Table 2.4.1, Page 2.22.

| Catchment ID | Soil Description | Land Use ¹ | Runoff Coefficient less than 25-year | Runoff Coefficient for 25-year | Runoff Coefficient for 50-year | Runoff Coefficient for 100-year ² |
|------------------------------|------------------|-----------------------|--------------------------------------|--------------------------------|--------------------------------|--|
| Catchment – 18-1 East | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |
| Catchment – 18-2 West | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |
| Catchment – 19 - East | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |
| Catchment 19 – 2 West | Loamy Sand | Pasture | 0.25 | 0.28 | 0.30 | 0.31 |

Note: 1. Pasture is used to consider that trees do not cover most catchment areas.
2. The runoff coefficients included a 10% increase to consider the 25-year storm events, a 20% increase to consider the 50-year storm events, and a 25% increase to consider the 100-year storm events.²

The runoff coefficients listed in **Error! Reference source not found.** are for coastal-type basins. For interior drainage basins where the critical runoff events are generally a result of summer rainstorms, the runoff coefficients can be selected from the TAC Drainage Manual. Highway 8 is in interior BC, so runoff coefficients calculated based on the TAC Drainage Manual (in Table 2-2) are selected for the storm runoff calculations for this project.

2.3.3. Time of Concentration (TC)

The time of concentration for each catchment area was calculated using the following four methods:

1. Kirpich Formula
2. Water Management Method
3. Hathaway Formula
4. Bransby Williams Formula

The following subsections provide a brief overview of these methods.

Kirpich Formula

This method uses the following equation to determine the time of concentration in natural basins with well-defined channels, overland flow on bare earth, or mowed grassed roadside channels:

$$t_c = \frac{0.00032L^{0.77}}{S^{0.385}}$$

Where:

t_c is the time of concentration, hr

L is the total stream length, m

S is the average slope, m/m

² RTAC Drainage Manual Volume 1 (1982), Table 2.4.1, Page 2.22.

Water Management Method

This method was developed by the Ministry of Environment and Parks and is limited to catchment areas up to 10 km². As such, it applies to this project. The time of concentration in this method primarily depends on the slope and area of each catchment. The MoE defines the basin slopes as follows:

- Flat approximately 0% slope
- Rolling approximately 1% slope
- Moderate approximately 2.5% slope
- Steep greater than 10% slope

Figure 2.9 shows the chart from Figure 1020.B of the BC Supplement to TAC Geometric Design Guide, which is used to check the time of concentration.

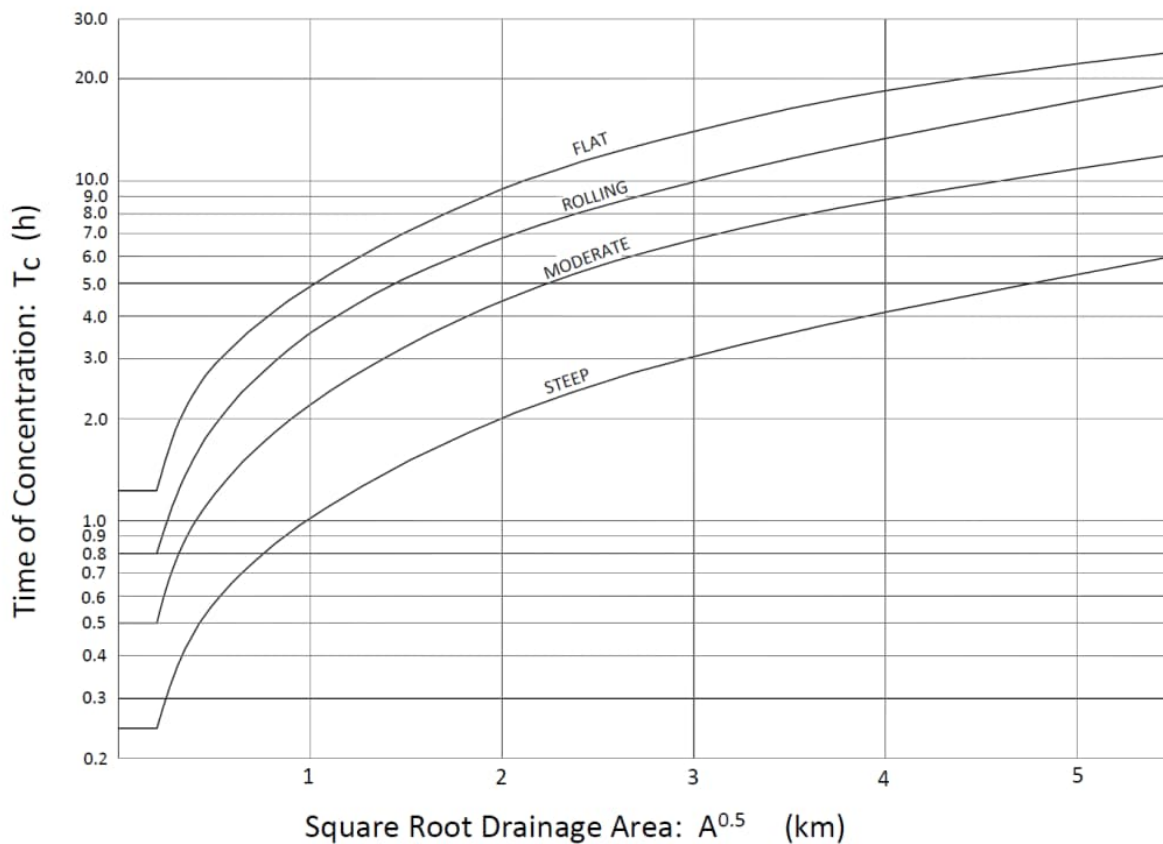


Figure 2.9 Chart for Water Management Method

Hathaway Formula

For areas such as small urban or agriculture catchments or small interior basins with light forest, the following equation can be used to determine the time of concentration:

$$t_c = \frac{(rL)^{0.467}}{1.65 S^{0.234}}$$

Where:

t_c is the time of concentration, hr

L is the total stream length, km

S is the average slope, m/m

r is the roughness coefficient (provided on Page 1020-5 of the BC Supplement to TAC)

For the roughness coefficient, AECOM selected a value of 0.7, corresponding to “Coniferous Timber Land.”

Bransby Williams Formula

The following equation is used to calculate the time of concentration in this method:

$$t_c = 0.605 \frac{L}{A^{0.1} S^{0.2}}$$

Where

t_c is the time of concentration, hr

L is the total stream length, km

S is the average slope, m/m

A is the catchment area, km²

Selecting Time of Concentration

The Hathaway Method applies to small interior basins with light forests. All the catchments within Project E are small interior basins with light forests, so the results from the Hathaway Method were primarily applied. Also, the time of concentration calculated using the Water Management Method for Catchment – 16, Catchment – 17 and Catchment – 19 matches those calculated by the Hathaway Method. However, it was found that the Hathaway Method underestimated the time of concentration for the larger catchments (Catchment – 18-1 East). For this larger catchment, the time of concentration provided by the Water Management Method was used. The Kirpich Method is used for natural basins with well-defined channels, and the Bransby-Williams Method is commonly used for catchments with runoff coefficients larger than 0.4. It was found that the results from these methods were too conservative. Therefore, the results from the Hathaway Method were selected for Catchment – 16, Catchment – 17, Catchment – 18-2 West and the whole Catchment - 19. The result from the Water Management Method was chosen for Catchment – 18-1 East.

Table 2-3 is a summary of the calculated time of concentration and the selected time of concentration for peak flow determination.

Table 2-3 Summary of Time of Concentration Selection

| Catchment ID | Hathaway Method (hr) | Water Management Method (hr) | Kirpich Method ¹ (hr) | Bransby Williams Method (hr) | Selected Time of Concentration (hr) |
|-----------------------|-------------------------|---------------------------------|-------------------------------------|---------------------------------|--|
| Catchment - 16 | 0.71 | 0.65 | 0.22 | 0.41 | 0.71 |

| Catchment ID | Hathaway Method (hr) | Water Management Method (hr) | Kirpich Method ¹ (hr) | Bransby Williams Method (hr) | Selected Time of Concentration (hr) |
|------------------------|-------------------------|---------------------------------|-------------------------------------|---------------------------------|--|
| Catchment - 17 | 0.69 | 0.70 | 0.21 | 0.39 | 0.69 |
| Catchment – 18-1 East | 2.00 | 2.15 | 1.23 | 2.13 | 2.15 |
| Catchment – 18-2 West | 0.80 | 0.80 | 0.27 | 0.50 | 0.80 |
| Catchment – 19-1 East | 0.56 | 0.45 | 0.15 | 0.31 | 0.56 |
| Catchment – 19 -2 West | 0.62 | 0.50 | 0.18 | 0.35 | 0.62 |

Note: 1. For overland flow on grassed surfaces, the time of concentration results from the Kirpich Method are multiplied by 2³.

2.4. Precipitation Data

Intensity Duration Frequency (IDF) curves were utilized to determine the rainfall intensities for the project catchment area. The closest rain gauge station with over 10 years of recorded data is:

- ID #1114741 – Lytton, 21 years of recorded data, 1970 to 1991

Table 2-4 shows the current rainfall intensities and interpolation equation coefficients for station ID #1114741.

Table 2-4 Lytton Rain Gauge Station (ID#1114741) Current IDF Data

| Duration | Return Period | | | | | | |
|-----------------------|----------------|--------|---------|---------|---------|----------|--------|
| | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year | |
| 5-min. | 18 | 24.2 | 28.4 | 33.6 | 37.5 | 41.3 | |
| 10-min. | 13.5 | 19.3 | 23.2 | 28 | 31.7 | 35.3 | |
| 15-min. | 11 | 15.9 | 19.1 | 23.2 | 26.2 | 29.2 | |
| 30-min. | 8.5 | 12.1 | 14.4 | 17.4 | 19.6 | 21.8 | |
| 1-hour | 6.7 | 8.9 | 10.4 | 12.3 | 13.7 | 15.1 | |
| 2-hour | 5.3 | 6.9 | 8 | 9.4 | 10.4 | 11.4 | |
| 6-hour | 3.4 | 4.3 | 4.8 | 5.5 | 6.1 | 6.6 | |
| 12-hour | 2.2 | 2.8 | 3.2 | 3.7 | 4.1 | 4.4 | |
| 24-hour | 1.3 | 1.7 | 1.9 | 2.3 | 2.5 | 2.7 | |
| Equation Coefficients | A | 6.4 | 8.6 | 10 | 11.9 | 13.3 | 14.6 |
| | B | -0.435 | -0.456 | -0.465 | -0.473 | -0.478 | -0.482 |
| | t ₀ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

The coefficients in the tables above are used in the following equation:

$$i \left(\frac{mm}{hr} \right) = A * (t + t_0)^B$$

³ BC Supplement to TAC, section 1020.04

2.4.1. Climate Change Adjusted Future Rainfall Intensities

As of March 2019, MoTT provided consultants with Technical Circular T-04/19 to outline climate change adaptation considerations in engineering design for BC Ministry of Transportation and Transit projects. The purpose of the technical circular is to engage consultants in considering climate change and extreme weather events and determining how the design can reasonably be adapted to increase resiliency under these events.

At the 50% detailed design stage, AECOM used the MoTT-accepted IDF CC Tool 7.5, developed by the Western University of Ontario. In this tool, AECOM selected the PCIC—Bias Corrected (CMIP6) model and the SSP5.85 scenario, representing the upper boundary of the range of climate change scenarios. Table 2-5 summarizes the climate change scenario rainfall intensity estimates for the 2-year to 100-year return periods using the IDF CC Tool.

Table 2-5 Lytton Rain Gauge Station (ID#1114741) Year 2100 IDF Data

| Duration | Return Period | | | | | | |
|------------------------------|----------------------|--------|---------|---------|---------|----------|--------|
| | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year | |
| 5-min. | 19.56 | 26.58 | 32.34 | 41.19 | 49.24 | 58.85 | |
| 10-min. | 14.17 | 19.06 | 23.74 | 32.62 | 41.95 | 53 | |
| 15-min. | 11.69 | 15.09 | 18.51 | 25.32 | 33.1 | 42.06 | |
| 30-min. | 9.22 | 12.42 | 15.18 | 19.85 | 24.34 | 29.65 | |
| 1-hour | 7.3 | 9.78 | 11.78 | 14.82 | 17.54 | 20.79 | |
| 2-hour | 5.94 | 8.11 | 9.65 | 11.49 | 12.96 | 14.39 | |
| 6-hour | 3.87 | 5.02 | 5.82 | 6.81 | 7.6 | 8.34 | |
| 12-hour | 2.58 | 3.42 | 3.86 | 4.32 | 4.6 | 4.84 | |
| 24-hour | 1.56 | 2.08 | 2.35 | 2.63 | 2.8 | 2.94 | |
| Equation Coefficients | A | 7.5 | 9.9 | 12.1 | 15.8 | 20.9 | 23.4 |
| | B | -0.454 | -0.450 | -0.479 | -0.535 | -0.619 | -0.635 |
| | t₀ | 0.061 | 0.052 | 0.072 | 0.102 | 0.194 | 0.143 |

Table 2-6 compares the present-day and 2100 climate change scenario intensities for a 100-year storm and summarizes the average increase in precipitation.

Table 2-6 Comparison of 100-year Rainfall Data between Current and Future (2100) Scenarios

| Duration | Current 100 year | 2100 Climate-Adjusted 100-year | % Change |
|----------------|------------------|--------------------------------|----------|
| 5-min. | 41.3 | 58.85 | 42.49% |
| 10-min. | 35.3 | 53 | 50.14% |
| 15-min. | 29.2 | 42.06 | 44.04% |
| 30-min. | 21.8 | 29.65 | 36.01% |
| 1-hour | 15.1 | 20.79 | 37.68% |
| 2-hour | 11.4 | 14.39 | 26.23% |
| 6-hour | 6.6 | 8.34 | 26.36% |
| 12-hour | 4.4 | 4.84 | 10.00% |

| Duration | Current 100 year | 2100 Climate-Adjusted 100-year | % Change |
|-------------------------|------------------|--------------------------------|----------|
| 24-hour | 2.7 | 2.94 | 8.89% |
| Average % Change | | | 31.32% |

The average percentage of change from the IDF CC Tool is similar to the recommended percentage (30%) in the Highway 8 Drainage Design Criteria⁴ Therefore, a 30% increase for climate change was applied to all return periods and durations, aligning with the approach taken throughout the corridor.

2.5. Peak Design Flows

Since the project's drainage areas are within rural watersheds and are smaller than 10 km², AECOM used the Rational Method to calculate the peak design flows. The Rational Method formula is defined as follows:

$$Q_p = \frac{CiA}{360}$$

The total flow volumes were also calculated using the Rational Method by modifying the formula above. The modified formula is as follows:

$$V = 10 * CiAt_c$$

Where:

Q_p is the peak flow (m³/s)

V is the total flow volume (m³)

C is the runoff coefficient

i is the rainfall intensity (mm/hr)

A is the drainage area (ha)

t_c is the time of concentration (hr)

Table 2-7 summarises the current peak flow rates and volumes

Table 2-7: Summary of Current Storm Peak Flow Rates (2yr to 100 yr) and Runoff Volumes

| Catchment ID | 2-Year Peak Flow Rate (m ³ /s) | 2-Year Total Runoff Volume (m ³) | 5-Year Peak Flow Rate (m ³ /s) | 5-Year Total Runoff Volume (m ³) | 10-Year Peak Flow Rate (m ³ /s) | 10-Year Total Runoff Volume (m ³) | 25-Year Peak Flow Rate (m ³ /s) | 25-Year Total Runoff Volume (m ³) | 50-Year Peak Flow Rate (m ³ /s) | 50-Year Total Runoff Volume (m ³) | 100-Year Peak Flow Rate (m ³ /s) | 100-Year Total Runoff Volume (m ³) |
|------------------------------|---|--|---|--|--|---|--|---|--|---|---|--|
| Catchment - 16 | 0.181 | 461 | 0.245 | 625 | 0.285 | 728 | 0.375 | 956 | 0.457 | 1168 | 0.524 | 1337 |
| Catchment - 17 | 0.213 | 526 | 0.289 | 713 | 0.337 | 832 | 0.442 | 1092 | 0.540 | 1334 | 0.619 | 1528 |
| Catchment - 18-1 East | 1.539 | 11915 | 2.036 | 15756 | 2.351 | 18195 | 3.058 | 23672 | 3.715 | 28751 | 4.235 | 32776 |

⁴ Highway 8 – Drainage Design Criteria | Prepared for Ministry of Transportation and Infrastructure -McElhanney-Associated JV

| Catchment ID | 2-Year Peak Flow Rate (m ³ /s) | 2-Year Total Runoff Volume (m ³) | 5-Year Peak Flow Rate (m ³ /s) | 5-Year Total Runoff Volume (m ³) | 10-Year Peak Flow Rate (m ³ /s) | 10-Year Total Runoff Volume (m ³) | 25-Year Peak Flow Rate (m ³ /s) | 25-Year Total Runoff Volume (m ³) | 50-Year Peak Flow Rate (m ³ /s) | 50-Year Total Runoff Volume (m ³) | 100-Year Peak Flow Rate (m ³ /s) | 100-Year Total Runoff Volume (m ³) |
|------------------------------|---|--|---|--|--|---|--|---|--|---|---|--|
| Catchment – 18-2 West | 0.364 | 1049 | 0.492 | 1416 | 0.573 | 1649 | 0.751 | 2163 | 0.917 | 2640 | 1.049 | 3022 |
| Catchment – 19-1 East | 0.062 | 125 | 0.085 | 170 | 0.099 | 199 | 0.130 | 262.00 | 0.159 | 320 | 0.182 | 367 |
| Catchment – 19-2 West | 0.096 | 213 | 0.131 | 290 | 0.153 | 338 | 0.201 | 445 | 0.245 | 543 | 0.281 | 623 |

Table 2-8 summarises the climate-adjusted peak flow rates and volumes.

Table 2-8 Summary of 2100 Storm Peak Flow Rates (2yr to 100 yr) and Runoff Volumes

| Catchment ID | 2100 2-Year Peak Flow Rate (m ³ /s) | 2100 2-Year Total Runoff Volume (m ³) | 2100 5-Year Peak Flow Rate (m ³ /s) | 2100 5-Year Total Runoff Volume (m ³) | 2100 10-Year Peak Flow Rate (m ³ /s) | 2100 10-Year Total Runoff Volume (m ³) | 2100 25-Year Peak Flow Rate (m ³ /s) | 2100 25-Year Total Runoff Volume (m ³) | 2100 50-Year Peak Flow Rate (m ³ /s) | 2100 50-Year Total Runoff Volume (m ³) | 2100 100-Year Peak Flow Rate (m ³ /s) | 2100 100-Year Total Runoff Volume (m ³) |
|------------------------------|--|---|--|---|---|--|---|--|---|--|--|---|
| Catchment - 16 | 0.235 | 600 | 0.318 | 812 | 0.371 | 947 | 0.487 | 1243 | 0.595 | 1518 | 0.681 | 1738 |
| Catchment - 17 | 0.277 | 684 | 0.375 | 927 | 0.438 | 1082 | 0.575 | 1420 | 0.703 | 1735 | 0.805 | 1987 |
| Catchment – 18-1 East | 2.001 | 15490 | 2.646 | 20482 | 3.056 | 23653 | 3.976 | 30773 | 4.829 | 37377 | 5.505 | 42609 |
| Catchment – 18-2 West | 0.473 | 1363 | 0.639 | 1840 | 0.745 | 2144 | 0.976 | 2811 | 1.192 | 3432 | 1.364 | 3928 |
| Catchment – 19-1 East | 0.081 | 163 | 0.110 | 222 | 0.129 | 259 | 0.169 | 341 | 0.207 | 416 | 0.237 | 477 |
| Catchment – 19-2 West | 0.125 | 277 | 0.170 | 377 | 0.198 | 440 | 0.261 | 578 | 0.319 | 706 | 0.365 | 809 |

2.6. Comparison Methods

According to the BC Supplement to TAC, Section 1020.06, although the Rational Method is suitable for rural watersheds up to 10 km², it may become less reliable at the upper half of the rural watershed size ranges (from 5 km² to 10 km²), and other methods should be used for comparison, where feasible, to confirm the order of magnitude for the design flow. For Project E, there is no catchment with a size larger than 5 km². However, Catchment – 18-1 East has a total area of 4.83 km², close to 5 km². To check the reliability of the design flow for this catchment, AECOM has used two other methods: the SCS Unit Hydrograph Method and the Regional Frequency Analysis. The details are discussed in the subsections below.

2.6.1. SCS Unit Hydrograph Method

The SCS Unit Hydrograph Method is a method that is recommended in the BC Supplement to TAC, Section 1020.06, for drainage areas less than 10 km². This method establishes a relationship between rainfall, retention and runoff. The retention or potential storage in the soil is represented by the selected curve number (CN). The CN is a function of soil type, ground cover, and Antecedent Moisture Condition (AMC).

For Catchment – 18-1 East, the soil type is within the hydrological soil group B, and the land cover is poor-condition pasture. AECOM selected the AMC III category to consider saturated conditions during the design storm event. So, the CN selected for Catchment – 18-1 East is 91. AECOM also recalculated the time of concentration for the SCS Unit Hydrograph calculations using the Lag Method, which includes the CN, to consider the soil storage effect on the time of concentration. The current 100-year peak flow rate from the SCS Unit Hydrograph Method is 4.178 m³/s. According to Table 2-7, the current 100-year peak flow rate from the Rational Method is 4.235 m³/s.

AECOM only tested the current 100-year peak flow rate for Catchment – 18-1 East for comparison purposes. The result shows that the peak flow rate calculated by the SCS Unit Hydrograph Method is close to that from the Rational Method calculations.

2.6.2. Regional Frequency Analysis

In addition to the SCS Unit Hydrograph Method, AECOM also considered the Regional Frequency Analysis. This method uses a statistical approach to estimate the storm flows of an ungauged watershed based on the relationships of available flow data and drainage areas of corresponding gauged watersheds. The accuracy of this method depends on similarities of the hydrological characteristics (such as watershed size, land cover, soil type, precipitation pattern, runoff pattern, location, and attenuation inside the watershed) between the reference watersheds and the target watershed. Based on this, AECOM selected four (4) Water Survey of Canada gauging stations for the Regional Frequency Analysis.

- Chataway Creek near the Mouth (08LG066)
- Guichon Creek above Tunkwa Lake Diversion (08LG056)
- Bethsaida Creek above Highland Valley Road (08LG055)
- Witches Brook near Merritt (08LG009)

The results from the Regional Frequency Analysis are lower than those from the Rational Method. However, the watersheds reporting to these gauging stations are much larger than Catchment – 18-1 East (the smallest watershed area is more than three times compared to Catchment – 18-1 East), and there are no nearby gauging stations with the smaller watershed areas. Using larger watershed flows for regional frequency analysis on a smaller watershed is inaccurate because the hydrologic characteristics of a watershed significantly change with its size, leading to different runoff patterns, peak flow magnitudes, and time of concentration, meaning a larger basin's flow data cannot accurately represent the flood behavior of a smaller basin, even if they are geographically close; essentially, a larger watershed will typically have a more attenuated peak flow due to increased storage capacity, while a smaller watershed will experience quicker runoff and higher peak flows per unit area.

Also, the BC Supplement to TAC, Section 1020.06, only recommends the Regional Frequency Analysis for drainage areas larger than 10 km².

Therefore, AECOM did not consider the Regional Frequency Analysis results sufficiently comparable to Catchment – 18-1 East.

3. Proposed Design and Risk Discussion

3.1. Site 16

The 100-year peak flow rate and total flow volume under the 2100 climate change scenario are 0.681 m³/s and 1738 m³, respectively. The existing Site 16 highway segment does not have a culvert crossing to release the storm flow to the Nicola River, so there is a risk of highway overtopping and pavement structure washout during 100-year design storm events. It should be noted that without a culvert to discharge the storm runoff to the river, the more frequent storm events may also result in highway overtopping and pavement structure washout in Site 16.

However, according to the BC Soil Map information, the soil within Site 16 is rapidly-drained sandy loam, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). Although there are no existing storage areas in Site 16, according to the site survey in May 2024, the soil infiltration will promote drainage for this site.

Also, there was no drainage in the existing condition, and no record showed this segment of Highway 8 experienced pavement washout due to drainage from the mountainside. This history suggests a low probability of washout during frequent storm events, with an estimated likelihood of 0.02 - 0.007 annually based on EGBC risk assessment.⁵

Highway 8 is a Rural Arterial Road primarily serving local traffic with low traffic volumes. Key considerations include:

- Road Closures: Temporary closures for repairs are acceptable, given the minimal impact on traffic flow and volumes. The Highway DCS design proposed a SADT number of 700.
- Repair Costs: If overtopping and pavement damage occur, less than \$100,000 in repair costs per washout are expected, with repairs completed one week after the event. The repair cost for this Rural Arterial Road is lower than for highways with high traffic volumes. Therefore, the overall risk of not installing a culvert at Site 16 is acceptable.

Archaeological and Environmental Constraints

Furthermore, the Ministry confirmed that Site 16 has a known archaeological site adjacent to the highway, and excavation or any disturbance to existing ditches within this site will have adverse impacts. Also, the atmospheric river event did not impact the north side of the existing highway.

To justify the risk, AECOM estimated the consequence of highway overtopping and pavement washout at Site 16 based on the EGBC Flood Risk Matrix, assigning the following ratings:

Table 3-1 Site 16 Risk Rating

| Risk Category | Description | Rating |
|---------------------------------|--|----------------|
| Safety (Number of Lives) | Minimal safety risks due to rural nature and low traffic volume. | 1 (Negligible) |
| Economic | Estimated repair cost of <\$100,000 per event, manageable within one week of occurrence. | 3 (Moderate) |
| Social & Cultural | Minor disruptions to connectivity; road closures acceptable. | 2 (Minor) |
| Intangibles | Slight inconvenience with no long-term impacts. | 2 (Minor) |
| Ecological | Avoids disturbance to archaeological and natural resources. | 2 (Minor) |

⁵ Engineers and Geoscientists British Columbia (EGBC). (2018). Legislated flood assessments in a changing climate in BC (Version 2.1). Engineers and Geoscientists British Columbia

Note: The detailed risk assessment matrix for Site 16 is in Appendix B.

Based on the ratings, AECOM ranks Site 16 in the Low Risk (L) category, meaning no immediate risk reduction measures are necessary. Therefore, AECOM's assessment of the site, guided by the EGBC Flood Risk Matrix, supports maintaining existing conditions without adding new culverts.

It should be noted that the soil's hydraulic conductivity or infiltration rate is a dynamic parameter that may change over time due to the soil's moisture content, groundwater level, compaction, the non-uniform ditch surface materials (coarse rock to silty sand) from the response phase construction, and the gradual accumulation of finer-grained soil particles (adjacent weathering) and organics. Therefore, ongoing monitoring of the drainage is necessary.

The project accepts this condition with the intent of implementing ongoing monitoring of the area, particularly during and after extreme rain events. If the monitoring reports a high frequency of overtopping and pavement washout or unacceptable consequences, the option of adding new culverts may be considered, and additional analyses will be needed to design the new culverts.

3.2. Site 17

The 100-year peak flow rate and total flow volume for Site 17 under the year 2100 climate change modelling scenario are 0.805 m³/s and 1987 m³, respectively. The existing Site 17 highway segment doesn't have a culvert crossing to release the storm flow to the Nicola River, so there is a risk of highway overtopping and damage to the pavement structure during the 100-year storm events.

However, the project proposes using the area northeast of Highway 8 as an infiltration basin and accepting the risk of overtopping and pavement structure washout during the 100-year storm events. The total available basin area is approximately 7050 m².

According to the BC Soil Map information, the soil within Site 17 is rapidly drained sandy loam, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). Therefore, the total infiltrated depth during the design storm event (assuming the storm's duration is twice the time of concentration) will be 49.47 mm. Based on the stage-storage curve generated from the combined existing survey and proposed highway surface, the basin area needs to be 4078 m² to detain and infiltrate the 100-year storm runoff. The estimated 100-year water surface elevation is 264.3 m, 1.2 m below the lowest bottom of the pavement structure within the Site 17 highway segment (considering 400 mm pavement structure). This required basin area is smaller than the total area available for detention and infiltration. Therefore, by utilizing the area northeast of Highway 8 for infiltration, the risk of highway overtopping and pavement washout is low.

It should be noted that the available area for detention and infiltration is not designed as an infiltration basin, so the stage-storage information generated based on the combined survey and road design surface may vary due to any future changes in the road design.

In the response phase, the road subgrade in Site 17 was reconstructed with coarse materials such as gravel. The infiltration rate of these materials can be considered higher than that of the pre-event sandy loam soil from the BC Soil Map. However, the soil's hydraulic conductivity or infiltration rate is a dynamic parameter that may change over time due to the soil's moisture content, groundwater level, compaction, the non-uniform ditch surface materials (coarse rock to silty sand) from the response phase construction, and the gradual accumulation of finer-grained soil particles (adjacent weathering) and organics. Therefore, the infiltration analysis in this memo still used the parameters from the BC Soil Map.

The project accepts this condition with the intent of implementing ongoing monitoring of the area, particularly during and after extreme rain events. If the monitoring reports a high frequency of overtopping and pavement washout or unacceptable consequences, the option of adding new culverts may be considered, and additional analyses will be needed to design the new culverts.

3.3. Site 18

According to the hydrological analysis, the drainage catchment area reporting to Site 18 is 5.58 km². The design of the highway ditches (on the mountainside) for Site 18 follows the existing pattern with two low points. Therefore, Catchment - 18 was divided into two sub-catchments, 18-1 East and 18-2 West, to follow the highway ditch design.

The west sub-catchment (18-2) covers a 0.74 km² drainage area that drains to a depression area around Station 1801+70, which offers detention storage. Under the 100-year storm event with climate change, this west sub-catchment is estimated to contribute a 100-year peak flow of 1.364 m³/s with a total runoff volume of 3928 m³. The depression area has a total storage volume of 4040 m³ below the highway pavement structure. According to the BC Soil Map information, the soil within Site 18 is rapidly drained sandy loam, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). Therefore, with the depression area detaining and infiltrating the storm runoff from the west sub-catchment 18-2, the risk of highway overtopping and pavement washout at this location is low.

For the west sub-catchment (18-2), the project accepts using the depression area to detain and infiltrate the stormwater from the east sub-catchment, with the intent of implementing ongoing monitoring of the area, particularly during and after extreme rain events. If the monitoring reports a high frequency of overtopping and pavement washout or unacceptable consequences, the option of adding new culverts may be considered, and additional analyses will be needed to design the new culverts.

The east sub-catchment (18-1) covers a 4.83 km² drainage area. With climate change, this sub-catchment will generate a peak flow rate of 5.505 m³/s and a total flow volume of 42609 m³ (a detailed summary of peak flow rates and total flow volumes under different return periods are in Table 2-8 and Table 2-9). According to the aerial photos, the survey photos and the stream network from iMap BC, a gully runs through this sub-catchment and outlet at the low point (approximately at Station 1803+10). In the response phase, this highway segment lacks a culvert crossing to release the large storm flow from the gully to the Nicola River.

According to the BC Soil Map information, the soil within Site 18 is rapidly drained sandy loam, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). An eroded area can provide detention storage around the low point where the gully outlets. This eroded area has a total storage volume of 5959 m³ below the highway pavement structure to detain and infiltrate the storm runoff. However, considering the size of the catchment area, projected peak flows, and the high runoff volumes, the storage volume and the infiltration are insufficient.

Therefore, keeping Site 18-1 East in its existing condition may result in undesirable outcomes that are likely to happen with an estimated likelihood of **0.07 - 0.02** annually based on EGBC risk assessment probability ranges.⁶

If no action is taken and this site is kept in its existing condition, the following is likely to happen:

- Unlike Site 16, where smaller flows allow for manageable risks, the larger catchment area and higher peak flows at Site 18-1 make overtopping and washouts more frequent, requiring costly, repetitive repairs.
- Frequent washouts would necessitate road closures, leading to significant traffic disruptions and increased risks for motorists during storm events.
- Repair costs for repeated washouts would escalate quickly, far exceeding the one-time investment in proper culvert infrastructure

⁶ Engineers and Geoscientists British Columbia (EGBC). (2018). *Legislated flood assessments in a changing climate in BC (Version 2.1)*. Engineers and Geoscientists British Columbia

Similarly to Site 16, the risk of highway overtopping and pavement washout at Site 18-1 East was estimated using the EGBC Flood Risk Matrix, as shown in Table 3-2.

Table 3-2 Site 18-1 East Risk Rating

| Risk Category | Description | Rating |
|------------------------------|---|--------------|
| Safety | Frequent overtopping poses safety risks for motorists and road users. | 3 (Moderate) |
| Economic | High cumulative repair costs and indirect economic impacts from closures. Likely to take several weeks to complete repairs. Costs predicted between \$100,000 and \$1,000,000 | 4 (Major) |
| Social & Cultural | Significant disruptions to connectivity due to repeated road closures. | 3 (Moderate) |
| Intangibles | Prolonged inconvenience for users and reduced reliability of critical infrastructure. | 3 (Moderate) |
| Ecological | Proper culvert installation minimizes environmental impacts from uncontrolled runoff. | 2 (Minor) |

Note: The detailed risk assessment matrix for Site 18 is in Appendix C.

Based on the ratings and predicted frequency of an undesirable outcome, AECOM estimates Site 18 as the High Risk (H) category if no action is taken, meaning the risk is unacceptable. A medium-term risk reduction plan must be developed and implemented in a reasonable (<5 years) time frame; planning should begin as soon as feasible.

To mitigate this drainage risk, two 1500 mm diameter CSP culverts are proposed to be sufficient for the storm runoff from a 100-year event with climate change. Another option of proposing a box culvert was also investigated. That option requires a 2400 mm x 1500 mm concrete box culvert. After comparing these two options, it was determined that the two CSP culverts are preferred over a large concrete box culvert for both economy and constructability. The tables below summarize the HY-8 culvert modelling results for both options.

Table 3-3 Summary of Culvert Hydraulic Analysis for Site 18-1 East – Current 1-100 yr flow

| Option ID | Material | Number of Barrel | Rise x Span (Diameter) (mm) | Length (m) | Slope (%) | Current Peak Flow Rate (m ³ /s) | HW (m) | HW/D | Pass/Fail |
|-----------------|----------|------------------|-----------------------------|------------|-----------|--|--------|------|-----------|
| Option 1 | CSP | 2 | 1400 | 28.4 | 2.0 | 4.235 | 1.21 | 0.86 | Pass |
| Option 2 | CONC | 1 | 1500x1800 | 28.4 | 2.0 | 4.235 | 1.38 | 0.92 | Pass |

Table 3-4 Summary of Culvert Hydraulic Analyses for Site 18-1 East – Climate adjusted 1-100 yr flow

| Option ID | Material | Number of Barrel | Rise x Span (Diameter) (mm) | Length (m) | Slope (%) | 2100 Peak Flow Rate (m ³ /s) | HW (2100) (m) | HW/D (2100) | Pass/Fail |
|-----------------|----------|------------------|-----------------------------|------------|-----------|---|---------------|-------------|-----------|
| Option 1 | CSP | 2 | 1500 | 32.3 | 2.0 | 5.505 | 1.38 | 0.92 | Pass |
| Option 2 | CONC | 1 | 1500x2400 | 32.3 | 2.0 | 5.505 | 1.35 | 0.90 | Pass |

After discussing with the Ministry, AECOM proposes a design variance for Site 18-1, requesting a culvert design to accommodate a 10-year return period flow with headwater lower than the pavement structure instead of the originally recommended 100-year flows with headwater below the top of the culverts.

Compared to the original design, which requires 2 x 1500 mm CSP culverts or a single 2400 mm x 1500 mm box culvert, the design variance proposes a 1200mm CSP culvert that is more cost-effective with a low risk under larger storm events. It should be noted that the variance request compares the 10-year and 100-year return period events for the scenario with the culvert option, whereas the risk rating presented in this memo reflects the scenario where the site is kept in its existing condition with no culvert. The design variance is detailed in Appendix A.

To prevent fish from entering the culvert and getting stranded in the ditch on the mountainside, the culvert inlet and outlet have been set at 256.25 m and 255.76 m, respectively, to be above the frequent 2-year river water level. AECOM also proposed a duckbill check valve with an end wall at the culvert outlet to prevent water and fish from entering the culvert and upstream when the river water level rises above the 2-year level. The option of flattening the ditch on the mountainside has also been investigated. However, this option is not deemed feasible because the depression area at Station 1801+70 is lower than the ditch bottom at the culvert inlet, and fish will still be stranded in the depression area.

3.4. Site 19

The total catchment area for Site 19 is approximately 0.28 km². A preliminary hydrological analysis indicated a 100-year storm (with climate change) peak flow of 0.602 m³/s and a total runoff volume of 1,287 m³. Catchment - 19 was subdivided into east and west sub-catchments based on topography, the existing culvert, and the notable depression area on the east side, providing natural detention potential. Table 3-5 summarizes storm peak flow rates and total flow volumes of both sub-catchments.

Table 3-5: Site 19 East and West Catchment Analysis

| Catchment ID | Catchment Area (km ²) | Stream Length (km) | Average Channel Slope (%) | Current 100-Year Peak Flow Rate (m ³ /s) | Current 100-Year Total Runoff Volume (m ³) | 2100 Climate Adjusted 100-Year Peak Flow Rate (m ³ /s) | 2100 Climate Adjusted 100-Year Total Runoff Volume (m ³) |
|------------------------------|--------------------------------------|-----------------------|------------------------------|--|---|--|---|
| Catchment – 19-1 EAST | 0.11 | 0.95 | 62.1 | 0.182 | 367 | 0.237 | 477 |
| Catchment – 19-2 WEST | 0.18 | 1.09 | 53.9 | 0.281 | 623 | 0.365 | 809 |

The east sub-catchment (19-1) covers 0.11 km². The downstream end of the east sub-catchment contains a natural depression, offering detention storage. Under the 100-year storm event with climate change, this east sub-catchment is estimated to contribute a 100-year peak flow of 0.237 m³/s with a total runoff volume of 477 m³. The bottom of the depression area was noted at 248.6 m, and to collect 477 m³ of water, the water surface will reach 251.1 m, just below the pavement structure. According to the BC Soil Map information, the soil within Site 19 is rapidly-drained loamy sand, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). Over time, the stored runoff is expected to infiltrate, reducing direct discharge to the culvert.

For the east sub-catchment 19-1, the project accepts using the depression area to detain and infiltrate the stormwater from the east sub-catchment, with the intent of implementing ongoing monitoring of the area, particularly during and after extreme rain events. If the monitoring reports a high frequency of overtopping and pavement washout or unacceptable consequences, the option of adding new culverts may be considered, and additional analyses will be needed to design the new culverts.

The west sub-catchment (19-2) covers 0.18 km². Hydrological analysis indicates that under the 100-year storm event with climate change, the west sub-catchment generates a peak flow of 0.365 m³/s. Runoff from the west sub-catchment (19-2) is conveyed to an existing 600 mm diameter CSP culvert. HY-8 hydraulic models assessed its performance under current and climate-adjusted 100-year peak flows. Tables 3-6 and 3-7 present the results.

Table 3-6 Summary of Existing Culvert Analyses for Site 19 West Sub catchment – Current Flow

| Option Description | Material | Number of Barrel | Diameter (mm) | Length (m) | Slope (%) | Peak Flow Rate (m ³ /s) | HW (2100) (m) | HW/D (2100) | Pass/Fail ¹ |
|--------------------|----------|------------------|---------------|------------|-----------|------------------------------------|---------------|-------------|------------------------|
| Ex. Culvert | CSP | 1 | 600 | 19.837 | 0.09 | 0.281 | 0.66 | 1.1 | Fail |

Note 1: Pass/Fail Classification represents the Ministry's HW/D <1 requirement per the BC Supplement to TAC

Table 3-7 Summary of Existing Culvert Analyses for Site 19 West Sub catchment – Climate Adjusted Flow

| Option Description | Material | Number of Barrel | Diameter (mm) | Length (m) | Slope (%) | 2100 Peak Flow Rate (m ³ /s) | HW (2100) (m) | HW/D (2100) | Pass/Fail ¹ |
|--------------------|----------|------------------|---------------|------------|-----------|---|---------------|-------------|------------------------|
| Ex. Culvert | CSP | 1 | 600 | 19.837 | 0.09 | 0.365 | 0.85 | 1.42 | Fail |

Note 1: Pass/Fail Classification represents the Ministry's HW/D <1 requirement per the BC Supplement to TAC

According to the HY-8 hydraulic modelling results, the 600 mm CSP culvert cannot meet the Ministry's headwater requirement under current and climate-adjusted flows. However, the headwater elevation during a 100-year storm event with climate change will still be about 0.78 m lower than the bottom of the pavement structure (assuming the total depth of the pavement structure is 400 mm).

To address the hydraulic requirement issue, two primary alternatives were evaluated:

Option 1 – Maintain Existing Culvert, with inlet and outlet clearing.

- Clear all debris and rock buildup at the inlet and outlet to maintain the existing culvert's intended hydraulic capacity.
- Tables 3-8 and 3-9 show that the 600 mm diameter culvert yields HW/D > 1 under current and climate-adjusted conditions, not meeting the Ministry requirement. However, the HW depth remains 0.78m below the pavement structure.
- Although the headwater will be above the crown of the culvert, the maximum ponding area in the ditch upstream of the culvert will be small. Therefore, the impact of ponding on the surrounding areas will be minor.
- According to the BC Soil Map information, the soil within Site 19 is rapidly-drained loamy sand, which falls into the Hydraulic Soil Group B as per the National Engineering Handbook, Part 630 Hydrology by the United States Department of Agriculture (USDS). The hydraulic conductivity of this soil type is 36.068 mm/hour (1.42 inch/hour). The infiltration within the ponding area will promote drainage.

Option 2 – Install a New Upsized Culvert

- Replace the 600 mm culvert with a 750 mm diameter culvert with the same slope as the existing culvert (0.09%).
- Tables 3-8 and 3-9 summarize modelling results, demonstrating that under both current and climate-adjusted 100-year storm conditions, the HW/D <1 requirement is satisfied, indicating a Pass.
- Require an additional cost of approximately \$30,000.

Table 3-8 Option 2 Summary Install a New Upsized Culvert Current Peak Flows

| Option Description | Material | Number of Barrel | Diameter (mm) | Length (m) | Slope (%) | Peak Flow Rate (m ³ /s) | HW (2100) (m) | HW/D (2100) | Pass/Fail ¹ |
|-------------------------|----------|------------------|---------------|------------|-----------|------------------------------------|---------------|-------------|------------------------|
| Proposed Culvert | CSP | 1 | 750 | 19.837 | 0.09 | 0.281 | 0.56 | 0.75 | Pass |

Note 1: Pass/Fail Classification represents the Ministry's HW/D <1 requirement per the BC Supplement to TAC

Table 3-9 Option 2 Summary Install a New Upsized Culvert Climate Adjusted Flows

| Option Description | Material | Number of Barrel | Diameter (mm) | Length (m) | Slope (%) | 2100 Peak Flow Rate (m ³ /s) | HW (2100) (m) | HW/D (2100) | Pass/Fail ¹ |
|-------------------------|----------|------------------|---------------|------------|-----------|---|---------------|-------------|------------------------|
| Proposed Culvert | CSP | 1 | 750 | 19.837 | 0.09 | 0.365 | 0.66 | 0.88 | Pass |

Note 1: Pass/Fail Classification represents the Ministry's HW/D <1 requirement per the BC Supplement to TAC

For the west sub-catchment 19-2, although Option 1 does not meet the requirement of HW/D<1, the headwater elevation for Option 1 remains below the pavement structure. The risk of highway overtopping and pavement washout is low. The project will accept Option 1 with the intent of implementing ongoing monitoring of the area, particularly during and after extreme rain events. If the monitoring reports a high frequency of overtopping and pavement washout or unacceptable consequences, the drainage of this site needs to be re-assessed, and Option 2 may be considered.

3.5. Summary of Recommendations & Risks

Table 3-10 below is a summary of recommendations and risks for all four sites.

Table 3-10 Summary of Recommendations & Risks

| Location | Existing Culvert Size (mm) | Design Flow Without Climate Change (m ³ /s) | Culvert Size to Convey Design Flow Without Climate Change (mm) | Design Flow With Climate Change (30% increase) (m ³ /s) | Culvert Size to Convey Design Flow With Climate Change (mm) | Consequence of No Work |
|------------------------------|----------------------------|--|---|--|---|--|
| Site 16 | None | 0.524 | N/A | 0.681 | N/A | Without a culvert, overtopping is unlikely but may occur during 100-year events. Repairs can be managed within a week. There is no existing drainage within this highway segment and no record of pavement washout due to drainage from the mountainside. The overall risk is low. |
| Site 17 | None | 0.619 | N/A | 0.805 | N/A | Without a culvert, overtopping is expected, but the well-drained, loamy sand can accommodate runoff. Monitoring will be needed to ensure sufficient infiltration and address any rising risks. |
| Site 18 -1 | None | 4.235 | Two CSP Culverts (1400 mm each) or 1 Box Culvert (1500 x 1800 mm) | 5.505 | Two CSP Culverts (1500 mm each) or One Concrete Culvert 1500x2400mm | Without culverts, overtopping will occur frequently due to high peak flows. Pavement washouts will require repeated repairs, leading to significant traffic disruptions and higher cumulative costs. |
| Site 18 -2 | None | 1.049 | N/A | 1.364 | N/A | Runoff will continue to infiltrate and detain in the existing natural depression. There is a low risk of flooding or overtopping due to existing detention storage. Monitoring will be needed to ensure sufficient infiltration and address any rising risks. |
| Site 18 -1 (Design Variance) | None | 2.351 | One 1000 mm CSP Culvert | 3.056 | One 1200 mm CSP Culvert | Overtopping will occur during larger storm events, such as the 100-year events. However, the culvert can accommodate more frequent storm events, such as the 10-year events, so the risk is reduced to low. Monitoring of the culvert performance will be needed. |
| Site 19 -1 | None | 0.182 | N/A | 0.237 | N/A | Runoff will continue to infiltrate and detain in the existing natural depression. There is a low risk of flooding or overtopping due to existing detention storage. Monitoring will be needed to ensure sufficient infiltration and address any rising risks. |
| Site 19 -2 | 600 | 0.281 | Keep the existing 600mm CSP culvert | 0.365 | Keep the existing 600mm CSP culvert | The existing culvert does not meet the Ministry's HW/D requirements for current and climate-adjusted flows. However, it can keep the headwater below the pavement structure, and overtopping is unlikely. |

Memo
BC MoTT - Highway 8 Reinstatement

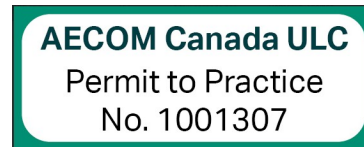
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Appendix A – Design Variance Request – Site 18-1 East Catchment

(See the Design Variance Request Letter included in this package)

Appendix B – Risk Assessment Matrix – Site 16

Site 16 - Leave site in the existing condition

FLOOD RISK EVALUATION

| | | | RISK EVALUATION AND RESPONSE | | | | | | | |
|---|---|-------------------|--|--|--|---|--|--|--|--|
| | | | VH | H | M | L | VL | | | |
| LIKELIHOOD DESCRIPTIONS Likelihood of Undesirable Outcome | | | VH | Very High | Risk is unacceptable short-term (before next flood season); Risk reduction required; long-term Risk reduction plan must be developed and implemented | | | | | |
| | | | H | High | Risk is unacceptable; medium-term Risk reduction plan must be developed and implemented in a reasonable (<5 years) time frame; planning should begin as soon as feasible | | | | | |
| | | | M | Moderate | Risk may be tolerable; more detailed review required; reduce Risk to low where reasonably practicable | | | | | |
| | | | L | Low | Risk is tolerable; continue to monitor if resources allow | | | | | |
| LIKELIHOOD DESCRIPTIONS | | PROBABILITY RANGE | VL | L | M | H | VH | | | |
| Scenario can be expected on average every other year | Very Likely | 0.5 – 0.2 | M | H | H | VH | VH | VH | | |
| Scenario typically occurs on average every 10 years | Likely | 0.2 – 0.07 | L | M | H | H | VH | VH | | |
| Scenario typically occurs on average every 50 years | Moderate | 0.07 – 0.02 | L | L | M | H | H | VH | | |
| Scenario occurs on average every 100 years | Unlikely | 0.02 – 0.007 | VL | L | M | H | H | H | | |
| Scenario occurs on average every 200 years | Very Unlikely | 0.007 – 0.004 | VL | VL | L | L | M | H | | |
| Scenario occurs on average every 500 years | Extremely Unlikely | 0.004 – 0.0013 | VL | VL | VL | L | L | M | | |
| CONSEQUENCE DESCRIPTIONS | INDICES | | 1 | 2 | 3 | 4 | 5 | 6 | | |
| | | | Negligible | Minor | Moderate | Major | Severe | Catastrophic | | |
| | SAFETY (INJURY/LOSS OF LIFE) | | Minor injuries of few individuals | Major injury of 1 person | Major injury of several persons | Single fatality | <10 fatalities | >10 fatalities | | |
| | ECONOMIC (MONETARY LOSSES) | | Negligible; no business interruption; <\$1,000 | Some asset loss; <\$10,000 damages | Serious asset loss; several days business interruption; <\$100,000 | Major asset loss; several weeks business interruption; <\$1 million | Severe asset loss; several months business interruption; <\$10 million | Total loss of asset; 1 year or more business interruption; >\$10 million | | |
| | SOCIAL AND CULTURAL | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Recoverable within months | Long-term (years) loss of social and cultural values | Complete loss of significant social and cultural values | | |
| | INTANGIBLES (PERSONAL SUFFERING) | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Personal hardship; usually recoverable within months | Leaves significant personal hardship for years | Irreparable personal hardship | | |
| | ECOLOGICAL (FLORA AND FAUNA) | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Recoverable within months | Severe species loss | Irreparable species loss | | |

Figure E - 4: Example Risk matrix to determine the relative level of Flood Risk for Proposed Developments.

Appendix C – Risk Assessment Matrix – Site 18-1

Site 18 - Leave site in the existing condition

FLOOD RISK EVALUATION

| | | | RISK EVALUATION AND RESPONSE | | | | | | | |
|---|---|----------------|--|--|--|---|--|--|--|--|
| | | | VH | H | M | L | VL | | | |
| LIKELIHOOD DESCRIPTIONS Likelihood of Undesirable Outcome | | | VH | Very High | Risk is unacceptable short-term (before next flood season); Risk reduction required; long-term Risk reduction plan must be developed and implemented | | | | | |
| | | | H | High | Risk is unacceptable; medium-term Risk reduction plan must be developed and implemented in a reasonable (<5 years) time frame; planning should begin as soon as feasible | | | | | |
| | | | M | Moderate | Risk may be tolerable; more detailed review required; reduce Risk to low where reasonably practicable | | | | | |
| | | | L | Low | Risk is tolerable; continue to monitor if resources allow | | | | | |
| LIKELIHOOD DESCRIPTIONS | PROBABILITY RANGE | | VL | Very Low | Risk is broadly acceptable; no further review or Risk reduction required | | | | | |
| Scenario can be expected on average every other year | Very Likely | 0.5 – 0.2 | M | H | H | VH | VH | VH | | |
| Scenario typically occurs on average every 10 years | Likely | 0.2 – 0.07 | L | M | H | H | VH | VH | | |
| Scenario typically occurs on average every 50 years | Moderate | 0.07 – 0.02 | L | L | M | H | H | VH | | |
| Scenario occurs on average every 100 years | Unlikely | 0.02 – 0.007 | VL | L | L | M | H | H | | |
| Scenario occurs on average every 200 years | Very Unlikely | 0.007 – 0.004 | VL | VL | L | L | M | H | | |
| Scenario occurs on average every 500 years | Extremely Unlikely | 0.004 – 0.0013 | VL | VL | VL | L | L | M | | |
| CONSEQUENCE DESCRIPTIONS | INDICES | | 1 | 2 | 3 | 4 | 5 | 6 | | |
| | | | Negligible | Minor | Moderate | Major | Severe | Catastrophic | | |
| | SAFETY (INJURY/LOSS OF LIFE) | | Minor injuries of few individuals | Major injury of 1 person | Major injury of several persons | Single fatality | <10 fatalities | >10 fatalities | | |
| | ECONOMIC (MONETARY LOSSES) | | Negligible; no business interruption; <\$1,000 | Some asset loss; <\$10,000 damages | Serious asset loss; several days business interruption; <\$100,000 | Major asset loss; several weeks business interruption; <\$1 million | Severe asset loss; several months business interruption; <\$10 million | Total loss of asset; 1 year or more business interruption; >\$10 million | | |
| | SOCIAL AND CULTURAL | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Recoverable within months | Long-term (years) loss of social and cultural values | Complete loss of significant social and cultural values | | |
| | INTANGIBLES (PERSONAL SUFFERING) | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Personal hardship; usually recoverable within months | Leaves significant personal hardship for years | Irreparable personal hardship | | |
| | ECOLOGICAL (FLORA AND FAUNA) | | Negligible impact | Slight impact; recoverable within days | Moderate impact; recoverable within weeks | Recoverable within months | Severe species loss | Irreparable species loss | | |

Figure E - 4: Example Risk matrix to determine the relative level of Flood Risk for Proposed Developments.

Appendix D – Design Criteria Sheet for Climate Change Resilience

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)

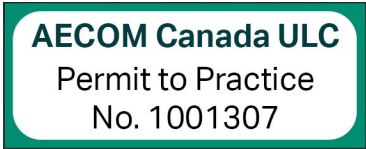
Project: *Highway 8 – Project E – Drainage – Sites 16 to 19*
 Type of work: *Rehab/Reconstruction, Culverts*
 Location: *Highway 8 between Merrit and Spencer Bridge*
 Discipline: *Hydrotechnical*

| Design Component | Design Life or Return Period | Design Criteria + (Units) | Design Value Without Climate Change (m ³ /s) | Change in Design Value from Future Climate | Design Value Including Climate Change | Adaptation Cost Estimate (\$) | Comments / Notes / Deviations / Variances |
|-------------------------------------|------------------------------|--|---|--|---------------------------------------|-------------------------------|---|
| Site 16 | 100 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 0.524 | +30% | 0.681 | N/A | No change in design |
| Site 17 | 100 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 0.619 | +30% | 0.805 | N/A | No change in design |
| Site 18 -1 East Variance Request | 10 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 2.351 | +30% | 3.056 | \$5,000 | Size increase to 1200 mm from 1000 mm |
| Site 18-2 West | 100 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 1.049 | +30% | 1.364 | N/A | No change in design |
| Site 19 -1 East | 100 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 0.182 | +30% | 0.237 | N/A | No change in design |
| Site 19 – 2 West | 100 yr RP | Flow Rate (m ³ /s) HW/D <1 (m) | 0.281 | +30% | 0.365 | \$0 | Keep the existing 600mm CSP Culvert |

Explanatory Notes / Discussion:

Refer to HW-8 Drainage Design Memorandum Project E: Sites 16-19, dated April 7, 2025

Recommended by: Engineer of Record: _____ Chris Liu _____
(Print Name / Provide Seal & Signature)



Date: _____ April 7, 2025 _____

Engineering Firm: _____ AECOM _____

Accepted by BCMoTI Consultant Liaison: _____
(For External Design)

Deviations and Variances Approved by the Chief Engineer: _____
Program Contact: Chief Engineer BCMoTI