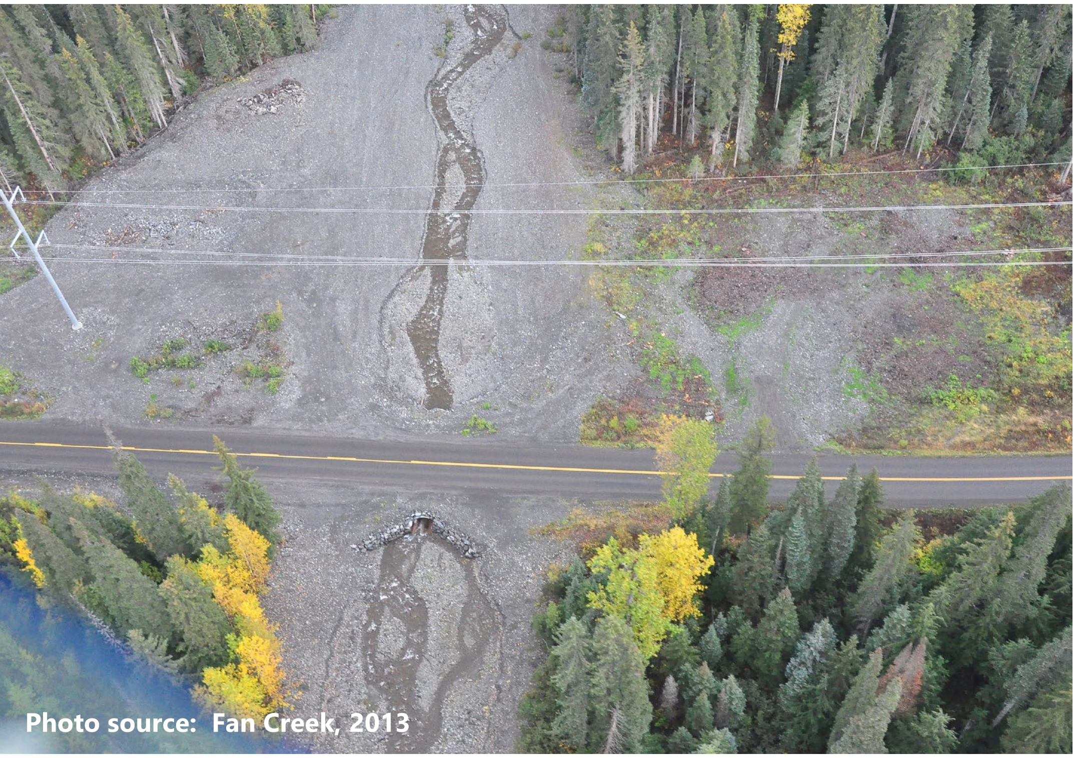

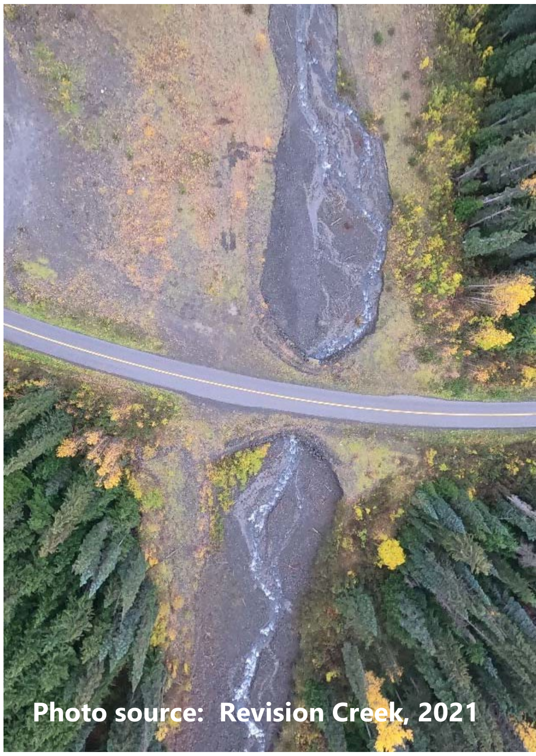

Replacement of Highway 37 Culverts at Fan and Revision Creeks

Hydrotechnical Design Brief

Prepared by:

Northwest Hydraulic Consultants Ltd.
30 Gostick Place
North Vancouver, BC V7M 3G3
Tel: 604.980.6011
www.nhcwater.com

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Prepared under the Direction of:

PROFESSIONAL
PROVINCE OF
D. J. GOOLD
28281
BRITISH COLUMBIA
ENGINEER

2025-06-13

Permit to Practice
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Des Goold, P.Eng.
Principal

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1 INTRODUCTION

The BC Ministry of Transportation and Transit (MoTT) intends to carry out Project 38016 (the Project) to replace two steel multiplate pipe arch culverts (Structure Nos. 08791 and 08792) that carry Fan and Revision Creeks across Highway 37, north of Bell 2, BC. The culverts were installed in 1972. Urgency ratings of 4 to 5 have been assigned to the culverts due to aggradation issues related to the Creeks and physical wear.

MoTT has retained Northwest Hydraulic Consultants Ltd. (NHC) under Contract 831C1173 to carry out detailed hydrotechnical design for the Project.

This design brief provides a condensed summary of the hydrotechnical design for both crossings and is intended as a reference document for the Project.

1.1 Previous Assessments

NHC has previously undertaken geomorphological assessments of the three crossings and established the hydrotechnical design basis for culvert replacement. This work included a description of geology and sediment supply in the area, a regional hydrological analysis and climate change assessment, as well as culvert replacement options.

In addition to this hydrotechnical design brief, NHC has also prepared and submitted the following reports to MoTT:

- "Replacement of Highway 37 Culvert at Red Flat, Revision and Fan Creeks, Geomorphological Assessment and Hydrotechnical Design Basis, Overview Report (Final)" (NHC, 2021)
- "Replacement of Highway 37 Culvert at Fan Creek, Geomorphological Assessment and Hydrotechnical Design Basis, Final Report" (NHC, 2021)
- "Replacement of Highway 37 Culvert at Revision Creek, Geomorphological Assessment and Hydrotechnical Design Basis, Final Report" (NHC, 2021)

1.2 Scope of the detailed hydrotechnical design

The scope of hydrotechnical design for replacement of the Fan, and Revision Creek culverts is as follows:

- Update existing hydraulic models of the hybrid bridge design at Fan and Revision Creeks.
- Based on output from the hydraulic models, conduct waterway hydraulic calculations for scour, riprap sizing, etc. at each crossing.

- Prepare Channel Improvement drawings outlining channel excavations, training works and riprap protection.
- Support MoTT's internal team, COWI (structural design lead), Urban Systems Ltd. (highway design lead) and R.F. Binnie (Project Manager) with hydrotechnical design input as and when required.

1.3 Design codes and regulations

The following design codes and reference documents have been used for the detailed hydrotechnical design:

Design Codes

- CAN/CSA-S6-19 in conjunction with the MoTT's Supplement to S6-19
- BC Supplement to TAC Geometric Design Guide 2019

Ministry Standards and Guidelines

- BC MoTT 2025 Standard Specifications for Highway Construction
- MoTT Resilient Infrastructure Engineering Design – Adaptation to the Impacts of Climate Change and Weather Extremes (2019)

Hydrotechnical Design Guidelines

- Hydraulic Design of Stable Flood Control Channels (NHC, 1984)
- TAC Guide to Bridge Hydraulics (2025)
- Developing Climate Change-Resilient Designs for Highway infrastructure in British Columbia (Version 2.0; EGBC, 2020)

Individual creek reports and the Overview report outlined in Section 1.1 as part of the previous study were also referenced for the detailed design portion of the study.

2 HYDROTECHNICAL DESIGN PARAMETERS

2.1 Design peak flows

The design floods for the new bridges are the 200-year annual peak (instantaneous) flows plus 20% to account for future climate change. These flows are used as the basis for all other hydrotechnical analysis and design (e.g. scour estimates and river training works).

Estimates of the annual maximum daily flow (QPD) have been made using regression equations for BC developed by NHC as part of the BC Extreme Flood Project (NHC, 2021). Estimates of annual peak instantaneous flow (QPI) were made by establishing an appropriate ratio QPI:WPD from proxy Water Survey of Canada (WSC) gauges with watershed area sizes and physiographic properties close to those of the subject creeks. The average QPI: QPD ratio for WSC Station 08DA012 was applied to Fan and Revision Creeks.

Climate change adjustments were made to the estimated design peaks flows. NHC's literature review and conceptual understanding of the region's flood hydrology identify it as having relatively high sensitivity to a changing climate. In NHC's prior research experience, this is common in transitional hydrologic regions. While spring freshet magnitudes (~ QPD) may decrease due to a decrease in total frost-free days, an increase in rainfall and rainfall intensity in autumn will likely result in higher annual QPIs. Due to increases in temperature, flood timing will likely shift further into fall and winter as rainfall increases while snowfall decreases. NHC recommends that the design 200-year QPIs for the subject Creeks be increased by 20% to account for future climate change. The current estimates of 200-year QPI and recommended design QPI are presented in Table 2.1.

Table 2.1 Summary of the estimated design peak flows

Stream	Current 200 Year QPI (m^3/s)	Climate Change Increase	Design 200 Year QPI (m^3/s)
Fan Creek	25.9	+20%	31.0
Revision Creek	28.0		33.6

2.2 Design flood levels and velocities

HEC-RAS 1D, steady-state hydraulic modelling software has been used to assess the hydraulics in the subject creeks. The hydraulic model geometry is developed from a combined ground surface developed in 2021 The models extend approximately 200 m upstream and 160 m downstream of each culvert. A summary of the design flood levels, average velocities, and maximum velocities for the two creeks and respective replacement options are shown in Table 2.2.

Table 2.2 Summary of the estimated design flood levels and velocities

Stream	Peak Discharge (m^3/s)	Upstream Flood Level[1] (m)	Average Velocity (m/s)	Hydraulic Depth (m)
Fan Creek	31.0	644.4	3.5	1.0
Revision Creek	33.6	671.4	3.3	1.1

Notes:

1. Flood levels are at the upstream face of the upstream highway bridge; average velocities and depths are within the bridge openings.

2.3 Bridge clearance

The supplement to CHBDC S6-14 recommended the that there is a minimum clearance of 1.5 m between the soffit and 200-year design flood elevation for bridge crossings (MoTT, 2016). As summarized in the sections below, both Fan Creek and Revision Creek proposed crossings achieve minimum clearance.

2.3.1 Fan Creek

The low soffit elevation of the proposed bridge is approximately 647.4 m, at the upstream face, and at this location the estimated 200-year design flood level is El. 644.4 m, providing a minimum clearance of 3.0 m.

2.3.2 Revision Creek

The low soffit elevation of the proposed bridge is approximately 672.9 m, at the downstream face, and at this location the estimated 200-year design flood level is El. 670.9 m, providing a minimum clearance of 2.0 m.

2.4 Channel dimensions beneath bridge

2.4.1 Fan Creek

Fan Creek constricts to a 7 m wide channel with boulder armouring at the bridge crossing. There is 4.33 meters of clearance between the channel invert and the bridge, which accommodates 1.5 m of future channel aggradation while meeting the minimum standard for flood clearance.

2.4.2 Revision Creek

Revision Creek constricts to a 7 m wide channel with boulder armouring at the bridge crossing. There is 3.33 meters of clearance between the channel invert and the bridge, which accommodates 0.5 m of future channel aggradation while meeting the minimum standard for flood clearance.

2.5 Contraction Scour

The 200-year design contraction scour for Fan and Revision Creeks has been estimated using the Contraction Scour Method (FHWA, 2012; TAC, 2004b) with the following inputs.

- 200-year design flow: 31 m^3/s; 33.6 m^3/s
- Channel slope: 0.05 m/m
- Uncontracted top width: 21 m; 17.5 m
- Contracted top width: 7 m

- Bottom width at bridge opening: 7 m
- Depth of flow at approach: 1 m/ 1.1 m
- Mean particle size (D50): 50 mm

In both cases, the contraction scour depth is approximately 1.0 m below the 200-year design flood level, or 0.3 m above the bottom of the channel.

2.6 Natural scour

Natural scour was estimated using a modified form of Blench's Regime Depth Method (Blench, 1957) in which a "Z" factor is applied to the regime depth to obtain an estimate of scoured depth below the design water surface.

2.6.1 Fan Creek

- Water surface width: 21 m
- 200-year design flow: 31 m^3/s
- Channel slope: 0.05 m/m
- Z factor: 2.5
- D50: 53 mm
- 200-year design flow: El. 644.85 m

The natural scour depth is 1.5 m below the 200-year design flood level, or 0.8 m below the bottom of the channel.

2.6.2 Revision Creek

- Water surface width: 17.5 m
- 200-year design flow: 33.6 m^3/s
- Channel slope: 0.05 m/m
- Z factor: 2.5
- D50: 70 mm

The natural scour depth is 1.0 m below the 200-year design flood level, or 0.5 m below the bottom of the channel.

3 CHANNEL IMPROVEMENT DESIGN

3.1 Erosion Protection of the Bridges

The size of riprap for the crossings has been determined using the U.S Army Corps of Engineers method (USACE, 1994).

3.1.1 Fan Creek

The following site inputs were used to determine riprap size:

- 200-year design flow water surface width*: 7.6 m
- Centreline radius of channel bend: 24 m
- 200-year average channel velocity: 2.4 m/s
- Future 200-year depth of water along protected slopes: 0.8 m
- Factor of Safety: 1.2
- Coefficient of Stability, Cs: 0.3 (angular rock)
- Velocity distribution coefficient, Cv: 1.2
- Thickness coefficient, Ct: 1.0
- Side slope factor, K: 0.9 (2H: 1V slope)

* Conservatively assumes a single, primary flow channel of this width

The resulting estimates of D30 and D50 for graded riprap are 435 mm and 633 mm, respectively. MoTT Class 500-kg riprap is recommended for the protection of bridge abutments and the upstream and downstream channel. The riprap flares out to the side to protect the approaches upstream and downstream of the structure. The minimum slope for erosion protection is 1.5H:1V. The depth of the toe key trench varies as per drawing 8792-15, Highway 37 Fan Creek Bridge Channel Improvements Typical Sections. A layer of non-woven geotextile fabric shall be placed under all sloping riprap protection to provide a suitable filter layer between the existing bank and the riprap.

3.1.2 Revision Creek

The following site inputs were used to determine riprap size:

- 200-year design flow water surface width: 7.4 m
- Centreline radius of channel bend: 27.1 m
- 200-year design flow average channel velocity: 2.5 m/s
- Future 200-year depth of water along protected slopes: 1.0 m
- Factor of Safety: 1.2

- Coefficient of Stability, Cs: 0.3 (angular rock)
- Velocity distribution coefficient, Cv: 1.2
- Thickness coefficient, Ct: 1.0
- Side slope factor, K: 0.9 (2H: 1V slope)

* Conservatively assumes a single, primary flow channel of this width

The resulting estimates of D30 and D50 for graded riprap are 438 mm and 638 mm, respectively. MoTT Class 500-kg riprap is recommended for the protection of bridge abutments and the upstream and downstream channel. The riprap flares out to the side to protect the approaches upstream and downstream of the structure. The minimum slope for erosion protection is 1.5H:1V. The depth of the toe key trench varies as per drawing 8791-15, Highway 37 Revision Creek Bridge Channel Improvements Typical Sections. A layer of non-woven geotextile fabric shall be placed under all sloping riprap protection to provide a suitable filter layer between the existing bank and the riprap.

3.2 Scour Protection through Bridges

Scour protection through the bridge in the confined channels has been determined using the particle densiometric Froude number for estimating sediment transport (Aguirre-Pe et al., 2003).

3.2.1 Fan Creek

The following site inputs were used to determine stable riprap size:

- Channel slope: 0.063 m/m
- Average depth velocity: 5.3 m/s
- Angle of repose: 40º
- Depth of flow: 1.20 m

The resulting estimated stable D50 riprap size is 688 mm which correlates with MoTT Class 500-kg riprap. The channel bed from approximately stations 200+00 to 200+25 are to have 900 mm (+/- 100 mm) boulders placed in a checkerboard pattern with the voids filled with stream gravel.

3.2.2 Revision Creek

The following site inputs were used to determine stable riprap size:

- Channel slope: 0.045 m/m
- Average depth velocity: 4.2 m/s
- Angle of repose: 40º

- Depth of flow: 1.20 m

The resulting estimated stable D50 riprap size is 555 mm which correlates with MoTT Class 250-kg riprap. The channel bed from approximately stations 200+01 to 200+24 are to have 900 mm (+/- 100 mm) boulders placed in a checkerboard pattern with the voids filled with stream gravel.

3.3 Excavation of Gravel Stockpile Berms

For both Fan Creek and Revision Creek the channel banks downstream of the bridge will be modified by excavating the gravel stockpile berms to allow for natural avulsion reducing the gravel removal maintenance frequency.

3.4 Revision Creek Cut-Off Berm

To protect the Highway 37 road embankment south of the creek and a powerline tower, located approximately 250 m southeast of the crossing, a cut-off berm is to be constructed south of the channel modified area. To provide slope protection, 100-kg riprap is to be installed along the north side-slope of the berm with a 0.7 m toe key trench. The berm is to be constructed to have 3.5m crest with 1.5H:1V side slopes.

4 CONSTRUCTION CONSIDERATIONS

4.1 Pre-construction surveys

Due to the known scour, aggradation, and avulsion of Fan Creek and Revision Creek a survey should be conducted prior to construction to confirm excavation quantities.

4.2 Monthly flows and flow durations

Mean monthly flows were estimated for Fan and Revision Creek by scaling Kelly Creek, WSC Station 08DA012, monthly flow data by the drainage area of the creeks using a scaling exponent of 1. WSC Station 08DA012 has a drainage area of 8.64 km^2

4.2.1 Fan Creek

Fan Creek's mean monthly flow data was determined by scaling WSC Station 08DA012 monthly flow using Fan Creek's Highway 37 crossing drainage area of 8.92 km^2. Table 4.1 summarizes Fan Creek's mean monthly flow estimates.

Table 4.1 Fan Creek Mean Monthly Flow Estimates

Month	Average Flow (m^3/s)
April	0.5
May	0.9
June	0.8
July	0.5
August	0.4
September	0.5
October	0.6
November- March	Creek Typically Frozen / No Flow

4.2.2 Revision Creek

Revision Creek's mean monthly flow data was determined by scaling WSC Station 08DA012 monthly flow using Revision Creek's Highway 37 crossing drainage area of 9.86 km^2. Table 4.2 summarizes Revision Creek's mean monthly flow estimates.

Table 4.2 Revision Creek Mean Monthly Flow Estimates

Month	Average Flow (m^3/s)
April	0.6
May	1.0
June	0.9
July	0.5
August	0.4
September	0.5
October	0.6
November- March	Creek Typically Frozen / No Flow

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