CV-216 By-Pass Culvert Crossing Design Brief

Final Report

Prepared for:

Baffinland Iron Mines

Prepared by:

Nunami Stantec Limited

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STANTEC LIMITED

Limitations and Sign-off

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Abbreviations

Baffinland	Baffinland Iron Mines
BEHI	Bank Erosion Hazard Index
CN	Curve Number
CSP	Corrugated Steel Pipe
DEM	Digital Elevation Model
DFO	Department of Fisheries and Oceans Canada
DTM	Digital Terrain Model
DWE	Diffusion Wave Equation
ECCC	Environment and Climate Change Canada
ESC	Erosion and Sediment Control
FS	Factor of Safety
HEC	Hydraulic Engineering Center
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modelling System
HEC-RAS	Hydraulic Engineering Center's River Analysis System
IDF	Intensity Duration Frequency
NLCD	National Land Cover Database
Nunami Stantec	Nunami Stantec Limited
RGA	Rapid Geomorphic Assessment
RSAT	Rapid Stream Assessment Technique
SCS	Soil Conservation Services
SI	Stability Index
SPOT	Species Passage Optimization Tool
SSP	Socio-Economic Pathways
SWE	Shallow Water Equation
SWE	Snow Water Equivalence
USACE	U.S. Army Corps of Engineers
USCS	Unified Soils Classification System
WSE	Surface Water Elevations

YoY	Young of Year
2D	Two-Dimensional

1 Introduction

Baffinland Iron Mines (Baffinland) requested the professional services of Nunami Stantec Ltd. (Nunami Stantec) to develop a design that can be constructed as soon as possible to limit transportation and flooding risks to by-pass replacement culvert crossing for the failed CV-216 culvert crossing located at kilometer 80.5 on the Milne Inlet Tote Road. The Tote Road connects the Milne Inlet port with the Mary River mine site. The site has experienced structural and hydrologic conveyance issues since the replacement culvert installation in the spring of 2024. The presence of subsurface ice and inadequate foundation stability are considered to be primary factors contributing to the crossing failure. Despite additional mitigation efforts in April 2025, the culvert crossing failed in July 2025, compromising traffic safety, fish passage and hydraulic performance. A replacement design that can be implemented as soon as possible to limit transportation and flooding risks is required to restore road access, flow conveyance and fish passage, which is detailed in the following design brief.

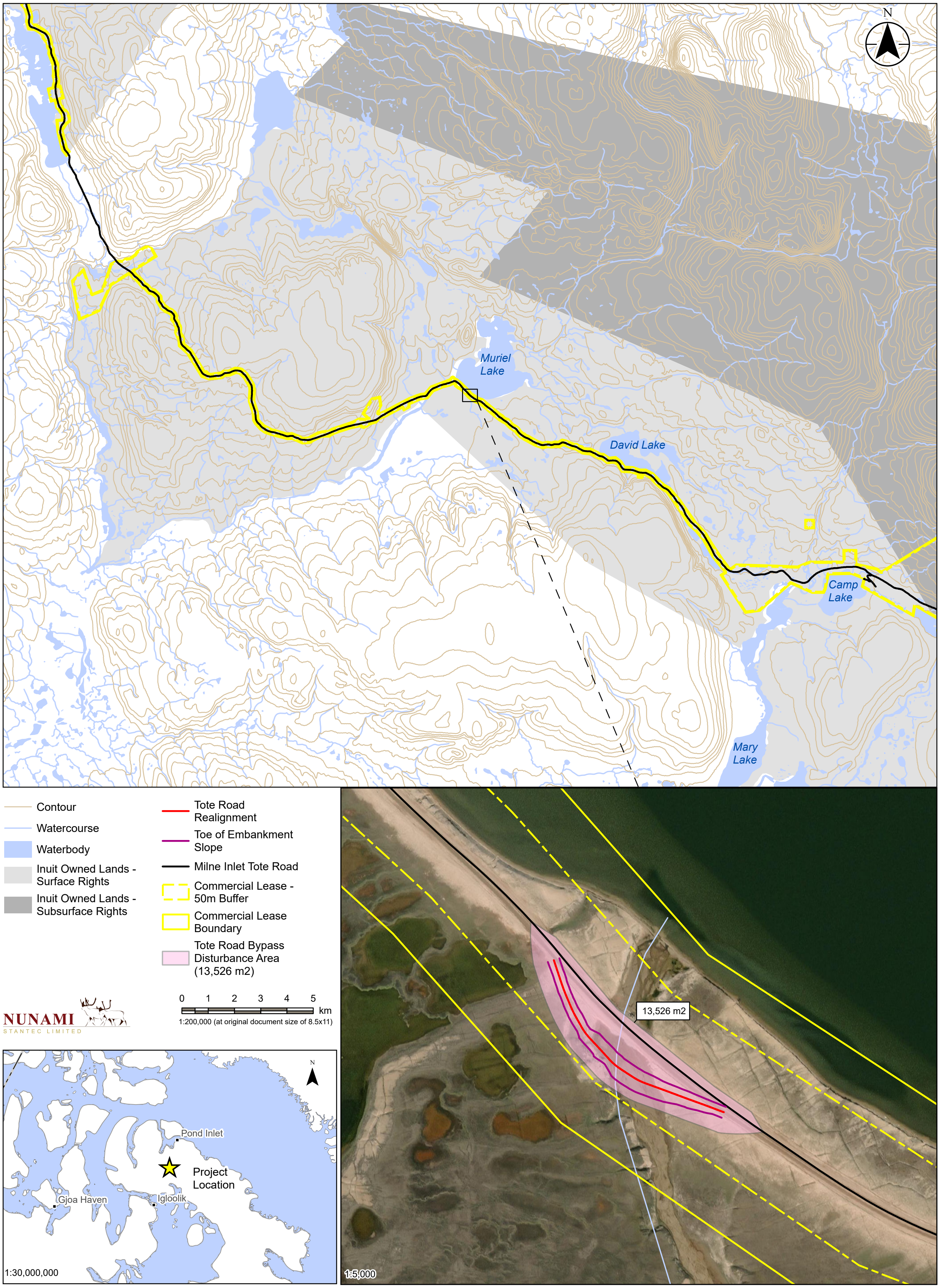
Fish passage was impacted at the CV-216 site due to damaged culverts and sediment accumulation. Fish habitat monitoring was conducted in the spring of 2024 at the site. At the time of monitoring, it was noted that substrate had accumulated in the apron and inside the culvert, and continued accumulation would impact fish passage. At the time of monitoring, six small (45-60 mm) juvenile Arctic Char were captured upstream, indicating successful fish passage (NSC 2024).

The proposed CV-216 culvert crossing replacement and associated realigned road centreline is located approximately 33 m upstream from the existing Tote Road centreline. This is to construct the crossing and road realignment away from the area of inadequate foundation stability and maintain the road within the commercial lease limit (Figure 1).

2 Design Objective

The design objectives for the replacement at CV-216 are as follows:

- Provide a design which can be constructed as soon as possible to limit transportation and flooding risks (i.e., Fall 2025), to restore road access and provide flow conveyance, prioritizing the use of on-site materials available at the Baffinland Mary River site
- Allow passage for a minimum of 50% of Arctic char (*Salvelinus alpinus*) for monitored lengths along the Tote Road and present during July and August mean monthly flows
- Culvert crossing conveys the 25-year event without overtopping the roadbed within the channel footprint
- Reduce likelihood of thermal degradation of underlying subsurface ice
- Protect the road embankments and crossing channel bed from erosion and scour


N
Muriel Lake
David Lake
Camp Lake
Mary Lake
Contour
Watercourse
Waterbody
Inuit Owned Lands - Surface Rights
Inuit Owned Lands - Subsurface Rights
Tote Road Realignment
Toe of Embankment Slope
Milne Inlet Tote Road
Commercial Lease - 50m Buffer
Commercial Lease Boundary
Tote Road Bypass Disturbance Area (13,526 m2)
NUNAMI
STANTEC LIMITED
0 1 2 3 4 5
km
1:200,000 (at original document size of 8.5x11)
N
Pond Inlet
Project Location
Gjoa Haven
Igloolik
1:30,000,000
13,526 m2
1:5,000

3 Basis of Design

3.1 Data

3.1.1 Bathymetric Data

Nunami Stantec conducted a localized bathymetric survey for both upstream and downstream sections of the crossing using a Trimble S7 robotic total station. The survey captured thalweg, edge-of-water profiles, culvert inverts, and cross-sectional geometry. The final survey data was georeferenced using a Baffinland LiDAR-derived digital terrain model (DTM) to provide accurate conversion to UTM coordinates.

3.2 Fluvial Geomorphic Conditions

To assess the existing condition of the crossing, site visits were conducted by Nunami Stantec on July 27 and August 11, 2025. A photolog of site condition containing photos from the site visit is provided in Appendix A.

The channel is irregular in form with lateral bars as the dominant sediment pattern. The watercourse exhibited signs of rapid vertical incision and slow lateral erosion. Lab results confirmed that the channel bed substrate is poorly graded sand. Lateral bank erosion, bed scour and channel degradation were noted as potential hazards at the crossing.

On the upstream side of the culvert crossing, the culverts were crushed or had subsided into the channel bed with flows potentially going through the collapsed culverts or within the pore space of the roadbed aggregate. The surrounding banks and bed consisted of loose sand, which was observed to crumble under minimal finger pressure. During the August site visit, fish were observed upstream of the culvert crossing within pools adjacent to the roadbed.

Downstream site conditions observed a potential backwater effect from Muriel Lake. Fish were observed swimming in pools. The banks and bed were composed of medium-fine sand with silt, and algae growth is present both on the sand and at the watercourse mouth near Muriel Lake.

A combination of geomorphic and erosion assessments were used to evaluate the stream conditions at the crossing. The Rapid Geomorphic Assessment (RGA) is a widely accepted method for classifying a stream reach based on its geomorphic evolution, identifying signs of aggradation, degradation, widening, and planimetric form adjustment to assign a stability class. Each indicator was scored based on observed geomorphic features. The calculated Stability Index (SI) for the reach is 0.40, placing it in the transitional category. This suggests that while the channel morphology is generally within the expected range for similar hydrographic conditions, there is frequent evidence of instability. Notably, widening and degradation were the most prominent adjustment processes observed.

To complement this, the Rapid Stream Assessment Technique (RSAT) provides a semi-quantitative evaluation of overall stream health and functionality, incorporating physical, biological, and chemical indicators to guide restoration and management priorities. Each category is scored based on field observations, with the cumulative score used to classify the stream condition. The total RSAT score of 16.18 places the reach in the “Fair” condition category. This suggests moderate levels of channel instability, sediment accumulation, and habitat degradation within the existing upstream channel, which may be indicative of watershed perturbations and reduced ecological integrity. The culvert crossing design will need to account for these existing upstream channel conditions.

The Bank Erosion Hazard Index (BEHI) assesses the susceptibility of stream banks to erosion by examining factors such as bank height, rooting depth, bank angle, and soil composition, helping to quantify erosion risk and inform stabilization strategies. The bank height and bank full height were both measured at 0.63 m, with a root depth of 0.05 m, indicating limited vegetative reinforcement. The bank material was predominantly sand, which increases susceptibility to erosion. Based on the calculated values and adjustment factors, the total BEHI score places the reach in the “Moderate” erosion risk category. The detailed RGA, RSAT and BEHI assessments are included in Appendix A.

3.3 Fish and Fish Habitat

Fish use and fish habitat were assessed at CV-216 in 2021 by North/South Consultants (NSC 2021). At the culvert location, the stream is a third order stream that flows into Muriel Lake approximately 100 m downstream of the crossing. Habitat upstream of the crossing is characterized by shallow flow (<0.05 m) and low gradient (1.7%), with observed velocities less than 0.15 m/s. The stream can flood rapidly during freshet and major storm events, shifting from a shallow, braided channel to a large, single channel that occupies the bankfull width (NSC 2021).

During 2021 surveys, NSC noted that Arctic char and ninespine stickleback were present upstream and downstream of CV-216, with stickleback being more abundant and likely using the habitat for foraging, and spawning (NSC 2021). Sampling was also conducted as part of monitoring efforts in 2021, 2023, and 2024 (Baffinland 2021, 2024a, 2025a). No fish were captured upstream or downstream of the crossing in fall 2021 (Baffinland 2021), spring 2023 (Baffinland 2024a), or summer 2023 (Baffinland 2024a). Sampling in spring 2024 yielded six char and one stickleback upstream of the crossing.

4 Design Criteria and Available Materials

4.1 Design Criteria

The design criteria that were taken into consideration are as follows:

Hydrotechnical Design Criteria:

- Design Event: 25-Year return period, 24-hour duration storm event without overtopping the roadbed within the channel crossing
- Fish Passage Requirement: 50% passage for 85 mm Arctic char in July and 40 mm Arctic char in August (KP 2024)

Geotechnical Design Criteria:

- Reduce the likelihood of thermal degradation of underlying ice, using readily implemented solutions limited to on-site materials. This includes avoiding excavations into massive ice, and providing cutoff walls limited to embankment sideslopes.
- Provide road embankment geometry which meets minimum requirements for sideslope stability

Structural Design Criteria:

- Adequate depth of cover for culverts

General Design Criteria:

- Provide adequate information to support Section 3 and schedule 2 of the Fisheries Act to meet requirements for a 34.4(2)(b) and 35(2)(b) Fisheries Act Authorization (Emergency Situations)
- Provide a design which can be designed and constructed as soon as possible (i.e., Fall 2025), to restore road access and provide flow conveyance, prioritizing the use of on-site materials available at the Baffinland Mary River site
- Culvert installation will be field fit to accommodate changes in the road alignment during construction

4.2 Materials

The construction materials available at the Baffinland Mary River site for the CV-216 culvert crossing replacement are summarized in Table 1.

Table 1 Materials Available at the Mary River site

Material	Type
Aggregate	32 Special
	¾” Road Capping (RM)
	4” to 12” Rip Rap
	4” Minus
	8” Minus
	24” Rock
Culverts	Corrugated Steel Pipe (CSP) (600mm to 1800 mm diameter)
	Corrugated Steel Multi-Plate Arch Pipes (various sizes)
Bentonite Cut-Off Walls	Volclay CP-200 Powdered Bentonite
	Sand, from locally obtained natural deposits

5 Design Analyses

5.1 Hydrotechnical Analyses

Hydrotechnical analyses methods used to design the culvert replacement include hydrologic and hydraulic modelling to determine design flow flows and levels, and velocity ranges to assess fish passage and scour and erosion controls at the CV-216 replacement crossing. A fish passage assessment was conducted using the SPOT tool (Di Rocco and Gervais 2025) to assess if the appropriate length of Arctic Char is able to swim through the proposed design. Additional details of the hydrotechnical analyses are provided in Appendix B.

The hydrologic model was developed using the Hydrologic Engineering Center's Hydrologic Modelling System (HEC-HMS) hydrologic model (USACE Hydrologic Engineering Center 2025) for CV-216 to estimate design flow rates for the culvert crossing to be input into the hydraulic model to assess flood flow hydraulics and levels. The HEC-HMS hydrologic model was calibrated for the Tote Road area using Baffinland provided hydrometric station H04 flow data pro-rated for the CV-225 culvert crossing as it is relatively close in proximity to the H04 station and had a similar size watershed area.

The watershed boundaries were delineated using HEC-HMS. Details on watershed delineation is provided in Appendix B. Figure 2 shows the HEC-HMS watershed delineation and the total watershed area was delineated at approximately 27.11 km^2. Table 2 presents the summary of the subbasin parameters.

Climate data from climate station Pond Inlet A was then input into the hydrologic model for the design storm events. The meteorological model for design storm events was set up using a 24-hour duration SCS Type I distribution to estimate peak flows based on CSA (S503:20) recommendations and meteorological records analysis, this assessment used an SCS Type I temporal distribution to design storm events. The climate change adjusted intensity duration frequency (IDF) curve for the shared socio-economic pathways (SSP) 2-4.5 scenario for the 2031-2060 period was obtained for Pond Inlet A to calculate the precipitation for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year return periods (ClimateData.ca 2025). Table 3 summarizes the precipitation for a 24-hour event for the 2–100-year return periods. The design flow events were simulated as the SSSP2-4.5 2 to 100-year return period events with the 75th percentile snowmelt value (6 mm).

Figure 2 Watershed Delineation

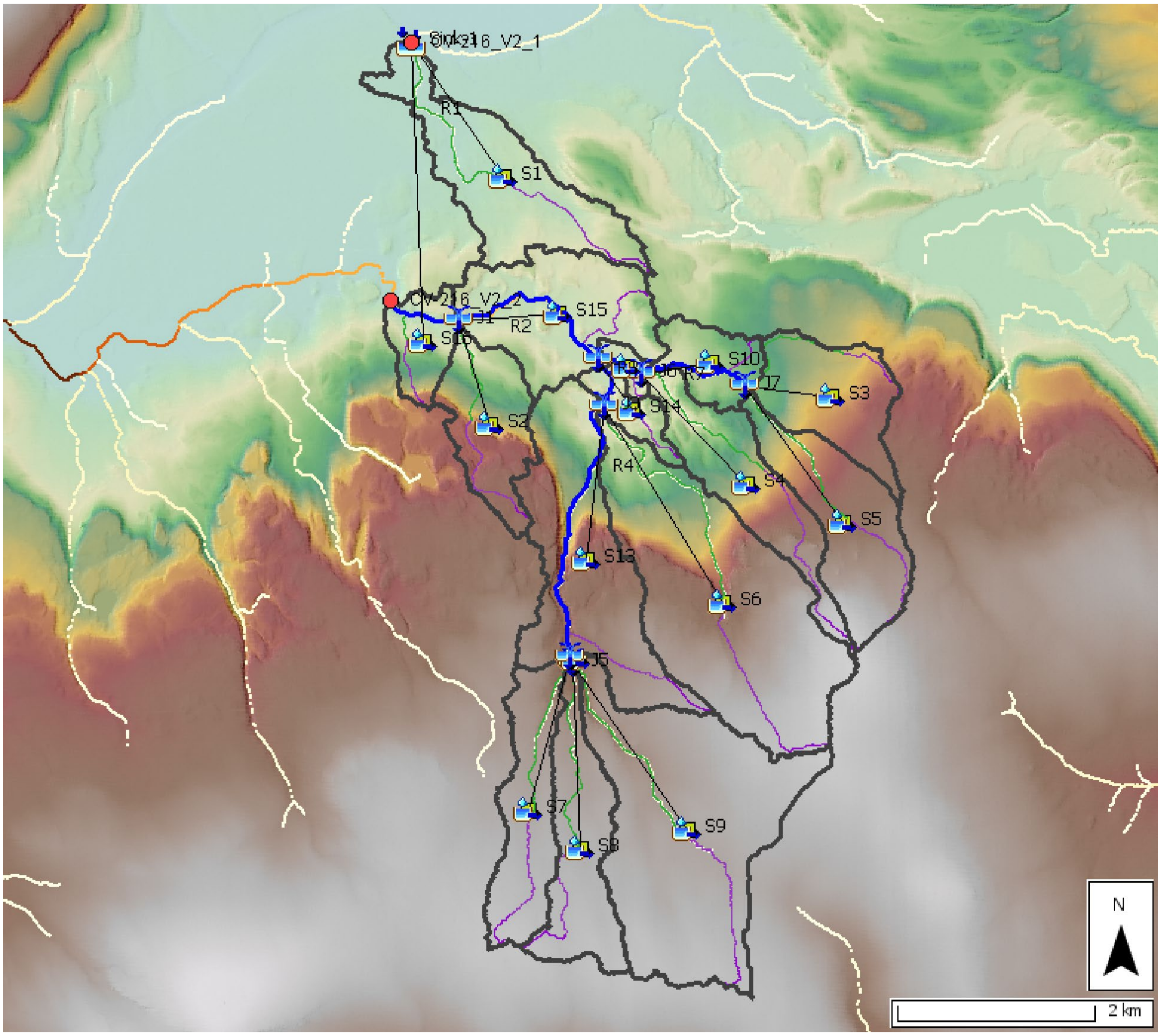


Table 2 Summary of Parameters

Subbasin ID	Area (km^2)	CN	Lag Time (min)	Time of Concentration (hr)
S1	2.21	84	725	20.1
S2	1.27	82	321	8.9
S3	1.40	84	362	10.1
S4	1.56	84	469	13.0
S5	1.79	85	506	14.1
S6	4.43	84	609	16.9
S7	1.47	83	822	22.8

Subbasin ID	Area (km^2)	CN	Lag Time (min)	Time of Concentration (hr)
S8	1.57	85	895	24.8
S9	4.54	85	901	25.0
S10	0.69	83	290	8.1
S11	0.17	84	160	4.4
S12	0.01	83	53	1.5
S13	2.89	83	445	12.4
S14	0.41	84	228	6.3
S15	2.06	85	416	11.5
S16	0.63	83	170	4.7
R1	-	84	320	8.9
R2	-	85	1,714	47.6
R3	-	84	361	10.0
R4	-	83	573	15.9
R5	-	83	50	1.4
R6	-	84	346	9.6
R7	-	83	428	11.9
Total	**27.11**	**-**	**-**	**-**

Table 3 SSP2-4.5 Precipitation for 24-hour duration events for various return periods

Return Period	Precipitation (mm)
2-year	21.1
5-year	26.4
10-year	33.6
25-year	38.4
50-year	43.2
100-year	45.6

The CV-216 hydrologic model for design storm events were set up using a 24-hour duration SCS Type I distribution to estimate peak flows. The duration of the storm was chosen based on the critical time of concentration which is 20.1 hours. Table 4 presents the hydrologic model estimated peak flow rates.

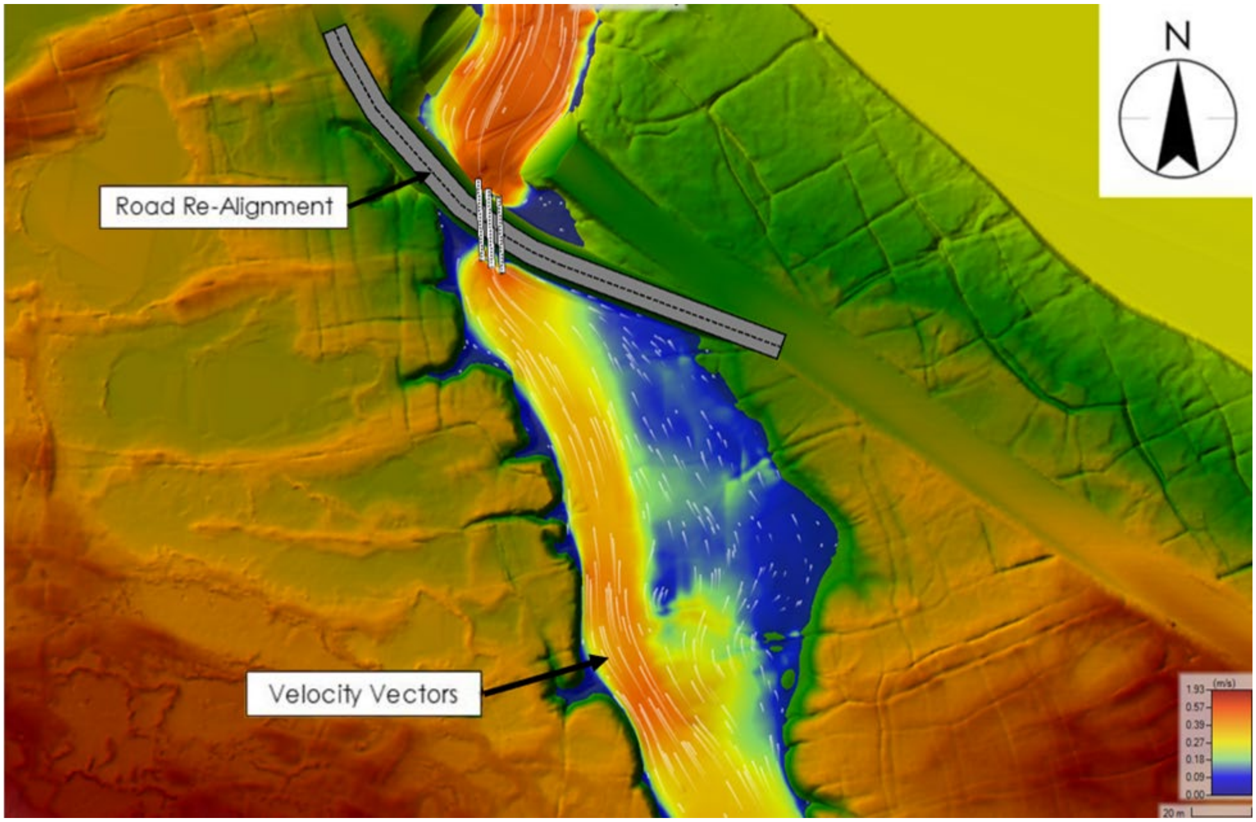
Table 4 CV-216 Climate Change Adjusted Design Storm Event with Snowmelt Peak Flow Rates

Return Period	Peak Flow Rate (m^3/s)
2	6.6
5	9.2
10	11.7
25	14
50	16
100	17.6

Nunami Stantec developed a two-dimensional (2D) hydraulic model (the model) based on the bathymetry and LiDAR data to inform the replacement culvert design. To create the model, Nunami Stantec used River Analysis System (HEC-RAS version 6.4.1) developed by the Hydraulic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE).

The hydraulic model was used to design the replacement culvert crossing configuration by verifying that the road does not overtop within the active channel for a 25-year return period, 24-hour duration design storm event (Figure 3). The developed replacement culvert design is detailed in Section 6.

Figure 3 Flooding and Water Velocity Map for a 25-Year Return Period Design Storm Event



The flows for fish passage were determined using the mean monthly unit discharge presented in Table 5.

Table 5 Fish Passage Assessment July and August Mean Monthly Unit Flow Rates

Month	Mean Monthly Unit Flow Rates (l/s/km^2)
July	41.2
August	22.1

The 2D hydraulic model was used to assess fish passage during the July and August mean monthly flow conditions. The species passage optimization tool (SPOT) was used to evaluate the feasibility of fish passage (Di Rocco and Gervais 2025; Katapodis and Gervais 2016). Table 6 summarizes the hydraulic model velocity inputs used for fish passage assessment. Fish passage was based on Arctic char, for which the SPOT tool has species-specific data. Details on the fish passage assessment are provided in Appendix B.

Table 6 SPOT Tool Assessment

Month	Fish Size (mm)	SPOT Tool Criteria Velocity (m/s)	Modelled Velocities (m/s)	Distance (m)
July	85	0.39	0.3 – 0.45	29/30
August	40	0.21	0.15 – 0.3	

Based on the fish passage assessment using the SPOT tool for July and August, 50% or more of the Arctic char age class for each month can pass the proposed CV-216 replacement culvert configuration.

5.2 Geotechnical Analyses

A geotechnical drilling investigation program for CV-216 was conducted on July 11, 2025. Drilling services were provided by M-Roc Ltd. completed under the continuous supervision of Nunami Stantec geotechnical personnel. Three (3) boreholes were drilled using a track-mounted Sandvik Ranger DX800 air-rotary drill rig with observations taken on soil stratigraphy, frozen soil conditions, and seepage/sloughing conditions. Details on the field investigation program are provided in Appendix C.

The drilling program consisted of using 51 mm diameter drill rods advanced to a maximum depth of 21.1 m. Samples were collected from the pulverized return cuttings blown to the surface. The boreholes were backfilled with soil cuttings (excluding frozen soils or ice) and surrounding material. All samples were visually inspected in the field for material types and transferred to our Winnipeg laboratory for further inspection and testing.

Following the departure of the Nunami Stantec team, borehole BH216-02 was re-drilled by Baffinland, and one (1) thermistor string with datalogger was installed on August 17, 2025, to allow monitoring of ground temperature measurements. The thermistor installation details are indicated on the borehole records in Appendix B. Ground temperature data has not yet been downloaded by Baffinland at this time. Details of the investigation program are provided in Appendix C.

Geotechnical site conditions including soil stratigraphy, frozen soil conditions, and seepage/sloughing conditions were assessed during the field investigation. The general stratigraphy near CV-216 consisted of granular fill, overlying poorly graded sand with silt, underlain by a deposit of massive ice of suspected glacial origin. Detailed descriptions of the seepage and soil sloughing conditions encountered are provided on the borehole records. The borehole records along with an explanation of the symbols and terms are available in Appendix D. A summary of observations and testing conducted for the soil layers encountered are provided in Appendix C.

Following the geotechnical field investigation, a geomorphologic review was conducted to assess the field findings and provide additional interpretation of the geotechnical findings. The following are key observations made from review of the borehole findings, topographic information, and drone and satellite imagery:

- A large thermokarst-glacial lake is present along the Tote Road at this location. Likely originally a kettle lake, which further expanded by thermokarst processes. Kettle lakes are formed by the melting of relict glacier ice and the shape of kettle lakes is normally oval; classic thermokarst lakes are formed by the melting of ice-rich permafrost along the periphery of the kettle lakes, and the shape of thermokarst lakes become irregular and serrated (as observed at this site).
- Thermokarst depressions are abundant along the road, formed by the melting of ice-rich permafrost.
- The road is underlain by massive ground ice, including ice wedges (ice-wedge polygonal networks are visible in the satellite imagery) and buried glacier ice.

Based on the findings of the geotechnical investigation, and our understanding of the proposed by-pass design, the following key geotechnical concerns have been identified:

- Thermal degradation of massive ice below and adjacent to the crossing
- Slope stability of embankment side slopes.

These geotechnical concerns are discussed in detail in Appendix C and the mitigative measures recommended are discussed below.

To reduce the thermal degradation of the massive ice, measures should be taken to reduce the potential for water coming in direct contact against exposed massive ice and prevent water flow within native materials or culvert fill below the ground surface.

The slope stability analysis was performed using the software SLOPE/W, developed by GeoSlope International Inc. to evaluate the road embankment side slopes of the replacement culvert crossing. The slope stability analysis is discussed in detail in Appendix C. The following are the key findings of the analysis:

- A 0.3 m thick riprap layer along the upstream embankment side slope is required to reach the target FS at the proposed 2H:1V sideslope.
- A 1.0 m thick riprap along the downstream embankment side slope, and 24” diameter stone gravity toes at the bottom of the slope are required to reach the target FS at the proposed 1.5H:1V sideslope.
- Shallow slip surfaces within the riprap fill were excluded from the analyses by specifying the minimum slip surface depth. Shallow slip surfaces within the riprap may occur, which do not impact embankment integrity, however, would necessitate maintenance (i.e., restoration of the riprap).

6 Culvert Design

6.1 Culvert Configuration

The design configuration resulting from the 2D hydraulic model detailed in Section 5.1 is a triple barrel culvert with two 1800 mm corrugated steel pipes (CSP) (A and C) embedded 300mm and one centre (B) multiplate corrugated steel pipe arch with a 2440 mm span and 1750 mm rise embedded 20% (or 350 mm) (Figure 10). The embedment assists with fish passage and provides separation from the underlying massive ice zone (Magura 2007). A design detail summary for each culvert is provided in Table 7.

Figure 4 Culvert Design Configuration Cross-Section

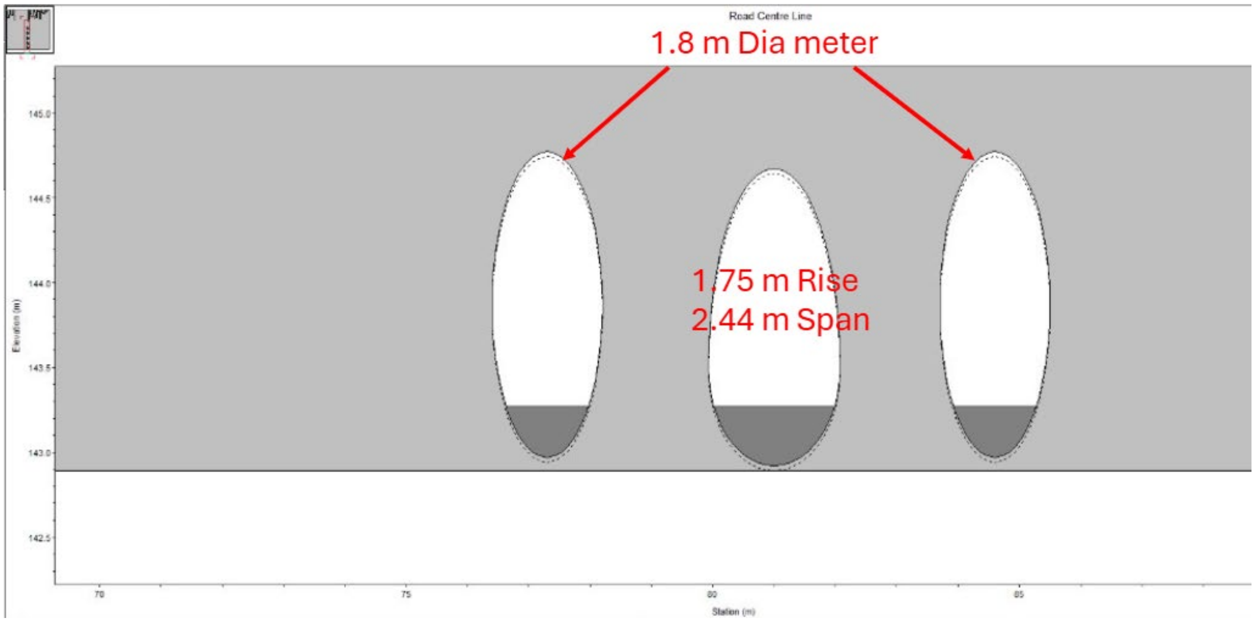


Table 7 Culvert Design Attributes and Model Results (looking downstream)

Parameter	Left (A)	Centre (B)	Right (C)
Material	Corrugated Steel	Corrugated Steel, Multi-Plate	Corrugated Steel
Shape	Circle	Pipe Arch	Circle
Internal Dimension	1800 mm	2440 Span 1750 Rise	1800 mm
Embedment	15% or 300mm	20% or 350 mm	15% or 300mm
Slope	0.1%	0.1%	0.1%
HW/D	0.75	0.80	0.74
WSC – Inlet	142.97 m	142.92 m	142.97 m
WSC – Outlet	142.941 m	142.891 m	142.941m

During construction no embedment material will be placed within the centre (B) culvert. Existing sand from the upstream channel bed will eventually be transported and deposited in the center culvert to fill to the embedment depth. Using native sand characteristic of this specific watercourse will enable the watercourse to maintain embedment in equilibrium with natural sediment transport and will avoid internal culvert damage.

6.2 Riprap Sizing and Scour Depth

Riprap size was estimated using the Pilarczyk's equation (Transportation Research Board 2006) and scour was calculated using a variety of methods. Results are summarized in Table 8.

Table 8 Riprap and Scour Calculation Results

Parameter	Method	Result
Rock Size	Pilarczyk	Upstream: 5 mm Downstream: 370 mm
Scour Depth	Lacey	0.88 m
	Blench (USBR)	1.03 m
	Blench (TAC)	3.93 m
	USACE	4.13 m
	Neil	4.73 m

The upstream area can be protected using fine riprap (D_{50} of 6") available on site and the downstream area can be protected using coarse rock (D_{50} of 12"). The rip rap should not contain more than 10% fines (less than 37.5 mm diameter), and have a maximum diameter no more than 1.5x the D_{50} value. The thickness of the downstream side of the rip rap is also governed by the slope stability requirements in Section C.1.5. which indicates that a 0.30 m riprap layer is required on the upstream slope (2x a D_{50} of 6") and 1.0 m downstream (~3x a D_{50} of 12") The toe stones at the toes of the upstream and downstream slopes are proposed as gravity slope toes and will have a D_{50} of 24". Refuge stones (D_{50} of 24") are to be placed at the culvert outlets to provide refuge to fish. Similarly existing fish refuge pool shaped features downstream of the culverts will be rimmed with stones with a D_{50} of 24" to provide refuge. Note that the aggregate available at site will need to be sieved of finer material before placement.

6.3 Construction

Clean-line[1] estimates for materials and excavation required to realign the road and install the new culvert configuration are summarized in Table 9.

Table 9 Material Quantity Estimates

Item	Quantity[1]
Fine Riprap (D_{50} 6”)	99.9 m^3
Coarse Riprap (D_{50} 12”)	489.2 m^3
Toe Riprap, Refuge Stones (D_{50} 24”)	60 (total)
¾” Minus	105.8 m^3
4” Minus	1,481.7 m^3
Culvert (Arch Pipe)	29.2 m
Culvert (CSP)	58.6 m
Bentonite Sand Mix Layer	180.3 m^3
Excavation	227.1 m^3
Fill	1,718.6 m^3

Note:
Quantities output from Civil3D software do not account for settlement, void spacing, or compaction.

The extent of the road realignment from toe of embankment upstream to toe of bank downstream has an in-water area of 1,358 m^2. The existing road and culvert crossing to be removed from the unnamed watercourse has an area within the channel of 1,048 m^2.

Mitigation measures will be applied to reduce the potential impacts to fish and fish habitat during construction of the new crossing at CV-216. Mitigations include those in DFO's Measures to Protect Fish and Fish Habitat (DFO 2024a) and Standards and Codes of Practice (DFO 2024b). Site isolation and fish salvage will be implemented by Baffinland (or contractor) to confirm no fish are present in the construction area during instream work. Salvaged fish will be removed and replaced in the stream outside of the zone of influence. Erosion and sediment control (ESC) measures will be installed by Baffinland (or contractor) during installation or post-installation, as needed. Construction equipment will also remain outside of the wetted width of the stream, where possible, to minimize disturbance of habitat and introduction of sediment. Machinery will be inspected for leaks prior to use, and refueling will take place at least 30 m from any waterbody to avoid the introduction of deleterious substances to the water. Hydrologic isolation measures (if required) are to be designed and installed by Baffinland (or contractor).

7 Monitoring and Maintenance

During construction, roads and water crossings are to be inspected regularly for signs of degradation and maintenance requirements. Routine visual inspections will be conducted by trained personnel and will occur regularly including after heavy precipitation events, and construction activities. Road safety, stability, and erosion are several of the main factors that will be investigated during the routine inspections. A Stantec Nunami construction inspector will confirm elevations, materials/gradations, thicknesses, compaction, bentonite mixing and placement, slope angles and culvert joint collaring and multiplate construction. The inspector will report their findings in a post-construction report.

Environmental monitoring, including monitoring of suspended sediment (e.g. turbidity), is to be conducted throughout the construction of the culvert as was done previously (Baffinland 2024b). Post-construction monitoring will include water quality monitoring upstream and downstream of the crossing using the Water Crossing Monitoring Form in Appendix C of Baffinland's Roads Management Plan (Baffinland 2020). This includes the evaluation of the potential entry of roadbed fill into the channel, and streambed scour or bank erosion. Further, environmental monitoring will be done by Baffinland to confirm the viability and success of fish passage at each crossing during the open water season. Fish-bearing crossings have been monitored annually since 2008/2009 with results provided to DFO each year. Monitoring includes assessments at each crossing of fish habitat, fish use, and accessibility of fish-bearing crossings (fish passage) (Baffinland 2025b).

8 Limitations and Constraints

This design brief for the replacement design of CV-216 was completed with the understanding that the existing culvert crossing was actively failing and a replacement design was required to restore the roadway, flow conveyance and fish passage as soon as possible. To facilitate rapid repair, Nunami Stantec provided this design brief with the following limitations:

- Road realignment routing in proximity to existing crossing, as selected by Baffinland due to environmental permitting constraints.
- Design was limited to materials readily available or already present on site, and construction methods which could be readily implemented by Baffinland.
- Design intended as "Emergency" measures to provide immediate road access, based on site-specific modelling conducted.

As part of the geotechnical field investigation completed by Nunami Stantec in July of 2025, extensive massive ice was identified under the existing CV-216 crossing location. The presence of massive ice under the foundation was identified as a concern for long-term crossing stability. The area of the proposed realignment crossing was not assessed during the geotechnical field investigation, but it is reasonable to assume that conditions are similar to those encountered at the current CV-216 crossing. Similar adverse performance issues may occur at the realignment crossing location in the short or long term. If acceptable performance prevails for the longer term in the realignment crossing area, Baffinland may choose to adopt an observational approach to monitor and maintain the crossing. Baffinland should understand that there is additional risk with this approach and that performance monitoring and mitigation plans should be in place to manage risk related to performance issues which may arise. The proposed design crossing will be monitored and maintained to manage risk related to performance issues, as described in Section 7 of this report.

This design brief has been prepared for the sole benefit of Baffinland and its associated regulatory process, and may not be used by any third party without the express written consent of Nunami Stantec and Baffinland. Any use which a third party makes of this design brief is the responsibility of such third party. Such third party agrees that Nunami Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

This design brief is based on information provided by Baffinland. Nunami Stantec has a right to reasonably rely on the information and data provided by Baffinland or obtained from generally acceptable sources within the industry without independent verification except to the extent such verification is expressly included in the services. Unless expressly stated otherwise, assumptions, data and information supplied by, or gathered from other sources upon which Nunami Stantec's opinion as set out herein is based has not been verified by Nunami Stantec and Nunami Stantec makes no representation as to its accuracy and disclaims all liability with respect thereto.

Preparation of this design brief, and all associated work, was conducted in accordance with the normally accepted standard of care for the specific professional service provided to Baffinland. No other warranty is made and Nunami Stantec does not guarantee the performance of the project in any respect, only that its engineering work and judgements rendered meet the standard of care.

9 Summary & Next Steps

The CV-216 by-pass replacement culvert crossing for the failed CV-216 culvert crossing located at kilometer 80.5 on the Milne Inlet Tote Road consists of three corrugated steel culverts (two high flow straight barrel; one embedded central pipe arch) to provide road access, address structural and hydrologic conveyance issues and fish passage within the unnamed watercourse to Muriel Lake. The level of excavation for the culvert crossing design has reduced excavation to the extent feasible to reduce thermal degradation of the underlying subsurface ice. Roadbed sideslope cutoff walls using a bentonite sand mix on the upstream and downstream slopes within the channel are proposed to reduce seepage through the roadbed and around the culverts to reduce likelihood of thermal degradation of the underlying subsurface ice. The proposed design allows passage for a minimum of 50% of Arctic char of monitored lengths along the Tote Road during July and August.

The following activities are recommended to support the construction of and maintain the culvert crossing:

- Retain Nunami Stantec to provide construction support to oversee construction in the field, confirm that the design objectives are met, and to provide engineering support as required to respond to construction questions.
- Maintain adequate component waterbody setbacks to account for regulatory buffers crossing infrastructure thus reducing potential environmental effects of the project.
- Implement erosion and sedimentation controls throughout construction and operation. Early adoption of these controls will achieve site stabilization and reduce the sediment accumulation volume, and the frequency of clean-out required.
- Following monitoring and maintenance plans for the constructed crossing.

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Appendix A Fluvial Geomorphic Assessment

Photo 1: Culvert Crossing CV216 – Upstream side looking upstream

Photo 2: Culvert Crossing CV216 – Downstream side looking downstream

Photo 3: Culvert Crossing CV216 – Inlet

Photo 4: Culvert Crossing CV216 – Outlet

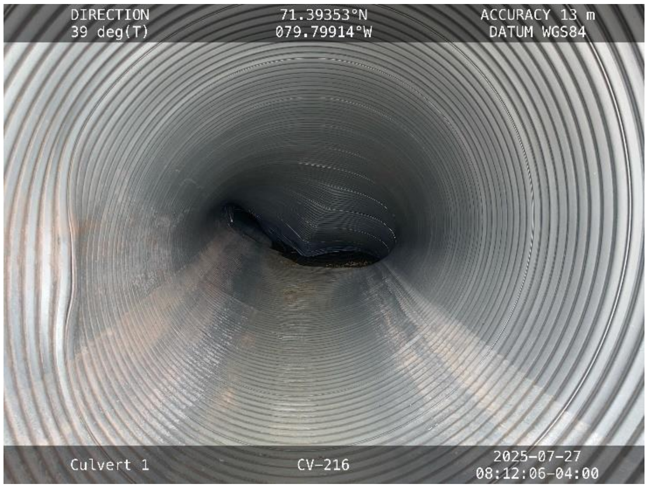

Photo 5: Culvert Crossing CV216 – Culvert 1 upstream

Photo 6: Culvert Crossing CV216 – Culvert 2 upstream

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Client/Project
Client Baffinland
Project Name Baffinland Culvert
Month Year: 2025
Project Number:
169525601
Appendix
A.1
Page
1 of 3
Title
PHOTOGRAPHIC RECORD

Photo 7: Culvert Crossing CV216 – Culvert 3 upstream

Photo 8: Culvert Crossing CV216 – Culvert 4 upstream

Photo 9: Culvert Crossing CV216 – Culvert 5 upstream

Photo 10: Culvert Crossing CV216 – Culvert 1 downstream

Photo 11: Culvert Crossing CV216 – Culvert 2 downstream

Photo 12: Culvert Crossing CV216 – Culvert 3 downstream

Photo 13: Culvert Crossing CV216 – Culvert 4 downstream

Photo 14: Culvert Crossing CV216 – Culvert 5 downstream

STANTEC CONSULTING LIMITED **RAPID GEOMORPHIC ASSESSMENT**

Watercourse:		**Date:**	27-Jul-25
Location:	Baffinland, Baffin Island, NU	**Reach:**	CV216

FORM/	GEOMORPHIC INDICATOR		PRESENT		FACTOR
PROCESS	NO (2)	DESCRIPTION (3)	NO (4)	YES (5)	VALUE (6)
Evidence of Aggradation (AI)	1	Lobate bar		X	
	2	Coarse material in riffles embedded		X	
	3	Siltation in pools	X		
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials	X		
	7	Deposition in overbank zone	X		
		SUM OF INDICES	3	4	0.57
Evidence of Degradation (DI)	1	Exposed bridge footings	N/A	N/A	
	2	Exposed sanitary/storm sewer/pipeline/etc.	N/A	N/A	
	3	Elevated stormsewer outfall(s)	X		
	4	Undermined gabion baskets/concrete aprons/etc.		X	
	5	Scour pools d/s of culverts/stormwater outlets		X	
	6	Cut face on bar forms	X		
	7	Head cutting due to knick point migration	X		
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank	X		
	10	Channel worn into undisturbed overburden/bedrock	X		
		SUM OF INDICES	5	3	0.38
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/ect.	X		
	2	Occurrence of large organic debris	X		
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Gabion baskets/concrete walls/ect. out flanked		X	
	7	Length of basal scour > 50% through subject reach	X		
	8	Exposed length of previously buried pipeline/cable/ect.	N/A	N/A	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation	N/A	N/A	
		SUM OF INDICES	4	4	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	X		
	2	Single thread to multiple channel	X		
	3	Evolution of pool-riffle form to low bed relief form	X		
	4	Cutoff channel(s)	X		
	5	Formation of island(s)	X		
	6	Thalweg alignment out of phase with meander form	X		
	7	Bar forms poorly formed/reworked/removed		X	
		SUM OF INDICES	6	1	0.14
STABILITY INDEX (SI) = (AI + DI + WI + PI) / m					**0.40**

Source: MOE 2003

0.00 - 0.21 = Stable **0.22 - 0.40 = Transitional** **0.41-1.00 = In Adjustment**

NOTES Surveyor:

STANTEC CONSULTING LIMITED		**RAPID STREAM ASSESSMENT TECHNIQUE**	
Watercourse:		**Date:**	27-Jul-25
Location:	Baffinland, Baffin Island, NU	**Reach:**	CV216

Evaluation Category	**Relative Significance**	**Excellent**	**Good**	**Fair**	**Poor**	**Score**
Channel Stability	* Indicative of hydrologic regime alteration and general condition of aquatic habitat * Provides insight into past, present and future morphological changes	>80% of bank network stable	71-80% of bank network stable	50-70% of bank network stable	<50% of bank network stable	1
		Stream bends stable. Outer bank height < 0.6m above stream	Stream bends stable. Outer bank height 0.6 - 1m above stream	Stream bends unstable. Outer bank height 1 - 1.3m above stream	Stream bends unstable. Outer bank height > 1.3 m above stream	3
		0-1 recent large tree falls/mile. Exposed tree roots are old.	2-3 recent large tree falls/mile. Exposed tree roots are predominantly older	4-5 recent large tree falls/mile. Young exposed tree roots are common.	>5 recent large tree falls/mile. Young exposed tree roots are abundant	10
		bottom 1/3 of bank is resistant plant material and/or soil matrix	bottom 1/3 of bank is generally resistant plant material and/or soil matrix	bottom 1/3 of bank is erodible material, plant/soil matrix compromised	bottom 1/3 of bank is highly erodible material, plant/soil matrix severely compromised	1
		Channel cross-section is V or U shaped	Channel cross-section is V or U shaped	Channel cross-section is trapezoidal	Channel cross-section is trapezoidal	6
Point Range		9-11	6-8	3-5	0-2	4.2
Channel Scouring/ Sediment Deposition	* Relates to level of uncontrolled stormwater runoff, sediment load and transport, and degradation of instream habitat	Riffle embeddness <25% sand/silt (35% if large mainstem reach)	Riffle embeddness 25-49% sand/silt (35-59% if large mainstem reach)	Riffle embeddness 50-75% sand/silt (60-85% if large mainstem reach)	Riffle embeddness >75% sand/silt (>85% if large mainstem reach)	0
		High number of deep pools <30% composed of sand/silt	Moderate number of deep pools 30-50% substrate composed of sand/silt	Low number of deep pools 60-80% substrate composed of sand/silt	Few, if any, deep pools >80% substrate composed of sand/silt	0.5
		Streambed streak marks and/or sediment deposits are absent	Streambed streak marks and/or sediment deposits are uncommon	Streambed streak marks and/or sediment deposits are common	Streambed streak marks and/or sediment deposits are very common	0.5
		Fresh sand deposits in channel and on overbank areas are absent	Fresh sand deposits in channel uncommon. Small localized overbank deposition	Fresh sand deposits in channel common. Small localized overbank deposition	Fresh sand deposits in channel very common. Heavy sand deposition over major porition of overbank area	7
		Point bars are few, small, stable, and well vegetated with little sand	Point bars are small, stable, and well vegetated with little sand	Point bars are moderate/large, unstable, with high amounts of sand	Point bars are moderate/large, unstable, with high amounts of sand at most stream bends	0
Point Range		7-8	5-6	3-4	0-2	1.6
Physical Instream Habitat	* Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well balaced aquatic community	Wetted perimeter >85% of bottom channel width (>90% for mainstem reaches)	Wetted perimeter 61-85% of bottom channel width (66-90% for mainstem reaches)	Wetted perimeter 40-60% of bottom channel width (45-65% for mainstem reaches)	Wetted perimeter <40% of bottom channel width (<45% for mainstem reaches)	5.5
		Riffle, run, pool habitat present. Diverse velocities and depth of flow	Some mix of riffle, run, pool features. Relatively diverse velocities and depth of flow	Few pools present. Riffle and run dominant, generally slow and shallow	Dominated by one habitat type (usually run) and one velocity/depth (usually slow/shallow)	3.5
		Riffle substrate is large (cobble, gravel, boulders) wit little sand. >50% cobble	Riffle substrate has a good portion of cobbles and gravel. 25-49% cobble	Riffle predominantly small cobble, gravel, and sand. 5-24% cobble	Riffles predominantly gravel with high percentage of fines. <5% cobble	0
		Riffle depth >0.20 m	Riffle depth 0.15-0.19 m	Riffle depth 0.10-0.14 m	Riffle depth <0.10 m	5.5
		Pool depth >0.60 m Good overhead cover	Pool depth 0.45-0.59 m Some overhead cover	Pool depth 0.0.30-0.44 m little or no cover	Pool depth <0.30 m no cover	3.5
		no channel alteration, no significant point bar formation or enlargement	slight amount of channel modification, slight increase in point bar formation or enlargement	moderate channel modification, moderate increase in point bars	extensive channel modification or point bar formation/enlargement	3.5
		Riffle/pool ration 0.9-1.1 : 1	Riffle/pool ration 0.7-0.89 : 1 or 1.11-1.3 : 1	Riffle/pool ration 0.5-0.69 : 1 or 1.31-1.5 : 1	Riffle/pool ration <0.49 : 1 or <1.51 : 1	3
		Summer afternoon temperature < 20 degrees Celcius	Summer afternoon temperature 20-24 degrees Celcius	Summer afternoon temperature 24-26 degrees Celcius	Summer afternoon temperature >27 degrees Celcius	7.5
Point Range		7-8	5-6	3-4	0-2	4

Water Quality	* Indicative of watershed perturbation/ general level of human activity, point and nonpoint source loads, and aquatic habitat conditions.	Substrate fouling level 0-10% (rock underside)	Substrate fouling level very light - light (11-20%)	Substrate Fouling level moderate (21-50%)	Substrate fouling level very high (>50%)	7.5
		TDS <50 mg/L	TDS 50-100 mg/L	TDS 101-150 mg/L	TDS >151 mg/L	5
		Clear water with objects visible >0.9 m	Objects visible 0.45-0.89 m	Objects visible 0.15-0.44 m	Objects visible <0.15	3.5
		No odour	Slight organic odour	slight - moderate odour	moderate to strong organic odour	7.5
Point Range		7-8	5-6	3-4	0-2	5.875
Riparian Habitat Conditions	*Provides insight into changes in energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of riparian buffer >200' with mature forests on both sides	Forested buffer generally >100' along major portion of both banks	Riparian area predominantly wooded by major localized gaps	Riparian area mostly non-woody vegetation, narrow width	0.5
		canopy coverage >80% (>60% for large mainstem areas)	canopy coverage 60-79% (45-59% for large mainstem areas)	canopy coverage 50-59% (30-44% for large mainstem areas)	canopy coverage <50% (<30 for large mainstem areas)	0.5
Point Range		6-7	4-5	2-3	0-1	0.5
Biological Indicators	* Best overall indication of stream health and level of watershed perturbation	diverse macroinvertebrates present dominated by flathead mayflies, stoneflies, and cased caddisflies (very few snails or leeches)	mayflies and caddisflies present (stoneflies absent). Good overall diversity	pollution tolerant species present (caddisflies, snails, midgeflies, aquatic worms)	poor diversity generally dominated by midgeflies, aquatic worms, and snails	
		moderate to high number of macroinvertebrates	moderate to high number of macroinvertebrates	low to moderate number of macroinvertebrates	low number of macroinvertebrates	
Point Range		7-8	5-6	3-4	0-2	
Total Score (42-50 Excellent, 30-41 Good, 16-30 Fair, <16 Poor)						16.175
Condition						Fair

Stream:
Location: **Baffinland, Baffin Island, NU**
Station: **CV-216**
Observers: **MKJ**
Date: **07/27/2025**
Stream Type:
Valley Type:

BEHI Score (Fig. 3-7)

Study Bank Height / Bankfull Height (C)

Study Bank Height (m) =	0.63 **(A)**	**Bankfull Height** (m) =	0.63 **(B)**	(A) / (B) =	1.00 **(C)**	0.0

Root Depth / Study Bank Height (E)

Root Depth (m) =	0.05 **(D)**	**Study Bank Height** (m) =	0.63 **(A)**	(D) / (A) =	0.08 **(E)**	9.3

Weighted Root Density (G)

Root Density as % =	5 **(F)**	(F) x (E) =	0.4 **(G)**	10.0

Bank Angle (H)

Bank Angle as *Degrees* =	50 **(H)**	3.5

Surface Protection (I)

Surface Protection as % =	5 **(I)**	10.0

Bank Material Adjustment:

Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

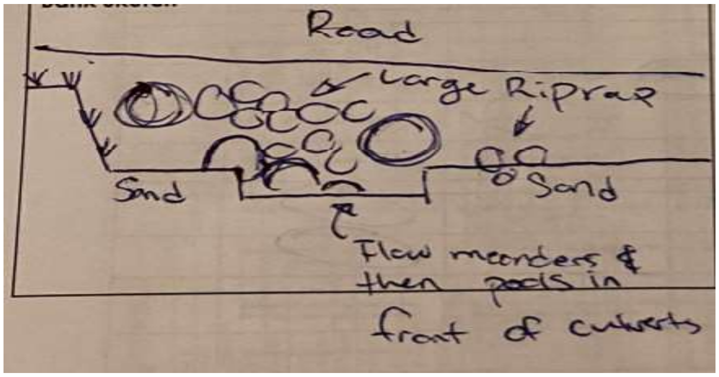
Bank Material Adjustment: 10

Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

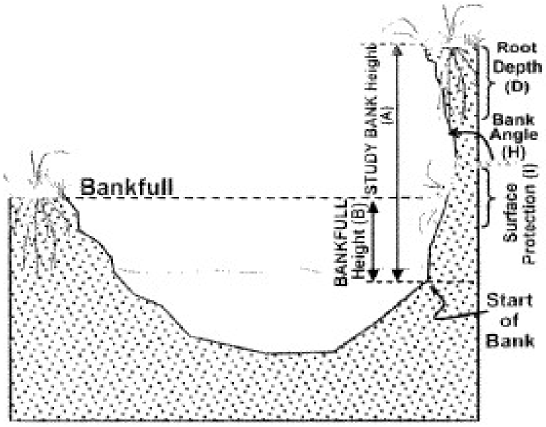
Very Low	Low	Moderate	High	Very High	Extreme
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50

Adjective Rating and **Total Score**: **Very High** 42.8

Bank Sketch



Flow meanders & then pools in front of culverts



Appendix B Hydrotechnical Analyses

This section describes the hydrotechnical analyses methods used to design the culvert replacement and summarizes the results. The analyses include hydrologic and hydraulic modelling to determine design flow flows and levels, and velocity ranges to assess fish passage and scour and erosion controls at the CV-216 replacement crossing. A fish passage assessment was conducted using the SPOT tool (Di Rocco and Gervais 2025) to assess if the appropriate length of Arctic char is able to swim through the proposed design.

B.1 Hydrologic Model

A Hydrologic Engineering Center's Hydrologic Modelling System (HEC-HMS) hydrologic model (USACE Hydrologic Engineering Center 2025) was developed for the CV-216 crossing to estimate design flow rates for the culvert crossing to be input into the hydraulic model to assess flood flow hydraulics and levels.

B.1.1 Methods

Climate Data

Climate data was incorporated into the hydrologic model as the meteorological model on which the hydrological model runs. There is a paucity of continuous, long-term climate stations in the far north. Nearby station climate data assessed as model inputs was for the Mary River and Milne Port climate stations operated by Baffinland and the Pond Inlet A climate station (Climate ID: 2403204) operated by Environment and Climate Change Canada (ECCC). Other climate stations exist, however, their records are either too short to develop long-term return periods, have been discontinued for some time or have highly incomplete records and were thus not included in this assessment. Figure 5 presents the locations of climate stations used in relation to the Tote Road site.

Figure 5 Climate and Hydrometric Station Locations

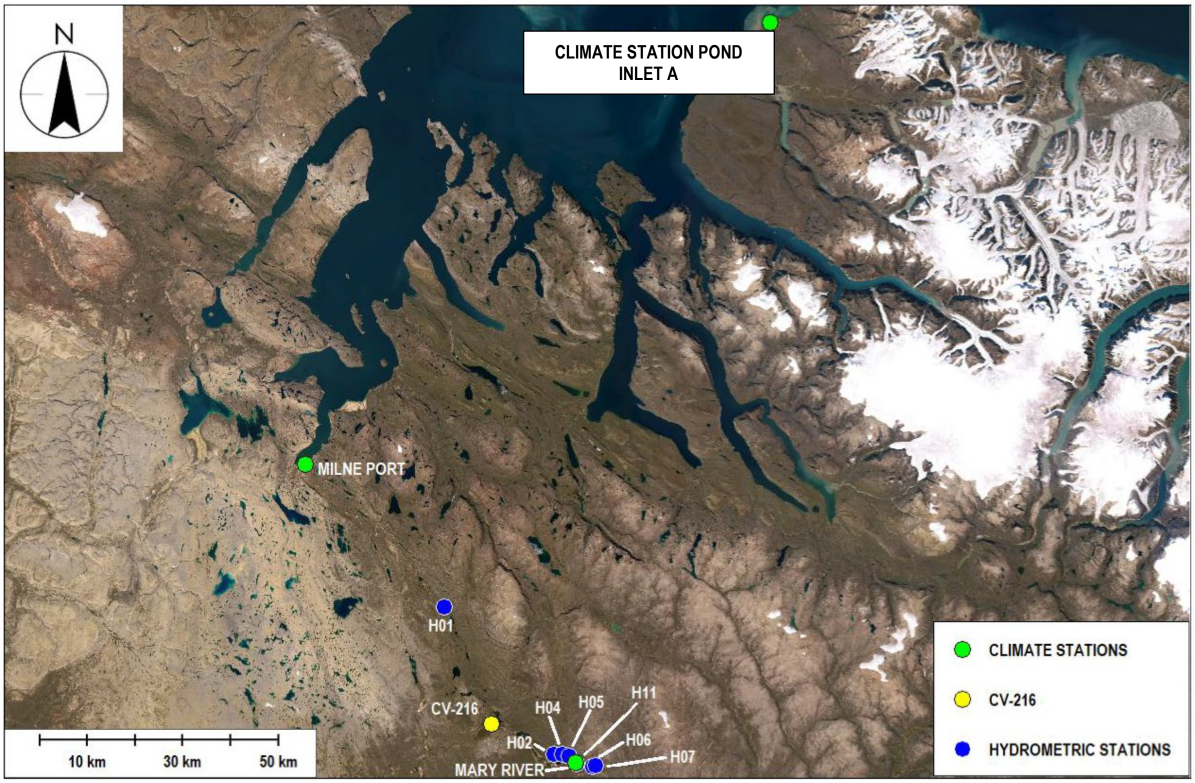


Table 10 summarizes the climate stations used in the hydrologic model.

Table 10 Summary of Climate Stations

Source	Climate Station
Baffinland	Mary River
	Milne Port
Environment and Climate Change Canada	Pond Inlet A (Climate ID: 2403204)

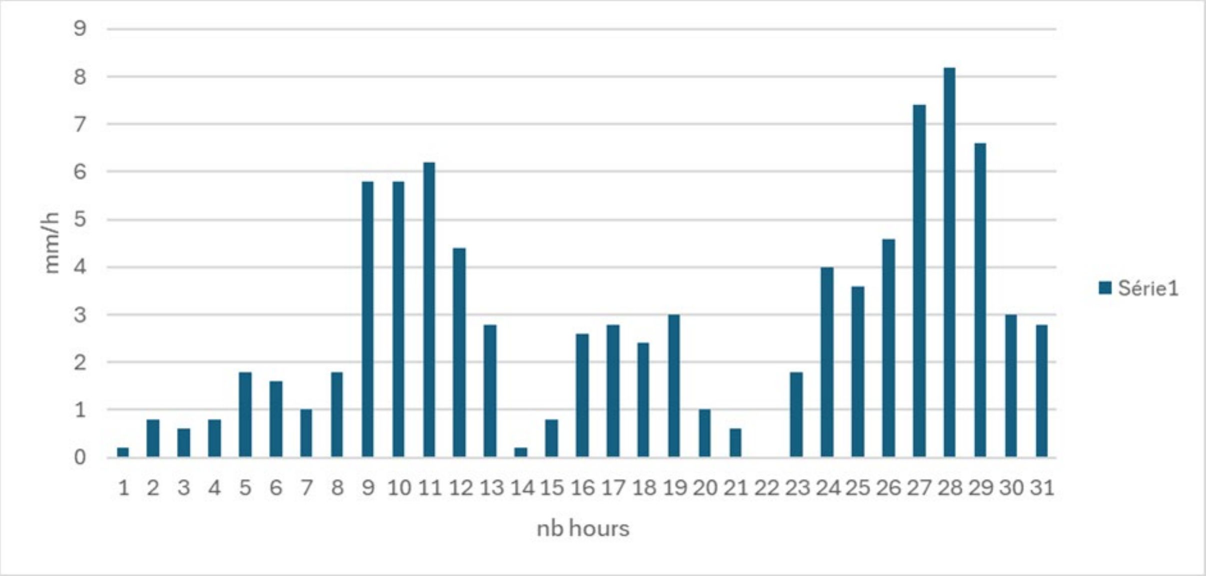
Pond Inlet A was used as the climate data source for the design events as it has the longest climate record and is in relatively close proximity (160 km) to the Tote Road culvert crossings. ECCC has developed an Intensity-Duration-Frequency (IDF) curve and table for the Pond Inlet A climate station, providing rainfall records for the 2-to-100-year return period storms. The snowmelt depth used to develop the design flows was the 75th percentile of the snow water equivalence (SWE) for the climate data from Pond Inlet A, which was calculated to be 6 mm. This was then added to the precipitation depth from the IDF curve to develop the design flows.

The meteorological model for design storm events was set up using a 24-hour duration SCS Type I distribution to estimate peak flows. CSA S503:20 “Community drainage planning, design, and maintenance in northern communities”, (CSA 2021) indicates:

- Cooler temperatures in northern Canada mean that thunderstorms are rare, resulting in few convective weather patterns that produce high-intensity rainfall.
- The U.S. Soil Conservation Service (SCS, now NRCS) recommends the use of an SCS Type I storm for non-coastal portions of Alaska, representing a low-intensity peak temporal distribution.

Further, the Mary River mine site meteorological station recorded an extreme storm event in September 2024 which deposited 89 mm over a period of 31 hours. The September 2024 storm hyetograph is depicted in Figure 6 and demonstrates lower peak intensity than that of a Type II storm and more reflective of a Type I storm distribution. As a result of CSA recommendations and meteorological records analysis, this assessment used an SCS Type I temporal distribution to design storm events.

Figure 6 Extreme storm event recorded in September 2024 at the Mary River Mine Site (Baffinland 2025, pers. comm.)



Climate Change Analysis

To account for projected climate change impacts on hydrology, the hydrologic model used climate-adjusted inputs for the design storm events at CV-216. The climate change adjusted intensity duration frequency (IDF) curve for the shared socio-economic pathways (SSP) 2-4.5 scenario for the 2031-2060 period was obtained for Pond Inlet A to calculate the precipitation for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year return periods (ClimateData.ca 2025). This climate change threshold and climate forecast horizon was used to capture the rapid rate of climate change occurring in the far north and the planned design life of the proposed culvert crossing. Table 11 summarizes the precipitation for a 24-hour event for the 2–100-year return periods for the SSP 2-4.5 scenario.

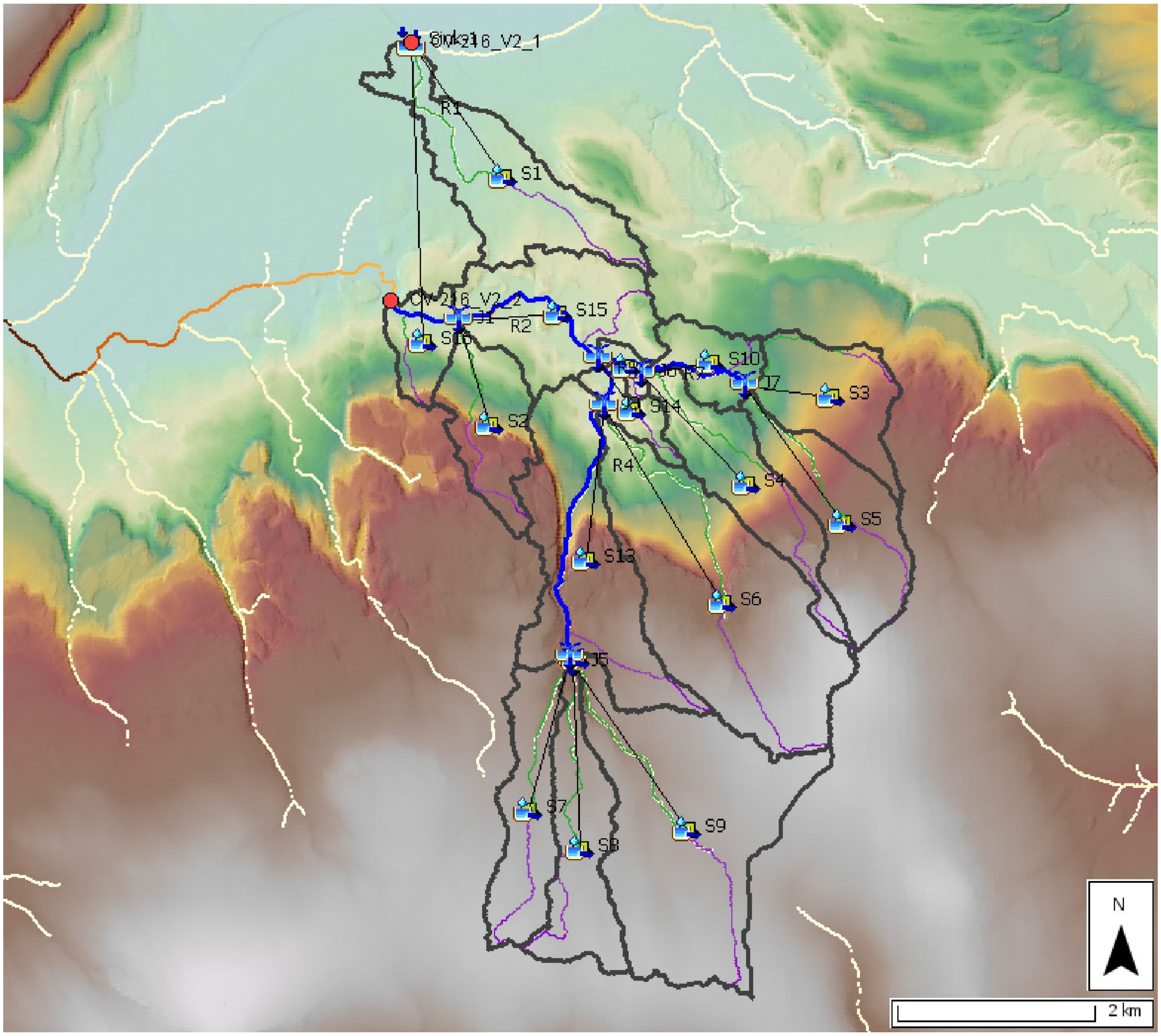
Table 11 SSP 2-4.5 Precipitation for 24-hour duration events for various return periods

Return Period	Precipitation (mm)
2-year	21.1
5-year	26.4
10-year	33.6
25-year	38.4
50-year	43.2
100-year	45.6

Watershed Delineation

The watershed boundaries were delineated using HEC-HMS. The delineation process utilized publicly available elevation data obtained from the Polar Geospatial Center's ArcticDEM (Porter et al. 2023) to be input into the model as terrain data. The terrain data was then pre-processed with HEC-HMS to pre-process sinks, drainage and identify streams. The delineation was conducted by defining an outlet and allowing the software to generate flow paths and catchment boundaries based on the terrain data. The total watershed area was delineated at approximately 27.11 km^2. Table 13 presents the summary of the subbasin areas delineated using HEC-HMS (Table 13).

Figure 7 CV-216 Watershed Delineation



Loss Method – SCS Curve Number

The loss method was based on the Soil Conservation Services (SCS) curve number (CN), an empirical surface runoff method developed by the US Department of Agriculture. A composite CN for each watershed was determined by taking the weighted averages of classifications defined from both the North American Land Cover (Commission for Environmental Cooperation 2020) and Global Hydrologic Soil Groups (Oak Ridge National Laboratory 2020). A specific SCS Curve Number was assigned to each land cover condition dependent on the soil group type. HEC-HMS uses hydrologic soil group definitions (A, B, C, and D), and the watershed area was determined to be Soil Group C with a moderately high runoff potential (<50% sand and 20-40% clay) to represent the low vegetation cover and permafrost dominated landscape. Table 12 presents the CN values associated with each class of land cover.

Table 12 Defined CN for different Land Cover Types

Classification ID	North American Land Cover	Corresponding CN
12	Sub-polar or Polar Grassland-Lichen-Moss	86
13	Sub-polar or Polar Barren-Lichen-Moss	81
16	Barren Lands	81
17	Urban and Built-up	98
18	Water	100

The watershed and subbasin areas were imported into GIS software to quantify the land cover and soil class areas within each. The areas within each subbasin were then weighted to the total area to calculate the weighted CN. Table 13 presents the composite CN for each subbasin.

Lag Time and Time of Concentration

The Watershed Lag Method developed by Mockus in 1961 is used for a broad set of conditions ranging from heavily forested steep channels to meadows and smooth surfaces (NRCS 2008). The formulas used are as follows:

$$L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900Y^{0.5}}$$

$$L = 0.6 * t_c$$

where,

L = lag (h)
t_c = time of concentration (hours)
ℓ = flow length (ft)
Y = average watershed land slope (%)
S = maximum potential retention (in) = 1,000/CN – 10

Table 13 presents the summary of the calculated lag times and time of concentrations for each subbasin. The longest flowpath for the entire watershed results in a time of concentration of 73 hours. The critical time of concentration for the watershed is at subbasin S1, which has a time of concentration of 20.1 hours. The outlet of subbasin S1 coincides with the location of the proposed culverts, and thus a 24-hour duration storm was chosen for design purposes as it was close to the critical time of concentration of 20.1 hours.

Table 13 CV-216 Summary of Parameters

Subbasin ID	Area (km^2)	CN	Lag Time (min)	Time of Concentration (hr)
S1	2.21	84	725	20.1
S2	1.27	82	321	8.9
S3	1.40	84	362	10.1
S4	1.56	84	469	13.0
S5	1.79	85	506	14.1
S6	4.43	84	609	16.9
S7	1.47	83	822	22.8
S8	1.57	85	895	24.8
S9	4.54	85	901	25.0
S10	0.69	83	290	8.1
S11	0.17	84	160	4.4
S12	0.01	83	53	1.5
S13	2.89	83	445	12.4
S14	0.41	84	228	6.3
S15	2.06	85	416	11.5
S16	0.63	83	170	4.7
R1	-	84	320	8.9
R2	-	85	1,714	47.6
R3	-	84	361	10.0
R4	-	83	573	15.9
R5	-	83	50	1.4
R6	-	84	346	9.6
R7	-	83	428	11.9

Calibration

To support the calibration of the hydrologic model, hydrometric station data was provided by Baffinland for six seasonal sites (June to September) within the Tote Road area (Figure 5). Seasonal water level and manual flow measurements have been monitored to develop rating curves for the various sites and predicted open water season flows at each of the sites from 2006 to 2024. Flow data from H04 was selected to support hydrologic model calibration for the Tote Road culvert crossings as it had a watershed area that was at the mid-point with respect to area (8.3 km^2) for the culvert crossing watersheds being planned for replacements or retrofits in 2025/26, including CV-216.

The HEC-HMS hydrologic model was calibrated for the Tote Road area using hydrometric station H04 flow data pro-rated for the CV-225 culvert crossing with a catchment area of 6.66 km^2. Table 14 summarizes the inputs to the hydrologic model. The CV-225 crossing watershed was used for model calibration as it is relatively close in proximity to the H04 station and had a similar watershed area to H04. The calibrated model used Milne Port precipitation data as the H04 peak flow times aligned better with its precipitation events than precipitation for the same runoff events at Pond Inlet A and the Mary River mine site. Temperature data was sourced from the Pond Inlet A station.

Table 14 CV-225 Summary of Parameters

Subbasin ID	Area (km^2)	CN	Lag Time (min)	Time of Concentration (hr)
S1	0.82	83	445	12.3
S2	1.69	85	541	15.0
S3	1.68	83	464	12.9
S4	1.45	85	400	11.1
S5	1.03	86	298	8.3
R1	-	86	283	7.9
R2	-	85	498	13.8

The calibration involved iterative adjustments to model parameters, including loss method, transform methods and baseflow characteristics to optimize the simulated data to align with the observed data. Hydrographs for simulated and observed flows were compared for the August to September 2019 period. The result shows that the model successfully captured the timing and magnitude of peak flow events, particularly the peaks during August. While the simulated flows tended to slightly overestimate the peaks during late August and mid-September, the overall alignment of hydrographs indicates that the model reasonably reflects the watershed's hydrologic response under high-flow conditions.

The calibration results compare observed and simulated flow data for the CV-225 watershed. The final calibrated model showed satisfactory agreement with the observed flows, indicating that the data sourced from climate station Pond Inlet A were appropriate for simulating the watershed hydrology at the site.

B.1.2 Results

The CV-216 hydrologic model for design storm events were set up using a 24-hour duration SCS Type I distribution to estimate peak flows. The SCS Type I distribution is applicable to Arctic climates (CSA 2021). Flow rates were determined by assessing each subbasin individually. The duration of the storm was chosen based on the critical time of concentration which is 20.1 hours. The 25-year return period storm event was selected as the design event for flood levels upstream of the crossing to avoid roadbed overtopping.

Table 15 CV-216 Climate Change Adjusted Design Storm Event Predicted and Factor of Safety Adjusted Peak Flow Rates

Return Period	Peak Flow Rate (m^3/s)
2	6.6
5	9.2
10	11.7
25	14
50	16
100	17.6

B.2 Hydraulic Model

B.2.1 Methods

Nunami Stantec developed a two-dimensional (2D) hydraulic model (the model) based on the bathymetry and LiDAR data to inform the replacement culvert design. To create the model, Nunami Stantec used River Analysis System (HEC-RAS version 6.4.1) developed by the Hydraulic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE). HEC-RAS can perform 2D unsteady flow simulations using either Shallow Water (SWE) or Diffusion Wave equations (DWE) (USACE 2024). The 2D hydraulic model used SWE for more accurate results. HEC recommends using the SWE set for the following situations:

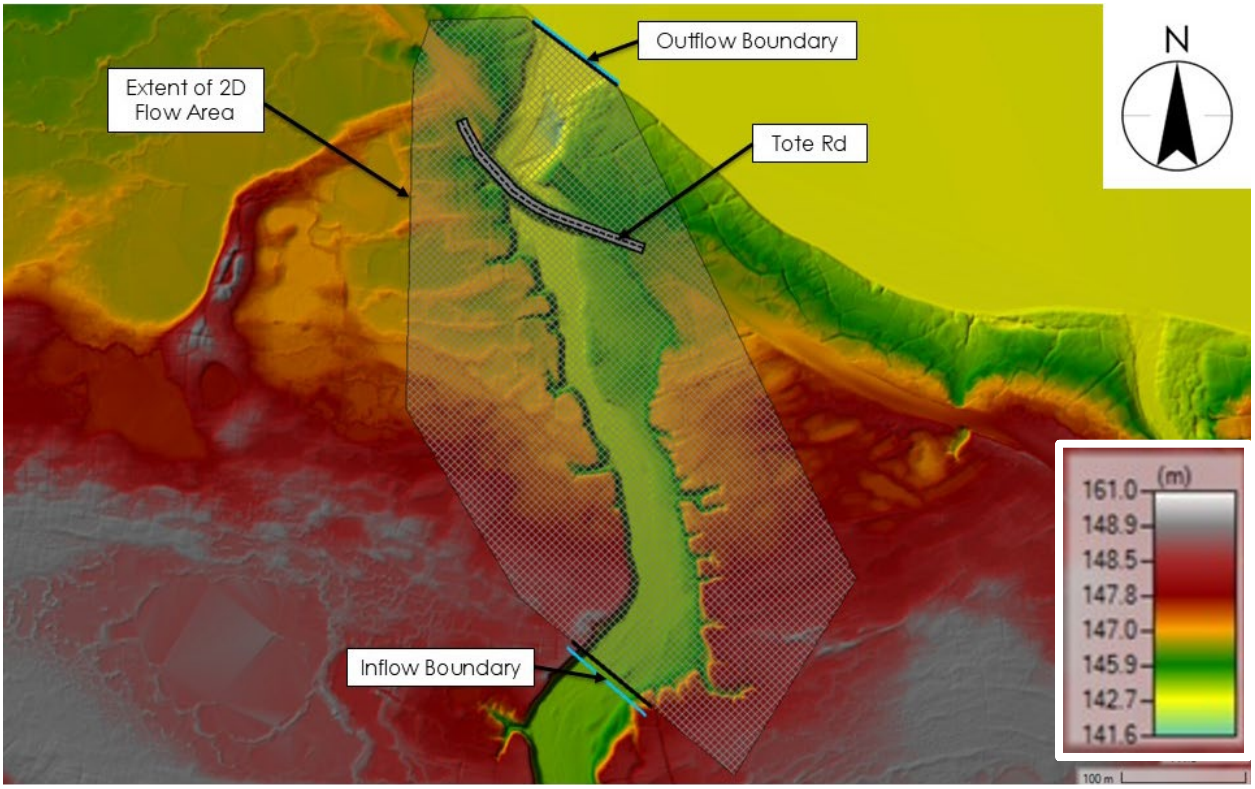
- Highly dynamic flood waves,
- Abrupt contractions and expansions,
- Flat sloping river systems,
- Tidally influenced conditions,
- General wave propagation modelling,
- Super elevation around bends,
- Detailed velocities and water surface elevations at structures, and
- Mixed flow regimes.

The 2D hydraulic model was prepared using RAS Mapper, a tool with geospatial capabilities included with HEC-RAS. RAS Mapper develops and visualizes terrain models to help analyze hydraulic models and visualize results (USACE 2024).

B.2.2 Model Setup

HEC-RAS requires geometric, hydrologic, and hydraulic data to compute water depths and flows. A DEM developed from a combination of bathymetry, LiDAR provided by Baffinland, The existing road alignment was removed from the DEM surface to match the road toe elevation throughout the footprint, and a custom surface representing the proposed road alignment was incorporated into the terrain model for the 2D hydraulic analysis (Figure 8). The footprint area of the removed road was 1,985 m², while the footprint area of the custom road was 1,736 m².

Figure 8 HEC-RAS Model Domain



The inflow boundary condition was set as a hydrograph. The hydrograph was set up to mimic steady flow conditions by starting the simulation at 0 m^3/s and then linearly increasing the flow up to the design flows. The outflow boundary condition was set as a normal depth of 0.01 m/m.

Land cover conditions were defined for the terrain based on the North American Environmental Atlas – Land Cover 2020 map (Commission for Environmental Cooperation 2020). Manning's n values were determined based on National Land Cover Database (NLCD) land cover type. The HEC-RAS 2D Manual provides estimates of Manning's n values for each NLCD land cover type (USACE 2024). Refer to Table 16 for the corresponding Manning's n values for each defined land cover condition. The channel bed assumed a Manning's N of 0.026, and the sand within the culvert was assumed to have a value of 0.03.

Table 16 Manning's N for Model Land Cover Conditions

Land Cover Condition	Manning's N
Sub-polar or Polar Grassland-Lichen-Moss	0.08
Sub-polar or Polar Barren-Lichen-Moss	0.03
Barren Lands	0.03
Urban and Built-up	0.035
Water	0.035

B.2.3 Results

The hydraulic model was used to design the replacement culvert crossing configuration by verifying that the road does not overtop within the active channel for a 25-year return period, 24-hour duration design storm event (Figure 3). The developed replacement culvert design is detailed in Section 6. Figure 9 shows the hydrograph for the 25-year design event.

Figure 9 Hydrograph for 25-year design event

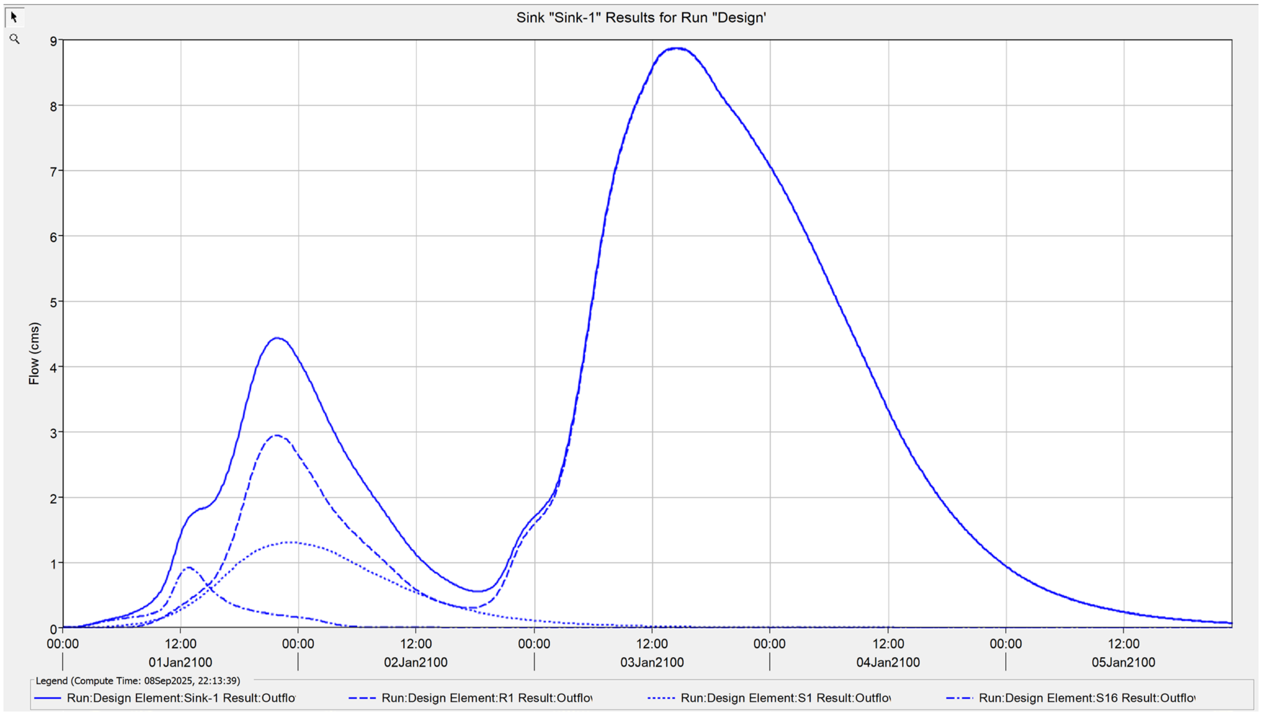
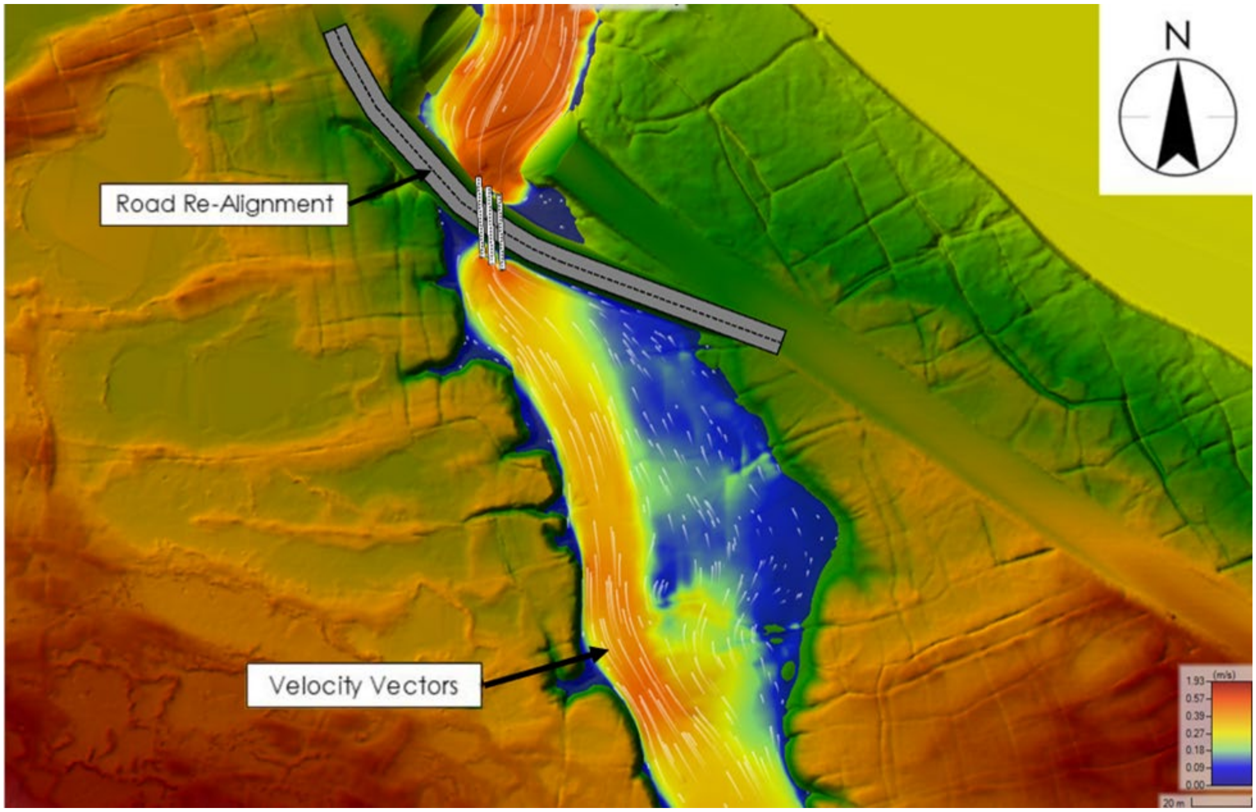


Figure 10 Flooding and Water Velocity Map for a 25-Year Return Period Design Storm Event



B.2.4 Fish Passage Assessment

B.2.4.1 Methods

Fish Passage Flows

The flows for fish passage were determined using the mean monthly unit discharge presented in Table 5. The calculated flows were input into the model to determine the velocities to allow 50% fish passage. This was based on the use of the criteria to allow passage of 50% of the appropriate size class of fish by Golder for adult Arctic Grayling which was approved by DFO (Golder 2021a and 2021b). In addition, DFO approved the use of the criteria to allow passage of 50% of the appropriate size class of fish for the Tote Road culverts in the CMO (KP 2024). Daily flows for the months of July and August at the hydrometric stations provided by Baffinland presented below were used to calculate the mean monthly unit discharge rates. The unit flows assessed for July and August at monitored stations are reflective of low evapotranspiration and lingering snowmelt and upper active zone permafrost zone melt yielding relatively high unit flow rates. The unit flow rate average values were applied to the watershed area of CV-216 to determine the average July and August flows against which fish passage was assessed.

Additionally, Magura (2007) studied how embedded CSP culverts affect internal flow velocities with implications for fish passage. The study used a 0.62 m diameter CSP with a 10% gravel substrate embedment and tested various slope and flow conditions with plotted isovels for half and full water levels. The study observed that embedded culverts created zones of reduced velocity near the bed and walls of the culvert that assist with fish passage through the culvert. The low-velocity regions within the culvert, influenced by secondary currents and boundary roughness provide a navigation pathway for fish swim through the culvert crossing (Magura 2007).

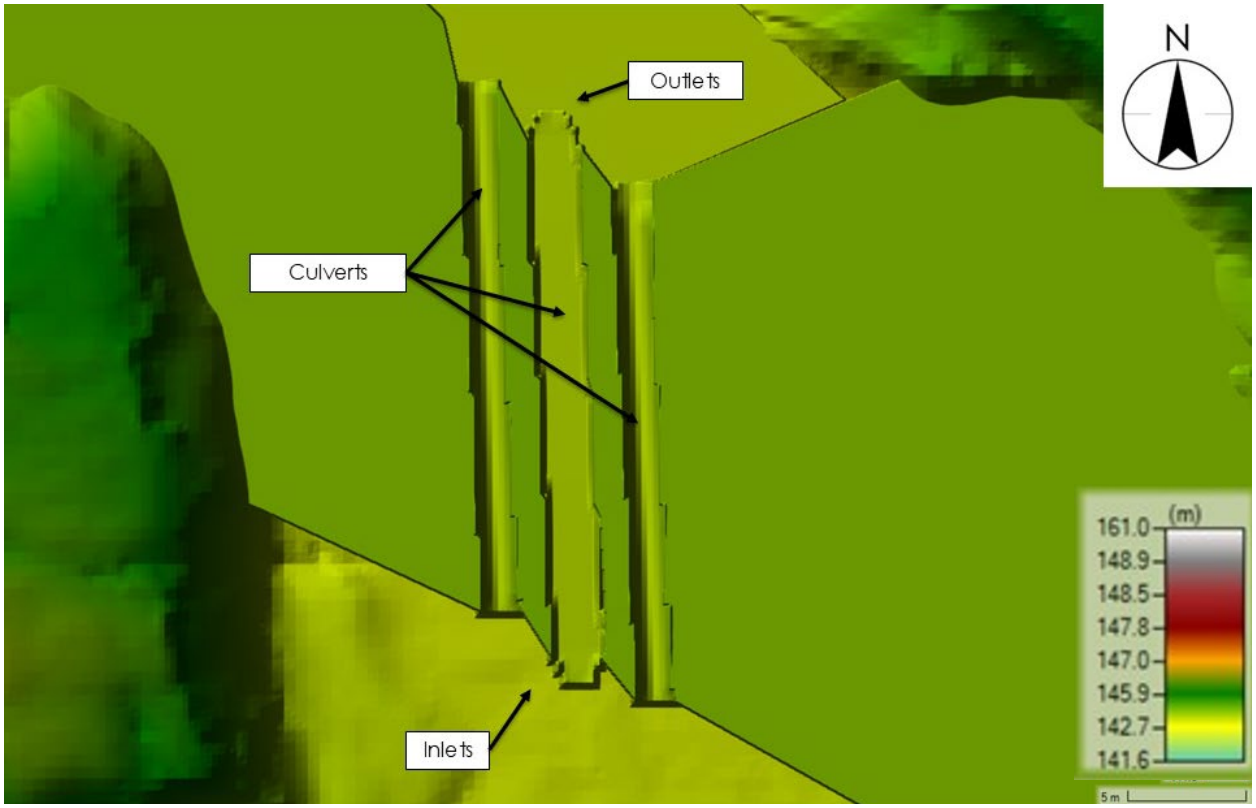
Table 17 Fish Passage Assessment July and August Mean Monthly Unit Flow Rates

Hydrometric Stations	Catchment Area (km^2)	July		August	
		Mean Monthly Unit Flow Rates (l/s/km^2)	Years Assessed	Mean Monthly Unit Flow Rates (l/s/km^2)	Years Assessed
H01	250	37.57	2014 - 2022	19.62	2014-2024
H02	210	67.22	2012-2022	26.50	2014-2022
H04	8.3	29.01	2014-2022	18.19	2011-2024
H05	5.3	30.28	2010-2024	20.62	2010-2024
H06	240	62.84	2015-2024	22.34	2010-2020
H11	3.6	20.64	2011-2022	25.53	2011-2024
Average Monthly Unit Flow Rates (l/s/km^2)		41.2		22.1	

Hydraulic Model Setup

The same 2D hydraulic model detailed in Appendix B.2 was used to assess fish passage during the July and August mean monthly flow conditions. For the month of July the flow was calculated as 1.118 m^3/s and 0.6 m^3/s for August To analyze the velocity through a culvert, a surface mimicking an open-channel flow in the culvert was used in place of a roadway as the culverts would behave similar to open channels in these lower average July and August flow conditions (Figure 11).

Figure 11 Hydraulic Model Terrain for Fish Passage Assessment



SPOT Tool

The species passage optimization tool (SPOT) was used to evaluate the feasibility of fish passage (Di Rocco and Gervais 2025). The proposed design for the July and August average hydraulic model velocity results were lowest along the culvert walls over the culvert length. The SPOT tool compares hydraulic conditions (velocity and length) with species-specific swimming capabilities to estimate a percent passing as observed by Katapodis and Gervais (2016). Table 6 summarizes the hydraulic model velocity inputs used for fish passage assessment. The assessment was consistent with methods that were previously applied for the new crossing design for CV-216 and other Tote Road crossings (KP 2024). Fish passage was based on Arctic char, for which the SPOT tool has species-specific data. The 85 mm length class in July are Young of Year (YoY) from the previous year whereas the 40 mm size class would be YoY from the current year migrating upstream to escape larger predatory fish in Muriel Lake downstream. On Baffin Island arctic char fry emerge from gravel reeds in July at about 25 mm and reach 40 mm by August.

Table 18 SPOT Tool Assessment

Month	SPOT Tool Criteria Velocity (m/s)	Modelled Velocities (m/s)	Distance (m)
July	0.39	0.3 – 0.45	29/30
August	0.21	0.15 – 0.3	

B.2.4.2 Results

Water depths within the culverts for the July and August flow rates are presented in Figure 12 and Figure 13, respectively. Plan view figures of the modelled velocities within the culverts for July and August are presented in Figure 14 and Figure 15, respectively.

Velocities were measured at 0.1 m distance from the pipe wall at three cross sections in each culvert, as shown in Figure 16 and Figure 17. For July, the model results demonstrate velocities of 0.3 m/s to 0.45 m/s taken from approximately 0.1 m from the edge of the culverts (Figure 16). Using the SPOT tool detailed above, 50% of 85 mm long Arctic Char can swim in 0.39 m/s for the 29-30 m culvert length indicating that >50% of the Arctic char age class can pass the culverts. For August, the model results demonstrate velocities of 0.15 m/s to 0.3 m/s taken from approximately 0.1 m from the edge of the culverts (Figure 17). Similarly in August, 50% of 40 mm long Arctic Char can swim in 0.21 m/s for the 29-30 m culvert length indicating that >50% of the Arctic char age class can pass the culverts. The assessments conducted for July and August demonstrate that fish can pass the proposed CV-216 replacement culvert configuration. assessments conducted for July and August demonstrate that fish can pass the proposed CV-216 replacement culvert configuration.

Figure 12 July Water Surface Elevation Profile Along Pipe Arch

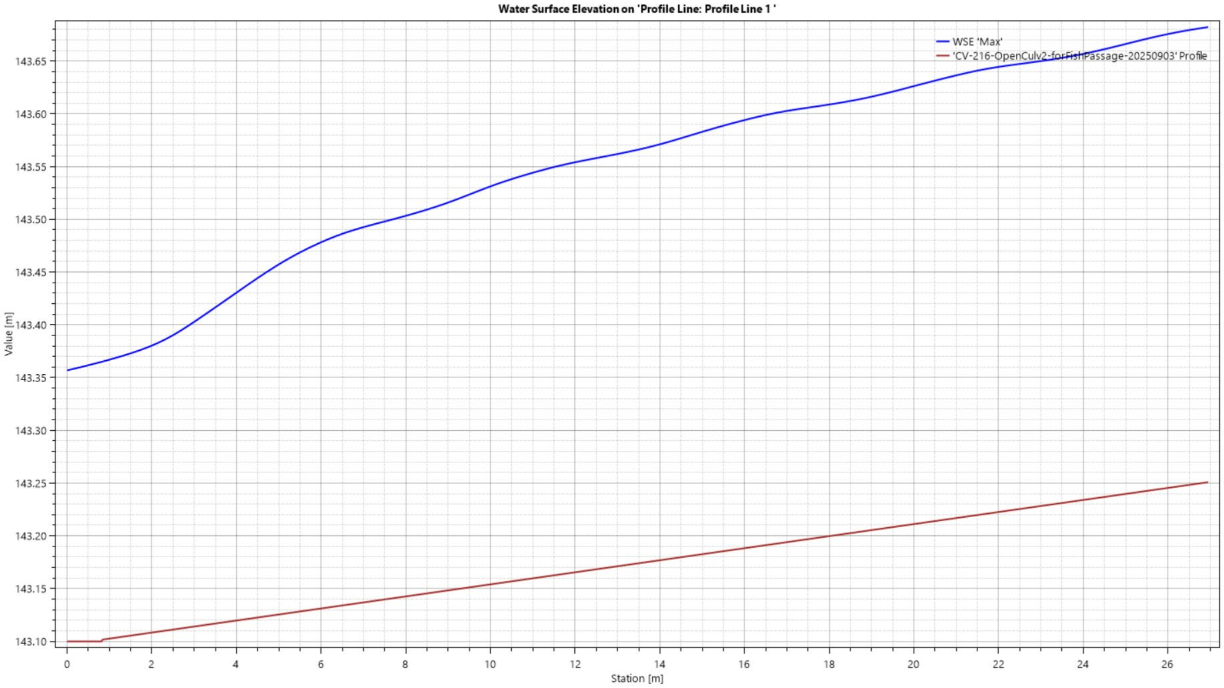


Figure 13 August Water Surface Elevation Profile Along Pipe Arch

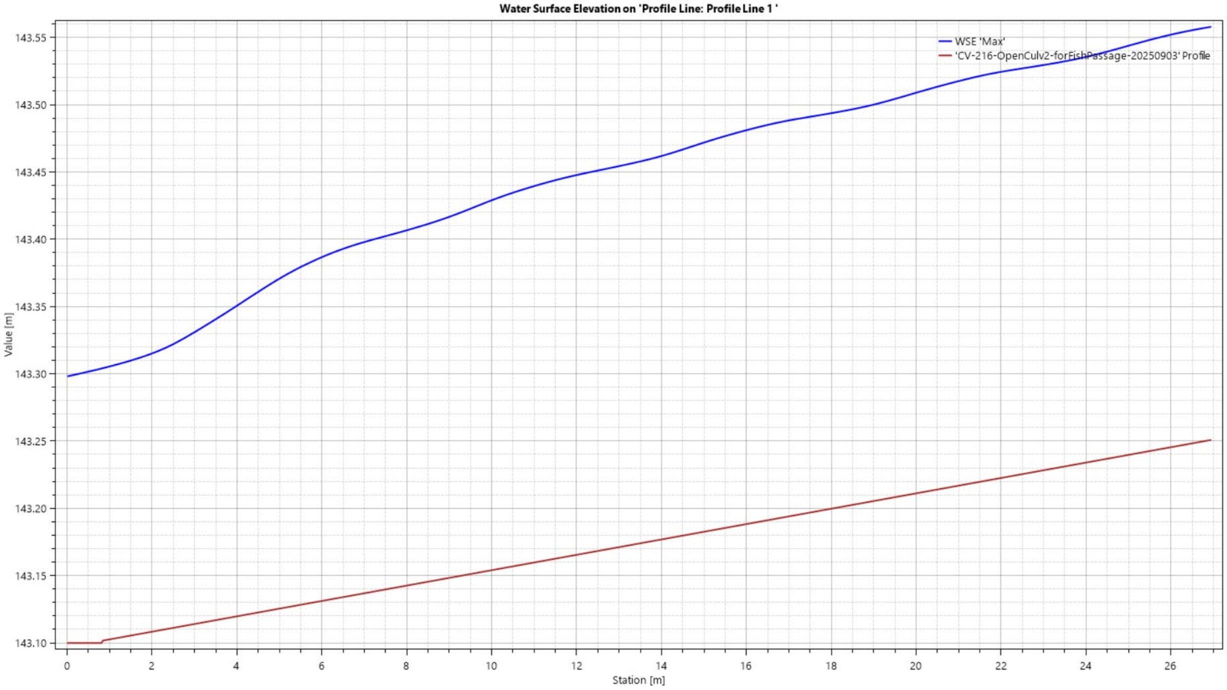


Figure 14 Velocity Results for July Fish Passage

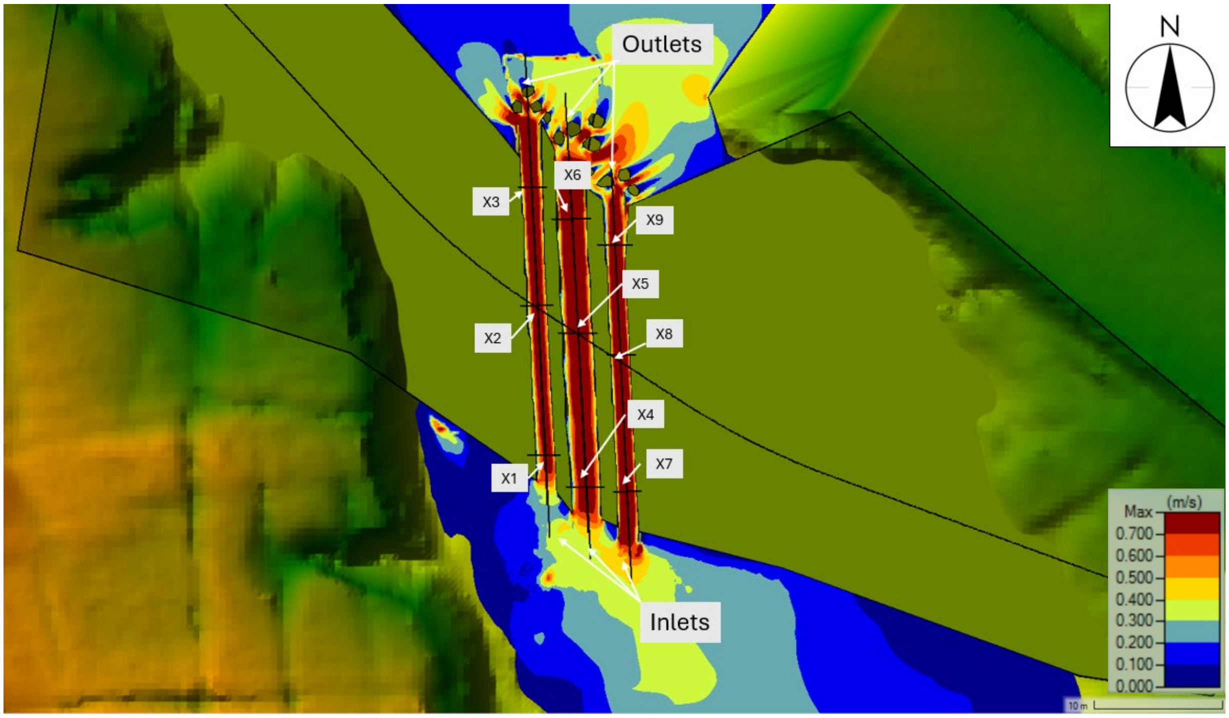


Figure 15 Velocity Results for August Fish Passage

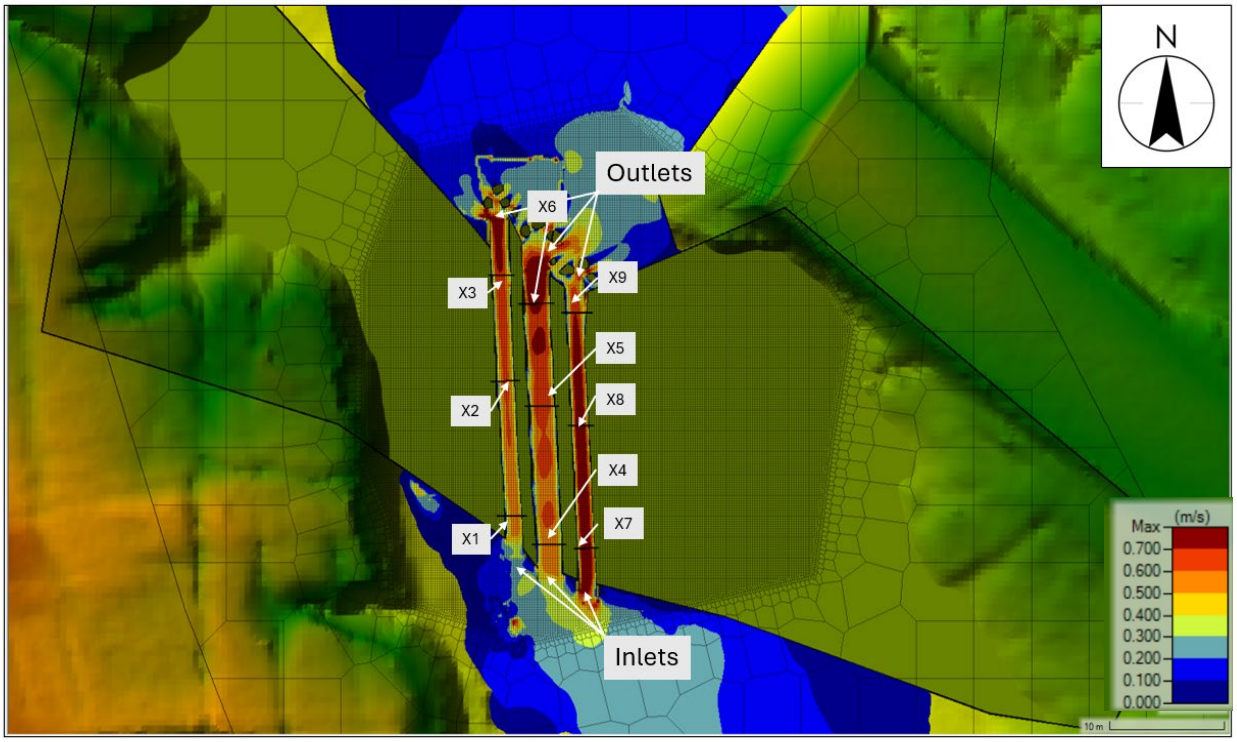


Figure 16 Cross-Sectional Velocity Results for July Fish Passage

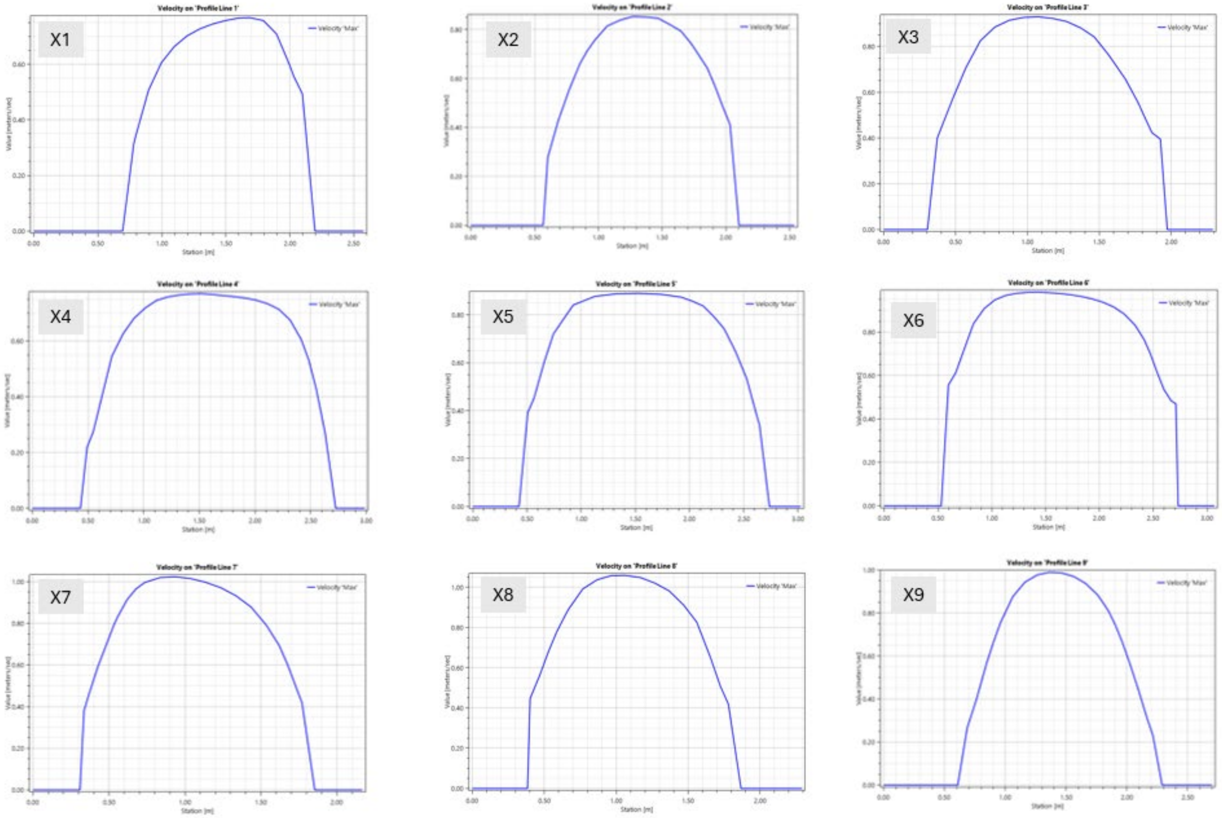
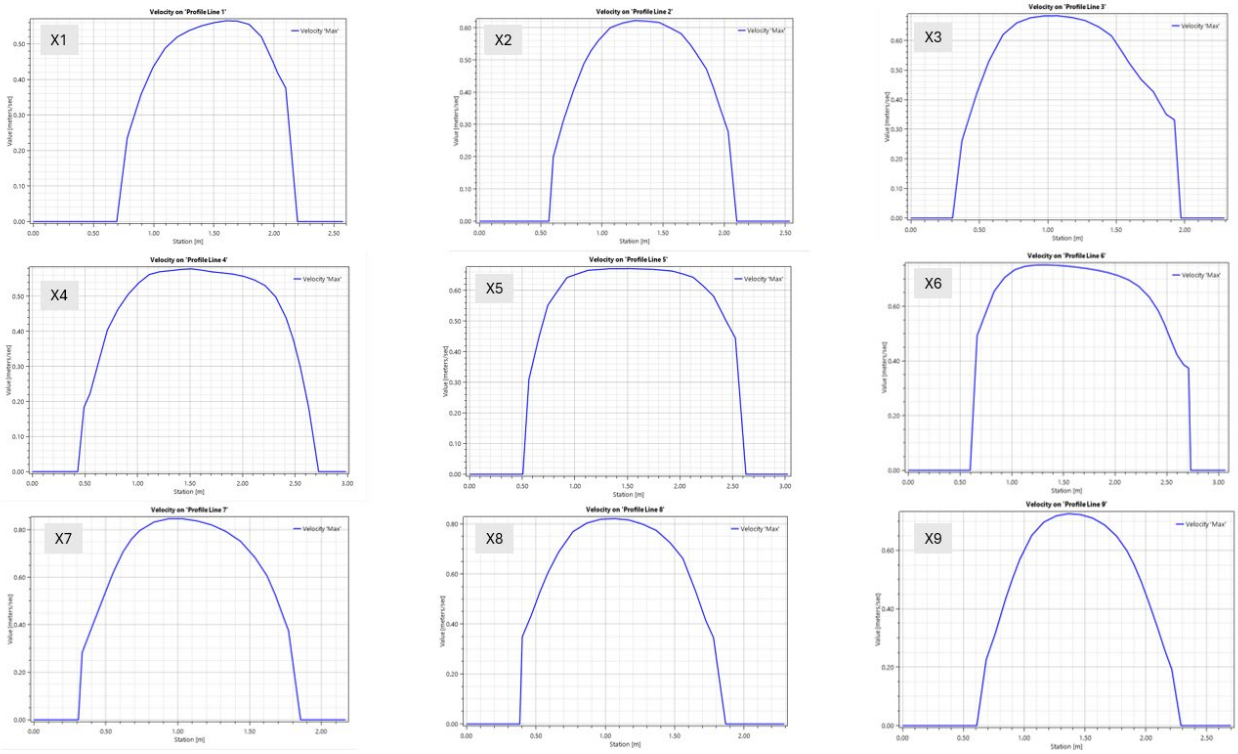


Figure 17 Cross-Sectional Velocity Results for August Fish Passage



Appendix C Geotechnical Analyses

C.1 Investigation Program

The geotechnical drilling investigation program for CV-216 was conducted on July 11, 2025. Drilling services were provided by M-Roc Ltd. completed under the continuous supervision of Nunami Stantec geotechnical personnel. Three (3) boreholes were drilled using a track-mounted Sandvik Ranger DX800 air-rotary drill rig with observations taken on soil stratigraphy, frozen soil conditions, and seepage/sloughing conditions. Borehole BH216-01 was drilled on the road surface, BH216-02 was drilled on the toe of the southbound embankment, and borehole BH216-03 was drilled on the toe of the northbound embankment. The borehole locations are shown on the Borehole Location Plan provided in Appendix D. The detailed borehole records are provided in Appendix D which includes a summary sheet outlining the symbols and terms used on the borehole records.

The drilling program consisted of using 51 mm diameter drill rods advanced to a maximum depth of 21.1 m. Due to the air-rotary process required to advance the boreholes, the structure of the frozen soils and any ground ice were heavily disturbed. Samples were collected from the pulverized return cuttings blown to the surface. The boreholes were backfilled with soil cuttings (excluding frozen soils or ice) and surrounding material. All samples were visually inspected in the field for material types and transferred to our Winnipeg laboratory for further inspection and testing.

Following the departure of the Nunami Stantec team, borehole BH216-02 was re-drilled by Baffinland, and one (1) thermistor string with datalogger was installed on August 17, 2025, to allow monitoring of ground temperature measurements. The thermistor installation details are indicated on the borehole records in Appendix D. Ground temperature data has not yet been downloaded by Baffinland at this time.

C.1.1 Stratigraphy

Geotechnical site conditions including soil stratigraphy, frozen soil conditions, and seepage/sloughing conditions were assessed during the field investigation. The general stratigraphy near CV-216 consisted of granular fill, overlying poorly graded sand with silt, underlain by a deposit of massive ice of suspected glacial origin. Detailed descriptions of the seepage and soil sloughing conditions encountered are provided on the borehole records. The borehole records along with an explanation of the symbols and terms are available in Appendix D.

A summary of observations and testing conducted for the soil layers encountered are provided below. Soils were classified in the field and on the borehole records in detail using the Unified Soils Classification System (USCS). Due to the air-rotary drilling process required to advance the boreholes, the structure of collected soil and ice samples was heavily disturbed.

C.1.1.1 Granular Fill

Surficial granular fill was encountered in boreholes BH216-01 and BH216-02. A depth of 2.9 m (approx. Elev. 143.6 m) was observed in borehole BH216-01 but was terminated early due to sloughing. The granular fill extended to a depth of 2.1 m (approx. Elev. 142.5 m) in borehole BH216-02. The granular fill was tan in colour and consisted of crushed rock material with a maximum 20 mm aggregate diameter. The moisture content of the granular fill ranged from 9% to 12% (overall average of approximately 10%).

C.1.1.2 Poorly Graded Sand (SP-SM) with Silt

Poorly graded sand with silt was encountered below the granular fill in borehole BH216-02 and on the surface of borehole BH216-03. Poorly graded sand with silt was identified at the grade level and beneath the granular fill layer, extending to depths between 2.7 m and 3.2 m (approximately Elev. 141.4 to 142.1 m). The poorly graded sand with silt was medium grained in size and brown in colour. The moisture content of the poorly graded sand with silt ranged from 12% to 15% (overall average of approximately 14%).The poorly graded sand with silt encountered was in an unfrozen state.

C.1.1.3 Massive Ice

The term “Massive Ice” is a comprehensive term used to describe large masses of ground ice, including ice wedges, pingo ice, buried glacier ice, and large ice lenses. Massive ice was encountered below the poorly graded sand in boreholes BH216-02 and BH216-03. The top of the massive ice was encountered at a depth ranging from 2.7 to 3.2 m (approx. Elev. 141.4 to 142.1 m). The base of the thick ice layer was not reached within the depths explored in the boreholes. In borehole BH216-02, the ice extended to 21.1 m (approximately Elev. 123.5 m), which corresponded to the maximum drill rod depth for that borehole. The massive ice was clear in appearance, with very little sediment inclusions. The gravimetric moisture content of the massive ice was approximately 15,040% (i.e., practically pure ice with negligible sediment). The significant thickness and purity of the massive ice suggest it is predominantly of glacial origin (i.e., a buried glacier). The upper several meters of the massive ice deposit may consist of ice wedge material that formed separately from the surface after the glacial ice was buried.

C.1.2 Geomorphology

Following the geotechnical field investigation, a geomorphologic review was conducted to assess the field findings and provide additional interpretation of the geotechnical findings. The following are key observations made from review of the borehole findings, topographic information, and drone and satellite imagery:

- A large thermokarst-glacial lake is present along the Tote Road at this location. Likely originally a kettle lake, which further expanded by thermokarst processes. Kettle lakes are formed by the melting of relict glacier ice and the shape of kettle lakes is normally oval; classic thermokarst lakes are formed by the melting of ice-rich permafrost along the periphery of the kettle lakes, and the shape of thermokarst lakes become irregular and serrated (as observed at this site).
- Thermokarst depressions are abundant along the road, formed by the melting of ice-rich permafrost.
- The road is underlain by massive ground ice, including ice wedges (ice-wedge polygonal networks are visible in the satellite imagery) and buried glacier ice.

C.1.3 Geotechnical Concerns

Based on the findings of the geotechnical investigation, and our understanding of the proposed by-pass design, the following key geotechnical concerns have been identified:

- Thermal degradation of massive ice below and adjacent to the crossing
- Slope Stability of Embankment Side Slopes

These geotechnical concerns are discussed, with mitigative measures recommended in the following sections.

C.1.4 Thermal Design Considerations

The primary geotechnical concern for the by-pass is thermal degradation of massive ice below and adjacent to the crossing. Thermal degradation (i.e., thawing) of the massive ice can result in the following problems:

- Loss of support beneath the culverts, which can impact culvert inlet/outlet elevations and results in culvert sagging/strain and rupture of culvert joints. Thawing of massive ice beneath the culvert results in proliferation of a thaw bulb of water in a liquid state, beneath the culvert. The ensuing loss of structural support combined with the weight of the overlying embankment results in the sagging of the culverts beneath the footprint of the embankment, centered primarily where the loading is highest (i.e., at the centre of the embankment). This leads to differential settlement of the culverts, with the largest settlements occurring at the centreline of the embankment, and the culvert inlets and outlets tipping upwards and becoming perched, relative to the culvert segments beneath the centre of the embankment.
- Interruption of surface drainage due to thaw subsidence of the streambed, leading to ponding of water on the upstream side of the embankment and the promotion of thermokarst processes adjacent to the embankment.
- Thaw settlement leading to unintended alteration of drainage (e.g., ponding water in localized depressions, exacerbated by perching of culverts due to differential settlement), which can then contribute to even more thawing of permafrost.
- Loss of support for the road embankment, leading to longitudinal cracking along road
- Compromised integrity of the massive ice in the vicinity of the proposed by-pass, at the existing failed CV-216 crossing alignment. The foundation ice at the existing CV-216 crossing has likely thawed significantly, creating a thaw bulb at that location.

For context, all the problems above appear to have occurred at the existing CV-216 crossing.

The primary mechanism for thermal degradation of the massive ice is convective heat transfer from water. This can occur from 1) stream water flowing in direct contact over the ice, or 2) water flow through porous material below the ground surface (i.e., flow within native materials or culvert fill). As noted in the list above, problems of thermal degradation compound one another and can result in rapid deterioration of the massive ice. This also occurred at the failed CV-216 crossing.

To reduce the thermal degradation of the massive ice, measures should be taken to reduce the potential for water coming in direct contact against exposed massive ice and prevent water flow within native materials or culvert fill below the ground surface. The following measures are recommended to reduce these risks (although they will likely not entirely mitigate the risks):

- Avoid excavations that expose massive ice during construction, including limiting excavation depths of culvert crossings to the extent feasible
- Provide bentonite cutoff walls along embankment sideslopes and beneath culverts
- Provide horizontal bentonite aprons at culvert inlets and outlets
- Minimize ponding of water particularly on upstream side of by-pass, by minimizing spatial extent of step-pools (where possible), and steaming of culverts prior to spring runoff to avoid upstream ponding.

C.1.5 Slope Stability Analysis

C.1.5.1 Methodology

The slope stability analysis was performed using the software SLOPE/W, developed by GeoSlope International Inc. SLOPE/W is a two-dimensional computer program that performs slope stability computations using limit equilibrium methods. The Morgenstern-Price method (Morgenstern and Price 1965) with a half-sine function for interslice forces was selected for performing the computations in SLOPE/W. The method uses both circular and non-circular shear surfaces, satisfies both moment and force equilibrium, and is considered to be the current industry state of practice. The computer model investigates many potential failure surfaces and, depending on the method of analysis used, can present the results in the form of contours of computed factor of safety against sliding.

Stability of a slope is typically generalized as a ratio of the forces that resist failure divided by the forces that drive failure. This unitless fraction is called a Factor of Safety (FS). Factors of safety that are unity (1.0) or less indicate that driving forces exceed resisting forces and from a geotechnical engineering perspective, the slope has failed or is highly unstable.

Due to the natural variability of soils, water surface elevations (WSE), and groundwater level conditions that affect the driving and resisting forces unpredictably, the geotechnical engineering industry typically requires a minimum FS of 1.5 for long-term steady state (normal operation summer and/or winter water level, etc.) scenarios and 1.3 for short-term transient (construction, flood, post flood rapid drawdown, etc.) scenarios.

C.1.5.2 Analysis Geometry

For this site, the slope stability analysis was performed to evaluate the road embankment side slopes of the replacement culvert crossing. This has been performed by evaluating the upstream and downstream road embankment stability. The upstream sideslope is 2H:1V, and the downstream sideslope is 1.5H:1V.

C.1.5.3 Analysis Scenarios

Two (2) analysis scenarios have been evaluated to review the stability of the side slopes of the replacement culvert crossing. Each scenario is outlined in the following points.

1. **Scenario 1 – Normal Water Levels:** This scenario consists of evaluating the slope stability of the replacement culvert crossing utilizing the proposed cross-section geometry, loading from ore hauling trucks, and normal water levels described in Section C.1.5.4.

2. **Scenario 2 – Critical Water Levels**: This scenario consists of evaluating the slope stability of the replacement culvert crossing utilizing the proposed cross-section geometry, loading from ore hauling trucks, and critical water levels described below in Section C.1.5.4

C.1.5.4 Water Level Conditions

The water levels used in the slope stability analyses of the replacement culvert crossing are outlined in the following points.

- The normal water level has been assumed to range from 143.31 m and 144.05 m on the downstream and upstream side, respectively, to showcase a 2-year flow event. Although the 2-year flow event exceeds typical flows, it is industry design practice to consider 2-year flow events as maximum "normal" water levels.
- The critical water level has been assumed to range from elevations of 143.40 m and 144.30 m on the downstream and upstream side, respectively, to showcase a 25-year flow event.

C.1.5.5 Slip Surface Details

Slip surface details utilized in the slope stability analyses are outlined in the following points.

- Slip surfaces were defined using the entry and exit method as described below:
  - The entry point has been set as a range along the top of the road, extending along the upper side slope of the road embankment.
  - The exit point has been set as a range along the lower side slope of the road embankment, extending along the riprap apron and the existing ground surface.
- Minimum slip surface depths of 0.5 m on the upstream side and 1.0 m on the downstream side have been utilized to avoid shallow surficial slip surfaces within the riprap material.
- Only circular slip surfaces have been evaluated.

C.1.5.6 Soil Strength Parameters

Based upon available information, laboratory testing results and correlations, typical values, and our experience with similar soil conditions, the effective shear strength parameters for the fill and in-situ materials at this site that have been used for the slope stability analyses are shown on Table 19.

Table 19 Summary of Effective Shear Strength Parameters

Material	Unit Weight (kN/m^3)	Effective Friction Angle (°)	Effective Cohesion (kPa)
Bentonite/Sand Mix	19	30	10
Fill and Sand	18	30	0
Granular Fill	20	36	0
Ice	Impenetrable		
Riprap	20	40	0

C.1.5.7 Results

The slope stability results for the normal and critical water level conditions are provided in Table 20.

Table 20 Slope Stability Results

Water Level Conditions	Side Slope	Minimum Slip Surface Depth (m)	Target FS	Estimated FS	Figure No.
Normal	Downstream	1.0	1.5	1.5	1
	Upstream	0.5	1.5	1.5	2
Critical	Downstream	1.0	1.3	1.5	3
	Upstream	0.5	1.3	1.5	4

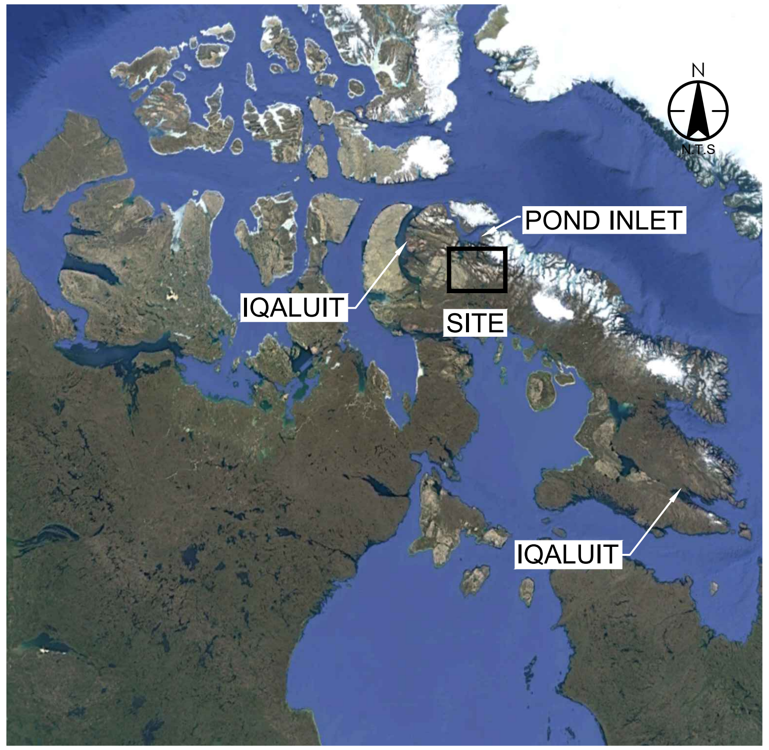
C.1.5.8 Summary and Recommendations

Based on the results of the slope stability review shown in Table 20, the following can be concluded:

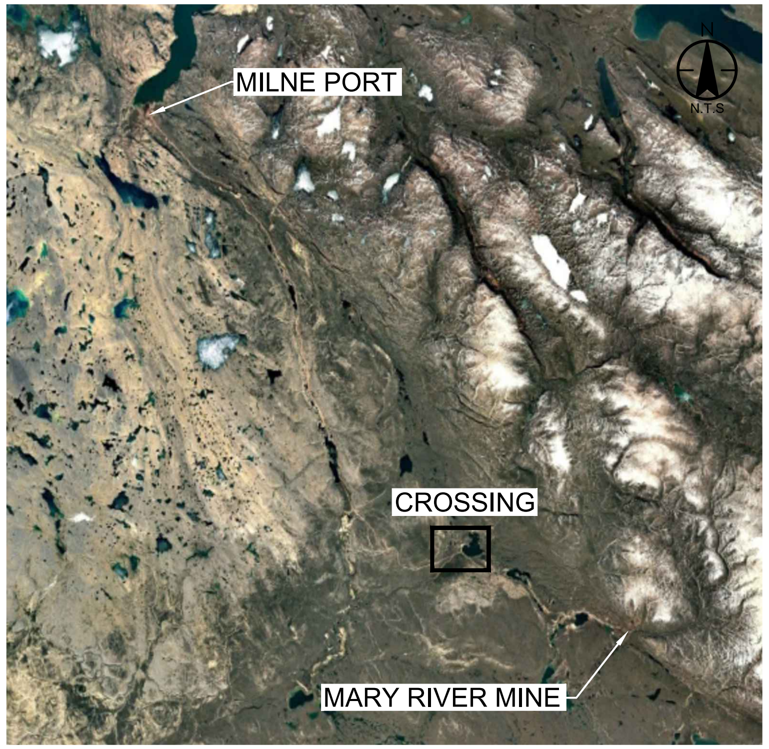
- A 0.3 m thick riprap layer along the upstream embankment side slope and a 0.225 m thick upstream apron is required to reach the target FS at the proposed 2H:1V sideslope.
- A 1.0 m thick riprap along the downstream embankment side slope and a 0.450 m thick downstream apron are required to reach the target FS at the proposed 1.5H:1V sideslope.
- Shallow slip surfaces within the riprap fill were excluded from the analyses by specifying the minimum slip surface depth. Shallow slip surfaces within the riprap may occur, which do not impact embankment integrity, however, would necessitate maintenance (i.e., restoration of the riprap).

Appendix D Geotechnical Investigation

KEY PLAN



SITE PLAN



CROSSING PLAN

TOTE ROAD (KM 81)

Stantec Consulting Ltd.
Suite 500, 311 Portage Avenue
Winnipeg MB R3B 2B9
Tel: (204) 489-5900
www.stantec.com

	By	Appd	YYYY.MM.DD
For Report	JB	AP	2025.09.05

Issued

	Dwn.	Dsgn.	Chkd.	YYYY.MM.DD
Project Number: 169525664	JB	-	AP	2025.09.05

🔴 APPROXIMATE BOREHOLE LOCATION
🔵 APPROXIMATE BOREHOLE AND THERMISTOR LOCATION

Client/Project
BAFFINLAND IRON MINES CORPORATION
TOTE ROAD CULVERTS - CV-216 (KM 81)

Project No.
169525664

Title
BOREHOLE LOCATION PLAN

Revision
0

Date
2025/09/05

Reference Sheet
-

Figure No.
1

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis

Rootmat	vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of visible and invisible fragments of decayed organic matter
Till	unstratified glacial deposit which may range from clay to boulders
Fill	material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure

Desiccated	having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of regular alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

Terminology describing soil types

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris)

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on Page 2. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

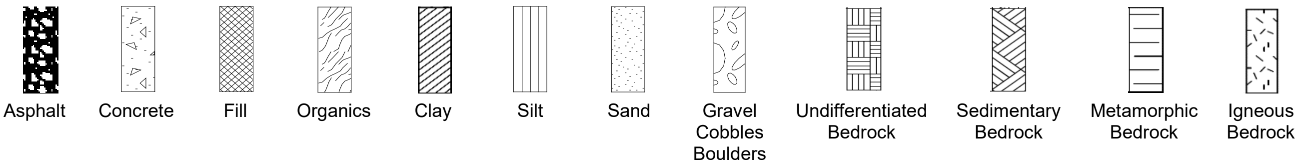
Terminology describing consistency of cohesive soils

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc. Not all bedrock strata plots are shown.



SAMPLE TYPE

AS, BS, GS	⋈	Auger sample; bulk sample; grab sample
DP	▧	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	‖	Piston sample
SO	◢	Sonic tube
SS	■	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	▨	Shelby Tube or thin wall tube
SV	⋈	Shear vane
RC *HQ, NQ, BQ, etc.*	▮▮	Rock Core; samples obtained with the use of standard size diamond coring bits.

WATER LEVEL

▼ **Measured**:
in standpipe, piezometer, or well

▽ **Inferred**:
seepage noted or water level measured during or at completion of drilling

RECOVERY FOR SOIL SAMPLES

The recovery is recorded as the length of the soil sample recovered in the direct push, split spoon sampler, Shelby Tube, or sonic tube.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test (SPT): the number of blows of a 140-pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50 for 75 mm or 50/75 mm). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60-degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

⊤↓	Single packer permeability test; test interval from depth shown to bottom of borehole
⊤⊥	Double packer permeability test; test interval as indicated
○↓	Falling head permeability test using casing
▽↓	Falling head permeability test using well point or piezometer

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Total Core Recovery (TCR) denotes the sum of all measurable rock core recovered in one drill run. The value is noted as a percentage of recovered rock core based on the total length of the drill run.

Solid Core Recovery (SCR) is defined as total length of solid core divided by the total drilled length, presented as a percentage. Solid core is defined as core with one full diameter.

Rock Quality Designation (RQD) is a modified core recovery that incorporates only pieces of solid core that are equal to or greater than 10 cm (4") along the core axis. It is calculated as the total cumulative length of solid core (> 10 cm) as measured along the centerline of the core divided by the total length of borehole drilled for each drill run or geotechnical interval, presented as a percentage. RQD is determined in accordance with ASTM D6032.

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock quality

Rock Mass Quality	Rock Quality Designation Number (RQD)	Alternate (Colloquial) Rock Mass Quality	
Very Poor Quality	0-25	*Very Severely Fractured*	*Crushed*
Poor Quality	25-50	*Severely Fractured*	*Shattered or Very Blocky*
Fair Quality	50-75	*Fractured*	*Blocky*
Good Quality	75-90	*Moderately Jointed*	*Sound*
Excellent Quality	90-100	*Intact*	*Very Sound*

Terminology describing rock strength

Strength Classification	Grade	Field Estimates of Uniaxial Compressive Strength	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	Indented by thumbnail	<1
Very Weak	R1	Crumbles under firm blows of geological hammer, can be peeled with a pocketknife	1 – 5
Weak	R2	Peeled by pocketknife with difficulty, shallow indentations made by firm blow with point of geological hammer	5 – 25
Medium Strong	R3	Cannot be scraped or peeled with a pocketknife, can be fractured with single firm blow of geological hammer	25 – 50
Strong	R4	More than one blow with geological hammer to fracture	50 – 100
Very Strong	R5	Many blows with geological hammer to fracture	100 – 250
Extremely Strong	R6	Can only be chipped with geological hammer	>250

Terminology describing rock weathering

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

Terminology describing rock with respect to discontinuity and bedding spacing

Spacing (mm)	Discontinuities Spacing	Bedding
>6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

BOREHOLE RECORD

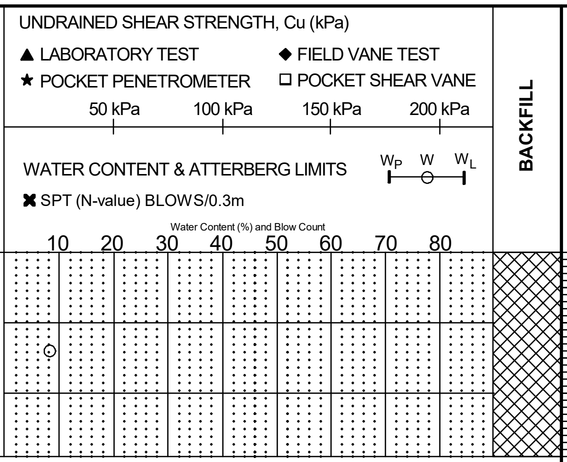
BH216-01

CLIENT: **Baffinland Iron Mines Corporation**
PROJECT: **Baffinland Iron Mines Tote Road Culverts**
LOCATION: **Baffin Island, Nunavut**
DATE BORED: **July 11 2025**

BH COORDINATES: 7921692.9 N 542785.63 E
WATER LEVEL: **N/A**

PROJECT NO.: **169525664**
BH ELEVATION: **146.5m**
DATUM: **NAD 83**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS	BACKFILL
0	146.5	**FILL:** Tan crushed granular fill - 20 mm maximum aggregate size	▨	GS	1				▨
2.9	143.6	**End of Borehole** • Soil sloughing was observed during drilling at a depth of 2.0 m. • No groundwater seepage was observed during drilling. • Borehole was terminated at a depth of 2.9 m due to sloughing. • Borehole was backfilled with cuttings and surrounding native material. • Borehole elevation is approximate only, borehole was not surveyed.							



BACKFILL SYMBOL: ■ ASPHALT ▨ GROUT ▨ CONCRETE ■ BENTONITE ▨ DRILL CUTTINGS ⁝ SAND ▨ SLOUGH

Drilling Contractor: M-Roc Ltd.	Logged By: AP/JB
Drilling Method: 51 mm Air Track	Reviewed By: AP
Completion Depth: 2.9 m	Page 1 of 1

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BOREHOLE RECORD

BH216-02

CLIENT: **Baffinland Iron Mines Corporation**

PROJECT: **Baffinland Iron Mines Tote Road Culverts**

LOCATION: **Baffin Island, Nunavut**

DATE BORED: **July 11 2025**

BH COORDINATES: 7921695.91 N 542785.98 E

WATER LEVEL: **N/A**

PROJECT NO.: **169525664**

BH ELEVATION: **144.62m**

DATUM: **NAD 83**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
0	144.6	**FILL:** Tan crushed granular fill - 20 mm maximum aggregate size		GS	1			
	142.5	Brown poorly graded medium grain **SAND (SP-SM)** with silt - trace clay		GS	2			Sieve/Hydro at 2.1 m G S M C 0% 93% 5% 2%
	141.4	**ICE** - clear		GS	3			

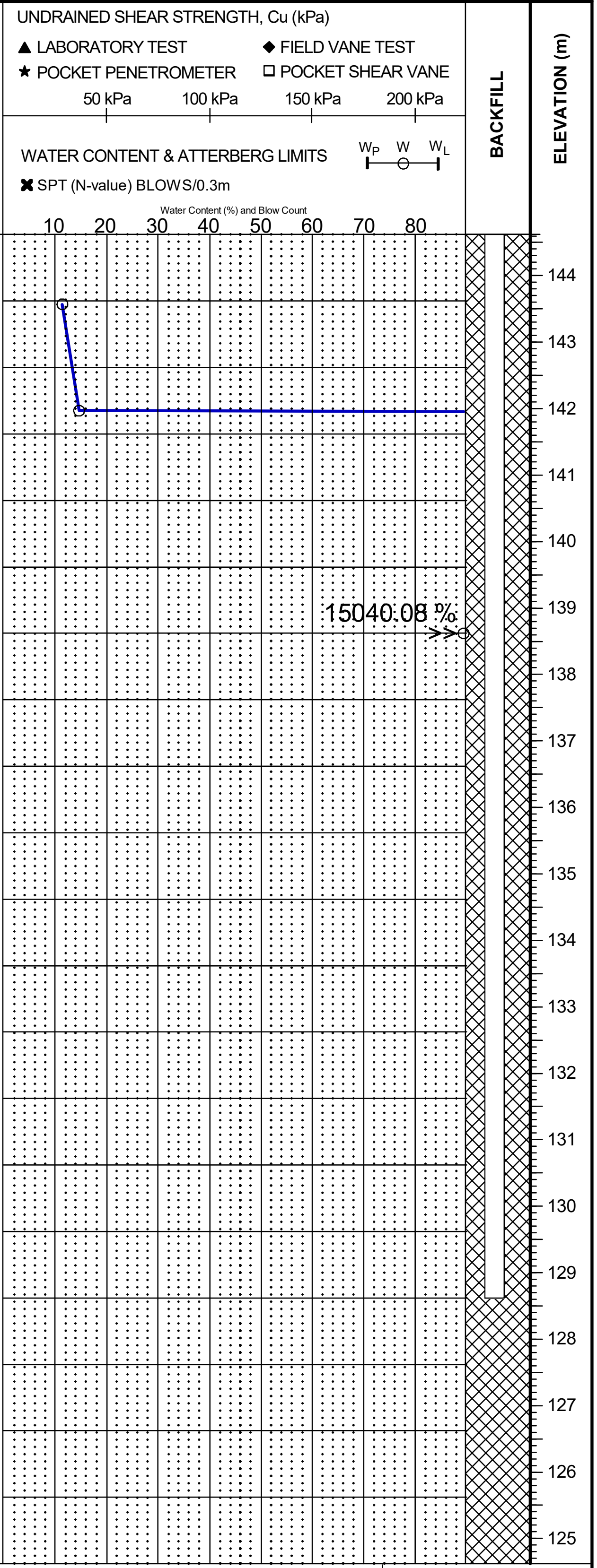
UNDRAINED SHEAR STRENGTH, Cu (kPa)

▲ LABORATORY TEST ◆ FIELD VANE TEST

★ POCKET PENETROMETER ☐ POCKET SHEAR VANE

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

✖ SPT (N-value) BLOWS/0.3m



Drilling Contractor: M-Roc Ltd.		Logged By: AP/JB
Drilling Method: 51 mm Air Track		Reviewed By: AP
Completion Depth: 21.1 m		Page 1 of 2

BACKFILL SYMBOL ▩ ASPHALT ▨ GROUT ▧ CONCRETE

■ BENTONITE ▩ DRILL CUTTINGS ▨ SAND ▩ SLOUGH

Stantec

BOREHOLE RECORD

BH216-02

CLIENT: **Baffinland Iron Mines Corporation**

PROJECT: **Baffinland Iron Mines Tote Road Culverts**

LOCATION: **Baffin Island, Nunavut**

DATE BORED: **July 11 2025**

BH COORDINATES: 7921695.91 N 542785.98 E

WATER LEVEL: **N/A**

PROJECT NO.: **169525664**

BH ELEVATION: **144.62m**

DATUM: **NAD 83**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm) or TCR %	SAMPLES N-VALUE or RQD %	OTHER TESTS / REMARKS	UNDRAINED SHEAR STRENGTH, Cu (kPa) ▲ LABORATORY TEST ◆ FIELD VANE TEST ★ POCKET PENETROMETER ☐ POCKET SHEAR VANE 50 kPa 100 kPa 150 kPa 200 kPa WATER CONTENT & ATTERBERG LIMITS W_P W W_L ✖ SPT (N-value) BLOWS/0.3m Water Content (%) and Blow Count 10 20 30 40 50 60 70 80	BACKFILL	ELEVATION (m)
20										⊠	124
21	123.5										

End of Borehole
- No soil sloughing or groundwater seepage was observed during drilling.
- Borehole was terminated at a depth of 21.1 m due to the maximum drill depth achieved.
- Thermistor installed to a depth of 16.0 m.
- Borehole was backfilled with cuttings and surrounding native material.

DEPTH (m): 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

ELEVATION (m): 124 123 122 121 120 119 118 117 116 115 114 113 112 111 110 109 108 107 106 105

BACKFILL SYMBOL ▩ ASPHALT ▨ GROUT ▧ CONCRETE
■ BENTONITE ⊠ DRILL CUTTINGS ⁘ SAND ▦ SLOUGH

Drilling Contractor: M-Roc Ltd.	Logged By: AP/JB
Drilling Method: 51 mm Air Track	Reviewed By: AP
Completion Depth: 21.1 m	Page 2 of 2

Stantec

BOREHOLE RECORD

BH216-03

CLIENT: **Baffinland Iron Mines Corporation**

PROJECT: **Baffinland Iron Mines Tote Road Culverts**

LOCATION: **Baffin Island, Nunavut**

DATE BORED: **July 11 2025**

BH COORDINATES

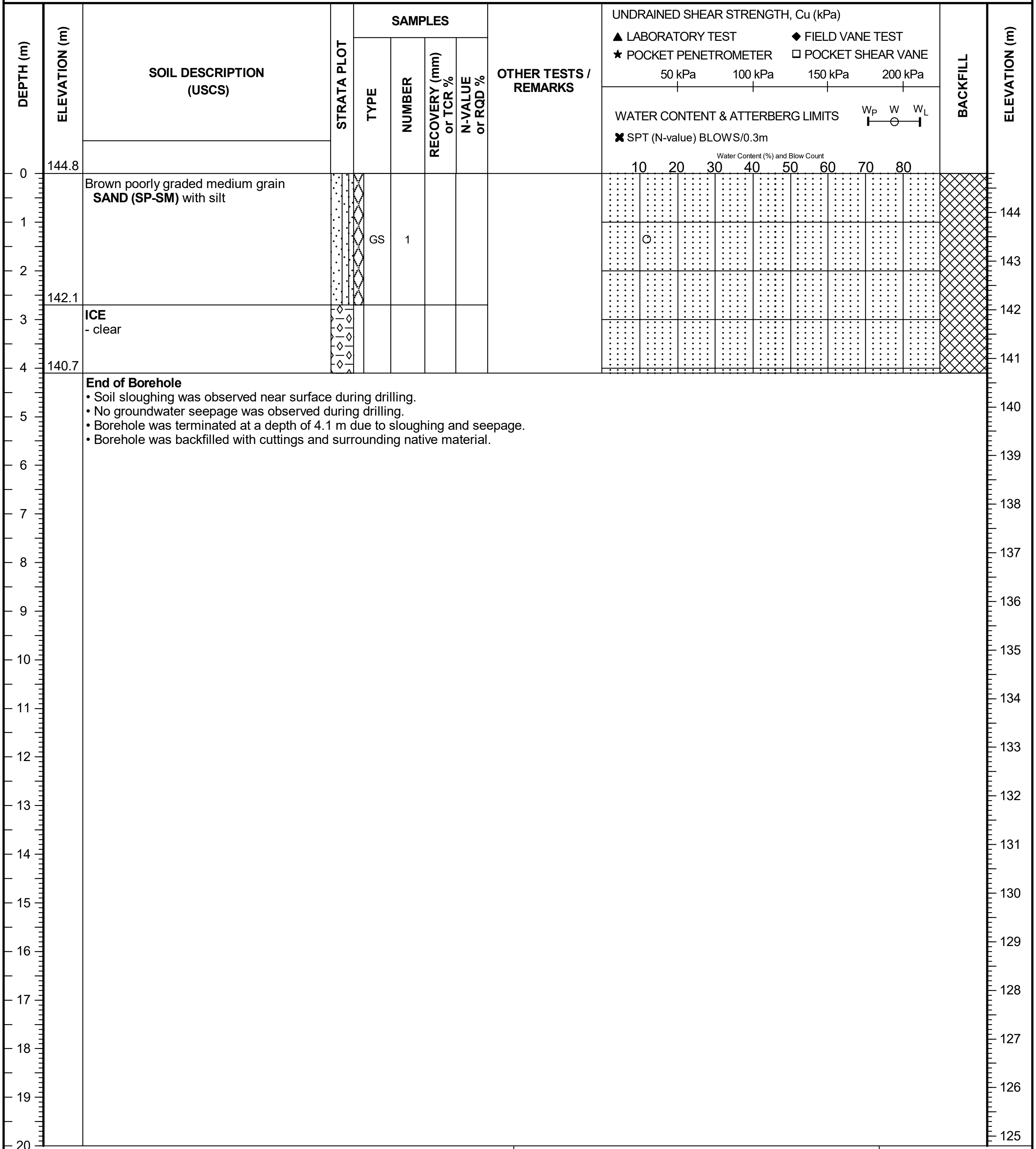
7921709.53 N 542803.99 E

WATER LEVEL: **N/A**

PROJECT NO.: **169525659**

BH ELEVATION: **144.80m**

DATUM: **NAD 83**



Elevation (m)	Soil Description (USCS)	Type	Number
144.8	Brown poorly graded medium grain **SAND (SP-SM)** with silt	GS	1
142.1	**ICE** - clear		
140.7			

End of Borehole
- Soil sloughing was observed near surface during drilling.
- No groundwater seepage was observed during drilling.
- Borehole was terminated at a depth of 4.1 m due to sloughing and seepage.
- Borehole was backfilled with cuttings and surrounding native material.

BACKFILL SYMBOL ▩ ASPHALT ▨ GROUT ▧ CONCRETE
■ BENTONITE ⊠ DRILL CUTTINGS ⁘ SAND ▩ SLOUGH

Drilling Contractor: M-Roc Ltd.

Drilling Method: 51 mm Air Track

Completion Depth: 4.1 m

Logged By: AP/JB

Reviewed By: AP

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
🟦	Bentonite/Sand Mix	Mohr-Coulomb	19	10	30	1
🟫	Fill and Sand	Mohr-Coulomb	18	0	30	1
🟧	Granular Fill	Mohr-Coulomb	20	0	36	1
⬜	Ice	Bedrock (Impenetrable)				1
🟪	Riprap	Mohr-Coulomb	20	0	40	1

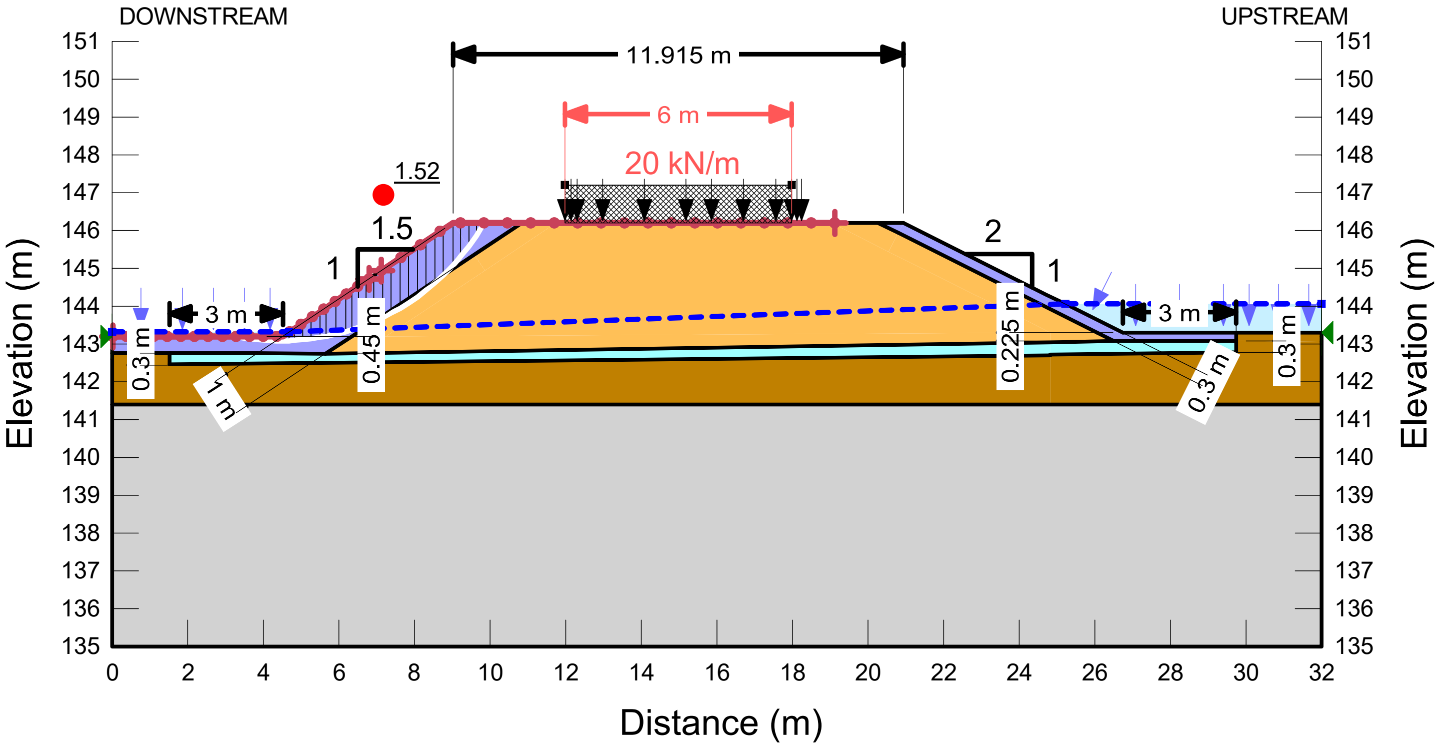


Figure 1: CV-216 Bypass, Proposed Conditions, Normal GWL, Downstream

Date: 09/08/2025

Project Number: 169525664

Created By: Beltran, Joy / Checked By: Piamsalee, Aron

Scale: 1:200

Directory: \\ca0002-ppfss02\shared_projects\169525659\data\field_data\geo\analysis\cv-216\169525659_baffinland_cv-216_bypass_20250908.gsz

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
🟦	Bentonite/Sand Mix	Mohr-Coulomb	19	10	30	1
🟫	Fill and Sand	Mohr-Coulomb	18	0	30	1
🟧	Granular Fill	Mohr-Coulomb	20	0	36	1
⬜	Ice	Bedrock (Impenetrable)				1
🟪	Riprap	Mohr-Coulomb	20	0	40	1

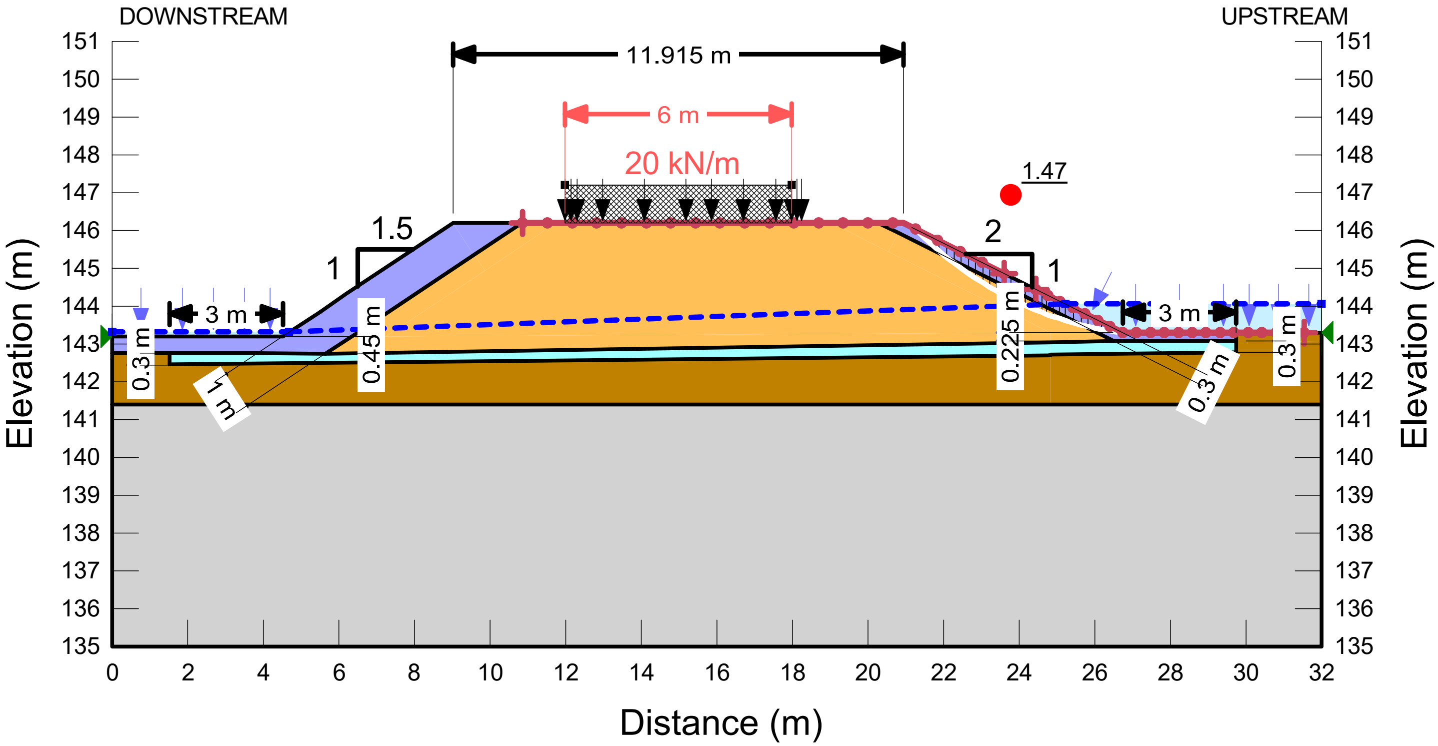


Figure 2: CV-216 Bypass, Proposed Conditions, Normal GWL, Upstream	Date: 09/08/2025
Project Number: 169525664	Created By: Beltran, Joy / Checked By: Piamsalee, Aron	Scale: 1:200

Directory: \\ca0002-ppfss02\shared_projects\169525659\data\field_data\geo\analysis\cv-216\169525659_baffinland_cv-216_bypass_20250908.gsz

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Color	**Name**	**Slope Stability Material Model**	**Unit Weight (kN/m³)**	**Effective Cohesion (kPa)**	**Effective Friction Angle (°)**	**Piezometric Surface**
🟦	Bentonite/Sand Mix	Mohr-Coulomb	19	10	30	1
🟫	Fill and Sand	Mohr-Coulomb	18	0	30	1
🟧	Granular Fill	Mohr-Coulomb	20	0	36	1
⬜	Ice	Bedrock (Impenetrable)				1
🟪	Riprap	Mohr-Coulomb	20	0	40	1

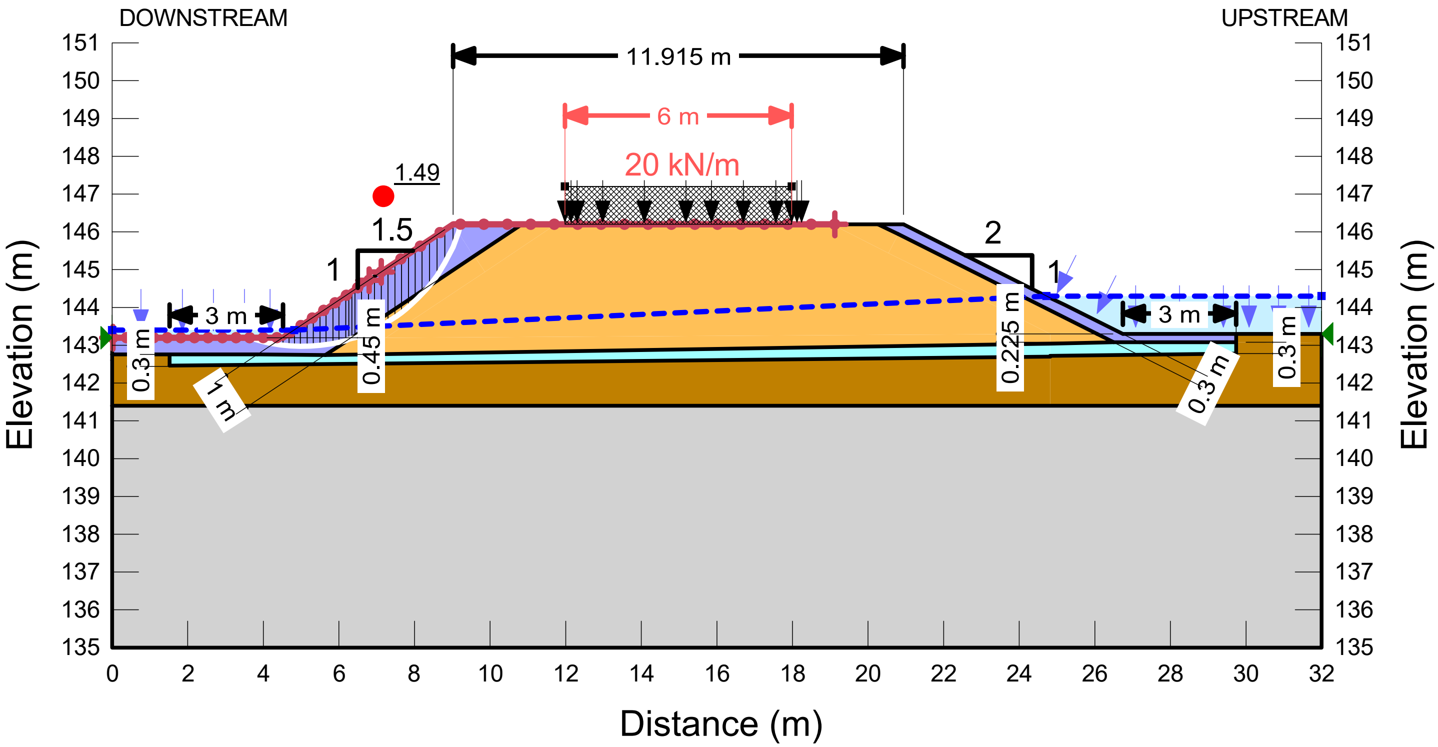

Figure 3: CV-216 Bypass, Proposed Conditions, Critical GWL, Downstream

Date: 09/08/2025

Project Number: 169525664

Created By: Beltran, Joy / Checked By: Piamsalee, Aron

Scale: 1:200

Directory: \\ca0002-ppfss02\shared_projects\169525659\data\field_data\geo\analysis\cv-216\169525659_baffinland_cv-216_bypass_20250908.gsz

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
🟦	Bentonite/Sand Mix	Mohr-Coulomb	19	10	30	1
🟫	Fill and Sand	Mohr-Coulomb	18	0	30	1
🟧	Granular Fill	Mohr-Coulomb	20	0	36	1
⬜	Ice	Bedrock (Impenetrable)				1
🟪	Riprap	Mohr-Coulomb	20	0	40	1

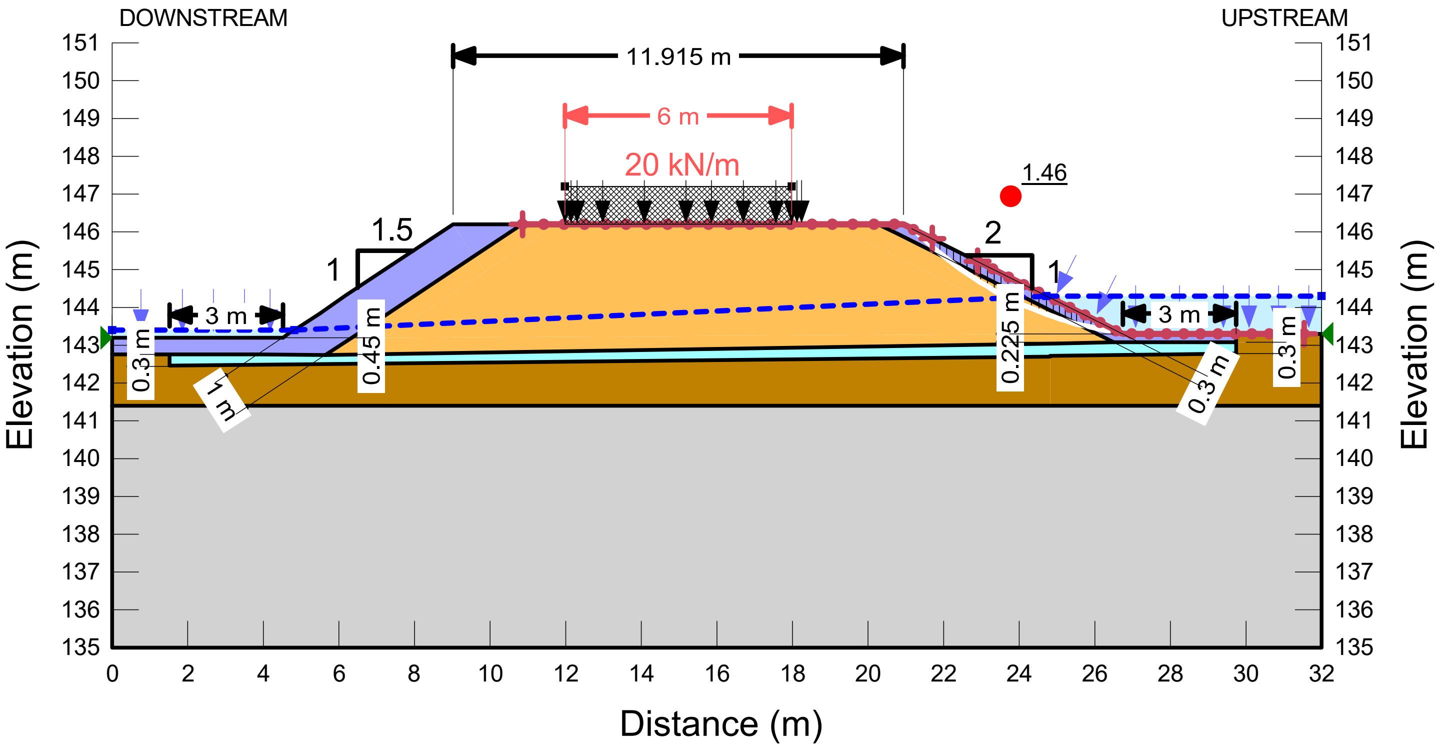

Figure 4: CV-216 Bypass, Proposed Conditions, Critical GWL, Upstream	Date: 09/08/2025
Project Number: 169525664	Created By: Beltran, Joy / Checked By: Piamsalee, Aron
Scale: 1:200	

Directory: \\ca0002-ppfss02\shared_projects\169525659\data\field_data\geo\analysis\cv-216\169525659_baffinland_cv-216_bypass_20250908.gsz

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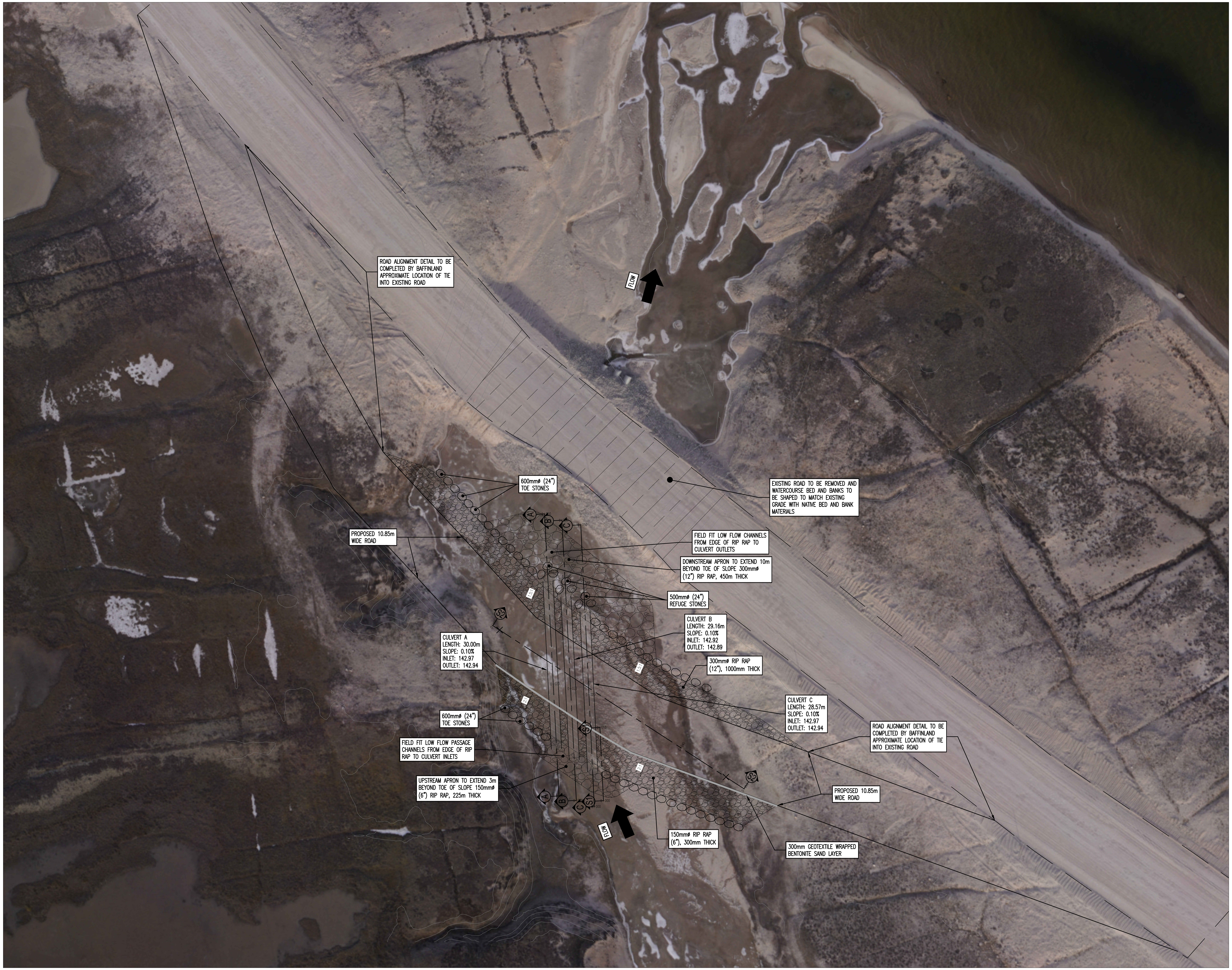
Appendix E Design Drawings



File: C:\Local\Baffinland\2025.08.15 Culvert Plans\CV-216_PLAN&SECTIONS.dwg - Revised by <Marchione, Carlo> : Wed, Sep 10, 2025 , 7:44 PM

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Issued

Client/Project

Baffinland

RETROFIT & REPLACEMENT OF CULVERTS

Title

REPLACEMENT OF CULVERT CV-216
PLAN VIEW

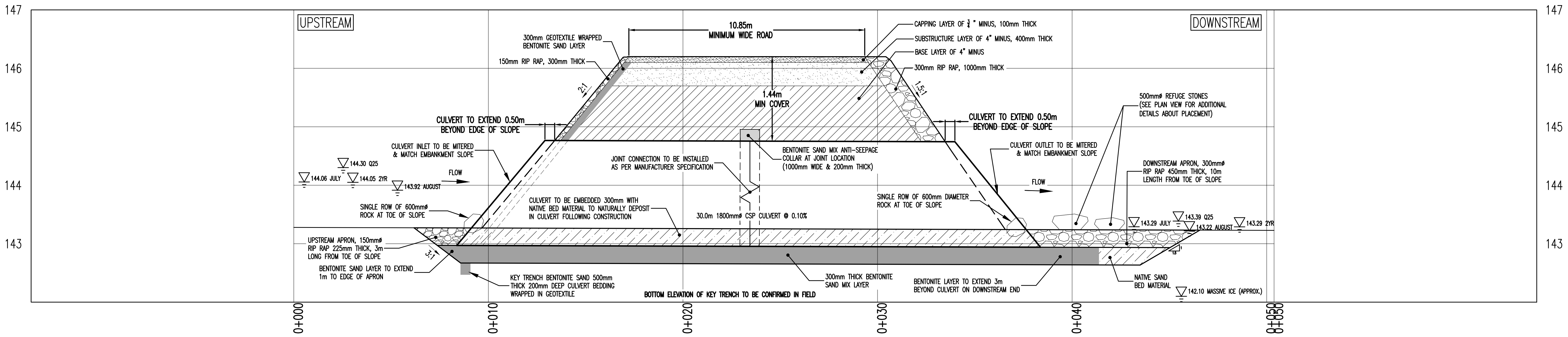
Project No.
1695 25664

Scale
1:300

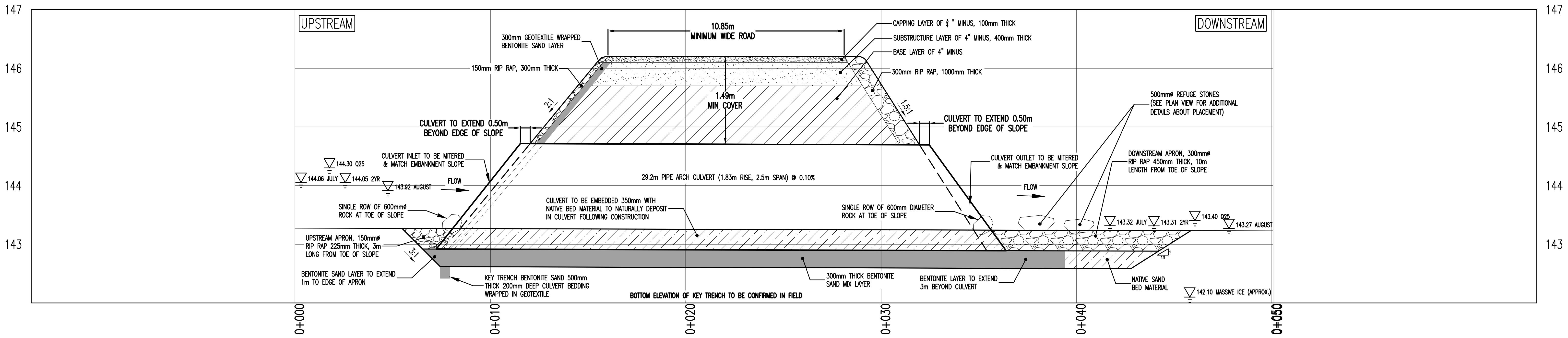
File No.

Drawing No.
C-100

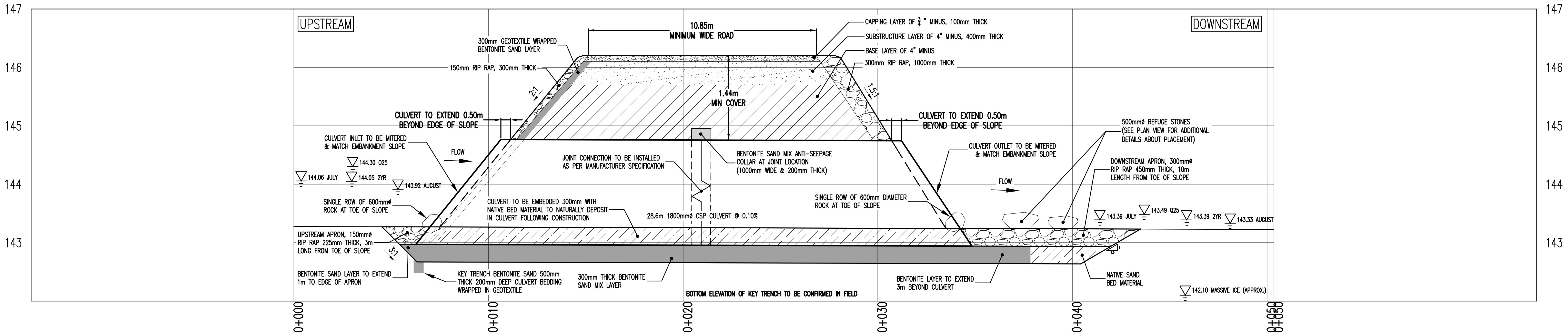
CV-216 A (LEFT)



CV-216 B (CENTRE)



CV-216 C (RIGHT)



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NOTES

RIP RAP:

1) NO MORE THAN 10% FINES (<37.5mm)
2) MAXIMUM RIP RAP SIZE TO BE NO MORE THAN 1.5x THE D50 VALUE

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RETROFIT & REPLACEMENT OF CULVERTS

Title

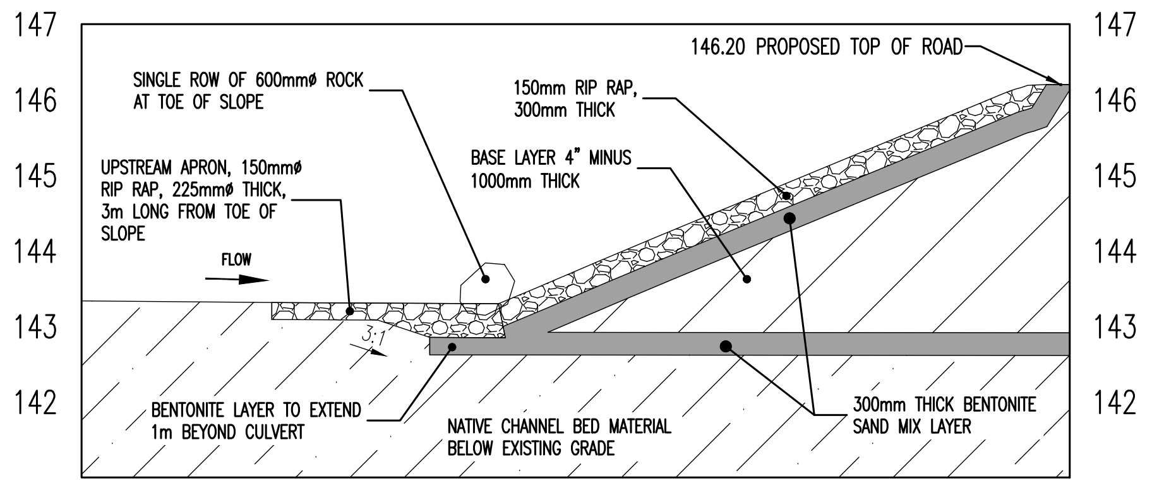
REPLACEMENT OF CULVERT CV-216
PROFILE VIEW

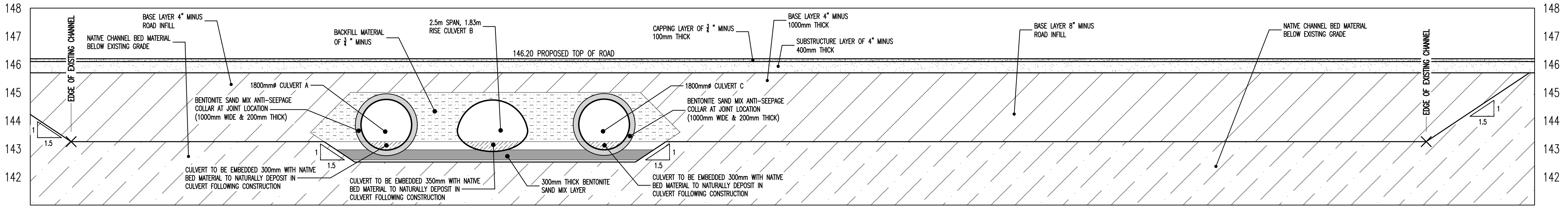
Project No.
1695 25664

Scale
H 1:150 V 1:50

File No.

Drawing No.
C-101





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NOTES

RIP RAP:

1) NO MORE THAN 10% FINES (<37.5mm)
2) MAXIMUM RIP RAP SIZE TO BE NO MORE THAN 1.5x THE D50 VALUE

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RETROFIT & REPLACEMENT OF CULVERTS

Title

REPLACEMENT OF CULVERT CV-216
SECTION VIEW

Project No.
1695 25664

Scale
1:100

File No.

Drawing No.
C-102

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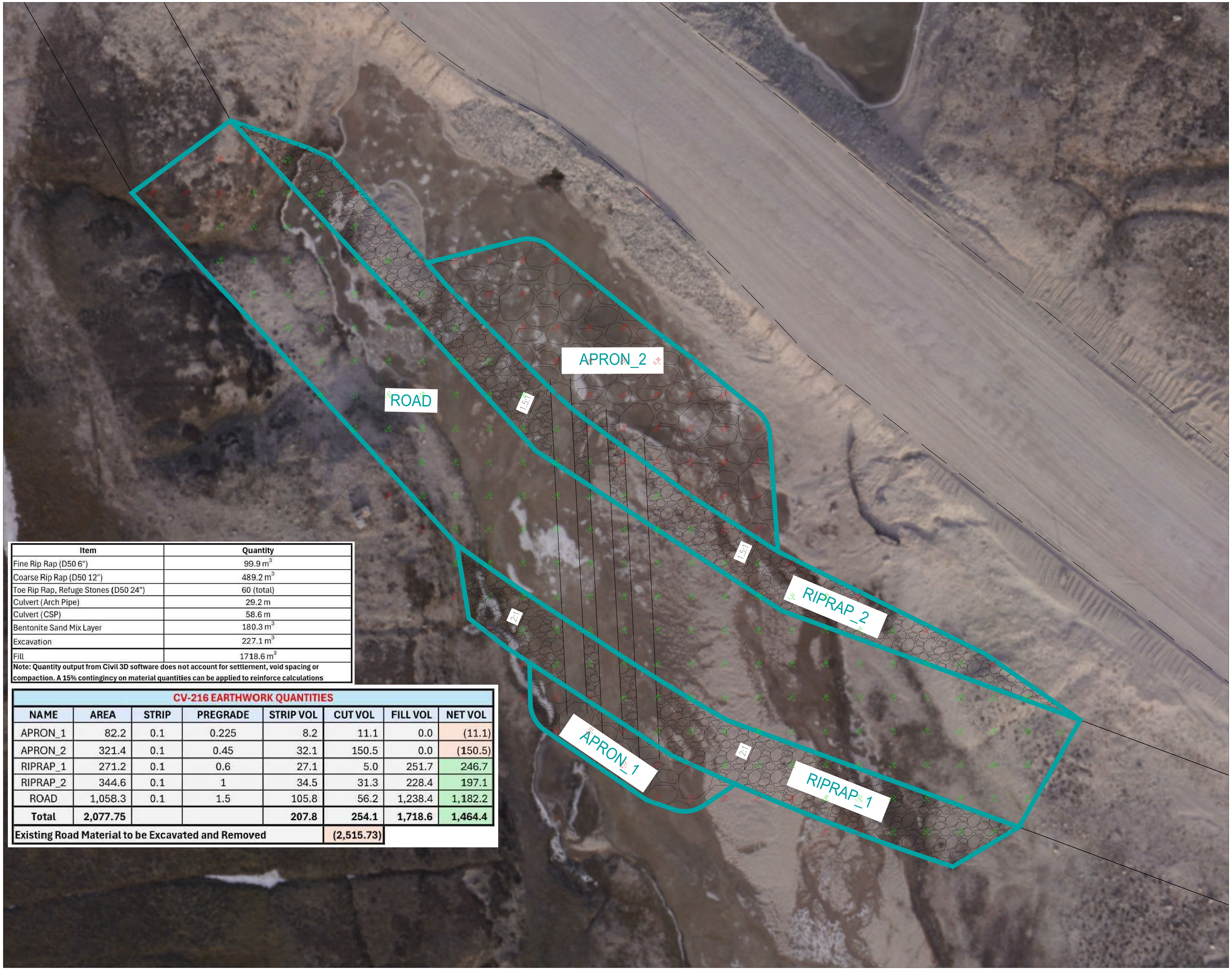

Item	Quantity
Fine Rip Rap (D50 6")	99.9 m^3
Coarse Rip Rap (D50 12")	489.2 m^3
Toe Rip Rap, Refuge Stones (D50 24")	60 (total)
Culvert (Arch Pipe)	29.2 m
Culvert (CSP)	58.6 m
Bentonite Sand Mix Layer	180.3 m^3
Excavation	227.1 m^3
Fill	1718.6 m^3

Note: Quantity output from Civil 3D software does not account for settlement, void spacing or compaction. A 15% contingincy on material quantities can be applied to reinforce calculations

CV-216 EARTHWORK QUANTITIES

NAME	AREA	STRIP	PREGRADE	STRIP VOL	CUT VOL	FILL VOL	NET VOL
APRON_1	82.2	0.1	0.225	8.2	11.1	0.0	(11.1)
APRON_2	321.4	0.1	0.45	32.1	150.5	0.0	(150.5)
RIPRAP_1	271.2	0.1	0.6	27.1	5.0	251.7	246.7
RIPRAP_2	344.6	0.1	1	34.5	31.3	228.4	197.1
ROAD	1,058.3	0.1	1.5	105.8	56.2	1,238.4	1,182.2
Total	**2,077.75**			**207.8**	**254.1**	**1,718.6**	**1,464.4**
Existing Road Material to be Excavated and Removed					**(2,515.73)**		

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RETROFIT & REPLACEMENT OF CULVERTS

Title

REPLACEMENT OF CULVERT CV-216
EARTHWORKS

Project No. 1695 25664
Scale 1:150
File No.
Drawing No. C-103

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