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Toronto, August 10th, 2019

Mr. Alexandre Lavallée
Agnico Eagle Mines Limited
Agnico Eagle - Nunavut Office
11600 rue Louis-Bisson, Suite 540
Mirabel, Quebec, Canada J7N 1G9

By email: alexandre.lavallee@agnicoeagle.com

Subject: Whale Tail Dike Remedial Drilling and Grouting Program As Built Report
Our file: 669034-0000-4GER-0001 Rev 00

Dear Sir,

We are pleased to submit the final version of the as-built report mentioned in the above subject.

Do not hesitate to communicate with the undersigned should you have further questions regarding the content of this report.

Truly yours,

SNC LAVALIN INC.

Nina Quan, P.Eng.
#PEO: 100110574
Project Manager
Mining and Metallurgy

NQ/bsp

List of Revisions

Revision					Revised pages	Remarks
#	Prep.	Rev.	App.	Date		
00	TX/SV/MS	AEB/HB	NQ	August 10th, 2020		FINAL

Notice to Reader

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Executive Summary

AEM proceeded the Whale Tail Dike Remedial Drilling and Grouting program from November 2nd, 2019 to March 25th, 2020. The objective of the program was to achieve a minimum of 40% (or 240m^3/hr) reduction of the total observed seepage of 600 m^3/hr to a residual total seepage inflow of about 360 m^3/h. The program was planned in staged approach which involved Phase I: drilling and grouting of downstream and upstream 5m deep blankets. Upon the completion of Phase I, an evaluation would be carried out based on the observed grout take and performance of the blanket grouting to determine if Phase II - drilling and grouting of the upstream grout curtain is required.

The execution of the Drilling and Grouting program began in November 2nd, 2019 with downstream casing installation, casing plug grouting, bedrock drilling and grouting. Upon completion of about more than 80% of the downstream blanket grouting, the upstream casing installation started on February 22nd, 2020. The drilling and grouting upstream blanket proceeded up until March 25th, 2020 when the construction was adjourned. AEM reported the inferred seepage of 230m^3/hr. The estimated rate combined with the progress of piping installation and contingency plans developed. AEM concluded that the risk of overwhelming the water treatment plant at freshet 2020 has been reduced to an acceptable level to AEM.

As of March 25th, 2020, the planned scope of work was partly completed to 95% of the grouted downstream blanket holes and only 2% of the grouted upstream blanket holes for an overall progress of about 35% of planned remedial grouting program-Phase I. Grout take data analysis of the downstream blanket grouting showed that the highest grout take was recorded in Primary holes and Tertiary holes. The high grout absorption in Primary holes could be explained by many re-grouting phases in Primary holes due to open joints and potential high seepage flow. High absorption in Tertiary holes may be explained by the grouting of few Tertiary holes before grouting of Secondary holes and also by the high number of Tertiary holes in comparison to Secondary holes. Since the number and length of the holes of each generation is different, the average grout absorption per meter per each hole generation of the WTD downstream blanket grouting holes was compared. The average grout take per metre confirmed the decreasing grout take tendency from the Primary to the Quaternary holes type which demonstrates the efficiency of the split spacing method. Grout take decreased by 28% from Primary to Secondary, by 38% from Secondary to Tertiary and by 36% from Tertiary to Quaternary. The overall decrease from Primary holes to Quaternary holes is about 71%.

No data analysis was done for the WTD upstream blanket grouting since only six (6) Primary holes were grouted so far.

1.0 INTRODUCTION

1.1 Context

Agnico Eagle Mines Limited, Meadowbank Division ("AEM'') is in the process of developing the Whale Tail Pit, a satellite deposit on the Amaruq property. The Amaruq Exploration property is a 408 km² site located on Inuit Owned Land, approximately 150 km north of the Hamlet of Baker Lake and approximately 50 km northwest of the Meadowbank Mine in the Kivalliq region of Nunavut.

The Meadowbank Mine is an approved mining operation and AEM is extending the life of the mine by constructing and operating the Whale Tail Pit. As part of this infrastructure, Whale Tail Dike (WTD) is an important water retention and dewatering dike required for mining the Whale Tail Pit located in the north part of the Whale Tail Lake. The construction of the WTD, up to elevation of El.157 meter above sea level (masl), took place from June 2018 to February 2019 and the dewatering of downstream side (North Basin) commenced in March 2019. During the process of downstream dewatering, seepage flow higher than the theoretical estimated amount was observed at the downstream of the Dike. Due to the available surface storage, water treatment capacity and discharge licensing requirements, seepage reduction is required to minimize the risk of overwhelming the Amaruq water treatment plant at freshet 2020.

SNC-Lavalin was retained by AEM to design the remedial drilling and grouting program to further reduce the seepage through the WTD bedrock foundation. The objective of the program, presented by AEM in Meeting No. 4 (October 17th, 2019), was to achieve a minimum of 40% (or 240m^3/hr) reduction of the total estimated seepage of 600 m^3/hr to a residual total seepage inflow of about 360 m^3/h.

1.2 Description of Whale Tail Dike

The Whale Tail Dike (WTD) is a zoned embankment structure constructed on a shallow plateau of the Whale Tail Lake Floor to control the lake water to flow toward the Whale Tail Pit during mining operation.

The Dike is comprised of rockfills at both the upstream and the downstream slopes, coarse and fine filter materials, and a cut-off wall composed of cement-bentonite. The dike is approximately 835m long. From the original ground, its height is about 8m, the crest has a minimal width of 13.4m and was built to elevation of 159 meter above sea level (mals).

The cement-bentonite (CB) cut-off wall was constructed at the centre of the Dike through the fine filter materials and extended to a minimum of 1 m into bedrock. The as built records indicate that the average rock socket depth was1.37 m with depths ranging from 0.47 m to 3.6 m. The CB secant pile has a crest elevation of 157.0 masl which is 1 m higher than the Dike design water level of 156.0 masl. Thermal cover rockfill of 2.0 m thick was placed between secant pile top elevation and the final crest elevation of the dike at 159 masl.

The original design in 2018 of the grout curtain program comprised a single row of grout holes 10 to 15 m deep along the Dike axis between Stations 0+180 and 0+730 to mitigate the potential seepage through the Dike foundation. Based on the as-built report of WTD, a single row grout curtain was constructed partially along the WTD alignment between Stations 0+180 and 0+516 due to frozen bedrock conditions. The curtain grouting was installed from the WTD crest at elevation 157.0 masl before the construction of the remaining

rockfill platform to elevation 159 masl. Grout curtain holes were drilled with an off-set of ±0.7 m from the centreline of the Dike to the upstream (South Pond) side and was extended to ±10 m into the bedrock. The grout curtain was carried out at a Primary Hole spacing of 12 m with Secondary and Tertiary Holes added by split-spacing method. The ±10 m deep curtain grouting was generally carried out in three (3) stages. The first two (2) stages were about 4.0 m long while the interface stage was about 2.0 m long.

1.3 Objective and Scope

This as-built report describes and summaries the remedial drilling and grouting work carried out by AEM from October 31st, 2019 to March 25th, 2020 and includes the following:

- An overview of the project, the design, the technical specifications and drawings;
- A summary of design modifications;
- A summary of grouting committee recommendations;
- Simplified work instructions and fieldwork instructions;
- Schedule and Construction activities;
- Quality control and quality assurance tasks, compilation of data obtained from the field grouting program and analyses;
- As-built drawings; and
- Conclusions.

It is noted that the remedial drilling and grouting program was planned in staged approach which involves Phase I: drilling and grouting of downstream and upstream 5m deep blankets. Upon the completion of Phase I, an evaluation will be carried out based on the observed grout take and performance of the blanket grouting to determine if Phase II - drilling and grouting of the upstream grout curtain is required.

On March 25th, 2020 AEM decided to suspend the grouting work due to the inferred seepage of 230 m^3/hr was reported. The estimated rate combined with the progress of piping installation and contingency plans developed, AEM concluded that the risk of overwhelming the treatment plant at freshet 2020 has been reduced to an acceptable level to AEM. The email letter notifying the suspension is discussed in Section 7 of the report. At this time, only downstream blanket grouting was almost completed and drilling and grouting of upstream blanket was just started. This report covers the work executed up to March 25, 2020 on downstream and upstream blankets.

1.4 Roles and Responsibility

The technical documents including the Drawings and Technical Specifications were developed by SNC-Lavalin following the recommendations from the Technical Grouting Committee as per AEM request. The technical documents were reviewed by AEM's engineering team and the Technical Grouting Committee. The Technical Grouting Committee consisted of three members: Mr. Peter White (Grouting Specialist), Dr. Donald Bruce (Geosystems LP), and Mr. Grant R. Bonin (Golder Associates) was established by AEM as technical grouting advisory board. The Technical Grouting Committee reviewed and provided recommendations on the design of the drilling and grouting program, technical specifications and the contractor's drilling and grouting method. The execution of the drilling and grouting construction was followed

by the Technical Grouting Committee's recommendations obtained after each Grouting Committee Meeting. Kivalliq Contractors Group Ltd (KCG) was contracted by AEM for the construction of the downstream and upstream blanket grouting and on-site laboratory testing. The AEM representative was the Geotechnical Engineer on-site who is responsible for managing, planning the grouting work, and providing information on the seepage rates as well as thermistor data interpretation.

The Quality Control (QC) program was carried out by GHD consultant (GHD), under the direction of KCG. GHD role was in charge of the quality control of casing installation, bedrock drilling, bedrock grouting and grouting materials as per the Technical Specifications.

SNC-Lavalin was responsible for the design of the remedial drilling and grouting work (as per the Technical Grouting Committee's recommendations) and the quality assurance (QA) program on-site with the presence of QA site engineer and served as a technical support for the blanket grouting. The lead of QA site engineer oversaw the QA site engineer's report from SNC-Lavalin home office. SNC-Lavalin also provided technical inputs and overseeing compliances with Drawings and Technical Specifications.

Except for the key personnel from the Contractor (and sub-contractor), SNC-Lavalin QA site engineer and GHD QC supervisor personnel that worked on-site on a regular basis were on a 2-week in and 2-week out rotation.

The parties and key personnel that were involved during the construction of the grouting work are listed in the Table 1-1.

Table 1-1: Key Personnel involved during the Remedial Drilling and Grouting Work

Name	Title
Agnico Eagle (AEM)	
Thomas Lépine	Technical Specialist and EoR
Alexandre Lavallée	Project Lead
Frédérick L. Bolduc	Geotechnical coordinator
Jesse Clark	Geotechnical coordinator
Pier-Éric McDonald	AEM Representative (Geotechnical engineer)
Patrice Gagnon	AEM Representative (Geotechnical specialist)
Marion Habersetzer	AEM Representative (Geotechnical engineer)
Technical Grouting Committee	
Peter White	Grouting Specialist
Donald Bruce	Geosystems LP
Grant R. Bonin	Golder Associates
SNC-Lavalin – design and quality assurance (QA)	
Yohan Jalbert	Project manager (August 2019-Nov 15th, 2019)
Nina Quan	Project manager (Nov.15th, 2019 -March 25, 2020)
Hafeez Baba	Project Technical Adviser/Reviewer
Tom Xue	Grouting specialist and designer, Lead of the QA site engineer
Abdellah El Bensi	Grouting specialist and designer
Saleem Muhammed	Grouting engineer and QA site engineer
Sebastien Viau	Grouting engineer and QA -site engineer
Jin Dong Du	Grouting engineer and QA site engineer
Paul Yong	Grouting engineer and QA site engineer
GHD consultant – Quality control (QC)	
Daniel Pedneault	QC Project manager
Jean-Philippe Boutin	Quality control technician
Jean-Michel Royer	Quality control technician
Maryska Beauregard	Quality control technician
Pierre Hourani	Quality control technician

Name	Title
Amadou Oury Diallo	Quality control Inspector
Hugues Potvin	Quality control Inspector
Mathieu Brisson	Quality control Inspector
Kivalliq Contractors Group Ltd – Contractor	
Francois Collard	Site Representative
Alex Boily	Site Representative
Dale Burton	Site Representative
Jeannot Gagnon	Project Manager
Audrey Bilodeau	Assistant project manager
Alex Penney	Assistant project manager
William Lavoie	Assistant project manager
Maxime Côté	Quality control representative
Ken Lachance	Grouting specialist
Sebastien Fleury	Grouting specialist
Marc-André Blackburn	Lead surveyor
Mikaël Lévesque	Lead surveyor

2.0 STAGES OF DESIGN

2.1 Design, Technical Specifications and Drawings

The Technical Specifications and Drawings for the remedial drilling and grouting program were issued on January 6th, 2020. Table 2-1 presents the list of Technical Specifications and list of drawings "Issued for Construction" (IFC). The Technical Specifications and Drawings are shown in Appendix A (A-1).

Table 2-1: Technical Specifications and Construction Drawing List

No.	Title	Revision
669034-0000-40EF-0001	Technical Specifications for the Whale Tail Dike Foundation Blanket Grouting	Rev 00
669034-2000-4GDD-0001	Remedial Work Downstream and Upstream Blankets Planview and Details	Rev 00
669034-2000-4GDD-0002	WTD Downstream and Upstream Remedial Work Longitudinal Sections	Rev 00
669034-2000-4GDD-0003	WTD Remedial Work Upstream and Downstream Blankets Sections and Details	Rev 00

2.2 Summary of Design Modifications

Based on the site conditions, WTD as-built data, seepage measurements and geophysical investigation results, the remedial drilling and grouting program was designed and consisted of a single row of upstream grout curtain extended to 20 m below the bedrock surface along the Dike alignment from Stations 0+180 to 0+750. The drilling and grouting work was proposed to be carried out in 2 to 3 stages of 5.0 m and 1 interface stage to cover the rock socket section. The Technical Specifications and Design Drawings (611913-E531-40EF-0001) Rev PB were issued for AEM and Technical Grouting Committee review and comments on September 27th, 2019. Shortly after the issuance of Rev PB, a minor correction was made in Section 5.3 and 5.4 and the Technical Specification (611913-E531-40EF-0001) Rev PC was issued on October 3rd, 2019.

The preliminary design was reviewed and discussed in the Grouting Committee Meeting No.4 held on October 17th, 2019 in Montreal. As per discussions and recommendations from the Technical Grouting Committee (GC), the design was modified by SNC-Lavalin to consist of one row of downstream blanket (5m deep) and one row of upstream grout curtain. The Technical Specifications and Design Drawings were updated to 669034-0000-40EF-0001 Rev PD and issued on October 28th, 2019 for further review and comments.

The Technical Specifications and Design Drawings underwent further revision to incorporate the recommendations presented in the GC's letter dated October 27th, 2019 and comments from AEM. The key changes in this revision were to remove upstream curtain grouting (as per AEM's comments). The modified design includes Phase I: two rows of blanket holes 5m deep, one downstream and one upstream. Upon the completion of Phase I, an evaluation would be carried out based on the observed grout take and performance of the blanket grouting to determine if Phase II - drilling and grouting of the upstream grout curtain is required. The Technical Specifications and Design Drawings Rev PE was issued on November 27th, 2019.

The Technical Specifications and Design Drawings Rev PE were approved and finalized to Rev 00 and issued on January 10th, 2020. The list of changes on Technical Specifications is presented in Appendix A (A-4).

2.3 Technical Grouting Committee Recommendations

The Grouting Committee was composed of the Technical Committee members, SNC-Lavalin, AEM and KCG (the Contractor). A total of eight (8) Grouting Committee Meetings were held through the course of the project: Seven (7) online meetings and one (1) meeting in person in Montreal. In this as-built report, the recommendations drawn from Meeting No. 4 and onwards are summarized since the recommendations from the first three meetings were considered as guidelines for the establishment of the preliminary design. Meeting No.4 was to discuss in depth about the design, work procedure and work sequence and Contractor's capability. Meetings No.5 to 8 were to discuss on the work progress, field grout takes and observations, working method and grout mix design. The recommendations obtained at the end of each meeting were applied to the on-going execution work procedure. Table 2-2 presents the key recommendations from the Technical Grouting Committee for each meeting. SNC-Lavalin's presentation and the meeting minutes containing the Technical Grouting Committee's recommendations are shown in Appendix B. It is noted that Meeting No.7 and No.8 were only two weeks apart. This was due to Committee members the recommendations obtained after Meeting No.7 to deepen the downstream blanket holes to 15m instead of focusing on the upstream blanket. Meeting No.8 was added to get clarifications from the Technical Grouting Committee.

Table 2-2: Summary of Technical Grouting Committee Recommendations

Meeting No.	Date	Summary of Recommendations
No.4	October 17th, 2019	The meeting took place to discuss comments on SNC-Lavalin Technical Specifications and Drawings Rev PC, AEM's presentation outlining the scope of work and objectives of the project, and the Contractor's capability. Recommendations: - The grout mix design should be kept simple; - To achieve the 40% reduction target, the big discontinuities will have to be targeted. - Contact area between secant piles and rock foundation is a critical area. Rock socket depth varies between 0.7m to 3.7 m, thus the target area should be between 3 to 5 m depth. Contact grouting shall be done by downstage grouting. - Grouting of downstream blanket and the contact grouting at the upstream side of the secant piles should be done by downstaging grouting method. Grouting can be down with simple mixes (lower C/W ratio). - Plugging the bottom end of the casing (by tremie method) to ensure the tightness of the rock interface prior to start drilling the hole in bedrock foundation. - Casing embedment of 0.3 m in rock; - The grouting should be done in at least two areas to comply with the minimal required space between two simultaneously grouted holes. - Drilling and grouting holes at downstream blanket will be P at 12m, S at 6m, T at 3m, while in the upstream Q will be required at 1.5m. - No super primaries for the holes in the downstream blanket. - Upstream grout curtain should be done by downstage method.
Draft Letter	Oct 27th, 2019	The Technical Grouting Committee issued the Draft Letter to summarize their recommendations based on Meeting No.4 and provided more specific details. Recommendations: - A minimum two-row curtain (or blanket of grout holes) at both the upstream and downstream side of the secant pile wall be constructed; - A thixotropic, washout resistant cementitious grout is recommended to be injected.

Meeting No.	Date	Summary of Recommendations
		- Celbex (the thixotropic additive) must be added “in-line” utilising a separate open-throat progressive cavity pump to accommodate the different dosage of Celbex additive. - Cement hydration is challenging at cold water temperatures. To accelerate curing, add 2% by weight of calcium chloride. - The use of downstage drilling and grouting techniques is encouraged. This include sealing the annular spaced of any installed casing (casing plugging) prior to grouting the bedrock below to avoid grout permeating upwards along the annular space and into the fine filter materials. - Staff shall be mobilized to operate at least two casing rigs to keep the installation of casings well ahead of the drilling and grouting. - Upstream row shall be spaced at 12m centres, off set 6m from the downstream row and split-spaced to Quaternary order holes creating a curtain of grout holes at 1.5 centres. - The suggested depth below the base of the adjacent secant piles that the cap should be extended is 3m. - All casing be installed 0.3m into competent bedrock and should never be installed deeper than 0.5m above the bottom of the adjacent secant pile. - It was suggested that after completing the blanket grouting work, the success of the proposed works carried out be assessed. The necessity to add additional upstream rows of grout holes, and/or deepen the upstream row of grout holes.
No. 5	December 5th, 2020	The meeting was held to discuss construction issues such as: casing installation, high grout take in Primary hole, and the use of thicker grout mix. <u>Recommendations:</u> - The blanket program should switch to down-stage grouting. An initial stage of 1.5m below the casing followed by injection. Once the grout sets the hole can be drilled to target depth. - The team needs to utilize the open throat pump to inject Celbex in-line with the grout pump, so that higher percentages of Celbex can be injected. - The onsite team needs to document any holes that may have had the casing pushed to below 300mm of the secant pile

Meeting No.	Date	Summary of Recommendations
No.6	January 13rd, 2020	The meeting topics included the use of Celbex in Open Throat Pump, the use of Mix D, drilling and grouting of the blanket holes in two stages, and grouting sequence of downstream and upstream blanket. Recommendations: The committee recommends systematic grouting of all Primary holes, followed by grouting of all Secondary holes on the downstream alignment. After evaluation of drilling and grouting data from Primary and Secondary holes grouting of Tertiary holes may be prioritized on a targeted basis.
No.7	March 5th, 2020	The meeting took place to discuss the strategy for upstream grouting (i.e what can be done to get ready for spring freshet while doing upstream blanket). Recommendations: - Only the drilling and grouting of Primary and Secondary order holes along the downstream blanket holes should be considered between sta. 0+176.5 and 0+266.5 – no Tertiary holes. - After completing the requested Quaternary order holes, along the upstream row of blanket holes, particularly between sta. 0+520 and 0+750, the Primary and Secondary order of blanket holes should be completed to 5m depth into bedrock. If possible, logistically, all of the Primary order holes should be completed before starting Secondary order holes. - Whether or not the drilling and grouting of Tertiary order holes along the upstream blanket holes are required will be based on observed grout takes. Casing should still be installed in the event that they are required. - To investigate whether or not seepage is deeper seated (and potentially reduce the noted seepage), the downstream row of grout holes should be deepened – particularly between sta. 0+520 and 0+750 to a minimum of 15m depth below the installed casings. The extent of grouting works at depth to be completed along the downstream row is to be determined based on observed grout takes. It may be necessary to close the curtain between targets and/or deepen an upstream row of grout holes.

Meeting No.	Date	Summary of Recommendations
No.8	March 19th, 2020	The meeting was added to obtain clarifications on recommendations provided after Meeting No.7 regarding deepening of the downstream blanket holes to 15m instead of focusing on the upstream blanket as originally outlined in the Technical Specifications and Drawings. Recommendations: - Complete downstream required Quaternary holes; - Primary holes from 0+520 to 0+750, 5m depth in bedrock; - Secondary holes from 0+520 to 0+750, 5m depth in bedrock; - Tertiaries (as required if really needed) from 0+520 to 0+750, 5m in bedrock; - Re-evaluate (Committee Meeting beginning of April). Two possible outcomes: either seepage flow is same (deeper flow) or seepage flow reduced.

2.4 Simplified Work Instructions and Fieldwork Instructions

2.4.1 Simplified Work Instructions

Simplified work instructions was a technical memorandum issued to provide brief instructions for starting the drilling and grouting of the blanket holes at the WTD foundation. It was a guideline to allow the work to start timely before the issuance of the final Technical Specifications and Drawings. This document prepared by SNC-Lavalin was subject to changes and updates based on the field encountered conditions, Technical Grouting Committee's recommendations and finalized project Technical Specifications.

The Site Work Instructions for Drilling and Blanket Grouting (Document No.669034-0000-40CA-0001) was issued by SNC-Lavalin to AEM on November 19th, 2019. The document was prepared based on the Grouting Committee Letter dated on October 25th, 2019 and the comments received from the Technical Specifications Rev PD. The document provided guidelines and sequence to carry out two-row of blanket grouting in phase approach using a stable thick grout with water cement ratio of W/C = 0.5 as the starting point and main grout mix aiming seal wide open discontinuities and fractures instead of conventional way of starting with thinner mixes to simplify the mix change process. Celbex (the thixotropic additive) will be added "in-line" utilising a separate open-throat progressive cavity pump to accommodate the different dosage of Celbex additive as required to seal highly fractured bedrock and closing holes with excessive grout take.

The Site Work Instructions were updated (Document No.669034-0000-40CA-0001 Rev 01) and issued by SNC-Lavalin to AEM on January 8th, 2020 to incorporate (1) the modification of the Mix C+ by reducing the Calcium Chloride dosage and (2) the conditions for drilling and grouting the blanket in two (2) stages.

In March 2020, an addendum (Document No. 669034-0000-40CA-0001 Addendum No.1) was added to the Site Work Instructions to provide additional instructions based on the recommendations of the Technical Grouting Committee after Meeting No.8. The recommendations were to complete the downstream blanket grouting of Primary, Secondary, Tertiary and Quaternary holes prior to starting the upstream blanket grouting. As for upstream blanket grouting, the focus was between station 0+750 to 0+520 with Primary, Secondary holes and Tertiary holes shall be added as required. The Site Instructions are included in the Appendix A (A-2).

2.4.2 Field Work Instructions

A total of three (3) Field Work Instructions were prepared by SNC-Lavalin QA Site Engineer issued during the drilling and grouting work. Field Instructions No.1 was issued via email dated December 3rd, 2019. This document was about grout mix change procedures during the blanket hole grouting and re-grouting. Field Work Instructions No.2, document numbered 669034-2000-60NV-0001 Rev 00, applied to grouting and re-grouting of Primary holes with the application of Celbex using open throat pump. Field Work Instructions No.3 was the revised Field Work No.2 with update to introduce mix D. All Field Work Instructions are presented in the Appendix A (A-2).

2.5 Construction Documentations

AEM was responsible for collection, distribution and storage of related construction documentation which includes the following:

- WTD design and construction documents;
- Investigation reports;
- Willowstick survey report;
- Thermistors data analysis;
- SNC-Lavalin IFC Drawings and Technical Specifications;
- Site Instructions and Field Work Instructions;
- Contractor Submittals;
- Survey Data and Documents;
- AEM Daily Construction Report;
- AEM – SNC Weekly Meeting Minutes;
- QC Casing Installation Reports;
- QC Rock Drilling Reports;
- QC Grouting Reports;
- QC Grout Mix Quality Test Results;
- QA Daily and Weekly Reports;
- As-Built Drilling and Grouting Profiles.

3.0 SITE DESCRIPTION AND GEOLOGICAL SETTING

3.1 Site Description

The AEM Amaruq Mine is located approximately 150 km north of the hamlet of Baker Lake and about 50 km northwest of the Meadowbank Mine in the Kivalliq region of Nunavut. Site access can be made by charter flight between Mirabel Airport in Montreal and Meadowbank Airstrip or by water through an all-season road connecting Between Baker Lake and Meadowbank.

The Meadowbank region located within a low Arctic Ecoclimate is described as one of coldest and driest regions in Canada. Winter conditions typically between October and May next year, with temperature ranging from +5° C to -40° C. The deep cold weather conditions present many challenges and have great impact on the project in term of design, logistic, drilling and grouting operations, schedule and cost.

3.2 Geological Setting

Based on the geotechnical investigations (carried out from 2015 to 2018), the subsurface profile generally consists of sand and gravel with cobbles and boulders and/or glacial till overburden overlying weathered bedrock. The bedrock encountered in the boreholes varies from greywacke (sedimentary) to diorite (intrusive). Both lithologies are deformed with an oblique foliation structure varying from weak to very strong in intensity. The most dominant structures are the foliations and then the veinlets. The Rock Quality Designation (RQD) values along the dike foundation vary significantly with a typical average in the range of

25 to 70%. The rock can be characterized as close to very close jointed with poor to fair quality based on the joint spacing and RQDs according to ISRM (1981).

Stereonet plots from televiewer surveys performed in 2017 geotechnical investigation shown on Figure 3-1 revealed 4 joint sets in the dam foundation bedrock, with predominant join set dipping approximately 38 to 45 degree toward the southeast. The apertures of the open joints typically range from 0.55 to 80 mm with an average aperture of about 6.0 to 7.0 mm. Some of the joints classified as “open joints” by the televiewer were filled with soil type material or gouge since the coring procedure washed material out of the joints. Broken zones with width vary from a few hundred to thousand millimetres were also encountered in the geotechnical investigation.

Ice and more frequently silt-infilled discontinuities can be observed in near surface bedrock which is typically highly weathered and fractured

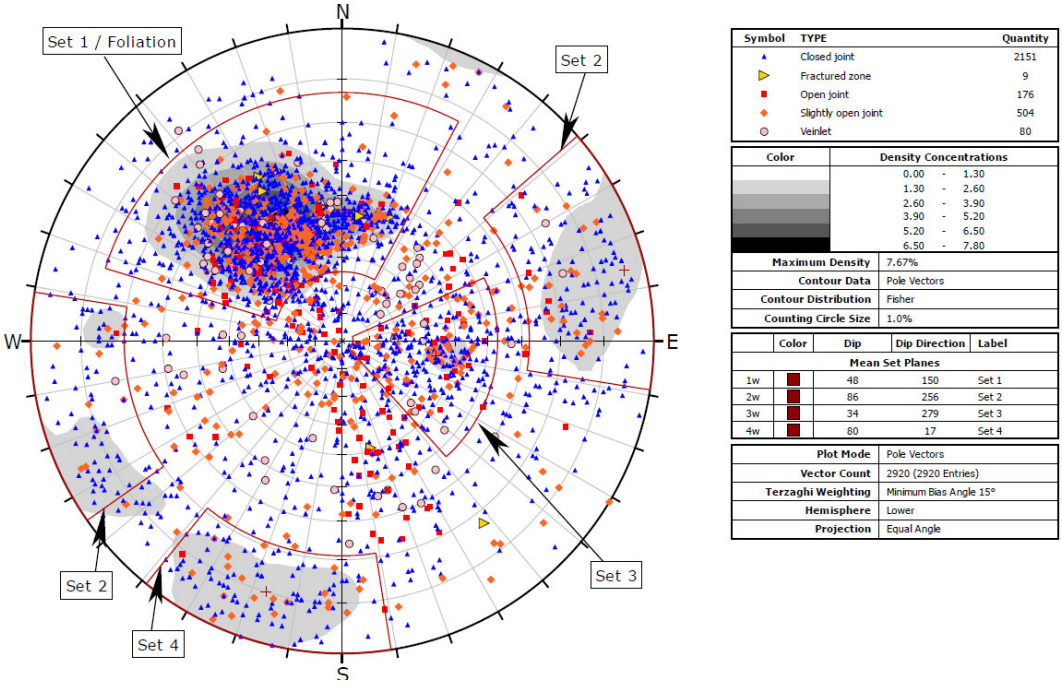

Figure 3-1: WTD 2017 Geotechnical Investigation – Main Joint Set Stereonet

4.0 CONSTRUCTION ACTIVITIES

4.1 Schedule and Construction Activities

The construction of the Remedial Drilling and Grouting program was carried out by AEM from November 2nd, 2019 to March 25th, 2020. Table 4-1 presents the construction timeline of the project.

Table 4-1: Timeline of the Construction of the Remedial Drilling and Grouting Program

Activity	Beginning	End
Downstream Casing Installation	November 2nd, 2019	March 12th, 2020
Trial Grout Mix Program	November 14th, 2019	November 17th, 2019
Downstream Casing Plug	November 19th, 2019	March 17th, 2020
Downstream Bedrock Drilling	November 26th, 2019	March 24th, 2020
Downstream Blanket Grouting	November 30th, 2019	March 25th, 2020
Upstream Casing Installation (last casing installed P-487)	February 22th, 2020	March 12th,2020
Upstream Casing Plug (last casing plugged P-487)	March 9th, 2020	March 21th, 2020
Upstream Bedrock Drilling (last hole drilled P-679)	March 21st, 2020	March 23rd, 2020
Upstream Blanket Grouting (last hole grouted P-679)	March 23rd, 2020	March 25th, 2020
Drilling and Grouting Suspension	March 25th, 2020	

4.2 Field Conditions and Site Preparation

During the planning of remediation grouting program in 2019-2020, the eastern boundary of the WTD foundation permafrost zone was estimated between Stations 0+750 to 0+775 and western boundary of the permafrost zone was estimated between Stations 0+150 and 0+175. Prior to the start of the blanket grouting and to preserve the integrity of the cut-off wall, the blanket grout holes were drilled with an offset of 0.7 m from the centreline of the cut-off wall for both downstream and upstream blanket to avoid grout holes to intersect the cut-off wall.

Some instrumentation shacks located on the dike were interfering the blanket alignment. Some instruments and their protection were removed prior to start casing drilling and at some locations, a decision was made to adjust the alignment of the grout blanket to install casing at acceptable offset from the design alignment. At four (4) locations (T-335.5, T-359.5, P-440.5 and P-609.5) the buried instrumentation cables could not be located and confirmed at the time. It was decided to skip those locations but later AEM decided to install casings at three (3) of those skipped locations (T335.5, P-440.5 and P-609.5) but at the time of grouting program suspended only one casing at P-609.5 had been installed.

The location of the secant pile wall centre line was marked prior to start staking the locations for the downstream casings. Stations were marked every 10 m spacing along the north edge of the WTD.

Extreme weather conditions such as winter blizzard, or temperature falls below -40°C without windchill during the blanket grouting posed challenges to grouting activities. In blizzard conditions most of the time the work was stopped and crew was moved from site in a group of vehicles guided by loader to protect the safety of the manpower and equipment.

To handle extreme weather conditions, the grouting was carried out from inside the grouting shack in controlled temperature but some supporting activities e.g supply of dry cement, water, fuel and moving unit was affected by the extreme weather and sometimes grouting activities have to stop due to extreme cold weather and visibility problems. Although the grout injection was performed from inside the injection unit, section of the hose between the bottom of the sea-can and the ground surface was uncovered and in extreme weather conditions grouting had to stop when was no grout flow to avoid grout freeze in the hose. Ground surface and slopes of the WTD were covered with snow and snow banks were built on both sides for safety reasons. A loader kept maintain the dike surface by cleaning snow and spreading gravels to avoid slippery conditions. Slippery conditions were very common around injection unit and rock drilling dome due to cleaning and drilling water. Access to the dike was from east end and the west end was blocked by snow bank until February. After February, access was only from East side. Radio communication was used between the different crews working on the dike and anyone entering the dike informed the WTD supervisor for permission.

4.3 Contractor's Submittals

The following documents were submitted by the Contractor (KCG) to AEM for approval. These documents are summarized in the Appendix D (D-1):

- Detailed work plan casing and bedrock drilling;
- Detailed work plan grouting operations; and
- Manufacturer's specifications and material safety data sheets for MasterGlenium 3030, MasterMatrix UW450, Celbex and Liquid sodium silicate handling & storage and material safety data sheet.

4.4 Trial Acceptance Tests (Grout Mix Design)

Field trial tests were completed prior to start grouting to finalize the mix design and to verify the adequacy of the equipment, materials and procedures as per specifications and applicable standards presented in the Technical Specifications.

Field checks had been performed by SNC-Lavalin QA site engineer to verify the contractor capability of performing required tasks including the contractor's personnel skills, equipment, material and procedures as well as onsite laboratory preparedness for mix design and Quality Assurance and Quality Control (QA/QC) testing.

Trial grout mixes were tested to ensure that they met the viscosity, stability and strength requirements. Seven (7) mixes; Mix A, Mix A+, Mix B, Mix B+ Mix C+, Mix D and Mix E with different water-cement ratios and admixtures were tested on site between November 14th and November 17th, 2019. The Quality Control (QC) representative from GHD conducted tests on the grout mixes to assess the physical properties of each mix. The trial mix tests were conducted using a full batch with 120 kg of dry cement per batch.

Dry cement used in the grouting program was procured between 2017 and 2019 and was stored in 1000 kg bags. Cement was screened and placed in 20 kg buckets in order to control the quantity of cement used in the grout mix. It was noticed that the cement from 1000 kg bags was contaminated with pieces of plastics, wood and cement lumps. A screen was installed at the inlet of the agitating tank, but it was not enough to remove all impurities. The impurities caused the grout return valve clogged and causing the uncontrolled

flow of grout towards hole, which may be one of the reasons for excessive spikes in the pressure-time graph as seen in some of the grout holes.

Grouting materials used in the grout mixes were provided by AEM and are listed below:

- Bulk HE cement in 1000 kg bag;
- Fresh clean Water heated;
- MasterGlenium 3030 water reducing admixture;
- Rheomac UW 450 anti-washout admixture;
- Celbex 653 Thixotropic Additive;
- Calcium chloride accelerating agent.

A summary of the trial mixes is presented in Table 4-2.

Table 4-2: Summary of Trail Acceptance Test Results

Ingredient	Unit	Mix A	Mix A+	Mix B	Mix B+	Mix C	Mix C+	Mix D	Mix E
Water	Litre	84	84	72	72	60	60	60	60
Cement Type III	kg	120	120	120	120	120	120	120	120
Calcium Chloride (2% by weight)	kg	2.4	2.4	2.4	2.4	2.4	2.4	1.2	2.4
Celbex (0.2% by weight)	kg	-		-			0.24		
Glenium 3030NS	ml		480		480				
Rheomac UW 450	ml							500	250
Properties									
Marsh Funnel time	second	30	30	41	32	68	77	154	163
Specific Gravity	g/cm^3	1.62	1.62	1.73	1.67	1.8	1.8	1.75	1.75
Bleeding after 2 hours	%	5	2	1	4	1	0	-	-
Filtration coefficient	min-1/2		0.02				.06	.061	

Notes

- Glenium 3030NS and Rheomac UW 450 were frozen and AEM confirmed with the supplier that these admixtures can be used after defreeze. KGC has a doubt that the Rheomac UW 450 was stored for long time in a cold weather and it may have changed its properties and this was monitored closely during the production.
- KGC didn't have Vicat apparatus on site initially to do initial and final set time of the grout. The vicat apparatus was broken during transportation to site. Vicat tests were performed during grouting work in progress after new apparatus arrived.
- Grout filtration test was performed on Mix A+ during trial test and filtration tests for other mixes were performed during work in progress.
- After started adding Celbex through the open throat pump, contractor stopped using Celbex in the mixer or agitating tank. Contractor refused to add 0.2% of Celbex by unit weight of dry cement in the mixer or agitator tank. The mix with water cement ratio of 0.5 and 2% of calcium chloride by weight of dry cement was given the name as Mix C and previously named Mix C with 0.2% of Celbex by weight of dry cement was given name Mix C+.
- Tests were performed on Mix C prior to use first time and then regularly during the grouting process as required by specifications.

4.5 Execution of Drilling and Grouting

4.5.1 Casing Installation

4.5.1.1 General

Casing drilling and installation through rockfill used as a thermal cover and fine filter down to bedrock interface was required to carry out the bedrock grouting without caving in non-cohesive material. Steel casings were installed through the dam fill material and embedded 300 to 500 mm in bedrock.

At the start of the casing installation work, SNC-Lavalin prepared a casing location Excel file to provide coordinates of each grout hole, the length of the casing and the minimum offset from the axis of the secant pile cut-off wall. The length of the casing was defined based on the as-built rock profile of the dam and the length of the rock socket of the secant pile cut-off wall provided by AEM. The length of the casing in certain locations was adjusted on site according based on rock conditions and field observations.

The coordinates of the casing in the instrumentation zones were created based on the instrumentation as-built location provided by AEM and incorporated in the casing location Excel file provided by SNC-Lavalin. Field verification of the casing location in the instrumentation zones was carried out prior to start drilling. Location was adjusted in the field to create more room for drilling and injection unit as shown in Photo 17 Appendix E - Photographs.

Each casing location was surveyed by the KCG survey team before the casing drilling process began. The maximum inaccuracy of grout hole casing positioning was 50 mm in any direction. Casing locations were staked by the surveyor and maximum casing length and hole ID were marked on each stake.

Steel casings, 115 mm diameter, were installed using down the hole drill rig equipped with the eccentric system for the drill rod and steel pipe to simultaneously use drilling bit fixed on the bottom of the hole hammer. When first casing length was installed in the fine filter material, a cable and lock pin was used to raise the second casing and rod at the same time and two (2) drill rods were tightened together and the second casing was welded with the first casing installed. This process was repeated until the required length of the casing was reached.

Once the bedrock was reached, the casing was socketed about 300 mm to 500 mm maximum into bedrock and the top casing length was cut to stick-up length of about 0.3 m above ground. It was initially planned to advance casing 300 to 500 mm maximum below as-built level of the secant pile casing surveyed during the secant pile wall construction on 2018. During casing installation, it was found that the actual bedrock level, in many holes, was deeper than the provided as-built level or the bedrock was weathered and highly fractured. This issue was discussed in the weekly meeting between AEM and SNC and during the Grouting Committee Meeting held on December 5th, 2019. It was decided to install casings minimum 0.3 m to 0.5 m into competent bedrock regardless of the as-built bottom elevation of secant pile casing. The secant pile wall is socketed 1.0 m in rock. If the casings were pushed below 1.0 m, an un-grouted section might still exist. Casings already installed to the provided levels without embedment into competent bedrock were extended and pushed deeper into bedrock to ensure a minimum 0.3 m to 0.5 m into competent bedrock. The objective of installing the casing into competent rock was to minimize potential hole collapse during the bedrock drilling and to avoid grout leakage during grouting process of either casing plugging and blanket grouting in bedrock.

Steel casings were installed vertically using a drill rig equipped with a DTH (down the hole hammer) which provided a required control of the casing verticality through the dam body down to bedrock. After installation, each casing vertical deviation was checked with DeviShot-quickstart inclinometer to verify if the deviation did not exceed 2% of the casing length. The control of the deviation of the casing is deemed very important in order to avoid hole crossing the cut-off wall of the dike. The inclinometer was used without centralizer as technically required.

The equipment used for casing installation are listed below:

- Robit DTH-Rec. drilling rig with an eccentric drill bit and a 3" DTH hammer as shown in Photo 15 Appendix E;
- Drilling rods;
- Generator; and
- Compressor.

All required downstream blanket casings for Primary, Secondary and Tertiary holes were installed prior to starting the installation of the upstream blanket casings. Only casings for required Quaternary holes and other few holes located in the exclusion zone due to instrumentation buried cables were installed later.

4.5.1.2 Casing Installation Challenges

As mentioned above, it was initially planned to install the casing down to the bottom elevation of the secant pile wall built in 2018. However, frequent caving was observed during the bedrock drilling of the first holes because either the bedrock was not reached or bedrock was highly fractured. Challenges with casing not embedded into bedrock including the following:

- Casing can't be plugged properly with excessive grout take under very low or no pressure;
- Difficulties in rock drilling: no water return, washout fine filter material;
- Blow back of mud in casing;
- Difficulties to grout bedrock and hole collapsing;
- Excessive grout takes at low pressure and difficulty in closure during grouting.

4.5.1.3 Installation of Downstream Blanket Casings

Installation of downstream blanket casings was started on November 2nd, 2019 and it was stopped on March 12th, 2020. The installation was started from the East abutment and progressed towards the West abutment of the WTD.

Steel casing for Primary, Secondary and Tertiary holes were all installed prior to start rock drilling of the downstream blanket because of tight space management for heavy equipment on the crest of the dam. Final hole spacing on the crest after completion of the installation of all planned casings is 3.0 m center to center. This spacing was reduced, in some areas of the downstream blanket, to only 1.5 m center to center after completion of the installation of all required Quaternary hole casings. These holes were required based on Tertiary holes grouting results and were installed between February 25th, 2020 to March 12th, 2020.

Downstream blanket casing of the WTD are located at minimum offset of 0.7 m from the secant pile wall center line which corresponds to about 0.2 m from the downstream face of the secant pile wall. The offset was increased to about 1.20 m from the center line of the secant pile to avoid crossing and cutting the buried

instrumentation cables in the instrumentation zones at the vicinity of the instrumentation shack. Instrumentation zone along downstream blanket alignment is indicated in Table 4-3.

Table 4-3: Downstream Blanket – Location of Instrumentation Zones

Zone number	Location
1	0+176 to 0+195
2	0+206.5
3	0+218 to 0+237
4	0+254 to 0+261
5	0+314 to 0+330
6	0+350 to 0+366
7	0+410 to 0+471
8	0+560 to 0+594
9	0+671 to 0+675
10	0+707 to 0+720

Exclusion zone is either the area where the as-built location of the buried instrument cable is not available or not accurate enough to allow for the installation of the casing with certainty of not damaging the buried instruments. Four (4) casings (T-335.5, T-359.5, P-440.5 and P-609.5) located in exclusion zones were initially cancelled but later three (3) of those casings (T-335.5, T-359.5, and P-609.5) were relocated at locations provided by AEM.

A total of 18 casings initially installed based on provided casing length were extended down to be embedded 300 mm to 500 mm in the competent bedrock. A total of 5 grout holes (T-395.5, P-488.5, T-521.5, P-524.5 and T-533.5) were relocated beside their initial locations in the same alignment because the original holes were abandoned due to broken casing shoe and was replaced with new holes. At the hole Q664, during casing installation water communication was observed through previously installed casing at Q667.

4.5.1.4 Installation of Upstream Blanket Casings

Installation of upstream blanket casings was started on February 22nd, 2020 and it was stopped on March 12th, 2020. All Primary and Secondary holes casing were installed from the East end of the WTD to station 0+487 except hole P-667 and all Tertiary holes casing were installed from the East end of the WTD to station 0+526 except hole T-670. No casing at the upstream blanket was installed west of station 0+487 at the time of the adjournment of remedial drilling and grouting activities

As of March 25th, 2020 (work was suspended) the final hole spacing on the crest of the dike was 3.0 m center to center from Stations 0+748 to 0+526 and 6.0 m center to center from Stations 0+526 to 0+487.

Upstream blanket casings of the WTD are located at minimum offset of 0.7 m from the secant pile wall center line from Stations 0+748 to 0+520, which corresponds to about 0.2 m from the upstream face of the secant pile wall. The offset was increased to about 1.20 m from the secant pile wall center line between Stations

0+520 and 0+180 in the area of the existing curtain grouting alignment which was at 0.9 m upstream of the secant pile center line.

The offset of the upstream blanket alignment from the center line of the secant pile was increased to avoid crossing and cutting buried instrumentation cables in the instrumentation zones at the vicinity of the instrumentation shack. Instrumentation zones along usptream blanket alignment are indicated in Table 4-4.

During the installation of the upstream casings, water communication was observed between nine (9) following casings: T-538, P-583, S-589, S-625, T-634, S-637, P-691, S-697 and T-700.

Table 4-4: Upstream Blanket – Location of Instrumentation Zones

Zone number	Location
1	0+254 to 0+261
2	0+353 to 0+360
3	0+434 to 0+439.5
4	0+560.5
5	0+663.5 to 0+678
6	0+702 to 0+707
7	0+725 to 0+749

4.5.1.5 Casing Installation Quality and Progress

The downstream blanket comprised of 192 planned casings including Primary, Secondary and Tertiary holes. No additional Quaternary casing was planned for the downstream blanket at the beginning of the work. A total of 189 Primary, Secondary and Tertiary hole casings were installed from November 2nd to December 6th, 2019. Hole P-609.1, located in an exclusion zone, was installed later on February 28th, 2020. This hole was initially located at Station 0+608.5 but had to be relocated to Station 0+609.1 and renamed to P-609.1. Due to conflict with buried instrumentation cables, the other 3 remaining casings, T335.5, T-359.5 and P440.5, were not installed before the adjournment of the grouting works on March 25th, 2020.

After the completion of all Primary, Secondary and Tertiary holes grouting, 24 Quaternary holes were added in zones of high grout takes for a total of 213 casings installed along the WTD downstream blanket alignment.

Upstream blanket comprised of 384 planned casings including all Primary, Secondary, Tertiary and Quaternary holes. Only 80 casings were installed at the WTD upstream blanket before the adjournment of the grouting works on March 25th, 2020. It was decided that only Primary and Secondary holes are mandatory and the Tertiary holes will be added, as required, based on previous holes grout take.

Installation progress of downstream and upstream blanket casings is shown on Figure 4-1 and Figure 4-2, respectively. Quantities of installed casings are summarized in Table 4-5 and shown on Figure 4-3.

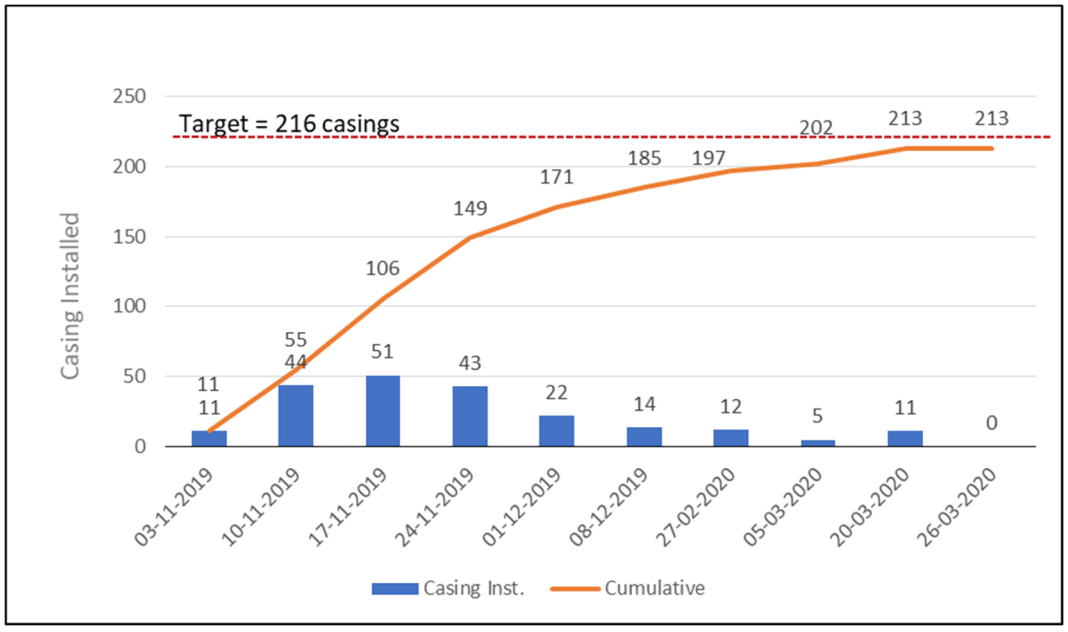

Figure 4-1: Downstream Casing Installation Progress

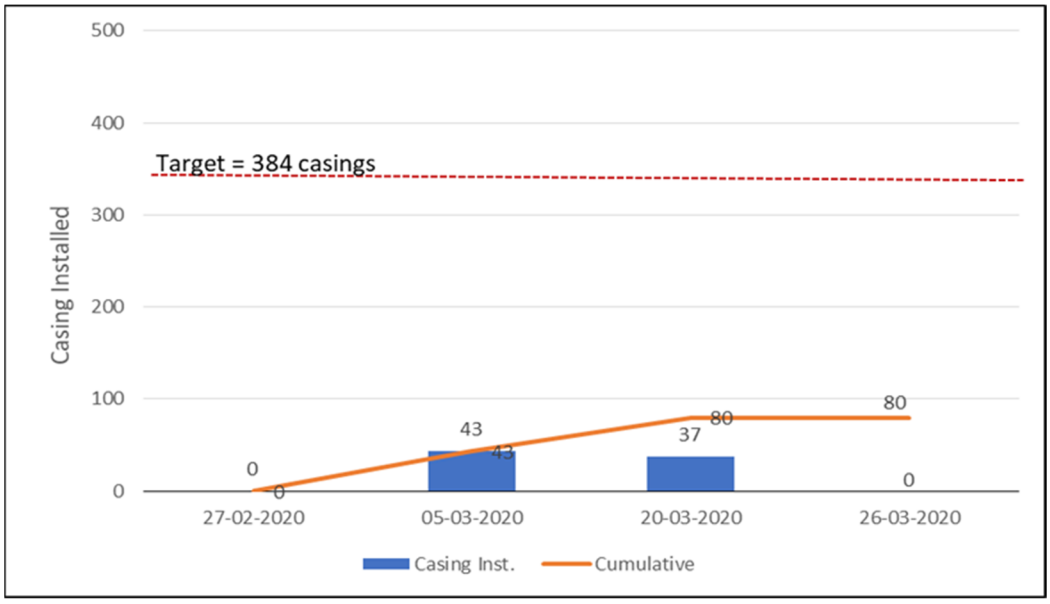

Figure 4-2: Upstream Casing Installation Progress

Table 4-5: Downstream and Upstream Blankets – Casing Installation Quantities

	Planned	Added	Total	Installed	Installed (%)
Downstream Blanket	192	24	216	213	99%
Upstream Blanket	384	0	384	80	21%
Total	576	24	600	293	49%

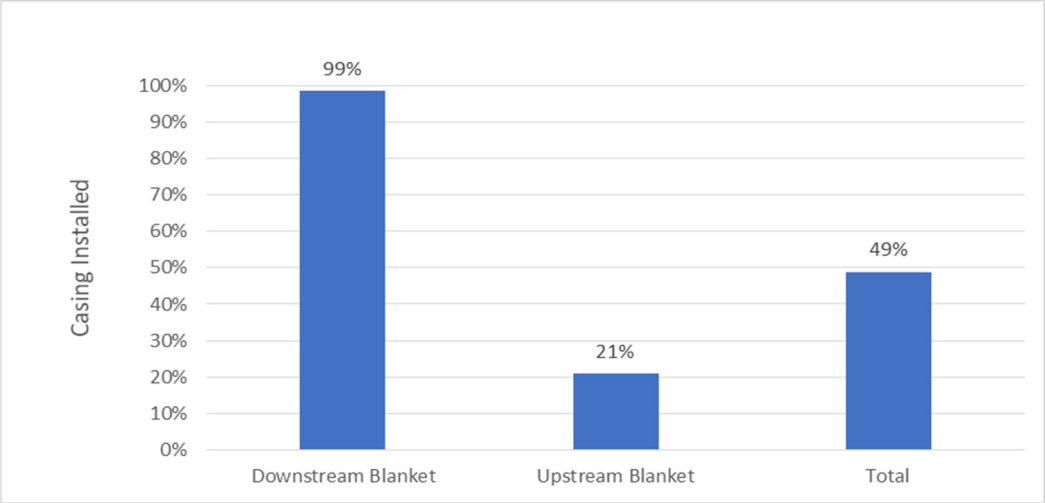

Figure 4-3: Casing Installation Progress

4.5.2 Casing Plug Grouting

4.5.2.1 General

Casing grout plug is required to prevent grout leakage by sealing the annulus space and contact surface between the steel casing and the surrounding rock with grout prior to start grouting. The objective is (1) to fill voids between steel casing and the rock and (2) to consolidate the fractured rock around the socketed casing to be able to handle the grouting pressure of the blanket holes.

After casing installation is completed and all quality checks were carried out and accepted including inclination, bottom casing elevation and rock socket length, the casing bottom is cleaned with flowing water to the satisfaction of the Engineer. Few casings where secant pile cement bentonite slurry was encountered were very difficult to clean. The cleaning was halted before all the slurry mud can be removed.

Injection unit used in the grouting of the rock was used to mix and inject the casing plug grout into the hole. Formula of grout Mixes C and C+ used to grout casing plugs is indicated on Table 4-6.

Table 4-6: Casing Plug – Grout Mix C/C+ (with Celbex)

Water / Cement Ratio	0.5
Calcium Chloride	2%
Celbex 653 (Only Mix C+)	0.2%

Prior to start pressure grouting of the casing plug using a packer, about 15 litres of grout mix C or C+ was injected into the hole to displace existing water using tremie grouting method. The packer placed at about 2 m above the bottom of the hole was then inflated using air compressor and portable water pump.

Casing plug grouting was performed by KCG at low flow and low grouting pressure to avoid casing upward movement and wasting of the grout. Casing plug was assumed completed when pressure refusal at maximum effective pressure or maximum grout volume was reached. The maximum volume was about 2 times the theoretical volume of the casing. In few holes, where cement bentonite was encountered, it was very difficult to grout the casing plug due to the slurry mud.

4.5.2.2 Downstream Blanket Casing Plug

Casing plug grouting of downstream blanket casings was performed for all 213 installed casings between November 19th, 2019 and March17th, 2020. In most holes, the grouting of the plug was carried out after the cleaning of the casing bottom. In the holes where cement bentonite mud was observed at the bottom, the following solutions were used in few cases where the mud could not be cleaned before the grouting of the casing plug started:

- Plug grouting in holes T-635.5, Q-682, T725.5 and T-731.5 was performed even with the presence of mud,
- Hole T-593.5 was re-drilled down to the bottom of the casing before grouting the plug;
- No plug grouting was attempted in few holes before bedrock drilling. the casing plugging was performed after bedrock drilling as per the following procedures:
  - Grouting of the bedrock was performed without casing plug in holes T-446.5, T-575.5, and T-599.5. The packer was completely installed in the casing.
  - In holes T-197.5, P-680.5, P-716.5, T-719.5, S-722.5, T-725.5, and T-728.5, the packer was first installed half in bedrock and half in the casing to grout the bedrock first. After the refusal, the packer was lifted upward and installed completely in casing to grout the upper portion of bedrock and the casing plug that had not been grouted.

Only 30 casing plugs out of 213 casing plugs reached the maximum volume before reaching the maximum pressure allowed.

4.5.2.3 Upstream Blanket Casing Plug

Casing plug grouting was performed from March 9th, 2020 to March 21st, 2020. Only two (2) installed casings (P-523 and P-655) were not plugged before the adjournment of the works on March 25th, 2020. In 18 holes, packer was placed above water level due to ice build-up along casing that compromise the packer sealing with the casing. A total of 17 casing plugs out of 78 reached the maximum volume before reaching the maximum pressure allowed.

4.5.2.4 Casing Plug Progress and Quantities

Downstream blanket comprised of 192 planned casing plugs for all Primary, Secondary and Tertiary hole casings. 24 Quaternary hole casing plugs were added for a total of 216 casing plugs. Only 213 casing plugs were grouted; the other three (3) remaining casing plugs for T335.5, T-359.5 and P440.5 were not grouted because the casings were not installed due to conflict with buried instrumentation cables in restriction zones. 10 of 213 casing plugs were grouted only after the drilling and grouting of the rock was complete.

Upstream blanket comprised of 384 planned casing plugs for all Primary, Secondary, Tertiary and Quaternary hole casings. From 80 installed casings, 78 casing plugs were grouted at the WTD upstream blanket before the adjournment of the grouting works.

Installation progress of downstream and upstream blanket casings is shown on Figure 4-4 and Figure 4-5, respectively. Quantities of grouted casings are summarized in Table 4-7 and shown on Figure 4-6. Total volumes of grout mix C/C+ used for grouting the casing plugs of downstream and upstream blankets are: 18,815 litres and 5,558 litres respectively.

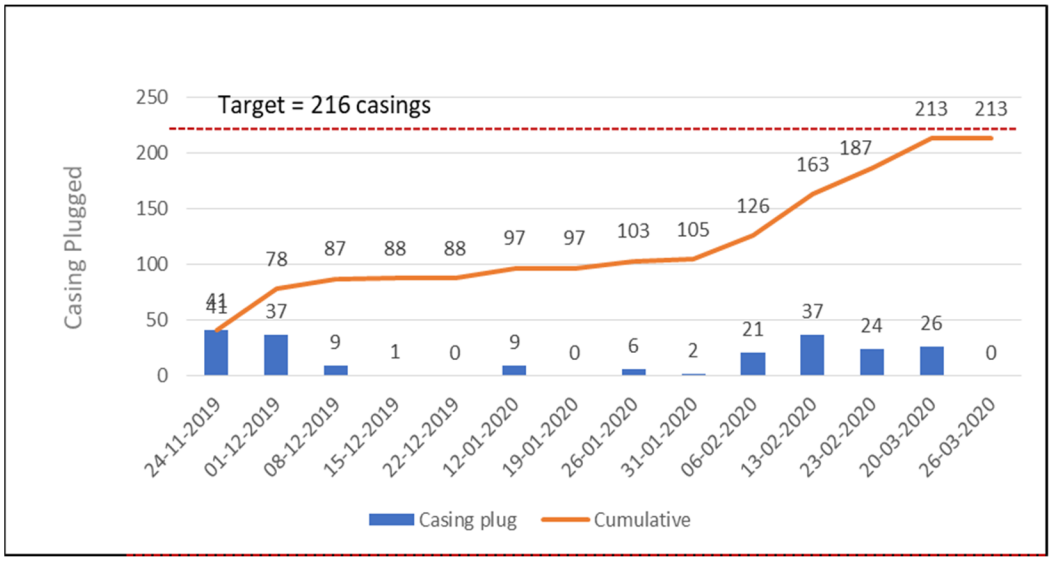

Figure 4-4: Downstream Casing Plug Grouting Progress

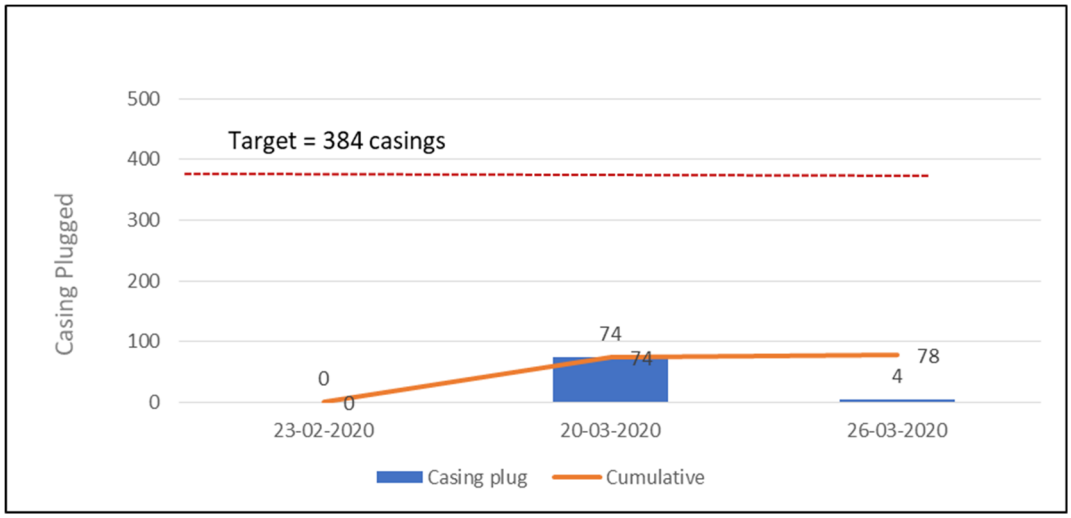

Figure 4-5: Upstream Casing Plug Grouting Progress

Table 4-7: Downstream and Upstream Blanket – Grouted Casing Plug Quantities

	Planned	Added	Total	Installed	Installed (%)
Downstream Blanket	192	24	216	213	99%
Upstream Blanket	384	0	384	78	20%
Total	576	24	600	291	49%

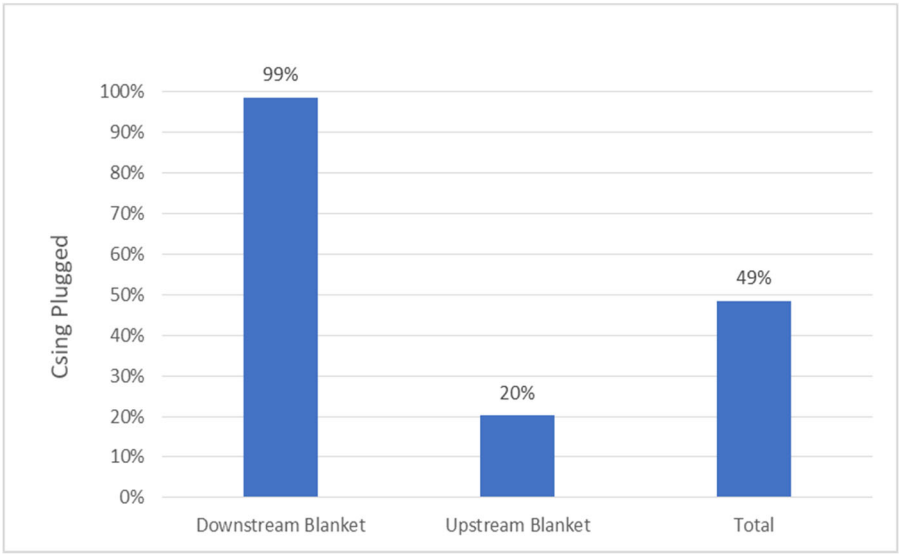

Figure 4-6: Casing Plug Grouting Progress

4.5.3 Bedrock Drilling

4.5.3.1 General

Rock drilling was done from inside the drilling dome to protect drilling equipment from extreme cold weather conditions and prevent drilling water from freezing during drilling operations. Bedrock drilling was executed in conformity with split spacing method; Primary holes were drilled first, followed by Secondary, Tertiary and finally Quaternary, where required.

In general, except for about 10 holes, blanket grout holes were drilled through pre-installed casings, after the casings were plugged and the grout has reached its final set time, to the required depth of about 5 m in bedrock.

Blanket holes in the rock foundation of WTD were drilled using Tamrock top hammer drill rig with drilling rods of 3.6 m long and drill bit of 90 mm diameter equipped with water flush line to wash out rock cuttings from the hole.

The driller controlled the depth of hole by counting number of drill rods and final depth was measured with measuring tape after completion. After completion of the drilling, the hole was washed with clean water injected at the bottom for 6 minutes or until the water coming out of the hole was clear and free from rock cuttings. Cleaned holes were protected from clogging or obstruction. Water level was noted on the drilling logs but the accurate water level was measured after water level inside the hole was stabilized prior to start grouting. Hole deviation was not performed in the bedrock portion of the hole as instructed by AEM since this portion of the hole is below the secant pile wall. The equipment used for rock drilling is listed below:

- Tamrock top hammer water flushing drill rig;
- Drill rods;
- Generator;
- Electric heaters;
- Water supply and tank.

Drilling of the rock could only be started once the grout of the casing plug reached its final set time.

4.5.3.2 Drilling Stages

Drilling of the first Primary and Secondary holes from the East abutment of the downstream blanket was done in a single stage of 5m length. Due to high grout take and difficulties encountered during the grouting of Primary holes, in the meeting held on December 5th, 2019 (Appendix B), the Technical Grouting Committee recommended to drill and grout remaining blanket holes in two (2) short stages of 1.5 m and 3.5 m length, respectively, using downstage drilling and grouting method. Due to the following issues noticed after drilling and grouting 12 Secondary holes, see Table 4-8; using two stages of 1.5 m and 3.5 m:

- Drilling and grouting in two stages required more time, coordination and logistics;
- Most of Secondary holes first stage between 0 to 1.5 m were closed by pressure without reaching Vmax of the stage;
- Most of the Secondary holes stages between 1.5 to 5 m exceeded Vmax and were re-grouted.

AEM, SNC-Lavalin and KGC agreed, during weekly construction meeting, to perform the drilling and grouting in one single stage of 5 m for all the remaining blanket holes, except in the 2 following cases:

- when the water loss occurs during the drilling of the first 1.5 m of the hole in rock;
- When the hole collapsed (caving-in) during drilling due to poor bedrock conditions.

In these cases, drilling and grouting could be carried out in 2 short stages of 1.5 m for the first stage and 3.5 m for the second stage, using the downstage grouting method. SNC-Lavalin issued the Site Work Instructions Rev 01 to implement this rock drilling procedure on January 8, 2020 (Appendix A-2). Table 3-8 details the holes where two stages drilling was required.

Table 4-8: Two Stages Drilling and Grouting Holes

Hole	Remarks
S-614,5	Water loss at el. 145.8 masl
S-626,5	Water loss at el. 145.5 masl
S-638,5	Water loss at el. 145.4 masl
S-650,5	Water loss at el. 145.4 masl
S-662,5	Water loss at el. 145.7 masl
S-674,5	Water loss at el. 145.8 masl
S-686,5	Water loss at el. 146.1 masl and hole caved to el. 146.1 masl
S-698,5	Water loss at el. 146.5 masl
S-710,5	Water loss at el. 142.0 masl, broken rock at el. 143.7 masl
S-722,5	Water loss at el. 143.0 masl
S-734,5	Water loss at el. 146.2 masl, hole caved to el. 145.9 masl
S-746,5	Water loss at el. 145.6 masl

4.5.3.3 Downstream Blanket Rock Drilling

WTD downstream blanket rock drilling was started on November 26th, 2019 and it was stopped on March 24th,2020. Drilling and grouting was performed in one single stage of 5 m in 194 holes out of 206 holes at the WTD downstream blanket. Two stages drilling were only used in 12 Secondary holes between Stations 0+746 and 0+614.5 as listed in Table 11. It was decided by the Client and Contractor that the bedrock drilling and grouting could be performed in sections by priority. Thus, instead of drilling and grouting all Primary holes on the entire WTD length before the beginning of the drilling for the Secondary and subsequent sequences after, the drilling and grouting work was focused more on section from Stations 0+750 to 0+475. The rock drilling sequence of downstream blanket holes at the WTD was as follow:

- P-749.5 to P-476.5 from November 26th, 2019 to December 1st, 2019, except 6 Primary holes that were performed later in that section (see below);
- S-749.5 to S-602.5 from December 11th to December 15th, 2019;

- T-749.5 to T-611.5 from January 11th to 15th, 2020;
- P-464.5 to P-452.5 on January 21st, 2020;
- T-605.5 to T-599.5 on January 25th, 2020;
- P-590.5 to P-446.5 from January 26th to January 29th,2020;
- T-593.5 to T-443.5 from January 29th to February 2nd, 2020;
- P-428.5 to P-380.5 on February 3rd and 4th, 2020;
- S-434.5 to S-386.5 on February 9th and 10th, 2020;
- P-368.5 to P-260.5 from February 10th to 12th, 2020;
- T-437.5 to T-383.5 on February 17th, 2020;
- S-374.5 to S-266.5 from February 17th to 21st, 2020;
- P-248.5 to P-176.5 on February 21st, 2020;
- T-377.5 to T-269.5 on February 25th and 26th, 2020;
- S-254.5 to S-182.5 on February 26th and 27th, 2020;
- T-263.5 to T-179.5 from February 29th to March 2nd, 2020;
- Q-739 to Q-478 from March 9th to March 24th, 2020;

Primary holes drilled and grouted later in section P-749.5 to P-476.5

- P (0+548.5 to 0+560.5) on January 21st, 2020;
- P (0+584.5 to 0+572.5) on January 14th, 2020;
- P-609.1 on March 14th, 2020;
- P-596.5 on December 13th, 2019.

As per article 5.2.6 of the Technical Specification, minimum distance between two drilled holes in bedrock is 12 m, in some cases, Tertiary holes were drilled at a distance of only 6 m from each other due to the logistic, schedule and construction constraints. Reduction of the minimum distance between drilled holes to 6.0 m was proposed by KCG and accepted by AEM and SNC-Lavalin during the daily coordination meeting on January 16, 2020 (Appendix F) provided that all Primary and Secondary holes in the area were already grouted.

4.5.3.4 Upstream Blanket Bedrock Drilling

WTD upstream blanket bedrock drilling was started on March 21st, 2020 and stopped on March 23rd, 2020. Bedrock collapsed in hole P-715 at the depth of 14.3 m (about 1 m below top of bedrock) thus, bedrock drilling and grouting was performed in two (2) stages in that hole. However, only the first stage was drilled and grouted before the adjournment of the works. Second stage will have to be performed when the works will resume. No caving or water loss in the first 1.5 m in bedrock was observed in the other holes drilled at the WTD upstream blanket so these holes were drilled in one 5m stage.

4.5.3.5 Water Level Monitoring

Water level was measured in each hole after bedrock drilling and before the bedrock grouting by the QC representative from GHD using a water level meter. The water level measured was used to calculate effective pressure for the grouting. Water level was found at depth varying between 5.15 and 15.81 m but mostly around 6 to 9 m (about elevation 150 masl to 153 masl) as shown on Figure 4-7. The depth of 15.81 m measured at the East end of the WTD (Station 0+749.5) seems to be an erratic value.

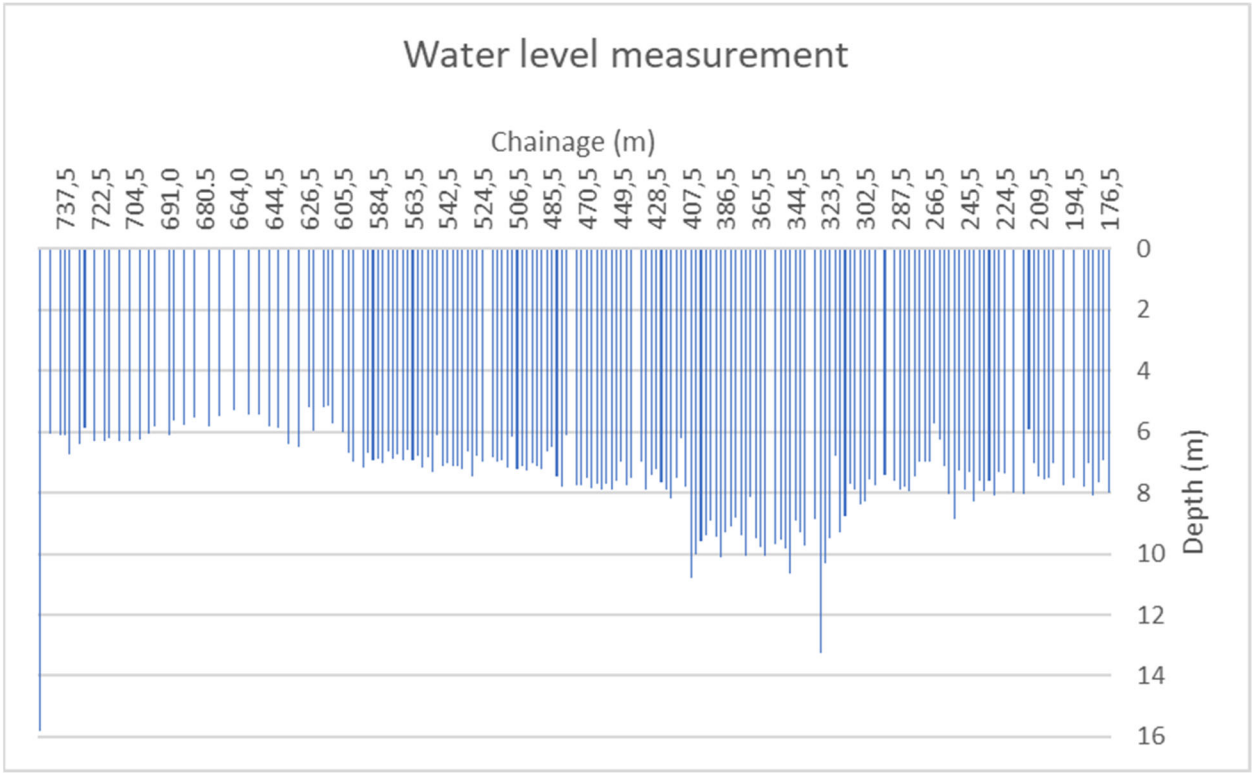

Figure 4-7: Downstream Blanket Drilling – Measured Water Level in the Holes

4.5.3.6 Rock Drilling Progress and Quantities

Downstream blanket comprised of 216 blanket holes including 192 planned Primary, Secondary and Tertiary holes and 24 additional Quaternary holes. A total of 206 holes were drilled to 5 m in bedrock and the remaining 10 holes (Q-193, Q-197, Q-199, Q-220, Q-223, Q-292, Q-295, T335.5, T-359.5, P440.5) were not drilled before adjournment of the works on March 25th, 2020. A total of 12 Secondary holes from 206 drilled holes were drilled in two (2) rock stages of 1.5 and 3.5 m as indicated in Table 4-9. All the other holes were drilled in one stage of 5.0 m.

Upstream blanket comprised of 384 planned casing plugs for all Primary, Secondary, Tertiary and Quaternary hole casings. From 80 installed casings, only six (6) holes were drilled in bedrock at the WTD upstream blanket.

Bedrock drilling progress of downstream and upstream blankets is shown on Figure 4-8 and Figure 4-9, respectively. Quantities of drilled holes in the bedrock are summarized in Table 4-9 and shown on Figure 4-10. Total drilled length in the rock mass for downstream blanket and upstream blanket are 1,068m and 27m, respectively.

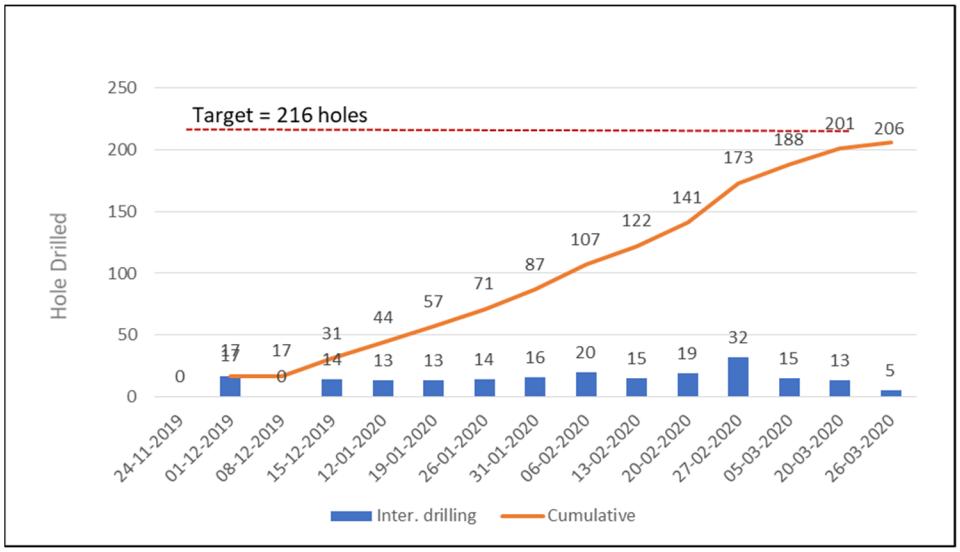

Figure 4-8: Downstream Blanket Drilling Progress

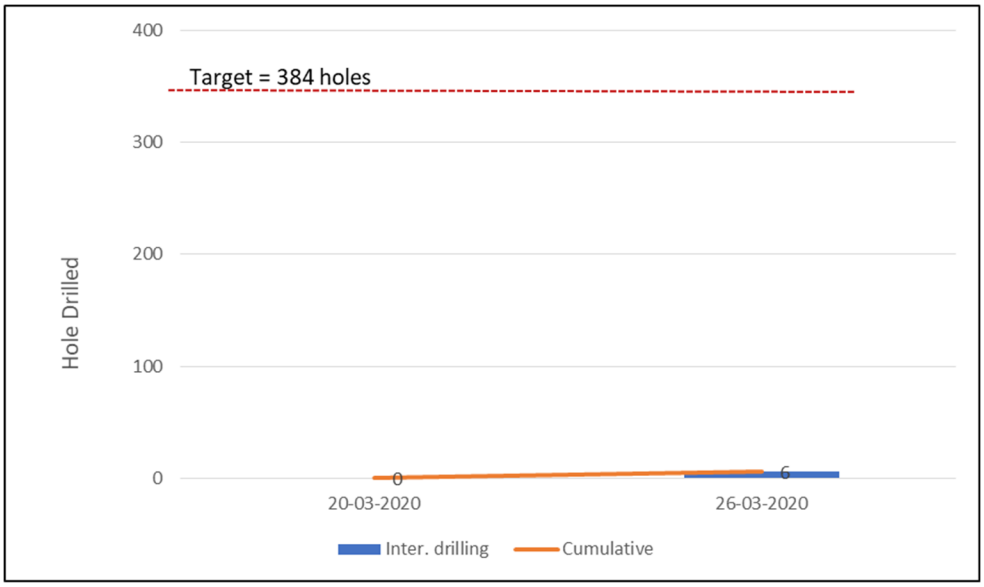

Figure 4-9: Upstream Blanket Drilling Progress

Table 4-9: Downstream and Upstream Blankets – Rock Drilling Quantities

	Planned	Additional	Total	Drilled	%
Downstream Blanket	192	24	216	206	95%
Upstream Blanket	384	0	384	6	2%
Total	576	24	600	211	35%

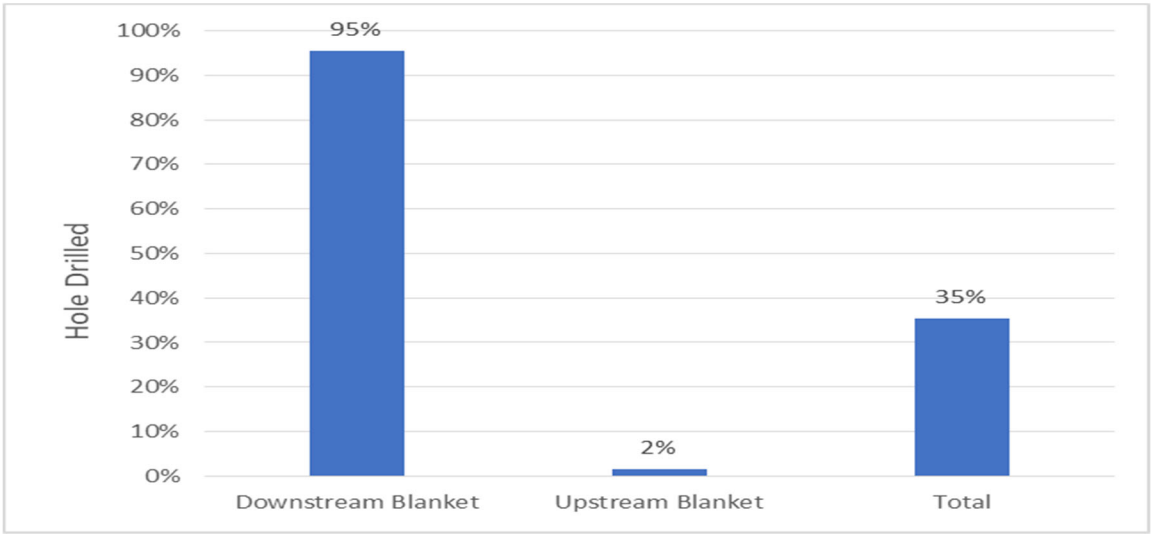

Figure 4-10: Upstream and Downstream Blanket Drilling Progress

4.5.4 Bedrock Grouting

4.5.4.1 Injection Unit

Grout injection unit consisted of 2 attached Sea-Can A and B. Sea-Can A is shown on Photo 2 (Appendix E) and Sea-Can B is shown on Photo 3 (Appendix E). While bulk cement storage and batching were at a separate location. Sea-Can A (mixing room) contains the generator, the water tank equipped with the water heater and all the required equipment for grout mixing. In particular, a balance to validate the amount of Celbex and calcium chloride before added in the mixer and a flowmeter to measure the amount of water for the mix. The list of equipment in Sea-Can A is listed below:

- High Speed Colloidal Mixer;
- Agitator tank;
- Water flowmeter;
- Measuring scale;
- Measuring cup for admixtures;
- Digital thermometer;

- Generator;
- Heated water tank;
- QC apparatus (Marsh Funnel, Mud Balance, Bleeding tube, Thermometer etc.).

Sea-Can B (control room) contains the control unit (permeation grout monitor), the heat canon and all pipes, packers and hoses required including:

- Flowmeter and pressure control box;
- Data monitoring system;
- Electric heaters;
- Pressure hoses, pipes and couplings;
- Pneumatic packers, 65 mm diameter;
- Pressure gauges;
- Open throat pump and;
- Measuring scale for Celbex etc.

Grouting and laboratory testing equipment were provided by KCG. All pressure gauges, water flowmeter, grout flowmeter and QC lab testing equipment were checked on site to confirm the accuracy. The mixing unit was capable of mixing grout with high speed high-shear with rotation speed of 1,200 and 1,500 RPM and retention tank had a capacity of 500 litres with paddle rotation of up to 100 RPM. 25 mm inside diameter and rated 30 bars safe working pressure grout hoses and fittings were used. Injection unit was equipped with automated data recording system to record and show real time pressure and flow chart on monitor screen. The grouting equipment provided continuous grout circulation throughout the circuit and permitted accurate pressure control by operation of valves. An open throat pump was provided by the Contractor to use with higher percentage of Celbex in high grout take holes.

4.5.4.2 Grout Mixing and Delivery

Cement was brought to the injection unit in 20 litres buckets. Each bucket was filled with 20 kg of HE Portland cement at the batch plan from a 1000 kg bulk cement bag. Buckets were left in the Sea-Can at the batch plant until cement reached the right temperature. A special attention was given to maintain a good rotation of the prepared 20 kg bucket to avoid clogging of cement left too long in the buckets before being used.

20 kg cement buckets were delivered on a covered pallet with a zoom boom from the batch plant to the injection unit. The pallet contains 24 of 20 kg cement buckets. Injection unit communicated with the zoom boom operator when cement was needed. Admixtures were also delivered with the same equipment.

Water was delivered to the injection unit with a water tanker truck. The water tanker truck filled the 2,000 L water tank in the injection unit when required, typically twice a day.

Cement, water and admixture were mixed in the mixer before being transferred to the retention tank. QA representative was in constant communication with the batcher in order to give instruction to adjust grout mix depending on the grout take and pressure measured.

The injection pump was connected to the agitator tank and to the data recording and monitoring system. Grout was delivered to the hole using hoses and packers capable of withstanding a maximum injection

pressure. The inflatable parkers were inflated with an air compressor and windshield washer fluid using hand water pump.

4.5.4.3 Grouting Process

Before starting the rock grouting, head loss calculations in the grout lines for different mixes were completed during the field trial tests. Gauge pressure for different mix types were calculated by adding 0.2 bars per length of overburden and 0.5 bars per length in the bedrock measured vertically and by incorporating the effect of ground water level, grout column head and head loss due to friction inside the grout lines.

Blanket grouting of the WTD was executed using stable grout mix verified and approved during a field acceptance trial. Formula of the grout mixes are indicated in Section 4.4 of this report.

After drilling and washing the hole, the grouting was carried out using upstage grouting method in holes that were drilled in only on stage of 5m or using downstaging method in the holes drilled in 2 stages.

Split spacing method was used in a sequence to obtain the desired control of the seepage and rock consolidation. Primary holes were drilled and grouted first, followed by Secondary, then Tertiary and finally Quaternary. Primary, Secondary and Tertiary holes were mandatory, Quaternary holes were added if the high grout take exceeded 200 l/m. Split spacing sequence was not respected in few areas as described in Section 4.5.4.7 Issues and Challenges.

Packer was lowered down in the hole to just above the bottom of the casing and filled with grout to displace water or air prior to inflate packer with air and water. Two pressure gauges were installed on the system, the first one was on the grout monitor for real time monitoring and second one right at the hole collar. Flowrate and pressure were controlled by monitor operator by adjusting the diaphragm valve installed on the return line.

Grouting was continued until grout refusal was reached with specified grouting pressure or maximum volume. For high grout take holes, grout was switched from low density grout to high density grout using anti-wash admixtures and if no pressure refusal was achieved using high density grout with anti-wash admixtures, holes were re-grouted using Celbex added in open throat pump.

When grout communication occurred between different holes, packer was installed in the hole where it communicated to stop grout loss. The hole already started continued as usual until pressure refusal or maximum volume was reached. The second hole was then immediately grouted while the packer in the first hole was kept inflated.

4.5.4.4 Grouting Volume and Pressure Monitoring

Grout flow rate, injection pressure and total volume were continuously monitored and recorded in real time with a Data Recording System. A pressure gauge was also installed at each hole collar as shown in Photo 19 (Appendix E).

The maximum effective grouting pressures were calculated as follow: 0.2 bar per meter measured vertically from the working platform to the top of bedrock, plus 0.5 bar per meter measured from the bedrock surface to the mid-point of a stage. The applied grouting pressure was calculated considering the pressure loss in the system and the hydraulic head relating to depth below surface and corresponding water elevation.

For injection of Celbex-assisted cementitious grout using Open Throat Pump, the maximum grouting pressure was established to 10 bar at the hole collar to prevent hydro-jacking and hydrofracturing of the rock foundation.

4.5.4.5 Mix Change Process during Grouting

When the injection started with mix B and no noticeable increase in the grouting pressure was observed after about 400 L (± 80 L/m), grout mix was changed to thicker mix C and if no noticeable increase in the grouting pressure was observed after a total of about 800 L (±160 L/m), grout mix C was changed to mix D.

When the injection started with mix C and no noticeable increase in the grouting pressure was observed after about 400 L (±80 L/m), a thicker mix (mix D) was used.

In both cases, if no noticeable increase in the grouting pressure was observed after a total injected volume of about 1,500 L (± 300 L/m), Rheomac ratio was doubled until refusal or until the maximum volume allowed were reached. If refusal criteria were not met before a total grout volume of 400 L/m (±2,000 L), the grouting process was adjourned and the hole was re-grouted later.

4.5.4.6 Re-Grouting Process

Prior to re-grouting, the grout elevation was checked inside the hole. If grout level inside the hole was above the bottom of the casing, the hole was backfilled and if grout level inside the hole was below the bottom of the casing, re-grouting was required.

The re-grouting process changed through time. It was initially planned that when high grout take was observed without noticeable pressure increase, thicker mixes (Mix C with 0,2% of Celbex or Mix D) was used and only once at P-680.5 mix E was used. It was later found that, in some cases, the thicker mixes (Mix C with 0,2% of Celbex or Mix D) were not thick enough to achieve refusal and a second or third re-grouting process were required to close the hole.

Instead of using two component system for Cementitious grout and liquid Sodium Silicate as mentioned in the technical specification, the Grouting Committee proposed to increase the Celbex ratio in the mix by adding directly and manually Celbex in the open throat pump installed next to the collar of the hole because enhanced Celbex grout mix became too thick to pass thought the grouting system. A field instruction to use Celbex with open throat pump was issued by SNC-Lavalin and is included in Appendix A-2.

The re-grouting process with open throat pump began after a period equal or greater to a grout final set time and start with mix C. Unless noticeable increase in the grouting pressure was met early in the re-grouting process, Celbex was manually and gradually added in the open throat pump to the grout mix after a total of injected grout volume of 40 L/m.

During the Grouting Committee meeting held on January 13rd, 2020, it was decided to add Celbex in the open throat pump by visual observation and increased until pressure start building up and then continued until refusal. Total Celbex used was calculated after the grouting completed for the hole. Initially 0.3% Celbex was added directly into the Open Throat Pump and it was increased progressively by 0.2% increment as necessary. Photo 20 of Appendix E shows the use of Celbex in open throat pump.

4.5.4.7 Issues and Challenges

Four Tertiary holes (T611.5, T617.5, T623.5, T629.5) drilled by mistake while Secondary holes S614.5 and S626.5 were yet been grouted. As per specification Tertiary holes shall be drilled in rock after Secondary holes has been grouted and grout reached its final set time. In order to compensate this a dummy packer was installed at the Secondary hole and Tertiary holes on both sides of the that Secondary holes were grouted. No communication was noticed in Secondary holes, hence Secondary holes were grouted after the grout has reached its final set time in adjacent Tertiary holes. Photo 22 (Appendix E) shows the set-up of dummy packer at Secondary holes while grouting adjacent Tertiary hole. A Non-Conformance Report (NCR) has been issued for this discrepancy and included in Appendix D (D-8).

In all cases, the packer was first installed at the bottom of the casing. The packer was installed such that the entire length of the packer was located in casing except in a few holes where the packer was set half in the casing and half in bedrock when no plug grouting has been performed (holes T-197.5, P-680.5, P-716.5, T-719.5, S-722.5, T-725.5 and T-728.5) or when it was found that the plug was ineffective (hole P-704.5).

Two (2) packers were lost during bedrock grouting process (holes P524.5 and T-719.5) when the packer got stuck in the hole.

Use of Celbex as a thixotropic admixture in the grout mix during the grouting with the open throat pump created the following issues:

- The injection unit could not pump the grout with Celbex under a flow of 15 L/min. grout became too thick and clogs the grouting lines which became very hard to clean.
- The rate of added Celbex in the open throat pump is difficult to control since it is added manually. The Celbex is not appropriately mixed with the grout.
- Temperature of the grout changed after adding calcium Chloride, this may impact Celbex behaviour.
- Fluctuation in the grouting pressure showing very high pressure on the gauge. High pressure combined with high grout flow would cause hydro-jacking of the foundation.
- Refusal criteria were not applicable. Refusal criteria were established for grouting with open throat pump.

4.5.4.8 Refusal Criteria

In general, grouting of a stage was considered complete when the maximum pressure was reached and the flow to maintain that pressure was less than 3 litres per minute, measured over 5 minutes period.

When using Celbex with open throat pump, Celbex was added manually and Celbex dose was increased gradually by looking at the pressure response. Grouting was stopped when pressure at the collar gauge reached 10 bar at a constant flowrate of 15 l/min. All stages re-grouted using the high content Celbex grout and Open Throat Pump have reached the refusal at maximum pressure Pmax. Hence no re-grouting was required.

In few holes requiring re-grouting, but where the open throat pump with Celbex were not used, if the refusal was reached at maximum volume, the grouting was stopped and the level of the grout was measured in the casing. The hole was considered closed when the level of the grout was above the bottom level of the casing.

4.5.4.9 Hole Backfilling

Once the grouting in the hole was completed and the refusal criteria was met for the stage, the hole was either backfilled (5 m long stage) or either left open for the second stage drilling and grouting in the case of a 1.5 m long stage. For the holes where re-grouting was required or where injected grout volume exceeded 1,000L (200L/m), the holes were backfilled only after verification of final grout level next day. After the rock grouting of the hole was complete, the hole was backfilled with the available grout in the tank.

4.5.4.10 Blankets Progress and Quantities

Downstream blanket comprised 216 blanket holes including 192 planned Primary, Secondary and Tertiary holes and 24 additional Quaternary holes. Only 206 holes were grouted 5 m in bedrock, the remaining 10 holes were not drilled (see section 4.5.3.6 for boreholes list) before adjournment of the works on March 25th, 2020.

A total of 12 Secondary holes out of 206 holes were grouted in two (2) stages of 1.5 and 3.5 m using downstage rock grouting method. All the other holes were grouted in one stage of 5.0 m. Summary of drilling and grouting quantities of downstream blanket are indicated in Table 4-10.

Upstream blanket comprised of 384 planned casing plugs for all Primary, Secondary, Tertiary and Quaternary hole casings. From 80 installed casings, only 6 holes were drilled and grouted in bedrock at the WTD upstream blanket.

Bedrock grouting progress of downstream and upstream blankets is shown on Figure 4-11 and Figure 4-12, respectively. Quantities of grouted holes in the bedrock are summarized in Table 4-11 and shown on Figure 4-13. Total volumes of grout mix used for grouting the rock of downstream and upstream blankets are: 93,055 litres and 378 litres, respectively.

Table 4-10: Downstream Blanket – Summary of Drilling and Grouting Quantities

	DRILLING	GROUTING Volume in Liters					
Holes Generation	**0-5m**	**1 Stage**	**2 Stage**	**Re-grouting -1**	**Re-grouting-2**	**Re-grouting-3**	**Total Volume (L)**
Primary Holes	**240.85**	**24,673**		**8,102**	**2,368**	**236**	**35,379**
Secondary Holes	**200.51**	**9,298**	**8,789**	**3,157**			**21,243**
Tertiary Holes	**501.32**	**33,112**					**33,112**
Quaternary Holes	**79.41**	**3,321**					**3,321**

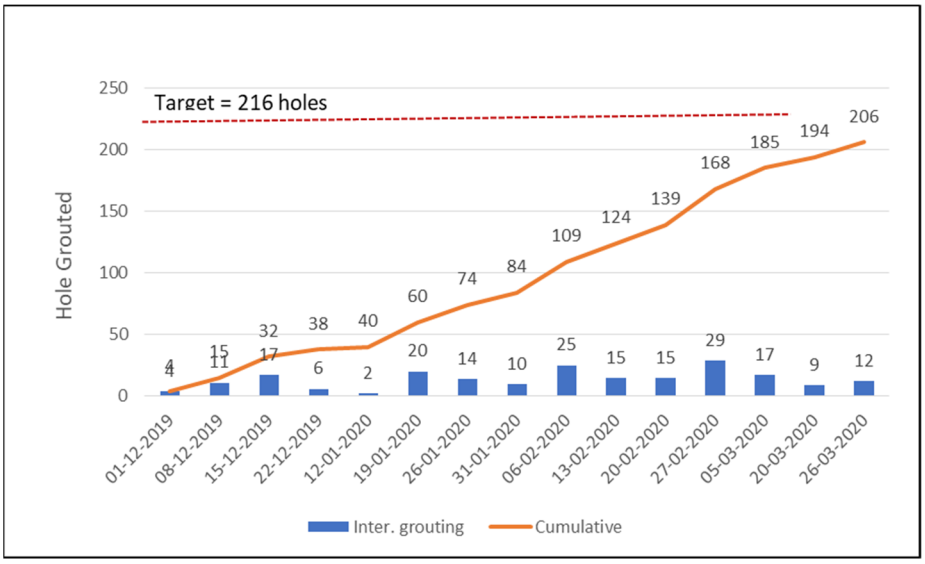

Figure 4-11: Downstream Blanket Grouting Progress

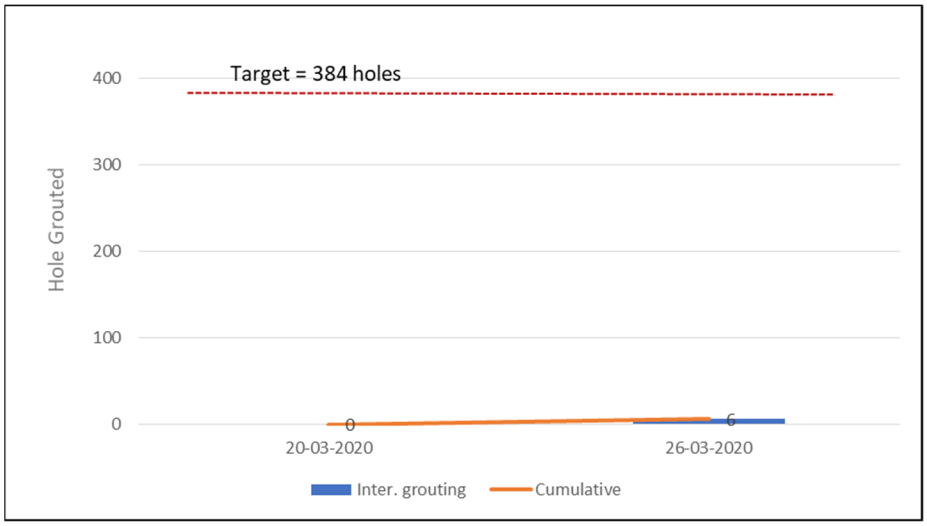

Figure 4-12: Upstream Blanket Grouting Progress

Table 4-11: Upstream and Downstream Blankets – Grouting Progress

	Planned	Additional	Total	Grouted	%
Downstream Blanket	192	24	216	206	95%
Upstream Blanket	384	0	384	6	2%
Total	576	24	600	212	35%

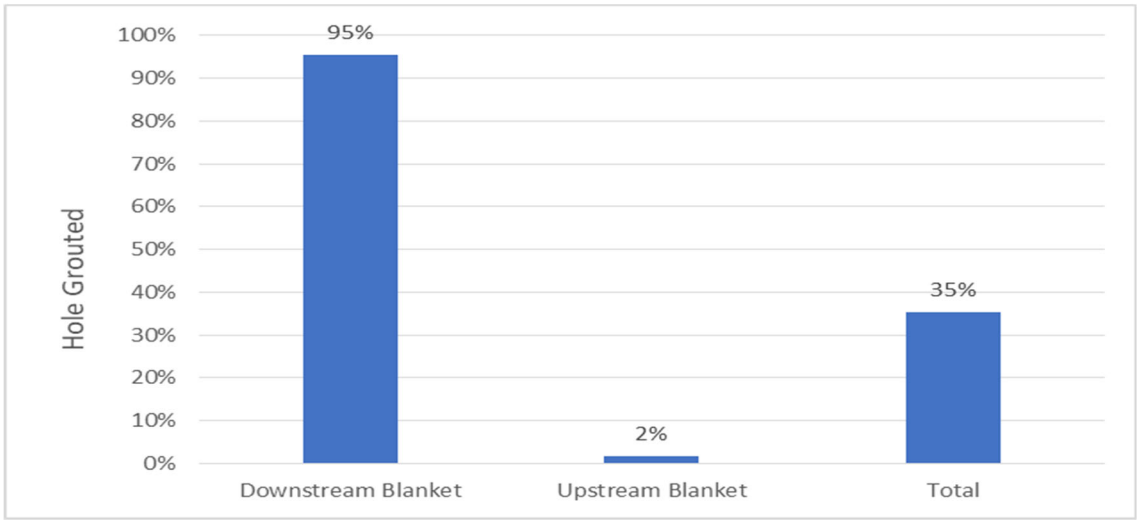

Figure 4-13: Upstream and Downstream Blankets – Grouting Progress

4.5.4.11 WTD Blanket Grouting Data Analysis

No data analysis was done for WTD upstream blanket grouting since only six (6) Primary holes were grouted so far. For data analysis of WTD downstream blanket grouting, statistical graphs were produced to highlight the grout absorption as a function of grout hole generation and the grouting stage depth.

Figure 4-14 shows the total absorption of grout in litres for each hole generation of WTD downstream blanket holes. The analysis of this graph indicates that the highest grout take was recorded in Primary holes and Tertiary holes. The high grout absorption in Primary holes could be explained by many re-grouting phases in Primary holes due to open joints and potential high seepage flow. High absorption in Tertiary holes may be explained by the grouting of few Tertiary holes before grouting of Secondary holes and also by the high number of Tertiary holes in comparison to Secondary holes. Only 24 holes of Quaternary holes were grouted and many of them were closed by pressure.

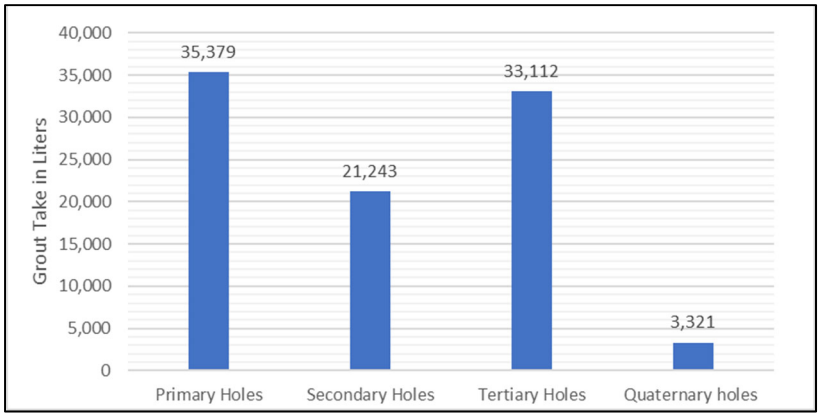

Figure 4-14: WTD Downstream Blanket – Grout Absorption by Hole Generation (litres)

Figure 4-15 shows the average grout absorption per metre per each generation of the WTD downstream blanket grouting holes. The purpose of this graph is to compare the grout take per metre in each type of grouted hole since the number and the length of the holes of each generation is different from the others. The average grout take per metre confirmed the decreasing grout take tendency from the Primary to the Quaternary holes which demonstrates the efficiency of the split spacing method. Grout take decreased by 28% from Primary to Secondary, by 38% from Secondary to Tertiary and by 36% from Tertiary to Quaternary. The overall decrease from Primary holes to Quaternary holes is about 71%. The figure shows the grout take per metre by hole sequence at the WTD downstream blanket.

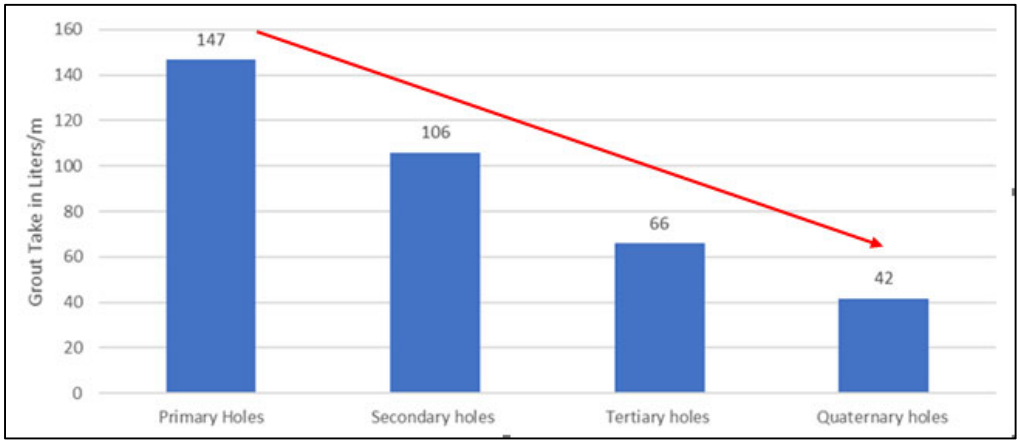

Figure 4-15: WTD Downstream Blanket – Grout Absorption by Hole Generation (litres/m)

5.0 QUALITY CONTROLS AND QUALITY ASSURANCE (QC/QA)

5.1 General

The Contractors, KCG and the sub-contractor GHD, were responsible for carrying out construction QC Testing, inspection and measurements. One (1) SNC-Lavalin QA site engineer was present in all day shifts (6 am to 6 pm) from November 9th, 2019 to December 19th, 2019, and January 11th, 2020 to March 25th, 2020. Normally, three (3) QC representatives were present on site, depending on construction activities:

- One (1) day-shift and one (1) night-shift QC for the casing drilling activities follow-up;
- One (1) day-shift QC for the blanket grouting activities follow-up;

All QC representatives were GHD employees and worked under the direct supervision of the Contractor KCG. The QA and QC worked on a 2-week rotation basis. A Daily Construction Meeting for Whale Tail Dike blanket grouting activities was held every morning among personnel of the Contractor (KCG), the QA representative (SNC Lavalin) and the Client (AEM). The Daily and weekly reports from the QA that detailed the various activities required for the WTD blanket grouting are presented in Appendix C-1 and C-2 respectively. Pictures were taken by QA site engineer from various components of the work shown in Appendix E. Limited number of the photos were attached in the QA daily and weekly reports.

5.2 On-Site Testing Laboratory

Contractor on-site testing laboratory was equipped with the following apparatus required to carry out the quality tests of the grout:

- Mud balance;
- Marsh cones;
- Bleeding cylinders;
- Cube molds;
- Thermometer;
- Vicat needle apparatus; and
- Pressure filtration device.

Mud balance, Marsh cone, pressure gauge and flowmeter were calibrated on site few times during the grouting program.

5.3 Casing Installation

Casing installation was performed by KCG on both day and night shifts. Two (2) QC representatives from GHD were present full time on site to supervise casing installation work and produced casing installation report at the end of each shift. SNC-Lavalin QA site engineer was also present full time on site to verify the QC reports to ensure the conformity of the carried work with technical requirements. Casing installation details were described in QA daily and weekly reports included in Appendix C1 and C2. The QC casing installation reports are included in Appendices D-2 and D-3. Casing alignment was measured by the KCG using a borehole inclinometer. The casing deviation table is included in Appendices D-4 and D-5. The as-built casing installation details are included in Appendix D-6.

5.4 Casing Plug Grouting

Casing plug grouting was performed by KCG on day shift only. The QC representatives were present full time on site to supervise casing plug cleaning, mixing and batching of grout mix, the grouting setup and process, and produced casing plug grouting reports at the end of the shift each day.

SNC-Lavalin QA site engineer was present full time on site to supervise the cleaning and plug grouting works and provided instructions regarding effective pressure, maximum volume and grout mix. He also carried out the verification of the QC reports to ensure the conformity of the carried work with technical requirements. Casing depth and water level measurements were also performed by the QC representatives after the casing installations and prior to grouting operation. Grout laboratory test carried out during the grouting of the casing plug are listed in Section 5.6. Casing plug grouting details were described in QA daily and weekly reports included in Appendices C-1 and C-2 and the grout register Appendix D-7. QC casing plug reports are included in Appendix D-9. As-built casing plug grouting details are included in Appendix I.

5.5 Bedrock Drilling

Rock drilling by KCG was performed on day shift only and drilling report was prepared by drilling supervisor. Only one SNC-Lavalin QA site engineer was available during the day shift and the priority was given to ongoing bedrock grouting works. Although he was not supervising directly the rock drilling, he provided instructions regarding the extension of the casing due to quality of the rock, water level, 1 stage or 2 stages drilling and the final length of the hole. The QA representative also carried out the verification of the QC reports to ensure the conformity of the carried work with technical requirements and the actual site conditions. Rock drilling details were described in QA daily and weekly reports included in Appendices C1 and C2. QC rock drilling reports are included in Appendix D-11. As-built rock drilling profile and details are included in Appendix I.

5.6 Bedrock Grouting

Bedrock grouting by KCG was performed on day shift only. QC representatives from GHD were present full time on site to supervise hole cleaning, mixing and batching of grout mix, the grouting setup and process and produced rock grouting reports at the end of the shift each day.

SNC-Lavalin QA site engineer was present full time on site during the grouting to supervise the cleaning of the hole and provided instructions regarding effective pressure, maximum volume and grout mix. The QA representative was involved in the grout mix quality control testing to ensure that the grout is stable grout mix with appropriate physical proprieties. The QA representative in consultation with Contractor's grouting specialist or supervisor made decisions on grout mix changes and re-grouting requirements. He also carried out the verification of the QC reports to ensure the conformity of the carried work with technical requirements.

The following laboratory tests were performed during grouting operation by the QC representative once per 5 batches of same grout mix, minimum twice per shift and each time when grout mix changes or whenever advised by SNC-Lavalin QA site engineer:

- Specific-gravity by mud balance;
- Marsh flow cone to verify the viscosity;
- Grout temperature readings at the holding tank; and
- Grout bleeding graduated cylinder.

Grout compressive strength and Vicat initial set time testing were performed once per each mix type during the field acceptance or as advised by SNC-Lavalin QA site engineer. Pressure filtration testing was carried out on Mix A, Mix C+ and Mix D. Laboratory testing results summary table can be found in Appendix D-7.

5.7 Check Holes

Two (2) holes in the most problematic area S746.5 and S686.5 were re-drilled by KCG on January 11, 2020 as per the request from AEM to check if the grouting completed was effective or whether there was still water seepage in the open hole. S746.5 was found by QA/QC supervisors dry after drilling suggesting of effective grouting and seepage cut off at this location. Hole was backfilled with grout after confirmation.

At S686.5, initially the hole has caved in around 13.0 m depth and was re-grouted using open throat pump with Celbex. During the re-drilling of the hole the grout penetration was down to 14.2m, which is 1.2 m below the initial depth the hole. A little bit of water was encountered at the bottom of the hole and during grouting attempt it took only 61.7 liters of grout at 2 bar injection pressure which indicated the major fractures and openings intercepted by this hole had been successfully sealed by grout.

6.0 AS-BUILT DRAWINGS

As-built drawings showing the drilling and grouting profile were prepared by the KCG and checked by SNC-Lavalin QA Site Engineer. The drawings are shown in Appendix I.

7.0 WORK SUSPENSION

On March 25th, 2020, AEM notified SNC-Lavalin, and KCG about their decision to suspend the Remedial Drilling and Grouting program. AEM reported the inferred seepage of 230 m^3/hr. The estimated rate combined with the progress of piping installation and contingency plans developed, AEM concluded that the risk of overwhelming the water treatment plant at freshet 2020 has been reduced to an acceptable level to AEM. The decision was in effect immediately on the on-going activities. At this time, only downstream blanket grouting was completed and drilling and grouting of upstream blanket was just started. It was planned to place safety pylons on the U/S casings those were installed but not grouted before the adjournment of the grouting works but could not be confirmed before the QA representative demobbed form site.

The email notification letter is presented in the Appendix H.

8.0 CONCLUSIONS

This report is to present to AEM a summary of the WTD Remedial Drilling and Grouting as-built data, including background information, design and engineering documents, major recommendations from the Grouting Committee, construction activities, QC/QA records, as-built drawings.

The design work of the Remedial Drilling and Grouting project started in early September 2019 and had been evolved as the project progresses according to the site conditions, progresses of the constructions, discussions and recommendations from Grouting Committee.

As per the approved Technical Specifications and Drawings, WTD Remedial Drilling and Grouting project comprised of the construction of a two-row blanket grouting on both upstream and downstream sides of the existing Cut-off wall. In essence, the two-row blanket will function as a two-row short grout curtains upon completion in mitigating shallow seepage through the WTD bedrock foundation by sealing the major wide-open structural discontinuities and fractured zones at shallow depth. The two-row of about 5m deep blanket grouting will also consolidate and improve the integrity of the shallow bedrock to allow grouting of the bedrock at depth to be carried out properly.

The construction work of the WTD Remedial Drilling and Grouting project started on November 2nd, 2019. The field work was suspended by AEM on March 25th, 2020, when SNC-Lavalin received a notification email

from AEM informing SNC-Lavalin about AEM decision to suspend the construction activities related to WTD Remedial Drilling ad Grouting Project – Phase I. AEM reported the inferred seepage of 230 m^3/hr. The estimated rate combined with the progress of piping installation and contingency plans developed, AEM concluded that the risk of overwhelming the water treatment plant at freshet 2020 has been reduced to an acceptable level to AEM.

A summary of completed work during this period is as follow:

- Installation of the casing by KCG started from the East end of the downstream blanket progressing to the west end of the dike. About 99% of all planned and additional casing were installed and plugged for a total of 213 out of 216 casings, including all Primary, Secondary, Tertiary and required Quaternary holes. Only three (3) holes in exclusion area were not installed prior to suspension of the work. For the upstream blanket, only 80 casings were installed and 78 were installed and plugged including Primary holes, Secondary and Tertiary holes between the East end of the dike and Station 0+487. This represents a progress of about 20% for the installation and the casing plug grouting of the upstream blanket. The casing installation overall progress for downstream and upstream blankets is about 49%.
- Bedrock drilling was carried out by KCG in one stage of 5 m in all downstream and upstream blankets holes except for about 12 Secondary holes. 206 holes were drilled in bedrock of the downstream blanket while only six (6) holes were drilled in the upstream blanket rock foundation. This represents about 95% and 2% for the downstream and upstream blankets, respectively, for an overall progress of about 35%.
- Planned scope of work was partly completed to 95% of grouted downstream blanket holes and only 2% of grouted upstream blanket holes for an overall progress of about 35% of planned remedial grouting program-Phase I.

Data analysis of downstream blanket grouting shows that the rock grout absorption in litre per meter of rock was reduced by about 71% from Primary holes to Quaternary holes using spilt spacing method. This was achieved after injection of about 93,055 liters of grout in 1069 m of drilled length in rock foundation.

In the upstream blanket only six (6) holes were drilled where the total grout absorption is about 2,378 litres and a total drilled length of about 27 m.

9.0 PERSONNEL

This report was prepared by Tom Xue (Sections 1-3 and 8), Muhammad Saleem (Section 4) and Sebastien Viau (Section 5). The Sections 4 and 5 was reviewed by Tom Xue.

The overall report was reviewed by Abdellah El Bensi and Hafeez Baba.

We trust that this report is to your satisfaction. Should you have any questions, please do not hesitate on contacting us.

SNC LAVALIN INC.

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REGISTERED PROFESSIONAL ENGINEER
H.U. BABA
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2020-08-12
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PERMIT TO PRACTICE
SNC-LAVALIN INC.
Signature NAME Hafeez Baba
Date DATE 2020-08-12
PERMIT NUMBER: P 260
The Association of Professional Engineers, Geologists and Geophysicists of NWT/NU

10.0 REFERENCE

SNC-Lavalin, 2020. SNC-Lavalin Inc., As-Built Report of Whale Tail Dike Rev PC, 658309-0000-56ER-0001 Rev PC, April 2020.