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Supplier Document

CNL Whiteshell Reactor 1 – Phase 1000 Grout Formulation Testing Report

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REPORT

Canadian Nuclear Laboratories Ltd.

CNL Whiteshell Reactor 1 - Phase 1000 Grout Formulation Testing Report

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1.0 INTRODUCTION AND SCOPE OF WORK

Canadian Nuclear Laboratories (CNL) has requested Golder Associates Ltd (Golder) to provide support for the activities around the decommissioning of the Whiteshell Reactor 1 (WR-1) facility, in the form of Bulk Fill grout formulation testing.

There are two primary deliverable Phases under the Grout Formulation Assessment are:

- Phase 1000 – Grout Testing
- Phase 2000 – Grout Formulation Design Package

This report summarizes the final findings associated with Phase 1000 – Grout Testing.

A report under separate cover will be produced summarizing Phase 2000 – Grout Formulation Design Package.

CNL has worked with Savannah River National Laboratory (SRNL) in developing recommended grout mixtures based on SRNL's previous experiences with In Situ Decommissioning (ISD). A set of requirements for grouts were developed based on the configuration of the facility and presented in: *WLDP-2600-TSW-002 Rev. 2 Appendix B of Test Plan by Savannah River National Laboratory – Flowable Non-Structural Grout January 19, 2018.*

The purpose of the grout formulation scope of work is to confirm the final Bulk Fill grout recipe. The final grout recipe needs to meet two sets of criteria:

- Fresh properties including bleed water, slump flow, etc. (Table 1 of the SRNL Test Plan)
- Cured properties including strength, hydraulic conductivity, etc. (Table 2 of the SRNL Test Plan)

The work completed for the grout formulation assessment included the following:

- Acquiring the materials per the recommended formulation using locally (Pinawa, Manitoba) sourced materials meeting the associated ASTM / CSA standards.
- Performing the testing on Bulk Fill recipe.
- Compiling all test results and quality checks performed and producing a final report with all results on the recommended mix design.

2.0 NOMENCLATURE

The following abbreviations are used in the report and technical memos:

- Type GU cement is General Use or ordinary Portland cement (OPC) or normal Portland cement (NPC)
- Type HS cement is sulphate resistant Portland cement
- BFS is ground iron blast furnace slag
- FA is Class F Fly Ash
- UCS is unconfined compressive strength

- SRNL is Savannah River National Laboratory
- PSD is particle size distribution
- SG is specific gravity
- ASTM is American Society for Testing and Materials
- HRWR is High-range Water Reducer
- VMA is Viscosity Modifying Admixture
- QA is quality assurance
- QC is quality control

3.0 ASTM - CSA REFERENCES

The Savannah River National Laboratory (SRNL) document provided by CNL was used as the basis of Golder's development of the grout formulation for CNL WR1.

The SRNL recipe makes reference to ASTM standards and Golder has assessed them against the corresponding CSA standards and created a concurrence table comparing the ASTM standards to the applicable CSA standards for the grout Raw Materials, Fresh, and Cured Properties.

Since Golder largely conducted the grout properties' testing based on the ASTM standards, Golder analysed both ASTM and CSA standard test methods to determine if the differences between the two standards would require any additional retesting as presented in Table 1.

The results of the comparison between CSA and ASTM standards indicates that no re-testing is required.

Table 1: ASTM - CSA Standards' Concurrence

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
Raw Material Sand	ASTM C33/C33M	Standard Specification for Concrete Aggregates	CSA A23.1	4.2.3 Materials and Concrete Properties	There is negligible difference between the ASTM and CSA Standards. The only difference is the sieve mesh sizes are slightly different between the ASTM and CSA Standards which would potentially produce a slightly different PSD curve. However, when the materials tested were compared to each other using both sieve sizes the results were the same. The fine and coarse aggregate samples meet the grading requirements for the CSA Standard. No further testing is required. ASTM Fine Aggregate Fine Aggregate grading: 9.5 mm – 100% passing 4.75 mm – 95 to 100% passing 2.36 mm – 80 to 100% passing 1.18 mm – 50 to 85% passing 600 µm – 25 to 60% passing 300 µm – 5 to 30% passing 150 µm – 0 to 10% passing 75 µm – 0 to 3.0% passing depending on the if the concrete is subject to abrasion or not CSA Fine Aggregate Fine Aggregate grading FA1 (not blending aggregates) 10 mm – 100% passing 5 mm – 95 to 100% passing 2.5 mm – 80 to 100% passing 1.25 mm – 50 to 90% passing 630 µm – 25 to 65% passing

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
					315 µm – 10 to 35% passing 160 µm – 2 to 10% passing 80 µm – 0 to 3% passing; this limit shall be 5% if the clay size material (finer than 2 µm) does not exceed 1% of the total fine aggregate sample
Raw Material Water	ASTM C94	Standard Specification for Ready-Mixed Concrete	CSA A23.1	4.2.2 Water	The water used in Golder's Laboratory testing referenced in the report meets the requirements for the CSA Standard. No further testing is required.
Raw Material Admixtures	ASTM C494/C494M	Standard Specification for Chemical Admixtures for Concrete	CSA A23.1	4.2.4.3 Chemical Admixtures	The CSA Standard states that chemical admixtures shall conform to the requirement of ASTM C494/C494M when flowing concrete is applicable. No further testing is required.
Raw Material Blended Cements	ASTM C595/C595M and ASTM C618	Standard Specification for Blended Hydraulic Cements	CSA A3000	Cementitious Materials Compendium	CSA does not have a standard for blends in which Fly Ash is more than 50% by mass and ASTM does not have a standard for blends in which Fly Ash is more than 40% by mass. The limits stated in the CSA and ASTM standards are considered as guidelines where the actual performance target results are the governing factors for the blend ratios selected. The Portland cement / FA blends tested were based on the SRNL recipe as provided by CNL. Class F Fly Ash is referenced in CSA A3000.

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
Grout Properties – Fresh Properties Air Content	ASTM C231/C231M	Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method	CSA A23.2-4C	Air Content of Plastic Concrete by the Pressure Method	The only difference between the ASTM and CSA Standards being CSA has a time constraint on the testing. The testing in Golder's Laboratory was within the specified time constraint therefore CSA Standards were met, no further testing is required.
Grout Properties – Fresh Properties Bleed Water	ASTM C232/C232M	Standard Test Method for Bleeding of Concrete	CSA A23.2-1B	Testing for Properties of Flowable Grout	The ASTM Standard calculates % bleeding based on the mass of the bleed water and the sample whereas the CSA Standard calculates % bleeding based on the volume of the bleed water and sample. Given there was zero water bleed during Golder's Laboratory testing program, both ASTM and CSA Standard requirements were met. No further testing is required.
Grout Properties – Fresh Properties Time of Setting	ASTM C403/C403M	Standard Test Method for Time of Setting Concrete Mixtures by Penetration Resistance	CSA A23.1	J.7.1.1 Contents of Quality Plan	Clause J.7.1.1 refers to the project specification or quality control plan that may define some qualification requirements. Tests that can be included are referred to in Table J.1. In Table J.1 under Fresh Concrete Properties indicated Set Time to be tested as per ASTM C403. No further testing is required.
Grout Properties – Fresh Properties Segregation	ACI 237R / ASTM C1610/C1610 M	Standard Test Method for Static Segregation of Self-Consolidating	CSA A23.1	8.6.1.2	CSA A23.1 clause 8.6.1.2 refers to test methods of workability characteristics in Table 22. Table 22 refers to ASTM C1610 for Column Segregation. ASTM C1610 provides more in-depth details on the test procedure as well as the column specifications and therefore the ASTM standard was used. No further testing is required.

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
		Concrete Using Column Technique			
Grout Properties - Fresh Properties Slump Flow / Dynamic Working Time	ASTMC1611/C 1611M	Standard Test Method for Slump Flow of Self-Consolidating Concrete	CSA A23.2-19C	Slump Flow of Concrete	The ASTM is more stringent than the CSA procedure with the exception that the ASTM doesn't state the T_{50} value is to be determined with the slump cone in the upright position. Given that slump flow was completed with the slump cone in the upright position in Golder's Laboratory during the test program, the CSA Standard requirements have been met. No further testing is required.
Grout Properties – Fresh Properties pH	ASTM D4972	Standard Test Method for pH of Soils	N/A	N/A	To Golder's knowledge, there is no CSA Standard for pH Determination. The standard used by Golder's Laboratory for conducting pH determination is ASTM D4972. No further testing is required.
Grout Properties – Fresh Properties Static Working Time	ASTM D6103/D6103 M	Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)	N/A	N/A	To Golder's knowledge, there is no CSA Standard for Flow Consistency of CLSM. Golder followed the ASTM standard for the Static Working Time procedure. The standard used by Golder's Laboratory for the Dynamic Working Time is an inhouse procedure using a 4"x4" cylinder that was developed based on Golder's experience. Golder has used this procedure on other similar projects to WR-1 including: - Decommissioned Madawaska Mine backfill - Sable Pipeline decommissioning - Falco Mine backfill - NPD grout backfill program

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
Grout Properties – Cured Properties UCS	ASTM D2166/D2166 M	Standard Test Method for Unconfined Compressive Strength of Cohesive Soil	N/A	N/A	To Golder's knowledge, there is no CSA Standard for testing unconfined compressive strength of cohesive soil. No further testing is required.
Grout Properties – Cured Properties UCS	ASTM C39/C39M	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens	CSA A23.2-9C	Compressive Strength of Cylindrical Concrete Specimens	There are no differences between standards as applied for cylinders over 10 kN. No further testing is required.
Grout Properties – Cured Properties Effective Porosity	ASTM C642	Standard Test Method for Density, Absorption and Voids in Hardened Concrete	CSA A23.2-11C	Water Content, Density, Absorption, and Voids in Hardened Concrete, Grout or Mortar	In Section 1 of the CSA standard, it states "this test method is substantially in accordance with ASTM C642". The only material difference is the test age of samples and the drying technique. CSA says 28 days unless otherwise specified. All testing was done at 28 days and the drying method was irrelevant as all samples needed to be 100% dry/100% saturated so the method was irrelevant. Therefore, no further testing is required.
Grout Properties – Cured Properties Dry Bulk Density	ASTM C642	Standard Test Method for Density, Absorption and Voids in Hardened	CSA A23.2-11C	Water Content, Density, Absorption, and Voids in Hardened Concrete, Grout or Mortar	In Section 1 of the CSA standard, it states "this test method is substantially in accordance with ASTM C642". The only material difference is the test age of samples and the drying technique. CSA says 28 days unless otherwise specified. All testing was done at 28 days and the drying method was irrelevant as all samples needed to be 100%

Test	ASTM Number	ASTM Title	CSA Number	CSA Title	Notes
		Concrete			dry/100% saturated. Therefore, no further testing is required.
Grout Properties – Cured Properties Effective Diffusivity	ASTM C1308 EPA method 1315 ANSI/ANS 16.1 Or alternative method for determining ion diffusion through the aqueous phase in a porous solid e.g., ASTM C1202	Standard Test Method for Accelerated Leach Test for Measuring Contaminant Releases from Solidified Waste	N/A	N/A	To Golder's knowledge, there is no CSA Standard for this test. Therefore, no further testing is required.
Grout Properties – Cured Properties Hydraulic Conductivity	ASTM D5084 (Method A)	Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter	N/A	N/A	To Golder's knowledge, there is no CSA Standard for the measurement of hydraulic conductivity of saturated porous materials using a flexible wall permeameter. There is also no rigid wall permeameter CSA standard. The standard used by Golder's Laboratory is ASTM D5084 Method A. No further testing is required.

4.0 RAW MATERIALS USED IN THE TESTING PROGRAM

The raw materials' test results used in the various phases of testing are outlined in this memo and the Stage 0 and Stage 1 testing summary dated July 31, 2019.

The raw materials came largely from the region around WR1:

- Sand and aggregate supplied from a local quarry
- Potable water from Sudbury, which was determined through analysis to be similar to the unprocessed Winnipeg River water near the site
- Cement binder from CRH Americas, Inc. in Ontario and Class F Fly Ash from North Dakota
- Sika admixtures from a supplier in Canada and Diutan Gum from a supplier in the USA

Additional considered sources of the raw materials are provided in the Material Quantities and Cost Estimate for Bulk Fill Grout as part of the Grout Plan Summary.

If an alternative source of raw materials are proposed, a contractor will be required to demonstrate that their proposed raw materials can result in the Fresh and Cured grout properties specified in the testing report.

For all of the raw materials the technical specifications are outlined in the standards (ASTM and/or CSA).

The key technical requirement of the aggregate is the particle size distribution (PSD) and the specification for the aggregate is per ASTM C33/C33M. CSA A23.1:19 / A23.3:19 makes reference to the ASTM C33 standard and there is negligible difference between the two. The only difference is the sieve mesh sizes are slightly different between the ASTM and CSA Standards which would produce a slightly different PSD curve, potentially. However, when the materials tested were compared to each other using both standard's sieve sizes, the results were the same. The sand samples meet the grading requirements for the CSA Standard and the CSA standards will be used in future testing.

The water technical specification is ASTM C94 / CSA A23.1 and the CSA standard was used.

Admixtures are covered under the technical specification ASTM C494/C494M. The CSA Standard A23.1 4.2.4.3 states that chemical admixtures shall conform to the requirement of ASTM C494/C494M when flowing concrete, is applicable.

CSA Standard A3000 indicates as a guideline that the maximum amount of Fly Ash to be added to a blended cement is 50% by mass, and the ASTM Standard C595/C595M indicates as a guideline that the maximum amount of Fly Ash to be added to a blended cement is 40% by mass. Both standards rely on the successful testing results for deviation from their guidelines. The blend for WR1 contains 77% Fly Ash by mass, which is the amount specified in the SRNL recipe provided by CNL and was what the testing was based on. The quantity of Fly Ash in blended cement as tested has been shown to be acceptable in achieving the Cured Property target criteria.

Some variation in the raw materials is inevitable but as has been seen on other similar projects the general proportions of materials should remain consistent. The cement, sand, and admixture quantities are guidelines that if followed should produce a grout that meets the Fresh and Cured grout requirements. The only performance based requirements are that the Fresh and Cured grout properties are met so if required some variation on quantities is acceptable.

For example, the water content can be varied to meet the Fresh Property specifications. Since the moisture content of the sand can be variable and therefore the water addition rate may be adjusted to suit. It is not possible to apply tolerances to the amount of water added since the range of moisture contents of the sand are not fixed. Ultimately, it is not of concern since the overall grout mix will still have to meet the Fresh and Cured properties.

All testing was carried out using locally available aggregate and binder materials. If an alternative source of material is proposed, a contractor will be required to demonstrate that their proposed raw materials can result in the Fresh and Cured grout properties specified in the testing report.

Raw materials testing to confirm adherence to specifications will be conducted on a regular basis per the contractors Inspection and Testing Plan (ITP).

5.0 TESTING SUMMARY

The testing for grout recipes was carried out in three stages:

- Stage 0 – Material Characterization
  - This stage tested the index properties of the sand and aggregate feed materials.
- Stage 1 – Screening Testing for Bulk Fill
  - Three mixes containing both sand and aggregate were tested using the following binders:
    - Type GU (OPC)
    - Type GU (OPC) / Class F Fly Ash (FA) blend
    - 90% ground iron blast furnace slag (BFS) and 10% Type GU (OPC)
  - A fourth mix was tested using only sand and the BFS/GU binder blend.
- Stage 2 – Full Fresh and Cured Property testing on the preferred results of Stage 1 Bulk Fill and UCS Testing:
  - Conducted using both ordinary Portland (Type GU) and sulphate resistant (Type HS) cement combined with Class F Fly Ash (FA) to compare results between the two formulations.
  - It should be noted that the original scope of work included Stage 2 testing of Low pH grout, but this program was eliminated at the request of CNL.

During each stage, grout formulations were tested and modified as required targeting CNL’s specified performance criteria. Once a preferred mix design was identified, the program was advanced to the next subsequent stage of testing.

A technical memo was compiled for Stage 0 and 1, as well as for Stage 2 testing and the results were discussed with the CNL technical team prior to proceeding to the next stage. These technical memorandums are presented in Appendix A. Details of the testing carried out and results from each stage are summarized in the following sections.

5.1 Stage 0 and 1 Testing

5.1.1 Stage 0 Material Characterization Testing

The Stage 0 testing was aimed at determining the material characteristics of the primary raw materials to be used in the grout formulation such as:

- Particle size distribution, specific gravity, mineralogy and chemistry of the coarse and fine aggregates
- Water chemistry of the water to be used for recipe production
- pH of all raw materials

The Particle Size Distribution (PSD) has direct impacts on production in terms of recipe consistency and thus ease of production and ultimate performance. One key requirement related to the PSD is to avoid having a bimodal material (i.e., gap graded), as this can promote segregation and limited strength gain and permeability. The sample tested showed no gap grades and as such was deemed acceptable.

Specific Gravity (SG) is a key property used in the calculation of the grout yield. While some variation is expected during production, keeping the material (and thus the SG) consistent will make volume tracking easier during production. The SG tested was within the expected range for these types of materials.

Chemical and mineralogical analyses results indicated typical values for alluvial sands and there was no indication of potentially problematic minerals such as micas or clays.

There were no deleterious or non-typical results obtained for the raw materials, so grout formulation testing proceeded to Stage 1.

The detailed results are presented in Attachments A-1 through A-3 of the Stage 0 and Stage 1 Testing Summary Attachment A.

5.1.2 Stage 1 Screening Testing

Stage 1 testing was conducted in order to identify the most promising grout formulation that met the Bulk Fill Mix Design Criteria presented in Table 2.

Table 2: Bulk Fill Mix Design Criteria

Test	Measurement Parameter	Criteria	Purpose of Measurement
pH - ASTM D4972	Initial	<13.5	pH levels of around 11.9 to 12 are required in order to mitigate lead dissolution
	1 hr	<13.5	
24 Hour Bleed Water - ASTM C232	ASTM	0%	Water bleed of 0% is required in order to eliminate the need for liquid removal during execution and to help prevent shrinkage after deposition
	24hr Test	0%	
Slump Flow - ASTM C1611		660 mm +/-50	Slump flow is important to provide a flat profile upon deposition and to enable the grout to move into the congested areas. This can be managed/alleviated by having multiple discharge points during execution

Test	Measurement Parameter	Criteria	Purpose of Measurement
Visual Stability Index (VSI) - ASTM C1611		0	Visual Stability Index is important to limit segregation and the creation of cold joints during execution
Set time - ASTM C403	Final	2 - 12 hours	Set time is important to allow a reasonable amount of curing time between subsequence lifts of grout. This can also be managed by having multiple discharge locations during execution
UCS MPa - ASTM D2166 / C39	7 days	>0.34 MPa	UCS is important to have enough strength development in a reasonable amount of time to prevent grout subsidence and to limit permeability

Four trial Bulk Fill mix designs were prepared and screened. Each mix contained various binder types and blends thereof, and varying proportions of the raw material and consistent addition rates of water and admixtures.

The Bulk Fill recipes formulated for the Stage 1 testing are presented in Table 3.

Table 3: Stage 1 Bulk Fill Recipes

Materials	Mix 1 - GU	Mix 2 – GU/Fly Ash	Mix 3 – GU/BFS	Mix 4 – GU/BFS- Sand Only
Portland Cement Type I/II (ASTM C150) (kg/m^3)	386	89	---	---
Type 90/10 Cement (90% BFS / 10% OPC) (kg/m^3) (ASTM C595)	---	---	386	386
Fly Ash Class F (ASTM C618) (kg/m^3)	---	297	---	---
Sand (quartz) (ASTM C33) (kg/m^3)	1165	1074	1142	1609
Gravel (granite) No. 8 (ASTM C33) (kg/m^3)	475	475	475	---
Water (kg/m^3)	247	247	247	247
Polycarboxylate polymer (ASTM C494 B & F) HRWR max. (L/m^3)	3.1	3.1	3.1	3.1
Diutan Gum based VMA (ASTM C494) (g/m^3)	262	262	262	262

The results of the Bulk Fill Screening Tests are presented in Table 4.

Table 4: Stage 1 - the Bulk Fill Screening Results

Test		Mix 1 - GU	Mix 2 – GU/Fly Ash	Mix 3 – GU/BFS	Mix 4 – GU/BFS- Sand Only
pH – ASTM D4972	Initial	12.5	11.9	12.0	11.9
	1 Hr	12.5	11.9	11.7	11.9
24 Hour Water Bleed – ASTM C232	ASTM	0%	0%	0%	0%
	24 Hr Test	0%	0%	0%	0%
Slump – ASTM C1611		11”	11”	11”	11”
Slump Flow – ASTM C1611		685 mm	730 mm	735 mm	630 mm
T50 Slump Flow (seconds)		1.18	0.67	1.47	0.54
Visual Stability Index (VSI) - ASTM C1611		0	0	0	0
Set time - ASTM C403		6.5hrs	12hrs	7.5hrs	9.15hrs
UCS - ASTM D2166 / C39	7 day	28.1Mpa	4.4Mpa	13.0Mpa	13.4Mpa

The slump flow test is used to assess the stability and horizontal free flow of self-consolidating concrete (SCC), or in this case grout, in the absence of obstructions. The diameter of the concrete circle is a measure of the filling ability of the concrete, and visual observation of the concrete spread is noted to characterize the stability of the mixture. The slump flow test however gives no indication of the ability of the concrete to pass between reinforcement without blocking. However, it can give some indication of resistance to segregation. A visual observation of the concrete spread is noted to characterize the stability of the mixture. The index assigned to describe the visual observation of mixture stability is subjective and is intended for use in developing SCC mixtures and for internal quality control purposes by producers. The T_{50} (50 centimeter) flow time is a secondary indication of flow. A lower time indicates greater flowability.

The slump flow test was performed with the slump cone in the upward position and the T_{50} value was recorded and is presented in Table 4.

In Golder’s experience, it is valuable to measure both slump and slump flow which allows use of the database to compare material behavior with other similar mixes. To that end, both measurements were taken and reported during this program.

Generally, the mixes passed the design criteria targets with the exception of Mix 2 and Mix 3 exceeding the Slump Flow criteria. Adjusting the Slump Flow to conform with the target criteria is typically not problematic. The first step is usually to reduce the addition rate of the Polycarboxylate polymer (SIKA 2100) which normally reduces the slump flow. Reducing the SIKA 2100 does not typically affect the other material properties. The Sika, Diutan gum and water addition quantities were the same for all mixes. However, it was noted that the slump flow was lower for the Mix 4 sand only blend which could be attributed to the increased surface area associated with the sand only blend.

Due to the availability of Class F Fly Ash in Manitoba and lack of availability of BFS, it was recommended that Mix 2, GU / Fly Ash be carried forward to Stage 2 of the testing program with a modification. The recommended modification was to use the GU / Fly Ash binder with fine aggregate i.e. sand only. Eliminating the coarse aggregate, as demonstrated by the results of Mix 4, has no substantial impact on the performance results.

Reducing the number of raw materials required in the grout formulation for Bulk Fill will simplify the material handling and mixing process and offer the potential for cost savings through the elimination of the coarse aggregate.

5.1.3 Stage 0 and 1 Testing Conclusions

Some of the key learnings and observations obtained during Stage 0 and Stage 1 testing are as follows:

- The raw materials available in the Pinawa area are amenable to formulating the Bulk Fill grout recipe.
- Significantly higher than target UCS values were observed for all recipes tested, indicating a potential opportunity to reduce the binder addition rate. However, further testing to determine the effects of a reduction would need to be carried out.
- The binder's secondary purpose is to increase fines in the formulation. Therefore, there may be other, less costly alternatives that could be added to supplement the necessary fines. Examples of alternative materials are provided in the "Phase 2000 Grout Formulation Design Package".
- Due to limited availability of BFS, and readily available Class F Fly Ash in Manitoba, only the recipes containing Fly Ash were advanced to Stage 2 testing.
- The use of sand only, eliminating aggregate from the Bulk Fill recipe, achieved results within the target parameters. The removal of aggregate can potentially reduce costs and the complexity of the producing the Bulk Fill. The cost of the aggregate and sand is provided in the "Phase 2000 Grout Formulation Design Package"
- A recipe containing sand only and Class F Fly Ash proved suitable and was recommended to be advanced to Stage 2 testing.
- For both PSD and SG, keeping records during testing and execution will ease the management of changes to grout production performance.

5.2 Stage 2 Testing

Stage 2 testing focused on the Fresh and Cured properties of the Bulk Fill selected recipe using both Type GU and Type HS cement.

5.2.1 Recipe Development

The testing was broken up into 2 separate batches for each the Type GU and Type HS cements', Fresh Properties and Cured Properties with each batch being 0.04 m^3.

This was done to confirm that the recipe met the requirements of the Fresh Properties specification before casting the cylinders for the Cured Properties.

In the laboratory environment there was no issue with reproducibility between batches. The order of addition and mixing requirements were developed as part of the process and were utilized by different lab technicians and similar results were obtained.

In terms of scale up from lab to production levels, Golder has completed multiple similar projects since the early 2000s and the grout mixing equipment being considered has the proven ability to effectively mix aggregate, binder and admixtures in the required quantities. Scale up has never been problematic in the past even over multiple year grouting programs. With a total volume of ~8,000 m^3 required in the WR1 program, this should be a single year program and is not expected to pose a problem with CNL WR1.

Table 5 presents the Bulk Fill recipes that were tested.

Table 5: Stage 2 - Bulk Fill Recipe

Materials	Bulk Fill (GU) (water to binder ratio of 0.60)	Bulk Fill (HS) (water to binder ratio of 0.60)
Type GU Cement (kg/m^3) (ASTM C595)	89	---
Type HS Cement (kg/m^3) (ASTM C595)	---	89
Fly Ash Class F (kg/m^3) (ASTM C618)	297	297
Sand (quartz) (ASTM C33) (kg/m^3)	1570	1570
Water (ASTM C94) (kg/m^3)	232	232
SIKA Visco Crete 2100 (ASTM C494 B & F) (kg/m^3)	1.77	1.49
Diutan Gum based VMA (ASTM C494) (kg/m^3)	0.26	0.26

The Fresh and Cured Bulk Fill Target Criteria as well as the results of the testing using the GU/Fly Ash and HS/Fly Ash binders are presented in Tables 6, 7 and 8.

Table 6: Stage 2 - Screening - Fresh Properties - Bulk Fill

Test (Fresh Properties)		Criteria Target	Bulk Fill (GU/Fly Ash)	Bulk Fill (HS/Fly Ash)
pH - ASTM D4972 – after mixing for 30 min.	Initial (1)	<13.5	12.4	12.0
	1 hr (2)		12.4	12.3
	1 hr – mixed (3)		12.6	12.5
24 Hour Water Bleed – ASTM C232	ASTM	0% (vol)	0%	0%
	24 Hr Test		0%	0%
Slump – ASTM C1611		N/A (4)	273 mm	286 mm

Test (Fresh Properties)		Criteria Target	Bulk Fill (GU/Fly Ash)	Bulk Fill (HS/Fly Ash)
Slump Flow – ASTM C1611		660 +/- 51 mm	625 mm	650 mm
T50 Slump Flow (seconds)		N/A (4)	1.04	0.50
Visual Stability Index (VSI) - ASTM C1611		0	0	0
Initial Set time - ASTM C403		2-12 hrs	9.5 hrs	14.5 hrs (5)
Air Content – ASTM C231		<8% vol	3.6%	4.0%
Segregation – ACI 237R – (ASTM C1610) (6)		None	0%	0%
Static Work Time – (ASTM D6103)	0 min	>30 min	302 mm	247 mm
	30 min		271 mm	223 mm
	45 min		263 mm	213 mm
Dynamic Work Time – (ASTM C1611)	0 min	>60 min	302 mm	285 mm
	30 min		280 mm	265 mm
	60 min		283 mm	265 mm

Notes:
All pH tests were conducted in accordance with ASTM D4972
(1) - Wet mixture and 10ml of distilled water added prior to testing
(2) - pH of supernatant - sample was allowed to sit undisturbed
(3) - pH of re-homogenized sample
(4) - not applicable, conducted for information purposes only
(5) - result was discussed with CNL and it was agreed that the grout placement sequence and scheduling thereof, could be adjusted to suit
(6) - The ASTM C1610 Standard for Column Segregation tests was used since the ASTM standard goes into more detail than the ACI standard.

5.2.2 Slump Flow

In Golder's experience, it is valuable to measure both slump and slump flow which allows use of our database to compare material behavior with other similar mixes. To that end, both measurements were taken and reported during this program.

A summary of the slump related tests is as follows:

- Slump flow and slump (full and mini)
- Dynamic work time – mini slumps

5.2.3 Visual Stability Index

Visual Stability Index (VSI) tests ASTM C1611, were conducted and returned values of “0” in both Portland cement / Fly Ash batches, conforming to the Target Criteria. VSI of 0 is rated as “highly stable” while a 1 is "stable". In Golder's experience with similar grout recipes a VSI of 0 or 1 is acceptable and will achieve the performance requirements.

The ASTM C1610 Standard for Column Segregation tests was used since the ASTM standard goes into more detail than the ACI 237R standard. Specifically, the comparable CSA 23.1 test, clause 8.6.1.2 refers to test methods of workability characteristics in *Table 22*. *Table 22* refers to ASTM C1610 for Column Segregation. ASTM C1610 provides more in-depth details on the test procedure as well as the column specifications and therefore the ASTM standard was used.

The procedure did not require modification. Based on the PSD of the fine aggregate, ~ 1% of the material could be retained on the 4.75 mm sieve. This was confirmed while doing the segregation testing as there was material retained on the sieve after washing.

5.2.4 Initial Set Time

The observed value for the HS/FA Blend of 14.5 hours was slightly above the SRNL's upper target of 12 hours. However, the observed value for the GU/FA Blend was 9.5 hours. Both are representative of the set times experienced with other Portland / Fly Ash cements.

The set time solely affects the timing of placement for successive lifts of grout which will affect the sequencing of successive pours but has no effect on the performance of the grout as demonstrated in the compressive strength results. Since the grout execution program is a 'single shift only' operation, most grout pours will have at least 12 hours if not more of set time before a subsequent pour.

The 2 hour set time is the minimum to avoid setting in the line/equipment during the grouting operation.

As a result, the observed set time is not of concern.

5.2.5 Static and Dynamic Working Time

For Dynamic Working Time, the ASTM standard is more stringent than the CSA standard with the exception that the ASTM standard doesn't state the T_{50} value is to be determined with the slump cone in the upright position. So, this portion of the CSA standard was applied.

Using the ASTM standard provides a level of conservatism in the assessment which is why ultimately that standard was used.

The Static and Dynamic Working Time requirements were outlined in Whiteshell Reactor #1 Grout Fill Requirements WLDP-26000-0041-000 which state targets of >/=30 minutes and >60 minutes respectively. The documents state that measurements of Static Working Time should be taken at intervals of 15 minutes, and Dynamic Working Time measurements to be taken at intervals.

Dynamic testing was completed using Golder's inhouse procedure for mini slumps that has been developed and tested over many years of experience. Static and Dynamic testing completed on recipes was tested at 15 minute intervals with no change noted within the first 30 minutes. Therefore, it was determined that 30 minute intervals were sufficient. The time intervals used in the testing were 0, 30, and 60 minutes. The material was visually inspected at each interval and was evaluated as to its pumpability using empirical methods.

The evaluation of pumpability e.g., potential loss of flow during the Static and Dynamic Working Time ultimately provides data for pump sizing, delivery hole spacing, idle grout time, and flush time. So ultimately, virtually any loss of flow is manageable within the context of the timeframe of deposition.

5.2.6 Air Content

The Whiteshell Reactor #1 Grout Fill Requirements WLDP-26000-0041-000 states a target of <8 vol% however no minimum is defined.

The observed air content values of 3.6% and 4.0% for the GU and HS based grouts respectively, met the target of <8%.

With respect to a minimum air content, air content is usually referenced if the grout is going to come in contact or be exposed to below freezing temperatures. Frost depth in Winnipeg is approximately 2.5 m. Taking this into account the bulk of the facility is well below the frost depth and as such will not undergo freeze-thaw cycles, in addition there will be an engineered cover of approximately 2.75 m thick placed over the grouted facility, therefore no minimum air content value is required.

By following the recipe as defined, the air content should be at the level where it needs to be to satisfy the targets and the freeze considerations are not relevant. At the top of the facility, the grout will have an engineered cover and a depth of cover on top of the cap that will equate to more than 2.5 m.

5.2.7 Unconfined Compressive Strength

The standards applied to the unconfined compressive strength (UCS) tests were ASTM C39 and ASTM D2166.

To Golder's knowledge, there is no CSA standard for testing unconfined compressive strength of cohesive soil indicated as ASTM D2166 in the SRNL Compressive Strength criteria. The standards used are a combination of the 2 standards. For cylinders under 10kN load ASTM D2166 was used and for cylinders above 10kN load ASTM C39/CSA 23.2-9C was used. The low strength load frame can be used for loads up to 10kN and meets the requirements of D2166 and the high strength load frame is used for cylinders above 10kN and meets the requirements for ASTM C39/CSA 23.2-9C.

An UCS program was carried out to assess the Bulk Fill strength using 76 x 152 mm cylinders. The cylinders were cured in a high humidity environment maintained at 20 to 25°C. Three cylinders were cast per curing period and the UCS results of the three cylinders were averaged. The test results are presented in Table 7.

Since the curing conditions have a major impact on the compressive strength measured it is important to state that the moisture room curing conditions fall under CSA A23.1:19 3C. The standard states that relative humidity (RH) of the room must be not less than 95%. RH is not recorded but the curing room contains a fogger that runs constantly so it is effectively 100%. The required temperature is 23°C ±2.

Table 7: Stage 2 Cured Properties - Bulk Fill – UCS Testing

Test (Cured Properties)		Criteria Target	Bulk Fill (GU/Fly Ash)	Bulk Fill (HS/Fly Ash)
UCS - ASTM D2166 / C39	7 day **(ASTM D2166)**	>0.34 MPa	3.3 MPa	2.9 MPa
	14 day **(ASTM D2166)**	N/A(1)	6.8 MPa	5.3 MPa
	28 day **(ASTM C39)**	>3.4 MPa	15.7 MPa	9.5 MPa
	90 day **(ASTM C39)**	>4.8 MPa	23.7 MPa	20.5 MPa
	180 day **(ASTM C39)** (1)	N/A	23.9 MPa	23.6 MPa
	365 day **(ASTM C39)** (1)	N/A	23.6 MPa	26.5 MPa

(1) – Not stipulated by SRNL
N/A – not applicable

As mentioned earlier, three cylinders were tested per curing period and the standard deviation in UCS results is presented in Table 8 and Table 9.

Table 8: UCS Results for Individual Cylinders – GU/Fly Ash

Test	Cylinder	UCS (MPa)						UCS Standard Deviation					
		Curing 7 days (ASTM D2166)	Curing 14 days (ASTM D2166)	Curing 28 days (ASTM C39)	Curing 90 days (ASTM C39)	Curing 180 days (ASTM C39)	Curing 365 days (ASTM C39)	Curing 7 days	Curing 14 days	Curing 28 days	Curing 90 days	Curing 180 days	Curing 365 days
UCS – ASTM D2166 / C39 – Curing Room (22°C)	1	3.5	6.4	15.1	22.6	22.8	30.0	0.17	0.42	0.52	1.16	1.32	1.07
	2	3.1	7.2	16.2	24.9	25.4	28.4						
	3	3.3	6.8	15.8	23.5	23.4	30.5						

Table 9: UCS Results for Individual Cylinders – HS/Fly Ash

Test	Cylinder	UCS (MPa)						UCS Standard Deviation					
		Curing 7 days (ASTM D2166)	Curing 14 days (ASTM D2166)	Curing 28 days (ASTM C39)	Curing 90 days (ASTM C39)	Curing 180 days (ASTM C39)	Curing 365 days (ASTM C39)	Curing 7 days	Curing 14 days	Curing 28 days	Curing 90 days	Curing 180 days	Curing 365 days
UCS – ASTM D2166 / C39 – Curing Room (22°C)	1	3.1	5.4	9.4	20.9	N/A [1]	26.8	0.31	0.20	0.13	0.50	0.11	0.38
	2	2.9	5.4	9.6	20.0	23.7	26.5						
	3	2.4	5.1	9.4	20.6	23.5	26.1						

Note 1: Apparatus error caused cylinder result to be invalid. Result omitted from data.

5.2.8 Other Cured Properties

ASTM doesn't specify a cure time for Effective Porosity and Dry Bulk Density other than this, CSA states "The test age shall be at least 28 days unless otherwise specified". There is no specified cure time for Hydraulic Conductivity.

That said, all tests were completed at 28 days of curing to be consistent among all the tests.

Table 10: Stage 2 Cured Properties - Bulk Fill – Other Metrics

Test	Criteria Target	Bulk Fill (GU/Fly Ash)	Bulk Fill (HS/Fly Ash)
Effective Porosity – (ASTM C642) (1)	≤ 40 %	24.8 %	24.8 %
Dry bulk density – (ASTM C642)	2100 kg/m^3	2007 kg/m^3	2007 kg/m^3
Hydraulic Conductivity – (ASTM D5084 – Method A)	<0.03 meters/yr.	0.0004 metres/yr.	0.0002 metres/yr.

Note: 1 – Total void volume

5.3 Stage 2 Testing Conclusions

The Stage 2 testing program for both the GU and HS blends meet the target requirements outlined in the SRNL recipes for Bulk Fill with the exception being the Dry Bulk Density and the Initial Set Time for the HS/Fly Ash blend.

As stated in the SRNL Cured Property Requirements (Table 2) Document WLDP-26000-TSW-002 Page B-4 Rev.2, the target value for dry bulk density is 2100 kg/m^3. The stated SRNL value reflects a recipe containing both sand and aggregate; however, the Golder tested Bulk Fill recipes do not contain aggregate since it was determined that the fresh and cured property targets could be achieved through the use of sand alone. With this in mind the achieved test results for Dry Bulk Density of 2007 kg/m^3 have been deemed acceptable as tested, by CNL.

The slightly higher Initial Set Time for the HS/Fly Ash blend was discussed with CNL and determined not to be problematic.

The development of effective Bulk Fill recipes, using locally available raw materials, was achieved for the Fresh and Cured property targets set forth in the SRNL guidelines, with the noted exceptions and their explanations.

6.0 OTHER TESTING COMMENTARY

Heat of hydration measurements and modelling is planned to be performed during larger scale lab testing by:

- Installing thermocouples into the 1 m^3 tote-sized grout block, and
- Using lab-scale calorimetry test results as input into numeric modeling of large volumes.

The best options for reducing the heat of hydration are to substitute a large portion of the Portland cement in the mixture with a supplementary cementitious material (e.g., Fly Ash) and keeping the total cementitious content as low as possible. CNL WR1's grout recipe has 77% Class F Fly Ash in its cementitious materials blend, and its total cementitious material content is 386 kg/m3 which is comparable with typical concrete mixtures and its water-to-cementitious ratio is 0.6 which is higher than typical concrete mixtures which will help reduce the peak temperature and any differential temperatures within the larger grout mass placed.

7.0 RAW MATERIALS ADDITION SEQUENCE

The addition sequence of raw materials into the grout recipes is important in order to obtain the target wet properties. The addition sequence for the Bulk Fill grout mixture will be presented in chronological order in the following section, with commentary as appropriate.

7.1 Bulk Fill

- Sand
- Water
- Cement (GU or HS/Fly Ash)
- Admixture (the SIKA 2100 and Diutan Gum must be premixed until the Gum is dispersed in the SIKA before being added to the grout mixture)

Test results indicated some variability in the quantity of admixtures required, and it may be necessary to add additional SIKA / Diutan Gum mixture to the grout mix in order to obtain the target slump flow.

8.0 CONSIDERATIONS PRIOR TO IMPLEMENTATION

8.1 Raw Materials

- Availability of Class F Fly Ash:
  - Class F Fly Ash has become less available in Western Canada recently. One of the larger current suppliers, Lafarge, has indicated that the availability from their current source in western Canada cannot be guaranteed in 2019 and beyond. The original supplier used in this phase of the program, CRH Canada Group, has indicated that they will not be able to supply the quantity of Class F Fly Ash required for the execution phase of the project. However other sources may include Lafarge AB, Minnesota and Virginia. Class F Fly Ash has varying properties depending on the coal source so any change in supplier or location of supply should be followed by verification testing.
  - Impact to Grout Performance: There are multiple sources of supply of Fly Ash and after verification testing there should be no impact on grout performance.
- Availability of other raw materials in general:

- Some of the products for testing are highly specialized (e.g., Diutan Gum) and sourcing them in bulk quantities for the execution phase of the program will require a dedicated level of procurement with plenty of lead time and coordination with suppliers.
- Impact to Grout Preparation: This does not pose a risk to the preparation of an acceptable grout, simply planning is required.

- Raw material suppliers for the execution phase of the project may differ from those used for the testing phase:
  - Material quality verification testing will likely be required once an execution contractor has been selected. The material suppliers selected for this lab testing program were proven to provide acceptable materials as is evident in the successful formulation of the grout which proves there is at least one acceptable source of supply. If another source of supply is ultimately used, verification testing will allow the adjustment of the grout recipe to obtain the desired grout performance targets.
  - At the time the material supplier is selected, the suppliers' QC programs should be verified.
  - It is believed that the Winnipeg River water will be used in the grout formulations in the execution phase of the project. The quality of this water will vary by season. Therefore, it is recommended that the quality of the water be monitored and tested during the execution phase.
  - Impact to Grout Performance: Material availability and water quality are not expected to have a material impact on grout performance and will only be part of the implementation planning.
- Large scale flowability and behaviour:
  - An indication of these characteristics can be determined when/if larger scale flow loop, flume, and congested area filling tests are conducted in future phases of work.
  - Impact to Grout Performance: This does not pose a risk to the successful execution phase formulation of a suitable grout, since the lab testing conducted indicated that varying the proportions of the grout's constituents to suit the requirements is possible. It is another level of verification.
- Admixture dosage rates and mixing time may differ between bench scale and larger scale testing:
  - A clearer understanding of this item can be gained when/if larger scale flow loop, flume, and congested area tests are conducted in future phases of work.
  - Impact to Grout Performance: This does not pose a risk to the successful execution phase formulation of a suitable grout, since the lab testing conducted indicated that varying the proportions of the grout's admixtures to suit the requirements is possible.

8.2 Grout Preparation and Placement - Execution Considerations

- Storage of raw materials:
  - All materials, particularly in large bulk quantities, must be stored according to the manufacturer's recommendation to avoid spoil and wastage.

- Impact to Grout Performance: The establishment and implementation of manufacturers storage and handling procedures prior to the execution phase will promote raw materials' integrity and effectiveness in grout performance.

- Wrong sequence of addition of raw materials and admixtures:
  - Performance of the grout mixtures is sensitive to the sequence of addition and mixing times of respective additives and admixtures. This will need to be monitored and tested during larger scale testing.
  - Impact to Grout Performance: Full-scale pre-execution testing, along with the establishment of procedures and processes, will provide acceptable mixing protocols that will formulate an acceptable grout.
- Insufficient preparation time of admixtures:
  - SIKA 2100 and Diutan Gum must be properly pre-mixed prior to their addition to the grout recipes.
  - Impact to Grout Performance: Full-scale pre-execution testing, along with the establishment of procedures and processes, will provide acceptable mixing protocols that will formulate an acceptable grout.
- The placement of out of specification grouts:
  - Well documented QA/QC procedures must be developed and adhered to in order to monitor grout properties upon their preparation and placement (Fresh and Cured properties). Examples of the appropriate QA/QC procedures are provided in the "Phase 2000 Grout Formulation Design Package"
  - Impact to Grout Performance: This does not pose a risk to grout performance since adherence to the proper QA/QC procedures will identify out of specification grouts that will be adjusted or discarded.
- Well established and properly performed housekeeping and cleaning procedures must be in place and adhered to:
  - These procedures will mitigate the possibilities of lost time due to plugged equipment, failures, etc.
  - Impact to Grout Performance: This does not pose a risk to grout performance since the establishment of procedures and processes for properly cleaning the mixing plant, delivery pump and delivery lines will be established in the pre-execution phase.
- Season in which the execution phase is conducted:
  - Cold weather and cold raw material temperatures may have an effect on the curing rate of the Bulk Fill thereby impeding set time during colder weather operations. Testing was not conducted on the effects associated with low temperature raw materials.
  - Literature indicates that cement hydration requires a minimum temperature of 2º C to start the process. However, Golder's experience has been to typically use backfill material with a temperature of at least 5º C which generally requires heated water as the aggregates can be cold/frozen.
- Equipment used for the delivery of the grout into a distribution system pump:

- Should the execution contractor choose to deliver the grout using Ready-mix trucks, the effectiveness of being able to discharge the entire contents of the truck due to the grouts' high slump consistency should be confirmed. A clearer understanding of the effects of the delivery mechanism can be gained when/if larger scale flow loop, and flume tests are conducted in future phases of work.
- General waste management and disposal of off-spec batches:
  - From an equipment cleaning and maintenance aspect, designated locations must be established to dispose of waste materials.
  - A suitable off-spec disposal location will need to be selected on the WR-1 site.
- Instrumentation and/or datalogger failure:
  - Procedures within the QA/QC plan need to establish the frequency of calibration tests for the grout mixing process and equipment. Examples of the appropriate QA/QC procedures are provided in the "Phase 2000 Grout Formulation Design Package"
- Larger scale testing before actual filling:
  - Larger scale testing could require final adjustment to mixing order, mixing time, or dosage quantities to meet the specified QA/QC performance of the grout mix. Larger scale testing prior to starting the execution phase will help to mitigate against variability in mix performance.

9.0 ADVANTAGES ASSOCIATED WITH THE FINAL BULK FILL RECIPE TESTED

As a result of the successful testing of Bulk Fill recipes containing only sand, there may be a cost saving for the Bulk Fill grout through elimination of the aggregate supply. This may also simplify the delivery, storage and mixing process since one less raw material needs to be metered into the Bulk Fill preparation process. The use of Class F Fly Ash instead of only OPC provides cost savings, sulphate resistance, and lower heat of hydration.

10.0 CONCLUSIONS AND RECOMMENDATIONS

The development of an effective Bulk Fill recipe, using locally available raw materials, was achieved for the Fresh and Cured property targets set forth in the SRNL guidelines. The preferred Bulk Fill recipe includes sand, without the addition of aggregate, and the binder and admixtures in the recommended proportions.

Since the ordinary Portland / Class F Fly Ash (GU/Fly Ash) blend performed acceptably in meeting the criteria targets and is likely to be less costly than the HS/Fly Ash binder blend, it is recommended that the ordinary Portland / Class F Fly Ash blend be used in the execution phase.

Regardless of the blend selected, it is expected that the requirement will be to have two binder constituents, be that either ordinary Portland or HS, in combination with Class F Fly Ash.

Larger scale testing is recommended to more closely establish execution associated variables such as the effective mixing time required to get a homogeneous mixture for both grout formulations.

Prior to the commencement of the Execution Phase of the project, the material and execution considerations should be reviewed and discussed with the selected contractor.

11.0 GOLDER LABORATORY QUALITY ASSURANCE (Q/A)

In the course of conducting the Bulk Fill grout formulation testing, Golder has used the ASTM standards stipulated in the SRNL document along with applying its standard quality control procedures.

Appendix B presents:

- The Fresh and Cured property's test results for the final Stage 2 Mix 2 Bulk Fill testing for Type HS cement.
- Examples of a Job Safety Analysis (JSA), a Standard Work Procedure (SWP), a Work Instructions (WI), and a rough work sheet associated with the development of the Stage 1 mix design.
- The lab process flow chart which outlines the process flow of lab testing conducted in Golder's Process and Infrastructure Design laboratory.
- The index page of Golder's standard lab procedures manual.

11.1 Quality Assurance and Quality Control (QA/AC) during the Execution Phase

The preliminary versions of the Quality Management Plan (QMP) and Inspection and Testing Plan (ITP) are a part of the Grout Fill Plan. They include the tests and the standards, frequencies, and reporting requirements. These are preliminary in nature and will be finalized by the grouting contractor once secured.

12.0 STUDY LIMITATIONS

This report was prepared for the exclusive use of Canadian Nuclear Laboratories (CNL) on the test program to confirm the grout recipes for backfilling of the Whiteshell facility. The report, which specifically includes all tables, figures and appendices, is based on measurements and observations made and data and information collected during the laboratory studies conducted by Golder Associates Ltd. (Golder) for CNL. The test results are based solely on the ambient conditions of the laboratory at the time the measurements and tests were conducted.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The sample(s) provided for the tests are assumed to be representative of material found at the site. The test data given herein pertains to the sample(s) provided and may not be applicable to material from other production periods or zones. Assessment of the sample environmental conditions and possible hazards associated with the material composition is based on the results of chemical analysis of samples which are possibly from a limited number of locations. However, it is never possible, even with exhaustive sampling and testing, to dismiss the possibility that part of the material characteristics may remain undetected. The results found from the tests may not be reproducible under the field conditions.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by CNL, communications between Golder and CNL, and to any other reports prepared by Golder for CNL relative to the specific site described in the report, tables, drawings, figures and appendices. ***In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.***

No other party may use or rely on this report or any portion thereof without Golder's express written consent. Any use, which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

Golder Associates Ltd.

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Lead Engineer

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https://golderassociates.sharepoint.com/sites/26836g/technical work/rfi017 response to cnsc comments on testing/phase 1000 summary report/18101723_r1_phase 1000 summary rpt_stages 0+1+2_3_may 20, 22.docx

APPENDIX A

Technical Memorandums

GOLDER
MEMBER OF WSP

TECHNICAL MEMORANDUM

DATE May 12, 2022 18101723 Rev 1

TO Nohman Ishfaq
Canadian Nuclear Laboratories

CC

FROM Sue Longo; Bruno Mandl **EMAIL Sue.Longo@wsp.com**

CNL PO 526830 - STAGE 0 AND STAGE 1 TESTING SUMMARY

1.0 INTRODUCTION

Canadian Nuclear Laboratories (CNL) has retained Golder Associates Ltd. (Golder) to carry out a laboratory testing program to confirm the grout recipes for backfilling of the Whiteshell Reactor 1 (WR-1) facility. Two formulations were recommended/provided based on the Savannah River National Laboratory (SRNL) formulations. The two formulations are: one for regular Bulk Fill and one for a pH 10 Fill (Low pH Fill).

Based on the results of Golder's current work for CNL at the Nuclear Power Demonstration (NPD) facility, the SRNL recipes recommended in the RFP will be modified to suit local conditions, available materials, and to minimize the cost impact of the performance criteria.

The overall scope of work is to develop suitable recipes for the site-specific application at WR-1. The recipes need to meet two sets of criteria related to:

- Fresh properties e.g., water bleed, slump flow, etc.
- Cured properties e.g., strength, hydraulic conductivity, etc.

A complete list of the evaluation criteria can be found in the CNL RFP# 725818 "Technical Scope of Work (TSW), WLDP-26000-TSW-002 Rev 2" Appendix B titled "Test Plan by Savannah River National Laboratory – Flowable Non-Structural Grout", "Table 1 - Fresh Property Requirements for WR-1 ISD grouts", and "Table 2 - Cured Property Requirements for WR-1 ISD grouts".

This memorandum will be one of several associated with Task 3 (Reporting) of Phase 1000 (Grout Formula Testing), Task 2 (Testing Program).

The Task 2 Testing Program is divided into 5 Stages.

- Stage 0 – Material Characterization
- Stage 1 – Screening Testing
- Stage 2 – Full Fresh and Cured Property testing on preferred result of Stage 1 Bulk Fill and UCS Testing

- Stage 3 – Screening testing for Low pH Fill
- Stage 4 – UCS Testing for Low pH Fill
- Stage 5 – Full Fresh and Cured Property testing on preferred result of Stage 3 for Low pH Fill

This memo summarizes the Stage 0 and Stage 1 testing programs.

2.0 SAMPLE RECEIPT

2.1 Sample Receipt

Samples received by Golder's Sudbury laboratory are summarized in Table 1. All samples were received in good condition with all seals intact. The total weight of the shipments was 2750 kg. The samples were shipped via Purolator and Manitoulin Transport.

Table 1: Sample Receipt Summary

<table>
<tr><th>Date</th><th>Amount / Container</th><th>Source</th><th>Label as Received</th><th>Golder Sample ID</th></tr>
<tr><td>Aug 20, 2018</td><td>4 – 1L plastic bottles</td><td>CNL Whiteshell</td><td>WRI-FW-01 17 August 2018</td><td>18101723 Raw River Water</td></tr>
<tr><td rowspan="5">Sept 10, 2018</td><td>6 – 20L pails</td><td>CRH – Mississauga</td><td>GU</td><td>18101723 GU</td></tr>
<tr><td>8 – 20L pails</td><td>CRH - Coal Creek, North Dakota</td><td>Fly ash</td><td>18101723 Fly ash</td></tr>
<tr><td>8 – 20L pails</td><td>CRH – Mississauga</td><td>Slag</td><td>18101723 Slag</td></tr>
<tr><td>3 – 200L drums</td><td>Lehigh - Inland Pit</td><td>18101723 Coarse Aggregate</td><td>18101723 Coarse Aggregate</td></tr>
<tr><td>5 – 200L drums</td><td>Lehigh - Inland Pit</td><td>18101723 Fine Aggregate</td><td>18101723 Fine Aggregate</td></tr>
</table>

3.0 STAGE 0 - MATERIAL CHARACTERIZATION

Material characterization is carried out to establish baseline properties which define a 'fingerprint' of the material tested. This data is valuable to assess representative sampling to compare against future samples.

Index testing is carried out in order to give an indication of the grout characteristics of a sample which includes fresh and cured property testing (pH, Set Time, Slump Flow, Visual Stability Index, and UCS testing).

For the results obtained for Stage 0, please refer to Attachment A-1 – Material Characterization.

4.0 TESTING STAGES

4.1 Stage 1 – Screening Testing

The Stage 1 Bulk Fill recipes that were tested are presented in Table 2. The Design Criteria and Bulk Fill Testing Results are presented in Tables 3 and 4 respectively.

The index testing that was completed on the raw material samples e.g., water and sand and aggregate can be found in Attachment A-1. Photographs are located in Attachment B-1.

Table 2: Stage 1 Bulk Fill Recipes

Materials	Mix 1 - GU	Mix 2 – GU/Fly ash	Mix 3 – GU/BFS	Mix 4 – GU/BFS-Sand Only
Portland Cement Type I/II (ASTM C150) (kg/m^3)	386	89	---	---
Type 90/10 Cement (90% BFS / 10% OPC) (kg/m^3) (ASTM C595)	---	---	386	386
Fly Ash Class F (ASTM C618) (kg/m^3)	---	297	---	---
Sand (quartz) (ASTM C33) (kg/m^3)	1165	1074	1142	1609
Gravel (granite) No. 8 (ASTM C33) (kg/m^3)	475	475	475	---
Water** (kg/m^3)	247	247	247	247
Polycarboxylate polymer (ASTM C494 B & F) HRWR max. (L/m^3)	3.1	3.1	3.1	3.1
Diutan Gum based VMA (ASTM C494) (g/m^3)	262	262	262	262
Note: GU is ordinary Portland cement and BFS is ground iron Blast Furnace Slag				

The design criteria applied for Stage 1 of the testing program were obtained from the SRNL Fresh and Cured Properties, “Tables 1 and 2 of the Technical Scope of Work”. Table 3 summarizes the criteria.

Table 3: Bulk Fill Mix Design Criteria

Test	Measurement Parameter	Criteria	Purpose of Measurement
pH - ASTM D4972	Initial	<13.5	pH levels of around 11.9 to 12 are required in order to mitigate lead dissolution
	1 hr	<13.5	
24 Hour Bleed Water - ASTM C232	ASTM	0	Water bleed of 0 is required in order to eliminate the need for liquid removal during execution and to help prevent shrinkage after deposition
	24hr Test	0	
Slump Flow - ASTM C1611		660 mm +/-50	Slump flow is important to provide a flat profile upon deposition and to enable the grout to move into the congested areas. This can be managed/alleviated by having multiple discharge points during execution
Visual Stability Index (VSI) - ASTM C1611		0	Visual Stability Index is important to limit segregation and the creation of cold joints
Set time - ASTM C403	Final	2 - 12 hours	Set time is important to allow a reasonable amount of curing time between subsequence lifts of grout. This can also be managed by having multiple discharge locations during execution
UCS MPa - ASTM D2166 / C39	7 days	>0.34 MPa	UCS is important to have enough strength development in a reasonable amount of time to prevent grout subsidence and to limit permeability

Table 4: Stage 1- Bulk Fill Recipes Results

Test		Mix 1 - GU	Mix 2 – GU/Fly ash	Mix 3 – GU/BFS	Mix 4 – GU/BFS-Sand Only
pH – ASTM D4972	Initial	12.5	11.9	12.0	11.9
	1 Hr	12.5	11.9	11.7	11.9
24 Hour Water Bleed – ASTM C232	ASTM	0	0	0	0
	24 Hr Test	0	0	0	0
Slump – ASTM C1611		279 mm	279 mm	279 mm	279 mm
Slump Flow – ASTM C1611		685 mm	730 mm	735 mm	630 mm
Visual Stability Index (VSI) - ASTM C1611		0	0	0	0
Set time - ASTM C403		6.5 hrs	12 hrs	7.5 hrs	9.15 hrs
UCS - ASTM D2166 / C39	7 day	28.1 MPa	4.4 MPa	13.0 MPa	13.4 MPa

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Particle Size Distribution (PSD) has direct impacts on production in terms of recipe consistency and thus ease of production and ultimate performance. One key with the PSD is to avoid having a bimodal material i.e. gap grades as this can promote segregation and limited strength gain and permeabilities.

Specific Gravity (SG) is a key property used in the calculation of the grout yield produced and while some variation is expected during production, keeping the material and thus this value consistent will make volume tracking easier during production as well as performance.

For both PSD and SG, keeping records during testing and execution will make managing changes on grout production performance easier to do.

Chemical and mineralogical analyses results indicated typical values for alluvial sands and there was no indication of potentially problematic minerals such as micas or clays.

All of the mixes passed the design criteria targets with the exception of Mix 2 and Mix 3 exceeding the Slump Flow criteria. Adjusting the Slump Flow to conform with the target criteria is typically not problematic. The first step is usually to reduce the addition rate of the Polycarboxylate polymer (SIKA 2100) which normally reduces the slump flow. Reducing the SIKA 2100 does not typically affect the other material properties, but this should be tested and confirmed. The Sika, Diutan gum and water addition quantities were the same for all mixes. However, it was noted that the slump flow was lower for the Mix 4 sand only blend which could be attributed to the increased surface area associated with the sand only blend. That said, further tests would be required to confirm this supposition.

As noted in Table 4, the much higher than target UCS values, suggest a possibility to reduce the overall cost of the grout mixture through the lowering of binder addition rates; however, this would require additional investigation and testing. Typically, 50 to 60 percent of the grout mixture costs are associated with binder. In this grout formulation the secondary purpose of the binder is to add sufficient fines to the mix to meet target material properties. However, there might be other fine material, dependent on availability, that might be added in place of the binder to achieve all the desired criteria and reduce the overall costs.

Due to the availability of fly ash in Manitoba, it is recommended that Mix 2, GU / Fly Ash be carried forward to Stage 2 of the testing program. In Stage 2, consideration should also be given to the use of GU / Fly Ash with fine aggregate only. By eliminating the coarse aggregate, the mix will be simpler and easier to execute, and as suggested by the results of Mix 4 there is no substantial difference in results. Reducing the number of different raw materials required in the grout formulation for Bulk Fill will simplify the material handling and mixing process and offer the potential for a cost saving.

6.0 STUDY LIMITATIONS

This report was prepared for the exclusive use of Canadian Nuclear Laboratories (CNL) on the test program to confirm the grout recipes for backfilling of the Whiteshell facility. The report, which specifically includes all tables, figures and appendices, is based on measurements and observations made and data and information collected during the laboratory studies conducted by Golder Associates Ltd. (Golder) for CNL. The test results are based solely on the ambient conditions of the laboratory at the time the measurements and tests were conducted.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The sample(s) provided for the tests are assumed to be representative of material found at the site. The test data given herein pertains to the sample(s) provided and may not be applicable to material from other production periods or zones. Assessment of the sample environmental conditions and possible hazards associated with the material composition is based on the results of chemical analysis of samples which are possibly from a limited number of locations. However, it is never possible, even with exhaustive sampling and testing, to dismiss the possibility that part of the material characteristics may remain undetected. The results found from the tests may not be reproducible under the field conditions.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by CNL, communications between Golder and CNL, and to any other reports prepared by Golder for CNL relative to the specific site described in the report, tables, drawings, figures and appendices. ***In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.***

No other party may use or rely on this report or any portion thereof without Golder's express written consent. Any use, which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

7.0 CLOSURE

If there are any questions regarding this report, please do not hesitate to contact the undersigned.

Golder Associates Ltd.

Bruno Mandl, P.Eng.
Lead Engineer

Sue Longo, P.Eng., MBA
Principal - Project Manager

BM/SL/mc

Attachments:

Attachment A-1 - Stage 0 - Material Characterization
Attachment A-2 - ICP-MS Results
Attachment A-3 - Water Chemistry
Attachment B - Photographs

https://golderassociates.sharepoint.com/sites/26836g/Technical%20Work/Forms/AllItems.aspx?viewpath=%2Fsites%2F26836g%2FTechnical%20Work%2FForms%2FAllItems%2Easpx&OR=Teams%2DHL&CT=1651252167580&params=eyJBcHBOYW1lIjoiVGVhbXMtRGVza3RvcCIsIkFwcFZlcnNpb24iOiIyNy8yMjA0MDExMTQwOSJ9&id=%2Fsites%2F26836g%2FTechnical%20Work%2FRFI017%20Response%20to%20CNSC%20comments%20on%20testing%2FStage%200%20and%201%20Memo&viewid=a35c964e%2De147%2D45f9%2D9246%2D2bf9f0598dd8

ATTACHMENT A-1

Stage 0 - Material Characterization

1.0 MATERIAL CHARACTERIZATION – SAMPLE PREPARATION AND INDEX TESTING

1.1 Hazard Assessment

Prior to handling the samples, each pail was assessed separately for hazardous gases. The gas analysis results are presented in Table A-1.

Table A-1: Sample Hazard Assessment

Date	Label as Received	Golder Sample ID	VOC (ppm)	HCN (ppm)	H_2S (ppm)
Aug 20, 2018	WRI-FW-01 17 August 2018	18101723 Raw River Water	0	0	0
Sept 10, 2018	18101723 Coarse Aggregate	18101723 Coarse Aggregate	0	0	0
	18101723 Fine Aggregate	18101723 Fine Aggregate	0	0	0

VOC: Volatile Organic Compounds
HCN: Hydrogen Cyanide gas
H_2S: Hydrogen Sulphide gas

Metals analysis using Inductively Coupled Plasma with a Mass Spectrometer detector (ICP-MS) was performed on a composite sample obtained via individual pipe samples from each pail. This testing helps to identify health and safety hazards such as heavy metals which may be present. The sample was sent to an external laboratory for ICP-MS analysis. Attachment A-2 present the results.

1.2 Sample Preparation

Proper sample preparation technique is a critical first step to ensure proper homogenization of solids, representative sub-sampling and reproducibility of results.

The 18101723 Coarse Aggregate and 18101723 Fine Aggregate samples were homogenized using the cone and quartering technique. Subsequently, the samples were reduced to the required quantities for each test through the use of a rifle splitter.

1.3 Sample Shipping / External Testing

Sub-samples of the bulk sample(s) were collected and sent to AGAT Laboratories and XPS Centre for the purpose of water chemistry and chemical and mineralogical analyses. Table A-2 summarizes the shipping and external testing.

Table A-2: Sample Shipping

Date	Amount/Container	Golder Sample ID	Shipped To	Purpose
Aug 8, 2018	5 - 1 liter bottles	18101723 Raw River Water	AGAT Laboratories	Water analysis
	5 - 1 liter bottles	18101723 Sudbury Lab Tap Water		
Sept 11, 2018	181g	18101723 Coarse Aggregate		ICPMS
	141g	18101723 Fine Aggregate		
Sept 17, 2018	147g	18101723 Coarse Aggregate	XPS Centre	XRD/WRA/S
	132g	18101723 Fine Aggregate		

2.0 MATERIAL CHARACTERIZATION

2.1 Water Chemistry

The 18101723 Raw River Water and 18101723 Sudbury Lab Tap Water was analysed. The results are presented in Attachment A-3 which included among others, the following analyses:

- pH, Alkalinity, Turbidity, Hardness
- Major Anions
- Total Dissolved and Suspended Solids
- Total and Dissolved Metals

There were no significant differences in the two water samples, so the Stage 1 and subsequent Stages will all use Sudbury Lab Tap Water.

2.2 pH Analysis

Table A-3 presents the pH of each sample and the temperature at which it was measured.

Table A-3: pH Analysis

Sample	pH	Temperature (°Celsius)
18101723 Coarse Aggregate	8.2	24
18101723 Fine Aggregate	8.0	24
18101723 River Water	7.5	24
18101723 Sudbury Lab Tap Water	7.3	24

2.3 Particle Size Distribution

Particle size distribution (PSD) was determined using mechanical sieving and a Fritsch laser particle size analyzer according to ASTM D4464.

Specific values are presented in Table A-4. The gradation parameter DXX, tabulated in microns, refers to the average particle diameter that XX% by weight of material is smaller than.

Figures A-1 and A-2 present the results in graphical form along with the acceptable upper and lower PSD envelopes. Both aggregates are within the bounds of the PSD envelopes and therefore acceptable for use.

Table A-4: Particle Size Distribution

Sample	D10 (µm)	D30 (µm)	D50 (µm)	D60 (µm)	D80 (µm)
18101723 Coarse Aggregate	3432	5388	6634	7238	8441
18101723 Fine Aggregate	197	423	671	843	1631

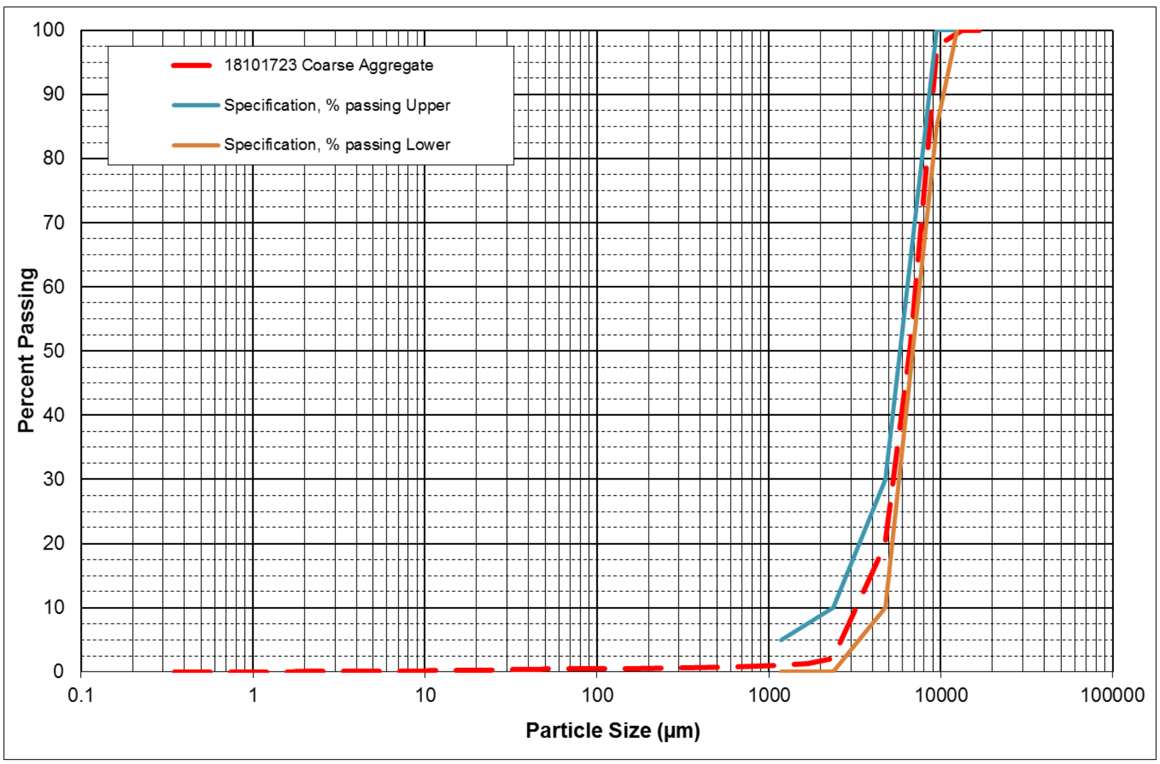

Figure A-1: PSD Results - 18101723 Coarse Aggregate

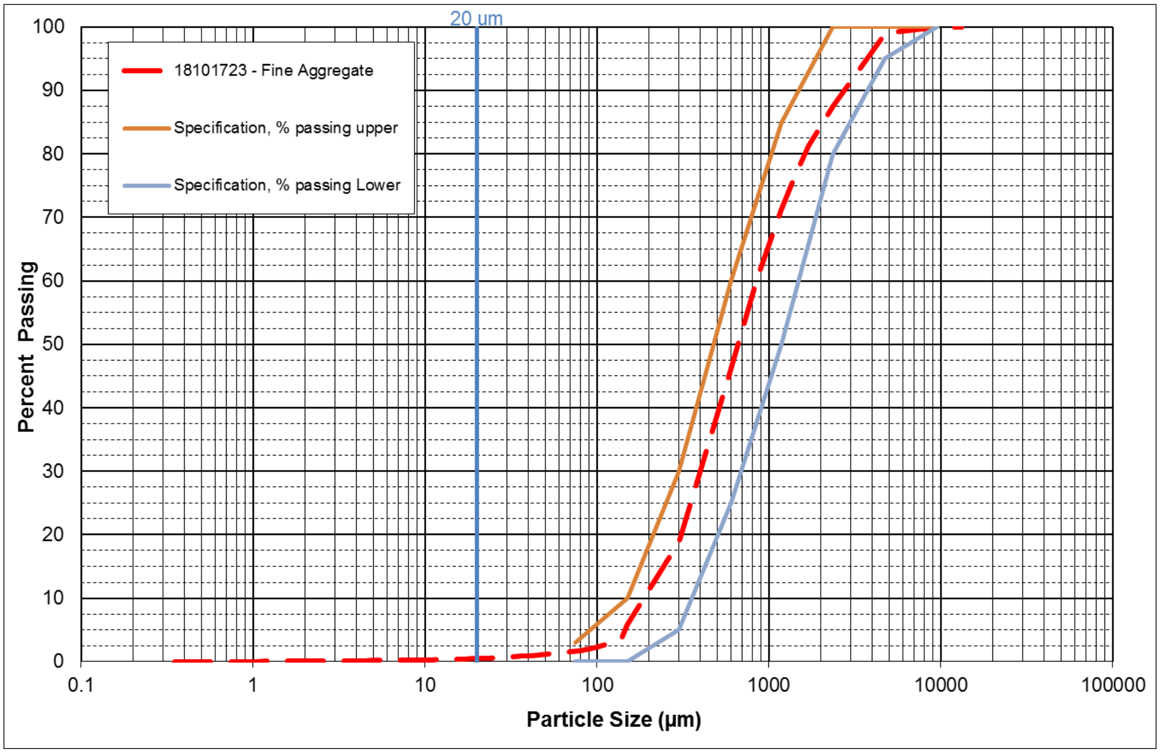

Figure A-2: PSD Results - 18101723 Fine Aggregate

2.4 Specific Gravity

The specific gravity (SG) of the sample was determined using vacuum de-aired water. Each slurry sample was also vacuum de-aired prior to SG measurement. The results are presented in Table A-5.

Table A-5: Specific Gravity Results

Sample	Average
18101723 Coarse Aggregate	2.64
18101723 Fine Aggregate	2.64

2.5 Chemistry and Mineralogy

Chemical and mineralogical analyses were performed using whole rock analysis (WRA) by inductively coupled plasma (ICP) and X-ray diffraction (XRD) via semi-quantitative analysis by Rietveld Method, respectively whereas sulphur analysis was performed by LECO method. The results are presented in Table A-6 to Table A-8 as well as Figure A-3 and A-4.

Table A-6: Chemical Composition (wt%)

SAMPLE	18101723 Coarse Aggregate	18101723 Fine Aggregate
Al_2O_3	10.6	6.48
BaO	0.059	0.039
CaO	12.8	15.2
Cr_2O_3	0.011	0.0025
Fe_2O_3	2.02	1.07
K_2O	2.77	1.42
LOI	12.7	17.9
MgO	4.17	5.70
MnO	0.037	0.022
Na_2O	2.97	1.92
P_2O_5	0.076	0.044
SiO_2	52.2	48.0
SrO	0.036	0.027
TiO_2	0.215	0.106
Total	100.664	97.9305

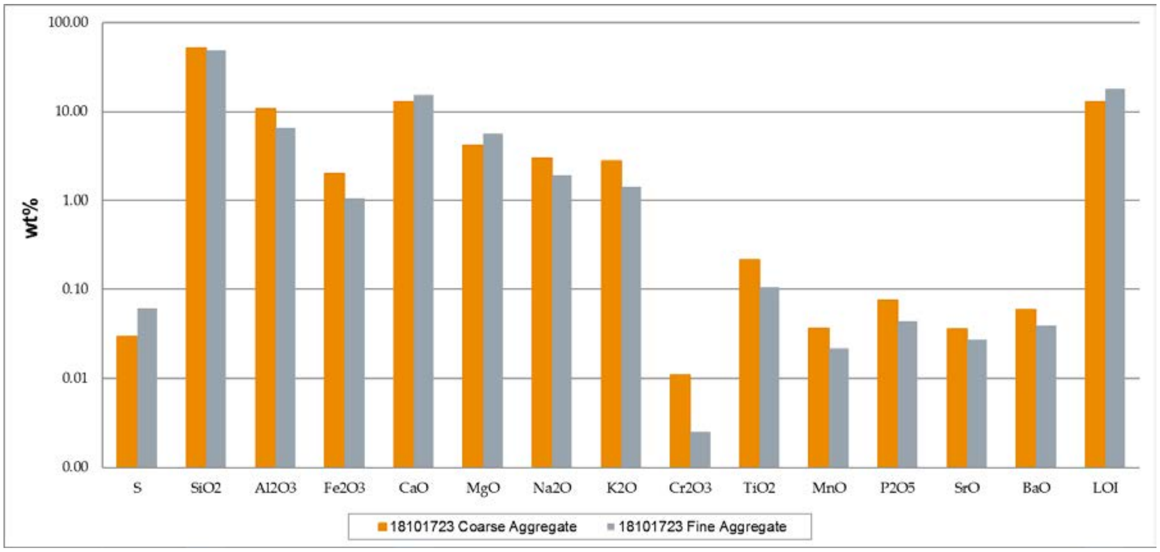

Figure A-3: Chemical Composition

Table A-7: Semi-quantitative Mineralogical Composition

Sample		**18101723 Coarse Aggregate**	**18101723 Fine Aggregate**
Mineral SQ-XRD	Chemical Formula	Wt%	
Albite	$NaAlSi_3O_8$	29.12	21.04
Dolomite	$CaMg(CO_3)_2$	21.96	25.87
Quartz	SiO_2	16.52	28.90
Calcite	$CaCO_3$	14.76	10.20
Microcline	$KAlSi_3O_8$	9.19	9.53
Phlogopite	$KMg_3(Si_3Al)O_{10}(OH)_2$	3.35	0.87
Clinochlore	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	3.26	0.86
Actinolite	$Ca\text{-}MgFe^{+2}\text{-}SiO_2\text{-}OH$	1.84	2.73
Total		**100.00**	**100.00**

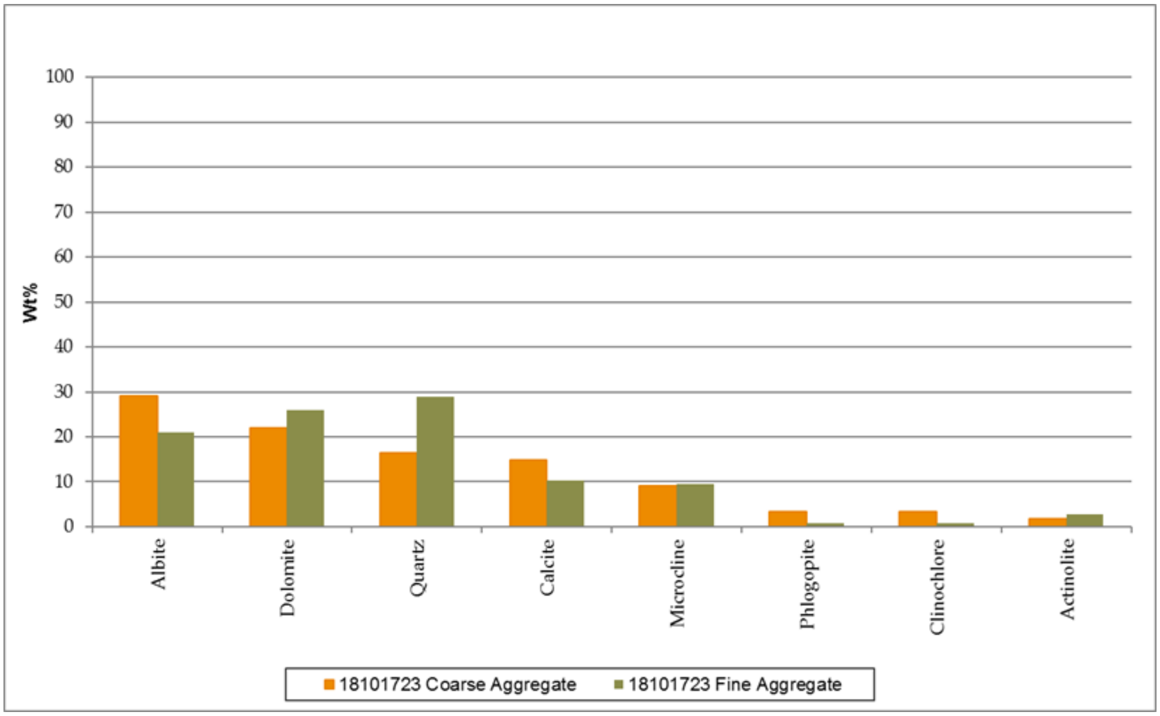

Figure A-4: Semi-quantitative Mineralogical Composition

Table A-8: LECO Sulphur Analysis

Sample	Sulphur (wt%)
18101723 Coarse Aggregate	0.030
18101723 Fine Aggregate	0.062

END OF ATTACHMENT A-1

ATTACHMENT A-2

ICP-MS Results

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
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FAX (905)712-5122
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CLIENT NAME: GOLDER ASSOCIATES
33 MACKENZIE STREET SUITE 100
SUDBURY, ON P3C4Y1
(705) 524-6861

ATTENTION TO: Mark Labelle

PROJECT: 18101723

AGAT WORK ORDER: 18U383881

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Supervisor

DATE REPORTED: Sep 13, 2018

PAGES (INCLUDING COVER): 7

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 18U383881
PROJECT: 18101723

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CLIENT NAME: GOLDER ASSOCIATES
ATTENTION TO: Mark Labelle
SAMPLING SITE:
SAMPLED BY:

Metal Scan (Soil)

DATE RECEIVED: 2018-09-11
DATE REPORTED: 2018-09-13

			SAMPLE DESCRIPTION:	18101723 Coarse Aggregate	18101723 Fine Aggregate
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	2018-09-10	2018-09-10
Parameter	Unit	G / S	RDL	9539199	9539201
Aluminum	µg/g		5	5510	1940
Antimony	µg/g		0.8	<0.8	<0.8
Arsenic	µg/g		1	1	2
Barium	µg/g		2	47	16
Beryllium	µg/g		0.5	<0.5	<0.5
Bismuth	µg/g		0.1	<0.1	<0.1
Boron	µg/g		5	9	6
Cadmium	µg/g		0.5	<0.5	<0.5
Calcium	µg/g		10	89000	82200
Cerium	µg/g		0.01	65.6	16.5
Cesium	µg/g		0.01	1.28	0.38
Chromium	µg/g		2	18	5
Cobalt	µg/g		0.5	4.3	2.2
Copper	µg/g		1	8	4
Europium	µg/g		1	<1	<1
Gallium	µg/g		0.50	2.95	1.01
Iron	µg/g		50	10200	5010
Lanthanum	µg/g		0.1	32.3	8.7
Lead	µg/g		1	3	2
Lithium	µg/g		0.5	21.8	6.5
Magnesium	µg/g		10	33000	28400
Manganese	µg/g		5	233	116
Mercury	µg/g		0.10	<0.10	<0.10
Molybdenum	µg/g		0.5	<0.5	<0.5
Nickel	µg/g		1	8	5
Niobium	µg/g		0.05	0.62	0.50
Phosphorus	µg/g		5	461	230
Potassium	µg/g		10	2640	690

Certified By: Amanjot Bhela

CHARTERED AMANJOT BHELA CHEMIST — ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 18U383881
PROJECT: 18101723

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CLIENT NAME: GOLDER ASSOCIATES
SAMPLING SITE:

ATTENTION TO: Mark Labelle
SAMPLED BY:

Metal Scan (Soil)

DATE RECEIVED: 2018-09-11

DATE REPORTED: 2018-09-13

Parameter	Unit	G / S	RDL	18101723 Coarse Aggregate	18101723 Fine Aggregate
SAMPLE TYPE:				Soil	Soil
DATE SAMPLED:				2018-09-10	2018-09-10
				9539199	9539201
Rubidium	µg/g		0.010	29.5	7.48
Scandium	µg/g		0.1	1.8	559000
Selenium	µg/g		0.8	<0.8	<0.8
Silicon	µg/g		5	701	429
Silver	µg/g		0.4	<0.4	<0.4
Sodium	µg/g		10	152	108
Strontium	µg/g		5	42	37
Sulfur	µg/g		20	999	1130
Tellurium	µg/g		0.1	<0.1	<0.1
Thallium	µg/g		0.4	<0.4	<0.4
Thorium	µg/g		0.4	14.8	3.0
Tin	µg/g		1	<1	<1
Titanium	µg/g		50	576	227
Tungsten	µg/g		0.50	<0.50	<0.50
Uranium	µg/g		0.50	1.03	<0.50
Vanadium	µg/g		1	18	9
Yitrium	µg/g		0.05	4.10	2.36
Zinc	µg/g		5	30	12
Zirconium	µg/g		0.5	5.8	2.4

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard
9539199-9539201

Certified By: Amanjot Bhela

CHARTERED AMANJOT BHELA CHEMIST — ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO

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AGAT Laboratories

Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES

AGAT WORK ORDER: 18U383881

PROJECT: 18101723

ATTENTION TO: Mark Labelle

SAMPLING SITE:

SAMPLED BY:

Soil Analysis

RPT Date:			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Metal Scan (Soil)															
Aluminum	9535589		8040	8280	2.9%	< 5	94%	70%	130%	91%	80%	120%	89%	70%	130%
Antimony	9535589		<0.8	<0.8	NA	< 0.8	104%	70%	130%	82%	80%	120%	82%	70%	130%
Arsenic	9535589		2	2	NA	< 1	103%	70%	130%	103%	80%	120%	105%	70%	130%
Barium	9535589		54	55	1.8%	< 2	100%	70%	130%	97%	80%	120%	106%	70%	130%
Beryllium	9535589		<0.5	<0.5	NA	< 0.5	104%	70%	130%	114%	80%	120%	106%	70%	130%
Bismuth	9535589		<0.1	<0.1	NA	< 0.1	104%	70%	130%	108%	80%	120%	105%	70%	130%
Boron	9535589		6	6	NA	< 5	100%	70%	130%	104%	80%	120%	104%	70%	130%
Cadmium	9535589		<0.5	<0.5	NA	< 0.5	101%	70%	130%	117%	80%	120%	122%	70%	130%
Calcium	9535589		94500	92700	1.9%	< 10	95%	70%	130%	94%	80%	120%	98%	70%	130%
Cerium	9535589		32.8	32.5	0.9%	< 0.01	105%	80%	120%	99%	80%	120%	103%	70%	130%
Cesium	9535589		0.76	0.72	5.4%	< 0.01	107%	80%	120%	102%	80%	120%	105%	70%	130%
Chromium	9535589		13	14	7.4%	< 2	103%	70%	130%	105%	80%	120%	104%	70%	130%
Cobalt	9535589		5.8	5.9	1.7%	< 0.5	103%	70%	130%	106%	80%	120%	103%	70%	130%
Copper	9535589		11	11	0.0%	< 1	107%	70%	130%	112%	80%	120%	109%	70%	130%
Europium	9535589		< 1	< 1	NA	< 1	105%	70%	130%	98%	80%	120%	104%	70%	130%
Gallium	9535589		2.64	2.84	7.3%	< 0.50	99%	70%	130%	93%	80%	120%	101%	80%	120%
Iron	9535589		13400	13800	2.9%	< 50	108%	70%	130%	102%	80%	120%	110%	70%	130%
Lanthanum	9535589		14.8	14.3	3.4%	< 0.1	104%	70%	130%	102%	80%	120%	100%	70%	130%
Lead	9535589		6	6	0.0%	< 1	104%	70%	130%	106%	80%	120%	103%	70%	130%
Lithium	9535589		9.6	9.5	1.0%	< 0.5	108%	70%	130%	116%	80%	120%	104%	70%	130%
Magnesium	9535589		8030	7720	3.9%	< 10	94%	70%	130%	86%	80%	120%	97%	70%	130%
Manganese	9535589		353	366	3.6%	< 5	104%	70%	130%	105%	80%	120%	107%	70%	130%
Mercury	9535589		<0.10	<0.10	NA	< 0.10	111%	70%	130%	100%	80%	120%	103%	70%	130%
Molybdenum	9535589		<0.5	<0.5	NA	< 0.5	107%	70%	130%	105%	80%	120%	108%	70%	130%
Nickel	9535589		12	12	0.0%	< 1	103%	70%	130%	104%	80%	120%	100%	70%	130%
Niobium	9535589		0.546	0.507	7.4%	< 0.05	103%	80%	120%	95%	80%	120%	107%	70%	130%
Phosphorus	9535589		677	720	6.2%	< 5	93%	80%	120%	89%	80%	120%	107%	70%	130%
Potassium	9535589		1330	1260	5.4%	< 10	97%	70%	130%	95%	80%	120%	101%	70%	130%
Rubidium	9535589		10.6	11.0	3.7%	< 0.010	102%	80%	120%	99%	80%	120%	109%	80%	120%
Scandium	9535589		3.2	3.2	0.0%	< 0.1	101%	70%	130%	93%	80%	120%	100%	70%	130%
Selenium	9535589		<0.8	<0.8	NA	< 0.8	99%	70%	130%	100%	80%	120%	107%	70%	130%
Silicon	9535589		495	479	3.3%	< 5	NA	70%	130%	95%	80%	120%	98%	70%	130%
Silver	9535589		<0.4	<0.4	NA	< 0.4	88%	70%	130%	108%	80%	120%	110%	70%	130%
Sodium	9535589		223	219	1.8%	< 10	96%	70%	130%	95%	80%	120%	101%	70%	130%
Strontium	9535589		153	159	3.8%	< 5	102%	70%	130%	105%	80%	120%	108%	70%	130%
Sulfur	9535589		1130	1100	2.7%	< 20	115%	70%	130%	97%	80%	120%	105%	70%	130%
Tellurium	9535589		< 0.1	< 0.1	NA	< 0.1	104%	70%	130%	96%	80%	120%	106%	70%	130%
Thallium	9535589		<0.4	<0.4	NA	< 0.4	99%	70%	130%	101%	80%	120%	95%	70%	130%
Thorium	9535589		2.9	3.1	6.7%	< 0.4	102%	80%	120%	102%	80%	120%	107%	70%	130%

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Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES

PROJECT: 18101723

SAMPLING SITE:

AGAT WORK ORDER: 18U383881

ATTENTION TO: Mark Labelle

SAMPLED BY:

Soil Analysis (Continued)

RPT Date:			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper
Tin	9535589		<1	<1	NA	< 1	104%	70%	130%	111%	80%	120%	106%	70%	130%
Titanium	9535589		320	310	3.2%	< 5	97%	70%	130%	98%	80%	120%	104%	70%	130%
Tungsten	9535589		< 0.50	< 0.50	NA	< 0.50	105%	70%	130%	97%	80%	120%	106%	70%	130%
Uranium	9535589		<0.50	<0.50	NA	< 0.50	105%	70%	130%	107%	80%	120%	103%	70%	130%
Vanadium	9535589		21	22	4.7%	< 1	100%	70%	130%	102%	80%	120%	101%	70%	130%
Yitrium	9535589		11.0	11.7	6.2%	< 0.05	102%	80%	120%	99%	80%	120%	109%	70%	130%
Zinc	9535589		67	68	1.5%	< 5	106%	70%	130%	112%	80%	120%	110%	70%	130%
Zirconium	9535589		6.9	7.3	5.6%	< 0.5	104%	70%	130%	102%	80%	120%	103%	70%	130%

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL

Certified By: Amanjot Bhela

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO — CHARTERED — AMANJOT BHELA — CHEMIST

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Method Summary

CLIENT NAME: GOLDER ASSOCIATES
PROJECT: 18101723
SAMPLING SITE:

AGAT WORK ORDER: 18U383881
ATTENTION TO: Mark Labelle
SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Aluminum	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Antimony	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Arsenic	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Barium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Beryllium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Bismuth	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Boron	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Cadmium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Calcium	MET-93-6105	EPA SW-846 3050B & 6010C	ICP/OES
Cerium	MET-93-61003	EPA SW-846 3050B & 6020A	ICP-MS
Cesium	MET-93-61003	EPA SW-846 3050B & 6020A	ICP-MS
Chromium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Cobalt	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Copper	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Europium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Gallium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Iron	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Lanthanum	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Lead	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Lithium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Magnesium	MET-93-6105	EPA SW-846 3050B & 6010C	ICP/OES
Manganese	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Mercury	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Molybdenum	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Nickel	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Niobium	MET-93-6103	EPA SW 846 3050B & 6020A	ICP-MS
Phosphorus	MET-93-6103	EPA SW 846-3050B & 6020A	ICP-MS
Potassium	MET-93-6105	EPA SW-846 3050B & 6010C	ICP/OES
Rubidium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Scandium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Selenium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Silicon	MET-93-6105	EPA SW 846-3050B & 6010C	ICP/OES
Silver	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Sodium	MET-93-6105	EPA SW-846 3050B & 6010C	ICP/OES
Strontium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Sulfur	MET-93-6105	EPA SW-846-3050B & 6010C	ICP/OES
Tellurium	MET-93-6103	EPA SW 846 3050B & 6020A	ICP-MS
Thallium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Thorium	MET-93-1003	EPA SW 846 3050B & 6020A	ICP-MS
Tin	MET-93-6103	EPA SW 846 3050B & 6020A	ICP-MS
Titanium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Tungsten	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Uranium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Vanadium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Yitrium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Zinc	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Zirconium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS

AGAT Laboratories

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1 Sm

Chain of Custody Record

Laboratory Use Only

Arrival Temperature:
AGAT WO #: 18U383881
Lab Temperature: 8.6 9 8.4
Notes: On ice

Client Information:

Company: Golder Associates
Contact: PED Laboratory
Address: 33 Mackenzie, Suite 100
Sudbury, ON P3C 4Y1
Phone: 705-524-6861 Fax: 705-524-1984
Project: 18101723 PO: 881900
AGAT Quotation #:

Please note, if quotation number is not provided, client will be billed full price for analysis.

Regulatory Requirements:

- ☐ Regulation 153/09 (reg. 511 Amend.)
  - Table ____ (Indicate one)
  - ☐ Ind/Com
  - ☐ Res/Park
  - ☐ Agriculture
  - Soil Texture (check one): ☐ Coarse ☐ Fine
- ☐ Sewer Use
  - Region ____ (Indicate one)
  - ☐ Sanitary
  - ☐ Storm
- ☐ Regulation 558
- ☐ CCME
- ☐ Other (specify) ____
- ☐ Prov. Water Quality Objectives (PWQO)
- ☐ None

Turnaround Time Required (TAT) Required*

Regular TAT

☐ 5 to 7 Working Days

Rush TAT (please provide prior notification)
Rush Surcharges Apply

☐ 3 Working Days
☐ 2 Working Days
☑ 1 Working Day

OR

Date Required (Rush surcharges may apply):

*TAT is exclusive of weekends and statutory holidays

Invoice To:

Same: Yes ☑ No ☐
Company:
Contact:
Address:

Is this a drinking water sample? (potable water intended for human consumption) ☐ Yes ☑ No
If "Yes", please use the *Drinking Water Chain of Custody Form*

Is this submission for a **Record of Site Condition**? ☐ Yes ☑ No

Legend Matrix

GW	Ground Water	**O**	Oil
SW	Surface Water	**P**	Paint
SD	Sediment	**S**	Soil

Report Information – reports to be sent to:

1. Name: Mark Labelle
   Email: mlabelle@golder.com
2. Name: Alex McRobbie
   Email: amcrobbie@golder.com

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Comments Site/Sample Information	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl- ☐ CN- ☐ EC ☐ FOC ☐ Cr+6- ☐ SAR ☐ NO_2/NO_3 ☐ N-Total ☐ Hg ☐ pH	Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2	VOC: ☐ VOC ☐ THM ☐ BTEX	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	TCLP:	Sewer Use	WADCN
18101723 Coarse Aggre	2018-09-10	14:30:00	S	1			X															
18101723 Fine Aggrega	2018-09-10	14:30:00	S	1			X															

Samples Relinquished by (print name & sign)	Date/Time	Samples Received by (Print name & sign)	Date/Time	
Vicki Newman [signature]	Sept 10, 2018 13[illegible]	Holly Squires [signature]	11SEPT18 1345	Pink Copy – Client
		Sima [signature] 18/9/12	8:25	Yellow + Golden Copy – AGAT White Copy – AGAT

Page 1 of 1
NO:

END OF ATTACHMENT A-2 - ICP-MS RESULTS

ATTACHMENT A-3

Water Chemistry

AGAT Laboratories

5835 COOPERS AVENUE
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CANADA L4Z 1Y2
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http://www.agatlabs.com

CLIENT NAME: **GOLDER ASSOCIATES**
33 MACKENZIE STREET SUITE 100
SUDBURY, ON P3C4Y1
(705) 524-6861

ATTENTION TO: **Mark Labelle**

PROJECT: **18101723**

AGAT WORK ORDER: **18U376633**

WATER ANALYSIS REVIEWED BY: **Nivine Basily, Inorganics Report Writer**

DATE REPORTED: **Aug 27, 2018**

PAGES (INCLUDING COVER): **6**

VERSION*: **1**

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 18U376633
PROJECT: 18101723

5835 COOPERS AVENUE
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CANADA L4Z 1Y2
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http://www.agatlabs.com

CLIENT NAME: GOLDER ASSOCIATES
ATTENTION TO: Mark Labelle
SAMPLING SITE:
SAMPLED BY:Vicki Newman

Inorganic Chemistry (Water)

DATE RECEIVED: 2018-08-22
DATE REPORTED: 2018-08-27

			SAMPLE DESCRIPTION:	18101723 River Water	18101723 Sudbury Lab Tap Water
			SAMPLE TYPE:	Water	Water
			DATE SAMPLED:	2018-08-22	2018-08-22
Parameter	**Unit**	**G / S**	**RDL**	**9492921**	**9492940**
pH	pH Units		NA	7.53	7.25
Total Hardness (as CaCO3)	mg/L		0.5	46.4	50.0
Total Dissolved Solids	mg/L		20	84	94
Total Suspended Solids	mg/L		10	43	<10
Total Solids	mg/L		10	132	112
Alkalinity (as CaCO3)	mg/L		5	47	24
Fluoride	mg/L		0.05	<0.05	0.36
Chloride	mg/L		0.10	1.83	11.2
Nitrate as N	mg/L		0.05	<0.05	<0.05
Nitrite as N	mg/L		0.05	<0.05	<0.05
Sulphate	mg/L		0.10	3.11	27.1
Ammonia as N	mg/L		0.02	<0.02	<0.02
Chemical Oxygen Demand	mg/L		5	7	<5
Total Kjeldahl Nitrogen	mg/L		0.10	0.78	0.16
Total Phosphorus	mg/L		0.02	0.09	0.44
Turbidity	NTU		0.5	37.6	<0.5
Calcium	mg/L		0.05	12.7	16.9
Magnesium	mg/L		0.05	3.56	1.90
Sodium	mg/L		0.05	2.52	8.09
Potassium	mg/L		0.05	0.83	0.47
Aluminum	mg/L		0.004	0.228	0.024
Arsenic	mg/L		0.003	<0.003	<0.003
Cadmium	mg/L		0.001	<0.001	<0.001
Chromium	mg/L		0.003	<0.003	<0.003
Cobalt	mg/L		0.001	<0.001	<0.001
Copper	mg/L		0.003	0.004	0.064
Iron	mg/L		0.010	0.298	<0.010
Lead	mg/L		0.001	0.002	<0.001

Certified By: Nivine Basily

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 18U376633
PROJECT: 18101723

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CLIENT NAME: GOLDER ASSOCIATES
SAMPLING SITE:
ATTENTION TO: Mark Labelle
SAMPLED BY:Vicki Newman

Inorganic Chemistry (Water)

DATE RECEIVED: 2018-08-22 **DATE REPORTED: 2018-08-27**

			SAMPLE DESCRIPTION:	18101723 River Water	18101723 Sudbury Lab Tap Water
			SAMPLE TYPE:	Water	Water
			DATE SAMPLED:	2018-08-22	2018-08-22
Parameter	**Unit**	**G / S**	**RDL**	**9492921**	**9492940**
Manganese	mg/L		0.002	0.103	<0.002
Mercury	mg/L		0.0001	<0.0001	<0.0001
Molybdenum	mg/L		0.002	<0.002	<0.002
Nickel	mg/L		0.003	<0.003	0.007
Zinc	mg/L		0.005	0.005	0.006

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By: Nivine Basily

Results relate only to the items tested and to all the items tested

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Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES | **AGAT WORK ORDER: 18U376633**
PROJECT: 18101723 | **ATTENTION TO: Mark Labelle**
SAMPLING SITE: | **SAMPLED BY:Vicki Newman**

Water Analysis

RPT Date:			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Inorganic Chemistry (Water)															
pH	9490418		6.86	6.70	2.4%	NA	99%	90%	110%						
Total Dissolved Solids	9490431		360	362	0.6%	< 20	100%	80%	120%						
Total Suspended Solids	9492921	9492921	43	45	NA	< 10	98%	80%	120%						
Alkalinity (as CaCO3)	9490418		10	9	NA	< 5	99%	80%	120%						
Fluoride	9492799		<0.25	<0.25	NA	< 0.05	99%	90%	110%	106%	90%	110%	100%	80%	120%
Chloride	9492799		91.2	105	14.4%	< 0.10	94%	90%	110%	110%	90%	110%	108%	80%	120%
Nitrate as N	9492799		0.91	1.04	NA	< 0.05	91%	90%	110%	106%	90%	110%	100%	80%	120%
Nitrite as N	9492799		<0.25	<0.25	NA	< 0.05	NA	90%	110%	105%	90%	110%	97%	80%	120%
Sulphate	9492799		189	218	14.2%	< 0.10	93%	90%	110%	103%	90%	110%	101%	80%	120%
Ammonia as N	9487406		<0.02	<0.02	NA	< 0.02	100%	90%	110%	95%	90%	110%	88%	80%	120%
Chemical Oxygen Demand	9492940	9492940	<5	<5	NA	< 5	103%	80%	120%	95%	90%	110%	95%	70%	130%
Total Kjeldahl Nitrogen	9489981		0.68	0.60	13.9%	< 0.10	100%	80%	120%	101%	80%	120%	100%	70%	130%
Total Phosphorus	9493848		0.03	0.03	NA	< 0.02	92%	90%	110%	94%	90%	110%	98%	80%	120%
Turbidity	9492921	9492921	37.6	37.5	0.3%	< 0.5	101%	90%	110%						
Calcium	9487853		61.0	60.9	0.2%	< 0.05	101%	90%	110%	102%	90%	110%	104%	70%	130%
Magnesium	9487853		21.2	21.7	2.2%	< 0.05	94%	90%	110%	95%	90%	110%	95%	70%	130%
Sodium	9487853		5.25	5.15	1.9%	< 0.05	101%	90%	110%	101%	90%	110%	99%	70%	130%
Potassium	9487853		2.15	2.14	0.4%	< 0.05	101%	90%	110%	100%	90%	110%	101%	70%	130%
Aluminum	9486265		0.008	0.005	NA	< 0.004	94%	90%	110%	93%	90%	110%	105%	70%	130%
Arsenic	9486265		0.048	0.047	0.7%	< 0.003	102%	90%	110%	97%	90%	110%	103%	70%	130%
Cadmium	9486265		<0.001	<0.001	NA	< 0.001	101%	90%	110%	101%	90%	110%	103%	70%	130%
Chromium	9486265		<0.003	<0.003	NA	< 0.003	100%	90%	110%	98%	90%	110%	93%	70%	130%
Cobalt	9486265		<0.001	<0.001	NA	< 0.001	102%	90%	110%	98%	90%	110%	89%	70%	130%
Copper	9486265		<0.003	<0.003	NA	< 0.003	101%	90%	110%	99%	90%	110%	85%	70%	130%
Iron	9486265		2.41	2.49	3.3%	< 0.010	100%	90%	110%	97%	90%	110%	80%	70%	130%
Lead	9486265		<0.001	<0.001	NA	< 0.001	98%	90%	110%	99%	90%	110%	93%	70%	130%
Manganese	9486265		0.089	0.092	3.3%	< 0.002	101%	90%	110%	100%	90%	110%	116%	70%	130%
Mercury	9489937		<0.0001	<0.0001	NA	< 0.0001	100%	90%	110%	99%	90%	110%	94%	80%	120%
Molybdenum	9486265		<0.002	<0.002	NA	< 0.002	102%	90%	110%	99%	90%	110%	103%	70%	130%
Nickel	9486265		<0.003	<0.003	NA	< 0.003	99%	90%	110%	97%	90%	110%	87%	70%	130%
Zinc	9486265		<0.005	<0.005	NA	< 0.005	101%	90%	110%	103%	90%	110%	100%	70%	130%

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: Nivine Basily

AGAT Laboratories

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http://www.agatlabs.com

Method Summary

CLIENT NAME: GOLDER ASSOCIATES **AGAT WORK ORDER: 18U376633**

PROJECT: 18101723 **ATTENTION TO: Mark Labelle**

SAMPLING SITE: **SAMPLED BY:Vicki Newman**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Water Analysis			
pH	INOR-93-6000	SM 4500-H+ B	PC TITRATE
Total Hardness (as CaCO3)	MET-93-6105	EPA SW-846 6010C & 200.7	CALCULATION
Total Dissolved Solids	INOR-93-6028	SM 2540 C	BALANCE
Total Suspended Solids	INOR-93-6028	SM 2540 D	BALANCE
Total Solids	INOR-93-6028	SM 2540 B	BALANCE
Alkalinity (as CaCO3)	INOR-93-6000	SM 2320 B	PC TITRATE
Fluoride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Chloride	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Nitrate as N	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Nitrite as N	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Sulphate	INOR-93-6004	SM 4110 B	ION CHROMATOGRAPH
Ammonia as N	INOR-93-6059	QuikChem 10-107-06-1-J & SM 4500 NH3-F	LACHAT FIA
Chemical Oxygen Demand	INOR-93-6042	SM 5220 D	SPECTROPHOTOMETER
Total Kjeldahl Nitrogen	INOR-93-6048	QuikChem 10-107-06-2-I & SM 4500-Norg D	LACHAT FIA
Total Phosphorus	INOR-93-6022	SM 4500-P B&E	SPECTROPHOTOMETER
Turbidity	INOR-93-6044	SM 2130 B	NEPHELOMETER
Calcium	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Magnesium	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Sodium	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Potassium	MET-93-6105	EPA SW-846 6010C & 200.7	ICP/OES
Aluminum	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Arsenic	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Cadmium	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Chromium	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Cobalt	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Copper	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Iron	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Lead	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Manganese	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Mercury	MET-93-6100	EPA SW 846 7470 & 245.1	CVAAS
Molybdenum	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Nickel	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS
Zinc	MET-93-6103	EPA SW-846 6020A & 200.8	ICP-MS

AGAT Laboratories

TURBIDITY | Med

RUSH!

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905.712.5100 Fax: 905.712.5122
webearth.agatlabs.com

Laboratory Use Only

Work Order #: 18U376633

Cooler Quantity:

Arrival Temperatures: 5 | 5.4 | 6

Custody Seal Intact: ☐ Yes ☐ No ☐ N/A

Notes: Gin ICe

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)

Report Information:

Company: Golder Associates
Contact: Mark Labelle
Address: 33 MacKenzie St, Suite 100
Sudbury Ontario P3C 4Y1
Phone: 705-524-6861 Fax: 705-524-1984
Reports to be sent to:
1. Email: mlabelle@golder.com
2. Email: amcrobbie@golder.com

Regulatory Requirements: ☑ No Regulatory Requirement

(Please check all applicable boxes)

☐ Regulation 153/04
Table ___ (Indicate One)
☐ Ind/Com
☐ Res/Park
☐ Agriculture
Soil Texture (Check One)
☐ Coarse
☐ Fine

☐ Sewer Use
☐ Sanitary
☐ Storm
Region ___ (Indicate One)

☐ Regulation 558
☐ CCME
☐ Prov. Water Quality Objectives (PWQO)
☐ Other ___ (Indicate One)

Is this submission for a **Record of Site Condition?** ☐ Yes ☐ No

Report Guideline on *Certificate of Analysis* ☐ Yes ☐ No

Turnaround Time (TAT) Required:

Regular TAT ☐ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)
☑ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day

OR Date Required (Rush Surcharges May Apply):

Please provide prior notification for rush TAT
**TAT is exclusive of weekends and statutory holidays*

Project Information:

Project: 18101723
Site Location:
Sampled By: Vicki Newman
AGAT Quote #: 175099 PO: 881900
Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes ☑ No ☐

Company:
Contact:
Address:
Email:

Sample Matrix Legend

B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Field Filtered - Metals, Hg, CrVI Y / N	Turbidity	PH,ALK	TDS, TS, TSS, Hardness	TKN, NH3, TP, COD	Mercury	CL,No2,NO3,Fl,SO4	Cations (K,mg,ca,na)	Metals (Al,As,Cd,Cr,Co,Cu,	Fe,Pb,Mn,Mo,Ni, Zn)
18101723 River Water	03/22/2018	13:00	5	W		N	☑	☑	☑	☑	☑	☑	☑	☑	☑
18101723 Sudbury Lab Tap Water	08/22/2018	13:00	5	W		N	☑	☑	☑	☑	☑	☑	☑	☑	☑

Samples Relinquished By (Print Name and Sign):	Date	Time	Samples Received By (Print Name and Sign):	Date	Time
Vicki Newman [signature]	08/22/2018	13:30	HOLLY SGOUROS [signature]	22AUG18	1510
Samples Relinquished By (Print Name and Sign):			Samples Received By (Print Name and Sign): Sima [signature]	18/8/23	905
Samples Relinquished By (Print Name and Sign):			Samples Received By (Print Name and Sign):		

Page 1 of 1

Nº:

END OF ATTACHMENT A-3 - WATER CHEMISTRY

ATTACHMENT B

Photographs

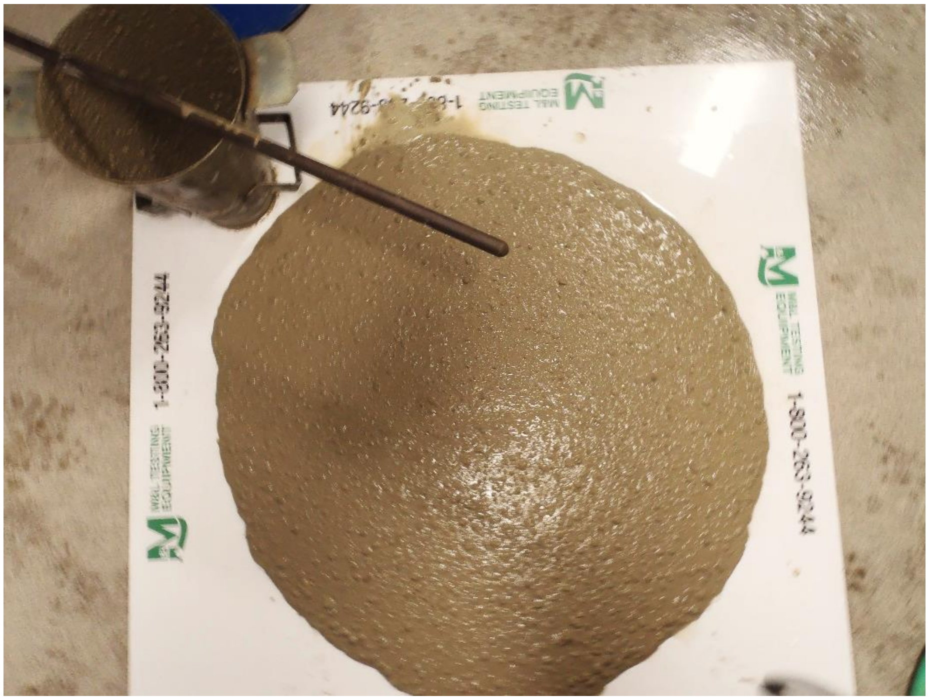
ATTACHMENT B - PHOTOGRAPHS	Project : 18101723 – Stage 0 & 1
Golder Associates Ltd.	Date : September 2018
Client : CNL – Grout Testing	Inputted By : Nick Desormiers
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 1

Mix 1 - GU – Slump Flow – 685 mm

Photograph 2

Mix 2 – GU/Fly ash - Slump Flow – 730 mm



ATTACHMENT B - PHOTOGRAPHS	**Project : 18101723 – Stage 0 & 1**
Golder Associates Ltd.	**Date : September 2018**
Client : CNL – Grout Testing	**Inputted By : Nick Desormiers**
Site Name : Sudbury Laboratory	**Checked By : Mark Labelle**

Photograph 3

Mix 3 – GU/BFS - Slump Flow – 735 mm

Photograph 4

Mix 4 – GU/BFS – Sand Only - Slump Flow – 630 mm

ATTACHMENT B - PHOTOGRAPHS	Project : 18101723 – Stage 0 & 1
Golder Associates Ltd.	Date : September 2018
Client : CNL – Grout Testing	Inputted By : Vicki Newman
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 5

Mix 1 – GU - UCS Testing – 28.1 Mpa – 7 day

Photograph 6

Mix 1 – GU - UCS Testing – 28.1 Mpa – 7 day

ATTACHMENT B - PHOTOGRAPHS	**Project : 18101723 – Stage 0 & 1**
Golder Associates Ltd.	**Date : September 2018**
Client : CNL – Grout Testing	**Inputted By : Vicki Newman**
Site Name : Sudbury Laboratory	**Checked By : Mark Labelle**

Photograph 7

Mix 2 – GU/Fly ash - UCS Testing – 4.4 Mpa – 7 day

Photograph 8

Mix 2 – GU/Fly ash - UCS Testing – 4.4 Mpa – 7 day

ATTACHMENT B - PHOTOGRAPHS	Project : 18101723 – Stage 0 & 1
Golder Associates Ltd.	Date : September 2018
Client : CNL – Grout Testing	Inputted By : Vicki Newman
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 9

Mix 3 – GU/BFS - UCS Testing – 13.0 Mpa – 7 day

Photograph 10

Mix 3 – GU/BFS - UCS Testing – 13.0 Mpa – 7 day

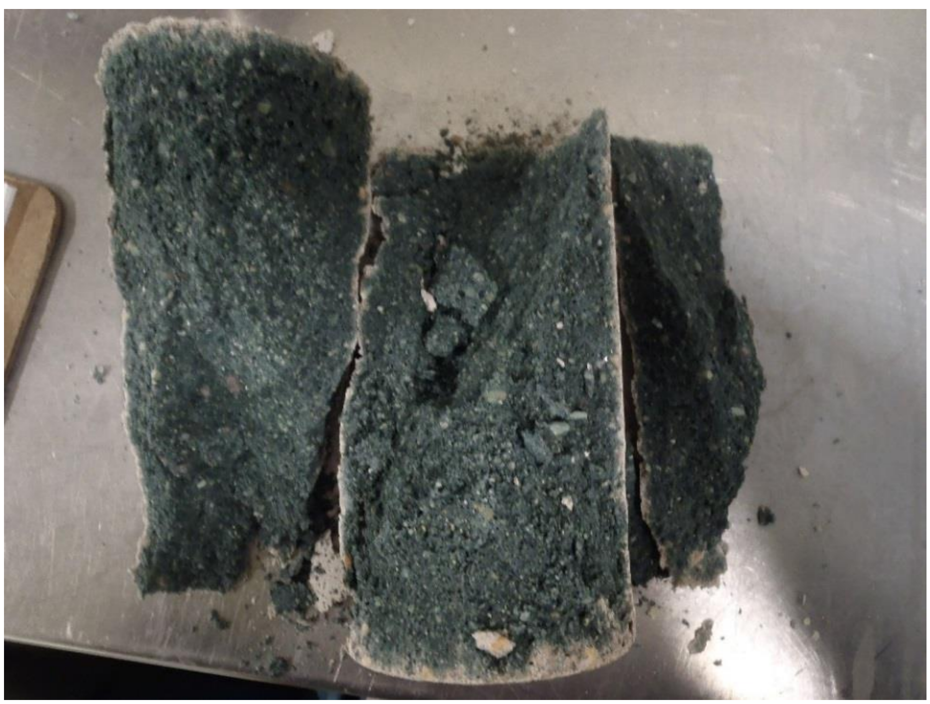
ATTACHMENT B - PHOTOGRAPHS	Project : 18101723 – Stage 0 & 1
Golder Associates Ltd.	Date : October 2018
Client : CNL – Grout Testing	Inputted By : Vicki Newman
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 11

Mix 4 – GU/BFS – Sand Only - UCS Testing – 13.4 Mpa – 7 day

Photograph 12

Mix 4 – GU/BFS – Sand Only - UCS Testing – 13.4 Mpa – 7 day



END OF ATTACHMENT B - OBSERVATION PHOTOS

GOLDER
MEMBER OF WSP

TECHNICAL MEMORANDUM

DATE May 12, 2022 — 18101723 Rev 1

TO Nohman Ishfaq
Canadian Nuclear Laboratories

CC Victoria Newman

FROM Sue Longo; Bruno Mandl — **EMAIL Sue.Longo@wsp.com**

CNL PO 526830 - STAGE 2 BULK FILL TESTING SUMMARY

1.0 INTRODUCTION

Canadian Nuclear Laboratories (CNL) has retained Golder Associates Ltd. (Golder) to carry out a laboratory testing program to confirm the grout recipes for backfilling of the Whiteshell Reactor 1 (WR-1) facility. Two formulations were recommended/provided based on the Savannah River National Laboratory (SRNL) formulations. The two formulations are: one for regular Bulk Fill and one for a pH 10 Fill (Low pH Fill).

Based on the results of Golder's current work for CNL at the Nuclear Power Demonstration (NPD) facility, the SRNL recipes recommended in the RFP will be modified to suit local conditions, available materials, and to minimize the cost impact of the performance criteria. There are several grout property requirements as stated by SRNL, that are very restrictive and may or may not be necessary depending on the backfill methodology chosen.

The overall scope of work is to develop suitable recipes for the site-specific application at WR-1. The recipes need to meet two sets of criteria related to:

- Fresh properties e.g., water bleed, slump flow, etc.
- Cured properties e.g., strength, hydraulic conductivity, etc.

A complete list of the evaluation criteria can be found in the CNL RFP# 725818 "Technical Scope of Work (TSW), WLDP-26000-TSW-002 Rev 2" Appendix B titled "Test Plan by Savannah River National Laboratory – Flowable Non-Structural Grout", "Table 1 - Fresh Property Requirements for WR-1 ISD grouts", and "Table 2 - Cured Property Requirements for WR-1 ISD grouts". It should be noted that the testing program associated with Low pH grout was removed, and a testing program utilizing sulphate resistant cement (HS) was added at the request of CNL.

Sulphate resistant cement (HS) grout testing was added based on the fact that the hydrogeological model indicated the presence of potentially high sulphate concentrations in the ground water in the area of the WR-1 reactor, and the information provided by CNL that sulphate resistant structural concrete had been used in the building's structure that could be subjected to the sulphate containing ground water.

2.0 STAGE 2 TESTING

2.1 Stage 2 - Recipe Development Task

The Stage 2 Bulk Fill Recipes for Type HS and Type GU binders are presented in Table 1 and the results are presented in Tables 2 to 4. Photographs associated with the testing program are presented in Attachment A.

Table 1: Stage 2 - Bulk Fill Recipe

Materials	Bulk Fill (GU) (water to binder ratio of 0.60)	Bulk Fill (HS) (water to binder ratio of 0.60)
Type GU Cement (kg/m^3) (ASTM C595)	89	---
Type HS Cement (kg/m^3) (ASTM C595)	---	89
Fly Ash Class F (kg/m^3) (ASTM C618)	297	297
Sand (quartz) (ASTM C33) (kg/m^3)	1570	1570
Water (ASTM C94) (kg/m^3)	232	232
SIKA Visco Crete 2100 (ASTM C494 B & F) (kg/m^3)	1.77	1.49
Diutan Gum based VMA (ASTM C494) (kg/m^3)	0.26	0.26

Table 2: Stage 2 - Screening - Fresh Properties - Bulk Fill

Test (Fresh Properties)		Criteria Target	Bulk Fill (GU/Fly ash)	Bulk Fill (HS/Fly ash)
pH - ASTM D4972 – after mixing for 30 min.	Initial (1)	<13.5	12.4	12.0
	1 hr (2)		12.4	12.3
	1 hr – mixed (3)		12.6	12.5
24 Hour Water Bleed – ASTM C232	ASTM	0% (vol)	0%	0%
	24 Hr Test		0%	0%
Slump – ASTM C1611		N/A (4)	273 mm	286 mm
Slump Flow – ASTM C1611		660 ±51 mm	625 mm	650 mm
Visual Stability Index (VSI) - ASTM C1611		0	0	0
Initial Set time - ASTM C403		2-12 hrs	9.5 hrs	14.5 hrs (5)
Air Content – ASTM C231		<8% vol	3.6%	4.0%
Segregation – ACI 237R – (ASTM C1610)		None	0%	0%
Static Work Time – (ASTM D6103)	0 min	>30 min	302 mm	247 mm
	30 min		271 mm	223 mm
	45 min		263 mm	213 mm
Dynamic Work Time – (ASTM C1611)	0 min	>60 min	302 mm	285 mm
	30 min		280 mm	265 mm
	60 min		283 mm	265 mm

Notes:

All pH tests were conducted in accordance with ASTM D4972

(1) - Wet mixture and 10ml of distilled water added prior to testing

(2) - pH of supernatant - sample was allowed to sit undisturbed

(3) - pH of re-homogenized sample

(4) – conducted for information purpose only

(5) – result was discussed with CNL, and it was agreed that the grout placement sequence and scheduling thereof, could be adjusted to suit

As indicated, pH testing was conducted according - ASTM D4972. The ASTM D4972 test method is specific to the testing procedure to be used and states:

- When making measurements with the pH electrode, place the electrode into the partially settled suspension to mitigate the suspension effect.
- For both methods (distilled water and calcium chloride solution), begin with an air-dried soil, weigh out approximately 10 g of air-dried soil. Place in a glass container and add approximately 10 ml of water or calcium chloride solution. Mix thoroughly and let stand for 1 hour.

An unconfined compressive strength (UCS) program was carried out to assess the Bulk Fill strength using 76 x 152 mm cylinders. The cylinders were cured in a high humidity environment maintained at 20 to 25°C. Three cylinders were cast per curing period and the UCS results of the three cylinders were averaged. The averaged test results are presented in Table 3.

Table 3: Stage 2 Cured Properties - Bulk Fill – UCS Testing

Test (Cured Properties)		Criteria Target	Bulk Fill (GU/Fly ash)	Bulk Fill (HS/Fly ash)
UCS - ASTM D2166 / C39	7 day	>0.34 MPa	3.3 MPa	2.9 MPa
	14 day	N/A (1)	6.8 MPa	5.3 MPa
	28 day	>3.4 MPa	15.7 MPa	9.5 MPa
	90 day	>4.8 MPa	23.7 MPa	20.5 MPa
	180 day (1)	N/A (1)	23.9 MPa	23.6 MPa
	365 day (1)	N/A (1)	23.6 MPa	26.5 MPa

Note (1)– Not applicable and not stipulated by SRNL

Table 4 presents the results of other cured properties of 28 day cured Bulk Fill.

Table 4: Stage 2 Cured Properties - Bulk Fill – Other Metrics

Test	Criteria Target	Bulk Fill (GU/Fly ash)	Bulk Fill (HS/Fly ash)
Effective Porosity – (ASTM C642)	≤ 0.4 vol %	0.248 vol. %	0.248 vol. %
Dry bulk density – (ASTM C642)	2100 kg/m^3	2007 kg/m^3	2007 kg/m^3
Hydraulic Conductivity – (ASTM D5084 – Method A)	<0.03 meters/yr.	0.0004 m/yr.	0.0002 m/yr.

3.0 ANALYSIS

Portland cements are comprised of four main chemical components: Tricalcium silicate (C_3S), Dicalcium silicate (C_2S), Tricalcium aluminate (C_3A) and Tetracalcium aluminoferrite (Ca_4A). Table 5 shows the recommended chemical requirements of the two Portland cements from CSA A3001.

Table 5: Recommended Chemical Requirement of GU and HS Cement per CSA A3001.

Property, Maximum %	GU Cement (%)	HS Cement (%)
Loss of ignition	3.0	3.0
Insoluble residue	1.5	0.75
Sulphur trioxide (SO_3) when $C_3A \leq 8\%$	3.0	2.5
Magnesium oxide (MgO)	5.0	5.0
C_3A content (typical)	8-12	5

When water is introduced to cement, the first component that participates in hydration is C_3A. Hence, one of the main components that controls the setting time of a mixture is the C_3A content of the cement. On the other hand, the hydrated phases of C_3A are susceptible to sulphate attack; therefore, the amount of C_3A in Type HS cement must be limited to provide sulphate resistance. Even though no limit for C_3A is specified for GU cement, typically GU cements have 8-12% C_3A content. The longer setting time and lower early compressive strength of the grout mix made with HS cement as compared to the one made with GU cement can be attributed to the lower C_3A content of the HS cement. Theoretically, the lower C_3A content of the HS cement should not affect the ultimate compressive strength of the grout mix; however, lower 7 to 90-day UCS results were obtained for the grout mix made with HS cement. The lower value was still significantly above the target compressive strength. Since the reactions in the HS cement take place at a lower rate, the hydration products could have formed and orientated in a more organized manner causing a denser cemented grout which potentially can explain the reduced hydraulic conductivity measured for the HS grout mix.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Stage 2 testing program meets the requirements outlined in the SRNL recipes for Bulk Fill with the exception of the Initial Set Time for the Bulk Fill (HS/Fly ash), and agreed to be acceptable by CNL, and the Dry Bulk Density. As stated in the SRNL Cured Property Requirements (Table 2) Document WLDP-26000-TSW-002 Page B-4 Rev.2, the target value for dry bulk density is 2100 kg/m^3. It is suspected that the stated SRNL value reflects a recipe containing both sand and aggregate; however, the Golder tested Bulk Fill recipes do not contain aggregate since it was determined that the fresh and cured property criteria targets could be attained through the use of sand alone. With this in mind the achieved test results for Dry Bulk Density of 2007 kg/m^3 have been deemed acceptable as tested, by CNL.

Therefore, both the GU and HS cement samples met the requirements of the fresh and cured properties testing program.

5.0 STUDY LIMITATIONS

This report was prepared for the exclusive use of Canadian Nuclear Laboratories (CNL) on the test program to confirm the grout recipes for backfilling of the Whiteshell facility. The report, which specifically includes all tables, figures and appendices, is based on measurements and observations made and data and information collected during the laboratory studies conducted by Golder Associates Ltd. (Golder) for CNL. The test results are based solely on the ambient conditions of the laboratory at the time the measurements and tests were conducted.

The services performed, as described in this report, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The sample(s) provided for the tests are assumed to be representative of material found at the site. The test data given herein pertains to the sample(s) provided and may not be applicable to material from other production periods or zones. Assessment of the sample environmental conditions and possible hazards associated with the material composition is based on the results of chemical analysis of samples which are possibly from a limited number of locations. However, it is never possible, even with exhaustive sampling and testing, to dismiss the possibility that part of the material characteristics may remain undetected. The results found from the tests may not be reproducible under the field conditions.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by CNL, communications between Golder and CNL, and to any other reports prepared by Golder for CNL relative to the specific site described in the report, tables, drawings, figures and appendices. ***In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.***

No other party may use or rely on this report or any portion thereof without Golder's express written consent. Any use, which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, Golder should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

6.0 CLOSURE

If there are any questions regarding this report, please do not hesitate to contact the undersigned.

Golder Associates Ltd.

Bruno Mandl, P.Eng.
Lead Engineer

Sue Longo, P.Eng., MBA
Principal - Project Manager

BM/SL/mc

Attachments:

Attachment A - Photographs

https://golderassociates.sharepoint.com/sites/26836g/technical work/rfi017 response to cnsc comments on testing/stage 2 memo/18101723 whiteshell tm stage 2 april 29, 2022 rev1.docx

ATTACHMENT A

Photographs

ATTACHMENT A - PHOTOGRAPHS	**Project : 18101723 - Stage 2**
Golder Associates Ltd.	**Date : November 2018**
Client : CNL – Bulk Fill Grout Testing	**Inputted By : Nick Desormiers**
Site Name : Sudbury Laboratory	**Checked By : Mark Labelle**

Photograph 1

Stage 2
Bulk Fill – GU/Flyash
– Slump Flow
– 622.5mm

Photograph 2

Stage 2
Bulk Fill – GU/Flyash
– Slump Flow
– 622.5mm

ATTACHMENT A - PHOTOGRAPHS	Project : 18101723 - Stage 2
Golder Associates Ltd.	Date : November 2018
Client : CNL – Bulk Fill Grout Testing	Inputted By : Matthew Johnston
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 3

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 3.3 MPa
– 7 days

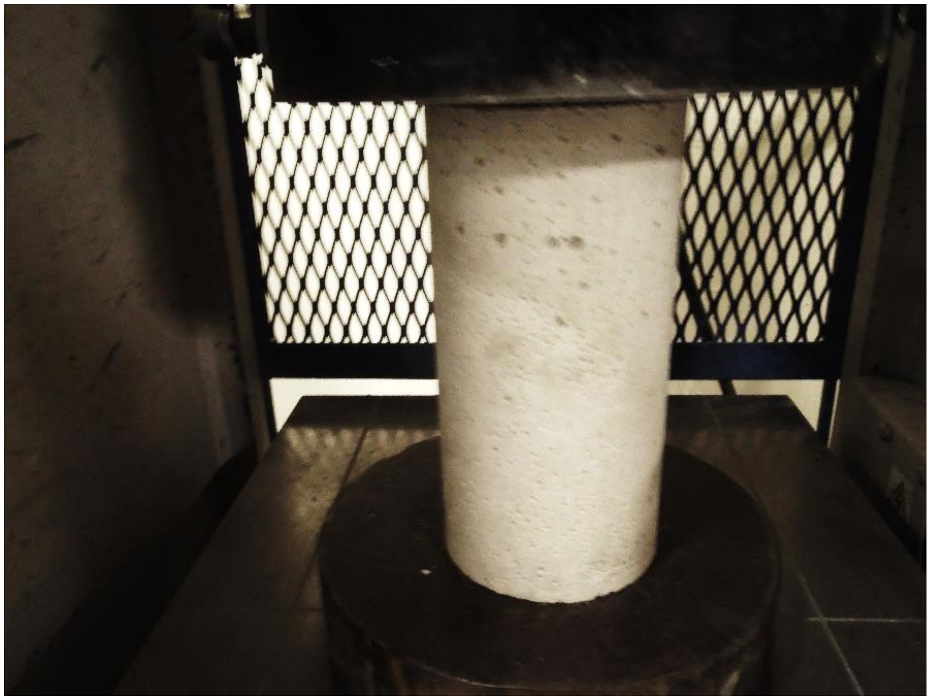
Photograph 4

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 3.3 MPa
– 7 days

ATTACHMENT A - PHOTOGRAPHS	Project : 18101723 - Stage 2
Golder Associates Ltd.	Date : December 2018
Client : CNL – Bulk Fill Grout Testing	Inputted By : Matthew Johnston
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 5

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 15.7 MPa
– 28 days



Photograph 6

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 15.7 MPa
– 28 days

ATTACHMENT A - PHOTOGRAPHS	Project : 18101723 - Stage 2
Golder Associates Ltd.	Date : February 2019
Client : CNL – Bulk Fill Grout Testing	Inputted By : Matthew Johnston
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 7

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 23.7 MPa
– 90 days

Photograph 8

Stage 2
Bulk Fill – GU/Flyash
– UCS Testing
– 23.7 MPa
– 90 days

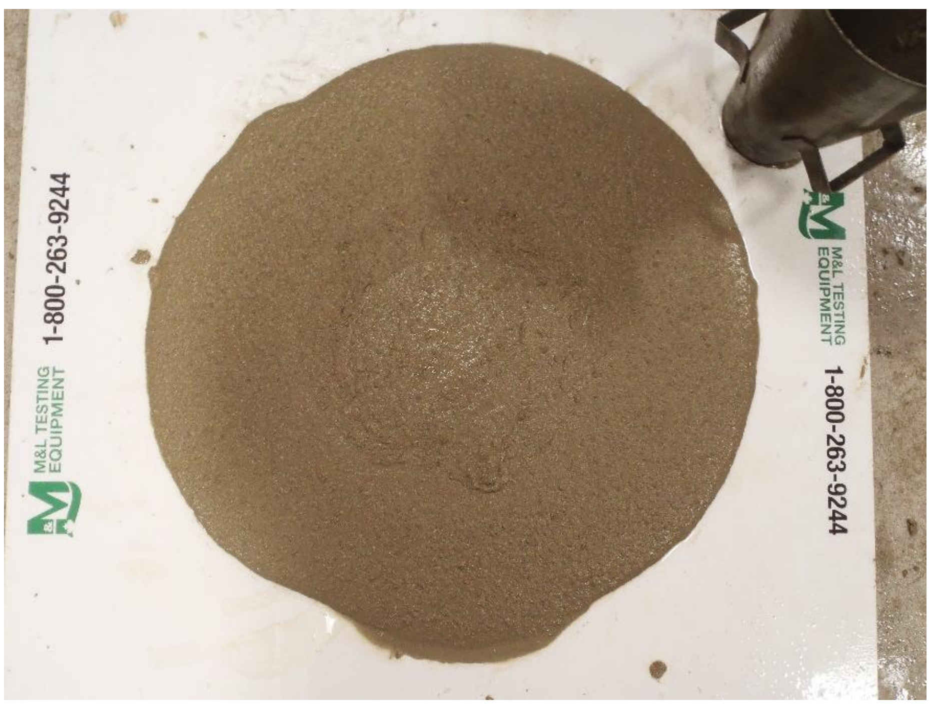
ATTACHMENT A - PHOTOGRAPHS	Project : 18101723 - Stage 2
Golder Associates Ltd.	Date : January 2019
Client : CNL – Bulk Fill Grout Testing	Inputted By : Nick Desormiers
Site Name : Sudbury Laboratory	Checked By : Mark Labelle

Photograph 9

Stage 2
Bulk Fill – HS/Flyash
– Slump Flow
– 650mm

Photograph 10

Stage 2
Bulk Fill – HS/Flyash
– Slump Flow
– 650mm



ATTACHMENT A - PHOTOGRAPHS	**Project : 18101723 - Stage 2**
Golder Associates Ltd.	**Date : January 2019**
Client : CNL – Bulk Fill Grout Testing	**Inputted By : Matthew Johnston**
Site Name : Sudbury Laboratory	**Checked By : Mark Labelle**

Photograph 11

Stage 2
Bulk Fill – HS/Flyash
– UCS Testing
– 2.9 MPa
– 7 days

Photograph 12

Stage 2
Bulk Fill – HS/Flyash
– UCS Testing
– 2.9 MPa
– 7 days

ATTACHMENT A - PHOTOGRAPHS	**Project : 18101723 - Stage 2**
Golder Associates Ltd.	**Date : February 2019**
Client : CNL – Bulk Fill Grout Testing	**Inputted By : Kim Callens**
Site Name : Sudbury Laboratory	**Checked By : Mark Labelle**

Photograph 11

Stage 2
Bulk Fill – HS/Flyash
– UCS Testing
– 9.5 MPa
– 28 days

Photograph 12

Stage 2
Bulk Fill – HS/Flyash
– UCS Testing
– 9.5 MPa
– 28 days

END OF ATTACHMENT A - OBSERVATION PHOTOS

GOLDER

APPENDIX B

Golder Laboratory QA

Golder Associates Ltd.
pH of soils test - ASTM 4972

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11, 2019

		Status	Reviewer	Date Complete
Data Entry		**Complete**	**ND**	**2019-01-11**
Data Review	**1st Review**	**Complete**	**VN**	**2019-01-15**
	2nd Review	**Complete**	**ML**	**2019-01-16**

Method A - Read on pH meter

pH Meter: Oakton 110

Date Standards Changed: 2018-12-20

Check Standards

Certified Value @ 25°C	4.01	7.00	10.01	12.46
Temperature	21.8	21.3	21.3	21.6
Corrected Value (temp.)	4.00	7.01	10.05	12.60
As Found Value	3.94			
Standardized Value	4.03	7.02	10.03	12.59

Results

Sample	pH in Distilled Water (1:1 (w:s) ratio) initial	pH in Distilled Water (1:1 (w:s) ratio) after 1 hr	pH in Distilled Water (1:1 (w:s) ratio) after 1 hr mixing	Temp (°C)
18101723 Stage 2 - Mix 2	12.04	12.23	12.49	20.6

Sample	pH in Calcium Chloride (0.01M) initial	pH in Calcium Chloride (0.01M) after 1 hr	Temp (°C)
18101723 Stage 2 - Mix 2	10.66	11.03	20.6

Golder Associates Ltd.
24 Hour Water Bleed

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11, 2019
Sample:	18101723 - Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry		Complete	ND	2019-01-11
Data Review	1st Review	Complete	VN	2019-01-14
	2nd Review	Complete	ML	2019-01-16

Mix Number:	**Stage 2 - Mix 2**				
Exposed Sample Area (CM²)	**NA**	**Tare**	**NA**	**Mass of water in sample (g)**	0
Total Mass of batch (g)		**Tare + sample**	**NA**		
Mass of water in batch (g)		**Sample mass(g)**	**#VALUE!**		

Time (minutes)	Acc. Water Bleed (mL)	Rate of bleeding (mL/min)	Volume of bleed per unit area of surface (mL/cm³)
10	0	0.00	#VALUE!
20	0	0.00	#VALUE!
30	0	0.00	#VALUE!
40	0	0.00	#VALUE!
70	0	0.00	#VALUE!
100	0	0.00	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!
		#DIV/0!	#VALUE!

Accumulated Bleed %	#DIV/0!
Density of water extracted =	#DIV/0!
Mass of Water Extracted (g)=	

Minutes	Acc. Water Bleed (mL)	Rate of Bleeding (mL/Min)	Volume of bleed per unit area of surface (mL/cm³)
1440		0.00	#VALUE!

Accumulated Bleed %	#DIV/0!
Density of water extracted =	1.006
Mass of Water Extracted (g)=	0

Golder Associates Ltd.

Slump Flow - ASTM C1611

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11, 2019
Sample:	18101723 Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry		**Complete**	**ND**	**2019-01-11**
Data Review	**1st Review**	**Complete**	**VN**	**2019-01-14**
	2nd Review	**Complete**	**ML**	**2019-01-16**

Mix Number:		Stage 2 - Mix 2
Diamter(mm) (d1)	=	650
Diamter(mm) (d2)	=	650
50mm Tolerance	=	0
Slump Flow(mm)		650
VSI (Visual Stability Index)		0
T_{50} Value		0.5
Actual Slump (inches)		11 1/4

`

Notes:

Golder Associates Ltd.
Screw Vikat Test

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11, 2019
Sample:	18101723 Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry		Complete	KC	2019-01-14
Data Review	1st Review	Complete	VN	2019-01-16
	2nd Review	Complete	ML	2019-01-18

Time (Clock)	Time (elapsed Hours)	Depth (mm)	Notes
10:00:00	0	14	full screw depth
11:30:00	1.5	14	full screw depth
13:30:00	3.50	14	full screw depth
14:00:00	4.00	14	full screw depth
15:00:00	5.00	14	full screw depth
16:15:00	6.25	14	full screw depth
17:30:00	7.50	14	full screw depth
18:30:00	8.50	14	full screw depth
22:00:00	12.00	2	
22:30:00	12.50	1	top is "springy"
23:00:00	13.00	1	top is "springy"
0:30:00	14.50	0	

Golder Associates Ltd.

Segregation/Stability - ASTM ACI 237R Coulmn Test

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11. 2019
Sample:	18101723 Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry		**Complete**	**ND**	**2019-01-11**
Data Review	**1st Review**	**Complete**	**VN**	**2019-01-14**
	2nd Review	**Complete**	**ML**	**2019-01-16**

CA_T is the mass of coarse aggregate in the top section of the column
CA_B is the mass of coarse aggregate in the Bottom section of the column

	Mass (g)
CA_T	90.98
CA_B	86.61

Segregation percent	-4.92

Air Content - ASTM C231

Air Content	4.00%

Golder Associates Ltd.
Static/Dynamic Working Time

Client:	CNL - Whiteshell
Project Number:	18101723
Date:	January 11, 2019
Sample:	18101723 Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry		**Complete**	**ND**	**2019-01-11**
Data Review	**1st Review**	**Complete**	**VN**	**2019-01-14**
	2nd Review	**Complete**	**ML**	**2019-01-16**

Static Working Time

Time	Diameter 1 (cm)	Diameter 2 (cm)	Average (cm)
0 minutes	25	24.5	24.75
15 minutes	22.5	22.5	22.5
30 minutes	22.5	22	22.25
45 minutes	21.5	21	21.25
60 minutes	21	21	21

Dynamic Working Time

Time	Diameter 1 (cm)	Diameter 2 (cm)	Average (cm)
0 minutes	28	29	28.5
30 minutes	26	27	26.5
60 minutes	27	26	26.5
75 minutes	26	26	26

Golder Associates Ltd.
UCS Testing Form

Client:	CNL Whiteshell
Project Number:	18101723
Date:	2018-11-29
Sample:	18101723 Stage 2 - Mix 2

		Status	Reviewer	Date Complete
Data Entry				
Data Review		**Complete**	**MJ**	**2019-07-15**
	1st Review	**Complete**	**VN**	**2019-07-17**
	2nd Review	**Complete**	**ML**	**2019-07-19**

Cylinder Size: 3" x 6" (76 x 152 mm)
Mix Number: Stage 2- Mix 2
Binder Type: 18101723 Client HS/ Client Flyash
Sample Type: 100% 18101723 fine aggregate
Mix Type: **100% 18101723 Fine Aggregate, Client HS/Client Flyash**
Pressure Units: (kPa)

Cylinder No.	Average Density (kg/m3)	***Load* (kN) at Curing Time (days)**				
		7	**14**	**28**	**90**	**180**
1		14.42	25.53	43.57	95.32	
2	2180	13.35	24.94	44.69	91.18	110.88
3		11.57	23.66	42.80	94.72	109.94
Average *Strength*	**(kPa)**	2884	5288	9493	20495	23605
Average *Strength*	**(PSI)**	418.3	767.0	1376.8	2972.6	3423.6

	Weight	*Height (m)*	*Diameter (m)*	*Fracture Type*
7	1.5154	0.151	0.076	Shear
	1.5114	0.151	0.076	Cone and Split
	1.5128	0.151	0.076	Cone and Split
14	1.5064	0.151	0.077	Cone
	1.5114	0.151	0.077	Cone
	1.5108	0.151	0.077	Cone
28	1.5152	0.150	0.077	Cone
	1.5158	0.152	0.077	Cone
	1.5208	0.151	0.076	Cone
90	1.5245	0.150	0.076	Cone
	1.5203	0.151	0.076	Cone
	1.5221	0.151	0.077	Cone and Split
180				
	1.5310	0.151	0.077	Cone
	1.5212	0.151	0.077	Cone

ASTM C642
Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

GOLDER

Project: CNL_WR-1 Grout Formulation_MN
Project #: 18101723
Date: February 28, 2019

Aborption after immersion	11.3%
Aborption after immersion and Boiling	11.6%
Bulk density dry	2.01 Mg/m^3
Bulk density after immersion	2.23 Mg/m^3
Bulk denisty after immersion and boiling	2.24 Mg/m^3
Apparent density	2.62 Mg/m^3
Volume of permeable voids	23.4%
Absolute density of solid part of specimen (assumed)	2.67 Mg/m^3
Total Void Volume	24.8%

Remarks: ______________________

Issued by: [signature]
Tina Gauthier, Laboratory Manager

HYDRAULIC CONDUCTIVITY TEST

ASTM D 5084 (CONSTANT HEAD - Method A)

SAMPLE IDENTIFICATION

PROJECT NUMBER	18101723	SAMPLE	Stage 2 Mix2 28 days
PROJECT TITLE	CNL_WR-1 _MN	SAMPLE DEPTH, m	-
BOREHOLE NUMBER	-	DATE	February 27, 2019

SPECIMEN PROPERTIES AND DIMENSIONS (INITIAL)

SAMPLE HEIGHT, cm	6.43	UNIT WEIGHT, kN/m^3	21.07
SAMPLE DIAMETER, cm	5.21	DRY UNIT WEIGHT, kN/m^3	18.88
SAMPLE AREA, cm^2	21.35	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	137.29	VOLUME OF SOLIDS, cm^3	97.89
TOTAL MASS, g	294.97	VOLUME OF VOIDS, cm^3	39.40
DRY MASS, g	264.31	VOID RATIO	0.40
WATER CONTENT, %	11.6		

SATURATION STAGE

CELL PRESSURE, kPa	210.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	200.00	DURATION, min	2,532
BACK PRESSURE, kPa	200.00	B COEFFICIENT	0.96

CONSOLIDATION STAGE

CELL PRESSURE, kPa	210.00	EFFECTIVE CONSOLIDATION STRESS, kPa	10
HEAD PRESSURE, kPa	200.00	DURATION, min	1,482
BACK PRESSURE, kPa	200.00	VOLUME CHANGE, cm^3	1.70
		DRAINAGE	Top and Bottom

SPECIMEN PROPERTIES AND DIMENSIONS (AFTER CONSOLIDATION)

SAMPLE HEIGHT, cm	6.40	SAMPLE AREA, cm^2	21.18
SAMPLE DIAMETER, cm	5.19	SAMPLE VOLUME, cm^3	135.60

HYDRAULIC CONDUCTIVITY STAGE

CELL PRESSURE, kPa	330	EFFECTIVE CONSOLIDATION STRESS, kPa	100
HEAD PRESSURE, kPa	230	DURATION, min	16062
BACK PRESSURE, kPa	200	HYDRAULIC GRADIENT, i	48

SPECIMEN PROPERTIES AND DIMENSIONS (FINAL)

SAMPLE HEIGHT, cm	6.40	UNIT WEIGHT, kN/m^3	-
SAMPLE DIAMETER, cm	5.19	DRY UNIT WEIGHT, kN/m^3	19.12
SAMPLE AREA, cm^2	21.18	SPECIFIC GRAVITY, assumed	2.70
SAMPLE VOLUME, cm^3	135.60	VOLUME OF SOLIDS, cm^3	97.89
TOTAL MASS, g	297.97	VOLUME OF VOIDS, cm^3	37.70
DRY MASS, g	264.31	VOID RATIO	0.39
WATER CONTENT, %	12.7		

TEST RESULTS

ELAPSED TIME TO STEADY STATE FLOW (min)	10353.0
DURATION OF STEADY STATE FLOW (min)	5709
INFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	0.3
OUTFLOW VOLUME UNDER STEADY STATE FLOW (cm^3)	0.2
INFLOW TO OUTFLOW RATIO	1.25
HYDRAULIC CONDUCTIVITY (INFLOW) (m/s)	7.21E-12
HYDRAULIC CONDUCTIVITY (OUTFLOW) (m/s)	5.77E-12
HYDRAULIC CONDUCTIVITY, K, m/s	6.49E-12
HYDRAULIC CONDUCTIVITY AT STANDARD TEMPERATURE, K_{20}, m/s	**6.05E-12**

NOTES:

Effective consolidation stress assigned, by client.

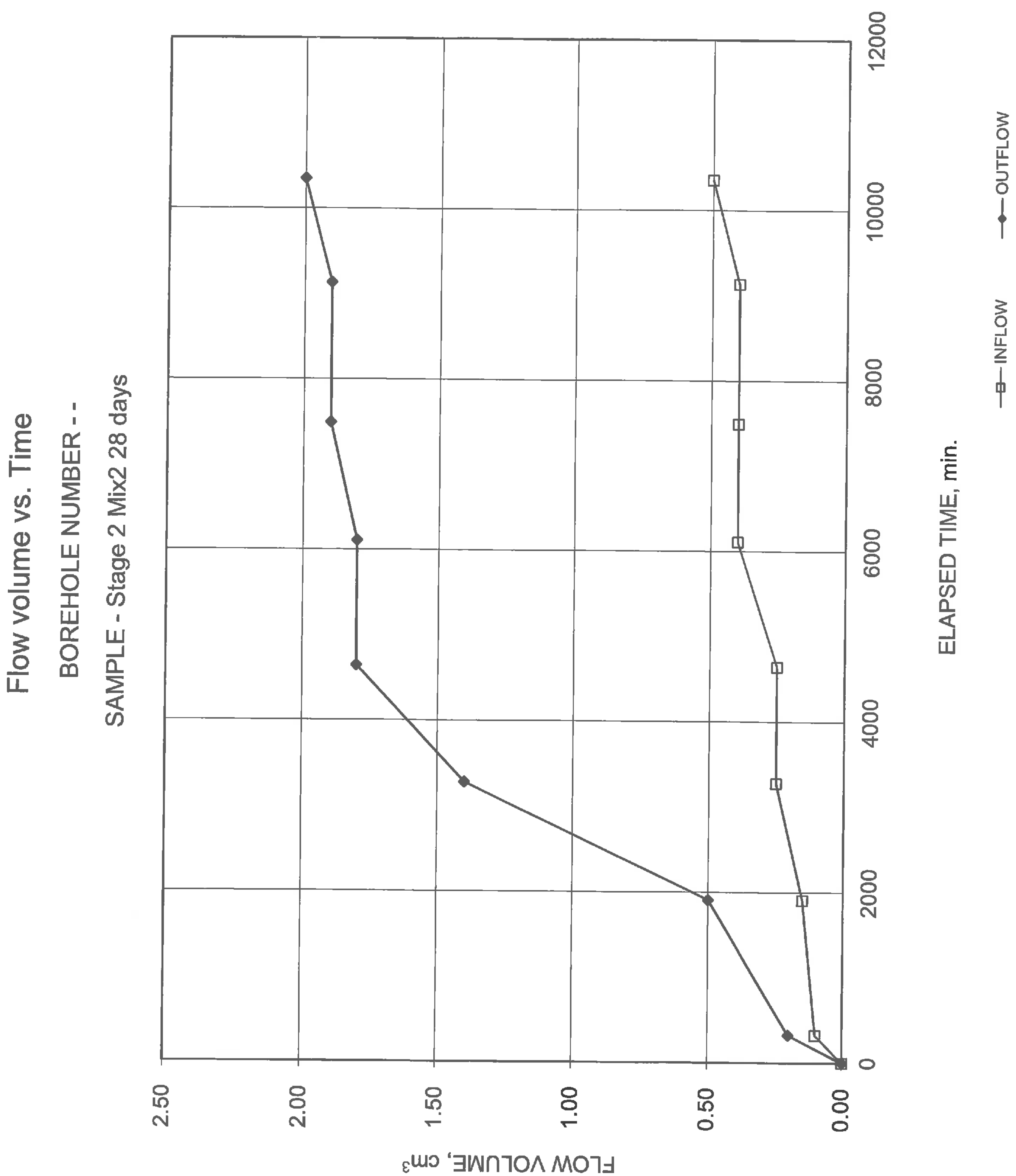
PERMEANT FLUID	Deaired tap water
AVERAGE TEST TEMPERATURE	23.0 °C

Prepared By: LH

Golder Associates

Checked By:MM

HYDRAULIC CONDUCTIVITY TEST ASTM D5084-METHOD A	Project title: CNL_WR-1 _MN



Project number : 18101723
Prepared by : LH

Golder Associates

Checked by : MM

GOLDER

JOB SAFETY ANALYSIS WORKSHEET

Work Safe Home Safe

Location: PID Lab, Sudbury, ON **Testing Equipment: Vicat Meter**

JOB STEP NO.	JOB STEPS List the steps required to perform the task. (in the sequence they are actually performed)	POTENTIAL HAZARD List the potential hazards associated with each job step that could cause Illness / injury when the job step is performed.	REQUIRED HAZARD CONTROL(S) List the control measures required to eliminate or minimize the risk of illness / injury in each job step.
1	Refer to ASTM C191 – Time of Setting for the entire testing procedure. Pre-inspect Vicat Meter, inspect locking bolts, lock ring, needle, plunger bar and entire base for excessive wear or damage.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
2.	Once sample is obtained and ready to be tested: determine if 50mm needle or 10mm bolt will be used for testing and screw into plunger bar counterclockwise.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
3.	Place testing sample directly under needle / bolt. Plunger bar may have to be raised. Turn locking bolt (on right side of meter) counterclockwise to loosen (always hold onto plunger bar while adjusting height)	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
4.	Lower needle / bolt until it is just touching the surface of the sample.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
5.	Set measuring guide marker to 0 (red#) by turning locking bolt (on left side of meter) counterclockwise to loosen. Once marker is set to 0 (red #) turn locking bolt clockwise to lock in place.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
6.	Set lock ring (around plunger bar) to either 50mm or 10.3mm (dependent on needle or bolt use). Use screw driver with socket attachment to loosen or tighten ring. The lock ring stops the plunger bar from dropping past the desired level.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training

GOLDER

Work Safe Home Safe

JOB SAFETY ANALYSIS WORKSHEET

Location: PID Lab, Sudbury, ON **Testing Equipment: Vicat Meter**

JOB STEP NO.	JOB STEPS List the steps required to perform the task. (in the sequence they are actually performed)	POTENTIAL HAZARD List the potential hazards associated with each job step that could cause Illness / injury when the job step is performed.	REQUIRED HAZARD CONTROL(S) List the control measures required to eliminate or minimize the risk of illness / injury in each job step.
7.	Release plunger bar by turning locking bolt (on right side of meter) counterclockwise.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training
8.	Read and record insertion depth off the measuring marker. Continue taking measurements periodically, following ASTM C191 – Time of Setting procedure.	• Pinch points	• Wear appropriate personal protective equipment (PPE) • Training

Employee Signature ______________________________ Date ________________

Lab Manager Signature ______________________________ Date ________________

Please provide a list of Personal Protective Equipment required for this job in the box below.

Work gloves, disposable Nitrile gloves, Safety glasses, Steel toed safety boots or shoes, lab coat.

This electronic document will automatically expand to allow space for extra rows of information. Make sure to print enough sheets when using paper copies.

GOLDER

STANDARD WORK PROCEDURE:

COMPRESSION LOAD FRAME

SWP Number: 2 **Version Number & Date**: 1.1 **Superseded Version Number & Date (if applicable):** 1.0	**Effective Date: 06.01.2009** **Review Date: 02.26.2018**

Revision / Reviewed by:

Name: Alex McRobbie Position: Lab Technician ______________ Signature Date

Approved by:

Name: Mark Labelle Position: Lab Manager ______________ Signature Date

TITLE

HM-2800 Series Master Loader Compression Testing Frame

BACKGROUND

The HM-2800 Series Master Loader Compression Testing Frame is designed for applications requiring multi-purpose loading systems. It is ideal for road construction projects, educational institutions, and start-up laboratories. Its modular design minimizes initial costs and allows easy upgrades as desired. The HM-2800 Series Digital Master Loader has been designed for testing that complies with ASTM D1883, D2850, D2166, D4767, and D1559 and AASHTO T193, T296, T297, T208, T245, and T246 standards. The HM-3000 Series Digital Master Loader has been designed to provide all the basic functions required to carry out soil and Marshall testing in a single instrument.

PURPOSE

This procedure covers the safe operation and maintenance of the HM-2800 Series Master Loader Compression Testing Frame.

1. SAFETY

1.1. SAFETY WARNING

Operators should take care to operate this machine *under* the maximum load restrictions (50kN). (Check attached load cell rating for maximum configured load). The HM-2800 Series Master Loader Compression Testing Frame is programmed at the factory to provide safety shutdown if the upper or lower maximum travel is exceeded.

ENGINEERING CONTROLS

- Safety shutdown if the upper or lower maximum travel is exceeded
- Emergency stop button

ADMINISTRATIVE CONTROLS

- Standard Work Procedures
- Posted Safe Operation Guidelines
- Hands On Training for Proper Use
- Routine Task Observations
- Safety Shares

REQUIRED PERSONAL PROTECTIVE EQUIPMENT

- Eye protection
- Approved Steel Toe Safety Shoes
- Lab Coats
- Work Gloves

1.2. ELECTRICAL SAFETY

Electrical Warnings

Typically, there is no reason for the operator to open the machine. However, if the customer's engineers attempt to change settings to the circuit board connected to the back panel, the machine must always be unplugged before this operation. Unplugging the internal connection to the back-panel circuit board while the machine is under power will result in permanent damage to the circuit board.

Hazards: Contact with electricity

- Never modify plug in any way and ensure plug prongs are in good condition.
- Do not circumvent grounding by use of adapters or modified extension cords.
- Do not abuse the power cord; never use the cord for carrying, pulling or unplugging the unit.
- Avoid body contact with grounded surfaces (pipes) as this increases risk of electrical shock if ground on unit becomes faulty.

- Keep cord away from heat, oil, sharp objects or moving parts
- Do not use the HM-2800 Series Master Loader Compression Testing Frame if power cord is damaged
- Do not use the HM-2800 Series Master Loader Compression Testing Frame if the switch does not turn it on and off
- Ensure that plug matches the power outlet
- Do not operate the HM-2800 Series Master Loader Compression Testing Frame in explosive atmospheres, such as in the presence of flammable liquids, gases or dust
- Only use recommended extension cords (check the operator's manual)

1.3. PERSONAL SAFETY

Hazards (caught in, caught on, pinch points):

- Do not wear loose clothing or jewellery
- Wear PPE as outlined in Section 1.3
- Tie back long hair
- Keep clothing and gloves away from moving parts
- Always perform pre-operational inspections, looking for binding of moving parts, stressed welds, breakage of parts and any other condition that may prevent the proper operation of the unit
- Notify supervisor if the HM-2800 Series Master Loader Compression Testing Frame is damaged or misaligned
- Alert bystanders prior to operating the HM-2800 Series Master Loader Compression Testing Frame
- Only use the HM-2800 Series Master Loader Compression Testing Frame for its intended use
- Stay alert and attentive to surroundings
- Remove adjusting keys or wrench prior to start up
- Do not use if the HM-2800 Series Master Loader Compression Testing Frame appears to be damaged or misaligned
- Do not leave the HM-2800 Series Master Loader Compression Testing Frame running unattended
- Do not force the HM-2800 Series Master Loader Compression Testing Frame, take care to operate the unit **under** the maximum load restrictions (maximum load = 50kN)
- Do not over-reach, keep proper balance and footing at all times
- Never reach between platens when the lower platen is advancing.
- Ensure large adjustment nuts are secure to the head frame before running test.
- Ensure that adjustments made to the head frame are done so evenly and gradually by moving both adjustment nuts to avoid hanging up the head frame.
- Avoid pinch points between sample and upper platen.
- Ensure that the upper platen is freely moving prior to use.
- Observe and do not exceed load capacity of load cell attached to the load frame.

2. PROCEDURE

The following procedure must be followed to ensure the safe operation of the HM-3000 Series Master Loader Compression Testing Frame. The HM-3000 Series Master Loader Compression Testing Frame must only be operated by trained personnel.

1. Perform Pre-Operational Inspection, inform supervisor if non-conforming.

2. Ensure that all communication between computer, data logger and load frame has finished

3. Ensure proper load cell is attached to the unit (if you have to change the load cell, be aware that the upper platen is heavy when you are removing it) firmly support the platen while removing

4. Ensure that lower platen is lowered to allow placement of sample between upper and lower platens

5. Raise the sample until there is a slight gap (about 1/4") between the top of the sample and the upper platen by using the "Up" button

6. Check clearance of displacement transducer and adjust if necessary

7. Ensure that the speed is set to 2 mm/min by pressing the SPEED button. Press SETUP to return to the main screen

8. From the data logger press 'setup', then F2 (Run Test), then select type of test from menu (usually Unconfined Test)

9. Press the 'run' button on la and test will start

10. Data logger will automatically stop recording data once peak load has been reached and then 15% regression is reached.

11. Press the stop button on the load frame, then the stop / down button to lower the platen. Beware top of cylinder may stick to top platen, remove by hand once platen has been lowered.

12. Take pictures of broken cylinder. Record load and strain on test sheet.

13. Download data (from data logger) to computer and save on server.

14. If finished testing, turn off power switches on load frame and data logger.

3. MAINTENANCE

- To clean, wipe down the surfaces of upper and lower platen of the HM-2800 Series Master Loader Compression Testing Frame with damp cloth
- Have the HM-2800 Series Master Loader Compression Testing Frame serviced by qualified repair person
- If upper platen is stiff, apply oil

4. CALIBRATION BACKUP

Calibration backups are required following the yearly scheduled calibrations. The procedure is as follows;

1. Turn on load frame and start up HMTS software
2. Select ‘Tools’ → ‘Calibration’
3. Select ‘Device 1’ → ‘Channel 1’
4. Select ‘Export Calibration’ and send to;
5. N:\Admin_Paste\LAB\Lab Calibration Checks\Load Frame Calibration\‘Year’
6. Replace ‘Year’ with the current year of calibration. Save each file as the channel being stored (Channel1.CEF, Channel2.CEF…)
7. Repeat steps 1 to 4 for each channel

Calibrations can also be stored in the load frame to an internal backup storage location, the procedure is as follows;

1. Turn off load frame
2. Hold the F1 button, and turn load frame back on
3. Wait for beep, then release F1
4. Press F1 again and 4 quick beeps should follow

To restore these internal calibrations, in the event that the software is not functioning;

1. Turn the load frame off
2. Hold F3
3. Turn load frame back on, wait for 3 beeps
4. Calibrations should be restored

This procedure to restore calibrations can only be used when absolutely sure that the backed-up calibrations are current with the most recent calibration year. The software must be the first method for calibration since the file dates are available.

5. RELATED DOCUMENTATION

- The HM-2800 Series Master Loader Compression Testing Frame Instruction Manual
- Safe Operation Guidelines & Pre-Operational Checklist
- ASTM D2166

6. COMPRESSION LOAD FRAME

6.1. SAFE OPERATION GUIDELINES & PRE-OPERATIONAL CHECKLIST

- Listen for abnormal sounds during advance and retreat of lower platen.
- Inspect platen flexible boot for wear, tears, moisture and dirt.
- Check and clean area around load frame.
- Ensure all wiring is clear from moving parts and moisture.
- Check all wiring for damage, fraying or broken connectors
- Do not use equipment that is damaged or not working as it should be (inform supervisor)
- Use proper PPE
- Do not wear loose clothing or jewellery
- Keep hair, clothing and gloves away from moving parts
- Never reach between platens when the lower platen is advancing
- Keep hands and other body parts as well as foreign objects outside of “danger zone”
- Equipment must be serviced by qualified technicians (supplier or vendor)

Table 1 Maximum Capacity Ratings

Load Cell	Channel	Maximum Capacity
TS10K	1	50kN
TS2K	2	10kN
Displacement transducer	3	51 mm
HM-2300.005	4	2.5kN

WORK INSTRUCTIONS:

SAMPLE RECEIPT

WI Number: 5 **Version Number & Date**: V1.5 **Superseded Version Number & Date (if applicable):** V1.4	**Effective Date: 01.23.2008** **Review Date: 02.26.2018**

Revision / Reviewed by:

Name: Alex McRobbie Position: Lab Tech. Signature ____________ Date: ____________

Approved by:

Name: Mark Labelle Position: Lab Manager Signature ____________ Date: ____________

TITLE
Sample Receipt

BACKGROUND
Proper sample receipt procedures are important to prevent mishandling of potentially hazardous samples and to provide documentation of sample receipt.

PURPOSE
This document covers the procedures for receiving and documenting samples. This document covers the use of material handling equipment, scales, and labelling systems.

INSTRUCTIONS
Sample receiving is performed by Golder Associates lab technologists, observing health and safety policies and this document. **Only certified employees are permitted by law to use the narrow aisle stacker.** A breakdown of the procedure is presented below:

1. Wearing task appropriate PPE is required and important when receiving samples;
   - Lab Coat (if necessary)
   - CSA approved boots (always)
   - Eye Protection (always)
   - Gloves (Task appropriate) (always)

2. Observe conditions of outdoor receiving pad and ensure area is clean and snow or ice is removed prior to receiving samples.

3. Do not step outside of building until truck is backed up.

4. Check alignment of truck's receiving gate with receiving pad and notify truck driver if adjustment is required.

5. Notify driver of incline in parking lot.

   Before driver moves samples onto trucks receiving gate, ensure that samples are securely loaded on a structurally sound pallet. While staying behind the yellow line ensure samples are carefully transferred by the driver from truck to receiving area using the proper material handling equipment i.e.: pallet jack. Remain behind yellow line while driver is loading and lowering the lift gate. Continue to stay behind yellow line and instruct driver where to place the pallet containing samples in receiving area.

6. Perform initial inspection on containers, checking for integrity and swelling. Do not handle containers if they appear abnormal, notify truck driver and contact supervisor. Also verify shipment received corresponds with what is listed on shipping form (i.e.: # of units, weight's, identification labels, etc).

   - If containers from a domestic location are damaged, leaking or swollen notify supervisor. Shipment may or may not be accepted.
   - If containers from an international location are damaged, leaking or swollen carefully accept the shipment ensuring not to worsen the condition of the containers and notify supervisor

7. Place shipment (using appropriate moving equipment i.e.: pallet jack, dolley, etc.) in a location ensuring that exit and hallway are not obstructed.

8. Inspect shipment for project information and check if MSDS is available.

9. Record condition of sample containers / seals in sample log. The following must be noted upon sample arrival;

   - Note temperature of container. Elevated temperatures could be due to oxidation of sulphur-bearing minerals. Oxidation could cause the contents to be under pressure and the drum must be quarantined and labelled accordingly. Do not attempt to open container. Notify supervisor immediately.
   - Inspect for swelling or abnormal shape of drum, which indicates the contents could be under pressure. Swelling can also be due to previous freeze / thaw cycles. Do not attempt to open container. Notify supervisor immediately.
   - Leaking, damaged or improperly sealed drums – contain spill and prevent liquid from entering nearby drains, label drum and quarantine.

10. Notify supervisor or project manager of any abnormal sample characteristics, damaged sample containers or broken seals.

11. Fill out sample receipt log in the paste lab master workbook ensuring that the following are complete:

    - Date Received
    - Project Number
    - Client
    - Sample ID (As Received)
    - Sample ID (Golder)
    - MSDS
    - Container Temperature (observation only: warm, cold, room temperature…)
    - Container Pressure (observation only: yes, no)
    - Weight
    - Method of Containment (MoC) condition
        - Seals Intact
        - Temperature
        - Swelling
        - Damage
    - Sample Description
    - Shipped Via
    - Company

    If information to complete all the fields is missing, highlight the cells in yellow and fill out as soon as possible (remove highlight when complete).

    Ensure that the Sample ID (As Received) field contains all information and labelling as found on the containers.

12. Fill out Sample Receipt portion of "Sample Receipt / Hazard Assessment" form.

13. Place all paperwork (shipping documents, MSDS…) that arrived with the sample in the project folder

14. Take photos of the shipment as well as labels on containers and damaged areas of containers. Place digital copies of photos in project folder on server.

15. If sample containers are in good condition, consult with task lead then proceed to hazard assessment (refer to WI 13).

18101723 - Stage 1 - Mix 1 - OPC Only

Intruction: Yellow cells require user input

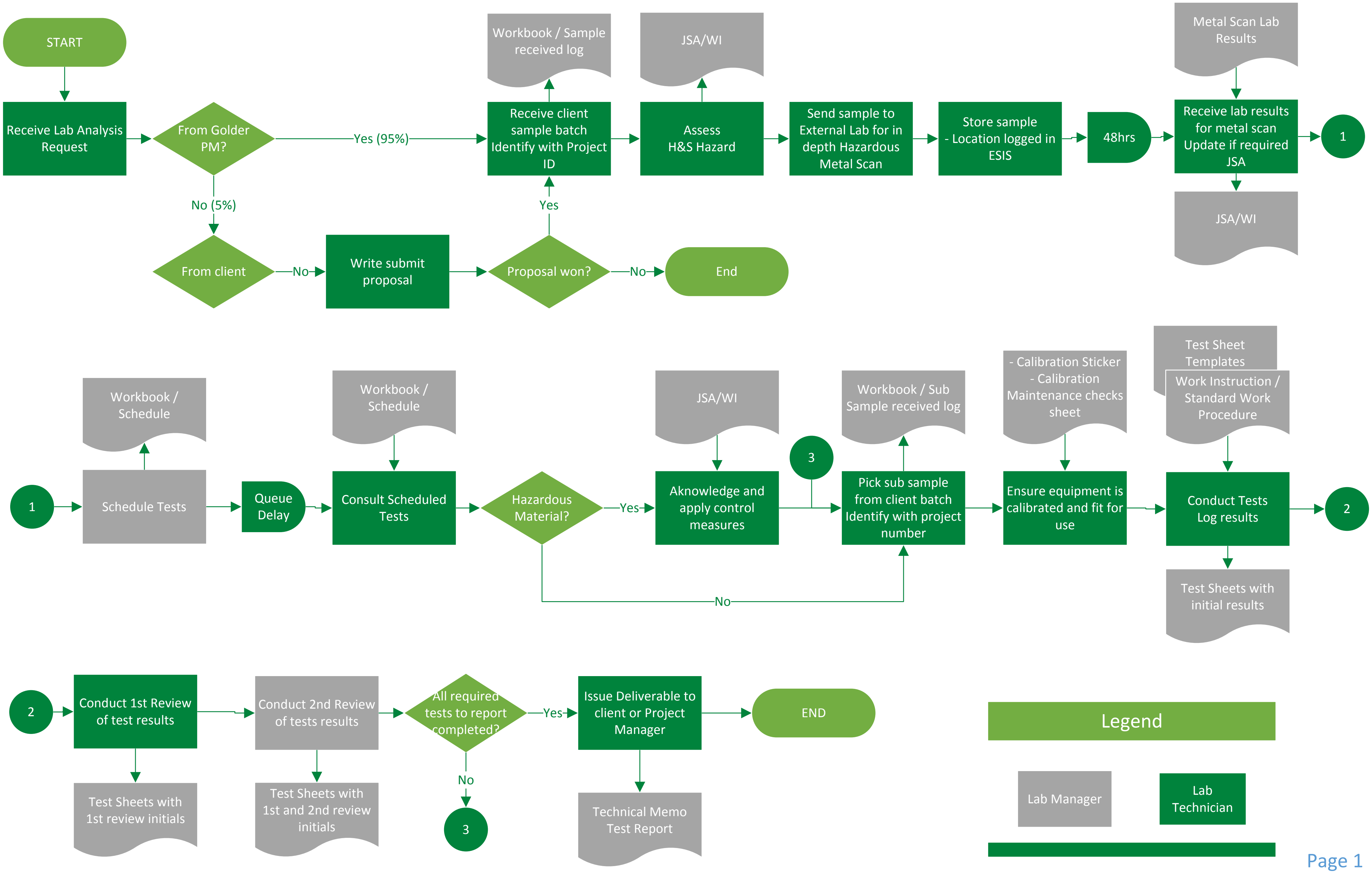
Batch Volume 0.018 m^3

Ingredient	Design (kg/m^3)	Density (kg/m^3)	Volume (m^3)	Adjusted (kg/m^3)	Batch mass (kg)
Type I/II Cement	386	3150	0.123	386	6.95
Fly ash	0	2300	0.000	0	0.00
Water	247.0	1000	0.247	226	4.07
Gravel	475.0	2674	0.178	476	8.56
Sand	1165.0	2636	0.442	1186	21.34
HRWR - Sika Viscocrete 2100	3.1	1060	0.003	3.1	0.056
VMA - Diutan Gum	0.26	1000	0.000	0.26	0.005
Total	2276.4		0.992	2276.4	

w/cm	0.6399
Cementitious content	386
Fly ash replacement (%)	0

PASTE LAB CORE PROCESS

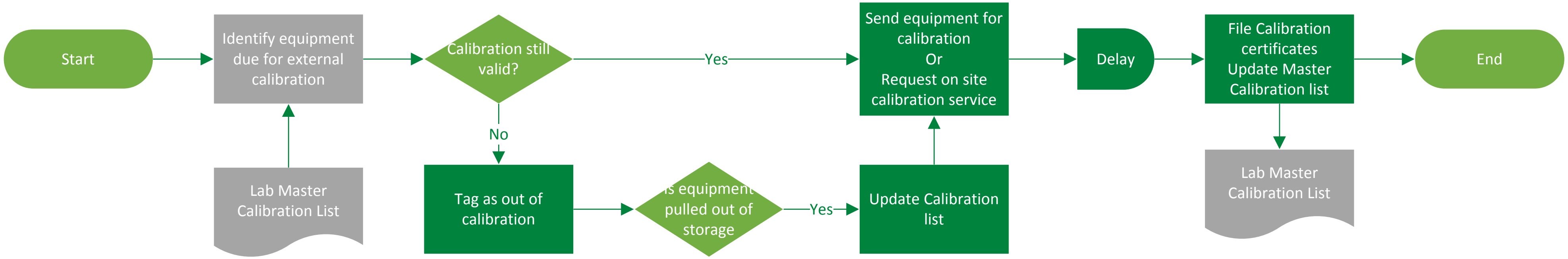
March 19, 2018



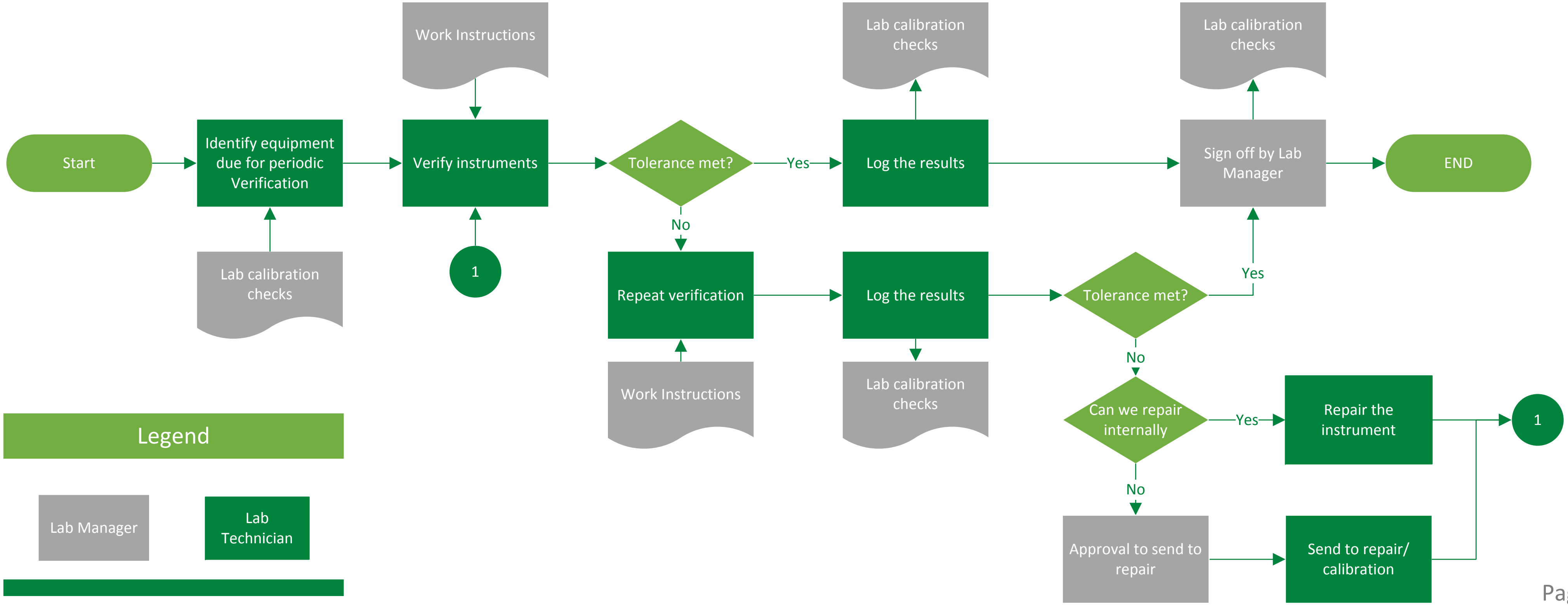
PASTE LAB EXTERNAL CALIBRATION AND INTERNAL VERIFICATION OF EQUIPMENT

March 19, 2018

Annual External Calibration of Equipment



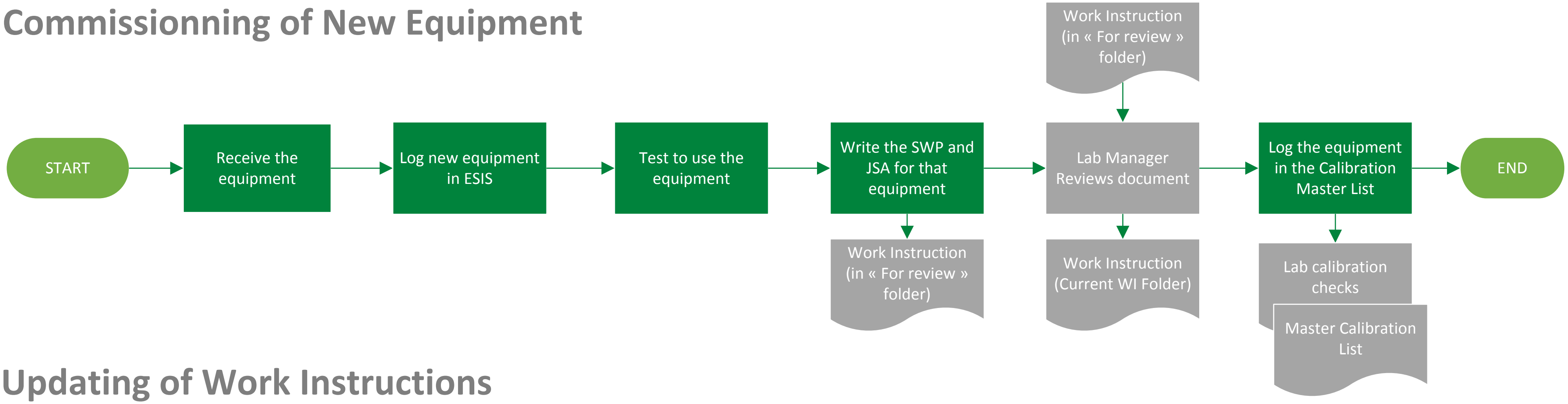
Bi-Weekly Internal Verification of Equipment



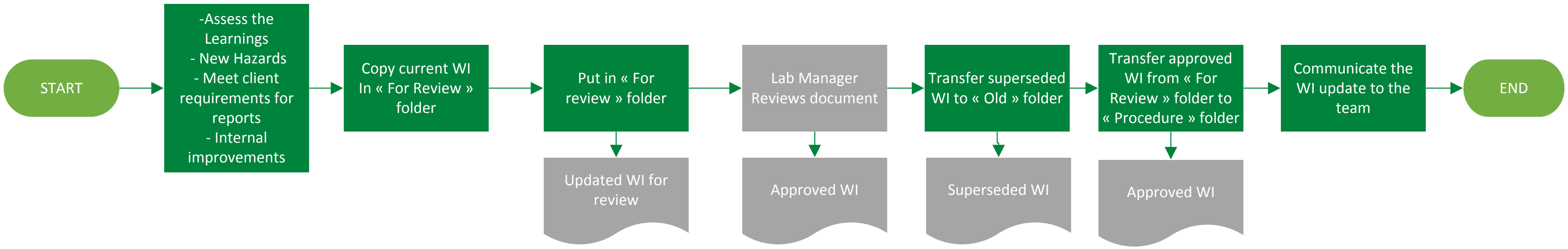
WORK INSTRUCTION UPDATE AND TRAINING

March 19, 2018

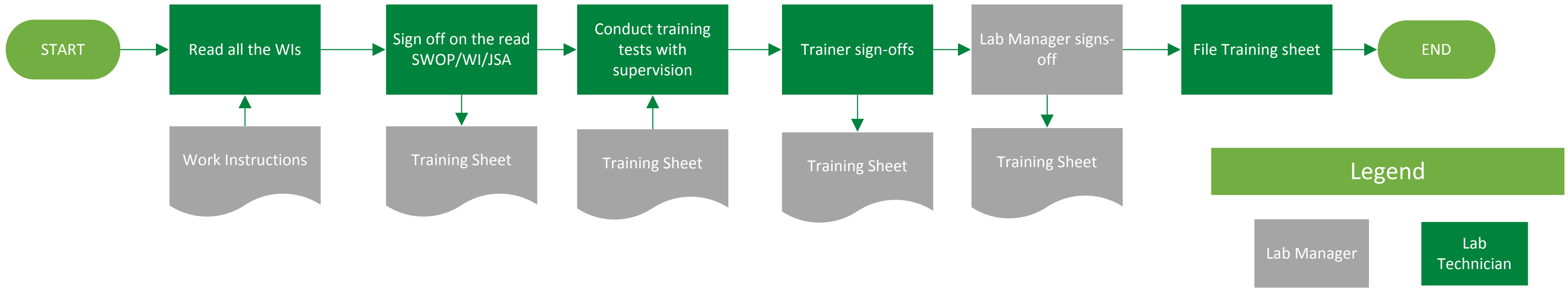
Commissionning of New Equipment



Updating of Work Instructions

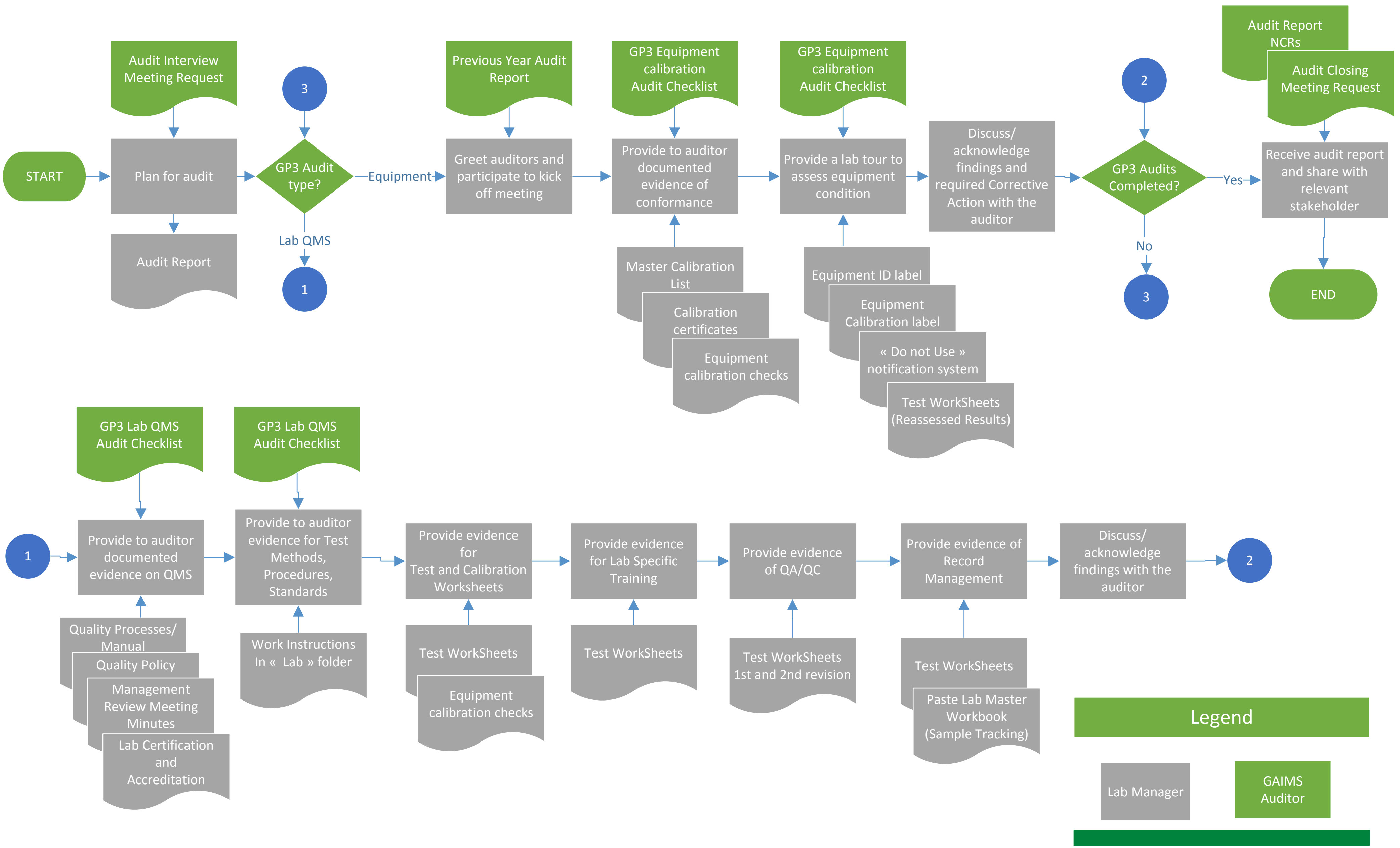


Training of New Lab Technician



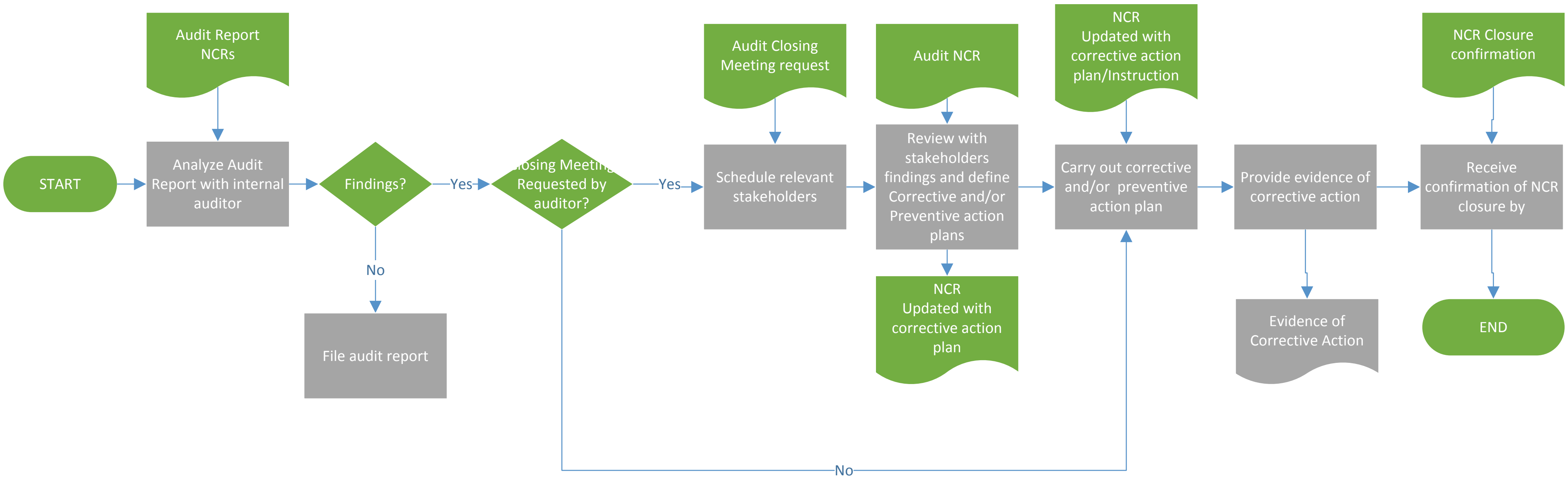
LAB GP3 INTERNAL AUDITS FOR EQUIPMENT CALIBRATION AND QUALITY MANAGEMENT SYSTEM

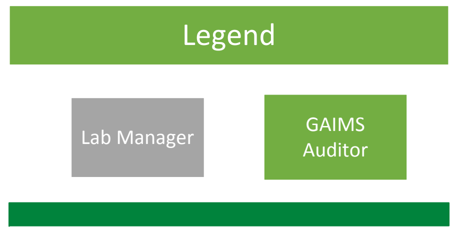
March 19, 2018



LAB CORRECTIVE ACTION FOR NON-CONFORMANCE FROM GP3 INTERNAL AUDITS

March 19, 2018





GOLDER'S PROCESS AND INFRASTRUCTURE DESIGN (PID) SUDBURY LAB

Laboratory Reference Document Binder

Table of Contents

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