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Upper Kawartha DSR
Burleigh Falls Dam
2014 Geotechnical Site Investigation Report
FINAL

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1.0 INTRODUCTION

KGS Group was retained by Public Works and Government Service Canada (PWGSC) to complete a geotechnical investigation at the Burleigh Falls Dam which is part of the Trent Severn Canal System. The purpose of the geotechnical investigation was to confirm the concrete and bedrock quality below the South Abutment Pier and Pier #1 as water boiling and underseepage had been previously identified. Water boiling was observed during the 2013 site inspection but the extent is unknown. In addition to identifying the cause of the water boiling, the investigation also included test hole drilling to determine the soil types and relevant engineering properties of the North (Left) Earthfill Embankment and foundation materials, and to measure piezometric conditions within the embankment structure. The material properties and piezometric data will be incorporated into the evaluation of the geotechnical performance of the structure as part of the Dam Safety Review (DSR) currently being undertaken for PWGSC. Any additional investigations that may be required to design potential remedial measures recommended from the DSR are not included in this current scope of work.

The scope of this current assignment included the following:

- Core through the spillway structure and underlying bedrock in the vicinity of the South Abutment Pier and Pier #1 to confirm quality of concrete and bedrock and to determine whether or not voids are present between the concrete and the underlying bedrock.
- Install standpipe piezometers at the concrete/bedrock interface and in the underlying bedrock to measure piezometric levels under the structure.
- Complete water pressure testing (Lugeon Testing) at the concrete bedrock interface and in the underlying bedrock to estimate the hydraulic conductivity at the interface and in the underlying bedrock.
- Complete test holes and install standpipe piezometers to measure piezometeric elevations within the North (Left) Earthfill Embankment for use in the stability analyses as part of the DSR;
- Complete an assessment of the foundation conditions at the North (Left) Earthfill Embankment;
- Perform diagnostic laboratory index testing on select soil samples to identify material properties relevant to the evaluation. The testing consisted of grain size analyses and moisture content tests;
- Preparation of a summary report of all works performed including the results of the investigation program, the results of the piezometric monitoring to date and the

recommended embankment and foundation material strength parameters to be used in the stability evaluation for the DSR.

2.0 BACKGROUND

The Burleigh Falls Dam is located in the town of Burleigh Falls, ON. The main dam is 241 m in length and was constructed in 1912. It consists of a concrete gravity dam founded on bedrock with a total of twelve (12) stoplog weirs. The dam is operated to maintain navigation water levels on the Trent River and to provide water control of the watershed.

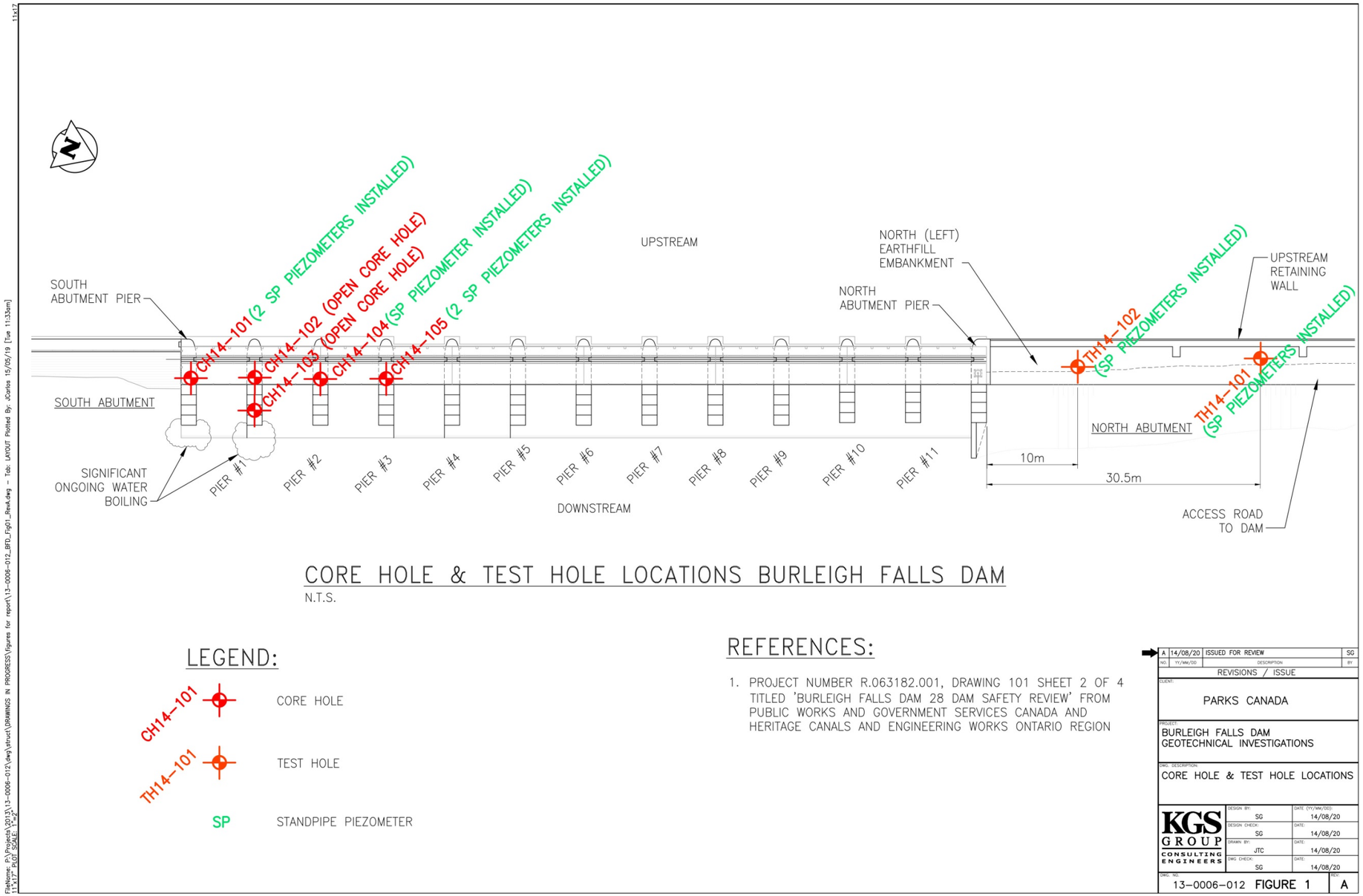
The dam was partially rehabilitated in the early 1990's by refacing of the piers. Significant, ongoing water boiling has been identified downstream of South Abutment Pier and Pier #1; however the cause and extent of the water boiling is unknown.

A historical records review (Rehabilitation Proposal for Burleigh Falls Dam by H.G Acres & Company Limited, 1964) revealed that the date when the water boiling was first observed was not known, but it has been flowing since at least 1958. At that time the boiling was observed at the aprons of the sluiceway between South Abutment Pier and Pier #1 and very slight leakage was observed at the base of the apron between Piers #1 and #2. Significant flowing water / boiling was observed at the South Abutment Pier and Pier #1 during the 2013 inspection. Possible remediation methods proposed by H.G. Acres included injection of grout into the foundation area and the construction of an impervious blanket upstream of the structure. There was no information available at the time of the review which indicates whether or not any remediation work had been carried out at the site. Concrete and bedrock coring was reported to have been completed at the aprons by H.G. Acres. However there was no drilling information available as part of that work program.

A test hole was completed on the upstream side of the dam in 1960 by the Department of Public Works - Development Engineering Branch in order to determine the elevation of the bedrock and nature of fill above the upstream face of the dam in order to facilitate potential repairs. The test hole was located 1.5 m upstream of the face of the dam between the South Abutment Pier and Pier #1. The drilling indicated that the upstream fill consisted of boulders and sand and that the depth to bedrock was approximately 11 m below the top of dam structure. A copy of the 1960 test hole is included in Appendix A.

There is one (1) earthfill embankment structure associated with the Burleigh Falls Dam – the North (Left) Earthfill Embankment which forms the north abutment of the dam. The configuration of the Burleigh Falls Dam and the North (Left) Earthfill Embankment is shown on Figure 2.0-1. It should be noted that the Burleigh Falls Dam site also includes the Lock 28 structure located north of the dam; however this structure is not part of this geotechnical investigation program being completed as part of the DSR.

FIGURE 2.0-1
APPROXIMATE TEST HOLE LOCATIONS – BURLEIGH FALLS DAM



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3.0 2014 INVESTIGATION PROGRAM

3.1 TEST HOLE DRILLING AND SAMPLING PROGRAM

A drilling and sampling program was completed in July/August 2014 with drilling services provided by OGS Inc. of Almonte, Ontario under continuous KGS Group supervision. A total of seven (7) test holes were completed at the following locations:

- One (1) core hole (CH14-101) at the South Abutment Pier of Burleigh Falls Spillway;
- Two (2) core holes (CH14-102 and CH14-103) at Pier #1 of Burleigh Falls Dam: one (1) completed from the top deck of the spillway and one (1) from the top of the pier nose;
- One (1) core hole (CH14-104) at Pier #2;
- One (1) core hole (CH14-105) at Pier #3; and
- Two (2) test holes (TH14-101 and TH14-102) on the downstream side of the North (Left) Earthfill Embankment.

All of the test holes were completed using a portable drill rig equipped with casing-wash boring and coring capabilities as shown on Photos 3.1-1 and 3.1-2.

Typically soil samples from the North (Left) Earthfill Embankment (TH14-101 and TH14-102) were collected using a split spoon sampler with a nearly continuous sampling interval and Standard Penetration Tests (SPT). All samples were visually classified in the field according to the Unified Soil Classification System (USCS). Concrete and bedrock coring was advanced 0.3 m below the embankment fills at the North (Left) Earthfill Embankment.

Concrete and bedrock coring at the pier structures was advanced to depths ranging from 7.8 m to 11.1 m to determine the quality of the concrete, the underlying bedrock and to investigate the nature of the concrete to bedrock contact. All core samples were logged for concrete quality, bedrock type and quality, with measurements of fracture details, material infill and Rock Quality Designation (RQD).

PHOTO 3.1-1
PORTABLE DRILL RIG AT CH14-103

PHOTO 3.1-2
PORTABLE DRILL RIG AT TH14-102

A total of seven (7) standpipe piezometers were installed:

1. Within the embankment materials
2. At the concrete/bedrock interface
3. In the underlying bedrock.

The locations of the piezometers are shown in plan on Figure 2.0-1. Detailed test hole logs and bedrock fracture logs incorporating all field observations, laboratory testing results and instrumentation details are included in Appendix B. Photographs of recovered soil and bedrock core samples are included in Appendix C.

3.3 LABORATORY TESTING

A laboratory testing program was performed on select samples to determine the relevant engineering index characteristics of the North (Left) Earthfill Embankment materials relative to the stability evaluation being completed as part of the DSR. Diagnostic testing included two (2) grain size analyses and five (5) moisture content analyses. Results are shown on Figure A-1 and on the test hole logs in Appendix A. The laboratory testing was completed at the Golder Associates Ltd. Soil Laboratory in Mississauga, Ontario with the following American Society for Testing and Materials (ASTM) Standards used for the soil testing:

- ASTM D422 - Standard Test Method for Particle-Size Analysis of Soils;
- ASTM D1140 - Test Method for Amount of Material in Soils Finer than the No. 200 Sieve; and
- ASTM D2216 - Standard Test Method for Laboratory Determination of Water (Moisture).

4.0 INVESTIGATION RESULTS

4.1 STRATIGRAPHY

A summary of the 2014 drilling program is presented on Table 4.1-1. The approximate locations of the test holes are shown on Figure 2.0-1 with test hole logs and detailed fracture logs included in Appendix B.

TABLE 4.1-1
BURLEIGH FALLS DAM - SUMMARY OF 2014 DRILLING PROGRAM

Location	Test Hole #	Northing (m)	Easting (m)	Total Depth Drilled (Approx., m)	Concrete Coring (m)	Bedrock Coring (m)
South Abutment Pier	CH14-101 (Top Deck)	4937511	721829	12.8	9.5	3.3
Pier #1	CH14-102 (Top Deck)	4937522	721827	12.8	10.7 (see Note 1)	0.9
	CH14-103 (Pier Nose)	4937522	721823	13.7	8.81 (see Note 2)	3.6
Pier #2	CH14-104 (Top Deck)	4937529	721826	14.1	11.1 (See Note 3)	2.8
Pier #3	CH14-105 (Top Deck)	4397536	721823	10.5	7.8	2.7
Location	**Test Hole #**	**Northing (m)**	**Easting (m)**	**Total Depth Drilled (Approx., m)**	**Embankment Fill (m)**	**Concrete /Bedrock Coring (m)**
Left Earthfill Embankment	TH14-101 (D/S Side)	4937616	721809	3.8	3.5	0.3
	TH14-102 (D/S Side)	4937637	721805	5.8	5.5	0.3

NOTES:

1. A 1.2 m void was identified during drilling at the concrete/bedrock interface at CH14-102.
2. A 1.3 m void was identified during drilling at the concrete/bedrock interface at CH14-103.
3. A 50 mm gap was identified during drilling at the concrete/bedrock interface at CH14-104.

4.1.1 North (Left) Earthfill Embankment of Burleigh Falls Dam

The North (Left) Earthfill Embankment consists of an earthfill section with a concrete retaining wall on the upstream side that ties into the Left (North) Abutment of the spillway structure. The

crest of the embankment is approximately 4.0 m wide and provides vehicle access to the North Abutment area.

Embankment Fill Material

The fill material encountered within the North (Left) Earthfill Embankment generally consisted of rockfill and sand fill overlying bedrock. The depth of the embankment fill as determined from the test holes (TH14-101 and TH14-102) drilled from the crest of the embankment varied from 3.5 to 5.5 m. The crest elevation of the embankment at the test hole locations was El. 243.92 m.

Topsoil was encountered from ground surface to a depth of 0.3 m in both test holes. Below the topsoil was angular, blasted rockfill that extended to a depth of 1.3 m to 1.5 m. The rockfill was grey in colour, with angular rock fragments and contained some sand and some silt. Below the rockfill was sand fill. The sand fill was brown in colour, fine to medium grained, moist, very loose to loose in consistency and contained trace amounts of fine grained gravel, coarse grained sand and trace silt and clay sized material. Two (2) grain size analyses were completed on the sand fill as summarized below on Table 4.1-2.

TABLE 4.1-2
BURLEIGH FALLS DAM: SUMMARY OF INDEX CHARACTERISTICS

Test hole #	Sample Depth (m)	Moisture Content (%)	Grain Size Distribution (%)						
			Gravel	Sand				Silt	Clay
				Coarse	Medium	Fine	Sand Total		
TH14-101	2.0	11.8	9.2	4.6	48.0	32.6	85.2	5.6	0
	2.7	19.5							
	3.4	13.9							
TH14-102	2.1	16.2	6.4	5.7	38.7	43.5	87.9	4.4	1.3
	2.7	13.1							

It should be noted that the use of the portable drill rig at TH14-101 and TH14-102 required the use of a 1/3 standard weight hammer. SPT values in the embankment fill materials have been corrected to reflect the reduced hammer weight.

Corrected SPT N-values of approximately 4 blows per 300 mm (ranging between 1 and 6) were recorded in the sand fill. It should be noted that at depths between 2.2 m and 2.7 m in TH14-101 gravel and cobble sized rockfill material was encountered during drilling and elevated SPT values ranging from 23 to 32 were recorded.

Concrete and Bedrock

Below the North (Left) Earthfill Embankment coring of the bedrock and concrete was completed to a depth of 0.3 m at TH14-101 and TH14-102. Granitic bedrock was encountered below the embankment fill at TH14-101. The bedrock was grey-pink in colour, medium to coarse grained and appeared massive with no signs of weathering.

At TH14-102 the footing of the upstream concrete wall of the embankment was encountered at a depth of 5.2 m. In general, the concrete was observed to be in good condition. There were no indications of significant cracking or other forms of deterioration.

4.1.2 Burleigh Falls Spillway Structure

Five (5) core holes were completed through the Burleigh Falls Spillway structure to determine the quality of the concrete, the underlying bedrock, and to investigate the nature of the concrete to bedrock contact beneath the structure. Ongoing, extensive water boiling and seepage has been observed downstream of the structure in the vicinity of South Abutment Pier and Pier #1. The locations of the core holes are shown on Figure 2.0-1 and a summary of the core hole depths is included on Table 4.1-1.

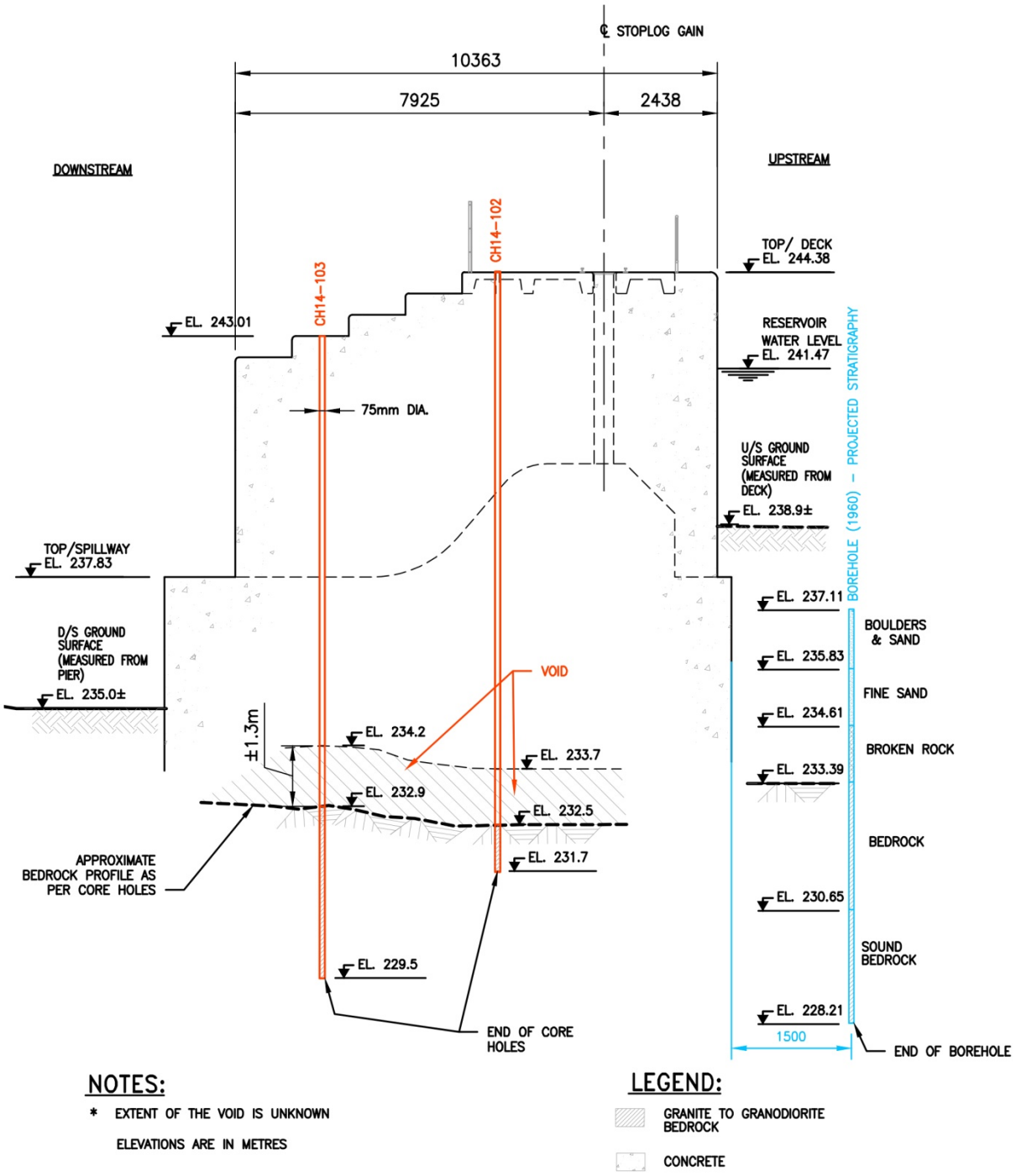
Concrete

Concrete coring through the pier structures extended to depths ranging from 7.8 m to 11.1 m. Core holes were completed from the top deck of the spillway structure, except CH14-102 which was completed on the downstream nose of Pier #1 as shown in cross section on Figure 4.1-1.

In general the concrete used to construct the Burleigh Falls Dam was typical of concrete from the late 19th / early 20th century and was comprised of poorly distributed angular to rounded aggregate particles up to 200 mm (8”) in size. The concrete had a high proportion of paste with very little smaller sized aggregate. Most of the aggregate consisted of granite and/or granodiorite with occasional limestone particles. Typical concrete compressive strength for the time period that Burleigh Falls Dam was constructed is estimated to range between 20 MPa to 25 MPa.

Numerous construction joints were noted throughout the structure during coring activities. Signs of possible seepage along a construction joint at 7.5 m depth was noted at CH14-102 and CH14-103, both located on Pier #1.

FIGURE 4.1-1
CROSS SECTION OF BURLEIGH FALLS DAM PIER #1



CROSS SECTION OF PIER 1

N.T.S.

Concrete to Bedrock Contact

A concrete to bedrock contact was identified through the coring program at three (3) of the five (5) core hole completed at the Burleigh Falls Spillway Structure as follows:

- *South (Right) Abutment Pier CH14-101:* unbonded, nearly horizontal interface.
- *Pier #2 CH14*-104*:* 50 mm gap at concrete to bedrock interface.
- *Pier #3 CH14-105:* unbonded, nearly horizontal interface.

There was no concrete to bedrock interface at core holes CH14-102 and CH14-103, located on Pier #1 as a 1.2 to 1.3 m deep void was encountered at depths of 10.7 m and 10.1 m, respectively (see Figure 4.1-1).

Downhole Video Survey

A downhole video survey was completed at CH14-102 and CH14-103 to investigate the nature of the void and potentially estimate its aerial extent. The survey was completed by Acu Flow Services of Peterborough, ON with continuous KGS Group supervision. The survey consisted of lowering a standard portable front view camera on a cable connected to a laptop computer for real time viewing and recording. Photographs (screen shots) showing the condition of the void and the concrete to bedrock interface are presented in Photos 4.1-1 to 4.1-6. The downhole video survey showed a significant void between the bottom of the concrete structure and the top of the bedrock (see Photos 4.1-2, 4.1-4 and 4.1-5). Granular sand, gravel, cobble sized material was noted on top of the bedrock surface (see Photo 4.1-4). Floating debris in the water column indicated that the flow of water was turbulent and appeared significant in volume. The aerial extent of the void could not be determined with the front view camera.

In addition to CH14-102 and CH14-103 the downhole survey was also completed at CH14-101 where the concrete to bedrock contact was observed to be good with no voids or separation (see Photo 4.1-6). It should be noted that the video has been recorded into DVD format and submitted to PWGSC.

It should be noted that PWGSC / PCA has informed KGS Group that any further investigation work of this void will be undertaken under a separate capital project.

PHOTO 4.1-1
VOID AT PIER #1 (CH14-102)

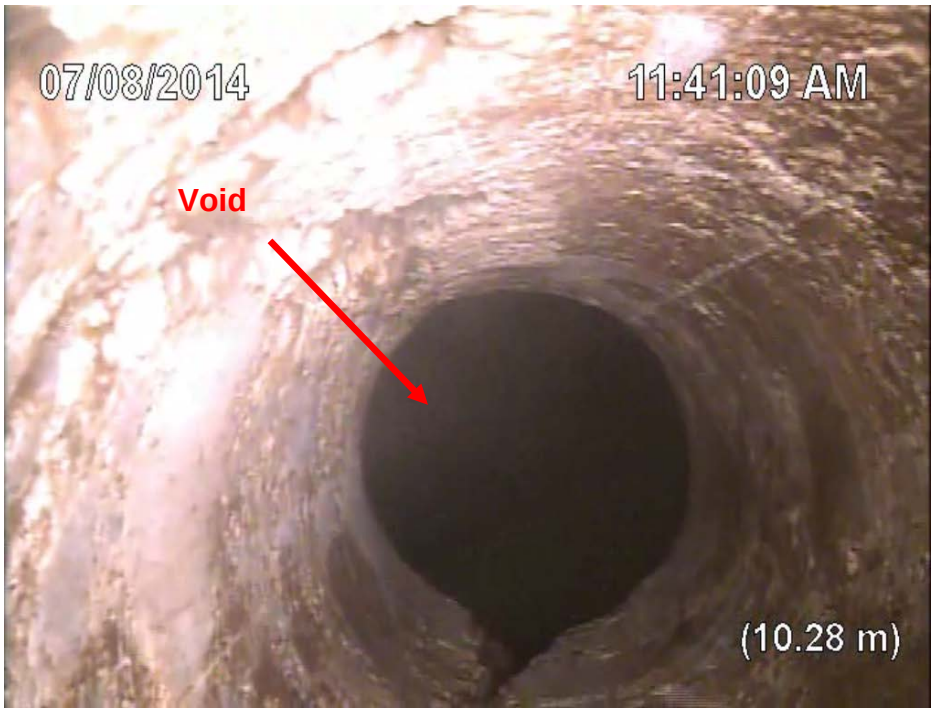


PHOTO 4.1-2
CONDITION OF VOID AT PIER #1 (CH14-102)

PHOTO 4.1-3
VOID AT PIER #1 (CH14-103)

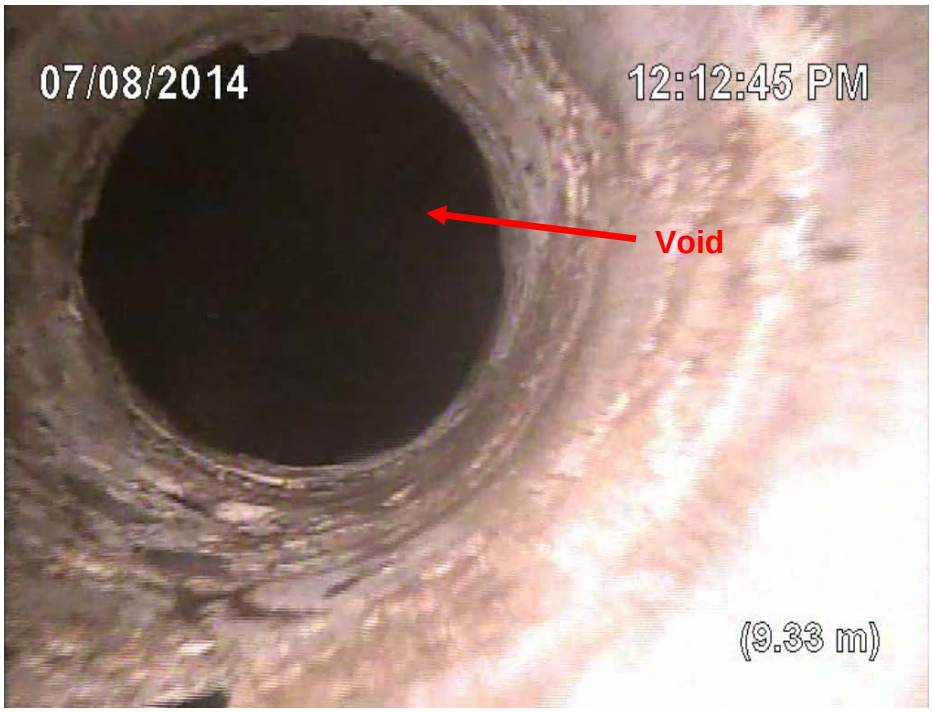


PHOTO 4.1-4
CONDITION OF VOID AT PIER #1 (CH14-103)

PHOTO 4.1-5
CONDITION OF VOID AT PIER #1 (CH14-103)

PHOTO 4.1-6
CONCRETE TO BEDROCK CONTACT AT SOUTH ABUTMENT PIER (CH14-101)

Bedrock

Coring was advanced 0.8 m to 3.6 m into the bedrock at the five (5) core holes to determine the quality of the underlying bedrock. Regionally the bedrock is mapped as early felsic plutonic rocks. Coring identified that the bedrock was a granite to granodiorite. The bedrock was grey to pink in colour, with a medium to coarse grained groundmass, locally poor to massive and relatively competent with some signs of staining. At the site the granite to granodiorite was found to be in poor to very good condition with the Rock Quality Designation (RQD) ranging from 35% to 100%. Typical unconfined compressive strength of competent granite bedrock ranged between 75 MPa to 200 MPa.

It should be noted that at the completion of bedrock coring at CH14-102 and CH14-103, where the void was observed, granular debris was washed into the core holes from the turbulent flow.

4.2 WATER PRESSURE TESTING RESULTS

Water pressure Lugeon testing (WPT) was completed in CH14-101 and CH14-105 in the concrete, at the concrete to bedrock interface and in the bedrock. The equipment used for WPT consisted of two main components: the flow meter assembly and the packer assembly both provided by OGS Inc. WPT was carried out after the completion of the core hole drilling and the testing was performed using a mechanical set of double packers with an interval of 1.5 m. A five step WPT test was performed with each step lasting approximately 5 minutes. The flow meter and pressure gauge readings were recorded every minute at each pressure step.

Interpretations of the WPT results were determined from the water quantity injection rates and pressure applied during the test. Assessed Lugeon values were determined for each of five successive pressure steps and flow conditions were interpreted based on flow variations with pressure for each test. A single Lugeon is defined as a 1 litre per minute per meter (of test interval), normalized to a pressure of 10 bars (1000 kPa). The assessment of the water pressure test used the guidelines presented by Houslby, 1976. The results of the water pressure testing are summarized on Table 4.2-1.

The water pressure testing completed in the concrete at CH14-101 noted lower flow rates and is consistent with laminar flow (approximate Lugeon Value of 11). Testing at the concrete to

bedrock interface and in the underlying bedrock reported values of approximately 80 Lugeons with test values indicative of turbulent flow. At CH14-105 testing in the underlying bedrock reported values of approximately 30 Lugeons, indicative of turbulent flow. Graphical representations of the test results are included in Appendix D.

It should be noted that under ideal conditions (i.e. homogeneous and isotropic) one Lugeon is equivalent to permeability value k, of 1.3 X 10^{-5} cm/sec (Fell et al 2005). Table 4.2-2 describes rock mass conditions typically associated with different ranges of Lugeon values.

TABLE 4.2-1
SUMMARY OF WATER PRESSURE TESTING RESULTS AND EVALUATION
REPORTED LUGEON VALUES OF TESTED COREHOLES

	Test ID	Test Interval Depth (m)		Lugeon		Water Take (l / min)	Test Interval Depth (m)	Test Pressure (kPa)
		Top	Bottom					
CH14-101	Concrete	6.55	8.08	Step 1	11.2	1.89	1.53	110.84
				Step 2	10.7	2.95	1.53	179.79
				Step 3	11.5	4.39	1.53	248.74
				Step 4	12.7	3.49	1.53	179.79
				Step 5	12.9	2.19	1.53	110.84
	Concrete to Bedrock Interface	8.08	9.60	Step 1	100.1	14.76	1.52	97.05
				Step 2	88.7	16.80	1.52	124.63
				Step 3	81.2	18.78	1.52	152.21
				Step 4	89.9	17.03	1.52	124.63
				Step 5	102.6	15.14	1.52	97.05
	Bedrock	10.52	12.04	Step 1	97.4	15.14	1.52	102.25
				Step 2	86.3	17.03	1.52	129.83
				Step 3	79.1	18.93	1.52	157.41
				Step 4	86.7	17.11	1.52	129.83
				Step 5	96.9	15.06	1.52	102.25
CH14-105	Concrete to Bedrock Interface	6.4	7.92	Step 1	69.7	12.26	1.52	115.74
				Step 2	60.9	14.53	1.52	157.11
				Step 3	57.5	17.33	1.52	198.48
				Step 4	62.5	14.91	1.52	157.11
				Step 5	70.6	12.41	1.52	115.74
	Bedrock	7.85	9.37	Step 1	32.1	5.68	1.52	116.53
				Step 2	29.0	8.18	1.52	185.48
				Step 3	25.8	9.99	1.52	254.43
				Step 4	28.2	7.95	1.52	185.48
				Step 5	34.2	6.06	1.52	116.53

TABLE 4.2-2
CONDITION OF ROCK MASS DISCONTINUITIES
ASSOCIATED WITH DIFFERENT LUGEON VALUES

Lugeon Range	Classification	Hydraulic Conductivity Range (cm/sec)	Condition of Rock Mass Discontinuities
<1	Very Low	$< 1 \times 10^{-5}$	Very tight
1-5	Low	1×10^{-5} - 6×10^{-5}	Tight
5-15	Moderate	6×10^{-5} - 2×10^{-4}	Few partly open joints
15-50	Medium	2×10^{-4} - 6×10^{-4}	Some open joints
50-100	High	6×10^{-4} - 1×10^{-3}	Many open joints
>100	Very High	$> 1 \times 10^{-3}$	Open, closely spaced or voids

4.3 PIEZOMETRIC MONITORING RESULTS

As described in Section 3.1, seven (7) standpipe piezometers were installed to monitor groundwater conditions within the embankment fill, at the concrete/bedrock interface and in the underlying bedrock. In addition to the installation of seven (7) standpipe piezometers, core holes CH14-102 and CH14-103 were left open to allow for water level monitoring. The standpipe piezometers have been monitored a total of three (3) times since installation. Results of the groundwater level monitoring are summarized on Table 4.3-1.

4.3.1 North (Left) Earthfill Embankment of Burleigh Falls Dam

In general the standpipe piezometer readings indicated that the groundwater elevation within the North (Left) Earthfill Embankment soils was relatively steady (El. 240.4 m± at TH14-101 and El. 238.8 m± at TH14-102) over the monitoring period November 2014 to January 2015 (approximately 20 mm to 110 mm of water in the standpipe piezometers). It should be noted that the standpipe piezometers were dry during the monitoring events completed in August, 2014 and April 2015.

4.3.2 Burleigh Falls Spillway Structure

The standpipe readings at the concrete to bedrock interface (i.e. core holes with a 50 mm gap or less) varied between El. 239.78 m and El. 240.98 m over the monitoring period November 2014 to April 2015, approximately 0.08 m to 1.15 m below reservoir levels recorded over the same monitoring period.

Monitored water levels in the bedrock at CH14-101 were approximately 0.63 m below the reservoir level during the monitoring period November 2014 to April 2015. At CH14-105 water levels were 1.9 m to 2.9 m± below the reservoir level. These recorded water levels likely reflect the quality of the underlying bedrock, poor to fair at CH14-101 and good to very good at CH14-105.

Water levels at the concrete to bedrock interface and in the bedrock suggest that there is a connection between these areas and the upstream reservoir. The upstream water level of the reservoir varied between El.240.80 m and El.241.48 m over the monitoring period.

The nested standpipe piezometers in CH14-101 recorded water levels in the bedrock approximately 0 m to 0.5 m higher than levels at the concrete to bedrock interface over the period November 2014 to April 2015. It should be noted that water boiling was observed downstream of the South Abutment where CH14-101 is located.

The nested standpipe piezometers in CH14-105 recorded water levels at the concrete to bedrock contact 1.8 m to 2.6 m higher than levels in the bedrock over the period November 2014 to April 2015.

4.4 SEEPAGE

The piezometric elevations measured at the concrete to bedrock interface are comparable to the reservoir levels (El. 240.80 m and El. 241.48 m). Therefore full uplift pressure should be assumed for stability analyses performed for the spillway structure. The influence of the observed void found below Piers # 1 and #2 on the stability of the spillway structure should also be considered.

The poor quality of the bedrock observed in CH 14-101, 103 and 104 and the observed turbulent flow through the unbonded surface at CH14-101 are evidence that active seepage is occurring through the bedrock foundation beneath the concrete structure.

TABLE 4.3-1
SUMMARY OF PIEZOMETRIC MONITORING DATA – STANDPIPE PIEZOMETERS

Test Hole Number	TH14-101	TH14-102	CH14-101	CH14-101	CH14-102	CH14-103	CH14-104	CH14-105	CH14-105	Reservoir level (m)
Operating Level[1]	241.47 m	241.47 m	241.47 m	241.47 m	241.47 m	241.47 m	241.47 m	241.47 m	241.47 m	
Downstream Water Level	234.35 m	234.35 m	234.35 m	234.35 m	234.35 m	234.35 m	234.35 m	234.35 m	234.35 m	
Ground Elevation	243.92 m	243.92 m	244.38 m	244.38 m	244.38 m	243.01 m	244.38 m	244.38 m	244.38 m	
Piezometer	Standpipe	Standpipe	Standpipe	Standpipe	Open Core Hole	Open Core Hole	Standpipe	Standpipe	Standpipe	
Screened Zone	240.42 to 241.32 m	238.72 to 239.62 m	231.58 to 234.18 m	234.78 to 235.88 m	231.68 m	229.51 m	233.08 to 237.38 m	233.88 to 234.98 m	236.48 to 238.58 m	
Monitoring Zone	Sand Fill	Sand Fill	Bedrock	Concrete to Bedrock Interface	Bedrock	Bedrock	Concrete to Bedrock Interface	Bedrock	Concrete to Bedrock Interface	
Date	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	Water Level (m)	
August 16/17, 2014	Dry	Dry	241.13[2]	241.03[2]	240.83	240.11	241.08[2]	238.38[2]	241.08[2]	241.48
November 25, 2014	240.42	238.84	240.43	240.43	240.78	240.11	240.75	239.18	240.98	241.06
January 12, 2015	240.47	238.82	NM[4]	NM[4]	NM[4]	NM[3]	NM[4]	NM[4]	NM[4]	240.80
April 13, 2015	Dry	Dry	240.28	239.78	240.48	239.61	240.48	238.08	240.68	240.93

NOTES:

1. Operating Level of reservoir upstream of Burleigh Falls Dam
2. Water levels measured at the completion of drilling – assumed not static
3. Not Monitored – unsafe winter conditions
4. Not Monitored – Frozen

5.0 GEOTECHNICAL ENGINEERING ASSESSMENTS

5.1 ENGINEERING PARAMETERS FOR THE EMBANKMENT MATERIALS

Representative engineering properties of the embankment fills for the Burleigh Falls Dam North (Left) Earthfill Embankment are presented on Table 5.1-1. The soil strength parameters of the embankment fill soils were estimated from the in situ Standard Penetration Tests (SPT), laboratory index testing using empirical correlations, as well as previous experience with similar soil materials. The ranges of shear strength parameters have been provided to represent the variations observed during the site investigation program. It should be noted that advanced laboratory tests were not completed on the embankment fills as part of this investigation program.

TABLE 5.1-1
EFFECTIVE SHEAR STRENGTH PARAMETERS FOR EARTHFILL EMBANKMENT MATERIALS

Material	Recommended Φ' for Analyses	Representative Lower and Upper Bounds, Φ'	Density based on SPT	Cohesion, c' (kPa)	Estimated Unit Weight, γsat (kN/m3)
North (Left) Earthfill Embankment of Burleigh Falls Dam					
Rock Fill	40°	-	-	0	18.0
Sand Fill	30°	28° to 32°	Loose	0	19.5

6.0 CLOSURE

- This geotechnical program was undertaken to confirm the concrete and bedrock quality below South Abutment Pier and Pier #1 of the Burleigh Falls Dam as water boiling and underseepage had been previously identified. Water boiling was observed during the 2013 site inspection but the extent was unknown. In addition to identifying the cause of the water boiling, the investigation also included test hole drilling to determine the soil types and relevant engineering properties of the Left Earthfill embankment and foundation materials, and to determine piezometric conditions within the embankment necessary to carry out stability analyses as part of the DSR.

- A total of seven (7) test holes were drilled during the exploratory program. Two (2) test holes were completed at the Left Earthfill Embankment to investigate the embankment fill materials and foundation soils and five (5) core holes were completed at the spillway structure to investigate the nature of the concrete and bedrock underlying the structure. Seven (7) standpipe piezometers were installed in the test holes to monitor groundwater levels within the earthfill embankment, at the concrete to bedrock interface and in the bedrock.

- The fill materials encountered at the Left Earthfill Embankment of the Burleigh Falls Dam consisted of a thin layer of topsoil, rockfill and sand fill overlying bedrock. Bedrock encountered at TH14-101 consisted of granitic bedrock that was grey–pink in colour, with a medium to coarse grained groundmass and appeared massive with no signs of weathering.

- Coring of the concrete at the Burleigh Falls spillway structure noted that the concrete contained a relatively poor distribution of crushed aggregate with some boulder sized rock fragments up to 200 mm diameter.

- The concrete to bedrock interface was identified at three (3) of the core holes (CH14-101, CH14-104 and CH14-105). The concrete to bedrock interface at these locations was noted to be nearly horizontal and ranged from an unbonded interface to having a 50 mm wide gap. The concrete to bedrock interface could not be determined at CH14-102 and CH14-103 at Pier #2 as a 1.2 m to 1.3 m deep void was encountered 10.1 m to 10.7 m below the top of the structure.

- A down hole video survey at CH14-102 and CH14-103 confirmed the presence of a significant void below the spillway structure. Granular gravel and sand sized material was noted on the bedrock surface and floating debris in the water column indicated that the flow was turbulent and appeared significant in volume. Further investigation and assessment of the void will be undertaken under a separate project to determine the most appropriate remedial action.

- The aerial extent of the void could not be determined from the down hole video survey.

- Bedrock below the Burleigh Falls Spillway structure consisted of granite to granodiorite. The bedrock was found to be in poor to very good condition with RQD values ranging from 35% to 100%.

- Water pressure testing in the concrete noted lower flow rates consistent with laminar flow while testing at the concrete to bedrock interface and in the bedrock reported values indicative of turbulent flow.

- The piezometric data revealed that groundwater levels in the Left Earthfill Embankment soils were steady during the monitoring period.

- Water levels monitored at the South Abutment Pier and Piers #1 to #3 at the concrete to bedrock interface and in the bedrock below the spillway structure suggest that there is a connection with the upstream reservoir.

- The soils strength parameters of the embankment fill were estimated based on the field observations, the laboratory testing results with empirical correlations and previous experience with similar materials.

7.0 STATEMENT OF LIMITATIONS AND CONDITIONS

7.1 THIRD PARTY USE OF REPORT

This report has been prepared for Public Works and Government Services Canada (PWGSC) to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

7.2 GEOTECHNICAL INVESTIGATION STATEMENT OF LIMITATIONS

The geotechnical investigation findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations are based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions found at and within the depth of the test holes drilled by KGS Group at this site

APPENDICES

APPENDIX A

1960 DEPARTMENT OF PUBLIC WORKS TEST HOLE LOG

Copy of Form S. #2/E
Revised.

DEPARTMENT OF PUBLIC WORKS - DEVELOPMENT ENGINEERING BRANCH,
TESTING LABORATORIES
OTTAWA - CANADA

BORINGS - SAMPLING AND SOILS TESTING FORM
(Soil Mechanics Section)

1. Fill out this Form and check items related to your requirements.
2. Supply a plan and/or sketches showing: Soundings and/or Elevation of the ground with reference to a given datum, the location of requested Borings and/or Test Pits, and, if applicable, the General Lay-out of work with a detailed cross-section of the structure.
3. Forward these documents, in triplicate, to TESTING LABORATORIES, D.P.W., OTTAWA, Attn: Mr. M. LeBel.
4. Retain a copy for your records

1. LOCATION OF WORK: (give Place, County and Province)
Burleigh Falls, Peterborough County, Ontario.

2. NAME OF DISTRICT OFFICE: **Trent Canal Office**
3. DATE BORINGS REQUIRED: **--**
4. DATE REPORT REQUIRED: **Prior - June 1/60**

5. NATURE OF WORK: Building: Bridge: Pavement: Breakwater:
Wharf: Wall: Dredging: Other: **Dam.**

6. TYPES OF STRUCTURE CONTEMPLATED: Timber Cribwork: Bulkheads:
S. S. Piling: Timber: Concrete Sheet Piling: Pile Bents:
Timber: Steel: Concrete: Rubble Mound Concrete Caissons:
Others (Describe): **Repairs to Substructure.**

7. FIELD WORK DESIRED:
1 Boring, Location as per Plan T.C. 2454-A, to be taken off Dam.

8. DETAILED INTERPRETATION AND RECOMMENDATIONS DESIRED:
To determine precise level of bedrock and nature of fill above foundation. Carry bore hole to 50 feet below deck of dam.

9. REMARKS: (give a brief description of the project)
In order to stop leaks through the dam, it is proposed to erect a cofferdam & expose the face of the dam to facilitate repairs.

10. STATE TO WHOM PLAN AND REPORT SHOULD BE SENT:
W. W. Gruber, Room 330, Hunter Building, Ottawa.
Extra copy to - W. D. Bennett (See below).

11. DEPARTMENT: **Transport**
12. BRANCH: **Marine Works**
13. DIVISION: **Canals**
14. OTHER: **---**
15. SUBMITTED BY: (give Name and Position) **W. D. Bennett, Suptg. Engr.**
16. DATE: **May 27/60**

TO WHOM SHOULD BORINGS TECHNICIAN REPORT WHEN READY TO COMMENCE
W. D. Bennett, Suptg. Engr., Trent Canal, Post Office Building, Charlotte Street, Peterborough, Ontario. Tel. RIverside 24291.

KH/21/3/58

BURLEIGH FALLS DAM

SURVEY Burleigh Falls. Peterborough County, Ont.

HOLE NO. 1 FOREMAN F.B. Kell. A6

DATE AND TIME	1960 MATERIAL	DEPTH FROM	DEPTH TO	ELEV.	NO. OF SAMPLE	REMARKS AND SKETCHES
June 21	ELEVATION OF Water			792.53		Location 6 FT. OUT From Top
	Water	0.0	14.8	777.73		OF DAM, Elev. Deck of DAM 792.33
	Boulders & sand	14.8	19.0	771.53		
	Fine Sand	19.0	23.0	769.53		Note
	Bed Rock	23.0				Rock broken From 23.0 FT.
	1 ST Run	23.0	25.0	767.53		to 27.0 FT. Small seams.
	2 nd "	25.0	27.0	765.53		This Rock is very SOFT down To
	3 rd "	27.0	29.0	763.53		36.0 FT. From 36.0 FT. to 44.0 FT.
	4 " "	29.0	34.0	758.53		Hard Red granite.
	5 " "	34.0	39.0	753.53		
	6 " "	39.0	44.0	748.53		
	Bottom of Hole	44.0				
						Drilled 2.0 FT. Rec, 2.0 FT.
						" 2.0 " " 1.5 "
						" 2.0 " " 2.0 "
						" 5.0 " " 5.0 "
						" 5.0 " " 5.0 "
						" 5.0 " " 5.0 "
						21.0 20.5

DEV. 894 (TESTING LABS.)

APPENDIX B

2014 KGS GROUP TEST HOLE LOGS AND DETAILED FRACTURE LOGS

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH 14-101**

CLIENT PWGSC
PROJECT Burleigh Falls Dam
SITE Left Earthfill Embankment
LOCATION 30.5 m North of Left Abutment of Spillway Structure (D/S side)
DRILLING METHOD Casing, Wash Boring and Coring (48 mm diameter), Portable Rig (Manual 1/3 Weight Hammer)

JOB NO. **13-0006-012**
GROUND ELEV. **243.92**
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED **23/07/2014**
UTM (m) N **4,937,616** E **721,809**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ / DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ / PL MC LL / %
243	1	5		**EMBANKMENT FILL (0.0 - 3.5 m)** **Topsoil Fill (0.0 - 0.3 m)** Dark brown, moist, grass at the surface. **Rockfill (0.3 - 1.3 m)** Grey, blast rock angular rock pieces, some sand, some silt.							
				Sand Fill (1.3 - 3.5 m) Brown, moist, very loose to loose, fine to medium grained, trace fine grained gravel, trace silt.				S1	0	▲3 ▲4 ▲5 ▲5 ▲7	
242	2			-Trace gravel, occasional cobbles. -Grain Size Distribution: Gravel (9.2%), Sand (85.2%), Silt (5.6%) and Clay (0%) at +- 2.0 m. -Cored from 2.2 to 2.7 m. -Large granitic boulder from 2.2 m to 2.7 m.				S2	38	▲6 ▲32 ▲23	
						2.6					
241	3	10						S3	38	▲6 ▲3 ▲3 ▲3 ▲4	
240.4				SPT refusal on bedrock / boulder at +/- 3.5 m.		3.5		S4	56	▲5 ▲13 ▲50 (0 mm penetration)	
240.1				**GRANITE TO GRANODIORITE BEDROCK** Grey-pink, medium to coarse grained, no signs of weathering		3.8					
240	4			**END OF HOLE AT 3.8 m.** Notes: 1. Test hole completed on July 23, 2014. 2. Test hole open to 3.8 m and wet at the bottom. 3. Installed standpipe piezometer to a depth of 3.5 m.							
		15									
239											

SAMPLE TYPE ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
OGS Inc.	SN	SG	21/12/15

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH 14-102**

CLIENT PWGSC
PROJECT Burleigh Falls Dam
SITE Left Earthfill Embankment
LOCATION 10 m North of Left Abutment of Spillway Structure (D/S side)
DRILLING METHOD Casing, Wash Boring and Coring (48 mm diameter), Portable Rig (Manual 1/3 Weight Hammer)

JOB NO. **13-0006-012**
GROUND ELEV. **243.92**
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED **22/07/2014**
UTM (m) N **4,937,637** E **721,805**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE	SAMPLE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ / DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ / PL MC LL / %
243	1	5		**EMBANKMENT FILL (0.0 - 5.2 m)** **Topsoil Fill (0.0 - 0.3 m)** Dark brown, moist, grass at the surface. **Rockfill (0.3 - 1.5 m)** Grey, blast rock angular rock pieces, some sand, some silt.							
242	2			**Sand Fill (1.5 - 5.2 m)** Brown, moist, very loose to loose , fine to medium grained,trace fine grained gravel, trace silt, trace clay. -Grain Size Distribution: Gravel (6.4%), Sand (87.9%), Silt (4.4%) and Clay (1.3%) at +- 2.1 m.				S1	4	7, 5, 1, 1	
								S2	46	2, 3, 1, 3, 5, 7	
241	3	10		-No recovery betwwen 3.8 m and 4.0 m.				S3	46	6, 8, 15, 9, 9, 9	
240	4	15		-Cored from 4.0 to 5.2 m. -Large granitic boulder from 4.0 m to 5.2 m.		4.3		S4	0		
239	5										
238.7				**CONCRETE** Upstream concrete retaining wall.		5.2					
238.1				**END OF HOLE AT 5.8 m.**		5.8					
238	6	20		Notes: 1. Test hole completed on July 22, 2014. 2. Test hole opened to 5.8 m and wet at the bottom. 3. Installed standpipe piezometer to a depth of 5.2 m.							
237											

SAMPLE TYPE ☒ Split Spoon

CONTRACTOR	INSPECTOR	APPROVED	DATE
OGS Inc.	SN	SG	21/12/15

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-101**

CLIENT PWGSC

PROJECT Burleigh Falls Dam

SITE Spillway Concrete Structure

LOCATION Right (South) Abutment Pier, 4 m from U/S edge of the dam (Top Deck) 4,937,511 N 721,829 E

DRILLING METHOD Coring (75 mm diameter) , Portable Rig

JOB NO. **13-0006-012**

GROUND ELEV. **244.38**

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED **22/07/2014**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				CONCRETE Poorly distributed crushed aggregate, some large pieces of aggregate to 200 mm.			R1		100	
				-Construction joint at +- 0.45 m. No evidence of seepage through concrete.			R2		100	
	1						R3		100	
		5					R4		100	
	2						R5		100	
	3	10					R6		100	
							R7		100	
	4						R8		100	
		15					R9		100	
	5						R10		100	
	6	20					R11		100	

CONTRACTOR OGS Inc.

INSPECTOR SN

APPROVED SG

DATE 21/12/15

Prepared By: SN

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO.
CH 14-101

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
							R12		100	
		25				7.9	R13		100	
	8						R14		100	
						8.5	R15		100	
	9	30		-Unbonded bedrock to concrete interface. -A nail was observed at the bedrock - concrete interface. -Nearly horizontal bedrock to concrete interface, sloping at 85° to the core axis.						
234.9				**GRANITE TO GRANODIORITE BEDROCK** Grey-pink, medium to coarse grained, no signs of weathering. -Refer to attached geological detail fracture log.		9.6	R16		100	100
	10					10.2	R18		100	44
		35								
	11						R19		100	53
	12	40					R20		100	66
231.5				**END OF HOLE AT 12.9 m.**		12.9				
	13			Notes: 1. Core hole completed on July 23, 2014. 2. Core hole opened to 12.9 m. 3. Water level at 3.3 m from the surface. 4. Installed two standpipe piezometers, one at a depth of 9.6 m (bedrock to concrete interface) and one at 12.9 m.						
		45								
	14									
	15	50								

CONTRACTOR: OGS Inc.
INSPECTOR: SN
APPROVED: SG
DATE: 21/12/15

GEOTECHNICAL-CORING P:\PROJECTS\2013\13-0006-012\DESIGN\GEOLOGS\BURLEIGH FALLS_CORE HOLES.GPJ

Prepared By: SN

KGS GROUP	**GEOLOGICAL DETAIL FRACTURE LOG**	Hole No.	CH 14-101
		Sheet	1 of 2
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	July 22, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	9.45 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
9.45	Top of Rock					X																
9.50	MB	90		X			X															
9.73	MB	90		X			X															
10.01	MB	90		X			X															
10.16	H	85	X				X					X										
10.16-10.29		45	X				X					X										
10.44	MB	80		X			X															
10.44-10.71	V	0	X				X					X										
10.71-10.92	BZ											X										
10.92	MB	90	X				X					X										
11.0	H	90			X		X															
11.06	MB	90			X		X															
11.26	H	90	X				X					X										
11.46	H	90		X			X					X										
11.46-11.63	BZ											X										
11.63	MB	90			X		X															
11.63-11.85	BZ																				X	
12.06	H	90		X			X															
APPROVED:				SHIFT:									DATE:									

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	CH 14-101
		Sheet	2 of 2
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	July 22, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	9.45 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
12.24	H	90		X			X					X										
12.38	SH	60	X				X					X										
12.43	H	90		X			X					X										
12.63	H	90			X		X															
12.73	H	90			X		X															
12.77	H	90			X		X															
12.88	EOH	90																				

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-102**

CLIENT PWGSC

PROJECT Burleigh Falls Dam

SITE Spillway Concrete Structure

LOCATION Pier # 1, 4 m from U/S edge of the dam (Top Deck) 4,937,522 N 721,827 E

DRILLING METHOD Coring (75 mm diameter) , Portable Rig

JOB NO. **13-0006-012**

GROUND ELEV. **244.38**

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED **24/07/2014**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				CONCRETE Poorly distributed crushed aggregate, some large pieces of aggregate to 200 mm.			R1		100	
				-Construction joint at +- 0.45 m. No evidence of seepage through concrete.			R2		100	
							R3		100	
	1						R4		100	
							R5		100	
		5					R6		100	
							R7		100	
	2						R8		100	
							R9		100	
							R10		100	
							R11		100	
	3	10		-Possible construction joint at +- 2.9 m. No evidence of seepage through concrete.			R12		100	
							R13		100	
							R14		100	
	4						R15		100	
		15					R16		100	
	5						R17		100	
	6	20					R18		100	
							R19		100	
				-Possible construction joint at +- 6.8 m. Evidence of seepage through concrete.			R20		100	

CONTRACTOR **OGS Inc.**

INSPECTOR **SN**

APPROVED SG

DATE 21/12/15

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-102**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				-Possible construction joint at +- 7.5 m. Evidence of seepage through concrete.			R21		100	
							R22		100	
	8	25					R23		100	
							R24		100	
	9	30					R25		100	
	10						R26		100	
233.7		35		-Core barrel dropped from 10.7 m to 11.9 m during coring.						
	11			**VOID** Presence of some cobbles and sand observed inside the void from the underwater camara survey.			R27		0	
232.5	12	40		**GRANITE TO GRANODIORITE BEDROCK** Grey-pink, medium to coarse grained, massive, competent, no signs of weathering. -Refer to attached geological detail fracture log.			R28		100	88
231.7				**END OF HOLE AT 12.7 m.**						
	13			Notes: 1. Core hole completed on July 31, 2014. 2. Gravel and sand sized debris washed into core hole at completion of drilling. Core hole open to 11.9 m. 3. Water level at 3.6 m from the surface. 4. Core hole was not grouted and remains open.						
		45								
	14									
	15	50								

CONTRACTOR **OGS Inc.** | INSPECTOR **SN** | APPROVED SG | DATE 21/12/15

GEOTECHNICAL-CORING P:\PROJECTS\2013\13-0006-012\DESIGN\GEOLOGS\BURLEIGH FALLS_CORE HOLES.GPJ

Prepared By: SN

KGS GROUP	**GEOLOGICAL DETAIL FRACTURE LOG**	Hole No.	CH 14-102
		Sheet	1 of 1
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	July 24, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	11.94 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
11.94	Top of Rock					X																
12.26	H	90			X		X														X	
12.63	H	90			X		X														X	
12.68	SH	60		X			X					X										
12.73	EOH	90																				
APPROVED:			SHIFT:										DATE:									

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-103**

CLIENT PWGSC

PROJECT Burleigh Falls Dam

SITE Spillway Concrete Structure

LOCATION Pier # 1, 8 m from U/S edge of the dam (Pier Nose) 4,937,522 N 721,823 E

DRILLING METHOD Coring (75 mm diameter) , Portable Rig

JOB NO. **13-0006-012**

GROUND ELEV. **243.01**

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED **29/07/2014**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				CONCRETE Poorly distributed crushed aggregate, some large pieces of aggregate to 200 mm.			R1		100	
							R2		100	
	1						R3		100	
		5					R4		100	
	2						R5		100	
	3	10					R6		100	
							R7		100	
	4						R8		100	
		15								
	5						R9		100	
	6	20					R10		100	
							R11		100	

CONTRACTOR **OGS Inc.**

INSPECTOR **SN**

APPROVED SG

DATE 21/12/15

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-103**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
		25		-Possible construction joint at +- 7.4 m. Evidence of seepage through concrete.			R12		100	
	8									
				-Core barrel dropped from 8.8 m to 10.1 m during coring.			R13		100	
234.2										
	9	30		**VOID** Presence of some cobbles and sand observed inside the void from the underwater camara survey.			R14		0	
232.9	10			**GRANITE TO GRANODIORITE BEDROCK** Grey-pink, medium to coarse grained, no signs of weathering. -Refer to attached geological detail fracture log.			R15		67	66
		35								
	11									
	12	40					R16		100	87
							R17		100	100
							R18		100	100
	13						R19		100	100
229.5				**END OF HOLE AT 13.5 m.**						
		45		Notes: 1. Core hole completed on July 30, 2014. 2. Gravel and sand sized debris washed into core hole at completion of drilling. Core hole open to 10.1 m. 3. Water level at 3.0 m from the surface. 4. Core hole was not grouted and remains open.						
	14									
	15	50								

CONTRACTOR **OGS Inc.**

INSPECTOR **SN**

APPROVED SG

DATE 21/12/15

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	CH 14-103
		Sheet	1 of 1
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	July 29, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	10.06 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
10.06	Top of Rock					X																
10.06-10.21	BZ	90																			X	
10.51	H	90			X		X														X	
10.81	H	90			X		X														X	
10.81-10.91	BZ																					
10.91	H	90			X		X														X	
10.96	MB	90			X		X															
10.96-11.11	BZ																					
11.29	H	90			X		X														X	
11.52	H	90			X		X														X	
12.65	H	90	X				X					X										
11.77	MB	90			X		X															
11.77-11.94	BZ																					
12.15	MB	90			X		X															
13.08	MB	90			X		X															
13.54	EOH	90																				

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-104**

CLIENT PWGSC

PROJECT Burleigh Falls Dam

SITE Spillway Concrete Structure

LOCATION Pier # 2, 4 m from U/S edge of the dam (Top Deck) 4,937,529 N 721,826 E

DRILLING METHOD 75 mm diameter concrete coring and 50 mm bedrock coring, Portable Rig

JOB NO. **13-0006-012**

GROUND ELEV. **244.38**

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED **13/08/2014**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				CONCRETE Poorly distributed crushed aggregate, some large pieces of aggregate to 200 mm. -Construction joint at +- 0.45 m. No evidence of seepage through concrete.			R1		100	
	1						R2		100	
		5								
	2						R3		100	
							R4		100	
	3	10								
							R5		100	
	4						R6		100	
		15								
	5						R7		100	
						5.5				
	6	20					R8		100	
						7.0				

CONTRACTOR OGS Inc.

INSPECTOR SN

APPROVED SG

DATE 21/12/15

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO.
CH 14-104

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				-Possible construction joint at +- 7.0 m. Evidence of seepage through concrete.			R9		100	
		25					R10		100	
	8									
							R11		100	
	9	30								
							R12		100	
	10									
		35								
233.3	11						R13		100	0
233.1				-Evidence of +- 50 mm gap at concrete to bedrock interface.		11.3				
				GRANITE TO GRANODIORITE BEDROCK			R14		77	38
	12			Grey-pink, medium to coarse grained, no signs of weathering.			R15		100	67
		40		-Refer to attached geological detail fracture log.						
	13						R16		90	35
230.6		45		**END OF HOLE AT 13.7 m.**						
	14			Notes: 1. Core hole completed on August 15, 2014. 2. Core hole opened to 11.3 m. 3. Water level at 3.0 m from the surface. 4. Installed a standpipe piezometer at a depth of 11.3 m below grade. 5. Bedrock core hole filled with sand at completion of coring and unable to install standpipe piezometer at the bottom of the hole.						
	15									
		50								

CONTRACTOR: OGS Inc.
INSPECTOR: SN
APPROVED: SG
DATE: 21/12/15

Prepared By: SN

GEOTECHNICAL-CORING P:\PROJECTS\2013\13-0006-012\DESIGN\GEOLOGS\BURLEIGH FALLS_CORE HOLES.GPJ

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	CH 14-104
		Sheet	1 of 1
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	August 13, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	11.28 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
11.28	Top of Rock					X																
11.28-11.46	BZ																				X	
11.46	MB	90			X		X															
11.46-11.58	BZ																					
11.83	MB	90			X		X															
11.89	H	90			X		X														X	
12.09	H	90			X		X														X	
12.24	H	90			X		X														X	
12.29	MB	90			X		X															
12.42	H	90			X		X														X	
12.49	H	90			X		X														X	
12.57	H	90			X		X														X	
12.69	H	90			X		X														X	
12.82	H	90			X		X														X	
12.87	H	90			X		X														X	
12.92	H	90			X		X														X	
13.07	H	90			X		X														X	
13.24	H	90			X		X														X	
13.29	H	90			X		X														X	
13.29-13.74	BZ																				X	
13.74	EOH	90																				

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **CH 14-105**

CLIENT PWGSC

PROJECT Burleigh Falls Dam

SITE Spillway Concrete Structure

LOCATION Pier # 3, 4 m from U/S edge of the dam (Top Deck) 4,937,536 N 721,823 E

DRILLING METHOD Coring (75 mm diameter) , Portable Rig

JOB NO. **13-0006-012**

GROUND ELEV. **244.38**

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED **15/08/2014**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				CONCRETE Poorly distributed crushed aggregate, some large pieces of aggregate to 200 mm.			R1		100	
				-Construction joint at +- 0.45 m. No evidence of seepage through concrete.			R2		100	
	1						R3		100	
							R4		100	
		5					R5		100	
	2						R6		100	
							R7		100	
							R8		100	
	3	10					R9		100	
							R10		100	
	4						R11		100	
		15					R12		100	
	5					5.3	R13		100	
	6	20				5.8	R14		100	

CONTRACTOR OGS Inc.

INSPECTOR SN

APPROVED SG

DATE 21/12/15

Prepared By: SN

GEOTECHNICAL-CORING P:\PROJECTS\2013\13-0006-012\DESIGN\GEO\LOGS\BURLEIGH FALLS_CORE HOLES.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO.
CH 14-105

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
				-Unbonded bedrock to concrete interface. -Nearly horizontal bedrock to concrete interface, sloping at 85° to the core axis.			R15		100	
236.6	8	25		**GRANITE TO GRANODIORITE BEDROCK** Grey-pink, medium to coarse grained, no signs of weathering. -Refer to attached geological detail fracture log.		7.9	R16		100	91
	9	30					R17		100	81
						9.4				
	10						R18		100	95
233.9						10.5				
		35		**END OF HOLE AT 10.5 m.** Notes: 1. Core hole completed on August 16, 2014. 2. Core hole opened to 10.5 m. 3. Water level at 6.0 m from the surface. 4. Installed two standpipe piezometers, one at a depth of 7.8 m below grade and one at a depth of 10.5 m.						
	11									
	12	40								
	13									
		45								
	14									
	15	50								

CONTRACTOR: OGS Inc.
INSPECTOR: SN
APPROVED: SG
DATE: 21/12/15

KGS GROUP	**GEOLOGICAL DETAIL FRACTURE LOG**	Hole No.	CH 14-105
		Sheet	1 of 1
Site / Location	Burleigh Falls Dam	Client	PWGSC
Contractor	OGS Drilling Ins.	Project	Upper Kawartha Sites
Core Diameter	75 mm	Project No.	13-0006-012
Method	HQ Coring	Logged By	SN
		Date Drilled	August 15, 2014
Bearing of Hole		Depth to Water Table	
Angle From Horizontal	Vertical	Date	
Depth to Rock Surface	7.77 m		

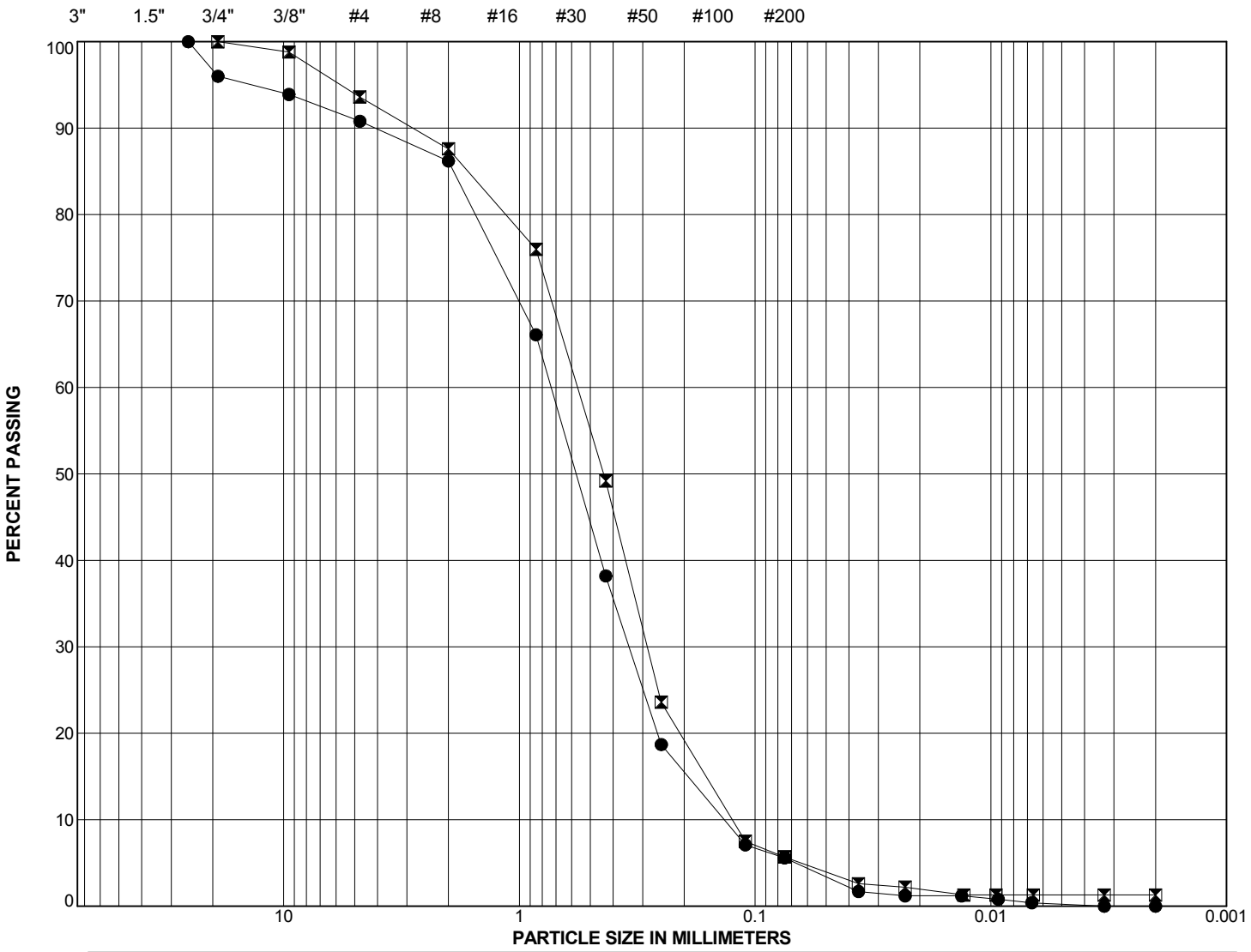
DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION										JOINT FILLING									
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANAR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT	Oxidized
7.77	Top of Rock					X																
8.02	H	90	X				X					X										
8.52-8.77		45	X				X					X										
8.61	MB	90		X			X															
8.77	MB	90		X			X															
8.97	MB	90		X			X															
9.10	MB	90		X			X															
9.27	MB	90		X			X															
9.52	MB	90		X			X															
9.57	H	90			X		X														X	
10.22	MB	90		X			X															
10.46	EOH	90																				

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

SIEVE ANALYSIS

HYDROMETER ANALYSIS



GRAVEL		SAND			SILT	CLAY
coarse	fine	coarse	medium	fine		

SYMBOL	HOLE	DEPTH (m)	SAMPLE #	% GRAVEL	% SAND	% SILT	% CLAY	% SILT & CLAY	Cu	Cc	CLASSIFICATION
●	*TH 14-101*	*2.7*	*S3*	*9.2*	*85.2*	*5.6*	*0.0*	*5.6*	*5.4*	*1.2*	
⧓	*TH 14-102*	*2.1*	*S2*	*6.4*	*87.9*	*4.4*	*1.3*	*5.7*	*4.5*	*1.2*	

SIEVE ANALYSIS P:\PROJECTS\2013\13-0006-012\DESIGN\GEO\LOGS\BURLEIGH FALLS.GPJ

KGS GROUP

PWGSC

Burleigh Falls Dam

GRAIN SIZE ANALYSES

December 2015	Figure A-1	Page 1 of 1

APPENDIX C

RECOVERED SAMPLE PHOTOS

North (Left) Earthfill Embankment
Sand Fill

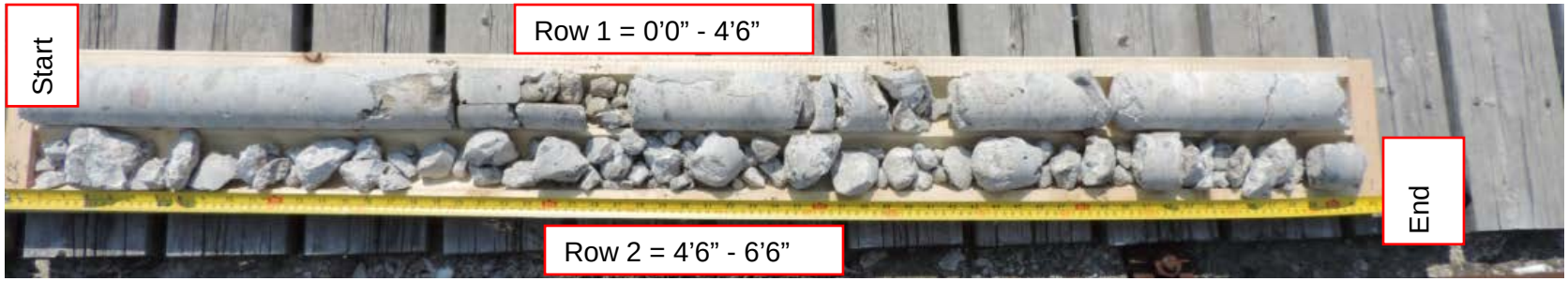
TH 14-101 Sample 2 (6'3''-8'3'')
SPT count (7,6,32,23) Recovery 9"

North (Left) Earthfill Embankment
Sand Fill

TH 14-102 Sample 3 (9'-11')
SPT count (5,7,6,8) Recovery 11"

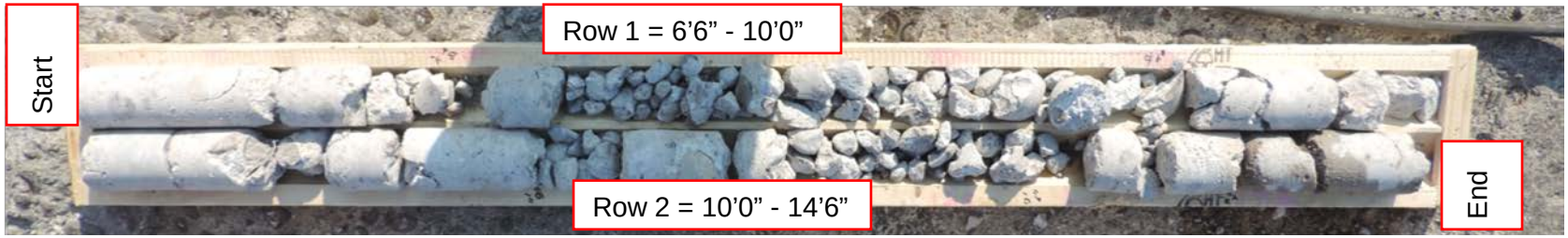
North (Left) Earthfill Embankment
Rock Fill

TH 14-102 Core sample (1’-5’)



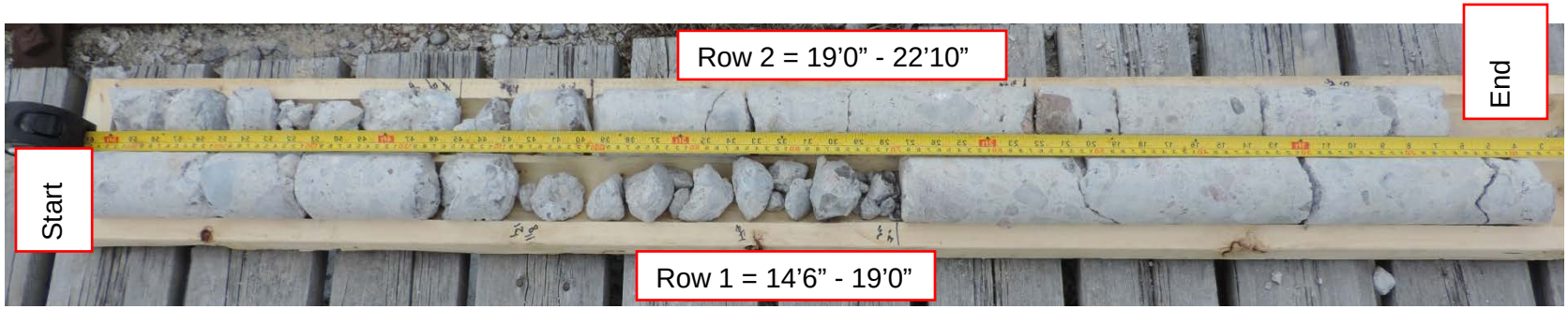
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Concrete core sample (0'0''- 6'6")



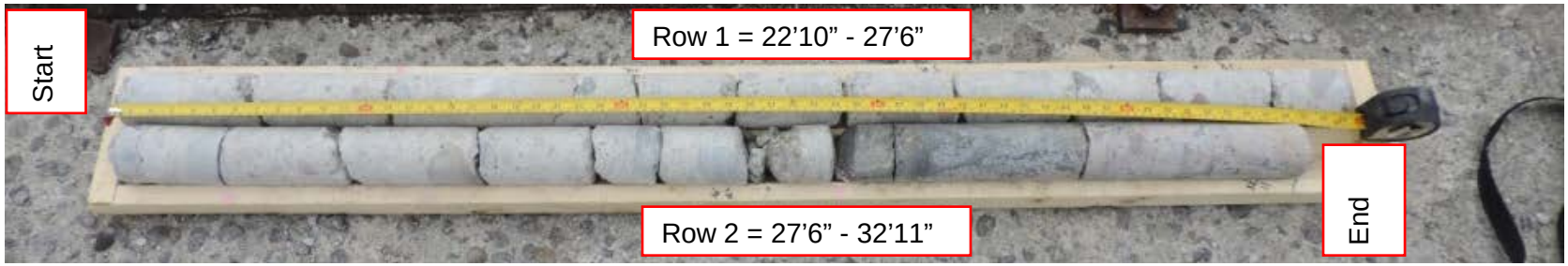
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Concrete core sample (6'6''- 14'6")



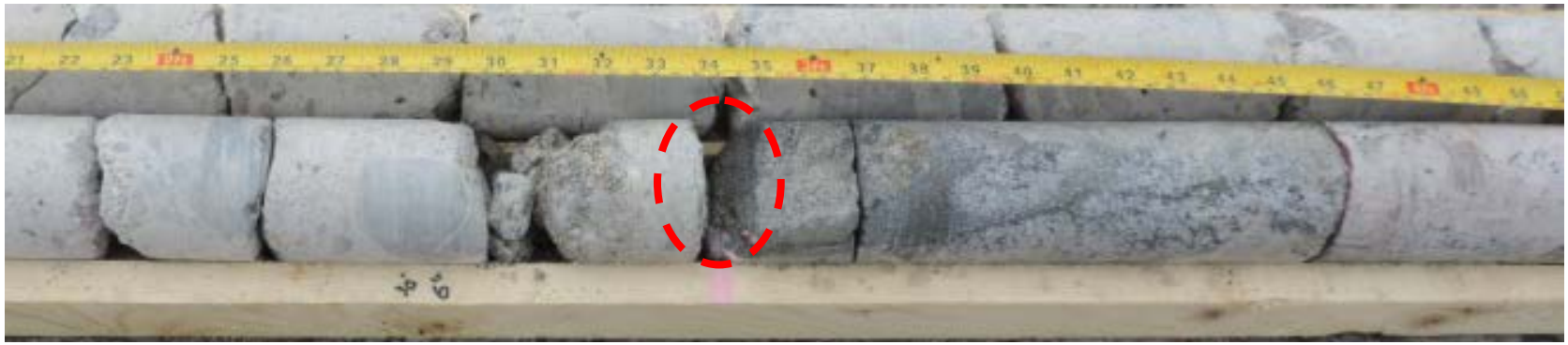
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Concrete core sample (14'6''- 22'10")



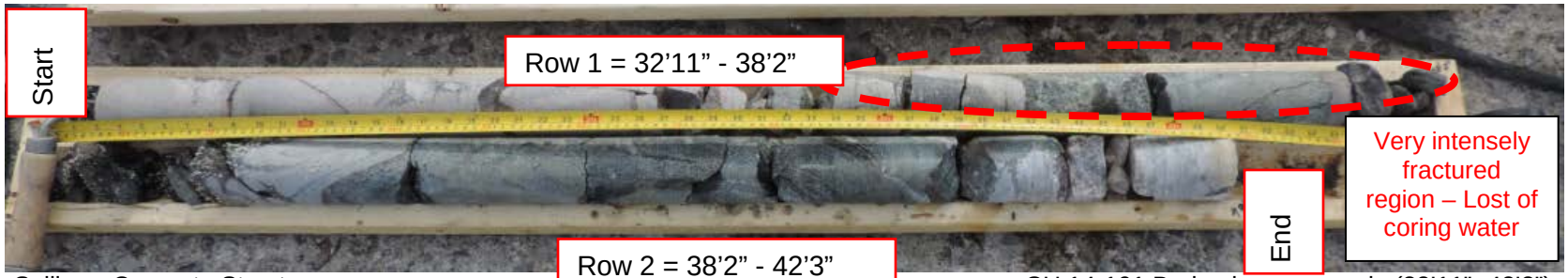
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Concrete core sample (22'10''- 31'0")
CH 14-101 Bedrock core sample (31'0''- 32'11")



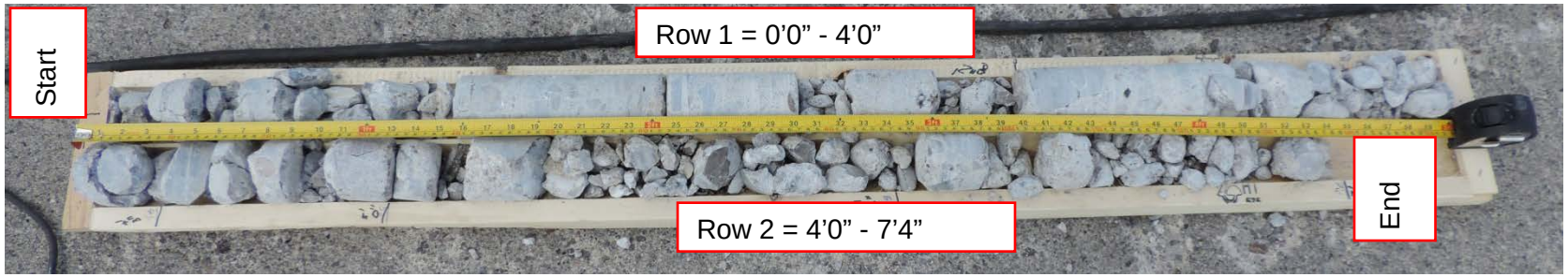
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Concrete-Bedrock interface



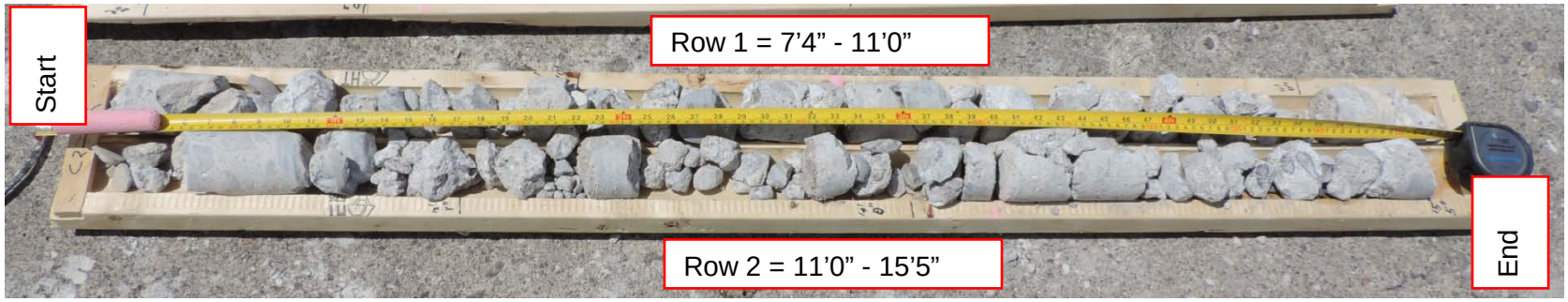
Spillway Concrete Structure
South (Right) Abutment Pier

CH 14-101 Bedrock core sample (32'11"- 42'3")



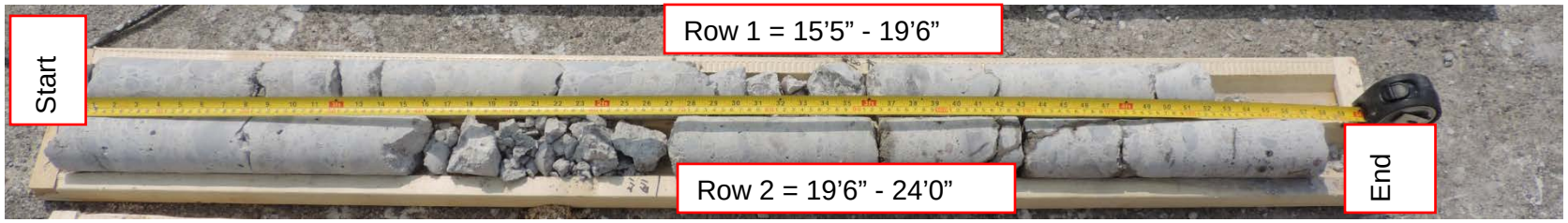
Spillway Concrete Structure
Pier # 1

CH 14-102 Concrete core sample (0'0''- 7'4")



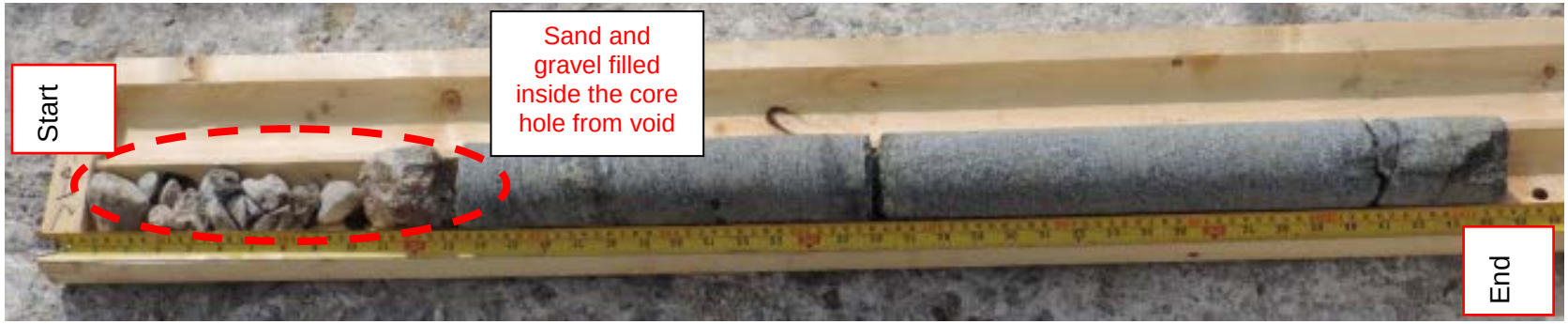
Spillway Concrete Structure
Pier # 1

CH 14-102 Concrete core sample (7'4''- 15'5")



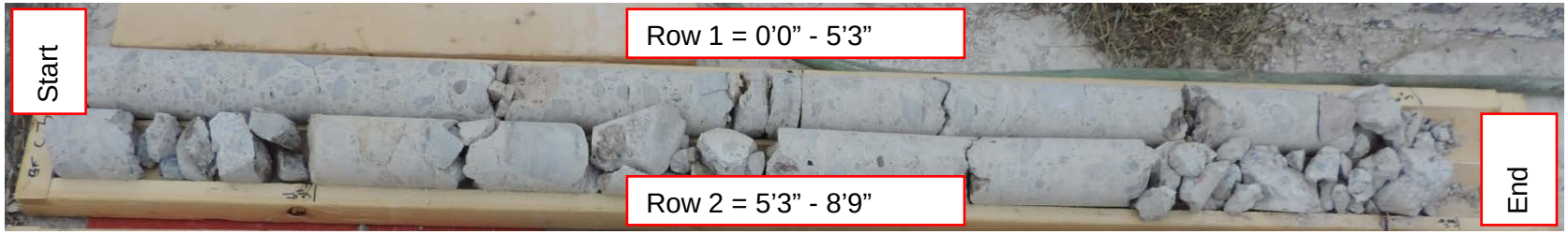
Spillway Concrete Structure
Pier # 1

CH 14-102 Concrete core sample (15'5''- 24'0")



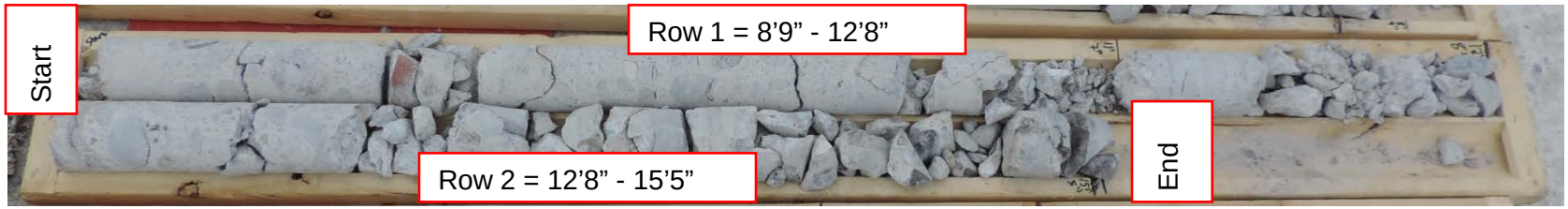
Spillway Concrete Structure
Pier # 1

14-102 Bedrock core sample (39.0'- 42.0')



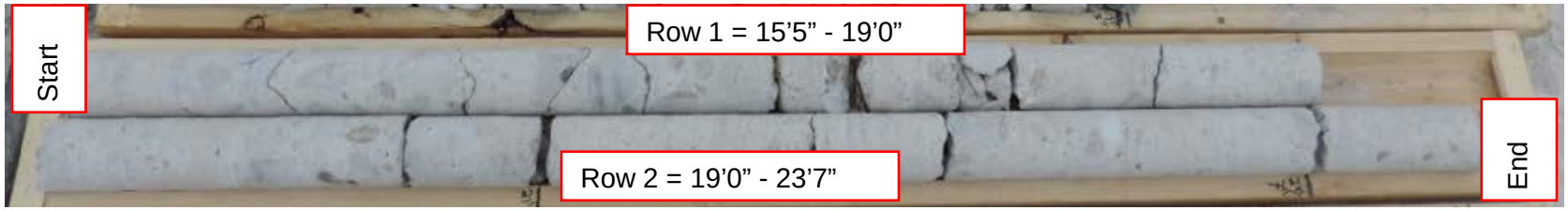
Spillway Concrete Structure
Pier # 1 (Pier Nose)

CH 14-103 Concrete core sample (0’0’’- 8’9”)



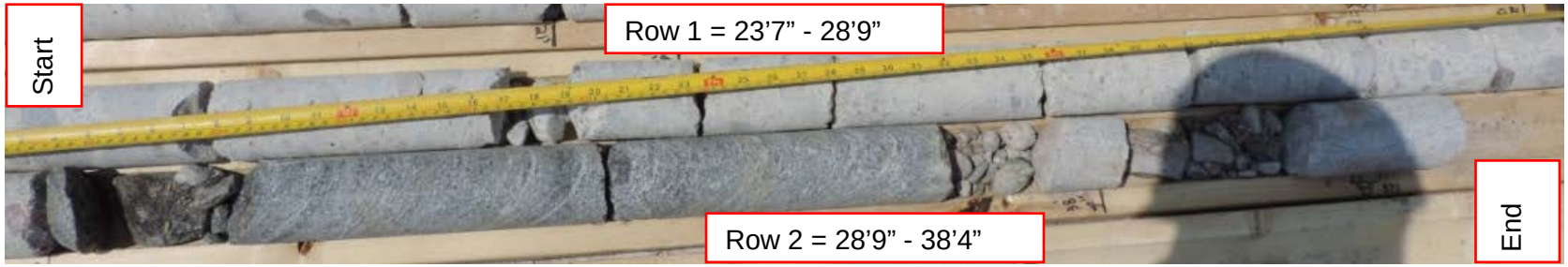
Spillway Concrete Structure
Pier # 1 (Pier Nose)

CH 14-103 Concrete core sample (8’9’’- 15’5”)



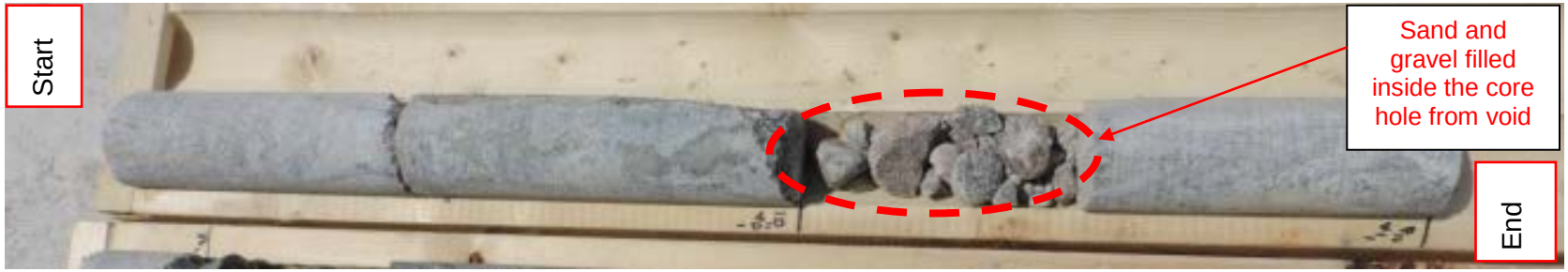
Spillway Concrete Structure
Pier # 1 (Pier Nose)

CH 14-103 Concrete core sample (15’5’’- 23’7”)



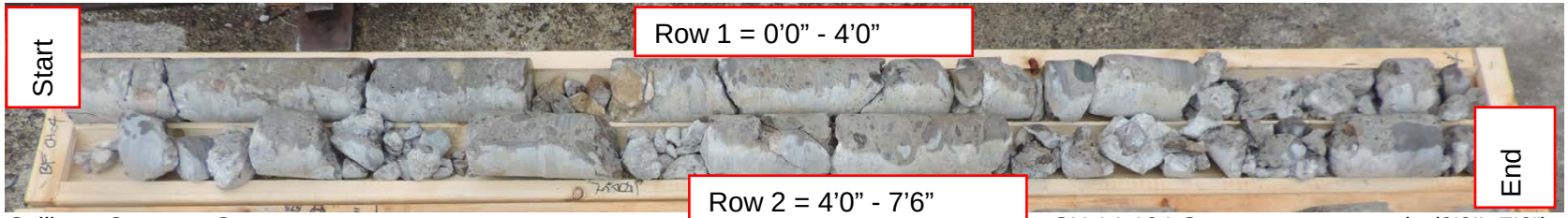
Spillway Concrete Structure
Pier # 1 (Pier Nose)

CH 14-103 Concrete core sample (23'7''- 29'0")
CH 14-103 Bedrock core sample (33'0''- 38'4")



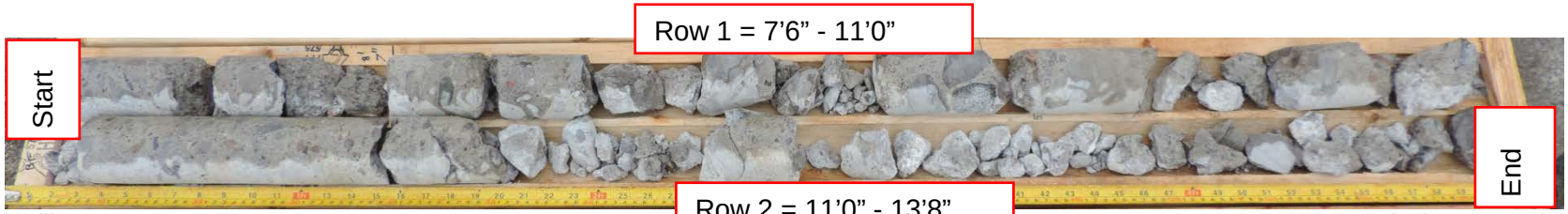
Spillway Concrete Structure
Pier # 1 (Pier Nose)

CH 14-103 Bedrock core sample (38'4"- 41'6")



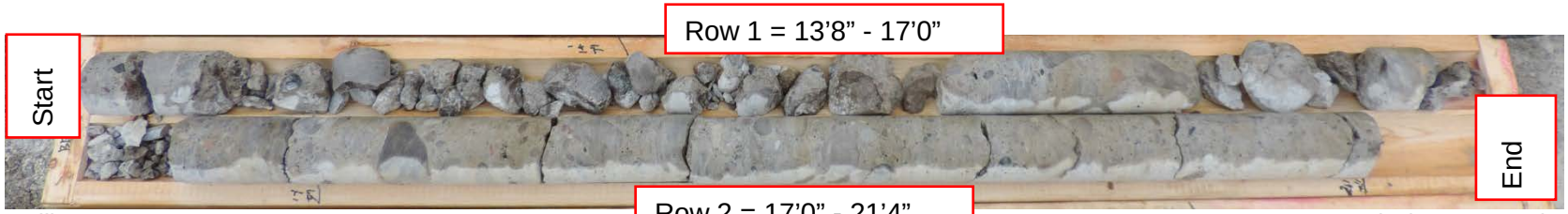
Spillway Concrete Structure
Pier # 2

CH 14-104 Concrete core sample (0'0''- 7'6")



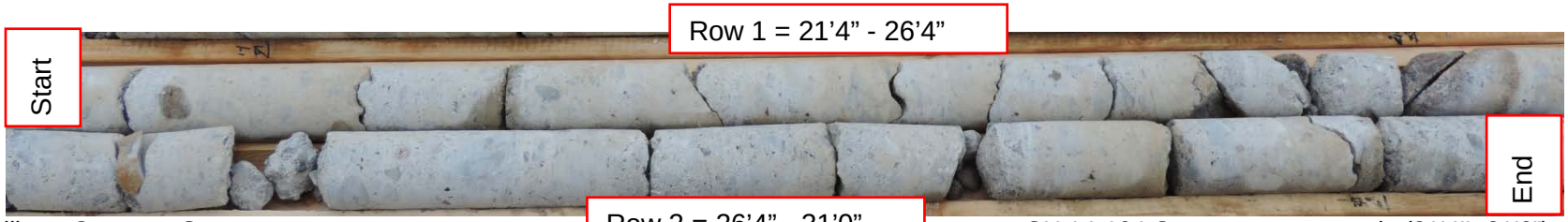
Spillway Concrete Structure
Pier # 2

CH 14-104 Concrete core sample (7'6''- 13'8")



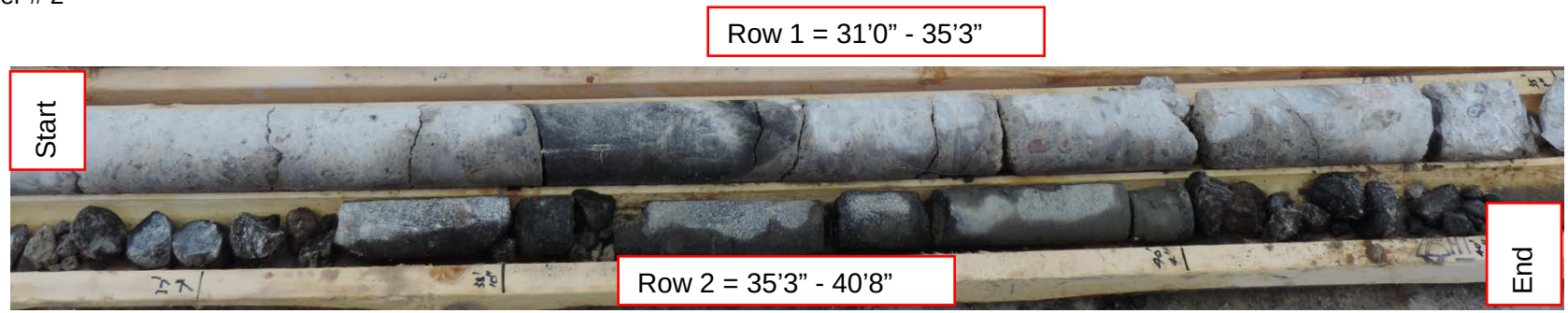
Spillway Concrete Structure
Pier # 2

CH 14-104 Concrete core sample (13'8''- 21'4")



Spillway Concrete Structure
Pier # 2

CH 14-104 Concrete core sample (21’4’’- 31’0”)



Spillway Concrete Structure
Pier # 2

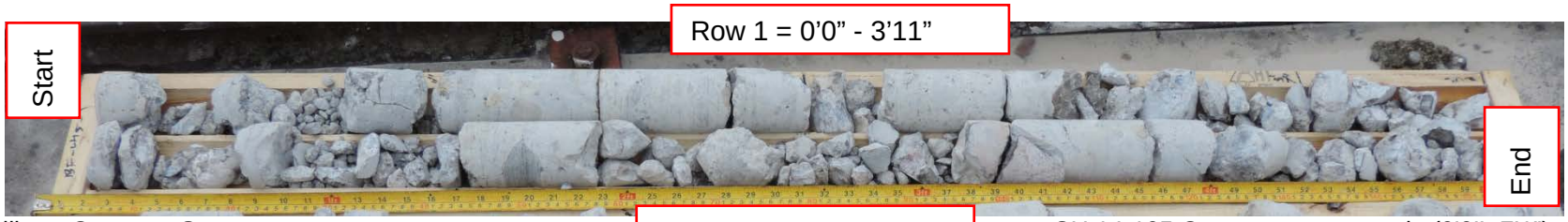
CH 14-104 Concrete core sample (31’0’’- 36’10”)
CH 14-104 Bedrock core sample (37’0’’- 40’8”)

Spillway Concrete Structure
Pier # 2

CH 14-104 Bedrock core sample (40’8’’- 44’0”)

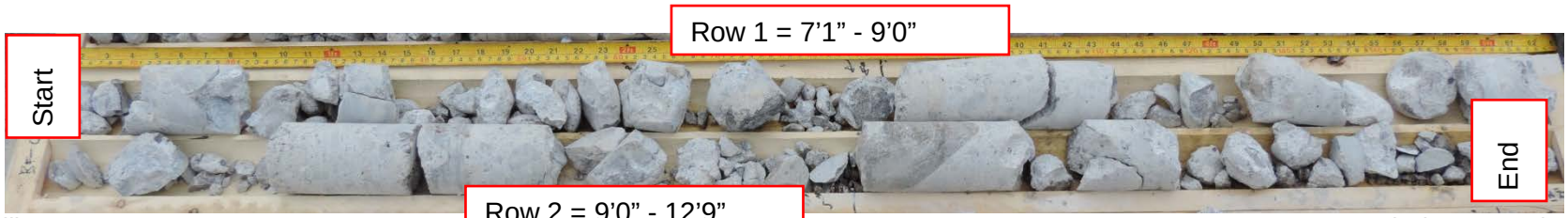
Spillway Concrete Structure
Pier # 2

CH 14-104 Bedrock core sample (43’6’’- 46’3”)



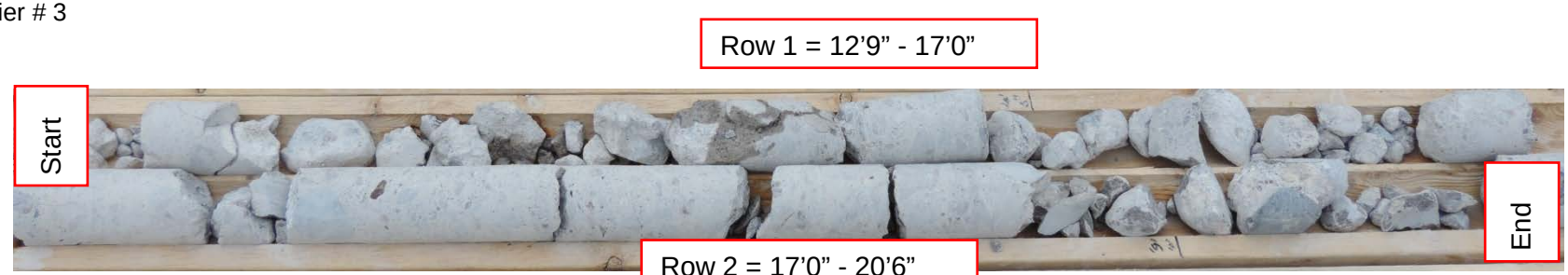
Spillway Concrete Structure
Pier # 3

CH 14-105 Concrete core sample (0'0''- 7'1")



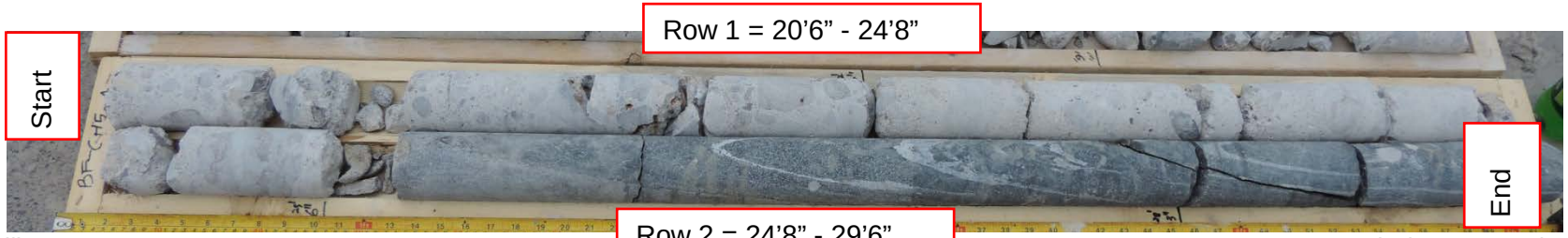
Spillway Concrete Structure
Pier # 3

CH 14-105 Concrete core sample (7'1''- 12'9")



Spillway Concrete Structure
Pier # 3

CH 14-105 Concrete core sample (12'9''- 20'6")



Spillway Concrete Structure
Pier # 3

CH 14-105 Concrete core sample (20’6’’- 25’6”)
CH 14-105 Bedrock core sample (25’6’’- 29’6”)

Spillway Concrete Structure
Pier # 3

CH 14-105 Concrete-Bedrock interface

Spillway Concrete Structure
Pier # 3

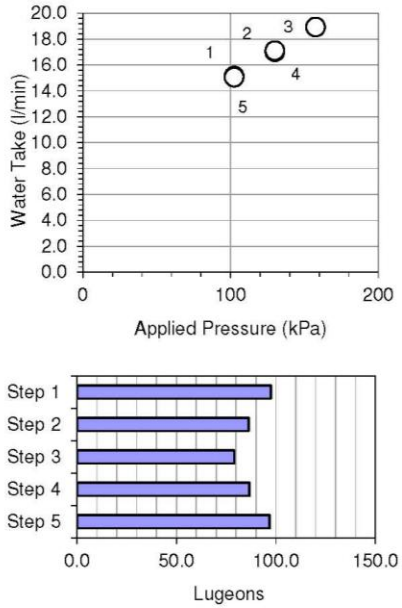
CH 14-105 Bedrock core sample (29’6’’- 34’4”)

APPENDIX D

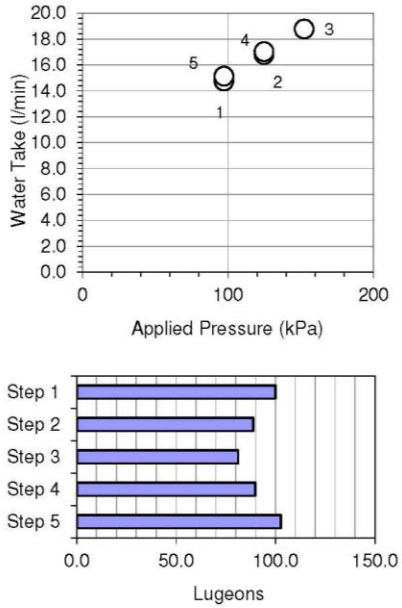
GRAPHICAL REPRESENTATION OF WATER PRESSURE TESTING RESULTS

CH14-101

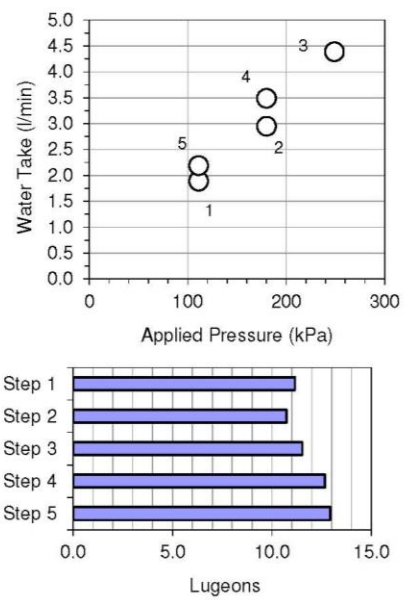
Bedrock



Bedrock-Concrete

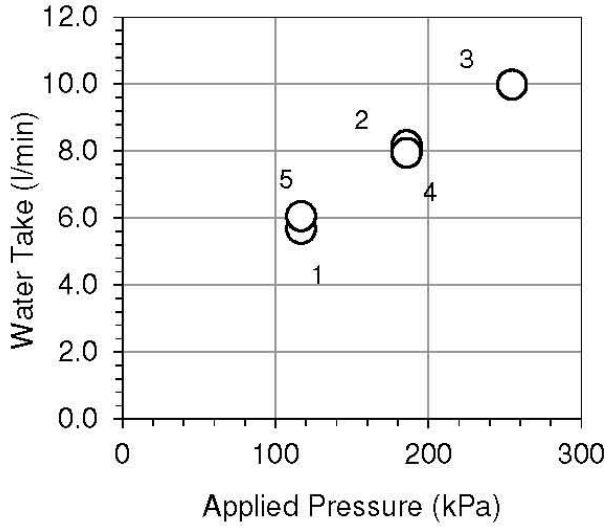


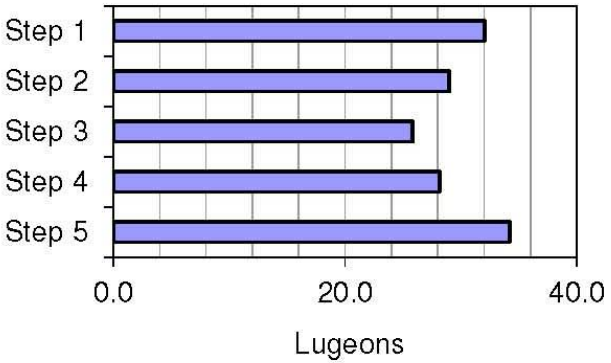
Concrete



CH14-105

Bedrock





Bedrock-Concrete