September 4, 2015

COLLIERY DAMS, NANAIMO, BC

Auxiliary Spillway - Preliminary Design Report

Submitted to:
Toby Seward
City of Nanaimo
455 Wallace Street
Nanaimo, BC
V9R 5J6

REPORT

Report Number: 1314470516-032-R-Rev0

Distribution:

2 copies - City of Nanaimo
1 copy - Golder Associates Ltd.

Golder Associates

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

This report summarizes the findings of recent work carried out by Golder Associates Ltd. (Golder) for the City of Nanaimo (City) on the Lower Colliery Dam in Nanaimo BC. These studies, carried out principally in August 2015, were primarily related to further design development of the auxiliary spillway for the Lower Dam. A conceptual design for the auxiliary spillway was presented in a previous report (Golder, 2015). Due to the limited time available to design and construct the spillway, design and construction are being carried out under a compressed time frame, and it is necessary to submit the design in a series of reports as the work is undertaken, rather than a single report following the completion of design. This report summarizes recent findings and design work related to the geotechnical investigations undertaken at the site, and further development of design concepts based on the improved geotechnical understanding.

The design presented in this report is of a preliminary nature (not detailed design); as such designs and layouts presented in this report are preliminary and subject to change as the design is developed. We understand that this report will be submitted to the Province of BC (Water Management Branch, Dam Safety Section) as part of the permitting process for the project.

2.0 GEOTECHNICAL ENGINEERING

2.1 Geotechnical Investigations

A subsurface geotechnical investigation at the proposed auxiliary spillway site, consisting of an initial test pitting phase and second drilled borehole phase, was conducted on August 6, 2015 and from August 17 to 21, 2015, respectively. The investigation program was carried out under the full-time supervision of Golder geotechnical staff who logged the subsurface conditions encountered and provided direction on sampling procedures, testing depths, and final depths of boreholes. Samples were carefully packed and stored prior to transport to the Golder laboratory in Burnaby.

2.1.1 Test Pit Investigation

A total of four testpits (TP15-01 to TP15-04) were putdown to depths between 2.7 m and 4.6 m using a Case 590 backhoe, supplied by City of Nanaimo. An additional two test pit locations (TP15-05 and TP15-06) were putdown further along the spillway alignment, using a hand shovel to depths of 0.5 m and 0.7 m. Grab samples were collected from select intervals as the test pits were excavated. The test pits were terminated at the maximum reach of the equipment, the maximum depth allowable to maintain hole stability, or practical excavation refusal. Test pits were backfilled upon completion and the disturbed ground surface covered with straw. A record of the soil and rock conditions encountered in the test pits can be found in the Record of Testholes, Appendix A, Annex A.

2.1.2 Borehole Investigation

A total of three boreholes (BH15-01 to BH15-03) were putdown to depths between 8.8 m to 17.4 m using a HT 750 Rubber Track Mounted Rotary Drill, supplied and operated by Foundex Explorations Ltd. of Surrey, BC. All boreholes were advanced using an HWT-sized (121 mm outside diameter) or PWT-sized (159 mm outside diameter) mud-rotary tricone bit. Sampling of the soils was primarily carried out with Standard Penetration Tests (SPTs) driven at select intervals within the boreholes. After drilling to the desired sample depth, SPTs were carried out using a 50 mm diameter heavy wall split-spoon sampler, and driven using a 140 lb. (63.5 kg) automatic trip hammer with a 30 inch (760 mm) drop height. The number of blows required to advance the sampler 12 inches (300 mm) was recorded. Upon retrieval of the sampler, the SPT split tube was opened, and the recovered soil was classified, photographed and stored in labeled bags, and transported to the Golder Burnaby laboratory facility for testing of select samples.

Where bedrock was encountered, PWT casing was seated a nominal depth into rock and PQ-size coring equipment, fitted with a stepped diamond core bit, was used to advance the boreholes and obtain continuous rock core samples.

Each core run was advanced to a maximum length of 1.5 m, and the inner core barrel was retrieved by wire line, bringing the recovered core to the surface where it was placed in core boxes. Once the borehole coring was completed, the core was transported to Golder's Laboratory in Burnaby where samples were selected for further testing. Individual rock characteristics such as weathered state, structure, intact rock strength estimates and discontinuity conditions (type, shape, roughness and infill) were recorded in accordance with the ISRM Suggested Methods (1981).

Detailed descriptions of the soil and bedrock conditions encountered are presented in the Record of Testhole Sheets compiled in Appendix A, Annex A. Laboratory testing results are provided in Appendix A, Annex B. The rock core photograph is presented in Appendix A, Annex C.

2.1.3 Monitoring Well Installations

Monitoring wells were installed in boreholes BH15-01 and BH15-02 during the 2015 investigation. The monitoring wells were installed in sandy overburden soils, immediately above the very dense till-like soil contact and near the spillway invert elevation. Following installation, the piezometer screens were developed by removing approximately five well volumes of water from the piezometers. Following well development, field slug testing was performed on both piezometers to induce an instantaneous change in water level, for in situ assessment of hydraulic properties of the soils adjacent to the piezometer screen.

Both monitoring wells were completed with flush-mounted road boxes under the supervision and direction of Golder field staff. Monitoring well installations at BH15-01 and BH15-02, and backfilling at BH15-03 was completed in accordance with the BC Groundwater Protection Regulation. Installation and backfill details are summarized on Record of Borehole logs in Appendix A, Annex A.

2.1.4 Water Level Monitoring

Groundwater level measurements were taken following completion of drilling and well development. The measurements were collected using a water level meter. Groundwater monitoring results, for the piezometers, are presented in Table 1.

Table 1: Water Level Monitoring at 2015 Boreholes

Borehole	Elevation at Ground Surface (m)	Elevation at Top of Pipe (m)	Top of Screen (m)	Bottom of Screen (m)	Water Elevation (m)
Reservoir Level	-	-	-	-	71.63
BH15-01	74.85	74.79	69.36	67.84	71.26
BH15-02	74.55	74.52	68.45	67.23	70.45

During test pitting, groundwater seepage inflow was observed in test pits TP15-01, 02, and 03 at elevations of 71.1 m, 71.1 m, and 70.9 m, respectively. No groundwater seepage was observed at test pits TP15-04, 05, and 06.

2.1.5 Laboratory Testing

Upon completion of the field investigation work, Golder carried out laboratory testing on selected soil and rock samples obtained from the test pits and boreholes. The specific laboratory tests included the following:

- Water content determination tests (ASTM D2216);
- Grain size distribution analysis tests (ASTM C136, D422);
- Plasticity (Atterberg limit) determination tests (ASTM D4318); and,
- Uniaxial Compressive Strength (UCS) of rock core (ASTM D7012 – Method C).

The results of the laboratory testing are presented in Appendix A, Annex B and summarized on the Record of testhole log sheets presented in Appendix A, Annex A.

2.2 Interpreted Geotechnical Conditions

The following sections describe the generalized subsurface conditions encountered during the investigation. Details of the subsurface conditions encountered in individual test pits and boreholes are reported in Appendix A, Annex A. Our interpretation of the generalized soil stratigraphy along the proposed alignment section is presented on Figure 3.

2.2.1 Topsoil

All test pits and boreholes, with the exception of TP15-05 and TP15-06, encountered topsoil at ground surface, extending to depths of between about 0.1 m and 0.2 m. The topsoil generally consisted of leafy, decomposed, organic matter.

2.2.2 Silt with varying sand and gravel

A deposit of fine-grained non-cohesive soil was encountered at test pits TP15-05 and 06. The unit was encountered at surface and terminated immediately above bedrock at depths of 0.4 m and 0.7 m. The unit was generally comprised of brown silt, with trace to some sand and gravel, and was observed to contain a boulder at TP15-06. No laboratory tests were performed on samples collected from this unit.

2.2.3 Gravel, some sand to gravelly Sand

A deposit of gravel and sand was encountered at all boreholes, and test pits TP15-01 to TP15-03. The unit contact was immediately below the topsoil, with a thickness between 1.1 m and 2.6 m. The unit was generally comprised of brown-grey, moist to dry, sand and gravel of varying percentages, with trace to some silt, and containing cobbles and boulders. Based on SPT blow counts during drilling, the relative density of the unit is generally compact.

Laboratory test results for this deposit are summarized below in Table 2.

Table 2: Summary of Laboratory Testing on Samples from Gravel, some sand to gravelly Sand

Borehole	Sample (Depth)	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)		
			Plastic Limit	Liquid Limit	Gravel	Sand	Fines
TP15-01	Sa. 2 (1.22 – 1.46 m)	-	-	-	86	11	1
TP15-02	Sa. 1 (0.70 – 0.85 m)	-	-	-	75	23	2

2.2.4 Sand, trace gravel to gravelly

A deposit of sand was encountered at all boreholes and testpits TP15-01 to TP15-04. The unit was encountered at depths between 0.2 m and 2.7 m, with a thickness between 1.1 m and 2.9 m. The unit was generally comprised of grey, moist to wet, fine to coarse grained sand, with trace gravel to gravelly and trace silt. Groundwater seepage inflow near the base of this unit was typically observed into the open excavations during test pitting. Based on SPT blow counts during drilling, the relative density of the unit is generally compact to dense.

Laboratory test results for this deposit are summarized below in Table 3.

Table 3: Summary of Laboratory Testing on Samples from Sand, trace gravel to gravelly

Borehole	Sample (Depth)	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)		
			Plastic Limit	Liquid Limit	Gravel	Sand	Fines
TP15-01	Sa. 8 (3.05 – 3.35 m)	-	-	-	0	90	10
TP15-02	Sa. 4 (3.20 – 3.35 m)	-	-	-	26	73	1
TP15-03	Sa. 3 (2.44 – 2.59 m)	-	-	-	7	84	9

2.2.5 Clayey Silt to Silty Clay, trace sand to sandy

A deposit of fine-grained cohesive soils were encountered at all boreholes and testpits TP15-01, 03, and 04. The unit was encountered at depths between 1.1 m and 4.9 m, with a thickness between 0.4 m and 1.4 m. The unit was generally comprised of grey, clayey silt to silty clay, with varying percentages of fine to coarse sand. Based on SPT blow counts during drilling and observations during test pitting, the relative density of the unit varies from soft to very stiff.

Laboratory test results for this deposit are summarized below in Table 4.

Table 4: Summary of Laboratory Testing on Samples from Clayey Silt to Silty Clay, trace sand to sandy

Borehole	Sample (Depth)	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)		
			Plastic Limit	Liquid Limit	Gravel	Sand	Fines
TP15-01	Sa. 10 (4.27 – 4.36 m)	23	17	25	1	25	74
TP15-01	Sa. 11 (4.36 – 4.42 m)	18	-	-	-	-	-
TP15-02	Sa. 6 (3.96 – 4.11 m)	28	-	-	-	-	-
TP15-03	Sa. 4 (3.35 – 3.51 m)	23	-	-	-	-	-
TP15-03	Sa. 5 (3.96 – 4.11 m)	21	13	22	0	11	89
TP15-03	Sa. 6 (4.36 – 4.42 m)	19	-	-	-	-	-
TP15-04	Sa. 2 (1.16 – 1.22 m)	21	-	-	-	-	-
TP15-04	Sa. 3 (1.83 – 1.98 m)	34	26	39	-	-	-
BH15-02	Sa. 4 (5.18 – 5.79 m)	27	14	26	-	-	-

2.2.6 Silty Sand to Silt and Sand

A deposit of silt and sand was encountered at all boreholes. The unit was encountered at depths between 5.3 m and 5.9 m, with a thickness between 0.4 m and 1.7 m, generally thinning towards the southeast, and inferred to pinch out at approximately chainage 0+055 (Figure 3). The unit was generally comprised of brown-grey, moist, fine to medium grained sand and silt, with varying percentages, and trace to some gravel. Based on SPT blow counts during drilling, the relative density of the unit is generally compact to very dense.

Laboratory test results for this deposit are summarized below in Table 5.

Table 5: Summary of Laboratory Testing on Samples from Silty Sand to Silt and Sand

Borehole	Sample (Depth)	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)		
			Plastic Limit	Liquid Limit	Gravel	Sand	Fines
BH15-01	Sa. 4B (5.33 – 5.64 m)	-	-	-	1	75	41
BH15-02	Sa. 5 (6.71 – 7.24 m)	-	-	-	14	64	22
BH15-03	Sa. 4B (5.26 – 5.64 m)	-	-	-	1	35	64

2.2.7 Till-like Soils

Very dense, till-like soils very encountered at boreholes BH15-01 and 02. he unit was encountered at depths between 7.1 m and 7.2 m, and both boreholes were terminated within the unit. The unit was generally comprised of grey silt, fine to coarse grained sand, and fine to coarse grained gravel, of varying percentages. Fissured silty clay and laminations of fine silty sand were encountered within the unit, though were not observed in the upper 3 to 4 m. Based on SPT blow counts during drilling, the relative density of the unit is generally very dense.

The till-like soils unit is inferred to pinch out between approximate chainages 0+040 and 0+050 on Figure 3, and were not encountered in BH15-03.

Laboratory test results for this deposit are summarized below in Table 6.

Table 6: Summary of Laboratory Testing on Samples from Silty Sand to Silt and Sand

Borehole	Sample (Depth)	Natural Moisture (%)	Atterberg Limits (%)		Particle Size Distribution (%)		
			Plastic Limit	Liquid Limit	Gravel	Sand	Fines
BH15-01	Sa. 5B (7.01 – 7.32 m)	-	-	-	10	49	41
BH15-02	Sa. 6 (8.23 – 8.46 m)	-	-	-	38	42	20
BH15-02	Sa. 8 (10.97 – 11.28 m)	15	33	21	2	45	53

2.2.8 Bedrock

Bedrock was encountered at all boreholes and test pits located east of chainage 0+050 (BH15-03, TP15-03, -04, -05 and -06) between depths of 0.4 m and 5.6 m. Based on nearby bedrock outcrops, core recovered from BH15-03, and observations during test pitting, bedrock consists of unweathered, massive, grey conglomerate, with sub-rounded to sub-angular clasts up to approximately 40 mm diameter, cemented in a fine to coarse sandy matrix. Sub-horizontal breaks in core recovered at BH15-03 were generally fresh, and are inferred to be a result drilling induced breaks, resulting in a Rock Quality Designation (RQD) between 85% and 98%.

Based on drilling penetration rate at BH15-01 and observations in test pit TP15-04, the conglomerate bedrock may be overlain with a thin (less than 0.5 m thickness) layer of moderately to highly weathered sandstone. It should be noted that weak, friable sandstone may be present along the spillway channel.

Laboratory testing on PQ-size rock core recovered at BH15-03 is summarized below in Table 7.

Table 7: Summary of Rock Core Laboratory Testing

Borehole	Sample Depth (m)		Uniaxial Compression Strength (MPa)	Rock Strength	Rock Type
	From	To			
BH15-03	6.86	7.04	60.7	R4 (Strong)	Conglomerate
BH15-03	7.62	7.80	67.5	R4 (Strong)	Conglomerate

2.3 Geotechnical Design and Construction Issues

A preliminary assessment of the geotechnical design and construction issues has been developed based on the findings of the geotechnical investigation. Design recommendations related to the foundations for the permanent structures are presented in Appendix B. Additional recommendations related to the control of groundwater and seepage, both during the construction stage and during the permanent operation of the spillway are presented in this section.

As shown on the attached figures, excavation for the foundations of the weir and bridge structures will be in the range of four to five metres below the groundwater table and below reservoir level. The sandy soils which will be encountered in the excavation will be unstable when excavated at these depths below the groundwater table, and must be controlled by incorporation of measures to limit groundwater ingress into the excavation.

A number of options for controlling the groundwater have been considered as part of the project design. Although a decision has not yet been made in regards to a preferred option, one option which has been identified is presented on Figures 6A and 6B. This option included construction of a cut-off wall around the perimeter of the excavation. The cut-off wall would extend from the about 72 m elev (at or above the groundwater table) and would extend through the sandy soil layers into the lower permeability underlying glacial till. The cut-off would extend across the west, north and south sides of the excavation. The downstream extent of the walls is to be determined based on hydrogeological modelling which is currently underway. The cut-off shown in Figures 6A and 6B would also be used to provide excavation support in order to limit the width of the excavation and reduce the footprint of the excavation. The cut-off could be constructed using a number of different methods, including jet-grouted columns, secant piles, deep soil mixing, and other equivalent methods.

The cut-off, as shown on the figures, would also be incorporated into the permanent structure as a means to reduce uplift pressures on the foundations, and as a means to reduce groundwater seepage to the drainage system and the downstream spillway channel. As shown on the figures, the proposed cut-off and shoring system would require the excavation to be carried out in a staged manner,

- Stage 1 excavation – excavate to a suitable elevation from which the cut-off wall would be constructed.
- Stage 2 excavation – Excavate within the cut-off wall, with the installation of anchors (if required) with each excavation lift, to subgrade level.
- Stage 3 excavation – - removal of the soil plug and cut-off wall in the forebay area following erection of the weir and bridge and related downstream structures.

The design of this construction and permanent cut-off and excavation support system will be further developed in the upcoming stages of the project.

3.0 HYDROTECHNICAL ENGINEERING

3.1 Design Flow

Spillway discharges have been developed (Golder, 2014: Appendix H) for a range of return periods up to and including the Inflow Design Flood (IDF) (Table 8). Based on CDA (2013) guidelines for a very-high consequence dam, the IDF is 2/3 of the way between the 1:1000-year and the Probable Maximum Flood (PMF). The peak outflow for the IDF after routing through the reservoir is 144 m^3/s (Golder, 2014: Appendix H).

Table 8: Summary of Spillway Discharges

Return Period (y)	Peak Outflow (m^3/s)
2	22.8
5	35.1
10	44.0
25	55.3
50	64.0
100	73.5
200	83.9
1000	107
IDF[(a)]	144

Note: (a) The IDF has no defined return period.

3.2 Labyrinth Spillway Design

The auxiliary spillway has been designed as a labyrinth structure (Figure 4, 5). The labyrinth design is based on the methodology of Tullis et al. (1995) and Crookston and Tullis (2013), which provide weir discharge coefficients that are a function of the upstream head, weir height, and weir apex angle. The coefficients are derived from scaled laboratory experiments for a quarter-round weir-crest profile (Figure 7).

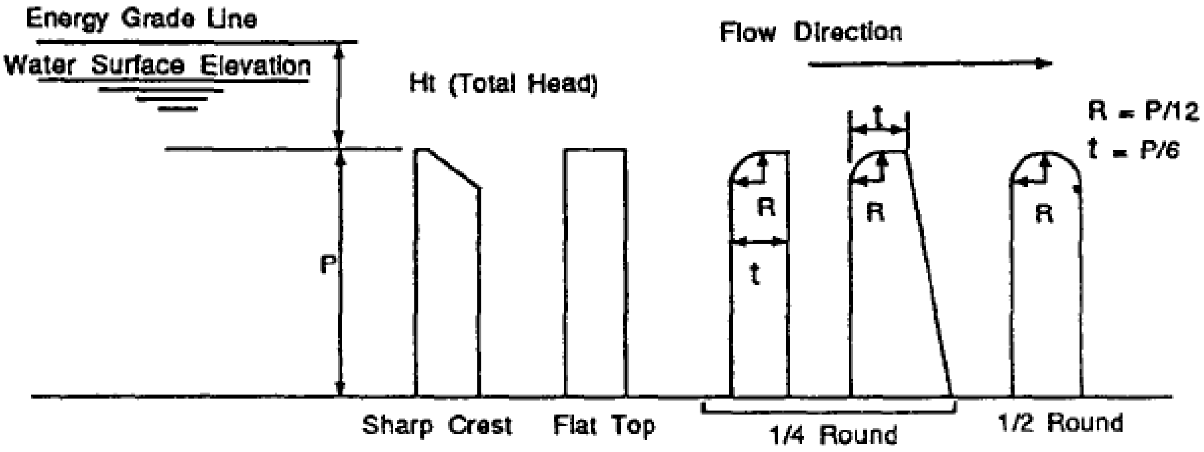


Figure 7: Crest profile types for the auxiliary spillway (from Tullis et al., 1995)

The initial design was assessed using the commercially available FLOW-3D software package, which is supported and created by Flow Science Inc[1]. FLOW-3D is a three-dimensional computational fluid dynamics (CFD) software that utilizes the finite volume method to spatially discretize the Navier-Stokes equations throughout a given domain. The model computes water surface elevations, depth, 3 components of velocity, and non-hydrostatic pressure distribution. Examples of the results for the auxiliary spillway at the design flow are shown in Figure 8. The model includes the labyrinth weir and extends downstream of the two bridge piers.

In addition to confirming the feasibility of the labyrinth weir, the FLOW-3D model was used to refine the design. In the revised design a 1/2 round crest profile (Figure 7) has been used to increase the capacity of the auxiliary weir. This resulted in a gain of approximately 10% in the discharge capacity of the auxiliary spillway, which resulted in lower pond level and increased freeboard at the design flow.

---

[1] http://www.flow3d.com/

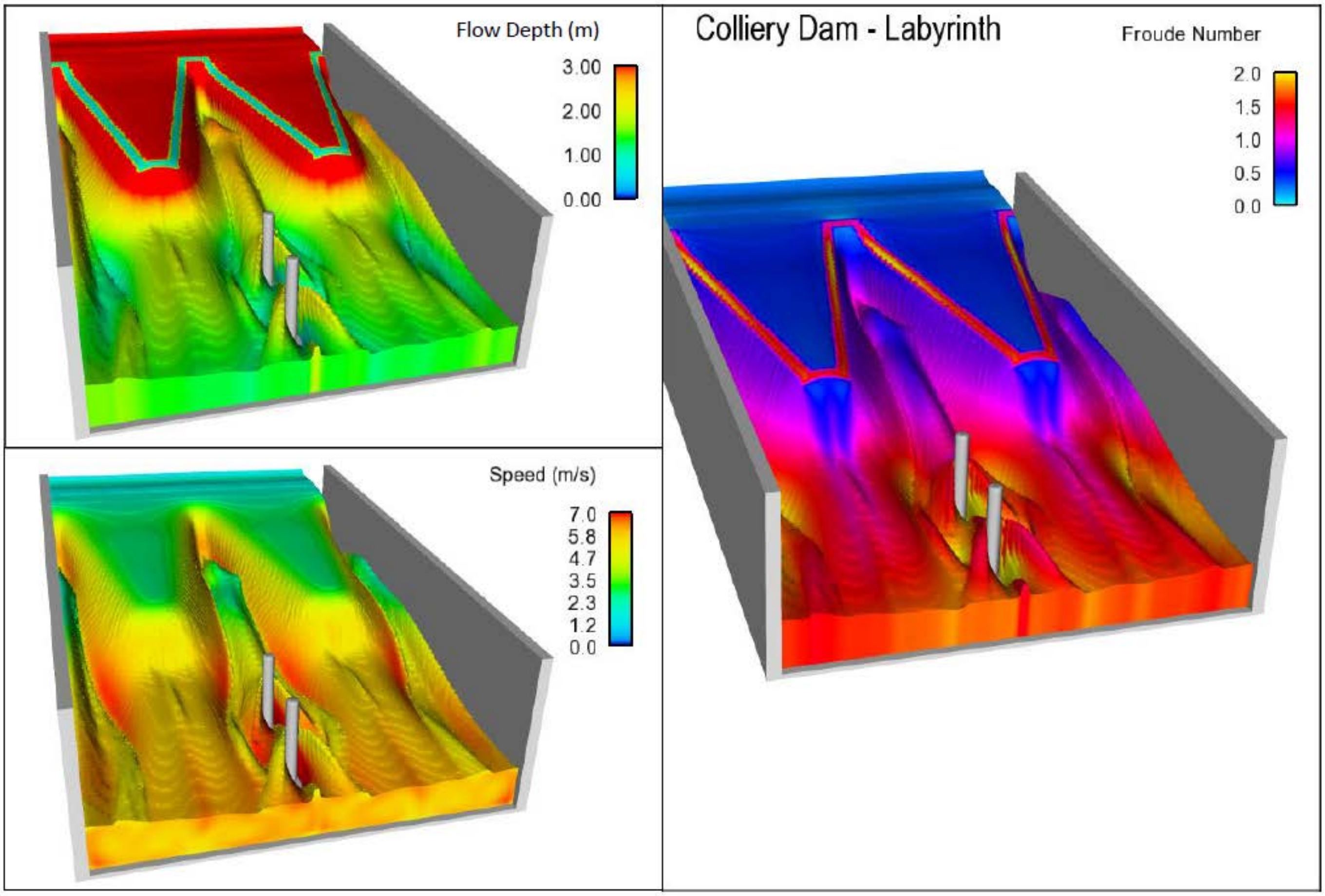


Figure 8: Visual results from FLOW-3D for the IDF.

The crest of the labyrinth spillway has been set at an elevation of 72.10 metres above sea level (masl), which is 0.5 m above the crest of the main spillway. The auxiliary spillway will pass flow when the discharge through the main spillway exceeds about 7 m^3/s, which is expected to occur more than once annually during large rain storm events.

The combined capacity of the main and auxiliary spillways is sufficient to pass the IDF discharge of 144 m^3/s, while providing approximately 0.18m of freeboard (Table 9).

Table 9: Summary of Design Flows

Return Period (y)	Pond Elevation (masl) (b)	Peak Outflow (m^3/s)			Freeboard (m) (c)
		Main Spillway	Auxiliary Spillway	Total	
2	72.32	12.7	10.1	22.8	1.11
5	72.44	16.0	19.1	35.1	0.99
10	72.51	18.3	25.7	44.0	0.92
25	72.60	21.1	34.2	55.3	0.83
50	72.66	23.3	40.7	64.0	0.77
100	72.73	25.7	47.8	73.5	0.70
200	72.81	28.4	55.5	83.9	0.62
1000	72.97	34.7	72.3	107	0.46
IDF(a)	73.43	46.3	97.7	144	0.18

Notes: (a) The IDF has no defined return period.

(b) Metres Above Sea Level.

(c) Relative to the main dam crest at 73.43 masl.

3.3 Forebay

The entrance velocity in the auxiliary spillway forebay is approximately 2 m/s for the IDF. Below the normal water level (71.6 masl) the forebay is a trapezoidal section with a base width of approximately 20 m and will be lined with Class 10kg riprap (Table 10).

Table 10: Class 10 kg Riprap Approximate Dimensions (mm). From BC MOTI (2008)

D_{15}	D_{50}	D_{85}	Thickness
90	195	280	350

3.4 Downstream Channel

A channel will be constructed downstream of the spillway to convey the flow to Harewood Creek (Figures 4 and 5). The general dimensions of the trapezoidal channel are a base width of 6.0 m and longitudinal gradient of 3%. There is a steeper (5%) transitional section immediately downstream of the bridge that narrows from a base width of 13.8 m down to 6.0 m. The invert of the channel and much of the side slopes are generally expected to be excavated into bedrock (Figure 5). Non bedrock areas will be armoured with Class 250kg riprap (Table 11). The tail alignment of the downstream channel provides clearance to the root structures of several large diameter trees just to the north of the channel exit. The trees and root zones will be flagged on site as signal for tree protection to the contractor.

Table 11: Class 250 kg Riprap Approximate Dimensions (mm). From BC MOTI (2008)

D_{15}	D_{50}	D_{85}	Thickness
260	565	815	1000

The downstream channel capacity is approximately 60 m^3/s. Channel maintenance may be required on riprap lined sections of the channel when flows exceed this value.

3.5 Low Level Outlets

Two low-level round sluice gate outlets are to be included to allow drawdown of the reservoir level for emergency repairs and scheduled maintenance, and to provide opportunity for augmentation of low flows in the Chase River during prolonged dry periods. As indicated in previous project reports, it is advantageous to be able to draw down the reservoir in the event of damage occurring to the Lower Dam, in particular following a severe earthquake. The larger of the two gates (supplemented with flow from the smaller gate) will be used for such emergency drawdown purposes. It is anticipated that the smaller of the two gates will be used for used for other purposes, such as flow augmentation. Standard circular “off the shelf” Armtec[2] sliding sluice gates are proposed (Figure 9).

---

[2] www.armtec.com

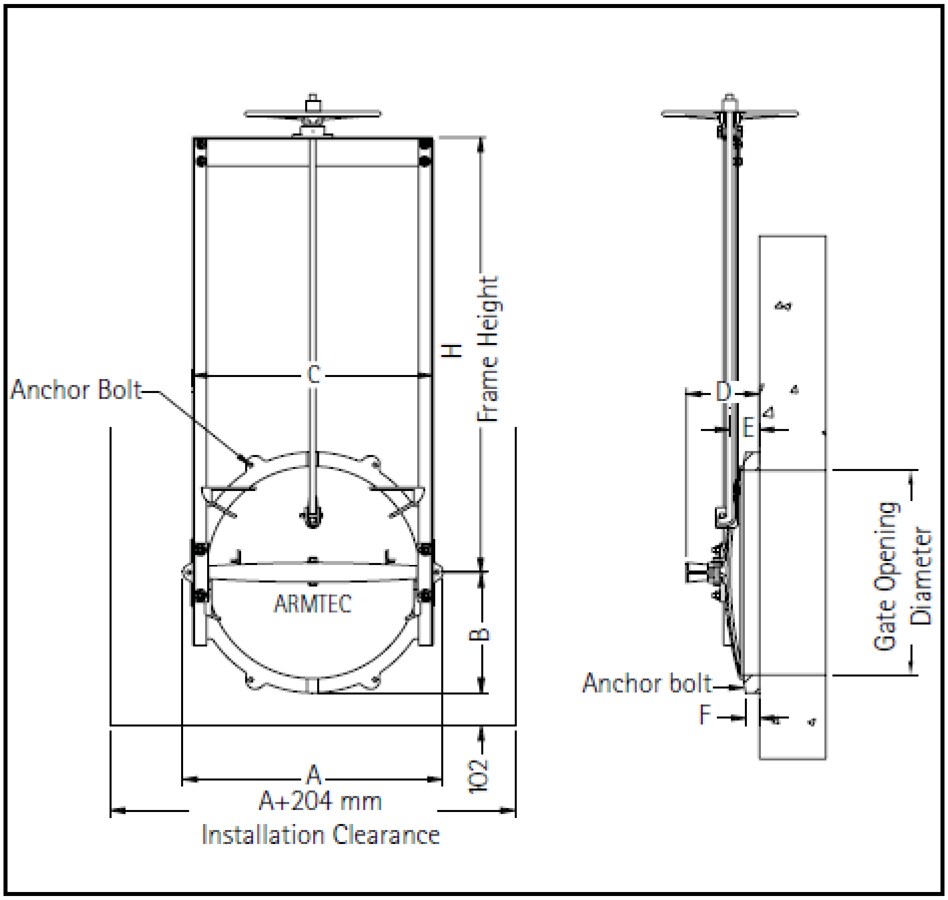


Figure 9: Standard Configuration of a circular cast iron sliding sluice gate (www.armtec.com).

The sluice gates are to be located at the midpoint along the outer labyrinth walls (Figure 4), with the inverts positioned 69.3 masl (200mm above the labyrinth floor). The larger gate will have a nominal diameter of 1067 mm (42"), and a smaller gate with a nominal diameter of 610 mm (24"). The combined capacity of the two sluice gates at the normal operation level (71.6 masl) is 6.3 m^3/s. With no inflows to the reservoir (i.e. during dry summer months), the two gates have capacity to draw the reservoir level down 2 m to 69.6 masl within 6 hours. The rate of reservoir drawdown is reduced depending upon inflows to the reservoir. For a typical winter baseflow into the reservoir of 1.6 m^3/s (Golder 2014: Appendix E), the two gates have capacity to draw the reservoir level down 0.53 m to 70.07 masl within 6 hours.

4.0 STRUCTURAL ENGINEERING

Structural engineering is being undertaken by Herold Engineering Limited. An over view of the current structural concept is presented in Appendix C.

5.0 AESTHETICS AND LANDSCAPE DESIGN

Colliery Dam Park is an important public amenity requiring special considerations for park users, maintaining habitat and ecological values, and aesthetics. The installation of the auxiliary spillway infrastructure will cause disturbance to the park that requires care and attention to minimize short and long term impacts.

The approach to landscape design and site restoration is to carefully construct the facility in ways that will result in the spillway providing the intended engineering and public safety benefits, but also accommodate park functions such as user circulation, park views, and forest character so that in time the spillway blends into the park similar to other dam components.

The labyrinth, forebay and downstream channel is sited to best advantage using a multiple accounts criteria that includes risk management, costs, minimizing site disturbance and tree loss, and minimizing inconvenience to the park user. Tree retention, including minimizing construction related impacts to root zones and soil structures are important factors in the design and construction of the spillway.

There will be a number of trees and vegetation requiring removal due to spillway construction and related activities such as truck and machine access, materials handling and storage, ground water management, sediment controls, etc. Golder will establish the limits of excavation required for construction, and communicate with the general contractor areas that are acceptable for construction staging and other activities. Protected areas will be marked and fenced on site with the understanding that no incursions into the protected zones will be allowed.

A set of landscape drawings and specifications will be included in the construction contract documents. The landscape documents will outline:

- a general layout and grading of finished park restoration, including limit of work zone and make good line
- tree removals and protection zones,
- clearing and grubbing specifications,
- organic soils stripping, storage, conservation, and amendments (if required) specifications, and
- develop a re-vegetation strategy including tree replacement ratio, a planting plan that illustrates tree, shrub and groundcover species and sizes

6.0 FURTHER WORK

As indicated in previous correspondence, design development will be undertaken in parallel with construction planning and execution. A civil work contractor has now been procured. This contractor was selected via a qualification process - ability to mobilize to site quickly was a key criteria. Once the contract is executed, it is anticipated the contractor will begin mobilizing to site. This will require close coordination with a separate cutoff wall contractor, as certain site preparation activities must occur in advance of the cutoff wall, and mass earthworks cannot begin until after the cut-off wall is completed.

Design development activities are ongoing to accommodate a cutoff wall as well as geotechnical, structural and aesthetic details. Final design will impact the excavation depth and thus the excavation limits. Tree clearing cannot begin until the excavation limits have been fixed. As previously indicated, detailed engineering and designs will be developed and presented in a separate upcoming design document.

7.0 CLOSURE

We trust that the information provided herein meets your present requirements. Should you have any questions regarding the above, please do not hesitate to contact us.

GOLDER ASSOCIATES LTD.

Thomas Madden

Bruce Downing, P. Eng.
Principal, Senior Geotechnical Engineer

for Chase Reid, E.I.T.
Geological Engineer

R Millar

DCrockett

Robert Millar, Ph.D., P. Eng./P. Geo.
Associate, Senior Hydrotechnical/Water Resources Engineer

Don Crockett, B.E.S.,M. Land. Arch.,BCSLA,CSLA
Principal, Senior Landscape Architect

BRD/TM/nnv

o:\final\2013\1447\13-1447-0516\1314470516-032-r-rev0\1314470516-032-r-rev0 aux spillway prelim design 04sep_15.docx

8.0 REFERENCES

ASTM C136/C136M-14 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, American Society for Testing and Materials.

ASTM D2216-10 Standard Test Methods for Laboratory Determination of Water (Moisture) Content in Soil and Rock by Mass, American Society for Testing and Materials.

ASTM D422-63(2007)e2 Standard Test Method for Particle-Size Analysis of Soils, American Society for Testing and Materials.

ASTM D4318-10e1 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, American Society for Testing and Materials.

ASTM D7012-14 Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures, American Society for Testing and Materials.

BC MOTI (British Columbia Ministry of Transportation and Infrastructure). 2008. 2009 Standard Specifications for Highway Construction. Volume 1 of 2.

British Columbia Groundwater Protection Regulation, 2004.

Brown, 1981, “Rock Characterization Testing and Monitoring: ISRM Suggested Methods”, International Society for Rock Mechanics.

Crookston, B.M., and Tullis, B.P. 2013. Hydraulic Design and Analysis of Labyrinth Weirs. 1. Discharge Relationships. Journal of Irrigation and Drainage Engineering. 139 (5). 363-370.

Golder . 2014. Colliery Dams, Nanaimo, BC. Hydrology, Hydraulics, and Middle Dam Breach Analysis. Submitted to City of Nanaimo, July 25, 2014.

Golder Associates Ltd. 2015. Letter report on “Colliery Dams, Lower Dam – Development of Design Alternatives”, dated July 8, 2015.

Tullis, J.P., Amanian, N., and Waldron, D. 1995. Design of Labyrinth Spillways. Journal of Hydraulic Engineering. 121 (3). 247-255.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. 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 can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client’s expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder’s report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder’s report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder’s report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder’s report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder’s responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

NOT FOR CONSTRUCTION

PRELIMINARY

0 50 100
1:2,500 METRES

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD 2015-09-03
PREPARED RP
DESIGN JG
REVIEW -
APPROVED -

PROJECT
COLLIERY DAMS
NANAIMO, BC

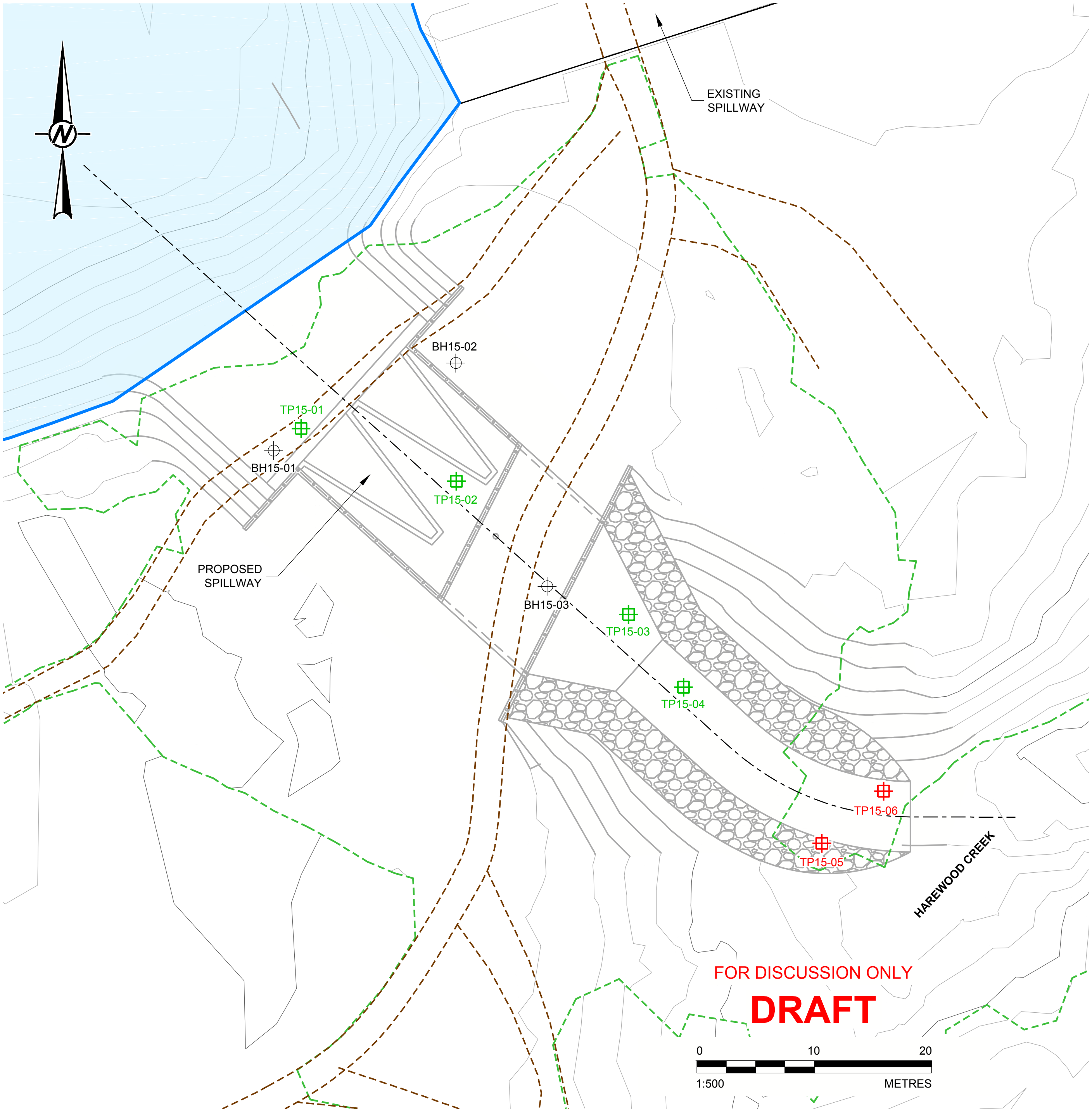
TITLE
LOCATION PLAN

PROJECT No. 13-1447-0516
PHASE 4000
Rev. A
FIGURE 1

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_004.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm
0



FOR DISCUSSION ONLY

DRAFT

LEGEND

⊕	TEST PIT LOCATION (EXCAVATOR)
⊕	TEST PIT LOCATION (HAND EXCAVATED)
⊕	BOREHOLE LOCATION
- - - - -	2015 SURVEY BOUNDARY
- - - - -	EXISTING PATHWAY

NOTE

1. AUXILIARY SPILLWAY CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
2. BOREHOLE AND TEST PIT LOCATION DATA FROM HEROLD ENGINEERING, CAD FILE: 0017-276 Civil Base.dwg, DATED: AUGUST 28, 2015.

CLIENT
CITY OF NANAIMO

PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

TITLE
GEOTECHNICAL INVESTIGATION PLAN

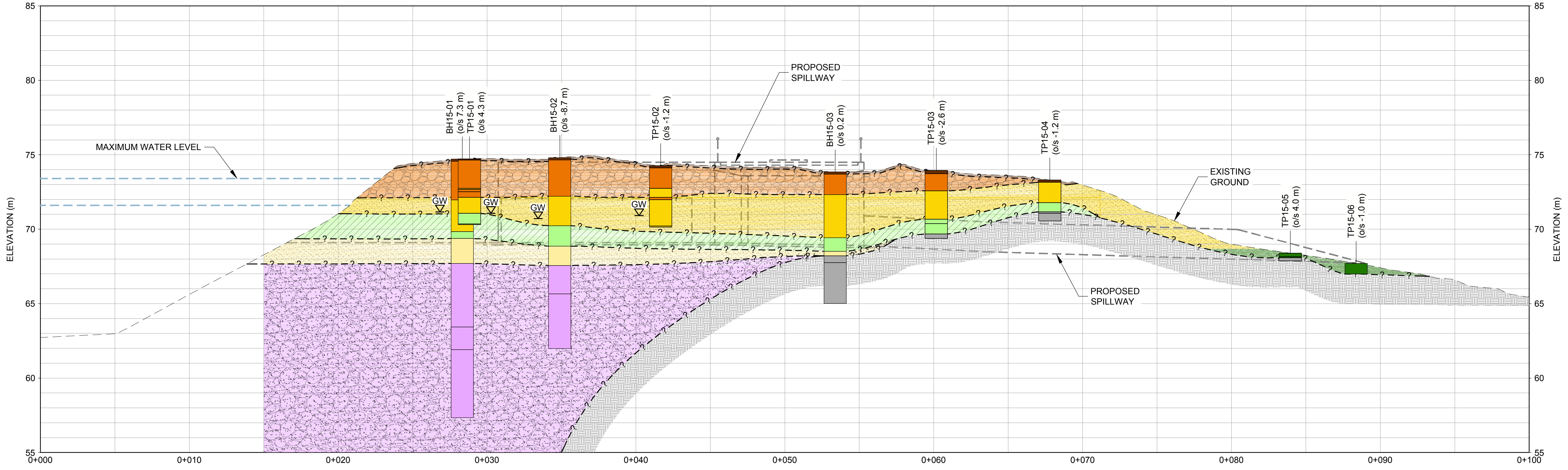
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	2

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_001.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

25 mm

0



SECTION A-A'
SCALE 1:300

FOR DISCUSSION ONLY

DRAFT

0 5 10
1:300 METRES

LEGEND

🟫	TOPSOIL	🟩	SILT WITH VARYING SAND AND GRAVEL
🟧	GRAVEL, SOME SAND TO GRAVELLY SAND	🟨	SILTY SAND TO SILT AND SAND
🟨	SAND, TRACE GRAVEL TO GRAVELLY	🟪	VARYING PERCENTAGES OF SILTY SAND, GRAVEL, SILTY CLAY (VERY DENSE)
🟩	CLAYEY SILT TO SILTY CLAY, TRACE SAND TO SANDY	⬜	BEDROCK
GW ▽	GROUNDWATER LEVEL	— — ? — — ? —	INFERRED STRATIGRAPHIC BOUNDARY

NOTE

1. AUXILIARY SPILLWAY CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.
2. ALL ELEVATIONS ARE IN METRES AND REFER TO GEODETIC DATUM.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
2. BOREHOLE AND TEST PIT LOCATION DATA FROM HEROLD ENGINEERING, CAD FILE: 0017-276 Civil Base.dwg, DATED: AUGUST 28, 2015.

CLIENT
CITY OF NANAIMO

CONSULTANT

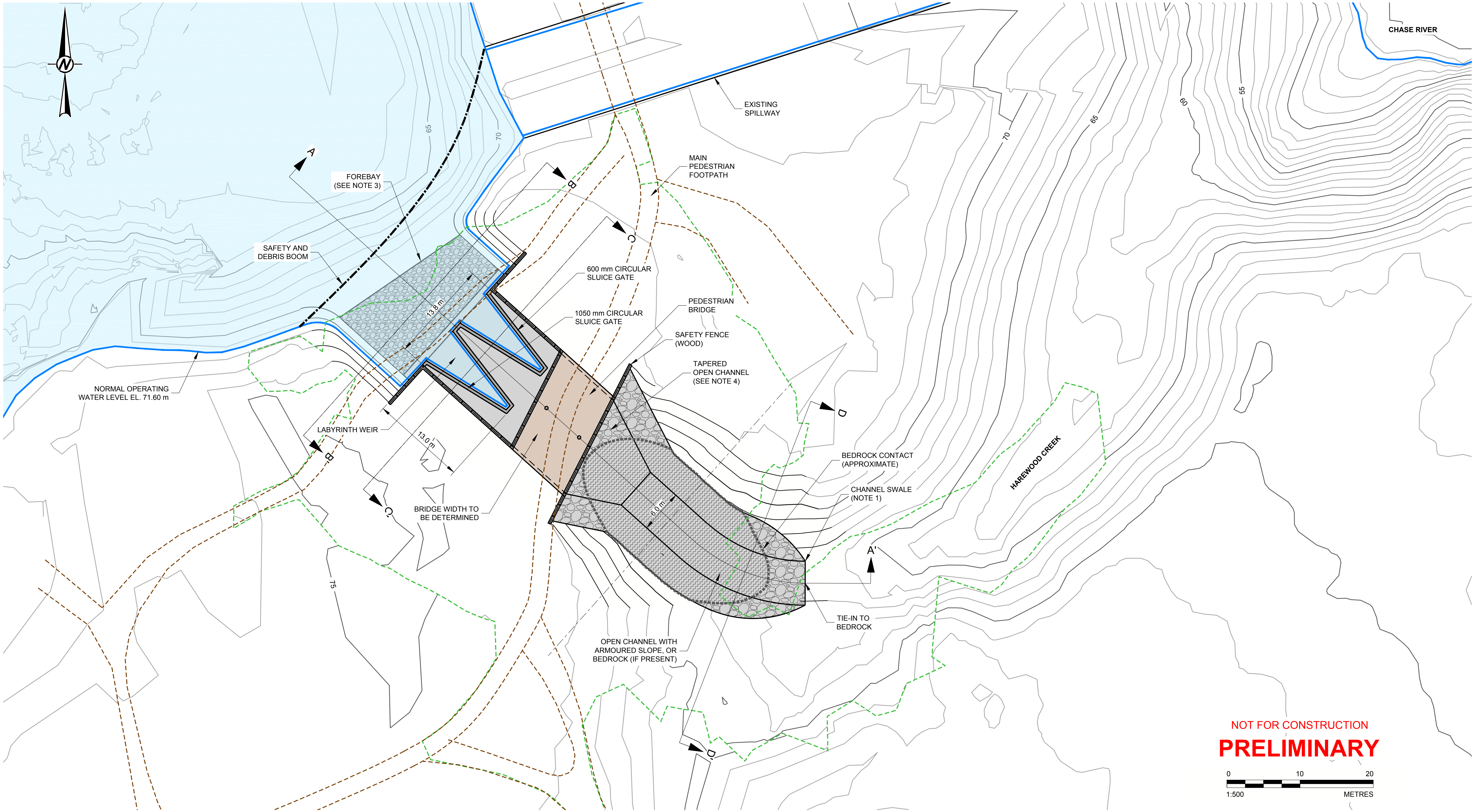
YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
INTERPRETED STRATIGRAPHIC PROFILE

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	3

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_001.dwg



NOT FOR CONSTRUCTION

PRELIMINARY

LEGEND

- - - 2015 SURVEY BOUNDARY
— RESERVOIR (AT REGULAR OPERATING LEVEL)
- - - EXISTING PATHWAY

NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.
3. CLASS 10 Kg RIPRAP
4. CLASS 250 Kg RIPRAP

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
AUXILLIARY SPILLWAY - PLAN

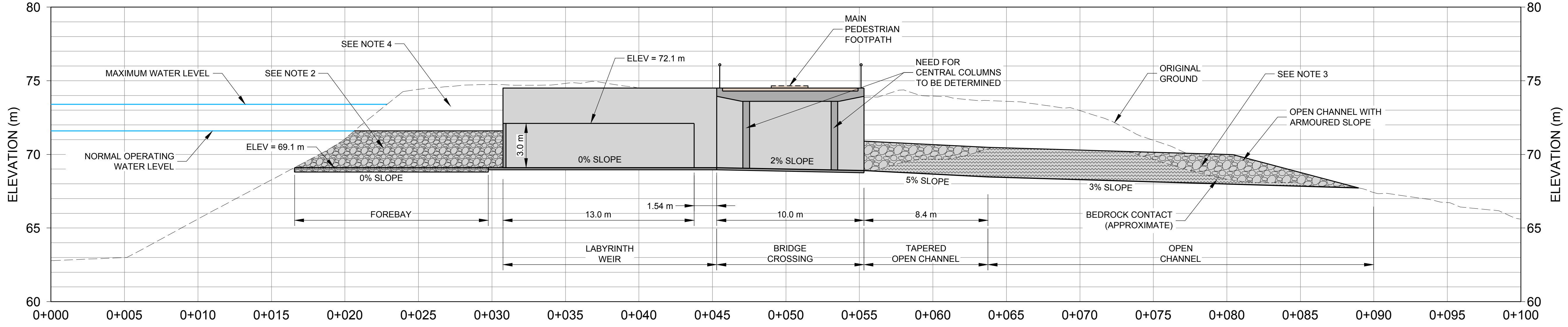
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	4

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_003.dwg

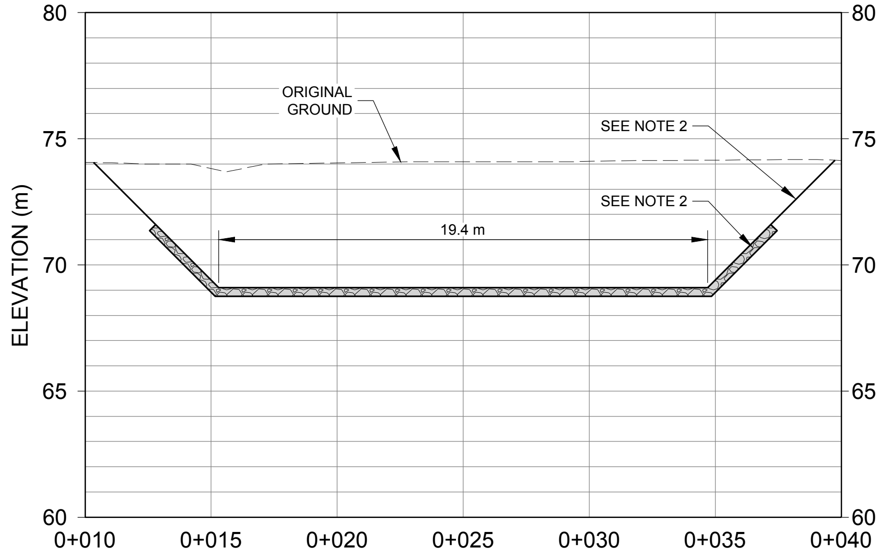
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

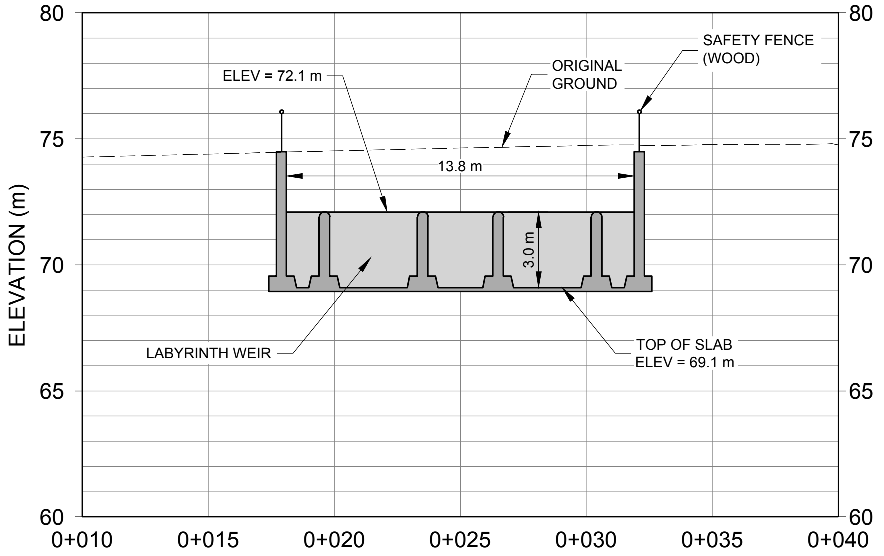
0



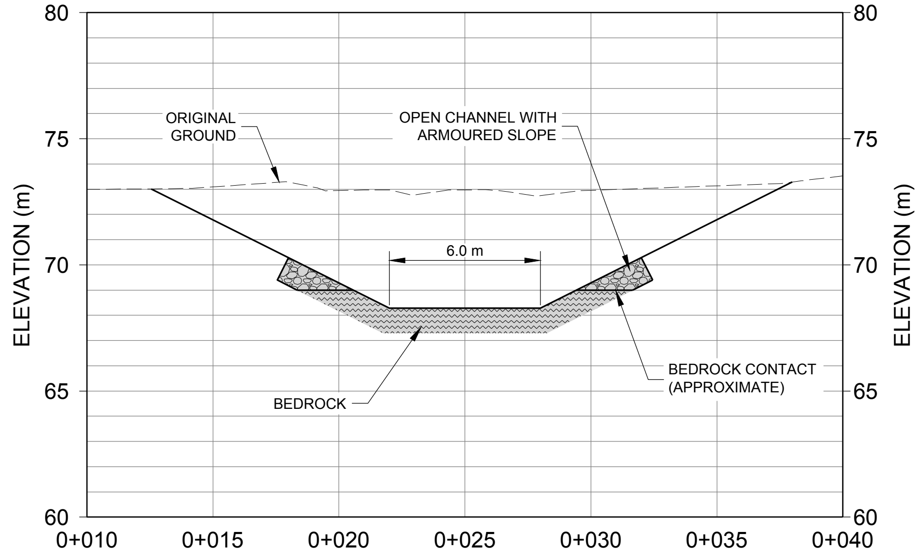
SECTION A-A'
SCALE 1:300



SECTION B-B'
SCALE 1:300



SECTION C-C'
SCALE 1:300



SECTION D-D'
SCALE 1:300

NOTE

1. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.
2. CLASS 10 Kg RIPRAP
3. CLASS 250 Kg RIPRAP
4. TREATMENT REQUIRED ABOVE WATERLINE.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.

NOT FOR CONSTRUCTION

PRELIMINARY

0 5 10
1:300 METRES

CLIENT
CITY OF NANAIMO

CONSULTANT

YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

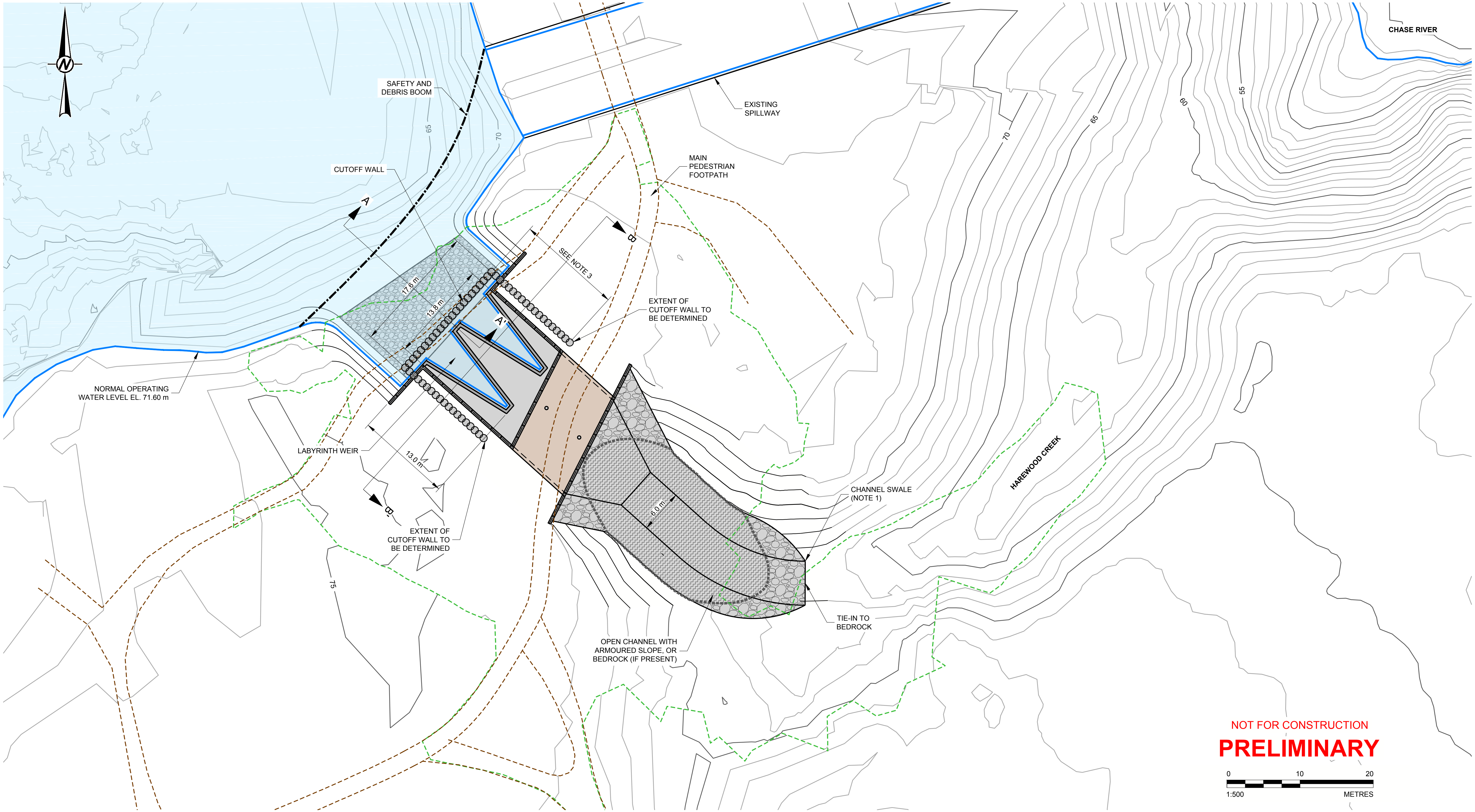
TITLE
AUXILLIARY SPILLWAY - PROFILE

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	5

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_003.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm



NOT FOR CONSTRUCTION

PRELIMINARY

LEGEND

▬ ▬	EXCAVATION LIMITS
- - -	2015 SURVEY BOUNDARY
──	RESERVOIR (AT REGULAR OPERATING LEVEL)
- - -	EXISTING PATHWAY

NOTE

1. DOWNSTREAM OF THIS POINT, CHANNEL SWALE TO BE TIED INTO EXISTING TOPOGRAPHY OF HAREWOOD CREEK.
2. FINAL CONFIGURATION SHOWN - CONSTRUCTION REQUIREMENTS NOT REPRESENTED ON THIS FIGURE.
3. LENGTH OF JET GROUT CUTOFF WALL IS SUBJECT TO SUBSURFACE AND SEEPAGE CONDITIONS.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.
3. WILLIS CUNLIFFE TAI & COMPANY LTD., PDF FILE: Appendix C - 1980 Repairs As-built.pdf, DATED: JULY 1978.
4. SEISMIC HAZARD ASSESSMENT MIDDLE AND LOWER CHASE DAMS, (EBA 2010).

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

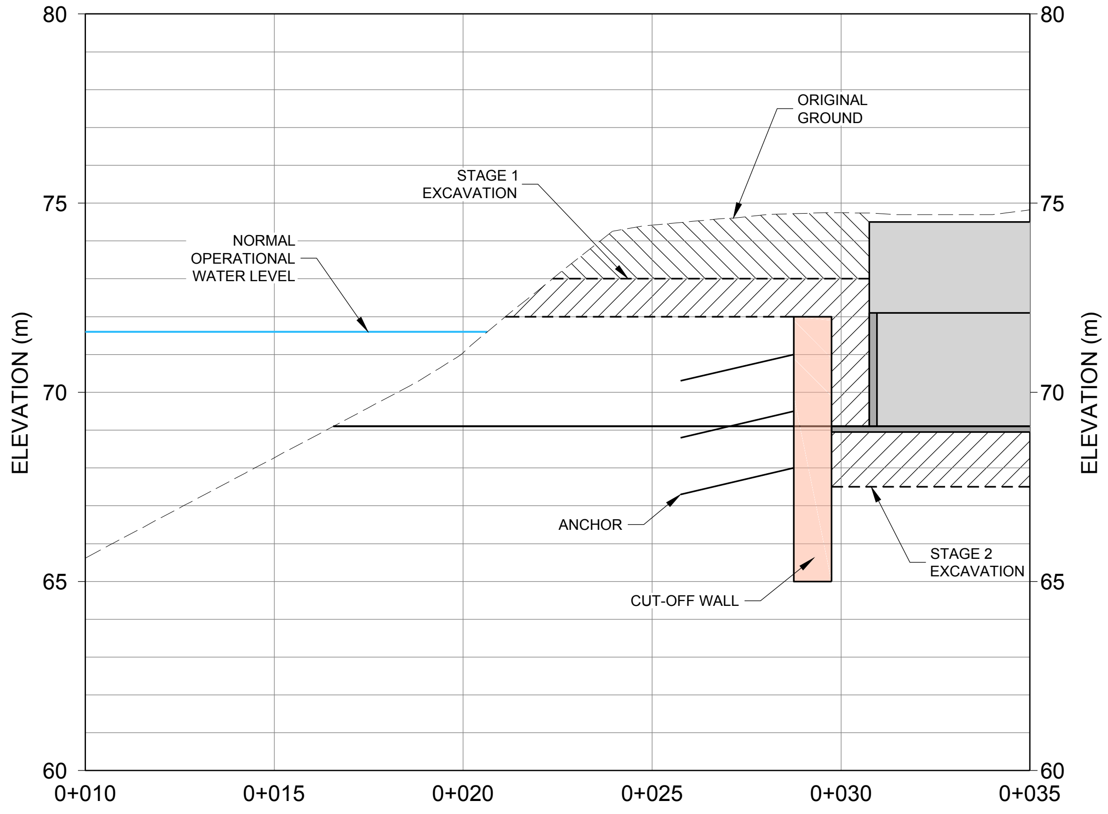
PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
EXCAVATION - CONCEPTUAL PLAN

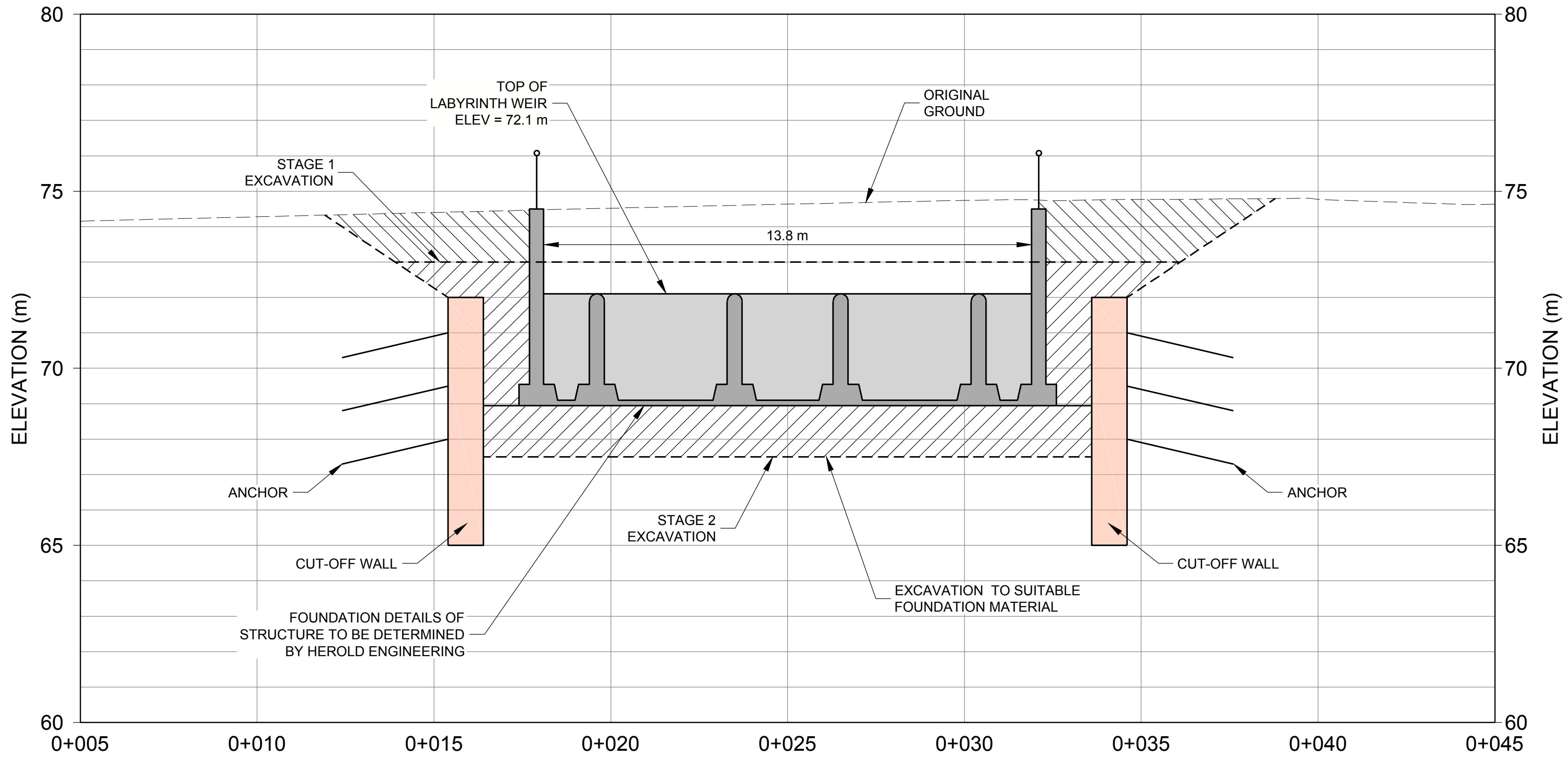
PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	6A

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_003.dwg

25 mm
0
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



SECTION A-A'
SCALE 1:200



SECTION B-B'
SCALE 1:200

LEGEND

▧	EXCAVATE IN THE DRY (SEE NOTE 1).
▨	EXCAVATE SOIL (SEE NOTE 2).

NOTE

1. STAGE 1 EXCAVATION APPROXIMATELY TO 73 m ELEVATION.
2. INSTALL JET GROUT CUT OFF WALL INTO TILL.
3. EXCAVATE SOIL DOWNSTREAM OF CUT OFF WALL, IN STAGES WITH ANCHOR SUPPORT REQUIRED.

REFERENCES

1. BATHYMETRIC AND TOPOGRAPHIC FROM CITY OF NANAIMO, CAD FILE: ACAD-C003-0 (BOUND).dwg, DATED: DECEMBER 20, 2013.
2. TOPOGRAPHIC DATA FROM HEROLD ENGINEERING, CAD FILE: collier park bwer dam 2003.dwg, DATED: OCTOBER 20, 2003.

NOT FOR CONSTRUCTION

PRELIMINARY

0 5 10
1:200 METRES

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-09-03
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
EXCAVATION - CONCEPTUAL PROFILES

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	6B

Path: \\golder.gds\gal\Burnaby\CAD-GIS\Client\City_of_Nanaimo\99_PROJECTS\13-1447-0516\02_PRODUCTION\3000\3300\ | File Name: 13-1447-0516_3000_3300_003.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

0

APPENDIX A

Geotechnical Investigation Data

Annex A

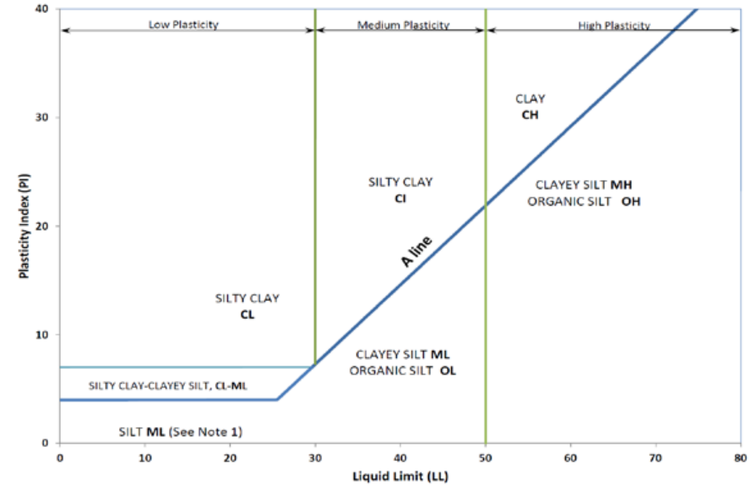
Record of Testhole Sheets

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10}xD_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% (see Note 2)	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

Golder Associates

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

PROJECT No.: 13-1447-0516 / 4000 / 4300

RECORD OF TEST PIT: TP15-01

SHEET 1 OF 1

CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446373.37 E: 429999.66 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

DATUM: Geodetic

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ◐ Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface		74.76											
0	Case 590 Backhoe Excavator Bucket	TOPSOIL													
		(SW/GW) SAND and GRAVEL to sandy GRAVEL, fine to course, sub-rounded to sub-angular gravel, trace to some silt, contains roots; brown; with cobbles; dry to moist.		0.08	G1	GS									
1		- 0.3m diameter boulder encountered at approx. 0.9m depth.			G2	GS			88	11	1				
					G3	GS									
2		**(SP)** SAND, medium to coarse, some gravel; brown-grey; moist.		72.78	G4	GS									
		(GP) GRAVEL, some sand; dark grey; moist.		72.55 2.21	G5	GS									
		(SW/GW) SAND and GRAVEL, fine to coarse, sub-rounded to sub-angular, contains roots; brown to brown-grey; moist.		72.17 2.59	G6	GS									
3		**(SP-SM)** SAND, fine to medium, trace gravel, some silt; grey; moist to wet.			G7	GS									
					G8	GS			0	90	10				
					G9	GS									Seepage Observed ▼ during Excavation
4		**(CL)** sandy SILTY CLAY, fine to coarse sand; grey mottled brown; w>PL, very stiff.		71.10 3.66	G10	GS		⊢○—⊖⊣	1	25	74				
		(CL) sandy SILTY CLAY, fine; grey; w>PL, soft to firm.		70.39 4.42	G11	GS									
5		End of Test Pit.													
		(Practical Refusal)													
		Environmental jar samples approx. depth: E1 - 0.2m to 0.5m E2 - 1.3m to 1.4m													
6															

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_TESTPIT WITH PHOTO JAYoung 9/4/15

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

PROJECT No.: 13-1447-0516 / 4000 / 4300

RECORD OF TEST PIT: TP15-02

SHEET 1 OF 1

CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446368.87 E: 430012.91 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

DATUM: Geodetic

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH nat V. + Q - ● rem V. ⊕ U - ◐ Cu, kPa Pocket Pen - ■ 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface		74.43											
0	Case 590 Backhoe Excavator Bucket	TOPSOIL		74.28 0.15											
		(GW-GM) sandy GRAVEL, fine to coarse, trace to some silt, contains roots; brown; with cobbles, dry to moist. - 0.28m diameter cobble encountered at approx. 0.8m depth.			G1	GS			75	23	2				
1															
		(SP) SAND, fine to medium, trace to some gravel; grey to grey-brown; moist. - 0.33m diameter boulder encountered at approximately 1.6m depth.		72.91 1.52	G2	GS									
2		**(SP)** gravelly SAND, fine to coarse, sub-rounded to sub-angular gravel, trace silt, contains roots; brown-grey; moist. - possible cinder piece found at approx. 2.2m depth.		72.30 72.15 2.29	G3	GS									
3		**(SP)** SAND, fine to coarse, trace gravel to gravelly, trace silt; brown-grey to grey; moist to wet.			G4	GS			26	73	1				Seepage Observed ▼ during Excavation
					G5	GS									
4		**(SM)** SILTY SAND, fine, trace plastic fines; brown; wet.		70.39 4.11	G6	GS		○							
		End of Test Pit. (Practical Refusal) Environmental jar samples approx. depth: E1 - 0.7m to 0.8m E2 - 1.4m to 1.5m E3 - 2.1m to 2.3m													
5															
6															

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_TESTPIT WITH PHOTO JAYoung 9/4/15

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446357.52 E: 430027.59 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

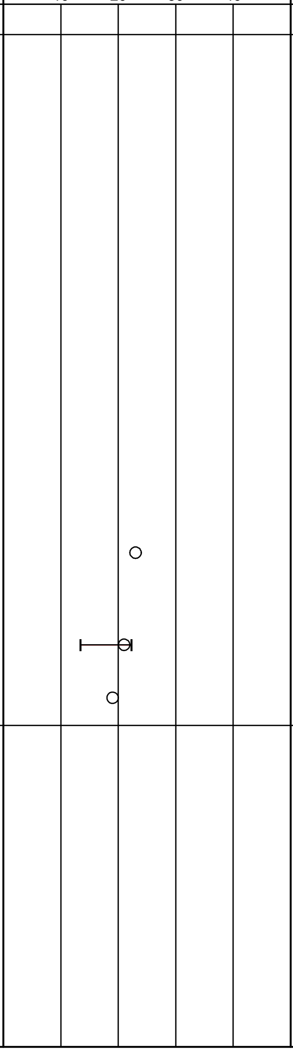
RECORD OF TEST PIT: TP15-03

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

SHEET 1 OF 1
DATUM: Geodetic

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH Cu, kPa / WATER CONTENT PERCENT	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface	74.17											
0	Case 590 Backhoe Excavator Bucket	TOPSOIL	0.00											
1		**(SW/GW)** sandy GRAVEL to SAND and GRAVEL, fine to coarse, sub-rounded to sub-angular gravel, trace silt, contains roots and cobbles; brown to light brown; dry to moist. - 0.23m diameter cobble encountered at approx. 1.1m depth.	73.94 0.23	G1	GS									
2 3		**(SP-SM)** SAND, fine to coarse, trace to some gravel, some silt; brown-grey; moist. - 0.36m diameter boulder and 0.25m diameter cobble encountered at approx. 1.5m depth.	72.80 1.37	G2 G3	GS GS			 7	 84	 9				
4		**(CL)** SILTY CLAY, some fine sand; mottled brown; w>PL, stiff to very stiff.	70.89 3.28	G4 G5	GS GS			 0	 11	 89				Seepage Observed ▼ during Excavation
		(CL) SILTY CLAY, some fine sand, trace gravel; grey; w>PL, soft to firm	69.90 4.27	G6	GS									
		Inferred BEDROCK.	69.67 4.57	G7	GS									
5 6		End of Test Pit. (Practical Refusal) Environmental jar samples approx. depth: E1 - 0.9m to 1.1m												



DEPTH SCALE
1 : 50

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_TESTPIT WITH PHOTO JAYoung 9/4/15

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446351.32 E: 430032.28 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF TEST PIT: TP15-04

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ◐ Pocket Pen - ■ 20 40 60 80 WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface		73.51											
0	Case 590 Backhoe Excavator Bucket	TOPSOIL		73.35 0.15											
1		**(SP)** SAND, fine, some silt, some gravel, contains roots; light brown; with cobbles, dry to moist.		72.36 1.14	G1	GS									
2		**(ML)** CLAYEY SILT, some sand, trace to some gravel, contains roots; brown-grey to grey motted brown - sub-angular to rounded cobbles up to 0.28m dia.		71.22 2.29	G2 G3 G4	GS GS GS									
		Inferred SANDSTONE.		70.92	G5	GS									
		Inferred CONGLOMERATE.		70.76 2.74											
3		End of Test Pit. (Practical Refusal)													
4															
5															
6															

DEPTH SCALE
1 : 50

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_TESTPIT WITH PHOTO JAYoung 9/4/15

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446337.99 E: 430044.08 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF TEST PIT: TP15-05

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

SHEET 1 OF 1

DATUM: Geodetic

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ◐ Pocket Pen - ■) 20 40 60 80; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
0		Ground Surface		68.23											
	Hand Excavated Shovel	**(ML)** SILT, trace sand, contains roots; dark brown; moist.		0.00	G1	GS									
		(ML) SILT, some sand, trace gravel; brown; moist.		68.01 0.23	G2	GS									
		BEDROCK		67.83 0.40											
		End of Test Pit. (Practical Refusal) Environmental jar samples approx. depth: E1 - 0.0m to 0.2m E2 - 0.2m to 0.4m		67.73 0.51											
1															

DEPTH SCALE
1 : 10

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446342.44 E: 430049.34 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF TEST PIT: TP15-06

EXCAVATION DATE: August 6, 2015

INCLINATION: -90°

SHEET 1 OF 1
DATUM: Geodetic

DEPTH SCALE METRES	EXCAVATION METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY %	SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ◐ Pocket Pen - ■) 20 40 60 80 / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl NP - Non-Plastic 10 20 30 40	GRADATION %: GRAVEL	GRADATION %: SAND	GRADATION %: FINES	PLASTICITY	FROZEN GROUND DESCRIPTION	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE, THERMISTOR INSTALLATION OR SEEPAGE OBSERVATION
		Ground Surface		68.00											
0	Hand Excavated Shovel	**(ML)** SILT, trace sand, contains roots; dark brown; moist. - 0.46m diameter boulder encountered at approx. 0.5m depth. - Bedrock encountered at 0.71m depth.		0.00	G1	GS									
		End of Test Pit. (Practical Refusal) Environmental jar samples approx. depth: E1 - 0.2m to 0.3m		67.29 0.71											
1															

DEPTH SCALE
1 : 10

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: TM
CHECKED: RCB

REV:
0

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_TESTPIT WITH PHOTO JAYoung 9/4/15

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446371.48 E: 429997.32 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF BOREHOLE: BH15-01

DRILLING DATE: August 18-19, 2015

INCLINATION: -90°

SHEET 1 OF 2
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 762mm

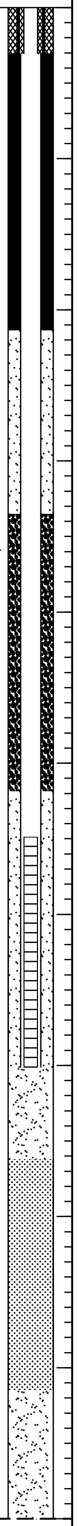
DRILLING RIG: HT-750 Track Mounted Rotary Drill
DRILLING METHOD: 121mm Tricone Mud Rotary

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; NP - Non-Plastic; 10 20 30 40
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ◐; Pocket Pen - ■; 20 40 60 80
GRADATION %: CLAY PARTICLE SIZE <= 0.002

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY %	BLOWS/0.3m	GRAVEL	SAND	FINES	SILT	CLAY
	Ground Surface	74.85									
0	TOPSOIL	74.69 0.15									
	(SW/GW) gravelly SAND to SAND and GRAVEL, fine to coarse, sub-rounded to sub-angular gravel, fine to coarse sand, trace silt; brown-grey; moist, compact.		1	SS	35	HB					
2			2	SS	45	19					
	(SP-SM) SAND, fine to medium, some silt; grey; moist, compact.	72.10 2.74									
4			3	SS	8	46					
5	**(CL)** sandy SILTY CLAY, fine to coarse sand; grey; w>PL, very stiff.	69.97 4.88	4A								
	(SM) SILTY SAND, fine; brown-grey; moist, very dense.	69.51 5.33	4B	SS	100	68	1	75	24		
			5A	SS	92	73					
7	**(SM/ML)** SAND and SILT, fine to coarse sand, some fine to coarse sub-rounded to angular gravel; grey; moist, very dense. (Till-like)	67.84 7.01	5B				10	49	41	32	9
8			6	SS	14	>50					
10			7	SS	85	>100					

CONTINUED NEXT PAGE

PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION



Flush Mount Well Cover
Bentonite Pellets
Filter Sand
8/21/2015 ▼
Bentonite Pellets
Filter Sand
2" Schedule 80 Slotted PVC Pipe
Filter Sand
Bentonite Pellets
Filter Sand

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: CR
CHECKED: RCB

REV: 0

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446371.48 E: 429997.32 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF BOREHOLE: BH15-01

DRILLING DATE: August 18-19, 2015
INCLINATION: -90°

SHEET 2 OF 2
DATUM: Geodetic
SAMPLER HAMMER, 64kg; DROP, 762mm

DRILLING RIG: HT-750 Track Mounted Rotary Drill
DRILLING METHOD: 121mm Tricone Mud Rotary

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; NP - Non-Plastic; 10 20 30 40
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ◐; Pocket Pen - ■; 20 40 60 80
GRADATION % (CLAY PARTICLE SIZE <= 0.002): GRAVEL, SAND, FINES, SILT, CLAY
PLASTICITY INDEX %; ORGANIC CONTENT %; ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY %	BLOWS/0.3m	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
10	**(SM/ML)** SAND and SILT, fine to coarse sand, some fine to coarse sub-rounded to angular gravel; grey; moist, very dense. (Till-like) *(continued)*	63.57 11.28				>100	Filter Sand
11	**(CL+SM)** SILTY CLAY, trace sand, fissured; grey; w<PL, very stiff. thickly laminated with SILTY SAND, fine; grey; moist, very dense.	62.04 12.80	8	SS	100	>100	Bentonite Pellets
13	**(SM+ML)** SILTY SAND, fine; grey; moist, very dense with interlayers of gravelly SILTY SAND, fine to coarse sand, fine to coarse sub-angular to angular gravel; and sandy SILTY CLAY, fine to coarse sand, trace coarse sub-rounded gravel.	57.47 17.37	9	SS	100	>100	Filter Sand
14			10	SS	100	>100	Bentonite Pellets
16			11	SS	100	>100	Filter Sand
17							Bentonite Pellets
17.37	End of Borehole.						

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_BOREHOLE_GRADATION (AUTO) JAYoung 9/4/15

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: CR
CHECKED: RCB

REV:
0

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446378.95 E: 430012.86 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF BOREHOLE: BH15-02

DRILLING DATE: August 20-21, 2015

INCLINATION: -90°

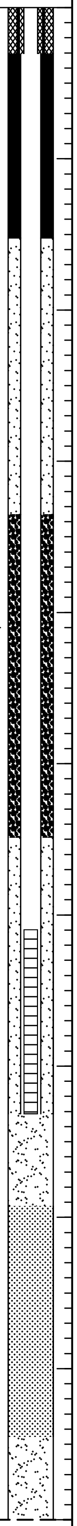
SHEET 1 OF 2
DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 762mm

DRILLING RIG: HT-750 Track Mounted Rotary Drill
DRILLING METHOD: 159mm Tricone Mud Rotary

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; NP - Non-Plastic; 10 20 30 40
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ◐; Pocket Pen - ■; 20 40 60 80
GRADATION %: CLAY PARTICLE SIZE <= 0.002

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	RECOVERY %	BLOWS/0.3m	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
	Ground Surface	74.55													
0	TOPSOIL	74.40													Flush Mount Well Cover
	(SP-SM) gravelly SAND, fine to coarse, sub-angular to angular gravel, some silt; brown; moist, compact.	0.15													
1			1	SS	58	19									Bentonite Pellets
2			2	SS	70	HB									Filter Sand
	(SP-SM) SAND, fine to medium, some silt; brown; moist, compact.	71.96 2.59													
3															
4			3	SS	79	21									8/21/2015 ▼ Bentonite Pellets
	(CL) sandy SILTY CLAY, fine to coarse sand; grey; w>PL, soft.	69.98 4.57													
5			4	SS	100	WH						12			Filter Sand
6	**(SM)** gravelly SILTY SAND, fine to coarse sand, fine, angular gravel; brown-grey, moist, dense.	68.61 5.94													51mm Schedule 80 Slotted PVC Pipe
7			5	SS	62	40	14	64	22						
	(SM/GM) SILTY SAND and GRAVEL, fine to coarse sand, fine to coarse sub-angular to angular gravel; grey; moist, very dense. [Till-like]	67.31 7.24													
8			6	SS	100	>100	38	42	20	15	5				Bentonite Pellets
9	**(CI/SC)** SILTY CLAY and SAND, fine to coarse, trace fine to coarse, sub-angular to angular gravel; grey; w>PL, very stiff. [Till-like]	65.41 9.14													
			~~7~~	~~SS~~	~~0~~	~~HB~~									Filter Sand
10	*CONTINUED NEXT PAGE*														



DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: CR
CHECKED: RCB

REV: 0

PROJECT No.: 13-1447-0516 / 4000 / 4300

RECORD OF BOREHOLE: BH15-02

SHEET 2 OF 2

CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446378.95 E: 430012.86 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

DRILLING DATE: August 20-21, 2015

DATUM: Geodetic

INCLINATION: -90°

SAMPLER HAMMER, 64kg; DROP, 762mm

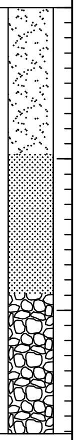
DRILLING RIG: HT-750 Track Mounted Rotary Drill
DRILLING METHOD: 159mm Tricone Mud Rotary

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl; NP - Non-Plastic; 10 20 30 40
SHEAR STRENGTH Cu, kPa: nat V. + Q - ●; rem V. ⊕ U - ◐; Pocket Pen - ■; 20 40 60 80

GRADATION % CLAY PARTICLE SIZE <= 0.002

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	BLOWS/0.3m	GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING
10	**(CI/SC)** SILTY CLAY and SAND, fine to coarse, trace fine to coarse, sub-angular to angular gravel; grey; w>PL, very stiff. [Till-like] *(continued)*													
11			8	GS			2	45	53	29	24	18		
			9	SS	100	>100								
12														
		61.74 12.81	10	SS	100	HB								
13	End of Borehole.													
14														
15														
16														
17														
18														
19														
20														

PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION



DEPTH SCALE
1 : 50

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: CR
CHECKED: RCB

REV:
0

PROJECT No.: 13-1447-0516 / 4000 / 4300

RECORD OF BOREHOLE: BH15-03

SHEET 1 OF 2

CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446359.92 E: 430020.65 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

DRILLING DATE: August 17-18, 2015

INCLINATION: -90°

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 762mm

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY %	SAMPLES BLOWS/0.3m	WATER CONTENT PERCENT Wp —○W— Wl; NP - Non-Plastic; 10 20 30 40; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ◐ Pocket Pen - ■; 20 40 60 80	GRADATION % (CLAY PARTICLE SIZE <= 0.002) GRAVEL	SAND	FINES	SILT	CLAY	PLASTICITY INDEX %	ORGANIC CONTENT %	ADDITIONAL LAB. TESTING	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
			Ground Surface		74.05														
0	HT-750 Track Mounted Rotary Drill	159mm Tricone Mud Rotary	TOPSOIL		73.90 0.15														Soil
			(SW/GW) sandy GRAVEL to SAND and GRAVEL, fine to coarse, sub-rounded to sub-angular, some silt; brown; moist, compact.			1	SS	77	>50										
1					72.53 1.52														
			(SP-SM) SAND, some silt, trace gravel, fine to medium sand, fine to coarse sub-angular gravel; brown-grey; moist, compact to dense.			2	SS	71	40										
						3	SS	83	26										
4					69.63 4.42														Cement-Bentonite Grout
			(CL) SILTY CLAY, trace fine sand; grey; w>PL, soft.		68.79 5.26	4A	SS	88	16										
5			**(ML/SM)** SILT and SAND, fine to coarse, trace gravel; grey; moist, compact.		68.41 5.64	4B					1	35	64	54	10				
			Weathered Bedrock		67.95 6.10	4C													
6			Bedrock Encountered. Refer to Record of DRILLHOLE log for continuation of rock description.																
7																			
8																			
9																			
10																			

DEPTH SCALE
1 : 50

Golder Associates

SOIL CLASSIFICATION SYSTEM: GACS
LOGGED: CR
CHECKED: RCB

REV: 0

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:BC_BOREHOLE_GRADATION (AUTO) JAYoung 9/4/15

PROJECT No.: 13-1447-0516 / 4000 / 4300
CLIENT: City of Nanaimo
PROJECT: Colliery Dam Auxilliary Spillway
LOCATION: Nanaimo, B.C.
N: 5446359.92 E: 430020.65 UTM NAD83 Zone: 10
Survey Provided by: Herold Engineering Limited

RECORD OF DRILLHOLE: BH15-03

DRILLING DATE: August 17-18, 2015

INCLINATION: -90°

SHEET 2 OF 2
DATUM: Geodetic

Refer to "Lithological and Geotechnical Soil and Rock Description Terminology" for accompanying legend and notes.

DEPTH SCALE METRES	DRILLING RIG	DRILLING METHOD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	INDICES: ROCK STRENGTH (R5 R4 R3 R2 R1); WEATHERING (W2 W3 W4); ALTERATION (2 3 4)	RECOVERY: TOTAL CORE % (80 60 40 20); RQD % (80 60 40 20)	FRACTURE INDEX PER 0.3	DISCONTINUITY DATA: DIP DIRECT. (beta) (90 180 270); DIP w.r.t. CORE AXIS (alpha) (0 30 60 90); TYPE AND SURFACE DESCRIPTION	Fault / Breccia / Gouge; Shear Zone; Lost Core; Broken Core	PIEZOMETER, STANDPIPE OR THERMISTOR INSTALLATION
			Cont'd from Record of Borehole.		67.95							
7 8	HT-750 Track Mounted Rotary Drill	PQ Diamond Coring	CONGLOMERATE, fresh, massive; grey; sub-rounded to sub-angular clasts to ~40mm in sandy matrix, strong.		6.10 65.21	1 2						Cement-Bentonite Grout
9			End of DRILLHOLE.		8.84							
10												
11												
12												
13												
14												
15												
16												

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: CR
CHECKED:

REV:
B

Annex B

Laboratory Test Results

Golder Associates

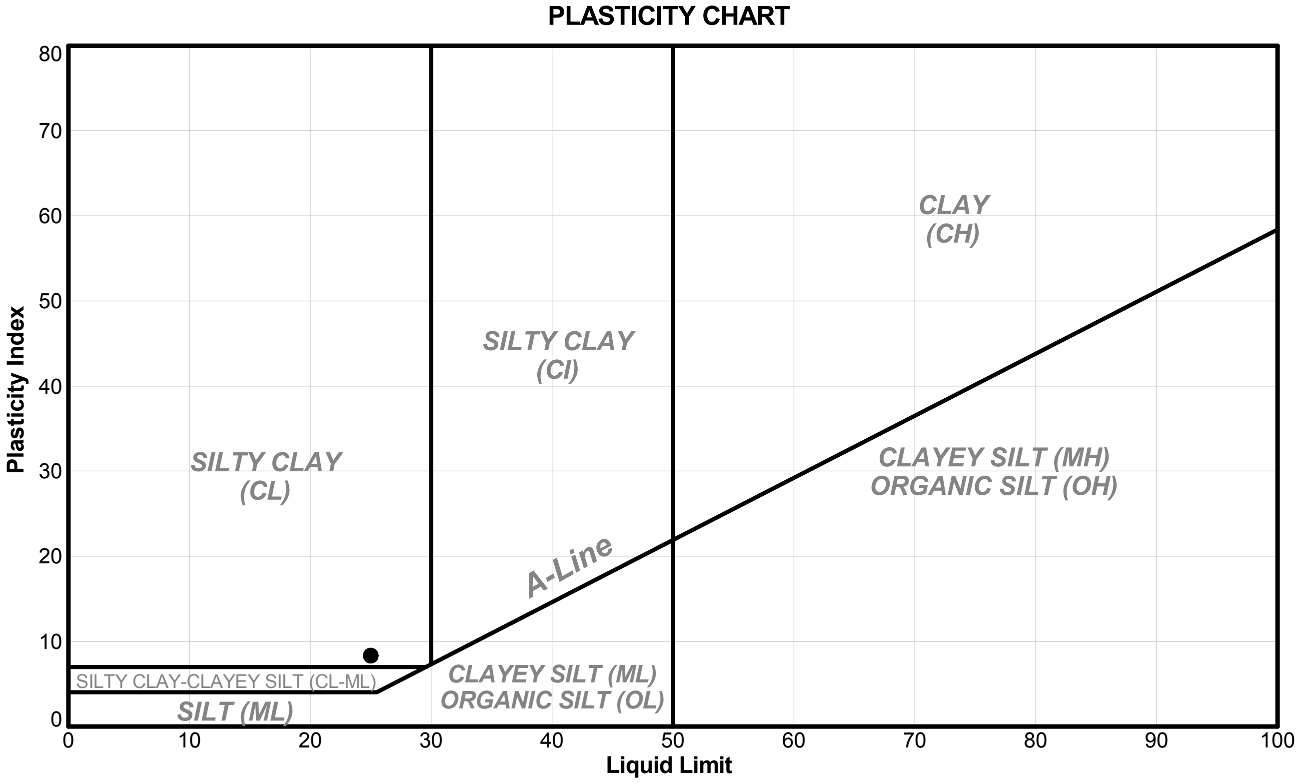
LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

Reference(s)
ASTM D 4318-10

Client:	City of Nanaimo	**Test Pit ID: TP15-01**
Project:	Colliery Dam Auxilliary Spillway	**Sample No.: G10**
Location:	Nanaimo, B.C.	**Depth Interval (m):** 4.27 to 4.36
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**

Other Remarks: **N/A**

Test Method: A-Multi Point **Preparation Method: Air Dried**



Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	TP15-01	G10	4.27	4.36	95	25	17	8.0	22.6	0.7

NP - NON-PLASTIC RESULT ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

OA/DC	**8/20/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) MMiller 8/24/15

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

Reference(s)
ASTM D 4318-10

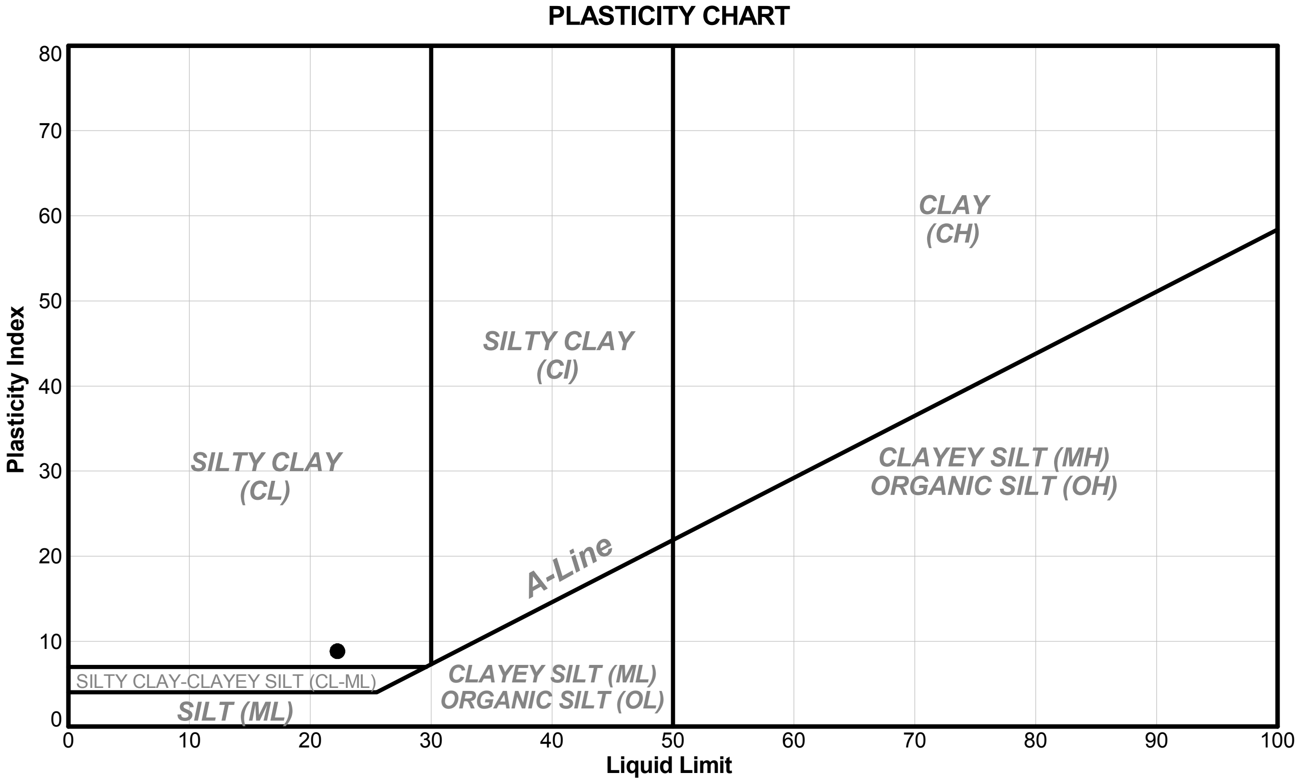
Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Test Pit ID: TP15-03
Sample No.: G5
Depth Interval (m): 3.96 to 4.11
Lab Schedule No.:

Other Remarks: **N/A**

Test Method: A-Multi Point
Preparation Method: Air Dried

PLASTICITY CHART



Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	TP15-03	G5	3.96	4.11	ND	22	13	9.0	21.4	0.9

NP - NON-PLASTIC RESULT ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

OA/DC	8/19/2015	LH	8/23/2015
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) MMiller 8/24/15

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

Reference(s)
ASTM D 4318-10

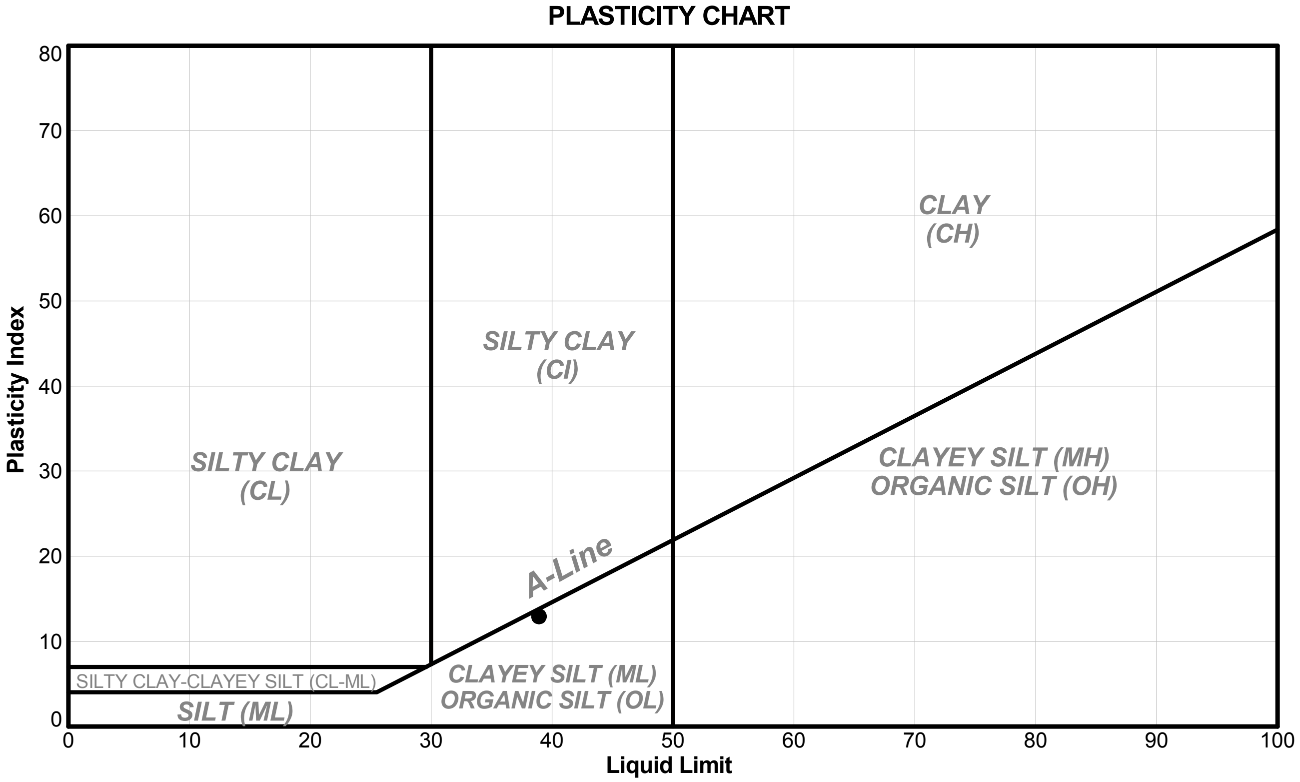
Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Test Pit ID: TP15-04
Sample No.: G3
Depth Interval (m): 1.83 to 1.98
Lab Schedule No.:

Other Remarks: **N/A**

Test Method: A-Multi Point
Preparation Method: Air Dried

PLASTICITY CHART



Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	TP15-04	G3	1.83	1.98	ND	39	26	13.0	34.3	0.6

NP - NON-PLASTIC RESULT   ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

OA/DC	8/20/2015	LH	8/23/2015
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) MMiller 8/24/15

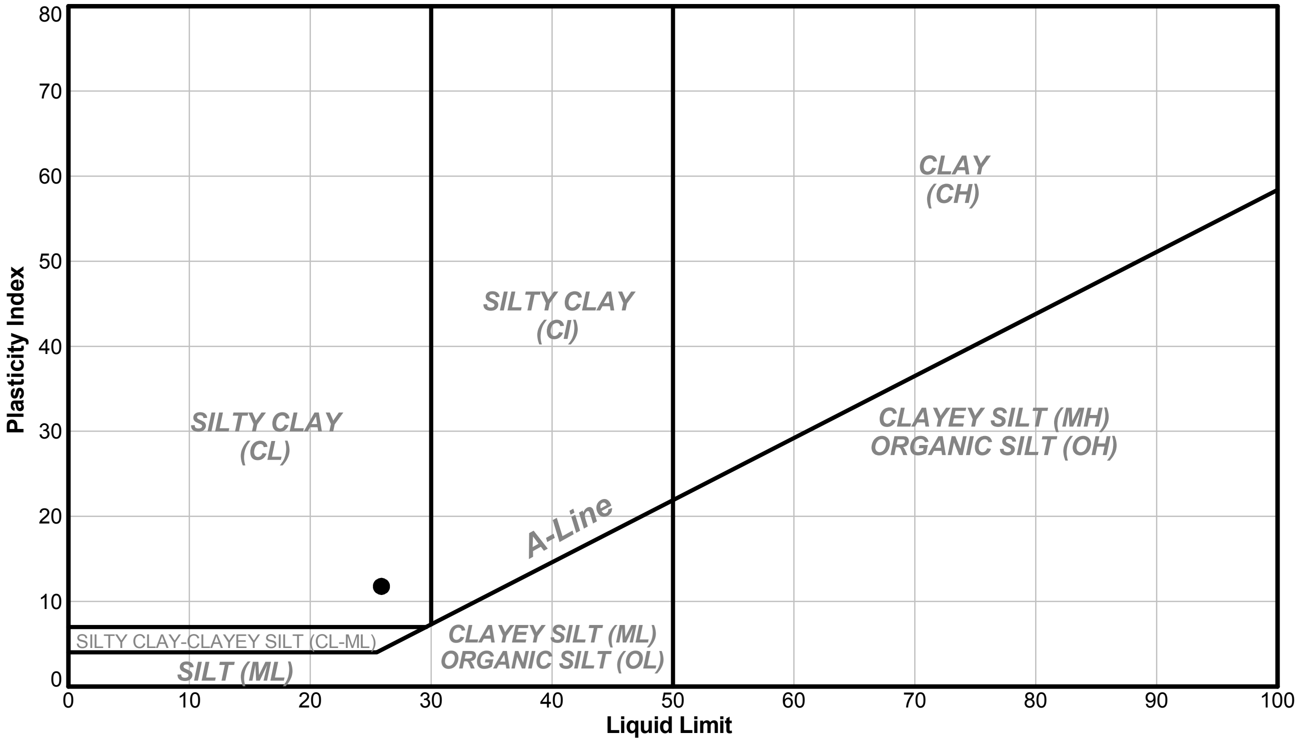
Golder Associates

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS	Reference(s) ASTM D 4318-10
Client: City of Nanaimo	**Borehole ID: BH15-02**
Project: Colliery Dam Auxilliary Spillway	**Sample No.: 4**
Location: Nanaimo, B.C.	**Depth Interval (m):** 5.18 to 5.79
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**

Other Remarks: **N/A**

Test Method: A-Multi Point | **Preparation Method: Air Dried**

PLASTICITY CHART



Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	BH15-02	4	5.18	5.79	ND	26	14	12.0	27.4	1.1

NP - NON-PLASTIC RESULT   ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

OA/RZ	**8/31/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) lhu 9/3/15

Golder Associates

LIQUID LIMIT, PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

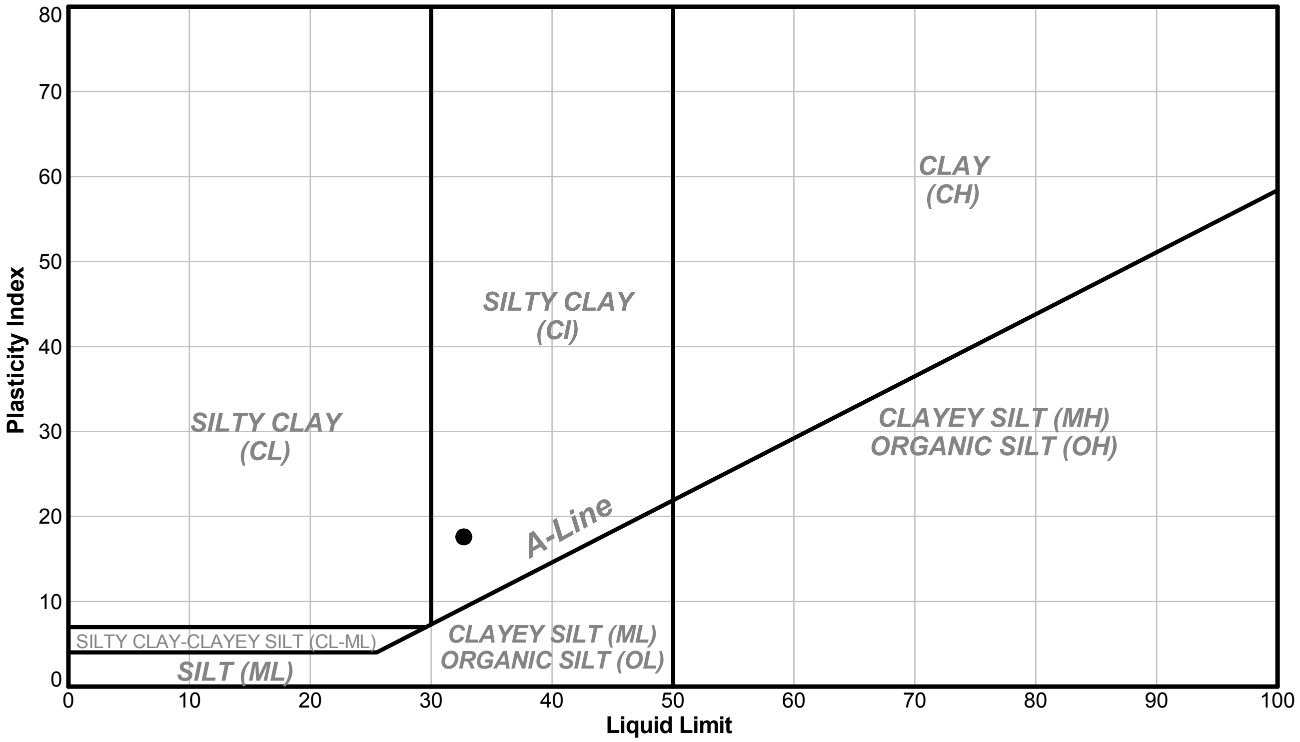
Reference(s)
ASTM D 4318-10

Client:	City of Nanaimo	**Borehole ID: BH15-02**
Project:	Colliery Dam Auxilliary Spillway	**Sample No.: 8**
Location:	Nanaimo, B.C.	**Depth Interval (m):** 10.97 to 11.28
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**

Other Remarks: **N/A**

Test Method: A-Multi Point | **Preparation Method: Air Dried**

PLASTICITY CHART



Sym.	Sample Location	Sample / Specimen Number	Depth (m)	Bottom (m)	Percent Passing #40 Sieve (%)	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Content (%)	Liquidity Index
●	BH15-02	8	10.97	11.28	65	33	15	18.0	20.7	0.3

NP - NON-PLASTIC RESULT ND - NOT DETERMINED

Note: The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

OA/RZ	**8/31/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

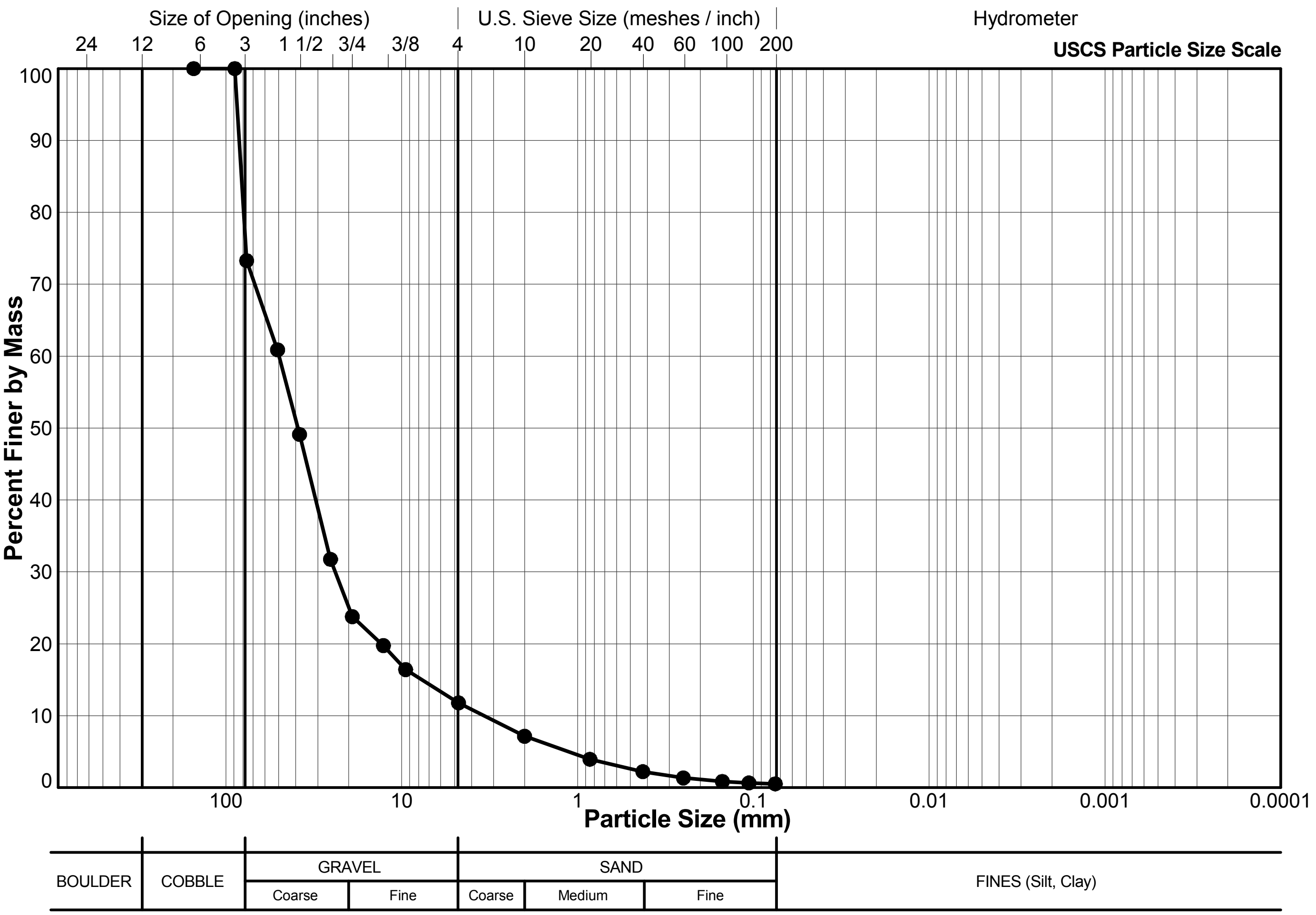
National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_ATTERBERG CASAGRANDE (SINGLE) lhu 9/3/15

Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	City of Nanaimo	**Sample Location:**	TP15-01
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	G2
Location:	Nanaimo, B.C.	**Depth Interval (m):**	1.22 to 1.46
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		73.3
2"	50.8		60.9
1 1/2"	38.1		49.1
1"	25.4		31.7
3/4"	19.1		23.8
1/2"	12.7		19.7
3/8"	9.5		16.4
#4 US MESH	4.75		11.8
#10 US MESH	2		7.1
#20 US MESH	0.85		3.9
#40 US MESH	0.425		2.2
#60 US MESH	0.25		1.3
#100 US MESH	0.15		0.9
#140 US MESH	0.106		0.6
#200 US MESH	0.075		0.5

RZ	8/18/2015	LH	8/23/2015
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

Golder Associates Ltd.
300-3811 North Fraser Way Burnaby, British Columbia Canada V5J 5J2
Tel: (604) 412 6899 Fax: (604) 412 6816 www.golder.com

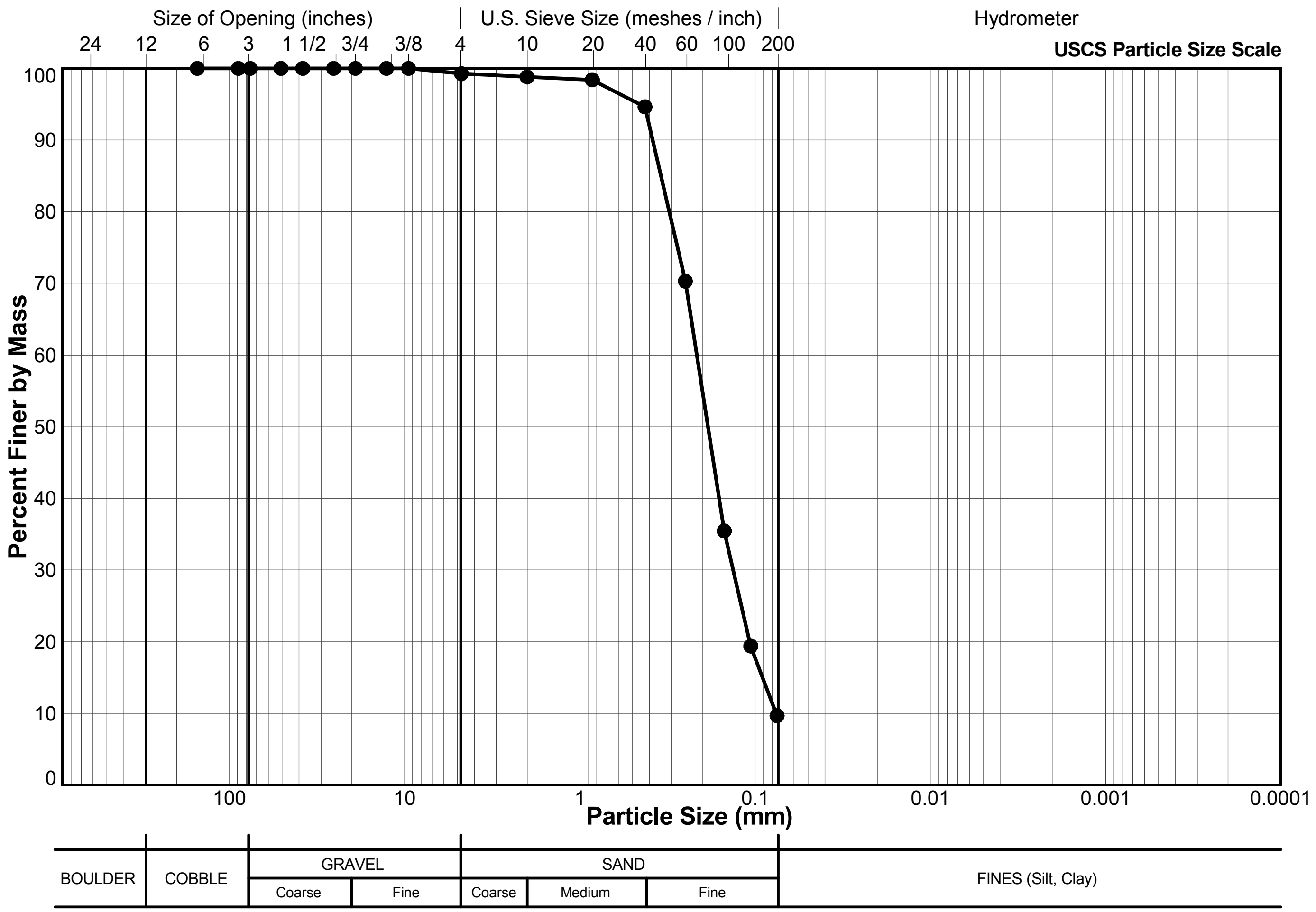
Golder Associates: Operations in Africa, Asia, Australasia, Europe, North America and South America

Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	City of Nanaimo	**Sample Location:**	TP15-01
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	G8
Location:	Nanaimo, B.C.	**Depth Interval (m):**	3.05 to 3.35
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		100.0
#4 US MESH	4.75		99.3
#10 US MESH	2		98.8
#20 US MESH	0.85		98.4
#40 US MESH	0.425		94.6
#60 US MESH	0.25		70.3
#100 US MESH	0.15		35.4
#140 US MESH	0.106		19.4
#200 US MESH	0.075		9.7

RZ	**8/18/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

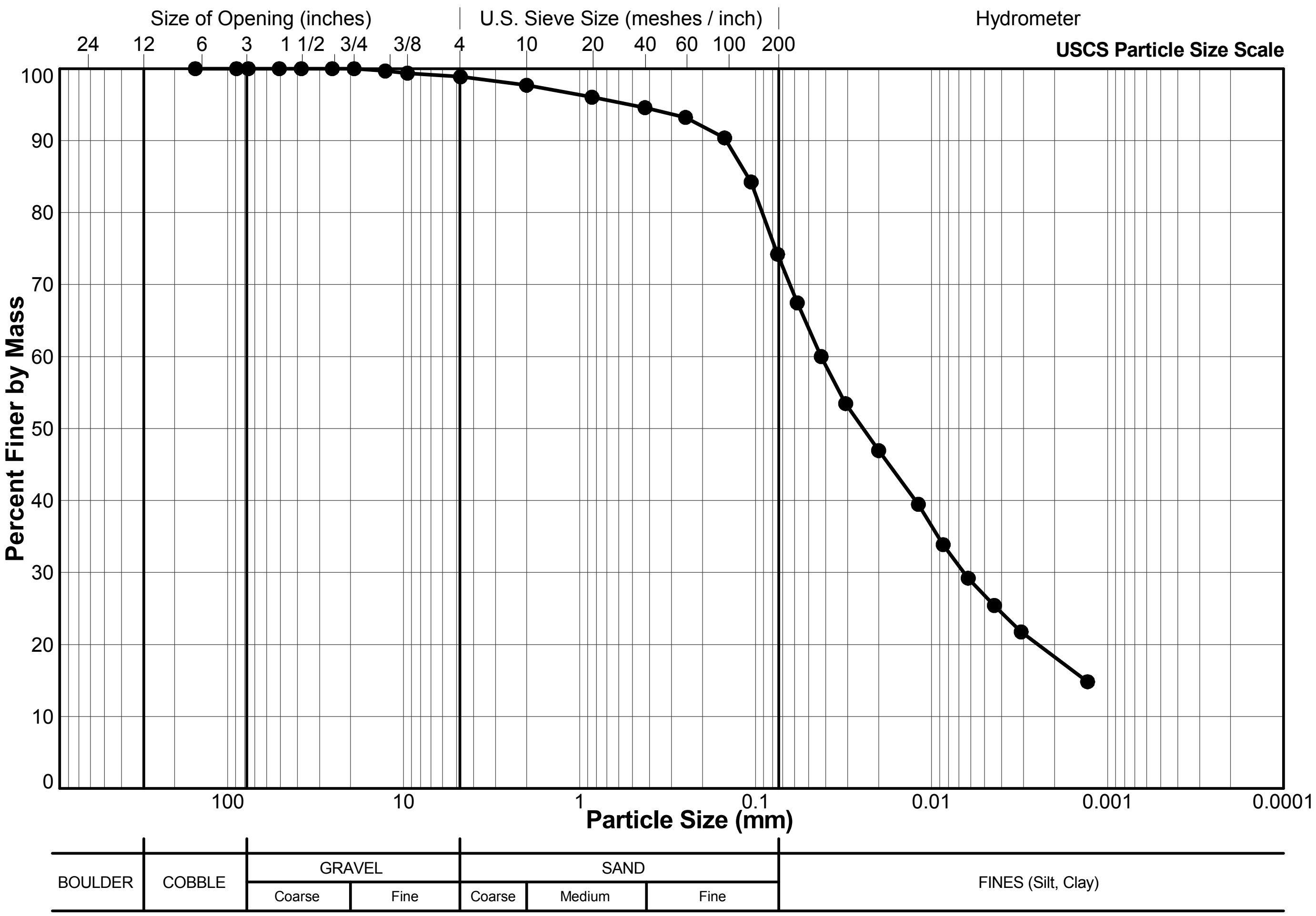
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: TP15-01
Sample No.: G10
Depth Interval (m): 4.27 to 4.36
Lab Schedule No.:



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		99.7
3/8"	9.5		99.4
#4 US MESH	4.75		98.9
#10 US MESH	2		97.7
#20 US MESH	0.85		96.0
#40 US MESH	0.425		94.6
#60 US MESH	0.25		93.2
#100 US MESH	0.15		90.4
#140 US MESH	0.106		84.3
#200 US MESH	0.075		74.2
		0.0580	67.5
		0.0424	60.0
		0.0308	53.5
		0.0200	46.9
		0.0119	39.5
		0.0086	33.9
		0.0062	29.2
		0.0044	25.4
		0.0031	21.7
		0.0013	14.8

AZ/OA	**8/19/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

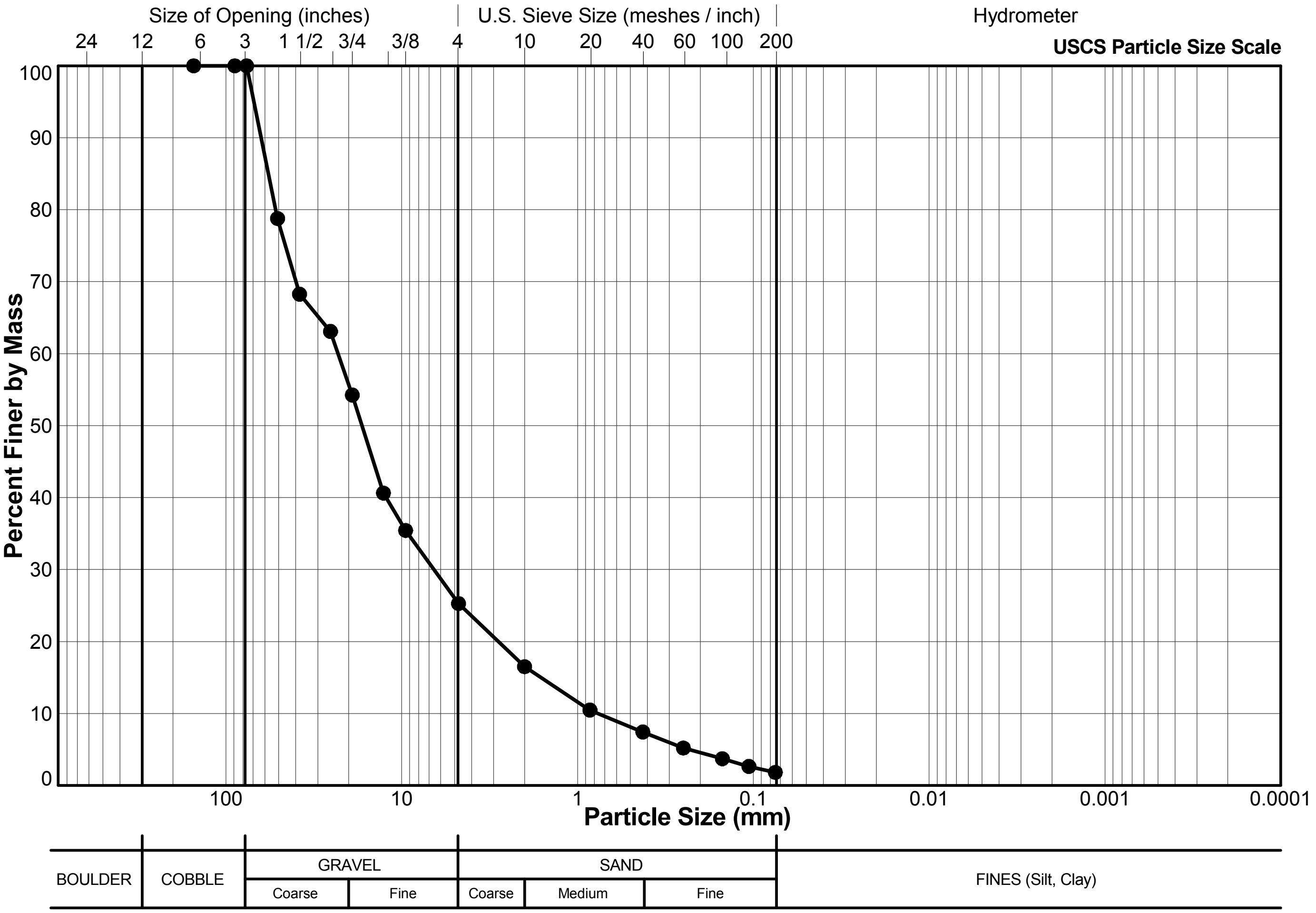
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: TP15-02
Sample No.: G1
Depth Interval (m): 0.70 to 0.85
Lab Schedule No.:



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		78.8
1 1/2"	38.1		68.3
1"	25.4		63.1
3/4"	19.1		54.2
1/2"	12.7		40.6
3/8"	9.5		35.4
#4 US MESH	4.75		25.3
#10 US MESH	2		16.5
#20 US MESH	0.85		10.5
#40 US MESH	0.425		7.4
#60 US MESH	0.25		5.2
#100 US MESH	0.15		3.7
#140 US MESH	0.106		2.6
#200 US MESH	0.075		1.8

RZ	**8/19/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

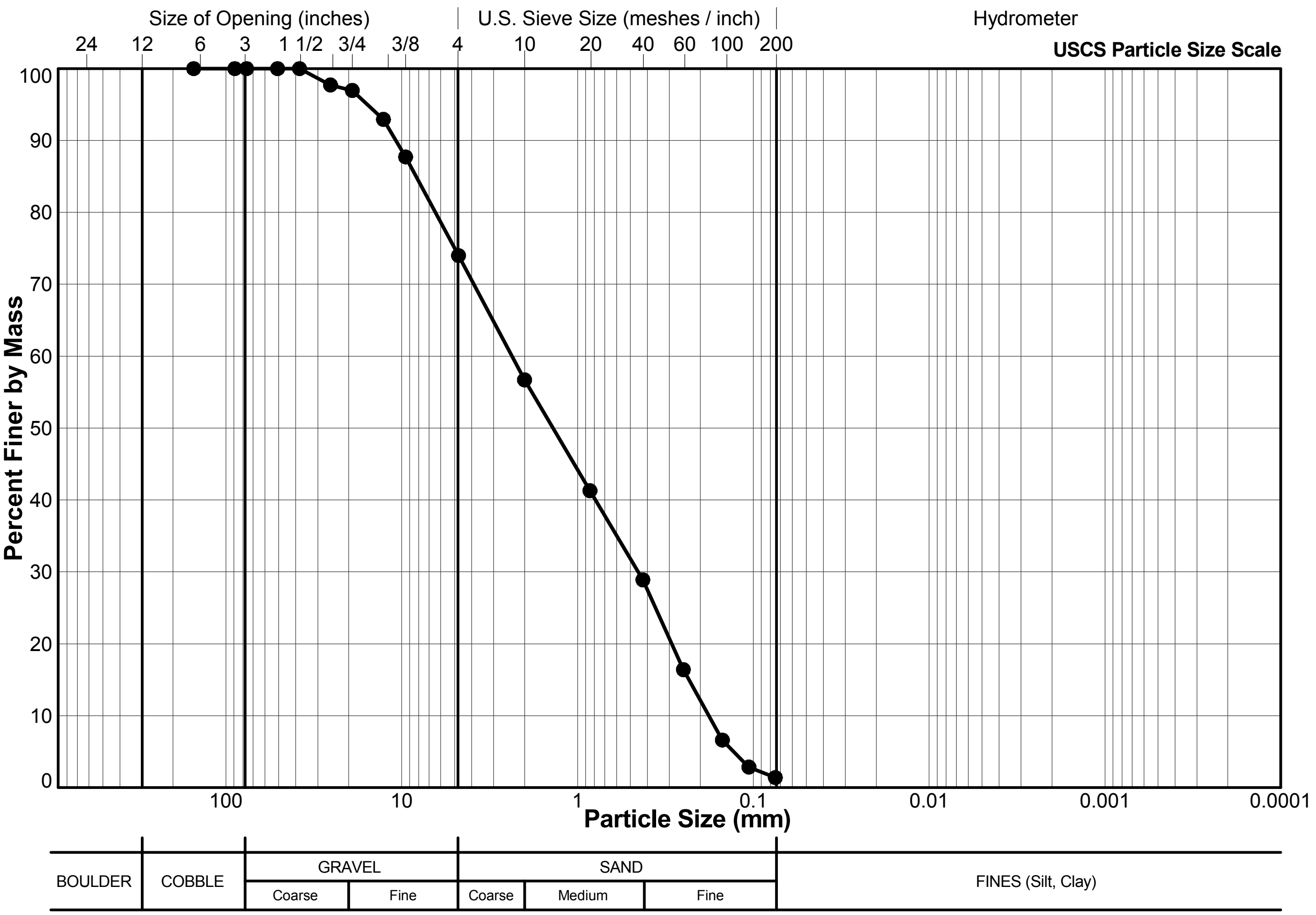
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client:	City of Nanaimo	**Sample Location:**	TP15-02
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	G4
Location:	Nanaimo, B.C.	**Depth Interval (m):**	3.20 to 3.35
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		97.7
3/4"	19.1		97.0
1/2"	12.7		92.9
3/8"	9.5		87.7
#4 US MESH	4.75		74.0
#10 US MESH	2		56.7
#20 US MESH	0.85		41.3
#40 US MESH	0.425		28.9
#60 US MESH	0.25		16.4
#100 US MESH	0.15		6.6
#140 US MESH	0.106		2.9
#200 US MESH	0.075		1.4

RZ	**8/19/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

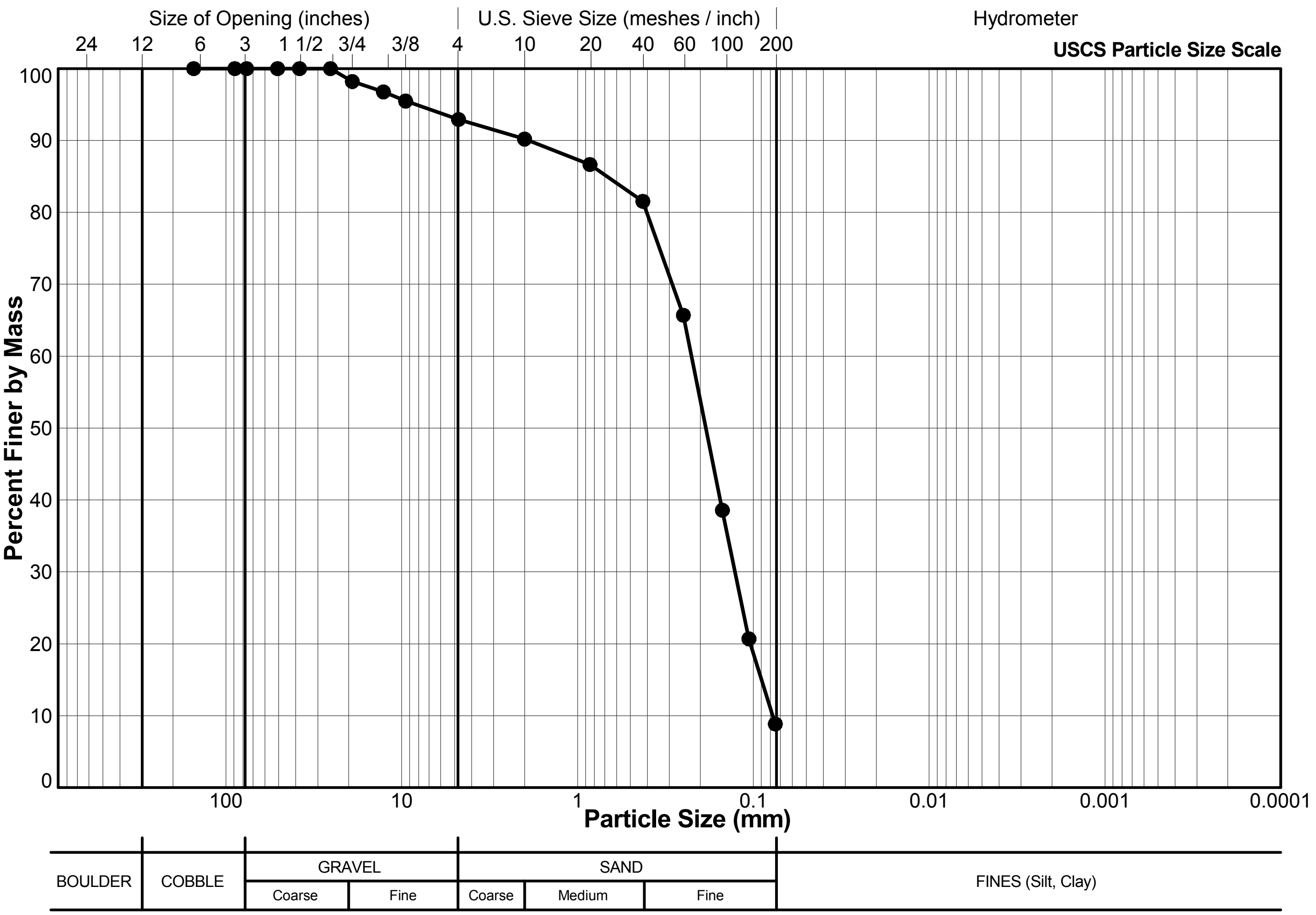
Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: TP15-03
Sample No.: G3
Depth Interval (m): 2.44 to 2.59
Lab Schedule No.:



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		98.2
1/2"	12.7		96.8
3/8"	9.5		95.5
#4 US MESH	4.75		92.9
#10 US MESH	2		90.2
#20 US MESH	0.85		86.7
#40 US MESH	0.425		81.5
#60 US MESH	0.25		65.7
#100 US MESH	0.15		38.6
#140 US MESH	0.106		20.7
#200 US MESH	0.075		8.8

RZ	**8/19/2015**	**LH**	**8/23/2015**
Tech	Date	Checked	Date

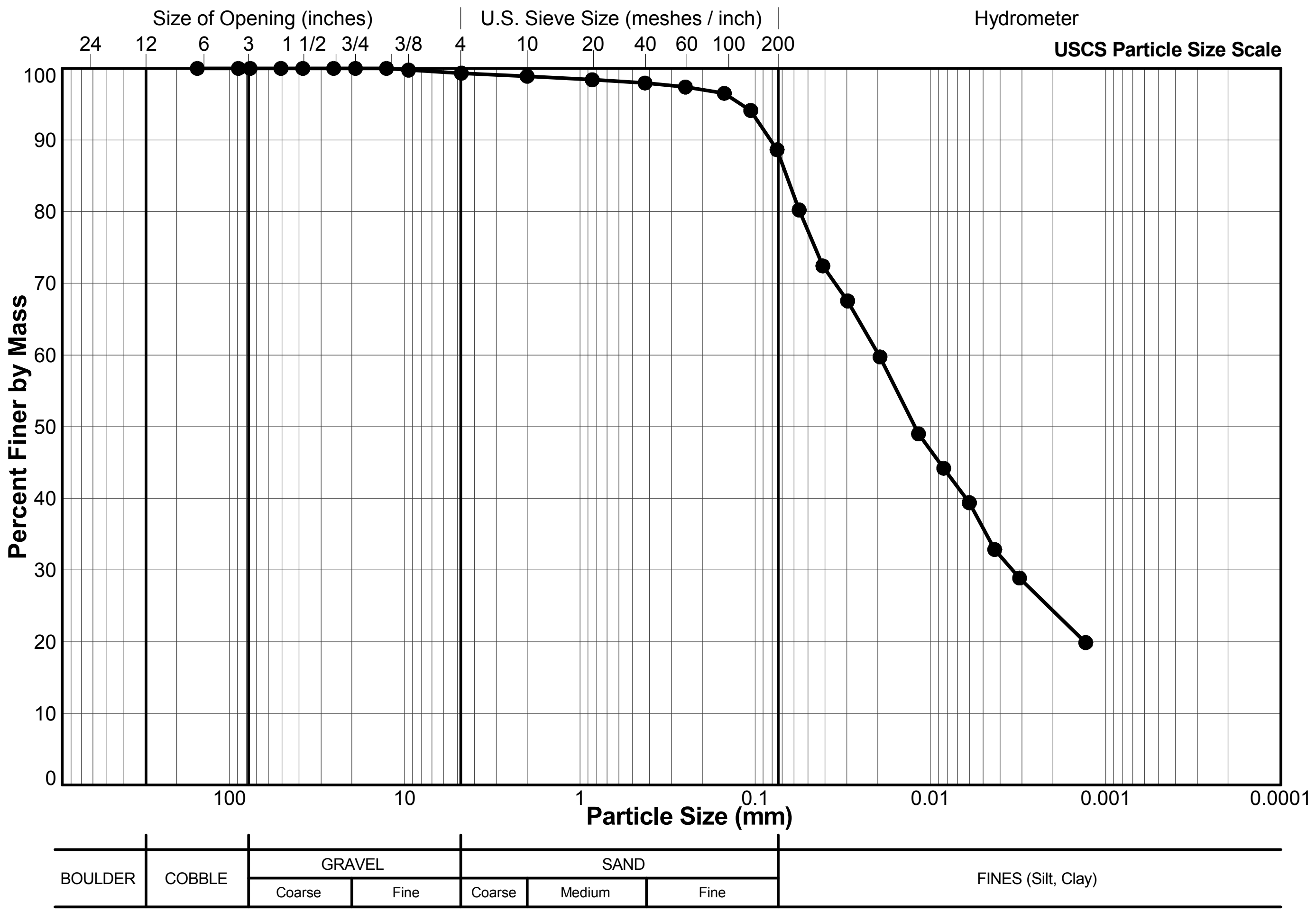
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	City of Nanaimo	**Sample Location:**	TP15-03
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	G5
Location:	Nanaimo, B.C.	**Depth Interval (m):**	3.96 to 4.11
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		99.8
#4 US MESH	4.75		99.3
#10 US MESH	2		98.9
#20 US MESH	0.85		98.4
#40 US MESH	0.425		98.0
#60 US MESH	0.25		97.4
#100 US MESH	0.15		96.5
#140 US MESH	0.106		94.1
#200 US MESH	0.075		88.6
		0.0561	80.2
		0.0411	72.4
		0.0297	67.5
		0.0194	59.7
		0.0117	49.0
		0.0084	44.2
		0.0060	39.4
		0.0043	32.9
		0.0031	28.9
		0.0013	19.9

OA	8/24/2015	LH	8/27/2015
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) MMiller 8/27/15

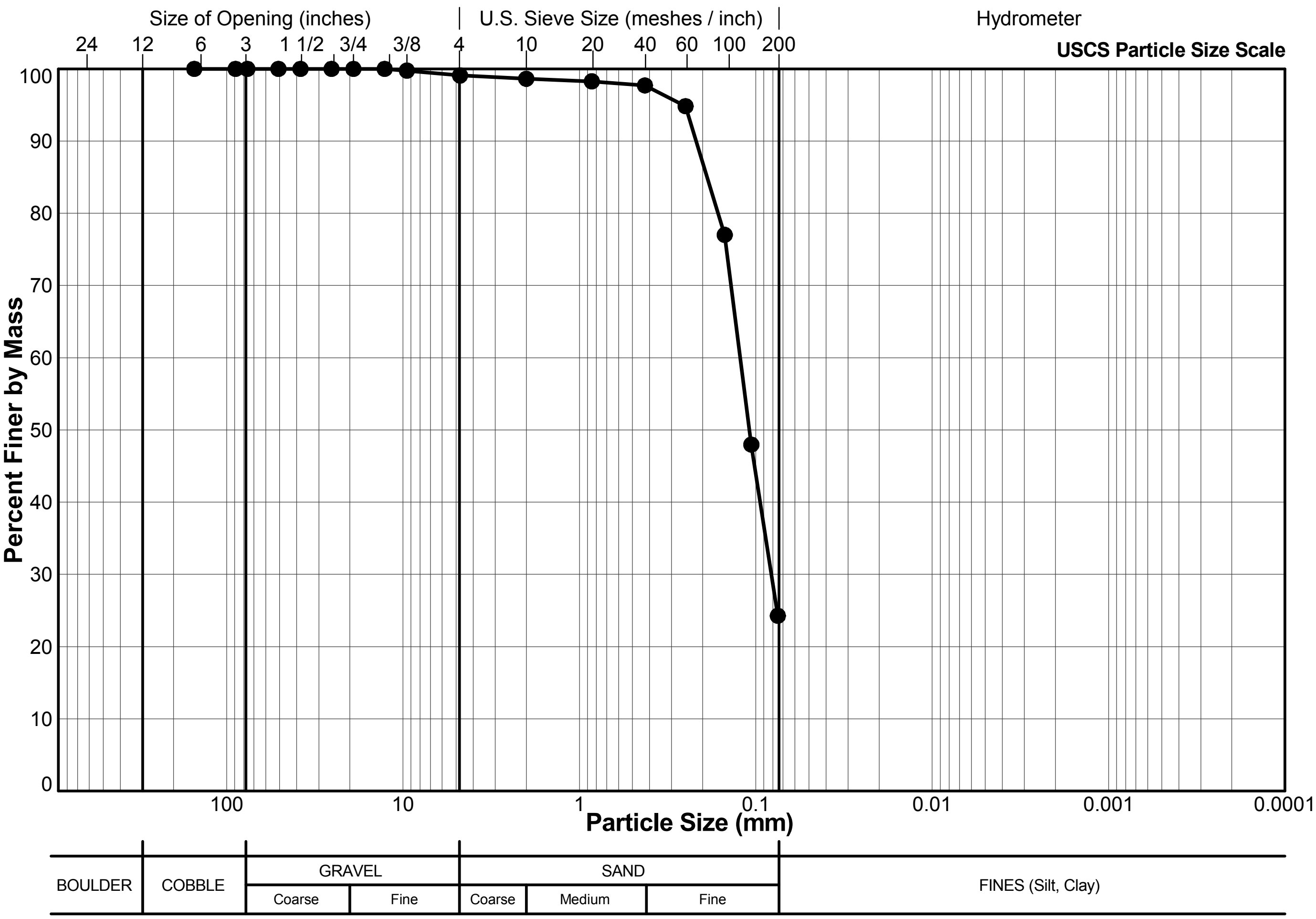
Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: BH15-01
Sample No.: 4 **Specimen:** 4B
Depth Interval (m): 5.33 to 5.64
Lab Schedule No.:



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		99.8
#4 US MESH	4.75		99.1
#10 US MESH	2		98.6
#20 US MESH	0.85		98.3
#40 US MESH	0.425		97.7
#60 US MESH	0.25		94.8
#100 US MESH	0.15		77.0
#140 US MESH	0.106		48.0
#200 US MESH	0.075		24.3

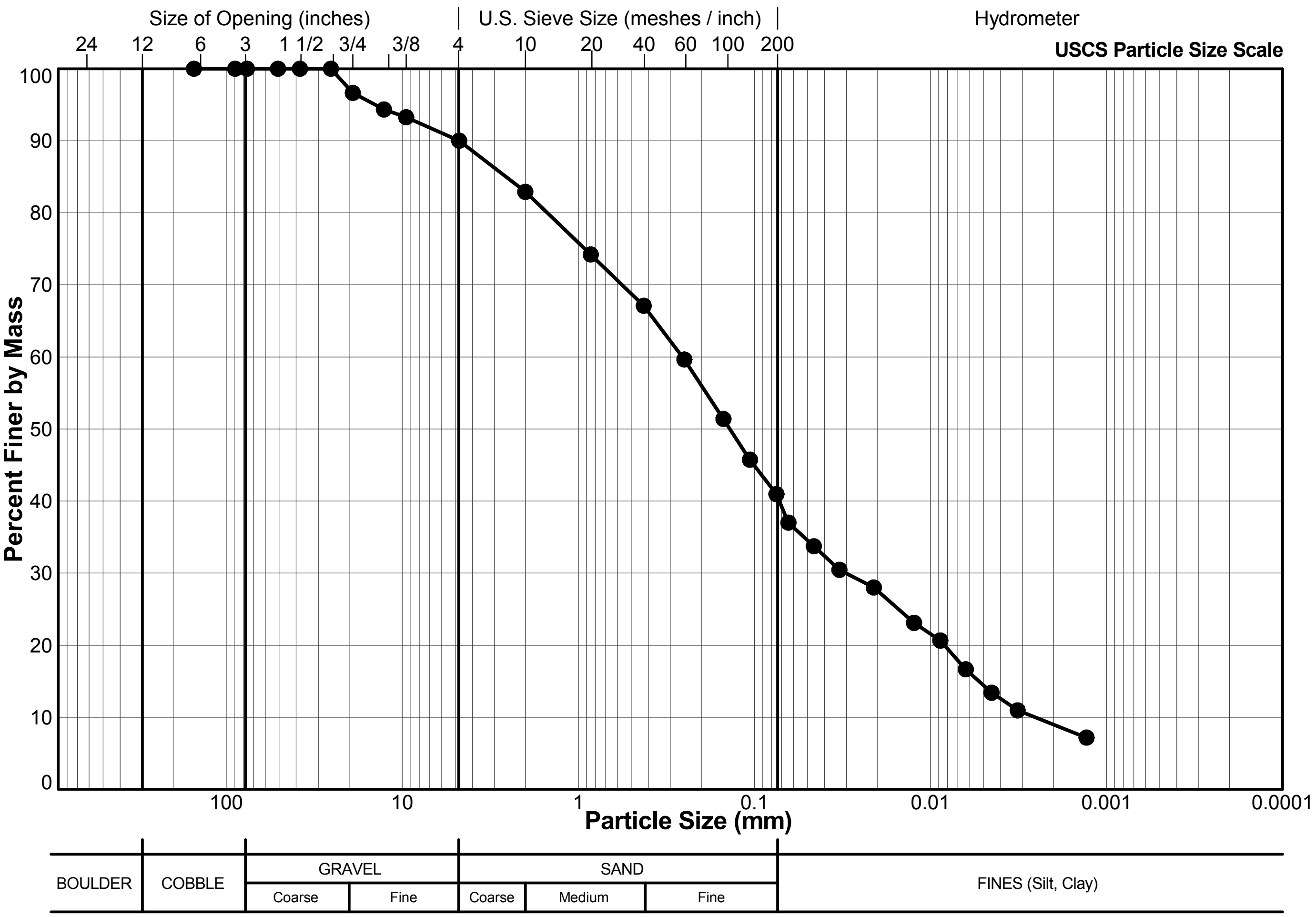
RZ	**8/31/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: BH15-01
Sample No.: 5 **Specimen:** 5B
Depth Interval (m): 7.01 to 7.32
Lab Schedule No.:



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		96.6
1/2"	12.7		94.3
3/8"	9.5		93.3
#4 US MESH	4.75		90.0
#10 US MESH	2		82.9
#20 US MESH	0.85		74.2
#40 US MESH	0.425		67.1
#60 US MESH	0.25		59.6
#100 US MESH	0.15		51.4
#140 US MESH	0.106		45.7
#200 US MESH	0.075		41.0
		0.0641	37.0
		0.0460	33.7
		0.0329	30.5
		0.0210	28.0
		0.0124	23.1
		0.0088	20.6
		0.0063	16.6
		0.0045	13.4
		0.0032	11.0
		0.0013	7.2

OA	**9/1/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

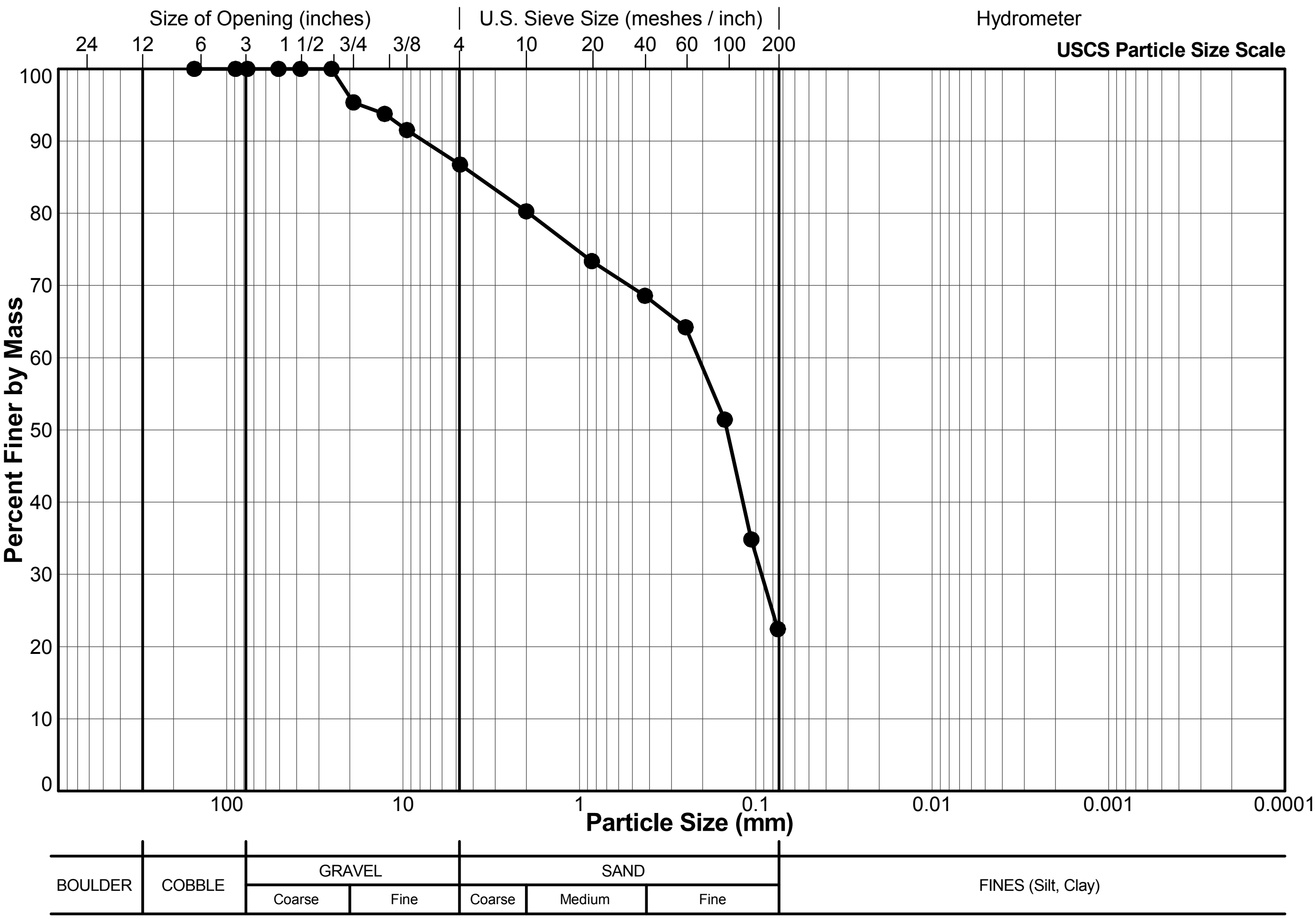
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 9/3/15

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM C136

Client: City of Nanaimo
Project: Colliery Dam Auxilliary Spillway
Location: Nanaimo, B.C.
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300

Sample Location: BH15-02
Sample No.: 5
Depth Interval (m): 6.71 to 7.24
Lab Schedule No.:



Legend

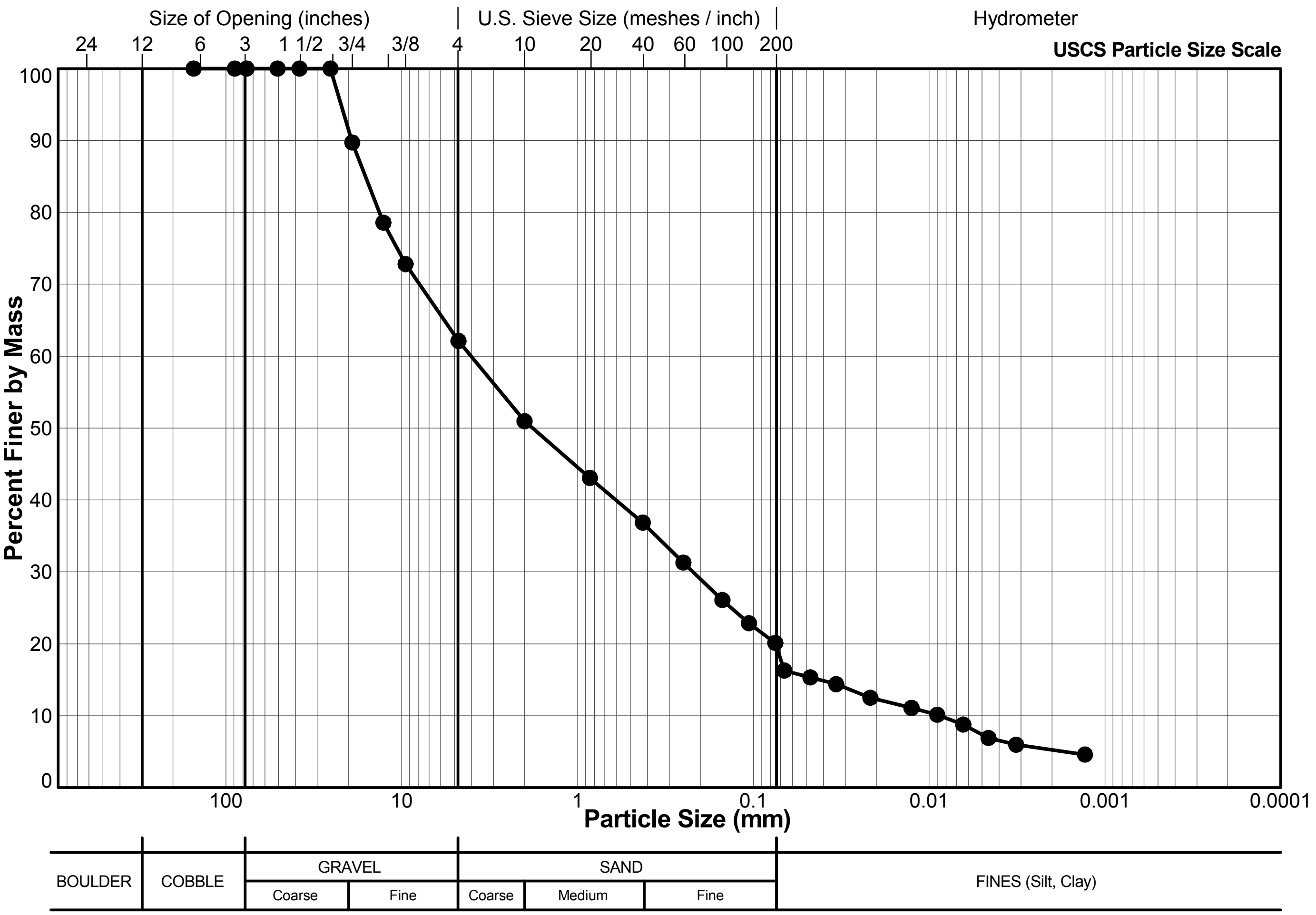
Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		95.4
1/2"	12.7		93.8
3/8"	9.5		91.5
#4 US MESH	4.75		86.7
#10 US MESH	2		80.3
#20 US MESH	0.85		73.4
#40 US MESH	0.425		68.6
#60 US MESH	0.25		64.2
#100 US MESH	0.15		51.4
#140 US MESH	0.106		34.8
#200 US MESH	0.075		22.4

RZ	**8/31/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	City of Nanaimo	**Sample Location:**	BH15-02
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	6
Location:	Nanaimo, B.C.	**Depth Interval (m):**	8.23 to 8.46
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		89.7
1/2"	12.7		78.6
3/8"	9.5		72.8
#4 US MESH	4.75		62.1
#10 US MESH	2		51.0
#20 US MESH	0.85		43.1
#40 US MESH	0.425		36.9
#60 US MESH	0.25		31.3
#100 US MESH	0.15		26.1
#140 US MESH	0.106		22.9
#200 US MESH	0.075		20.1
		0.0667	16.3
		0.0474	15.3
		0.0338	14.4
		0.0216	12.5
		0.0126	11.1
		0.0090	10.1
		0.0064	8.8
		0.0046	6.9
		0.0032	6.0
		0.0013	4.6

OA	**9/1/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

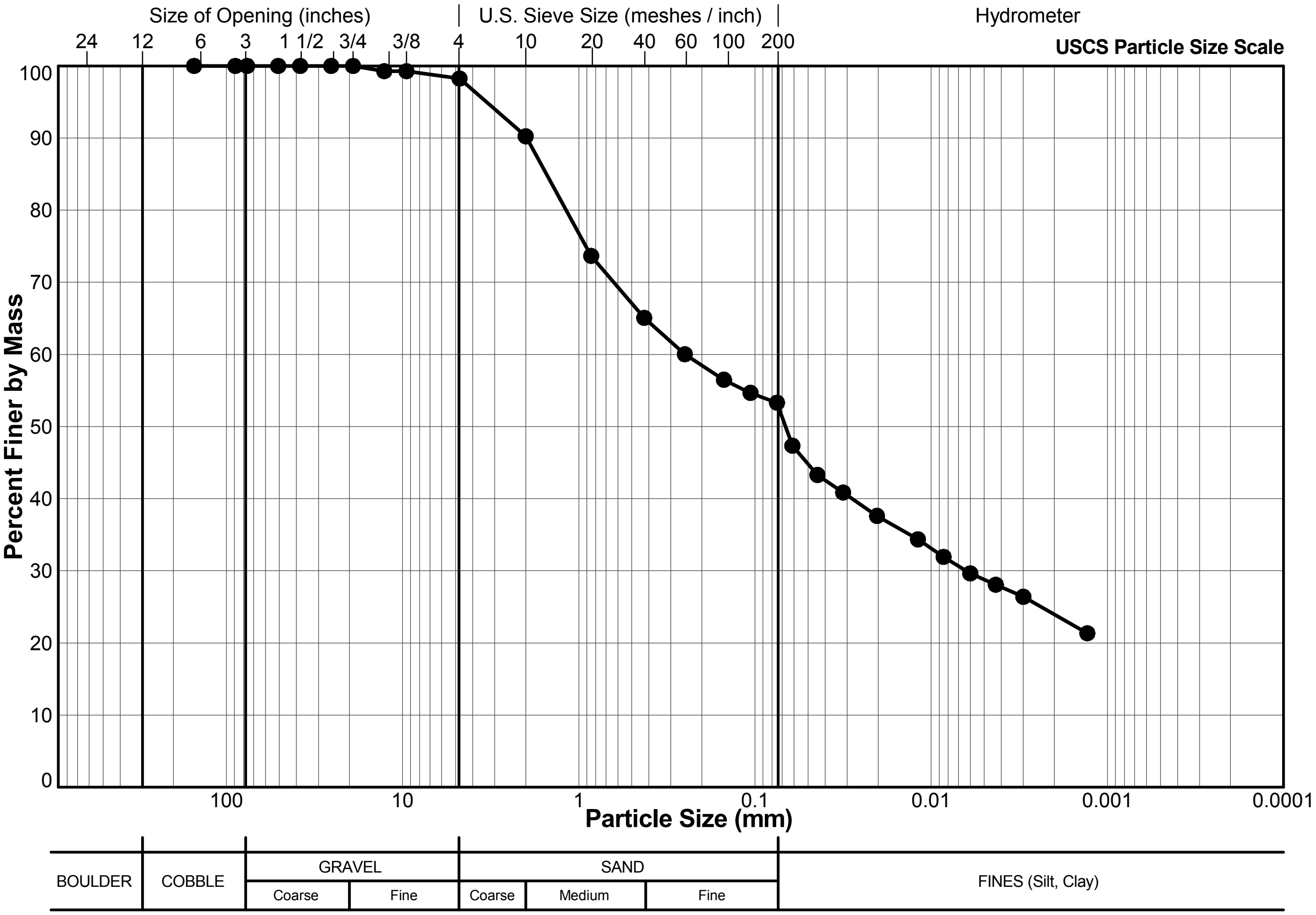
National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 9/3/15

Golder Associates

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client:	City of Nanaimo	**Sample Location:**	BH15-02
Project:	Colliery Dam Auxilliary Spillway	**Sample No.:**	8
Location:	Nanaimo, B.C.	**Depth Interval (m):**	10.97 to 11.28
Project No.:	13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**	



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		99.3
3/8"	9.5		99.3
#4 US MESH	4.75		98.3
#10 US MESH	2		90.2
#20 US MESH	0.85		73.7
#40 US MESH	0.425		65.1
#60 US MESH	0.25		60.0
#100 US MESH	0.15		56.5
#140 US MESH	0.106		54.7
#200 US MESH	0.075		53.3
		0.0613	47.3
		0.0442	43.3
		0.0316	40.9
		0.0203	37.6
		0.0119	34.4
		0.0085	31.9
		0.0060	29.6
		0.0043	28.1
		0.0030	26.4
		0.0013	21.3

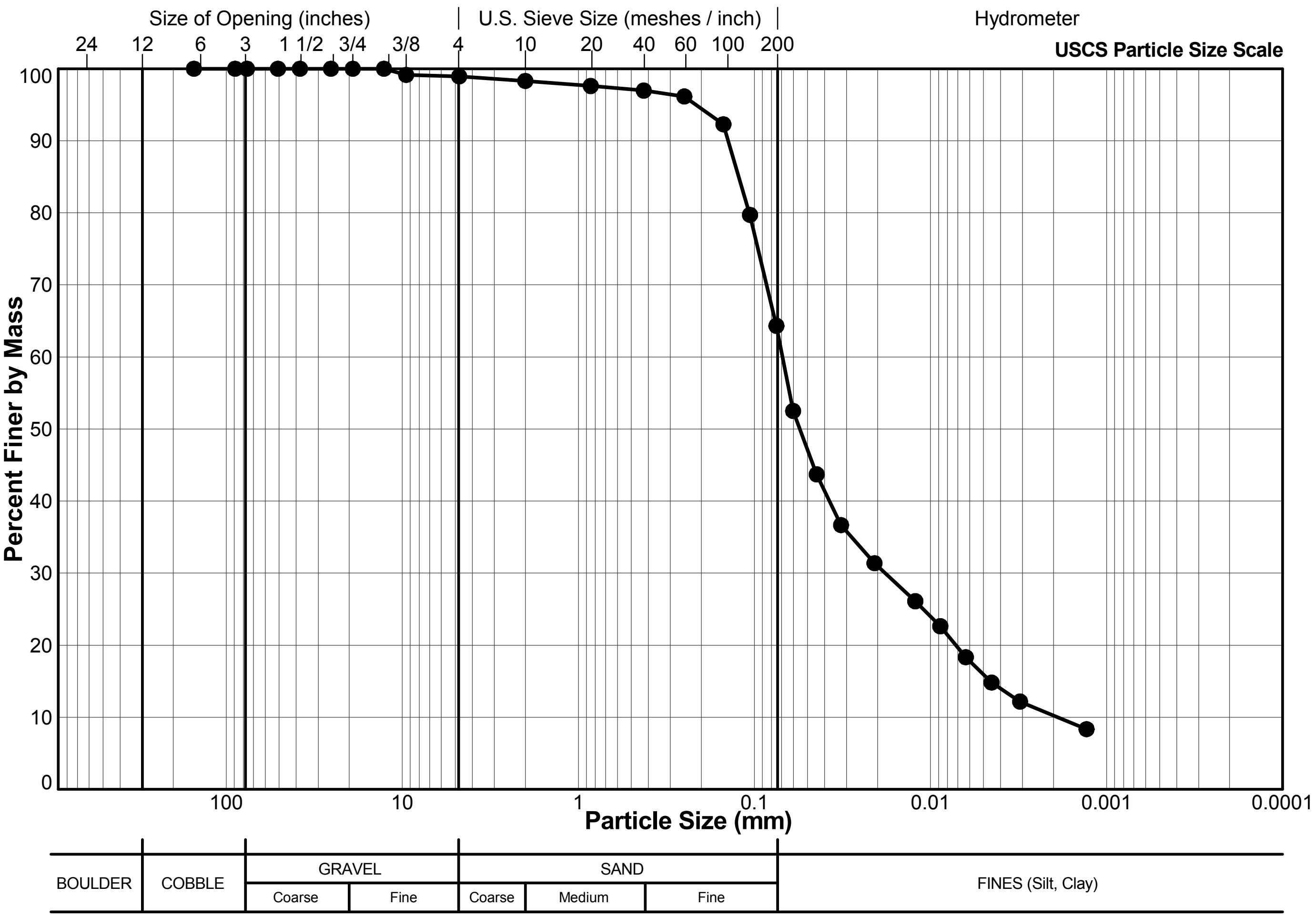
OA	**9/1/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 9/3/15

SUMMARY OF PARTICLE SIZE DISTRIBUTION

Reference(s)
ASTM D 422

Client: City of Nanaimo	**Sample Location:** BH15-03
Project: Colliery Dam Auxilliary Spillway	**Sample No.:** 4 **Specimen:** 4B
Location: Nanaimo, B.C.	**Depth Interval (m):** 5.26 to 5.64
Project No.: 13-1447-0516 **Phase:** 4000 **Task:** 4300	**Lab Schedule No.:**



Legend

Sieve Size (USS)	(mm)	Particle Size (mm)	Percent Passing
6"	152.4		100.0
3.5"	88.9		100.0
3"	76.2		100.0
2"	50.8		100.0
1 1/2"	38.1		100.0
1"	25.4		100.0
3/4"	19.1		100.0
1/2"	12.7		100.0
3/8"	9.5		99.1
#4 US MESH	4.75		98.9
#10 US MESH	2		98.3
#20 US MESH	0.85		97.6
#40 US MESH	0.425		97.0
#60 US MESH	0.25		96.1
#100 US MESH	0.15		92.3
#140 US MESH	0.106		79.7
#200 US MESH	0.075		64.3
		0.0603	52.5
		0.0443	43.7
		0.0322	36.7
		0.0208	31.4
		0.0122	26.1
		0.0088	22.6
		0.0063	18.3
		0.0045	14.8
		0.0031	12.2
		0.0013	8.3

OA	**9/1/2015**	**LH**	**3/9/2015**
Tech	Date	Checked	Date

National IM Server:GINT_GAL_NATIONALIM Unique Project ID:974 Output Form:_LAB_PARTICLE SIZE (W/ GRADATIONS) lhu 9/3/15

Sheet 1 of 1

WATER CONTENT DETERMINATION

Reference(s)
ASTM D 2216

Client:	City of Nanaimo	**Project No.:**	13-1447-0516 **Phase:** 4000 **Task:** 4300
Project:	Colliery Dam Auxilliary Spillway	**Lab Schedule No.:**	
Location:	Nanaimo, B.C.		

Sample Location	**Sample No.**	**Specimen No.**	**Depth Interval**		**Water Content (%)**
			Depth (m)	Bottom (m)	
BH15-02	**4**		5.18	5.79	**27.4**
BH15-02	**8**		10.97	11.28	**20.7**
TP15-01	**G10**		4.27	4.36	**22.6**
TP15-01	**G11**		4.36	4.42	**18.3**
TP15-02	**G6**		3.96	4.11	**28.5**
TP15-03	**G4**		3.35	3.51	**23.0**
TP15-03	**G5**		3.96	4.11	**21.4**
TP15-03	**G6**		4.36	4.42	**18.7**
TP15-04	**G2**		1.16	1.22	**20.9**
TP15-04	**G3**		1.83	1.98	**34.3**

National IM Server:GINT_GAL_NATIONALIM Unique Project ID: Output Form:_LAB_WATER CONTENT (REPORT) lhu 9/3/15

LH	9/3/2015
Checked	Date

Laboratory Determination of Uniaxial Compressive Strength of Intact Rock Core Specimens.

Summary of Test Results

ASTM D7012 Method C

Project No.: 13-1447-0516/4000/4300

Project: Colliery Dam

Location: Nanaimo, BC

Client: Foundex

Lab ID No: 342

Failure Modes

(1) Simple Extension
(2) Multiple Extension
(3) Multiple Fracturing
(4) Multiple Shear
(5) Single Shear
(6) Spalling
(7) Other

Note: (deg) measured from core axis

No.	Borehole	Sample	Depth	Dia	Ht	Area	Volume	Mass	Wet Density	Moisture	Dry Density	Maximum Load	Stress σ_u	Rock Type	Failure Mode	
	#	#	(ft)	(mm)	(mm)	(cm^2)	(cm^3)	(g)	(kg/m^3)	(%)	(kg/m^3)	(kN)	(MPa)		Type	(deg)
1	BH15-03	1	22'6" - 23'1"	80.39	176.97	50.76	898.24	2294.60	2555	0.89	2532	308.00	60.7	Not Provided	2/3	N/A
2	BH15-03	2	25' - 25'7"	80.41	180.17	50.78	914.94	2376.30	2597	0.79	2577	342.70	67.5	Not Provided	2/3	N/A

The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

G. Patton	September 1, 2015	L. Perrey	September 2, 2015
TESTED BY	DATE	CHECKED BY	DATE

Uniaxial Compressive Strength of Intact Rock Core Specimens (Method C)

ASTM D7012

Project No.:	13-1447-0516/4000/4300	**Borehole:**	BH15-03
Project:	Colliery Dam	**Sample Number:**	1
Location:	Nanaimo, BC	**Depth (ft):**	22'6" - 23'1"
Client:	Foundex	**Lab ID No:**	342

Testing Results

Max Load (kN)	**308.00**
Stress σ_u (MPa)	**60.7**
Pace Rate (kN/s)	1.25
Lithology	Not Provided

Sample Measurements

Diameter	(mm)	80.39
Height	(mm)	176.97
Area	(cm²)	50.76
Volume	(cm³)	898.24
Mass	(g)	2294.60
Moisture Content (%)		0.89
Wet Density	(kg/m³)	2555
Dry Density	(kg/m³)	2532

BEFORE TEST

Failure Mode

Type: **2/3**

Degrees:* **N/A**

* Degrees measured with respect to core axis.

The impact of any pre-existing feature on the test results will be noted in the comments, if applicable.

Notes

- Water content as received

Mode:

(1) Simple Extension
(2) Multiple Extension
(3) Multiple Fracturing
(4) Multiple Shear
(5) Single Shear
(6) Spalling
(7) Other

AFTER TEST

Comments

The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

G. Patton	September 1, 2015	L. Perrey	September 2, 2015
TESTED BY	DATE	CHECKED BY	DATE

Uniaxial Compressive Strength of Intact Rock Core Specimens (Method C)

ASTM D7012

Project No.:	13-1447-0516/4000/4300	**Borehole:**	BH15-03
Project:	Colliery Dam	**Sample Number:**	2
Location:	Nanaimo, BC	**Depth (ft):**	25' - 25'7"
Client:	Foundex	**Lab ID No:**	342

Testing Results

Max Load (kN)	**342.70**
Stress σ_u (MPa)	**67.5**
Pace Rate (kN/s)	1.25
Lithology	Not Provided

Sample Measurements

Diameter	(mm)	80.41
Height	(mm)	180.17
Area	(cm²)	50.78
Volume	(cm³)	914.94
Mass	(g)	2376.30
Moisture Content (%)		0.79
Wet Density	(kg/m³)	2597
Dry Density	(kg/m³)	2577

BEFORE TEST

Failure Mode

Type: **2/3**

Degrees:* **N/A**

* Degrees measured with respect to core axis.

The impact of any pre-existing feature on the test results will be noted in the comments, if applicable.

Notes

- Water content as received

Mode:

(1) Simple Extension
(2) Multiple Extension
(3) Multiple Fracturing
(4) Multiple Shear
(5) Single Shear
(6) Spalling
(7) Other

AFTER TEST

Comments

The test data given herein pertain to the sample provided only. This report constitutes a testing service only.

G. Patton	September 1, 2015	L. Perrey	September 2, 2015
TESTED BY	DATE	CHECKED BY	DATE

Annex C

Rock Core Photograph

BH15-03

6.10 m to 8.84 m (20’ to 29” ft.) depth

CLIENT
CITY OF NANAIMO

PROJECT
COLLIERY DAMS
NANAIMO, BC

CONSULTANT

YYYY-MM-DD	2015-09-02
PREPARED	C. REID
DESIGN	C. REID
REVIEW	T. MADDEN
APPROVED	B. DOWNING

TITLE
BH15-03
ROCK CORE PHOTOGRAPH
6.10 m to 8.84 m (20’ to 29’) DEPTH

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	**4000**	**A**	**A-1**

APPENDIX B

Geotechnical Design Recommendations Technical Memorandum

Golder Associates

TECHNICAL MEMORANDUM

DATE September 4, 2015 **PROJECT No.** 1314470516-031-TM-Rev0

TO Greg Beaveridge, P. Eng., Struct.Eng., M.I.Struct.E
Herold Engineering Ltd.

CC Bruce Downing, P. Eng. / Toby Seward, City of Nanaimo

FROM Thomas Madden, E.I.T./
Richard C. Butler, P. Eng., FEC **EMAIL** tmadden@golder.com

GEOTECHNICAL DESIGN RECOMMENDATIONS
AUXILIARY SPILLWAY, LOWER COLLIERY DAM
NANAIMO, BC

This technical memorandum briefly summarizes the subsurface conditions encountered at the site based on our recent geotechnical investigation, and provides the recommended geotechnical parameters as input to the structural design of the proposed auxiliary spillway structure.

1.0 SEISMIC CONSIDERATIONS

1.1 Background and Proposed Auxiliary Spillway

The failure consequence classification of the Lower Dam is 'Very High' and Golder understands from discussion with the City of Nanaimo that the auxiliary is not defined as a 'post-disaster structure'. Canadian Dam Association (CDA) Dam Safety Guidelines (2007) outline that the earthquake design ground motion (EDGM) should be selected based on the consequences of dam failure. Given the failure consequence designations of the lower dam (very high) and middle dam (high), the suggested earthquake levels for use in deterministic assessments for the dam structure are a 1-in-5,000 year event and a 1-in-2,500 year event, respectively (Table 6-1, CDA Dam Safety Guidelines, 2007).

The auxiliary spillway is designed to provide additional spillway capacity without impacting the existing spillway. It would only be activated in the event of a storm event and associated high water levels within the reservoir. This secondary spillway will consist of a labyrinth weir structure located to the south of the existing spillway and is outside of the footprint of the existing dam and spillway. The labyrinth weir has plan dimensions of approximately 13.8 m by 13.0 m with a height of 3 m. Water flows over the labyrinth weir downstream beneath a bridge structure. Downstream of the bridge, the water flows through a tapered open channel into a 6 m wide open channel before discharging into Harewood Creek.

The primary function of the auxiliary spillway is to provide secondary flood routing during a storm event, is not considered a substitute spillway, and is not directly or indirectly connected to or integral with the existing spillway and dam structure as an appurtenant structure. Further, CDA Guidelines require that designs are carried out to meet the design seismic event and the design storm event, as two independent events (i.e. not concurrent).

1.2 Seismic Design Parameters

Typically dams, and appurtenant structures, are located in remote areas and require site specific seismic hazard assessments to be carried out (CDA Dam Safety Guidelines, 2007). Since the auxiliary spillway is located within an urban region and close to the Lower Mainland, is not an appurtenant structure of the Lower Dam (not connected to, or contiguous with, the Lower Dam), and in consideration of the limited size of the auxiliary spillway (less than 3 m in height), Golder recommends that seismic hazard parameters and uniform hazard spectra seismic events, comparable to that for other commercial and industrial structures designed in conformance with the current (2010) National Building Code of Canada (NBCC) be adopted for use in design of the auxiliary spillway. Following discussions with Herold Engineering, Golder proposes that a 475 year return period seismic event is adopted for serviceability limit state (SLS) design and a 2,475 year return period seismic event is adopted for ultimate limit state (ULS) design of the structure.

Site-specific seismic motion parameters for the subject site were obtained from the National Resources Canada website (*http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index-eng.php*) and are summarized in Table 1 (see also Attachment 1). The ground motion parameters have been established for two return periods that correspond to a 10 % probability chance of exceedance in 50 years (equivalent to 1 in 475 year event) and 2 % probability of exceedance in 50 years (equivalent to 1 in 2,475 year event). They correspond to Class C ground motions, for soil profiles with an average N60 count of the upper 30 m greater than 50 blows per 300 mm.

Table 1: Site Specific Probabilistic Firm-Ground Motion Parameters (Site Class C)

Return Period	**PHGA**	**Sa (0.2)**	**Sa (0.5)**	**Sa (1.0)**	**Sa (2.0)**	**Approximate Magnitude**
475 Years (10% Probability of exceedance in 50 years)	0.268	0.532	0.357	0.181	0.089	M6.9
2,475 Years (2% Probability of exceedance in 50 years)	0.499	1.013	0.692	0.351	0.178	M7.0

Note: PHGA refers to peak horizontal ground acceleration; Sa refers to spectral acceleration for a given period.

These seismic hazard parameters are derived from the probabilistic hazard model developed by the Geological Survey of Canada (GSC). This model is based on the results of extensive work conducted by the GSC. This approach is industry standard and has been adopted in the National and BC Building codes for design of buildings and structures.

Golder did not carry out a detailed seismic hazard assessment for the auxiliary spillway which may consider the proximity of known or potential faults to the site with recorded seismicity over many years. We consider the probabilistic approach to be adequate for the design of the proposed auxiliary spillway. However, Golder's technical memorandum on 'Dynamic Soil-Structure Interaction Analysis of the Colliery Dam, Nanaimo', dated July 16, 2014, outlined an assessment of the seismic behaviour of the Lower Colliery Dam when subjected to the shaking levels corresponding to the 10,000-year (equivalent to the Maximum Credible Earthquake (MCE). "Firm-ground" peak horizontal accelerations applicable for a return period of 10,000-years were estimated by combining all available data on PGA as a function of the annual probability of exceedance. Based on the available data, the PGA that corresponds to a return period of 10,000-years is established as approximately equal to 0.8g. The NBCC PGA values for the more frequent (475-year and 2,475-year) earthquake events are considered to be consistent with that for the much lower probability MCE event.

1.2.1 Ground Motions and Foundation Factors for Spillway

The ground motions provided in Table 1 are representative of a firm-ground site; that is, a site with very dense soil or soft rock in the upper 30 m of the soil profile.

Since 2006, the BC Building Code (BCBC) has adopted the use of foundation factors that are dependent on local site soil conditions, shaking level, and site period. The effects of local site conditions are characterized based on the average strength properties of the soil/rock in the upper 30 m, and six difference site classes varying from Site Class A to F have been identified. For a given site class, the effects of shaking level and period are incorporated via the short-period and long-period foundation factors Fa and Fv defined in Tables 4.1.8.4B and 4.1.8.4C of the BCBC, respectively.

Based on the results of the investigation, the average standard penetration resistance, N60, in the upper 30 m of soil column is in excess of 50 blows per 300 mm at the site. Therefore the site is considered to be Site Class C and the corresponding site-specific short period and long-period foundation factors, Fa and Fv,, are 1.0.

The subsurface conditions are considered to have a very low potential for liquefaction for both design seismic events (1 in 475 year and 1 in 2,475 year return periods).

2.0 GEOTECHNICAL ASSESSMENT

2.1 General

Based on the results of the recent geotechnical investigation, the site of the proposed labyrinth weir and box culvert or bridge spanning the auxiliary spillway is underlain by compact sand and gravel soils to depths ranging from 1.4 m to 2.6 m below ground surface. Compact sand deposits, with minor amounts of silt, underlie the coarser granular soils and extend to depths of about 3.3 m to 4.9 m at individual testholes, which in turn are underlain by soft to stiff silty clay, with varying proportions of sand. A dense to very dense sand material, with varying amounts of silt and gravel, was encountered underling the fine-grained deposits within BH15-01 and BH15-02 at depths of 7.0 m and 7.2 m, respectively.

Very dense glacial till-like soils were encountered underlying these deposits within BH15-01 and BH15-02, with both boreholes terminated within these glacial deposits at depths of 17.4 m and 12.8 m, respectively. The silty clay layer within BH15-03 was underlain by an approximate 0.3 m thick compact silty sand layer at a depth of 5.3 m. Weathered conglomerate bedrock was encountered within BH15-03 at a depth of about 5.6 m and was underlain by fresh conglomerate at 6.1 m depth that extended to the borehole termination depth of roughly 8.8 m.

Groundwater was encountered at depths of 3.6 m and 4.1 m below ground surface within BH15-01 and BH15-02, respectively.

2.2 Foundation Design Recommendations

Based on existing design information, it is understood that the proposed labyrinth weir and box culvert will have a top of slab elevation of 69.1 m. The thicknesses of the footings or slab were not known at the time of preparation of this technical memorandum. The existing ground surface elevation at the location of the labyrinth weir and box culvert/bridge ranges from approximately El. +74 m to El. +75 m elevation.

Since the approximate depth from existing ground surface to the top of slab elevation ranges from about 5 m to 6 m across the site, it is anticipated that sand, with varying amounts of gravel and silt, and/or soft, silty clay will be encountered at and extend up to 1.5 m below the anticipated elevation of the underside of the footings and slab of the labyrinth weir.

Similar subsurface conditions are anticipated at the underside of at least a portion of the box culvert structure. However, conglomerate bedrock will likely be encountered close to the transition zone of the culvert structure and the channel and may underlie portions of the box culvert/bridge structure at or close to foundation grade. The extent of conglomerate at the site is not known since it was only encountered within the footprint of the weir and culvert at borehole BH15-03, at an approximate elevation of El. +68.2 m. At test-pit location TP15-04 located within the channel, inferred bedrock was encountered at an approximate elevation of El. +69.7 m.

The soft fine-grained soils are compressible and, as such, are not a suitable subgrade layer. Similarly, the sand material encountered at the proposed foundation and slab elevation of the weir within BH15-01 is saturated, with variable silt content, and is expected to be highly susceptible to disturbance and difficult to prepare suitably.

Till-like soils were encountered underling the sand and clayey silt at an approximate elevation of El. +67.7 m, within borehole BH15-01, and approximately El. +67.6 m, within BH15-02. Given the limited depth to till-like soils from the proposed top of slab elevation, we recommend and have assumed that the perimeter footings of the labyrinth weir and culvert or bridge will be founded on till-like soils and/or conglomerate bedrock, with a minimum embedment depth of 0.3 m.

For the structural slab located within the weir and culvert, we have assumed that this will be founded on well compacted structural fill that has been placed on top of the prepared till-like subgrade and/or bedrock subgrade to the underside of the slab.

The very dense, till like soils and the fresh conglomerate encountered are considered suitable for support of the proposed structure. The recommended bearing resistance of the intact sedimentary bedrock exceeds that of the till-like soil. However, for design purposes, we recommend that a single bearing capacity is adopted for the labyrinth weir and box culvert structures.

The recommended allowable bearing resistance under static loading for the spillway structure and the recommended friction coefficients for the interface contact between the structural slab and the foundation soils are provided in Table 2, below.

Table 2: Recommended Foundation Design Parameters for Footings

Parameter	Value
Allowable bearing pressure (Factor of Safety = 3)	617 kPa
Ultimate Limit State (ULS) Factored Bearing Resistance – Resistance factor Φ = 0.5 (Canadian Foundation Engineering Manual 2006)	925 kPa
Base Friction Coefficient (tan δ) – For concrete poured over crushed gravel base	0.55
Base Friction Coefficient (tan δ) – For concrete poured over non-plastic silt or stiff clay/silty base	0.35
Base Friction Coefficient (tan δ) – For concrete poured over sedimentary bedrock base	0.70

The modulus of subgrade reaction of the subgrade material may be used to estimate its elastic deformation characteristics. It is important to note, however, that the modulus of subgrade reaction is not fundamental soil property. In addition to the deformation characteristics of the subgrade, it is dependent on the geometry and stiffness of the structural member in contact with the subgrade material. We therefore recommend the following relationship be used in the determination of the modulus of subgrade reaction for structural analysis of a slab.

$$k = \sqrt[3]{\frac{E_s}{E_c}} \frac{E_s}{(1 - \nu_s{}^2)h}$$

Where,

k = Modulus of subgrade reaction (kPa/m);

E_s = Young's modulus of soil subgrade (kPa);

E_c = Young's modulus of structural element slab (kPa);

ν_s = Poisson's ratio of soil subgrade, and

h = thickness of slab (m).

The following range of soil parameters are recommended for substitution in the above equation:

E_s = 15,000 to 20,000 kPa, and

ν_s = 0.3 to 0.35.

2.3 Post – Construction Settlement

The undisturbed very dense till-like soils and conglomerate bedrock, expected to be encountered at foundation level of the labyrinth weir and box culvert structure, are not considered likely to compress significantly under the foundation loads imposed by these structures, provided subgrade preparation is carried out as recommended in Section 4.1. Consequently, significant long-term post construction settlements are not expected. Nominal construction total and differential settlement, less than 25 mm, is anticipated for foundations supported on intact, undisturbed till-like material and weathered rock.

3.0 LATERAL EARTH PRESSURE

The recommended geotechnical engineering parameters for the design of the proposed auxiliary spillway walls are presented in Table 3 and 4, below.

The parameters tabulated below are based on the following assumptions:

- The perimeter footings are founded on very dense till-like soils or sedimentary bedrock;
- Suitable subgrade preparation is carried out;

- The backfill around the spillway consists of free-draining structural fill having a fines content of less than 5 percent;
- The slope of the backfill surface around all spillway walls is horizontal;
- The back face of the wall is vertical; and
- No surcharge loads are applied on the backfill adjacent to the spillway that would induce lateral stress on the walls.

3.1 Static Loading Conditions

For rigid walls restrained from lateral movement (non-yielding), the static earth pressure forces acting on the wall may be calculated using the formulation given on Figure 1 and the parameters in Table 3 and 4.

Retaining wall structures which are free to rotate about their base enough to permit displacements at the top of the wall of at least 0.1 percent of the total height of the wall (stiff walls) may be designed using 75 percent of the rigid wall value.

For walls that are flexible and free to rotate sufficiently to develop active earth pressure conditions (at least 0.5 percent), the lateral earth pressure will correspond to Ka under static conditions and Kae under seismic conditions.

Table 3: Recommended Geotechnical Parameters for Design of Spillway - Static Condition

Parameter	Value
Unit weight of backfill, γ_f (kN/m^3)	20
Buoyant unit weight of backfill, γ_{fb} (kN/m^3)	10.2
Friction angle of backfill, Φ' (degrees)	34°
Normal Operating Water Level Elevation	+71.6 m
Coefficient of earth pressure at rest (K_0)	0.44
Coefficient of active earth pressure (K_a) – Coulomb theory	0.25
Coefficient of passive earth pressure (K_p) (Factor of Safety = 2 on peak) – Coulomb theory	4.3
Friction angle between wall and backfill – Coulomb theory (degrees)	22°

Retaining walls supporting surcharges, such as vehicle loads, building appurtenances, and/or sloping backfill should be designed to resist the additional lateral loads imposed by these surcharges.

It is recommended that all below grade walls have full effective drainage. The backfill material should have direct hydraulic connection to a perimeter tile drainage system at the base of the walls. The drain should consist of a perforated pipe surrounded by a suitable geotextile. If adequate drainage is not provided, the walls should be designed to withstand full hydrostatic pressures in addition to the lateral earth pressures. Refer to the attached figures for details of calculating the various loads on the below-grade walls.

3.2 Seismic Loading Conditions

For seismic conditions, the dynamic pressure under earthquake loading must be accounted for. If the walls of the spillway are rigid and non-yielding, it is recommended that the lateral earth pressure coefficient under seismic loading conditions be calculated using the procedure indicated on Figure 1 and a peak horizontal ground surface acceleration, A, of 0.268g for SLS design, and 0.499g for ULS design, as outlined in Table 1 and Table 4. The total lateral earth pressure under seismic conditions is computed by adding the dynamic component to the static earth pressure as indicated in the figure.

For deformable walls, where the wall is free to rotate between 0.1 to 0.2 percent of the height of the wall, H, the maximum seismic pressure may be calculated as 75 percent of the rigid wall value. The pressure should be redistributed in equivalent rectangular form over the embedded height of the wall.

For a sufficiently flexible wall, where movement at the top of the wall of at least 0.5 percent of H can be tolerated, the lateral earth pressure under seismic loading conditions can be determined using the Mononobe-Okabe method. For this scenario, it is recommended that the lateral earth pressure under seismic loading condition be calculated using the procedure indicated on Figure 2 and a dynamic earth pressure coefficient Kae of 0.34 for SLS design, or 0.45 for ULS design. The total lateral earth pressure under seismic loading conditions is computed by adding the dynamic component to the static earth pressure as indicated on Figure 2.

Table 4 below presents the lateral earth pressure coefficients for both static and seismic conditions for the different wall types outlined above.

Table 4: Lateral Earth Pressure Coefficients

Type of Wall	Tolerated Movement at Top of Wall	Static Conditions		Seismic Earth Pressure
		K_0	K_a	
Rigid Wall – Non Yielding	0% of H	0.44	N/A	Refer to Figure 1. A = 0.268 g (for SLS Design) A = 0.499 g (for ULS Design)
Stiff Wall	0.1% to 0.2 % of H	0.44	N/A	0.75 times non-yielding value. Redistribute as rectangular load.
Flexible Wall	>0.5% of H	N/A	0.25	Use Mononobe-Okabe method. K_{ae} = 0.34 (for SLS Design) K_{ae} = 0.45 (for ULS Design)

4.0 CONSTRUCTION CONSIDERATIONS

4.1 Subgrade Preparation

Within the footprint of the proposed labyrinth weir and box culvert, it is anticipated that saturated or wet sand with varying amounts of gravel and silt, and/or soft, silty clay will be encountered at the anticipated elevation of the underside of the structural slab. As discussed in Section 2.0 above, we recommend that these sand and clayey deposits are overexcavated and that the till-like material and/or conglomerate bedrock is exposed across the footprint of the structures. We recommend that the perimeter footings of the labyrinth weir and culvert will be founded on till-like soils or conglomerate bedrock, with a minimum embedment depth of 0.3 m. For the structural slab located within the perimeter footings, we recommend that this be founded on structural fill that has been placed on top of the prepared till-like subgrade or bedrock subgrade to the underside of the slab.

The exposed till-like subgrade should be cleaned and subexcavated, as required, to remove all loosened, saturated or otherwise unsuitable material and inspected by an experienced geotechnical engineer, prior to placement compacted Structural Fill, described below. Exposed, protruding cobbles or boulders encountered in the subgrade may require removal as they could result in locally hard support conditions for footings. Alternatively, structural design of the footings should be adjusted to accommodate the differential support conditions.

Although strong in their unweathered conditions, till-like soils are susceptible to loss of strength and erosion when exposed to weathering or seepage, particularly at localized granular and water-bearing zones. Care and attention should be exercised in not allowing the subgrade to be exposed to sustained wet weather or heavy traffic. Water should not be allowed to pond on the prepared subgrade surface. The approved subgrade should be covered with crushed gravel base course material, as described below, to avoid disturbance. Alternatively, it is recommended that consideration be given to initial placement of a minimum 50 mm thickness of lean concrete immediately following completion of subgrade preparation to minimize potential disturbance or softening prior to or during placement of the Structural fill or pouring of foundations.

The conglomerate, although very dense and strong in place, is also moderately to highly susceptible to softening and disturbance when exposed following excavation, in particular in the presence of seepage or ponding of surface runoff. It is recommended that a 50 mm working mat of lean mix concrete should be placed over the entire footing and slab excavation area immediately after cleaning and inspection.

4.2 Backfilling and Compaction Requirements

The prepared subgrade for the slabs of the labyrinth and box culvert should be brought up to underside of the slabs using clean 19 mm crushed gravel as a suitable base course layer. Structural fill material should be in conformance with the latest Master Municipal Construction Documents (MMCD).

Backfill around the outside of the labyrinth and culvert structure should consist of Structural Fill, defined as well-graded, free-draining sand, or sand and gravel, containing less than 5 percent material passing the USS No. 200 sieve size.

Structural fill and backfill should be placed in lifts not exceeding 300 mm loose thickness and compacted to 95 percent of the modified Proctor maximum dry density (MPMDD) for the material.

To avoid overstressing and damage to walls, heavy compaction equipment should be avoided adjacent to below grade walls. Only light hand operated compaction equipment should be utilized in these areas.

Clear crushed gravels are not recommended for use as structural fill or backfill due to the potential for infiltration of fines from surrounding soils into these materials, thereby resulting in loss of ground and support.

5.0 CLOSURE

We trust that this is sufficient for your immediate requirements. Should you have any queries or comments, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

Thomas Madden

Thomas Madden, E.I.T.
Geotechnical Engineer

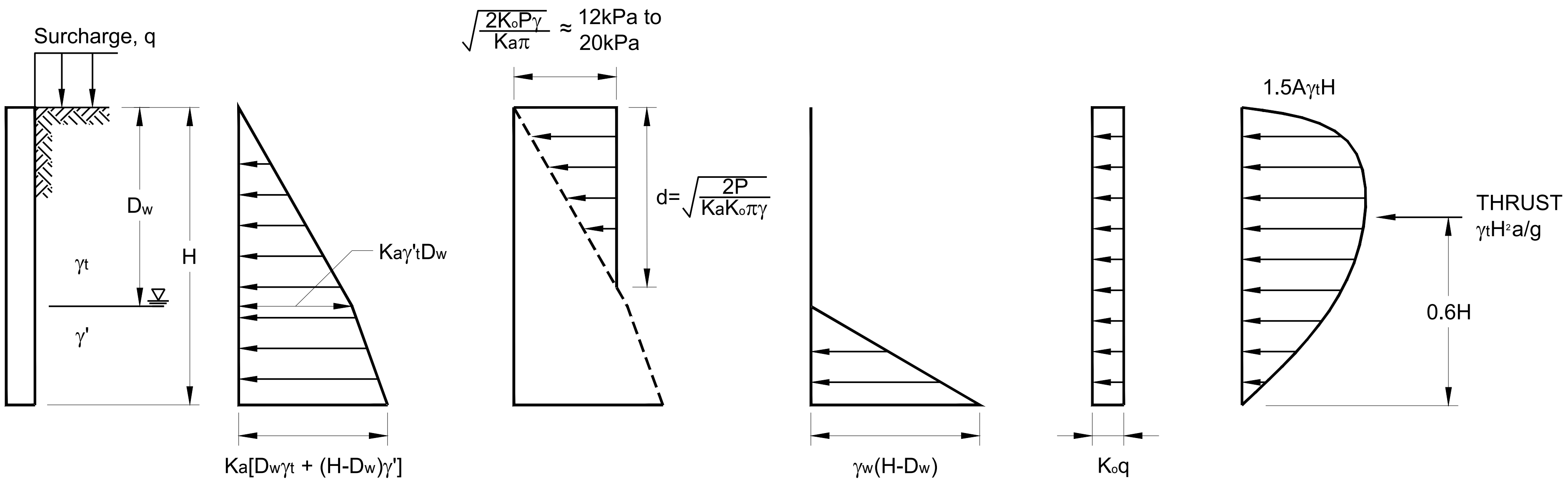
Richard C. Butler, P. Eng., FEC
Principal

TBM/RCB/nnv

Attachments: Figure 1: Lateral Earth Pressure Diagram for Rigid Wall (Non-Yielding)
Figure 2: Lateral Earth Pressure Diagram for Flexible Wall (Yielding)
Attachment 1: 2010 National Building Code Seismic Hazard Calculation

o:\final\2013\1447\13-1447-0516\1314470516-031-tm-rev0\1314470516-031-tm-rev0 geotech design 04sep_15.docx

Restrained Wall (Non-Yielding) - Level Ground Surface



(i) STATIC

(ii) COMPACTION STRESSES
(pressure distribution approximate)

(iii) HYDROSTATIC

(iv) SURCHARGE

(v) SEISMIC
(parabolic pressure distribution - shown as approximate)

γ_w = Water Unit Weight
γ_t = Total Unit Weight
γ' = Buoyant Unit Weight
K_o = At-rest Coefficient of Lateral Earth Pressure
K_a = Active Co-efficient of Lateral Earth Pressure

q = Surcharge
D_w = Depth to Water Table
H = Height of Wall
d = Depth Over Which Compaction Stresses are Applicable
a = Peak Horizontal Acceleration

$$P \text{ (Roller Load)} = \frac{\text{Dead Weight of Roller + Centrifugal Force}}{\text{Width of Roller}}$$

NOTES

1. SEE TECHNICAL MEMORANDUM 13-1447-0516, DATED SEPTEMBER 4, 2015 FOR DESIGN PARAMETERS.
2. FOR STATIC CONDITIONS: CONSIDER THE COMBINED ACTION OF (i)+(iii)+(iv) FOR OVERTURNING, SLIDING AND BEARING, AND CONSIDER THE COMBINED ACTION OF (i)+(ii)+(iii)+(iv) FOR STRUCTURAL DESIGN.
3. FOR SEISMIC CONDITIONS: CONSIDER THE COMBINED ACTION OF (i) + (iii) + (iv) + (v). CONSIDER (iv) FOR DEAD LOADS ONLY.

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

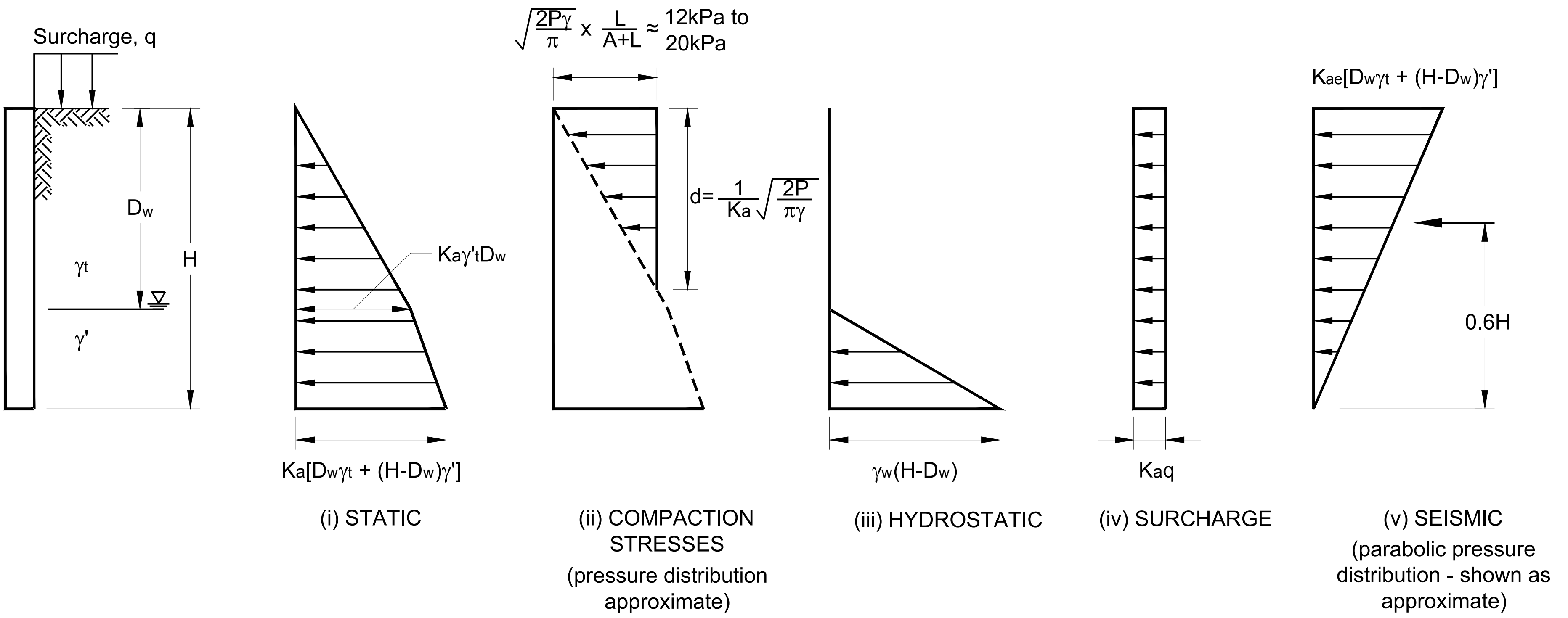
YYYY-MM-DD	2015-08-31
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
LATERAL EARTH PRESSURE DIAGRAM FOR RESTRAINED WALL (NON-YIELDING)

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	1

Flexible Wall (Yielding) - Level Ground Surface



γ_w = Water Unit Weight
γ_t = Total Unit Weight
γ' = Buoyant Unit Weight
K_a = Active Co-efficient of Lateral Earth Pressure
q = Surcharge

D_w = Depth to Water Table
H = Height of Wall
d = Depth Over Which Compaction Stresses are Applicable
K_{ae} = Dynamic Active Co-efficient of Lateral Earth Pressure

P (Roller Load) = $\frac{\text{Dead Weight of Roller + Centrifugal Force}}{\text{Width of Roller}}$

NOTES

1. SEE TECHNICAL MEMORANDUM 13-1447-0516, DATED SEPTEMBER 4, 2015 FOR DESIGN PARAMETERS.
2. FOR STATIC CONDITIONS: CONSIDER THE COMBINED ACTION OF (i)+(iii)+(iv) FOR OVERTURNING, SLIDING AND BEARING, AND CONSIDER THE COMBINED ACTION OF (i)+(ii)+(iii)+(iv) FOR STRUCTURAL DESIGN.
3. FOR SEISMIC CONDITIONS: CONSIDER THE COMBINED ACTION OF (i) + (iii) + (iv) + (v). CONSIDER (iv) FOR DEAD LOADS ONLY.

CLIENT
CITY OF NANAIMO

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-08-31
PREPARED	RP
DESIGN	JG
REVIEW	-
APPROVED	-

PROJECT
COLLIERY DAMS
NANAIMO, BC

TITLE
LATERAL EARTH PRESSURE DIAGRAM FOR FLEXIBLE WALL (YIELDING)

PROJECT No.	PHASE	Rev.	FIGURE
13-1447-0516	4000	A	2

ATTACHMENT 1 -
2010 National Building Code Seismic Hazard Calculation

2010 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Requested by: , Golder Associates Ltd. August 24, 2015

Site Coordinates: 49.1492 North 123.9616 West

User File Reference: Colliery Dam

National Building Code ground motions:
2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA (g)
1.013	**0.692**	**0.351**	**0.178**	**0.499**

Notes. Spectral and peak hazard values are determined for firm ground (NBCC 2010 soil class C - average shear wave velocity 360-750 m/s). Median (50th percentile) values are given in units of g. 5% damped spectral acceleration (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are tabulated. Only 2 significant figures are to be used. ***These values have been interpolated from a 10 km spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the calculated values.*** Warning: You are in a region which considers the hazard from a deterministic Cascadia subduction event for the National Building Code. Values determined for high probabilities (0.01 per annum) in this region do not consider the hazard from this type of earthquake.

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.2)	0.245	0.532	0.726
Sa(0.5)	0.163	0.357	0.489
Sa(1.0)	0.082	0.181	0.248
Sa(2.0)	0.040	0.089	0.123
PGA	0.125	0.268	0.360

References

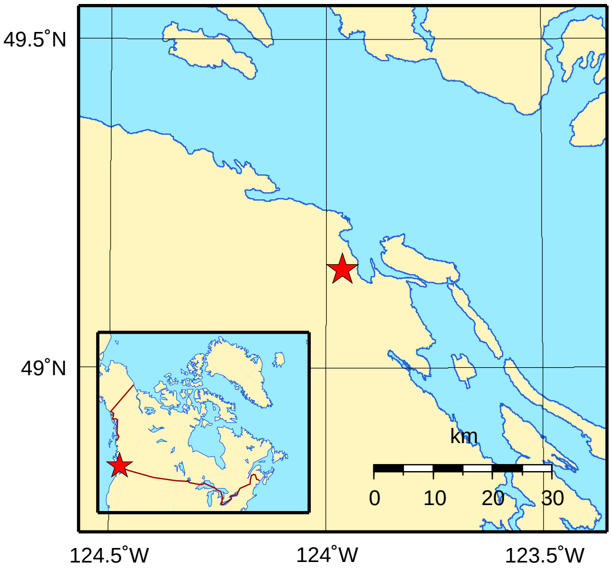
National Building Code of Canada 2010 NRCC no. 53301; sections 4.1.8, 9.20.1.2, 9.23.10.2, 9.31.6.2, and 6.2.1.3
Appendix C: Climatic Information for Building Design in Canada - table in Appendix C starting on page C-11 of Division B, volume 2

User's Guide - NBC 2010, Structural Commentaries NRCC no. 53543 (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File xxxx
Fourth generation seismic hazard maps of Canada: Maps and grid values to be used with the 2010 National Building Code of Canada (in preparation)

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



APPENDIX C

Structural Design Development Report

City of Nanaimo – Lower Colliery Dam Remediation
Structural Design Development
September 4, 2015

Table of Contents

Page

STRUCTURAL DESIGN DEVELOPMENT

1 SUMMARY

The lower colliery dam has been reviewed with respect to several remediation alternatives as per the June 30, 2015 Structural Design Development Report. It is understood that of the two options proposed, the design of the auxiliary spillway has been selected.

This Design Development Report is to be considered preliminary for the purpose of conceptual design. The final size and location of footings, walls and slabs are subject to change depending on final layout and further structural analysis completed.

2 STRUCTURAL COMMENTARY

2.1 Proposed Construction for the Auxiliary Spillway

The proposed auxiliary spillway structure at the Nanaimo Colliery Lower Dam site is progressing through conceptual design. The auxiliary spillway structure is proposed to be located to the south of the existing lower dam. While the design concept may be modified due to site constraints as well as user group input, the proposed design rationale is as described below.

The spillway is proposed to consist of:

- Reinforced concrete apron slab and wing walls to train the water into the spillway
- Reinforced concrete labyrinth weir with two sluice gate valves for seasonal reservoir water level adjustment and/or to adjust water flow levels downstream.
- 5-8m wide Precast/Pre-stressed concrete box girder bridge structure that will either clear span over the spillway opening or be supported by a center pier. The purpose of the bridge structure will be for pedestrian access across this structure and maintain a similar trail alignment.
  - It has been proposed that the bridge be supplied with an earthen topping to keep the natural appearance of the park and as such will be accounted for in the bridge loading criteria.
- Reinforced concrete walls/bridge abutment and spillway slab extending from the front of the labyrinth weir to the approximate extents of the downstream edge of the bridge structure.

2.2 Proposed Design Progression - Structural Engineering:

The structural engineering design progression is anticipated to be as follows:

- Complete preliminary foundation design for the spillway/bridge structure.
  - Elevations and final design of foundations will be subject to geotechnical reports / site excavation findings.

- Progress with weir labyrinth design.
    - Labyrinth design is subject to foundation design but can progress based on preliminary geotechnical data.
- Progress with bridge design.
    - Bridge loading design must be completed for foundation design, final design drawings and detailing for the bridge.

2.3 Structural Design Considerations:

Based on the geotechnical and hydro-technical data produced in draft level reports from Golder Associates there are no significant geological or environmental risks foreseen that would prevent the completion of the proposed design.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
Suite 200 - 2920 Virtual Way
Vancouver, BC, V5M 0C4
Canada
T: +1 (604) 296 4200