Appendix H

Proposed South Gate KNP, BC - Geotechnical Assessment – August 2016

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MEMORANDUM	Proposed South Gate Kootenay National Park, British Columbia Geotechnical Assessment
Report Date:	August 17, 2016
McElhanney No.	2511-00668-00

To: **Darren McNamara P.Eng**
Lake Louise, Yoho & Kootenay Field Unit
Parks Canada

P.O Box 214 Lake Louise, AB T0L 1E0

CC: **Simon Armstrong-Bayliss, EIT**
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1.0 Introduction

This memorandum presents a summary of the subsurface conditions observed during the field excavation program and geotechnical recommendations for the Kootenay National Park South Gate Relocation project. McElhanney has prepared this geotechnical assessment in accordance with our proposal, dated April 8, 2016.

McElhanney Consulting Services Ltd. (MCSL) understand that the Kootenay National Park (KNP) South Gate is to be upgraded and relocated from the existing location to the Red Rock Wall parking lot location, located approximately 2km east of the existing gate. This is anticipated to include the construction of two east bound lanes either side of a gate house building, to be located within the existing parking lot area. The parking lot currently is asphalt surfaced that is thought to be approximately 20 years old. The existing adjacent Highway 93S to the north is a secondary highway which functions as the main access to the park, as well as an arterial connector between the East Kootenay and Banff National Park, as well as Highway #1 and Alberta. The highway and park are open to traffic year round.

This memorandum describes the geotechnical assessment completed for the project, and describes the recommended geotechnical design parameters to support the geometric design of the South Gate upgrade.

2.0 Scope of Work

The scope of work for the geotechnical assessment included:

- Preparation of a geotechnical assessment plan;
- Completion of a BC One Call, prior to commencement of the subsurface testing;
- Commissioning and completion of Utility Locates onsite to ensure test hole clearance;
- Completion of a geotechnical excavation program which consisted of a total of four (4) testholes within and around the existing parking lot area and nearby highway;

- Completion limited geotechnical laboratory testing on representative samples;
- Prepared this memorandum providing a summary of the subsurface conditions encountered and geotechnical recommendations for roadway and small building design.

The purpose of the geotechnical assessment was to evaluate the existing road and sub-surface ground conditions, and in conjunction with McElhanney's civil design services provide preliminary and final geometric design and paving gradation and material thickness for access roads, and recommendations for building construction, prior to putting the project to Tender.

3.0 Field Assessment and Laboratory Testing

McElhanney completed a geotechnical excavation assessment within and adjacent the parking lot and highway. The intent of the field program was to characterize the existing subsurface conditions. The assessment was carried out May 19th, 2016 and consisted of four testpits (TH16-01 through TH16-04) at locations shown on the appended Testhole Plan (Drawing 00668-G01). Two testholes (TH16-01 and TH16-04) were excavated adjacent the existing highway nearby proposed highway entrance and exit locations, and two testholes (TH16-02 and TH16-03) were excavated in the parking lot nearby future proposed location of the gate house and gate lanes. The testholes were excavated using a Komatsu PC200 excavator, and ranged in depth from 1.7 to 3.2 meters below ground surface (mbgs).

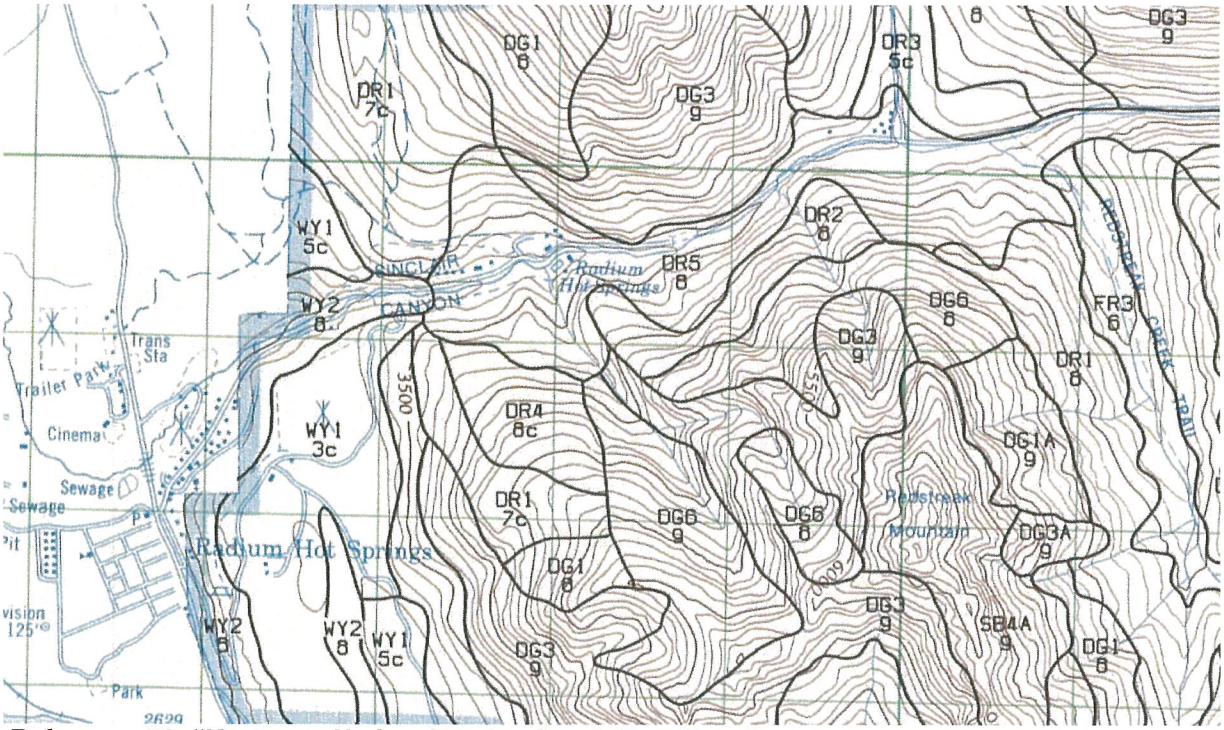
McElhanney supervised the excavation, logged and sampled the testholes. The subsurface soils were sampled primarily from in situ. Dynamic Cone Penetrometer testing was also performed by MCSL as each test hole advanced. The results of each of those tests are appended to this report. A summary of the subsurface conditions encountered are provided on the testhole summary logs included in Appendix A. Following completion of the testholes, the holes were backfilled and compacted, and the top of the parking lot testholes capped with crushed gravel and asphalt.

Soil samples were transported to Artech's laboratory in Cranbrook, BC where selected samples were submitted for index testing including moisture content, gradation sieve analysis and Atterberg Limits. The laboratory results are included on the borehole logs and detailed results are included in Appendix B. The soils encountered were classified in accordance with the Modified Unified Classification System for soils included in Appendix A.

4.0 Subsurface Conditions

4.1 Background Geology

Figure 4-1 Site Location with Soil Mapping Information:



Reference #1: "Kootenay National Park – South Map Sheet"

The site is positioned within the Sinclair Creek canyon, with steep mountainous sidesloped valley and exposed rock above. The valley bottom itself typically comprised of ice contact stratified drift materials overlying bedrock at depth. These glacial deposits are typically comprised of "a random mixture of morainal, glaciofluvial, and, less frequently, glaciolacustrine sediments". This brief description was obtained from Reference #1: *PL Achuff, WD Holland, GM Coen, K Van Tighem (1984). Report No.60 and Mapping of the British Columbia Soil Survey, Ecological (Biophysical) Land Classification of Kootenay National Park. Edmonton, AB: Environment Canada, Agriculture Canada, Alberta Institute of Pedology.* The following is a section of that report which directly describes the soil region DR5 as obtained from the mapping (as shown below):

> DR5 has steep (45-70%), short, straight slopes produced by the action of present or historical streams on glacial deposits of valley benchlands and walls. DR5 is mapped as two opposing erosional scarps separated by a narrow fluvial plain or as a single erosional scarp bounded upslope by glacial landforms, below by broad glaciofluvial terraces or fluvial floodplains on the valley bottomland. The erosional slopes are inclined and the fluvial deposits may be deep or shallow over bedrock. Occasionally, appreciable amounts of bedrock have been exposed by erosion (*e.g.* DR5 + R tract along Whitetail Creek). Gullies oriented perpendicular to the contour dissect the steep DR5 slopes. Gullied land may also occur in DR1, DR2, DR3, and DR4.

Observations are consistent with this description. We anticipate that, based on the location of the site at the valley bottom and its nearby location to the creek, that a mixture of glaciofluvial and morainal materials are likely present at depth on the site. Colluvial soils may also be present near the surface given the steep side slopes of the canyon/valley. The native soils

observed are consistent with typical morainal materials of the area (unsorted granular soils with some fines).

4.2 Subsurface Observations

In general, the soils encountered during field excavation program consisted of sand and gravels, and sandy gravels with variable silt content, however; till or till like material at depth were also observed in two of the four locations. Test holes within the parking area contained asphalt at the surface, and the test holes adjacent the highway in the boulevard contained surficial layer of deleterious fills, debris and topsoil. A summary of subsurface soils are provided in Table 4-1 and detailed below.

Table 4-1: Testhole Summary

Testhole	Depth of Hole (m)	Asphalt Surface (mm)	Topsoil / Deleterious Fill (m)	Sand and Gravel Fill (m)	Silty Sandy Gravel Fill (m)	Till (m)	Ground water
TH16-01	2.6	-	0-0.10	0.1-0.8	0.8-2.4	2.4-2.8+	NE
TH16-02	3.0	100-145	-	0.15-0.8	0.8-1.9	1.9-3.0+	NE
TH16-03	3.2	50-180*	-	0.18-3.2+	-	-	NE
TH16-04	1.7	-	0-0.15	0.15-1.7+	-	-	NE

Notes: * indicates asphalt and combined oiled gravel layers are 0.18m thick; but top asphalt layer is 50mm thick
NE = Not encountered

- **Asphalt Surface Treatment:** A layer of an asphaltic surface was encountered in both testholes within the parking lot up to a maximum thickness of 100mm in TH16-02. In TH16-03, we witnessed that 50mm of asphalt is underlain in one location by a thin layer of crushed gravel product treated with oil, and another layer of asphalt extending to a total depth of 200mm. This likely occurs in other locations in the parking lot area to various depths and degrees from previous surfacing treatments and grading.

- **Surficial Topsoil/Deleterious Fill:** Organic silt with gravel, debris, and wood waste was observed in TH16-01 and TH16-04 in the boulevard area adjacent to the highway (north) and parking lot (south). This layer ranged in thickness from 100-150mm.

- **Sand and/or Gravel:** Deposits of sand and gravel fills and/or sandy gravels fills were encountered in all of the testholes to varying degrees, ranging from 0.65m to 3m thick. These units contained variable silt content (ranging from trace silt to silty) and were compact to dense, brown and generally damp-moist. The surfacing aggregate beneath the asphalt in the parking lot area is 0.12-0.25m in thickness and consists of a 75mm minus gravel and sand with some-trace fines. Generally the subgrade strength of the granular fill layers was very good, with a noticeable reduction in strength and an increase in moisture with depth in the silty sandy gravel fill layer encountered from 0.8-2.4m in TH16-01. A summary of the sieve analyses completed on representative samples is included in Table 4-2.

Table 4-2: Summary of Sieve Analyses – Sand and Gravel Fills

Borehole	Sample Depth (m)	Moisture Content (%)	Soil Classification	Gradation (%)		
				Gravel	Sand	Fines (Silt/Clay)
TH16-01	0.3	3.1	GW-GM	55	35	10
TH16-01	1.1	6.8	GM	53	24	23
TH16-02	0.15	2.8	SW-SM/GW-GM	45	48	7
TH16-02	0.55	4.3	GW-GM	58	31	11
TH16-02	1.2	5.9	GM	57	24	19
TH16-03	0.2	3.7	SW-SM/GW-GM	40	53	7
TH16-03	0.35	3.0	GW-GM	54	38	8
TH16-04	0.5	3.1	GW-GM	57	35	8
TH16-04	1.5	2.8	GM	54	31	15

- **Glacial Till:** A deposit of Sand Till was observed in two of the testholes (TH16-01 and TH16-02) beginning at 1.9-2.4 mbgs, and extending beyond the depth of each testhole. This layer is anticipated to be present at depth below TH16-03 and TH16-04, and is within the proposed area. The Till was predominately sand with some gravel, silt and clay, and was dense to very dense, light grey to light brown, and damp. This material was observed to have slight to low cohesion. A summary of the Atterberg Limits completed on representative samples is included in Table 4-3.

Table 4-3: Summary of Atterberg Limit Analyses – Silt Till

Testhole	Sample Depth (m)	Soil Classification	Moisture (%)		
			Sample Moisture	Plastic Limit	Liquid Limit
TH16-01	2.4	CL	13.8	17	26
TH16-02	3.0	CL	14.9	18	25

4.3 Groundwater Conditions

Groundwater was not encountered within the depths of termination (up to 3.2 mbgs) of the testholes at the time of the field assessment. It should be noted that the assessment was completed in the late spring during a relatively warm and dry season, which likely would provide for lower than normal groundwater levels. Groundwater levels will likely fluctuate due to seasonal variations, such as after periods of heavy rainfall or snow melt.

5.0 Discussion and Recommendations

The following sections provide geotechnical recommendations for support of geometric road design for the project, as well as the construction of the gate house building. The recommendations in this report should be read in conjunction, unless otherwise noted, with the most current BC Ministry of Transportation and Infrastructure Standard Specifications for Highway Construction, and with the final detailed geometric design drawings by McElhanney.

5.1 Subgrade Conditions

Based on the assessment the anticipated subgrade conditions for the road upgrade are expected to predominately granular soils (sand and gravel, gravelly sand and/or sandy gravel) with variable silt content. Areas of till (moraine) were encountered in two testholes at depth, and till soils may also be encountered in some areas during subgrade preparation. The compact to dense granular soils and till subgrade conditions are considered suitable for the proposed road and buildling upgrades.

5.2 Subgrade Preparation

Stripping of organic soils and sub-excavation of loose/soft subgrade soils will be required in the footprints of the proposed road construction. The following recommendations are provided:

1. To facilitate construction of the new road, sub-excavation into the existing ground a minimum of 150 mm will be required. In the footprint of the proposed roadways or new structures, any existing loose/soft, wet soils or fills at or immediately below subgrade elevations should be removed down to compact to dense subgrade conditions.

2. All stripped and/or sub excavated foundation subgrades should be reviewed in the field by a geotechnical engineer or their representative, to confirm that loose/soft, wet, weakened and organic soils and/or fills have been appropriately removed prior to pavement structure construction. Proof-rolling will be necessary.

3. Subject to field review at the time of construction, any completed sub-excavated areas should be backfilled with fill as approved by the geotechnical engineer. The fill material should be compacted to a minimum of 98% Standard Proctor Maximum Dry Density (SPMDD), unless identified differently in subsequent sections of this report.

4. The upper 300 mm beneath the pavement structure should be compacted to 100% SPMDD.

5. The finished subgrade should be crowned or sloped at a minimum 2% cross fall to promote drainage.

5.3 Pavement Structure

The gate vehicle lanes (road) are low volume roads with an annual estimated vehicle count of approximately 1,250 (2016) to 1,900 (2035) vehicles per direction per year. The road speed will be low to slow and stop at the gatehouse, and an anticipated average speed at 15 km/hour. The turning deccel/acceleration lanes to enter the gatehouse lanes will contain the same volume of traffic.

It is understood the pavement structure will be sub-excavated and the final pavement surface will be at or near flush with the adjacent ground elevation. Based on the testholes completed the subgrade soils appear to consist of predominately granular soils and/or till.

For the purposes of design the following is recommended:

1. Based on the anticipated low vehicle volumes and the loading of primarily light passenger vehicles only, the following pavement structure is recommended:

Table 5-1 Recommended Pavement Structure

Pavement Layer	Minimum Thickness	Geosynthetic Specification
Asphalt Concrete	75 mm	-
Granular Base Course	150 mm	-
Geosynthetic Reinforcement*	N/A	Geogrid Tensar TX 160 or approved equivalent.

** A geosynthetic reinforcement has been considered in place of additional granular structure that would be required to support the anticipated vehicle loading.*

2. Asphalt concrete mix and aggregate should meet MOTI specifications of a minimum Asphalt Class 1 Medium Mix quality.

3. Granular Base Course should meet MOTI specifications for Well Graded Base (WGB) as summarized in Table 5-2, or an approved equivalent.

Table 5-2 Specifications for Granular Base Course

Sieve Designation (mm)	Granular Base Course 25 mm Minus
25	100
19	80-100
9.5	50-85
4.75	35-70
2.36	25-50
1.18	15-35
0.300	5-20
0.075	0-5

5. Base course shall be placed not to exceed a compacted lift thickness of 150 mm and within 3% of the optimum moisture conditions as determined by the optimum moisture-soil density relationship (ASTM D698) and compacted to at a minimum 100% SPMDD.

6. Frequency and locations of testing shall be under the direction of the Engineer. All fill placement and compaction operations should be observed by the geotechnical engineer or their representative and conform to the MOTI Standard Specifications for Highway Construction.

7. A medium grade non-woven geotextile (Nilex 4551 or approved equivalent) should be installed if finer grained subgrade soils (silty sand and gravel, till) are encountered to provide separation from the granular base course.

The non-woven geotextile should meet the following specifications:

Grab Tensile Strength (N)[1]	>710
Mullen Burst Strength (kPa)[2]	>2100
Puncture Strength (N)[3]	>420
Equivalent Opening Size (µm)[4]	120<EOS<220

(1) ASTM D-4632*
(2) ASTM D-3786*
(3) ASTM D-4833*
(4) ASTM D-4751
* Based on Minimum Average Roll Values (ASTM C-4759)

5.4 Future Road Maintenance

It should be noted that pavement surfaces will deteriorate and exhibit cracking overtime and routine maintenance (ie. crack sealing) will assist in maximizing the life expectancy of the pavement structure. To improve the pavement life expectancy it is recommended that regular maintenance including filling and sealing of cracks before wetter seasons be considered to reduce the potential of increased pavement damage occurring from surface water infiltration into cracks and subgrade soils.

5.5 Building Recommendations

MCSL understands that the proposed gate house structure will consist of a 1 storey conventionally constructed building, with slab-on-grade and no basement. The following recommendations are provided for

5.5.1 Building Siting and Site Preparation

1. All deleterious fill and any organics/topsoil, as well as any silty, soft or unsuitable material shall be removed from the building site down to compact to dense sand and gravel or glacial till. This layer shall be compacted to minimum 99% Standard Proctor Density and verified by a qualified geotechnical engineer.

5.5.2 Foundations

Shallow foundations (i.e. strip and/or spread footings) are considered suitable at the site. The recommendations for shallow foundations are provided below:

1. A factored Ultimate Limit State (ULS) soil bearing resistance of 120 kPa is recommended for shallow footings, when placed at a depth of 2m or less below the surface.

2. A maximum Serviceability Limit State (SLS) soil bearing resistance of 95 kPa for strip and spread footings on approved bearing subgrade of dense sand and gravel or glacial till. The recommended soil bearing resistances are expected to have settlements of less than the maximum of 25 mm for strip and spread footings constructed with a minimum width of 0.6m (24") and maximum width of 1.2m, provided the soil bearing in accordance with the above noted recommendations.

3. ULS and SLS bearing resistance values calculated in accordance with the Canadian Foundation Engineering Manual (Canadian Geotechnical Society, 2006).

4. We recommend that footings for permenantly heated structures have a minimum of 1.35m of cover below finished grade for frost protection. Isolated and/or unheated footings shall extend to 1.8m below

5. Footings for the proposed buildings must be founded on approved, undisturbed, unfrozen, inorganic, native soil.

6. We recommend that additional reinforcing steel be placed in the strip footing at the crossing location of any planned utility (water/sewer) service trench. We recommend that 5-15M reinforcing bars extending 1m beyond the edge of trench each way be placed at such locations.

7. We recommend the excavation and building siting be confirmed by a qualified geotechnical engineer prior to foundation placement.

8. Seepage or surface water runoff must not be allowed to enter foundation excavations. Any water or snow that collects in the footing excavation must be removed and subgrade soils be allowed to dry prior to construction of the footings.

9. Concrete footings must not be placed on frozen soils, nor should soils beneath the footing be allowed to freeze during or after construction; therefore, the footing subgrade must be protected from freezing during and after construction.

10. Concrete footings should be protected from freezing and proper curing conditions should be provided as per Canadian Standard Association (CSA) concrete specifications.

11. We understand that the building will not contain a basement or crawlspace. If this changes and a portion of the structure will be set below grade, then we recommend a draintile and drainrock (groundwater collection) system be installed along the base of the footings outside the building footprint, and discharge down below the building. The system should, at a minimum meet the BC Building Code Section 9.14.3 requirements. We further recommend that:
    - The pipe is placed approx. 0-100mm below footing grade, and preferably directly on top of geotextile fabric;
    - Draintile pipe be placed along the perimeter and connect to a header pipe along the edge;
    - Pipe is min. 100mm dia. perforated, with perforations at 4 and 8 o'clock;
    - Pipe should slope at minimum 1% and drain to a solid collector pipe and discharge to a frost-free outfall downslope of the structure;
    - Extend drainrock a min. 300mm over the pipe, and ensure geotextile is wrapped over the drainrock on the exterior of the foundation back to the wall before backfill;

- We recommend that PVC SDR 28 or 35 pipe be used.

5.5.3Foundation Wall Backfill and Waterproofing

For foundation walls the following recommendations are provided:

1. Foundation wall backfill should be sufficiently compacted such that future settlement is mitigated.

2. In order to reduce the potential for unbalanced lateral pressures on the foundation walls the placement and compaction of wall backfill should be carried simultaneously in the inside and outside of the walls. For foundation wall backfill above slab-on-grade we recommend that the main floor system be installed prior to exterior backfill.

3. Final grades along the external foundation wall should be designed with a gradient of at least 5% over a distance of 1.5m to direct water away from the building. *Surface water,* including build-up of snow and ice, cannot be allowed to be present up against or within 1m of the foundation walls above slab.

4. For any foundation walls above slab elevation of which are backfilled with the native soils, we recommend that two layers of emulsified asphalt waterproofing product be applied with a drainboard (Delta MS or approved equivalent) as a minimum.

5. Backfill around foundation walls shall be free-draining compacted granular material.

5.5.4Grade Supported Floor Slabs

The following recommendations are provided for grade supported floor slabs:

1. Concrete slab on grades should be placed over a compacted granular pad. Where additional grade is necessary, we recommend that it be backfilled with engineered fill compacted to 99% standard proctor density in 200mm lifts.

2. We recommend a minimum of 125 mm thick crushed gravel base layer *(or drainrock)* be placed below the underside of the floor slab prior to concrete placement. The base course should be compacted as per above.

3. If there are backfilled foundation walls above a sub slab or crawlspace elevation, we recommend that a heavy-duty vapour barrier – min 6mm poly – should be provided on the underside of the building floor slab with sealed joints and be sealed back to the foundation wall. Any penetrations through the poly (plumbing, etc) shall be sealed and waterproof.

5.5.5Suitability of Existing Soil

For backfill outside of the structure, it is recommended that the topsoil, silty gravel, and native glacial till soils should not be used in areas where the owner wishes to minimize future potential for saturation, settlement and frost heave. Such areas

may be under driveways, patios, and other surface improvements. These soils are known to be sensitive to moisture in a remoulded state (backfill), and are not recommended for structural backfill purposes.

5.5.6 Lateral Earth Pressures for Retaining/Foundation Walls

For the purposes of any required retaining wall (or foundation wall) design, it is recommended that the following design criteria is considered. For seismic conditions, the total active thrust will likely be the determining factor in the wall design.

Table 5-3: Summary of Retaining Wall Lateral Pressure Design Parameters

Anticipated Soil Backfill Parameters				Coulomb Earth Pressure Coefficients			
Friction Angle (°)	**Cohesion (kPa)**	**Dry Density (kg/m³)**	**Friction Angle of Wall-Backfill Interface (°)**	**K_O (at rest)**	**K_A (active)**	**K_P (passive)**	**K_{AE} (dynamic active)**
34	0	1920	24	0.56	0.28	3.55	0.34

K_{AE} was calculated using the Peak Ground Acceleration (as obtained from the National Resource Canada seismic website) for the site location (50.635N, -116.033W) which was determined to be:

[Ref: http://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php, for 2015 National Building Code Seismic Hazard Calculations]

PGA = 0.120g

Backfill behind the retaining wall shall be free-draining in order to reduce frost action up against the wall and facilitate drainage. We recommend the use of clean site granular fills or drain rock for this purpose. For the above noted values, it is assumed that the backfill slope is relatively level, the back face of the wall is near vertical, and the backfill is a clean, cohesionless granular material.

5.5.7 Site Seismic Classification

The parameters for Site Classification for the Seismic Site Response are based on the viewed and available density and consistency of the granular fills and underlying morainal soils. Given the observed dense native soils encountered in the test holes, it is recommended that the project site be considered Site Class C for the purposes of foundation design as per the British Columbia Building Code 2012 (Section 4.1.8.4).

6.0 Closure

This report has been prepared by McElhanney Consulting Services Ltd. for the benefit of Parks Canada Agency. This report is based on the results of geotechnical assessment and limited laboratory testing completed at the project site as noted. Note that possibly different and/or poorer soil conditions than those described in this report may be encountered between the test locations and in areas not specifically tested. The information and data contained herein represent McElhanney's best professional judgment in light of the knowledge and information available to McElhanney at the time of preparation. Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the client, its officers and employees.

McElhanney Consulting Services Ltd. denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this document or any of its contents without the express written consent of McElhanney and Parks Canada Agency.

This document was prepared in accordance with generally accepted geotechnical engineering principles and practice. No other warranty, expressed or implied, is made.

Should you have any queries, please do not hesitate to contact the undersigned.

Respectfully submitted,

McElhanney Consulting Services Ltd.

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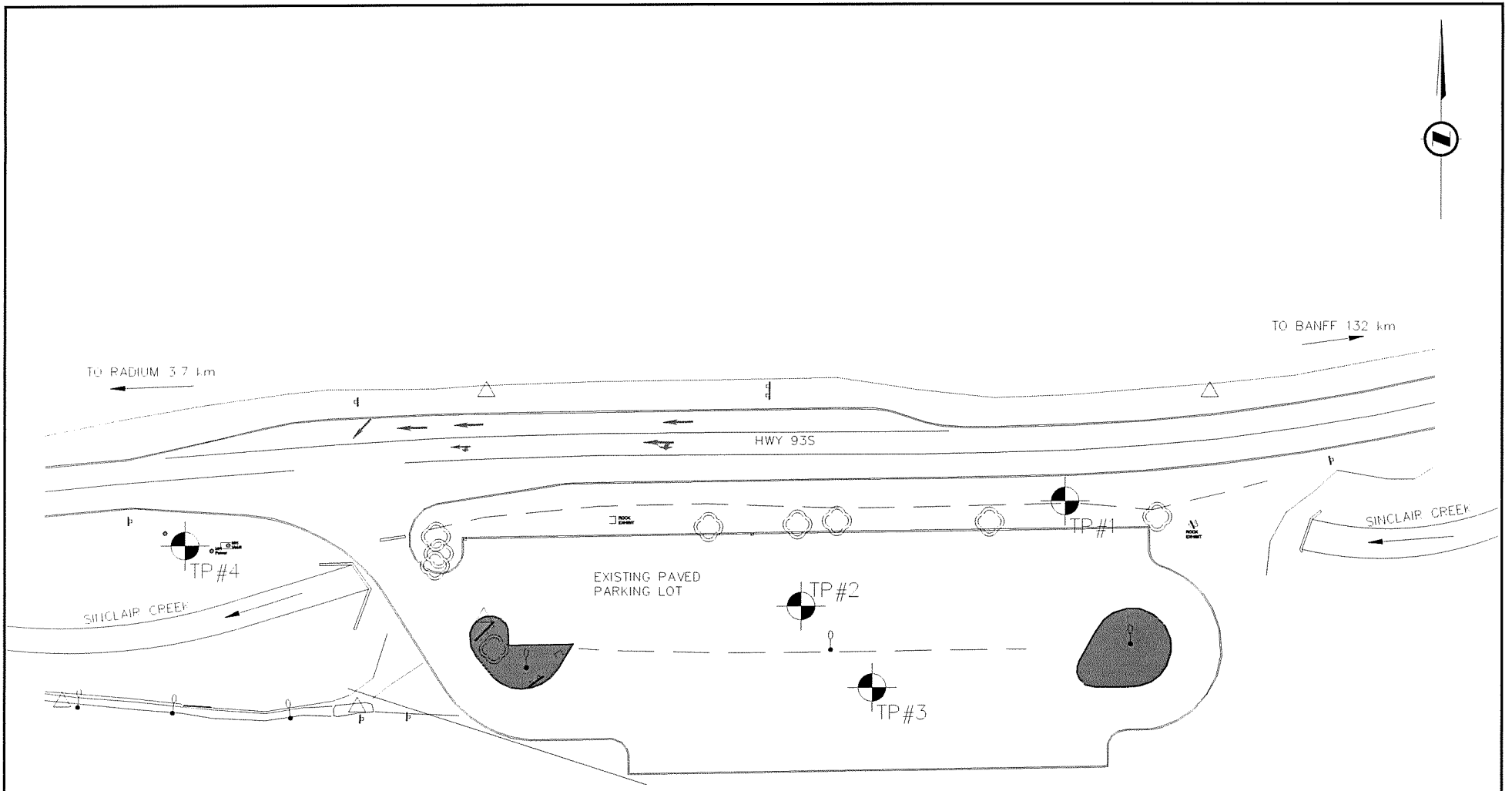
ATTACHMENTS
Drawings: Testhole Plan (Drawing No. 00668-G01)
Appendix A: Borehole Logs (TH16-01 through TH16-04)
Appendix B: Laboratory Test Results and DCP Test Results

Drawings

Testhole Plan (Drawing No. 00668-G01)



APPROXIMATE SITE LOCATION : 50.635 °N, −116.033 °W

SCALE 1:1000

McElhanney

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Designed: JPM	Checked: RWW	QC: RWW
Drawn: BCR	DATE: 08/16/2016	

NOTE: TEST HOLE LOCATIONS ARE APPROXIMATE

PROPOSED WEST GATE RELOCATION

SITE PLAN
PARKS CANADA
KOOTENAY NATIONAL PARK

Client Project No
-

Client Drawing No
-

MCSL Project No.
2511-00668-00

Drawing No.
SP-01

Sheet 1 of 1 Revision 0

Destroy all prints bearing previous number ▲

Appendix A

Testhole Logs (TH16-01 through TH16-04)

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TEST HOLE LOG

TEST HOLE No: # 1

McElhanney # 2511-00668-00 TEST LOCATION: See site plan DATE: May 19, 2016

PROJECT: KNP - West Gate ELEVATION DATUM:

REGION: Radium Hot Springs, B.C. INVESTIGATION METHOD: Komatsu PC200

DEPTH (meters)	ELEV. (meters)	SOIL PROFILE	SOIL DESCRIPTION	TEST SAMPLES	OTHER TEST COMMENTS
0.0					
0.1			Gravelly topsoil - Brown, damp, some 0.02m asphalt debris, some wood debris.		
			Sandy gravel fill - trace to some fines, Light brown, damp.	S-1 @ 0.3m	DCP @ 0.3m CBR = 12.2 Gradation @ 0.3 = 55% Gravel, 35% sand, 10% fines, moisture = 3.1%
0.6			Gravel fill - light brown, dry to damp, compact.		DCP @ 0.65m CBR = 13.9
0.8			Silty sandy gravel fill - trace clay, occasional cobbles, dry to damp. Light brown, loose, damp. moist to wet, occasional boulders (observed @ 1.1m, moist to wet).	S-2 @ 1.1m	DCP @ 1.1m CBR = 7.1 Gradation @ 1.1m = 53% Gravel, 24% sand, 23% fines, moisture = 6.84%
2.2			Some small wood debris observed.		
2.4				S-3 @ 2.4m	P.P. readings exceed 4.5 Atterburg @ 2.4m = CL LL = 26%, PL = 17%, moisture = 13.8%
2.6			Native till - some organics, light brown, sand, some gravel, silt and clay, slightly cohesive, damp, very dense.		

Excavation discontinued
No groundwater encountered

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TEST HOLE LOG

TEST HOLE No: # 2

McElhanney # 2511-00668-00 TEST LOCATION: See site plan DATE: May 19, 2016

PROJECT: KNP – West Gate ELEVATION DATUM:

REGION: Radium Hot Springs, B.C. INVESTIGATION METHOD: Komatsu PC200

DEPTH (meters)	ELEV. (meters)	SOIL PROFILE	SOIL DESCRIPTION	TEST SAMPLES	OTHER TEST COMMENTS
0.0					
0.15			Asphalt (existing) – 0.1m to 0.15m	S–1 @ 0.15m	DCP @ 0.15m CBR = 16 Gradation @ 0.15 = 45% Gravel, 48% sand, 7% fines, moisture = 2.8%
0.4			Sand and gravel fill – trace fines, Light brown, damp.	S–2 @ 0.55m	DCP @ 0.55m CBR = 49 Gradation @ 0.55 = 58% Gravel, 31% sand, 11% fines, moisture = 4.3%
0.8			Sandy gravel fill – some fines, light brown, dry to damp.		
1.9			Silty sandy gravel fill – trace clay, some fines, occasional cobbles, dry to damp. Light brown, loose, damp. moist to wet, occasional boulders observed @ 1.1m, moist to wet.	S–3 @ 1.1m	DCP @ 1.1m CBR = 5.7 Gradation @ 0.55 = 57% Gravel, 24% sand, 19% fines, moisture = 5.9%
3.0			Native till – some organics, light brown, sand, some gravel, silt and clay, slightly low cohesive, damp, very dense.	S–4 @ 3.0m	Atterburg @ 3.0m = CL LL = 25%, PL = 18%, moisture = 14.9%
			Excavation discontinued No groundwater encountered		

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Suite 200, 42 -8th Avenue S.
Cranbrook BC V1C 2P1
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FAX (250) 489 4522

TEST HOLE LOG

TEST HOLE No: # 3

McElhanney # 2511-00668-00 TEST LOCATION: See site plan DATE: May 19, 2016

PROJECT: KNP - West Gate ELEVATION DATUM:

REGION: Radium Hot Springs, B.C. INVESTIGATION METHOD: Komatsu PC200

DEPTH (meters)	ELEV. (meters)	SOIL PROFILE	SOIL DESCRIPTION	TEST SAMPLES	OTHER TEST COMMENTS
0.0					
			Asphalt/oiled gravels (existing)	S-1 @ 0.2m	DCP @ 0.22m CBR = 32 Gradation @ 0.2 = 40% Gravel, 53% sand, 7% fines, moisture = 3.7%
0.18			Sand and gravel fill - trace fines.		
0.3			Sandy gravel fill - trace fines, brown, compact, dry to damp.	S-2 @ 0.35m	DCP @ 0.35m CBR = 21 Gradation @ 0.35 = 54% Gravel, 38% sand, 8% fines, moisture = 3.0% DCP @ 0.75m CBR = 30
1.0			Sandy gravel fill - continued Light brown, very dense, moist, cobbles and boulders are more prevalent.		
			Damp to wet @ 3m.		
3.2			Excavation discontinued No groundwater encountered		

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TEST HOLE LOG

TEST HOLE No: # 4

McElhanney # 2511-00668-00 TEST LOCATION: See site plan DATE: May 19, 2016

PROJECT: KNP - West Gate ELEVATION DATUM:

REGION: Radium Hot Springs, B.C. INVESTIGATION METHOD: Komatsu PC200

DEPTH (meters)	ELEV. (meters)	SOIL PROFILE	SOIL DESCRIPTION	TEST SAMPLES	OTHER TEST COMMENTS
0.0					
0.15			Gravelly topsoil - Brown, damp, some 0.02m asphalt debris, some wood debris.		
			Sandy gravel fill - trace fines, brown, occasional cobbles, compact, damp.	S-1 @ 0.5m	DCP @ 0.4m CBR = 18 Gradation @ 0.5 = 57% Gravel, 35% sand, 8% fines, moisture = 3.1%
0.8					
0.13			Band of oiled gravel at 0.8m.		
			Sandy gravel fill - some fines, occasional cobbles, very dense, damp, slight cohesion.	S-2 @ 1.5m	DCP @ 1.34m CBR = 35 Gradation @ 1.5 = 54% Gravel, 31% sand, 15% fines, moisture = 2.8%
1.7			Excavation discontinued No groundwater encountered		

Appendix B

Laboratory Test Results
DCP Test Results

ARTECH CONSULTING LTD

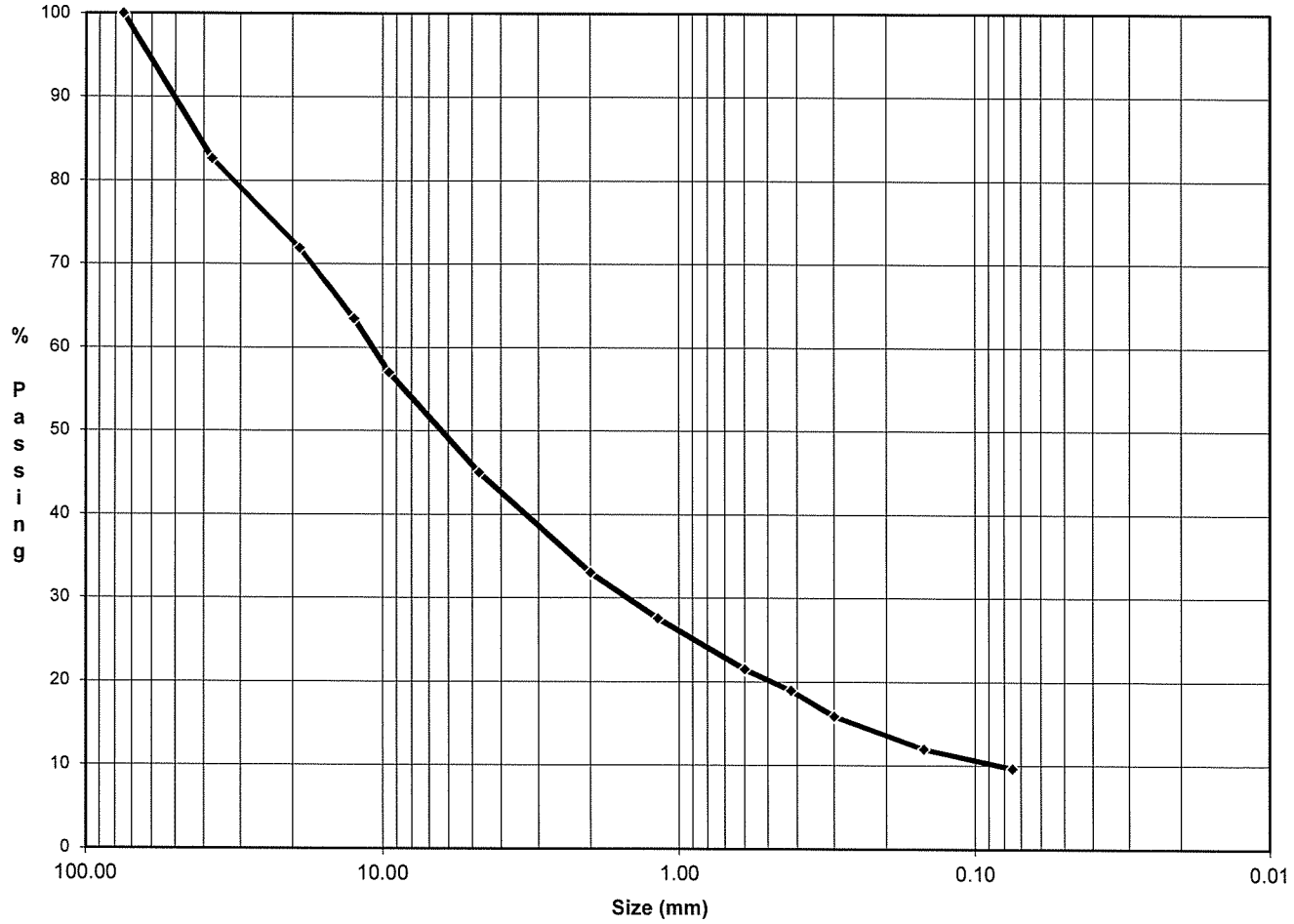
MATERIALS TESTING AND INSPECTION SERVICES
229 Industrial Road F, Cranbrook, BC V1C 6N4
Ph: 250/489-1940; Fax: 250/489-1667;
Email: info@artechconsulting.ca

GRADATION REPORT

Lab No: **S16-259**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP1 S-1 0.3m
Region: Radium, BC
Material type: Gravel and sand with a trace of silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	33.0	Medium sand
75.0	100.0	Gravel	1.180	27.5	
37.5	82.6		0.600	21.5	
19.0	71.9		0.420	18.9	Fine sand
12.5	63.4		0.300	15.9	
9.5	57.0		0.150	12.0	
4.75	45.0	Coarse sand	0.075	9.7	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 3.1

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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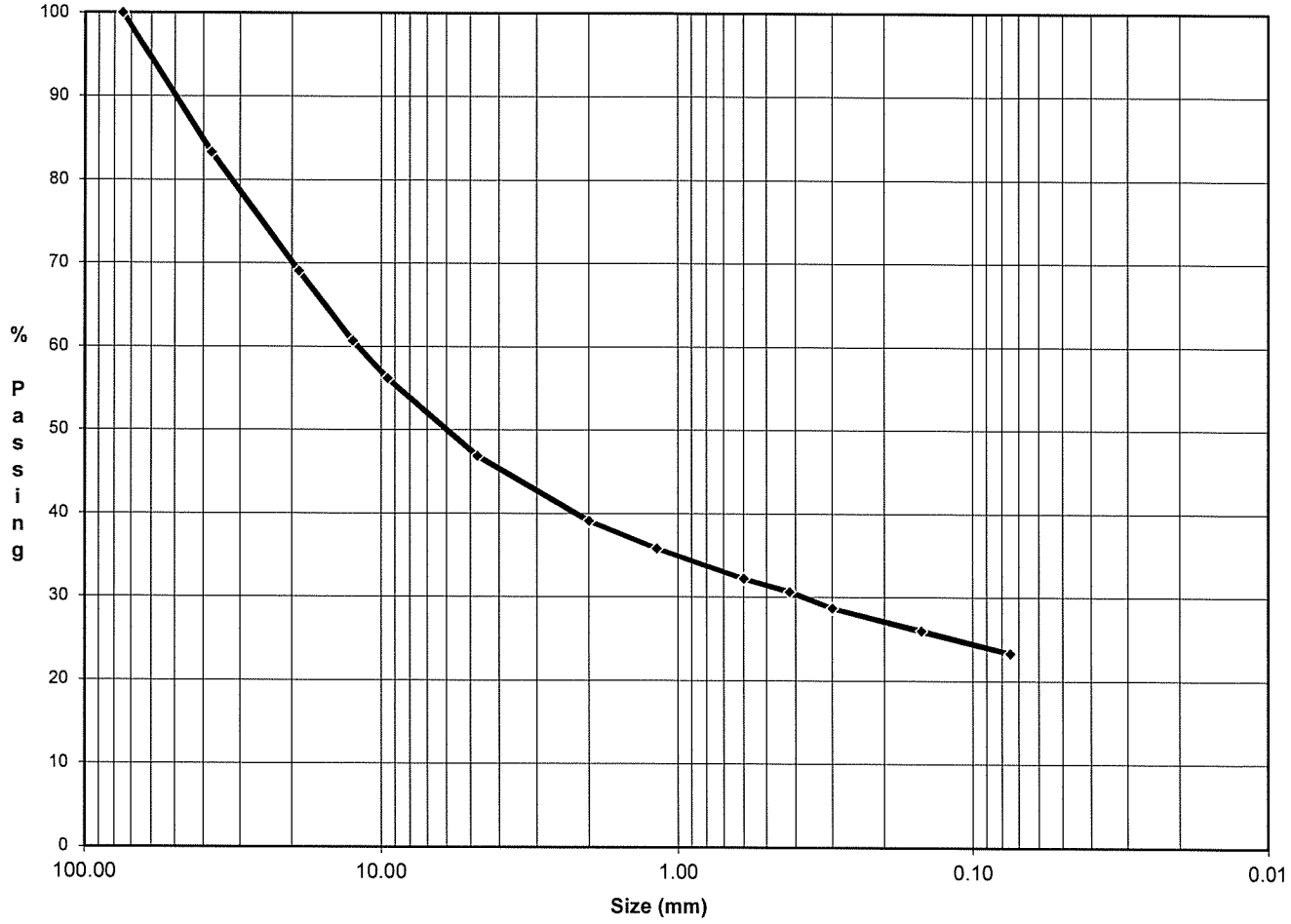
Email: info@artechconsulting.ca

GRADATION REPORT

Lab No: **S16-260**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP1 S-2 1.1m
Region: Radium, BC
Material type: Sandy, silty/clayey gravel

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	39.1	Medium sand
75.0	100.0	Gravel	1.180	35.7	
37.5	83.3		0.600	32.2	
19.0	69.0		0.420	30.6	Fine sand
12.5	60.6		0.300	28.6	
9.5	56.1		0.150	25.9	
4.75	46.9	Coarse sand	0.075	23.3	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 6.8

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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Email: info@artechconsulting.ca

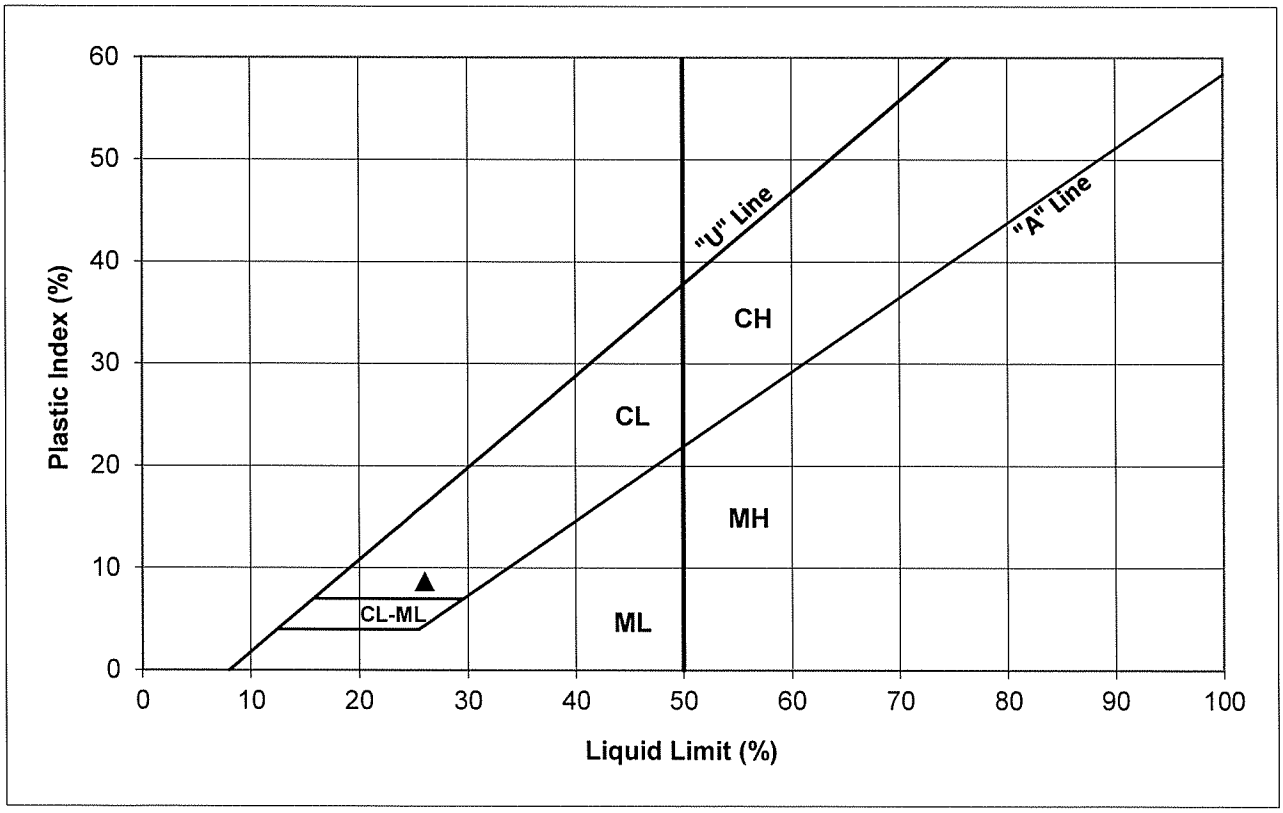
ATTERBERG LIMITS REPORT

Lab No: **S16-261**

Project: 2511-00668-00 Kootenay National Park
Region: Radium, BC
Sampling Details: Geotechnical Investigation

Date: May 25, 2016
File: 2016-11

Sample	Soil Classification (USCS)	Sample Moisture %	Liquid Limit %	Plastic Limit %	Plasticity Index %
TP1 S-3 2.4m	CL	13.8	26	17	9



Tested in accordance with ASTM D4318-00 Methods for the determination of liquid limits, plastic limits and plasticity indices of soils

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016
Per:

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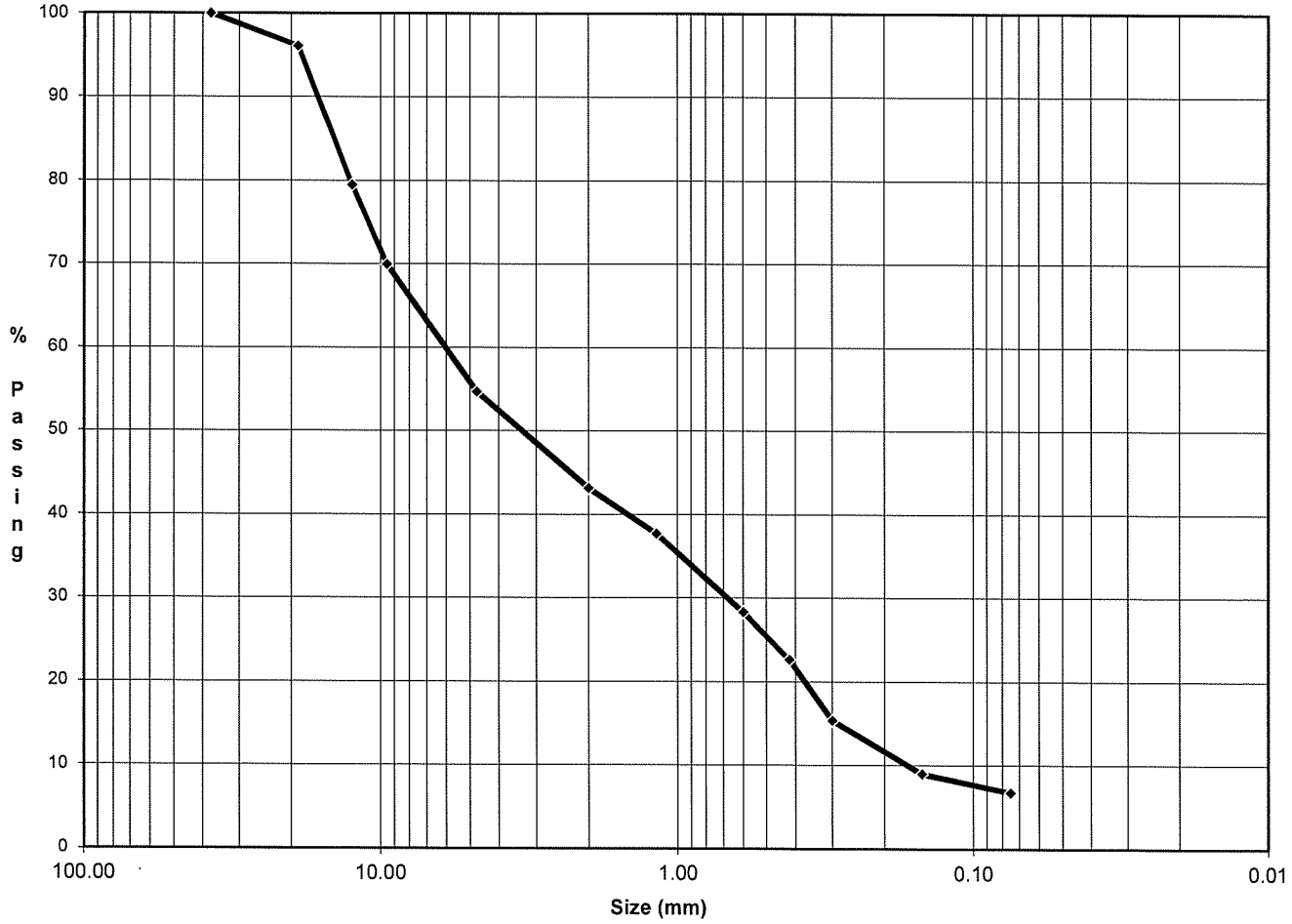
Email: info@artechconsulting.ca

GRADATION REPORT

Lab No: **S16-262**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP2 S-1 0.15m
Region: Radium, BC
Material type: Gravel and sand with a trace of silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	43.1	Medium sand
75.0		Gravel	1.180	37.7	
37.5	100.0		0.600	28.3	
19.0	96.1		0.420	22.6	Fine sand
12.5	79.5		0.300	15.3	
9.5	70.0		0.150	9.0	
4.75	54.6	Coarse sand	0.075	6.7	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 2.8

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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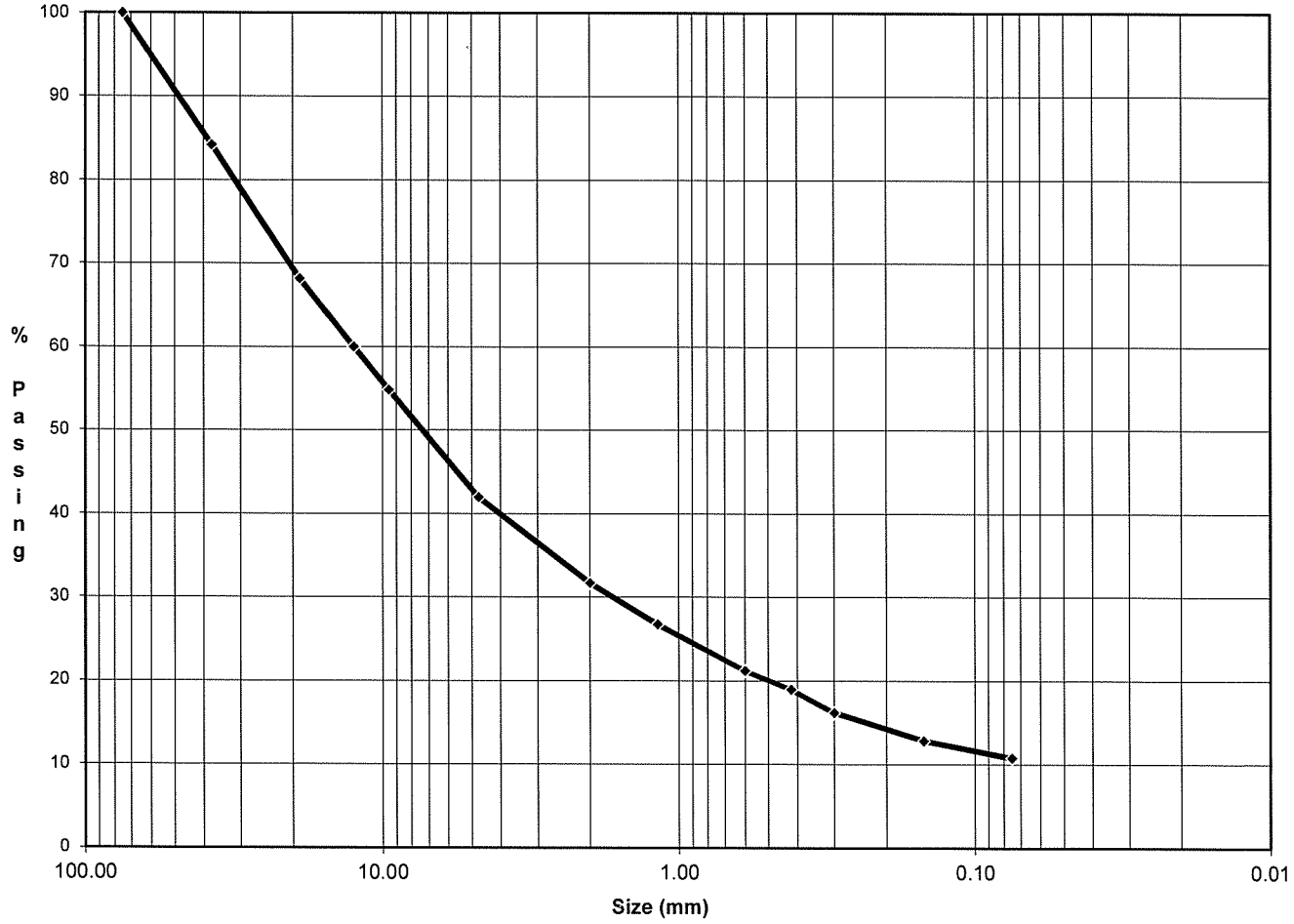
GRADATION REPORT

Lab No: **S16-263**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP2 S-2 0.55m
Region: Radium, BC
Material type: Sandy gravel with some silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	31.6	Medium sand
75.0	100.0	Gravel	1.180	26.7	
37.5	84.2		0.600	21.2	
19.0	68.2		0.420	18.9	Fine sand
12.5	59.9		0.300	16.1	
9.5	54.8		0.150	12.8	
4.75	41.9	Coarse sand	0.075	10.8	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 4.3

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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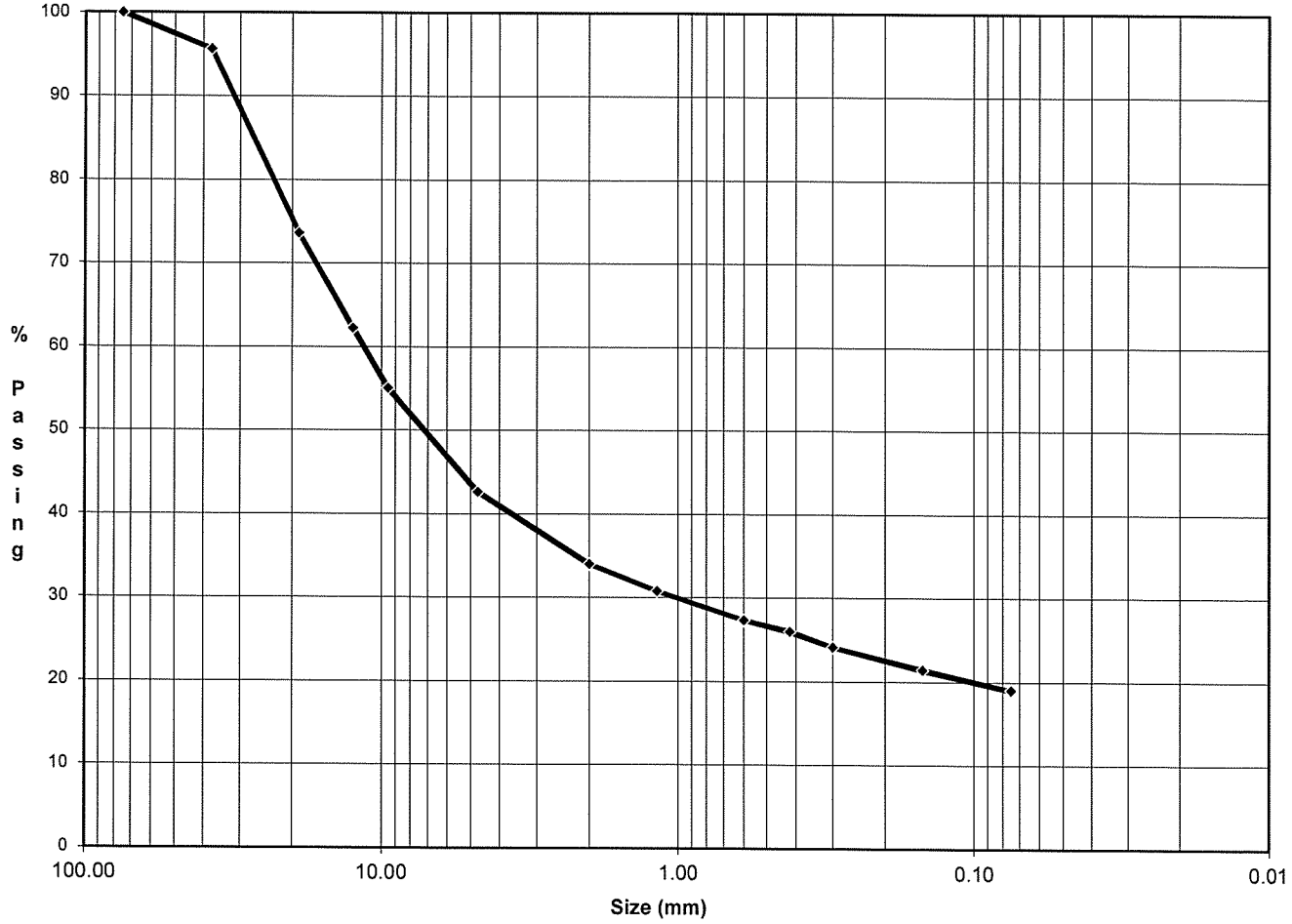
GRADATION REPORT

Lab No: **S16-264**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP2 S-3 1.2m
Region: Radium, BC
Material type: Sandy gravel with some silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	34.0	Medium sand
75.0	100.0	Gravel	1.180	30.8	
37.5	95.6		0.600	27.3	
19.0	73.6		0.420	25.9	Fine sand
12.5	62.2		0.300	24.1	
9.5	55.0		0.150	21.4	
4.75	42.6	Coarse sand	0.075	19.0	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 5.9

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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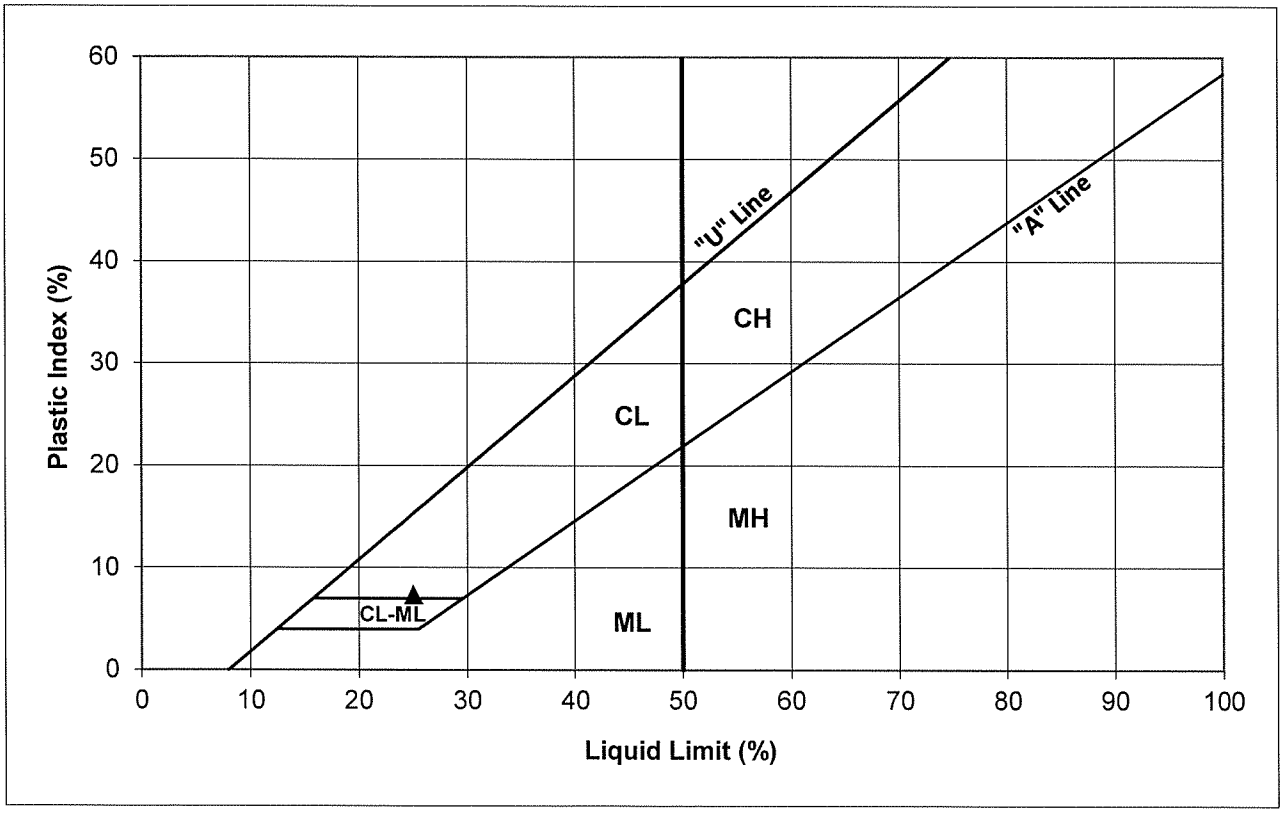
ATTERBERG LIMITS REPORT

Lab No: **S16-265**

Project: 2511-00668-00 Kootenay National Park
Region: Radium, BC
Sampling Details: Geotechnical Investigation

Date: May 25, 2016
File: 2016-11

Sample	Soil Classification (USCS)	Sample Moisture %	Liquid Limit %	Plastic Limit %	Plasticity Index %
TP2 S-4 3.0m	CL	14.9	25	18	7



Tested in accordance with ASTM D4318-00 Methods for the determination of liquid limits, plastic limits and plasticity indices of soils

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016
Per:

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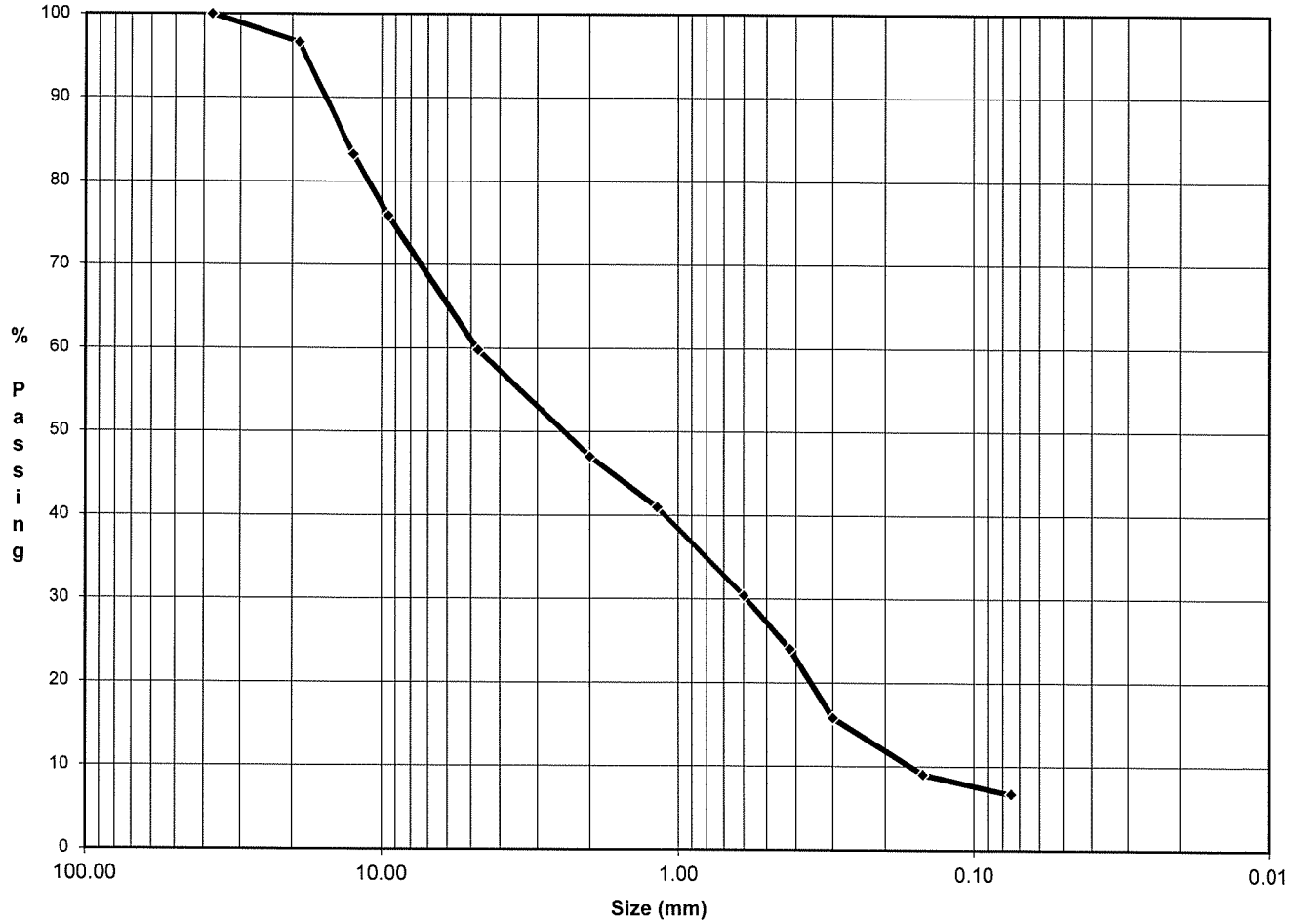
GRADATION REPORT

Lab No: S16-266
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP3 S-1 0.2m
Region: Radium, BC
Material type: Gravel and sand with a trace of silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	47.0	Medium sand
75.0		Gravel	1.180	40.9	
37.5	100.0		0.600	30.3	
19.0	96.6		0.420	24.0	Fine sand
12.5	83.2		0.300	15.8	
9.5	75.9		0.150	9.0	
4.75	59.8	Coarse sand	0.075	6.7	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 3.7

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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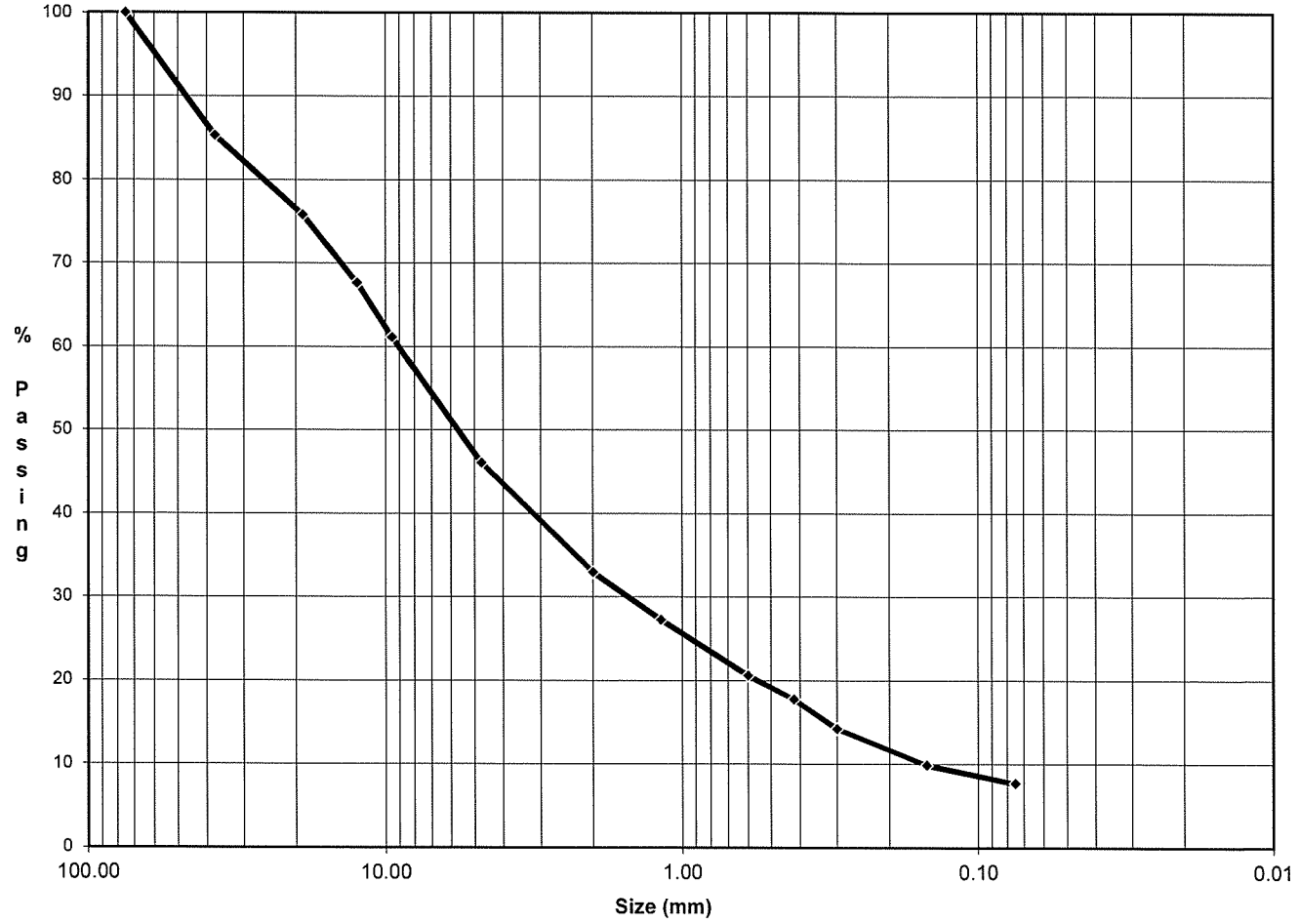
Email: info@artechconsulting.ca

GRADATION REPORT

Lab No: S16-267
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP3 S-2 0.35m
Region: Radium, BC
Material type: Gravel and sand with a trace of silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	33.0	Medium sand
75.0	100.0	Gravel	1.180	27.2	
37.5	85.3		0.600	20.6	
19.0	75.8		0.420	17.7	Fine sand
12.5	67.6		0.300	14.2	
9.5	61.1		0.150	9.9	
4.75	46.0	Coarse sand	0.075	7.7	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 3.0

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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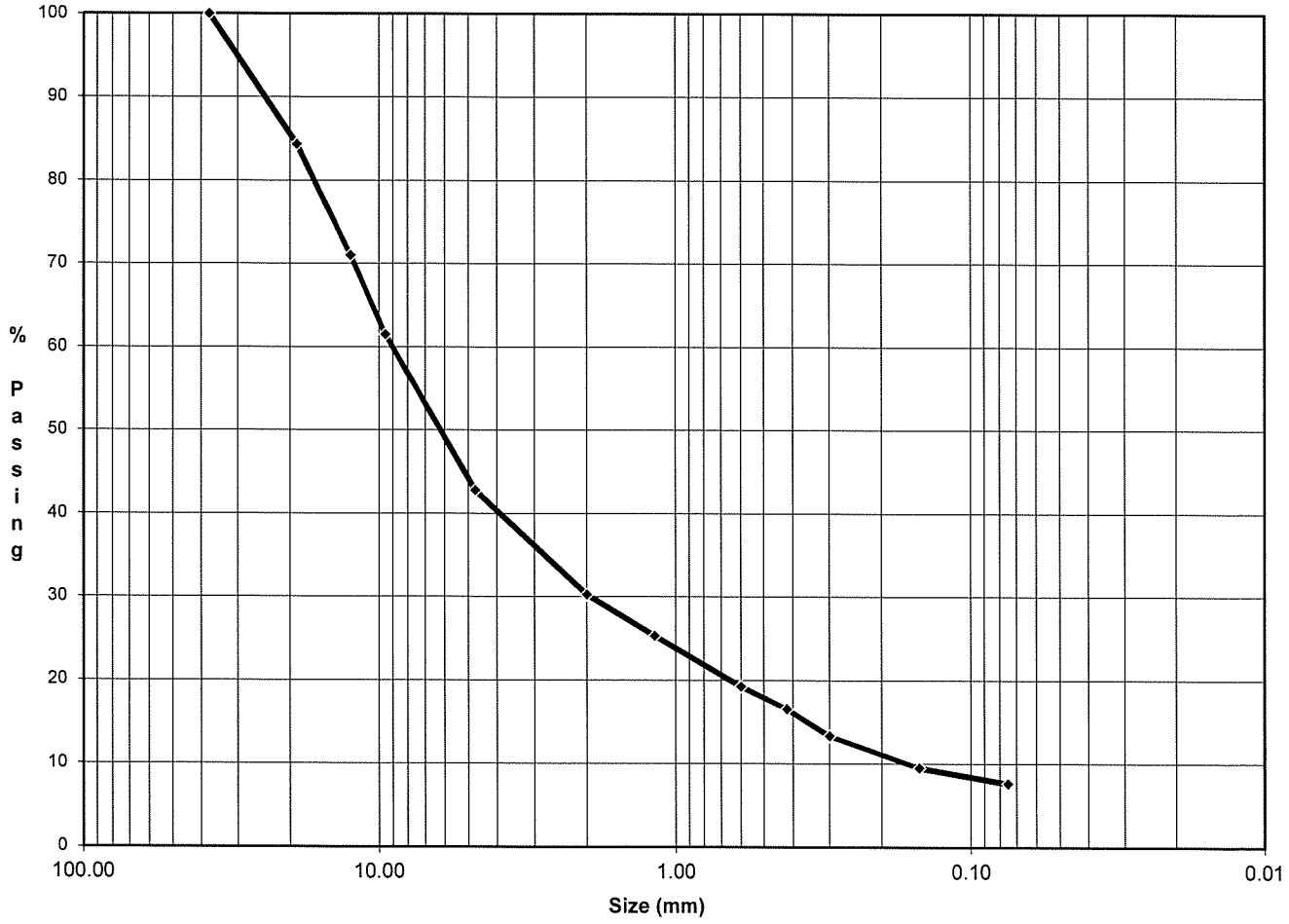
GRADATION REPORT

Lab No: S16-268
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP4 S-1 0.5m
Region: Radium, BC
Material type: Gravel and sand with a trace of silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	30.3	Medium sand
75.0		Gravel	1.180	25.3	
37.5	100.0		0.600	19.2	
19.0	84.4		0.420	16.5	Fine sand
12.5	71.0		0.300	13.3	
9.5	61.4		0.150	9.5	
4.75	42.7	Coarse sand	0.075	7.6	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 3.1

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

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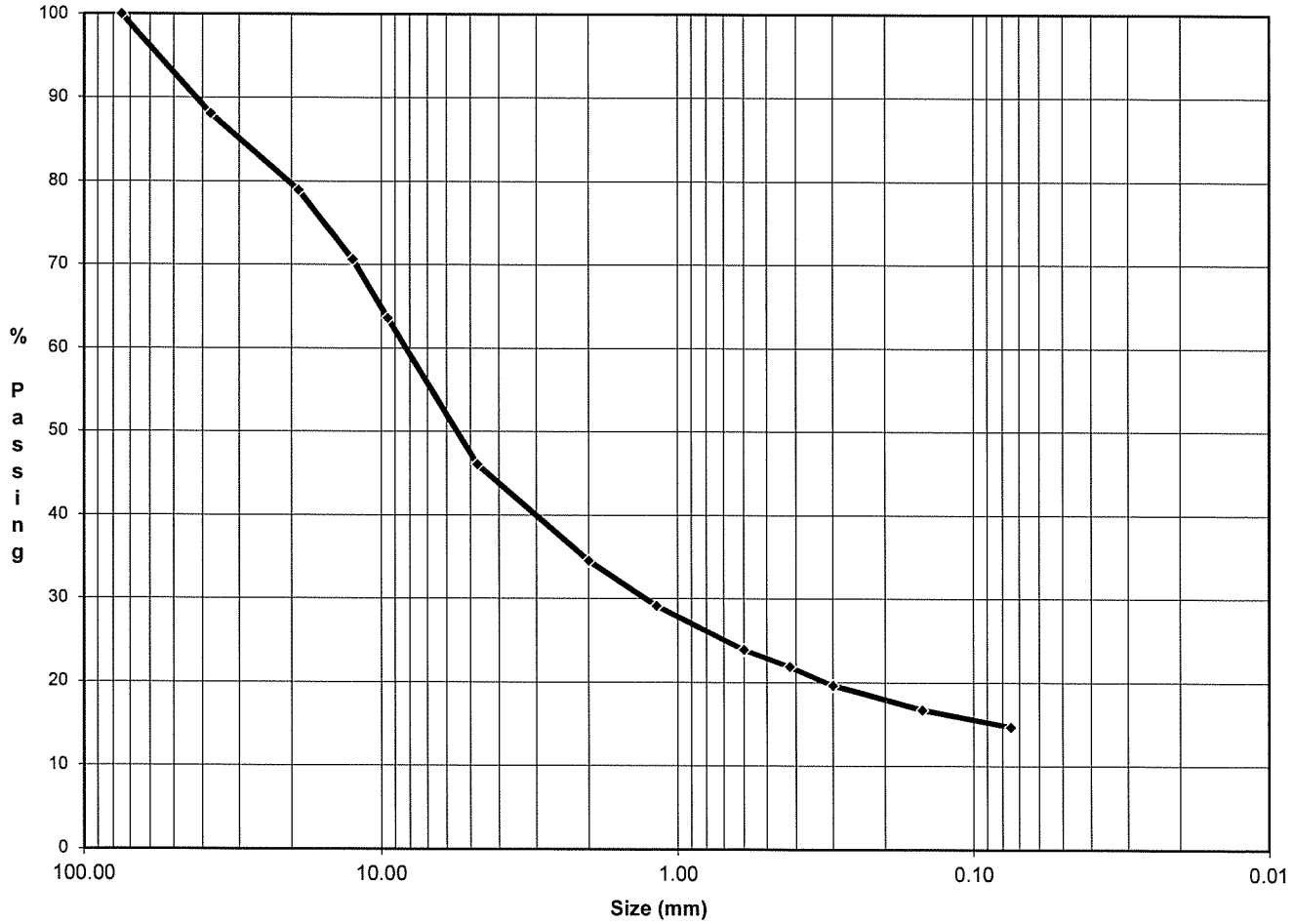
Email: info@artechconsulting.ca

GRADATION REPORT

Lab No: **S16-269**
Project: 2511-00668-00 Kootenay National Park
Our File: 2016-11
Sampling details: Geotechnical Investigation - TP4 S-2 1.5m
Region: Radium, BC
Material type: Sandy gravel with some silt/clay

Sieve Size	% Passing	Classification	Sieve Size	% Passing	Classification
100.0		Cobble	2.00	34.5	Medium sand
75.0	100.0	Gravel	1.180	29.1	
37.5	88.1		0.600	23.8	
19.0	78.9		0.420	21.9	Fine sand
12.5	70.6		0.300	19.6	
9.5	63.6		0.150	16.7	
4.75	46.1	Coarse sand	0.075	14.7	Silt/clay

% PASSING VS GRAIN SIZE



Tested in accordance with ASTM C136, C117 (washed gradation)

Moisture Content of Sample (%): 2.8

Reports: McElhanney - R. Gibbard
c.c:

Report Date: May 30, 2016

Per:

DCP TEST DATA

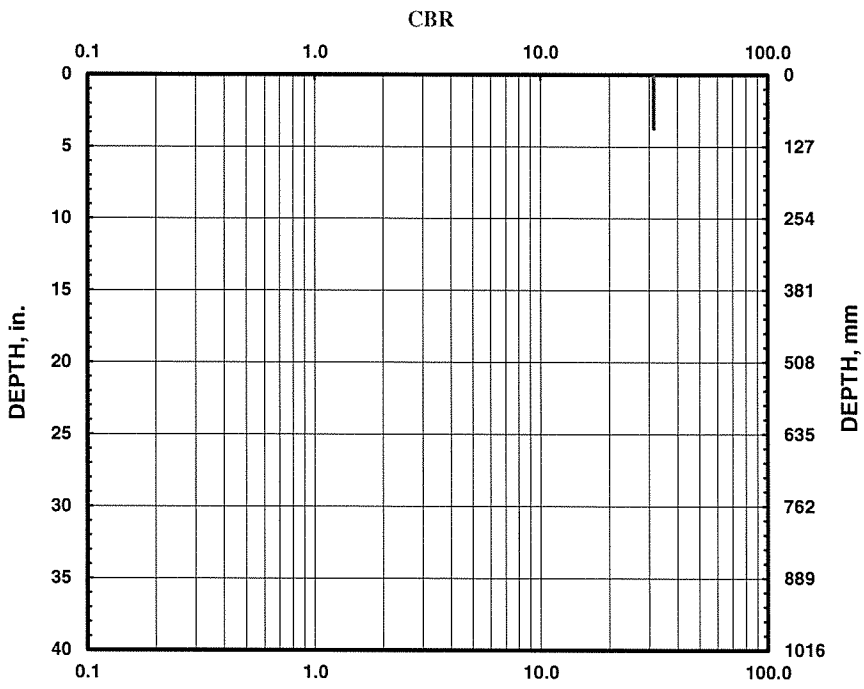
DCP #1
Depth =0.3m

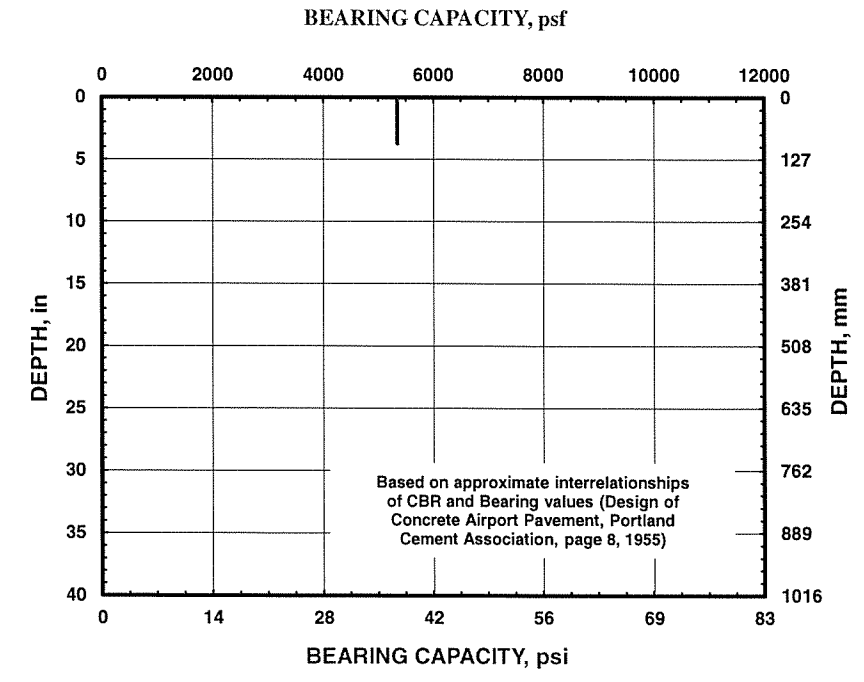
Project: *2511-00668-00*
Location: TP #1
Date: 19/05/2016
Soil Type(s): Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
13	95	1





DCP TEST DATA

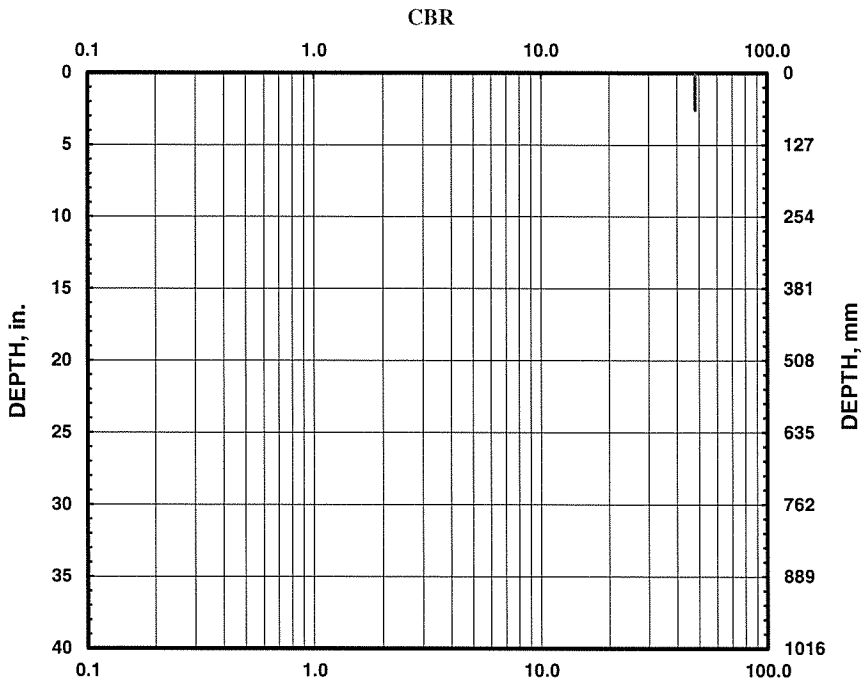
DCP #2
Depth =0.65

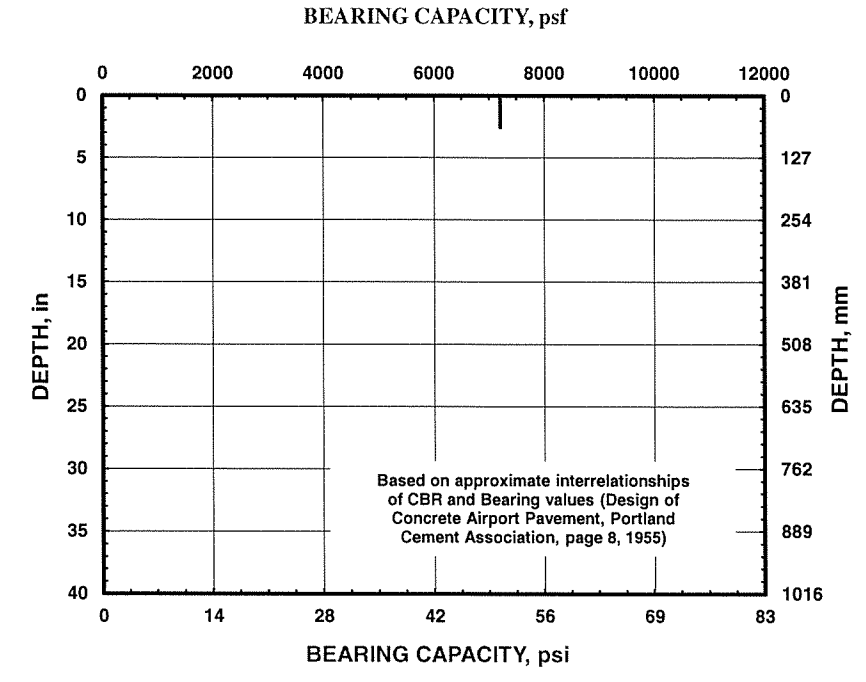
Project: *2511-00668-00* **Date:** 19/05/2016
Location: TP #1 **Soil Type(s):** Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
13	65	1





DCP TEST DATA

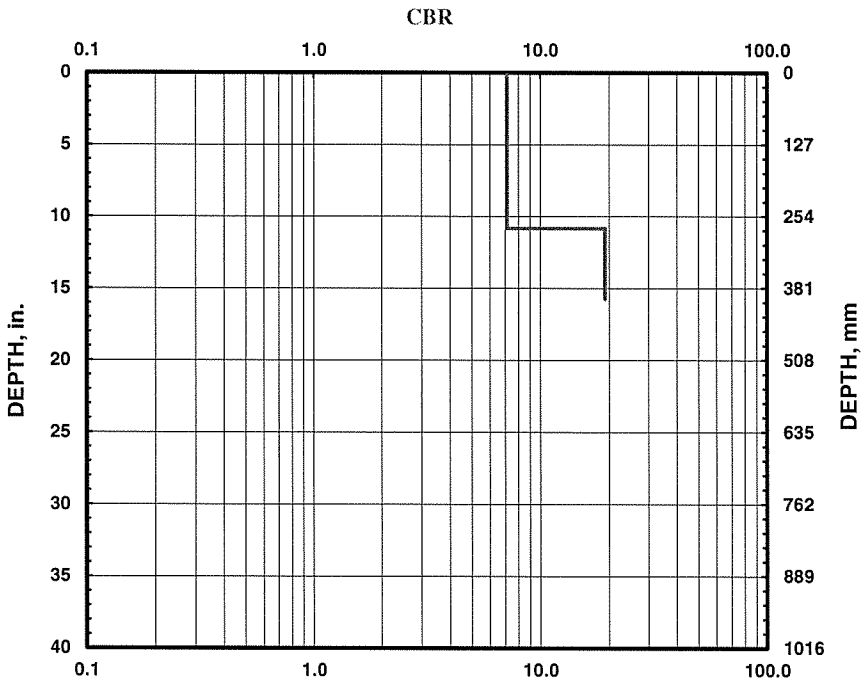
DCP #3
Depth =1.1m

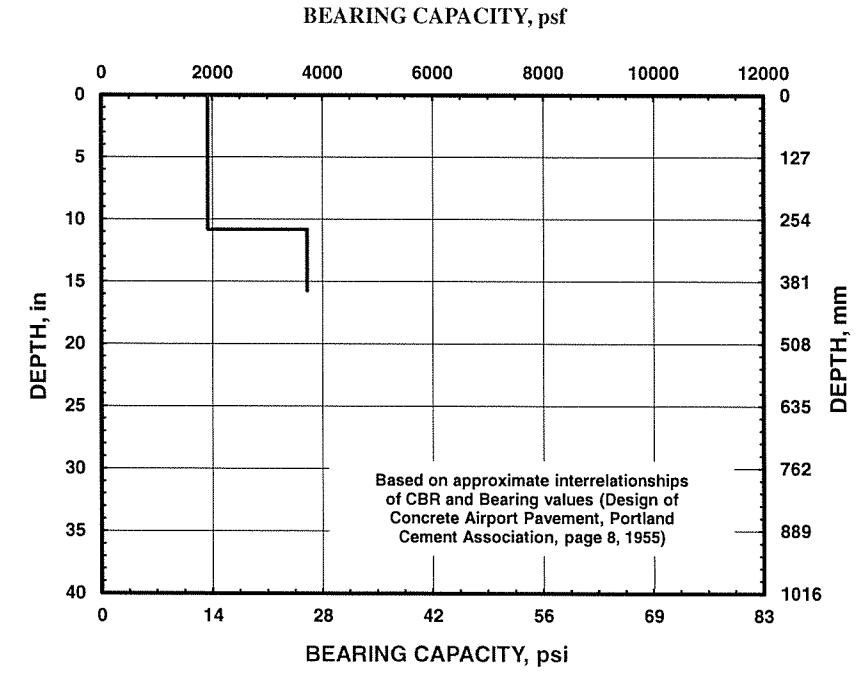
Project: *2511-00668-00* **Date:** 19/05/2016
Location: TP #1 **Soil Type(s):** Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
10	275	1
11	400	1





DCP TEST DATA

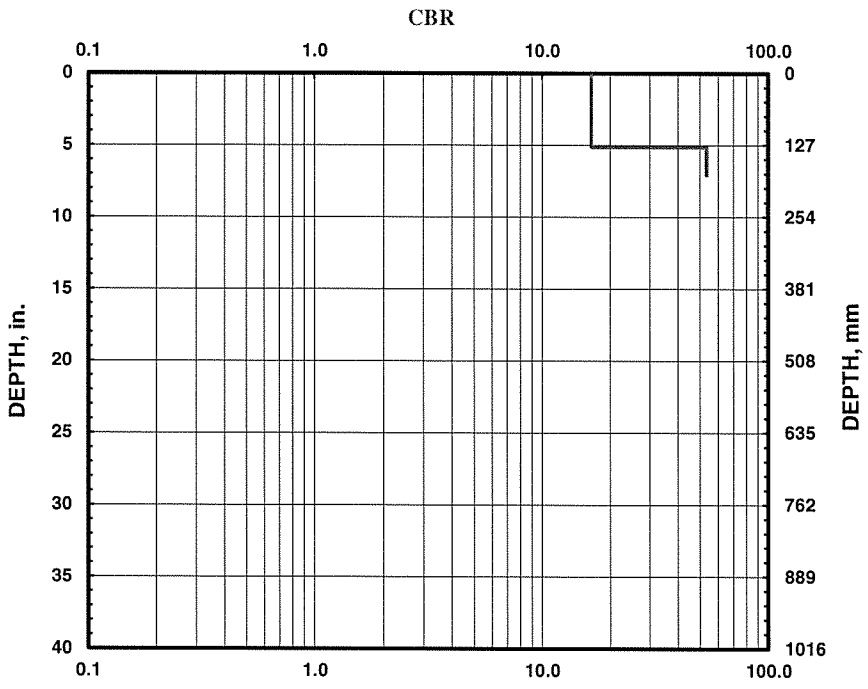
DCP #1
Depth =0.15m

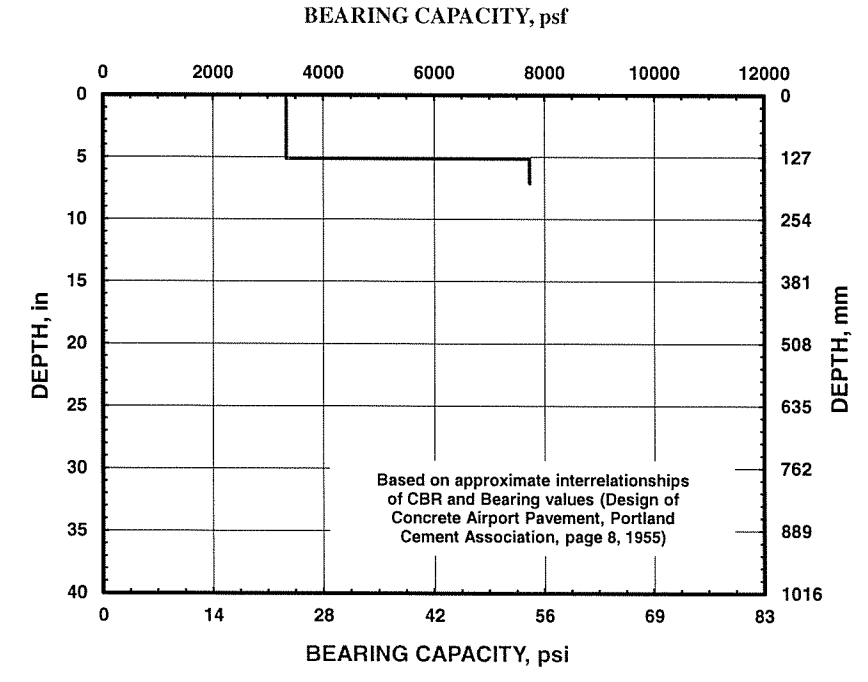
Project: *2511-00668-00*
Location: TP #2
Date: 19/05/2016
Soil Type(s): Gravel Crush

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
10	130	1
11	180	1





DCP TEST DATA

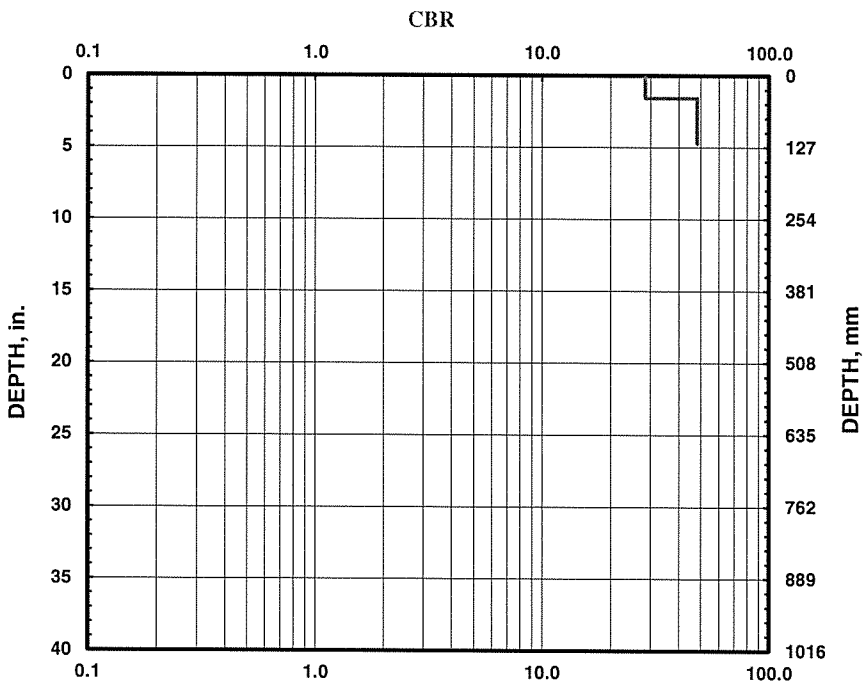
DCP #2
Depth =0.55m

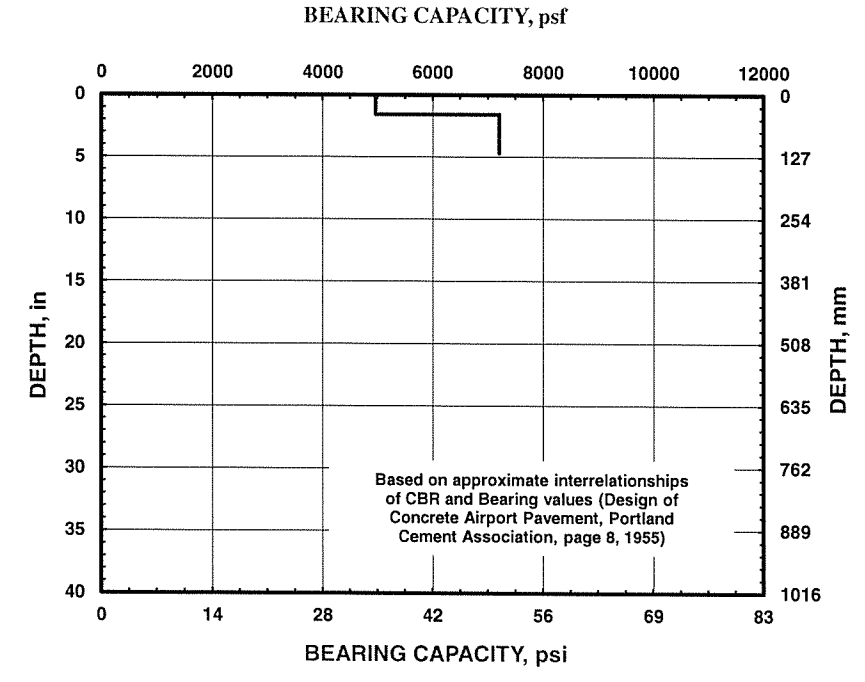
Project: *2511-00668-00*
Location: TP #2
Date: 19/05/2016
Soil Type(s): Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
5	40	1
16	120	1





DCP TEST DATA

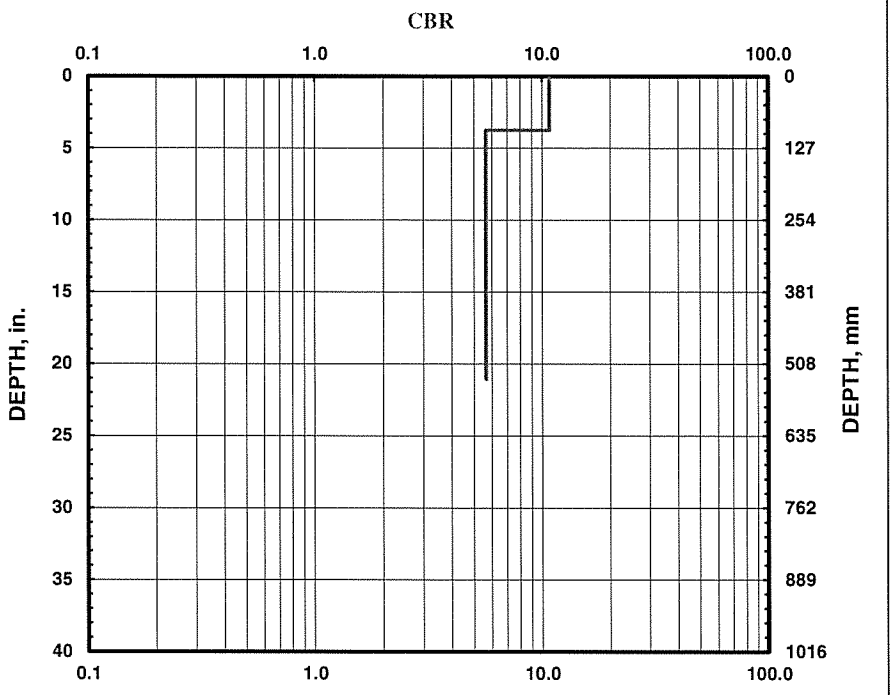
DCP #3
Depth =1.1m

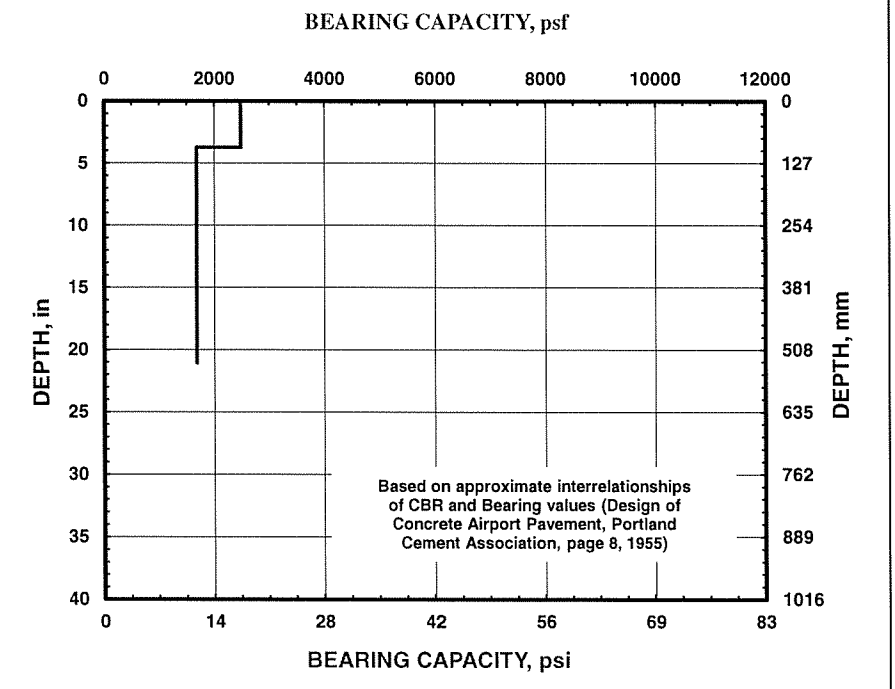
Project: *2511-00668-00* **Date:** 19/05/2016
Location: TP #2 **Soil Type(s):** Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
5	95	1
13	535	1





DCP TEST DATA

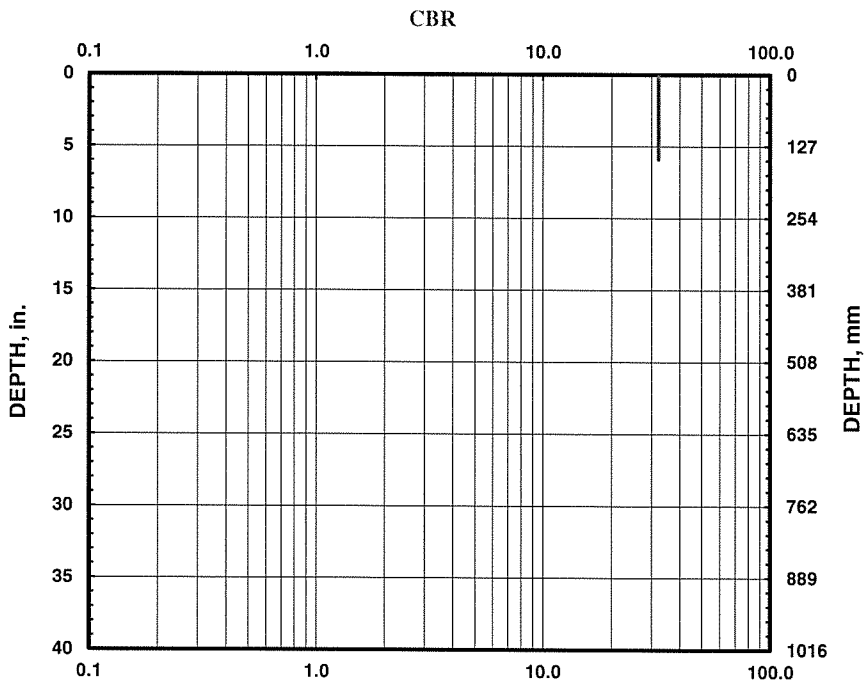
DCP #1
Depth =0.22m

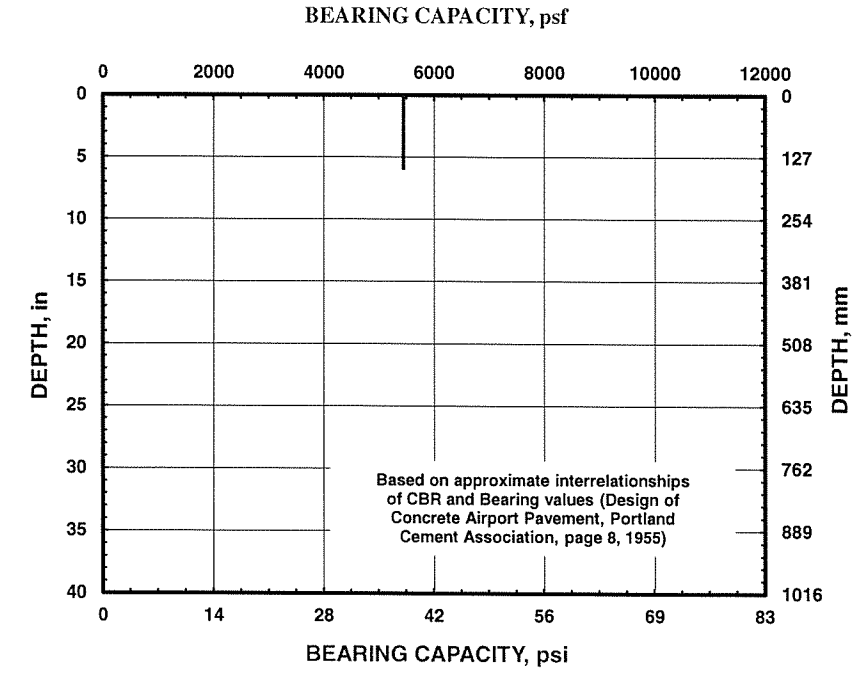
Project: *2511-00668-00*
Location: TP #3
Date: 19/05/2016
Soil Type(s): Gravel Crush

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
21	150	1
		1





DCP TEST DATA

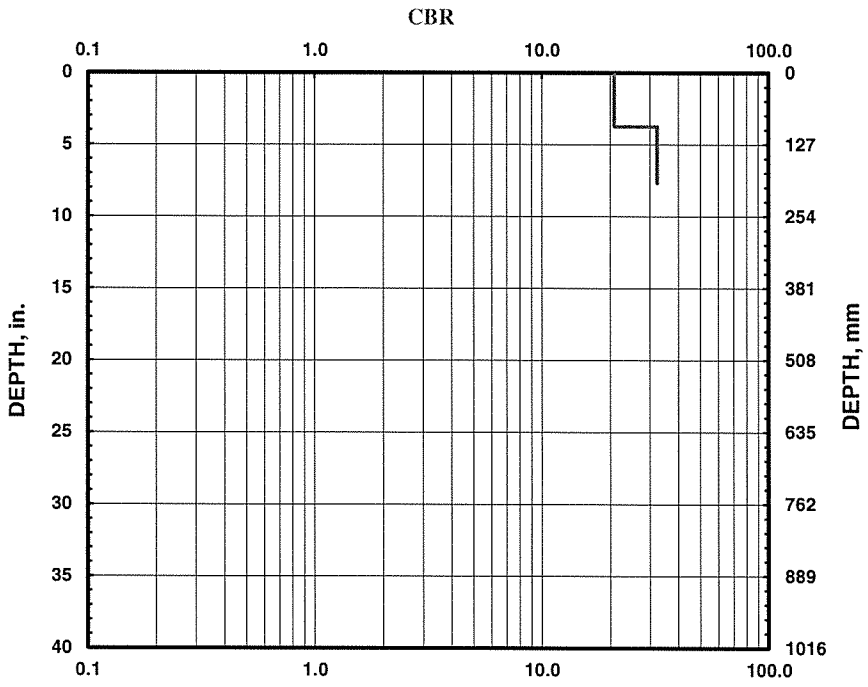
DCP #2
Depth =0.35m

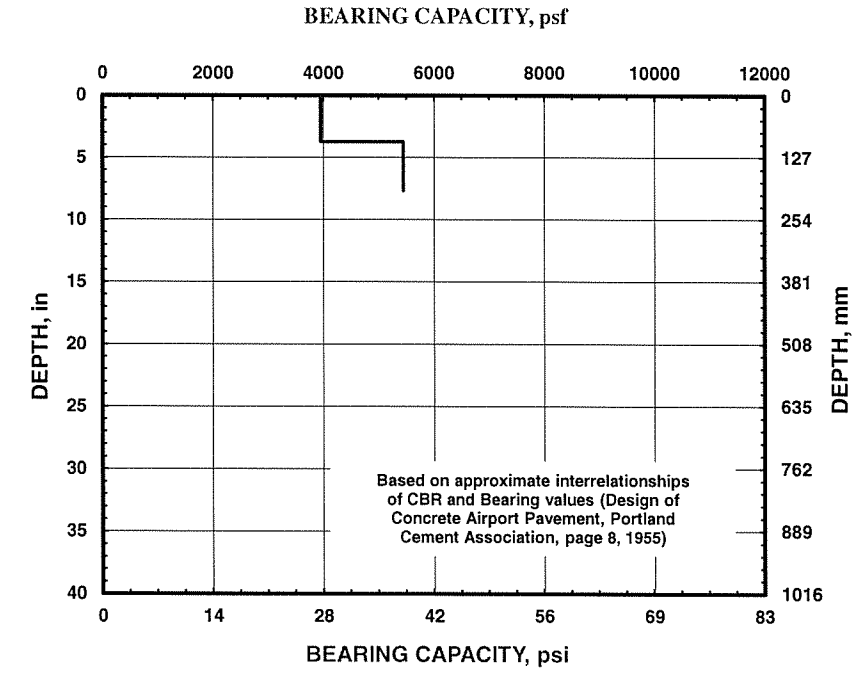
Project: *2511-00668-00*
Location: TP #3
Date: 19/05/2016
Soil Type(s): Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
9	95	1
14	195	1





DCP TEST DATA

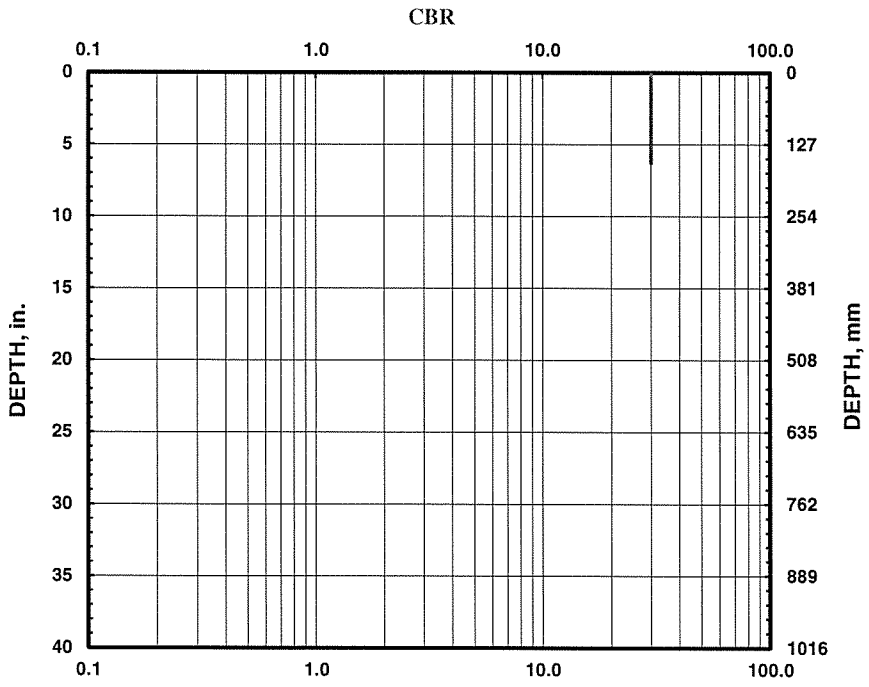
DCP #3
Depth =0.75m

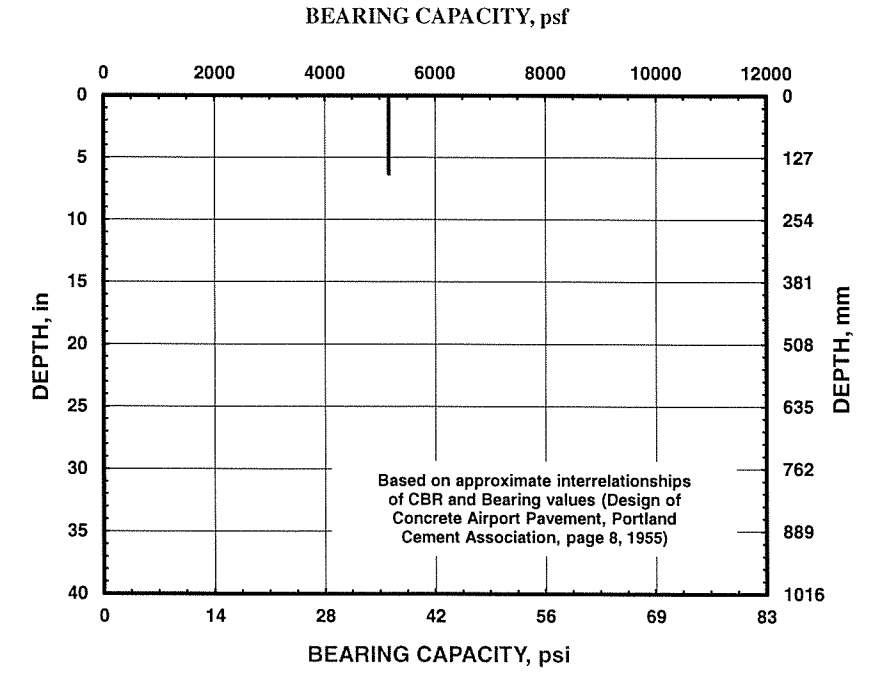
Project: *2511-00668-00*
Location: TP #3
Date: 19/05/2016
Soil Type(s): Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
21	160	1





DCP TEST DATA

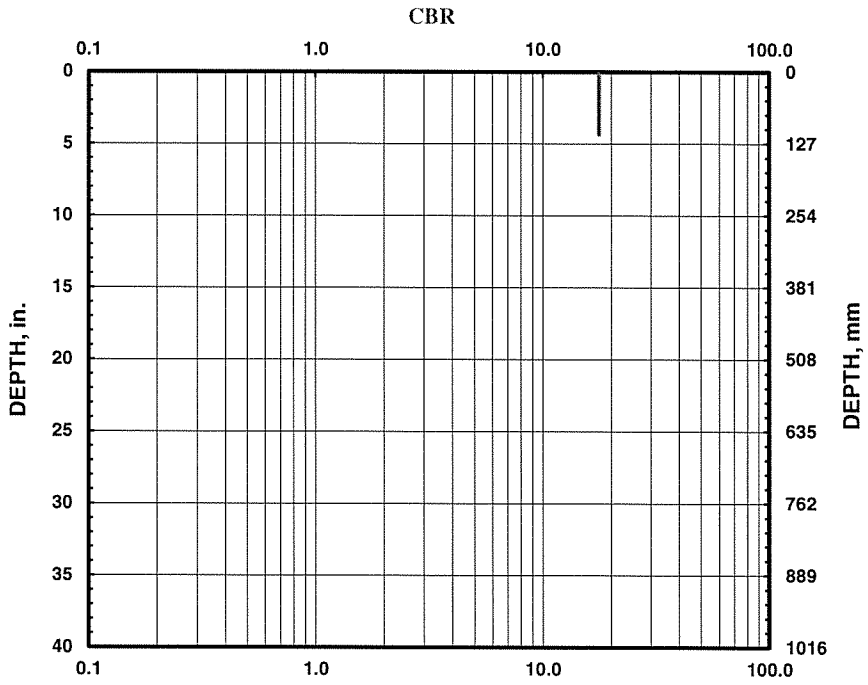
DCP #1
Depth =0.4m

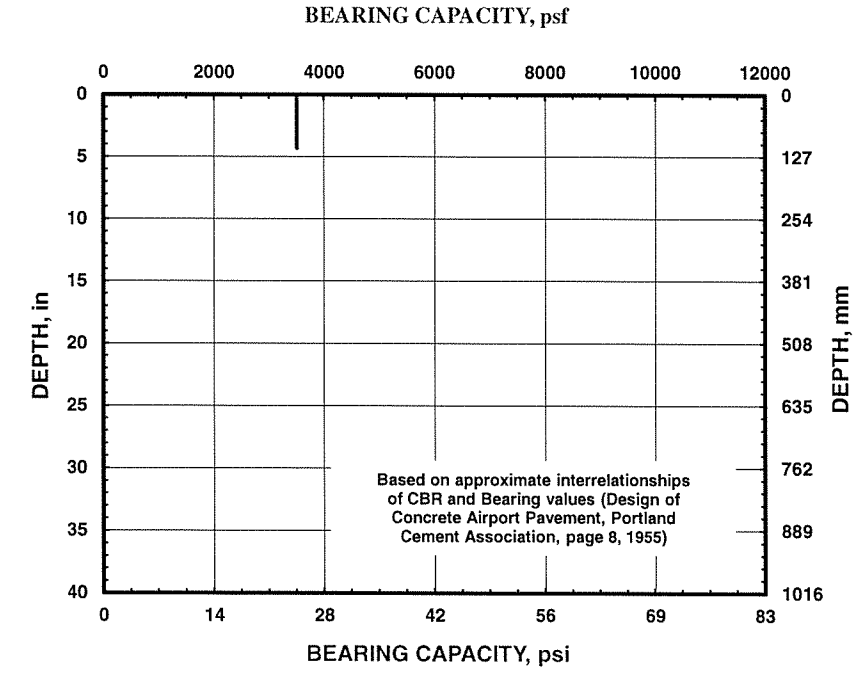
Project: *2511-00668-00* **Date:** 19/05/2016
Location: TP #4 **Soil Type(s):** Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
9	110	1





DCP TEST DATA

DCP #2
Depth =1.34m

Project: *2511-00668-00* **Date:** 19/05/2016
Location: TP #4 **Soil Type(s):** Gravel Fill

Hammer
- ○ 10.1 lbs.
- ◉ 17.6 lbs.
- ○ Both hammers used

Soil Type
- ○ CH
- ○ CL
- ◉ All other soils

No. of Blows	Accumulative Penetration (mm)	Type of Hammer
0	0	1
6	40	1