In-situ Permeability Testing at 14027 Hurontario Street, Inglewood, ON

Report #4545 – BVD Caledon
October 8, 2019

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1.0 INTRODUCTION

1.1 Terms of Reference

Mr. Bikram Dhillon (the Client), retained the services of A & A Environmental Consultants Inc. (A&A) to conduct in-situ permeability testing for a proposed development on a property located at 14027 Hurontario Street, Inglewood, Ontario. The in-situ permeability test was carried out using a Guelph Permeameter (GP) in accordance with ASTM D5126.There is no relationship between the client and A&A other than third party independent assessor. The site is located in the rural area of Inglewood, north of the City of Brampton. The subject site is located on the north corner of the intersection of Hurontario Street and King Street. The unit property is rectangular in shape and has approximately 31,800 m^2 of footprint area. This unit property is currently undeveloped with one vacant dilapidated building.

1.2 Scope of Work

The scope of work included the following where applicable:

- Identify Testing Locations;
- Identify the soil type at each location of testing;
- Perform a percolation test using Guelph Permeameter (GP) at each test location;
- Calculate The K_{FS}, infiltration rate, and percolation rate.

2.0 PERMEABILITY TEST METHOD AND FIELD PROCEDURES

2.1 Permeability Test Method

The in-situ permeability test was carried out using a GP in accordance with ASTM D5126. The GP measures permeability in the vadose zone above the water table. The vadose zone is where the soil is unsaturated. The steady flow of water from the unit produces a small inner saturated zone adjacent to the test holes. This is inside a larger wetted but unsaturated area. This creates a combined saturated-unsaturated flow. The GP measures the steady-state rate necessary to maintain a constant depth of water in a borehole above the water table. The field saturated hydraulic conductivity (K_{FS}) is calculated using and analytical solution.

2.2 Field Procedures

A summary of field procedures carried out is presented below:

- Excavate a cylindrical borehole to the desired depth in the material to be tested;
- Fill the permeameter with liquid and insert it in the well;
- Start the permeameter by raising the air-inlet tube out of the outlet port;
- Set the desired head (H) level by adjusting the height of the air-inlet tube;
- Monitor the rate of fall of the water surface in the reservoir until a steady rate, r, is attained.

The field work was carried out by an A&A consultant on August 9, 2019. Two infiltration tests were conducted using the GP within the proposed development. The test locations are shown in Figure 1. The test holes were prepared by using an auger that extended to approximately 0.5 m below ground level (mbgl). The shallow soils at the test hole locations are considered to be Category 3 according to the soil texture-structure category chart as seen in Appendix A for both testing locations. These soils are structured soils from clays through loams; also including unstructured medium and find sands. This soil type is most frequently applicable for agricultural soils. This soil is consistent with the borehole logs from the geotechnical investigation carried out on the site.

2.3 Hydraulic Conductivity and Infiltration Rate

The hydraulic conductivity measured in the unsaturated (vadose) zone is referred to as the "field-saturated" hydraulic conductivity (Kfs) (Reynolds et al, 1983). The Guelph Permeameter method measures the steady-state flow rate (Q) necessary to maintain a constant depth of water (H) in an uncased borehole. Kfs is then calculated from Q and H using the analytical solutions presented on Appendix A (after Reynolds et al., 1985).

The analytical solution input parameters include the following:

- Reservoir cross sectional area;
- Water height;
- Borehole radius;
- Soil texture; and
- Steady state rate of water level change.

An in-situ infiltration rate can be estimated using the empirical relationship between hydraulic conductivity and infiltration rate. The calculation of approximate infiltration rate is presented in Appendix A. Based on the results of the permeability testing, the soil hydraulic conductivity (Kfs), infiltration rate, and percolation time (T) at the two test locations are as follows:

Table 1 – Analytical Results

GP ID	K_{FS} (cm/s)	Approximate Infiltration Rate (mm/h)	Percolation Rate (min/cm)
GP1	1.27E-04	49.320	12.165
GP2	8.71E-05	44.585	13.457

The calculations for K_{FS}, infiltration, and percolation rate can be found in Appendix A for each testing location.

3.0 CONCLUSION

Mr. Bikram Dhillon (the Client), retained the services of A&A to conduct in-situ permeability testing for a proposed development on a property located at 14027 Hurontario Street, Inglewood, Ontario. The subject site is located on the north corner of the intersection of Hurontario Street and King Street. The unit property is rectangular in shape and has approximately 31,000 m^2 of footprint area. This unit property is currently undeveloped with one vacant dilapidated building. Based on the results of the permeability testing, the soil hydraulic conductivity (Kfs), infiltration rate, and percolation time (T) at the two test locations are as follows:

GP ID	K_{FS} (cm/s)	Approximate Infiltration Rate (mm/h)	Percolation Rate (min/cm)
GP1	1.27E-04	49.320	12.165
GP2	8.71E-05	44.585	13.457

SIGNED:

Thomas Demers, BASc. (Hons. Env.), EIT
Project Manager

I have reviewed Report #4545 – BVD Caledon In-situ Permeability Testing and concur with the findings herein.

SIGNED:

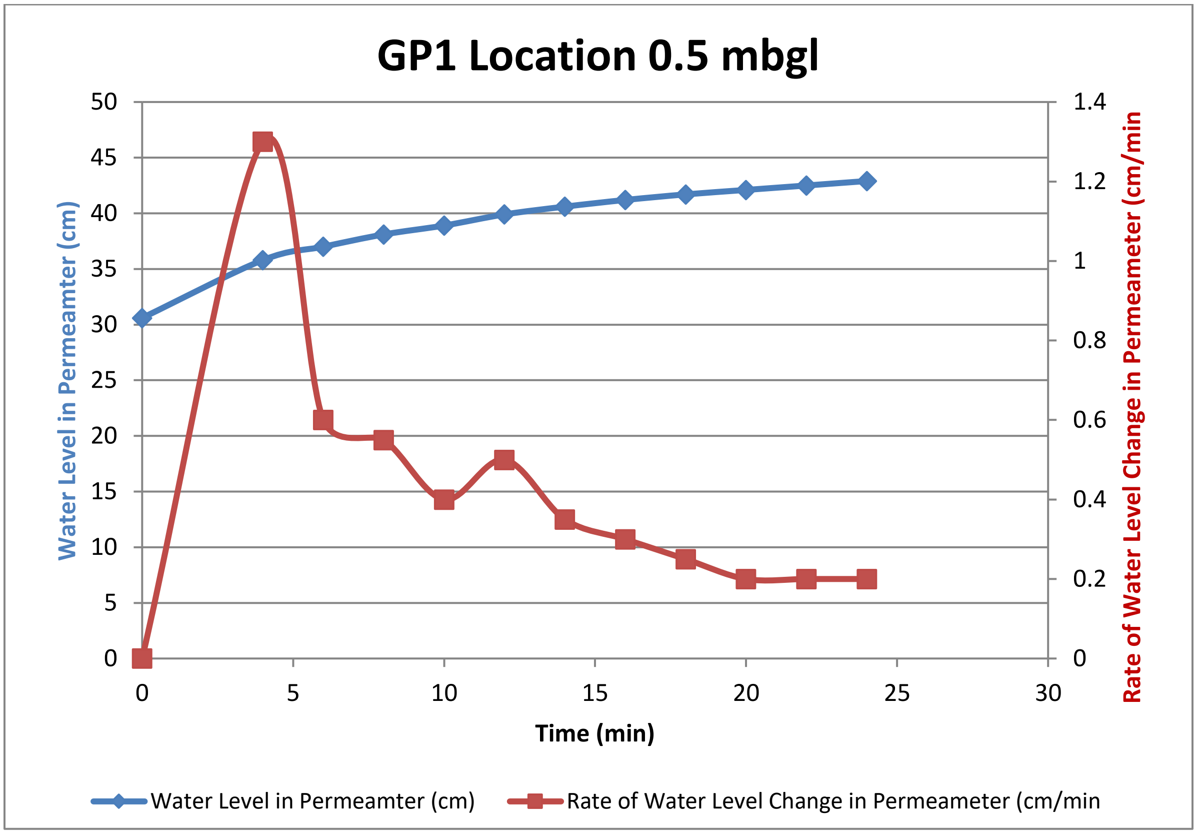
Dr. Ali A. Rasoul, Ph.D., EP, P. Geo., Q.P.
Senior Environmental Consultant

Figure 1 – Guelph Permeameter Testing Locations

APPENDIX A – Analytical Results

Guelph Permeameter Test Analysis

GP1



$$Hydraulic\ Conductivity, Field\ Saturated^{(1)} (K_{FS}) = 1.27E-04\ cm/s$$

$$Approximate\ infiltration\ rate^{(2)} = \left(\frac{K_{FS}}{6 \times 10^{-11}}\right)^{\frac{1}{3.7363}}\ mm/hr$$

$$= 49.320\ mm/hr$$

$$Percolation\ Time = (infilration\ rate\ )^{-1} \times (60\ min/hr) \times (10\ mm/cm)\ min/cm$$

$$= 12.165\ min/cm$$

Notes: (1) see Next page for calculation of Kfs

(2) Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997.

Supplementary Guidelines to Ontario Building Code 2018.

SG-6 Percolations Times and Soil Descriptions. Toronto, Ontario.

SOILMOISTURE® **Guelph Permeameter**

Input	(green)
Result	(yellow)

Single Head Method (1)

Reservoir Cross-sectional area in cm^2 (enter "35.22" for Combined and "2.16" for Inner reservoir):	35.22
Enter water Head Height ("H" in cm):	10
Enter the Borehole Radius ("a" in cm):	3
Enter the soil texture-structure category (enter one of the below numbers):	3

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
3. Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.
4. Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macropors, etc

Steady State Rate of Water Level Change ("R" in cm/min): 0.2000

Res Type	35.22				
H	10				
a	3		α^* =	0.12	cm^{-1}
H/a	3.333				
a*	0.12		C =	1.28754	
C0.01	1.218		Q =	0.1174	
C0.04	1.29				
C0.12	1.288		K_{fs} =	1.27E-04	cm/sec
C0.36	1.288			7.63E-03	cm/min
C	1.288			1.27E-06	m/sec
R	0.200			3.00E-03	inch/min
Q	0.117			5.01E-05	inch/sec
pi	3.142				
			Φ_m =	1.06E-03	cm^2/min

Single Head Method (2)

Reservoir Cross-sectional area in cm^2 (enter "35.22" for Combined and "2.16" for Inner reservoir):	35.22
Enter water Head Height ("H" in cm):	10
Enter the Borehole Radius ("a" in cm):	3
Enter the soil texture-structure category (enter one of the below numbers):	3

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
2. Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.
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Steady State Rate of Water Level Change ("R" in cm/min): 0.2000

Res Type	35.22				
H	10				
a	3		α^* =	0.12	cm^{-1}
H/a	3.33333				
a*	0.12		C =	1.28754	
C0.01	1.21841		Q =	0.1174	
C0.04	1.29023				
C0.12	1.28754		K_{fs} =	1.27E-04	cm/sec
C0.36	1.28754			7.63E-03	cm/min
C	1.28754			1.27E-06	m/ses
R	0.200			3.00E-03	inch/min
Q	0.1174			5.01E-05	inch/sec
pi	3.1415				
			Φ_m =	1.06E-03	cm^2/min

Calculation formulas related to shape factor (C). Where H_1 is the first water head height (cm), H_2 is the second water head height (cm), a is borehole radius (cm) and α^* is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only C_1 needs to be calculated while for two-head method, C_1 and C_2 are calculated (Zang et al., 1998).

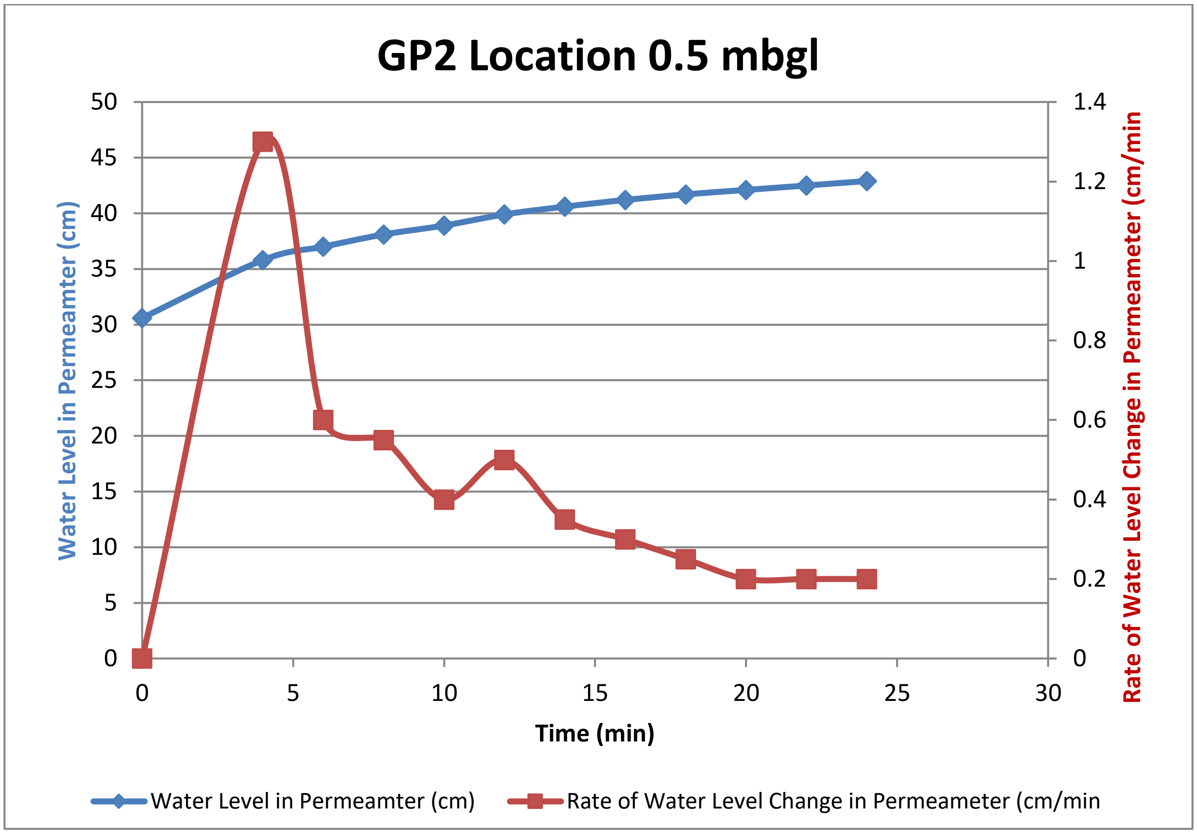
Soil Texture-Structure Category	$\alpha^*(cm^{-1})$	Shape Factor
Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.	0.01	$C_1 = \left(\frac{H_2/a}{2.081 + 0.121\,(H_2/a)}\right)^{0.672}$
Soils which are both fine textured (clayey or silty) and unstructured; may also include some fine sands.	0.04	$C_1 = \left(\frac{H_1/a}{1.992 + 0.091(H_1/a)}\right)^{0.683}$ $C_2 = \left(\frac{H_2/a}{1.992 + 0.091(H_2/a)}\right)^{0.683}$
Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093(H_1/a)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093(H_2/a)}\right)^{0.754}$
Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093(H_1/a)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093(H_2/a)}\right)^{0.754}$

Calculation formulas related to one-head and two-head methods. Where $\bar{R}$ is steady-state rate of fall of water in reservoir (cm/s), K_{fs} is Soil saturated hydraulic conductivity (cm/s), Φ_m is Soil matric flux potential (cm^2/s), α^* is Macroscopic capillary length parameter (from Table 2), a is Borehole radius (cm), H_1 is the first head of water established in borehole (cm), H_2 is the second head of water established in borehole (cm) and C is Shape factor (from Table 2).

One Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$	$K_{fs} = \frac{C_1 \times Q_1}{2\pi H_1^2 + \pi a^2 C_1 + 2\pi\left(\frac{H_1}{\alpha^*}\right)}$ $\Phi_m = \frac{C_1 \times Q_1}{(2\pi H_1^2 + \pi a^2 C_1)\alpha^* + 2\pi H_1}$
One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \frac{H_2 C_1}{\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $G_2 = \frac{H_1 C_2}{\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $K_{fs} = G_2Q_2 - G_1Q_1$ $G_3 = \frac{(2H_2^2 + a^2C_2)C_1}{2\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $G_4 = \frac{(2H_1^2 + a^2C_1)C_2}{2\pi\left(2H_1H_2(H_2 - H_1) + a^2(H_1C_2 - H_2C_1)\right)}$ $\Phi_m = G_3Q_1 - G_4Q_2$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	

Guelph Permeameter Test Analysis

GP2



$$Hydraulic\ Conductivity, Field\ Saturated^{(1)}(K_{FS}) = 8.71E - 05\ cm/s$$

$$Approximate\ infiltration\ rate^{(2)} = \left(\frac{K_{FS}}{6 \times 10^{-11}}\right)^{\frac{1}{3.7363}}\ mm/hr$$

$$= 44.585\ mm/hr$$

$$Percolation\ Time = (infilration\ rate)^{-1} \times (60\ min/hr) \times (10\ mm/cm)\ min/cm$$

$$= 13.457\ min/cm$$

Notes: (1) see Next page for calculation of Kfs

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SOILMOISTURE® **Guelph Permeameter**

Input
Result

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Enter the Borehole Radius ("a" in cm):	3
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Steady State Rate of Water Level Change ("R" in cm/min): 0.2000

Res Type	35.22			
H	15			
a	3	α*=	0.12	cm^{-1}
H/a	5			
a*	0.12	C =	1.66689	
C0.01	1.518	Q =	0.1174	
C0.04	1.629			
C0.12	1.667	K_{fs} =	8.71E-05	cm/sec
C0.36	1.667		5.23E-03	cm/min
C	1.667		8.71E-07	m/sec
R	0.200		2.06E-03	inch/min
Q	0.117		3.43E-05	inch/sec
pi	3.142			
		Φ_m =	7.26E-04	cm^2/min

Single Head Method (2)

Reservoir Cross-sectional area in cm^2 (enter "35.22" for Combined and "2.16" for Inner reservoir):	35.22
Enter water Head Height ("H" in cm):	15
Enter the Borehole Radius ("a" in cm):	3
Enter the soil texture-structure category (enter one of the below numbers):	3

1. Compacted, Structure-less, clayey or silty materials such as landfill caps and liners, lacustrine or marine sediments, etc.
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Res Type	35.22			
H	15			
a	3	α*=	0.12	cm^{-1}
H/a	5			
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C0.01	1.51827	Q =	0.1174	
C0.04	1.62914			
C0.12	1.66689	K_{fs} =	8.71E-05	cm/sec
C0.36	1.66689		5.23E-03	cm/min
C	1.66689		8.71E-07	m/ses
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Calculation formulas related to shape factor (C). Where H_1 is the first water head height (cm), H_2 is the second water head height (cm), a is borehole radius (cm) and α^* is microscopic capillary length factor which is decided according to the soil texture-structure category. For one-head method, only C_1 needs to be calculated while for two-head method, C_1 and C_2 are calculated (Zang et al., 1998).

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Most structured soils from clays through loams; also includes unstructured medium and fine sands. The category most frequently applicable for agricultural soils.	0.12	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093(H_1/a)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093(H_2/a)}\right)^{0.754}$
Coarse and gravely sands; may also include some highly structured soils with large and/or numerous cracks, macro pores, etc.	0.36	$C_1 = \left(\frac{H_1/a}{2.074 + 0.093(H_1/a)}\right)^{0.754}$ $C_2 = \left(\frac{H_2/a}{2.074 + 0.093(H_2/a)}\right)^{0.754}$

Calculation formulas related to one-head and two-head methods. Where R is steady-state rate of fall of water in reservoir (cm/s), K_{fs} is Soil saturated hydraulic conductivity (cm/s), Φ_m is Soil matric flux potential (cm²/s), a^* is Macroscopic capillary length parameter (from Table 2), a is Borehole radius (cm), H_1 is the first head of water established in borehole (cm) , H_2 is the second head of water established in borehole (cm) and $C$is Shape factor (from Table 2).

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One Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$	
Two Head, Combined Reservoir	$Q_1 = \bar{R}_1 \times 35.22$ $Q_2 = \bar{R}_2 \times 35.22$	$G_1 = \frac{H_2 C_1}{\pi(2H_1 H_2(H_2 - H_1) + a^2(H_1 C_2 - H_2 C_1))}$ $G_2 = \frac{H_1 C_2}{\pi(2H_1 H_2(H_2 - H_1) + a^2(H_1 C_2 - H_2 C_1))}$ $K_{fs} = G_2 Q_2 - G_1 Q_1$ $G_3 = \frac{(2H_2^2 + a^2 C_2)C_1}{2\pi(2H_1 H_2(H_2 - H_1) + a^2(H_1 C_2 - H_2 C_1))}$ $G_4 = \frac{(2H_1^2 + a^2 C_1)C_2}{2\pi(2H_1 H_2(H_2 - H_1) + a^2(H_1 C_2 - H_2 C_1))}$ $\Phi_m = G_3 Q_1 - G_4 Q_2$
Two Head, Inner Reservoir	$Q_1 = \bar{R}_1 \times 2.16$ $Q_2 = \bar{R}_2 \times 2.16$	