
**PROPOSED RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**



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1.0 INTRODUCTION

1.1 General

The proposed development is located on lots 521 and 525 Essa Road approximately 250m north of the Essa Road and Mapleton Avenue intersection. The property is legally described as Part of Lot 10, Lot 11, and Lot 12 of Registered Plan 1080 in the City of Barrie.

The subject site is approximately 0.44 hectares (1.1 acres) in area and is currently occupied by two (2) single-family residential homes. Access to the site is provided directly from Essa Road by two (2) separate asphalt driveways. The site is bounded by Essa Road to the east, a multi-residential senior citizen development to the north, a commercial development to the south, and a residential subdivision to the west. The location of the subject site is illustrated on Figure 1.

The property owner is proposing to construct three (3) blocks of three-storey back to back townhouse units, consisting of 12 units per block, and 12 row townhouse units. Access to the development will be provided from Essa Road in the southeast corner of the site.

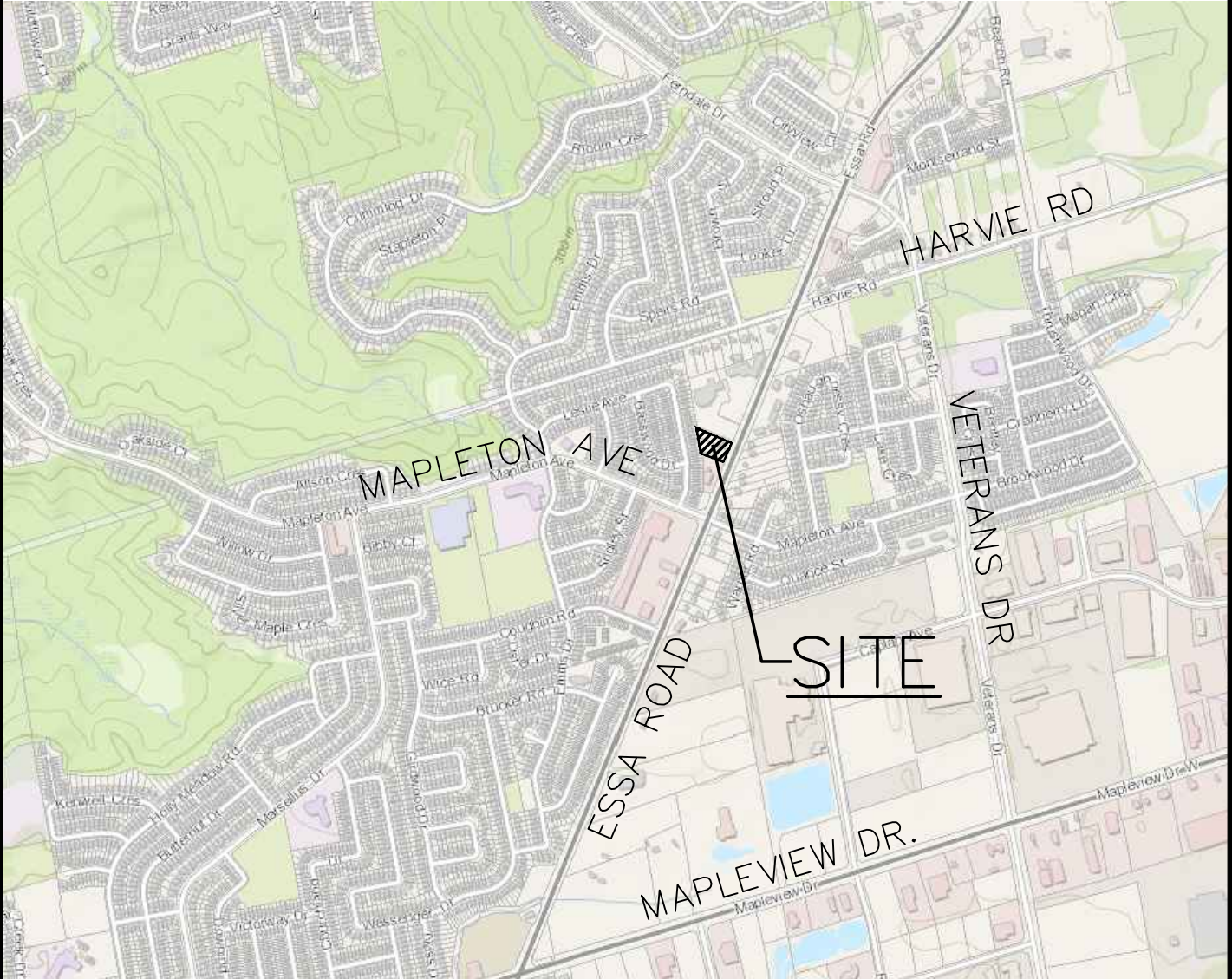
1.2 Purpose and Scope

Pinestone Engineering Ltd (PEL) has been retained by the property owner to prepare a Storm Water Management Report in support of a Site Plan Approval. The report describes the storm water quality and quantity control strategy for the site.

2.0 REFERENCE REPORTS

The following reports and studies have been used for reference in the preparation of this Storm Water Management Report:

- i) *City of Barrie Storm Drainage and Storm Water Management Policies and Design Guidelines, prepared by the City of Barrie Engineering Department, December 2017*
- ii) *LSCRCA Technical Guidelines for Storm Water Management Submissions, Effective Date: September 1, 2016*
- iii) *Lake Simcoe Protection Plan, June 2009*
- iv) *City of Barrie Development Manual, prepared by the City of Barrie Engineering Department, December 2017*
- v) *Ministry of the Environment Storm Water Management Planning and Design Manual, March 2003.*
- vi) *Low Impact Development Manual prepared by Credit Valley Conservation and Toronto and Region Conservation, 2010*
- vii) *City of Barrie Infiltration Low Impact Development Screening Process, 2017*
- viii) *LSCRCA Phosphorus Offsetting Policy, Effective Date: September, 2017*
- ix) *LSCRCA Water Budget Offsetting Policy, May 2019*




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521 AND 525 ESSA ROAD RESIDENTIAL DEVELOPMENT			
LOCATION PLAN			
DATE: MAY 2020	SCALE: N.T.S.	PROJECT No. 20-11501-B	FIGURE No. FIGURE 1

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3.0 EXISTING CONDITIONS

3.1 General

The site is currently occupied by two (2) detached single family residential dwellings. Access to both properties is provided directly from the recently reconstructed Essa Road. A 3m wide multi-use asphalt trail runs along the frontage of the property between Essa Road and the east property boundary. Tree stands exist along the south, and west property borders. The site is located within the City's urban servicing area and municipal services are available for connection along Essa Road. Existing services to the residential homes not being utilized for the proposed development will be removed.

3.2 Topography

Based on a review of the topographic survey provided by A. Aziz Surveyors, the property is relatively flat but generally slopes from a high point towards the west and eastern boundaries of the subject side. Elevations across the site range between 314.49m ASL at the northeast corner of the site to 313.71m ASL at the southwest corner.

3.3 Site Geology

A geotechnical investigation was completed by Peto MacCallum Ltd. in July 2018. Field work for this investigation consisted of 8 boreholes advanced to approximately 5m deep. Based on our review of their report, boreholes reveal topsoil was encountered over fill and native layers of clayey silty sand, and sand and silt till. Groundwater levels were monitored and recorded at each borehole numbers 1, 4, and 7 and range from 1.1m to 2.3m below the ground surface. The borehole groundwater monitoring results are tabulated in the hydrogeological report submitted by Peto MacCallum Ltd. in May 2019.

Based on the existing clay soil condition encountered throughout the site, infiltration of storm water into underlying native soils is not recommended.

A copy of the geotechnical investigation and hydrogeological report prepared by Peto MacCallum Ltd. are included in Appendix A.

3.4 Drainage Conditions

Drainage from the site is conveyed in the form of overland sheet flow towards the existing ditch inlet catch basins located at the northwest, and southern property limits. A small portion of external drainage enters the site from the existing multi-residential development to the north as overland sheet flow.

A 750mm diameter storm sewer exists along the frontage of the subject site on Essa Road and conveys drainage southerly towards Mapleton Avenue. Drainage is conveyed easterly along Mapleton Avenue before ultimately discharging to the Whiskey Creek Park storm water management facility (City Pond WK-05). This site is considered a "major

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development” as defined in the Lake Simcoe Protection Plan, therefore stormwater quality and quantity control measures are required in accordance with the Lake Simcoe Regional Conservation Authority (LSRCA).

4.0 PROPOSED DEVELOPMENT

The proposed development on the property consists of three (3) 12 unit, three-storey, back to back townhouse blocks, and 12 standard townhouses with individual driveways for a total of 48 units. Parking for the back-to-back townhouses will be provided by at grade parking under the building. Two (2) shared terrace areas and a landscape amenity area are also proposed. Access to the development will be provided by one (1) asphalt driveway from Essa Road in the southeast corner of the site.

As part of the site plan submission requirements, a hydrant flow test was also completed by Vipond Inc. on April 14th, 2020. The results indicate a static pressure of 50 psi (344 kPa) and residual pressure of 48 psi (331 kPa) at a flowrate of 1216 GPM (76.7 L/sec). A fire flow analysis memo has been submitted under separate cover.

Catchment 201, consisting of drainage from the buildings and driveways, will be directed to catch basins installed within the driveway. Stormwater will be attenuated within an inground SWM tank constructed below the foundation slab of Building #1. Attenuated flows will outlet through a Contech Stormfilter treatment vault prior to discharging offsite via a storm sewer connection to the existing storm sewer network on Essa Road. Catchment 202 consisting of landscape areas around the perimeter of the development will flow offsite uncontrolled to the existing perimeter catch basins like pre-development conditions.

Water and sanitary servicing for the development will be provided from existing services along Essa Road. It is noted that there may be an existing well and septic system on the property. If encountered, the well should be abandoned in accordance with Ontario Regulation 903. Any septic / pump tank(s) should be pumped out, crushed in place and material disposed of off-site at an approved dumpsite. Leaching bed pipes should also be removed if encountered on site.

5.0 HYDROLOGY

5.1 Design Criteria

Based on a review of the City of Barrie’s Storm Water Management (SWM) Guidelines and LSRCA Technical Guidelines, the following design criteria, in accordance with the current MECP SWM Planning and Design Manual (MECP, 2003) were established for the proposed development:

Quantity Control:

- Peak flow attenuation for the 2-year through 100-year storm events to pre-

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development rates based on the Modified Rational Method using the City of Barrie's WPCC IDF parameters.

Quality Control:

- The City of Barrie and the LSRCA in accordance with Ontario Regulation 219/09 regarding water quality and phosphorus loading to Lake Simcoe, requires that all new storm water management facilities provide as a minimum the “enhanced” level of protection in accordance with the MECP Storm Water Management Planning and Design Manual (MECP, 2003).
- Preparation of phosphorus and water balance calculations to meet City of Barrie and LSRCA requirements and the Lake Simcoe Protection Plan.
- Preparation of detailed erosion, sediment control and construction mitigation plan to be implemented as part of the construction program.

5.2 Design Storms

We have selected the following design storms as part of our evaluation:

- 2-year design storm
- 5-year design storm
- 10-year design storm
- 25-year design storm
- 50-year design storm
- 100-year design storm

Rainfall intensity - duration frequency (IDF) values for the Barrie Area were entered into an equation that expresses the time relationship intensity for specific frequency, in the form of:

$$i = \frac{a}{(t+b)^c}$$

where: i = intensity, mm/hr.
 t = Time of concentration, minutes
 a,b,c = constants developed to fit IDF curve

The design storm parameters are outlined in Table 1 below. A copy of the IDF values taken from the City's SWM guidelines is also included in Appendix B.

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**Table 1
Design Storm Parameters - Chicago Rainfall Distribution**

Rainfall Event	Parameter		
	A	B	C
2 Yr	678.085	4.699	0.7810
5 Yr	853.608	4.699	0.7660
10 Yr	975.865	4.699	0.7600
25 Yr	1146.275	4.922	0.7570
50 Yr	1236.152	4.699	0.7510
100 Yr	1426.408	5.273	0.7590

5.3 Drainage Catchments

One (1) pre-development and two (2) post-development catchments have been delineated for the site in order to estimate the corresponding peak runoff rates for the site. The pre-development catchment area represents the existing condition of the proposed development area, which consists of single-family residential development. The post-development catchments represent the proposed grading concept for the development area. The pre-development and post-development catchment parameters are listed in Table 2.

**Table 2
Sub-catchment Parameters**

Catchments	Area (m ²)	Slope (%)	Composite Runoff Coefficient "C"
Pre-Development			
101	4428	0.5	0.34
Post-Development			
201	3283	1.5	0.86
202	1145	1.0	0.27

Pre-development and post-development catchment areas are illustrated on drawings PRE-1 and POST-1 included in Appendix D (envelope at the rear of this report). Composition runoff values were increased for the 10 through 100-year storm events per Table 3.2 in the City's SWM guidelines.

5.4 Rational Method Results

The results from the 2 through 100-year peak storm events are listed in Table 3.

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**Table 3
Rational Method – Peak Flows**

	2Yr	5Yr	10Yr	25Yr	50Yr	100Yr
Pre-Development (m³/sec)						
Catchment 101	0.035	0.046	0.053	0.068	0.083	0.095
Total Pre-Development	0.035	0.046	0.053	0.068	0.083	0.095
Post Development (m³/sec)						
Catchment 201	0.065	0.086	0.100	0.128	0.150	0.164
Catchment 202	0.007	0.009	0.011	0.014	0.017	0.019
Total Post Development	0.072	0.095	0.110	0.142	0.166	0.183

Based on the calculated results using the Modified Rational Method, it is expected that post-development flows directed to Essa Road will increase due to the proposed construction of the buildings and paved driveway. Modified Rational Method design calculations are included in Appendix B.

6.0 STORM WATER MANAGEMENT PLAN

6.1 Quantity Control

As noted in the comparison of the pre-development and post-development flows, an increase in runoff will occur due to the proposed construction of the buildings and paved access driveway. To satisfy the selected design criteria, peak flow attenuation of post-development flows to pre-development levels for all storm events up to and including the 100-year storm event will be provided by directing roof drainage and driveway runoff to the proposed subsurface storage tank located beneath the parking level.

Peak flow attenuation for catchment 201 (buildings and asphalt driveway) will be achieved using a 91.2 cubic meter subsurface storage facility consisting of a cast in place holding tank constructed as part of the building construction. Peak flows will be controlled using a 130mm dia. orifice plate installed on the outlet pipe from CBMH#1 at an invert elevation of 312.50m. The maximum ponding elevation for the 5-year and 100-year events will be 313.27m and 314.21m, respectively. This limits ponding below the surface of the proposed driveway. Major overland flow from catchment 201 will overflow out of the grate at CBMH#1 and will be directed to Essa Road through the entrance once ponding levels exceed 314.40m within the driveway. The underside of the proposed tank will be set at an elevation of 314.45m which provides 0.24m of freeboard from the 100-year ponding limit. The SWM tank will also be equipped with a watertight lockable grate.

Drainage from catchment 202 which includes the perimeter landscape areas will continue to drain offsite uncontrolled like pre-development conditions. The existing property line

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drainage swale along the north limit is proposed to be re-graded at 0.5-1.0% to encourage positive drainage to the existing rear yard catch basin located in the City’s drainage easement in the northwest corner of the site. The swale design includes a Sorbtive Media trench equipped with an underdrain that will be connected to the existing rear yard catch basin.

The stage-storage-discharge relationship of the proposed storage facilities is summarized in Table 4.

**Table 4
Stage-Storage-Discharge Relationship of Storage Cells**

	Description	Control Stage (m)	Elevation (m)	Volume (m3)	Discharge (m3)
Catchment 201: Storage Tank (130mm dia. orifice at CBMH#1)	Orifice Invert	0.00	312.50	0	0.0000
	Tank Bottom	0.05	312.55	0.5	0.0013
	Contour	0.25	312.75	9.6	0.0157
	Contour	0.45	312.95	19.2	0.0226
	Contour	0.65	313.15	28.8	0.0279
	Contour	0.85	313.35	38.4	0.0323
	Contour	1.05	313.55	48.0	0.0362
	Contour	1.25	313.75	57.6	0.0397
	Contour	1.45	313.95	67.2	0.0429
	Contour	1.65	314.15	76.8	0.0459
	Contour	1.85	314.35	86.4	0.0487
	Driveway Overflow	1.90	314.40	88.8	0.0494
	U/S Tank	1.95	314.45	91.2	0.1937

Detailed Modified Rational Method calculations, including the control sizing for the orifice and weir are included in Appendix B. The location of the storm water management facilities and further design details are illustrated on the engineering drawings included in Appendix D (envelope at the rear of this report).

Table 5 summarizes the effectiveness of the proposed storm water management attenuation feature based on the hydrologic model results.

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**Table 5
Model Results – Modified Rational Method**

	2Yr	5Yr	10Yr	25Yr	50Yr	100Yr
Pre-Development (m³/sec)						
Catchment 101	0.035	0.046	0.053	0.068	0.083	0.095
Total Pre-Development	0.035	0.046	0.053	0.068	0.083	0.095
Post-Development (m³/sec)						
Catchment 201	0.065	0.086	0.100	0.128	0.150	0.164
Catchment 202	0.007	0.009	0.011	0.014	0.017	0.019
Total Post-Development	0.072	0.095	0.110	0.142	0.166	0.183
Post-Development with SWM (m³/sec)						
Catchment 201 (controlled)	0.026	0.030	0.034	0.040	0.044	0.047
Catchment 202 (uncontrolled)	0.007	0.009	0.011	0.014	0.017	0.019
Total Post-Development with SWM	0.033	0.040	0.044	0.054	0.061	0.066

6.2 Quality Control (Total Suspended Solids, Total Phosphorus, and Others)

The primary objective of the storm water management plan for this development is to maintain acceptable water quality within the receiving storm sewer and ultimate outfall, Lake Simcoe by maintaining existing site drainage patterns and flowrates. In order to provide water quality enhancement to an “enhanced” level of protection (80% TSS removal) for this development, we have incorporated a “treatment train” approach consisting of the following elements:

- The installation of a Contech Stormfilter Vault-Model SFPD 0811 (verified to remove a minimum of 80% TSS and 86% TP) sized for 80% TSS removal and 90% runoff capture. This underground stormwater treatment device houses rechargeable, media-filled cartridges that trap particulates and adsorb pollutants from stormwater runoff such as total suspended solids, hydrocarbons, nutrients, and metals.
- Provision of soft landscaping where feasible.
- Lot grading using minimal surface slopes.
- Suitable construction mitigation measures to be utilized during the site development.

The potential treatment alternatives have been evaluated with respect to their applicability for this development and implemented in a manner to achieve the best total suspended solids (TSS) removal possible. Table 6 summarizes the proposed measures that in conglomeration will provide an overall TSS removal of greater than or equal to 80% which

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meets or exceeds the criteria outlined.

**Table 6
Proposed Approach for Water Quality Treatment**

Catchment	Method	Effective TSS	Area (m2)	% Area of Site	Overall TSS Removal
201 - Rooftops and asphalt driveway	SFPD 0811 Stormfilter Vault	80%	3283	74	59.2
202 - Perimeter uncontrolled landscape area	Natural Filtration/Evapotranspiration	80%	1145	26	20.8
Total			4428	100	80.0

The SFPD 0811 Stormfilter Vault design report, performance verification, and the inspection and maintenance procedure are included in Appendix C.

According to section 2.3.2 of the LSRCA Technical Guidelines, any “major development” requires the removal of 80% of the annual Total Phosphorus (TP) load. The MECP’s P-Tool was utilized to determine pre and post development phosphorus loadings for the proposed development area. In the pre-development condition, low intensity residential development was used to determine the phosphorus loading. For the post-development condition, high intensity residential development was assumed for the development area. The calculated phosphorus loadings are illustrated in Table 7.

**Table 7
Pre & Post Phosphorus Loading**

	P Load (kg/yr)
Pre-Development	0.06
Post Development with no BMP's	0.58
Post Development with BMP's	0.15

Contech Engineered Solutions was retained to detail that the proposed Stormfilter Vault Model SFPD 0811 will provide an 86% reduction in total phosphorus (TP) for catchment 201, per the performance verification. Sizing calculations and a design report for the proposed treatment vault is included in Appendix C. To provide additional TP removal for catchment 202, the proposed side yard swale will include an Imbrium Systems Sorbtive Media amended trench. The trench will consist of a layer of engineered soil, mixed with Imbrium Sorbtive Media for enhanced total phosphorus removal benefit, and an underdrain encased in washed clearstone. Due to the seasonal high groundwater table, the trench will be wrapped in an impermeable liner. Per the Centre for Alternative Wastewater Treatment (CAWT) Field Report, the Imbrium Systems Sorbtive Media is accredited with a TP removal

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benefit of 90%. Refer to the performance report included in Appendix C. An overall 74.1% total post-development reduction can be achieved on the site by implementing best management practices, when considering the poor soil conditions for the purposes of infiltration for further phosphorus removal. Pre and post development phosphorus budget calculations are included in Appendix B.

The site must also conform to the Lake Simcoe Phosphorus Offsetting Program (LSPOP). The LSPOP requires that all new development must control 100% of the phosphorus from leaving the property, in order to maintain or improve the water quality of Lake Simcoe. Since this site does not achieve the zero-export target, a phosphorus budget is required in accordance with the LSPOP and the Lake Simcoe Protection Plan (LSPP).

Given that the phosphorus reduction needed to achieve net zero is 0.15 kg/year, the total amount of phosphorus needing to be offset is as follows:

$$0.15 \text{ kg/year} \times 2.5 \text{ (offset ratio)} = \mathbf{0.375 \text{ kg/year}}$$

A compensation fee is required by the LSRCA in accordance with the LSPOP for the phosphorus deficit of 0.375 kg/year.

As noted in the MECP's Storm Water Management Planning and Design Manual (SWMPD), an increase in water temperature is inevitable if an area is developed (i.e., urbanization causes stormwater temperature increases). The following techniques are proposed as "best management practices" to minimum the temperature increase associated with urbanization for this project:

- Surface grading that optimizes stormwater conveyance to subsurface infrastructure and eliminates surface extended detention storage.
- During design storm events up to and including the 100-year event, storm runoff will be conveyed underground using a network of storm sewer and attenuated within a subsurface SWM tank. From the report "Thermal Impacts of Urbanization included Preventative and Mitigation Techniques" published by the Credit Valley Conservation Authority (2011), the cooling of rainwater can occur in any number of ways that incorporates some form of buried conveyance method (storm-sewer network). Additional cooling of storm water is expected to be provided by the conveyance system prior to discharging to the existing storm sewer under Essa Road as heat is transferred from the stormwater to subsurface soils adjacent to the pipe via the pipe's walls.

As a result of road maintenance activities (sanding and salting) during the winter, there is an increased risk of groundwater contamination and clogging of subsurface filters. To minimize salt contamination, the use of minimal asphalt grades, and provision of snow storage areas have been delineated for the site that will drain into the proposed SWM facility during Spring thaw. Road sweeping once snowmelt is complete would also reduce the concentration of winter salt entering the storm sewer.

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6.3 Volume Control

Since the proposed development works for this site fall under the definition of a “major development” as outlined in the LSPP, volume control of stormwater is required in accordance with Section 2.2.2.2 of the LSRCA Technical Guidelines. Due to the high ground water table (1.1-2.3m below the ground surface), and poor native soil condition (silt and clay), infiltration-based practices are not recommended for use on this site. This property is considered a “site with restrictions” and is subject to Flexible Treatment Alternatives as outlined in Section 2.2.2.2 of the Technical Guidelines. To meet the requirements stipulated for Alternative #1, the site must retain runoff from a 12.5mm storm event for all impervious surfaces. For an overall impervious surface area of 3058m², 38.2m³ of runoff storage is required onsite. To provide additional runoff storage onsite, the proposed side yard swale will include a Sorbtive Media Trench with an engineered media layer, underdrain, and gravel storage layer. The trench will be wrapped in an impermeable liner because of the shallow condition of the seasonal groundwater table. With the addition of the Sorbtive Media Trench, the site will provide a runoff storage volume of 17.2m³ within the void space of the engineered media and gravel storage layer. With limited useable area, poor soil permeability, and high groundwater conditions, best management practices will not achieve the requirements of Alternative #1. As such, the requirements of Alternative #2 will be analyzed. To meet the requirements stipulated for Alternative #2, the site must achieve volume reduction to the maximum extent practicable (retain runoff from a 5mm storm event for all impervious surfaces). For an overall impervious surface area of 3058m², 15.3m³ of runoff storage is required onsite. With the implementation of the proposed Sorbtive Media Trench, a runoff storage volume of 17.2m³ will be provided onsite, which meets the criteria for Alternative #2 and satisfies the volume control requirement.

6.4 Water Budget

As per City policy 4.1.3 of the Storm Water Policy and Design Guidelines, sites less than 5 ha shall minimize any anticipated changes in the water balance between pre-development and post-development conditions and shall provide a minimum infiltration equivalent to the first 5mm of rainfall. Based on a total development area of 4,428m², the first 5mm of rainfall to be retained on the site for infiltration equates to 22.1m³. Initial abstraction values provided in the City’s SWM guidelines are shown in Table 8.

**Table 8
Initial Abstraction Values**

Cover	Initial Abstraction / Depression Storage (mm)
Woods	10
Meadows	8
Cultivated	7
Lawns	5
Impervious areas	2

Adapted from UNESCO, Manual on Drainage in Urbanized Areas, 1987

Using the values provided in Table 10 above, approximately 13.0m³ of rainfall will be

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retained on the site through initial abstraction in the post re-development condition.

Based on a review of the geotechnical report prepared for the site, and the infiltration techniques outlined in the MECP SWM Manual (2003) and the LID Manual (2010), infiltration measures are not suitable for the site given the poor soil condition and high seasonal groundwater table.

A water budget analysis was conducted in accordance with the LSRCA Technical Guidelines and the Lake Simcoe Protection Plan (LSPP) Water Budget Policy. The analysis follows the Thornthwaite and Mather approach, where surplus is estimated based on precipitation minus evapotranspiration (Steenhuis and Van Der Molen, 1986). The infiltration portion of the surplus is estimated by applying infiltration factors from Table 3.1 of the MECP SWMPD Manual. The water balance summary is provided in Table 9 below. A copy of the water budget analysis is provided in Appendix B.

**Table 9
Water Balance Summary**

Characteristic	Site		
	Pre-Development	Post-Development	Change (Pre to Post)
Inputs (Volumes)			
Precipitation (m3/yr)	4131	4131	0.0%
Run-on (m3/yr)	0	0	0.0%
Other Inputs (m3/yr)	0	0	0.0%
Total Inputs (m3/yr)	4131	4131	0.0%
Output (Volumes)			
Precipitation Surplus (m3/yr)	1812	2717	33.3%
Net Surplus (m3/yr)	1812	2716	33.3%
Evapotranspiration (m3/yr)	2318	1415	-63.9%
Infiltration (m3/yr)	665	261	-155.0%
Rooftop Infiltration (m3/yr)	0	0	0.0%
Total Infiltration (m3/yr)	665	261	-155.0%
Runoff Pervious Areas (m3/yr)	438	174	-152.1%
Runoff Impervious Areas (m3/yr)	709	2281	68.9%
Total Runoff (m3/yr)	1147	2455	53.3%
Total Outputs (m3/yr)	4131	4131	0.0%

Based on the results of the water balance analysis, the site yields an infiltration rate of 665 m³/year in the pre-development condition and 261 m³/year in the post-development condition. Since infiltration measures are not recommended, due to the seasonally high

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groundwater table and the clay soil condition, an offsetting fee is required by the LSRCA, in accordance with the LSPP Water Budget Policy, for the water balance deficit of 404 m³/year (665 m³/year – 261 m³/year).

7.0 EROSION AND SEDIMENT CONTROL

7.1 Mitigation Measures

Sedimentation and erosion control measures are required during construction and until such a time that site development has been completed and the driveway area has been paved.

The use of various siltation control measures will be implemented to protect the adjacent properties and receiving waterbodies from migrating sediments. These works include but may not be limited to:

- Installation of siltation fencing along the perimeter of the development area.
- Filter cloth / silt sack placement over drains.
- Installation of vehicle tracking mud mat at the entrance to the site.

Prior to carrying out site grading the siltation barriers and mud mats shall be in place. Any onsite storm sewer works will not be permitted to outlet to the municipal sewers until the site has been stabilized. The filter cartridges in the proposed Stormtech Vault should not be installed until the site has been stabilized.

Other temporary installations of silt fence or other appropriate measures may be required during grading to minimize silt migration from the site. The measures will need to be removed, replaced, and relocated as required during the construction period until the site works have been completed and vegetation established. During construction, all stockpiled material will be placed up-gradient of the siltation controls with additional siltation fencing installation around the stockpiles.

7.2 Monitoring and Maintenance During Construction

It is the responsibility of the contractor and owner to maintain the siltation control devices until suitable grass cover has been established upon completion of construction.

A regular review of the facilities by the contractor should be carried out during the construction period to ensure that the facilities are being properly maintained, and if necessary, replaced. Inspection reports are to be completed monthly and distributed to the owner, contractor, and City.

If site works are to continue through the winter and spring the engineer should be contacted by the owner to review the measures in place with the contractor on a regular basis to ensure that the facilities are adequate and in good working order.

RESIDENTIAL TOWNHOUSE DEVELOPMENT 521 & 525 ESSA ROAD – CITY OF BARRIE STORM WATER MANAGEMENT REPORT

All reasonable methods to control erosion and sedimentation are to be taken during construction. The contractor should inspect the siltation devices immediately after each rainfall. Damaged devices should be repaired immediately, and additional devices installed if necessary. Silt should be removed from the fencing and related siltation devices when deposits are noticeable.

Should the erosion control measures fail, and sediment migrate beyond the limits of the control works, additional sedimentation facilities may need to be installed in the area of the migration and down gradient to contain the sediment.

8.0 SUMMARY AND CONCLUSIONS

The findings of this report are summarized as follows:

- Attenuation of peak post-development flowrates to below pre-development levels will be provided by utilizing a subsurface storage tank located beneath the parking level. A 130mm dia. orifice plate installed on the outlet pipe from CBMH#1 will control flows to or below pre-development levels.
- Quality control for the development will be provided by a Contech Stormfiler Vault (Model SFPD 0811) sized to provide a minimum of 80% TSS removal and 86% removal of annual total phosphorus.
- Post-development phosphorus loadings for the site will be mitigated with the installation of a Contech Stormfiler Vault for catchment 201, and a Sorbtive Media trench for catchment 202. An offsetting fee is required by the LSRCA to compensate for the zero-target phosphorus deficit.
- Infiltration measures are not recommended due to the poor soil condition of the site and seasonally high groundwater table. An offsetting fee is required by the LSRCA to compensate for the water balance deficit.
- Suitable measures can be implemented during construction to protect the adjacent properties and receiving storm sewers from migrating sediments.

It is therefore recommended that:

- 1) This report and drawings be submitted to the City of Barrie and the LSRCA for review and approval.
- 2) The construction mitigation measures outlined in this report are utilized as a guideline for construction mitigation measures for this site.

**RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**

All of which is respectfully submitted.
PINESTONE ENGINEERING LTD.



Dwight Hordyk, EIT
Project Designer



Joe Voisin, P.Eng
Senior Engineer

**RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**

APPENDIX A

Geotechnical & Hydrogeological Investigation – Peto MacCallum Ltd.





**GEOTECHNICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT
521 AND 525 ESSA ROAD
BARRIE, ONTARIO**

**for
ENCORE DEVELOPMENT GROUP**

PETO MacCALLUM LTD.
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Distribution:
2 cc: Encore Development Group (+email)
1 cc: PML Barrie

PML Ref.: 18BF030
Report: 1
July 2018

July 12, 2018

PML Ref.: 18BF030
Report: 1

Mr. Bryan Toteda
Encore Development Group
110 Adesso Drive
Unit 8
Concord, Ontario
L4K 3C5

Dear Mr. Toteda

**Geotechnical Investigation
Proposed Residential Development
521 and 525 Essa Road
Barrie, Ontario**

Peto MacCallum Ltd. (PML) is pleased to present the results of the geotechnical investigation recently completed at the above noted project site. Authorization for the work described in this report was provided by Mr. B. Toteda in the signed Engineering Services Agreement dated April 23, 2018.

Three apartment buildings (about 450 m² each) and twelve townhouse units (about 480 m² total) are proposed for the property at 521 and 525 Essa Road in Barrie. All buildings will be slab-on-grade and four storeys. A parking garage is planned at the ground floor of the apartments, with three residential floors above the parking garage. Site servicing, paved parking and access are planned for the site. The current planned site configuration is shown on Drawing 1, appended. An existing residence currently occupies each site and both will be demolished prior to site development.

The purpose of this investigation was to assess the subsurface conditions at the site, and based on this information, provide comments and geotechnical engineering recommendations for building foundations, site servicing, and pavement design.

Geoenvironmental services (observations, recording, testing or assessment of the environmental conditions of the soil and ground water) were not within the terms of reference for this assignment, and no work has been carried out in this regard. If excess soils requiring transportation off-site are generated, a program of sampling and chemical testing will be needed to determine the chemical properties of the soil to evaluate appropriate Receiving Site options, in accordance with the MOECC document; Management of Excess Soil – A Guide for Best Management Practices, January, 2014.

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The comments and recommendations provided in this report are based on the site conditions at the time of the investigation, and are applicable only to the proposed works as addressed in the report. Any changes in the proposed plans will require review by PML to assess the validity of the report, and may require modified recommendations, additional investigation and/or analysis.

INVESTIGATION PROCEDURES

The field work for this investigation was conducted on June 11 and 12, 2018, and consisted of Boreholes 1 to 8 advanced to 5.0 m depth. Borehole locations are shown on Drawing 1, appended.

Boreholes locations were established in the field by PML based on a site concept plan provided by the Client and site access. Co-ordination of clearances of underground utilities was provided by PML with the aid of a sub-contracted private utility locating company. Boreholes were drilled cognizant of utility locates.

The boreholes were advanced using continuous flight solid stem augers, powered by a track mounted D-25 drill rig, equipped with a manual hammer, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a member of PML's engineering staff.

Topsoil encountered at the surface of the boreholes was measured and samples of the material were collected.

Representative samples of the soils were recovered at frequent depth intervals for identification purposes using a conventional split spoon sampler. Standard penetration tests were carried out simultaneously with the sampling operations to assess the strength characteristics of the substrata. The ground water conditions in the boreholes were assessed during drilling by visual examination of the soil samples, the sampler, and drill rods as the samples were retrieved, and measurement of water in the open boreholes upon completion, if any.



Piezometers comprised of 32 mm diameter PVC pipe (1.5 m of cut slots at the base), filter sand, bentonite seal and flush-mounted protective casing were installed in three boreholes to permit monitoring of the ground water table. Boreholes without piezometers were backfilled in accordance with O.Reg. 903. As per O.Reg. 903, piezometers become the property of the Owner and will have to be decommissioned when no longer required by the Owner. PML would be pleased to assist in this regard.

Ground surface elevations were referenced to the following Temporary Bench Mark (TBM) provided by the Client, as shown on Drawing 1, and described as follows:

TBM: Temporary Bench Mark
Top of Flange of Fire Hydrant No. 3986
Elevation 314.35 (metric, geodetic)

All recovered samples were returned to our laboratory for moisture content determination and detailed examination to confirm field classification. Grain size analyses were carried out on two samples of the major soil types. The results are presented in Figures 1 and 2, attached. Accompanying Atterberg Limits testing was also completed on one of the samples.

SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Log of Borehole sheets for details of the subsurface conditions, including soil classifications, inferred stratigraphy, Standard Penetration Test N values (N values), ground water observations, piezometer installation details and the results of laboratory moisture content determinations and Atterberg Limits testing.

Due to the soil sampling procedures and the limited size of samples, the depth/elevation demarcations on the borehole logs must be viewed as “transitional” zones, and cannot be construed as exact geologic boundaries between layers. PML should be retained to assist in defining the geological boundaries in the field during construction, if required.

Topsoil was encountered over fill and native layers of clayey silt, silty sand, and sand and silt till. A description of the distribution of the subsurface conditions encountered is provided below.



Topsoil was present at the surface of all boreholes, being 120 to 200 mm thick.

Below the topsoil, a fill unit composed of variable sand and silt content, with trace gravel and local trace organics noted, was observed in all boreholes with the exception of Borehole 1. The fill carried to 0.7 to 2.9 m depth (elevation 312.3 to 313.4). The layer was moist to very moist, with moisture contents of 3 to 25%. N Values were 4 to 26, typically less than 10, indicating variable conditions.

Underlying the fill or topsoil, a native clayey silt layer was encountered in Boreholes 1 to 3 and 5 to 7, carrying to 1.4 to 4.0 m depth (elevation 310.5 to 312.8). A sample of the material from Borehole 6 was submitted for grain size analysis and the results are presented on Figure 1, appended. Atterberg Limits testing showed the material to have a plastic limit of 17% and a liquid limit of 25%. The layer was firm to very stiff based on N Values of 4 to 22, and was about the plastic limit to wetter than plastic limit with moisture contents of 12 to 26%.

Beneath the native clayey silt layer in Borehole 2, a local silty sand layer was encountered to 2.1 m depth (elevation 312.0). The material was compact (N Value of 18) and was very moist with a moisture content of 21%.

A basal silt and sand till deposit was encountered below the upper soil units in all boreholes extending to the 5.0 m depth of exploration in all boreholes. The unit comprised silty sand to sandy silt with trace gravel. Cobbles and boulders were noted. A sample of the material was submitted for grain size analysis and the results are presented on Figure 2, appended. The relative density of the till unit was compact to very dense with N Values of 11 to 65. The till was moist to very moist, with local wet seams, and moisture contents of 7 to 12%.

A summary of the first water strike during drilling, the water/wet cave measurements conducted upon completion of the boreholes, and the water levels recorded in the piezometers on June 20, 2018 is summarized below:



BOREHOLE	FIRST WATER STRIKE DURING DRILLING		WATER LEVEL UPON COMPLETION OF AUGERING		WATER LEVEL IN PIEZOMETERS JUNE 20, 2018	
	Depth (m)	Elevation	Depth (m)	Elevation	Depth (m)	Elevation
1	3.4	310.8	3.7	310.5	1.1	313.1
2	4.6	309.5	No Water	No Water	--	--
3	4.6	310.0	4.0	310.6	--	--
4	4.6	310.2	4.1	310.7	2.3	312.5
5	3.7	310.8	4.0	310.5	--	--
6	4.6	309.9	4.0	310.5	--	--
7	4.0	311.2	4.1	311.1	2.3	312.9
8	4.6	310.2	4.4	310.4	--	--

Based on the above, ground water at the site is residing in wet seams within the till unit. Localized areas of perched water across the site are possible, especially above the till or clayey silt layer.

Ground water levels will fluctuate seasonally, and in response to variations in precipitation.

GEOTECHNICAL ENGINEERING CONSIDERATIONS

General

Three apartment buildings (about 450 m² each) and twelve townhouse units (about 480 m² total) are proposed for the property at 521 and 525 Essa Road in Barrie. All buildings will be slab-on-grade and four storeys. A parking garage is planned at the ground floor of the apartments, with three residential floors above the parking garage. Site servicing, paved parking and access are planned for the site. The current planned site configuration is shown on Drawing 1, appended. An existing residence currently occupies each site and both will be demolished prior to site development.



Site Grading and Engineered Fill

The grading for the site has not been set however, for purposes of this report, it is assumed that the ground floor slab for the proposed buildings will be at about elevation 315.0, slightly above the existing site grades across the site. Based on this, exterior footings would normally be founded at about elevation 313.5, with interior footings at about elevation 314.4.

At these levels, the boreholes show the floor slabs and some footings would be founded on existing fill or firm portions of native clayey silt, which are unsuitable to support footings or floor slabs. As such it is recommended that existing fill be removed and grades raised with engineered fill. Both footings and floor slabs could then be supported on engineered fill, locally footings would be supported on native soils.

In the area of the existing houses, the in-situ fill and foundations will have to be removed, such that the extent of the excavation extends to native soil in all directions. It is noted that fill may be deeper around the existing houses than indicated at the borehole locations.

Reference is made to Appendix A for guidelines for engineered fill construction. The following general highlights are provided:

- Strip existing topsoil, fill, firm clayey silt (Borehole 1), and other deleterious materials down to native inorganic soil. The excavated soil should be segregated and stockpiled for reuse or disposal. Existing house foundations and associated fill will be removed and the excavation will have to extend to native soil in all directions;
- The clayey silt will typically be exposed as the subgrade soil may become sensitive to traffic if wet or allowed to get wet. Proofroll exposed subgrade, if not wet, using a heavy roller to targeted 100% Standard Proctor maximum dry density, under geotechnical review;
- Following geotechnical review and approval of the subgrade, spread approved material in maximum 200 mm thick lifts and uniformly compacted to 100% Standard Proctor maximum dry density in building areas and 95% Standard Proctor maximum dry density in pavement or site servicing areas. If



wet subgrade conditions are present the initial lift or two of engineered fill shall comprise Granular B Type II;

- Subject to geotechnical review during construction, the excavated sand to silty sand fill is only selectively suitable for reuse as engineered fill, subject to remove of organics, topsoil, oversized (over 150 mm) or otherwise deleterious material. A slight grade raise is anticipated at the site and as such imported fill is anticipated. Imported fill should be utilized under buildings or other structures, with on-site soils used in landscaped areas. Imported material should comprise OPSS Select Subgrade Material (SSM) or OPSS Granular B Type I. Other sources of imported material should be reviewed by our office to ensure suitability;
- The engineered fill pad must extend at least 1 m beyond the structure to be supported, then outwards and downwards at no steeper than 45° to the horizontal to meet the underlying approved native subgrade. In this regard, strict survey control and detailed documentation of the lateral and vertical extent of the engineered fill limits should be carried out to ensure that the engineered fill pad fully incorporates the structure to be supported;
- Engineered fill construction must be carried out under full time field review by PML, to approve sub-excavation and subgrade preparation, backfill materials, placement and compaction procedures, and to verify that the specified compaction standards are achieved throughout.

Foundations

As noted above, footings are anticipated at about elevation 314.4 and 313.5. At these levels, footings will be supported on engineered fill and locally the underlying native soil. Footings supported on native soil and/or engineered fill can be designed for a geotechnical bearing resistance at Serviceability Limit State (SLS) of 150 kPa, and a factored bearing resistance at Ultimate Limit State (ULS) of 225 kPa.

It is noted that in the area of the existing houses, fill will likely be present below the depths noted at the borehole locations. As such, as discussed above, existing fill and foundations once fully removed will have to be replaced with engineered fill.



The geotechnical bearing resistance at SLS is based on 25 mm or settlement in the bearing stratum with differential settlement not exceeding 75% of the value.

Footings subject to frost action should be provided with a minimum 1.2 m of earth cover or equivalent.

Prior to placement of structural concrete, all founding surfaces should be reviewed by PML to verify the design bearing capacity is available, or to reassess the design parameters based on the actual conditions revealed in the excavation.

Seismic Design

Based on the soil profile revealed in the boreholes, Site Classification D is applicable for Seismic Site Response as set out in Table 4.1.8.4.A of the Ontario Building Code (2012). Based on the type and relative density of the soil cover at the site there is a low potential for liquefaction of soils to occur.

Floor Slab-on-Grade

Floor slab-on-grade construction is feasible on engineered fill, constructed as discussed earlier.

A minimum 200 mm thick base layer of crushed stone (nominal 20 mm size) is recommended directly beneath the floor slab. Where a vapour sensitive floor finish is to be used then the use of polyethylene sheeting or similar means should be incorporation as a vapour barrier.

Exterior grades should be established to promote surface drainage away from the building.

Site Servicing

Design details were not finalized at the time of this report. For purposes of this report, inverts are assumed to be up to 3.0 m below existing grades.



Trench Excavation and Ground Water Control

Trench excavation and ground water control are described later in the report under Excavation and Ground Water Control.

Pipe Bedding

Engineered fill or native clayey silt, silty sand, or till is expected at invert levels which is considered satisfactory for pipe support.

Where existing fill or other deleterious material is encountered at the design invert level, such material should be sub-excavated and replaced with an increased thickness of bedding material, subject to geotechnical field review and approval.

Standard Granular A bedding, in accordance with OPSS, compacted to 95% Standard Proctor maximum dry density should be satisfactory. For flexible pipes, bedding and cover material should comprise OPSS Granular A. For rigid pipes, the bedding material should comprise OPSS Granular A and cover material may comprise select native soil free of oversized material.

Trench Backfill

Backfill in trenches should comprise select inorganics soil and be placed in maximum 200 mm thick loose lifts compacted to at least 95% Standard Proctor maximum dry density to minimize post construction settlement in the backfill. Topsoil, organic, excessively wet, frozen, oversized (greater than 200 mm), or otherwise deleterious material should not be incorporated as trench backfill. The moisture content of the trench backfill should be within 2% of the optimum moisture content in order to achieve the specified compaction and be close to optimum moisture content in the upper 1 m to prevent subgrade instability issues. Ideally the backfill should comprise excavated site soil, in order to minimize differential frost heave.



The excavated granular soils will comprise fill, native silty sand, and the till deposit. The native inorganic granular soil should generally be acceptable for reuse subject to geotechnical review during construction and moisture content control. The excavated clayey silt should be utilized in landscaped areas only.

Earthworks operations should be inspected by PML to verify subgrade preparation, backfill materials, placement and compaction efforts and ensure the specified degree of compaction is achieved throughout.

Excavation and Ground Water Control

It is anticipated that excavation for the engineered fill/apartment building foundations and site servicing will extend to about 3.0 m below existing grade possibly deeper in the area of the existing houses for removal of existing fill and foundations. Excavation will encounter fill and native clayey silt/silty sand/till. Harder digging and the presence of boulders should be expected within the till deposit.

Subject to the ground water control as discussed below, the site soils encountered at the site should be considered as Type 3 soil requiring excavation sidewalls to be constructed at no steeper than one horizontal to one vertical (1H:1V) from the base of the excavation in accordance with the Occupational Health and Safety Act.

The ground water table was generally encountered below the anticipated excavation depths noted above. Accordingly, it is expected that nuisance ground water seepage should be managed using conventional sump pumping techniques. The presence of perched water above the till or clayey silt should also be expected.

Water taking in Ontario is governed by the Ontario Water Resources Act (OWRA) and the Water Takings and Transfer Regulation O. Reg. 387/04. Section 34 of the OWRA requires anyone taking more than 50,000 L/d to notify the Ministry of the Environment and Climate Change (MOECC). This requirement applies to all withdrawals, whether for consumption, temporary construction dewatering, or permanent drainage improvements. Where it is assessed that more



than 50,000 L/d but less than 400,000 L/d of ground water taking is required, the Owner can register online via the Environmental Activity and Sector Registry (EASR) system. Where it is assessed that more than 400,000 L/d of ground water taking is required then a Category 3 Permit-to-Take-Water (PTTW) is required.

Based on the conditions revealed in the boreholes, a PTTW or registry on the EASR is not anticipated as the excavation will be above the ground water table. Excavation and ground water control requirements should be reviewed when design details are finalized.

Pavement Design and Construction

Based on the boreholes, it is anticipated that the pavement subgrade will comprise moderately frost susceptible sand/silt fills. Based on this, the following pavement structure thicknesses are recommended:

	LIGHT DUTY (CAR PARKING)	HEAVY DUTY (FIRE ROUTE)
Asphalt (mm)	90	110
Granular A Base Course (mm)	150	150
Granular B Subbase Course (mm)	300	450
Total Thickness (mm)	540	710

It is not intended to remove all of the existing fill from under the proposed pavement. However, in order to minimize potential settlement issues it is recommended that following rough grading to the subgrade level, subgrade preparation should include proofrolling and compacting the exposed subgrade with a heavy vibratory compactor to 95% Standard Proctor maximum dry density under geotechnical review. Any unstable zones identified during this process should be sub-excavated and replace with compacted select site material, subject to geotechnical field review.

Imported material for the granular base and subbase should conform to OPSS gradation specifications for Granular A and Granular B, and should be compacted to



100% Standard Proctor maximum dry density. Asphalt should be compacted in accordance with OPSS 310.

For the pavement to function properly, it is essential that provisions be made for water to drain out of and not collect in the base material. The incorporation of subdrains is recommended in conjunction with crowning of the final subgrade to promote drainage towards the pavement edge. Subdrains should be installed at least 300 mm below the subgrade level. Refer to OPSD 216 Series for details regarding pipe, filter fabric or filter sock, bedding and cover material. Maintenance hole/catchbasins should be backfilled with free draining material with frost tapers and stub drains extending out from structures. The above measures will help drain the pavement structure as well as alleviate the problems of differential frost movement between the catchbasins and pavement.

Geotechnical Review and Construction Inspection and Testing

It is recommended that the final design drawings be submitted to PML for geotechnical review for compatibility with site conditions and recommendations of this report.

Earthworks operations should be carried out under the supervision of PML to approve subgrade preparation, backfill materials, placement and compaction procedures and check the specified degree of compaction is achieved throughout.

Prior to placement of structural concrete, all founding surfaces must be inspected by PML to verify the design bearing capacity is available, or to reassess the design parameters based on the actual conditions.

The comments and recommendations provided in the report are based on information revealed in the boreholes. Conditions away from and between boreholes may vary, particularly where foundation and/or service trenches exist. Geotechnical review during construction should be ongoing to confirm the subsurface conditions are substantially similar to those encountered in the boreholes, which may otherwise require modification to the original recommendations.

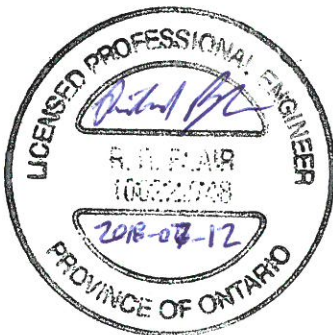


CLOSURE

We trust this report is complete within our terms of reference, and the information presented is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to call our office.

Sincerely

Peto MacCallum Ltd.



Richard Blair, P.Eng.
Project Engineer, Geotechnical Services

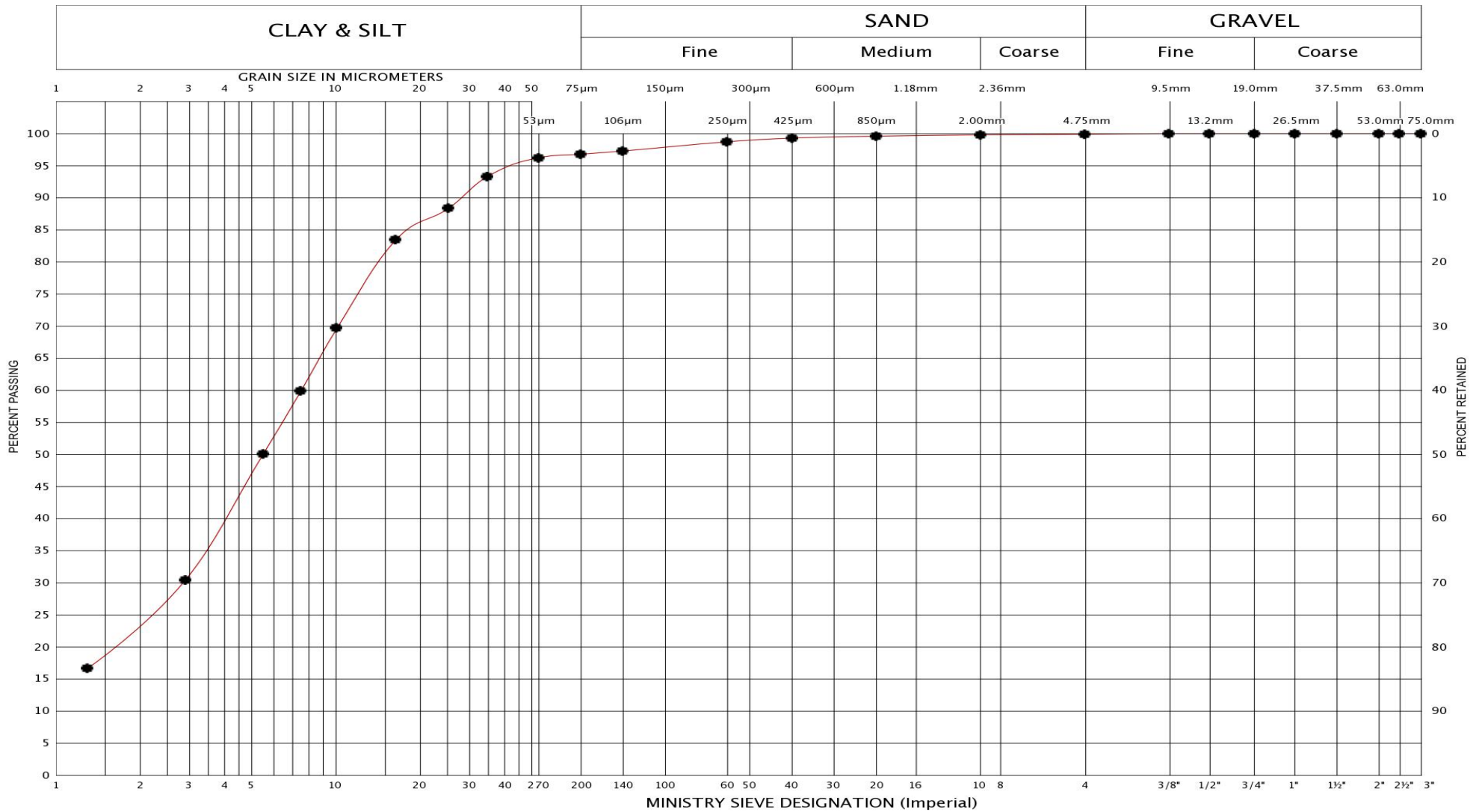


Geoffrey R. White, P.Eng.
Associate
Manager, Geotechnical and Geoenvironmental Services

RB/GRW:jlb

- Enclosures:
- Figures 1 and 2 - Particle Size Distribution Charts
 - List of Abbreviations
 - Log of Borehole Nos. 1 to 8
 - Drawing 1 - Borehole Location Plan
 - Appendix A – Engineered Fill

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	6
	SAMPLE	4
	SYMBOL	●

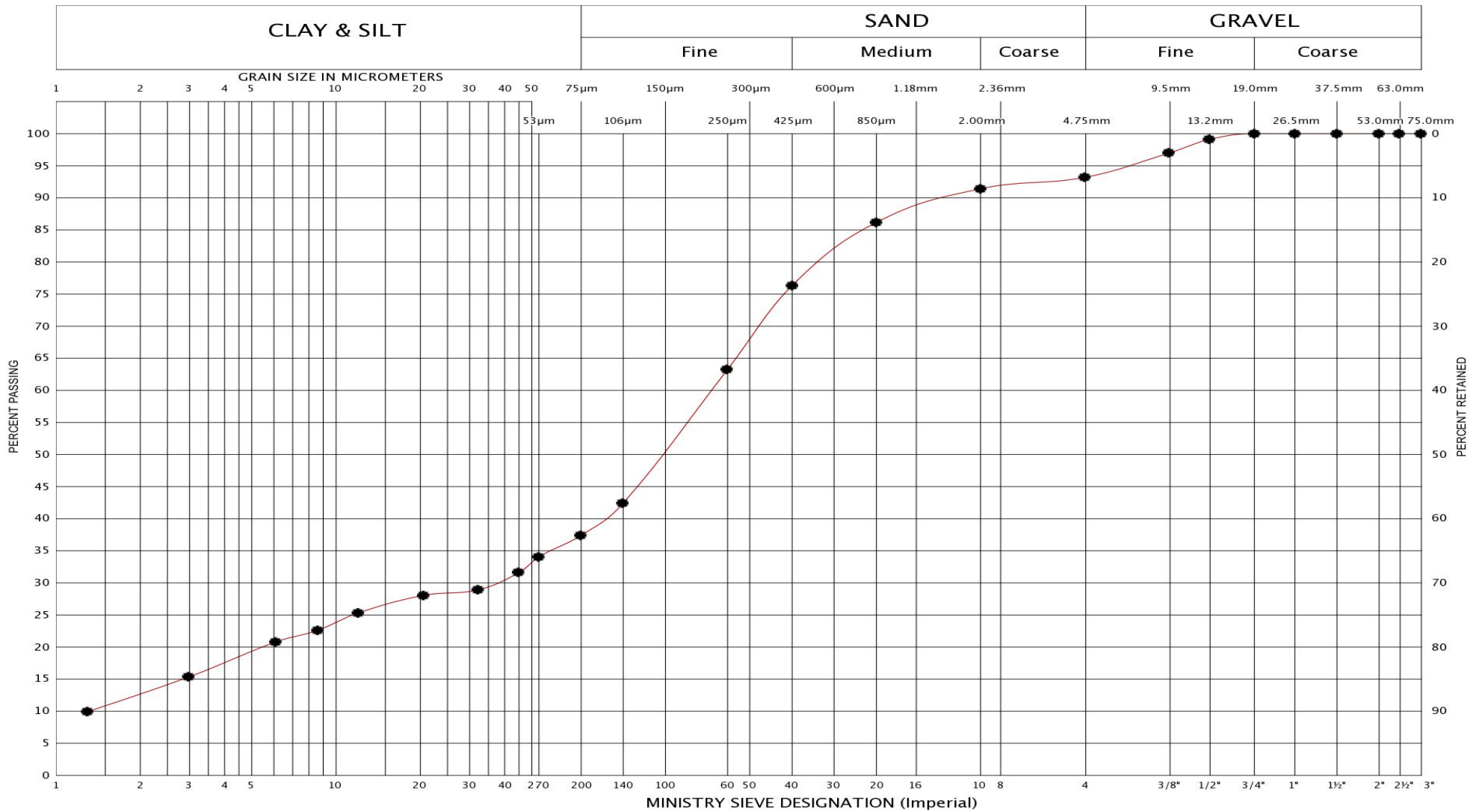
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, Trace Sand; PL: 17%; LL: 25%

FIG No.:	1
Project No.:	18BF030



UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	4
	SAMPLE	4
	SYMBOL	•



GRAIN SIZE DISTRIBUTION
TILL: Silty Sand, Trace Clay, Trace Gravel

FIG No.:	2
Project No.:	18BF030

LIST OF ABBREVIATIONS



PENETRATION RESISTANCE

Standard Penetration Resistance N: - The number of blows required to advance a standard split spoon sampler 0.3 m into the subsoil. Driven by means of a 63.5 kg hammer falling freely a distance of 0.76 m.

Dynamic Penetration Resistance: - The number of blows required to advance a 51 mm, 60 degree cone, fitted to the end of drill rods, 0.3 m into the subsoil. The driving energy being 475 J per blow.

DESCRIPTION OF SOIL

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described in the following terms:

<u>CONSISTENCY</u>	<u>N (blows/0.3 m)</u>	<u>c (kPa)</u>	<u>DENSENESS</u>	<u>N (blows/0.3 m)</u>
Very Soft	0 - 2	0 - 12	Very Loose	0 - 4
Soft	2 - 4	12 - 25	Loose	4 - 10
Firm	4 - 8	25 - 50	Compact	10 - 30
Stiff	8 - 15	50 - 100	Dense	30 - 50
Very Stiff	15 - 30	100 - 200	Very Dense	> 50
Hard	> 30	> 200		
WTLL	Wetter Than Liquid Limit			
WTPL	Wetter Than Plastic Limit			
APL	About Plastic Limit			
DTPL	Drier Than Plastic Limit			

TYPE OF SAMPLE

SS	Split Spoon	ST	Slotted Tube Sample
WS	Washed Sample	TW	Thinwall Open
SB	Scraper Bucket Sample	TP	Thinwall Piston
AS	Auger Sample	OS	Oesterberg Sample
CS	Chunk Sample	FS	Foil Sample
GS	Grab Sample	RC	Rock Core
	PH	Sample Advanced Hydraulically	
	PM	Sample Advanced Manually	

SOIL TESTS

Qu	Unconfined Compression	LV	Laboratory Vane
Q	Undrained Triaxial	FV	Field Vane
Qcu	Consolidated Undrained Triaxial	C	Consolidation
Qd	Drained Triaxial		

LOG OF BOREHOLE NO. 1

17T 602923E 4910588N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

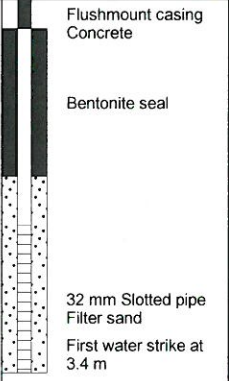
BORING DATE June 12, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC NATURAL LIQUID			UNIT WEIGHT	GROUND WATER OBSERVATIONS AND REMARKS		
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE				W _p			w	W _L
						50	100	150	200					
0.0	SURFACE ELEVATION 314.15													
0.20	TOPSOIL: Dark brown, sandy silt, trace gravel, very moist		1	SS	4	314								
313.95	CLAYEY SILT: Firm, brown to grey, clayey silt, trace sand, APL		2	SS	6	313								
1.4														
312.8	SILT AND SAND TILL: Compact to dense, brown, sandy silt to silty sand, trace gravel, cobbles and boulders, moist to very moist (wet seams)		3	SS	29	312								
2.0														
			4	SS	35	312								
3.0														
			5	SS	36	311								
4.0														
			6	SS	43	310								
5.0	BOREHOLE TERMINATED AT 5.0 m													
309.2														
6.0														
7.0														
8.0														
9.0														
10.0														
11.0														
12.0														
13.0														
14.0														
15.0														



Upon completion of augering Water at 3.7 m
Cave at 4.3 m
Water Level Readings:
Date Depth Elev.
2018-06-20 1.1 313.1

NOTES

LOG OF BOREHOLE NO. 2

17T 602919E 4910569N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 12, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS				
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	+									
0.0	SURFACE ELEVATION 314.10															
0.18	TOPSOIL: Brown, silty sand, trace gravel, moist		1	SS	5	314	50	100	150	200	10	20	30	40		
313.92	FILL: Brown, sand, trace gravel, trace silt, moist															
0.70	CLAYEY SILT: Stiff, brown to grey, clayey silt, trace sand, APL			2	SS	15	313									
313.40																
1.4	SILTY SAND: Compact, brown, silty sand, trace gravel, very moist			3	SS	18	312.7									
312.7																
2.1	SILT AND SAND TILL: Dense to very dense, brown, sandy silt to silty sand, trace gravel, cobbles and boulders, moist to very moist (wet seams)		4	SS	36	312.0										
312.0																
5.0				5	SS	44	311.0									
311.0																
4.0						310.0										
5.0	BOREHOLE TERMINATED AT 5.0 m		6	SS	59										First water strike at 4.6 m	
309.1															Upon completion of augering No water Cave at 2.1 m	

NOTES

LOG OF BOREHOLE NO. 3

17T 602952E 4910565N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 12, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC NATURAL LIQUID			UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS		
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	+ FIELD VANE Δ TORVANE ○ Qu				W _p			W	W _L
						▲ POCKET PENETROMETER ○ Q								
						DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST		WATER CONTENT (%)			GRAIN SIZE DISTRIBUTION (%) GR SA SI&CL			
						50	100	150	200					
						20	40	60	80					
SURFACE ELEVATION 314.55														
0.0	314.40		1	SS	7									
TOPSOIL: Brown, sand, trace gravel, trace silt, wet														
FILL: Brown, sandy silt to silty sand, trace gravel, moist to very moist														
1.0			2	SS	7									
1.4														
1.4	313.2		3	SS	8									
CLAYEY SILT: Stiff to very stiff, brown, clayey silt, trace sand, WTPL to APL														
2.0														
2.0			4	SS	15									
3.0														
3.0			5	SS	22									
4.0														
4.0	310.6		6	SS	43									
SILT AND SAND TILL: Dense, grey, sandy silt to silty sand, trace gravel, cobbles and boulders, moist (wet seams)														
5.0	309.6													
BOREHOLE TERMINATED AT 5.0 m														
First water strike at 4.6 m														
Upon completion of augering Water at 4.0 m Cave at 4.4 m														

NOTES

LOG OF BOREHOLE NO. 4

17T 602993E 4910561N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 11, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	+ FIELD VANE	△ TORVANE	○ Qu					
						50 100 150 200								
0.0	SURFACE ELEVATION 314.75													
0.15	TOPSOIL: Brown, sand, trace gravel, trace silt, moist		1	SS	13	314.60								Flushmount casing Concrete
1.0	FILL: Brown, silty sand, trace gravel, moist		2	SS	7	314								Bentonite seal
1.4	SILT AND SAND TILL: Compact to dense, brown, sandy silt to silty sand, trace clay, trace gravel, cobbles and boulders, moist (wet seams)		3	SS	20	313								32 mm Slotted pipe Filter sand
2.0			4	SS	11	312								
3.0			5	SS	17	311								
4.0														
4.6	Becoming grey		6	SS	38	310								First water strike at 4.6 m
5.0	BOREHOLE TERMINATED AT 5.0 m													Upon completion of augering Water at 4.1 m No cave Water Level Readings: Date Depth Elev. 2018-06-20 2.3 312.5

NOTES

LOG OF BOREHOLE NO. 5

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 11, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC NATURAL LIQUID			UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS	
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	+ FIELD VANE Δ TORVANE ○ Qu		LIMIT	MOISTURE	LIMIT			WATER CONTENT (%)
						▲ POCKET PENETROMETER ○ Q							
						DYNAMIC CONE PENETRATION ×							
						STANDARD PENETRATION TEST ●							
						50	100	150	200				
						20	40	60	80	10	20	30	40
0.0	SURFACE ELEVATION 314.50												
0.15 314.35	TOPSOIL: Brown, sand, some silt, trace gravel, moist		1	SS	7								
	FILL: Brown, sandy silt, trace gravel, trace organics, moist		2	SS	9								
1.0													
1.4 313.1	CLAYEY SILT: Very stiff, brown to grey, clayey silt, trace sand, trace gravel, APL		3	SS	20								
2.0													
2.1 312.4	SILT AND SAND TILL: Compact to dense, brown, sandy silt to silty sand, trace gravel, cobbles and boulders, moist to very moist (wet seams)		4	SS	16								
3.0													
4.0													
4.6 309.9	Becoming grey		5	SS	24								
5.0 309.5	BOREHOLE TERMINATED AT 5.0 m		6	SS	30								
5.0													First water strike at 3.7 m
6.0													Upon completion of augering Water at 4.0 m Cave at 4.3 m
7.0													
8.0													
9.0													
10.0													
11.0													
12.0													
13.0													
14.0													
15.0													

NOTES

LOG OF BOREHOLE NO. 6

17T 602922E 4910537N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 12, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE						
0.0	SURFACE ELEVATION 314.50											
0.16	TOPSOIL: Brown, silty sand, trace gravel, moist		1	SS	9	314						
314.34	FILL: Brown, silty sand, trace gravel, moist		2	SS	14							
1.0												
1.4												
313.1	CLAYEY SILT: Stiff to very stiff, brown to grey, clayey silt, trace sand, trace gravel, APL to WTPL		3	SS	10	313						
2.0												
			4	SS	13	312						
3.0												
			5	SS	17	311						
4.0												
4.0	SILT AND SAND TILL: Very dense, brown, sandy silt to silty sand, trace gravel, cobbles and boulders, very moist (wet seams)		6	SS	65	310						First water strike at 4.6 m
310.5												
5.0	BOREHOLE TERMINATED AT 5.0 m											Upon completion of augering Water at 4.0 m Cave at 4.4 m
309.5												
6.0												
7.0												
8.0												
9.0												
10.0												
11.0												
12.0												
13.0												
14.0												
15.0												

NOTES

LOG OF BOREHOLE NO. 7

17T 602964E 4910525N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 11, 2018

ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			ELEVATION SCALE	SHEAR STRENGTH (kPa)				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W _L	UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		+ FIELD VANE Δ TORVANE ○ Qu								
							▲ POCKET PENETROMETER ○ Q								
						DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST ×				WATER CONTENT (%)					
						50 100 150 200				10 20 30 40					
						20 40 60 80									
0.0	315.15	SURFACE ELEVATION 315.15													
0.12	315.03	TOPSOIL: Brown, sand, trace gravel, trace silt, moist	1	SS	4										Flushmount casing Concrete
		FILL: Brown, sand trace gravel, trace silt, moist to very moist	2	SS	5										Bentonite seal
1.0			3	SS	15										
2.1	313.1	Becoming silty sand	4	SS	26										
2.9	312.3	CLAYEY SILT: Very stiff, brown, clayey silt, trace sand, WTPL	5	SS	21										
4.0	311.2	SILT AND SAND TILL: Compact, grey, sandy silt to silty sand, trace gravel, cobbles and boulders, very moist (wet seams)	6	SS	15										32 mm Slotted pipe Filter sand First water strike at 4.0 m
5.0	310.2	BOREHOLE TERMINATED AT 5.0 m													Upon completion of augering Water at 4.1 m No cave Water Level Readings: Date Depth Elev. 2018-06-20 2.3 312.9

NOTES

LOG OF BOREHOLE NO. 8

17T 602975E 4910529N

PROJECT Proposed Residential Development - 521 and 525 Essa Road

PML REF. 18BF030

LOCATION Barrie, Ontario

BORING DATE June 11, 2018

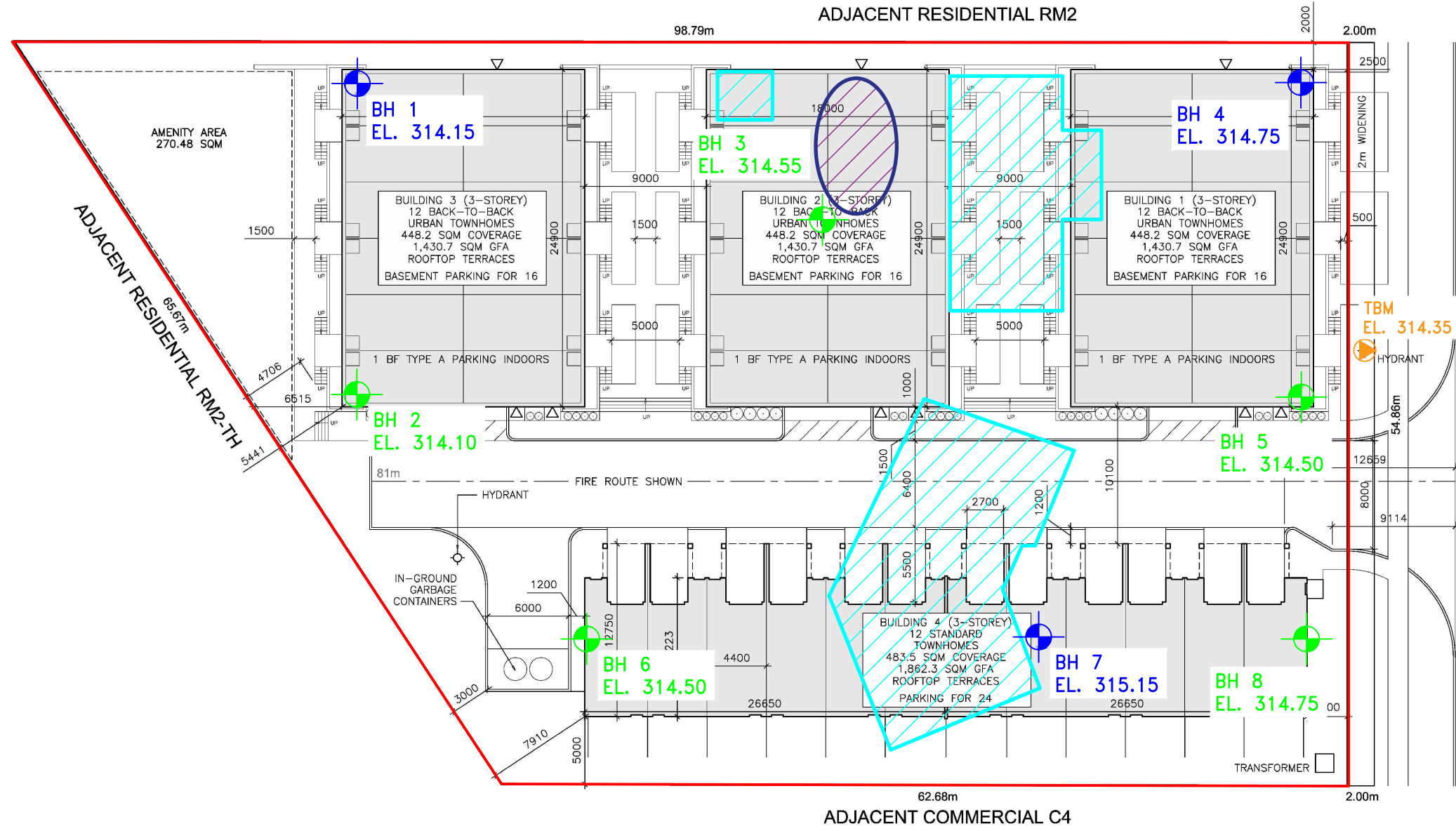
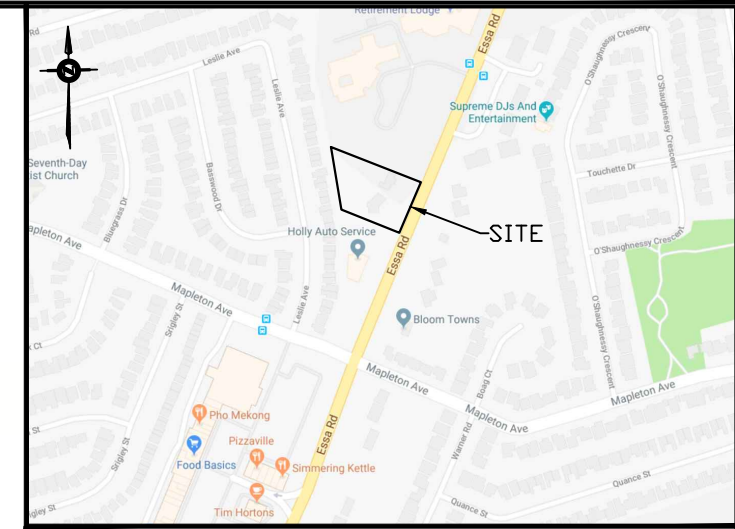
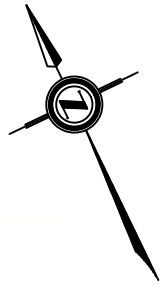
ENGINEER GW

BORING METHOD Continuous Flight Hollow Stem Augers

TECHNICIAN AT

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)				PLASTIC NATURAL LIQUID			UNIT WEIGHT kn/m ³	GROUND WATER OBSERVATIONS AND REMARKS	
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE				w _p	w	w _L			WATER CONTENT (%)
						+ FIELD VANE Δ TORVANE ○ Qu									
						▲ POCKET PENETROMETER ○ Q									
DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST						×									
						20 40 60 80				10 20 30 40			GRAIN SIZE DISTRIBUTION (%) GR SA S&CL		
0.0	SURFACE ELEVATION 314.75														
0.18 314.57	TOPSOIL: Dark brown, silty sand, trace gravel, moist		1	SS	4										
	FILL: Brown, sandy silt, trace gravel, wood pieces, very moist		2	SS	8										
			3	SS	5										
2.1 312.7	SILT AND SAND TILL: Compact to dense, brown to grey, sandy silt to silty sand, trace gravel, cobbles and boulders, moist (wet seams)		4	SS	26										
			5	SS	22										
			6	SS	47										
5.0 309.8	BOREHOLE TERMINATED AT 5.0 m														First water strike at 4.6 m
															Upon completion of augering Wet cave at 4.4 m

NOTES



ESSA ROAD

KEY PLAN
BARRIE, ONTARIO

LEGEND:

- SITE LIMITS
- ▨ APPROXIMATE LOCATION OF EXISTING BUILDINGS TO BE DEMOLISHED
- ▨ APPROXIMATE LOCATION OF EXISTING ABOVE GRADE POOL TO BE REMOVED
- BOREHOLE 1 (WITH PIEZOMETER) SURFACE ELEVATION
- BOREHOLE 2 SURFACE ELEVATION
- TEMPORARY BENCH MARK TOP OF FLANGE OF FIRE HYDRANT #3986 ELEVATION 314.35 (METRIC, GEODETIC)

REFERENCE:
BASE PLAN PROVIDED BY CLIENT.

0m 5 10 15 20 25
SCALE

BOREHOLE LOCATION PLAN

PROPOSED RESIDENTIAL DEVELOPMENT
521 AND 525 ESSA ROAD
BARRIE, ONTARIO



DRAWN	RB	DATE	SCALE	PML REF.	DRAWING NO.
CHECKED	CW	JULY 2018	AS SHOWN	18BF030	1
APPROVED	GW				



APPENDIX A

Engineered Fill

The information presented in this appendix is intended for general guidance only. Site specific conditions and prevailing weather may require modification of compaction standards, backfill type or procedures. Each site must be discussed, and procedures agreed with Peto MacCallum Ltd. prior to the start of the earthworks and must be subject to ongoing review during construction. This appendix is not intended to apply to embankments. Steeply sloping ravine residential lots require special consideration.

For fill to be classified as engineered fill suitable for supporting structural loads, a number of conditions must be satisfied, including but not necessarily limited to the following:

1. Purpose

The site specific purpose of the engineered fill must be recognized. In advance of construction, all parties should discuss the project and its requirements and agree on an appropriate set of standards and procedures.

2. Minimum Extent

The engineered fill envelope must extend beyond the footprint of the structure to be supported. The minimum extent of the envelope should be defined from a geotechnical perspective by:

- at founding level, extend a minimum 1.0 m beyond the outer edge of the foundations, greater if adequate layout has not yet been completed as noted below; and
- extend downward and outward at a slope no greater than 45° to meet the subgrade

All fill within the envelope established above must meet the requirements of engineered fill in order to support the structure safely. Other considerations such as survey control, or construction methods may require an envelope that is larger, as noted in the following sections.

Once the minimum envelope has been established, structures must not be moved or extended without consultation with Peto MacCallum Ltd. Similarly, Peto MacCallum Ltd. should be consulted prior to any excavation within the minimum envelope.

3. Survey Control

Accurate survey control is essential to the success of an engineered fill project. The boundaries of the engineered fill must be laid out by a surveyor in consultation with engineering staff from Peto MacCallum Ltd. Careful consideration of the maximum building envelope is required.

During construction it is necessary to have a qualified surveyor provide total station control on the three dimensional extent of filling.

4. Subsurface Preparation

Prior to placement of fill, the subgrade must be prepared to the satisfaction of Peto MacCallum Ltd. All deleterious material must be removed and in some cases, excavation of native mineral soils may be required.

Particular attention must be paid to wet subgrades and possible additional measures required to achieve sufficient compaction. Where fill is placed against a slope, benching may be necessary and natural drainage paths must not be blocked.

5. Suitable Fill Materials

All material to be used as fill must be approved by Peto MacCallum Ltd. Such approval will be influenced by many factors and must be site and project specific. External fill sources must be sampled, tested and approved prior to material being hauled to site.

6. Test Section

In advance of the start of construction of the engineered fill pad, the Contractor should conduct a test section. The compaction criterion will be assessed in consultation with Peto MacCallum Ltd. for the various fill material types using different lift thicknesses and number of passes for the compaction equipment proposed by the Contractor.

Additional test sections may be required throughout the course of the project to reflect changes in fill sources, natural moisture content of the material and weather conditions.

The Contractor should be particularly aware of changes in the moisture content of fill material. Site review by Peto MacCallum Ltd. is required to ensure the desired lift thickness is maintained and that each lift is systematically compacted, tested and approved before a subsequent lift is commenced.

7. Inspection and Testing

Uniform, thorough compaction is crucial to the performance of the engineered fill and the supported structure. Hence, all subgrade preparation, filling and compacting must be carried out under the full time inspection by Peto MacCallum Ltd.

All founding surfaces for all buildings and residential dwellings or any part thereof (including but not limited to footings and floor slabs) on structural fill or native soils must be inspected and approved by PML engineering personnel prior to placement of the base/subbase granular material and/or concrete. The purpose of the inspection is to ensure the subgrade soils are capable of supporting the building/house foundation and floor slab loads and to confirm the building/house envelope does not extend beyond the limits of any structural fill pads.

8. Protection of Fill

Fill is generally more susceptible to the effects of weather than natural soil. Fill placed and approved to the level at which structural support is required must be protected from excessive wetting, drying, erosion or freezing. Where adequate protection has not been provided, it may be necessary to provide deeper footings or to strip and recompact some of the fill.

9. Construction Delay Time Considerations

The integrity of the fill pad can deteriorate due to the harsh effects of our Canadian weather. Hence, particular care must be taken if the fill pad is constructed over a long time period.

It is necessary therefore, that all fill sources are tested to ensure the material compactability prior to the soil arriving at site. When there has been a lengthy delay between construction periods of the fill pad, it is necessary to conduct subgrade proof rolling, test pits or boreholes to verify the adequacy of the exposed subgrade to accept new fill material.

When the fill pad will be constructed over a lengthy period of time, a field survey should be completed at the end of each construction season to verify the areal extent and the level at which the compacted fill has been brought up to, tested and approved.

In the following spring, subexcavation may be necessary if the fill pad has been softened attributable to ponded surface water or freeze/thaw cycles.

A new survey is required at the beginning of the next construction season to verify that random dumping and/or spreading of fill has not been carried out at the site.

10. Approved Fill Pad Surveillance

It should be appreciated that once the fill pad has been brought to final grade and documented by field survey, there must be ongoing surveillance to ensure that the integrity of the fill pad is not threatened.

Grading operations adjacent to fill pads can often take place several months or years after completion of the fill pad.

It is imperative that all site management and supervision staff, the staff of Contractors and earthwork operators be fully aware of the boundaries of all approved engineered fill pads.

Excavation into an approved engineered fill pad should never be contemplated without the full knowledge, approval and documentation by the geotechnical consultant.

If the fill pad is knowingly built several years in advance of ultimate construction, the areal limits of the fill pad should be substantially overbuilt laterally to allow for changes in possible structure location and elevation and other earthwork operations and competing interests on the site. The overbuilt distance required is project and/or site specified.

Iron bars should be placed at the corner/intermediate points of the fill pad as a permanent record of the approved limits of the work for record keeping purposes.

11. Unusual Working Conditions

Construction of fill pads may at times take place at night and/or during periods of freezing weather conditions because of the requirements of the project schedule. It should be appreciated therefore, that both situations present more difficult working conditions. The Owner, Contractor, Design Consultant and Geotechnical Engineer must be willing to work together to revise site construction procedures, enhance field testing and surveillance, and incorporate design modifications as necessary to suit site conditions.

When working at night there must be sufficient artificial light to properly illuminate the fill pad and borrow areas.

Placement of material to form an engineered fill pad during winter and freezing temperatures has its own special conditions that must be addressed. It is imperative that each day prior to placement of new fill, the exposed subgrade must be inspected and any overnight snow or frozen material removed. Particular attention should be given to the borrow source inspection to ensure only nonfrozen fill is brought to the site.

The Contractor must continually assess the work program and have the necessary spreading and compacting equipment to ensure that densification of the fill material takes place in a minimum amount of time. Changes may be required to the spreading methods, lift thickness, and compaction techniques to ensure the desired compaction is achieved uniformly throughout each fill lift.

The Contractor should adequately protect the subgrade at the end of each shift to minimize frost penetration overnight. Since water cannot be added to the fill material to facilitate compaction, it is imperative that densification of the fill be achieved by additional compaction effort and an appropriate reduced lift thickness. Once the fill pad has been completed, it must be properly protected from freezing temperatures and ponding of water during the spring thaw period.

If the pad is unusually thick or if the fill thickness varies dramatically across the width or length of the fill pad, Peto MacCallum Ltd. should be consulted for additional recommendations. In this case, alternative special provisions may be recommended, such as providing a surcharge preload for a limited time or increase the degree of compaction of the fill.



**HYDROGEOLOGICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPEMENT
521 AND 525 ESSA ROAD
BARRIE, ONTARIO**

for

ENCORE DEVELOPMENT GROUP



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1 cc: PML Barrie

PML Ref.: 18BF030
Report: 2
May 2019

May 9, 2019

PML Ref.: 18BF030
Report: 2

Mr. Bryan Toteda
Encore Development Group
110 Adesso Drive, Unit 8
Concord, Ontario
L4K 3C5

Dear Mr. Toteda

**Hydrogeological Investigation
Proposed Residential Development
521 and 525 Essa Road
Barrie, Ontario**

Peto MacCallum Ltd. (PML) is pleased to present the results from the hydrogeological investigation recently completed for the above noted project site. Authorization for this work was provided by Mr. B. Toteda in an email dated April 3, 2019.

Three apartment buildings (about 450 m² each) and twelve townhouse units (about 480 m² total) are proposed for the property at 521 and 525 Essa Road in Barrie. All buildings will be slab-on-grade and four storeys. A continuous parking garage is planned at the ground floor of the apartments, with three residential floors above the parking garage. Site servicing, paved parking and access are planned for the site. The current planned site configuration is shown on Drawing 2-1, appended. An existing residence currently occupies each site and both will be demolished prior to site development.

Reference is made to Report 1, dated July 12, 2018, where results of the geotechnical investigation and geotechnical engineering recommendations were provided for the site.

The purpose of this supplemental hydrogeological investigation was to provide additional information and recommendations for the site plan approval. This report characterizes the existing hydrogeological conditions including ground water levels, gradient and flow direction, provides a site-specific climate-based water balance, and in-situ permeability testing results.

The comments and recommendations provided in this report are based on the site conditions at the time of the original geotechnical field investigation and supplemental hydrogeological investigation and are applicable only to the proposed residential development as addressed in the report. Any changes in the proposed plans will require review by PML to assess the validity of this report, and may require modified recommendations, additional investigation and/or analysis.

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INVESTIGATION PROCEDURES

PML attended site on April 24, 2019 and completed Test Pits 1 to 3 to a depth of 0.7 to 2.0 m below existing grade at the locations show on Drawing 2-1, attached. The test pit locations were dug to carry out in-situ Guelph Permeameter (GP) tests.

PML laid out and surveyed the test pits. Co-ordination of clearances of underground utilities was provided by PML in addition to a private utility locator. The test pits were excavated cognizant of the underground utility locates.

The test pits were excavated with a mini rubber track mounted backhoe supplied and operated by a local excavator contractor working under the full-time supervision of field staff from PML. The test pits were backfilled upon completion.

All recovered soil samples were returned to our laboratory for detailed examination to confirm field classification. Three samples of the major soil units were submitted for grain size analysis. Grain size analysis test results are presented on Figures 1 to 2, appended.

Ground water levels in the three monitoring wells that were installed during PMLs geotechnical investigation were obtained in March, April and May. A final reading is scheduled for June and will be reported separately.

SITE SETTING

The site comprises the properties at 521 and 525 Essa Road in Barrie. The site is on the west side of Essa Road and is about 0.46 Ha in size. Currently the site is occupied by two residential dwellings that are to be demolished prior to construction. The site situated in a primarily residential and commercial area. Residential dwellings are to the north and west, and an automotive garage to the south.



Physiography and Topography

The site is located within the physiographic region known as the Peterborough Drumlin Field (Chapman and Putnam, 1984). In the vicinity of the site the land is characterized as a drumlinized till plain comprising moderately stony to stony, silty sand to sand deposits of the Newmarket Till.

The Ontario Department of Agriculture Soil Report notes the near surface soils are part of the Dundonald Series, sandy loam (good drainage) with smooth gently sloping topography.

The borehole elevations indicate about 1.0 m of relief across the site. The elevations of the boreholes range from elevation 315.15 to 314.10.

Drainage and Surface Water Flow

There are no water courses on the site. Surface drainage on site is expected to follow the topography in the area and flow towards the northwest.

GEOLOGY AND SUBSURFACE CONDITIONS

Geology

Bedrock below the overburden is mapped as limestone, dolostone, shale, arkose, and sand stone of the Simcoe Group from the Middle Ordovician period of the Paleozoic era of the Phanerozoic eon. Bedrock is anticipated at depths greater than 60 m based on the Ontario Division of Mines Bedrock Topography Series for the Barrie Area Map P979.

Subsurface Conditions

Reference is made to our geotechnical report for details regarding the subsurface conditions. The scope of this hydrogeological work, focused on the near surface conditions in the test pits. The Log of Test Pit sheets are appended.

In general, test pits encountered fill and native layers of silty sand, and sand and silt till overlying clayey silt.



HYDROGEOLOGICAL CONSIDERATIONS

Aquifers and Local Ground Water Use

The water wells recorded by the Ministry of Environment, Conservation and Parks (MECP) within the 500 m study area are tabulated in Appendix A. A total of 41 Water Well Records (WWR) were identified. Twenty-four records indicated the wells were for some form of domestic water use (private, commercial and/or livestock), five were for ground water monitoring and four wells were listed as not used. Bedrock was not encountered in any of the WWRs.

The wells ranged in depth from 4.0 to 61.0 m below the ground surface with fresh water encountered typically in this range. The wells were developed in sand with variable clay, silt and gravel content, clayey silt and/or silty clay till.

Municipal water is available in the vicinity of the site. It should be noted that the site is outside of any Well Head Protection Areas (WHPAs) and/or Intake Protection Zones (IPZs).

Ground Water

The ground water level monitoring to-date in the three boreholes with wells is summarized below including the first water strike (ground water first encountered during drilling), the ground water levels measured in the boreholes upon completion of augering, and measured in the wells during four subsequent site visits.

Borehole	First Strike Depth (m) / Elevation	Upon Completion Depth (m) / Elevation	Water Level in Wells Depth (m) / Elevation			
			20/06/2018	27/03/2019	24/04/2019	08/05/2019
1	3.4 / 310.8	3.7 / 310.5	1.1 / 313.1	0.0 / 314.2	0.0 / 314.2	0.23 / 313.9
4	4.6 / 310.2	4.1 / 310.7	2.3 / 312.5	1.9 / 312.9	1.4 / 313.4	1.6 / 313.2
7	4.0 / 311.2	4.1 / 311.1	2.3 / 312.9	2.2 / 313.0	2.1 / 313.1	2.1 / 313.1

Based on the above, the stabilized ground water table ranged from 0.0 to 2.2 m below existing grade (elevation 312.5 to 314.2).



Ground water levels are subject to seasonal fluctuations, and in response to variations in precipitation.

Hydraulic Gradient

Based on the water levels measured on April 24, 2019, the shallow ground water flow direction is to the southeast towards Essa Road. The water levels measured show a 1.1 m variation across the site with a ground water elevation of 314.2 at Borehole/Monitoring Well 1 and a ground water elevation of 313.1 at Borehole/Monitoring Well 7, resulting in a hydraulic gradient of 0.9%.

Infiltration Assessment

Three test pits were completed and two GP tests were conducted in each test pit on April 24, 2019. The first test was completed at depths of 0.3 to 1.3 m and the second test was completed at depths of 0.5 to 2.0 m. Test pit locations were selected to provide site coverage. GP test depths were selected ensuring unsaturated native soil conditions. The test locations are shown on Drawing 2-1. For each test, the water level drop in the GP chamber was visually monitored and recorded until a steady infiltration rate was reached.

From the GP testing a field saturated Hydraulic Conductivity (K_{fs}) was estimated utilizing the Zhang et al. (1998) method:

$$K_{fs} = \frac{C_1 \times Q_1}{2\pi H_1^2 + \pi \alpha^2 C_1 + 2\pi \left(\frac{H_1}{\alpha}\right)}$$

Where,

C = shape factor dependent on the soil texture-structure (Zhang et al., 1998)

Q = the steady-state rate of fall of water in reservoir (cm/s)

H = hydraulic head (cm)

α = borehole radius (cm)



An approximate relationship between K_{fs} and the infiltration rate was established in the TRCA/CVC Low Impact Development Stormwater Management Planning and Design Guide and was utilized to determine approximate infiltration rates:

$$\text{Infiltrate Rate} = \sqrt[3.7363]{\frac{K_{fs}}{6 \times 10^{-11}}}$$

The test locations and results are summarized below:

Test Pit	Material Type	Estimated, K_{fs} (cm/sec)	Unfactored Infiltration Rate (mm/hr)
GP 1	Silty Sand	10^{-4} to 10^{-5}	60.8
GP 2	Silty Sand to Silt and Sand	10^{-4} to 10^{-5}	19.4
GP 3	Clayey Silt	10^{-5} to 10^{-6}	14

Particle Size Distribution

Three soil samples were submitted for grain size analysis and Hydraulic Conductivity (K) was estimated based on the particle size distribution. The results of the laboratory testing are included in Figures 1 and 2 and the estimate of Hydraulic Conductivity is summarized in the table below.

Test Pit	Depth (m)	Soil Type	Estimated K (cm/sec)
GP 1	2.0	Silty Sand	10^{-5} to 10^{-6}
GP 2	0.3	Silty Sand	$< 10^{-6}$
GP 3	1.8	Clayey Silt	$< 10^{-6}$

The Vukovic & Soro method was used to assess K.

The K value derived from the particle size distribution curve does not take into consideration site specific details such as compaction, soil structure, organic content and/or the degree of saturation.



PRELIMINARY WATER BALANCE

Climate

The site is located in Barrie, west of Lake Simcoe within Simcoe County. The climate of Barrie is humid-continental, characterized by changeable weather patterns. Barrie's location relative to Georgian Bay and Lake Simcoe, can result in disparities in weather over short distances. From Environment Canada data, the average annual temperature recorded at the Barrie Water Pollution Control Centre (WPCC), which is located on the central portion of the City, averages 6.9°C. With the highest monthly average temperature in July, at 20.8°C and the lowest monthly average temperature in January, at -7.7°C. The average annual precipitation recorded at the Barrie WPCC is 932.9 mm.

Water Balance: Pre-Development

To determine the amount of ground water infiltration relative to existing site conditions, a pre-development water balance was carried out to provide an estimate of the volume of infiltrating precipitation at the site. This method is based on classic storm water management principles and generally over-estimates the volume of runoff, providing a conservative assessment of infiltration volume. It is noted that the equations were developed for heavy rainfall events of short duration, where as a large volume of the precipitation occurs at a light to moderate rate over an extended period of time and would result in a much higher volume of infiltration.

For the purposes of our analysis, the following parameters were assumed:

- The amount of rainwater infiltration was based on information at the nearest Environment Canada Monitoring Station, located at the Barrie WPCC. The annual precipitation was recorded to be 932.9 mm/year, and the water surplus was computed to be 347 mm/year (computed by the Thornthwaite and Mather Method).
- The water available for infiltration was computed using the following infiltration factors:

Topography.....	0.30
Soil.....	0.20
Cover.....	0.10
Total.....	0.60



- By multiplying the water surplus of 347 mm/year by the infiltration factor of 0.60, the infiltration was computed to be 208.2 mm/year.

The total existing catchment area for infiltrating precipitation was computed as follows:

- Total Approximate Site Area = 4,571 m² (0.46 Ha)
- Total Approximate Impermeable Surface Area (two buildings and two paved driveways are known to be on the site) = 700 m²

Total Site Area less the Impermeable Surface Area = 3,871 m²

The total pre-development infiltration at the site (potential for ground water recharge) is calculated to be 805,942.2 L/year.

Development Impact Assessment

Water Balance: Post Development

In order to assess the effect of site development, a post-development water balance for the site was carried out using the same approach and infiltration factors noted above. It is understood that development plans include:

- Buildings 1 to 3 (urban town homes including underground parking) with a total impermeable surface of 1,791 m², representing 39% of the entire site;
- Building 4 (standard town homes including driveways) with an impermeable surface of 652 m², representing 14% of the entire site;
- Paved road way (675 m²);
- Permeable green space including required setbacks, tree protection area, amenity area and green space (1,453 m²).



The total post-development area for infiltrating precipitation was computed as follows:

- Total Site Area = 4,571 m² (0.46 ha)
- Total Impermeable Surface Area (buildings and paved roads) = 3,118 m²
- Total Site Area less the Impermeable Surface Area = 1,453 m²

Based on the current site conditions and proposed site development plan, the total post development infiltration at the site (potential for ground water recharge) is calculated to be 302,514.6 L/year, having a reduction of site infiltration of approximately 62%.

Development Considerations

Ground Water Recharge Management

The Low Impact Development (LID) guidelines call for the pre and post-development ground water infiltration volumes to be maintained as much as practically possible. The assessment provided above indicates a significant reduction in the volume of surface water infiltration following redevelopment of the site; hence, implementation of measures to reduce the infiltration deficit should be considered.

Mitigation Measures, Opportunities and Constraints

The following measures should be considered to reduce the post-development infiltration:

- Reduce the area of the impermeable surfaces.
- Create swales/depressed areas that will retard the rate of storm water runoff and promote infiltration.
- Promote surface water flow from impermeable surfaces into the infiltration facilities, as opposed to directing surface water to catchbasins connected to the municipal storm sewers.
- Ensure that roof drains are not connected to the municipal storm water control system.
- Reduce the slope of the ground surface to promote increased infiltration.



CLOSURE

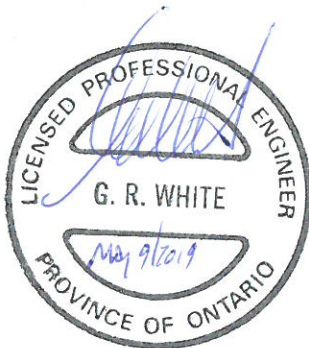
We trust this report is complete within our terms of reference, and the information provided is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to call our office.

Sincerely

Peto MacCallum Ltd.



Alicia Kimberley, MSc., P.Geo.
Manager, Hydrogeological Services



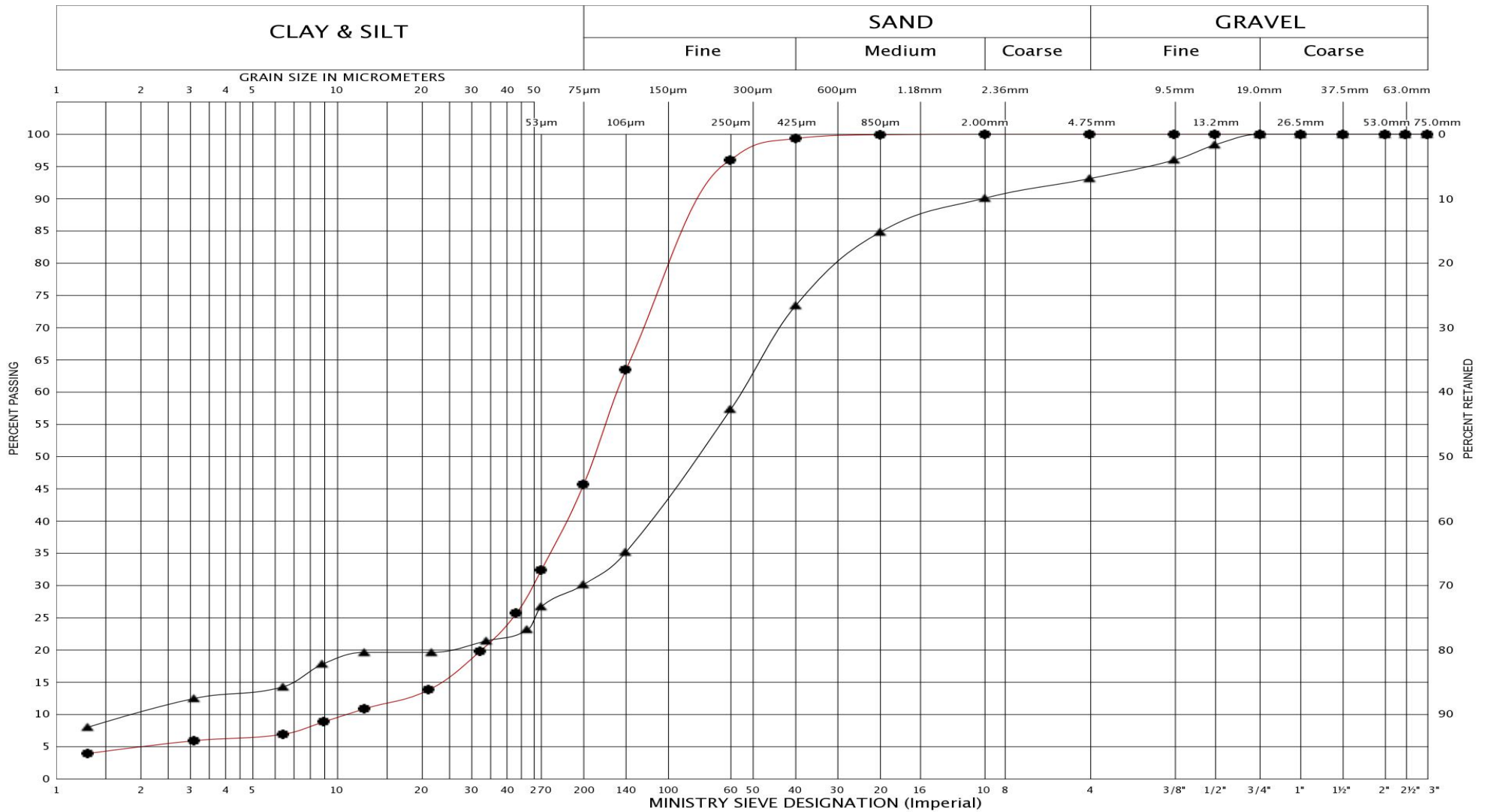
Geoffrey R. White, P.Eng.
Associate
Manager, Geotechnical and Geoenvironmental Services

AK/GRW;jlb

Enclosure(s):

Figures 1 to 2 – Grain Size Distribution Charts
List of Abbreviations
Log of Test Pits GP1 to GP3
Drawing No. 2-1 - Site Plan
Drawing 2-2 – Hydrogeological Section A-A'
Appendix A – MECP WWRs
Appendix B – Statement of Limitations

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	GP 2	GP 1
	SAMPLE	3	4
	SYMBOL	●	▲

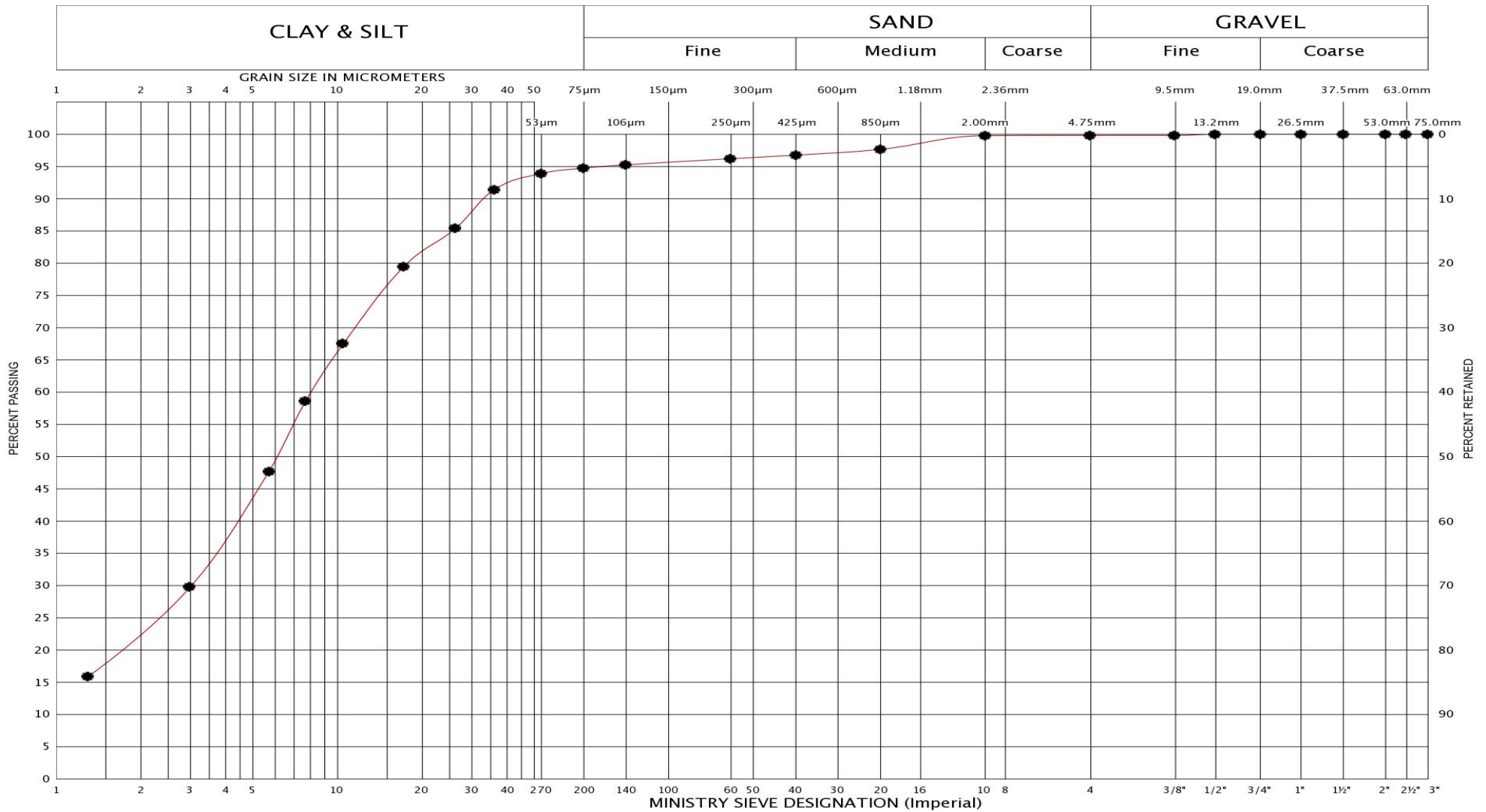
GRAIN SIZE DISTRIBUTION SILTY
SAND TILL, Trace Clay, Trace Gravel

FIG No.: 1

Project No.: 18BF030



UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	GP 3
	SAMPLE	4
	SYMBOL	•

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, Trace Sand

FIG No.: 2

Project No.: 18BF030

LIST OF ABBREVIATIONS



PENETRATION RESISTANCE

Standard Penetration Resistance N: - The number of blows required to advance a standard split spoon sampler 0.3 m into the subsoil. Driven by means of a 63.5 kg hammer falling freely a distance of 0.76 m.

Dynamic Penetration Resistance: - The number of blows required to advance a 51 mm, 60 degree cone, fitted to the end of drill rods, 0.3 m into the subsoil. The driving energy being 475 J per blow.

DESCRIPTION OF SOIL

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described in the following terms:

<u>CONSISTENCY</u>	<u>N (blows/0.3 m)</u>	<u>c (kPa)</u>	<u>DENSENESS</u>	<u>N (blows/0.3 m)</u>
Very Soft	0 - 2	0 - 12	Very Loose	0 - 4
Soft	2 - 4	12 - 25	Loose	4 - 10
Firm	4 - 8	25 - 50	Compact	10 - 30
Stiff	8 - 15	50 - 100	Dense	30 - 50
Very Stiff	15 - 30	100 - 200	Very Dense	> 50
Hard	> 30	> 200		
WTLL	Wetter Than Liquid Limit			
WTPL	Wetter Than Plastic Limit			
APL	About Plastic Limit			
DTPL	Drier Than Plastic Limit			

TYPE OF SAMPLE

SS	Split Spoon	ST	Slotted Tube Sample
WS	Washed Sample	TW	Thinwall Open
SB	Scraper Bucket Sample	TP	Thinwall Piston
AS	Auger Sample	OS	Oesterberg Sample
CS	Chunk Sample	FS	Foil Sample
GS	Grab Sample	RC	Rock Core
	PH	Sample Advanced Hydraulically	
	PM	Sample Advanced Manually	

SOIL TESTS

Qu	Unconfined Compression	LV	Laboratory Vane
Q	Undrained Triaxial	FV	Field Vane
Qcu	Consolidated Undrained Triaxial	C	Consolidation
Qd	Drained Triaxial		

LOG OF BOREHOLE NO. GP1

PROJECT Proposed Residential Development - 521 and 525 Essa Road
LOCATION Barrie, Ontario
BORING METHOD Excavator

BORING DATE April 24, 2019

PML REF. 18BF030
ENGINEER GW
TECHNICIAN JR

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)		PLASTIC LIMIT			NATURAL MOISTURE CONTENT			LIQUID LIMIT			UNIT WEIGHT kN/m ³	GROUND WATER OBSERVATIONS AND REMARKS
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	+ FIELD VANE Δ TORVANE ○ Qu				w _p	w	w _L	WATER CONTENT (%)					
						▲ POCKET PENETROMETER ○ Q							DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST ●					
						50	100	150	200				10	20	30	40		
0.0	SURFACE ELEVATION 314.90																	
0.20	TOPSOIL: Brown, sand, trace gravel, trace silt, moist		1	GS														
314.70	FILL: Brown, silty sand, moist		2	GS														
1.0						314												
1.1	SAND AND SILT: Brown, sand and silt, moist		3	GS														GP Test 1
313.8			4	GS														GP Test 2
2.0	TEST PIT TERMINATED AT 2.0 m					313												Upon completion of augering No water Sloughing at 1.6 m
312.9																		
3.0																		
4.0																		
5.0																		

NOTES

LOG OF BOREHOLE NO. GP2

17T

PROJECT Proposed Residential Development - 521 and 525 Essa Road
LOCATION Barrie, Ontario
BORING METHOD Excavator

BORING DATE April 24, 2019

PML REF. 18BF030

ENGINEER GW

TECHNICIAN JR

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)				PLASTIC NATURAL LIQUID			UNIT WEIGHT	GROUND WATER OBSERVATIONS AND REMARKS	
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	+ FIELD VANE	Δ TORVANE	○ QU	○ Q	LIMIT	MOISTURE CONTENT	LIMIT			kN/m ³
						50	100	150	200	w _p	w	w _L			
						DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST				WATER CONTENT (%)					
						20	40	60	80	×	10	20	30	40	
0.0	SURFACE ELEVATION 314.70														
0.20	TOPSOIL: Brown, sand, trace gravel, trace silt, moist		1	GS											
314.50	SILTY SAND: Brown, silty sand, moist to wet		2	GS											GP Test 1
			3	GS											GP Test 2
0.70	TEST PIT TERMINATED AT 0.7 m														Upon completion of augering Water at 0.6 m No sloughing
314.00															
1.0															
2.0															
3.0															
4.0															
5.0															

NOTES

LOG OF BOREHOLE NO. GP3

17T

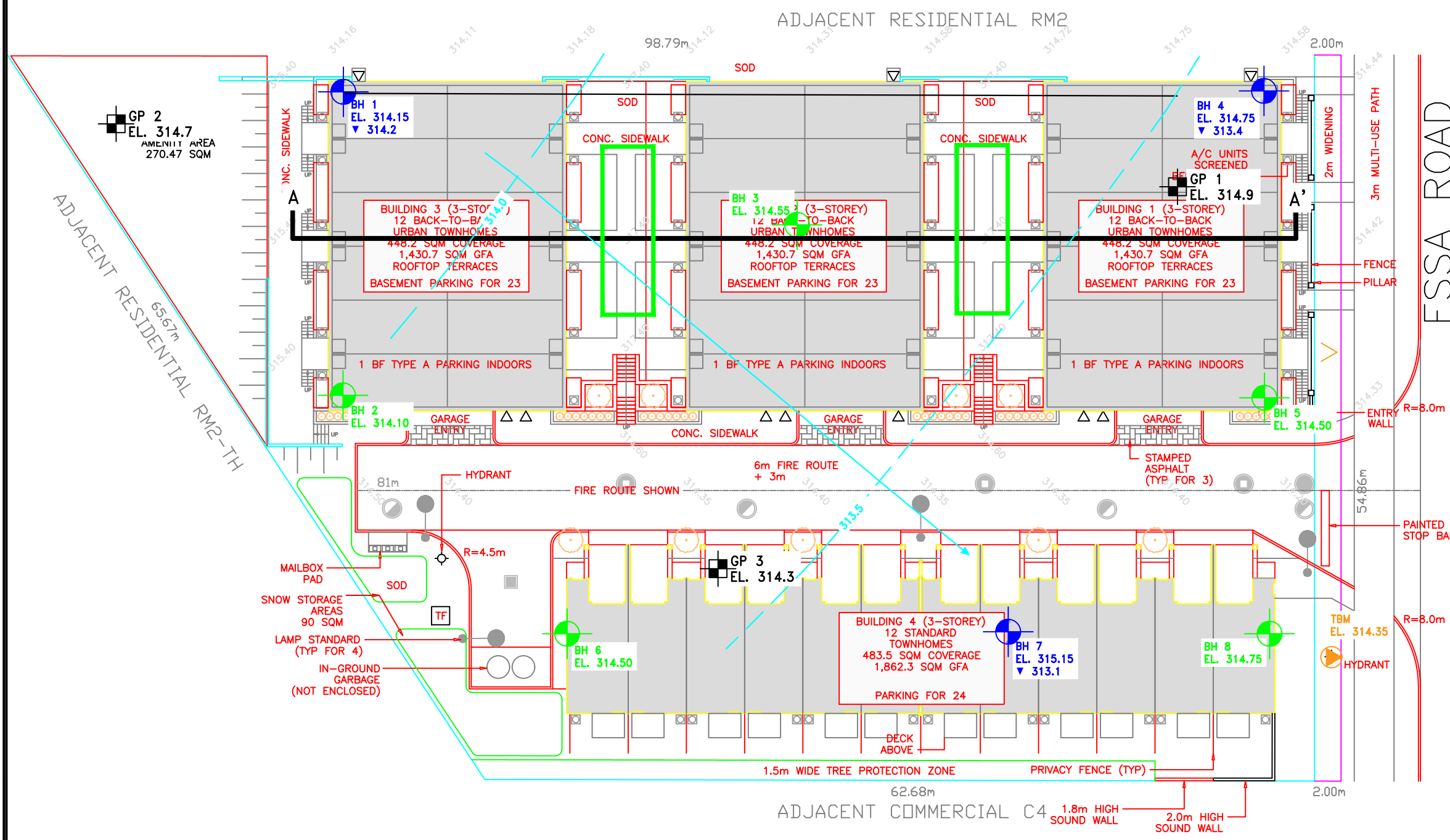
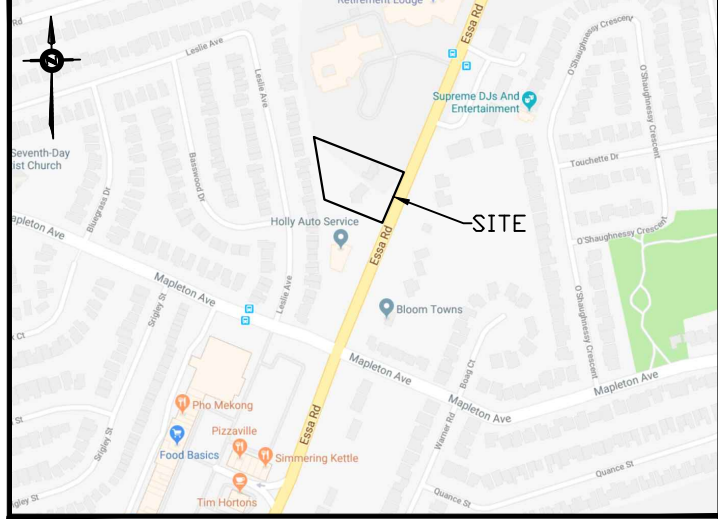
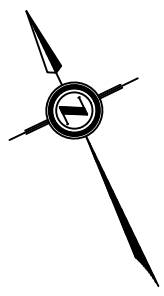
PROJECT Proposed Residential Development - 521 and 525 Essa Road
LOCATION Barrie, Ontario
BORING METHOD Excavator

BORING DATE April 24, 2019

PML REF. 18BF030
ENGINEER GW
TECHNICIAN JR

SOIL PROFILE			SAMPLES			SHEAR STRENGTH (kPa)				PLASTIC NATURAL LIQUID			UNIT WEIGHT	GROUND WATER OBSERVATIONS AND REMARKS		
DEPTH ELEV (metres)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	+ FIELD VANE Δ TORVANE ○ Qu				LIMIT	MOISTURE CONTENT			LIMIT	
							▲ POCKET PENETROMETER ○ Q									
						DYNAMIC CONE PENETRATION ×				WATER CONTENT (%)						
						STANDARD PENETRATION TEST ●				Wp — W — Wl						
						50	100	150	200				10	20	30	40
						20	40	60	80							
0.0	SURFACE ELEVATION 314.25															
0.25	TOPSOIL: Brown, sand, trace gravel, trace silt, moist		1	GS		314										
314.00	FILL: Brown, silty sand, moist		2	GS												
1.0																
1.4																
312.8	SILTY SAND: Brown, silty sand, moist to wet		3	GS											GP Test 1	
1.6																
312.6	CLAYEY SILT: Grey, clayey silt, wet		4	GS											GP Test 2	
1.8																
312.4	TEST PIT TERMINATED AT 1.8 m														Upon completion of augering No water Sloughing at 1.3 m	
2.0																
3.0																
4.0																
5.0																

NOTES



KEY PLAN BARRIE, ONTARIO

LEGEND:

- BH 1** BOREHOLE 1 (WITH MONITORING WELL)
EL. 314.15 SURFACE ELEVATION
▼ 313.1 GROUND WATER ELEVATION (APRIL 24, 2019)
- BH 2** BOREHOLE 2
EL. 314.10 SURFACE ELEVATION
- GP 1** GUELPH PERMEAMETER
EL. 314.7 SURFACE ELEVATION
- TBM** TEMPORARY BENCH MARK
EL. 314.35 TOP OF FLANGE OF FIRE HYDRANT #3986
ELEVATION 314.35 (METRIC, GEODETIC)
- PROPOSED STORM WATER MANAGEMENT TANK
- A A' HYDROGEOLOGICAL SECTION
- 314.0 - APPROXIMATE GROUND WATER CONTOUR
SHALLOW AQUIFER
- INFERRED GROUND WATER FLOW DIRECTION

REFERENCE:
BASE PLAN PROVIDED BY CLIENT.

0m 5 10 15 20 25

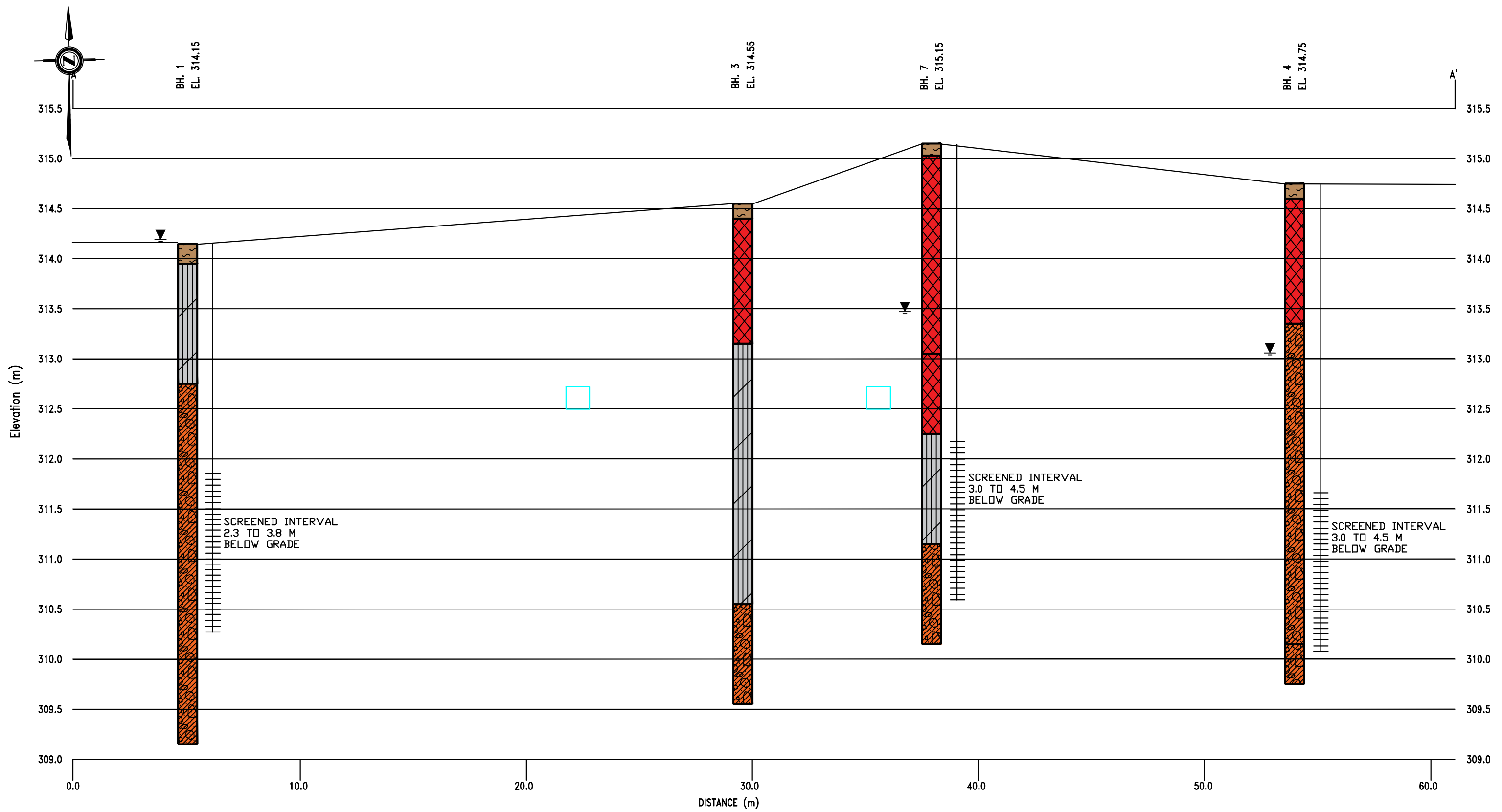
SCALE

SITE PLAN

PROPOSED RESIDENTIAL DEVELOPMENT
521 AND 525 ESSA ROAD
BARRIE, ONTARIO



DRAWN	AK	DATE	SCALE	PML REF.	DRAWING NO.
CHECKED	CW	MAY 2019	AS SHOWN	18BF030	2-1
APPROVED	CW				



HYDROGEOLOGICAL SECTION A-A'

PROPOSED RESIDENTIAL DEVELOPMENT
521 AND 525 ESSA ROAD
BARRIE, ONTARIO

PML Peto MacCallum Ltd.
CONSULTING ENGINEERS

DRAWN	AK	DATE	SCALE	PML REF.	DRAWING NO.
CHECKED	GW	MAY, 2019	AS SHOWN	18BF030	2-2
APPROVED	GW				



APPENDIX A

MECP WWRs



TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 12 005	17 603005 4910442 W	2016/04 7499	36			NU		7275569 (Z204286) A	
INNISFIL TOWNSHIP	17 602934 4910422 W	2016/04 7499						7275568 (Z204285) A	
INNISFIL TOWNSHIP	17 603110 4910769 W	2015/12 7215						7260073 (C31909) A197191 P	
INNISFIL TOWNSHIP CON 12 004	17 602943 4910479 W	2015/06 7391	2	8			0004 10	7244307 (Z117445) A098202	BRWN GRVL SAND STNS 0002 BRWN CLAY SAND 0005 GREY CLAY SAND SLTY 0010 GREY CLAY SAND SLTY 0015
INNISFIL TOWNSHIP	17 603224 4910848 W	2011/11 7241	1.5			MT	0010 10	7174638 (Z143414) A126471	BRWN FILL 0010 GREY SILT CLAY TILL 0020
INNISFIL TOWNSHIP	17 603231 4910867 W	2011/11 7241	1.5			MT	0010 10	7174637 (Z143415) A126470	BRWN FILL 0010 GREY SILT CLAY TILL 0020
INNISFIL TOWNSHIP CON 12 004	17 602891 4910127 W	2010/12 7314						7157916 (M05775) A093144 A	
INNISFIL TOWNSHIP CON 12 004	17 602912 4910111 W	2010/01 7238	0.79	UT 0030		MO	0021 16	7147833 (Z114066) A091560	BRWN SAND GRVL 0038
BARRIE CITY	17 602997 4910411 W	2009/11 2514	36			NU		7139176 (Z91918) A080954 A	15
BARRIE CITY	17 602912 4910103 W	2009/11 7215				TH	0005 10	7136882 (Z107512) A093130	BRWN FILL 0002 BRWN SAND SILT 0012 GREY CLAY SAND 0015
BARRIE CITY	17 602904 4910113 W	2009/11 7215				TH	0005 10	7136881 (Z107515) A093144	BRWN FILL 0002 BRWN SILT SAND 0015
INNISFIL TOWNSHIP CON 12 005	17 603491 4910612 W	2005/07 3108						5740508 (Z30593) A	PRDG 0031
INNISFIL TOWNSHIP	17 603500 4910622 W	2005/07 3108				NU		5740507 (Z30595) A	PRDG 0025
INNISFIL TOWNSHIP CON 12 004	17 602926 4910401 W	2004/05 7230	1.97	FR 0005		NU	0005 12	5739117 (Z15071) A011694	BRWN FILL GRVL SILT 0003 BRWN SAND SILT CLAY 0005 GREY SAND SILT LOOS 0008 GREY CLAY SILT DNSE 0017
INNISFIL TOWNSHIP CON 12 005	17 603290 4910199 L	1987/07 4919	30 30	UK 0040	40/56//:1	DO		5722349 (05049)	BRWN LOAM HARD 0001 BRWN SAND PCKD 0062



TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 12 005	17 602964 4910823 W	1984/01 2514	6	FR 0055	44/56/10 /1:0	DO	0060 3	5719022 ()	BRWN CLAY SILT SAND 0042 GREN MSND 0063
INNISFIL TOWNSHIP CON 12 005	17 603064 4910773 W	1980/07 3660	5	FR 0170	147/175/ 5/2:0	DO	0186 4	5716815 ()	BRWN SAND GRVL 0030 GREY CLAY 0058 GREY SAND CLAY 0080 GREY CLAY 0105 BRWN SAND DRY 0170 BRWN SAND WBRG 0190
INNISFIL TOWNSHIP CON 12 005	17 603014 4910623 W	1979/11 3203	5	FR 0019	44/62/6/ 1:0	DO	0073 3	5716539 ()	PRDG 0049 GREY SAND 0076 GREY CLAY 0076
INNISFIL TOWNSHIP CON 12 005	17 603311 4910873 W	1978/12 3135	5	UK 0155	155/165/ 10/2:0	CO DO	0181 4	5715885 ()	BRWN LOAM 0001 BRWN SAND CLAY 0032 GREY CLAY 0040 BRWN SAND DRY 0155 BRWN SAND 0185
INNISFIL TOWNSHIP CON 12 004	17 602964 4910323 W	1977/02 3742	30	FR 0010	6/30/4/4: 0	DO		5715044 ()	LOAM 0001 BRWN CLAY LTCL 0005 GRVL 0010 BLUE CLAY LTCL 0036
INNISFIL TOWNSHIP CON 12 004	17 602914 4910173 W	1977/02 3413	30	FR 0044	15/35/3/:	DO		5715042 ()	LOAM 0001 BRWN CLAY LTCL 0010 BLUE CLAY LTCL 0044
INNISFIL TOWNSHIP CON 12 004	17 602914 4910273 W	1977/02 3413	30	FR 0043	10/35//:	DO		5715041 ()	LOAM 0001 BRWN CLAY LTCL 0010 BLUE CLAY LTCL 0043
INNISFIL TOWNSHIP CON 12 005	17 602914 4910773 W	1977/05 4608	30	FR 0015	10///:	DO		5714922 ()	CLAY STNS 0015 GREY CLAY 0025
INNISFIL TOWNSHIP CON 12 005	17 603414 4910793 W	1977/03 3660	5	FR 0153	140/145/ 6/1:0	DO	0161 3	5714107 ()	RED SAND 0015 GREY CLAY GRVL 0040 BRWN FSND CLAY 0050 BLUE CLAY 0092 BRWN SAND CLAY 0153 GREY MSND 0158 BRWN MSND 0164
INNISFIL TOWNSHIP CON 12 005	17 603114 4910823 W	1975/01 2804	30	FR 0023		DO		5712158 ()	BLCK LOAM 0001 BRWN CLAY STNS 0030 GREY CSND DRY 0035
INNISFIL TOWNSHIP CON 12 004	17 603002 4910372 W	1974/06 4608		FR 0008	8///:	DO		5711269 ()	BRWN GRVL 0002 BRWN CLAY 0012 BRWN GRVL 0015
INNISFIL TOWNSHIP CON 12 004	17 602982 4910306 W	1974/06 4608	30	FR 0010	10///:	DO		5711113 ()	BRWN SAND 0004 BRWN CLAY 0007 BRWN CLAY 0025
INNISFIL TOWNSHIP CON 12 004	17 602984 4910330 W	1974/06 4608	30	FR 0008	8///:	DO		5711112 ()	BRWN SAND 0002 BRWN CLAY 0012 BRWN CLAY 0018
INNISFIL TOWNSHIP CON 13 005	17 603214 4910983 W	1969/08 4608	30	FR 0042 FR 0052	42/48//1: 0	DO		5706557 ()	BRWN CLAY STNS 0015 GREY CLAY 0035 GREY MSND 0052
INNISFIL TOWNSHIP CON 12 005	17 603204 4910894 W	1964/10 2514	6	FR 0077	48/70/10 /2:0	ST DO	0077 3	5701445 ()	LOAM 0001 FILL 0005 BRWN CLAY BLDR 0015 BLUE CLAY BLDR 0040 MSND 0080
INNISFIL TOWNSHIP CON 12 005	17 603121 4910825 W	1962/09 3715	30	FR 0025	15/20/2/ 24:0	CO		5701444 ()	LOAM 0002 BRWN CLAY 0025
INNISFIL TOWNSHIP CON 12 005	17 602981 4910747 W	1962/05 3715	30	FR 0015	15//3/24: 0	DO		5701443 ()	CLAY 0023 GRVL 0030



TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 12 005	17 603460 4910703 W	1960/11 3512	5					5701442 () A	FSND 0100 BLUE CLAY 0150 FSND 0250 BLUE CLAY 0350 FSND 0430 BLUE CLAY 0450 FSND 0477
INNISFIL TOWNSHIP CON 12 005	17 603455 4910715 W	1960/10 3512	4					5701441 () A	FSND 0100 BLUE CLAY 0120
INNISFIL TOWNSHIP CON 12 004	17 602851 4910772 W	1966/10 4608	30	FR 0012	12//2/:	DO		5701439 ()	BRWN CLAY STNS 0030
INNISFIL TOWNSHIP CON 12 004	17 602931 4910808 W	1966/09 4608	30	FR 0012	12//2/:	DO		5701438 ()	BRWN CLAY STNS 0028
INNISFIL TOWNSHIP CON 12 004	17 602881 4910435 W	1965/03 2514	6	FR 0155	155/165/ 8/2:0	CO	0188 3	5701436 ()	LOAM 0001 YLLW CLAY 0015 BLUE CLAY 0021 SILT 0024 GREY CLAY 0048 SILT CLAY 0066 FSND 0072 SILT CLAY 0092 MSND GRVL 0155 MSND 0191
INNISFIL TOWNSHIP CON 12 005	17 603017 4910745 W	1965/02 2514	6 5	FR 0059	47/55/4/ 2:0	DO	0053 3	5701435 ()	PRDG 0049 MSND 0059 BLUE CLAY MSND 0065 BLUE CLAY 0066
INNISFIL TOWNSHIP CON 12 004	17 602744 4910388 W	1961/03 1308	30	FR 0045	45//13/8: 0	DO		5701434 ()	BRWN CLAY MSND 0005 GRVL 0011 CLAY MSND 0030 BRWN MSND 0065
INNISFIL TOWNSHIP CON 12 004	17 602643 4910372 W	1951/10 5510	4	FR 0052	42/43/4/ 1:0	ST DO	0052 10	5701433 ()	LOAM MSND 0002 CLAY STNS 0022 MSND 0062



APPENDIX B

Statement of Limitations

STATEMENT OF LIMITATIONS



This report is prepared for and made available for the sole use of the client named. Peto MacCallum Ltd. (PML) hereby disclaims any liability or responsibility to any person or entity, other than those for whom this report is specifically issued, for any loss, damage, expenses, or penalties that may arise or result from the use of any information or recommendations contained in this report. The contents of this report may not be used or relied upon by any other person without the express written consent and authorization of PML.

This report shall not be relied upon for any purpose other than as agreed with the client named without the written consent of PML. It shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. A portion of this report may not be used as a separate entity: that is to say the report is to be read in its entirety at all times.

The report is based solely on the scope of services which are specifically referred to in this report. No physical or intrusive testing has been performed, except as specifically referenced in this report. This report is not a certification of compliance with past or present regulations, codes, guidelines and policies.

The scope of services carried out by PML is based on details of the proposed development and land use to address certain issues, purposes and objectives with respect to the specific site as identified by the client. Services not expressly set forth in writing are expressly excluded from the services provided by PML. In other words, PML has not performed any observations, investigations, study analysis, engineering evaluation or testing that is not specifically listed in the scope of services in this report. PML assumes no responsibility or duty to the client for any such services and shall not be liable for failing to discover any condition, whose discovery would require the performance of services not specifically referred to in this report.

STATEMENT OF LIMITATIONS



The findings and comments made by PML in this report are based on the conditions observed at the time of PML's site reconnaissance. No assurances can be made and no assurances are given with respect to any potential changes in site conditions following the time of completion of PML's field work. Furthermore, regulations, codes and guidelines may change at any time subsequent to the date of this report and these changes may affect the validity of the findings and recommendations given in this report.

The results and conclusions with respect to site conditions are therefore in no way intended to be taken as a guarantee or representation, expressed or implied, that the Site is free from any contaminants from past or current land use activities or that the conditions in all areas of the Site and beneath or within structures are the same as those areas specifically sampled.

Any investigation, examination, measurements or sampling explorations at a particular location may not be representative of conditions between sampled locations. Soil, ground water, surface water, or building material conditions between and beyond the sampled locations may differ from those encountered at the sampling locations and conditions may become apparent during construction which could not be detected or anticipated at the time of the intrusive sampling investigation.

Budget estimates contained in this report are to be viewed as an engineering estimate of probable costs and provided solely for the purposes of assisting the client in its budgeting process. It is understood and agreed that PML will not in any way be held liable as a result of any budget figures provided by it.

The Client expressly waives its right to withhold PML's fees, either in whole or in part, or to make any claim or commence an action or bring any other proceedings, whether in contract, tort, or otherwise against PML in any way connected with advice or information given by PML relating to the cost estimate or Environmental Remediation/Cleanup and Restoration or Soil and Ground Water Management Plan Cost Estimate.

June 6, 2019

PML Ref.: 18BF030
Report: 3

Mr. Bryan Toteda
Encore Development Group
110 Adesso Drive, Unit 8
Concord, Ontario
L4K 3C5

Dear Mr. Toteda

Ground Water Level Monitoring
521 and 525 Essa Road
Barrie, Ontario

Previously, PML completed a geotechnical investigation (Report 1, dated July 12, 2018) and a hydrogeological investigation (Report 2, dated May 9, 2019) for the above noted project. As part of Report 2, four sets of water level measurements were required. One final set of water level measurements for June 2019 was required to complete our scope of work after issuance of Report 2.

The final set of water level measurements were carried out on June 6, 2019 and do not impact the recommendations provided in Report 2. The water level data from the four site visits is summarized below.

Borehole	Borehole Ground Surface Elevation	Water Levels in Wells (Depth (m) / Elevation)			
		27/03/2019	24/04/2019	08/05/2019	06/06/2019
1	314.15	0.0 / 314.2	0.0 / 314.2	0.2 / 313.9	0.3 / 313.9
4	314.75	1.9 / 312.9	1.4 / 313.4	1.6 / 313.2	2.0 / 312.8
7	315.15	2.2 / 313.0	2.1 / 313.1	2.1 / 313.1	2.2 / 313.0

It is noted that, as per O.Reg. 903, the monitoring wells are property of the Owner and will have to be decommissioned if no longer required. PML would be pleased to assist in this regard.

We trust this report is complete within our Terms of Reference. Please do not hesitate to call if you have any questions.

Sincerely

Peto MacCallum Ltd.



Geoffrey R. White, P.Eng.
Associate
Manager, Geotechnical and Geoenvironmental Services

JR/GRW:jb

Distribution:

1 cc: Encore Development Group Mr. Bryan Toteda (email only)
1 cc: Innovative Planning Solutions Ms. Vanessa Simpson, B.ID, M.PI. (email only)
1 cc: PML Barrie

19 Churchill Drive, Barrie, Ontario L4N 8Z5
Tel: (705) 734-3900 Fax: (705) 734-9911
E-mail: barrie@petomacallum.com

**RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**

APPENDIX B

Storm Water Management Calculations



3.2.1 Service Area

The drainage system shall be designed to accommodate all upstream drainage areas plus any external area tributary to the system for the existing, interim and ultimate development conditions, as determined by the delineation of appropriate topographic mapping and the preparation of drainage plans.

3.2.2 Design Flow

Storm sewer systems with a drainage area ≤ 50 ha shall be designed to convey the 1:5 year (minimum) design storm using the Rational Method and the City's IDF regression equation for rainfall intensity unless otherwise approved or directed by the City. Storm sewer systems with a drainage area > 50 ha shall be designed using an approved computer program and verified with the Rational Method. The storm sewer design shall be based on the larger of the two flows calculated using the computer model and the Rational Method. Under no circumstances shall the storm system be designed in a surcharged condition.

The design of the storm sewers shall be computed using the City of Barrie's Storm Sewer Design Sheet as provided in **Appendix A**.

All storm sewers shall be designed according to the Rational Formula where:

$$Q = \frac{(C)(i)(A)}{360}$$

where,

- Q = the design flow in (m³/s)
- C = the site specific runoff coefficient
- A = the drainage area (ha)
- i = rainfall intensity (mm/hr)

The rainfall intensity shall be calculated in accordance with the following table and equation:

Table 3.1: Barrie WPCC IDF Curve Parameters - Adjusted to Account for Climate Change

Parameter	Return Period					
	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
A	678.085	853.608	975.865	1146.275	1236.152	1426.408
B	4.699	4.699	4.699	4.922	4.699	5.273
C	0.781	0.766	0.760	0.757	0.751	0.759

Rainfall Intensity, I (mm/hr) = $A/(t_d+B)^C$, where t is time duration in minutes
Parameters based on rain gauge data for the period 1979 – 2003 for the Barrie WPCC Station #6110557

Based on a review of the literature, the IDF intensity values for Barrie WPCC Station were increased by 15% before calculating a, b, c values to account for climate change

$$i = \frac{A}{(t_d + B)^C}$$

where,

- i = the rainfall intensity (mm/hr)
- t_d = the storm duration (minutes)
- A, B, C = a function of the local intensity-duration data.

The storm duration is set to the time of concentration (i.e. the sewer inlet time plus the time of travel in the pipe or channel) for the total cumulative drainage area to the node of interest. The maximum inlet time for the first pipe of a storm sewer system is 10 minutes.

The runoff coefficient shall be calculated in accordance with the following table:

Table 3.2: Runoff Coefficients (Rational C) (5-yr to 10-yr) Based on Hydrologic Soil Group

Land Use	Runoff Coefficient "C"		
	A-AB	B-BC	C-D
Cultivated Land, 0 - 5% grade	0.22	0.35	0.55
Cultivated Land, 5 - 10% grade	0.30	0.45	0.60
Cultivated Land, 10 - 30% grade	0.40	0.65	0.70
Pasture Land, 0 - 5% grade	0.10	0.28	0.40
Pasture Land, 5 - 10% grade	0.15	0.35	0.45
Pasture Land, 10 - 30% grade	0.22	0.40	0.55
Woodlot or Cutover, 0 - 5% grade	0.08	0.25	0.35
Woodlot or Cutover, 5 - 10% grade	0.12	0.30	0.42
Woodlot or Cutover, 10 - 30% grade	0.18	0.35	0.52
Lakes and Wetlands	0.05	0.05	0.05
Impervious Area (i.e., buildings, roads, parking lots, etc.)	0.95	0.95	0.95
Gravel (not to be used for proposed parking or storage areas)	0.40	0.50	0.60
Residential – Single Family	0.30	0.40	0.50
Residential – Multiple (i.e., semi, townhouse, apartment)	0.50	0.60	0.70
Industrial – light	0.55	0.65	0.75
Industrial – heavy	0.65	0.75	0.85
Commercial	0.60	0.70	0.80
Unimproved Areas	0.10	0.20	0.30
Lawn, < 2% grade	0.05	0.11	0.17
Lawn, 2 - 7% grade	0.10	0.16	0.22
Lawn, > 7% grade	0.15	0.25	0.35

Adapted from Design Chart 1.07, Ontario Ministry of Transportation, "MTO Drainage Management Manual," MTO. (1997)

An approximation of the runoff coefficient can be calculated based on the following relationship with:

$$c = (0.7)(TIMP) + 0.2$$

where,

c = the runoff coefficient

TIMP = total impervious fraction (dimensionless)

The runoff coefficient shall be adjusted for return period events greater than the 10-yr storm per the following table:



Table 3.3: Runoff Coefficient Adjustment for 25-yr to 100-yr Storms

Return Period	Runoff Coefficient "C"
25 years	$C_{25} = 1.1 \cdot C_5$
50 years	$C_{50} = 1.2 \cdot C_5$
100 years	$C_{100} = 1.25 \cdot C_5$

Adapted from Design Chart 1.07, Ontario Ministry of Transportation,
"MTO Drainage Management Manual," MTO, (1997).

Note: When applying the runoff coefficient adjustment, the maximum c-value should not exceed 1.0.

Given that the direct connection of foundation drains to the storm sewer is not permitted, a detailed HGL analysis is typically not required unless deemed otherwise by the City due to special circumstances. Refer to **Section 7.3** for details regarding HGL analysis requirements.

The calculation of total percent impervious (TIMP) values for modeling shall be in accordance with **Section 7.2.5** (**Table 7.6**).

3.2.3 Pipe Capacity and Size

The storm sewer capacity shall be calculated using the Manning's equation assuming the pipe is flowing full as follows:

$$Q = \left[\frac{1}{n} \right] A (R)^{\frac{2}{3}} (S)^{\frac{1}{2}}$$

where,

- Q = the pipe capacity (m³/s)
- n = the Manning roughness value
- R = the hydraulic radius (m)
- S = the sewer pipe slope (m/m).

A maximum inlet time of 10 minutes shall be used for the first pipe of a storm sewer system.

The velocity of flow in the storm sewer (assuming pipe flowing full) shall be calculated as follows:

$$v = \left[\frac{Q}{A} \right]$$

where,

- Q = flow in the pipe when flowing full (m³/s)
- A = cross sectional area of the pipe (m²)

The appropriate roughness coefficients shall be used as identified in **Table 3.4**.

The minimum size for a storm sewer (within a street) shall be 300 mm in diameter. No decrease of pipe size from a larger size upstream to a smaller size downstream shall be allowed regardless of the increase in grade.

3.2.4 Roughness Coefficients

The following roughness coefficients shall be used for hydraulic calculations of storm sewers:

521-525 Essa Road

MODIFIED RATIONAL METHOD - PRE-DEVELOPMENT CATCHMENT 101

City of Barrie

Project Number: 17-11306.1B
 Date: April 18, 2020
 Design By: JHV
 File: C:\Users\dwiho\OneDrive - Pinestone Engineering Ltd\11501B Essa Road Townhomes\SWM Rev 2, April 2020\MRM SWM Calculations - JHV Final.xls

IDF Curve Parameters				Intensity (mm/hr)
Storm Event	A	B	C	
2 year	678.085	4.699	0.7810	83.11
5 year	853.608	4.699	0.7660	108.92
10 year	975.865	4.699	0.7600	126.55
25 year	1146.275	4.922	0.7570	148.15
50 year	1236.152	4.699	0.7510	164.22
100 year	1426.408	5.273	0.7590	180.15

$T_c = 10.0$ minutes

$$i = \frac{A}{(t_c + B)^C}$$

I = average rainfall intensity (mm/hr)
 A,B,C, = the IDF equation coefficients (dimensionless)
 T_c = time of concentration (min)

Runoff Coefficients	
Land Use	"C"
Unimproved Area	0.30
Pasture Land	0.40
Woodlot	0.35
Lakes / Swamps	0.05
Impervious Area	0.95
Building Area	0.95
Gravel	0.60
Lawn	0.17
X	0.00
Y	0.00
Z	0.00

Time of Concentration Calculations:

Catchment Parameters		
Catchment ID	=	101
Catchment Area	=	0.4428 ha
Flow Length	=	35 m
Slope	=	0.005 m/m
Weighted Runoff Coefficient	=	0.34

Pre-Development Runoff Coefficients:

Catchment	Total Area (m ²)	Unimproved Area (m ²)	Pasture Area (m ²)	Woodlot Area (m ²)	Lakes/Swamps Area (m ²)	Impervious Area (m ²)	Building Area (m ²)	Gravel Area (m ²)	Lawn Area (m ²)	X Area (m ²)	Y Area (m ²)	Z Area (m ²)	Weighted C
101	4,428			95			950		3,383				0.34

Runoff Coefficient Adjustment for 25-100 yr Storm Events:

Catchment	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
101	0.34	0.34	0.34	0.38	0.41	0.43

Pre-Development Peak Flow Rates:

Catchment	2-Year (m ³ /s)	5-Year (m ³ /s)	10-Year (m ³ /s)	25-Year (m ³ /s)	50-Year (m ³ /s)	100-Year (m ³ /s)
101	0.035	0.046	0.053	0.068	0.083	0.095

Notes:

- 1) Runoff coefficients from City of Barrie Storm Drainage and SWM Policies and Design Guidelines Table 3.2
- 2) Runoff coefficients for events greater than the 10 year storm have been adjusted as per City Policies and Guidelines Table 3.3

521-525 Essa Road

MODIFIED RATIONAL METHOD - POST DEVELOPMENT CATCHMENT 201

City of Barrie

Project Number: 17-11306.1B
 Date: April 18, 2020
 Design By: JHV
 File: C:\Users\dwiho\OneDrive - Pinestone Engineering Ltd\11501B Essa Road Townhomes\SWM Rev 2, April 2020\MRM SWM Calculations - JHV Final.xls

IDF Curve Parameters				Intensity (mm/hr)
Storm Event	A	B	C	
2 year	678.085	4.699	0.7810	83.11
5 year	853.608	4.699	0.7660	108.92
10 year	975.865	4.699	0.7600	126.55
25 year	1146.275	4.922	0.7570	148.15
50 year	1236.152	4.699	0.7510	164.22
100 year	1426.408	5.273	0.7590	180.15

$T_c = 10.0$ minutes

$$i = \frac{A}{(t_c + B)^C}$$

I = average rainfall intensity (mm/hr)
 A,B,C, = the IDF equation coefficients (dimensionless)
 T_c = time of concentration (min)

Runoff Coefficients	
Land Use	"C"
Unimproved Area	0.30
Pasture Land	0.40
Woodlot	0.35
Lakes / Swamps	0.05
Impervious Area	0.95
Building Area	0.95
Gravel	0.60
Lawn	0.17
X	0.00
Y	0.00
Z	0.00

Time of Concentration Calculations:

Catchment Parameters		
Catchment ID	=	201
Catchment Area	=	0.3283 ha
Flow Length	=	20 m
Slope	=	0.015 m/m
Weighted Runoff Coefficient	=	0.86

Pre-Development Runoff Coefficients:

Catchment	Total Area (m ²)	Unimproved Area (m ²)	Pasture Area (m ²)	Woodlot Area (m ²)	Lakes/Swamps Area (m ²)	Impervious Area (m ²)	Building Area (m ²)	Gravel Area (m ²)	Lawn Area (m ²)	X Area (m ²)	Y Area (m ²)	Z Area (m ²)	Weighted C
201	3,283						2,918		365				0.86

Runoff Coefficient Adjustment for 25-100 yr Storm Events:

Catchment	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
201	0.86	0.86	0.86	0.95	1.00	1.00

Post-Development Peak Flow Rates:

Catchment	2-Year (m ³ /s)	5-Year (m ³ /s)	10-Year (m ³ /s)	25-Year (m ³ /s)	50-Year (m ³ /s)	100-Year (m ³ /s)
201	0.065	0.086	0.100	0.128	0.150	0.164

Notes:

- 1) Runoff coefficients from City of Barrie Storm Drainage and SWM Policies and Design Guidelines Table 3.2
- 2) Runoff coefficients for events greater than the 10 year storm have been adjusted as per City Policies and Guidelines Table 3.3

521-525 Essa Road

MODIFIED RATIONAL METHOD - POST DEVELOPMENT CATCHMENT 202

City of Barrie

Project Number: 17-11306.1B
 Date: April 18, 2020
 Design By: JHV
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IDF Curve Parameters				Intensity (mm/hr)
Storm Event	A	B	C	
2 year	678.085	4.699	0.7810	83.11
5 year	853.608	4.699	0.7660	108.92
10 year	975.865	4.699	0.7600	126.55
25 year	1146.275	4.922	0.7570	148.15
50 year	1236.152	4.699	0.7510	164.22
100 year	1426.408	5.273	0.7590	180.15

Tc = 10.0 minutes

$$i = \frac{A}{(t_c + B)^c}$$

I = average rainfall intensity (mm/hr)
 A,B,C = the IDF equation coefficients (dimensionless)
 T_c = time of concentration (min)

Runoff Coefficients	
Land Use	"C"
Unimproved Area	0.30
Pasture Land	0.40
Woodlot	0.35
Lakes / Swamps	0.05
Impervious Area	0.95
Building Area	0.95
Gravel	0.60
Lawn	0.17
X	0.00
Y	0.00
Z	0.00

Time of Concentration Calculations:

Catchment Parameters		
Catchment ID	=	202
Catchment Area	=	0.1145 ha
Flow Length	=	30 m
Slope	=	0.01 m/m
Weighted Runoff Coefficient	=	0.27

Pre-Development Runoff Coefficients:

Catchment	Total Area (m ²)	Unimproved Area (m ²)	Pasture Area (m ²)	Woodlot Area (m ²)	Lakes/Swamps Area (m ²)	Impervious Area (m ²)	Building Area (m ²)	Gravel Area (m ²)	Lawn Area (m ²)	X Area (m ²)	Y Area (m ²)	Z Area (m ²)	Weighted C
202	1,145					140			1,005				0.27

Runoff Coefficient Adjustment for 25-100 yr Storm Events:

Catchment	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
202	0.27	0.27	0.27	0.29	0.32	0.33

Post-Development Peak Flow Rates:

Catchment	2-Year (m ³ /s)	5-Year (m ³ /s)	10-Year (m ³ /s)	25-Year (m ³ /s)	50-Year (m ³ /s)	100-Year (m ³ /s)
202	0.007	0.009	0.011	0.014	0.017	0.019

Notes:

- 1) Runoff coefficients from City of Barrie Storm Drainage and SWM Policies and Design Guidelines Table 3.2
- 2) Runoff coefficients for events greater than the 10 year storm have been adjusted as per City Policies and Guidelines Table 3.3

521-525 Essa Road

MODIFIED RATIONAL METHOD - PRE TO POST DEVELOPMENT FLOW SUMMARY

City of Barrie



Project Number:

17-11306.1B

Date:

April 18, 2020

Design By:

JHV

File:

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Storm Event	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
	(m ³ /s)	(m ³ /s)	(m ³ /s)	(m ³ /s)	(m ³ /s)	(m ³ /s)
Pre-Development Catchment 101	0.035	0.046	0.053	0.068	0.083	0.095
Total Pre-Development Flow	0.035	0.046	0.053	0.068	0.083	0.095
Post Development Catchment 201 (controlled)	0.065	0.086	0.100	0.128	0.150	0.164
Post Development Catchment 202 (uncontrolled)	0.007	0.009	0.011	0.014	0.017	0.019
Total Post Development Flow	0.072	0.095	0.110	0.142	0.166	0.183
Total Difference from Post to Pre	0.038	0.049	0.057	0.074	0.084	0.089
Allowable Post Development flow from Catchment 201	0.028	0.037	0.042	0.055	0.066	0.076

521-525 Essa Road

Quantity Control Storage Calculations - Catchment 201
 City of Barrie

Project Number: 17-11306.1B
 Date: April 18, 2020
 Design By: JHV
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2 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 0.86
 Release Rate 25.5 l/sec <= allowable of 0.028 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m³/sec)	Release Rate (m³/sec)	Required Storage Volume (m³)
10.0	83.1	0.066	0.026	24.26014395
11	78.9	0.063	0.026	24.50525904
12	75.2	0.060	0.026	24.60931678
13	71.9	0.057	0.026	24.59241681
14	68.9	0.055	0.026	24.47078141
15	66.1	0.052	0.026	24.25767186
16	63.6	0.050	0.026	23.96405316
17	61.3	0.049	0.026	23.59908461
18	59.2	0.047	0.026	23.17048788
19	57.2	0.045	0.026	22.68482718
20	55.4	0.044	0.026	22.14772522
21	53.7	0.043	0.026	21.56403175
22	52.1	0.041	0.026	20.93795649
23	50.7	0.040	0.026	20.27317507
24	49.3	0.039	0.026	19.57291416
25	48.0	0.038	0.026	18.84002051
26	46.8	0.037	0.026	18.07701742
27	45.6	0.036	0.026	17.28615118
28	44.5	0.035	0.026	16.46942953
29	43.5	0.034	0.026	15.62865387
30	42.5	0.034	0.026	14.76544614
31	41.6	0.033	0.026	13.88127156
32	40.7	0.032	0.026	12.97745798
33	39.8	0.032	0.026	12.05521224
34	39.0	0.031	0.026	11.11563433
35	38.3	0.030	0.026	10.15972942
36	37.5	0.030	0.026	9.188418407
37	36.8	0.029	0.026	8.202546899
38	36.1	0.029	0.026	7.202893168
39	35.5	0.028	0.026	6.190175026
40	34.9	0.028	0.026	5.165055865
41	34.3	0.027	0.026	4.128149975
42	33.7	0.027	0.026	3.08002723
43	33.1	0.026	0.026	2.021217229
44	32.6	0.026	0.026	0.952212975
45	32.1	0.025	0.026	-0.126525854
46	31.6	0.025	0.026	-1.214569995
47	31.1	0.025	0.026	-2.311517988
48	30.7	0.024	0.026	-3.416993846
49	30.2	0.024	0.026	-4.530644956
50	29.8	0.024	0.026	-5.652140194
51	29.4	0.023	0.026	-6.781168224

<- Required Volume

Control Flow:

Orifice Flow
 Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
313.06	0.49	0.0255	25.5

*Orifice Flow = C * Area * (2*9.81 * Hydraulic Head) ^0.5*
 where C = 0.62, A = area of the orifice and H = hydraulic head

5 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 0.86
 Release Rate 30.5 l/sec <= allowable of 0.037 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m ³ /sec)	Release Rate (m ³ /sec)	Required Storage Volume (m ³)
10.0	108.9	0.086	0.030	33.5632588
11	103.6	0.082	0.030	34.11473515
12	98.8	0.078	0.030	34.48218214
13	94.5	0.075	0.030	34.69152071
14	90.6	0.072	0.030	34.76370612
15	87.0	0.069	0.030	34.71589595
16	83.8	0.067	0.030	34.56229838
17	80.8	0.064	0.030	34.31479913
18	78.1	0.062	0.030	33.98343244
19	75.5	0.060	0.030	33.57674001
20	73.2	0.058	0.030	33.10204794
21	71.0	0.056	0.030	32.56568318
22	69.0	0.055	0.030	31.97314445
23	67.0	0.053	0.030	31.32923846
24	65.2	0.052	0.030	30.63818968
25	63.6	0.050	0.030	29.90372934
26	62.0	0.049	0.030	29.12916824
27	60.5	0.048	0.030	28.31745683
28	59.0	0.047	0.030	27.47123498
29	57.7	0.046	0.030	26.59287351
30	56.4	0.045	0.030	25.68450918
31	55.2	0.044	0.030	24.7480741
32	54.0	0.043	0.030	23.78532083
33	52.9	0.042	0.030	22.79784366
34	51.9	0.041	0.030	21.78709696
35	50.9	0.040	0.030	20.75441092
36	49.9	0.040	0.030	19.70100517
37	49.0	0.039	0.030	18.62800059
38	48.1	0.038	0.030	17.5364296
39	47.3	0.038	0.030	16.42724515
40	46.5	0.037	0.030	15.30132863
41	45.7	0.036	0.030	14.15949681
42	44.9	0.036	0.030	13.00250794
43	44.2	0.035	0.030	11.83106719
44	43.5	0.035	0.030	10.64583147
45	42.8	0.034	0.030	9.447413705
46	42.2	0.033	0.030	8.236386639
47	41.6	0.033	0.030	7.013286287
48	41.0	0.033	0.030	5.778614975
49	40.4	0.032	0.030	4.5328441
50	39.8	0.032	0.030	3.276416607
51	39.3	0.031	0.030	2.009749229

<- Required Volume

Control Flow:

Orifice Flow

Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
313.27	0.7	0.0305	30.5

Orifice Flow = C * Area * (2*9.81 * Hydraulic Head) ^0.5
 where C = 0.62, A = area of the orifice and H = hydraulic head

10 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 0.86
 Release Rate 33.8 l/sec <= allowable of 0.042 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m ³ /sec)	Release Rate (m ³ /sec)	Required Storage Volume (m ³)
10.0	126.5	0.100	0.034	39.97126971
11	120.4	0.096	0.034	40.73458729
12	114.9	0.091	0.034	41.28452381
13	109.9	0.087	0.034	41.65099569
14	105.4	0.084	0.034	41.85820416
15	101.3	0.080	0.034	41.92597701
16	97.6	0.077	0.034	41.87074347
17	94.1	0.075	0.034	41.70625527
18	91.0	0.072	0.034	41.44412843
19	88.0	0.070	0.034	41.09425643
20	85.3	0.068	0.034	40.66512918
21	82.8	0.066	0.034	40.1640824
22	80.4	0.064	0.034	39.59749455
23	78.2	0.062	0.034	38.97094403
24	76.1	0.060	0.034	38.28933571
25	74.1	0.059	0.034	37.55700367
26	72.3	0.057	0.034	36.77779531
27	70.6	0.056	0.034	35.95514068
28	68.9	0.055	0.034	35.09210996
29	67.4	0.053	0.034	34.19146158
30	65.9	0.052	0.034	33.25568251
31	64.5	0.051	0.034	32.28702244
32	63.1	0.050	0.034	31.28752265
33	61.9	0.049	0.034	30.25904081
34	60.6	0.048	0.034	29.2032721
35	59.5	0.047	0.034	28.12176747
36	58.4	0.046	0.034	27.01594946
37	57.3	0.045	0.034	25.88712582
38	56.3	0.045	0.034	24.73650147
39	55.3	0.044	0.034	23.56518895
40	54.3	0.043	0.034	22.37421755
41	53.4	0.042	0.034	21.16454135
42	52.6	0.042	0.034	19.93704636
43	51.7	0.041	0.034	18.69255679
44	50.9	0.040	0.034	17.43184065
45	50.1	0.040	0.034	16.15561471
46	49.4	0.039	0.034	14.86454895
47	48.7	0.039	0.034	13.55927053
48	48.0	0.038	0.034	12.24036735
49	47.3	0.038	0.034	10.90839124
50	46.6	0.037	0.034	9.56386086
51	46.0	0.036	0.034	8.207264294

<- Required Volume

Control Flow:

Orifice Flow

Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
313.43	0.86	0.0338	33.8

Orifice Flow = C * Area * (2*9.81 * Hydraulic Head)^{0.5}
 where C = 0.62, A = area of the orifice and H = hydraulic head

25 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 0.95
 Release Rate 39.8 l/sec <= allowable of 0.055 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m ³ /sec)	Release Rate (m ³ /sec)	Required Storage Volume (m ³)
10.0	148.2	0.129	0.040	53.73525094
11	141.1	0.123	0.040	55.01892284
12	134.7	0.118	0.040	56.02568378
13	129.0	0.113	0.040	56.79388051
14	123.8	0.108	0.040	57.35462074
15	119.0	0.104	0.040	57.73345336
16	114.7	0.100	0.040	57.95159431
17	110.7	0.097	0.040	58.02683643
18	107.0	0.093	0.040	57.97423552
19	103.6	0.090	0.040	57.80663481
20	100.5	0.088	0.040	57.53507117
21	97.5	0.085	0.040	57.16909328
22	94.8	0.083	0.040	56.71701354
23	92.2	0.080	0.040	56.18610946
24	89.8	0.078	0.040	55.58278617
25	87.5	0.076	0.040	54.91270852
26	85.3	0.074	0.040	54.1809094
27	83.3	0.073	0.040	53.39187918
28	81.4	0.071	0.040	52.54964001
29	79.6	0.069	0.040	51.65780792
30	77.8	0.068	0.040	50.71964515
31	76.2	0.067	0.040	49.73810428
32	74.6	0.065	0.040	48.71586587
33	73.1	0.064	0.040	47.65537048
34	71.7	0.063	0.040	46.55884628
35	70.3	0.061	0.040	45.42833275
36	69.0	0.060	0.040	44.2657012
37	67.8	0.059	0.040	43.07267265
38	66.6	0.058	0.040	41.85083336
39	65.4	0.057	0.040	40.60164843
40	64.3	0.056	0.040	39.32647377
41	63.3	0.055	0.040	38.02656661
42	62.2	0.054	0.040	36.70309478
43	61.3	0.053	0.040	35.35714495
44	60.3	0.053	0.040	33.98972996
45	59.4	0.052	0.040	32.60179528
46	58.5	0.051	0.040	31.19422488
47	57.6	0.050	0.040	29.7678464
48	56.8	0.050	0.040	28.32343582
49	56.0	0.049	0.040	26.86172168
50	55.2	0.048	0.040	25.38338882
51	54.5	0.048	0.040	23.88908183

<- Required Volume

Control Flow:

Orifice Flow
 Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
313.76	1.19	0.0398	39.8

*Orifice Flow = C * Area * (2*9.81 * Hydraulic Head) ^0.5
 where C = 0.62, A = area of the orifice and H = hydraulic head*

50 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 1.00
 Release Rate 43.9 l/sec <= allowable of 0.066 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m ³ /sec)	Release Rate (m ³ /sec)	Required Storage Volume (m ³)
10.0	164.2	0.151	0.044	64.24100897
11	156.3	0.144	0.044	65.85999139
12	149.2	0.137	0.044	67.15921899
13	142.8	0.131	0.044	68.18321197
14	137.1	0.126	0.044	68.96802086
15	131.8	0.121	0.044	69.54320921
16	127.0	0.117	0.044	69.9332953
17	122.6	0.113	0.044	70.15881932
18	118.5	0.109	0.044	70.23714591
19	114.7	0.105	0.044	70.18307648
20	111.2	0.102	0.044	70.00932241
21	108.0	0.099	0.044	69.72687511
22	104.9	0.096	0.044	69.34529862
23	102.0	0.094	0.044	68.87296311
24	99.4	0.091	0.044	68.31723313
25	96.8	0.089	0.044	67.68462044
26	94.5	0.087	0.044	66.98090926
27	92.2	0.085	0.044	66.21125951
28	90.1	0.083	0.044	65.38029255
29	88.1	0.081	0.044	64.49216284
30	86.2	0.079	0.044	63.55061818
31	84.3	0.078	0.044	62.55905058
32	82.6	0.076	0.044	61.52053955
33	81.0	0.074	0.044	60.437889
34	79.4	0.073	0.044	59.31365894
35	77.9	0.072	0.044	58.15019273
36	76.4	0.070	0.044	56.9496407
37	75.1	0.069	0.044	55.71398066
38	73.7	0.068	0.044	54.44503574
39	72.5	0.067	0.044	53.14449003
40	71.2	0.065	0.044	51.81390231
41	70.1	0.064	0.044	50.45471809
42	68.9	0.063	0.044	49.06828031
43	67.8	0.062	0.044	47.65583875
44	66.8	0.061	0.044	46.21855845
45	65.8	0.060	0.044	44.75752717
46	64.8	0.060	0.044	43.27376205
47	63.9	0.059	0.044	41.76821559
48	63.0	0.058	0.044	40.24178097
49	62.1	0.057	0.044	38.69529692
50	61.2	0.056	0.044	37.12955203
51	60.4	0.056	0.044	35.54528865

<- Required Volume

Control Flow:

Orifice Flow

Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
314.02	1.45	0.0439	43.9

*Orifice Flow = C * Area * (2 * 9.81 * Hydraulic Head)^{0.5}*
 where C = 0.62, A = area of the orifice and H = hydraulic head

100 Year Storm Event

Total Area 0.3283 ha.
 Runoff Coefficient 1.00
 Release Rate 46.7 l/sec <= allowable of 0.076 (m3/sec)
 Tc 10.0

Time (mins.)	Intensity (mm/hr)	Peak Inflow (m ³ /sec)	Release Rate (m ³ /sec)	Required Storage Volume (m ³)
10.0	180.2	0.166	0.047	71.35457819
11	171.7	0.158	0.047	73.35338221
12	164.1	0.151	0.047	74.99301853
13	157.2	0.145	0.047	76.32251677
14	151.0	0.139	0.047	77.38179368
15	145.3	0.134	0.047	78.20373549
16	140.1	0.129	0.047	78.81572564
17	135.3	0.124	0.047	79.24078447
18	130.9	0.120	0.047	79.49843231
19	126.7	0.117	0.047	79.60535206
20	122.9	0.113	0.047	79.57590399
21	119.4	0.110	0.047	79.42253047
22	116.0	0.107	0.047	79.15607725
23	112.9	0.104	0.047	78.78605102
24	109.9	0.101	0.047	78.3208277
25	107.2	0.099	0.047	77.76782221
26	104.6	0.096	0.047	77.1336279
27	102.1	0.094	0.047	76.42413191
28	99.8	0.092	0.047	75.64461112
29	97.5	0.090	0.047	74.79981262
30	95.4	0.088	0.047	73.89402138
31	93.4	0.086	0.047	72.93111764
32	91.5	0.084	0.047	71.91462571
33	89.7	0.082	0.047	70.84775572
34	88.0	0.081	0.047	69.73343949
35	86.3	0.079	0.047	68.57436143
36	84.7	0.078	0.047	67.37298539
37	83.2	0.076	0.047	66.13157789
38	81.7	0.075	0.047	64.85222848
39	80.3	0.074	0.047	63.53686756
40	79.0	0.073	0.047	62.18728196
41	77.7	0.071	0.047	60.80512875
42	76.4	0.070	0.047	59.3919474
43	75.2	0.069	0.047	57.94917059
44	74.1	0.068	0.047	56.47813377
45	72.9	0.067	0.047	54.98008374
46	71.9	0.066	0.047	53.45618625
47	70.8	0.065	0.047	51.90753285
48	69.8	0.064	0.047	50.33514704
49	68.8	0.063	0.047	48.73998975
50	67.9	0.062	0.047	47.12296435
51	67.0	0.062	0.047	45.4849211

<- Required Volume

Control Flow:

Orifice Flow

Orifice Diameter = 0.13
 Orifice Area = 0.0133
 Orifice Centroid = 312.57

Storage Elevation (m)	Hydraulic Head (m)	Flow (m3/sec)	Flow (L/sec)
314.21	1.64	0.047	46.7

$Orifice\ Flow = C * Area * (2 * 9.81 * Hydraulic\ Head)^{0.5}$

where C = 0.62, A = area of the orifice and H = hydraulic head

521-525 Essa Road
STAGE STORAGE DISCHARGE RELATIONSHIP
 City of Barrie

Project Number: 17-11306.1B
 Date: May 12, 2020
 File: Z:\Project Documents\11501B 521-525 Essa Road Townhomes\SWM Rev 2, April 2020\MRM SWM Calculations - JHV Final.xls



Orifice Calculations			
$Q_o = C_d \cdot A_o \cdot (2 \cdot g \cdot H_o)^{0.5}$			
	Orifice 1	Orifice 2	Orifice 3
C_d	0.62	0	0
Centroid (m)	312.57	1000	1000
Width (m)	0.000	0.000	0.000
Diameter/Height (m)	0.130	0.000	0.00
Type (H/V)	V	V	V

C_d	Description
0.62	Orifice Plate
0.8	Orifice Tube

Weir Calculations	
$Q_w = C_w \cdot (H_w)^{1.5} \cdot ((L - 0.2 \cdot H_w) + (0.8 \cdot \tan(\theta)) \cdot H_w)$	
C_w	1.60
Invert (m)	314.4
Length (m)	8
Side Slope (H:V)	1
Side Slope (rad)	0.785

Stage Discharge Relationship for Retention Tank

Stage	Active Volume	Orifice 1								Weir Flow	Total Flow	Comments
		Area	H_o	Flow								
m	m^3	m^2	m	m^3/s						m^3/s	m^3/s	
312.50	0	0.0133	0.00	0.0000					0.0000	0.0000		Orifice Invert
312.55	0.5	0.0133	0.00	0.0013					0.0000	0.0013		Tank Bottom
312.57	1.5	0.0133	0.00	0.0026					0.0000	0.0026		Orifice Centroid
312.60	2.4	0.0133	0.04	0.0068					0.0000	0.0068		
312.65	4.8	0.0133	0.09	0.0106					0.0000	0.0106		
312.70	7.2	0.0133	0.14	0.0134					0.0000	0.0134		
312.75	9.6	0.0133	0.19	0.0157					0.0000	0.0157		
312.80	12	0.0133	0.24	0.0177					0.0000	0.0177		
312.85	14.4	0.0133	0.29	0.0195					0.0000	0.0195		
312.90	16.8	0.0133	0.34	0.0211					0.0000	0.0211		
312.95	19.2	0.0133	0.39	0.0226					0.0000	0.0226		
313.00	21.6	0.0133	0.44	0.0240					0.0000	0.0240		
313.05	24	0.0133	0.49	0.0254					0.0000	0.0254		
313.10	26.4	0.0133	0.54	0.0267					0.0000	0.0267		
313.15	28.8	0.0133	0.59	0.0279					0.0000	0.0279		
313.20	31.2	0.0133	0.64	0.0290					0.0000	0.0290		
313.25	33.6	0.0133	0.69	0.0302					0.0000	0.0302		
313.30	36	0.0133	0.74	0.0313					0.0000	0.0313		
313.35	38.4	0.0133	0.79	0.0323					0.0000	0.0323		
313.40	40.8	0.0133	0.84	0.0333					0.0000	0.0333		
313.45	43.2	0.0133	0.89	0.0343					0.0000	0.0343		
313.50	45.6	0.0133	0.94	0.0352					0.0000	0.0352		
313.55	48	0.0133	0.99	0.0362					0.0000	0.0362		
313.60	50.4	0.0133	1.04	0.0371					0.0000	0.0371		
313.65	52.8	0.0133	1.09	0.0380					0.0000	0.0380		
313.70	55.2	0.0133	1.14	0.0388					0.0000	0.0388		
313.75	57.6	0.0133	1.19	0.0397					0.0000	0.0397		
313.80	60	0.0133	1.24	0.0405					0.0000	0.0405		
313.85	62.4	0.0133	1.29	0.0413					0.0000	0.0413		
313.90	64.8	0.0133	1.34	0.0421					0.0000	0.0421		
313.95	67.2	0.0133	1.39	0.0429					0.0000	0.0429		
314.00	69.6	0.0133	1.44	0.0437					0.0000	0.0437		
314.05	72	0.0133	1.49	0.0444					0.0000	0.0444		
314.10	74.4	0.0133	1.54	0.0452					0.0000	0.0452		
314.15	76.8	0.0133	1.59	0.0459					0.0000	0.0459		
314.20	79.2	0.0133	1.64	0.0466					0.0000	0.0466		
314.25	81.6	0.0133	1.69	0.0473					0.0000	0.0473		
314.30	84	0.0133	1.74	0.0480					0.0000	0.0480		
314.35	86.4	0.0133	1.79	0.0487					0.0000	0.0487		
314.40	88.8	0.0133	1.84	0.0494					0.0000	0.0494		Driveway Overflow Weir
314.45	91.2	0.0133	1.89	0.0500					0.1436	0.1937		U/S Tank

521-525 Essa Road
Storage Volume Calculations
City of Barrie

Project Number:
 Date:
 Design By:
 File:

17-11306.1B
 April 18, 2020
 JHV



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Storage Tank Size
 6mx8m
 Area = 48m²
 Volume per 5cm = 2.4m³
 Tank Height = 1.9m

Weir Overflow through
 Driveway Entrance to Essa = 314.40

U/S Tank

Stage	SWM TANK Volume (m3)	
	312.55	0
	312.6	2.4
	312.65	4.8
	312.7	7.2
	312.75	9.6
	312.8	12
	312.85	14.4
	312.9	16.8
	312.95	19.2
	313	21.6
	313.05	24
	313.1	26.4
	313.15	28.8
	313.2	31.2
	313.25	33.6
	313.3	36
	313.35	38.4
	313.4	40.8
	313.45	43.2
	313.5	45.6
	313.55	48
	313.6	50.4
	313.65	52.8
	313.7	55.2
	313.75	57.6
	313.8	60
	313.85	62.4
	313.9	64.8
	313.95	67.2
	314	69.6
	314.05	72
	314.1	74.4
	314.15	76.8
	314.2	79.2
	314.25	81.6
	314.3	84
	314.35	86.4
	314.4	88.8
	314.45	91.2


521-525 Essa Road
FLOW SUMMARY WITH SWM IN EFFECT
 City of Barrie



Project Number: 17-11306.1B
 Date: April 18, 2020
 Design By: JHV
 File:

C:\Users\dwiho\OneDrive - Pinestone Engineering Ltd\11501B Essa Road Townhomes\SWM Rev 2, April 2020\MRM SWM Calculations - JHV Final.xls

Storm Event	2 Year (m ³ /s)	5 Year (m ³ /s)	10 Year (m ³ /s)	25 Year (m ³ /s)	50 Year (m ³ /s)	100 Year (m ³ /s)
Pre-Development Catchment 101	0.035	0.046	0.053	0.068	0.083	0.095
Total Pre-Development Flow	0.035	0.046	0.053	0.068	0.083	0.095
Post Development Catchment 201 (controlled)	0.026	0.030	0.034	0.040	0.044	0.047
Post Development Catchment 202 (uncontrolled)	0.007	0.009	0.011	0.014	0.017	0.019
Total Post Development Flow (with SWM)	0.033	0.040	0.044	0.054	0.061	0.066

521 & 525 Essa Road Residential Development				STORM SEWER DESIGN SHEET				Design Parameters									
City of Barrie								ENGINEERING AND PUBLIC WORKS Drainage Area Plan No: N/A								100 YEAR STORM	
Project Number: 20-11501B Date: May 6, 2020 Design By: DPH Checked By: JHV File: Z:\Project Documents\11501B 521-525 Essa Road Townhomes\SWM Rev 2, April 2020\Storm Sewer Design Sheet (Barrie IDF).xls																Q=kA ^{1.49} R, k=0.00278 Manning's "n" 0.013 Intensity (I) = a/(tc+b) ² Min. Velocity 0.800 m/s a = 1426.408 Max. Velocity 6.000 m/s b = 5.273 c = 0.759	
LOCATION				STORMWATER FLOW								DESIGN					
STREET	AREA NUMBER	MANHOLE LOCATION		AREA (A)	RUNOFF COEFF. (C)	A x C	CUMUL. A x C	CONCENTRATION TIME		RAIN INTENSITY (I)	FLOW (Q)	PIPE SIZE	LENGTH	SLOPE	CAPACITY	FULL FLOW VELOCITY	ACTUAL VELOCITY
		FROM MH	TO MH					TOTAL	IN PIPE								
				<i>ha</i>		<i>ha</i>	<i>ha</i>	<i>min</i>	<i>min</i>	<i>mm/hr</i>	<i>L/s</i>	<i>mm</i>	<i>m</i>	<i>%</i>	<i>L/s</i>	<i>m/s</i>	<i>m/s</i>
Catchment 201	201	SFPD 0811	Ex. Storm Sewer					100 YEAR CONTROLLED DESIGN FLOW FROM MODIFIED RATIONAL METHOD CALCULATIONS			47.00000	300	20.5	0.50	68.37776	0.9673	1.0424



Project DEVELOPMENT Summary

DEVELOPMENT: 521 & 525 Essa Road Residential Development

Subwatershed: Barrie Creeks

Total Pre-Development Area (ha): 0.4428	Total Pre-Development Phosphorus Load (kg/yr): 0.06
--	--

Pre-Development Land Use	Area (ha)	P coeff. (kg/ha)	P Load (kg/yr)
Low Intensity Development	0.4428	0.13	0.06

POST-DEVELOPMENT LOAD

Post-Development Land Use	Area (ha)	P coeff. (kg/ha)	Best Management Practice applied with P Removal Efficiency	P Load (kg/yr)
High Intensity - Residential	0.0645	1.32	NONE	0.09

High Intensity - Residential	0.05	1.32	Sorbitive media interceptors <i>Imbrium Sorbitive Media Trench</i>	90%	0.01
------------------------------	------	------	---	-----	------

NOTE: BMP efficiency has been adjusted from the reference provided value by 11% (from 79% to 90%)

High Intensity - Residential	0.3283	1.32	Other <i>CONTECH Stormfilter SFPD 0811</i>	86%	0.06
------------------------------	--------	------	---	-----	------

Post-Development Area Altered:	0.44		P Load (kg/yr)
Total Pre-Development Area:	0.44		
Unaffected Area:	0		
		Pre-Development:	0.06
		Post-Development:	0.58
		Change (Pre - Post):	-0.53
		915% Net Increase in Load	
		Post-Development (with BMPs):	0.15
		Change (Pre - Post):	-0.09
		164.77% Net Increase in Load	

521 & 525 ESSA ROAD RESIDENTIAL DEVELOPMENT

CLIMATIC WATER BUDGET: CLIMATE NORMAL 1981-2010 (BARRIE WPCC): Potential Evapotranspiration

Barrie, Ontario

Project Number: 20-11501B

Date: April 22nd, 2020

Design By: DPH



Calculations Based on Thornthwaite Equation (1948)										
Month	Mean Temperature (°C)	Heat Index "i"	"α"	PET - Potential Evapo- transpiration non corrected (mm)	Daylight Correction Factor (L/12)	Number of Days per Month (N)	PTE - Potential Evapo-transpiration corrected (mm)	Total Precipitation (mm)	Surplus (mm)	Deficit (mm)
January	-7.7	0.0	0.49	0.0	0.76	31	0.0	82.5	82.5	0.0
February	-6.6	0.0	0.49	0.0	0.87	28	0.0	61.8	61.8	0.0
March	-2.1	0.0	0.49	0.0	0.99	31	0.0	58.1	58.1	0.0
April	5.6	1.2	0.51	25.2	1.12	30	28.2	62.2	34.0	0.0
May	12.3	3.9	0.56	59.0	1.23	31	75.0	82.4	0.0	-7.4
June	17.9	6.9	0.61	88.5	1.30	30	115.0	84.8	0.0	30.2
July	20.8	8.7	0.64	104.1	1.27	31	136.6	77.2	0.0	59.4
August	19.7	8.0	0.63	98.1	1.18	31	119.7	89.9	0.0	29.8
September	15.3	5.4	0.59	74.7	1.25	30	93.4	94	0.6	0.0
October	8.7	2.3	0.53	40.6	0.92	31	38.6	77.5	38.9	0.0
November	2.7	0.4	0.50	11.5	0.80	30	9.2	88.9	79.7	0.0
December	-3.5	0.0	0.49	0.0	0.74	31	0.0	73.6	73.6	0.0
Totals		36.8	1.08				615.7	932.9	429.2	112.0

Annual Heat Index I = 36.8

Total Water Deficit **112.0**
 Total Water Surplus **317.2**

Notes:

- 1) Water budget adjusted for latitude and daylight
- 2) (°C) Represents calculated mean of daily temperatures for the month
- 3) Precipitation and Temperature data from the Barrie WPCC at latitude 44° 22' 33.012" N, longitude 79° 41' 23.010" W, elevation 221.00m ASL.
- 4) Total water surplus is calculated as total precipitation minus potential evapotranspiration

521 & 525 ESSA ROAD RESIDENTIAL DEVELOPMENT

WATER BUDGET PRE-DEVELOPMENT

Barrie, Ontario
 Project Number:
 Date:
 Design By:

20-11501B
 April 22nd, 2020
 DPH



Catchment Designation	Pre-Development Condition				
	Woodlands	Lawn	Paved	Building	Totals
Area(m2)	95	3383	0	950	4428
Pervious Area (m2)	95	3383	0	0	3478
Impervious Area (m2)	0	0	0	950	950
Infiltration Factors					
Topography Infiltration Factor	0.3	0.3	0.3	0.3	
Soil Infiltration Factor	0.2	0.2	0.2	0.2	
Land Cover Infiltration Factor	0.2	0.1	0	0	
MOE Infiltration Factor (Sum)	0.7	0.6	0	0	
Actual Infiltration Factor	0.7	0.6	0	0	
Run-off Coefficient	0.35	0.17	1	1	
Run-off from impervious surfaces*	0	0	0.8	0.8	
Inputs (per Unit Area)					
Precipitation (mm/yr)	933	933	933	933	933
Run-on (mm/yr)	0	0	0	0	0
Other inputs (mm/yr)	0	0	0	0	0
Total inputs (mm/yr)	933	933	933	933	933
Outputs (per Unit Area)					
Precipitation Surplus (mm/yr)	317	317	746	746	409
Net Surplus (mm/yr)	317	317	746	746	409
Evapotranspiration (mm/yr)	616	616	187	187	524
Infiltration (mm/yr)	222	190	0	0	150
Rooftop Infiltration (mm/yr)	0	0	0	0	0
Total Infiltration (mm/yr)	222	190	0	0	150
Runoff Pervious Areas (mm/yr)	95	127	0	0	99
Runoff Impervious Areas (mm/yr)	0	0	746	746	160
Total Runoff (mm/yr)	95	127	746	746	259
Total Outputs (mm/yr)	933	933	933	933	933
Difference (Inputs - Outputs)	0	0	0	0	0
Inputs (Volumes)					
Precipitation (m3/yr)	89	3156	0	886	4131
Run-on (m3/yr)	0	0	0	0	0
Other inputs (m3/yr)	0	0	0	0	0
Total Inputs (m3/yr)	89	3156	0	886	4131
Outputs (Volumes)					
Precipitation Surplus (m3/yr)	30	1073	0	709	1812
Net Surplus (m3/yr)	30	1073	0	709	1812
Evapotranspiration (m3/yr)	58	2083	0	177	2318
Infiltration (m3/yr)	21	644	0	0	665
Rooftop Infiltration (m3/yr)	0	0	0	0	0
Total Infiltration (m3/yr)	21	644	0	0	665
Runoff Pervious Areas (m3/yr)	9	429	0	0	438
Runoff Impervious Areas (m3/yr)	0	0	0	709	709
Total Runoff (m3/yr)	9	429	0	709	1147
Total Outputs (m3/yr)	89	3156	0	886	4131
Difference (Inputs - Outputs)	0	0	0	0	0

* Evaporation from impervious areas was assumed to be 20% of precipitation value

521 & 525 ESSA ROAD RESIDENTIAL DEVELOPMENT
WATER BUDGET POST DEVELOPMENT WITHOUT MITIGATION

Barrie, Ontario

Project Number:

20-11501B

Date:

April 22nd, 2020

Design By:

DPH



Catchment Designation	Post Development Condition				
	Woodlands	Lawn	Paved	Building	Totals
Area(m2)	0	1370	0	3058	4428
Pervious Area (m2)	0	1370	0	0	1370
Impervious Area (m2)	0	0	0	3058	3058
Infiltration Factors					
Topography Infiltration Factor	0.3	0.3	0.3	0.3	
Soil Infiltration Factor	0.2	0.2	0.2	0.2	
Land Cover Infiltration Factor	0.2	0.1	0	0	
MOE Infiltration Factor (Sum)	0.7	0.6	0	0	
Actual Infiltration Factor	0.7	0.6	0	0	
Run-off Coefficient	0.35	0.17	1	1	
Run-off from impervious surfaces*	0	0	0.8	0.8	
Inputs (per Unit Area)					
Precipitation (mm/yr)	933	933	933	933	933
Run-on (mm/yr)	0	0	0	0	0
Other inputs (mm/yr)	0	0	0	0	0
Total inputs (mm/yr)	933	933	933	933	933
Outputs (per Unit Area)					
Precipitation Surplus (mm/yr)	317	317	746	746	614
Net Surplus (mm/yr)	317	317	746	746	613
Evapotranspiration (mm/yr)	616	616	187	187	320
Infiltration (mm/yr)	222	190	0	0	59
Rooftop Infiltration (mm/yr)	0	0	0	0	0
Total Infiltration (mm/yr)	222	190	0	0	59
Runoff Pervious Areas (mm/yr)	95	127	0	0	39
Runoff Impervious Areas (mm/yr)	0	0	746	746	515
Total Runoff (mm/yr)	95	127	746	746	554
Total Outputs (mm/yr)	933	933	933	933	933
Difference (Inputs - Outputs)	0	0	0	0	0
Inputs (Volumes)					
Precipitation (m3/yr)	0	1278	0	2853	4131
Run-on (m3/yr)	0	0	0	0	0
Other inputs (m3/yr)	0	0	0	0	0
Total Inputs (m3/yr)	0	1278	0	2853	4131
Outputs (Volumes)					
Precipitation Surplus (m3/yr)	0	435	0	2282	2717
Net Surplus (m3/yr)	0	435	0	2281	2716
Evapotranspiration (m3/yr)	0	843	0	572	1415
Infiltration (m3/yr)	0	261	0	0	261
Rooftop Infiltration (m3/yr)	0	0	0	0	0
Total Infiltration (m3/yr)	0	261	0	0	261
Runoff Pervious Areas (m3/yr)	0	174	0	0	174
Runoff Impervious Areas (m3/yr)	0	0	0	2281	2281
Total Runoff (m3/yr)	0	174	0	2281	2455
Total Outputs (m3/yr)	0	1278	0	2853	4131
Difference (Inputs - Outputs)	0	0	0	0	0

* Evaporation from impervious areas was assumed to be 20% of precipitation value

521 & 525 ESSA ROAD RESIDENTIAL DEVELOPMENT

WATER BUDGET SUMMARY

Barrie, Ontario

Project Number: 20-11501B

Date: April 22nd, 2020

Design By: DPH



Characteristic	Site				
	Pre-Development	Post Development	Change (Pre to Post)	Post Development with Mitigation	Change (Pre to Post with Mitigation)
Inputs (Volumes)					
Precipitation (m3/yr)	4131	4131	0.0%	4131	0.0%
Run-on (m3/yr)	0	0	0.0%	0	0.0%
Other Inputs (m3/yr)	0	0	0.0%	0	0.0%
Total Inputs (m3/yr)	4131	4131	0.0%	4131	0.0%
Output (volumes)					
Precipitation Surplus (m3/yr)	1812	2717	33.3%	2717	33.3%
Net Surplus (m3/yr)	1812	2716	33.3%	2716	33.3%
Evapotranspiration (m3/yr)	2318	1415	-63.9%	1415	-63.9%
Infiltration (m3/yr)	665	261	-155.0%	261	-155.0%
Rooftop Infiltration (m3/yr)	0	0	0.0%	0	0.0%
Total Infiltration (m3/yr)	665	261	-155.0%	261	-155.0%
Runoff Pervious Areas (m3/yr)	438	174	-152.1%	174	-152.1%
Runoff Impervious Areas (m3/yr)	709	2281	68.9%	2281	68.9%
Total Runoff (m3/yr)	1147	2455	53.3%	2455	53.3%
Total Outputs (m3/yr)	4131	4131	0.0%	4131	0.0%

Table 3.1: Hydrologic Cycle Component Values

	Water Holding Capacity mm	Hydrologic Soil Group	Precipitation mm	Evapo-transpiration mm	Runoff mm	Infiltration *																								
Urban Lawns/Shallow Rooted Crops (spinach, beans, beets, carrots)																														
Fine Sand	50	A	940	515	149	276																								
Fine Sandy Loam	75	B	940	525	187	228																								
Silt Loam	125	C	940	536	222	182																								
Clay Loam	100	CD	940	531	245	164																								
Clay	75	D	940	525	270	145																								
Moderately Rooted Crops (corn and cereal grains)																														
Fine Sand	75	A	940	525	125	291																								
Fine Sandy Loam	150	B	940	539	160	241																								
Silt Loam	200	C	940	543	199	199																								
Clay Loam	200	CD	940	543	218	179																								
Clay	150	D	940	539	241	160																								
Pasture and Shrubs																														
Fine Sand	100	A	940	531	102	307																								
Fine Sandy Loam	150	B	940	539	140	261																								
Silt Loam	250	C	940	546	177	217																								
Clay Loam	250	CD	940	546	197	197																								
Clay	200	D	940	543	218	179																								
Mature Forests																														
Fine Sand	250	A	940	546	79	315																								
Fine Sandy Loam	300	B	940	548	118	274																								
Silt Loam	400	C	940	550	156	234																								
Clay Loam	400	CD	940	550	176	215																								
Clay	350	D	940	549	196	196																								
<p>Notes: Hydrologic Soil Group A represents soils with low runoff potential and Soil Group D represents soils with high runoff potential. The evapotranspiration values are for mature vegetation. Streamflow is composed of baseflow and runoff.</p> <p>* This is the total infiltration of which some discharges back to the stream as base flow. The infiltration factor is determined by summing a factor for topography, soils and cover.</p> <table border="0"> <tr> <td><u>Topography</u></td> <td>Flat Land, average slope < 0.6 m/km</td> <td>0.3</td> </tr> <tr> <td></td> <td>Rolling Land, average slope 2.8 m to 3.8 m/km</td> <td>0.2</td> </tr> <tr> <td></td> <td>Hilly Land, average slope 28 m to 47 m/km</td> <td>0.1</td> </tr> <tr> <td><u>Soils</u></td> <td>Tight impervious clay</td> <td>0.1</td> </tr> <tr> <td></td> <td>Medium combinations of clay and loam</td> <td>0.2</td> </tr> <tr> <td></td> <td>Open Sandy loam</td> <td>0.4</td> </tr> <tr> <td><u>Cover</u></td> <td>Cultivated Land</td> <td>0.1</td> </tr> <tr> <td></td> <td>Woodland</td> <td>0.2</td> </tr> </table>							<u>Topography</u>	Flat Land, average slope < 0.6 m/km	0.3		Rolling Land, average slope 2.8 m to 3.8 m/km	0.2		Hilly Land, average slope 28 m to 47 m/km	0.1	<u>Soils</u>	Tight impervious clay	0.1		Medium combinations of clay and loam	0.2		Open Sandy loam	0.4	<u>Cover</u>	Cultivated Land	0.1		Woodland	0.2
<u>Topography</u>	Flat Land, average slope < 0.6 m/km	0.3																												
	Rolling Land, average slope 2.8 m to 3.8 m/km	0.2																												
	Hilly Land, average slope 28 m to 47 m/km	0.1																												
<u>Soils</u>	Tight impervious clay	0.1																												
	Medium combinations of clay and loam	0.2																												
	Open Sandy loam	0.4																												
<u>Cover</u>	Cultivated Land	0.1																												
	Woodland	0.2																												

The storm duration is set to the time of concentration (i.e. the sewer inlet time plus the time of travel in the pipe or channel) for the total cumulative drainage area to the node of interest. The maximum inlet time for the first pipe of a storm sewer system is 10 minutes.

The runoff coefficient shall be calculated in accordance with the following table:

Table 3.2: Runoff Coefficients (Rational C) (5-yr to 10-yr) Based on Hydrologic Soil Group

Land Use	Runoff Coefficient "C"		
	A-AB	B-BC	C-D
Cultivated Land, 0 - 5% grade	0.22	0.35	0.55
Cultivated Land, 5 - 10% grade	0.30	0.45	0.60
Cultivated Land, 10 - 30% grade	0.40	0.65	0.70
Pasture Land, 0 - 5% grade	0.10	0.28	0.40
Pasture Land, 5 - 10% grade	0.15	0.35	0.45
Pasture Land, 10 - 30% grade	0.22	0.40	0.55
Woodlot or Cutover, 0 - 5% grade	0.08	0.25	0.35
Woodlot or Cutover, 5 - 10% grade	0.12	0.30	0.42
Woodlot or Cutover, 10 - 30% grade	0.18	0.35	0.52
Lakes and Wetlands	0.05	0.05	0.05
Impervious Area (i.e., buildings, roads, parking lots, etc.)	0.95	0.95	0.95
Gravel (not to be used for proposed parking or storage areas)	0.40	0.50	0.60
Residential - Single Family	0.30	0.40	0.50
Residential - Multiple (i.e., semi, townhouse, apartment)	0.50	0.60	0.70
Industrial - light	0.55	0.65	0.75
Industrial - heavy	0.65	0.75	0.85
Commercial	0.60	0.70	0.80
Unimproved Areas	0.10	0.20	0.30
Lawn, < 2% grade	0.05	0.11	0.17
Lawn, 2 - 7% grade	0.10	0.16	0.22
Lawn, > 7% grade	0.15	0.25	0.35

Adapted from Design Chart 1.07, Ontario Ministry of Transportation, "MTO Drainage Management Manual," MTO, (1997)

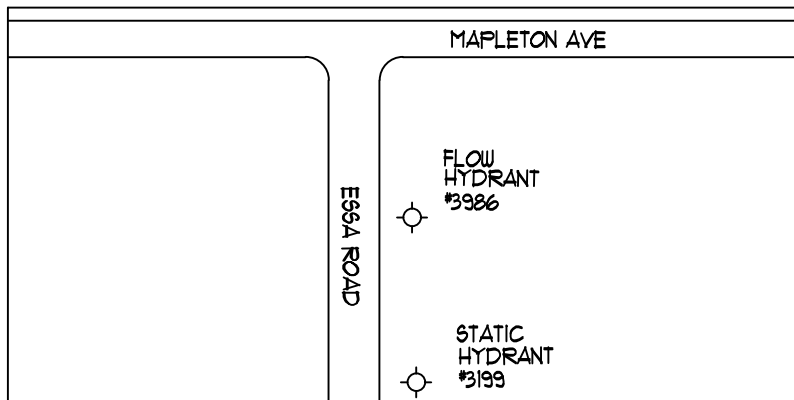
FLOW TEST RESULTS



DATE : APRIL 14, 2020 TIME : 10:30 AM

LOCATION : 521 ESSA ROAD
BARRIE
ONTARIO

TEST BY : VIPOND FIRE PROTECTION AND LOCAL PUC



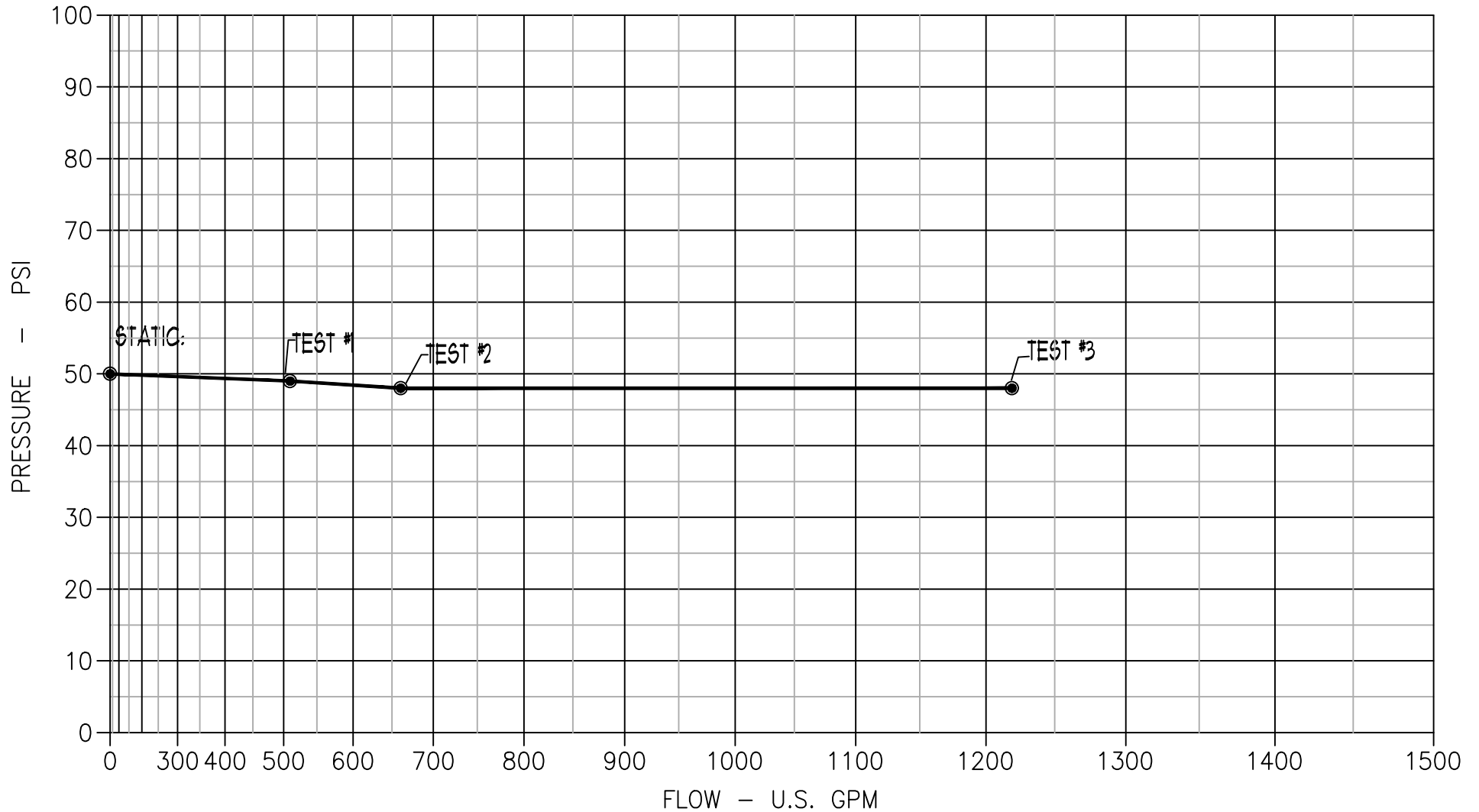
STATIC PRESSURE : 50 PSI UNDERGROUND TYPE & SIZE : N/A

TEST NO.	NO. OF NOZZLES	NOZZLE DIAMETER (INCHES)	DISCHARGE CO-EFFICIENT	RESIDUAL PRESSURE (PSI)	PITOT PRESSURE (PSI)	DISCHARGE (U.S.GPM)
1	1	1 3/4"	0.995	49	32	504
2	1	2 1/2"	0.90	48	15	653
3	2	2 1/2"	0.90	48	13	1216



521 ESSA ROAD	BY :	LEN K.
BARRIE	VIPOND OFFICE :	BARRIE
ONTARIO	TEST BY :	VIPOND & PUC
	DATE :	APRIL 14, 2020

STATIC:		RESIDUAL:		FLOW:
<u>50</u> PSI	TEST#1	<u>49</u> PSI	@	<u>504</u> GPM
	TEST#2	<u>48</u> PSI	@	<u>653</u> GPM
	TEST#3	<u>48</u> PSI	@	<u>1216</u> GPM



**RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**

APPENDIX C

Stormfilter Vault & Sorbtive Media Documentation





Determining Number of Cartridges for Flow Based Systems

Date

5/11/2019

Black Cells = Calculation

Site Information

Project Name	521 & 525 Essa Road Residential Development R2	
Project Location	Barrie, ON	
OGS ID	Stormfilter	
Drainage Area, Ad	0.82 ac	(0.33 ha)
Impervious Area, Ai	0.77 ac	
Pervious Area, Ap	0.05	
% Impervious	94%	
Runoff Coefficient, Rc	0.86	
Treatment storm flow rate, Q_{treat}	0.34 cfs	(9.49 L/s)
Peak storm flow rate, Q_{peak}	1.66 cfs	(47 L/s)

Filter System

Filtration brand	StormFilter
Cartridge height	27 in
Specific Flow Rate	1.00 gpm/ft ²
Flow rate per cartridge	11.25 gpm

SUMMARY

Number of Cartridges	14
Media Type	Phosphosorb

Event Mean Concentration (EMC)	120 mg/L
Annual TSS Removal	80%
Percent Runoff Capture	90%
Minimum Total Phosphorus Removal	80%

STORMFILTER® VAULT BUOYANCY CALCULATION SUMMARY



521-525 ESSA ROAD RESIDENTIAL

BARRIE, ON

MODEL SF0811

SITE DESIGNATION: WQ

Vault Dimensions (ft):

Vault Inside Length:	11.00
Vault Inside Width:	8.00
Vault Outside Length:	12.00
Vault Outside Width:	9.00
Access Opening Quantity:	3.00
Access Opening Diameter:	2.50
Top Slab Thickness:	0.67
Exterior Wall Thickness:	0.50
Base Slab Thickness:	0.50
Base Slab Extension:	0.00
Base Slab Extension Thk:	0.50

Internal Wall Dimensions (ft):

Height of Inlet Bay Wall:	5.46
Width of Inlet Bay:	3.25
Thickness of Inlet Bay Wall:	0.50
Vault Inside Height:	6.00
Number of Cartridges:	14
Weight per Cartridge (lbs):	85.00

Unit Weights (lbs/ft³):

Unit Weight of Concrete:	155
Unit Weight of Water:	62.4
Unit Weight of Saturated Soil:	48
Unit Weight of Unsaturated Soil:	110

Site Elevations (ft):

Groundwater Elevation:	1,028.22
Rim Elevation:	1,031.17
Depth of Cover (ft):	2.62
Inlet Pipe Invert Elev (ft):	1,024.90
Outside Bottom Elev (ft):	1,021.38
Top Slab Shoulder Elev (ft):	1,028.55
Height of GW above Top Slab (ft):	0.00

Buoyancy Calculation Assumptions:

1. The resistant forces from soil friction, pipe connections, and weight of non-concrete internal parts is not included.
2. The weight of castings and grade rings are ignored and assumed to balance with the weight of soil cover.
3. The structure is assumed to be empty of water and sediment.

Resistant Forces:	WEIGHT (LBS)	WEIGHT (TONS)
Top Slab:	8,878	4.4
Exterior Wall Section:	18,600	9.3
Inlet Bay Wall:	3,384	1.7
Base Slab (incl. Ext., Cart Bay Floor):	13,175	6.6
Overlying Saturated Soil:	0	0.0
Overlying Unsaturated Soil:	31,075	15.5
Weight of water in System:	0	0.0

TOTALS	75,112	37.6
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Upward Buoyant Force (lbs):	46069
Resistant Force (Weight - Down) (lbs):	75112
Net Force Down:	29,043
Safety Factor:	1.63

VERIFICATION STATEMENT

GLOBE Performance Solutions

Verifies the performance of

The Stormwater Management StormFilter®

Developed by CONTECH Engineered Solutions LLC
Scarborough, Maine, USA

Registration: GPS-ETV_2020-06-15_TAPE

In accordance with

ISO 14034:2016

**Environmental Management —
Environmental Technology Verification (ETV)**



John D. Wiebe, PhD
Executive Chairman
GLOBE Performance Solutions

June 15, 2020
Vancouver, BC, Canada



Verification Body
GLOBE Performance Solutions
404 – 999 Canada Place | Vancouver, B.C | Canada |V6C 3E2

Verification Overview

This Environmental Technology Verification (ETV) of The Stormwater Management StormFilter® (StormFilter) is the second part of a two-part verification process and entails the verification of performance claims (#3 – 9) based on field testing data collected in accordance with The Washington State Department of Ecology emerging stormwater treatment technologies, in accordance with guidelines identified by Ecology (2011) in the Technology Assessment Protocol – Ecology (TAPE). This complements the first part of the verification which verifies performance test data collected in accordance with the New Jersey Department of Environmental Protection (NJDEP) *Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device* (January, 2013).

Technology description and application

The Stormwater Management StormFilter® (StormFilter) is a manufactured treatment device that is provided by Contech Engineered Solutions LLC (Contech). The StormFilter improves the quality of stormwater runoff before it enters receiving waterways through the use of its customizable filter media, which removes non-point source pollutants. As illustrated in **Figure 1**, the StormFilter is typically comprised of a vault or manhole structure that houses rechargeable, media-filled filter cartridges. Stormwater entering the system percolates through these media-filled cartridges, which trap particulates and remove pollutants. Once filtered through the media, the treated stormwater is discharged through an outlet pipe to a storm sewer system or receiving water.

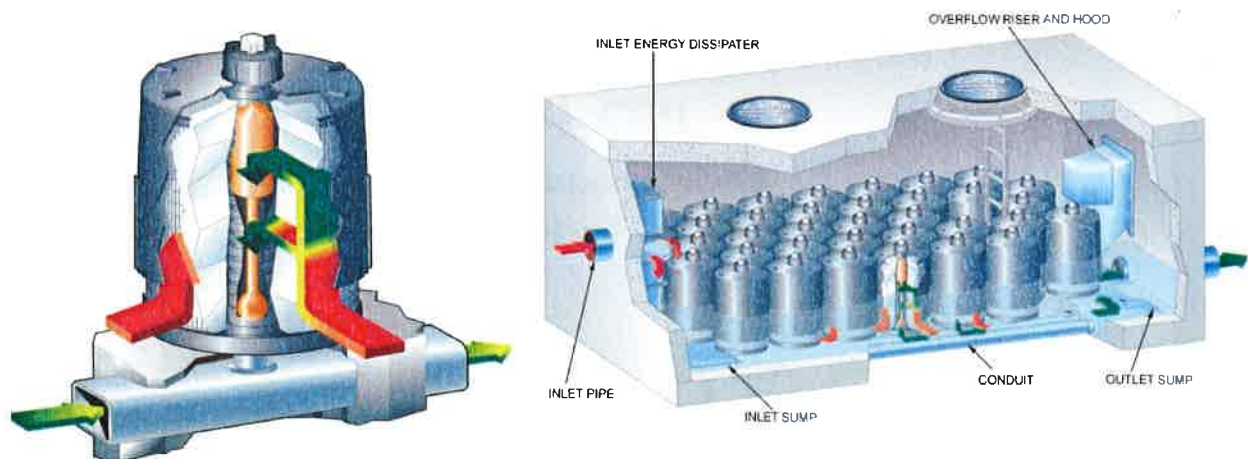


Figure 1 Individual StormFilter Cartridge (Left) and Typical Vault StormFilter Installation (Right)

Depending on the treatment requirements and expected pollutant characteristics at an individual site, the per cartridge filtration flow rate and driving head can be adjusted. The flow rate is individually controlled for each cartridge by a restrictor disc located at the connection point between the cartridge and the underdrain manifold.

Driving head is managed by positioning of the inlet, outlet, and overflow elevations. The StormFilter is typically designed so that the restrictor disc passes the design treatment rate once the water surface reaches the shoulder of the cartridge which is equivalent to the cartridge height. Since the StormFilter uses a restrictor disc to restrict treatment flows below the hydraulic capacity of the media the system

typically operates under consistent driving head for the useful life of the media. Site specific head constraints are also addressed by three different cartridge heights (low drop (effective height of 12 inches), 18, and 27 inches) which operate on the same principal and surface area specific loading rates.

The StormFilter requires a minimum of 1.8 ft, 2.3 ft and 3.05 ft of drop between inlet invert and outlet invert to accommodate the low drop, 18 and 27 inch cartridges, respectively, without backing up flow into the upstream piping during operation. When site conditions limit the amount of drop available across the StormFilter then flow is typically backed up into the upstream piping during operation to ensure sufficient driving head is provided. If desirable the StormFilter can be designed to operate under additional driving head.

The StormFilter is offered in multiple configurations including plastic, steel, and concrete catch basins; and precast concrete manholes, and vaults. Other configurations include panel vaults, CON/SPAN®, box culverts, and curb inlets. The filter cartridges operate consistently and act independently regardless of housing which enables linear scaling.

The StormFilter cartridge can house different types of media including perlite, zeolite, granular activated carbon (GAC), CSF® leaf media, MetalRx™, PhosphoSorb® or various media blends such as ZPG™ (perlite, zeolite and GAC). All of the media use processes associated with depth filtration to remove solids. Some media configurations also provide additional treatment mechanisms such as cation exchange, and/or adsorption, chelation, and precipitation. This verification is specific to a field evaluation of the StormFilter with PhosphoSorb® media.

Performance conditions

The data and results published in this Verification Statement were obtained from the field testing conducted on The Stormwater Management StormFilter® device, in accordance with the requirements outlined by the Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies Technology Assessment Protocol – Ecology (TAPE) as written by the Washington State Department of Ecology, (WADOE, 2011). Prior to starting the performance testing program, a quality assurance project plan (QAPP) was submitted to and approved by the State of Washington Department of Ecology.

Performance claim(s)

Performance Claim 3 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 23 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 89% removal of total suspended solids at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 4 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 23 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 79% removal of total phosphorus at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 5 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 23 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 56% removal of total nitrogen at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 6 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 21 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 77% removal of total copper at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 7 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 21 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 75% removal of total zinc at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 8 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 21 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 70% removal of total lead at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance Claim 9 (TAPE)

During field testing under the Washington State TAPE Protocol (2011) which was composed of 21 qualifying storm events, The Stormwater Management StormFilter®, with PhosphoSorb® media, demonstrated at least 80% removal of total aluminium at a range of treated flow rates up to the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm. This performance claim was verified at a 95% level of confidence.

Performance results

Performance Claim 3 (TAPE):

Raw data summarizing the percent removal of total suspended solids (TSS) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent TSS (mg/L)	Average Effluent TSS (mg/L)	Percent Removal (%)
LPR021012	182	63.0	65.4
LPR021412	539	32.0	94.1
LPR021712	387	48.0	87.6
LPR022012	246	5.0	98.0
LPR022412	512	43.0	91.6
LPR031012	360	27.0	92.5
LPR031212a	150	18.0	88.0
LPR032912b	370	47.0	87.3
LPR052412	510	43.0	91.6
LPR060112	780	16.0	98.0
LPR060412	580	32.0	94.5
LPR060712	570	120.0	79.0
LPR110612	40.0	10.0	75.0
LPR112312	110	5.0	95.5
LPR113012	230	17.0	92.6
LPR051713	94.0	6.0	93.6
LPR052113	389	24.0	93.8
LPR062513	308	21.0	93.2
LPR013014	170	17.0	90.0
LPR030314	280	95.0	66.1
LPR030814a	173	26.0	85.0
LPR011815	529	72.8	86.2
LPR020215	397	67.0	83.1
Sum	2022		
N (COUNT)	23		
Median	91.6		
STDEV.s	8.99		
VAR.s	80.7		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	89.0		

Performance Claim 4 (TAPE):

Raw data summarizing the percent removal of total phosphorus (TP) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent TP (mg/L)	Average Effluent TP (mg/L)	Percent Removal (%)
LPR021012	0.141	0.104	26.2
LPR021412	0.220	0.062	71.8
LPR021712	0.310	0.067	78.3
LPR022012	0.163	0.026	84.1
LPR022412	0.424	0.070	83.5
LPR031012	0.140	0.049	65.0
LPR031212a	0.150	0.037	75.3
LPR032912b	0.280	0.081	71.1
LPR052412	0.170	0.070	58.8
LPR060112	0.200	0.035	82.5
LPR060412	0.210	0.043	79.5
LPR060712	0.170	0.140	17.6
LPR110612	0.068	0.025	63.2
LPR112312	0.082	0.025	69.5
LPR113012	0.170	0.025	85.3
LPR051713	0.282	0.029	89.9
LPR052113	0.558	0.050	91.1
LPR062513	0.583	0.045	92.2
LPR013014	0.317	0.053	83.3
LPR030314	0.417	0.133	68.1
LPR030814a	0.261	0.051	80.3
LPR011815	0.649	0.124	80.9
LPR020215	0.693	0.100	85.6
Sum	1683		
N (COUNT)	23		
Median	79.5		
STDEV.s	18.5		
VAR.s	343.7		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	79.0		

Performance Claim 5 (TAPE):

Raw data summarizing the percent removal of total nitrogen (TN) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent TN (mg/L)	Average Effluent TN (mg/L)	Percent Removal (%)
LPR021012	1.06	0.265	75.1
LPR021412	1.20	0.531	55.9
LPR021712	1.58	0.638	59.5
LPR022012	0.696	0.265	61.9
LPR022412	1.11	0.265	76.0
LPR031012	1.72	0.265	84.5
LPR031212a	0.760	0.400	47.4
LPR032912b	1.23	0.265	78.5
LPR052412	1.85	0.400	78.4
LPR060112	2.40	0.872	63.7
LPR060412	1.06	0.327	69.1
LPR060712	0.579	0.555	4.1
LPR110612	0.569	0.555	2.5
LPR112312	0.515	0.515	0.0
LPR113012	1.22	0.515	57.6
LPR051713	1.37	0.250	81.8
LPR052113	0.531	0.248	53.4
LPR062513	0.619	0.253	59.2
LPR013014	0.240	0.212	11.8
LPR030314	0.530	0.230	56.6
LPR030814a	0.432	0.080	81.5
LPR011815	0.180	0.110	38.9
LPR020215	2.32	0.370	84.1
Sum	1281		
N (COUNT)	23		
Median	59.5		
STDEV.s	27.0		
VAR.s	727		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	56.0		

Performance Claim 6 (TAPE):

Raw data summarizing the percent removal of total copper (Cu) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent Cu (mg/L)	Average Effluent Cu (mg/L)	Percent Removal (%)
LPR021012	No data	No data	-
LPR021412	No data	No data	-
LPR021712	0.032	0.006	81.3
LPR022012	0.014	0.001	92.9
LPR022412	0.032	0.005	84.4
LPR031012	0.019	0.003	84.2
LPR031212a	0.012	0.003	75.0
LPR032912b	0.023	0.004	82.6
LPR052412	0.050	0.050	0.0
LPR060112	0.040	0.003	92.5
LPR060412	0.021	0.003	85.7
LPR060712	0.028	0.010	64.3
LPR110612	0.006	0.003	50.0
LPR112312	0.006	0.001	83.3
LPR113012	0.016	0.002	87.5
LPR051713	0.016	0.003	81.3
LPR052113	0.027	0.006	77.8
LPR062513	0.029	0.005	82.8
LPR013014	0.021	0.004	81.0
LPR030314	0.019	0.006	68.4
LPR030814a	0.018	0.002	88.9
LPR011815	0.055	0.010	81.8
LPR020215	0.044	0.007	84.1
Sum	1610		
N (COUNT)	21		
Median	82.6		
STDEV.s	20.06		
VAR.s	403		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	77.0		

Performance Claim 7 (TAPE):

Raw data summarizing the percent removal of total zinc (Zn) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent Zn (mg/L)	Average Effluent Zn (mg/L)	Percent Removal (%)
LPR021012	No data	No data	-
LPR021412	No data	No data	-
LPR021712	0.151	0.034	77.8
LPR022012	0.076	0.011	85.8
LPR022412	0.191	0.031	84.0
LPR031012	0.120	0.022	81.7
LPR031212a	0.068	0.017	75.0
LPR032912b	0.160	0.029	81.9
LPR052412	0.250	0.250	0.0
LPR060112	0.230	0.012	94.8
LPR060412	0.130	0.015	88.5
LPR060712	0.170	0.048	71.8
LPR110612	0.022	0.014	36.4
LPR112312	0.049	0.010	79.6
LPR113012	0.110	0.016	85.5
LPR051713	0.068	0.010	85.2
LPR052113	0.126	0.021	83.5
LPR062513	0.120	0.017	85.5
LPR013014	0.108	0.026	76.1
LPR030314	0.095	0.029	69.8
LPR030814a	0.088	0.013	84.8
LPR011815	0.151	0.039	74.4
LPR020215	0.192	0.038	80.2
Sum	1582		
N (COUNT)	21		
Median	81.7		
STDEV.s	20.69		
VAR.s	428		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	75.0		

Performance Claim 8 (TAPE):

Raw data summarizing the percent removal of total lead (Pb) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent Pb (mg/L)	Average Effluent Pb (mg/L)	Percent Removal (%)
LPR021012	No data	No data	-
LPR021412	No data	No data	-
LPR021712	0.013	0.003	73.7
LPR022012	0.005	0.001	79.6
LPR022412	0.015	0.003	77.3
LPR031012	0.009	0.002	78.5
LPR031212a	0.006	0.002	71.9
LPR032912b	0.012	0.003	75.0
LPR052412	0.025	0.025	0.00
LPR060112	0.016	0.005	68.8
LPR060412	0.013	0.001	90.8
LPR060712	0.013	0.005	62.3
LPR110612	0.001	0.001	0.0
LPR112312	0.002	0.001	50.0
LPR113012	0.005	0.001	80.0
LPR051713	0.004	0.001	74.8
LPR052113	0.009	0.009	0.336
LPR062513	0.009	0.002	82.5
LPR013014	0.006	0.001	80.5
LPR030314	0.007	0.003	62.1
LPR030814a	0.005	0.001	71.5
LPR011815	0.015	0.003	81.4
LPR020215	0.011	0.002	81.0
Sum	1342		
N (COUNT)	21		
Median	74.8		
STDEV.s	28.05		
VAR.s	787		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized median	70.0		

Performance Claim 9 (TAPE):

Raw data summarizing the percent removal of total aluminium (Al) by The Stormwater Management StormFilter®, with PhosphoSorb® media, at the design hydraulic loading rate of 1.67gpm/sq ft. of media surface for a standard height cartridge of 45.72 cm for 23 qualifying storm events (bootstrapped data).

Sample ID	Average Influent Pb (mg/L)	Average Effluent Pb (mg/L)	Percent Removal (%)
LPR021012	No data	No data	-
LPR021412	No data	No data	-
LPR021712	9.15	1.86	79.7
LPR022012	2.62	0.319	87.8
LPR022412	9.65	1.99	79.4
LPR031012	6.20	1.10	82.3
LPR031212a	4.30	0.810	81.2
LPR032912b	6.40	1.70	73.4
LPR052412	9.70	1.30	86.6
LPR060112	11.0	0.370	96.6
LPR060412	12.0	1.00	91.7
LPR060712	9.60	4.10	57.3
LPR110612	1.30	0.300	76.9
LPR112312	1.20	0.190	84.2
LPR113012	3.00	0.440	85.3
LPR051713	1.44	0.134	90.7
LPR052113	3.24	0.358	89.0
LPR062513	3.94	0.466	88.2
LPR013014	3.45	0.796	76.9
LPR030314	2.64	1.13	57.2
LPR030814a	1.67	0.342	79.5
LPR011815	5.32	1.17	78.0
LPR020215	3.85	1.20	68.8
Sum	1691		
N (COUNT)	21		
Mean (AVE)	80.5		
STDEV.s	10.13		
VAR.s	103		
Z (alpha)	1.65		
Z (beta)	1.29		
Hypothesized mean	80.0		

Verification

This verification was completed by the Verification Expert, the Centre for Advancement of Water and Wastewater Technologies (“CAWT”), contracted by GLOBE Performance Solutions, applying the International Standard **ISO 14034:2016 Environmental management – Environmental technology verification (ETV)**. Data and information provided by Contech Engineered Solutions LLC to support the performance claim included the following:

- Performance test report “The Stormwater Management StormFilter®- PhosphoSorb® at a Specific Flow Rate of 1.67 gpm/ft² – Performance Evaluation Report” prepared by Contech Engineered Solutions, November 8, 2017. This report is based on a field testing program conducted by Contech personnel at a roadway site in Zigzag, Oregon between January 2012 and February 2015. Testing was conducted in accordance with the 2011 version of the Washington Department of Ecology TAPE (TAPE, 2011).

What is ISO 14034:2016 Environmental management – Environmental technology verification (ETV)?

ISO 14034:2016 specifies principles, procedures and requirements for environmental technology verification (ETV) and was developed and published by the International Organization for Standardization (ISO). The objective of ETV is to provide credible, reliable and independent verification of the performance of environmental technologies. An environmental technology is a technology that either results in an environmental added value or measures parameters that indicate an environmental impact. Such technologies have an increasingly important role in addressing environmental challenges and achieving sustainable development.

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Limitation of verification - Registration: GPS-ETV_2020-06-15_TAPE

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**Mitchell Community College
Stormwater Treatment System Field Evaluation:**

Stormwater Management StormFilter® with PhosphoSorb Media at 1 gpm/ ft²

Abstract

This report presents the results of a twenty month field study conducted at The Mitchell Community College testing site located in the Town of Mooresville, NC. The study was conducted in an effort to demonstrate the effectiveness of The Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) in treating stormwater runoff with respect to the removal of solid and nutrient pollutants.

Testing of the StormFilter system was conducted for Total Suspended Solids (TSS), Suspended Sediment Concentration (SSC), Total Volatile Suspended Solids (TVSS), Total Phosphorus (TP), Dissolved Phosphorus (Diss. P), Ortho-phosphate (Ortho-P), and Particulate Phosphorus (PP) in accordance with the approved Project Plan, (Contech, 2010) as well as the conditions outlined in the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ) Preliminary Evaluation Period (PEP) program, (NCDENR, 2007).

Results from the twenty month study, that represented a total of 13 storm events and 23.73 inches of precipitation, show that the StormFilter system tested was highly effective in removing solid and nutrient pollutants from stormwater runoff. Significant reductions for solid and nutrient pollutants were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation (TSS 90.4% and TP 86.1%) and Summation of Load (SOL) efficiency calculation methods (TSS 90.9% and TP 87.1%).

Keywords

BMP; stormwater; TP; TSS; NCDENR DWQ PEP; StormFilter; media filter cartridge

Introduction

Contech Engineered Solutions LLC (formerly Contech Construction Products Inc., Stormwater360 Inc., and Stormwater Management Inc.) is the leading provider of innovative, long-term, stormwater treatment solutions, offering a variety of products, maintenance, laboratory, and engineering support to meet stormwater treatment needs. Contech Engineered Solutions LLC's patented product, the Stormwater Management StormFilter® (StormFilter) Stormwater Treatment System (system) is a Best Management Practice (BMP) designed to meet federal, state, and local requirements for treating stormwater runoff in compliance with the Clean Water Act. The StormFilter system improves the quality of stormwater runoff before it enters receiving waterways through the use of customizable filter media, which removes non-point source pollutants, including sediment particles, oil and grease, soluble metals, nutrients, and organics.

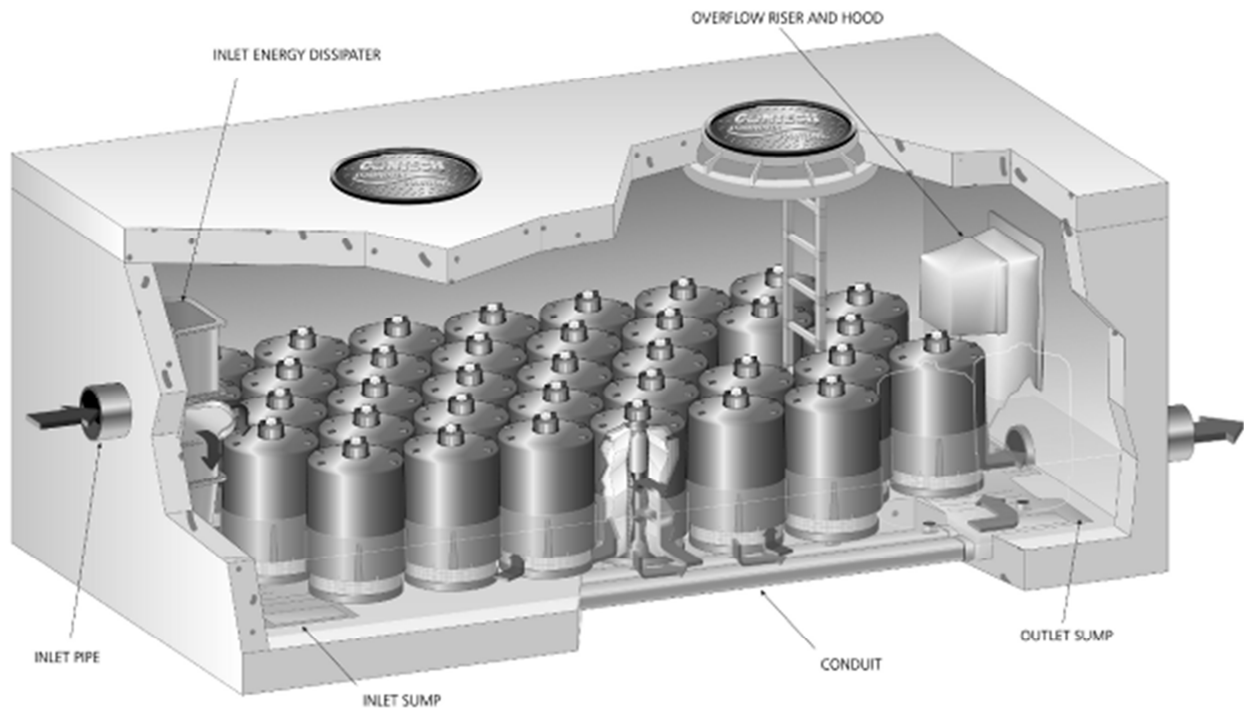


Figure 1. Standard StormFilter® Configuration.

The StormFilter system, as seen in Figure 1, is typically comprised of a vault that houses rechargeable, media-filled, filter cartridges. Stormwater entering the system percolates horizontally through these media-filled cartridges, where pollutant removal processes occur. Once filtered through the media, the treated stormwater is directed to a collection pipe and discharged to an open channel drainage way or storm sewer.

The StormFilter system is offered in a variety of configurations or containers depending on the specific application and site conditions: precast vault, box culvert vault, panel vault, manhole, and cast-in-place concrete. The StormFilter system is also offered in a steel catch basin or a concrete curb inlet configuration. The precast, manhole, and inlet configuration models utilize standard pre-manufactured units and arrive at the construction site with the filter cartridges and other internal components already in place to ease the installation process; the box culvert, panel vault, and cast-in-place units are customized for larger flows and require installation of cartridges at the site.

The Mitchell Community College StormFilter system installation (located in Mooresville, NC) was evaluated over a twenty month period following system maintenance in November of 2010. This project was managed by Contech in cooperation with the site owner and the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Water Quality (DWQ). Independent oversight of all aspects of the project was provided by Ryan Winston, M.S., Extension Associate Engineer in the Department of Biological and Agricultural Engineering at North Carolina State University. Independent sample handling services were provided by Pace Analytical Services (Pace) of Huntersville, NC, and independent laboratory work was conducted by Pace and Test America of Beaverton, OR. Monitoring over a twenty month period resulted in the collection of 13 qualified storm events representing 23.73 inches of cumulative precipitation.

Site and System Description

The Mitchell Community College testing site is located in the Town of Mooresville, NC. Mooresville is located in southern Iredell County in the Piedmont region of North Carolina. The town is located between the Charlotte metropolitan area and the city of Statesville, the County seat. Mooresville is located within 15 miles of three interstate highways and is approximately 23 miles from the Charlotte-Douglas International Airport. The testing site was located at the intersection of West Moore Avenue and North Academy Street, (Lat: 35°35'3.60"N, Lon: 80°48'47.76"W, Elevation AMSL: 862ft). The site was owned and operated by Mitchell Community College and used primarily for parking. The site was swept periodically, however minor amounts of sediment and organic debris were typically present on site. Based on information provided by the design engineer, the site was 68% impervious and the total drainage area for the site was 1.08 acres. An aerial view of the site from 2010 is shown in Figure 2. Stormwater runoff from the contributing drainage area was directed to the StormFilter system before eventually discharging into Reed's Creek Basin and ultimately Lake Norman.

Stormwater treatment for the site was provided by a StormFilter system, designed as a capture-and-treat system. The storage component of the system (tank) was comprised of a 30 inch diameter corrugated metal pipe (CMP) network designed to capture 75% of the calculated water quality volume (i.e. the runoff volume associated with the 1.0 inch event). The treatment component (StormFilter) was designed on a mass-loading basis and was required to meet the annual pollutant loading requirements of the site with a minimum estimated interval between maintenance of 1 year. The StormFilter contained a total of eight 18 inch tall, media filled filter cartridges operating at a maximum surface area specific flow rate of 1 gpm/ft² (7.5 gpm/cartridge). Each of the filter cartridges was filled with an innovative coated reactive perlite media (PhosphoSorb). The PhosphoSorb media employs both physical straining and adsorption as primary and secondary pollutant removal mechanisms respectively thus allowing the media to sequester both particulate and dissolved pollutants.

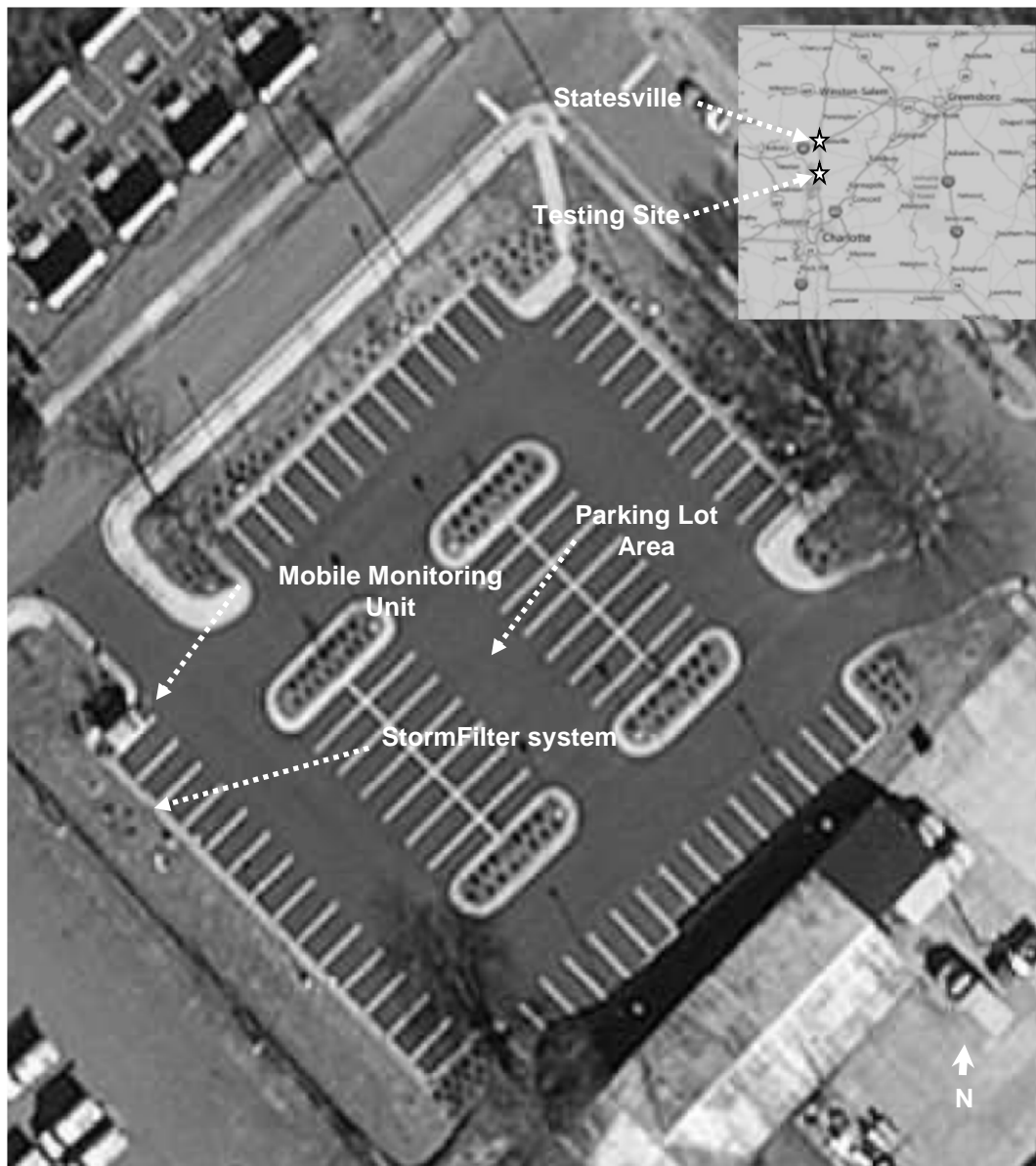


Figure 2. Aerial view of the Mitchell Community College testing site.

Sampling Design

The equipment and sampling techniques used for this study were in accordance with the Project Plan (Contech, 2010) developed by Contech in consultation with NCDENR DWQ. The Project Plan met the conditions outlined in the NCDENR DWQ preliminary evaluation period (PEP) program. Contech personnel were responsible for the installation, programming, and maintenance of the sampling equipment. Pace analytical provided independent sample retrieval, system reset, and sample submittal activities. Water sample processing and analysis was performed by Pace and Test America.

A Mobile Monitoring Unit (MMU) was provided, installed, maintained, and operated by Contech for sampling purposes. The MMU is a towable, fully enclosed, self-contained stormwater monitoring system specially designed and built by Contech for remote, extended-deployment stormwater monitoring. The design allows for remote control of sampling equipment, eliminates confined space

entry requirements, and streamlines the sample and data collection process. The MMU installed at the Mitchell Community College testing site is shown in Figure 3.



Figure 3. View of the Mobile Monitoring Unit (MMU) installed at the Mitchell Community College testing site.

Influent and effluent water quality samples were collected using individual ISCO 6712 Portable Automated Samplers configured for standard, individual, round, 1 liter wide-mouth HDPE bottles with sample bottles in the 1 through 12 positions for sample collection. The samplers were connected to individual 12V DC batteries recharged with solar panels. The influent sampler was equipped with an ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor for flow analysis and influent sample pacing. The effluent sampler was equipped with an ISCO 730 Bubbler Flow Module used in conjunction with a 6 inch diameter Thel-Mar Weir for flow analysis and effluent sample pacing. Each sampler was also connected to an ISCO SPA 1489 Digital Cell Phone Modem to allow for remote communication and data access. Rainfall was measured using a 0.01-in resolution Texas Electronics TR-4 tipping bucket-type rain gauge. The sample intake for each automated sampler was connected to a stainless steel sample strainer (9/16" diameter, 6" length, with multiple 1/4" openings) via a length of 3/8" ID Acutech Duality FEP/LDPE tubing. Sample strainers and flow measurement equipment were secured to the invert of the influent and effluent pipes using stainless steel spring rings.

Following a precipitation event, Contech personnel remotely communicated with the automated sampling equipment to confirm sample collection and dispatch personnel from Pace to retrieve the samples and reset the automated sampling equipment. Samples were delivered to Pace and Test America on ice (<4 degrees C) and accompanied by chain-of-custody documentation. Sample bottles were combined by Pace to create composite samples. Sample bottles were thoroughly shaken and sieved through a 2000µm sieve. Samples were then emptied into a cone splitter to obtain a single, composite sample (USGS, 1980). Composite samples were then submitted for analysis according to the analytical methods specified in Table 1. The field monitoring methods used for this study represent the current state-of-the practice, and are very similar to those used by researchers in North Carolina and elsewhere to evaluate Stormwater BMPs.

Table 1. Analytical methods used for analytical parameters of interest.

Parameter	Analytical Method
Total Suspended Solids (TSS)	SM2540 D
Suspended Sediment Conc. (SSC)	ASTMD3977
Total Volatile Suspended Solids (TVSS)	EPA 160.4
Total Phosphorus (TP)	EPA 365.1
Dissolved Phosphorus (Diss. P)	EPA 365.1

As per the Project Plan, the following quality control samples were used to assess the quality of both field sampling and analytical activities: equipment rinsate blanks, equipment field blanks, method blank, and duplicate analysis. Sample processing blank samples were not taken. Except for solids analyses that employ the use of the whole sample volume (SSC), all method blanks and duplicate analyses were handled by Pace and Test America. Since solids analyses that employ the use of whole sample volume (SSC) consume the entire sample volume, replicate samples were prepared in place of duplicate samples and analyzed to allow for the assessment of analytical accuracy. The results of equipment rinsate blanks and equipment field blanks are shown in Table 2 accompanied by associated decisions and action items for instances of detection. Equipment rinsate blanks and equipment field blanks were submitted for analysis of the following parameters TSS, TVSS, and TP.

Table 2. Instances of detection in equipment rinsate blank and equipment field blank samples.

Date	Blank Type	Detections	Action	% of Sample Pairs Affected
7/8/2011	Rinsate	None	None	0
6/28/2011	Field	None	None	0
6/14/2012	Field	None	None	0

Precipitation Measurement

Precipitation was measured with a Texas Electronics TR-4 tipping bucket-type rain gauge. The rain gauge was connected to an ISCO 6712 Automated Sampler programmed to record the total number of tips (0.01 inch per tip) every 5 minutes. Equipment calibrations performed on site during the monitoring period indicated that the rain gauge was working properly during the monitoring period.

A comparison of monthly precipitation totals measured at the NOAA NWS COOP weather station in Statesville, NC during the monitoring period to the 30 year monthly mean precipitation totals shows that precipitation in the area was below normal in 15 of the 20 months studied (Table 3). Rainfall was above normal in March (2011), July (2011), September (2011), November (2011), and May (2012) as seen in Table 3.

Table 3. Monthly precipitation totals compared to 30 year monthly mean precipitation totals (NOAA NWS COOP Weather Station Statesville, NC)

Month	NOAA NWS COOP Station Statesville, NC Precipitation Total (in.)	Percent of Monthly Precipitation Total Normal (%)	30 Year Monthly Precipitation Total Normal (in.)
November (2010)	1.08	33	3.30
December (2010)	2.63	72	3.64
January (2011)	1.59	42	3.83
February (2011)	1.76	50	3.55
March (2011)	5.66	127	4.45
April (2011)	2.72	80	3.42
May (2011)	3.82	92	4.15
June (2011)	1.78	40	4.49
July (2011)	6.26	158	3.95
August (2011)	3.29	90	3.67
September (2011)	4.89	120	4.07
October (2011)	2.39	69	3.45
November (2011)	4.14	125	3.30
December (2011)	3.32	91	3.64
January (2012)	1.8	47	3.83
February (2012)	1.81	51	3.55
March (2012)	2.64	59	4.45
April (2012)	1.77	52	3.42
May (2012)	6.43	155	4.15
June (2012)	4.36	97	4.49

For sampled storm events, rainfall durations ranged from 8 to 36 hours, rainfall depth ranged from 0.85 to 4.41 inches, and 15 and 30 minute maximum intensities were 3.28 and 1.90 inches/hour respectively. Based on design information provided by the design engineer, runoff was calculated using the Curve Number Method using a CN of 89. Calculated runoff volumes ranged from 5796 to 94,133 gallons as seen in Table 4.

Table 4. Precipitation and runoff statistics for sampled events at the Mitchell Community College testing site.

Event ID	Duration of storm event (hours)	Total Precipitation (in.)	P15 (in/hr)	P30 (in/hr)	Calculated Runoff Volume (gal)
MCC041611	8	1.04	1.32	0.96	9086
MCC051011	8	0.93	1.24	0.80	7126
MCC051611	22	1.04	0.40	0.26	9086
MCC062811	24	2.06	1.36	1.00	31611
MCC070811	13	4.41	3.28	1.90	94133
MCC073111	19	1.37	2.04	1.88	15674
MCC090511	36	1.94	1.92	0.96	28694
MCC092111	13	3.75	2.16	1.60	75933
MCC110311	24	1.40	0.56	0.50	16316
MCC111611	14	1.01	1.68	1.34	8538
MCC051312	21	1.82	1.28	0.92	25828
MCC052112	30	0.85	1.68	0.86	5796
MCC060612	30	2.11	1.00	0.88	32841

Flow Measurement

An ISCO 750 Area Velocity Flow Module with a Low Profile Area Velocity Flow Sensor was used to measure flow and pace sample collection at the influent sample location. An ISCO 730 Bubbler Flow Module was used in conjunction with a 6 inch diameter Thel-Mar Weir to measure flow and pace sample collection at the effluent sample location. Level measurements were adjusted by applying corrections that reflected differences between recorded and measured water surface elevations at the influent and effluent sampling locations. On average, 105% of the calculated total rainfall volume as runoff was measured, as effluent for the monitored events, as shown in Table 5.

Table 5. Percentage of calculated rainfall runoff volumes represented by actual measured runoff volumes at the Mitchell Community College testing site.

Event ID	Calculated Runoff Volume (gal)	Effluent Volume (gal)	Effluent Volume / Calc. Runoff Volume (%)
MCC041611	9086	12748	140
MCC051011	7126	9392	132
MCC051611	9086	18104	199
MCC062811	31611	26364	83
MCC070811	94133	49090	52
MCC073111	15674	16093	103
MCC090511	28694	35039	122
MCC092111	75933	67321	89
MCC110311	16316	20220	124
MCC111611	8538	9926	116
MCC051312	25828	13154	51
MCC052112	5796	4879	84
MCC060612	32841	21569	66

Stormwater Data Collection Requirements

Of the 13 qualifying storm events sampled; 1) the total rainfall was greater than 0.1 inches for all storm events sampled, 2) the minimum inter-event period was greater than 6 hours for all storm events sampled, 3) the minimum number of influent and effluent aliquots collected per storm event was ≥ 5 , 4) influent flow-weighted composite samples covered $\geq 50\%$ of the total storm flow for all storm events sampled with the exception of the MCC070811, MCC090511, MCC092111, MCC110311, MCC051312, and MCC060612 events, and 5) effluent flow-weighted composite samples covered $\geq 50\%$ of the total storm flow for all storm events sampled. All events have been determined to meet the conditions outlined in the PEP program as shown in Table 6.

Table 6. Stormwater data collection requirement results.

Event ID	Influent Coverage	Effluent Coverage	Influent Number of Aliquots	Effluent Number of Aliquots	Antecedent Dry Period > 6 hours	Event Depth (in.)
MCC041611	101%	100%	18	14	√	1.04
MCC051011	91%	79%	6	6	√	0.93
MCC051611	79%	90%	8	8	√	1.04
MCC062811	98%	97%	19	13	√	2.06
MCC070811	41%	98%	24	24	√	4.41
MCC073111	97%	98%	16	16	√	1.37
MCC090511	46%	90%	29	26	√	1.94
MCC092111	49%	93%	48	48	√	3.75
MCC110311	34%	60%	48	48	√	1.40
MCC111611	100%	100%	39	40	√	1.01
MCC051312	36%	92%	28	48	√	1.82
MCC052112	100%	74%	31	5	√	0.85
MCC060612	46%	73%	42	48	√	2.11

Data Analysis

Of the 13 qualifying storm events sampled, data verification and validation did not lead to the outright disqualification of any events due to obvious monitoring, handling or analytical errors, or the substantial exceedance of the design operating parameters. Event Mean Concentrations (EMC) from influent and effluent samples are summarized in Table 7-9.

Using SSC (<500 μ m) EMC results, the percent of corresponding SSC (<2000 μ m) EMC results was calculated. The calculated percentages of corresponding SSC (<2000 μ m) EMC results indicated the portion of material that was less than 500 μ m in size and are summarized in Table 10.

Using TVSS EMC results, the percent of corresponding SSC results was calculated. The calculated percentages of corresponding SSC (<2000 μ m) and SSC (<500 μ m) results indicated the percent of combustible materials that are assumed to be organic in nature and are summarized in Table 11.

Non-parametric statistical methods were used to evaluate correlations and differences between non-transformed influent and effluent EMCs since influent and effluent EMCs were generally not from the same statistical distribution. To test for positive correlations between influent and effluent EMCs, the Spearman Rank Order Correlation test was used (USGS, 1991). To evaluate the significance of differences between influent and effluent EMCs, the Mann-Whitney Rank Sum Test was used (USGS, 1991). For the Mann-Whitney Rank Sum Test the null hypothesis was that the two samples were not drawn from populations with different medians. A significant difference between influent and effluent EMCs was concluded when $P < 0.05$.

Detectible concentrations were observed for all parameters analyzed except for TSS for the MCC051011, MCC051611, MCC062811, MCC073111, MCC090511, MCC092111, MCC110311, and MCC060612 events; SSC (<2000 μ m) for the MCC073111, MCC051312, and MCC060612 events; SSC (<500 μ m) for the MCC051611, MCC051312, and MCC060612 events; TVSS (<2000 μ m) for the MCC111611 event; TVSS (<500 μ m) for the MCC110311 and MCC111611 events; TP for the MCC051611, MCC062811, MCC070811, MCC092111, MCC110311, MCC111611, MCC051312,

MCC052112, and MCC060612 events ; Diss. P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; Ortho-P for the MCC041611, MCC062811, MCC070811, MCC073111, MCC092111, MCC110311, MCC111611, MCC051312, and MCC060612 events; For values that were reported as non-detect, substitutions were made using half of the Method Reporting Limit (MRL) for statistical testing and calculation of efficiencies. For calculated parameters values calculated as ≤ 0 were reported as 0 for statistical testing and calculation of efficiencies.

Performance was calculated using the Efficiency Ratio (ER) efficiency calculation method. The ER method defines the efficiency as the average event mean concentration of pollutants over some time period.

$$ER = 1 - \frac{\text{mean effluent EMC}}{\text{mean influent EMC}}$$

The ER method assumes; 1) The weight of all storm events is equal regardless of the relative magnitude of the storm event and 2) that if all storm events at the site had been monitored, the average inlet and outlet EMCs would be similar to those that were monitored (URS/ EPA 1999). ER efficiency calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 7-19.

Performance was also calculated using the Summation of Loads (SOL) efficiency calculation method. The SOL method defines the efficiency as a percentage based on the ratio of the summation of all influent loads to the summation of all effluent loads.

$$SOL = 1 - \frac{\text{sum of all effluent loads}}{\text{sum of all influent loads}}$$

The SOL method assumes; 1) monitoring data accurately represents the actual entire total loads in and out of the BMP for a period long enough to overshadow any temporary storage or export of pollutants and 2) any significant storm events that were not monitored had a ratio of inlet to effluent loads similar to the storms events that were monitored (URS/ EPA 1999). In an effort to eliminate the introduction of potential bias associated with observed discrepancies between influent and effluent measured volumes it was assumed that the influent volume was equal to the effluent volume. Measured effluent volume was used to calculate loads for both the influent and effluent sample locations. Sum of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site are summarized in Tables 12,13, and 14.

Results

Based on the use of the Spearman Rank Order correlation test, positive correlations ($P < 0.05$) were determined between influent and effluent EMCs for Ortho-P.

Based on the use of the Mann-Whitney Rank Sum test, the difference in the median values between the influent and effluent EMCs is greater than would be expected by chance. Therefore, a statistically significant difference ($P < 0.05$) was observed for TSS, SSC ($< 2000\mu\text{m}$), SSC ($< 500\mu\text{m}$), TVSS ($< 2000\mu\text{m}$), TP, and PP as seen in Tables 7, 8, and 9.

Based on the use of the Mann-Whitney Rank Sum test, the difference in the median values between the influent and effluent EMCs is not great enough to exclude the possibility that the difference is due to

random sampling variability. A statistically significant difference ($P > 0.05$) was not observed for TVSS (<500 μm), Diss. P, and Ortho-P as seen in Tables 7, 8, and 9.

Suspended Solids Parameters

Influent EMCs for TSS ranged from 10.3 mg/l to 98.2 mg/l with a median of 27.6 mg/l and a mean of 34.6 mg/l. Corresponding effluent EMCs ranged from 1.3 mg/l to 6.6 mg/l with a median of 2.8 mg/l and a mean of 3.3 mg/l, resulting in an ER efficiency of 90.4%. Total event loadings for the study were 32.7 kg at the influent and 3.0 kg at the effluent sampling location, resulting in an SOL TSS efficiency of 90.9%.

Influent EMCs for SSC (<2000 μm) ranged from 17.7 mg/l to 2080.0 mg/l with a median of 53.4 mg/l and a mean of 231.0 mg/l. Corresponding effluent EMCs ranged from 1.9 mg/l to 7.2 mg/l with a median of 3.4 mg/l and a mean of 3.9 mg/l, resulting in an ER efficiency of 98.3%. Total event loadings for the study were 222.0 kg at the influent and 3.9 kg at the effluent sampling location, resulting in an SOL SSC efficiency of 98.3%. In general, the relationship between TSS and SSC (<2000 μm) was determined not to be significant based on the linear regression results for both influent ($R^2 = 0.0130$) and effluent ($R^2 = 0.410$) EMCs.

Influent EMCs for SSC (<500 μm) ranged from 9.0 mg/l to 393.0 mg/l with a median of 28.6 mg/l and a mean of 66.1 mg/l. Corresponding effluent EMCs ranged from 1.7 mg/l to 10.0 mg/l with a median of 2.8 mg/l and a mean of 4.4 mg/l, resulting in an ER efficiency of 93.4%. Total event loadings for the study were 63.3 kg at the influent and 4.0 kg at the effluent sampling location, resulting in an SOL efficiency of 93.7%. For each storm event, the percent of SSC (<2000 μm) represented by SSC (<500 μm) was calculated (Table 11). Influent and effluent median percentages of SSC (<2000 μm) were 68.0% and 94.2%, respectively. The percentage of corresponding SSC (<2000 μm) results indicated the portion of material that were less than 500 μm in size.

Volatile Suspended Solids Parameters

Influent EMCs for TVSS (<2000 μm) ranged from 1.1 mg/l to 99.2 mg/l with a median of 11.9 mg/l and a mean of 23.8 mg/l. Corresponding effluent EMCs ranged from 0.5 mg/l to 6.7 mg/l with a median of 3.0 mg/l and a mean of 2.9 mg/l, resulting in an ER efficiency of 87.7%. Total event loadings for the study were 24.6 kg at the influent and 2.9 kg at the effluent sampling location, resulting in an SOL efficiency of 88.2%. For each storm event, the percent of SSC (<2000 μm) represented by TVSS (<2000 μm) was calculated (Table 12). Influent and effluent median percentages of SSC (<2000 μm) were 29.0% and 65.1%, respectively. Percentage of corresponding SSC (<2000 μm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Influent EMCs for TVSS (<500 μm) ranged from 1.1 mg/l to 48.0 mg/l with a median of 7.3 mg/l and a mean of 11.6 mg/l. Corresponding effluent EMCs ranged from 0.6 mg/l to 5.3 mg/l with a median of 3.4 mg/l and a mean of 3.1 mg/l, resulting in an ER efficiency of 73.4%. Total event loadings for the study were 9.9 kg at the influent and 3.3 kg at the effluent sampling location, resulting in an SOL efficiency of 67.1%. For each storm event, the percent of SSC (<500 μm) represented by TVSS (<500 μm) was calculated (Table 12). Influent and effluent median percentages of SSC (<500 μm) were 31.4% and 86.4% respectively. Percentage of corresponding SSC (<500 μm) results indicated the percent of combustible materials that were assumed to be organic in nature.

Phosphorus Parameters

Influent EMCs for TP ranged from 0.07 mg/l to 0.90 mg/l with a median of 0.14 mg/l and a mean of 0.22 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.06 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 86.1%. Total event loadings for the study were 218.6 g at the influent and 28.1 g at the effluent sampling location, resulting in an SOL efficiency of 87.1%.

Influent EMCs for Diss. P ranged from 0.03 mg/l to 0.85 mg/l with a median of 0.05 mg/l and a mean of 0.16 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.16 mg/l with a median of 0.05 mg/l and a mean of 0.04 mg/l, resulting in an ER efficiency of 74.2%. Total event loadings for the study were 109.6 g at the influent and 35.9 g at the effluent sampling location, resulting in an SOL efficiency of 67.3%.

Influent EMCs for Ortho-P ranged from 0.03 mg/l to 0.86 mg/l with a median of 0.03 mg/l and a mean of 0.14 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.03 mg/l with a median of 0.03 mg/l and a mean of 0.03 mg/l, resulting in an ER efficiency of 82.5%. Total event loadings for the study were 102.8 g at the influent and 22.4 g at the effluent sampling location, resulting in an SOL efficiency of 78.2%.

Calculated influent EMCs for PP, calculated as the difference between TP and Diss. P, ranged from 0.02 mg/l to 0.23 mg/l with a median of 0.06 mg/l and a mean of 0.08 mg/l. Corresponding effluent EMCs ranged from 0.03 mg/l to 0.00 mg/l with a median of 0.00 mg/l and a mean of 0.01 mg/l, resulting in an ER efficiency of 91.3%. Total event loadings for the study were 97.7 g at the influent and 3.5 g at the effluent sampling location, resulting in an SOL efficiency of 96.4%.

Table 7. Suspended Solids Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (mg/l)		SSC (<2000µm) (mg/l)		SSC (<500µm) (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	21.2	6.2	55.7	7.2	45.8	7.3
MCC051011	98.2	5.1	90.6	4.6	104.0	5.1
MCC051611	21.8	2.8	51.0	6.2	9.6	1.9
MCC062811	10.3	1.4	18.0	3.0	9.0	2.6
MCC070811	18.2	3.3	29.7	3.8	16.0	3.0
MCC073111	28.4	2.5	17.7	2.7	29.1	4.0
MCC090511	25.1	2.5	81.8	2.5	74.5	2.4
MCC092111	27.6	1.3	86.0	1.9	20.4	1.7
MCC110311	23.6	1.3	2080.0	2.4	393.0	1.8
MCC111611	56.9	3.4	186.0	2.7	16.3	2.5
MCC051312	52.4	5.7	27.0	5.0	28.0	10.0
MCC052112	28.2	6.6	NT	NT	NT	NT
MCC060612	38.0	1.3	48.0	5.0	48.0	10.0
Min	10.3	1.3	17.7	1.9	9.0	1.7
Max	98.2	6.6	2080.0	7.2	393.0	10.0
Median	27.6	2.8	53.4	3.4	28.6	2.8
Mean	34.6	3.3	231.0	3.9	66.1	4.4
Efficiency Ratio	90.4%		98.3%		93.4%	
Mann-Whitney U statistic	0.000		0.000		4.000	
P value for U statistic	<0.001		<0.001		<0.001	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 8. Total Volatile Suspended Solids Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (mg/l)		TVSS (<500µm) (mg/l)	
	Influent	Effluent	Influent	Effluent
MCC041611	30.8	4.1	24.0	5.3
MCC051011	53.0	6.7	48.0	4.2
MCC051611	13.0	3.1	10.4	3.6
MCC062811	10.8	3.4	4.8	4.3
MCC070811	8.0	2.1	7.6	3.3
MCC073111	19.6	3.8	3.4	3.9
MCC090511	7.4	2.8	4.2	3.4
MCC092111	27.3	1.7	6.1	1.5
MCC110311	99.2	1.6	13.3	1.0
MCC111611	1.1	0.5	1.1	0.6
MCC051312	8.4	3.2	9.2	3.2
MCC052112	NT	NT	NT	NT
MCC060612	7.2	2.2	7.0	2.8
Min	1.1	0.5	1.1	0.6
Max	99.2	6.7	48.0	5.3
Median	11.9	3.0	7.3	3.4
Mean	23.8	2.9	11.6	3.1
Efficiency Ratio	87.7%		73.4%	
Mann-Whitney U statistic	11.000		0.000	
P value for U statistic	<0.001		0.667	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 9. Phosphorus Efficiency Ratio (ER) Efficiency Calculations and Statistical Testing for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (mg/l)		Diss. P (mg/l)		Ortho-P (mg/l)		PP (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	0.160	0.058	0.025	0.025	0.025	0.025	0.135	0.033
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	0.110	0.025	NT	NT	NT	NT	NT	NT
MCC062811	0.130	0.025	0.025	0.160	0.025	0.025	0.105	0.000
MCC070811	0.065	0.025	0.025	0.025	0.025	0.025	0.040	0.000
MCC073111	0.140	0.057	0.061	0.025	0.025	0.025	0.079	0.032
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	0.250	0.025	0.025	0.025	0.025	0.025	0.225	0.000
MCC110311	0.900	0.025	0.850	0.025	0.860	0.025	0.050	0.000
MCC111611	0.100	0.025	0.081	0.025	0.063	0.025	0.019	0.000
MCC051312	0.088	0.025	0.054	0.025	0.025	0.025	0.034	0.000
MCC052112	0.200	0.025	NT	NT	NT	NT	NT	NT
MCC060612	0.310	0.025	0.250	0.025	0.210	0.025	0.060	0.000
Min	0.065	0.025	0.025	0.025	0.025	0.025	0.019	0.000
Max	0.900	0.058	0.850	0.160	0.860	0.025	0.225	0.033
Median	0.140	0.025	0.054	0.025	0.025	0.025	0.060	0.000
Mean	0.223	0.031	0.155	0.040	0.143	0.025	0.083	0.007
Efficiency Ratio	86.1%		74.2%		82.5%		91.3%	
Mann-Whitney U statistic	0.000		23.000		27.000		2.000	
P value for U statistic	<0.001		0.074		0.077		<0.001	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 10. Calculated Percentages of material less than 500µm for the 13 events sampled at the Mitchell Community College testing site.

Event ID	SSC (<500µm)/ SSC (<2000µm) (%)	
	Influent	Effluent
MCC041611	82.2	100.0
MCC051011	100.0	100.0
MCC051611	18.9	31.1
MCC062811	49.8	86.0
MCC070811	53.9	79.9
MCC073111	100.0	100.0
MCC090511	91.1	98.4
MCC092111	23.7	85.9
MCC110311	18.9	75.2
MCC111611	8.8	90.1
MCC051312	100.0	100.0
MCC052112	NT	NT
MCC060612	100.0	100.0
Min	8.8	31.1
Max	100.0	100.0
Median	68.0	94.2
Mean	62.3	87.2

NT = Not tested

QC DQ = Quality Control Disqualification

Table 11. Calculated percentages of combustible materials that were assumed to be organic in nature for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm)/ SSC (<2000µm) (%)		TVSS (<500µm)/ SSC (<500µm) (%)	
	Influent	Effluent	Influent	Effluent
MCC041611	55.3	56.9	52.4	72.6
MCC051011	58.5	100.0	46.2	81.9
MCC051611	25.5	50.0	100.0	100.0
MCC062811	60.0	100.0	53.6	100.0
MCC070811	26.9	55.6	47.5	100.0
MCC073111	100.0	100.0	11.7	98.7
MCC090511	9.0	100.0	5.6	100.0
MCC092111	31.7	88.5	29.9	90.9
MCC110311	4.8	66.1	3.4	54.9
MCC111611	0.6	18.3	6.7	22.4
MCC051312	31.1	64.0	32.9	32.0
MCC052112	NT	NT	NT	NT
MCC060612	15.0	44.0	14.6	28.0
Min	0.6	18.3	3.4	22.4
Max	100.0	100.0	100.0	100.0
Median	29.0	65.1	31.4	86.4
Mean	34.9	70.3	33.7	73.5

NT = Not tested

QC DQ = Quality Control Disqualification

Table 12. Suspended Solids Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TSS (kg)		SSC (<2000µm) (kg)		SSC (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	1.0	0.3	2.7	0.3	2.2	0.4
MCC051011	3.5	0.2	3.2	0.2	3.7	0.2
MCC051611	1.5	0.2	3.5	0.4	0.7	0.1
MCC062811	1.0	0.1	1.8	0.3	0.9	0.3
MCC070811	3.4	0.6	5.5	0.7	3.0	0.6
MCC073111	1.7	0.2	1.1	0.2	1.8	0.2
MCC090511	3.3	0.3	10.8	0.3	9.9	0.3
MCC092111	7.0	0.3	21.9	0.5	5.2	0.4
MCC110311	1.8	0.1	159.2	0.2	30.1	0.1
MCC111611	2.1	0.1	7.0	0.1	0.6	0.1
MCC051312	2.6	0.3	1.3	0.2	1.4	0.5
MCC052112	0.5	0.1	NT	NT	NT	NT
MCC060612	3.1	0.1	3.9	0.4	3.9	0.8
Sum	32.7	3.0	222.0	3.9	63.3	4.0
SOL Efficiency	90.9%		98.3%		93.7%	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 13. Total Volatile Suspended Solids Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TVSS (<2000µm) (kg)		TVSS (<500µm) (kg)	
	Influent	Effluent	Influent	Effluent
MCC041611	1.5	0.2	1.2	0.3
MCC051011	1.9	0.2	1.7	0.1
MCC051611	0.9	0.2	0.7	0.2
MCC062811	1.1	0.3	0.5	0.4
MCC070811	1.5	0.4	1.4	0.6
MCC073111	1.2	0.2	0.2	0.2
MCC090511	1.0	0.4	0.6	0.5
MCC092111	7.0	0.4	1.6	0.4
MCC110311	7.6	0.1	1.0	0.1
MCC111611	0.0	0.0	0.0	0.0
MCC051312	0.4	0.2	0.5	0.2
MCC052112	NT	NT	NT	NT
MCC060612	0.6	0.2	0.6	0.2
Sum	24.6	2.9	9.9	3.3
SOL Efficiency	88.2%		67.1%	

NT = Not tested

QC DQ = Quality Control Disqualification

Table 14. Phosphorus Summation of Loads (SOL) Efficiency Calculations for the 13 events sampled at the Mitchell Community College testing site.

Event ID	TP (g)		Diss. P (g)		Ortho-P (g)		PP (g)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
MCC041611	7.7	2.8	1.2	1.2	1.2	1.2	6.5	1.6
MCC051011	NT	NT	NT	NT	NT	NT	NT	NT
MCC051611	7.5	1.7	NT	NT	NT	NT	NT	NT
MCC062811	13.0	2.5	2.5	16.0	2.5	2.5	10.5	0.0
MCC070811	12.1	4.6	4.6	4.6	4.6	4.6	7.4	0.0
MCC073111	8.5	3.5	3.7	1.5	1.5	1.5	4.8	1.9
MCC090511	NT	NT	NT	NT	NT	NT	NT	NT
MCC092111	63.7	6.4	6.4	6.4	6.4	6.4	57.3	0.0
MCC110311	68.9	1.9	65.1	1.9	65.8	1.9	3.8	0.0
MCC111611	3.8	0.9	3.0	0.9	2.4	0.9	0.7	0.0
MCC051312	4.4	1.2	2.7	1.2	1.2	1.2	1.7	0.0
MCC052112	3.7	0.5	NT	NT	NT	NT	NT	NT
MCC060612	25.3	2.0	20.4	2.0	17.1	2.0	4.9	0.0
Sum	218.6	28.1	109.6	35.9	102.8	22.4	97.7	3.5
SOL Efficiency	87.1%		67.3%		78.2%		96.4%	

NT = Not tested

QC DQ = Quality Control Disqualification

Residual Solids Assessment Results

In an effort to verify the capture of materials by the StormFilter system over the course of the monitoring period, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on November 3, 2011. The mass of materials contained in the system was estimated using a mean depth measurement and a texture based bulk density estimate. The mean depth of material captured by the StormFilter at the time of inspection was determined to be approximately 3 inches. A composite sample of the material captured by the StormFilter was collected and texture was determined in the field by hand texturing of the sample. Hand texture analysis of the composite sample revealed that the materials captured by the StormFilter had a loamy sand texture (USDA classification). The estimated mass of materials contained in the StormFilter, using the mean depth of material captured by the StormFilter and a bulk density assumption for loamy sand texture soils of 1.65 gm/cc, was approximately 150 kg.

Following the maintenance of the system on November 3, 2011 which involved the removal of accumulated solids from the system as well as the replacement of cartridges, a qualitative assessment of materials captured by the StormFilter system was performed during the site visit conducted on June 14, 2012. The mass and texture of materials contained in the system was estimated as described above. The mean depth of material captured by the StormFilter was determined to be approximately 0.5 inches; and had a loamy sand texture (USDA classification). The estimated mass of materials was approximately 25 kg.

Summary and Conclusion

The primary purpose of this report was to document StormFilter system performance with respect to solid and nutrient pollutant removal and quantify performance in accordance with the conditions outlined in the NCDENR DWQ PEP program. Between November (2010) and June (2012), a total of 13 qualifying storm events were monitored and were determined to meet the storm data collection requirements as per the conditions outlined in the NCDENR DWQ PEP program.

Significant reductions for solid and nutrient pollutant concentrations were observed between influent and effluent sampling locations using the Efficiency Ratio (ER) efficiency calculation (TSS 90.4% and TP 86.1%) and Summation of Load (SOL) efficiency calculation methods (TSS 90.9% and TP 87.1%). The capture of solids by the system was verified as part of the residual solids assessment during site visits conducted on November 3, 2011 and June 14, 2012.

Given that the solid performance standard for this project is based solely on TSS removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate suspended sediment removal efficiency based on specific particle size ranges, SSC samples were sieved prior to analysis. The particle size ranges that were isolated for this study included 2000 μ m to 1.5 μ m and 500 μ m to 1.5 μ m. The isolation of suspended solids removal efficiencies based on particles 2000 μ m to 1.5 μ m and particles between 500 μ m and 1.5 μ m resulted in an overall removal efficiency of 98.3% and 93.4% respectively using the ER efficiency calculation method and 98.3% and 93.7% respectively using the SOL efficiency calculation method. These results demonstrate performance greater than the performance goal of 85% removal of TSS. In addition to these results demonstrating performance greater than the performance goal of 85% removal of TSS, research by (Rutgers/ NJDEP, 2006) suggests the difference between TSS and SSC results becomes smaller as the particle size of the material analyzed becomes finer.

Given that the phosphorus removal performance standard for this project is based solely on TP removal efficiency, the review of additional data was required to further understand removal efficiency results. In an effort to isolate phosphorus removal efficiency based on speciation TP, Diss. P, Ortho-P, and PP results were isolated. TP, Diss. P, and Ortho-P results were provided by the analytical lab. PP was calculated as the difference between TP and Diss. P. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in an overall removal efficiency 86.1%, 74.2%, 82.5%, and 91.3% respectively using the ER efficiency calculation method. Removal efficiencies for TP, Diss. P, Ortho-P, and PP results resulted in an overall removal efficiency of 87.1%, 67.3%, 78.2%, and 96.4% using the SOL efficiency calculation method. These results not only demonstrate that the system was able to meet the performance goal but was able to attenuate TP captured by the system over the course of the study.

Results from the twenty month study, that represented a total of 13 storm events and 23.73 inches of precipitation, show that the StormFilter system tested was highly effective in removing solid and nutrient pollutants from the stormwater runoff.

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Revision History

Original

StormFilter Inspection and Maintenance Procedures



Maintenance Guidelines

The primary purpose of the Stormwater Management StormFilter® is to filter and prevent pollutants from entering our waterways. Like any effective filtration system, periodically these pollutants must be removed to restore the StormFilter to its full efficiency and effectiveness.

Maintenance requirements and frequency are dependent on the pollutant load characteristics of each site. Maintenance activities may be required in the event of a chemical spill or due to excessive sediment loading from site erosion or extreme storms. It is a good practice to inspect the system after major storm events.

Maintenance Procedures

Although there are many effective maintenance options, we believe the following procedure to be efficient, using common equipment and existing maintenance protocols. The following two-step procedure is recommended::

1. Inspection

- Inspection of the vault interior to determine the need for maintenance.

2. Maintenance

- Cartridge replacement
- Sediment removal

Inspection and Maintenance Timing

At least one scheduled inspection should take place per year with maintenance following as warranted.

First, an inspection should be done before the winter season. During the inspection the need for maintenance should be determined and, if disposal during maintenance will be required, samples of the accumulated sediments and media should be obtained.

Second, if warranted, a maintenance (replacement of the filter cartridges and removal of accumulated sediments) should be performed during periods of dry weather.

In addition to these two activities, it is important to check the condition of the StormFilter unit after major storms for potential damage caused by high flows and for high sediment accumulation that may be caused by localized erosion in the drainage area. It may be necessary to adjust the inspection/maintenance schedule depending on the actual operating conditions encountered by the system. In general, inspection activities can be conducted at any time, and maintenance should occur, if warranted, during dryer months in late summer to early fall.

Maintenance Frequency

The primary factor for determining frequency of maintenance for the StormFilter is sediment loading.

A properly functioning system will remove solids from water by trapping particulates in the porous structure of the filter media inside the cartridges. The flow through the system will naturally decrease as more and more particulates are trapped. Eventually the flow through the cartridges will be low enough to require replacement. It may be possible to extend the usable span of the cartridges by removing sediment from upstream trapping devices on a routine as-needed basis, in order to prevent material from being re-suspended and discharged to the StormFilter treatment system.

The average maintenance lifecycle is approximately 1-5 years. Site conditions greatly influence maintenance requirements. StormFilter units located in areas with erosion or active construction may need to be inspected and maintained more often than those with fully stabilized surface conditions.

Regulatory requirements or a chemical spill can shift maintenance timing as well. The maintenance frequency may be adjusted as additional monitoring information becomes available during the inspection program. Areas that develop known problems should be inspected more frequently than areas that demonstrate no problems, particularly after major storms. Ultimately, inspection and maintenance activities should be scheduled based on the historic records and characteristics of an individual StormFilter system or site. It is recommended that the site owner develop a database to properly manage StormFilter inspection and maintenance programs..





Inspection Procedures

The primary goal of an inspection is to assess the condition of the cartridges relative to the level of visual sediment loading as it relates to decreased treatment capacity. It may be desirable to conduct this inspection during a storm to observe the relative flow through the filter cartridges. If the submerged cartridges are severely plugged, then typically large amounts of sediments will be present and very little flow will be discharged from the drainage pipes. If this is the case, then maintenance is warranted and the cartridges need to be replaced.

Warning: In the case of a spill, the worker should abort inspection activities until the proper guidance is obtained. Notify the local hazard control agency and Contech Engineered Solutions immediately.

To conduct an inspection:

Important: Inspection should be performed by a person who is familiar with the operation and configuration of the StormFilter treatment unit.

1. If applicable, set up safety equipment to protect and notify surrounding vehicle and pedestrian traffic.
2. Visually inspect the external condition of the unit and take notes concerning defects/problems.
3. Open the access portals to the vault and allow the system vent.
4. Without entering the vault, visually inspect the inside of the unit, and note accumulations of liquids and solids.
5. Be sure to record the level of sediment build-up on the floor of the vault, in the forebay, and on top of the cartridges. If flow is occurring, note the flow of water per drainage pipe. Record all observations. Digital pictures are valuable for historical documentation.
6. Close and fasten the access portals.
7. Remove safety equipment.
8. If appropriate, make notes about the local drainage area relative to ongoing construction, erosion problems, or high loading of other materials to the system.
9. Discuss conditions that suggest maintenance and make decision as to whether or not maintenance is needed.

Maintenance Decision Tree

The need for maintenance is typically based on results of the inspection. The following Maintenance Decision Tree should be used as a general guide. (Other factors, such as Regulatory Requirements, may need to be considered)

1. Sediment loading on the vault floor.
 - a. If $>4"$ of accumulated sediment, maintenance is required.
2. Sediment loading on top of the cartridge.
 - a. If $>1/4"$ of accumulation, maintenance is required.
3. Submerged cartridges.
 - a. If $>4"$ of static water above cartridge bottom for more than 24 hours after end of rain event, maintenance is required. (Catch basins have standing water in the cartridge bay.)
4. Plugged media.
 - a. If pore space between media granules is absent, maintenance is required.
5. Bypass condition.
 - a. If inspection is conducted during an average rain fall event and StormFilter remains in bypass condition (water over the internal outlet baffle wall or submerged cartridges), maintenance is required.
6. Hazardous material release.
 - a. If hazardous material release (automotive fluids or other) is reported, maintenance is required.
7. Pronounced scum line.
 - a. If pronounced scum line (say $\geq 1/4"$ thick) is present above top cap, maintenance is required.



Maintenance

Depending on the configuration of the particular system, maintenance personnel will be required to enter the vault to perform the maintenance.

Important: If vault entry is required, OSHA rules for confined space entry must be followed.

Filter cartridge replacement should occur during dry weather. It may be necessary to plug the filter inlet pipe if base flows is occurring.

Replacement cartridges can be delivered to the site or customers facility. Information concerning how to obtain the replacement cartridges is available from Contech Engineered Solutions.

Warning: In the case of a spill, the maintenance personnel should abort maintenance activities until the proper guidance is obtained. Notify the local hazard control agency and Contech Engineered Solutions immediately.

To conduct cartridge replacement and sediment removal maintenance:

1. If applicable, set up safety equipment to protect maintenance personnel and pedestrians from site hazards.
2. Visually inspect the external condition of the unit and take notes concerning defects/problems.
3. Open the doors (access portals) to the vault and allow the system to vent.
4. Without entering the vault, give the inside of the unit, including components, a general condition inspection.
5. Make notes about the external and internal condition of the vault. Give particular attention to recording the level of sediment build-up on the floor of the vault, in the forebay, and on top of the internal components.
6. Using appropriate equipment offload the replacement cartridges (up to 150 lbs. each) and set aside.
7. Remove used cartridges from the vault using one of the following methods:

Method 1:

- A. This activity will require that maintenance personnel enter the vault to remove the cartridges from the under drain manifold and place them under the vault opening for lifting (removal). Disconnect each filter cartridge from the underdrain connector by rotating counterclockwise 1/4 of a turn. Roll the loose cartridge, on edge, to a convenient spot beneath the vault access.

Using appropriate hoisting equipment, attach a cable from the boom, crane, or tripod to the loose cartridge. Contact Contech Engineered Solutions for suggested attachment devices.

- B. Remove the used cartridges (up to 250 lbs. each) from the vault.



Important: Care must be used to avoid damaging the cartridges during removal and installation. The cost of repairing components damaged during maintenance will be the responsibility of the owner.

- C. Set the used cartridge aside or load onto the hauling truck.
- D. Continue steps a through c until all cartridges have been removed.

Method 2:

- A. This activity will require that maintenance personnel enter the vault to remove the cartridges from the under drain manifold and place them under the vault opening for lifting (removal). Disconnect each filter cartridge from the underdrain connector by rotating counterclockwise 1/4 of a turn. Roll the loose cartridge, on edge, to a convenient spot beneath the vault access.
- B. Unscrew the cartridge cap.
- C. Remove the cartridge hood and float.
- D. At location under structure access, tip the cartridge on its side.
- E. Empty the cartridge onto the vault floor. Reassemble the empty cartridge.
- F. Set the empty, used cartridge aside or load onto the hauling truck.
- G. Continue steps a through e until all cartridges have been removed.

8. Remove accumulated sediment from the floor of the vault and from the forebay. This can most effectively be accomplished by use of a vacuum truck.
9. Once the sediments are removed, assess the condition of the vault and the condition of the connectors.
10. Using the vacuum truck boom, crane, or tripod, lower and install the new cartridges. Once again, take care not to damage connections.
11. Close and fasten the door.
12. Remove safety equipment.
13. Finally, dispose of the accumulated materials in accordance with applicable regulations. Make arrangements to return the used **empty** cartridges to Contech Engineered Solutions.

Related Maintenance Activities - Performed on an as-needed basis

StormFilter units are often just one of many structures in a more comprehensive stormwater drainage and treatment system.

In order for maintenance of the StormFilter to be successful, it is imperative that all other components be properly maintained. The maintenance/repair of upstream facilities should be carried out prior to StormFilter maintenance activities.

In addition to considering upstream facilities, it is also important to correct any problems identified in the drainage area. Drainage area concerns may include: erosion problems, heavy oil loading, and discharges of inappropriate materials.

Material Disposal

The accumulated sediment found in stormwater treatment and conveyance systems must be handled and disposed of in accordance with regulatory protocols. It is possible for sediments to contain measurable concentrations of heavy metals and organic chemicals (such as pesticides and petroleum products). Areas with the greatest potential for high pollutant loading include industrial areas and heavily traveled roads.

Sediments and water must be disposed of in accordance with all applicable waste disposal regulations. When scheduling maintenance, consideration must be made for the disposal of solid and liquid wastes. This typically requires coordination with a local landfill for solid waste disposal. For liquid waste disposal a number of options are available including a municipal vacuum truck decant facility, local waste water treatment plant or on-site treatment and discharge.



Inspection Report

Date: _____ Personnel: _____

Location: _____ System Size: _____ Months in Service: _____

System Type: Vault Cast-In-Place Linear Catch Basin Manhole Other: _____

Sediment Thickness in Forebay: _____ Date: _____

Sediment Depth on Vault Floor: _____

Sediment Depth on Cartridge Top(s): _____

Structural Damage: _____

Estimated Flow from Drainage Pipes (if available): _____

Cartridges Submerged: Yes No Depth of Standing Water: _____

StormFilter Maintenance Activities (check off if done and give description)

Trash and Debris Removal: _____

Minor Structural Repairs: _____

Drainage Area Report _____

Excessive Oil Loading: Yes No Source: _____

Sediment Accumulation on Pavement: Yes No Source: _____

Erosion of Landscaped Areas: Yes No Source: _____

Items Needing Further Work: _____

Owners should contact the local public works department and inquire about how the department disposes of their street waste residuals.

Other Comments:

Review the condition reports from the previous inspection visits.

StormFilter Maintenance Report

Date: _____ Personnel: _____

Location: _____ System Size: _____

System Type: Vault Cast-In-Place Linear Catch Basin Manhole Other: _____

List Safety Procedures and Equipment Used: _____

System Observations

Months in Service: _____

Oil in Forebay (if present): Yes No

Sediment Depth in Forebay (if present): _____

Sediment Depth on Vault Floor: _____

Sediment Depth on Cartridge Top(s): _____

Structural Damage: _____

Drainage Area Report

Excessive Oil Loading: Yes No Source: _____

Sediment Accumulation on Pavement: Yes No Source: _____

Erosion of Landscaped Areas: Yes No Source: _____

StormFilter Cartridge Replacement Maintenance Activities

Remove Trash and Debris: Yes No Details: _____

Replace Cartridges: Yes No Details: _____

Sediment Removed: Yes No Details: _____

Quantity of Sediment Removed (estimate?): _____

Minor Structural Repairs: Yes No Details: _____

Residuals (debris, sediment) Disposal Methods: _____

Notes:



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Centre for Alternative Wastewater Treatment



Phosphorus Removal Performance of Bioretention Soil Mix Amended with Imbrium® Systems Sorbtive® Media

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February 2013

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Wastewater Treatment**

Phosphorus Removal Performance of Bioretention Soil Mix Amended with Imbrium® Systems Sorbtive® Media

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EXECUTIVE SUMMARY

A pilot study was undertaken by researchers at Fleming College in Ontario, Canada to assess the phosphorus removal performance of bioretention soil mix amended with Imbrium® Systems Sorbtive® Media AI 28x48. Five bioretention cells were constructed and filled with a soil mix comprised of sand, peat moss, and various percentages of the phosphorus adsorbent Sorbtive® Media. One cell was a control with no amendment, and four cells were amended with the additive blended in at 3%, 5%, 10%, and 17% volume basis, respectively.

Batches of artificial stormwater were spiked with potassium dihydrogen phosphate (KH_2PO_4) at target concentrations of 0.2, 0.4, 0.6, and 0.8 mg/L (P-basis). Starting with the artificial stormwater containing the lowest concentration of phosphorus, each bioretention cell was subjected to a series of daily simulated storm events of controlled water volume for five consecutive days. This five-day simulated storm series was undertaken five times for each of the four phosphorus concentrations. The total volume of spiked artificial stormwater applied to each cell was representative of two years of regional cumulative urban runoff for a drainage area five times the size of a bioretention cell.

Influent and effluent samples were collected for each cell and analyzed for total phosphorus and total dissolved phosphorus. Study results demonstrated a very substantial improvement in phosphorus removal with the amended bioretention soil compared to the control. Over the course of the study, the control cell's total phosphorus removal efficiency decreased from approximately 60% to 25%, while each of the amended cells maintained removal efficiency of up to 99% and at least 84% for the duration of the study. These results suggest that Sorbtive® Media, even when blended into the soil mix at only 3 - 5% volume basis, would be highly effective for improving phosphorus removal in bioretention installations. A similar benefit would be expected when using the amendment in bioswale, rain garden, green roof, and sand filter installations.

1 INTRODUCTION

1.1 Overview

An increasing focus of stormwater regulators and researchers is the impairment of water bodies due to nutrient loads transported in stormwater runoff. Regional authorities for watersheds in the U.S. and Canada have targeted phosphorus as a primary pollutant of concern. The widespread adoption of bioretention as a low-impact stormwater treatment practice has produced some well-documented water quality benefits, however, an increasing number of monitoring studies have detected substantial leaching of phosphorus from compost-containing bioretention installations.

The focus of this pilot study was to assess the phosphorus removal performance of bioretention soil mix amended with Imbrium® Systems Sorbtive® Media AI 28x48, an engineered granular media containing aluminum oxide and iron oxide that demonstrates substantial capacity for adsorption of dissolved phosphorus from stormwater runoff. In order to simulate natural stormwater runoff, this study utilized artificial stormwater spiked with various concentrations of potassium dihydrogen phosphate (KH_2PO_4). Spiked stormwater was applied to constructed bioretention cells containing a sand/peat soil mix amended with varying percentages of the additive.

Five bioretention cells were constructed and filled with soil mix and vegetated with a grass and wildflower mix. One cell was a control with no amendment, and four cells were amended with the additive blended in at 3%, 5%, 10%, and 17% volume basis, respectively. Batches of artificial stormwater were spiked with KH_2PO_4 at target concentrations of 0.2, 0.4, 0.6, and 0.8 mg/L (P-basis). Starting with the artificial stormwater containing the lowest concentration of phosphorus, each bioretention cell was subjected to a series of daily simulated storm events of controlled water volume for five consecutive days through an irrigation system. This five-day simulated storm series was undertaken five times for each of the four phosphorus concentrations, therefore each cell was subjected to 25 storm events at each phosphorus concentration, for a total of 100 storm events for each cell. The volume of water applied during each storm event was 990 liters. The total volume of spiked artificial stormwater applied to each cell was representative of two years of regional cumulative urban runoff for a drainage area five times the size of a bioretention cell.

The cells were located outdoors, and therefore were additionally subjected to actual rainfall precipitation; however, no exterior runoff from such rain events could enter the cells. Since the only phosphorus possibly present in such rainfall was from atmospheric sources, it was considered negligible for the purposes of this study and was not measured.

Influent and effluent samples were collected for each cell and analyzed for total phosphorus and total dissolved phosphorus. Phosphorus removal performance was examined as a function of Sorbtive® Media percentage in the soil mix, phosphorus concentration in the artificial stormwater, and cumulative phosphorus load. This information is useful in assessing the practicality of using Sorbtive® Media as a bioretention soil amendment to achieve regulatory phosphorus treatment benchmarks as well as media longevity in such applications.

1.2 Phosphorus and Stormwater Management

Increasing stormwater runoff, as a result of urbanization and consequent increase in landscape imperviousness, contributes to increased contaminant loadings that degrade receiving water quality and negatively affect aquatic ecosystems. A significant stormwater pollutant of concern is phosphorus due to the correlation of increased phosphorus concentrations in surface waters and eutrophication, toxic algae blooms and reduced dissolved oxygen concentrations (Fried et al, 2003). Phosphorus is a naturally occurring element found within rock, sediment, soil, and organic matter. Phosphorus is essential for life as it is a component of adenosine triphosphate (ATP), the energy transfer molecule needed for cellular processes carried out within all living matter (Darnell et al., 1990).

In stormwater phosphorus is generally present both in a dissolved phase and in a particulate-bound phase. The measurement of phosphorus in water samples is commonly quantified in two manners; Total Phosphorus (TP) and Total Dissolved Phosphorus (TDP). The quantification of Total Phosphorus includes the total of both particulate-bound and dissolved phase phosphorus, while Total Dissolved Phosphorus refers to the dissolved phase only. The separation of particulate-bound and dissolved phase phosphorus is conducted through filtration utilizing 0.45 micron membrane filters. Dissolved phosphorus may also be referred to as Total Filterable Phosphorus (TFP) and is represented by dissolved soluble reactive phosphorus (SRP) (orthophosphate) and hydrolysable phosphorus (DHP). Soluble reactive phosphorus is the fraction of phosphorus in surface water that readily contributes to eutrophication through the availability of phosphorus for excessive aquatic plant and algae growth.

Quantification of typical stormwater runoff quality by land use has found that particulate-bound phosphorus and dissolved phosphorus each contribute approximately 50% of the total phosphorus load in runoff from residential and commercial properties (Perry, Garbon, Lee). Phosphorus inputs to stormwater runoff may be from a variety of sources including lawn fertilizers, animal wastes and detergents (Hsieh et al, 2007).

Due to the concerns associated with stormwater impacts to aquatic and terrestrial ecosystems local governments, agencies, regulators and land developers seek cost-effective methods to manage stormwater. Many jurisdictions publish stormwater literature related to best management practices and methods to control stormwater impacts. In addition, many jurisdictions maintain surface water quality guidelines or policies that outline water quality criteria for many pollutants, including total phosphorus.

Structural stormwater best management practices (BMPs) are designed and constructed to attenuate peak stormwater flow, capture and treat runoff to improve water quality, contribute to groundwater recharge through infiltration, and facilitate Low Impact Development (LID) applications which are generally preferred by local governments, agencies and/or regulators to limit aquatic ecosystem impacts. Phosphorus removal performance varies depending on the BMP design. The widespread adoption of bioretention as a low-impact stormwater treatment practice has produced some well-documented water quality benefits, however, an increasing number of monitoring studies have detected substantial leaching of phosphorus from compost-containing bioretention installations (Hunt, Davis, Gulliver, Pitt, et al).

2 MATERIALS AND METHODS

2.1 Study Summary

The experimental design entailed passing simulated stormwater enriched with phosphorus through bioretention cells containing sand/peat soil mix amended with known concentrations of Sorbtive® Media AI 28x48. Stormwater exiting the bioretention cells was measured for phosphorus concentration (both as dissolved phosphorus and total phosphorus) to determine the percentage of phosphorus retained by each cell. The testing facility consisted of five individual bioretention cells, four of which had different concentrations of Sorbtive® Media (3%, 5%, 10% and 17% by volume). The fifth cell contained only the sand/peat soil mix and no amendment, and therefore represented a control that provided the ability to determine how much phosphorus was retained by the sand/peat mix alone.

Batches of artificial stormwater were spiked with KH_2PO_4 at target concentrations of 0.2, 0.4, 0.6, and 0.8 mg/L (P-basis). Starting with the artificial stormwater containing the lowest concentration of phosphorus, each bioretention cell was subjected to a series of daily simulated storm events of controlled water volume for five consecutive days, Monday through Friday, through an irrigation system. This five-day simulated storm series was undertaken five times (weekly over a 5-week period) for each of the four phosphorus concentrations. Progressing from the lowest concentration to the highest concentration, after 20 weeks each cell had been subjected to 25 storm events at each phosphorus concentration, for a total of 100 storm events for each cell. The volume of water applied during each storm event was 990 liters. The total volume of spiked artificial stormwater applied to each cell approximated the volume of cumulative runoff generated in this region over a two-year period by a drainage area five times the size of a bioretention cell.

The experiment utilized five 1000 L plastic totes installed as header tanks to supply the simulated stormwater to the bioretention cells (Figure 2-1). The desired stormwater application flow rate of approximately 7.6 L/min was pumped from each header tank through a series of perforated pipes running the length of each cell. Stormwater was applied to the surface of each cell through the irrigation system. Water collected in the underdrain piping of each cell drained into a common collection tank located below grade of the exit ports. Effluent samples were collected from each cell's drain pipe as the effluent exited into the collection tank. Treated water from the common collection tank was passively directed to an existing pond.

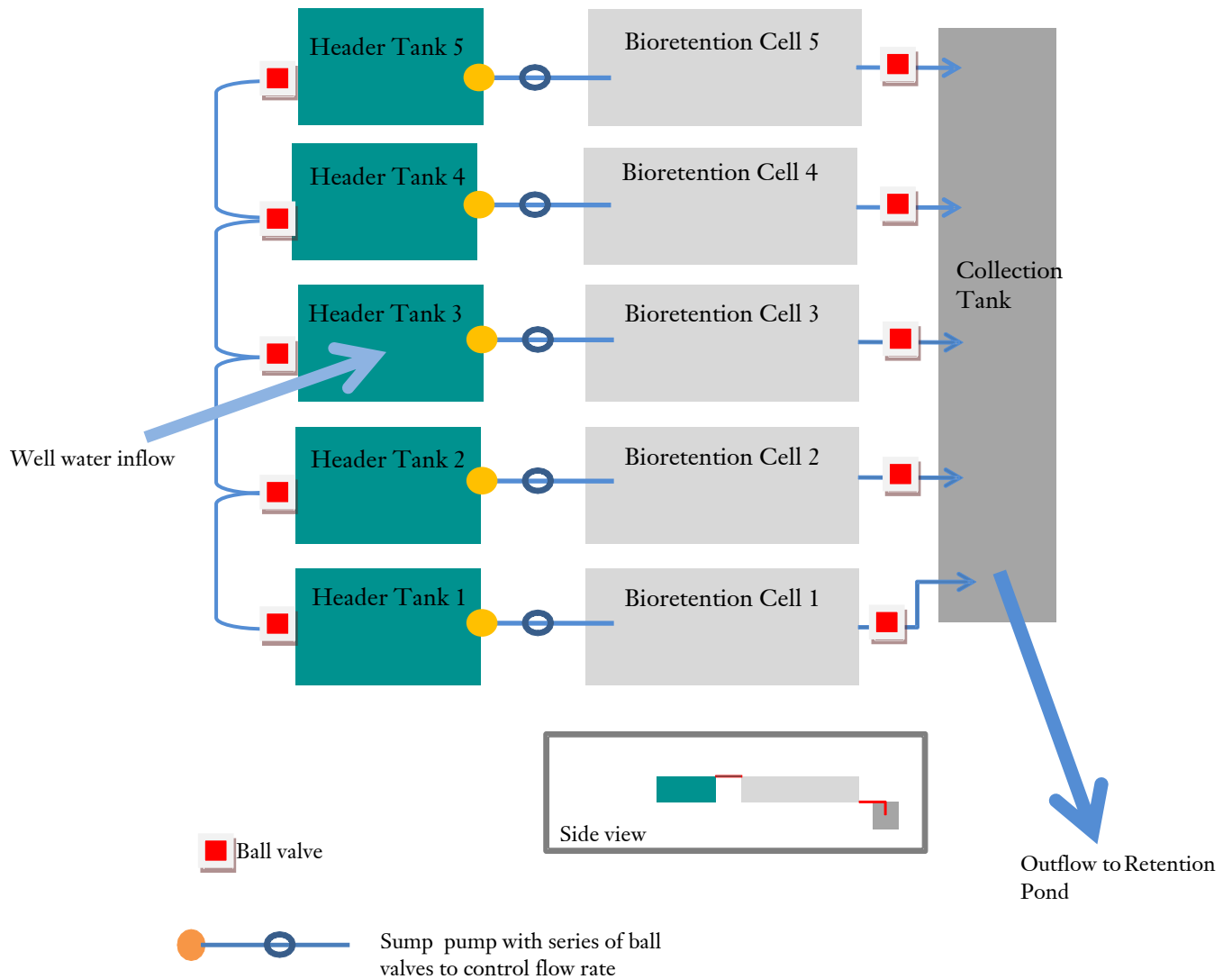


Figure 2-1 A schematic overview of the study site.

2.2 Bioretention cell construction

The five bioretention cells were constructed with identical configurations from prefabricated fibreglass reinforced plywood (FRP) troughs lined with rubberized pond liner to ensure the units were watertight. Each trough had an internal dimension of approximately 4.8 m (long) X 0.75 m (wide) X 0.75 m (high) for a total volume of approximately 2.7 m³ and was placed on grade with earth banked around the sides of the trough to provide extra support. The underdrain pipe was a 4.6 meter length of 3-inch diameter PVC drainage pipe with 2 rows of predrilled holes. The underdrain pipe was covered with window screen to prevent clogging from fines and centrally placed in the bottom of the trough for the collection of filtered storm water (Figure 2-2). The underdrain pipe was fitted to a two inch bulkhead connection. A 2-inch PVC effluent pipe, fitted with a ball valve for potential effluent flow restriction, ran from the trough to the common collection tank located below

grade of the exit port. Piping was positioned to allow for sample collection ease and ensure that each cell drained completely between simulated rain events (Figure 2-3).



Figure 2-2 Fibreglass reinforced plywood trough lined with pond liner with 3 inch PVC underdrain pipe running the length of the bioretention cell



Figure 2-3 Effluent collection pipes exiting the bioretention cells and directed to a sub grade collection tank

The bottom of each cell was lined with a 15 cm depth of half-inch granite stone to surround the underdrain pipe. The next layer was 3 cm of sand, topped by a 50 cm layer of soil. The sand was utilized to separate the bioretention soil mix from the coarse stone. The soil mix of the control cell (designated Bioretention Cell 1) contained only sand and peat moss. The other four cells (Bioretention Cells 2 through 5) contained soil mix comprised of sand/peat amended with various percentages of Sorbtive® Media AI 28x48. Front end loaders were used in the soil blending process. The appropriate amounts of sand, peat, and amendment were measured by hand using 23L plastic pails which were then poured into the bucket of a front end loader. The material was passed from bucket to bucket of two loaders to ensure uniform mixing. After the soil mix was thoroughly blended, the material was dumped into the cell using the front end loader (See Figure 2-4).



Figure 2-4 Mixing of bioretention soil between the buckets of two front end loaders and dumping of soil mix into the cell

The soil mix composition for each bioretention cell is summarized in Table 2-1.

Table 2-1 Bioretention Soil Mix Composition

Cell Number	Soil Mix Composition (% by volume)		
	Sand	Peat Moss	Sorbitive® Media
Bioretention Cell 1	85%	15%	0%
Bioretention Cell 2	82%	15%	3%
Bioretention Cell 3	80%	15%	5%
Bioretention Cell 4	75%	15%	10%
Bioretention Cell 5	68%	15%	17%

Each bioretention cell was vegetated with a mix consisting of commercially available Scotts® Premium Sun™ grass seed, MacKenzie® brand native grass and wildflower mix, and MacKenzie® brand low-growing wildflowers.

2.3 Water Volume and Flow Rates

The calculations for the storm flow rates and volumes were based on the following criteria:

- Average rainfall of 55 mm/month
- Drainage area treated is 5 times greater than the area of the bioretention cell
- Rainfall intensity of 25.4 mm/hr
- Bioretention cell area of 3.6 m²

Based on these criteria, each simulated storm event would have volume of 990 L (262 gal.) and flow rate of 7.62 L/min (2.01 gpm) with a duration of 130 minutes.

2.4 Artificial Stormwater Composition

The recipe for the artificial stormwater used in testing is shown in Table 2-2, and based on a 990 L volume of potable well water.

Table 2-2 Quantity of salts added to 990 L of well water to create artificial stormwater

Salt Compound	Quantity of Salt per 990 L (g)
Sodium Chloride (NaCl)	123.81
Calcium Chloride (CaCl ₂)	24.50
Sodium Sulphate (Na ₂ SO ₄)	23.35
Sodium Nitrate (NaNO ₃)	2.81
Potassium Chloride (KCl)	2.59
Magnesium Chloride Hexahydrate (MgCl ₂ ·6H ₂ O)	5.66

Target phosphorus concentrations in the artificial stormwater were varied between 0.2 mg/L and 0.8 mg/L P-basis. The mass of KH₂PO₄ added to each 990 L of artificial stormwater is shown in Table 2-3.

Table 2-3 Target phosphorus concentrations and respective quantities of KH₂PO₄ added to 990 L of artificial stormwater

Target P-basis concentration (mg/L)	Quantity of KH ₂ PO ₄ per 990 L (g)
0.2	0.87
0.4	1.74
0.6	2.61
0.8	3.48

2.5 Artificial Stormwater Preparation, Storage, and Metering

The header tanks consisted of graduated 1000 L plastic totes. Tank 3 was a central fill location where the outflow from the potable well was attached. Tanks were plumbed together in series through the use of the outlet port on each tank and were filled overnight via a timer with final volumes adjusted manually the following morning. Tanks were then isolated by valve before the artificial stormwater was prepared (See Figure 2-5). After addition of salts, the tanks were mixed for 1 hour before the simulated storm events were initiated.



Figure 2-5 Individual 1000 L header tanks plumbed in series to fill simultaneously and then isolated for addition of salts, mixing, and distribution of artificial stormwater to each bioretention cell.

Artificial stormwater was pumped from each header tank with a 1/6 HP sump pump and through an irrigation system comprised of 3/4-inch PVC pipe. Two solid pipes ran to the midpoint of each cell, and then split off to two equal length perforated pipes. Flow exiting the perforations naturally distributed across the full length and width of each cell (See Figure 2-6). Some water re-circulated back to the header tank. The target flow rate of 7.6 L/min was established to each cell by adjusting ball valves and measuring influent and effluent flows by means of bucket and stopwatch.

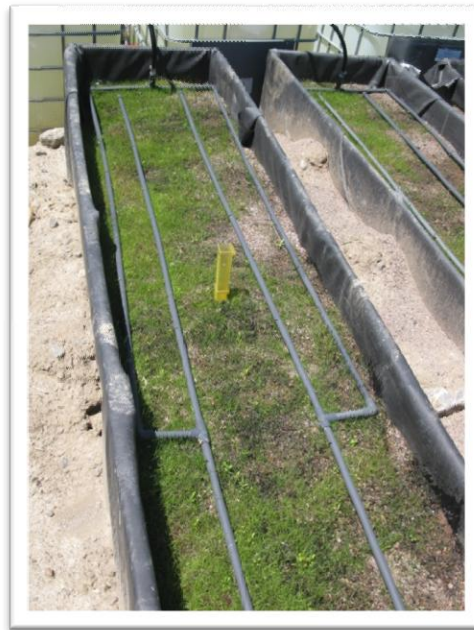


Figure 2-6 Artificial stormwater irrigation system

2.6 Stormwater Application Frequency, Sample Collection, and Sample Analysis

2.6.1 Frequency of dosing

Starting with the artificial stormwater containing the lowest concentration of phosphorus, each bioretention cell was subjected to a series of daily simulated storm events of controlled water volume for five consecutive days, Monday through Friday, through an irrigation system. This five-day simulated storm series was undertaken five times (weekly over a 5-week period) for each of the four phosphorus concentrations. Progressing from the lowest concentration to the highest concentration, after 20 weeks each cell had been subjected to 25 storm events at each phosphorus concentration, for a total of 100 storm events for each cell. The volume of water applied during each storm event was 990 liters. The total volume of spiked artificial stormwater applied to each cell approximated the volume of cumulative runoff generated in this region over a two-year period by a drainage area five times the size of a bioretention cell.

Natural rainfall events were recorded using rain gauges located in bioretention cells 1 and 5, as well as a SCADA recorded tipping bucket located on site at Fleming College.

2.6.2 Sample Collection and Analysis

Once per week, samples were taken from each header tank and from the corresponding exit port of each bioretention cell, midway through the simulated stormwater event. Potable well water and water from the collection pond was sampled as well. Samples were tested for total phosphorus (TP) and total dissolved phosphorus (TDP). Total phosphorus samples were digested in acid with

potassium persulfate followed by reaction with molybdate to create a blue colour change that could be detected using a discrete auto-analyser (SM 4500-P). Total dissolved phosphorus concentrations were determined in the same fashion as above, after filtration of the sample with a 0.45 micron filter.

The pH of artificial stormwater in each header tank and effluent from each bioretention cell was monitored on a daily basis.

3 RESULTS

3.1 Phosphorus Removal Performance

Measured values of total dissolved phosphorus and total phosphorus concentrations in the artificial stormwater (header tank samples) were consistently lower than the target phosphorus concentrations (See Table 3-1). The deviations between measured and target values decreased as the target concentration increased. In addition, dissolved phosphorus concentrations were consistently lower than total phosphorus concentrations. These results suggest that within the header tanks a portion of the phosphorus partitioned from the dissolved phase to a filterable colloidal or particulate-bound phase, with some precipitating out of solution or adsorbing to the vessel surfaces. For the purposes of determining the phosphorus removal performance of each bioretention cell, the measured values of total dissolved phosphorus and total phosphorus in the header tanks are used as the influent basis.

Table 3-1 Measured dissolved and total phosphorus expressed as a percentage of the target concentrations in artificial stormwater within header tank samples

Target P-basis concentration (mg/L)	Average TDP measured value (mg/L)	% of target	Average TP measured value (mg/L)	% of target
0.2	0.11	56	0.16	78
0.4	0.28	70	0.36	89
0.6	0.46	76	0.54	90
0.8	0.65	82	0.72	90

The mass of phosphorus, both dissolved and total, retained by a bioretention cell was determined by measuring the phosphorus concentration of the header tank sample and subtracting from this value the measured phosphorus concentration in the effluent from each cell. The influent volume was factored in. The mass of phosphorus retained by the cell for the sampled simulated storm event for a given week was multiplied by five to estimate the phosphorus mass retained for the week's total of five simulated storm events. The other four simulated storm events for a given week were not sampled. Retained phosphorus mass was summed for all twenty weeks to determine the estimated cumulative retained phosphorus mass.

The cumulative retained phosphorus mass for each cell is shown in Figure 3-1 (dissolved phosphorus) and Figure 3-2 (total phosphorus). The data represented in these figures illustrate that although the cells retained less dissolved phosphorus compared to total phosphorus, overall the trends remained the same. All the cells amended with Sorbtive® Media demonstrated nearly 3 times greater retained dissolved phosphorus mass, and nearly 2.5 times greater retained total phosphorus

mass, compared to the control cell with no Sorbtive® Media. Results for the 3% and 5% amendments were similar to each other, although slightly lower than the 10% and 17% amendments, which were also similar to each other.

The percentage of phosphorus removed by each bioretention cell for each of the four phosphorus concentrations tested is illustrated in Figure 3-3 (dissolved phosphorus) and Figure 3-4 (total phosphorus). Once again, the trends for dissolved phosphorus are similar to those for total phosphorus. At every phosphorus concentration, all the cells amended with Sorbtive® Media demonstrated much higher percent removal of phosphorus compared to the control cell with no Sorbtive® Media. The performance gap between the amended cells and the control cell widened as the phosphorus concentration increased. At the 0.2% target phosphorus concentration, mean dissolved phosphorus removal ranged 79-92% for the amended cells compared to 54% for the control cell. At the 0.8% target phosphorus concentration, mean dissolved phosphorus removal ranged 86-98% for the amended cells compared to 20% for the control cell. In the final week of the study, with 0.8% target phosphorus concentration in the artificial stormwater, percent removal of dissolved phosphorus was 82% for the 3% amendment, 97-98% for the 5%, 10%, and 17% amendments, and 11% for the control. These results demonstrate that the Sorbtive® Media maintained high phosphorus adsorptive capacity throughout the study, especially at the 5% and greater amendment levels.

Rainfall during the testing period was sporadic and the total weekly volume of rainwater added to individual bioretention cells was insignificant. The heaviest weekly rainfall generated approximately 68 L of extra water for each cell, compared to 4950 L of artificial stormwater applied to each cell each week.

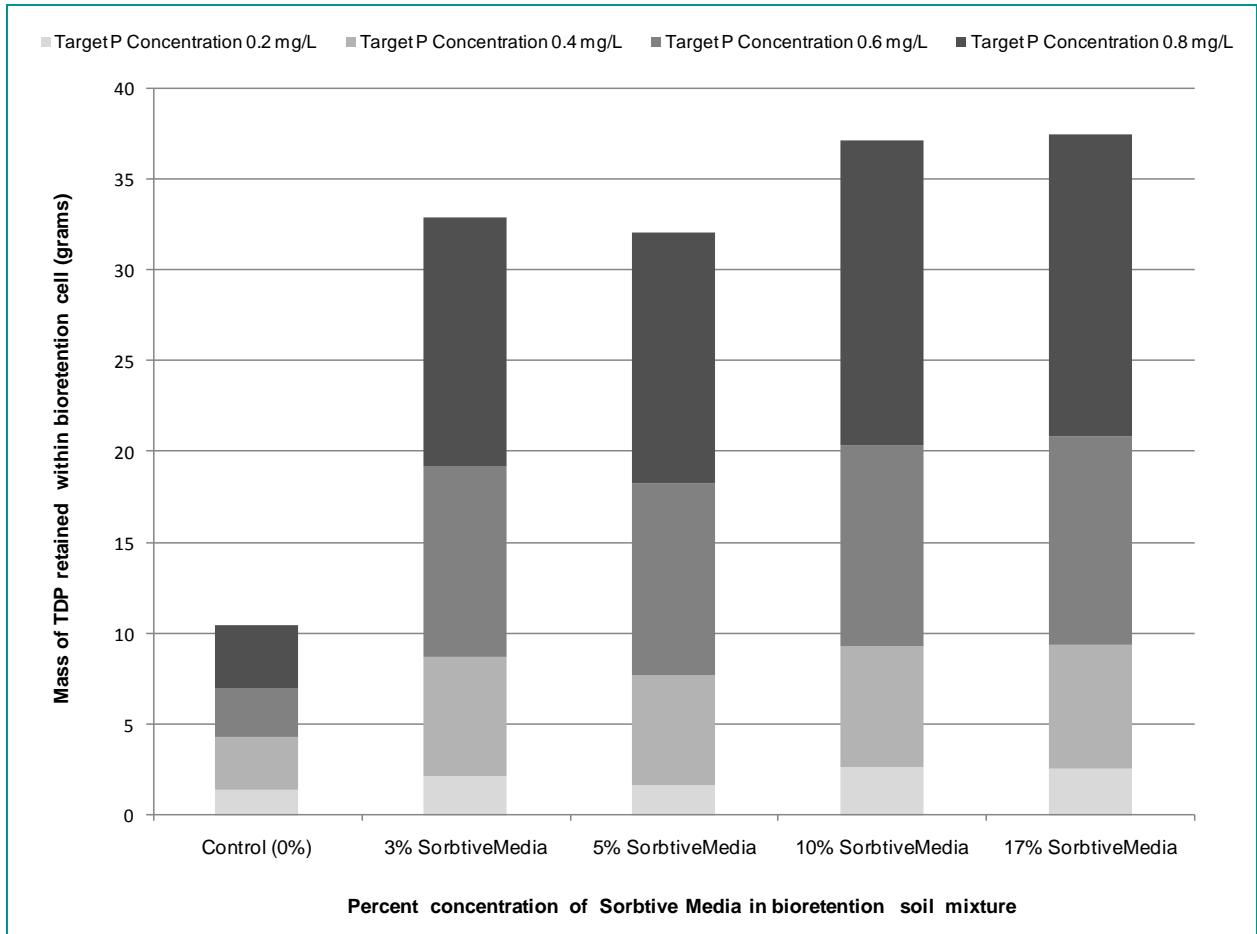


Figure 3-1 Cumulative mass of total dissolved phosphorus retained in each bioretention cell.

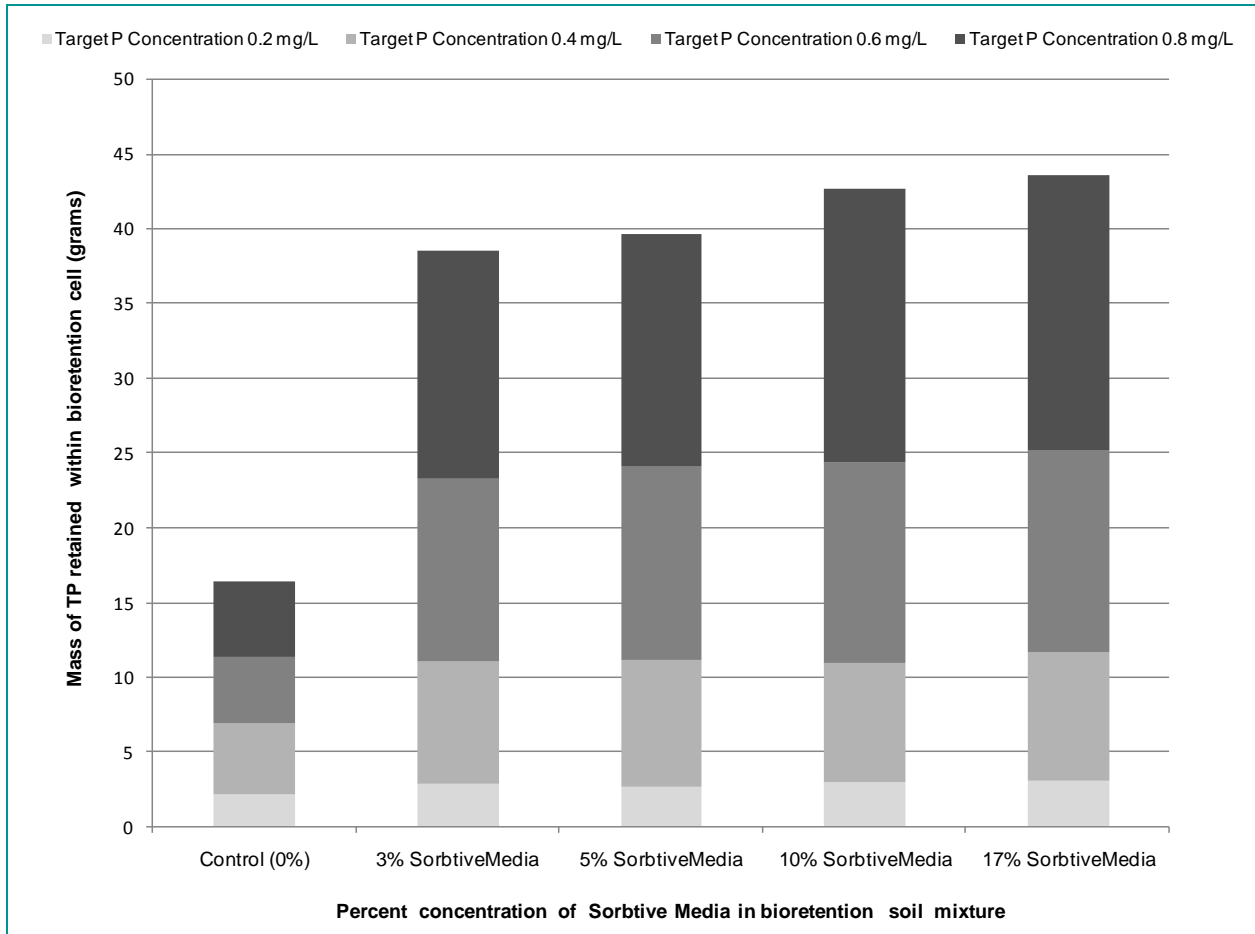


Figure 3-2 Cumulative mass of total phosphorus retained in each bioretention cell.

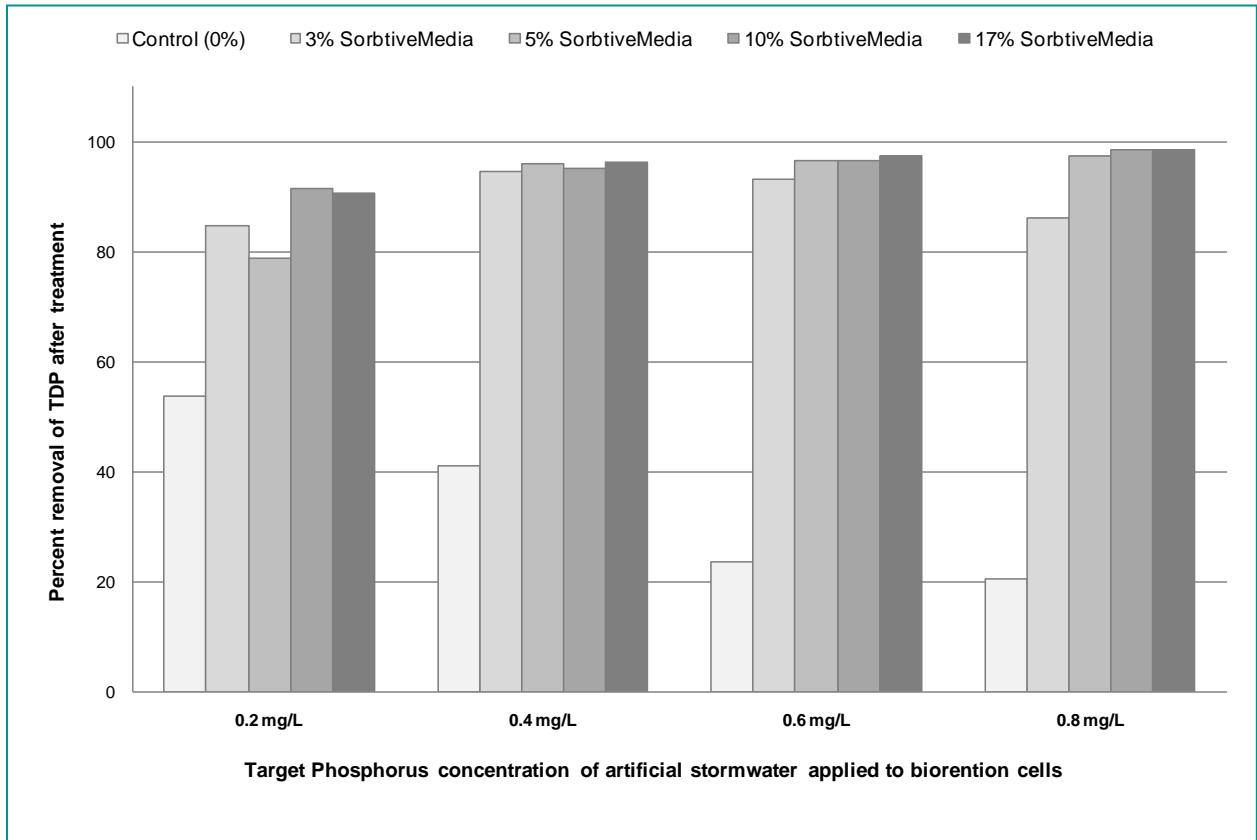


Figure 3-3 Percent removal of total dissolved phosphorus for each bioretention cell at each of four different target phosphorus concentrations

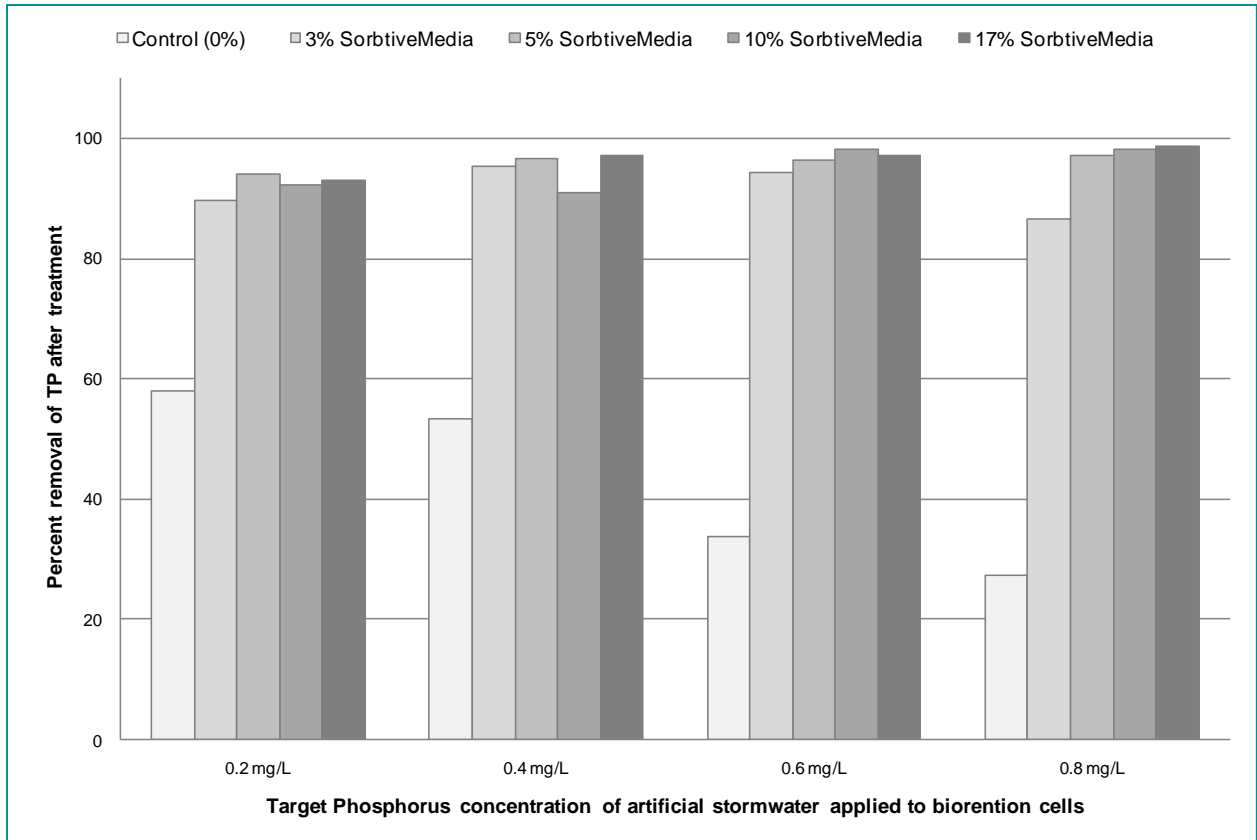


Figure 3-4 Percent removal of total phosphorus for each bioretention cell at each of four different target phosphorus concentrations

3.2 Effect on Effluent pH

The pH of artificial stormwater in each header tank and effluent from each bioretention cell was monitored on a daily basis. The data in Table 3-2 illustrates that minimal change in pH occurred as artificial stormwater was treated by each of the bioretention cells, and effluent pH remained well within regulatory discharge limits.

Table 3-2 pH measurements for influent and effluent of each bioretention cell

Target Phosphorus Conc (mg/L)	Control (0%)		3% Sorbtive® Media		5% Sorbtive® Media		10% Sorbtive® Media		17% Sorbtive® Media	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
0.2	7.29	7.57	7.28	7.52	7.21	7.32	7.30	7.29	7.33	7.02
0.4	7.30	7.72	7.31	7.80	7.28	7.73	7.31	7.67	7.31	7.35
0.6	7.40	7.81	7.38	7.86	7.33	7.79	7.39	7.79	7.38	7.61
0.8	7.50	7.81	7.41	7.84	7.33	7.88	7.38	7.78	7.39	7.67

4 CONCLUSIONS

The removal of phosphorus from stormwater using bioretention BMPs with a sand/peat soil mix can be greatly enhanced by amendment of the soil with Sorbtive[®] Media AI 28x48. Compared to a control with no Sorbtive[®] Media, amended bioretention cells demonstrated much greater removal of dissolved and total phosphorus on both a mass and percent removal basis. Over the course of this study, the control cell's total phosphorus removal efficiency decreased from approximately 60% to 25%, while each of the amended cells maintained removal efficiency of up to 99% and at least 84% for the duration of the study. These results suggest that Sorbtive[®] Media, even when blended into the soil mix at only 3 - 5% volume basis, would be highly effective for improving phosphorus removal in bioretention installations. A similar benefit would be expected when using the amendment in bioswale, rain garden, green roof, and sand filter installations.

Effluent pH is relatively unaffected by amendment of bioretention soil mix with Sorbtive[®] Media.

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6 APPENDICES

The following contains the data used to generate the Tables and Figures embedded within the body of the report

Appendix 1

Raw Data for Table 3-1; Measured dissolved and total phosphorus expressed as a percentage of the target concentrations in artificial stormwater within header tank samples.

Target P Concentration in Artificial Stormwater	Header Tank corresponding to Percent Sorbtive® Media Within Bioretention Cell	Week	TDP (mg/L)	% of Target Concentration	TP (mg/L)	% of Target Concentration
0.2 mg/L	Control (0%)	1	0.12	58.71	n.m.	n.m.
			0.11	54.73	n.m.	n.m.
			0.08	40.72	n.m.	n.m.
			0.12	60.23	n.m.	n.m.
			0.14	68.75	n.m.	n.m.
	Control (0%)	2	0.13	64.81	n.m.	n.m.
			0.16	79.62	n.m.	n.m.
			0.12	60.98	n.m.	n.m.
			0.13	65.85	n.m.	n.m.
			0.13	66.03	n.m.	n.m.
	Control (0%)	3	0.11	55.31	0.12	59.49
			0.10	47.65	0.09	43.80
			0.11	56.41	0.15	75.91
			0.11	55.86	0.09	44.16
			0.11	54.76	0.10	52.01
	Control (0%)	4	0.09	42.60	0.17	83.39
			0.08	41.15	0.17	87.04
			0.06	31.36	0.18	88.87
			0.11	56.74	0.15	77.19
			0.09	46.95	0.17	85.04
	Control (0%)	5	n.m.	n.m.	0.20	99.48
			n.m.	n.m.	0.19	93.64
			n.m.	n.m.	0.18	90.38
			n.m.	n.m.	0.19	93.81
			n.m.	n.m.	0.18	89.52
	<i>mean</i>		<i>0.11</i>	<i>55.46</i>	<i>0.16</i>	<i>77.58</i>
	<i>SD</i>		<i>0.02</i>	<i>11.32</i>	<i>0.04</i>	<i>18.63</i>

• *n.m.* = not measured

Target P Concentration in Artificial Stormwater	Header Tank corresponding to Percent Sorbtive® Media Within Bioretention Cell	Week	TDP (mg/L)	% of Target Concentration	TP (mg/L)	% of Target Concentration	
0.4 mg/L	Control (0%)	1	0.29	73.32	0.37	92.16	
	3%		0.29	72.67	0.37	91.70	
	5%		0.29	71.55	0.36	91.14	
	10%		0.28	69.78	0.37	91.51	
	17%		0.29	73.04	0.38	95.06	
	Control (0%)	2	0.24	60.97	0.35	87.23	
	3%		0.24	60.43	0.35	87.23	
	5%		0.20	49.52	0.35	87.32	
	10%		0.25	62.15	0.34	84.25	
	17%		0.24	61.24	0.35	88.40	
	Control (0%)	3	0.31	78.68	0.37	93.01	
	3%		0.31	77.05	0.37	91.83	
	5%		0.31	78.14	0.36	90.20	
	10%		0.31	78.68	0.37	93.28	
	17%		0.31	77.86	0.37	92.01	
	Control (0%)	4	0.27	67.03	0.35	88.19	
	3%		0.28	68.77	0.30	75.64	
	5%		0.20	50.09	0.35	87.18	
	10%		0.28	68.77	0.33	83.52	
	17%		0.29	72.25	0.34	85.26	
	Control (0%)	5	0.30	75.21	0.36	89.99	
	3%		0.29	71.65	0.34	85.24	
	5%		0.28	69.10	0.36	89.99	
	10%		0.29	73.57	0.36	89.80	
	17%		0.30	75.39	0.36	89.16	
		mean		0.28	69.48	0.36	88.81
		SD		0.03	8.08	0.02	4.04

Target P Concentration in Artificial Stormwater	Header Tank corresponding to Percent Sorbtive® Media Within Bioretention Cell	Week	TDP (mg/L)	% of Target Concentration	TP (mg/L)	% of Target Concentration	
0.6 mg/L	Control (0%)	1	0.45	74.49	0.54	90.27	
	3%		0.43	72.47	0.53	87.64	
	5%		0.42	69.36	0.56	92.53	
	10%		0.45	74.68	0.53	88.37	
	17%		0.46	77.18	0.54	90.57	
	Control (0%)	2	0.47	78.46	0.55	91.23	
	3%		0.47	78.58	0.53	88.83	
	5%		0.48	80.12	0.56	93.58	
	10%		0.48	79.44	0.55	92.41	
	17%		0.48	79.88	0.57	94.88	
	Control (0%)	3	0.43	71.86	0.52	86.36	
	3%		0.42	69.35	0.52	87.14	
	5%		0.43	71.03	0.52	87.38	
	10%		0.44	73.72	0.63	104.44	
	17%		0.46	76.78	0.53	87.56	
	Control (0%)	4	0.50	82.66	0.53	88.17	
	3%		0.50	83.74	0.52	86.62	
	5%		0.49	80.92	0.53	87.93	
	10%		0.49	81.46	0.54	89.67	
	17%		0.51	84.52	0.54	90.21	
	Control (0%)	5	0.45	75.31	0.53	87.78	
	3%		0.44	73.57	0.51	84.74	
	5%		0.39	64.45	0.55	90.95	
	10%		0.45	75.74	0.51	85.24	
	17%		0.46	77.23	0.63	104.66	
		mean		0.46	76.28	0.54	90.37
		SD		0.03	4.92	0.03	4.96

Target P Concentration in Artificial Stormwater	Header Tank corresponding to Percent Sorbtive® Media Within Bioretention Cell	Week	TDP (mg/L)	% of Target Concentration	TP (mg/L)	% of Target Concentration	
0.8 mg/L	Control (0%)	1	0.74	92.07	0.82	102.92	
	3%		0.72	90.52	0.81	101.78	
	5%		0.30	37.60	0.39	48.23	
	10%		0.77	95.90	0.83	103.79	
	17%		0.76	94.44	0.82	102.56	
	Control (0%)	2	0.68	84.76	0.74	92.43	
	3%		0.66	82.72	0.71	88.76	
	5%		0.63	78.73	0.72	90.39	
	10%		0.69	86.81	0.75	93.70	
	17%		0.67	83.54	0.74	92.34	
	Control (0%)	3	0.69	86.29	0.72	90.16	
	3%		0.64	80.41	0.68	85.04	
	5%		0.69	85.86	0.70	87.29	
	10%		0.69	85.76	0.73	90.78	
	17%		0.68	84.81	0.74	92.02	
	Control (0%)	4	0.70	87.89	0.75	93.68	
	3%		0.62	76.91	0.68	84.61	
	5%		0.66	82.30	0.69	86.62	
	10%		0.68	85.44	0.74	92.40	
	17%		0.71	88.63	0.76	95.39	
	Control (0%)	5	0.60	75.10	0.71	88.67	
	3%		0.57	71.38	0.69	86.60	
	5%		0.59	73.31	0.72	90.13	
	10%		0.62	77.17	0.72	90.55	
	17%		0.61	76.61	0.70	87.77	
		mean		0.65	81.80	0.72	90.34
		SD		0.09	11.18	0.08	10.34

Appendix 2

Raw Data for Figure 3-1; Cumulative mass of total dissolved phosphorus retained in each bioretention cell.

Target P concentration in artificial stormwater		0% Sorbtive® Media (Control)	
		Average TDP Grams Retained/day	Average TDP Grams Retained/week
0.2 mg/L	Week 1	0.09	0.45
	Week 2	0.10	0.50
	Week 3	0.03	0.15
	Week 4	0.03	0.14
	Week 5	0.03	0.14
	Treatment Sum		1.37
0.4 mg/L	Week 1	0.14	0.71
	Week 2	0.10	0.49
	Week 3	0.14	0.70
	Week 4	0.10	0.50
	Week 5	0.11	0.53
	Treatment Sum		2.94
0.6 mg/L	Week 1	0.17	0.84
	Week 2	0.13	0.67
	Week 3	0.09	0.47
	Week 4	0.06	0.32
	Week 5	0.07	0.36
	Treatment Sum		2.65
0.8 mg/L	Week 1	0.18	0.91
	Week 2	0.16	0.77
	Week 3	0.17	0.83
	Week 4	0.14	0.69
	Week 5	0.06	0.31
	Treatment Sum		3.51
Total sum			10.47

Target P concentration in artificial stormwater	3% Sorbtive® Media		
	Average TDP Grams Retained/day	Average TDP Grams Retained/week	
0.2 mg/L	Week 1	0.10	0.48
	Week 2	0.15	0.74
	Week 3	0.09	0.42
	Week 4	0.05	0.27
	Week 5	0.05	0.27
	Treatment Sum		2.18
0.4 mg/L	Week 1	0.28	1.37
	Week 2	0.23	1.14
	Week 3	0.29	1.45
	Week 4	0.26	1.29
	Week 5	0.27	1.33
	Treatment Sum		6.58
0.6 mg/L	Week 1	0.42	2.07
	Week 2	0.45	2.23
	Week 3	0.40	1.96
	Week 4	0.46	2.28
	Week 5	0.38	1.90
	Treatment Sum		10.44
0.8 mg/L	Week 1	0.65	3.22
	Week 2	0.59	2.90
	Week 3	0.55	2.71
	Week 4	0.52	2.58
	Week 5	0.47	2.31
	Treatment Sum		13.73
	Total sum		32.93

Target P concentration in artificial stormwater	5% Sorbtive® Media		
	Average TDP Grams Retained/day	Average TDP Grams Retained/week	
0.2 mg/L	Week 1	0.07	0.35
	Week 2	0.07	0.34
	Week 3	0.10	0.48
	Week 4	0.05	0.26
	Week 5	0.05	0.26
	Treatment Sum		1.70
0.4 mg/L	Week 1	0.28	1.37
	Week 2	0.19	0.93
	Week 3	0.30	1.50
	Week 4	0.19	0.94
	Week 5	0.27	1.32
	Treatment Sum		6.06
0.6 mg/L	Week 1	0.41	2.01
	Week 2	0.47	2.33
	Week 3	0.42	2.06
	Week 4	0.48	2.36
	Week 5	0.35	1.75
	Treatment Sum		10.51
0.8 mg/L	Week 1	0.29	1.41
	Week 2	0.62	3.07
	Week 3	0.67	3.33
	Week 4	0.65	3.20
	Week 5	0.57	2.83
	Treatment Sum		13.84
	Total sum		32.11

Target P concentration in artificial stormwater	10% Sorbtive® Media		
	Average TDP Grams Retained/day	Average TDP Grams Retained/week	
0.2 mg/L	Week 1	0.11	0.55
	Week 2	0.12	0.60
	Week 3	0.10	0.50
	Week 4	0.10	0.51
	Week 5	0.10	0.51
	Treatment Sum		2.68
0.4 mg/L	Week 1	0.27	1.33
	Week 2	0.23	1.11
	Week 3	0.30	1.50
	Week 4	0.27	1.31
	Week 5	0.28	1.40
	Treatment Sum		6.65
0.6 mg/L	Week 1	0.44	2.17
	Week 2	0.47	2.31
	Week 3	0.43	2.14
	Week 4	0.48	2.36
	Week 5	0.42	2.07
	Treatment Sum		11.05
0.8 mg/L	Week 1	0.76	3.74
	Week 2	0.68	3.39
	Week 3	0.67	3.34
	Week 4	0.67	3.33
	Week 5	0.61	3.01
	Treatment Sum		16.81
	Total sum		37.19

Target P concentration in artificial stormwater		17% Sorbtive® Media	
		Average TDP Grams Retained/day	Average TDP Grams Retained/week
0.2 mg/L	Week 1	0.13	0.63
	Week 2	0.12	0.59
	Week 3	0.10	0.49
	Week 4	0.08	0.42
	Week 5	0.08	0.42
	Treatment Sum		2.54
0.4 mg/L	Week 1	0.28	1.40
	Week 2	0.23	1.16
	Week 3	0.30	1.48
	Week 4	0.28	1.38
	Week 5	0.29	1.44
	Treatment Sum		6.86
0.6 mg/L	Week 1	0.45	2.24
	Week 2	0.47	2.32
	Week 3	0.45	2.23
	Week 4	0.50	2.46
	Week 5	0.44	2.19
	Treatment Sum		11.44
0.8 mg/L	Week 1	0.74	3.68
	Week 2	0.66	3.26
	Week 3	0.67	3.31
	Week 4	0.70	3.46
	Week 5	0.60	2.98
	Treatment Sum		16.69
	Total sum		37.54

Appendix 3

Raw Data for Figure 3-2; Cumulative mass of total phosphorus retained in each bioretention cell.

Target P concentration in artificial stormwater		0% Sorbtive® Media (Control)	
		Average TP Grams Retained/day	Average TP Grams Retained/week
0.2 mg/L	Week 1	0.07	0.33
	Week 2	0.07	0.33
	Week 3	0.05	0.27
	Week 4	0.10	0.51
	Week 5	0.13	0.66
	Treatment Sum		2.10
0.4 mg/L	Week 1	0.22	1.10
	Week 2	0.19	0.96
	Week 3	0.20	0.98
	Week 4	0.18	0.88
	Week 5	0.16	0.81
	Treatment Sum		4.72
0.6 mg/L	Week 1	0.26	1.29
	Week 2	0.21	1.06
	Week 3	0.18	0.91
	Week 4	0.09	0.47
	Week 5	0.15	0.75
	Treatment Sum		4.47
0.8 mg/L	Week 1	0.29	1.43
	Week 2	0.20	0.99
	Week 3	0.19	0.96
	Week 4	0.17	0.86
	Week 5	0.18	0.87
	Treatment Sum		5.11
	Total sum		16.40

Target P concentration in artificial stormwater	3% Sorbtive® Media		
	Average TP Grams Retained/day	Average TP Grams Retained/week	
0.2 mg/L	Week 1	0.08	0.41
	Week 2	0.08	0.41
	Week 3	0.07	0.35
	Week 4	0.16	0.81
	Week 5	0.18	0.88
	Treatment Sum		2.86
0.4 mg/L	Week 1	0.35	1.74
	Week 2	0.33	1.64
	Week 3	0.35	1.74
	Week 4	0.29	1.42
	Week 5	0.32	1.61
	Treatment Sum		8.15
0.6 mg/L	Week 1	0.50	2.47
	Week 2	0.51	2.55
	Week 3	0.50	2.50
	Week 4	0.48	2.37
	Week 5	0.46	2.30
	Treatment Sum		12.19
0.8 mg/L	Week 1	0.74	3.65
	Week 2	0.61	3.00
	Week 3	0.58	2.89
	Week 4	0.58	2.89
	Week 5	0.59	2.90
	Treatment Sum		15.32
	Total sum		38.52

Target P concentration in artificial stormwater	5% Sorbtive® Media		
	Average TP Grams Retained/day	Average TP Grams Retained/week	
0.2 mg/L	Week 1	0.02	0.10
	Week 2	0.02	0.10
	Week 3	0.14	0.70
	Week 4	0.17	0.83
	Week 5	0.17	0.85
	Treatment Sum		2.58
0.4 mg/L	Week 1	0.35	1.74
	Week 2	0.33	1.65
	Week 3	0.35	1.74
	Week 4	0.34	1.68
	Week 5	0.35	1.73
	Treatment Sum		8.53
0.6 mg/L	Week 1	0.53	2.61
	Week 2	0.55	2.73
	Week 3	0.51	2.55
	Week 4	0.52	2.56
	Week 5	0.50	2.48
	Treatment Sum		12.93
0.8 mg/L	Week 1	0.36	1.77
	Week 2	0.71	3.52
	Week 3	0.69	3.41
	Week 4	0.68	3.38
	Week 5	0.70	3.49
	Treatment Sum		15.56
	Total sum		39.59

Target P concentration in artificial stormwater	10% Sorbtive® Media		
	Average TP Grams Retained/day	Average TP Grams Retained/week	
0.2 mg/L	Week 1	0.10	0.49
	Week 2	0.10	0.49
	Week 3	0.08	0.39
	Week 4	0.14	0.71
	Week 5	0.18	0.88
	Treatment Sum		2.97
0.4 mg/L	Week 1	0.25	1.22
	Week 2	0.32	1.61
	Week 3	0.36	1.80
	Week 4	0.32	1.60
	Week 5	0.35	1.73
	Treatment Sum		7.95
0.6 mg/L	Week 1	0.52	2.58
	Week 2	0.54	2.70
	Week 3	0.62	3.05
	Week 4	0.53	2.61
	Week 5	0.50	2.46
	Treatment Sum		13.40
0.8 mg/L	Week 1	0.82	4.04
	Week 2	0.73	3.59
	Week 3	0.72	3.55
	Week 4	0.73	3.61
	Week 5	0.71	3.53
	Treatment Sum		18.32
	Total sum		42.64

Target P concentration in artificial stormwater	17% Sorbtive® Media		
	Average TP Grams Retained/day	Average TP Grams Retained/week	
0.2 mg/L	Week 1	0.09	0.45
	Week 2	0.09	0.45
	Week 3	0.09	0.47
	Week 4	0.16	0.79
	Week 5	0.17	0.84
	Treatment Sum		2.99
0.4 mg/L	Week 1	0.37	1.83
	Week 2	0.34	1.70
	Week 3	0.36	1.77
	Week 4	0.33	1.64
	Week 5	0.35	1.72
	Treatment Sum		8.66
0.6 mg/L	Week 1	0.52	2.60
	Week 2	0.56	2.77
	Week 3	0.52	2.55
	Week 4	0.53	2.63
	Week 5	0.60	2.95
	Treatment Sum		13.49
0.8 mg/L	Week 1	0.81	4.01
	Week 2	0.73	3.61
	Week 3	0.73	3.59
	Week 4	0.75	3.73
	Week 5	0.69	3.43
	Treatment Sum		18.37
	Total sum		43.51

Appendix 4.

Raw Data for Figure 3-3; Percent removal of total dissolved phosphorus for each bioretention cell at each of four different target phosphorus concentrations

Sorbitive® Media Within Bioretention Cell (%)	Percent Removal of Total Phosphorus				
	Control (0%)	3%	5%	10%	17%
Target Concentration: 0.2mg/L TDP					
Week 1	76.56	88.70	87.72	91.70	92.73
Week 2	78.05	93.72	56.57	92.41	90.15
Week 3	27.61	89.51	86.73	91.05	90.87
Week 4	32.91	66.67	84.06	91.19	89.35
Week 5	n.m.	n.m.	n.m.	n.m.	n.m.
Average	53.78	84.65	78.77	91.59	90.77
Standard Deviation	27.25	12.19	14.88	0.61	1.44
Target Concentration: 0.4 mg/L TDP					
Week 1	49.11	95.25	96.51	96.42	96.58
Week 2	40.99	94.88	94.95	90.59	95.92
Week 3	44.78	94.93	96.80	96.82	95.91
Week 4	34.56	94.27	95.06	96.36	96.54
Week 5	35.48	94.09	96.38	95.86	96.68
Average	40.98	94.68	95.94	95.21	96.33
Standard Deviation	6.16	0.48	0.87	2.60	0.38
Target Concentration: 0.6 mg/L TDP					
Week 1	37.76	96.27	97.60	97.77	97.73
Week 2	28.55	95.66	97.92	97.90	97.91
Week 3	22.00	95.08	97.65	97.74	97.83
Week 4	12.84	91.58	98.37	97.61	98.03
Week 5	16.19	86.89	91.20	92.02	95.35
Average	23.47	93.10	96.55	96.61	97.37
Standard Deviation	9.98	3.92	3.01	2.57	1.14
Target Concentration: 0.8 mg/L TDP					
Week 1	24.90	89.90	94.98	98.48	98.31
Week 2	22.99	88.49	98.41	98.56	98.50
Week 3	24.25	85.04	97.95	98.28	98.53
Week 4	19.72	84.83	98.12	98.54	98.59
Week 5	10.51	81.87	97.35	98.38	98.37
Average	20.47	86.03	97.36	98.45	98.46
Standard Deviation	5.92	3.19	1.39	0.12	0.11
• <i>n.m. = not measured</i>					

Appendix 5

Raw Data for Figure 3-4; Percent removal of total phosphorus for each bioretention cell at each of four different target phosphorus concentrations

Sorbitive® Media Within Bioretention Cell (%)	Percent Removal of Total Phosphorus				
	Control (0%)	3%	5%	10%	17%
Target Concentration: 0.2 mg/L TP					
Week 1	n.m.	n.m.	n.m.	n.m.	n.m.
Week 2	n.m.	n.m.	n.m.	n.m.	n.m.
Week 3	45.09	80.28	93.41	88.68	90.39
Week 4	61.34	94.26	94.37	93.52	94.12
Week 5	67.24	94.66	94.47	94.67	94.41
Average	57.89	89.73	94.08	92.29	92.97
Standard Deviation	11.47	8.19	0.58	3.18	2.25
Target Concentration: 0.4 mg/L TP					
Week 1	60.05	95.90	96.38	67.14	97.45
Week 2	55.54	95.21	95.27	96.38	97.17
Week 3	53.29	95.50	97.23	97.32	97.28
Week 4	52.80	95.04	97.13	97.01	96.99
Week 5	45.27	95.19	96.92	97.22	97.20
Average	53.39	95.37	96.59	91.01	97.22
Standard Deviation	5.37	0.34	0.81	13.35	0.17
Target Concentration: 0.6 mg/L TP					
Week 1	48.20	95.00	94.83	98.19	96.54
Week 2	38.95	96.60	98.22	98.20	98.24
Week 3	35.51	96.53	98.09	98.40	98.10
Week 4	17.79	92.28	98.02	98.14	98.15
Week 5	28.60	91.37	91.95	97.20	94.79
Average	33.81	94.35	96.22	98.03	97.16
Standard Deviation	11.40	2.42	2.78	0.47	1.50
Target Concentration: 0.8 mg/L TP					
Week 1	35.06	90.55	92.77	98.27	98.78
Week 2	27.08	85.26	98.20	96.81	98.65
Week 3	26.78	85.85	98.53	98.62	98.64
Week 4	23.18	86.18	98.42	98.65	98.69
Week 5	24.89	84.48	97.69	98.48	98.58
Average	27.40	86.47	97.12	98.17	98.67
Standard Deviation	4.56	2.37	2.45	0.77	0.08

• *n.m.* = not measured



Centre for Alternative Wastewater Treatment

Vision

The Centre for Alternative Wastewater Treatment (CAWT) at the School of Environmental and Natural Resource Sciences, Frost Campus, Fleming College is an internationally recognized research institute committed to excellence in research and education.

The CAWT conducts research in the areas of water and wastewater treatment science and communicates results in high quality publications. The Centre continues to expand research capacity and productivity over time.

The Centre fosters collaborative research partnerships with universities, government agencies, non-governmental organizations, and the private sector; and engages in opportunities to enhance student learning through the integration of applied research activities in student curricula.

The CAWT provides leadership to Fleming College in the expansion of research and innovation activities in other areas of the College.



cawt.ca

**RESIDENTIAL TOWNHOUSE DEVELOPMENT
521 & 525 ESSA ROAD – CITY OF BARRIE
STORM WATER MANAGEMENT REPORT**

APPENDIX D

Drawings (in envelope at rear of report)