Scoped
HYDROGEOLOGICAL ASSESSMENT
Cityview Drive Development
Guelph, Ontario

Prepared for:

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Project 281
July 2013

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1.0 INTRODUCTION

This report presents the findings of a scoped hydrogeological assessment of the proposed 15.2-ha Cityview Drive development property in Guelph, Ontario (Figure 1).

The assessment was completed to support the Environmental Impact Study being conducted at the property by Natural Resource Solutions Inc. (NRSI) and the stormwater management engineering design being completed by IBI Group.

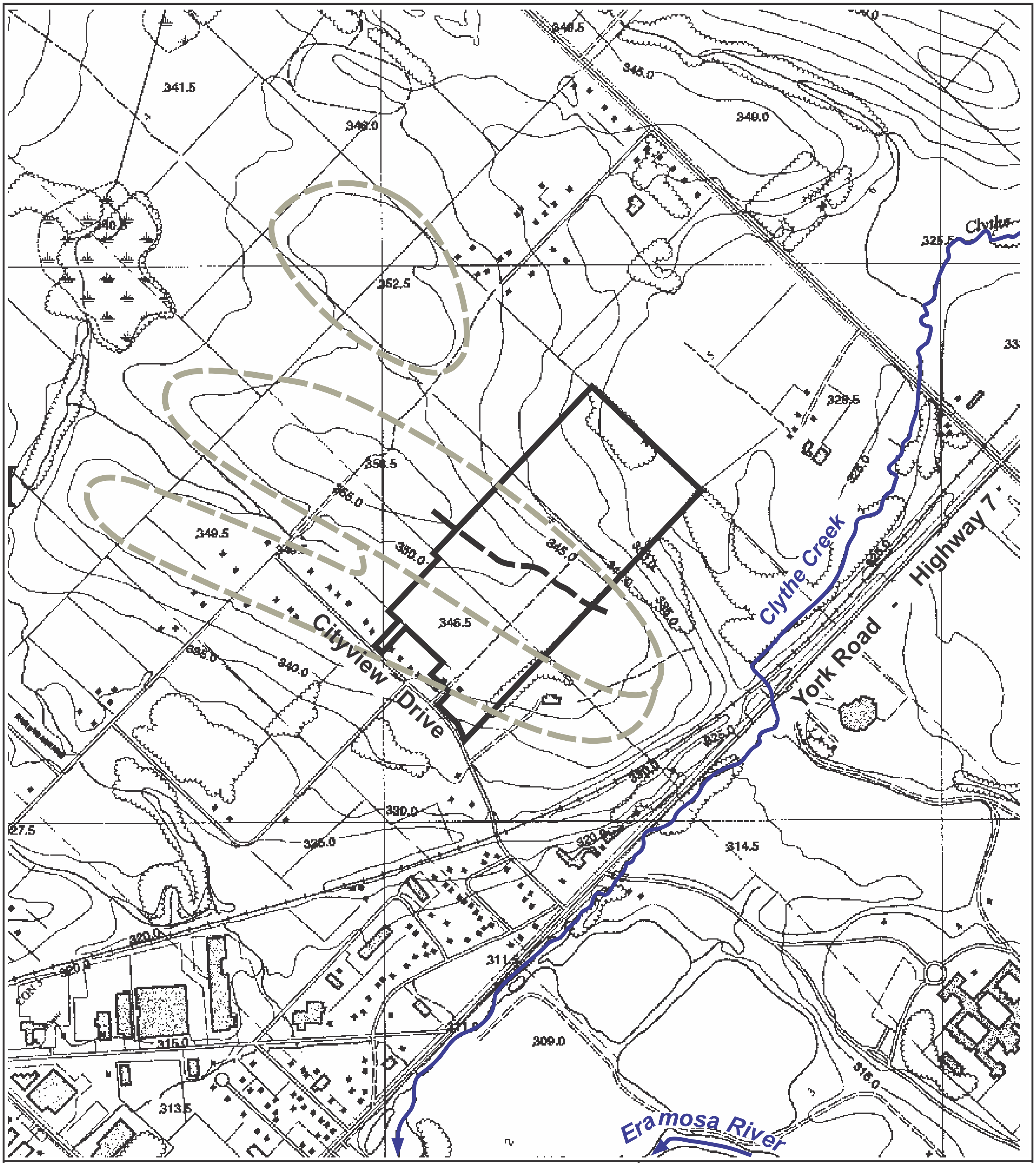
The specific objectives of the assessment are as follows:

1. To summarize the hydrogeological setting, using primarily data from previous investigations with particular emphasis on the shallow setting.

2. To assess the role (or function) that groundwater and surface water have in respect to the wetland features at the property.

3. Complete a pre- vs. post-development water budget analysis to support the stormwater management design and to ensure the Provincially Significant Wetland (PSW) on and adjacent to the property will be maintained.

4. To assess any water table restrictions to basement foundation construction.



LEGEND

▭ Subdivision Boundary

◌ Drumlin Hill

Topographic Divide

N

Map Source: Ontario Base Map Series, 1983.

Scale 1: 10,000

Figure 1
Site Location & Topographic Setting

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2.0 INVESTIGATION METHODS

2.1 Background Data Review

The following background data were reviewed as part of this assessment:

- 1:10,000 Ontario Base Map (1983).
- Pleistocene Geology of the Guelph Area, 1:63,360 (P. Karrow, 1968).
- Bedrock Topography of the Guelph Area, 1:50,000 (P. Karrow et al., 1979).
- Geotechnical Investigation, Proposed Residential Development (CVD Engineering, July 27, 2006).
- Borehole logs (Trow Associates Inc., January 11-20, 2010).
- Stormwater Management Design Report (IBI Group, July 2013).
- Environmental Impact Study, Cityview Drive Development (Natural Resource Solutions Inc., July 2013).

2.2 Borehole Drilling & Well Installation

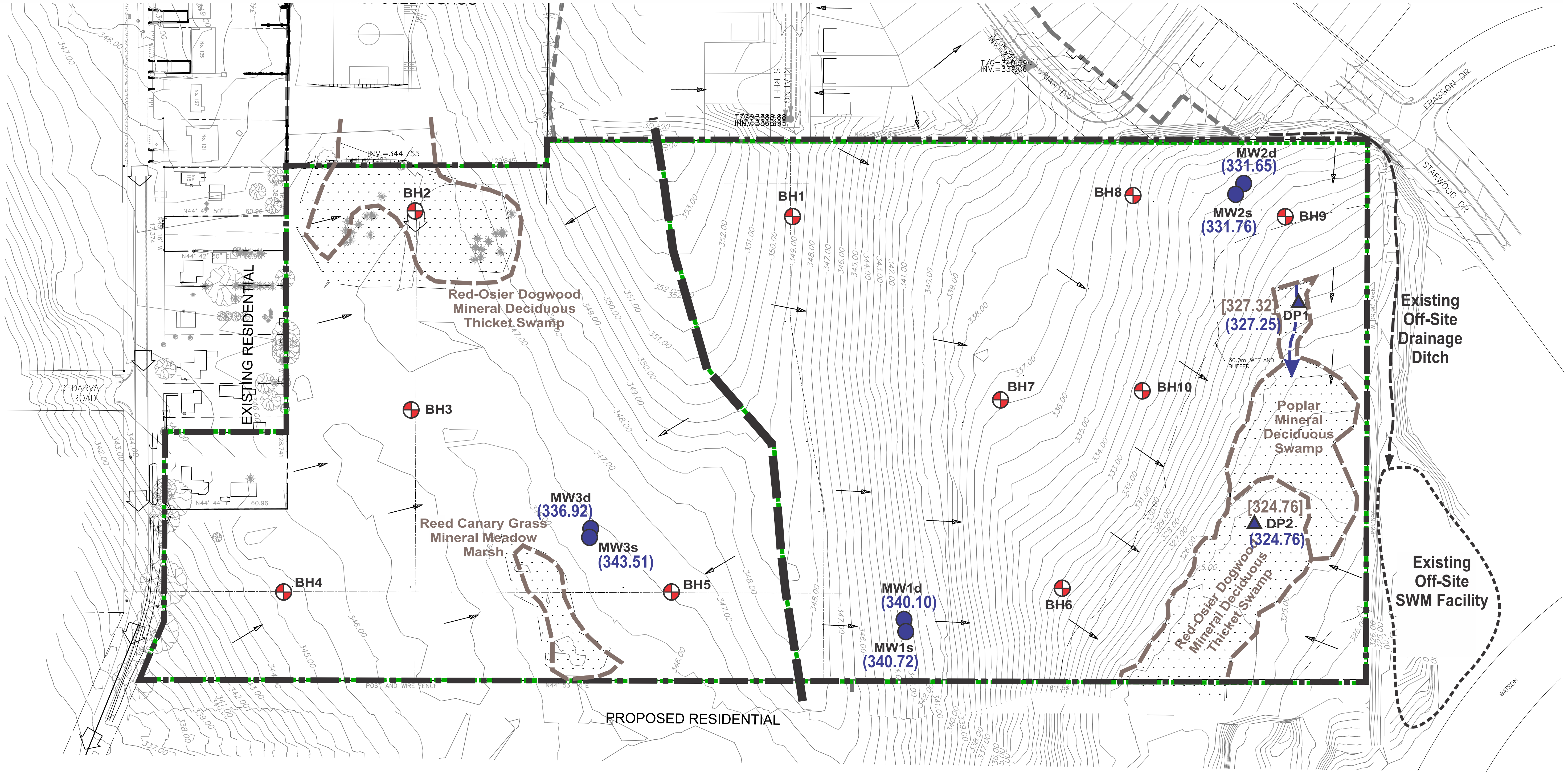
Chung & Vander Doelen Engineering Ltd. (CVD) completed a geotechnical field investigation on July 13-14, 2006 and this included the drilling of ten boreholes, BH1 to BH10, at the locations shown in Figure 2. Solid stem auger (SSA) drilling methods were employed for this investigation and each of the boreholes was extended to the 5-m depth. Appendix A provides the CVD's borehole logs.

Trow Associates Inc. completed a follow-up drilling program at the property on January 11-20, 2010 in an attempt to characterize the relationship between groundwater and wetlands at the property. The scope of work included drilling at three locations, MW1 to MW3, using hollow stem auger (HSA) methods and installation of two monitoring wells ("shallow" and "deep") in separate boreholes at each location. The borehole depths were as follows: MW1 (13.6 and 19 m), MW2 (4.6 and 6.4 m) and MW3 (16.6 and 23.6 m). The hydrogeological data available from these test locations has been incorporated into the overall interpretation provided in this report. The locations are shown in Figure 2 and Appendix A provides the Trow borehole/well logs.

2.3 Drive Point Piezometer Installation

Anderson Geologic installed two drive-point piezometers, DP1 and DP2, on April 6, 2011 at the locations shown in Figure 2. These were installed to provide data on the nature of the groundwater / surface water relationship at the Provincially Significant Wetland (PSW) located in the northeast end of the property. The piezometers were used for monitoring both groundwater and surface water levels (i.e., both inside and outside the piezometers). The locations were selected because, at the time (April 6), there was a modest trickle of flow in an ephemeral water course at DP1 and ponded water at DP2.

The piezometer screens are approximately 0.15-m long and 1.9-cm in diameter and were driven to the 1.0-m depth below ground level using a hand-operated driving system.



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Pre-Development Topographic Divide

Wetland Feature (Swamp or Marsh) Identified by NRSI

Ephemeral Stream

General Sheet Flow Runoff Direction

0 40 80 m

Scale 1:2,000

Figure 2
Existing Conditions & Test Locations

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2.4 Water Level Monitoring

The monitoring wells and drive-point piezometers were monitored for water levels on four occasions during the spring of 2011, between April 6 and May 30. It is noted that spring snowmelt in the Guelph area occurred at the end of March and first week of April. As well, May 2011 was an extremely rainy month with 160 mm recorded at the Waterloo-Wellington weather station, which is nearly 20% of the normal annual total in this area. As a result, the groundwater and surface water levels in the spring of 2011 are representative of seasonal 'high' conditions.

Table 1 provides a summary of the groundwater / surface water elevations from this monitoring. The well / piezometer reference elevations were surveyed by IBI Group in May 2011.

Table 1
Summary of 2011 Water Levels & Elevations - Cityview Drive

Well	Well Depth (m)	Top of Casing (TOC) Elevation (mASL)	Ground Surface Elevation (mASL)	Water Level (m below TOC)				Water Level Elevation (m ASL)			
				06-Apr-11	13-Apr-11	07-May-11	30-May-11	06-Apr-11	13-Apr-11	07-May-11	30-May-11
MW1s	13.6	344.04	343.02	3.63	-	3.75	3.32	340.41	-	340.29	340.72
MW1d	15.2	344.07	343.06	4.27	-	4.25	3.97	339.80	-	339.82	340.10
MW2s	4.6	333.10	331.96	1.43	1.50	1.47	1.34	331.67	331.60	331.63	331.76
MW2d	6.5	332.91	331.95	1.36	1.44	1.40	1.26	331.55	331.47	331.51	331.65
MW3s	16.6	347.20	346.42	3.94	-	3.85	3.69	343.26	-	343.35	343.51
MW3d	23.3	347.26	346.38	10.67	-	10.59	10.34	336.59	-	336.67	336.92
DP1 (Surface Water)				0.87	0.88	0.87	0.88	327.33	327.32	327.33	327.32
DP1	1.3	328.20	327.27	1.88 *	1.78	1.27	0.95	326.32 *	326.42	326.93	327.25
DP2 (Surface Water)				0.92	0.94 (dry)	0.92	0.90	324.74	324.72 (dry)	324.74	324.76
DP2	1.2	325.66	324.67	1.11 *	0.99	0.92	0.90	324.55 *	324.67	324.74	324.76

Notes: * - Water level not fully recovered from installation

3.0 SITE CHARACTERIZATION

3.1 Landuse and Ecological Features

The subject property is bounded to the northwest and southwest by existing residential lands, to the southeast by another proposed residential development property that is currently vacant, and to the northeast by vacant lands that also includes a stormwater management facility.

Existing landuse and vegetation communities at the property are described in detail by NRSI in their EIS. The southwestern approximately two-thirds of the property consist primarily of fallow agricultural lands that currently support mostly ‘dry’ old-field meadow vegetation communities, but also several hedgerows, a small tree plantation, and two small ‘non-evaluated’ wetland pockets (a mineral deciduous swamp along the northwest boundary and a mineral meadow marsh along the southeast boundary, as shown in Figure 2). There is also a house and small residential lot in the southwest along Cityview Drive.

The northeastern approximately one-third of the property is primarily ‘dry’ tree and thicket communities as well as a larger approximately 0.9-ha wetland, about half of which is part of the Clythe Creek Provincially Significant Wetland (PSW) Complex (i.e. the mineral deciduous thicket swamp portion) and an adjoining portion identified by NRSI as mineral deciduous swamp (Figure 2).

3.2 Topographic Setting & Drainage

Regional topography is shown in Figure 1 and detailed topography on the subject property is shown in Figure 2.

The property is located on the southern edge of two elongate hills that are two of many similar hills in the area (Figure 1). These hills are together known as the Guelph Drumlin Field, which extends for many kilometers all directions from the property. The hills are typically oriented northwest-southeast and the two drumlins that cross the subject property merge across the southwestern portion of the property (Figure 1).

Total relief across the property is about 30 m, falling steeply away from the axis (or topographic divide) of the central drumlin toward the northeast and less-steeply to the southwest toward the southernmost property corner. The peak elevation on the property is about 354 along the northwest property boundary and the lowest elevation is in the northeastern wetland at about 324 mASL (Figure 1).

To the southwest of the main divide, there is a ‘subdued’ topographic dip between the two drumlins before topography falls more steeply toward the southwest. The two small upland wetland features are located in this topographic dip, where surface water drainage is poor.

There is an absence of perennial water courses on the property. As a result, drainage occurs primarily as ‘sheet-flow’, following the moderate to steep slopes on the sides of the drumlins. Notwithstanding this general condition, the overland drainage is poor in the topographic dip between the drumlins and this clearly has contributed to the existence of the two small wet features in the upland area.

A small approximately 40-m long ephemeral water course exists in the northern end of the wetland (Figure 2). This water course does not extend northward into the woodlot beyond the wetland boundary delineated by NRSI and it becomes indistinguishable at its southern end within the larger wetland feature. This feature is discussed in more detail in Section 3.4.

Beyond the property limits, surface drainage features include a recently constructed stormwater ditch that wraps around the northern corner of the property and follows a southeasterly path adjacent to the property to a stormwater management pond (Figure 2). This ditch and pond were observed to be ‘dry’ during each visit to the site in the spring of 2011.

Clythe Creek is the nearest perennial water course, located about 300 m to the southeast of the property. This Creek flows in a southwesterly direction, eventually discharging to the Eramosa River (Figure 1).

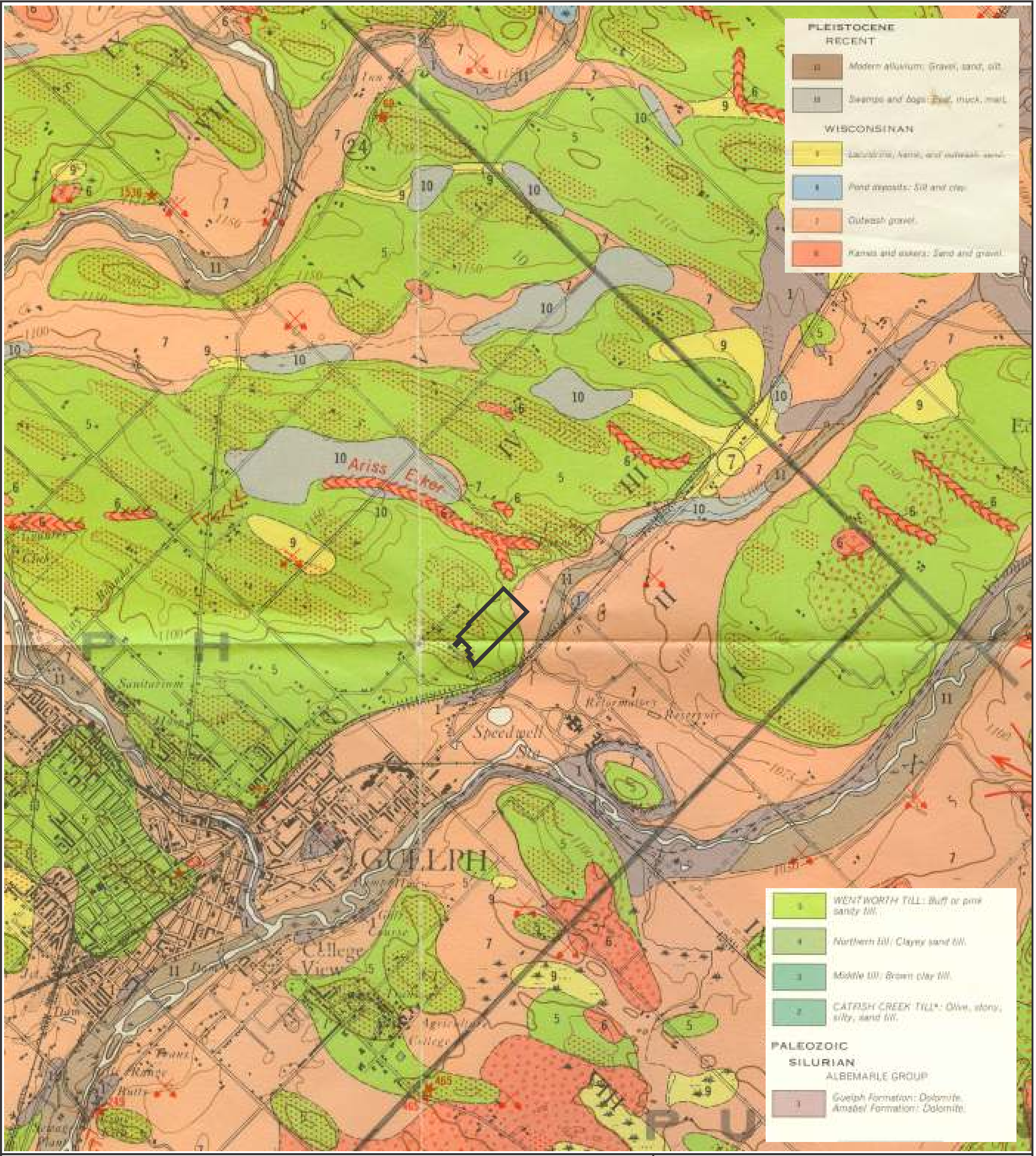
3.3 Geological Setting

Regional-scale surface geological mapping by Karrow (1968) is presented in Figure 3. The property is located in an area known as the Guelph Drumlin Field, an area with numerous drumlin hills, till plains and outwash valleys.

Karrow’s 1968 mapping indicates the property, in all but the easternmost corner, is underlain by the Wentworth Till (Unit 5, Figure 3). Later in a 1987 publication on the Cambridge area geology, Karrow determined that the Wentworth Till actually ends several kilometers to the southeast at the Paris Moraine and that the surficial till deposit northwest of the Moraine, and that is found in the drumlins at the subject property, is actually the sandy silt Port Stanley Till. Karrow’s mapping also indicates that the easternmost corner of the property is underlain by an outwash gravel deposit (Unit 7) that extends beneath the nearby Clythe Creek and Eramosa River valleys (Figure 3).

The borehole data confirm that the silt till deposit is both laterally extensive across the property (i.e. found at all thirteen drilling locations) and very thick (e.g. depths up to 23.5 m). This till was encountered to elevations of 328, 325.5 and 323 mASL, respectively at the three deep MW-test locations.

Other subsurface materials encountered in the drilling programs include silt below the 15-m depth at MW1 and near-surface layers of silt at the northeastern edge of the drumlin at MW2 (from 0 to 2.5 m), BH8 (from 3 to 5 m) and BH10 from (from 2 to 5 m). Silt was also encountered beneath the organic deposits at both DP1 and DP2, indicating that these areas of the wetland are underlain by silt. Also notable are the sporadic wet gravelly seams noted by CVD within the till deposit at nearly every drilling location. Such seams are not uncommon in drumlins, although the lateral continuity of the individual occurrences is typically limited.



LEGEND

Subdivision
Boundary

N

Map Source: Pleistocene Geology of the Guelph Area,
P. F. Karrow, (Map 2153), 1963.

Scale 1: 50,000

Figure 3
Surficial Geology

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Bedrock underlying the area is the Guelph Formation dolostone (Sanford, 1969), which is exposed near the property in the Clythe Creek valley to the south and east (Figure 3). Regional-scale mapping of the bedrock surface topography (by Karrow et al, 1979) is presented in Figure 4. This interpretation is based primarily on water well record data and the mapping indicates that bedrock underlies the property at about the 328 mASL elevation in the northeast and dips to the south-southwest to an elevation on the order of 315 mASL. While the 328 mASL elevation estimate in the northeast is clearly an over-estimate (since the elevation of the wetland itself is only about 325 mASL +/-), the map nevertheless suggests that the wetland is at or very close to bedrock.

3.4 Hydrogeological Setting

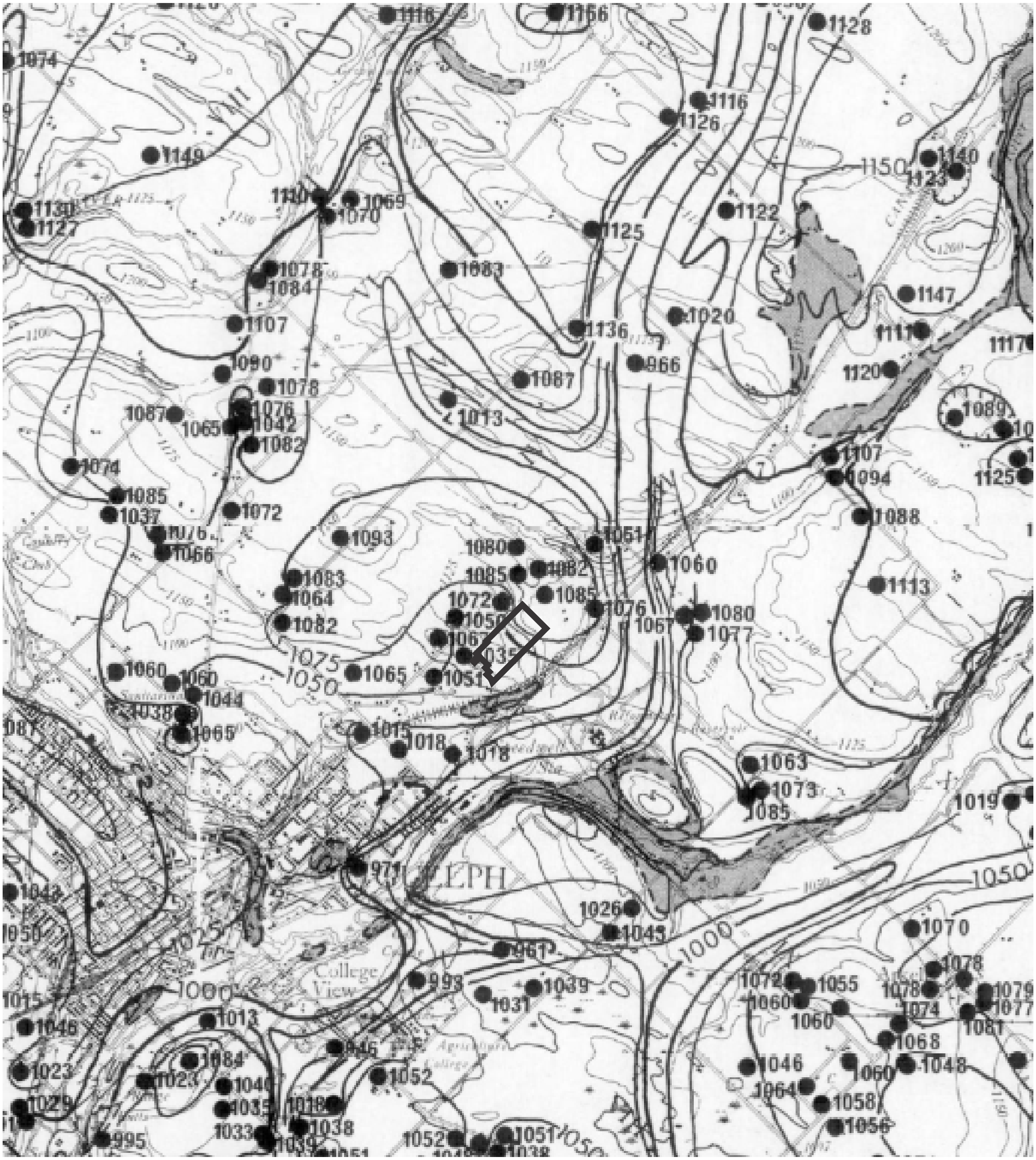
3.4.1 Water Table Depth and Configuration

With the temperate climate in Southern Ontario, it is typical to find a shallow water table within the upper few metres of low-permeability silt till deposits. This is because silt till is sufficiently permeable (often enhanced by near surface weathering) to allow <u>modest</u> infiltration to occur, but insufficiently permeable to allow the infiltrated water to drain quickly either vertically or laterally. In some settings, the water table can become ‘perched’ by clay layers, but this is not typically the case with the silt till drumlins in the Guelph area. Experience in these settings indicates that saturated conditions typically prevail throughout the vertical profile, albeit with limited overall groundwater infiltration rates through the till to deeper water bearing zones. The saturated conditions at each of the Trow monitoring wells (ranging from 4.5 to 23 m into the till deposit) confirms this to be the case at the subject property.

The precise configuration of the water table across the property is not discernible with the limited amount of data (see Table 1 and Figure 2) and since most of the monitoring wells are much deeper than the water table (i.e. the deeper wells measure ‘potentiometric’ pressures, not the water table). Nevertheless, the available data confirm that the seasonally high water table is <u>no deeper than</u> about 2.0 m across much of the upland area (e.g. at MW1 and MW3) and even less approaching the wetland (e.g. 0.2-0.3 m at MW2) and essentially at or just below ground surface within the wetland (e.g. at DP1 and DP2). The water table is expected to mimic topography, with the lateral component of shallow groundwater flow directed to the southwest and northeast away from the main topographic divide.

3.4.2 Groundwater / Surface Water Interaction and Wetland Function

A downward hydraulic gradient (i.e. a lower water elevation in the deeper vs. shallow wells) was measured at all three ‘nested’ well locations throughout the April / May 2011 monitoring period. This is particularly illuminating at MW2s/d because it illustrates the absence of an ***upward*** hydraulic gradient in the area approaching the wetland.



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Subdivision Boundary

Interpreted Bedrock Surface Elevation Contour (ft ASL)
(Note 1075 ft = 327.7 m, 1050 ft = 320 m)

Map Source: Bedrock Topography of the Guelph Area, P. F. Karrow et al, (Prelim Map 2224), 1979.

Figure 4
Bedrock Surface Topography

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Similarly, the surface water elevation along the water course at DP1 was consistently higher than the shallow groundwater elevation beneath the water course, indicating the water course was not receiving an upwelling of groundwater discharge. It is noted that on two of the four visits (April 6 and May 7) there was a modest trickle of flow observed and then only ponded water with no discernable flow on April 13 and May 30. Together, these data and observations suggest that the water course is ephemeral (i.e. transient), being fed intermittently by runoff and interflow, which is the very shallow subsurface lateral flow generated by recent runoff events. At DP2, the ponded surface water had completely dried up on April 13 and the surface water and shallow groundwater elevations were identical during the May visits. This again indicates the ephemeral nature of the surface water occurrence and no apparent groundwater upwelling.

To summarize, it is concluded that the northeastern wetland is fed directly by surface water runoff and interflow. There is no apparent upwelling or discharge of groundwater to the wetland, although shallow groundwater undoubtedly passes laterally beneath it and some of the surface water reaching it undoubtedly infiltrates to the water table.

In the case of the two small wetland features located in the upland area southwest of the topographic divide, each is situated in a topographic dip where surface water drainage is poor. The underlying low-permeability till deposit allows surface water to periodically accumulate in these low spots. The available data indicate these features are wholly supported by surface water runoff and there is no groundwater function.

4.0 WATER BUDGET ASSESSMENT FOR PSW

As described in Section 3.0, the water that reaches the surface of the northeastern wetland (including the PSW) is primarily runoff that originates from the lands northeast of the topographic divide, plus the precipitation that falls directly on the wetland itself. Although groundwater does not appear to directly discharge to the wetland surface, the *lateral component* of shallow groundwater flow likely contributes to maintaining saturated soil conditions beneath the wetland. As with the runoff component, the lateral groundwater contribution is derived from recharge that falls to the northeast of the divide, albeit in this case a significant portion of the infiltration is expected to move vertically through the till to the deep regional bedrock aquifer and would not pass beneath the wetland at all. The split between the lateral vs. vertical groundwater components is difficult to determine precisely, however, a 50-50 split is a reasonable estimate.

To ensure that the 'function' provided to the northeastern wetland by runoff and lateral groundwater flow is maintained during post-development, a standard pre- and post-development water budget assessment has been completed to provide direction to the SWM strategy.

Figures 5 and 6 show, respectively, the on-site pre-development and post-development areas that contribute water to the wetland. The pre-development catchment area (i.e. combined Areas 101-A,B,C) is approximately 8.49 ha and the reduced catchment area with direct overland flow contribution to the wetland (i.e. combined Areas 201-A,B,C) is approximately 4.89 ha. The easternmost 1.32-ha area (i.e. 101-C & 201-C) includes the wetland itself and, although relatively flat, it is sufficiently sloped to allow surface water (and shallow groundwater) to flow across the southeast property line. As shown in Figure 6, drainage from much of the developed area will be directed toward either the southwest or northeast storm sewer systems.

To supplement the reduced natural overland flow to the wetland, two SWM measures are proposed: a) direct rooftop runoff from available lots to the natural sloped area adjacent to the wetland, and b) direct a proportional amount of the treated stormwater flow from the northeast storm sewer (i.e. runoff from areas 202-A,B,C) to an appropriately located stormwater spreader on the edge of the development (i.e. just outside the wetland buffer zone). Details regarding these engineering measures are described in the SWM Report by IBI Group.

4.1 Pre- & Post-Development Water Budget Calculations

The standard approach used for this assessment is to use The Water Balance Method (WBM) of Thornthwaite and Mather (1957) as the basis for understanding the water budget components and use this in conjunction with stormwater designs to confirm the water budget requirements for the northeastern wetland.

The WBM was developed to quantify two basic climatic quantities: **evapotranspiration** and **water balance**, which is simply the balance of water between precipitation and evapotranspiration. This

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- Pre-Development Topographic Divide
- Wetland Feature (Swamp or Marsh) Identified by NRSI
- Ephemeral Stream
- General Sheet Flow Runoff Direction
- Steeply Sloped Grassed Area
- Steeply Sloped Vegetated/Treed Area
- Flat Vegetated/Treed Wetland Area

0 40 80 m

Scale 1:2,000

Figure 5
Pre-Development Water Budget

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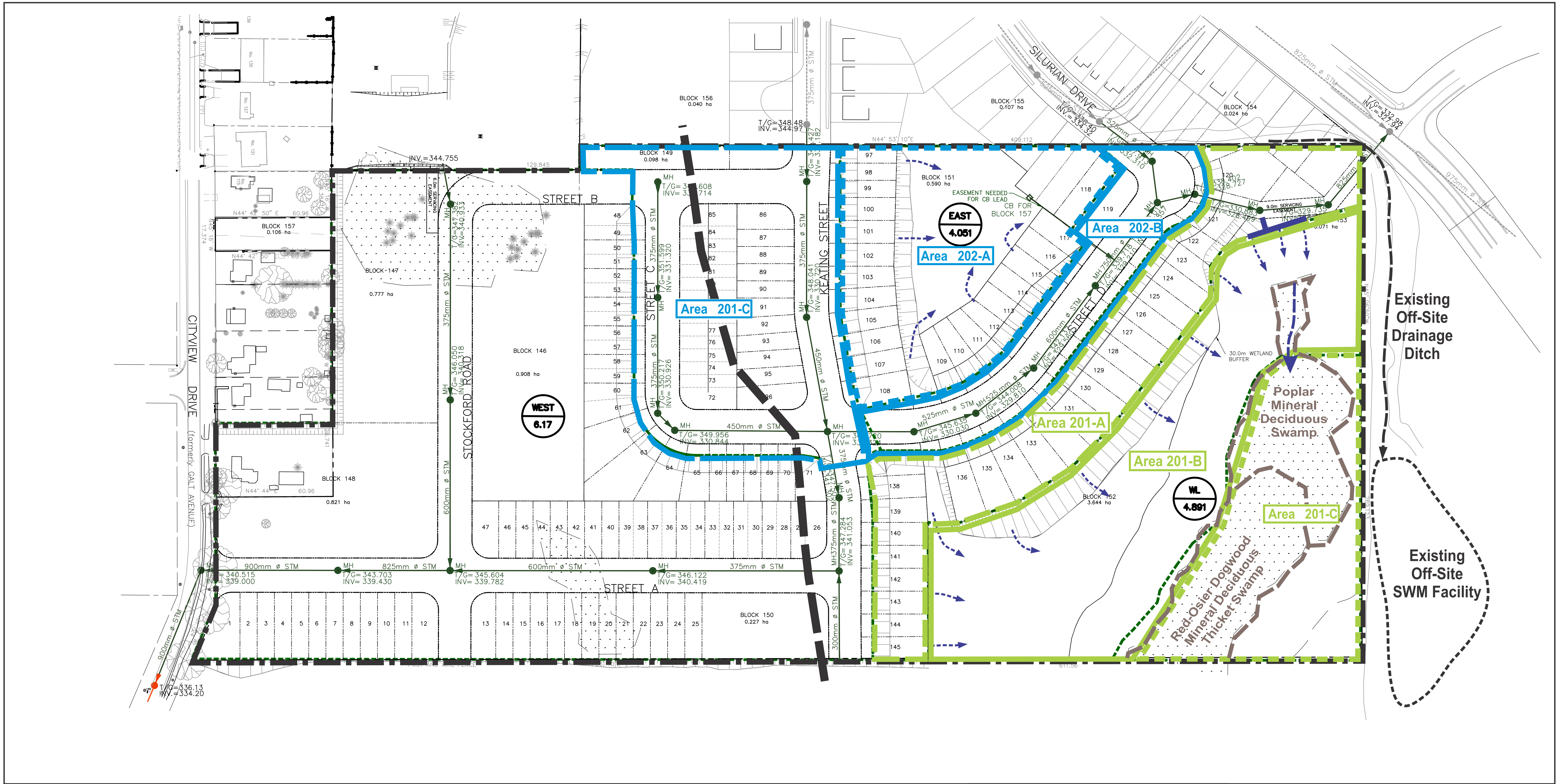

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Pre-Development Topographic Divide

Wetland Feature (Swamp or Marsh) Identified by NRSI

Ephemeral Stream

General Sheet Flow Runoff Direction in Pervious Areas

Proposed Stormwater Spreader

Mixed Pervious / Impervious Area Drained to East Sewer

Mostly Impervious Area Drained to East Sewer

Mostly Pervious Area Drained to East Sewer

Sloped Grassed Yards & Rooftop Area

Steeply Sloped Vegetated/Treed Area

Flat Vegetated/Treed Wetland Area

0 40 80 m

Scale 1:2,000

Figure 6
Post-Development Water Budget

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method utilizes monthly ‘average’ precipitation and temperature data, along with information about geographic location and prevailing soil and vegetation conditions in a given area, to calculate the monthly evapotranspiration and water balance. *[Note: To avoid confusion regarding Thornthwaite and Mather’s definition of ‘water balance’ as a specific parameter, the overall method of quantifying the various components is referred to as ‘water budget’, not water balance.]*

The WBM is often used, with some additional assumptions, to make approximations of other related parameters, such as soil moisture storage, water surplus / deficit and ‘runoff’. It is very important to note, however, that Thornthwaite and Mather refer to ‘runoff’ as the total sum of what is now commonly considered to be two separate components, **recharge** and **direct runoff**. Thornthwaite and Mather lump these components together because the WBM was developed for large watershed areas and ‘runoff’ is ultimately the total amount of water that flows out of a watershed. This combined-runoff is mathematically equivalent to the water balance quantity. Thornthwaite and Mather do not address or provide a methodology to determine what proportion of the combined-runoff (or water balance) is actually recharge vs. direct runoff.

Overall Water Budget

Precipitation (P) = Evapotranspiration (ET) + Water Balance

= Evapotranspiration (ET) + Combined-Runoff

= Evapotranspiration (ET) + Direct Runoff (RO) + Recharge (R)

Noting the above distinction, the WBM proportions the water balance into monthly combined-runoff quantities based on average climate conditions and several assumptions about the lag period before soil moisture surplus and snowmelt become combined-runoff. The pre- and post-development water balance calculations for the areas which contribute overland flow to the edge of the wetland (i.e. pre-development areas 101-A,B and post-development areas 201-A,B) are summarized in Tables 2 and 3 (Appendix B). It is apparent that the WBM assumptions result in a spreading of the combined-runoff throughout the year, which is potentially realistic for a long term average in a large watershed under average climate conditions, but not realistic for a small catchment area where a lengthy lag period is unlikely. As a result, the specific monthly values should not be considered particularly accurate. Rather, the yearly amounts are a better indicator of long term average conditions.

The MOE document ‘Stormwater Management and Planning Manual’ (2003) provides a rudimentary method for proportioning the water balance into recharge and direct runoff components based on three infiltration factors: topography, soil type and vegetative cover. This method was used to determine pre- and post-development water balance proportioning for each of the contributing areas with unique infiltration conditions. These individual recharge and direct runoff results are also summarized in Tables 2 and 3. The infiltration factors result in typically 65-70% runoff and 30-35% recharge, noting as well that only about 50% of the recharge is estimated to actually move horizontally toward the wetland (see above discussion).

Table 4 provides a summary of the pre- and post-development water budget amounts from the contributing areas toward the wetland (i.e. 100% of runoff and 50% of recharge). It is noted that the contributing water from areas 101-C/201-C are not included in this summary, since these amounts will remain unchanged with development. As summarized, an approximately 55.1% reduction in the water contribution from the adjacent lands is expected, due essentially to the 55.6% area reduction. By directing supplemental amounts of runoff from rooftops (about 2,503 m^3/yr from Lots 120-145) and from the northeast stormsewer (about 9,675 m^3/yr) toward the wetland buffer area, the overall water budget contribution from the land adjacent to the wetland will be maintained.

The stormwater spreader should be shallow in design to mimic the runoff/interflow-dominant character of the existing setting. The spreader should include an oil-grit separator and also provide a mechanism for water overflow to follow the natural topography toward the wetland. Any excess stormwater runoff from the northeast stormsewer would be directed to the existing off-site SWM pond. This will ensure that the wetland is not inundated with *excess* runoff.

The temporal (i.e. seasonal) distribution of runoff volumes will be generally maintained (i.e. volumes released are proportional to event size so that the largest annual events, in particular spring freshet, will still release the largest portions of the annual quantity). The temporal distribution will be further accomplished by the prevailing climate conditions. For example, the water volume released during a cool spring or fall period will more readily move through the buffer toward the wetland, because evapotranspiration is minimal and soil moisture is high. In contrast, the water released during a hot dry summer period will be further reduced by evapotranspiration and soil moisture replenishment, enhanced by the careful directing of water to the edge of the buffer and overland sheet flow through the buffer.

For the above reasons, it is not predicted there will be any significant reduction in the spring hydro-period nor any significant increased water occurrence in summer over what would have occurred under pre-development conditions, recognizing as well that this wetland feature is a ‘flow-through’ feature. In other words, the water entering the wetland largely infiltrates to the water table or flows further overland beyond the southeast boundary. The vegetation in the wetland has been established under variable water regimes and species are known to be tolerant of fluctuating moisture conditions.

Table 4
Annual Water Budget to Northeast Wetland (Pre & Post-Development)

	Wetland Water Budget Catchment	Area (m^2)	Runoff and Half Recharge Quantity (m^3/yr)	Pre - Post % Decline in Area (m^2)	Pre - Post % Decline in Runoff Quantity (m^3/yr)
Pre-Development	101-A	27,850	8,735		
	101-B	43,900	13,364		
	101-A & 101-B	**71,750**	**22,099**		
Post-Development	201-A	10,670	3,392		
	201-B	21,160	6,529		
	201-A & 201-B	**31,830**	**9,921**	**55.6%**	**55.1%**
	201-A (Rooftops) *	3,900	2,503		
	201-A (w/ Roof) & 201-B	**35,730**	**12,424**	**50.2%**	**43.8%**
	202 (Spreader) **	-	9,675		
	201-A (w/ Roof) & 201-B & 202 (Spreader)	**35,730**	**22,099**	**50.2%**	**0.0%**

Notes:

* The 201-A (Rooftops) runoff quantity is that gained by directing the rooftop runoff from Lots 120 to 145 to backyard pervious areas.

* The 202 (Spreader) runoff quantity is that required to balance the loss of runoff due to the decreased pervious area.

5.0 WATER TABLE CONSIDERATIONS FOR BASEMENTS

The pre-development shallow water table condition across the planned development area is typically within 1 to 3 metres of ground surface during seasonally wet periods. Experience indicates this is not an unusual occurrence in the low-permeability silt till soils atop the drumlin hills in the Guelph Area. Such shallow saturated soil conditions exist because the low-permeability soils do not allow adequate vertical or lateral drainage of infiltrating waters, often exacerbated by local-scale dead-end topography. This is particularly the case at the subject property, where surface water runoff is trapped in the subdued topographic low between the two drumlin hills southeast of the main topographic divide (see discussion in Section 3.2).

Experience indicates that, with the increased imperviousness and positive lateral drainage by storm sewers in the developed portions of the property, the shallow saturated soil conditions will be drastically reduced and the prevailing water table will typically be below basement levels. The occasionally higher water saturation conditions around basements after storm events should be adequately handled by standard foundation drainage and sump pump systems, noting that even when high saturation levels occur, the quantity of flow through such low-permeability soils is very low.

6.0 CONCLUSIONS

Based on the results of this hydrogeological assessment, the following conclusions and recommendations are provided:

1. An assessment of the hydrogeological conditions at the property has been completed using both regional geological mapping data and on-site borehole/well data, including groundwater and surface water level data collected during the very wet spring of 2011. The assessment focuses on defining the inter-relationship between groundwater, surface water and wetlands located at the property and that have been identified in an EIS completed for the development.

2. A detailed water budget assessment of the northeast wetland (partially a PSW) located on the property has been completed and this has identified the quantities of water that need to be directed to the wetland to maintain existing wetland water budget amounts. The assessment has been used to develop a strategy for post-development stormwater management of the wetland.

All of which is respectively submitted,
ANDERSON GEOLOGIC LIMITED

S. Anderson.

William (Sandy) Anderson, M.Sc., P.Eng.
Hydrogeologist and Environmental Engineer

APPENDIX A

Borehole Logs &
Monitoring Well Details

Enclosure No.: 1
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 1

Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

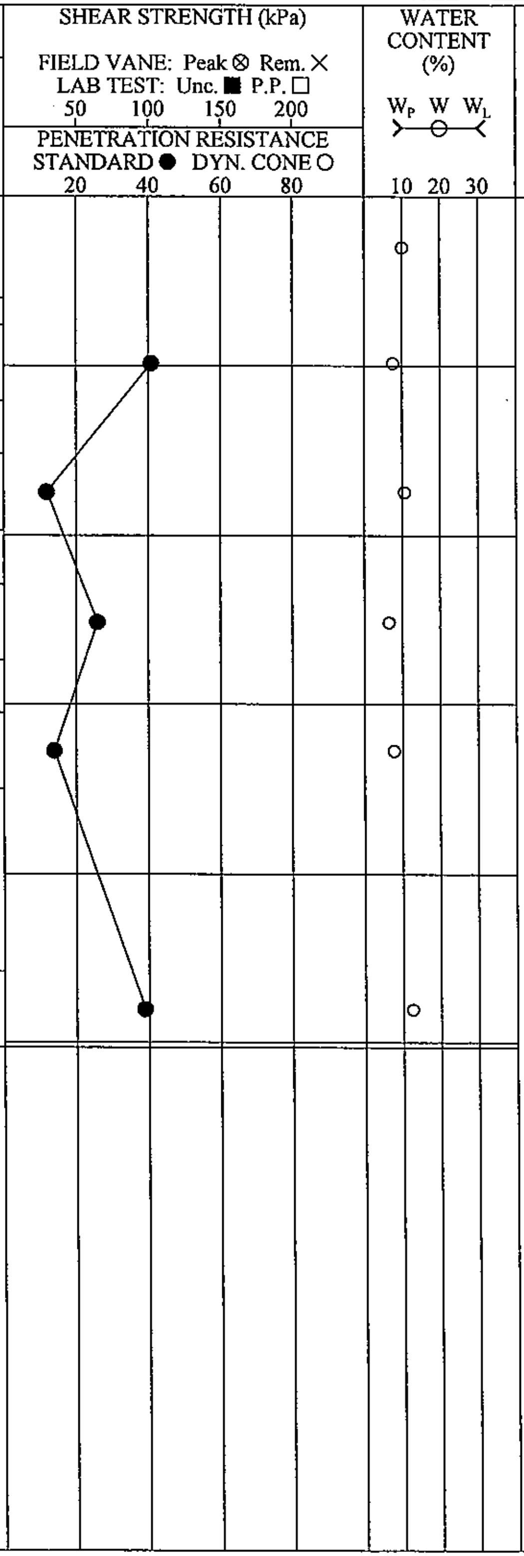
EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 13 06** TO **Jul 13 06**

SOIL LITHOLOGY

Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	REMARKS
	300 mm TOPSOIL				
0.30	compact to dense brown SANDY SILTTILL	1	AS		
	trace embedded gravel, trace clay, occ. wet gravelly seams	2	SS	41	
	moist to damp				
		3	SS	12	
		4	SS	26	
		5	SS	14	
	saturated layer				
		6	SS	39	
5.03	End of Borehole				no free water at completion



ENGINEER: **EYC**

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ENGINEERING LTD.
280 Victoria Street North, Unit 8
Kitchener, Ontario N2H 5E2
ph. (519) 742-8979, fx. (519) 742-7739

Enclosure No.: 2
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 2

Client:	**Clarity Mortgage Inc.**
Project:	**Proposed Residential Development, Cityview Drive**
Location:	**Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

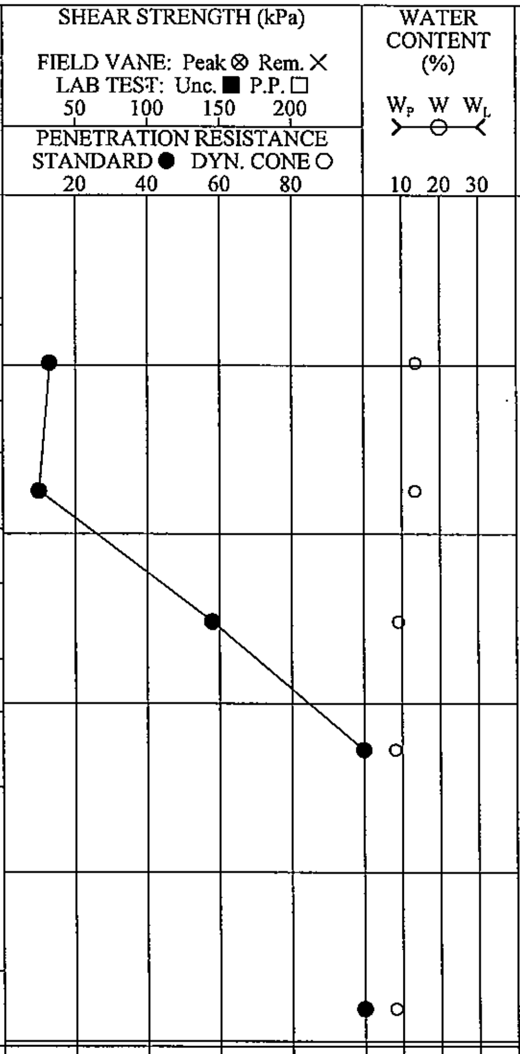
EQUIPMENT DATA

Machine:	**CME 55**
Method:	**S/S Auger**
Size:	**150 mm**
Date:	**Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY

Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	REMARKS
	600 mm TOPSOIL	1	AS		
0.60	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp ------- saturated layer ------ very dense	2	SS	13	
		3	SS	10	
		4	SS	58	
		5	SS	100	
		6	SS	100	
5.03	End of Borehole				no free water at completion



WELL DATA

ENGINEER: **EYC**

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Enclosure No.: 3
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 3

Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

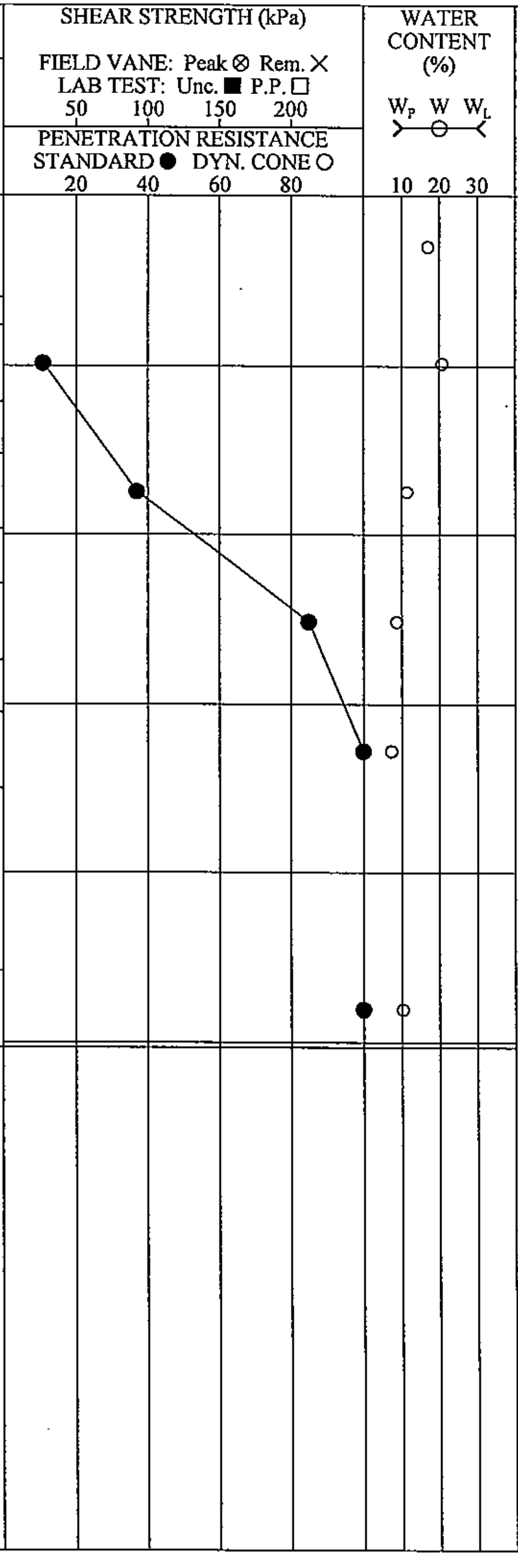
EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY

Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	REMARKS
	300 mm TOPSOIL	1	AS		
0.30	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp	2	SS	11	
	------- saturated layer	3	SS	37	
	—— very dense	4	SS	85	
		5	SS	100	
		6	SS	100	
5.03	End of Borehole				no free water at completion



ENGINEER: **EYC**

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CVD BOREHOLE 06-7-K5 CITYVIEW GUELPH.GPJ CVD_ENG.GDT 7/31/06

Enclosure No.: 4
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 4

Client: **Clarity Mortgage Inc.**

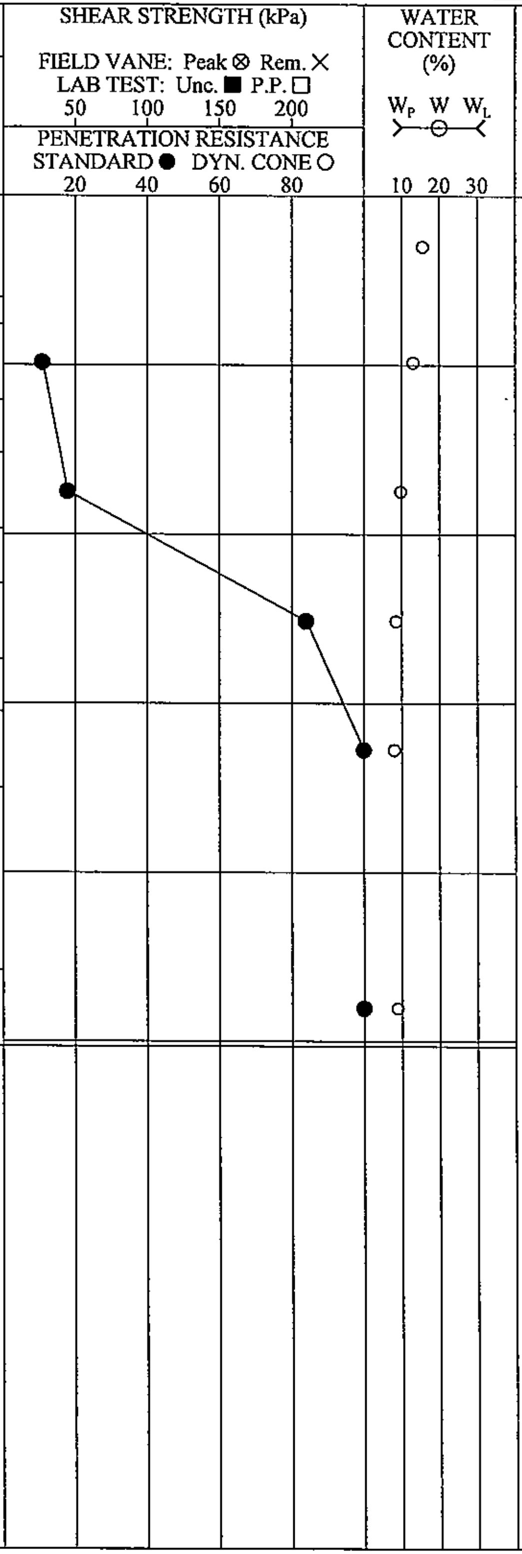
Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY		SAMPLE			
ELEV./ DEPTH (m)	DESCRIPTION Ground Elevation:	SAMPLE ID	TYPE	N-VALUE	REMARKS
	300 mm TOPSOIL	1	AS		
0.30	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp	2	SS	11	
		3	SS	18	
	------ very dense	4	SS	84	
		5	SS	100	
	------- saturated layer	6	SS	100	
5.03	End of Borehole				no free water at completion



WELL DATA | DEPTH (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5

ENGINEER: **EYC**

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Enclosure No.: 5
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 5

Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

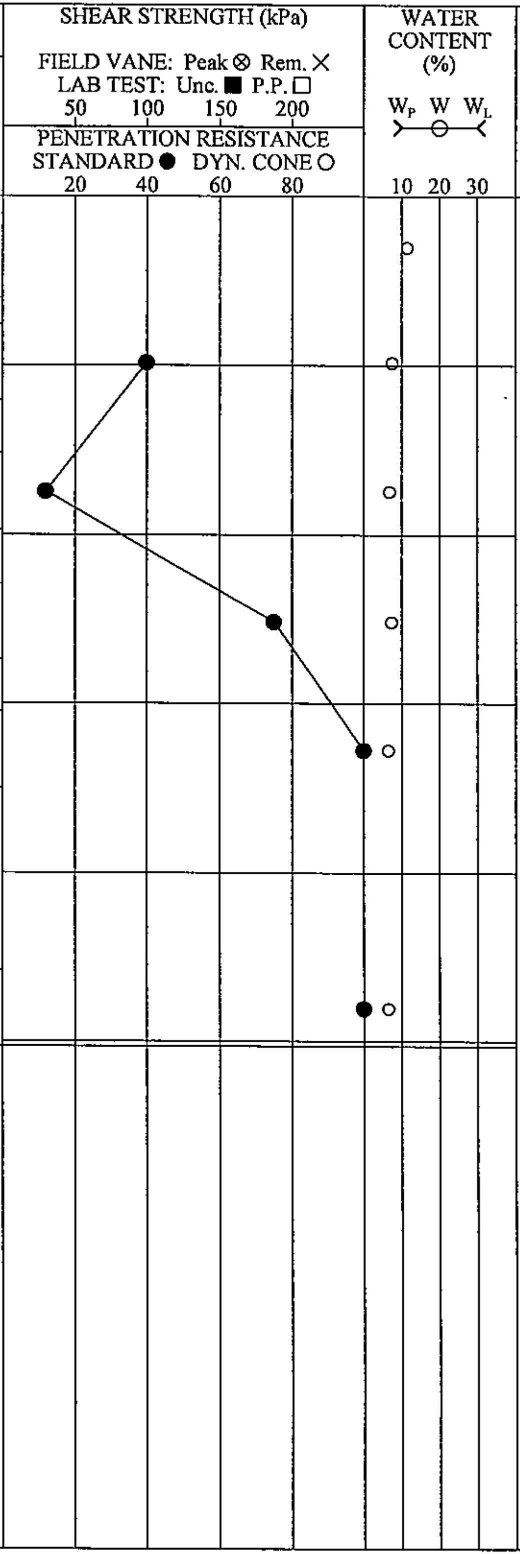
Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	REMARKS
	Ground Elevation:				
	300 mm TOPSOIL				
0.30	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp ------- very dense	1	AS		
		2	SS	40	
		3	SS	12	
		4	SS	75	
		5	SS	100	
		6	SS	100	
5.03	End of Borehole				no free water at completion



ENGINEER: **EYC**

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ENGINEERING LTD.
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Kitchener, Ontario N2H 5E2
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FILE No: 06-7-K5

BOREHOLE No. 6

Enclosure No.: 6
Sheet 1 of 1

CHUNG & VANDER DOELEN ENGINEERING LTD. CVD

Client:	**Clarity Mortgage Inc.**
Project:	**Proposed Residential Development, Cityview Drive**
Location:	**Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

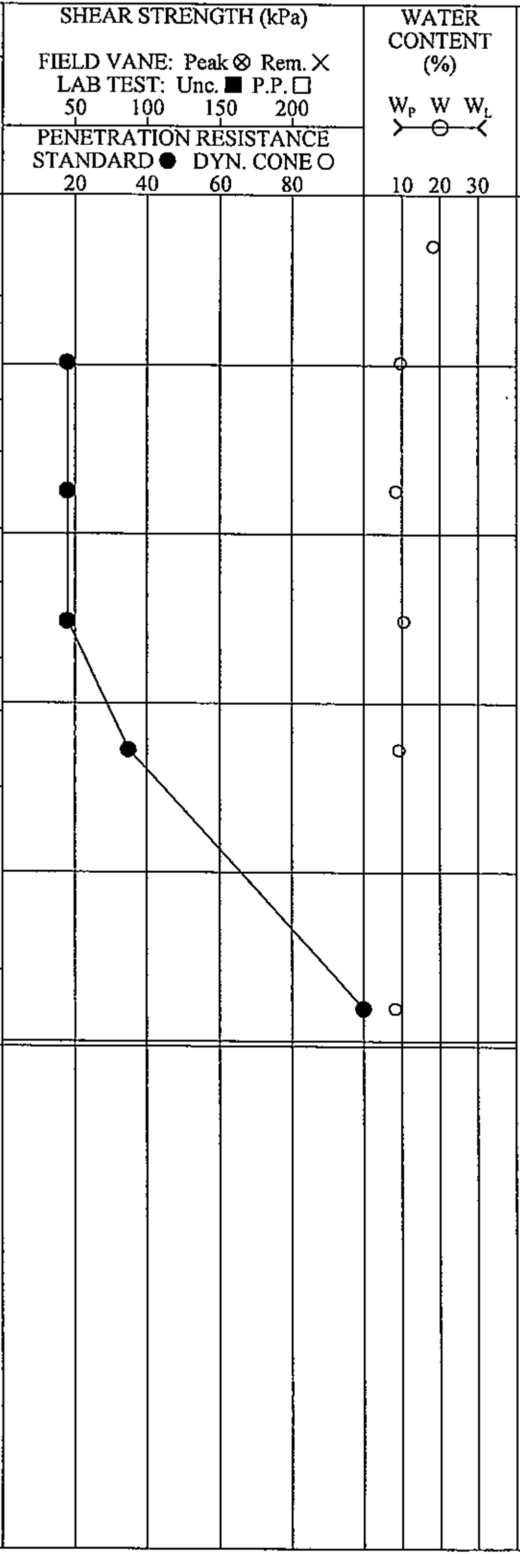
EQUIPMENT DATA

Machine:	**CME 55**
Method:	**S/S Auger**
Size:	**150 mm**
Date:	**Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY

Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	REMARKS
	500 mm TOPSOIL	1	AS		
0.50	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp	2	SS	18	
		3	SS	18	
		4	SS	18	
		5	SS	35	
	------- very dense	6	SS	100	
5.03	End of Borehole				no free water at completion



WELL DATA

ENGINEER: **EYC**

CHUNG & VANDER DOELEN
ENGINEERING LTD.
280 Victoria Street North, Unit 8
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CVD BOREHOLE 06-7-K5 CITYVIEW GUELPH.GPJ CVD_ENG.GDT 7/31/06

Enclosure No.: 7
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 7

Client: Clarity Mortgage Inc.

Project: Proposed Residential Development, Cityview Drive

Location: Part of Lots 25, 31 & 32, Registered Plan 35, Guelph

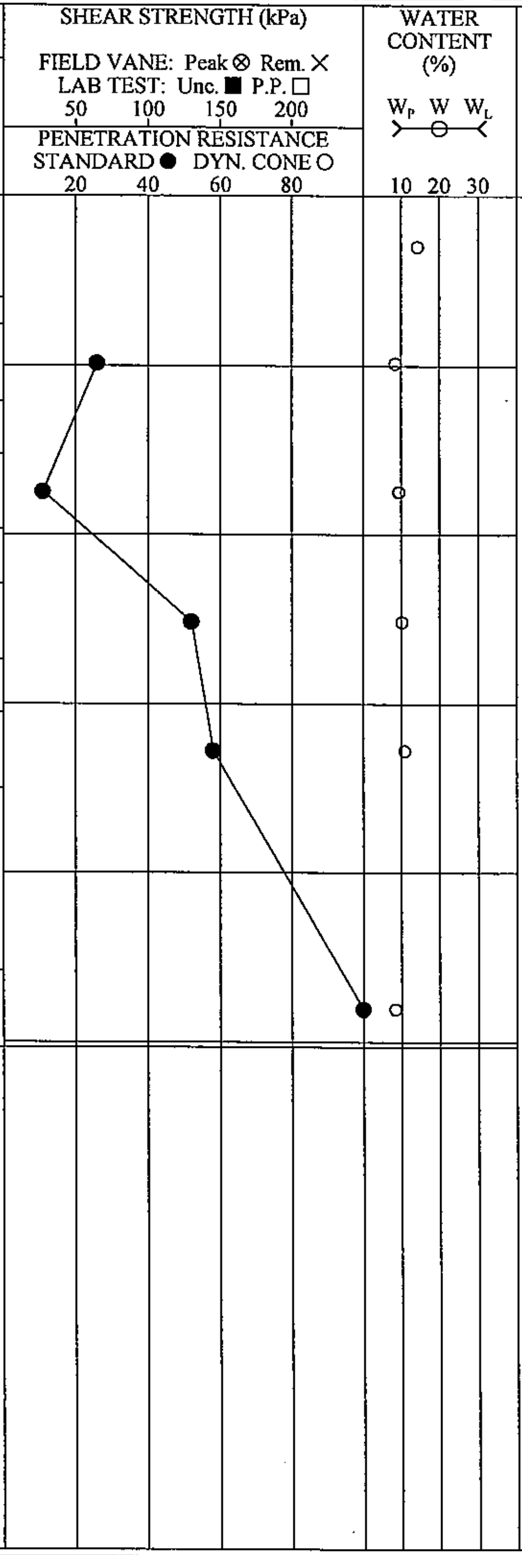
EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY / SAMPLE

Ground Elevation:

ELEV./DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE	WELL DATA	REMARKS
	300 mm TOPSOIL					
0.30	compact to very dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp	1	AS			
		2	SS	26		
		3	SS	11		
	very dense	4	SS	52		
		5	SS	58		
		6	SS	100		
5.03	End of Borehole					no free water at completion



ENGINEER: EYC

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Kitchener, Ontario N2H 5E2
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Enclosure No.: 8
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 8

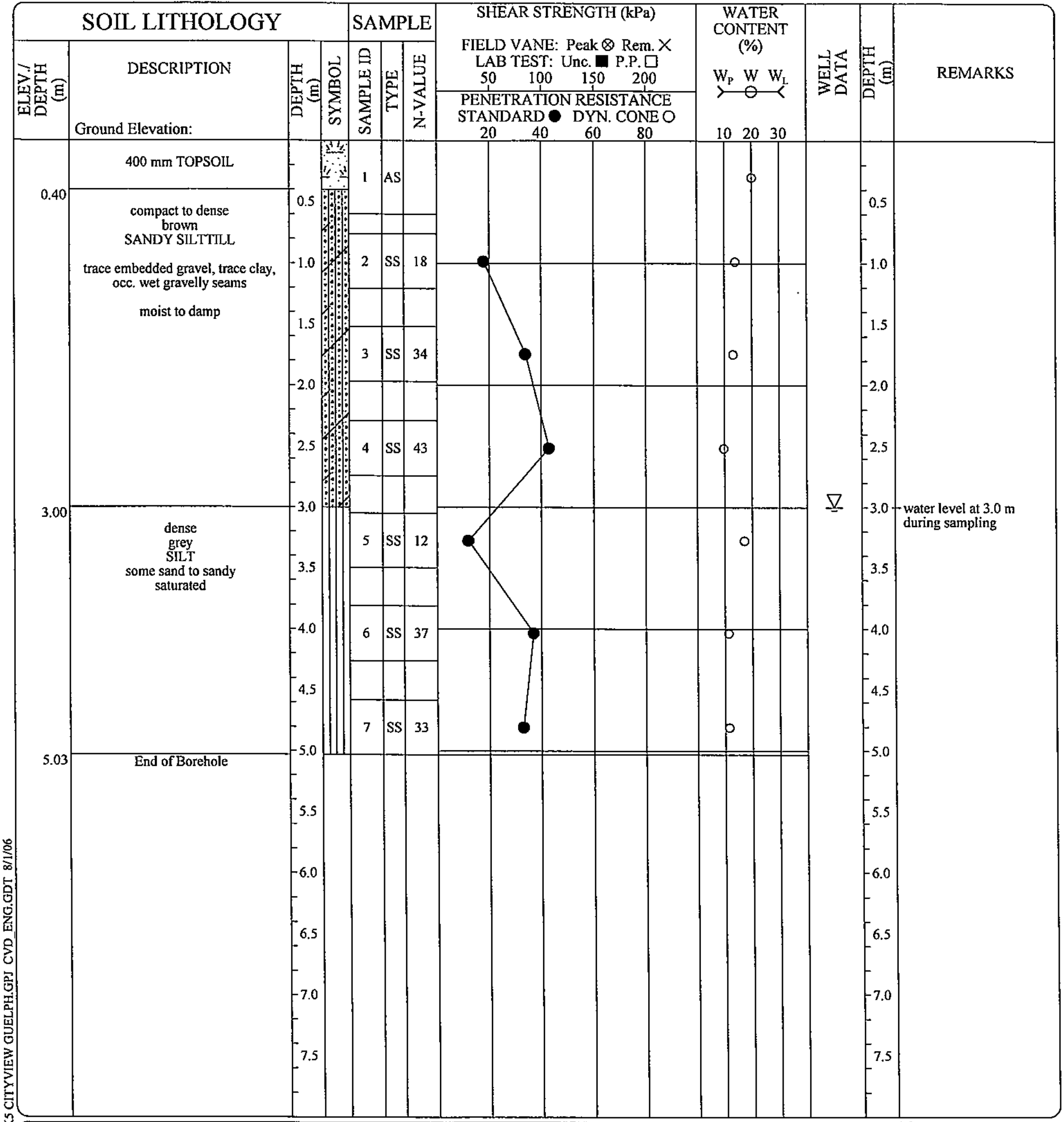
Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**



Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION
	400 mm TOPSOIL
0.40	compact to dense brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to damp
3.00	dense grey SILT some sand to sandy saturated
5.03	End of Borehole

SAMPLE ID	TYPE	N-VALUE
1	AS	
2	SS	18
3	SS	34
4	SS	43
5	SS	12
6	SS	37
7	SS	33

REMARKS: water level at 3.0 m during sampling

ENGINEER: **EYC**

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Kitchener, Ontario N2H 5E2
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Enclosure No.: 9
Sheet 1 of 1

FILE No: 06-7-K5

BOREHOLE No. 9

CHUNG & VANDER DOELEN CVD ENGINEERING LTD.

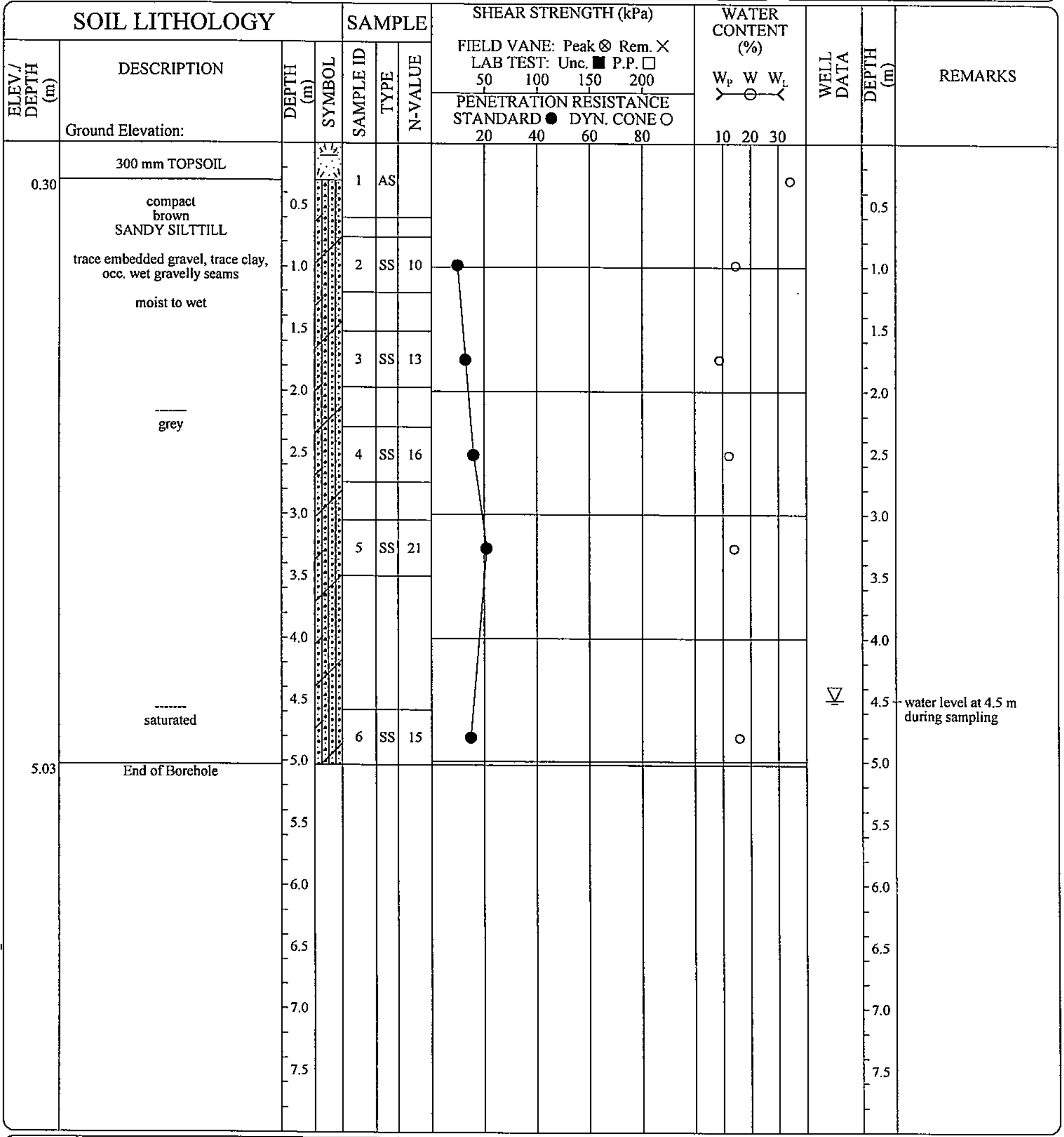
Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**



SOIL LITHOLOGY

ELEV./ DEPTH (m)	DESCRIPTION Ground Elevation:
	300 mm TOPSOIL
0.30	compact brown SANDY SILTTILL trace embedded gravel, trace clay, occ. wet gravelly seams moist to wet grey saturated
5.03	End of Borehole

SAMPLE

SAMPLE ID	TYPE	N-VALUE
1	AS	
2	SS	10
3	SS	13
4	SS	16
5	SS	21
6	SS	15

REMARKS

∇ 4.5 – water level at 4.5 m during sampling

ENGINEER: **EYC**

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ENGINEERING LTD.
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FILE No: 06-7-K5

BOREHOLE No. 10

Enclosure No.: 10
Sheet 1 of 1

CHUNG & VANDER DOELEN CVD ENGINEERING LTD.

Client: **Clarity Mortgage Inc.**

Project: **Proposed Residential Development, Cityview Drive**

Location: **Part of Lots 25, 31 & 32, Registered Plan 35, Guelph**

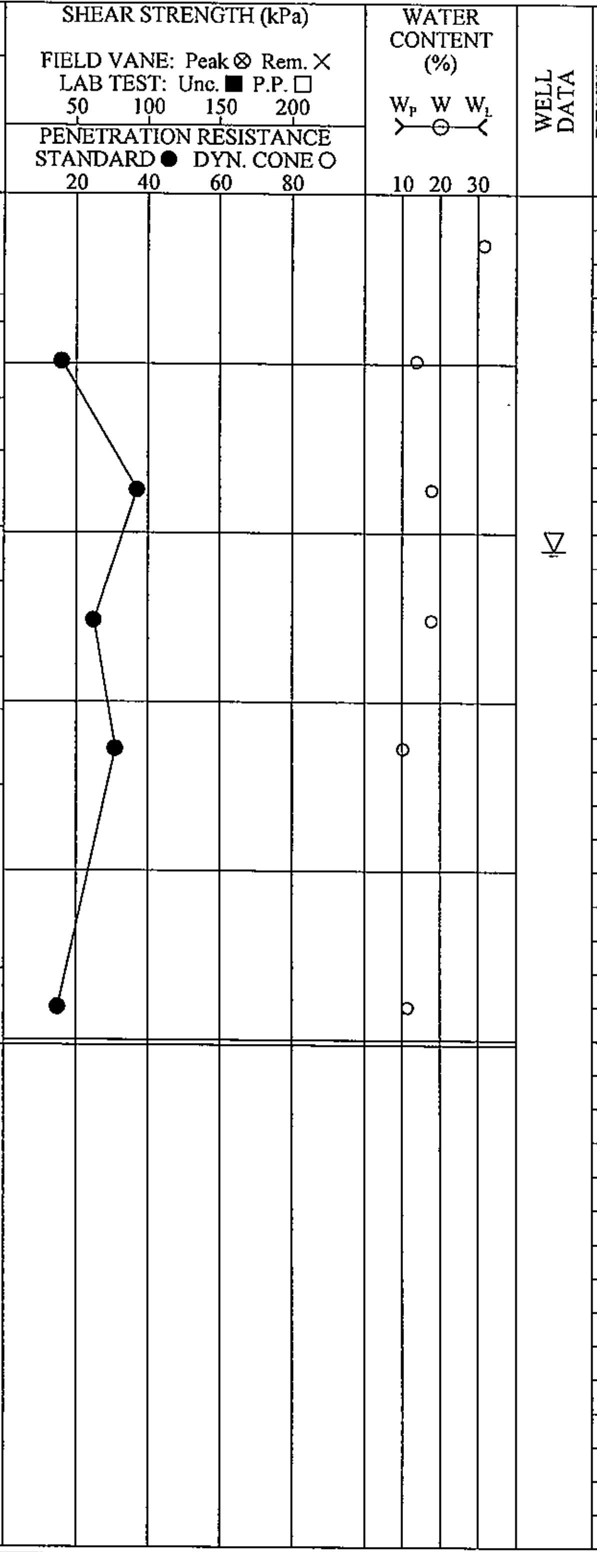
EQUIPMENT DATA

Machine: **CME 55**
Method: **S/S Auger**
Size: **150 mm**
Date: **Jul 14 06** TO **Jul 14 06**

SOIL LITHOLOGY

Ground Elevation:

ELEV./ DEPTH (m)	DESCRIPTION	SAMPLE ID	TYPE	N-VALUE
	900 mm TOPSOIL	1	AS	
0.90	compact to dense brown SANDY SILTTILL trace embedded gravel, trace clay moist to wet	2	SS	16
		3	SS	37
2.10	compact to dense grey SANDY SILT wet to saturated	4	SS	25
		5	SS	31
		6	SS	15
5.03	End of Borehole			



REMARKS

water level at 2.1 m during sampling

ENGINEER: **EYC**

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Kitchener, Ontario N2H 5E2
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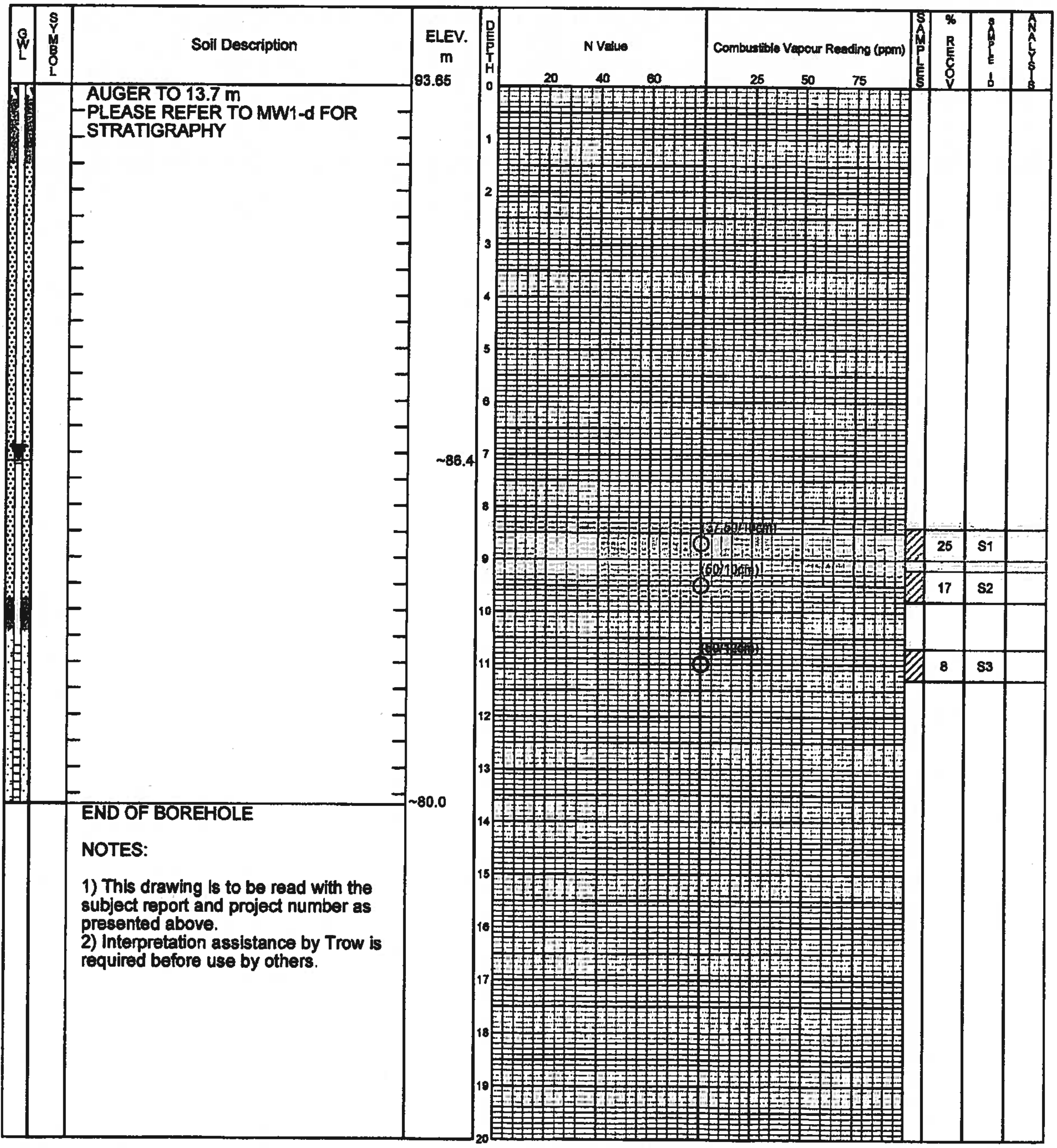
Log of Borehole MW1-s

Project No.	HAEN00399771A	Drawing No.	B2
Project:	Wetland Assessment	Sheet No.	1 of 1
Location:	Cityview Drive North, Guelph, ON Please refer to Borehole Location Plan		
Date Drilled:	January 11, 2010		
Drill Type:	Hollow Stem Augers		
Datum:	Relative (assume 100m)		

Chemical Analysis

BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		



AUGER TO 13.7 m
PLEASE REFER TO MW1-d FOR STRATIGRAPHY

END OF BOREHOLE

NOTES:

1) This drawing is to be read with the subject report and project number as presented above.
2) Interpretation assistance by Trow is required before use by others.

% RECOV	SAMPLE ID	ANALYSIS
25	S1	
17	S2	
8	S3	

ENVIRONMENTAL-HAMILTON LOGS.GPJ 1/28/10

Time	Water Level (m)	Depth to Cave (m)
January 14, 2010	6.40	
January 15, 2010	6.40	
January 20, 2010	6.41	
January 26, 2010	6.32	

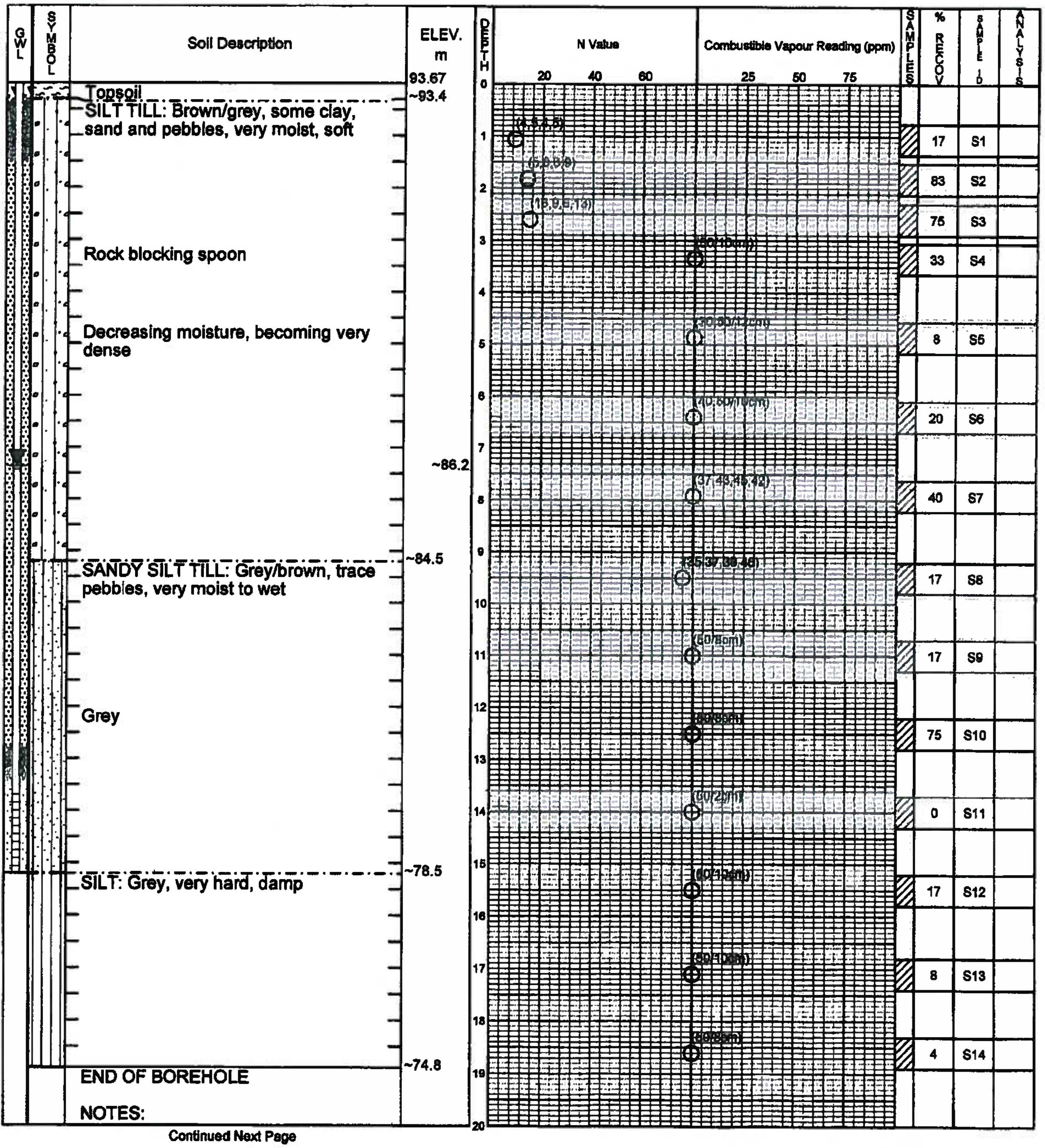
Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Log of Borehole MW1-d

Project No. HAEN00399771A
Drawing No. B1
Project: Wetland Assessment
Sheet No. 1 of 2
Location: Cityview Drive North, Guelph, ON
Please refer to Borehole Location Plan
Date Drilled: January 12, 2010
Drill Type: Hollow Stem Augers
Datum: Relative (assume 100m)

Chemical Analysis

BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		



Soil Description	ELEV. m
	93.67
Topsoil	~93.4
SILT TILL: Brown/grey, some clay, sand and pebbles, very moist, soft	
Rock blocking spoon	
Decreasing moisture, becoming very dense	
	~86.2
SANDY SILT TILL: Grey/brown, trace pebbles, very moist to wet	~84.5
Grey	
SILT: Grey, very hard, damp	~78.5
END OF BOREHOLE	~74.8
NOTES:	

% RECOV	SAMPLE ID	ANALYSIS
17	S1	
83	S2	
75	S3	
33	S4	
8	S5	
20	S6	
40	S7	
17	S8	
17	S9	
75	S10	
0	S11	
17	S12	
8	S13	
4	S14	

Continued Next Page

Time	Water Level (m)	Depth to Cave (m)
January 14, 2010	6.62	
January 15, 2010	6.62	
January 20, 2010	6.61	
January 26, 2010	6.51	

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Facsimile: 905-573-9693

Log of Borehole MW1-d

Project No. HAEN00399771A
Drawing No. B1
Project: Wetland Assessment
Sheet No. 2 of 2

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH	N Value 20 40 60	Combustible Vapour Reading (ppm) 25 50 75	SAMPLES	% RECOV	SAMPLE ID	ANALYSIS
		1) This drawing is to be read with the subject report and project number as presented above. 2) Interpretation assistance by Trow is required before use by others.	73.67	20						
				21						
				22						
				23						
				24						
				25						
				26						
				27						
				28						
				29						
				30						
				31						
				32						
				33						
				34						
				35						
				36						
				37						
				38						
				39						
				40						
				41						
				42						
				43						
				44						

ENVIRONMENTAL-HAMILTON LOGS.GPJ 1/28/10

Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Time	Water Level (m)	Depth to Cave (m)
January 14, 2010	6.62	
January 15, 2010	6.62	
January 20, 2010	6.61	
January 26, 2010	6.51	

Log of Borehole MW2-s

Project No. HAEN00399771A

Drawing No. B4

Project: Wetland Assessment

Sheet No. 1 of 1

Location: Cityview Drive North, Guelph, ON

Please refer to Borehole Location Plan

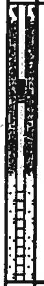
Date Drilled: January 13, 2010

Drill Type: Hollow Stem Augers

Datum: Relative (assume 100m)

Chemical Analysis

BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH	N Value (20, 40, 60)	Combustible Vapour Reading (ppm) (25, 50, 75)	SAMPLES	% RECOV	SAMPLE ID	ANALYSIS
		AUGER TO 4.6 m PLEASE REFER TO MW2-d FOR STRATIGRAPHY	82.66 ~81.0	0						
		END OF BOREHOLE	~78.1							

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

NOTES:

1) This drawing is to be read with the subject report and project number as presented above.
2) Interpretation assistance by Trow is required before use by others.

ENVIRONMENTAL-HAMILTON LOGS.GPJ 1/28/10

Time	Water Level (m)	Depth to Cave (m)
January 14, 2010	1.00	
January 15, 2010	1.00	
January 20, 2010	0	
January 26, 2010	0.66	

Trow
Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Log of Borehole MW2-d

Project No.	HAEN00399771A	Drawing No.	B3
Project:	Wetland Assessment	Sheet No.	1 of 1
Location:	Cityview Drive North, Guelph, ON Please refer to Borehole Location Plan		
Date Drilled:	January 13, 2010		
Drill Type:	Hollow Stem Augers		
Datum:	Relative (assume 100m)		

Chemical Analysis

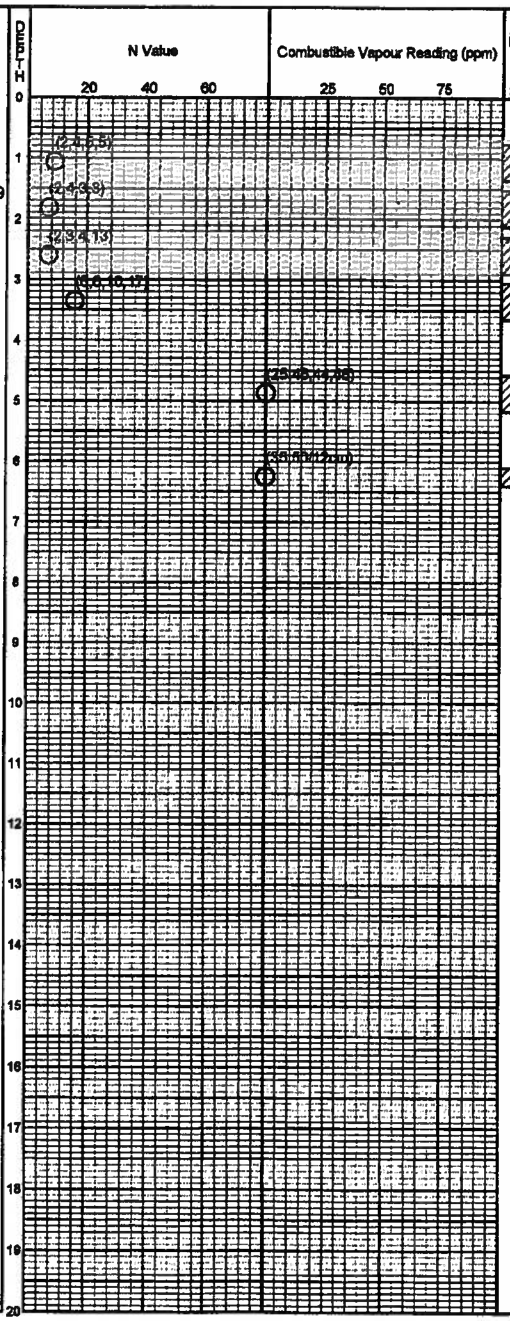
BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		

Soil Description	ELEV. m
	82.53
Topsoil, black silt with organics, very moist	~81.7
SANDY SILT: Grey, trace organics, very soft, very moist Rock blocking spoon	~80.9
	~80.2
SANDY SILT TILL: Brown, pebbles, very soft, wet	~79.4
SILT TILL: Grey, very moist to damp, becoming dense	~76.1

END OF BOREHOLE

NOTES:

1) This drawing is to be read with the subject report and project number as presented above.
2) Interpretation assistance by Trow is required before use by others.
3) Borehole advanced to inferred bedrock or boulder (auger refusal) at 6.4 m.



SAMPLES	% RECOV	SAMPLE ID	ANALYSIS
▨	50	S1	
▨	0	S2	
▨	50	S3	
▨	75	S4	
▨	50	S5	
▨	42	S6	

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Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Time	Water Level (m)	Depth to Cave (m)
January 14, 2010	1.42	
January 15, 2010	1.42	
January 20, 2010	1.09	
January 26, 2010	0.77	

Log of Borehole MW3-s

Project No. HAEN00399771A

Drawing No. B6

Project: Wetland Assessment

Sheet No. 1 of 1

Location: Cityview Drive North, Guelph, ON

Please refer to Borehole Location Plan

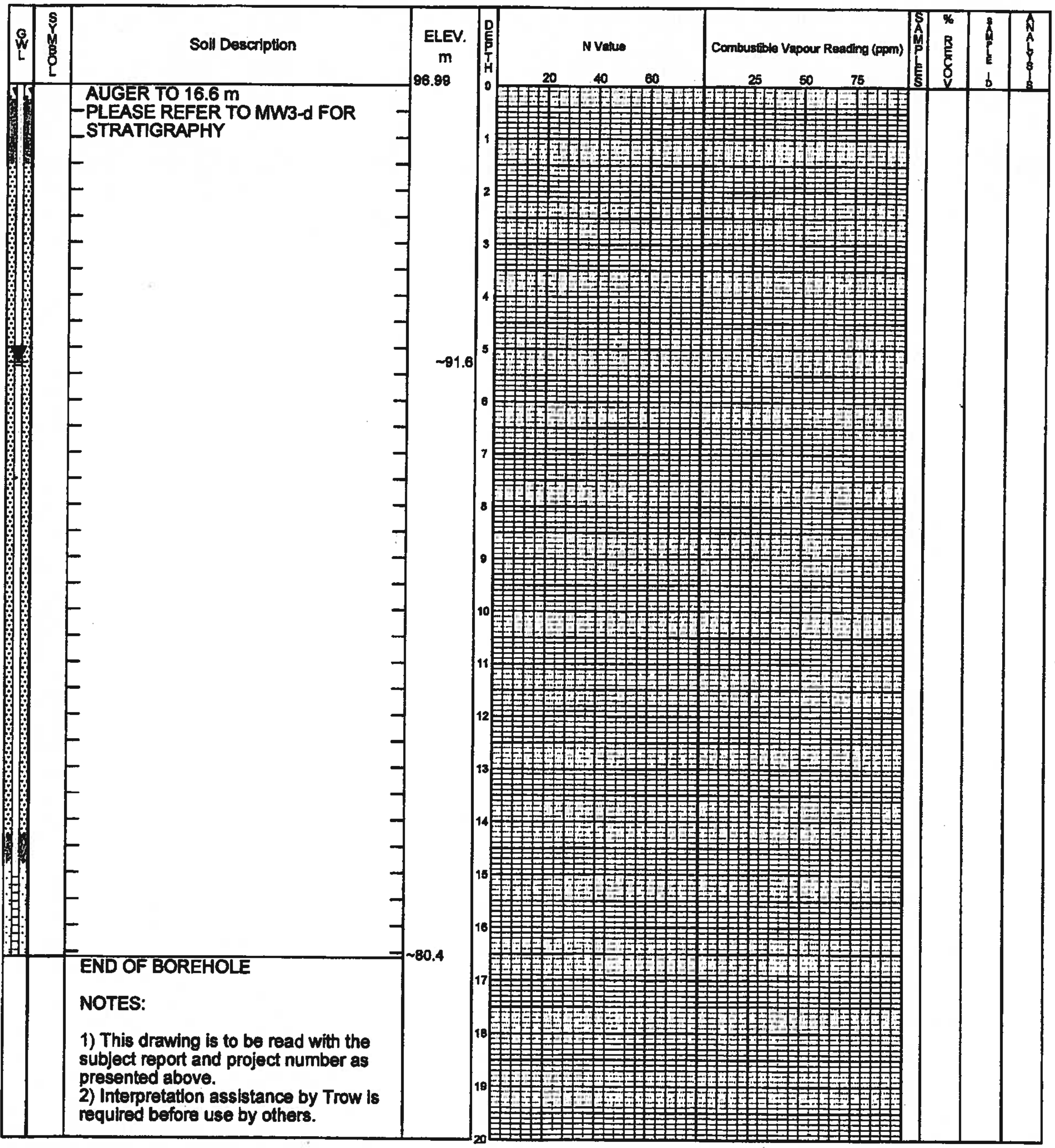
Date Drilled: January 14, 2010

Drill Type: Hollow Stem Augers

Datum: Relative (assume 100m)

Chemical Analysis

BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		



AUGER TO 16.6 m
PLEASE REFER TO MW3-d FOR STRATIGRAPHY

END OF BOREHOLE

NOTES:

1) This drawing is to be read with the subject report and project number as presented above.
2) Interpretation assistance by Trow is required before use by others.

Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Time	Water Level (m)	Depth to Cave (m)
January 20, 2010	14.7	
January 26, 2010	4.6	

Log of Borehole MW3-d

Project No. HAEN00399771A

Drawing No. B5

Project: Wetland Assessment

Sheet No. 1 of 2

Location: Cityview Drive North, Guelph, ON

Please refer to Borehole Location Plan

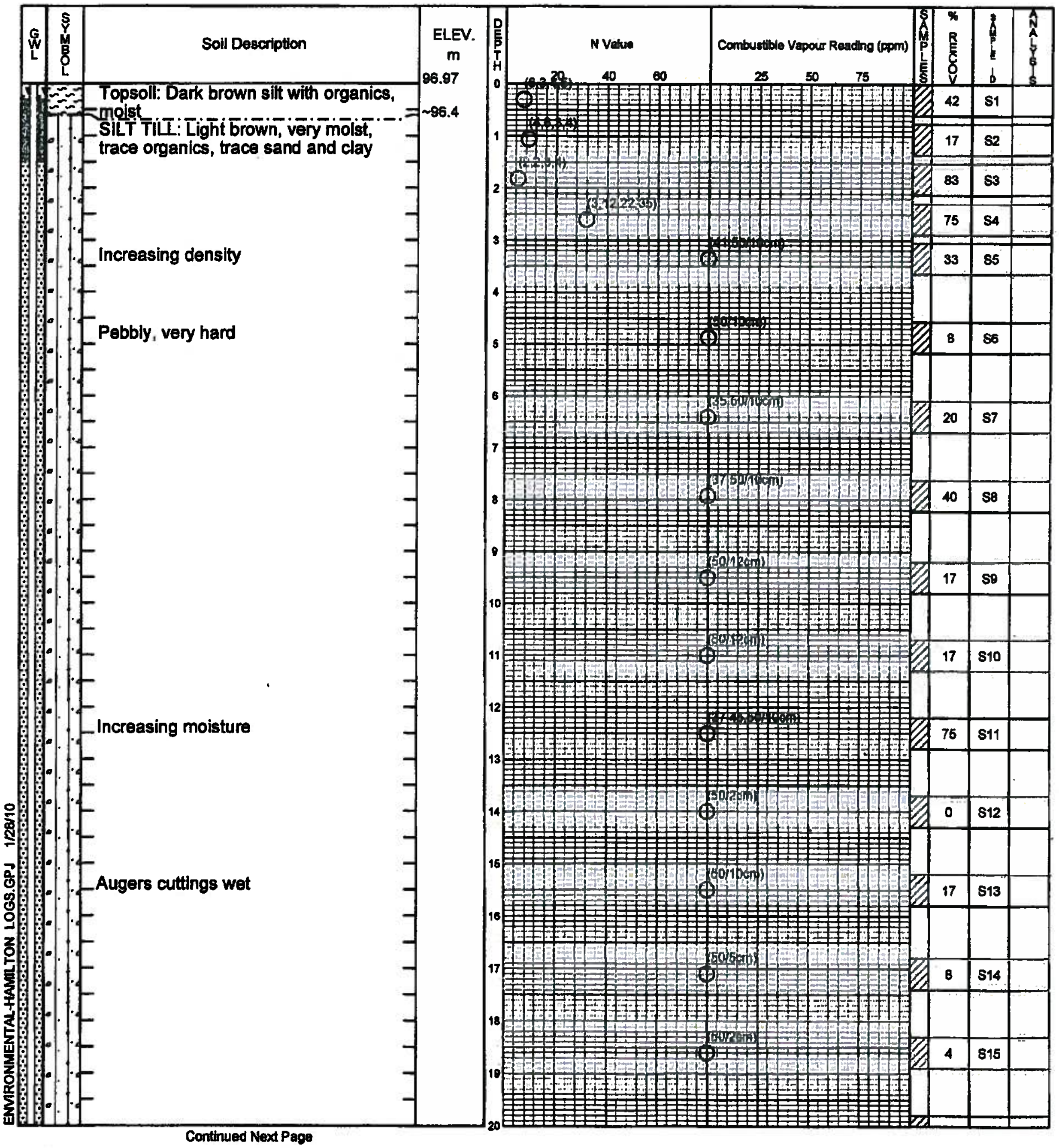
Date Drilled: January 20, 2010

Drill Type: Hollow Stem Augers

Datum: Relative (assume 100m)

Chemical Analysis

BTEX	Petroleum Hydrocarbons (F1) plus Benzene, Toluene, Ethylbenzene and Xylenes		
ING	Inorganics	PCB	Polychlorinated Biphenyls
MET	Metals	PHC	Petroleum Hydrocarbons (F2-F4)
PAH	Polycyclic Aromatic Hydrocarbons	VOC	Volatile Organic Compounds
*	Duplicate Sample		



Elev. (m)	Soil Description
96.97	Topsoil: Dark brown silt with organics, moist
~96.4	SILT TILL: Light brown, very moist, trace organics, trace sand and clay
	Increasing density
	Pebbly, very hard
	Increasing moisture
	Augers cuttings wet

% RECOV	SAMPLE ID
42	S1
17	S2
83	S3
75	S4
33	S5
8	S6
20	S7
40	S8
17	S9
17	S10
75	S11
0	S12
17	S13
8	S14
4	S15

Continued Next Page

ENVIRONMENTAL-HAMILTON LOGS.GPJ 1/28/10

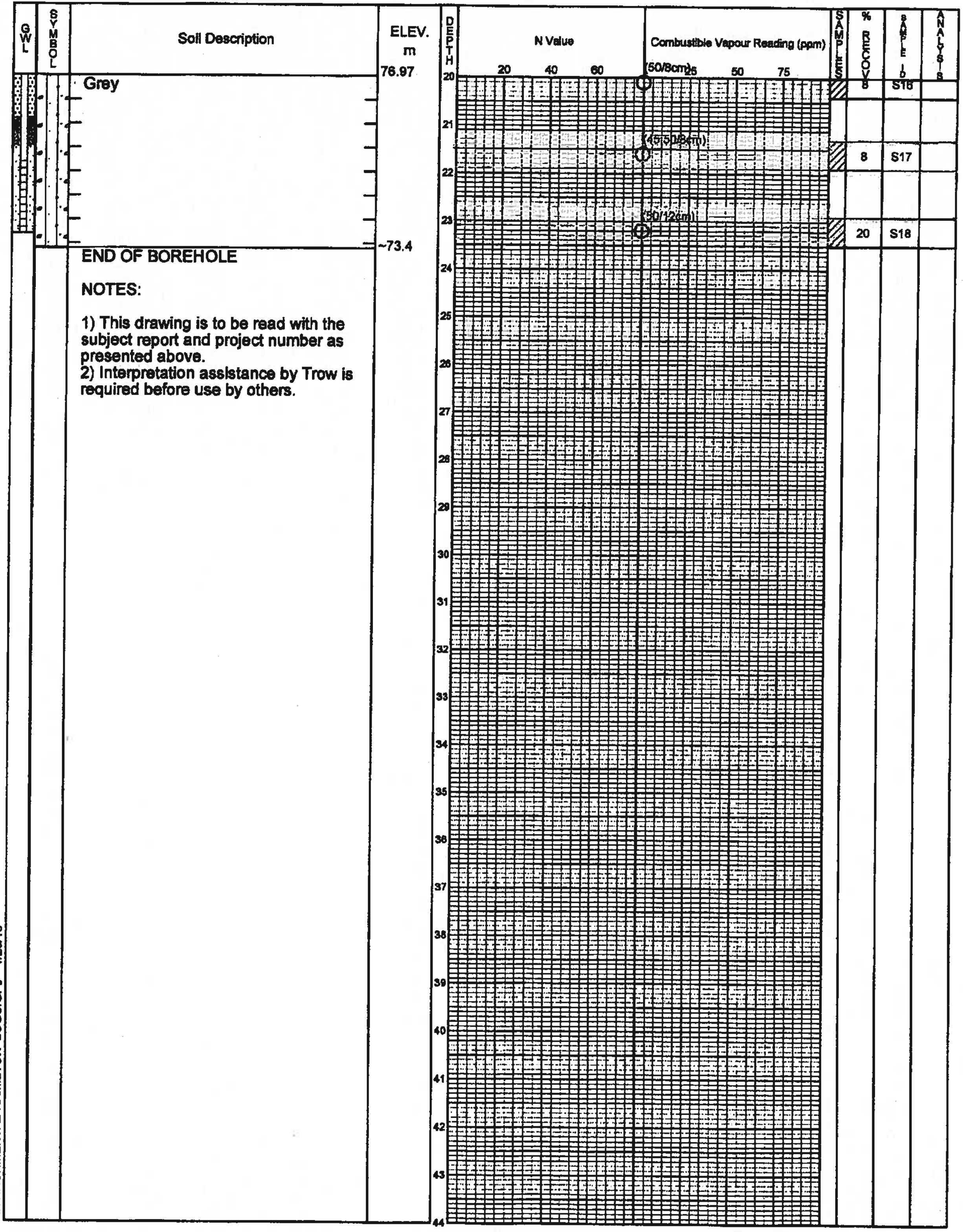
Time	Water Level (m)	Depth to Cave (m)
January 15, 2010	9.58	
January 20, 2010	10.9	
January 26, 2010		

Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Log of Borehole MW3-d

Project No. HAEN00399771A
Project: Wetland Assessment

Drawing No. B5
Sheet No. 2 of 2



% RECOV	SAMPLE ID
8	S16
8	S17
20	S18

Grey

END OF BOREHOLE

NOTES:

1) This drawing is to be read with the subject report and project number as presented above.
2) Interpretation assistance by Trow is required before use by others.

Trow
Trow Associates Inc.
Hamilton, Ontario
Telephone: 905-573-4000
Facsimile: 905-573-9693

Time	Water Level (m)	Depth to Cave (m)
January 15, 2010	9.58	
January 20, 2010	10.9	
January 26, 2010		

APPENDIX B

Pre- & Post-Development Water Balance Calculations

Tables 2 and 3

Table 2 (Page 1) - Pre Development Water Budget Calculations - Cityview Property Wetland

July 25 2013

Area 101-A (Steeply Sloped Grass Pasture): Evapotranspiration & Water Balance

Determination of Evapotranspiration and Water Balance - by Water Balance Method (Thornthwaite & Mather, 1957)

Precipitation: Waterloo-Wellington Normals (1966-1990), Vegetation: Deep-Rooted Pasture, Soil: Silt-Clay Loam

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	deg C	**6.59**		-7.3	-6.8	-1.5	5.8	12.5	17.0	19.9	18.7	14.3	8.0	2.5	-4.0
Heat Index (i)	-	**34.39**		0.00	0.00	0.00	1.25	4.00	6.38	8.10	7.37	4.91	2.04	0.35	0.00
UPET (unadjusted PET)	mm/day	**1.028**		0.00	0.00	0.00	0.90	1.98	2.71	3.19	2.99	2.27	1.25	0.38	0.00
latitude correction (r)	-			24.3	24.4	30.6	33.6	38	38.6	38.9	36	31.2	28.5	24.1	22.9
PET (Potential ET)	mm	**557.3**		0.0	0.0	0.0	30.2	75.1	104.7	124.1	107.7	70.8	35.6	9.1	0.0
Precipitation	mm	**917.0**	**100.0**	54.3	55.6	72.7	72.6	76.3	79.5	90.4	93.3	89.6	70.4	83.1	79.2
P - PET	mm			54.3	55.6	72.7	42.4	1.2	-25.2	-33.7	-14.4	18.8	34.8	74.0	79.2
Accum. Water Loss	mm							0.0	-25.2	-58.8	-73.2				
Soil Moisture Retention (Storage)	mm			250.0	250.0	250.0	250.0	250.0	226.0	196.0	186.0	204.8	239.6	250.0	250.0
Storage Change	mm			0.0	0.0	0.0	0.0	0.0	-24.0	-30.0	-10.0	18.8	34.8	10.4	0.0
AET (Actual ET)	mm	**548.0**	**59.8**	0.0	0.0	0.0	30.2	75.1	103.5	120.4	103.3	70.8	35.6	9.1	0.0
Water Balance as Surplus/Deficit	mm	**369.0**	**40.2**	54.3	55.6	72.7	42.4	1.2	-24.0	-30.0	-10.0	18.8	34.8	74.0	79.2

Determination of Water Balance as 'Combined-Runoff' (Recharge + Direct Runoff) - (for Large Watersheds using WBM Assumptions)

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Soil Moisture Surplus (SMS)	mm	**107.2**		0.0	0.0	0.0	42.4	1.2	0.0	0.0	0.0	0.0	0.0	63.6	0.0
Water Balance from SMS (Assumption 1)	mm	**107.2**		8.0	4.0	2.0	22.2	11.7	5.8	2.9	1.5	0.7	0.4	32.0	16.0
Accumulated Snow (Assumption 2)	mm	**261.8**		0.0	0.0	0.0	261.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Balance from Snow (Assumption 3)	mm	**261.8**		0.5	0.3	0.1	26.2	117.8	58.9	29.5	14.7	7.4	3.7	1.8	0.9
Water Balance as 'Combined-Runoff'	mm	**369.0**	**40.2**	8.5	4.3	2.1	48.4	129.5	64.8	32.4	16.2	8.1	4.1	33.8	16.9

Assumptions for Monthly 'Combined-Runoff' Estimations:

1 - Combined 'Runoff' from the Soil Moisture Surplus is assumed to be 50% in the first month and then 50% of the remaining soil surplus each following month.

2 - All Snow is Accumulated and Stored throughout Winter Sub-Zero Months (i.e. No melt until first above-zero month)

3 - Combined 'Runoff' from Snowmelt is assumed to be 10% of the Accumulated Snow in the first month and then 50% of the remaining snowmelt in each following month.

Area 101-A (Steeply Sloped Grass Pasture): Recharge & Direct Runoff Rates and Volumes

Determination of Recharge + Direct Runoff Components - using MOE Infiltration Factor Method (MOE 1995, 2003)

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water Balance as 'Combined-Runoff'	mm	**369.0**	**40.2**	8.5	4.3	2.1	48.4	129.5	64.8	32.4	16.2	8.1	4.1	33.8	16.9
Direct Runoff (70%)	mm	**258.3**	**28.2**	5.9	3.0	1.5	33.9	90.7	45.3	22.7	11.3	5.7	2.9	23.7	11.8
Recharge (30%)	mm	**110.7**	**12.1**	2.5	1.3	0.6	14.5	38.9	19.4	9.7	4.9	2.4	1.2	10.1	5.1

	MOE Infiltration Factors							Annual Rates			Area	Annual Volumes			
								Balance	Recharge	Runoff		Balance	Recharge	Runoff	Runoff
	Topography		Soil		Cover		Sum	(mm)	(mm)	(mm)	(m^2)	(m^3/yr)	(m^3/yr)	(m^3/yr)	+ 1/2 Re
Area 101-A	V. Hilly 7.5-15%	0.05	V. Dense Silt Till	0.1	Pasture Grass	0.15	0.3 (30 %)	369.0 100%	110.7 30%	258.3 70%	27,850	10,277	3,083	7,194	8,735

Table 2 (Page 2) - Pre Development Water Budget Calculations - Cityview Property Wetland

July 25 2013

Area 101-B (Steeply Sloped Vegetated/Treed Area): Evapotranspiration & Water Balance

Determination of Evapotranspiration and Water Balance - by Water Balance Method (Thornthwaite & Mather, 1957)

Precipitation: Waterloo-Wellington Normals (1966-1990), Vegetation: V. Deep-Rooted Vegetation/Trees Soil: Silt-Clay Loam

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	deg C	**6.59**		-7.3	-6.8	-1.5	5.8	12.5	17.0	19.9	18.7	14.3	8.0	2.5	-4.0
Heat Index (i)	-	**34.39**		0.00	0.00	0.00	1.25	4.00	6.38	8.10	7.37	4.91	2.04	0.35	0.00
UPET (unadjusted PET)	mm/day	**1.028**		0.00	0.00	0.00	0.90	1.98	2.71	3.19	2.99	2.27	1.25	0.38	0.00
latitude correction (r)	-			24.3	24.4	30.6	33.6	38	38.6	38.9	36	31.2	28.5	24.1	22.9
PET (Potential ET)	mm	**557.3**		0.0	0.0	0.0	30.2	75.1	104.7	124.1	107.7	70.8	35.6	9.1	0.0
Precipitation	mm	**917.0**	**100.0**	54.3	55.6	72.7	72.6	76.3	79.5	90.4	93.3	89.6	70.4	83.1	79.2
P - PET	mm			54.3	55.6	72.7	42.4	1.2	-25.2	-33.7	-14.4	18.8	34.8	74.0	79.2
Accum. Water Loss	mm							0.0	-25.2	-58.8	-73.2				
Soil Moisture Retention (Storage)	mm			400.0	400.0	400.0	400.0	400.0	376.0	345.0	333.0	351.8	386.6	400.0	400.0
Storage Change	mm			0.0	0.0	0.0	0.0	0.0	-24.0	-31.0	-12.0	18.8	34.8	13.4	0.0
AET (Actual ET)	mm	**551.0**	**60.1**	0.0	0.0	0.0	30.2	75.1	103.5	121.4	105.3	70.8	35.6	9.1	0.0
Water Balance as Surplus/Deficit	mm	**366.0**	**39.9**	54.3	55.6	72.7	42.4	1.2	-24.0	-31.0	-12.0	18.8	34.8	74.0	79.2
Determination of Water Balance as 'Combined-Runoff' (Recharge + Direct Runoff) - (for Large Watersheds using WBM Assumptions)															
Soil Moisture Surplus (SMS)	mm	**104.2**		0.0	0.0	0.0	42.4	1.2	0.0	0.0	0.0	0.0	0.0	60.6	0.0
Water Balance from SMS (Assumption 1)	mm	**104.2**		7.6	3.8	1.9	22.1	11.7	5.8	2.9	1.5	0.7	0.4	30.5	15.2
Accumulated Snow (Assumption 2)	mm	**261.8**		0.0	0.0	0.0	261.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Balance from Snow (Assumption 3)	mm	**261.8**		0.5	0.3	0.1	26.2	117.8	58.9	29.5	14.7	7.4	3.7	1.8	0.9
Water Balance as 'Combined-Runoff'	mm	**366.0**	**39.9**	8.1	4.1	2.0	48.3	129.5	64.7	32.4	16.2	8.1	4.1	32.3	16.1

Assumptions for Monthly 'Combined-Runoff' Estimations:

1 - Combined 'Runoff' from the Soil Moisture Surplus is assumed to be 50% in the first month and then 50% of the remaining soil surplus each following month.

2 - All Snow is Accumulated and Stored throughout Winter Sub-Zero Months (i.e. No melt until first above-zero month)

3 - Combined 'Runoff' from Snowmelt is assumed to be 10% of the Accumulated Snow in the first month and then 50% of the remaining snowmelt in each following month.

Area 101-B (Steeply Sloped Vegetated/Treed Area): Recharge & Direct Runoff Rates and Volumes

Determination of Recharge + Direct Runoff Components - using MOE Infiltration Factor Method (MOE 1995, 2003)

					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water Balance as 'Combined-Runoff'	mm	**366.0**	**39.9**		8.1	4.1	2.0	48.3	129.5	64.7	32.4	16.2	8.1	4.1	32.3	16.1
Direct Runoff (65%)	mm	**237.9**	**25.9**		5.3	2.7	1.3	31.4	84.2	42.1	21.0	10.5	5.3	2.7	21.0	10.5
Recharge (35%)	mm	**128.1**	**14.0**		2.8	1.4	0.7	16.9	45.3	22.7	11.3	5.7	2.8	1.4	11.3	5.6

	MOE Infiltration Factors							Annual Rates				Annual Volumes			
								Balance	Recharge	Runoff	Area	Balance	Recharge	Runoff	Runoff
	Topography		Soil		Cover		Sum	(mm)	(mm)	(mm)	(m^2)	(m^3/yr)	(m^3/yr)	(m^3/yr)	+ 1/2 Re
Area 101-B	V. Hilly 7.5-15%	0.05	V. Dense Silt Till	0.1	Woodland	0.2	0.35 (35 %)	369.0 100%	129.2 35%	239.9 65%	43,900	16,199	5,670	10,529	13,364
Total Areas 101-A and 101-B											71,750	26,476	8,753	17,723	22,099

Table 3 (Page 1) - Post Development Water Budget Calculations - Cityview Property Wetland

July 25 2013

Area 201-A (Sloped Lawns + Rooftops): Evapotranspiration & Water Balance

Determination of Evapotranspiration and Water Balance - by Water Balance Method (Thornthwaite & Mather, 1957)

Precipitation: Waterloo-Wellington Normals (1966-1990), Vegetation: Shallow-Rooted Grass, Soil: Silt Loam

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	deg C	**6.59**		-7.3	-6.8	-1.5	5.8	12.5	17.0	19.9	18.7	14.3	8.0	2.5	-4.0
Heat Index (i)	-	**34.39**		0.00	0.00	0.00	1.25	4.00	6.38	8.10	7.37	4.91	2.04	0.35	0.00
UPET (unadjusted PET)	mm/day	**1.028**		0.00	0.00	0.00	0.90	1.98	2.71	3.19	2.99	2.27	1.25	0.38	0.00
latitude correction (r)	-			24.3	24.4	30.6	33.6	38	38.6	38.9	36	31.2	28.5	24.1	22.9
PET (Potential ET)	mm	**557.3**		0.0	0.0	0.0	30.2	75.1	104.7	124.1	107.7	70.8	35.6	9.1	0.0
Precipitation	mm	**917.0**	**100.0**	54.3	55.6	72.7	72.6	76.3	79.5	90.4	93.3	89.6	70.4	83.1	79.2
P - PET	mm			54.3	55.6	72.7	42.4	1.2	-25.2	-33.7	-14.4	18.8	34.8	74.0	79.2
Accum. Water Loss	mm							0.0	-25.2	-58.8	-73.2				
Soil Moisture Retention (Storage)	mm			150.0	150.0	150.0	150.0	150.0	127.0	100.0	91.0	109.8	144.6	150.0	150.0
Storage Change	mm			0.0	0.0	0.0	0.0	0.0	-23.0	-27.0	-9.0	18.8	34.8	5.4	0.0
AET (Actual ET)	mm	**543.0**	**59.2**	0.0	0.0	0.0	30.2	75.1	102.5	117.4	102.3	70.8	35.6	9.1	0.0
Water Balance as Surplus/Deficit	mm	**374.0**	**40.8**	54.3	55.6	72.7	42.4	1.2	-23.0	-27.0	-9.0	18.8	34.8	74.0	79.2

Determination of Water Balance as 'Combined-Runoff' (Recharge + Direct Runoff) - (for Large Watersheds using WBM Assumptions)

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Soil Moisture Surplus (SMS)	mm	**112.2**		0.0	0.0	0.0	42.4	1.2	0.0	0.0	0.0	0.0	0.0	68.6	0.0
Water Balance from SMS (Assumption 1)	mm	**112.2**		8.6	4.3	2.2	22.3	11.7	5.9	2.9	1.5	0.7	0.4	34.5	17.2
Accumulated Snow (Assumption 2)	mm	**261.8**		0.0	0.0	0.0	261.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Balance from Snow (Assumption 3)	mm	**261.8**		0.5	0.3	0.1	26.2	117.8	58.9	29.5	14.7	7.4	3.7	1.8	0.9
Water Balance as 'Combined-Runoff'	mm	**374.0**	**40.8**	9.1	4.6	2.3	48.5	129.5	64.8	32.4	16.2	8.1	4.1	36.3	18.1

Assumptions for Monthly 'Combined-Runoff' Estimations:

1 - Combined 'Runoff' from the Soil Moisture Surplus is assumed to be 50% in the first month and then 50% of the remaining soil surplus each following month.
2 - All Snow is Accumulated and Stored throughout Winter Sub-Zero Months (i.e. No melt until first above-zero month)
3 - Combined 'Runoff' from Snowmelt is assumed to be 10% of the Accumulated Snow in the first month and then 50% of the remaining snowmelt in each following month.

Area 201-A (Modestly Sloped Lawns + Rooftops): Recharge & Direct Runoff Rates and Volumes

Determination of Recharge + Direct Runoff Components - using MOE Infiltration Factor Method (MOE 1995, 2003)

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water Balance as 'Combined-Runoff'	mm	**374.0**	**40.8**	9.1	4.6	2.3	48.5	129.5	64.8	32.4	16.2	8.1	4.1	36.3	18.1
Direct Runoff (70%)	mm	**261.8**	**28.5**	6.4	3.2	1.6	33.9	90.7	45.3	22.7	11.3	5.7	2.9	25.4	12.7
Recharge (30%)	mm	**112.2**	**12.2**	2.7	1.4	0.7	14.5	38.9	19.4	9.7	4.9	2.4	1.2	10.9	5.4

	MOE Infiltration Factors				Annual Rates				Annual Volumes			
					Balance	Recharge	Runoff	Area	Balance	Recharge	Runoff	Runoff
	Topography	Soil	Cover	Sum	(mm)	(mm)	(mm)	(m^2)	(m^3/yr)	(m^3/yr)	(m^3/yr)	+ 1/2 Re
Area 201-A	Sloped 0.1 2.5-5%	V. Dense 0.1 Silt Till	Lawn 0.1	0.3 (30 %)	374.0 100%	112.2 30%	261.8 70%	10,670	3,991	1,197	2,793	3,392
Rooftop Runoff to Backyards - Lots 120-145 (26 lots, 150m^2 roof area, 20% evapot, 60% runoff, 20% recharge)								3,900	2,861	715	2,146	2,503
Area 201-A (Including Supplemental Rooftop Runoff)								14,570	6,852	1,912	4,939	5,895

Table 3 (Page 2) - Post Development Water Budget Calculations - Cityview Property Wetland

July 25 2013

Area 201-B (Steeply Sloped Vegetated/Treed Area): Evapotranspiration & Water Balance

Determination of Evapotranspiration and Water Balance - by Water Balance Method (Thornthwaite & Mather, 1957)

Precipitation: Waterloo-Wellington Normals (1966-1990), Vegetation: V. Deep-Rooted Vegetation/Trees Soil: Silt-Clay Loam

	Units	Annual	% Total	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	deg C	**6.59**		-7.3	-6.8	-1.5	5.8	12.5	17.0	19.9	18.7	14.3	8.0	2.5	-4.0
Heat Index (i)	-	**34.39**		0.00	0.00	0.00	1.25	4.00	6.38	8.10	7.37	4.91	2.04	0.35	0.00
UPET (unadjusted PET)	mm/day	**1.028**		0.00	0.00	0.00	0.90	1.98	2.71	3.19	2.99	2.27	1.25	0.38	0.00
latitude correction (r)	-			24.3	24.4	30.6	33.6	38	38.6	38.9	36	31.2	28.5	24.1	22.9
PET (Potential ET)	mm	**557.3**		0.0	0.0	0.0	30.2	75.1	104.7	124.1	107.7	70.8	35.6	9.1	0.0
Precipitation	mm	**917.0**	**100.0**	54.3	55.6	72.7	72.6	76.3	79.5	90.4	93.3	89.6	70.4	83.1	79.2
P - PET	mm			54.3	55.6	72.7	42.4	1.2	-25.2	-33.7	-14.4	18.8	34.8	74.0	79.2
Accum. Water Loss	mm							0.0	-25.2	-58.8	-73.2				
Soil Moisture Retention (Storage)	mm			400.0	400.0	400.0	400.0	400.0	376.0	345.0	333.0	351.8	386.6	400.0	400.0
Storage Change	mm			0.0	0.0	0.0	0.0	0.0	-24.0	-31.0	-12.0	18.8	34.8	13.4	0.0
AET (Actual ET)	mm	**551.0**	**60.1**	0.0	0.0	0.0	30.2	75.1	103.5	121.4	105.3	70.8	35.6	9.1	0.0
Water Balance as Surplus/Deficit	mm	**366.0**	**39.9**	54.3	55.6	72.7	42.4	1.2	-24.0	-31.0	-12.0	18.8	34.8	74.0	79.2
Determination of Water Balance as 'Combined-Runoff' (Recharge + Direct Runoff) - (for Large Watersheds using WBM Assumptions)															
Soil Moisture Surplus (SMS)	mm	**104.2**		0.0	0.0	0.0	42.4	1.2	0.0	0.0	0.0	0.0	0.0	60.6	0.0
Water Balance from SMS (Assumption 1)	mm	**104.2**		7.6	3.8	1.9	22.1	11.7	5.8	2.9	1.5	0.7	0.4	30.5	15.2
Accumulated Snow (Assumption 2)	mm	**261.8**		0.0	0.0	0.0	261.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Balance from Snow (Assumption 3)	mm	**261.8**		0.5	0.3	0.1	26.2	117.8	58.9	29.5	14.7	7.4	3.7	1.8	0.9
Water Balance as 'Combined-Runoff'	mm	**366.0**	**39.9**	8.1	4.1	2.0	48.3	129.5	64.7	32.4	16.2	8.1	4.1	32.3	16.1

Assumptions for Monthly 'Combined-Runoff' Estimations:

1 - Combined 'Runoff' from the Soil Moisture Surplus is assumed to be 50% in the first month and then 50% of the remaining soil surplus each following month.
2 - All Snow is Accumulated and Stored throughout Winter Sub-Zero Months (i.e. No melt until first above-zero month)
3 - Combined 'Runoff' from Snowmelt is assumed to be 10% of the Accumulated Snow in the first month and then 50% of the remaining snowmelt in each following month.

Area 201-B (Steeply Sloped Vegetated/Treed Area): Recharge & Direct Runoff Rates and Volumes

Determination of Recharge + Direct Runoff Components - using MOE Infiltration Factor Method (MOE 1995, 2003)

				JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Water Balance as 'Combined-Runoff'	mm	**366.0**	**39.9**	8.1	4.1	2.0	48.3	129.5	64.7	32.4	16.2	8.1	4.1	32.3	16.1
Direct Runoff (65%)	mm	**237.9**	**25.9**	5.3	2.7	1.3	31.4	84.2	42.1	21.0	10.5	5.3	2.7	21.0	10.5
Recharge (35%)	mm	**128.1**	**14.0**	2.8	1.4	0.7	16.9	45.3	22.7	11.3	5.7	2.8	1.4	11.3	5.6

	MOE Infiltration Factors				Annual Rates			Area	Annual Volumes			
					Balance	Recharge	Runoff		Balance	Recharge	Runoff	Runoff
	Topography	Soil	Cover	Sum	(mm)	(mm)	(mm)	(m^2)	(m^3/yr)	(m^3/yr)	(m^3/yr)	+ 1/2 Re
Area 201-B	V. Hilly 0.05 7.5-15%	V. Dense 0.1 Silt Till	Woodland 0.2	0.35 (35 %)	374.0 100%	130.9 35%	243.1 65%	21,160	7,914	2,770	5,144	6,529

Total Areas 201-A (inlcuding Area 201-A supplemental rooftop runoff) and 201-B	35,730	14,765	4,682	10,083	12,424