Level I and II Hydrogeological Investigation Hidden Quarry Rockwood, Ontario

HARDEN ENVIRONMENTAL SERVICES LTD.
SEPTEMBER 2012

WWW.HARDENV.COM

Executive Summary

James Dick Construction Ltd. (JDCL) proposes to resume aggregate extraction from Part of Lot 1, Concession 6 in the Township of Guelph Eramosa. Sand and gravel has been extracted from this site on several occasions including for the construction of Provincial Hwy No. 7. The sand and gravel occurs as kame deposits and stony sand till deposits within the Paris Moraine complex. The site also contains well sorted glacial fluvial deposits of sand, gravel and silt. The dolostone bedrock formation beneath the site is the Amabel formation. The intent of James Dick Construction Ltd. is to extract both the sand and gravel and the dolostone from this site. The maximum depth of extraction will be approximately thirty metres below the water table. The extraction will be done without dewatering the excavation; therefore, minimal disturbance of water levels will occur.

The site is located on the Paris Moraine within the Grand River watershed and Blue Springs Creek subwatershed. Blue Springs Creek is located approximately one kilometer southeast of the site. Blue Springs Creek flows westerly and converges with the Eramosa River near Eden Mills. The Eramosa River is located approximately two kilometres northwest of the site, on the north side of the Paris Moraine.

The elevation of the site varies from 354 to 365 m AMSL compared with 382 m AMSL for the crest of the Paris Moraine and 325 m AMSL at Blue Springs Creek. This places the site approximately midway with respect to elevation between the crest of the moraine and Blue Springs Creek.

The overburden thickness in the area ranges from twenty five metres at the crest of the moraine to exposed bedrock outcrop near to the site. Overburden thickness at this site ranges from four to fifteen metres. The thinnest overburden occurs in the northwest area of the site. The overburden is mainly a product of the latest advance of the Lake Ontario ice lobe resulting in the deposition of the sandy Wentworth Till. Melt water sorted some of this till into sand, gravel and silt deposits as found at the site. Earlier glacial advances deposited silt tills that are also encountered at the site.

Drainage in the area is generally poorly developed due to the hummocky topography on the moraine; however, there are three nearby streams in which there is intermittent flow. Drainage is southward from the crest of the moraine towards Blue Springs Creek. Within 500 metres of the site there are no permanent streams between the crest of the moraine and Hwy 7 with the exception of a small stream originating at a spring on the Allen Farm on 6th Line (Tributary A) approximately 450 metres northwest of the site. Although this stream has perennial flow at the 6th Line, there is no permanent flow downstream (i.e. the stream loses water). There are streams with permanent flow between Hwy 7 and Blue Springs Creek located between 4th and 5th Line Nassagaweya and 5th and 6th Line Nassagaweya.

An intermittent stream is found within the site boundaries. The stream originates approximately 650 metres northwest of the site. Groundwater emerges from relatively permeable Wentworth Till deposits on the De Grandis property, enhanced by the construction of a pond. Water discharging from the pond flows through a Provincially Significant Wetland (Allen property) and into the JDCL property (Tributary B). Between the De Grandis property and the JDCL property there is limited loss of water due to silty surficial deposits. On the JDCL property, however, there is a total loss of stream flow for several months of the year. During periods of high flow, a culvert beneath Hwy #7 conveys stream flow onto the Brydson Farm and ultimately the drainage system ends at Blue Springs Creek.

There is a wetland located in the northwest corner of the site and wetlands found north and northeast of the site. The on-site wetland has an area of approximately one hectare and with the exception of a small pocket of open water, is observed to become largely dry during late summer and fall. There are no defined surface water channels associated with this wetland. This wetland occurs in a natural depression and is supported by runoff, direct precipitation and overburden groundwater from the north and west. Water losses from the wetland are evaporation, evapotranspiration, groundwater outflow downwards, southward and eastward.

The site is neither located in the Well Head Protection Area (WHPA) of the nearby Rockwood municipal wells, nor in the WHPA of the City of Guelph wells located in Puslinch Township. The Intake Protection Zone (IPZ-3) of the City of Guelph Eramosa River intake includes the on-site intermittent stream and all tributaries of the Eramosa River. The aggregate development of the site is not expected to contribute any storm water to surface water features as the site will drain internally.

Springs occur from overburden deposits on the southern flank of the Paris Moraine. Northwest of the site, this occurs in Lot 2, on both the Degrandis and Allen properties. These springs occur where the relatively permeable Wentworth Till deposits are underlain by a silt till deposit. The permeability contrast results in preferentially horizontal flow resulting in the discharge.

Horizontal groundwater flow is from the upland Paris Moraine area toward Blue Springs Creek. In general, this results in a northwest to southeast groundwater flow direction along the southern flank of the Paris Moraine. The predominant vertical groundwater flow direction is downwards.

Thirty-four groundwater monitors, eight surface water monitors and eleven surface water flow monitoring stations are included in the environmental monitoring at this site.

In general, groundwater only occurs above the bedrock in association with surface water features at the site, i.e. the northwest wetland and the on-site stream. Groundwater flow direction is generally from northwest to southeast. The on-site stream is not supported by groundwater from the site. The stream loses water along its entire reach within the subject property. Gravel and dolostone extraction will maintain a minimum setback distance of 20 - 30 metres from this feature.

The proposed extraction will remove the sand and gravel overburden at the site and the dolostone bedrock to an elevation of approximately 317 m AMSL. The sand and gravel will be extracted above the water table for the most part. A hydraulic barrier will be installed downgradient of the northwest wetland to minimize the loss of water from the wetland. The hydraulic barrier will retain groundwater levels beneath the wetland.

Extraction of the dolostone bedrock will be conducted with subaqueous methods. The rock will be made available through drill and blast methods and removed with a drag line. There will be no dewatering at this site.

It is estimated that the maximum disturbance of the potentiometric surface of the bedrock groundwater will be a 2.45 metre decrease along the northern edge of the quarry and at least a similar increase along the southern edge of the quarry.

A silt till overlies the bedrock in the vicinity of the northwest wetland. The silt till limits the hydraulic connection between the wetland and the bedrock, however, an increase in downward groundwater flow is likely to occur as a result of the aggregate extraction. The hydraulic barrier is designed to retain water in the wetland, thereby compensating for any potential loss of water via enhanced downward flow through the silt till. A pre and post extraction water balance for the wetland shows that during and after extraction the water balance of the wetland will be maintained. Hydraulic barriers have successfully been used to protect wetlands adjacent to other aggregate sites in Wellington County and elsewhere in Ontario.

The area of influence within the dolostone aquifer will extend beneath the Allen Wetland. Support hydrology for the wetland is neither derived from the bedrock aquifer nor is it reliant upon bedrock groundwater levels.

The area of influence will extend beneath the De Grandis and Allen springs. The springs arise from overburden groundwater originating from permeable sediments within the Paris Moraine to the north of the springs. Changes in the bedrock aquifer water levels in the source areas of these springs will be small and no significant change in spring discharge will occur.

Local water wells rely on the bedrock aquifer for a water supply. The decrease in water levels in bedrock wells will be minor compared to the available drawdown in the wells. The aquifer is productive and the maximum change in water levels is less than the natural seasonal variation and will not affect the yield of any local water wells.

The bedrock aquifer and wells completed in the bedrock aquifer are already subject to direct influence from surface water. All local streams experience a loss and at times a total loss of water as it recharges the aquifer below. In the process of doing so, agricultural nutrients and biological elements are being transported into the aquifer under existing conditions. This has resulted in the water quality of several local wells being impacted. While the quarry itself is not a potential source of contaminants, there is the potential for a transport pathway from the ground surface to the bedrock aquifer to be enhanced. The Region of Halton has already recognized the potential for biological issues in wells in this area and recommends that residences with bedrock wells be diligent with sampling for bacteriological contamination. In both phases of the Halton study it was noted that those wells with a recommended water treatment device (either a chlorinator or UV System) were significantly more likely to have bacteriologically safe drinking water.

Table of Contents Page No.

List of Figures
(Following Text)

List of Figures (Cont'd)

List of Appendices and Tables

1.0 INTRODUCTION

Harden Environmental Services Ltd. has been retained by James Dick Construction Ltd. (JDCL) to evaluate the potential impacts on groundwater and surface water resources from the proposed sand, gravel and dolostone extraction both above and below the water table in Lot 1, Concession 6, Township of Guelph/Eramosa, County of Wellington. Below-water-table extraction is proposed for the bedrock resource without dewatering. This approach minimizes the changes occurring to groundwater levels and results in a significant increase in groundwater storage.

The site is 38.08 ha in size and is located two kilometres east of Rockwood and 4.5 kilometres west of Acton. Figure 1.1 shows the site location within the Blue Springs Creek watershed. The site is located in an upland area of the Blue Springs Creek watershed. Figure 1.2 shows the Lot and Concession fabric local to the site. The site is located north of Provincial Highway No. 7 and east of the 6th Line Eramosa. Highway 7 is a municipal boundary between the Town of Milton and the Township of Guelph Eramosa. The road opposite the site in the Town of Milton is the 5th Line Nassagaweya. Lot numbers north of Highway 7 increase from Lot 1 and Lot numbers south of Hwy 7 decrease from Lot 32 in the Town of Milton (former Township of Nassagaweya). Figure 1.3 shows local topography and the site's location relative to significant features such as the Canadian National rail line, the Eramosa River and Blue Springs Creek.

The property is presently recognized on the County of Wellington's Official Plan as part of the Mineral Aggregate Overlay. The present zoning on the property is agriculture. Several areas of the site have previously been used for gravel extraction. A wetland is located along the western corner of the property boundary and an intermittent stream flows from northwest to southeast across the eastern half of the site.

This report describes in detail the groundwater and surface water resources around the site, the potential effects of the mining process on water resources and recommends actions that will minimize impacts to water resources. Features and properties discussed in this report are shown on Figure 1.4. This report has been written to satisfy the requirements of Level 2 hydrogeological reports as required under the Aggregate Resources Act. This Level 2 hydrogeological report includes a discussion of the following items:

- water wells;
- springs;
- groundwater aquifers;
- surface watercourses and bodies;
- discharge to surface water;
- proposed water diversion, storage and drainage facilities on site;

- methodology;
- description of the physical setting including local geology, hydrogeology, and surface water systems;
- water budget;
- groundwater modelling;
- impact assessment;
- mitigation measures, including trigger mechanisms;
- contingency plan;
- monitoring plan; and
- technical support data in the form of tables, graphs and figures, usually appended to the report.

The site is located in an area of secondary significance with regards to sand and gravel resources and within “Selected Bedrock Resource Area 1" (MNR, 1981). The bedrock resource is the Amabel Formation.

2.0 METHODOLOGY

2.1 DOCUMENT REVIEW

The first phase of this investigation included a review of previously written work related to the groundwater, geology, hydrology and hydrogeology of the area surrounding the site. The following documents and reports were included in the review:

- Hydrogeology and Ground Water Model of the Blue Springs Creek IHD Representative Drainage Basin, 1978, prepared by J.M.H. Coward and M Barouch of the Ontario Ministry of the Environment;
- Beak International Incorporated, 1999, Eramosa Blue Springs Creek Watershed Interim Report;
- Burt, A.K., 2011, Project Unit 08-003; The Orangeville Moraine Project: Preliminary Results of Drilling and Section Work;
- Burt, A.K. and Rainsford, DK.B., 2010, Project Unit 08-003, The Orangeville Moraine Project: Buried Valley Targeted Gravity Study;
- Eramosa River - Blue Springs Creek Linear Corridor Initiative, 1995, prepared by Procter and Redfern Limited for the Grand River Conservation Authority;
- Acton Property Lot 1 Concession 6, Township of Eramosa, County of Wellington Preliminary Report (June 1990) prepared by Ken W. Ingham P. Eng. for James Dick Construction Limited;
- Influence of Vertical Fractures in Horizontally-Stratified Rocks, by Todd M. Reichart, M.Sc. Thesis University of Waterloo;
- Aerial photographs for this site (April 1930, April 1964, June 1972, April 1980, May 1994 and Spring 2006);
- Published geological and hydrogeological maps and reports;
- Environment Canada precipitation data;
- Ministry of the Environment Water Well Records; and
- Gartner Lee Limited, April 2004, Guelph/Eramosa Township Regional Groundwater Characterization and Wellhead Protection Study

The Acton Property Lot 1 Concession 6, Township of Eramosa, County of Wellington Preliminary Report (June 1990) prepared by Ken W. Ingham provides site specific geological data. Portions of this report have been included in the relevant appendices of this report and are discussed throughout. Ken Ingham reported on the borehole completion and monitoring well installation at four locations (M1 to M4, inclusive) which are shown on Figure 2.1. Borehole logs and monitor completion details in Table A1 (Appendix A) have been prepared from this report and from discussions with the author. The Ingham report also indicates that a total of twenty three soil samples were submitted for grain size analysis. The results of these analyses are included in Appendix A.

The on-site project investigation completed by Harden Environmental commenced in April 1995 and has included excavating nine test pits, installation of twelve mini-piezometers, installation of eleven drive point monitors, installation of seven drilled monitors, establishing fifteen surface water monitoring locations, hydraulic testing, monitoring groundwater levels and geochemical sampling. These activities are described in detail in the following subsections.

2.2 SOIL SURVEY

A detailed soil investigation of the site was undertaken in September 1996. Seven test pits were excavated across the site (Figure 2.1). The soil stratigraphy observed in the test pits is shown in Appendix A. Soil samples were collected of representative geological units encountered. Four soil samples were submitted for grain size analyses. The results of these grain size analyses are found in Appendix A. Bedrock was encountered in test pit (TP2) at a depth of six metres below ground surface (mbgs).

Drive points were installed in the three test pits (TP1, TP2, and TP5) where the presence of groundwater was observed or suspected. Water levels measured in these monitors are provided in Appendix B (Table B1). The stand pipe at TP5 was destroyed prior to March 1997.

In February 2012, two additional test pits were excavated, one in the northeast corner of the property (TP8) and one along the eastern property boundary (TP9). The stratigraphy of the test pits is provided in Appendix A. Bedrock was encountered at TP9 at a depth of approximately 4.5 metres below ground surface (mbgs). Stand pipes were installed in test pits TP8 and TP9, water levels are provided in Appendix B (Table B1).

Four 25 mm holes were hand-augered in the northwest wetland. These locations are designated SP1 to SP4 with locations shown on Figure 2.2. A description of the soil profile is found in Table A2 in Appendix A.

Several 50 mm diameter holes were hand-augered with a Dutch Auger in the Allen Wetland. The locations of the holes are shown on Figure 2.3 and the soil descriptions are found in Table A2 Appendix A. Three samples were submitted for grain size analysis and are designated AW7, AW8 and AW11 in Appendix A.

Additional detailed soil testing was conducted for the Lot 1, Concession 6 E½. Eight boreholes were drilled and soils described in detail (England Naylor, 1989).

A summary of all grain size analyses is presented in Table A3.

2.3 GROUNDWATER MONITOR INSTALLATIONS

A summary table of all groundwater monitors is found in Table A1, borehole logs are found in Appendix A.

Four groundwater monitors were installed in the boreholes drilled by Ken Ingham in 1990. These are all of PVC construction and have a diameter of 50 mm. As summarized in Table A1, these monitors, designated as M1 through M4, are bedrock groundwater monitors.

Drive point groundwater monitors were installed at six locations (M5 to M10, inclusive) between April 1995 and April 1998. The purpose of these groundwater monitors is to monitor the shallow water table in the overburden aquifer and to show the interconnection between the on-site surface water in the stream, the pond and the shallow groundwater system. Drive point groundwater monitors placed in test pits (TP1, TP2, TP5, TP8, and TP9) were also installed in September 1996 and February 2012. These drive points were driven into the base of a test pit prior to the test pit being filled in with the native material.

The installation of these groundwater monitors was accomplished by driving a 0.6 metre long screened drive point into the ground. This screened drive point was threaded to 3 cm (1.25 inch) diameter steel pipe. The completion details of these monitors are provided in Table A1 and water level data collected from these monitors is provided in Table B1. M5 was installed through an existing shallow dug well.

In 2010, seven additional boreholes were drilled on Site with a combination auger and coring rig. Installation of two shallow bedrock monitoring wells and five overburden monitoring wells was completed within the drilled boreholes. These wells were labeled M1-S, M11, M12, M13-S, M13-D (bedrock), M14-S, and M14-D (bedrock). Borehole logs for the seven new borehole monitoring wells are present in Appendix A.

TP8 was installed to establish the relationship between groundwater and the northeast wetland. TP9 was installed to determine groundwater levels at the southern edge of the proposed quarry.

In July 2009, six mini-piezometers (MPS1, MPS2, MPN1, MPN2, MPE1, and MPE2) were installed in order to establish groundwater discharge/recharge relationships and calculate gradients along the perimeter of the on Site wetland feature (northwest wetland). The mini-piezometers are constructed of 18 mm steel pipe with a Solinst™ Drive Point Piezometer. Two additional mini-piezometers (MPW1 and MPW2) were installed in January 2011. Figure 2.1 provides the locations of these monitors and Table B1 summarizes the results of monitoring.

In December 2010, four mini-piezometers (MP1, MP2, MP3, and MP4) were installed along Tributary B to establish recharge/discharge relationships between the stream and the surrounding groundwater table. Figure 2.1 provides the locations of these monitors and Table B1 summarizes the results of monitoring.

2.4 SURFACE WATER MONITORING LOCATIONS

Fourteen surface water monitoring locations (RS1 and SW1 to SW12, inclusive) were established within and nearby to the Site (Figure 2.4) during the course of this investigation. The purposes and activities conducted at each of these locations varied. SW1 and SW6 (replaced destroyed SW1) were established in the northwest wetland to monitor the surface water levels in the open water portion of the wetland.

Surface water monitoring stations SW2, SW3, SW4, SW5, and SW7 (replaced destroyed SW2), SW8 and SW9 were established in Tributary B to monitor surface water levels (stage) in the stream. Stage measurements were measured on a staff gauge at each location (Table B2, Appendix B), which have been surveyed relative to the geodetic datum. SW5 was established adjacent to M9 to investigate the interaction between the surface water in the stream and the adjacent shallow groundwater levels. In addition to stage level measurements, in 2007 and 2008 stream flows were measured in the stream at SW7, and since 2009 stream flows have been measured immediately downstream of the small culvert at SW8 where the stream exits the property at the eastern boundary. Additionally, stream flow measurements and observations were recorded where the stream enters the site (SW4) and where it flows under Highway 7 (SW3). All surface water flow monitoring data is included in Table C1 Appendix C.

Stream flows and surface water levels have also been measured where Tributary A crosses under 6th Concession Road at hydrologic monitoring location RS1.

In late 2011 and early 2012, stream flows were measured in Tributary C at hydrologic monitoring station SW10. This represents flow in Tributary C prior to entering Concession 6.

Stream flow measurements were also obtained at SW11 and SW12 to verify the gaining/losing nature of Tributary C.

Stream flows were obtained at SW9 and SW4 to determine loss/gain within the Allen Wetland.

Stream discharge measurements were generally made with a Price 1210A velocity meter prior to and including 2007 and with a Marsh McBirney velocity meter post 2007 at all stream hydrologic monitoring locations. Prior to 1999, stream flows were measured with a pail at SW3.

2.5 HYDRAULIC TESTING

Hydraulic testing was conducted on monitors M6, M9 and M10 in April 1998. Additional testing was conducted in January 2011 at monitors adjacent to the on Site wetland at locations M1S, M6, M13S, M13D, M14S, M14D, MPS1, MPS2, MPW1, MPW2, MPN1, MPN2, MPE1, and MPE2. This testing was conducted using the Falling Head Method. The falling head method involves adding a known volume of water into the monitoring well and measuring the water level as it returns to pre-test or static level. The observed change in the water level with time was converted to a hydraulic conductivity using the Hvorslev method (Freeze and Cherry, 1979). The data obtained in April 1998 from M9 was also analyzed using the Bouwer-Rice method (Kruseman and de Ritter, 1991). The data and analyses of these tests are included in Appendix D and summarized in Table D1.

Falling head testing was conducted at bedrock groundwater monitors M1D, M2, M3 and M4 in November 2011. Results are provided in Table D1.

Monitors M2, M4 and well 6705627 were tested by installing a pump and removing water at a constant rate for a short duration. The pumping test data was graphed and analyzed for transmissivity using a method based on the semi-log graphical analysis method. The graphs are found in Appendix D and the results are summarized in Table D1.

A twenty-four hour pumping test was conducted in a well located in Lot 1, Concession 6 E½ in 1998 and reported in Harden, 1998. This well is 39.32 metres deep and penetrates the dolostone aquifer to a similar depth of the proposed quarry. Several observation wells were monitored during the test and estimates of transmissivity and storativity of the aquifer were obtained. The observations are found in Appendix D.

2.6 GROUNDWATER LEVEL MONITORING

Groundwater levels were obtained from monitoring wells, drive point monitors and staff gauges since April 1995. Groundwater levels were obtained using an electric water level meter. The data from all groundwater monitoring is provided in Appendix B as Table B1 and individual hydrographs are presented in figures B1 through B12. All monitoring points have been level surveyed relative to a NAD 83 geodetic datum allowing groundwater levels to be expressed as groundwater elevation data in metres above mean sea level (m AMSL).

2.7 WATER QUALITY

Water quality analyses were conducted on six groundwater monitors (M1 to M5, inclusive and TP1), four surface water bodies (Allen Farm Stream at RS1, on Site stream at SW3, on Site wetland at SW1, and Blue Springs Creek at 5th Concession Road) on November 21, 1996. The locations of these water quality sampling points are shown on Figure 2.5. The water at these locations was analyzed for general inorganic chemistry (anions and cations). The results of this testing are provided in Appendix E.

A water quality sample was obtained from on-site well No. 6705627 and the results are provided in Appendix E.

2.8 WATER WELL SURVEY

A review of the Ministry of the Environment (MOE) well records (February, 2012) for the area was conducted of all reported wells within a one kilometer radius of the site. This review revealed that a total of fifty-nine wells are reported to be present in this area. The reported MOE water well records within this one kilometre radius of the site are shown on Figure 2.6 and are included in Appendix F as Table F1. The locations of water wells shown on this figure are as reported by the MOE. Adjustments to well locations have been made for some wells following the water well survey and the adjusted well locations were used in the groundwater model, static water level reporting and top of bedrock reporting. Although all readily available MOE well records were collected for this area it is reasonable to assume that not all water wells in the area are identified or located accurately. As a result, a door-to-door water well survey was also conducted (1998 and 2011/12) to identify the neighbouring water wells and springs. The results of this water well survey are shown on Figure 2.7 and Table G1.

Based on the MOE water well records it was found that there are a total of five wells (8.2%) which are reported to be completed into the overburden aquifer. Most of these overburden wells (MOE wells # 6708802, 6708308, 6700542 [observation well drilled by MOE] and 2805656) are situated approximately one kilometre to the southwest of the site, near the bend in Highway No. 7. The fifth overburden well (MOE Well Number 2805499) is situated approximately one kilometre northeast of the site.

MOE well records show that the majority (91.8%) of the water wells within a one kilometre radius of the site obtain their water from the bedrock aquifer. There are no dry wells reported in this area and most of the wells appear to be capable of being pumped at rates of greater than 0.61 L/s (8 IGPM), based on the pumping tests performed during well completion. These MOE well records also indicate that the available drawdown, based on the difference between the reported static level and one metre above the bottom of the well, are generally greater than five metres and the average is greater than nineteen metres.

The door-to-door survey identified twenty-three water wells within a five hundred metre radius of the site. The majority (91%) of these wells obtain their water from the bedrock aquifer. The survey identified two water wells (9%) which are completed into the overburden (No. 2 and 6). Well No. 6 is an unused water well situated in a field approximately 160 metres southwest of the site. This well was discovered through discussions with Mr. Gordon Ball. The depth of Well No. 6 is 3.58 metres below top of casing (m BTOC) and the water level on April 21, 1998 was 3.35 m BTOC. It is unknown whether this well has gone dry in the past.

Well No. 2 is no longer used by the neighbouring mushroom farm for their drinking water supply. It is occasionally used for cleaning purposes. According to the owner, the pumping rate from this dug well is approximately 1.36 L/s (18 IGPM) and the depth of this well is 3.97 metres below top of casing (m BTOC). Well No. 3 is being used seasonally in the cooling system for the mushroom farm at a rate of between 80 and 100 gallons per minute.

2.9 GROUNDWATER MODEL

A groundwater model was prepared from for an area of approximately six kilometers radius of the Site. Available data was input into Viewlog™ and Modflow™ to create a model of groundwater potentials for the bedrock aquifer. Details of the groundwater model and results are found in Appendix H.

The purpose of the model was to estimate the potential change in water levels in the bedrock aquifer.

3.0 PHYSICAL SETTING

The setting is described below in terms of; physiography, surface water features, geology, hydrogeology, climatic setting and hydrology.

3.1 PHYSIOGRAPHY

The site is located in the Horseshoe Moraine Physiographic region (Chapman and Putnam, 1984) (Figure 3.1). The site is located in the upland area of the Blue Springs Creek Watershed on the Paris Moraine (Figure 3.2). The Paris Moraine extends from Cambridge to Caledon. The maximum ground surface elevation of the moraine northwest of the site is approximately 382 m AMSL. At the crest of the moraine, the overburden thickness exceeds twenty five metres, however, at the site, the overburden thickness is generally less than eight metres. The crest of the moraine is the watershed boundary between Blue Springs Creek and the Eramosa River. The Eramosa River is located approximately 2.5 kilometers north of the site at an approximate elevation of 380 m AMSL. The Ontario Geological Survey has investigated a buried valley between the crest of the moraine and the Eramosa River and found that the valley infill is as much as 85 metres (Burt et. al, 2010). This suggests that the bedrock elevation at the bottom of the buried valley is less than 320 m AMSL, thus lower than the present day Blue Springs Creek. Glacial activity resulted in the filling of the bedrock valley north of the site but left the Blue Springs Creek valley open. The influence of the sand and gravel aquifers within the buried valley on regional groundwater flow has not been investigated. It is thought that the buried valley occupies an area of structural weakness in the bedrock, originating from the escarpment near Erin.

Blue Springs Creek is located 1000 m southeast of the site at an elevation of approximately 325 m AMSL. The Blue Springs Creek valley is broad and deeply incised into the surrounding bedrock. Between the site and Blue Springs Creek there are many rock outcrops.

The river valleys of the Eramosa River and Blue Springs Creek predate the most recent glacial advances and thus were not likely formed by meltwater from the glaciers that formed the Paris Moraine.

The elevation of the site ranges from 354 to 365 metres above mean sea level (m AMSL). The site has gently rolling topography with the exception of the southeast corner where higher relief is associated with hummocky terrain (Figure 3.3).

3.2 CLIMATIC SETTING

As part of their study of the Blue Springs Creek Basin Coward and Barouch (1978) conducted a water balance analysis using data from October 1966 to 1972. Using these data they calculated the following average annual values for the entire basin:

Annual Precipitation (P)	= 901 mm/yr
Annual Actual Evapotranspiration (AET)	= 517 mm/yr
Annual Evaporation (Open Water)	= 652 mm/yr

An updated study of climatic data obtained from the Environment Canada weather station at Shand Dam in Fergus, Ontario located twenty two kilometers northwest of the Site was performed. The last forty-six years of data from 1965 to 2011 was analyzed using the Thornthwaite method and the resulting average annual values are as follows:

Annual Precipitation (P) = 954 mm/yr
Annual Actual Evapotranspiration (AET) = 507 mm/yr

The annual variation in precipitation is significant, ranging from 640 mm/year to 1268 mm/year.

The Guelph-Eramosa study (Gartner Lee, 2004) used the Guelph Arboretum station data (1971 – 2000) and found that the annual precipitation was 923 mm/year and the potential evapotranspiration rate was 487 mm/year.

Based on these evaluations, the surplus water (precipitation less evapotranspiration) is between 384 and 436 mm/year. Coward and Barouch (1978) measured stream flow in Blue Springs Creek and estimated that water surplus in the basin was on average 366 mm/year.

3.3 HYDROLOGY

Surplus water (precipitation less evapotranspiration) either infiltrates, runs off the land into a surface water body or as occurs near this site, does both. The hummocky topography on the Paris moraine in general promotes infiltration by capturing surplus water in depressions, resulting in significant infiltration. Some of this water re-emerges as diffuse seepage or discrete springs. Combined with runoff, this emerged groundwater seasonally flows through water courses and depending on the volume of flow, the water course either re-infiltrates entirely or a portion flows overland to Blue Springs Creek. This pattern of infiltration, emergence, surface flow and re-infiltration occurs in Tributary A, Tributary B and Tributary C near to the site and likely other streams east of the site.

This hydrological pattern is due to the underlying geological environment. Conditions such as closed depressions and relatively permeable soils are observed in upland areas on the Paris Moraine to the north of the site. It is expected, therefore, that there is significant infiltration of groundwater. The Guelph Eramosa study (Gartner Lee, 2004) suggests an infiltration rate of between 221 and 442 mm/year for the local sediments. The Paris Moraine overlies older tills and potentially less permeable tills such as the Port Stanley till. This permeability contrast results in the preferential lateral groundwater flow, rather than downwards into the underlying bedrock aquifer. This results in the emergence of groundwater (Source areas of Tributaries A, B and C) on the side slope of the Paris Moraine and also prevents loss of stream flow in Tributaries A, B and C until more permeable sediments are encountered as occurs in Lots 1 and 2 in Concessions 5 and 6, Guelph-Eramosa Township.

The Blue Springs Creek valley is a significant incision into the dolostone aquifer and it is likely that the majority of infiltration in the watershed ultimately discharges to Blue Springs Creek.

The Ministry of the Environment provide a method of estimating infiltration in 'MOEE Hydrogeological Technical Information Requirements for Land Development Applications' (1995). Topography, soil type and land cover are used to estimate infiltration. Based on this method, the infiltration factor applicable to surplus water in this area ranges from 0.5 to 0.8. This results in estimated infiltration of between 192 and 348 mm/year. The calibrated model for the Guelph Eramosa study (Gartner Lee, 2004) suggests the following infiltration rates;

Glacial Till 63 mm/year
Hummocky Till 252 mm/year
Kames/Eskers 378 mm/year
Glacial Gravel 442 mm/year
Glacial Fluvial Sand 221 mm/year

There is a wide range of infiltration but in general the infiltration rates are expected to be relatively high in this area.

3.3.1 ON-SITE HYDROLOGY

The site is hummocky and as previously indicated has been modified in the past by anthropogenic activity. The modifications include:

- draining of the central depression by channeling the stream that passes through the property,
- sand and gravel extraction along 6th Line Eramosa,
- sand and gravel extraction near the northwest wetland and,
- sand and gravel extraction at the eastern corner of the site, along Highway No. 7

Eight micro-drainage areas were identified on-site, these are shown on Figure 3.4. The largest micro-drainage area (D2) is along the stream which flows through the site. Three of these micro-drainage areas (D5, D6 and D7) have internal drainage and thus contain runoff on-site. Micro-drainage areas D5 and D6 get runoff from off-site areas and only D1, D4 and D8 naturally direct runoff off-site. The culvert beneath 6th Line Eramosa at Highway No. 7 drains the small micro-drainage area D8. The runoff volume from all of these micro-drainage basins is believed to be small due to the high hydraulic conductivities of the surface sediments, the lack of any defined runoff channels and the lack of ponded water.

The hydrologic function of this site is therefore one of significant recharge of the bedrock aquifer.

3.4 SURFACE WATER FEATURES

The site is located one kilometre northwest of Blue Springs Creek within the Blue Springs Creek watershed (Figure 1.3). The site is also approximately two kilometres southeast of the Eramosa River (which flows through the town of Rockwood). The Blue Springs Creek watershed boundary is located at the height of land approximately 750 m north and west of the site. Flow in both the Eramosa River and Blue Springs Creek is westward.

A wetland area located along the northwestern corner property boundary is approximately one hectare (10,600 m^2) in size. Other than runoff originating within its catchment area (Area D6, Figure 3.4), there are no surface water inflows or outflows from this wetland. The water level in the pond within this wetland decreases by more than a metre between April and October. During the spring freshet the former gravel pit east of the wetland is also inundated, however at no time is there a connection between the two bodies of standing water. Perennial standing water has been observed in the wetland between 1995 and 2011 and also noted in historical aerial photographs (Appendix I). It has been noted that during periods of drought the wetland surface water area shrinks to approximately 50 m^2 and is principally located in the southern area of the wetland at SW1.

An intermittent stream (Tributary B) flows from the northwest to the southeast through the eastern half of the site (Figure 1.4). Flow has been observed in the stream during the spring freshet and after high intensity rainfall events. The stream is usually dry during the summer months. The headwaters for the stream include an upland wetland located northwest of the site (Allen wetland) and a spring-fed pond on the De Grandis property. Within the site, the stream has a well-defined channel, the southern section of which is man-altered. It appears that from a centrally located depression to the southern property limit, a channel has been dug to allow for the conveyance of water.

The stream flow onto the site (measured at SW4, Figure 2.1) ranges from 154 L/s to being dry. In 2006, Tributary B was dry at SW4 between June 22 and September 15. In 2008, Tributary B flowed all year at SW4. The volume of stream flow where Tributary B leaves the site ranges from 132 L/s to being dry. Measured at SW8, the stream flow in Tributary B ceases every year. The maximum loss of stream flow is approximately 24 L/s.

Two measurements at SW9 and SW4 confirm that Tributary B is losing water through the Allen Wetland. On March 27 and May 11, 2012 Tributary B lost approximately 6 L/s between SW9 and SW4.

Tributary A arises from a spring on the Allen property. The spring is enclosed in a stone crock and water is observed to flow around the stone crock. Flow in Tributary A occurs year-round. Tributary A flows southwesterly through the Ball Farm and if there is sufficient flow will pass beneath Hwy No. 7 and into a pond. There is no indication that this flow proceeds farther than the Eramosa-Milton Townline. The flow rate in Tributary A at 6th Line Eramosa ranges from 1.15 L/s to 69 L/s.

The flow rate in Tributary C at 7th Line Eramosa has been measured since November 2011 and has ranged from being dry to 53.13 L/s. This flow arises from springs and runoff in Lot 3, Concession 7. Similar to Tributary B, Tributary C loses most of, if not all of its flow prior to reaching Hwy No. 7. In March 2012, the flow rate in Tributary C was the same at 7th Line as it was at the northern edge of Lot 1, Concession 6 E½, suggesting no change in flow where the silty till soils are at the ground surface. From the northern edge of Lot 1, Concession 6 E½, to Highway No. 7, however, Tributary C lost 25 L/s on February 2nd and 23rd 2012.

The Brydson Spring, Tributary D and possibly wetland and ponds located between Hwy 7 and Blue Springs Creek have bedrock groundwater as their source.

3.4.1 SURFACE WATER CHEMISTRY

Four surface water samples were collected for water analyses. In general the surface water is fresh (low chloride content). These surface water samples met the PWQO's for parameters tested.

Elevated nitrate concentrations (8.2 and 9.0 mg/L) was observed in two samples (Tributary A and B respectively) which suggests that there is some contamination of these surface water bodies. Considering that Tributary A and B emerge from active farms, it is likely that barnyard wastes or fertilizers are the source of nitrogen in the streams.

3.5 GEOLOGY

A description of the geological units in this area is provided in this section.

3.5.1 BEDROCK GEOLOGY

The site is located on the eastern rim of the Michigan Basin (Telford, 1978). The bedrock stratigraphy has a gentle southwestward dip of approximately 4 to 6 m per km (Livery, 1981). The bedrock surface in the vicinity of the site occurs at an elevation of between 344 and 371 m AMSL with the higher bedrock surface elevations occurring to the north and northeast of the site (Figure 3.5) Several bedrock valleys have been reported in the area including the bedrock valleys occupied by the Eramosa River and Blue Springs Creek (Procter and Redfern, 1995) (Burt, 2010).

The site is underlain by Silurian-aged dolostone. The core for M2 was logged prior to the preliminary assignment of the un-subdivided Amabel Formation into the Goat Island, Gasport, Irondequoit, Rockway and Merritton formations (Brunton, 2010). The overall thickness of the dolostone beneath the site is 43.7 metres as measured at on-site borehole M2. A well (MW-08-T3-06) drilled for the City of Guelph Tier 3 Source Water Protection study is located two kilometers north of the site. The well record identifies the presence of 4.5 metres of the Ancaster and Niagara Falls members of the Goat-Island Formation. The Gasport Formation is 44.5 metres thick at MW-08-T3-06 and the thickness of the Irondequoit, Rockway and Merritton Formations is less than 5 metres. The Vinemount and Reformatory formations are not present beneath this site. These formations occur to the west and can be found in outcrop in Rockwood.

Ingham (1990) describes the topmost part of the rock at M2 as bluish, grey, medium grained, medium to coarse porosity, vuggy and very fossiliferous.

The Cabot Head formation underlies the dolostone formations. The Cabot Head is a shale deposit and is found at an elevation of 308.8 m AMSL at M2.

A number of caves and underground caverns have been reported in the area near Rockwood and Eden Mills (Coward and Barouch, 1978). These caves are created by dissolution of the rock. The caves appear to be oriented at approximately 325 degrees from north (Karrow, 1968) in the direction of the biohermal bodies and are situated near the base of these bioherms. The presence of these caverns and the disappearance of streams in the area suggest some degree of solution enhanced permeability is occurring in the dolostone aquifer.

The bedrock surface elevation ranges from 346.9 to 353.2 m AMSL beneath the site. In general, the top of bedrock elevation decreases from north to south. There is a bedrock low located in the southeast corner of the site. The bedrock surface is found at an elevation of 340.88 m AMSL in MOE Well #2805483. There appears to be a local bedrock surface elevation high point in Lot 2, Concession 6 along 7th Line Eramosa. According to MOE Well #6715237 the bedrock surface has an elevation of approximately 366 m AMSL. There does not appear to be a bedrock high associated with the crest of the Paris Moraine. Bedrock in the Eramosa River valley outcrops at approximately 370 m AMSL and in the Blue Springs Creek valley from an elevation of 346 m AMSL to the river's edge at approximately 330 m AMSL.

3.5.2 OVERBURDEN

The quaternary geology obtained from the Ministry of Natural Resources is presented in Figure 3.6. In general, the immediate vicinity of the site was interpreted to be underlain by kame, esker and outwash deposits. Wentworth till deposits were interpreted to occur in the area as well. The quaternary geology map prepared by Burt (2011) is found in Figure 3.7. This map identifies extensive deposits of the Port Stanley till and Wentworth Till in the near vicinity to the site.

The unconsolidated geological material overlying the bedrock at the site is both morainal and fluvial in nature. This area of Southern Ontario had experienced several advances and retreats of the glacial ice sheets, the most recent occurring approximately 12,000 years ago. This glacial advance from southeast to northwest resulted in the deposition of the stony Wentworth Till including large boulder plucks. A sinuous ridge of glacial till embedded with large boulders occurs in the eastern part of the site, on the neighbouring property to the north and on the De Grandis property. The boulders are mainly of Paleozoic origin (dolostone) however, several large igneous boulders were also observed. The matrix within this till is a sandy to silty sand till with 70% sand and 30% silt and clay (sample from TP4). A similar deposit was found by Naylor (1989) in Lot 1 Concession 6 E½. In TP9, this till was underlain by consolidated olive green coloured silt till of relatively old origin (pers. Comm. Abigail Burt, 2012).

A surficial silt till is found within the site at M3 and northward beneath the Allen wetland (samples AW7, AW8 and AW11). This till has between 45 and 60% silt and at M3 is two metres thick.

Ice-contact stratified sediments are found mainly in the central and western portions of the site. Steep hummocky terrain in the south central portion of the site coincides with former borrow areas from the site and contain deposits of sand and gravel. Boreholes M12 and M11 find thick deposits of fine and medium grained sand and silt deposits in the northwestern portion of the site (borehole M12).

Sand and gravel extraction occurred in the northwestern portion of the site and a small wayside pit is found in the southwestern part of the site.

Geological cross-sections are presented in Figures 3.9 to 3.12 with a key map of cross section locations found on Figure 3.8. Water well record data for wells north of the site indicate a glacial till overlying bedrock (Figure 3.9), up to sixteen metres thick at well # 6706762. The bedrock surface has a relatively gentle downward slope from the Paris Moraine to just northwest of Blue Springs Creek where it suddenly decreases in elevation. Based on testpit and borehole data a silt or silt till layer is found to overly the dolostone bedrock in the western half of the site as observed in M1, M4, MW13, MW14, TP1, TP2 and TP3 (Figures 3.10 and 3.11). This layer is generally less than two metres thick. East of Tributary B, a sandy till is more prevalent above the bedrock although silt is found at TP8 and a dense silt till at TP9. In general, however, the basal silt till is thin or absent above the bedrock near Tributary B (Figure 3.12).

The presence of deposits of gravel, sand and silt indicates a period of fluvial action resulting in the sorting of the geological material. Sand and gravel deposits occur in a relatively high energy environment (e.g. glacial melt) and the silt deposits represent a lower energy (e.g. ice dam) period. The Blue Springs Creek valley was an outlet for glacial melt water. A very high energy environment existed south of the site as evidenced by the absence of overburden despite the Paris Moraine complex sediments deposited on both north and south sides of the valley (Figure 3.2).

The 1965 soil survey of Wellington County (Figure 3.13) identifies the site as being underlain by the Dumfries Sandy Loam with Parkhill Loam and muck to the north. The Parkhill loam is reported to have poor drainage. This coincides where the Allen Wetland is found, and the identification of a silt till in soil samples. The change from surficial silt till to a sand till or sand and gravel deposits coincides with the major loss of stream flow in Tributary B and C.

3.6 HYDROGEOLOGY

3.6.1 REGIONAL HYDROGEOLOGY

The Paris moraine is an area of significant infiltration due to the capture of surplus water in closed depressions and a relatively permeable matrix. Blue Springs Creek is an area of regional groundwater discharge from the bedrock aquifer.

Figure 3.14 provides a regional perspective of groundwater flow. Based on static water levels obtained from water well records, the groundwater with the greatest hydraulic potential is found north of the site co-incident with the crest of the Paris Moraine. Groundwater potentials of 380 m AMSL occur northeast of the site. These high groundwater potentials occur in the overburden sediments within the Paris moraine. The high potentials occur because of significant infiltration on the hummocky moraine and slow migration downward, impeded by silt within the sandy tills or by silt till within or beneath the moraine. Burt (2010) classifies the Paris Moraine/Wentworth till as an aquitard.

In general, at the crest of the Paris Moraine, groundwater has a westerly flow along the axis of the moraine. Along the northern flank of the moraine groundwater is diverted northward towards the Eramosa River. Along the southern flank of the moraine groundwater is diverted towards Blues Springs Creek.

Evidence of silt till layers beneath the moraine or within the moraine is found in several locations on the south slope of the Paris Moraine. Tributaries A, B, C and other streams east of the site arise from a permeability contrast within the moraine sediments. Groundwater infiltrating on the Paris moraine and percolating downwards encounters a layer of lower permeability. Based on soil samples obtained from the Allen wetland, this layer is a sandy silt till comprising greater than 50% silt. Groundwater then preferentially flows laterally in a southerly direction and emerges as surface water. The emergence of groundwater onto the ground surface is a relatively short-lived occurrence as within several hundred metres, the water re-infiltrates. Observations of flow in Tributary A, B and C confirm this. The re-infiltration occurs where sandy Wentworth Till occurs, kame sand and gravel occurs or where thin overburden overlying bedrock occurs. As observed in Tributary B southeast of the site, and Tributary D, a significant volume of groundwater can re-emerge from the bedrock within the Blue Springs Creek valley.

Regionally, groundwater discharges to the Eramosa River and Blue Springs Creek. The site and nearby environs are underlain by the regionally extensive Amabel Formation. The Amabel

Formation is an aquifer capable of supplying large quantities of water (both the City of Guelph and Rockwood rely on water from the Amabel formation).

A convergence of groundwater flow occurs in an area coincident with Tributary B, within Lot 1, Concession 6 and southeast to the Brydson Spring. The static water level in M3 is approximately four metres lower than at M13D and twelve metres lower than water levels along 7th Line Eramosa (Figure 3.15). This trend can be found along the southern edge of the site. A gentler hydraulic gradient between M3 and the Brydson Spring suggests an area of greater hydraulic conductivity in the bedrock.

3.6.1.1 GROUNDWATER SEEPAGE AND SPRINGS

A number of areas of groundwater discharge or springs have been identified in the 1978 MOE document (Coward and Barouch, 1978) and confirmed during the door-to-door water well survey. Three areas of discrete groundwater discharge situated more than 300 metres from the site have been identified to the northwest. One of the northwest areas of groundwater discharge is situated on the Allen Farm (Figure 1.4) at an elevation of approximately 361 m AMSL. This spring has a concrete casing over top with stones inside the casing. The static water level in the bedrock well (Well # 6708039) on the Allen Farm property was measured at 354.8 m AMSL, several metres lower than the spring. The land surface immediately to the north of the spring rises to an elevation of 380 m AMSL in a hummocky moraine feature (Figure 3.9). The static water levels in the bedrock shown on Figure 3.9 show that bedrock water levels decrease from the Paris Moraine southeasterly to Blue Springs Creek and remain below the ground surface. The source area of the spring is therefore interpreted to be the upland area immediately to the north of the spring.

The resulting stream from the spring feeds into two interconnected ponds located near to 6th Line Eramosa which then discharge to Tributary A that flows westerly beneath the 6th Line. Flow in this upper reach of the stream is perennial. South and west of the 6th Line however, the stream loses water and dries up on the Ball farm. Topographic maps indicate that this stream flows under Hwy No. 7, however, flow has only been observed under Hwy No. 7 during the spring thaw.

Groundwater discharge also occurs on the De Grandis property. Observations made at the De Grandis property include;

1) diffuse seepage of groundwater in areas north of the Allen Wetland
2) man-made berms along the southern edge of the man-made ponds

3) outflow of water from the ponds into two streams flowing on the Allen wetland

Groundwater seepage at the De Grandis property occurs from glacial till deposits at an elevation of 364 m AMSL. According to Ms. De Grandis, a pond was dug on the property in the 1980's for aquaculture and she identified several springs within the pond. She recalled that during the excavation much of the pond was dry and dug into 'clay', however, water was encountered along the northern edge of the excavation. The De Grandis house is supplied by water from a shallow dug well. The static water level in the well was measured to be very similar to the elevation of the pond water and was found to have a high yield (after 30 minutes of running a garden hose (approx. 20 L/min) there was no measurable change in the well water level. This indicates highly permeable overburden sediments. Large dolostone boulders are found in the vicinity of the De Grandis pond and this is interpreted to be the Wentworth till.

Overflow from the De Grandis pond flows onto the Allen property in two separate channels (Figure 2.4). These channels join within the Allen wetland and the combined flow carries onto the JDCL site (Tributary B). Outflow from the De Grandis pond is not regulated other than through a small breach in the containment berm. The discharge from the De Grandis pond varies significantly as measured from as much as 154 L/s at SW4 to having no discharge.

The land surface rises gently to the north of the De Grandis pond. Stony fields north of the ponds and extending north of the railway track provide good opportunity for infiltration.

Tributary C also emerges from the south slope of the Paris Moraine. The source of Tributary C in Lot 3 Concession 7 occurs at an elevation of approximately 375 m AMSL.

These springs occur in an upland area identified as significant groundwater recharge areas (GRCA, 2008). The recharge in this upland area is high as a result of permeable surficial sediments and closed drainage. The springs occur in an area identified as a regional groundwater recharge area for the bedrock aquifer and thus downward groundwater flow predominates. The springs are interpreted to arise from permeability contrast within the overburden. Sediments with relatively higher permeability facilitate high infiltration and sediments with relatively lower permeability impede the downward movement of percolating water, resulting in lateral movement and discharge at the ground surface as springs.

The Brydson spring occurs 400 metres southeast of the site at elevation of approximately 345 m AMSL. The Brydson Spring occurs in an area of thin overburden and likely represents discharge directly from the bedrock. This can be considered to be the re-emergence of Tributaries B and C.

3.6.1.2 SOURCE WATER PROTECTION

The site is not located in the well head protection areas (WHPAs) of either the Rockwood municipal wells or the City of Guelph wells.

Tributary B is a tributary to Blue Springs Creek and ultimately to the Eramosa River. The Intake Protection Zone (IPZ-3) of the City of Guelph intake on the Eramosa River includes all upstream areas (tributaries) of the Eramosa River and Blue Springs Creek watershed. Thus the IPZ-3 is assigned to all lands within 120 metres of Tributary B on the site. The IPZ-3 falling within the site boundary has the lowest vulnerability score of 1 (Aqua Resource, 2010) and thus is not a threat to the intake (pers. Communication Sandra Cooke, GRCA, August 15, 2012). The active excavation portions of the site will drain internally and it is not expected to have any storm water flow directed to Tributary B.

3.6.2 ON-SITE HYDROGEOLOGY

The site is located at an intermediate elevation on the southern slope of the Paris Moraine. The site is one of groundwater recharge occurring within many closed depressions and along the permeable corridor of Tributary B. There is the potential for localized groundwater discharge to a wetland occurring in the northwest corner of the site where percolating water encounters a silt layer. Water flowing on top of the silt layer seasonally discharges to the ground surface along the northern property limit where gravel extraction has removed aggregate above the silt layer. Emerging groundwater is observed to flow southerly. There is no other permanent surface water on-site other than in this wetland.

Groundwater potentials are the greatest in the western corner of the site and lowest in the eastern corner of the site. In general the groundwater flow direction is from west to east. The hydraulic potential in the overburden at M13 is recorded as high as 355.49 m AMSL in the spring of 2011.

Hydrographs of water levels obtained from on-site monitors are provided in Appendix B. There are up to seventeen years of records for monitors M1, M2, M3, M4, M5 and M6. The hydrographs show seasonal variation in water levels. The seasonal variation in water levels ranges from 0.8 to 2.5 metres for bedrock monitors and 1.0 to 2.4 metres for overburden monitors. There is no significant long term trend observed in the water levels.

Groundwater potentials in the overburden and bedrock are shown on Figures 3.16 and 3.17 respectively. Groundwater flows west to east across the site. The greatest groundwater potentials are found at M13 in both the bedrock and overburden.

The water table is not present in the overburden throughout the entire site. Saturated conditions within the overburden do not occur at M4, M7, M8, M11 or M12. At these locations the silt till or silt layer is absent or very thin. Groundwater occurring within the overburden does so above the silt till or silt layer generally in the northern portion of the site and percolates into the bedrock within the southern portion of the site. Notably, M11 is located 21 metres from Tributary B at a depth of 349.91 m AMSL (4.49 metres below streambed) and is dry. It is known that Tributary B is a losing stream as can be seen by the difference in hydraulic potentials between MP1, MP2 and SW5 and between MP3, MP4 and SW4. At these locations the hydraulic potentials measured in the mini-piezometers adjacent to the stream is less than that of the surface water feature. The losing nature of Tributary B is also recorded in the stream flow measurements.

Figure B9 is a hydrograph of M13 S/D (shallow and deep). The hydrograph shows that there is a consistent downward hydraulic gradient between the sand and gravel deposits overlying a silt till layer and the dolostone aquifer below. The silt till is 1.98 metres thick at this location. The average water level difference between the monitors is 0.59 metres resulting in a hydraulic gradient of 0.30 m/m across the silt till layer.

Figure B1 is a hydrograph of M1 S/D. MI S is completed in the silt till layer and MI D is completed in the dolostone. On average, there is a 1.6 metre difference in the observed water levels. The silt till is 1.58 metres thick resulting in a downward hydraulic gradient of 1.01 m/m.

3.6.2.1 HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY

The results of the hydraulic conductivity testing are presented in Table D1. The sand and gravel and silty sand layers at the site have relatively high hydraulic conductivity estimated between 1 x 10^{-5} m/s and 5 x 10^{-4} m/s. These layers are relatively efficient at transmitting water and under saturated conditions, will facilitate the movement of groundwater.

The sandy silt and silt till layers have hydraulic conductivity values of between 1 x 10^{-7} and 1 x 10^{-6} m/s. These layers are not impermeable, but transmit groundwater relatively poorly.

The transmissivity testing of the dolostone aquifer suggests that the bedrock has a transmissivity between 7.5 x 10^{-7} and 5 x 10^{-6} m/s (M2, M4 and Well # 6705627).

These results are similar to those obtained from a 24 hour pumping test conducted on the adjacent property. Harden Environmental conducted a test on well TW-2 in Lot 1, Concession 6 E½. TW-2 is 39.32 metres deep, a similar depth to the proposed quarry. The estimated transmissivity from the test data ranges from 20 to 150 m^2/day. The range in transmissivity arises from different responses measured in several monitoring wells during the test. Using an aquifer thickness of 40 metres, the hydraulic conductivity of the bedrock is estimated between 5×10^{-6} and 5×10^{-5} m/s.

There is no indication from this testing that there are significant zones of relatively high permeability at depth beneath the site. The drawdown in TW2 was 13 metres at a discharge rate of 1.36 L/s. The drawdown at on-site well # 6705627 was 1.8 m at a rate of 0.4 L/s after 100 minutes of pumping without stabilization of the water level. These wells extend to the approximate depth of the proposed quarry. On July 3rd 2012 the owner of the mushroom farm adjacent to the site stated that he was discharging approximately 400 L/min from a 60 metre deep well and that the pump, set at a depth of 50 metres was only operating intermittently because of insufficient water in the well. These observations suggest that a highly productive zone within the Amabel formation does not occur beneath this site.

The Guelph Eramosa Study used hydraulic conductivity values of 5×10^{-4} m/s and 1×10^{-5} m/s for the dolostone aquifer.

The detailed hydraulic testing conducted by the University of Guelph in nearby Tier 3 well MW-08-T3-06 found that hydraulic conductivity of the dolostone bedrock ranged from 8×10^{-7} m/s to 5×10^{-5} m/s.

3.6.2.1 RELATIONSHIP BETWEEN TRIBUTARY B AND GROUNDWATER

Tributary B flows along a rocky channel for the first 150 metres downstream from the northern site boundary. In this area Tributary B is underlain by glacial till. In the central portion of the site, Tributary B meanders through sandy sediments. In the southern portion of the site, Tributary B flows through man-made channels.

Two drive point monitors MP1 and MP2 were installed in November 2010 on either side of the stream at the location of SW5 and M9. A cross section depicting the water table in this location is shown in Figure 3.18. Figure 3.18 shows that in this location the stream is clearly recharging groundwater on both the sides of the stream. Similarly, two drive point monitors MP3 and MP4 were installed in November 2010 on either side of the stream at the location of SW4 (upstream property boundary). Each monitor was installed to a depth of four metres below ground surface and MP3 is six metres and MP4 is eight metres horizontal distance from the edge of the stream. Both were found to be dry in November 2010 whereas there was flow in the stream. In May

2011, both contained a water level that was found to be two metres below the stream surface water level at SW4. The water levels in these monitors are consistently below the stream level.

This evidence as well as stream flow measurements confirms that throughout the subject property, the stream is losing water to the underlying sediments.

3.6.2.2 RELATIONSHIP BETWEEN NORTHWEST WETLAND AND GROUNDWATER

The northwest wetland is located along 6th Line Eramosa at the northern property boundary. The wetland has been mapped in the field and has an area of approximately 10,600 m^2. There is an open water portion of the wetland that changes in extent seasonally. In the spring, the open water area is approximately 10,500 m^2 and during the summer and fall periods can shrink to less than 50 m^2 and occurs as a shallow pool in the southern part of the wetland. The total catchment area of the wetland is estimated to be 27,225 m^2 (Figure 3.4) based on topographic surveys and field observations. The western catchment boundary is the hedgerow along 6th Line. There are no culverts beneath the road and water sheeting across the road has not been observed suggesting that the middle of the road can be considered the edge of the surface water catchment area. The northern edge of the catchment extends onto the adjacent property as shown. To the east, the wetland boundary is sharp and found along an elevated hedgerow (natural or created by former aggregate operation). To the south, the ground elevation rises to an elevation of approximately 360 m AMSL in the conifer plantation. The surface water catchment of the wetland is approximately 30 metres south of the wetland within the plantation.

The elevation of the wetland ground surface ranges from 354.28 at SW1 to 354.71 m AMSL along the edge. The lowest elevation of the wetland occurs in the southern part of the wetland and has always been observed to have open water (frozen in the winter). There is a significant seasonal fluctuation in the surface water level in the wetland. A range of 354.2 (December 1997) to 355.73 (April 2000) has been observed. Annually the range in water level is as high as 1.45 metres (2007). In 2008 the surface water level in the pond fell by 1.24 metres between April and May.

During high runoff events such as the spring freshet, water also collects in the former extraction area northeast of the wetland. Even at the highest water level observed, there remains a physical separation between the wetland and water collected in the former extraction area. A water level difference is also maintained.

The surface of the bedrock beneath the wetland can be inferred from known bedrock elevations at boreholes M1 (349.53 m AMSL), M13 (350.2 m AMSL) and M14 (349.78 m AMSL). Therefore, based on the wetland ground surface elevations previously mentioned, the bedrock is found between 4.08 m and 5.18 m below the wetland surface. A silt till layer is found above the bedrock and the top elevations are summarized in Table A4. The thickness of this layer ranges between 1.67 m and 1.98 metres.

Four holes were hand augered through the wetland in order to characterize the underlying soils. Each hand auger hole encountered organic soils, a silty sand layer and a sand and gravel layer. Each hand auger hole was dug to auger refusal. A summary of the findings is presented in Table A2. The organic layer is found to be between 0.2 and 0.7 metres thick. The silty sand layer is between 0.2 and 1.45 metres thick. The thinnest portion of the silty sand occurs along the northern edge of the wetland and the thickest silty sand occurs along the western edge. The silty sand likely represents sediment carried into the wetland depression by runoff water from the surrounding area. The hand auger system did not allow for determining the thickness of the sand and gravel layer, but using the adjacent boreholes as a guide, the sand and gravel layer is between 0.8 and 2.3 metres thick beneath the wetland.

There are no observations of iron precipitates or marl that would signify the discharge of groundwater into the wetland. The relationship between the surface water level in the wetland and adjacent groundwater monitors is shown on Figure 3.19. MPN-1 and MPW-1 are located north and west of the northwest wetland as shown on Figure 2.4. M6 is located south of the wetland. The hydrographs show that in the spring the surface water level is very similar to the groundwater levels measured in MPN-1 MPW-1and M6. As observed in the fall of 2011, the water levels in all three groundwater monitors were more than 0.25 metres below the surface water level in the wetland. This means that the surface water in the wetland is perched above the groundwater system due to the organic layer lining the bottom of the wetland. As observed in the summer of 2012, the water level in M6, located within the wetland, is more than 0.5 metres below the pond level.

MPN-1 installed along the north and MPW-1 installed along the west part of the wetland confirm upward gradients (i.e. potential for groundwater discharge into the wetland) from the sand and gravel unit. MPS-1 installed along the south and MPE-1 installed along the east part of the wetland confirm downward gradients (i.e. potential for groundwater recharge from the wetland). As shown on Figure 3.16, groundwater flow radiates away from the southern and eastern wetland boundaries. The underlying silt till layer beneath the wetland retards movement of groundwater vertically between the overburden and bedrock aquifers. Water levels obtained at M13S and M13D show a downward hydraulic gradient between the overburden and bedrock aquifers at the wetland.

The potentiometric surface in the bedrock measured in M13D upgradient of the wetland has a maximum value of 354.95 m AMSL (May, 2011). At the same time the surface water level in the wetland was measured at 355.38 m AMSL and the piezometric level in the sand and gravel at MW13S was 355.49 m AMSL. The measurement in M13D represents the highest value of bedrock potentiometric surface found on-site. Therefore, with the wetland water level being higher than the bedrock water level, there is no potential for bedrock groundwater to discharge to either the wetland or the sand and gravel unit beneath the wetland. The silt till layer found between the wetland and the bedrock provides hydraulic separation of these hydrostratigraphic units.

3.6.2.3 ALLEN WETLAND

There is a Provincially Significant Wetland (PSW) located north of the Site. The watercourse (Tributary B) flowing through the wetland originates from a spring fed pond (Figure 2.4) north of the PSW. On-site measurements of stream flow at SW4 show that surface water flow from Tributary B will cease in the summer months.

The elevation of the wetland is between 360 and 363 m AMSL. The elevation of a depression in the Allen farm field adjacent to the wetland is 358.19 m AMSL based on a site level survey conducted by Harden Environmental on December 21, 2011 (Figure 3.20). The elevation of Tributary C, east of the wetland is 359 m AMSL (GRCA, 1 metre contours) and is thus also below the wetland elevation. These observations confirm that the only potential source of groundwater for the wetland is from the north. At the southern edge of the wetland (at the JDCL property) groundwater occurs below an elevation of 355 m AMSL (at TP8), several metres below the wetland.

Several holes were hand-augered within the wetland to determine the underlying geological materials (Figure 2.3). The soils found confirm that the wetland is underlain by a silt till containing between 40 and 60% silt. The soil survey map for Wellington County (Figure 3.13) identifies the wetland as being underlain by soils with poor drainage.

Diffuse groundwater seepage was observed along the northern edge of the wetland. This area is also underlain by relatively low permeability till and the seepage is interpreted to be interflow along the contact between the relatively permeable surficial till found on the De Grandis property and the silt till identified beneath the wetland.

The support hydrology for the Allen Wetland is direct precipitation, runoff and interflow from the north. Stream flow measurements of surface water leaving the wetland as measured at SW4 are summarized in Table C1. In general flow from the wetland ceases for one to three months in the summer however in 2008 and 2011 there was continuous flow. The flow rate was measured as high as 158 L/s.

Based on a review of aerial photographs, topographic maps and site visits, the stream flow enters the wetland from the De Grandis pond. Two outlets from the pond were observed resulting in two separate streams. One stream (northern branch) heads south westerly and the southern branch initially heads south easterly but turns sharply south westerly. The streams join at a confluence shown on Figure 2.4. The stream channels are ill defined at times and flow occurs over a broad area. Other times the channel is well defined. Two streamflow measurements obtained in 2012 confirm that from the confluence of the northern and southern branches to the JDCL site, Tributary B loses water. The nearest groundwater monitors to the Allen Wetland are TP8 (overburden) and M3 (bedrock). The ground elevations in the wetland are approximately 361 m AMSL and the groundwater level in TP8 is more than six metres below this elevation and in M3, more than 10 metres below the elevation of the wetland.

3.6.2.4 NORTHEAST WETLAND

A wetland exists off site near the northeastern corner of the property. A test pit excavation with drive point installation (TP8) completed on-site fifty metres from the wetland provides groundwater levels that are approximately 3.5 metres below the surface water in the wetland. The off-site wetland is not an area of groundwater discharge and is determined to be a perched feature. Surface soils in test pit TP8 were mainly comprised of a silty till.

3.6.3 GROUNDWATER CHEMISTRY

Six groundwater samples were obtained and analyzed for general water quality. The results of these analyses are found in Appendix E. In general the groundwater is fresh (low chloride content). These groundwater samples met all of the Ontario drinking water objectives (ODWOs) except for iron (M2, M5 and TP1) and magnesium (M5 and TP1).

Elevated nitrate concentrations (>5 mg/L) observed in two samples (M2 and M3). These elevated levels of nitrate suggest that there is some contamination of the groundwater from surface and near surface sources. Potential sources of nitrate include neighbouring septic systems and nearby farming practices.

The water quality of the bedrock aquifer obtained from on-site well # 6705627 is typical of the dolostone aquifer in this area.

4.0 MINING PLAN AND POTENTIAL HYDROLOGIC CHANGES

Based on the regional and local conditions discussed in Section 3.6.1 and the local conditions stated in Section 3.6.2, this section describes the process through which the mining plan has been developed and the resultant mining plan. The understanding of the groundwater and surface water flow regimes and how they interact has been considered during the development process.

4.1 MINING PROCESS

The mining plan for this pit/quarry will employ a mining technique used to minimize the disturbance of the groundwater flow system. JDCL proposes to remove the aggregate above the water table with traditional excavation equipment. However, below the water table JDCL will drill holes into the dolostone, break the rock with explosives and remove the broken rock with excavators or draglines stationed above the water table without dewatering. The proposed depth of extraction is thirty metres below the water table. Other than the blasting phase, this is a similar approach to traditional below-water-table sand and gravel extraction. The main hydrogeological benefit of this method over dewatering is the minimal disturbance to hydraulic potentials in the bedrock.

This method will not be unique to this site. James Dick Construction Ltd. is currently using this technique in their Guelph Limestone quarry and mining companies use this method almost exclusively for mining limestone in southwest Florida.

The proposed mining area is shown on Figure 4.1 and includes extraction both east and west of Tributary B. Details of the mine phasing are found on the site plans prepared by Stovel and Associates Inc. The mining of the bedrock will commence in the north half of the west pond and will proceed from north to south.

4.2 POTENTIAL IMPACT OF CREATION OF WATER BODY (PASSIVE IMPACT)

4.2.1 OVERBURDEN

There is at least seasonally saturated overburden found along the perimeter of the proposed quarry with the exception for the boundary along Provincial Hwy #7 and a portion bordering 6th Line Eramosa. Unmitigated, the groundwater in the till, sands and gravel will flow into the quarry thus “drawing” water from the overburden. Other than the northwest wetland, there are no environmental features sensitive to changes in the groundwater levels within the overburden. A hydraulic barrier will be constructed in the location shown on Figure 4.2 to prevent the draw of overburden groundwater into the excavation. The barrier, where constructed, will result in the maintenance of groundwater levels outside of the excavation area. The barrier is constructed by digging a trench downgradient of the wetland and replacing the sand and gravel with silt. The silt has a significantly lower hydraulic conductivity than the sand and gravel and thus retards the movement of groundwater. This results in water levels rising on the wetland side of the barrier. Calculations indicate that with the construction of the hydraulic buffer, there will be a slight surplus of water available to the wetland when compared to the current condition. It is recommended that a culvert be included in the buffer design that can be adjusted to prevent water accumulating in the wetland area.

The barrier will be keyed into the silt/silt till layer and will be 2.5 metres wide. The design horizontal hydraulic conductivity of the barrier is 5×10^{-8} m/s. Hydraulic barriers constructed of silt and clay have successfully been used elsewhere in Wellington County and in Peel Region. In the Reid's Heritage Homes pit, located in Puslinch Township, a total length of 1150 m of hydraulic barrier was installed. The barrier is installed between two and fourteen metres depth and has a post installation hydraulic conductivity of 1.8×10^{-10} m/s. Another 750 metre long barrier, 11 metres wide is effectively protecting Warnock Lake adjacent to the Caledon Sand and Gravel pit. The hydraulic conductivity of the Caledon Sand and Gravel barrier is estimated to be 1×10^{-10} m/s. The Roszell Pit, approved in Puslinch Township, proposes to use a 10 metre wide hydraulic barrier with a design hydraulic conductivity of 1×10^{-8} m/s to protect a PSW.

4.2.2 BEDROCK

The creation of a water body results in the same hydraulic potential in the aquifer along the perimeter of the water body. Presently groundwater flows from west to east as a result of an approximate six metre decrease in hydraulic potential in the bedrock aquifer. This general flow pattern will remain post extraction; however the hydraulic potential of the water body will be less than that of the present hydraulic potential in the bedrock in the northern portion of the quarry by approximately two and a half metres. This results in an increase in groundwater flow into the excavation and a decrease of the hydraulic potential in the bedrock aquifer in areas north of the site. This also results in an increase in hydraulic potential south of the site (i.e. groundwater levels will increase). A 3-D groundwater model was prepared to determine the area of influence as shown on Figure 4.3. The maximum drawdown at the northern edge of the West Pond is 2.45 metres. The predicted final water level in the West Pond is 348.6 m AMSL and in the East Pond is 348.4 m AMSL.

The creation of a water body will alter the water storage capacity at the site by creating significantly more water storage than presently exists. The additional storage will have a benefit to downstream wells, springs, ponds or streams during drier conditions.

4.3 IMPACTS ARISING FROM ROCK EXTRACTION BELOW THE WATER TABLE (ACTIVE IMPACT)

The removal of rock from below-the-water-table will lower the water level in the quarry thereby drawing water in from the surrounding rock body. Groundwater will flow into the quarry, replacing the volume of rock removed and thereby creating a significant reservoir of stored water. It is proposed to extract rock from this site at a rate of 700,000 tonnes per year. The approximate density of the dolostone is 2.6 tonnes per cubic metre, resulting in the potential removal of 270,000 cubic metres of rock per year.

Assuming that active mining will occur from April 1 through to December 24th, the annual extraction will occur over 235 working days. The extraction rate on average is therefore 1145 cubic metres per day.

The initial excavation into the rock (sinking cut) is estimated to be 50 metres by 25 metres, an area of 1250 square metres. The removal of 1145 cubic metres from this initial excavation will, assuming no inflow of water during the extraction, have a maximum drawdown of 0.91 metres per day. Groundwater will, however, flow into the excavation and replace the removed aggregate, thus limiting the daily drawdown. Analysis of the impact of a passive 2.45 metre drawdown (see Section 4.3.2) suggests that wells, streams, springs and wetlands will not be affected. Monitoring of the water level in the sinking cut and nearby monitors is recommended to verify that no off-site impacts are occurring. The initial rate of extraction can be moderated to minimize water level changes. The additional drawdown effect caused by the extraction will be muted once a body of water has been established.

The passive and active impacts are not additive since the maximum passive impact will occur when the active impact is negligible. For example, by the time the extraction is completed on the west side of Tributary B (passive impact at a maximum), the potential daily active drawdown will be less than one millimeter.

4.4 SITE HYDROLOGY

In Section 3.3 it was stated that a main hydrological function of this site is recharge. This function will not change. There will be no additional overland flow of water from the site. Micro drainage area D1 presently has the potential to contribute water off-site although this has not been observed, even under frozen ground conditions. Post extraction, this potential will be removed from the 2.57 hectares that will be captured in the quarry. This results in a potential increased contribution of 3600 m^3 of water to the aquifer annually. It is unlikely that the runoff from area D1 would contribute to Tributary C given the loss of water observed in Tributary C in that area. The lands onto which water from D1 could discharge are zoned industrial and have an approved site alteration plan.

The extraction area includes 17,865 m^2 of drainage area D2. Thus there will be a decrease in runoff from area D2 into Tributary B. The entire catchment area of Tributary B is estimated to be 585,156 m^2 upstream of monitoring station SW8 (Figure 4.4). The reduction in catchment area is 3% and thus no significant change in stream flow will occur.

The post extraction evapotranspiration rate will increase as a result of the development of open surface water. It is estimated that the evapotranspiration rate for the site is approximately 517 mm/year and open water evaporation is 652 mm/year. There will be approximately 13.9 hectares of open water resulting in a loss of 18,765 m^3/year compared to existing conditions. This loss of water to the aquifer is insignificant relative to the groundwater recharge occurring as a result of recharge beneath Tributary B[*] and Tributary C.

[*] The recharge occurring from Tributary B for a nine month period is approximately 500,000 m^3.

5.0 IMPACT ASSESSMENT

This section discusses how the development of the pit will affect the hydrologic and hydrogeological regimes.

Any changes to the groundwater flow system will be very gradual and will be detected with the recommended groundwater monitoring program. Any impact presented herein is based on the full development of the quarry without mitigation in the bedrock aquifer. A monitoring program is recommended to confirm the predictions made herein and contingencies such as cessation of mining below the water table, reducing the area of extraction or changing the configuration of the mining can be implemented to address issues that arise.

5.1 NORTHWEST WETLAND

There is the potential for an indirect change to the hydrology of the northwest wetland as a result of an alteration to the groundwater flow system adjacent to, and beneath the wetland. Figure 5.1 depicts the existing hydrologic conditions at the wetland. Groundwater, originating northwest of the wetland, flows beneath the wetland in the silty sand layer, sand and gravel and the bedrock aquifer. Downgradient of the wetland (southeast of M1), groundwater flow in the silty sand layer and sand and gravel layer ceases and there is only groundwater found in the bedrock. Presently, the wetland contributes water to the shallow groundwater flow system south of the wetland and a portion of the groundwater in the shallow groundwater system flows through the silt layer into the bedrock aquifer. The proposed bedrock extraction will result in an increase in the potential for water to flow from the shallow groundwater system into the bedrock as a result of an increase in the downward hydraulic gradient caused by a lowering of the hydraulic potential in the bedrock. The construction of the hydraulic barrier in the overburden will result in a decrease in shallow groundwater flow towards the south, thus offsetting the downward loss of water. Calculations indicate that with a hydraulic barrier in place there will be a slight surplus of water available to the wetland compared to existing conditions. As such, a culvert will be installed to prevent the wetland from becoming too inundated with water.

The construction of the hydraulic barrier will result in the retention of water in the area shown on Figure 5.1.

5.1.1 NORTHWEST WETLAND WATER BALANCE

A water balance approach has been taken to show that the proposed extraction will not significantly change the hydrological conditions of the wetland. The purpose of preparing a water balance is to show that there is a level of understanding of hydrological contributions to the wetland and predictions of impact to the wetland can be made by applying anticipated changes to the support hydrology of the wetland.

The water balance prepared for the northwest wetland considers the following hydrological components;

Inputs	Outputs
Precipitation (P)	Wetland Evapotranspiration (ET)
Runoff (RO)	Groundwater Out Horizontal (G_{oH})
Groundwater In (G_{in})	Groundwater Out Vertical (G_{oV})

Observations of the wetland suggest that there is no year over year increase or decrease in water stored. Depending on factors such as the snow pack, drought conditions or rainy years, the water stored in the wetland does vary, but in general, there is very little water stored in the wetland by the end of the fall. For the purpose of this water balance, an annual change in water storage is not considered.

The water balance of the wetland can then be presented as follows;

$P + RO + G_{in} = ET + G_{oH} + G_{oV}$

5. 1.1.1 NORTHWEST WETLAND WATER BALANCE EXISTING CONDITION

The input values to the water balance are as follows;

Precipitation

As discuss in Section 3.2, the annual rainfall ranges from 640 to 1268 mm/year. For this evaluation we have considered an average annual rainfall of 900 mm/year. An increase or decrease by 100 mm per year affects the overall water balance by approximately 4%, thus the water balance is not particularly sensitive to annual precipitation. Only direct precipitation on the wetland is considered in the precipitation parameter. Precipitation falling within the adjacent catchment area will contribute water to the wetland either as groundwater inflow or runoff. The volume of direct precipitation is estimated to be 9,531 m^3/year.

Runoff

The runoff rate from upland areas around the wetland is estimated to be 140 mm/year based on the overland flow estimate for the Blue Springs Creek (Coward and Barouch, 1978). The water balance is not sensitive to the estimate of runoff as the upland area of the wetland is relatively small. Decreasing the runoff to 70 mm/year changes the water balance by less than 2% and increasing the runoff value to 280 mm/year changes the water balance by less than 4%. The volume of runoff into the wetland is estimated to be 846 m^3/year.

Evapotranspiration

The Actual Evapotranspiration (AET) estimate established by Coward and Barouch is 517 mm/year. A Thornthwaite analysis of precipitation data from the Shand Dam suggests an AET of 507 mm/year. The evapotranspiration rate from the wetland itself is estimated to be 652 mm/year. This reflects the Potential Evapotranspiration considering that there is water available to the aquatic wetland plants for much of the growing season. The volume of evapotranspiration from the wetland is estimated to be 6,905 m^3/year.

Groundwater Inflow

Figure 3.15 depicts the groundwater flow pattern near to the northwest wetland. The shallow groundwater flow is predominantly easterly. The volume of groundwater flowing through the sand layer beneath the wetland is estimated using

$Q = k\ I\ A$ (Equation 1)

Where;

Q = volumetric groundwater discharge (m^3/year)
I = hydraulic gradient (m/m)
K = hydraulic conductivity and
A = cross sectional area through which groundwater passes (m^2).

The hydraulic gradient upgradient of the wetland is estimated using the difference in hydraulic potential between M13S and M14s. There is an average hydraulic gradient of 0.0078 m/m between these stations. The hydraulic conductivity is estimated to be 5 x 10^{-4} m/s based on in-situ testing at MW13S, MPN-1, and MPN-2. The saturated sand thickness is on average 2.5 metres and the length through which flow occurs is 165 metres (see Figure 4.2).

Based on these values, the annual flux of groundwater beneath the wetland from upgradient is 50,408 m^3/year. This estimate of groundwater flux is sensitive to changes in the estimate of hydraulic conductivity.

Groundwater Outflow Horizontal

Equation 1 is used to estimate the volume of groundwater flow downgradient of the wetland. A hydraulic gradient of 0.0078 is used based on the average hydraulic gradient between TP13S and MW14S. The hydraulic conductivity is estimated to be 3 x 10^{-4} m/s based on hydraulic testing at MPE-2. The saturated sand thickness is 3.3 metres and the flow field width is 165 metres.

The estimate of the annual flux of groundwater out of the wetland is 42,343 m^3/year.

Groundwater Outflow Vertical

There is a downward hydraulic gradient observed at both MW13S/D and MW1S/D. The silt till layer retards the downward movement resulting in the development of the wetland in this topographical depression. The silt till thickness is approximately two metres and the difference in hydraulic potential between the bedrock and the sand unit is on average 0.59 m at MW13S/D. The vertical hydraulic gradient across the silt till is 0.30. The vertical hydraulic conductivity is estimated to be 5 x 10^{-8} m/s. This is based on in-situ testing of MW14S (4.3 x 10^{-7} m/s) and MW1S (9 x 10^{-7} m/s) and applying a factor of 0.1[†] to account for the vertical nature of the flow. Thus a vertical hydraulic conductivity of between 4.3 x 10^{-8} and 9 x 10^{-8} m/s can be expected. The area over which this gradient is applied is the maximum size of the wetted perimeter of the wetland or 26,445 m^2 as shown on Figure 4.2. This is the area from the proposed barrier to the upgradient edge of the wetland. The estimated groundwater outflow volume is 12,301 m^3/year.

† Vertical hydraulic conductivity is commonly estimated to be 10% that of horizontal hydraulic conductivity.

Pre Extraction Water Balance Summary

Appendix J, Table J1 summarizes the water balance components for the northwest wetland before extraction occurs. The inputs and outputs from the wetland balance within 2% of the total input to the wetland. Thus, although the water balance is sensitive to the estimates of hydraulic conductivity, the balance between inputs and outputs from the wetland suggest that estimated parameters are reasonable.

5. 1.1.2 NORTHWEST WETLAND WATER BALANCE POST EXTRACTION CONDITION

The two areas anticipated to change post extraction are the horizontal and vertical components of groundwater flow out of the wetland. It is recognized that a hydraulic barrier will be needed to minimize the disturbance of groundwater flow in the shallow groundwater system downgradient of the wetland. The hydraulic barrier will be installed along the southern and eastern portions of the wetland as shown on Figure 4.2. The barrier will limit the outflow of groundwater downgradient of the wetland. There is also an expected change in the bedrock water levels beneath the wetland. According to the results of the 3-D Modflow model, the average drawdown beneath the wetland will be 1.53 metres. This was calculated by averaging the drawdown calculated for each model grid cell between the proposed barrier and the upgradient edge of the wetland. This will increase the flux of groundwater through the silt till layer and thus increase the volume of groundwater moving vertically out of the wetland.

The following changes are anticipated for the post extraction water balance

Groundwater Inflow

The hydraulic barrier will be longer than the wetland is wide, thus the volume of groundwater captured and directed into the wetland area will increase. The width of the flow field affected by the barrier is 210 metres in comparison to the width of the wetland of 165 metres. It is also estimated conservatively that the saturated thickness of the sand aquifer upgradient of the wetland will decrease by 0.5 metres in response to the drawdown created in the bedrock aquifer. The average decrease in potentiometric surface in the bedrock upgradient from the wetland is estimated by the groundwater model to be 0.8 metres (from the wetland to Tributary A), thus a decrease of 0.5 metres in the overburden is conservatively high. The volume of groundwater inflow is estimated to be 51,325 m^3/year.

Groundwater Outflow Horizontal

Groundwater outflow will be governed by the hydraulic conductivity of the hydraulic barrier and the width of the hydraulic barrier. The design hydraulic conductivity of the hydraulic barrier is 1 x 10^{-7} m/s. The elevation of the silt till beneath the barrier is approximately 351.5 m AMSL (MW14). The maximum water level on the upgradient side of the hydraulic barrier will be set at 355.73 m AMSL based on the maximum historical water level observed in the northwest wetland. The average water level in the wetland is 354.98 m AMSL resulting in there being 3.5 metres of water on the upgradient side of the hydraulic barrier. Assuming that the downgradient side of the barrier will be dry, the hydraulic gradient across a 2.5 metre wide barrier will be approximately 1.5. Using Equation1, the groundwater flux across the hydraulic barrier and thus out of the wetland via horizontal groundwater flow is estimated to be 6,623 m^3/year, a significant decrease from pre-barrier construction.

Groundwater Outflow Vertical

The vertical groundwater outflow will increase as a result of the expected water level change in the bedrock aquifer. The water level in the bedrock aquifer will, on average decrease by 1.53 metres, below the wetland. This will increase the hydraulic gradient between the wetland and the bedrock aquifer. The flux of groundwater across the silt till is estimated to be 44,647 m^3/year.

Post Extraction Water Balance Summary

Table J1 summarizes the post extraction water balance for the northwest wetland and compares it with the pre-extraction water balance.

There is a net increase in the water available to the wetland post-extraction. This is mainly due to the retention of water on the wetland side of the hydraulic barrier. The calculated 6 % increase in the water volume available to the wetland is not significant. An overflow culvert will be installed at an elevation of 355.8 m AMSL to ensure that the wetland is not flooded above historical high water level mark. The overflow will discharge into the quarry.

Water levels obtained from the northwest wetland and adjacent monitors have shown that the groundwater levels will seasonally be below the surface water level in the wetland. This shows that the wetland retains water in the absence of groundwater contributions and with vertically downward gradients between the open water and underlying groundwater. This suggests that the organic matte beneath the wetland retards the loss of water from the wetland, at least during the latter part of the year. This retention capability of the wetland sediments is additional natural protection not considered in the water balance analysis.

5.2 TRIBUTARY B

There is a minimum setback of 20 - 30 metres from Tributary B and from there a maximum slope of 2:1 in the overburden. It has been established that Tributary B does not get hydrological support from the groundwater system and the loss of water from Tributary B thus depends on the relative permeability of the underlying sediments. The proposed pit/quarry will not change the relationship of the stream to the underlying sediments, thus no change in the function of Tributary B will occur.

5.3 SPRINGS

Several springs emerge from the overburden to the north and northeast of the proposed quarry. These springs emerge from ground elevations of between 361 and 373 m AMSL and according to our observations and personal communications with property owners, have perennial flow. The source areas for each of these springs are both higher in elevation and more distant from the quarry than the springs themselves. In each instance, the flow from the springs travels southerly, away from the crest of the Paris Moraine.

5. 3.1 ALLEN FARM

The groundwater model predicts that the water level in the bedrock aquifer beneath the Allen Farm spring is 355 m AMSL. This is six metres below the ground surface where the spring emerges. The water level in the nearest well (at the Allen Farm) confirms that the water level in the bedrock aquifer is several metres below ground surface.

The Allen Farm spring flow is not derived from the bedrock aquifer. The spring flow is derived from the infiltration of water in the upgradient area into a relatively permeable deposit that upon encountering a lower permeability till layer, preferentially moves laterally towards the south and discharges where the ground surface intersects the lower permeability layer. The flow in the Allen Farm spring is perennial, thus the hydraulic potential of the source area must always exceed the elevation of the spring (approximately 361 m AMSL). Using the Allen Farm well as the closest indicator of hydraulic head in the bedrock, there is insufficient hydraulic potential in the bedrock to be the source of water for the spring. Flowing artesian conditions do not occur in bedrock wells in this area, another indication that the bedrock cannot be the source of water for the springs.

The groundwater model also predicts that the drawdown as a result of the mining will be approximately 0.8 metres in the dolostone aquifer, significantly less than the observed annual variation of 2.4 metres in the dolostone aquifer. This reduction in the water level in the bedrock will not affect the discharge of water from the spring as it is governed by the overburden source water elevation and the position of the confining layer, not bedrock groundwater levels.

5. 3.2 DE GRANDIS FARM

The groundwater discharge at the De Grandis Farm originates north of the spring-fed pond. Testing of the De Grandis dug well indicates very permeable conditions in the overburden, the source area of water for the spring fed pond. A water level change of 0.55 m is predicted for the dolostone aquifer beneath the De Grandis pond at full build-out of quarry. The model-predicted hydraulic potential of the dolostone beneath the De Grandis pond under pre-extractive conditions is approximately 358 m AMSL or three metres below the ground surface. This suggests that the bedrock aquifer is not the source area for the pond. The proposed extractive activities will not change the water supply of the house well or pond.

Extraction at the site will occur such that monitoring will confirm the model predictions well in advance of any significant change in water levels at the De Grandis property. For instance, extraction of the northern half of the west pond is predicted to result in a two centimeter change in the bedrock aquifer water levels beneath the De Grandis pond (Figure 5.2). Any changes that will occur will be gradual and will be detected by the proposed monitoring program.

5. 3.3 BRYDSON FARM

Water levels are predicted to rise along the southern edge of the quarry. The Brydson spring is located approximately 400 metres southeast of the quarry and will not experience any loss of flow.

5. 4 WATER WELLS

5. 4.1 WATER QUANTITY

There are several water wells within 120 metres of the site. An increase in water levels is predicted to occur south of the pit/quarry and no loss of well yield can occur south of the site.

The groundwater model predicts a 1.6 metre water level change in the dolostone aquifer for the nearest Water Well #5 (Figure 2.7). Considering that the aquifer yields are more than adequate for a residence, the small change in water level will not affect the use of the well and the predicted change in the water level is of the same magnitude as natural annual water level fluctuations. Although access to Water Well #5 was denied, it is assumed that the depth of the well is similar to other wells drilled in the area. The nearest well, Water Well #8, is 33.2 metres deep and has 27 metres of available drawdown. This is a significant amount of available drawdown in the dolostone aquifer and the small predicted change in available drawdown will not affect the use of the well.

5. 4.2 WATER QUALITY

There are two areas of water quality that require consideration.

First, the mining process introduces chemical explosives to the sub-aqueous environment to break the rock apart. A water proof emulsion will be used for the explosives. The emulsion is not soluble in water. In addition, the emulsion will be placed in drill holes fitted with tubular linings. The explosives are consumed at detonation. Sub-aqueous mining is being conducted at the Guelph Limestone Quarry in Guelph and in numerous quarries in Florida. Harden Environmental obtained a water quality sample from the Guelph Limestone Quarry four hours after detonation of the explosives. The sample was obtained from the quarry pond above the broken rock pile. The sample was analyzed for metals, polyaromatic hydrocarbons, volatile organic compounds and hydrocarbons. Water quality results are in Appendix E and summarized as follows;

- No detections of PAHs
- No F1 to F4 hydrocarbons
- No exceedence of Ontario Drinking Water Quality Standards for inorganic compounds
- No exceedences of Ontario Drinking Water Quality Standards for organic compounds.

It is our conclusion that sub-aqueous mining does not have a significant impact on water quality.

Secondly, the water body created will be susceptible to biological contamination introduced by wildlife. The bedrock aquifer is already susceptible to contaminants from the ground surface as recognized in several reports including Halton Rural Drinking Water Study, Phase 1 and City of Guelph Final Groundwater and Surface Water Vulnerability Report (Aqua Resources, March 2010). The water quality survey by Halton Region found that the water from 31% of drilled wells in their survey was unsafe for drinking. The Beak International (1999) study states that in the Blue Springs Creek watershed, the rapid movement of surface water into the bedrock leads to high susceptibility of contamination. Therefore, the quarry is being developed in an area already susceptible to contamination from the ground surface.

Several local homeowners already treat their drinking water or choose to purchase bottled water because of water quality concerns.

Surface water samples of Tributary A and Tributary B exhibited evidence of contaminants from upgradient farming activities with elevated nitrate concentrations. Groundwater samples from wells M2, M3 and M4 also have elevated nitrate concentrations indicative of the movement of nitrogen compounds from the ground surface into the bedrock aquifer. The thin or absent overburden is not effective protection for the bedrock aquifer.

Monitoring of the water quality in the ponds and dolostone aquifer will be conducted.

6.0 MONITORING PROGRAM AND CONTINGENCY MEASURES

6.1 ON-SITE MONITORING PROGRAM

Monitoring has been taking place at this site since 1995. An extensive database of background groundwater and surface water elevations and flow measurements has been developed. A detailed monitoring program will continue to ensure that sensitive features and surface water flows are maintained. The monitoring program is designed to identify trends towards unacceptable impacts early on to allow for time to implement contingence measures.

The monitoring program for this proposed pit/quarry involves the following activities:

- measuring groundwater levels,
- obtain water quality samples,
- monitoring water levels in the on-site wetland and stream, and
- stream flow measurements.

We recommend the following monitoring program.

Parameter	Monitoring Locations	Frequency
Groundwater Levels	M1 S/D, M2, M3, M4, M6, M13S/D, M14 S/D M, MPN1, MPN2, MPS1, MPS2, MPE1, MPE2, MPW1, MPW2, TP1, TP8, TP9	Monthly April to November, February
Groundwater Levels	M2, M3, TP1, M13 S/D M14 S/D	Weekly during first 3 months of extraction
Surface Water Levels	SW6	Monthly April to November
Surface Water Flow	SW4, SW8, SW3	Monthly April to November
Groundwater Quality	M2, M4	Annually
Surface Water Quality	West Pond, East Pond	Annually

6.2 PRE-BEDROCK EXTRACTION WATER WELL SURVEY

We recommend that a detailed water well survey be completed prior to the commencement of the extraction of bedrock resources. This survey will as a minimum include all wells in shaded area shown on Figure 6.1. The well survey will include the following;

- construction details of the well (drilled, bored, sandpoint etc..)
- depth of well and depth of pump
- location of well relative to septic system
- static water level
- history of water quantity or quality issues
- comprehensive water sample including bacteriological analysis, general chemistry, anions and metals
- one hour flow test.

The purpose of survey is to have a baseline evaluation of both water quality and water quantity in nearby water wells. Should an issue arise with a local water well, the baseline data can be used as a reference against future measurements.

6. 3 CONTINGENCY MEASURES

If the on-site monitoring results suggest that an unacceptable impact may occur to a feature, depending on the nature of the potential impact and the type of receptor one or more of the following contingencies could be considered:

- increase the length and/or width of barrier
- decreased rate (or stopping) subaqueous extraction
- change in configuration of mining or decrease in mining extent
- alter timing of extraction to coincide with high seasonal groundwater levels.

7.0 CONCLUSIONS

1) The proposed extraction will be conducted with conventional methods above the water table. Where the dolostone occurs below the water table, the rock will be removed by dragline after being broken by blasting. This results in a relatively minor disturbance to groundwater levels in the dolostone aquifer. The maximum predicted impact on water levels at the property boundary is 1.8 metres.

2) The on-site wetland is underlain by a layer of silt till. The proposed extraction will ultimately result in additional vertical movement of groundwater beneath the wetland. A hydraulic barrier will be constructed to retain water in the overburden sediments beneath the wetland, thus minimizing any impact to flora and fauna in the wetland. It is predicted that the water balance of the wetland will change by less than 4% of the present hydrologic inputs to the wetland. The groundwater level beneath the wetland naturally falls below the surface water level in the wetland, therefore. the wetland is capable of retaining water in the absence of groundwater support.

3) There is a net increase in the water available to the wetland post-extraction. This is mainly due to the retention of water on the wetland side of the hydraulic barrier. The calculated 6 % increase in the water volume available to the wetland is not significant. An overflow culvert will be installed at an elevation of 355.8 m AMSL to ensure that the wetland is not flooded above historical high water level mark.

4) There will be no negative impacts to off-site wetlands. The ground surface of the Allen wetland located north of the site is at least six metres above the groundwater level measured in nearby on-site monitor TP8. There is a loss of water in Tributary B as it passes through the Allen wetland and the wetland is situated at a higher elevation than lands to the west, south and east thereby eliminating the potential for groundwater contributions from those directions. The Allen wetland is therefore supported by direct precipitation, runoff from the property to the north (De Grandis) and interflow.

5) There will not be any loss of water to wetlands, ponds or streams downgradient of the site. It is predicted that water levels in the bedrock aquifer will increase downgradient of the quarry.

6) The measured surface water levels in the northeast wetland are 3.5 metres above the groundwater elevation measured in TP8 nearby. This wetland is not groundwater dependant and will not be affected by the proposed extractive activities.

7) Local residences obtain water from the dolostone aquifer. The minor disturbance to water levels in the dolostone aquifer will not significantly affect any water well with respect to quantity or quality of water available to the residence. The maximum predicted impact to the nearest water well is a drawdown of 1.6 metres. The aquifer in this area productive over a saturated thickness of more than forty metres, therefore no significant change in the yield in the nearest well, or any other well will occur.

8) Spring discharge on the Allen and De Grandis properties will not be affected by the proposed extraction. These springs occur in areas higher in elevation relative to the site and are sourced from permeable overburden sediments distant from the proposed quarry. Spring discharge on the Brydson Farm will not be negatively impacted by the proposed extraction.

9) The slow extraction process and extraction phasing will allow for monitoring to detect changes in groundwater levels in the overburden and dolostone. Should unexpected water level changes arise, mitigation measures will be implemented.

10) The predicted final water level in the West Quarry pond is 348.6 m AMSL and in the East Quarry Pond is 348.4 m AMSL.

8.0 RECOMMENDATIONS

Based on the findings of this environmental assessment conducted on Part Lot 1, Township of Guelph-Eramosa, County of Wellington, we present the following recommendations.

1. That James Dick Construction Ltd. adopts the monitoring program presented in this report.

2. That the mitigative measures described herein be implemented as described.

3. That the attached spill action plan (Appendix J) be implemented as described.

Respectfully submitted

Harden Environmental Services Ltd.

Stan Denhoed, P.Eng., M.Sc.
Senior Hydrogeologist

9.0 REFERENCES

Acton Property Lot 1 Concession 6, Township of Eramosa, County of Wellington Preliminary Report (June 1990) prepared by Ken W. Ingham P. Eng. for James Dick Construction Limited

Aqua Resources, March 2010, Final Groundwater and Surface Water Vulnerability Report, City of Guelph

Beak International Incorporated, 1999, Eramosa Blue Springs Creek Watershed Interim Report

Burt, A.K. and Rainsford, DK.B., 2010, Project Unit 08-003, The Orangeville Moraine Project: Buried Valley Targeted Gravity Study

Burt, A.K., 2011, Project Unit 08-003; The Orangeville Moraine Project: Preliminary Results of Drilling and Section Work

Chapman, J.L. and Putman, D.F., 1984, The Physiography of Southern Ontario

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 228

Coward, J. M. H. and Barouch, M., 1978, Hydrogeology and Ground Water Model of the Blue Springs Creek IHD Representative Drainage Basin, Ontario Ministry of the Environment, Water Resources Report 10, 108 p

Ecological Services Group, 1997, Environmental Impact Study of Proposed Mineral Aggregate Extraction on the Dick Property in Eramosa Property, 30 p

England Naylor Engineering Ltd., 1989, Geotechnical Component Hydrogeological Investigation - Proposed Rural Industrial Subdivision Eramosa Township

Eramosa River - Blue Springs Creek Linear Corridor Initiative, 1995, prepared by Procter and Redfern Limited for the Grand River Conservation Authority

Freeze, R. Allan and John A. Cherry, 1979, Groundwater, Prentice-Hall, Toronto, 604 p

Gartner Lee Limited, 1993, Surface and Subsurface Hydrology of the Credit River Escarpment Tributaries Headwaters Area, Prepared for the Credit Valley Conservation Authority

Gartner Lee Limited, April 2004, Guelph/Eramosa Township Regional Groundwater Characterization and Wellhead Protection Study

Grand River Conservation Authority, 2008, Grand River Watershed Characterization Report (Draft)

Grand River Conservation Authority, 2012, Geospatial Data (Contour - 1 metre, Virtual Drainage, Wetlands, Ortho-imagery 2006 - 30cm)

Harden Environmental Services Ltd., 1998, Industrial Subdivision, Blue Springs, Ontario, Stage 2 Hydrogeological Report

Hydrogeology and Ground Water Model of the Blue Springs Creek IHD Representative Drainage Basin, 1978, prepared by J.M.H. Coward and M Barouch of the Ontario Ministry of the Environment

Influence of Vertical Fractures in Horizontally-Stratified Rocks, by Todd M. Reichart, M.Sc. Thesis University of Waterloo

Karrow, P. F., Pleistocene Geology of the Guelph Area, Southern Ontario, Preliminary Map P. 189, Ontario Department of Mines, Scale 1:50000

Karrow, P.F., Miller, R.F., and Farrell, L., 1979, Guelph Area Southern Ontario; Ontario Geological Survey Preliminary Map P.2224 Bedrock Topography Series, Scale 1:50000

Ministry of Natural Resources, Land Information Ontario, 2011, Data Class Shape files: MNR (Contour, Lot Fabric Improved, OHN - Waterbody, OHN - Watercourse, ORN Segment with Address, Railway, Watershed Quaternary, Wetland Unit), OMAFRA (Soil Survey Complex), MMAH (Municipal Boundary - Lower and Single Tier, Municipal Boundary - Upper Tier and District)

Ministry of the Environment Water Well Records

National Air Photo Library, 2011, Aerial Photographs taken April 1930, April 1964, June 1972, April 1980 and May 1994

Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 128 – Revised

Procter and Redfern, 1995, Eramosa River - Blue Springs Creek Linear Corridor Initiative Appendices and Background Report for GRCA

Reichart, T.M., 1992, Influence of Vertical Fractures in Horizontally Stratified Rocks, M.Sc. Thesis University of Waterloo, 63 pp

Turner, M.E., 1978, Guelph - Amabel Aquifer, Ontario Ministry of the Environment, Hydrogeologic Map 78-4, Scale 1:100000