Daryl W. Cowell & Associates Inc.

October 23, 2009

Mr. Randy Scherzer
County of Grey
595, 9th Avenue
Owen Sound, ON N4K 3E3

Dear Mr. Scherzer:

Subject: Updated Karst Evaluation Report for Beaver Valley Village Proposed Plan of Subdivision, Part Lots 1&2, Concession 6, Municipality of Grey Highlands.

I am enclosing a copy of the recently completed karst update report in support of the above noted application. The report was previously sent to you, Ms. Lorelie Spencer (Municipality of Grey Higlands), R.J. Burnside (Don McNalty, Dave Marks and Herb Lemon), and Mr. Marcus Buck via e-mail. By way of this letter I am providing you with a hard copy of the report.

As I noted in my e-mail (dated October 20, 2009), I had discussed an earlier draft of the report with Mr. Marcus Buck, the county's karst peer review expert. You will need to get direction from him specifically but I believe we have reached consensus on the significant points.

I look forward to discussing this with you and the review team as required and pleas do not hesitate to call me if you would like additional information or have any comments.

Yours truly,

Daryl Cowell

Daryl Cowell, President

Cc/ Ms. Lorelie Spencer , Municipality of Grey Highlands

27 Rita Crescent,
R.R.#1, Tobermory, ON N0H 2R0
Ph: 519-596-8187
daryl.cowell@sympatico.ca

UPDATED KARST EVALUATION REPORT FOR BEAVER VALLEY VILLAGE PROPOSED PLAN OF SUBDIVISION

Municipality of Grey Highlands

Prepared for:
Mr. Martin Kiener

Prepared by:
Daryl W. Cowell & Associates Inc.
Consulting Geomorphologist
27 Rita Crescent,
RR#1 Tobermory, Ontario
N0H 2R0
519-596-8187

October 16, 2009

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BEAVER VALLEY VILLAGE
PROPOSED PLAN OF SUBDIVISION

1.0 INTRODUCTION

This report incorporates the results of karst field studies undertaken on November 27th, 2006 and presented in an earlier report ("Karst Evaluation Report for South Wodehouse Creek Proposed Plan of Subdivision", September 19, 2007) along with more recent field studies. Additional field studies were undertaken in September 2009 (September 1 and September 16) in response to peer review direction provided by Mr. Marcus Buck of Karst Solutions. Specifically, the objectives of the more recent studies were to investigate the location and characteristics of the spring or springs in Bowles Gully likely connected to the main sinkhole (ponor) that drains Wodehouse Creek on the subject property. This report has also been updated to include the various responses prepared to address other peer review comments provided by Mr. Buck and R.J. Burnside & Associates Limited[1].

The site consists of 29.74 ha including parts of Lots 1 & 2, Concession 6 in the Municipality of Grey Highlands (formerly Euphrasia Township) in Grey County on the west side of the Beaver Valley about 8 km east of Markdale. It is bordered on the west by the 7th Line, on the south by Bowles Bluff Drive, on the east by Windy Lane Drive and on the north by vacant lands and Sideroad 4A. The proposed development consists of 45 single family lots on uplands (Figure 1).

The subject lands consist of a high central moraine ridge surrounded on the west by a wetland and channel of a small tributary to Wodehouse Creek. This tributary flows north then east to join Wodehouse Creek north of the proposed development. Wodehouse Creek flows south to form the eastern edge of the proposed development. The lands consist of wet floodplain along the two channels and former agricultural fields on the moraine. Vegetation on the upland areas includes an old field, hedgerows, an old apple orchard, and a young hardwood forest.

The November 2006 field studies were undertaken principally to identify and inventory surface karst within and adjacent to the proposed development site. This included a complete circumnavigation of the proposed development lands including immediately adjacent lands. Estimates of flow were made at all tributaries and culverts draining into Wodehouse Creek in order to determine whether the creek was gaining or losing flow in the downstream direction which might indicate surface karst. These estimates were made without instrumentation which would be difficult and inaccurate given the low flows. Although the absolute flow volumes are order-of-magnitude, for this survey it was the relative flow volumes that were important in order to determine whether or not all of the

[1] Buck – e-mail comments and letter to Randy Scherzer (County of Grey) dated August 8, 2008 and November 3, 2008, respectively and R.J. Burnside & Associates Limited – letter to Ms. Kelley Coulter, Municipality of Grey Highlands.

observed surface flows on the property could be accounted for at the ponor. The entire site was then walked including along the edges of Wodehouse Creek and its western tributary, the moraine ridge was crossed in three locations, and walked along the crest. In addition, the area had previously been checked using aerial photos which provided a number of targets for field checking.

The September 2009 studies focussed principally on the sinkhole to spring connection including a thorough search along the face of the escarpment and lower slopes for springs/drainages (September 1); determination of flows at the ponor, spring and a downstream location (both dates); measurement of temperature and specific conductance at the three locations (both dates); sampling for nutrients and major ions (September 16, only); and a full day monitoring of downstream flows during a six-hour pumping test at two newly installed wells on the subject property (September 16)[2]. The downstream location was a culvert crossing on the Beaver Valley Ski Club property for which a stage-discharge curve had previously been developed. Once again, flows during the September 2009 studies were too low to be measured with standard instrumentation but to ensure the best accuracy, they were calculated using measurements of channel cross-sections along with stream velocity as determined by timing a floating object along a known distance. This method tends to overestimate flow volumes (since bed friction is not accounted for), however, the relative flow determinations between two locations or taken at one location over time will be comparable.

2.0 BACKGROUND

The study area lies within an area well known for the presence of karst. The Wodehouse Creek karst which lies to the north of the study area (immediately north of Sideroad 4A) was studied in detail by the author as the subject of an undergraduate thesis (Cowell 1973, Cowell and Ford 1975). This area was subsequently designated as a Provincially Significant Earth Science ANSI (Area of Natural and Scientific Interest) known as the Wodehouse Creek Karst and Dry Valley Complex ANSI. This ANSI was first designated by the author as a Candidate Nature Reserve as part of a larger assessment of earth science features along the Niagara Escarpment (Cowell and Woerns 1976). The boundaries of this ANSI were later proposed to be extended southward onto the subject site to include all of the dry valley, Wodehouse Creek, the ponor and overflow channel to Bowles Gully in 2007 (Cowell, letter and hand-drawn map provided to Mr. Phil Kor, Conservation Geologist, Ontario Parks, Peterborough). Other sinkholes are known to occur outside the subject lands and some of these have also been evaluated by the author with regard to proposed developments (e.g., Beaver Valley Woodlands) and the Niagara Escarpment study.

The term Karst refers to both a process and a suite of landforms. As a process, it is the chemical dissolution of certain soluble rocks (particularly limestone and dolostone) by

[2] This report should be read in conjunction with the Supplementary Hydrogeologic Evaluation Report by Ian D. Wilson Associates Limited, October 19, 2009.

dilute acids found in natural water (including rainfall, surface streams and lakes, and groundwater). Landforms created by this process include, *inter alia*, sinkholes which serve to drain surface waters into the bedrock; caves which conduct water through the bedrock; and springs or resurgences which form where the cave waters discharge back onto the surface.

Such karst landforms are common along the upper crest of the Niagara Escarpment and are particularly common in the Beaver Valley – Blue Mountains area. The relatively high density of sinkholes parallel to the escarpment face on both sides of the Beaver Valley is quite striking and is likely partly due to the horizontal shifting of the upper escarpment cap rock (stress release phenomenon) allowing surface waters to easily access the upper aquifer and initiate karst systems.

The determination of specific conductance and temperature for waters entering and emerging from dolostone bedrock provides important information pertaining to the karst process (Cowell and Ford 1980). Temperature is particularly important during the extremes of the year when air temperatures are near minimums (winter) or maximums (summer). Deeper bedrock aquifer temperatures approximate the annual average temperature for the region throughout the year compared to shallow bedrock which tends to fluctuate with air temperature. The average annual air temperature for the Owen Sound MOE weather station is +7.1°C (http://www.climate.weatheroffice.ec.gc.ca/) and Cowell and Ford (1980) found diffuse type springs (recharged by percolation water) to be consistently below about 10°C throughout the summer period as compared to conduit fed springs (e.g., recharged by sinking streams) which were warmer and fluctuated more widely in concert with air temperature. In winter, the deeper diffuse type springs and residual bedrock water would be expected to be warmer than the air temperature and surface waters.

Specific conductance is the measure of the capability of water to conduct electricity that is controlled by the dissolved ions in the water (ionic activity and content). Hence, the higher the specific conductance, the higher the concentration of dissolved substances in the solution. In dolostone dissolved ions would consist principally of Ca^{++} and Mg^{++} and anions of HCO_3^-. The solution of bedrock is controlled by numerous factors but all things equal, tends to be lower in winter/early spring than in mid-summer when plants and soil microbes can boost the solution process through the production of CO_2. Thus, all else equal, specific conductance measurements should indicate lower values in surface waters and shallow groundwaters with low bedrock residency times, than waters with greater contact with the bedrock.

Karst features have been identified in the Provincial Policy Statement (PPS, 1997 and 2005) as "hazardous sites". Policy 3.1.1 of the 1997 PPS notes that "Development will generally be directed to areas outside of…c) hazardous sites." "Hazardous sites" are further defined in the PPS as "property or lands that could be unsafe for development and site alteration due to naturally occurring hazards. These may include unstable soils…or unstable bedrock (karst topography)."

Although the hazard is related in the PPS to instability such as collapse, other hazards may include flooding, particularly if development takes place over the karst, and the conduct of contaminants to connecting groundwater systems and springs. Hence, developments proposed in karstic areas must account for the karst and either develop appropriate mitigation measures or avoid the karst.

3.0 GEOLOGICAL SETTING

The proposed development lies immediately above the brow of the escarpment on the west side of the Beaver Valley (west of the Beaver Valley Ski Club facilities). The underlying bedrock is the Amabel dolostone which forms a thick cap rock above shales and thinner dolostone bedrock units (Figure 2). The Amabel is largely a fractured aquifer whereby groundwater passes along fractures including joints and bedding planes from zones of recharge located above the escarpment to a discharge zone along the escarpment face. The Amabel is underlain by another carbonate unit – the Fossil Hill Formation which in turn is underlain by the Cabot Head Formation shales[3]. The lowest part of the Fossil Hill and the Cabot Head shales form an aquiclude that prevents further downward movement of groundwater and, hence vertical karst formation. As a result, numerous permanent and intermittent springs can be found along the escarpment face at or immediately above the contact of the Amabel with the Cabot Head.

The regional topographic gradient above the escarpment in this area is toward the west – southwest. However, many small streams such as Wodehouse Creek to the north of the study area drain toward the edge of the escarpment (Figure 3). The creek was prevented from crossing the escarpment by moraine ridges located north of the study area including the Tara Strands and the Gibraltar Moraine (Barnett 1992). The moraine ridges run along and parallel with the escarpment edge preventing the creek from crossing over the edge. Thus, Wodehouse Creek was forced to flow southerly until it found a breach in the moraine at Bowles Gully located east of the site. This effectively lengthened the channel which increased the opportunity for its underground capture by karst.

The location of stream capture is controlled by the presence of a surface stream channel and the coincident impingement of the channel with bedrock either via a rise in the bedrock surface into the channel or by the presence of more permeable soils. Once the stream is captured and surface waters are diverted into the bedrock, other sinkholes are likely to form in the immediate vicinity of the stream capture. The stream capture point is a type of sinkhole referred to as 'Streamsink' or 'Ponor'. As karstification proceeds in the area, other sinkholes referred to as 'Suffosion Sinkholes' may form. The latter are formed by the gradual subduction of surface soils downward into enlarging cavities at the interface between the soil and the surface of the bedrock. Both of these types of features are found well developed to the north of study area in the Wodehouse Creek ANSI (Figure 3).

[3] The stratigraphic nomenclature of the Silurian sequence of the Niagara Escarpment is currently being re-evaluated but this report uses the terminology in common usage as per the available literature.

Even though cave systems have formed of sufficient size to capture surface streams, the Niagara Escarpment karst is young in geological terms (<10,000 years) and the conduits tend to be small compared to well known cave systems in other parts of the world. Most are too small for human passage and are usually only a few millimetres to a few centimetres in size (Worthington 2006), however individual systems can have explorable passage (e.g., Eramosa Karst near Hamilton). Most Niagara Escarpment karst systems tend to reach capacity quickly resulting in flooding over the sinkholes during periods of highest flow such as during spring melt and following heavy storm events. Although these small conduits tend to concentrate flow through the aquifer, their effect is highly localized and 'normal' fractured aquifer flow tends to occur within very short distances of the karst.

4.0 STUDY AREA KARST

4.1 Soil Texture

The central north-south oriented moraine ridge on the property is part of the Tara Strands (Barnett 1992). The moraine ridges in this area consist of fine-grained soils that limit permeability and karst development. The karst tends to be focussed in the inter-morainal areas where soils are the thinnest (Cowell 1973, Cowell and Ford 1975). One soil sample was collected from below the B horizon at approximately 60 cm for texturing (sampled via a hand-held Dutch Auger). The sample was collected from the top of the moraine on the southernmost portion of the property for hand texturing. The texture of this sample was a gravely silty clay loam which indicates that the moraine and, hence, the area proposed for residential development has a low permeability and is not highly susceptible to karstification. Most of the rainfall on this part of the site likely drains as surface runoff and shallow groundwater into the adjacent valleys. As a result the shallow groundwater system is likely not connected to the bedrock aquifer (see associated hydrogeological evaluation by Wilson Associates).

4.2 Surface Drainage

Drainages entering the property were observed in order to estimate flow volumes. The main channel of Wodehouse Creek crosses the unopened road allowance of Sideroad 4A north of the study area (location "1" on Figure 1). This channel is supplemented by two small tributaries which cross the 7th Line through culverts (locations "2" and "3", Figure 1). The combined flow of these two tributaries joins Wodehouse Creek then flow southward to the point were the channel exits the subject lands. At this point the entire flow of the creek drains into a sinkhole complex located within its channel (location "4").

The estimated flows at the above locations were noted as <1 L/sec; <2 L/sec; <3 L/sec; and 7 to 10 L/sec, respectively. This indicates that the water flowing onto the site (<6L/sec) could be accounted for by the water exiting via the sinkhole complex. The additional flow at the sinkhole is due to additions within the property south of Sideroad

4A and suggests that there is little or no loss of surface waters to karst within this area other than at the ponor.

4.3 Sinkhole Karst Areas

Four karst areas consisting of one or more sinkholes were identified within and immediately adjacent to the property during the November 2006 studies. These are listed in Table 1 along with their UTM co-ordinates and shown on Figure 1. Sinkhole Karst Area "A" is the in-stream ponor of lower Wodehouse Creek and nearby incipient sinkholes. It is referred to as the "downstream" ponor to differentiate it from the larger ponor located upstream within the main Wodehouse Creek Karst. Karst Area A lies at the boundary of the property less than one kilometre upstream from the former waterfall at Bowles Gully at an elevation of between 401 and 402 mAMSL (based on interpolation from the Ontario Base Map).

The stream karst consists of three main sinkpoints that variously take water depending on flow levels in the creek (Photo 1). The lowest and most easterly sinkhole is directly in-line with the creek channel and is active at all flows. As flows increase, the two westerly off-channel sinkholes become activated in sequence. These three sinkholes are aligned exactly east-west which reflects one of the major joint orientations of the Amabel Formation (Cowell 1976). At the time of each field visit, only the lowest sinkpoint was active.

As all three sinkholes reach capacity, the creek overflows into the lower "dry" valley of the creek. This likely occurs at least once per year during the snowmelt period. Downstream of the ponor the channel bed rises to a level approximately 1.5 m higher than at the sinkpoint. Three small incipient suffosion sinkholes are beginning to form immediately downstream of the ponor but west of the main channel.

Table 1. Description and Location of Karst Areas in the Study Area

Sinkhole Karst Area	Description	UTM (NAD 83)	UTM (NAD 27)
A	Wodehouse downstream ponor – 3 in-stream sinkpoints and 3 higher level incipient suffosion sinkholes.	0535272 4911408	0535258 4911185
B	A series of 4 small suffosion sinkholes.	0535255 4911221	0535241 4910998
C	Small boulder filled suffosion sinkhole.	0534994 4911981	0534980 4911758
D	2 circular soak-away depressions	0534841 4911194	0534827 4910971

Karst Area B includes 4 suffosion sinkholes located on the eastern edge of the property and partly on the rear lot of 108 Windy Lane Drive (Table 1, Figure 1). Two of the sinkpoints show active subduction of soil with small collapse scars along their upper rims (Photo 2). These two depressions are beginning to coalesce along their rim and range from about 1 to 2 meters deep. The other two sinkholes are smaller and appear more stable. These lie a few meters to the northeast on the adjacent property on Windy Lane Drive. There are no permanent or ephemeral surface drainages into these sinkholes but they would receive snowmelt and direct precipitation.

The third sinkhole karst area (Area C) consists of a single small suffosion sinkhole immediately north of the study area on the lower part of the moraine (Photo 3). This feature lies at the base of an elm tree and has been filled with boulders. It is common for farmers to utilize sinkholes in this way and the tree helped mark the location of the sinkhole and rocks so it could be avoided during ploughing. The feature is only about 2 m across and does not show any evidence of active slumping. There are no permanent or ephemeral surface drainages into this sinkhole.

Karst Area D consists of two shallow, broad soak-away depressions within a small intermittent channel (Table 1, Figure 1). The channel drains into the west tributary of Wodehouse Creek downstream of location 3. The depressions are in the order of 6 to 8 m in diameter and less than one meter deep (Photo 4). They fill with water during heavy rainfall events and snowmelt periods but mostly overflow to the connecting channel. Over time water sitting in the depressions soaks away into the ground but there is no direct conduit connection through the soil to the bedrock and the features appear stable with no evidence of downward soil slumping or piping. They have been designated as a "Karst Area" to be conservative but there is no evidence to suggest they have developed karstic drainage through the underlying bedrock.

4.4 Ponor – Spring Connection

The nature of the sinkhole to spring connection was investigated in September 2009. The spring was located flowing from talus approximately 220 m east of the ponor at an elevation of approximately 375 mAMSL (Figure 4, Photo 5). No other active springs were found below the escarpment in Bowles Gully although a second area of possible emergence to the north was observed. If this feature is a spring it likely only flows for short periods during snowmelt. Water issuing from the active spring is not utilized for drinking water[4] and the only known use is during the winter for snow making at the Beaver Valley Ski Club (BVSC). The BVSC has a CofA (MOE Certificate of Approval) to withdraw up to 10% of the flow in this creek during the winter to supplement its snow making capability (D. Lobb, Manager, BVSC).

The karst system appears to consist of a short simple conduit following one or more joint planes. Although the low flow discharge was emerging from the talus, the main bedrock

[4] A local resident noted that her neighbour had formerly siphoned water for household use from this spring but has not for many years. The remains of a pipe was found near the spring but there is no evidence of any active use.

flow could be heard within the rock mass immediately below the talus line at the cliff face within the open east-west joint (Photo 6). A simple, direct conduit connection between the ponor in Karst Area A and the spring is indicated by the east-west orientation of the interpolated flow route coinciding with the joint plane orientation; the close proximity of the ponor and only active spring; chemistry and temperature (Table 2); and flow volumes.

Conductance and temperature were measured at the ponor and at the spring on both dates (September 1 and September 16). The conduit water could not be sampled directly within the bedrock but only after passing downward about 6 m through open talus. However, both temperature and conductance values are very similar to those at the ponor.

Temperature and specific conductance measurements at the two newly installed wells on the Beaver Valley Village lands were taken by sampling pump discharge and the results are also provided in Table 2. The wells intersect the regional bedrock groundwater under the site which was found to have significantly higher conductivities and lower temperatures showing little fluctuation over the course of the measurement period (approximately between 9:20 AM and 4:00 PM, Table 2).

Table 2. Specific Conductance and Temperature Measurements of Surface Waters Investigated in September, 2009.

Location	**Specific Conductance (µS/cm)[1,2]**		**Temperature °C**	
	September 1	**September 16**	**September 1**	**September 16**
Ponor	568	563	11.4	13.4
	561		14.1	
Spring	598	594	12.4	13.0
Ski Club Crossing	537	538	15.4	14.3
East Well	648	698	9.0	9.6
		693		9.4
		695		10.1
North Well		907		9.8
		904		10.1
		909		10.6
		862		10.2

1 Specific Conductance meter is a YSI EC300 compensated to 25°C.

2 September 1 Ponor – sampled at 10:30 and 13:00hrs; September 1 Spring – sampled at approx.12:00hrs; September 16 East Well – sampled at 9:20; 9:45 (with 1.5 m drawdown); 14:25hrs; and September 16 North Well – sampled at 10:40; 11:00; 14:20; and 16:00hrs.

Temperatures of the ponor and spring are warmer than the well water which is consistent with the former having more of a direct influence from atmospheric temperatures[5]. The temperature of the deeper groundwater, as noted above in Section 2.0, is controlled by the regional average annual temperature and is typically in the range measured at the two new wells. Significant contributions of groundwater to the spring would thus be expected to significantly increase the conductance and lower the measured temperature than those measured. The measured rise in conductance between the ponor and spring on both dates indicates that some groundwater is contributed from the bedrock, at least in the area immediately surrounding the karst conduit(s). However, this would account for no more than about 10% of that contributed at the ponor.

The lack of significant groundwater additions to the spring at the time of sampling is also shown by flows. The flow at the ponor was calculated as 12.3 L/sec compared to only 8.3 L/sec below the springs. The spring flow could not be determined where it emerged from the talus but was calculated at a small bridge crossing on the Beaver Valley Ski Club property, approximately 400 m downstream of the spring (Figure 4, Photo 7). The lower flow at the stream crossing compared to the ponor could be due to measurement error, storage in the bedrock, storage in the talus, and/or vegetative uptake. However, there was clearly no significant increase in flow at the crossing which supports the conclusion that there is no significant contribution from regional groundwater. This is further confirmed by the fact that during most summer-early fall periods all flow in this stream completely ceases (D. Lobb, Manager, BVSC), however the 2009 season has been wetter than normal.

4.5 Pumping Test

Although the flow, temperature, and conductance data indicate there is little or no regional groundwater contributions to the spring, the potential for impacts to spring flow due to well pumping was tested. This test involved the pumping of the two newly installed wells on the Beaver Valley Village property over a six-hour interval. Prior to the initiation of pumping a gauge was fixed to the side of the culvert at the Beaver Valley Ski Club crossing (Figure 4, Photo 7). The gauge was set to the bottom of the creek immediately adjacent to where the flow entered the culvert and placed so the flow would not artificially raise the water level at the gauge. Table 3 provides the results of the test. The measured levels record the depth of water in the channel at that the point.

The flow at the gauge was measured as 9.4 L/sec at the time of placement (08:05hrs). Flows into the ponor were 11.3 L/sec at the start (08:35hrs) of monitoring and 7.5 L/sec near the end of monitoring (17:45hrs). Table 3 indicates that levels at the lower crossing remained constant until after pumping was stopped at the east well[6]. Although the

[5] Overnight low was approximately 10°C on 01/09/09 and 9°C on 16/09/09; day maximums were 20°C and 17.6°C, respectively based on data available for Toronto. Heavy rain was recorded on August 29 with no additional significant rainfall prior to 16/09/09.

[6] East well pumping started at 9:11 and ended at 15:11 @ 22L/min; North well pumping started at 10:38 and ended at 16:38 @ 13 L/min.

subsequent change in flow at the spring could have been affected by pumping at the wells, the amount would be very minor as the total reduction in flow is dominated by the decrease in recharge to the ponor.

Table 3. Time – Flow Level Monitoring of Spring Discharge at Beaver Valley Ski Club Culvert During Active Well Pumping Test.

Time (hrs)	**Gauge Level (cm)**
08:00	6.8
10.26	6.8
12:35	6.8
14:00	6.8
15:10	6.8
16:15	6.7
17:20	6.6
18:30	6.5

4.6 Nutrient and Selected Metal Concentrations

Water samples were collected from the wells, ponor, spring and downstream crossing on September 16, 2009 for nutrients, major ions, and metals. Sample bottles were provided by the laboratory (Maxxam Analytics) and collected samples were refrigerated immediately then driven to the lab. Table 4 shows the results of some of the main parameters of concern. The concentrations of nutrients or metals were found to be quite low and none exceeded Ontario Drinking Water Standards (ODWS).

Table 4. Major Nutrients and Metals in Ground and Surface Waters (September 16, 2009)

Parameter	**Units**	**East Well (TW4)***	**Ponor**	**Spring**	**Crossing**
Total Ammonia-N	mg/L	ND	0.08	ND	ND
Total Organic Carbon	mg/L	0.7	2.8	2.0	1.4
Orthophosphate (P)	mg/L	ND	ND	ND	0.02
Total Phosphorus	mg/L	NA	0.02	0.03	0.02
Dissolved Sulphate (SO4)	mg/L	12	7	8	11
Dissolved Chloride	mg/L	44	8	20	18
Nitrite (N)	mg/L	ND	0.02	ND	ND
Nitrate (N)	mg/L	1.4	1.1	1.4	1.3
Total Lead	µg/L	ND	ND	ND	ND
Total Zinc	µg/L	ND	ND	ND	ND
Total Iron	µg/L		160	270	130

* ND = not detected; NA – not analysed

The ODWS for dissolved organic carbon, nitrite, and nitrate are 5, 1.0, 10.0 mg/L, respectively. The Ontario Water Quality Interim Objective for total phosphorus (TP) is below 0.03 mg/L to prevent excessive plant growth in rivers and streams. The interim objective for TP in rivers in springs was slightly exceeded at the spring but not downstream at the lower crossing.

Dissolved chloride increased between the spring and ponor by more than twice (8 mg/L to 20 mg/L). Some of this increase may be contributed from local groundwater (44 mg/L at the well), the increase from this source alone would require about 50% of the spring flow to be sourced from groundwater – this is much higher than the chemistry, temperature, or flow evidence indicates. Higher chloride concentrations at the spring is more likely due to local contributions from nearby houses and two roads that cross the path of the conduit as these are used most heavily in winter to access the ski facility.

5.0 CONCLUSIONS

(1) The downstream ponor (Karst Area A) is the most significant karst within the proposed development area and should be considered as a "hazardous site" under the PPS. This karst lies within the channel of Wodehouse Creek and serves to direct the creek to a main spring located on the escarpment face during most of the hydrological period. Virtually all of the underground conduit and the spring are outside of the development lands.

(2) Karst Area B is a significant suffosion sinkhole complex and is also considered to be a "hazardous site" under the PPS. The site should be avoided by direct development.

(3) Karst Area C is north of the proposed development area and should not be impacted. This small sinkhole is not active and should remain so provided no drainage is directed toward it. This feature could be filled and stabilized in the future if necessary.

(4) The two soak-away depressions in Karst Area D are not significant and may in fact not be karstic as they have not developed a conduit flow connection with the underlying bedrock. The proposed site plan does not incorporate this area directly and, as such, these could be left to continue to operate as under current conditions.

(5) The main area of the Wodehouse Creek Karst ANSI is located well upstream of the proposed development, thus there will be no impact of this proposed development either directly or indirectly (via runoff) on the main ANSI. The proposed boundary extension of the ANSI follows the creek bank within the easternmost extent of the development site with Karst Area A being the only karst within the downstream extension of the ANSI. This karst lies well outside of any proposed development (Figure 1). The proposed stormwater management facility will drain to Wodehouse Creek well upstream of the ponor and incorporates a simulated wetland which will result in an "enhanced" treatment level for stormwater prior to entering the creek.

Adjacent lands to both the channel and the in-stream sinkholes are designated as open space/stormwater management (Block 2, Figure 1) and will be dedicated to the municipality. Setbacks from the ANSI boundary to the nearest road (Street A) is greater than 50 m which exceeds commonly required setbacks of 15 to 30 m adjacent to surface karst features. Hence, the Wodehouse Creek ANSI and its downstream extension will not be impacted by the development.

(6) The ponor (Karst Area A) is connected to the spring in Bowles Gully via a short and direct connection with no evidence of significant regional bedrock groundwater contributions to the spring during low flow conditions. Such contributions during high flow conditions, particularly during spring snowmelt, may occur but these would be relatively short duration and would occur at the same time the ponor reaches capacity and overflows via the surface channel to the waterfall in Bowles Gully.

(7) The on-site karst appears to operating as a distinct conduit system throughout most of the hydrological period[7] with little or no connection to regional groundwater systems. This, along with lack of a hydraulic connection between the overburden groundwater system and the bedrock aquifer will prevent significant contamination to the karst system and downstream areas.

(8) One of the reviewers also raised the issue of potential water quantity and quality impacts to a Life Science ANSI in Bowles Gully due to potential changes at the springs. However the Grey County OP shows the ANSI to lie well south of the influence of the spring in Bowles Gully. In any case the results of the field studies indicate that flow at the springs will not be impacted by groundwater usage during most of the year, especially during the critical low flow period, and the only potential for contamination would be from site-runoff (see #7, above).

6.0 RECOMMENDATIONS

Karst Area A – avoid stormwater drainage directly into these sinkholes.

Karst Area B – protect by a 30 m naturally vegetated setback and avoid directing additional runoff toward the area.

Karst Area C – in the short term, avoid directing surface runoff toward the sinkhole and in the longer term this feature could be plugged.

Karst Area D – not significant and do not require any mitigation.

[7] Lower Wodehouse Creek, below the spring point in known to completely dry up during most summer periods (D. Lobb, Manager, Beaver Valley Ski Club), however remained active during 2009 due to above average rainfall amounts distributed throughout the summer period.

7.0 REFERENCES

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Daryl Cowell

Daryl W. Cowell (P.Geo. #791)

8.0 FIGURES

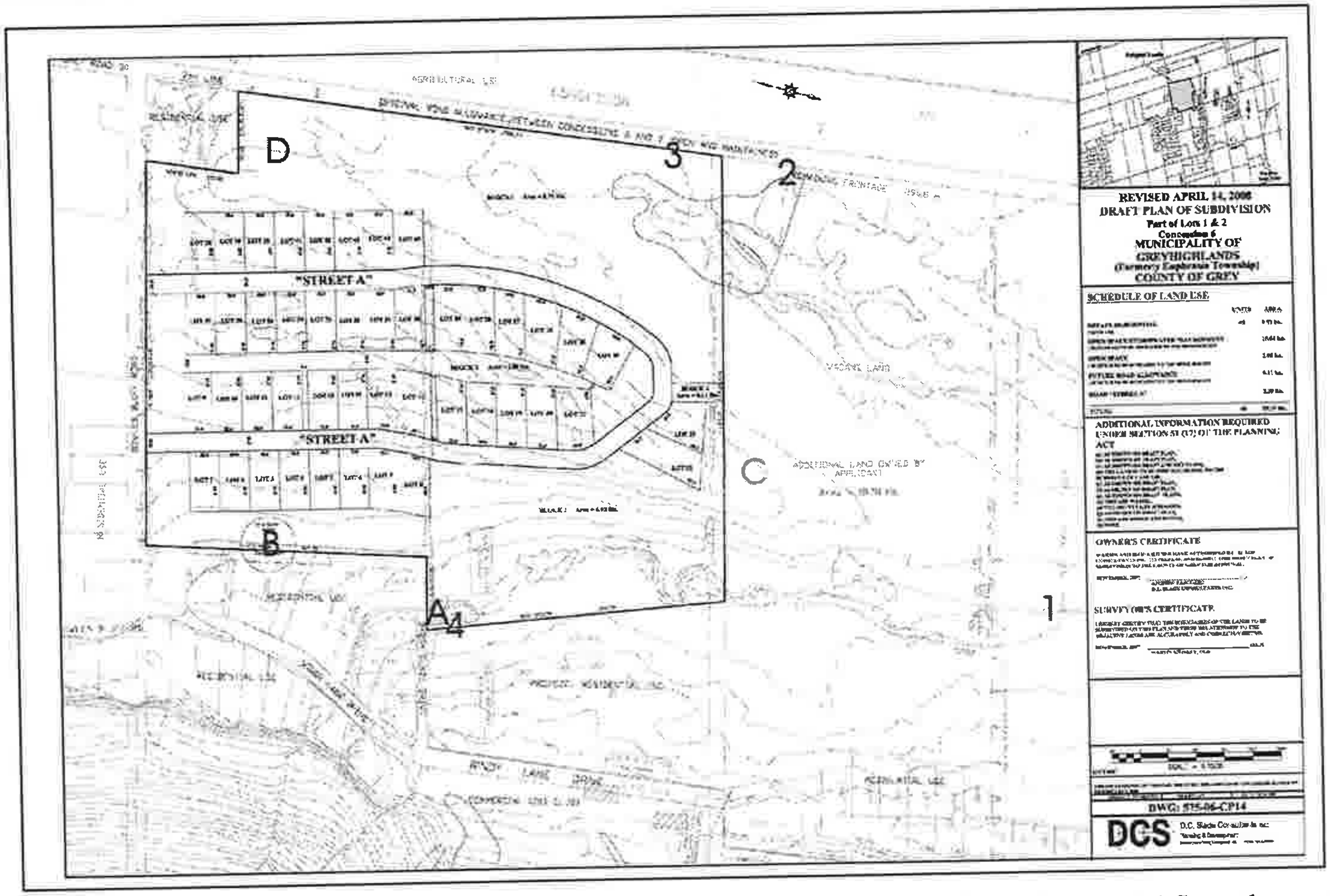


Figure 1. Concept plan for the proposed development showing the approximate locations of estimated flow observations (#1 – 4) and karst areas (A – D) (see text).

Series	Formation/Member	Lithology
Middle Silurian	Amabel A_c Colpoy Bay/Wiarton (reefal) A_b Colpoy Bay/Wiarton (non reefal) A_a Lions Head	Biohermal white to light grey dolostone White to light grey dolostone, streaky blue-grey mottles Light grey-tan dolostone, blue to purple mottles, chert nodules
	Fossil Hill	Fossiliferous micro-crystalline Dolostone
Lower Silurian	Cabot Head	Red with some green shales and occasional thin dolostone partings
	Manitoulin	Thin- to thick-bedded buff dolostone and calcareous dolostone
Upper Ordovician	Queenston	Red, Grey and Green Shales

Figure 2. Bedrock lithology of the Blue Mountains area (modified from Cowell 1976).

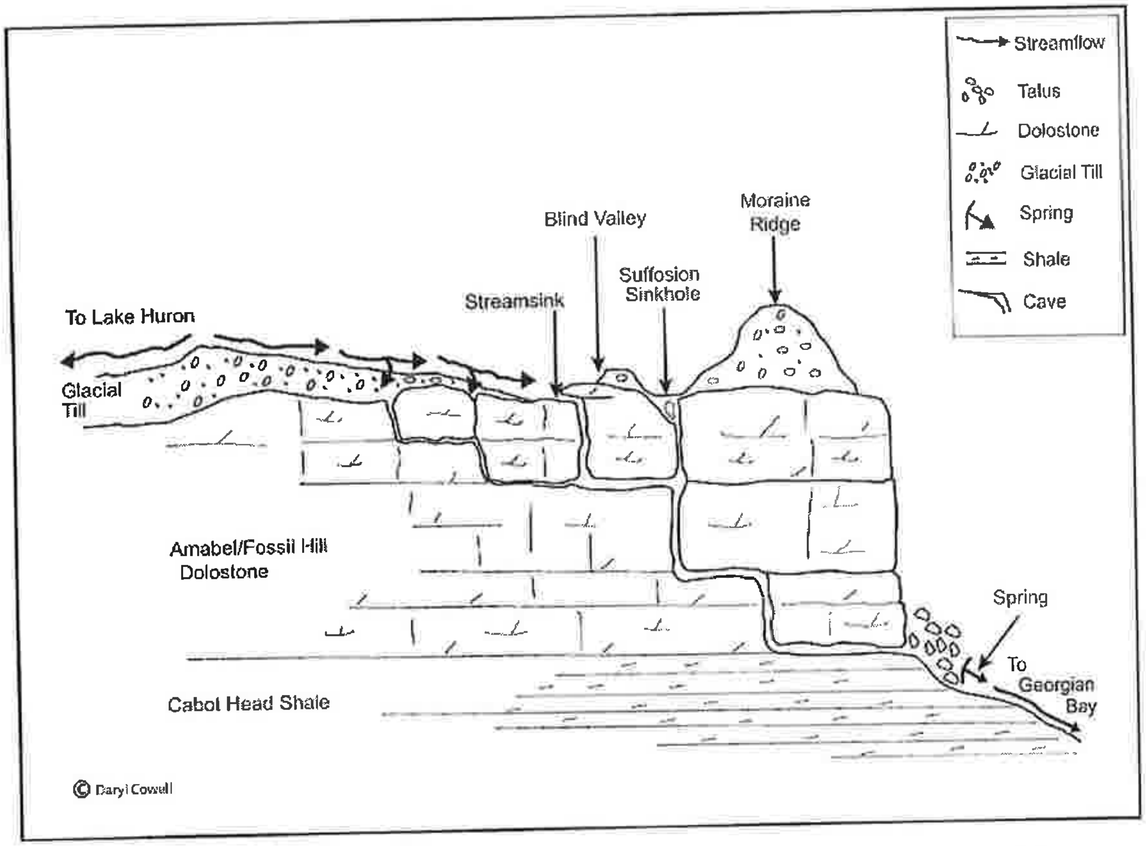
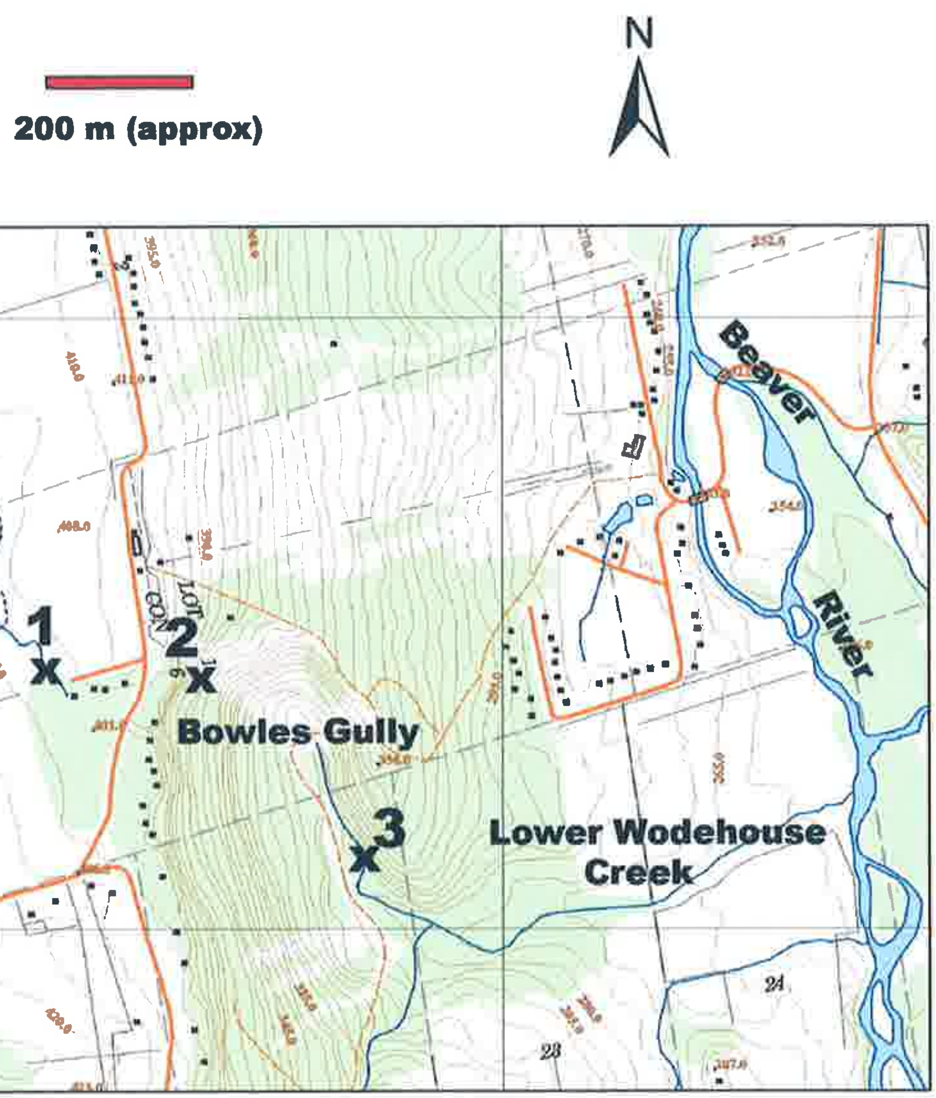


Figure 3. Schematic cross-section of karst system at Wodehouse Creek north of the Beaver Valley Village site (from Cowell 2004).

Figure 4
Location of Ponor (1), Spring (2) and
Beaver Valley Ski Club Stream Monitoring Location (3)
Beaver Valley Village Proposed Development



9.0 PHOTOGRAPHS

Photo 1. Downstream ponor of Wodehouse Creek where the creek exits the study site. The creek flows from the right and was completely captured by the sink to the right of the field book. Tow other overflow sinkholes lie side-by-side above the active sink (center – upper of photo).

Photo 2. Two small suffosion sinkholes beginning to coalesce on the south-eastern edge of the property.

Photo 3. Small rock-filled suffosion sinkhole at the base of an elm tree on the lower part of the moraine and north of the proposed development area.

Photo 4. Broad, shallow soak-away depression of Karst Area D near the southwest corner of study site.

Photo 5. Spring head in talus below main cliff face.

Photo 6. Main east-west joint plane between spring and ponor.

Photo 7. Bridge crossing with culverts on Beaver Valley Ski Club property where flow and gauge measurements were undertaken.