KARST EVALUATION REPORT
FOR
SOUTH WODEHOUSE CREEK
PROPOSED PLAN OF SUBDIVISION
(Municipality of Grey Highlands)

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1.0 INTRODUCTION

This report provides the results of karst field studies undertaken on November 27th, 2006 on the west side of the Beaver Valley about 8 km east of Markdale. 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. 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 localized on morainal 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.

Field studies 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 and are order-of-magnitude relative flows. 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.

2.0 BACKGROUND

The study area lies within an area well known for the presence of karst. A Provincially Significant Earth Science ANSI (Area of Natural and Scientific Interest) known as the Wodehouse Creek Karst and Dry Valley Complex ANSI lies north of the site to the north of Sideroad 4A. 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 escarpment (Cowell and Woerns 1976). The Wodehouse karst features were previously studied in detail by the author as the subject of an undergraduate thesis (Cowell 1973, Cowell and Ford 1975). Other sinkholes are known to occur in the area and some of these have also been evaluated by the author with regard to proposed developments.

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 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. Karst systems 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 Cabot Head Formation lies immediately beneath the Amabel and forms an aquiclude that prevents further downward movement of groundwater. Hence, numerous permanent and intermittent springs can be found along the escarpment face at or near the contact between the Amabel and Cabot Head formations.

The regional topographic gradient above the escarpment in this area is toward the west – southwest. However, many small streams such as Wodehouse Creek 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).

Even though cave systems have formed of sufficient size to capture the stream, the Niagara Escarpment karst is very young in geological terms (<10,000 years) and the conduits tend to be very small. They are too small for human passage and are usually in only the mm size range (Worthington 2006). As such, they 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 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.

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.

4.3 Karst Areas

Four karst areas were identified within and immediately adjacent to the property. These are listed in Table 1 along with their UTM co-ordinates and shown on Figure 1. 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 Wodehouse Creek Karst ANSI. Karst Area A lies at the boundary of the property less than one kilometre upstream from the former waterfall at Bowles Gully.

The in-stream sink include three main sinkpoints that variously take water depending on flow levels in the creek (Photo 1). The sinkholes take all of the flow of the creek with the two off-channel sinkholes activated in sequence as the in-channel sink reaches capacity and causes water levels to rise such as during snowmelt and heavy rain events. 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 the field visit, only the in-channel sinkpoint was active.

As all three sinkholes reach capacity during snowmelt, they overflow into the lower "dry" valley of the creek. However, this is likely rare as shown by the weaker channel definition downstream including a higher bed, 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

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 north on the adjacent property on Windy Lane Dr.

A small suffosion sinkhole lies 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.

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 and underlying bedrock. 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.

5.0 CONCLUSIONS

The downstream ponor and associated karst (Karst Area A) are the most significant karst in or surrounding the proposed development area. This karst lies within the channel of Wodehouse Creek, currently serving as the main outlet of the creek and associated lands and flowing to springs located on the escarpment face. This sinkhole will continue to operate naturally and will not be impacted by the proposed development. Stormwater facilities supporting the proposed development should not flow directly toward the sinkhole complex. Required setbacks for drainage to the stream will also suffice to protect the sinkholes.

Karst Area B is a significant suffosional sinkhole complex that should be avoided by development and stormwater flow. Drainage from the site should not be directed toward these sinkholes and a setback of 30 m should be implemented (Figure 1). Vegetation within this setback should be allowed to regenerate naturally.

Karst Area C is north of the Phase 1 proposed development area and should not be significantly 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.

The two soak-away depressions in Karst Area D are not significant as they have not developed a conduit flow connection with the underlying bedrock. If necessary, these features could be stabilized with fill and geotextile materials provided upstream drainage along its small intermittent creek is redirected. In the meantime, no additional drainage should be directed toward these features. 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.

The Wodehouse Creek Karst ANSI is located well to the north of the proposed development and is upstream along Wodehouse Creek. Thus there will be no impact of this proposed development either directly or indirectly (via runoff) on the ANSI.

6.0 RECOMMENDATIONS

Karst Area A – avoid stormwater drainage directly to 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 – features could be plugged if drainage is directed away from them, otherwise leave them to function as now.

7.0 REFERENCES

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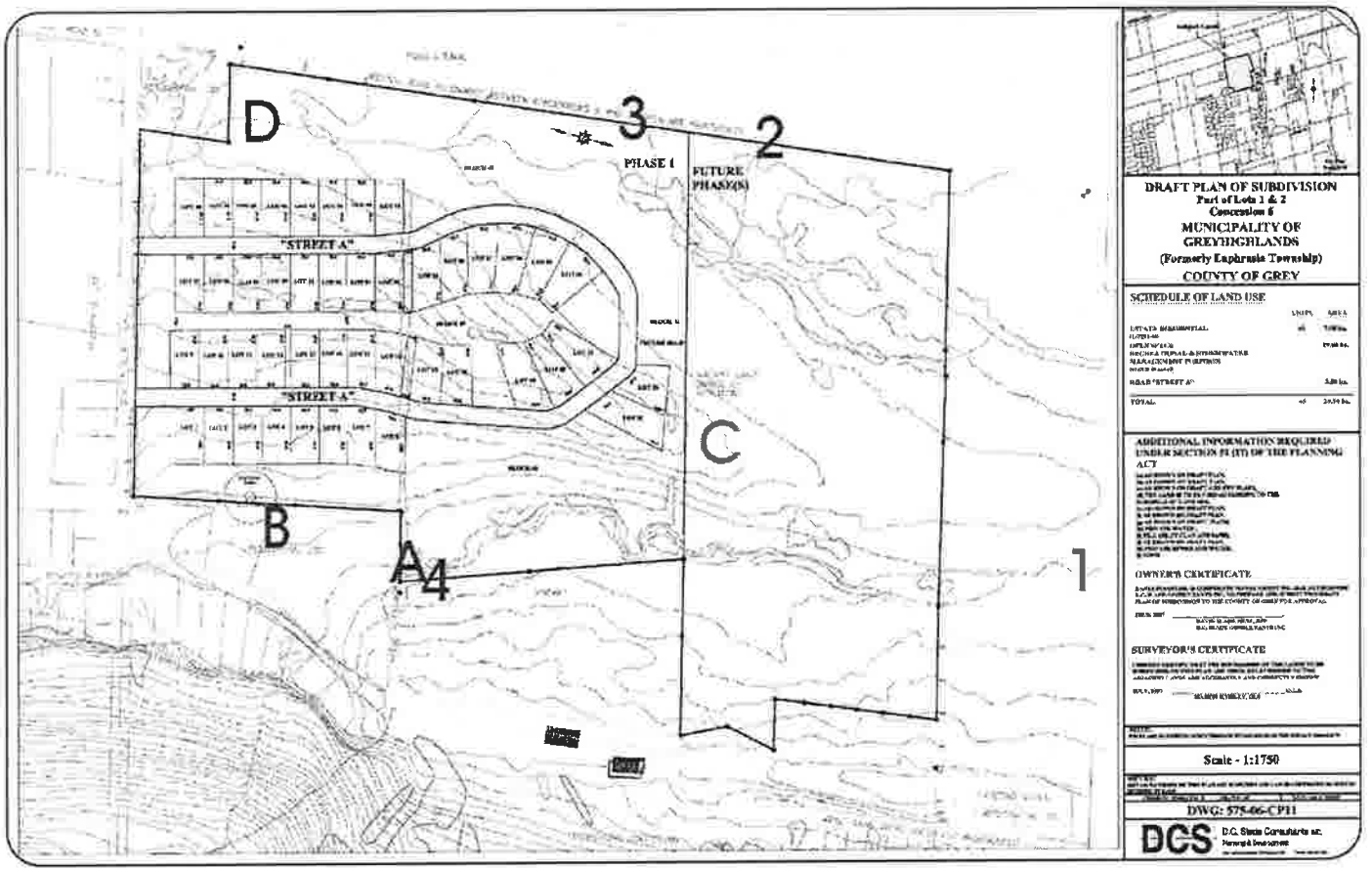

Figure 1. Concept plan for the proposed development showing the approximate locations of estimated flow observations (#1 – 4) and karst areas (A – D) (see text).

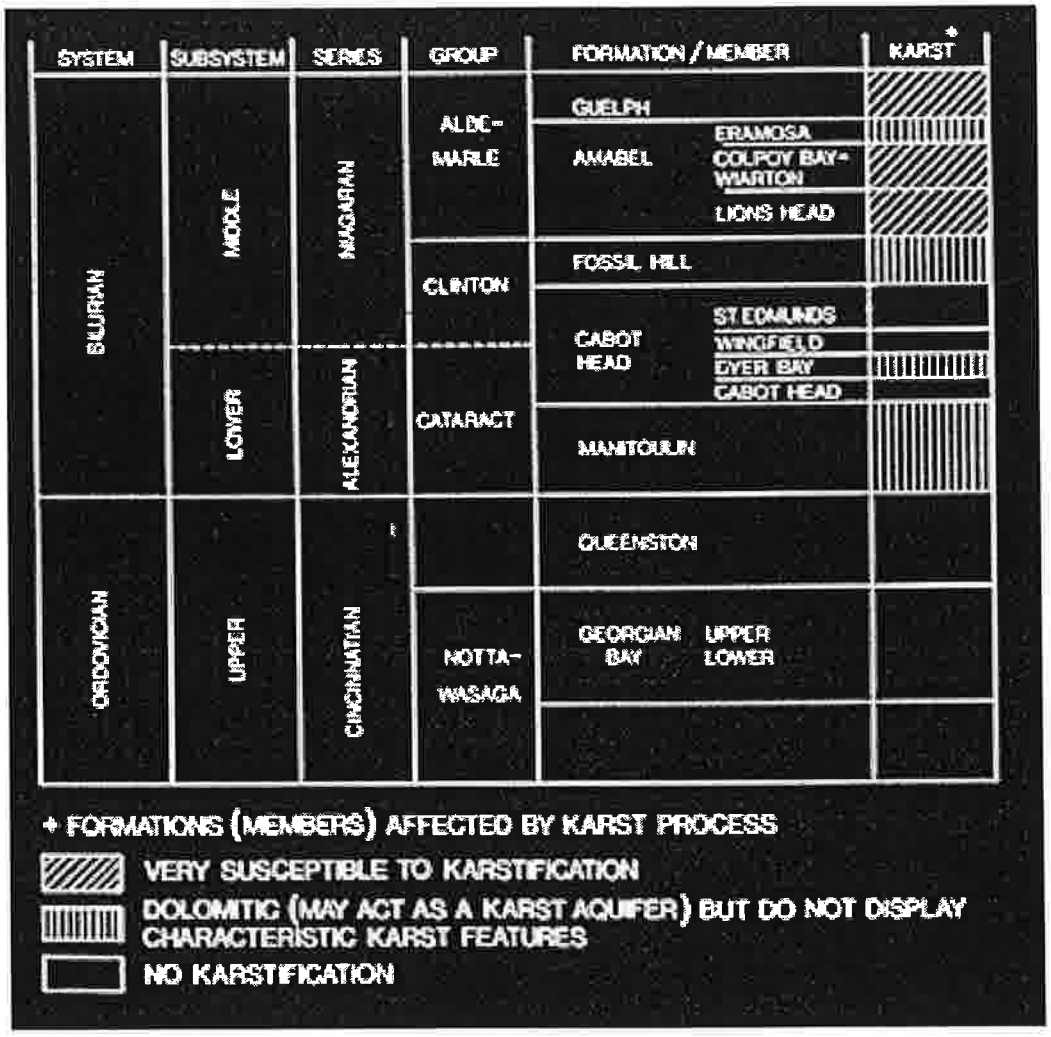

Figure 2. Geological cross-section of the Bruce Peninsula – Blue Mountains area (from Cowell 1976).

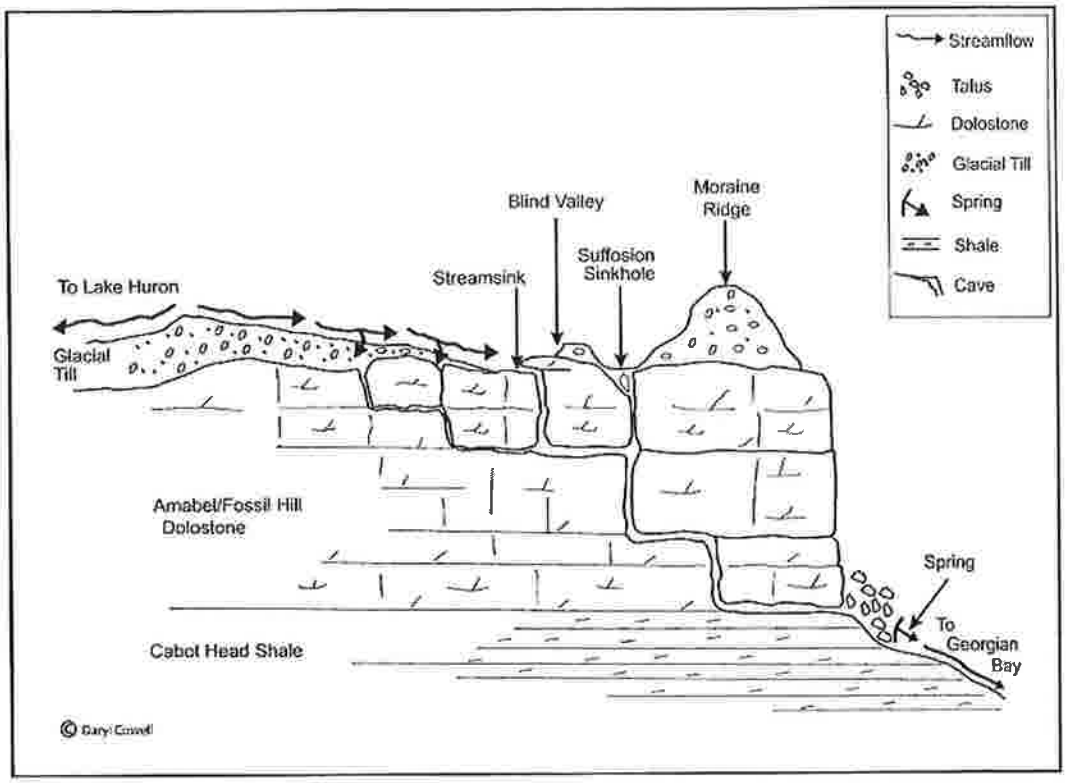

Figure 3. Cross-section of karstification at Wodehouse Creek (from Cowell 2004).

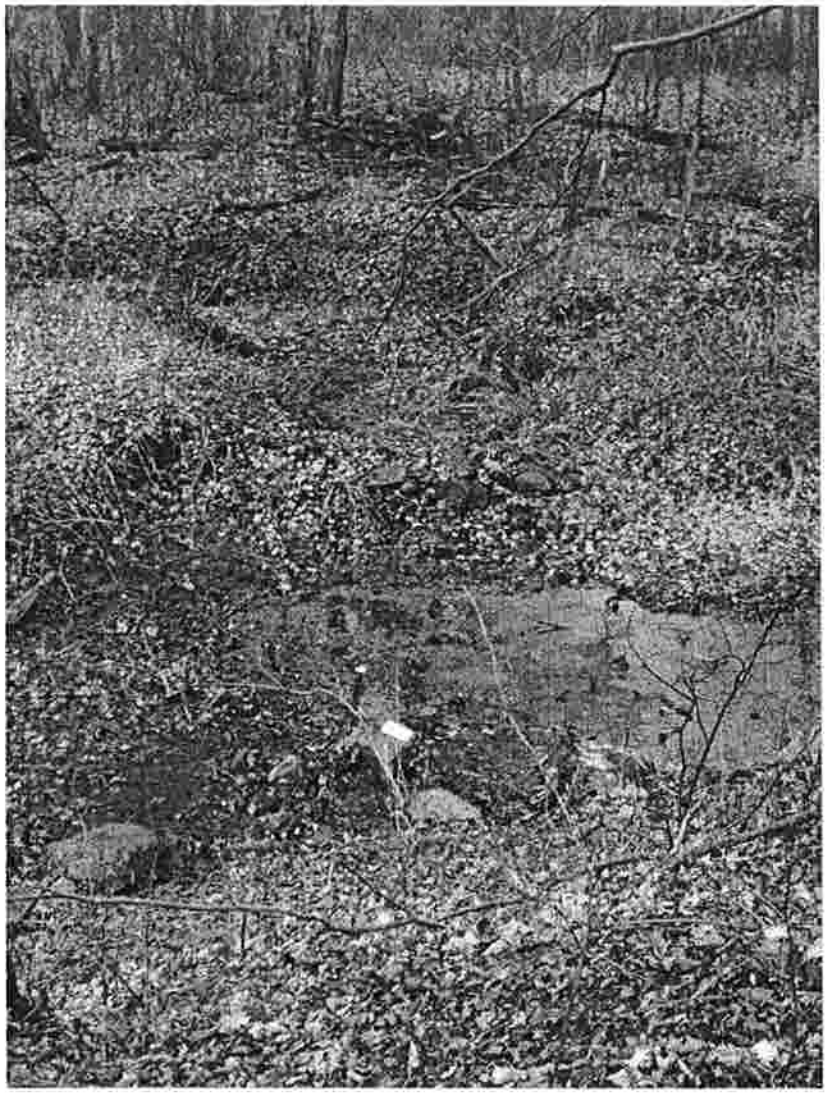

Photo 1. Downstream ponor of Wodehouse Creek where the creek exits the study site. The creek flows from the right and was completely captured by the sink to the right of the field book. Tow other overflow sinkholes lie side-by-side above the active sink (center – upper of photo).

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.