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Memorandum

Date: May 27, 2022

Project #: 2204101

To: Rodrick Sutherland & Kerstin Afante, Kaitlin Corporation

From: Dan McParland & Robin McKillop, Palmer

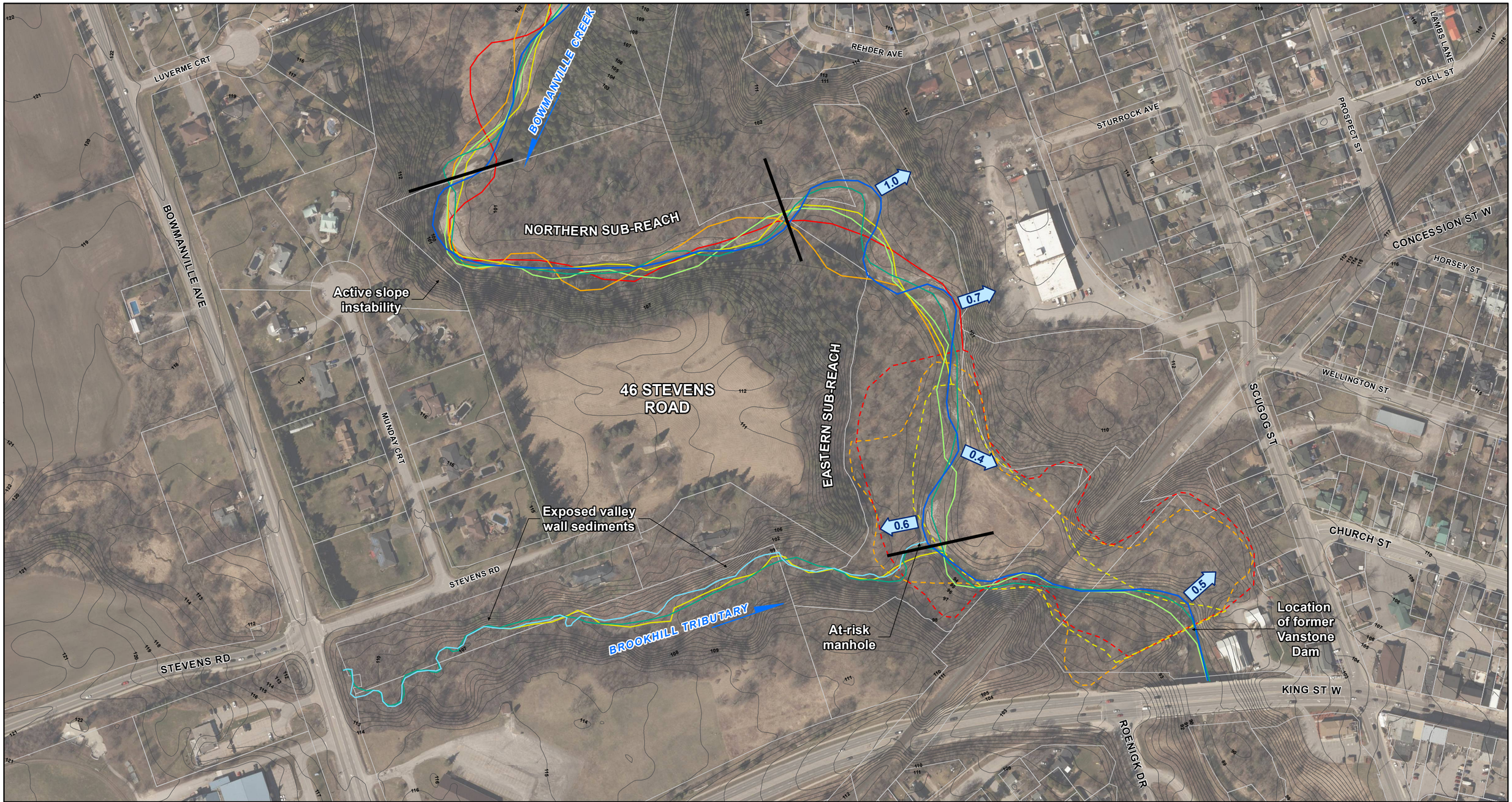
Re: Fluvial Geomorphological Assessment for the Proposed Residential Development at 46 Stevens Road, Clarington

1. Introduction

Palmer, on behalf of Kaitlin Corporation, completed a scoped fluvial geomorphological assessment for a proposed mixed-use and assisted care development at 46 Stevens Road, in Clarington (the subject property). Our assessment included Bowmanville Creek and its Brookhill Tributary (**Figure 1**), which parallel the north/east and southeast corner of the property, respectively, as a basis for establishing applicable toe erosion allowances in association with delineation of the erosion (slope) hazard limits by Soil Engineers Ltd. (Soil Engineers). Both watercourses exhibit a history of lateral adjustment and interaction with their confining valley walls, from which the proposed development is set back.

The requirement for a fluvial geomorphology assessment, and specifically the need for applicable toe erosion allowances alongside each of the two watercourses, was identified by Central Lake Ontario Conservation Authority (CLOCA) during a pre-consultation meeting on June 24, 2021. As per the *Technical Guidelines for Erosion Hazard Limits* (MNR, 2001), a toe erosion allowance must be incorporated into the delineation of the long-term stable top of slope (LTSTOS) wherever a meandering watercourse is within 15 m of the toe of slope. The original geotechnical assessment completed for the subject property by Soil Engineers (2008) did not account for toe erosion in its establishment of a LTSTOS along the northern edge of the property, where Bowmanville Creek locally abuts the toe of slope, and at the southeast corner of the property, where Brookhill Tributary is within 15 m of the toe of slope.

An overview of the physical setting and historical changes (Section 2) is followed by a summary of the methods (Section 3); a description of channel and valley wall morphology and erosional processes (Section 4); establishment of the toe erosion allowance (Section 5); and a summary of our assessment (Section 6).



LEGEND

- Surface Elevation Contour (1 m)[1]
- Sub-Reach Break
- Property Boundary
- X.X Migration Trajectory and Rate (m/yr)[2]

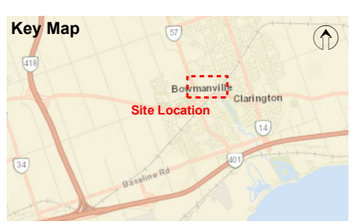
Historical Channel Centrelines

2020	1974
2016	1954
2005	1927
1988	

Historical Head Pond Extent

- 1974
- 1954
- 1927

1. Derived from *Ontario (Lidar-Derived) Digital Terrain Model*, LIO 2022
2. Time-averaged migration determined for meanders that exhibit systematic migration from 1988 to 2020



0 20 40 60 80 100
METRE SCALE

North American Datum 1983
Universal Transverse Mercator Projection Zone 17

Scale: 1:3,000
Page Size: Tabloid (11 x 17 inches)

Drawn: CV
Checked: DP
Date: May 25, 2022

NORTH

Source Notes:
Imagery (2020) provided by Clarington map service.

CLIENT
Kaitlin Corporation

PROJECT
46 Stevens Road Geomorphology Assessment

TITLE
Study Area and Historical Assessment

Palmer

REF. NO. 2204101-MR-101-A

Figure 1

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2. Physical Setting

The property is situated on the clay plain of Glacial Lake Iroquois (OGS, 2014a), at the edge of a broad and deep valley (up to 13 m of relief) incised through glacial deposits by Bowmanville Creek. Bowmanville Creek meanders across the valley bottom alongside the northern and eastern property limits. Brookhill Tributary parallels the southern property limit within a narrow valley with up to 11 m relief below adjacent tableland. Previous geotechnical investigations within the subject property (Soil Engineers, 2008) encountered silty clay underlain by silty clay till and/or very dense silty sand till at depth in boreholes drilled at the tops of slopes. Loose silty fine sand and compact gravelly sand was encountered in boreholes drilled within the valley bottoms. The upstream catchment areas of Bowmanville Creek and Brookhill Tributary are approximately 83.3 km^2 and 3.8 km^2 at their confluence, respectively, as estimated using the Ontario Flow Assessment Tool.

Agriculture is the dominant land use within the upstream catchments. However, residential and commercial development has occurred over the past half-century in the lower portions of the catchments, which would have altered the flow regime and sediment supply of Bowmanville Creek and Brookhill Tributary. Through time, riparian buffers have become wider and more densely vegetated. Localized bank and bed hardening structures are present along both watercourses.

The Vanstone Dam, which was located approximately 250 m downstream of the confluence of Bowmanville Creek and Brookhill Tributary (immediately upstream of King Street West), has had a profound influence on channel morphology near the subject property. Some variation of a dam or water control structure was present at that location since the late 18th century (Clarington Promoter, 2012). Within the aerial photograph record, the head pond extended up to 50 m into Brookhill Tributary and several hundred metres upstream along the Bowmanville Creek valley (**Figure 1**). The head pond (**Figure 2**) forced localized deposition of alluvial silts, sands and gravels. Variation in head pond extent led to complex and evolving depositional patterns and bar dynamics near the head pond margins. In 1986, the Vanstone Dam failed during a high flow event (Ecosystem Recovery Inc., 2019). Following failure of the dam, Bowmanville Creek and the lower sections of Brookhill Tributary rapidly incised through the deposited alluvial materials and underwent irregular lateral adjustments and locally developed a multi-thread pattern. Over the past 10 to 15 years, colonization of riparian vegetation and a reduction in channel instability have helped restore a single-thread, pool-riffle morphology.

Figure 2. Illustration of the head pond upstream of the former Vanstone Dam (Clarington Promoter, 2012)

3. Methods

The fluvial geomorphology of Bowmanville Creek and Brookhill Tributary was assessed through a combination of desktop and field investigations. We reviewed a number of important background information sources for the study area, including previously completed geotechnical (Soil Engineers, 2008) and geomorphology assessments (Ecosystem Recovery Inc, 2019); a LiDAR-derived hillshade and contours (Natural Resources Canada, High-Resolution Digital Elevation Model Mosaic); and Ontario Geological Survey physiography (OGS, 2014a) and surficial geology mapping (OGS, 2014b).

Orthophotography from 1954 and from 2000 though 2020 was accessed through The Municipality of Clarington's online webserver (https://gis.clarington.net/arcgis/rest/services/Basemaps). Additional aerial photographs from 1927, 1974, and 1988 were purchased from the National Air Photo Library and georeferenced in ArcGIS based on the 2020 orthophotography. Channel centrelines were delineated along Bowmanville Creek for various years from 1927 to 2020 as a basis for completing a comparative overlay analysis and determining time-averaged lateral erosion rates and trajectories at appropriate meanders near valley walls. The smaller channel width and dense riparian vegetation led to discontinuous channel centrelines along Brookhill Tributary.

Field reconnaissance was completed along both watercourses on May 6, 2022, to 'ground-truth' desktop-based interpretations and observe conditions that cannot be readily documented through desktop analyses. A discharge of 1.1 m^3/s was recorded at the Water Survey of Canada gauge (02HD006) at Jackman Road (approximately 1 km upstream of the subject property), which is slightly lower than the long-term mean annual flow (1.3 m^3/s). Spot checks of bankfull widths and depths were made along both watercourses. Particular attention was given to examining fluvial erosional patterns, any valley wall instabilities, and

materials comprising the channel bed/banks and valley walls. A Rapid Geomorphic Assessment (RGA; Ontario Ministry of the Environment, 2003) was completed along the study reach to document evidence of channel aggradation, degradation, widening and/or planimetric form adjustment. The RGA tool provides a useful checklist of evidence to consider, but its results are dependent on the presence or absence of a set number of specific features within a reach and thus must be interpreted carefully to ensure accuracy (McKillop, 2016).

4. Description of Channel and Valley Wall Morphology

4.1 Bowmanville Creek

Near the subject property, Bowmanville Creek exhibits a partly confined, irregular meandering planform on the bottom of a well defined valley. Along the northern property limit, the watercourse locally abuts its southern valley wall. The valley wall near the northwestern property limit (**Figure 1**) has shown signs of instability throughout the period of photographic record. A small slump, likely triggered by fluvial erosion of the slope toe, occurred near the northwestern property limit between 1988 and 2000 (**Figure 1**, **Photo 1**). Alongside the eastern property limit, the channel is located near the opposite (eastern) valley wall and is more than 15 m from the toe of western valley wall below the subject property. The channel has good access to the floodplain upstream of the limits of the historical head pond of the Vanstone Dam. Within the limits of the former head pond, the channel has become entrenched following incision through the pond sediments.

Photo 1. A slope failure near the northwestern property limit. The material deposited near the toe of slope is predominantly colluviated till.

Photo 2. Looking upstream along Bowmanville Creek at pool-riffle morphology, coarse lag deposits, and an accessible floodplain along the eastern property limit.

Bed morphology along Bowmanville Creek is predominantly pool-riffle, with pools located near meander apices. Average bankfull width and bankfull depth are approximately 15 m and 1.4 m, respectively. Bed material is dominated by coarse sands and gravels; however, cobble and boulder lag deposits were observed throughout the reach where the channel has eroded into till. Till was observed in the material recently deposited at the toe of slope near the northwestern property limit (**Photo 1**). Localized bank armouring was observed near the rail crossing and King Street West, downstream of the confluence with Brookhill Tributary. Riparian vegetation is a mixture of coniferous and deciduous trees and shrubs. Large wood does not exert a major influence on channel morphology. The results of the RGA suggest the study corridor is currently “transitional” with dominant modes of adjustment being degradation and channel widening, which are expected as the channel incises through the pond sediments (**Table 1**).

Photo 3. Looking westward towards the confluence of Bowmanville Creek (foreground) and Brookhill Tributary (background). The high outer bank of Bowmanville Creek, composed mainly of erodible pond-deposited sands, is near-vertical and is not easily overtopped by flood flows. Bowmanville Creek is migrating towards the manhole chimney.

Table 1. Summary results of RGA for Bowmanville Creek between the northern property limit and the Vanstone Dam

Form/Process	Index
Aggradation	0.29
Degradation	0.40
Widening	0.43
Planimetric Form Adjustment	0.00
Stability Index	**0.28**
Classification	**Transitional**

Along many meanders, the channel has systemically migrated within the valley bottom following the dam failure in 1986. Time-averaged migration rates from 1988 to 2020 ranged from 0.4 m/year to 1.0 m/year, with an average of 0.6 m/year (**Figure 1**). Migration rates will likely slow over the coming decades as equilibrium conditions are restored. As well, rapid channel incision within the former head pond sediments has formed high banks, which will help limit channel migration.

4.2 Brookhill Tributary

Downstream of Highway 57, Brookhill Tributary enters a defined valley. The depth and width of the valley increase downstream as the watercourse approaches its confluence with Bowmanville Creek. Brookhill Tributary is locally confined by both valley walls. In particular, fluvial erosion has over-steepened the toe of the northern valley wall at two locations upstream of the subject property (**Photo 4**, **Figure 1**). The channel steepens downstream. The channel has good access to its floodplain, except immediately upstream of the confluence with Bowmanville Creek where it has incised through pond deposits and become entrenched.

Photo 4. Looking downstream where Brookhill Tributary has locally eroded the toe of its valley wall.

Average bankfull width and bankfull depth are 5.0 m and 1.0 m, respectively. Width and depth increase near the confluence where the channel has incised through the pond deposits. Bank materials are predominantly alluvial sands and silts. Till is locally exposed on valley walls and along the channel bed. Bed material is dominated by coarse sands and gravel; however, cobble and boulder lag deposits were observed throughout the reach. Except immediately downstream of Highway 57, where trees have been recently felled, deciduous riparian vegetation is continuous along the channel. Bed morphology is strongly controlled by lag deposits and large wood (**Photo 5**). A manhole chimney is within the active channel, immediately upstream of the confluence with Bowmanville Creek (**Photo 6**). The results of the RGA suggest the study corridor is currently “in adjustment” with dominant modes of adjustment being widening and planimetric adjustment (**Table 1**). The channel is responding to upstream urbanization and a drop in base level following the Vanstone Dam failure and subsequent drainage of its head pond.

Photo 5. Looking downstream along Brookhill Tributary at a symmetric cross-section, lag boulder deposits, and large wood within the channel.

Photo 6. Looking downstream along Brookhill Tributary at an exposed manhole chimney immediately upstream of its confluence with Bowmanville Creek (background). Bowmanville Creek is migrating through pond-deposited sands towards the manhole chimney (Figure 1).

Table 2. Summary results of RGA for Brookhill Tributary between Highway 57 and its confluence with Bowmanville Creek

Form/Process	Index
Aggradation	0.14
Degradation	0.50
Widening	0.83
Planimetric Form Adjustment	0.67
Stability Index	**0.54**
Classification	**In Adjustment**

5. Toe Erosion Allowances

In the following subsections, recommended toe erosion allowances for the updated LTSTOS delineations are provided for two sub-reaches of Bowmanville Creek and Brookhill Tributary (**Figure 1**).

5.1 Bowmanville Creek – Northern Sub-reach

Within the Northern Sub-reach, the channel has abutted or paralleled the valley wall over the period of record. Ongoing valley wall instability is apparent near the northwestern property limit at the apex of a sharp meander (**Figure 1**, **Photo 1**). Downstream of the meander apex, alongside the proposed development, the channel has remained roughly parallel to the valley wall over the period of record without any signs of instability or systematic migration. Till was observed at depth in boreholes near the top of slope (Soil Engineers, 2008). Due to presence of till, lack of systematic migration alongside the proposed development, and relatively straight channel planform, a 6 m toe erosion is best applied to the LTSTOS for this sub-reach in accordance with Table 3 of MNR (2001) and observed migration along unconfined meanders in the Eastern Sub-reach (**Figure 1**).

5.2 Bowmanville Creek – Eastern Sub-reach

Within the Eastern Sub-reach, the channel has remained more than 15 m from the toe of slope below the subject property over the period of record. As per the MNR (2001) protocols, a toe erosion allowance is not required for establishment of the LTSTOS where the channel is beyond 15 m from the toe of slope.

5.3 Brookhill Tributary

Brookhill Tributary has migrated within the valley bottom over the period of record. Currently, it is within 15 m of the northern valley wall (subject property) for most of its length. Based on field observations and review of the LiDAR data, channel avulsions have been a recurring mode of adjustment. Systematic channel migration was not observed due to the channel avulsions and the dense canopy cover along the tributary. The valley wall sediments are exposed at two locations of impingement (**Figure 1**), where fluvial erosion has over-steepened the toe of slope. Till was observed at depth in boreholes near the top of slope (Soil Engineers, 2008) and within sediment exposures on the valley wall at the two sites of impingement. Due to the presence of till, narrow valley width, and lack of systematic migration, a 5 m toe erosion should be applied to the LTSTOS for this sub-reach in accordance with Table 3 of MNR (2001).

6. Summary

Palmer completed a scoped fluvial geomorphological assessment of Bowmanville Creek and Brookhill Tributary near 46 Stevens Road in Clarington as a basis for establishing applicable toe erosion allowances in association with delineation of the erosion (slope) hazard limits. Both channels are still responding to anthropogenic disturbances, most notably the presence and sudden drainage of a head pond upstream of the former Vanstone Dam. Based on desktop and field observations and MNR (2001), toe erosion allowances of 5 m and 6 m should be applied to the LTSTOS of Brookhill Tributary and the Northern Sub-reach of Bowmanville Creek, respectively (**Figure 1**). No toe erosion allowance is required to establish the LTSTOS along the Eastern Sub-reach of Bowmanville Creek because the channel is more than 15 m from the toe of slope.

7. Certification

This technical memorandum was prepared and reviewed by the undersigned:

Prepared By:

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Reviewed By:

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