Environmental Study Report

Wyecroft Road Improvements from Bronte Road to Kerr Street

Appendix C: Fluvial Geomorphology

Submitted to Town of Oakville
by IBI Group
January 2020

Wyecroft Road Improvements
Municipal Class Environmental Assessment

Fluvial Geomorphological Assessments
Fourteen Mile Creek and Tributary, Taplow Creek and Glen Oaks Creek

Prepared for:
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GEO Morphix Project No. 18049

GEO MORPHIX
Geomorphology
Earth Science
Observations

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1 Introduction

The Town of Oakville initiated a Schedule C Municipal Class Environmental Assessment (EA) for improvements to Wyecroft Road between Bronte Road and Kerr Street, south of Queen Elizabeth Way (QEW). Wyecroft Road is a major east-west corridor that consists of two lanes and includes a section of South Service Road West between Third Line and Fourth Line. It has a semi-rural cross section with roadside ditches as well as inconsistent boulevard treatments. The Town wishes to complete road improvements to address active transportation, land servicing needs, safety concerns, structural and pavement deficiencies, drainage issues, and approved and proposed changes in land use. IBI Group Professional Services (Canada) Inc. was retained to complete the Class EA on behalf of the Town of Oakville.

There are four regulated watercourses that travel in a generally north to south orientation that cross Wyecroft Road. These include Fourteen Mile Creek and one of its tributaries, and Taplow Creek and Glen Oaks Creek, which are tributaries of McCraney Creek (**Figure 1**). As the Class EA is to consider road improvement alternatives that may involve alteration/reconstruction of watercourse crossings, a fluvial geomorphological assessment of existing conditions, and identification of opportunities and constraints, for each watercourse is required. GEO Morphix Ltd. was therefore retained as a subconsultant to IBI Group to complete these watercourse assessments.

The following activities were completed in support of the geomorphological assessment:

- Review available background reports and mapping (e.g., geology and topography)
- Historical assessment using aerial photographs to identify past channel modifications and changes to the system due to land use
- Field assessments for portions of accessible channel upstream and downstream of each of the four crossings to document channel conditions, including stability via Rapid Geomorphic Assessments, and to verify the results of the desktop assessment
- Meander belt width analyses on a reach basis, where appropriate
- Prepare a report that summarizes existing watercourse conditions and meander belt widths, where appropriate
- Provide recommendations, such as erosion protection measures and/or watercourse enhancements, for consideration at the detailed design stage

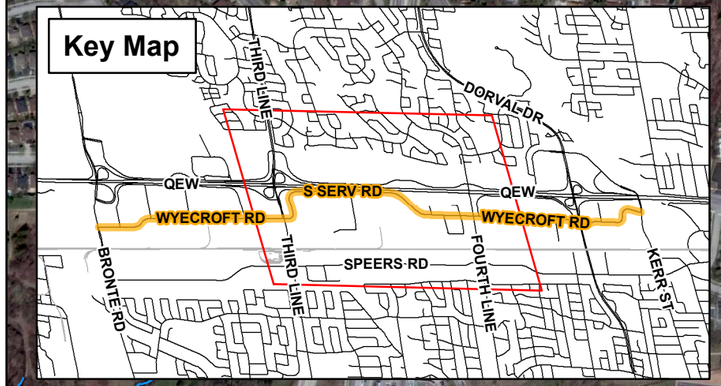
GEO MORPHIX

FIGURE 1

Reach Extents Assessed

Fourteen Mile Creek and
McCraney Creek
crossings along Wyecroft Road

Town of Oakville



THIRD LINE

14MCT-1

QUEEN ELIZABETH WAY

SOUTH SERVICE RD W

FOURTH LINE

Fourteen Mile Creek

14MC-1

Tributary of Fourteen Mile Creek

14MCT-2

TC-1

SOUTH SERVICE RD W

WYECROFT RD

Taplow Creek

Glen Oaks Creek

GO-1

WYECROFT RD

RAILWAY

McCraney Creek

SPEERS RD

Legend

- Reach break
- Extent assessed
- Waterflow

Reach Naming Convention

14MC	Fourteen Mile Creek
14MCT	Fourteen Mile Creek Tributary
TC	Taplow Creek
GO	Glen Oaks Creek

Reach break, and Extent assessed: GEO Morphix Ltd., 2018.
Waterflow: Town of Oakvile, 2018. Imagery: Google Earth Pro, 2016.

0 200
Metres

2 Study Site History

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics.

Aerial photographs from 1934 (partial coverage of the study area, scale 1:20,000), 1954 (scale 1:15,840), 1966 (scale 1:20,000) and 1978 (scale 1:10,000), and recent satellite imagery from Google Earth Pro were reviewed to complete the historical assessment. Refer to **Appendix A** for copies of the imagery.

The 1934 aerial photograph captured only the upstream portions (north of the present day QEW) of the McCraney Creek and tributary of Fourteen Mile Creek watersheds. In 1934, the predominant land uses near the study area were agriculture and rural residential. Natural riparian vegetation had been removed in upstream areas prior to 1934, likely to maximize land available for agriculture. However, several relatively small woodlots remained adjacent to each watercourse approximately midway between present day QEW and Upper Middle Road West. Narrow treed riparian areas were generally present along each watercourse downstream of the woodlots but were absent in vicinity of present day QEW. The road network appeared to be limited to single lanes and concessions, with driveways and access roads to agricultural fields. Immediately upstream and downstream of present-day QEW, both Taplow Creek and Glen Oaks Creek were straightened, likely for agricultural purposes. Channel straightening combined with woody vegetation removal would increase stream power and thus erosion potential, as well as decrease complexity with respect to channel morphology and aquatic habitat.

In 1954, the primary land uses remained agriculture and rural residential. What is now the GO Transit rail line was visible in the 1954 photograph, although it was constructed much earlier. The QEW was widened and residential subdivisions were being constructed southeast of the study area.

Between 1954 and 1978, there were significant land use changes south of the QEW to the Lake Ontario shoreline. Commercial/industrial development was establishing adjacent to the rail line. A portion of Wyecroft Road, between Kerr Street and Fourth Line, was constructed by 1978. Another portion of Wyecroft Road, between Third Line and Bronte Road, also appeared to be under construction. The portions of Wyecroft Road were apparently constructed to accommodate large commercial/industrial facilities. The construction of these facilities resulted in further alterations to the tributary of Fourteen Mile Creek and Glen Oaks Creek, as they became confined to narrow corridors between properties. Fourteen Mile Creek was also affected by the construction of a larger, more complex interchange at QEW and Third Line. Although also historically altered, Taplow Creek maintained a slightly meandering planform downstream of the QEW, and travelled adjacent to an agricultural field.

While intensive residential development occurred further south of the rail line to the Lake Ontario shoreline, lands north of the QEW remained largely under agricultural use in 1978. All four subject watercourses north of the QEW had a buffer with establishing woody riparian vegetation. Along Fourteen Mile Creek, an online pond was present northwest of Upper Middle Road and Bronte Road, approximately 3 km (Euclidean distance) upstream of the crossing at Wyecroft Road. This pond would have likely acted as a sediment sink and reduced sediment supply to downstream reaches.

Since 1978, industrial/commercial development continued to expand between the rail line and the QEW, as well as to the immediate north. Numerous residential subdivisions were also constructed north of the QEW. While the roads associated with the residential developments required crossing structures over the watercourses, these watercourses also had narrow corridors with apparently mature woody vegetation to allow at least some level of natural channel function. The online pond observed on the 1978 aerial photograph was also no longer present.

South of the QEW, the development of commercial/industrial facilities along the rail line intensified. Although the tributary of Fourteen Mile Creek and Glen Oaks Creek remained generally unchanged in this area from 1978, Taplow Creek was realigned and straightened by 2004, again to accommodate the construction of commercial/industrial facilities.

Overall, the land use changes associated with development within and upstream of the study area have resulted in a significant increase in impermeable surface. Due to the age of the surrounding development and the prevailing stormwater management practices at the time of construction, there are likely few measures to effectively prevent stormwater runoff from rapidly being conveyed to the receiving watercourses. For example, there is an apparent lack of stormwater management ponds in the residential area between the QEW and Dundas Street. In contrast, the newer residential developments north of Upper Middle Road West contain modern stormwater management facilities, which may have been designed with low impact development strategies when compared to older subdivisions to the south. The lack of stormwater management in the older, settled areas would likely result in flashy flow regimes, enhanced erosion potential and sediment transport, and possible downstream flooding issues within and downstream of the study area.

3 Existing Conditions

3.1 Watershed-scale Characteristics

3.1.1 Geology

Channel morphodynamics are largely governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

Local surficial geology along Fourteen Mile Creek, Taplow Creek and Glen Oaks Creek consists of Paleozoic Bedrock (OGS, 2010). The bedrock is comprised of shale, limestone, dolostone, and siltstone of the Queenston Formation (OGS, 2011). Upstream (north) of QEW, surficial geology consists of a shore bluff or scarp and clay to silt-textured till derived from glaciolacustrine deposits or shale.

The study area is located within the Iroquois Plain physiographic region, which extends from the South Slope to the north to Lake Ontario. Specifically, the study area is characterized as Shale Plains, while areas upstream (north) of QEW are located on drumlinized till plains (Halton-Hamilton Source Protection, 2012 and Chapman and Putnam, 1984).

The shale bedrock, through which all watercourses in the study area travel, is an erodible material although less so compared to alluvial fines. The shale, once exposed, is vulnerable to hydraulic forces as well as weathering (e.g., freeze-thaw cycles), and can break down into smaller particles with a platy form. Larger pieces of shale on the channel bed can become imbricated and form a natural armour layer on the bed surface and, in doing so, protect underlying substrate from being transported downstream.

3.1.2 Fourteen Mile Creek Watershed

Fourteen Mile Creek flows in a primarily northwest-southeast direction through the study area and has a total drainage area of approximately 40 km^2 (TSH *et al*., 2006). Its headwaters consist of three branches, originating north of Highway 407 in the Trafalgar Moraine, which is identified as an Earth Science Area of Natural and Scientific Interest (ANSI). This moraine extends from east of Bronte Creek

to just west of Sixteen Mile Creek north of Highway 407 and consists of reddish clayey till containing a significant amount of shale from the Queenston Formation (Chapman and Putnam, 1984). The area upstream of the QEW is designated as the Fourteen Mile Creek Valley Environmentally Significant Area (ESA) and has vegetated valley walls and floodplains (Halton-Hamilton Source Protection, 2012).

South of the QEW, there is one tributary that joins Fourteen Mile Creek. This tributary from the east was formerly a part of the McCraney Creek watershed but was diverted to discharge to Fourteen Mile Creek to address downstream flooding concerns along McCraney Creek. After crossing the QEW, the tributary travels south through the study area across South Service Road and then west along the GO Transit rail line to join Fourteen Mile Creek (Halton-Hamilton Source Protection, 2012). Land use in the headwaters consists of predominantly agricultural activities and rural residential development. The downstream portion of the catchment is highly urbanized, and includes commercial, industrial and residential land use.

Fourteen Mile Creek is known to support relatively healthy populations of Redside Dace (*Clinostomus elongatus*). This species is listed as endangered on the Species at Risk in Ontario (SARO) List and Schedule 1 of the *Species at Risk Act, 2002* (SARA). It therefore receives individual and habitat protection under the *Endangered Species Act, 2007* (ESA). At this time, a federal recovery strategy and formal definition of critical habitat has not been developed, and as such, this species receives only individual protection under SARA.

Fish community sampling was completed in April and May of 2002 and April 2005 as part of the North Oakville Creeks Subwatershed Study (TSH et al., 2006). Redside Dace were captured in the west branch of Fourteen Mile Creek in 2002 at two sampling stations located upstream of Dundas Street. The Natural Heritage Information Centre (NHIC) database, maintained by the MNRF, was accessed on June 11, 2018, to determine if recent records of Redside Dace occurred in vicinity of Wyecroft Road. Squares 17PJ0208, 17PJ0308 and 17PJ0408, each 1 km^2, contained records of Redside Dace from October 2000. The project team has subsequently confirmed with the MNRF that the main branch of Fourteen Mile Creek is considered regulated (occupied) Redside Dace habitat. NHIC database squares 17PJ0309 and 17PJ0409, which encompass the east tributary of Fourteen Mile Creek, also contained records of Redside Dace from 2000. Although consultation with the MNRF is ongoing, this tributary is assumed to contain regulated (contributing) Redside Dace habitat at this time.

According to Section 29.1 of Ontario Regulation 242/08 under the ESA, the extent of occupied Redside Dace habitat includes the meander belt width and 30 m vegetated riparian area on either side of the channel. Areas that are not vegetated (i.e., contain buildings or impervious surfaces) were not considered to contain regulated habitat as part of this study. Contributing habitat includes streams, headwater drainage features, groundwater discharge areas or wetlands that augment or maintains baseflow, coarse sediment supply or surface water quality of part of a stream or watercourse that contains occupied habitat, provided that the watercourse has an average bankfull width no greater than 7.5 m.

3.1.3 McCraney Creek Watershed (Taplow Creek and Glen Oaks Creek)

McCraney Creek has a relatively small drainage area of approximately 12.2 km^2 (Halton-Hamilton Source Protection, 2012). Similar to Fourteen Mile Creek, the headwaters of McCraney Creek originate north of Highway 407, in the Trafalgar Moraine. This system has two main tributaries: Taplow Creek and Glen Oaks Creek (Philips Engineering Ltd., 2008). These tributaries converge immediately north of the GO Transit rail line to form McCraney Creek, which continues in a southerly direction to Lake Ontario. Most of the catchment has been developed, with the exception of the headwater area. Urban storm sewers therefore discharge to the tributaries and help support perennial flow in the downstream reaches of McCraney Creek (Halton-Hamilton Source Protection, 2012).

The NHIC database was also reviewed for McCraney Creek. Redside Dace is not found in Taplow Creek or Glen Oaks Creek in the vicinity of Wyecroft Road. This is consistent with the Natural Environment Opportunities and Constraints Report prepared by LGL Limited (2012) in support of the Town of Oakville Transportation Master Plan (Switching Gears), which was finalized in February 2013.

3.2 Watercourse Characteristics

3.2.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are typically delineated based on changes in the following:

- Channel planform (pattern)
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

Four regulated watercourses cross Wyecroft Road within the study area: Fourteen Mile Creek, an unnamed tributary of Fourteen Mile Creek, and Taplow Creek and Glen Oaks Creek (tributaries of McCraney Creek). Typically, reaches are delineated following scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997) and the Toronto and Region Conservation Authority (2004). For this study, the full length of each reach was not verified due to site access limitations. Instead, the results of the desktop review of available information was used to first segment each watercourse in the vicinity of Wyecroft Road into reaches. Reach breaks (locations of adjoining reaches) were subsequently verified in the field. As the full length of each reach could not be assessed, **Figure 1** shows each reach to the extents verified in the field. **Table 1** provides a list of the reaches as well as their locations and the primary characteristics that define and distinguish each reach.

Table 1: Reaches of watercourses that cross Wyecroft Road

Reach	Extent Assessed	Length	Reach-defining Characteristics
14MC-1	100 m south of QEW to first meander bend downstream of Wyecroft Road	585 m	Confined valley; bedrock channel; confined pattern planform; mature, wooded riparian buffer
14MCT-1	Forested area north of QEW to QEW	75 m	Unconfined valley; bedrock channel; irregular meanders; immature, non-wooded riparian buffer
14MCT-2	Wyecroft Road to GE Distribution Centre.	130 m	Unconfined valley; Concrete-lined bed and banks; straight channel; no riparian vegetation

TC-1	125 m upstream and downstream from Wyecroft Road	250 m	Unconfined valley; Concrete cable block lined bed and banks; straight channel; immature riparian buffer.
GO-1	125 m upstream and downstream from Wyecroft Road	250 m	Unconfined valley; bedrock channel; narrow riparian buffer consisting of grasses and herbaceous species

3.2.2 General Reach Observations

A field investigation was completed on June 1, 2018 and included the following:

- Reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation
- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

These observations and measurements were collected for the four regulated watercourses in the vicinity of Wyecroft Road, and are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix B**. Field sheets – reach summaries, habitat sketch maps and rapid assessments – are provided in **Appendix C**.

Fourteen Mile Creek

Reach 14MC-1 is a bedrock channel conveying flows in an easterly direction from the QEW to the GO rail line. The channel occupies a confined valley with a wide and mature riparian buffer populated predominantly by deciduous trees. A well-defined riffle-pool sequence was present within the moderately-sloped channel, with exposed Paleozoic bedrock in the pools and platy cobbles and gravels in the riffles. Channel banks were composed of clay and silt and were typically near-vertical and frequently undercut. Willow rootlets were often observed at the base of channel banks. A valley wall contact was observed approximately 75 m upstream (northwest) of the Third Line crossing, and 100 m downstream (southeast) of the Wyecroft Road crossing. Average bankfull width and average maximum bankfull depth were 6.53 m and 0.93 m, respectively.

Flows are conveyed across Wyecroft Road through a twin box culvert (Crossing C1). The south barrel conveys flow up to approximately the bankfull discharge, as the north barrel has a well-vegetated bank that only allows flows to enter only during higher flow events. Immediately upstream of the culvert and approximately 5 m downstream of a confluence of Fourteen Mile Creek and a storm outfall channel originating at Third Line, a concrete weir spans the channel bed and provides grade control. On the downstream side of the south twin box culvert barrel, the south channel bank has developed at the outlet, constraining the flow path to a 2.5 m wide gap. A fallen tree at this location further impedes flow. This partial blockage of the south barrel has evidently caused flows to locally overtop the channel bank during storm events before spilling back into the channel.

Tributary of Fourteen Mile Creek

Reach 14MCT-1 is an irregularly meandering channel within an unconfined valley conveying flows southeastwards towards the QEW. The wide riparian buffer is composed of grasses and herbaceous

vegetation. The channel has riffles and pools, with exposed bedrock typically in the pools, and cobble and gravel in the riffles. The channel has a moderate gradient, and little erosion was noted along the channel banks. The average bankfull width within the reach was 2.9 m, and the average maximum bankfull depth was 0.53 m.

A 100-m long box culvert (Crossing C3), with a 3 m span and 1.5 m rise, conveyed flows across the QEW and South Service Road to Reach 14MCT-2. Notably, at the upstream end of the culvert, sandbags were found spanning the channel. The placement of these sandbags suggest that they may have been used to control creek flows during construction activities and subsequently forgotten. Within the box culvert, there were two drops that were about 0.3 m high, which likely inhibits fish passage. A third drop was observed at the culvert outlet; this drop did not appear to be a result of downstream channel degradation.

Reach 14MCT-2 is a straight, concrete-lined trapezoidal channel bounded by commercial/industrial properties. The bed is 3.25 m wide and has no morphological variability, and the channel banks have a 1.5:1 slope. The bankfull level was assumed to be demarcated by the discolouration on the concrete banks. The average bankfull width and average maximum bankfull depth within the reach were estimated to be 4.3 m and 0.80 m. While there was no in-stream vegetation within the first ~100 m downstream of South Service Road, reed canary grass and cattails were found along the channel margins farther downstream.

Taplow Creek

Reach TC-1 is a straightened channel lined with articulated concrete blocks. The channel travels in a southeasterly direction through a narrow (~15 m wide) corridor between commercial properties upstream of Wyecroft Road, crosses the road at an angle, and along Fourth Line south of Wyecroft Road before crossing Fourth Line just north of the GO rail line. Upstream of Wyecroft Road, riparian vegetation consisted of mostly 10- to 20-year-old deciduous trees and herbaceous vegetation, whereas south of Wyecroft Road, the immediate riparian area was vegetated with only grasses.

Due to the articulate concrete blocks that lined the channel, there was no complexity in the bed morphology. The articulate concrete blocks were in good condition and provided robust erosion protection to the channel. The average bed width was 1.60 m, and the average channel width and maximum depth were 3.3 and 0.76 m.

Immediately upstream and downstream of Wyecroft Road, retaining walls lined the channel to direct flows into and out of the twin box culvert (Crossing C6), which had 3 m barrel spans and 2 m rises. Although both barrels conveyed flows, most of the low flow passed through the east barrel due to the sediment deposition in the west barrel. At the outlet of the west barrel, a well-vegetated bar partially impeded flow.

Glen Oaks Creek

Reach GO-1 is a 10 to 20 m wide corridor with a previously straightened channel that travels in a southeasterly direction across Wyecroft Road. A narrow (<5 m wide) and fragmented strip of mature deciduous trees acted as the channel's riparian buffer. The channel had a riffle and pool bed morphology despite the generally straight channel alignment. Pool beds were typically composed of exposed bedrock, while riffle substrate consisted of cobbles and boulders. Bank materials were largely clay and silt with willow rootlets. Notably, bricks and concrete blocks were commonly found along the bed and banks, having presumably been deposited into the creek as waste material. The average bankfull width and average maximum bankfull depth were 3.45 and 0.76, respectively.

The Wyecroft Road crossing (Crossing C7) is a 6 m span box culvert. The channel was partly misaligned with the culvert inlet, as the western two-thirds of the culvert inlet was blocked by a well-vegetated bar. Within the culvert, there was sediment accumulation forcing flows to make a right angle turn near the inlet and continue along the western internal wall of the culvert due to sediment deposition along the opposite side. At the culvert outlet, the sediment deposition through the culvert extends beyond the culvert end and blocks the eastern two-thirds of the outlet.

3.2.3 Reconnaissance-level Assessments

Channel stability was semi-quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric form adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40) or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

Reaches were also classified according to a modified Downs (1995) Channel Evolution Model and the River Styles Framework (Brierley and Fryirs, 2005). The Downs Model describes successional stages of a channel as a result of a perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve or respond to an alteration to the system. The River Styles Framework (Brierley and Fryirs, 2005) provides a geomorphological approach to examining river character, behaviour, condition, and recovery potential.

These reconnaissance-level assessments can be applied to alluvial or semi-alluvial systems. For this study, only the reaches associated with Fourteen Mile Creek, 14MC-1, and its tributary, 14MCT-1, were eligible. The results of these assessments are summarized below in **Table 2**. Taplow Creek and Glen Oaks Creek were not assessed using these indices as Taplow Creek consisted of a hardened channel and Glen Oaks Creek was a channelized feature.

Table 2: Summary of reconnaissance-level assessments.

Reach	RGA			RSAT			Downs Channel Evolution Model	River Styles Framework
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Features		
14MC-1	0.28	In transition	Degradation, widening	30	Good	Channel Stability	E - enlarging	Meandering, mixed load
14MCT-1	0.12	In regime	Degradation	27	Good	Water Quality	S - stable	Meandering, suspended load

4 Meander Belt Width Assessment

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width, or erosion hazard assessment, estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining, for example, the potential limit of an activity (e.g., development) adjacent to a watercourse or the floodplain width required to restore a stream. In addition, the meander belt width forms the basis for determining the limits of regulated Redside Dace habitat in occupied and recovery reaches, as defined in Section 29.1 of Ontario Regulation 242/08.

The meander belt width was delineated only for Fourteen Mile Creek Reach 14MC-1 as this reach was the only one that was not straightened, channelized and armoured within the road allowance. To do so, available historical aerial imagery was reviewed to determine the largest amplitude of a meander bend of Fourteen Mile Creek relative to the general channel alignment, between Wyecroft Road and the GO rail line. A maximum meander amplitude of 42 m was measured in the 2015 First Base Solutions orthophoto provided by the Town of Oakville. The bankfull channel width was added to this value, as well as a 20% factor of safety. This resulted in a final meander belt width of 58 m. A 30 m buffer was applied to either side of the meander belt width at Wyecroft Road to define the regulated Redside Dace habitat limits, as per Section 29.1 of Ontario Regulation 242/08. The meander belt width and extent of regulated Redside Dace habitat are shown in **Appendix D**. Note that the extent of regulated habitat does not account for the built environment (e.g., existing roadways, buildings, other non-vegetated areas).

5 Summary

Fluvial geomorphological assessments of watercourses were completed in support of the Schedule C Municipal Class EA for the improvements to Wyecroft Road between Bronte Road and Kerr Street. The study included the characterization of the four regulated watercourses that cross Wyecroft Road – Fourteen Mile Creek, a tributary of Fourteen Mile Creek, Taplow Creek and Glen Oaks Creek – and involved desktop reviews and assessments, field investigations, and the delineation of meander belt width and regulated Redside Dace habitat for Fourteen Mile Creek.

The RGA results for Reach 14MC-1 indicated the reach was in transition (score of 0.28), with evidence of degradation and widening. Reach 14MCT-1 was assessed to be in regime (score of 0.12). Reach 14MC-1 was assessed to be in good condition according to the RSAT (score of 30), with channel stability as the limiting feature. The Fourteen Mile Creek tributary was also assessed to be in good condition (score of 27) with water quality as the limiting feature. RGAs and RSATs were not completed for Taplow Creek and Glen Oaks Creek as Taplow Creek consisted of a hardened channel and Glen Oaks Creek was channelized.

A meander belt width of 58 m was calculated for the main channel of Fourteen Mile Creek at Wyecroft Road, based on the maximum amplitude of the largest meander bend located downstream of Wyecroft Road, the average channel bankfull width, and a 20% factor of safety. A 30 m riparian buffer was added to either side of the meander belt width to delineate the extent of regulated (occupied) Redside Dace habitat, as per Section 29.1 of Ontario Regulation 242/08. Meander belt widths were not delineated for the Fourteen Mile Creek Tributary, Taplow Creek, or Glen Oaks Creek due to past straightening and armouring, which precluded the development of a sinuous channel planform.

6 Recommendations

It is understood that the preferred alternative for each crossing associated with the four regulated watercourses has been determined to be as follows:

- Crossing C1 (Fourteen Mile Creek) – replacement with 20 m clear span bridge
- Crossing C3 (Tributary of Fourteen Mile Creek) – extension of 3.06 m x 2.6 m box culvert
- Crossing C6 (Taplow Creek) – no change to twin 3.0 m x 1.8 m box culvert
- Crossing C7 (Glen Oaks Creek) – replacement with 6.1 m x 1.5 m open-bottom box culvert

With respect to Crossing C1 at Fourteen Mile Creek, the 58 m meander belt width could potentially be accommodated with an equivalent span crossing structure. However, such a large structure would be inconsistent with the size of the existing crossing structure at Third Line only 120 m upstream as well as the culvert across the GO Transit rail line. The proposed 20 m clear span bridge instead provides a more suitable and significantly improved replacement as its span is more than three times the bankfull channel width (6.53 m), which allows for the design of a bankfull channel through the clear span bridge as well as terrestrial wildlife passage.

The channel under the proposed clear span bridge should be designed based on principles of natural channel design while recognizing that there would be a lack of natural soil stabilization through vegetation establishment due to limited sunlight. It is therefore recommended that the channel boundary material and the overbank area for the full bridge span be comprised of riverstone that is hydraulically sized to resist entrainment. The depth of riverstone relative to the top of the overbank elevation should be greater than the depth of pools to ensure that the bridge footings are protected. It should be noted that the Ministry of the Environment, Conservation and Parks, which now administers the ESA, may have concerns with the extent of riverstone use, and an acceptable alternative may need to be explored.

To provide habitat complexity through the 23.9 m long clear span bridge, the channel morphology should vary with the inclusion of riffles and pools. The pools would ideally have a bankfull depth of 1 m or more, depending on the assessed stability of the channel cross-sectional geometry, as this depth would be suitable for Redside Dace. A veneer of gravel-sized riverstone on the channel bed would also benefit Redside Dace, understanding that this material could ultimately be redistributed or transported downstream as it may have a low entrainment threshold. A more permanent and highly recommended channel treatment that would enhance Redside Dace habitat would be to install large woody debris or root wads along the channel banks, particularly along the outside bank of channel bends. These wood features would not only provide microhabitat, but also a source of roughness to retard flow velocities. They can also promote bed scouring to maintain pool depths depending on the design.

It is understood that the alignment of South Service Road, east of Third Line, would be modified such that the proposed clear span bridge would be positioned downstream of the existing Crossing C1 structure. The newly opened channel section would therefore also need to be restored. This also provides an opportunity to remove the concrete weir at the existing culvert inlet, unless it still provides a function. The restoration approach outlined above for the channel through the clear span bridge should be utilized, but adapted with the recognition of the benefit afforded by sunlight availability. Here, the channel boundary materials can be more consistent with that found elsewhere in the reach. The shale bed cannot be easily replicated, but the transport of shale fragments from upstream may eventually be deposited to provide similar bed material composition. The banks should be restored with a form of bioengineering suitable based on the modelled hydraulics. This could simply involve woody plantings to provide soil stability (with a biodegradable erosion control blanket for immediate erosion protection), but should include large woody debris or root wads for enhanced stability and aquatic habitat.

Crossing C3 at the tributary of Fourteen Mile Creek is proposed to be extended on the south side of the road. The perched condition of Crossing C3 outlet could be addressed as part of the culvert extension and/or receiving channel restoration. Further discussion with the regulatory agencies is recommended as this tributary is currently considered to be a contributing Redside Dace reach, a designation that may change. Moreover, there are two additional drops within the culvert that may impede fish passage.

With respect to Crossing C6, there is an opportunity to improve conditions for fish, should this be desired. Currently, both barrels of the twin box culvert have sediment accumulation, but the east barrel has less with a low-flow channel travelling along one side. Culvert capacity may need to be restored by removing sediment, but a low-flow channel could still be installed through the east barrel for fish passage during baseflow conditions if the existing culvert is sufficiently embedded to allow for a certain depth of substrate that would be stable and not slide on the concrete slab (to be assessed at the detailed design stage). It should be noted, however, that substrate, or a functionally equivalent measure, would need to be placed in the west barrel to direct low flows through the east barrel, and this could affect culvert capacity to an extent that results in an unacceptable increase in upstream flooding potential. If the existing culvert is not embedded, the installation of baffles or other means of reducing low-flow velocities can be explored, but again its feasibility must be evaluated with consideration to culvert hydraulics/capacity, upstream flooding and the assessed importance of improving fish passage and habitat.

The replacement of Crossing C7 at Glen Oaks Creek with a longer open-bottom structure offers an opportunity to reinstate a low-flow channel across the road and improve fish habitat and passage. Similar to Crossing C1, natural channel design principles could be employed to develop a channel through the culvert. The replacement culvert will be longer than existing and therefore will require channel works. The channel beyond the proposed ends of the culvert can be restored so that it better aligns with the culvert. Bioengineered banks are recommended for the restored channel to provide aquatic habitat benefits and enhance stability.

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Appendix A
Historical Aerial Imagery

Location: Wyecroft Road, Town of Oakville
Year: 1934
Scale: 1:20,000
Source: National Air Photo Library

Location: Wyecroft Road, Town of Oakville
Year: 1954
Scale: 1: 15,840
Source: Ministry of Natural Resources and Forestry

Location: Wyecroft Road, Town of Oakville
Year: 1954
Scale: 1: 15,840
Source: Ministry of Natural Resources and Forestry

Location: Wyecroft Road, Town of Oakville
Year: 1954
Scale: 1: 15,840
Source: Ministry of Natural Resources and Forestry

Location: Wyecroft Road, Town of Oakville
Year: 1978
Scale: 1: 10,000
Source: Ministry of Natural Resources and Forestry

Location: Wyecroft Road, Town of Oakville
Year: 1978
Scale: 1: 10,000
Source: Ministry of Natural Resources and Forestry

Location: Wyecroft Road, Town of Oakville
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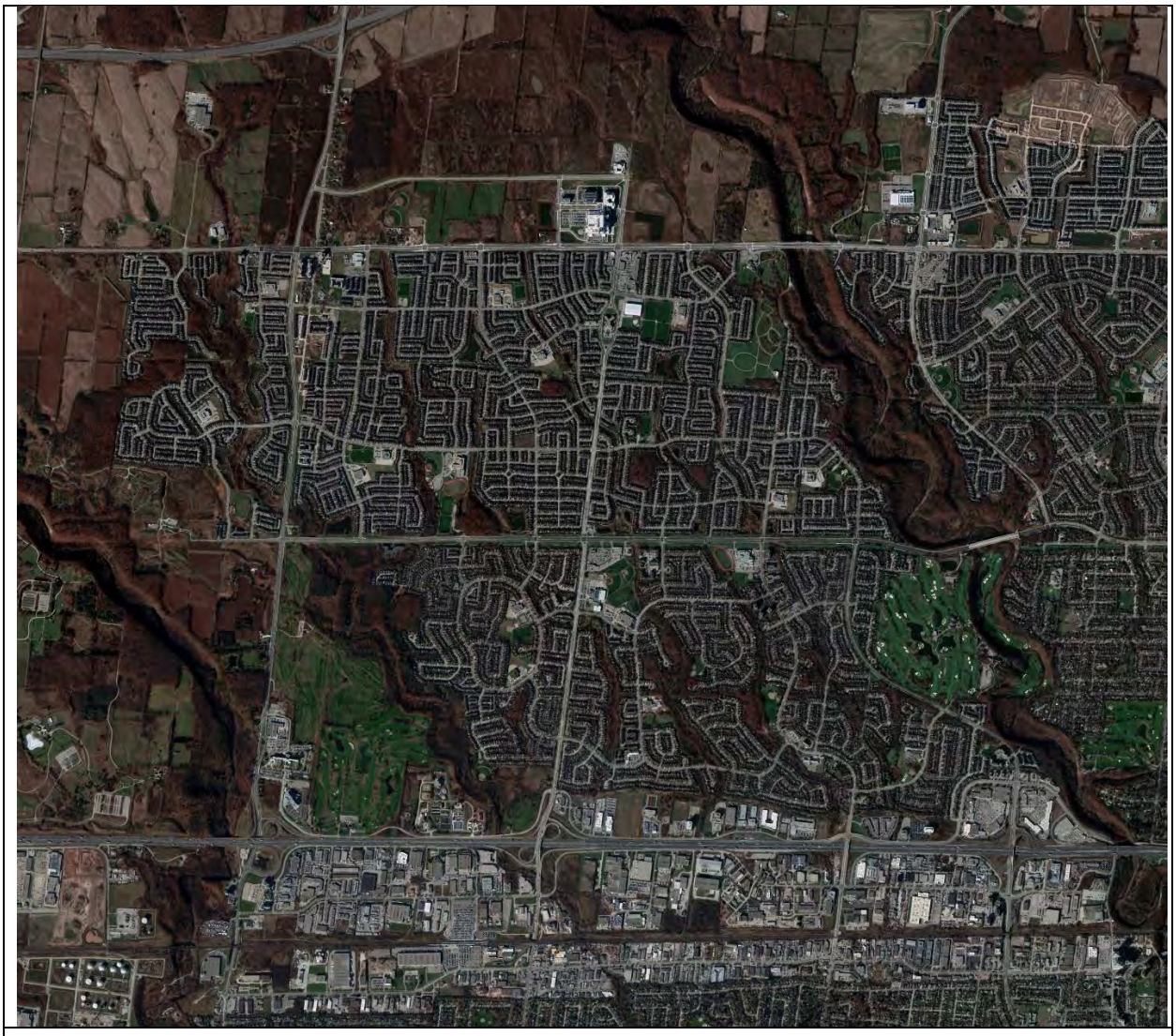
Location: Wyecroft Road, Town of Oakville
Year: 1978
Scale: 1: 10,000
Source: Ministry of Natural Resources and Forestry



Location: Wyecroft Road, Town of Oakville
Year: 2017
Scale: Not Applicable
Source: Google Earth Pro

Appendix B
Photographic Record

Photo 1 Reach 14MC-1: South of Queen Elizabeth Way (QEW) to 250 m downstream of South Service Road	
	Fourteen Mile Creek had a well established riparian buffer consisting of mature deciduous trees. Some debris (concrete blocks) were observed upstream of the Fourth Line crossing. Yellow arrow indicates flow direction
Photo 2 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	Several valley wall contacts were observed within the assessed portion of Fourteen Mile Creek, on both sides of the channel.

Photo 3 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	The channel bed was composed of bedrock throughout the reach, with surficial platy cobbles and gravels. Two small knickpoints were also observed, evidence of channel degradation.
Photo 4 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	The channel exhibited compound meanders within the valley, few point bars and low to moderate amounts of bank erosion on the outside of the bends.

Photo 5 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	The Third Line crossing was a bridge, with the channel and banks composed of large cobble-sized riverstone.
Photo 6 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	A small channel conveyed flows from a headwall located east of Third Line and discharged into Fourteen Mile Creek approximately 30 m from the South Service Road crossing. The channel was lined with cobbles and had significant algal growth.

Photo 7 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	A concrete weir spanned the channel immediately upstream of the South Service Road crossing.
Photo 8 Reach 14MC-1: South of QEW to 250 m downstream of Wyecroft Road	
	The South Service Road crossing was a twin box culvert, with the channel aligned with the southern culvert. The northern culvert was partially blocked by a well-vegetated bar.

Photo 9 Reach 14MC-1: South of QEW to 250 m downstream of Wyecroft Road	
	The northern culvert contained standing water.
Photo 10 Reach 14MC-1: South of QEW to 250 m downstream of Wyecroft Road	
	A bar formed along the north side of the southern box culvert.

Photo 11 Reach 14MC-1: South of QEW to 250 m downstream of Wyecroft Road	
	The channel was naturally constricted at the downstream end of the southern box culvert. A fallen tree transverse to the channel further impeded flows.
Photo 12 Reach 14MC-1: South of QEW to 250 m downstream of Wyecroft Road	
	Due to the channel constriction beyond the downstream end of the southern culvert, high flows have evidently overtopped the bank and eroded the south valley wall.

Photo 13 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	Channel conditions downstream of the South Service Road crossing were consistent with observations upstream, including valley wall contacts. In this instance, the channel laterally eroded Queenston Shale along the north side of the channel.
Photo 14 Reach 14MC-1: South of QEW to 250 m downstream of South Service Road	
	At the first meander bend downstream of the South Service Road crossing, the outside bank was eroded and a point bar formed on the inside of the bend.

Photo 15 Reach 14MCT-1: North of QEW	
	Upstream of the QEW, the channel had an irregularly meandering planform and conveyed flows through a corridor populated by deciduous trees and herbaceous plants.
Photo 16 Reach 14MCT-1: North of QEW	
	The channel showed evidence of degradation, including the presence of a suspended armour layer consisting of Queenston Shale within the banks, and parent material on the channel bed.

Photo 17 Reach 14MCT-1: North of QEW	
	Immediately upstream of the ~100 m long culvert conveying flows across the QEW and the South Service Road, sand bags spanned the channel creating a weir.
Photo 18 Reach 14MCT-1: North of QEW	
	Within the culvert, two drops each approximately 0.3 m high were observed. These may prevent upstream fish migration.

Photo 19 Reach 14MCT-2: QEW to GE Distribution Centre	
	Another drop was present at the culvert outlet at South Service Road. The channel banks were composed of concrete, but eroded along the toe in the vicinity of the culvert outlet.
Photo 20 Reach 14MCT-2: QEW to GE Distribution Centre	
	Downstream of South Service Road the channel was straight and concrete-lined with no morphological variability.

Photo 21 Reach 14MCT-2: QEW to GE Distribution Centre	
	Channel banks were generally 2 m high and had a 1.5:1 slope, with some erosion from abrasion exposing the supporting wire within the concrete.
Photo 22 Reach 14MCT-2: QEW to GE Distribution Centre	
	At the downstream extent of the assessed portion of the reach, cattail and reed canary grass were established along the channel margins.

Photo 23 Reach TC-1: 125 m North and South of South Service Road	 At the upstream end of the assessed portion of Taplow Creek, riparian vegetation included juvenile deciduous trees and herbaceous plants.
Photo 24 Reach TC-1: 125 m North and South of South Service Road	 The channel bed and banks were lined with articulated concrete blocks throughout the extent assessed. No erosion was noted to channel bed or banks.

Photo 25 Reach TC-1: 125 m North and South of South Service Road	
	The South Service Road crossing was a twin box culvert. While both culverts conveyed flow, the eastern culvert was partially blocked by a well-vegetated bar. Two-metre-high concrete retaining walls directed flow into the culvert.
Photo 26 Reach TC-1: 125 m North and South of South Service Road	
	At the outlet of the South Service Road culvert was a vegetated bar.

Photo 27 Reach TC-1: 125 m North and South of South Service Road	
	Within the western culvert, low-flow travelled along the west side of the culvert, and sediment was deposited along the east side.
Photo 28 Reach TC-1: 125 m North and South of South Service Road	
	Sediment has accumulated within the eastern culvert, with a narrow and shallow channel along the west side of the culvert.

Photo 29 Reach TC-1: 125 m North and South of South Service Road	
	Water cress, an indicator of groundwater upwelling, was observed downstream of the South Service Road crossing.
Photo 30 Reach TC-1: 125 m North and South of South Service Road	
	Taplow Creek downstream of South Service Road had a riparian buffer that lacked woody vegetation. The channel bed and banks were composed of articulated concrete blocks, consistent with upstream conditions.

Photo 31 Reach GO-1: 125 m north and south of Wyecroft Road	
	Glen Oaks Creek conveyed flows within a narrow corridor in which sparse mature deciduous trees provided some cover.
Photo 32 Reach GO-1: 125 m north and south of Wyecroft Road	
	In several locations the corridor lacked a riparian buffer, and debris from the adjacent industrial properties had been deposited into the creek.

Photo 33 Reach GO-1: 125 m north and south of Wyecroft Road	
	The channel bed was comprised of bedrock throughout the reach, with one knickpoint upstream of Wyecroft Road. Channel banks were generally composed of a silt and clay mixture with willow rootlets providing stability to the channel banks.
Photo 34 Reach GO-1: 125 m north and south of Wyecroft Road	
	The Wyecroft Road crossing was a 6 m wide box culvert which was partly misaligned with the existing channel.

Photo 35 Reach GO-1: 125 m north and south of Wyecroft Road	
	A well-vegetated bar blocked approximately three-quarters of the Wyecroft Road culvert inlet.
Photo 36 Reach GO-1: 125 m north and south of Wyecroft Road	
	A well-vegetated bar blocked approximately two-thirds of the Wyecroft Road culvert outlet, on the eastern side.

Photo 37 Reach GO-1: 125 m north and south of Wyecroft Road	
	The channel makes a 90° turn upon entering the Wyecroft Road culvert before following the western wall to the outlet.
Photo 38 Reach GO-1: 125 m north and south of Wyecroft Road	
	Downstream of Wyecroft Road, a continuous and narrow riparian buffer consisting of mature deciduous trees and herbaceous vegetation was present. The channel had a generally straight planform.

Photo 39 Reach GO-1: 125 m north and south of Wyecroft Road	
	Downstream of Wyecroft Road, the channel bed was bedrock, and the banks had a low slope comprised of a silt and clay with willow rootlets.

Appendix C
Field Sheets

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: 18049

Date:	2018-06-01	**Stream/Reach:**	14MC-1
Weather:	25°C, Overcast	**Location:**	Third Line / S. Service Rd., Oakville
Field Staff:	AB, BM2	**Watershed/Subwatershed:**	14 Mile Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 6,9 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 9 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1
Species: Deciduous

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☐ 1-4
- ☒ 4-10
- ☐ > 10

Age Class (yrs):
- ☐ Immature (<5)
- ☐ Established (5-30)
- ☒ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 5

Woody Debris
- ☒ Present in Cutbank
- ☒ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 5 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): E

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☒	☒	☐	☒	☐
Pool Substrate	☒	☐	☐	☐	☐	☒	☐
Bank Material	☒	☐	☐	☐	☐	☒	☐

Bankfull Width (m)	4	7.6	6.9	**Wetted Width (m)**	3.7	5.2	4.4
Bankfull Depth (m)	0.7	1.3	0.8	**Wetted Depth (m)**	0.3	0.31	0.12

*6.4, 6.7, 8
*0.75, 1.1, 0.9
5.9, 5.8, 4.9
0.16, 0.37, 0.1

Riffle/Pool Spacing (m): 40 | **% Riffles:** 10 | **% Pools:** 20 | **Meander Amplitude:** /

Pool Depth (m): 1.3 | **Riffle Length (m):** 10 | **Undercuts (m):** 0.5 | **Comments:** _____

Velocity (m/s): / / / **Wiffle ball / ADV / Estimated** _____

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☒ 60 – 90
- ☒ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☒ 60 – 100%

Notes:

Completed by: AB | Checked by: _____

Reach Characteristics Key

Table 1 Land Use
1. Forest
2. Pasture
3. Agricultural
4. Industrial
5. Park
6. Institutional
7. Residential
8. Golf Course
9. Commercial

Table 2 Valley Type
1. Unconfined
2. Confined
3. Partially Confined

Table 3 Channel Type

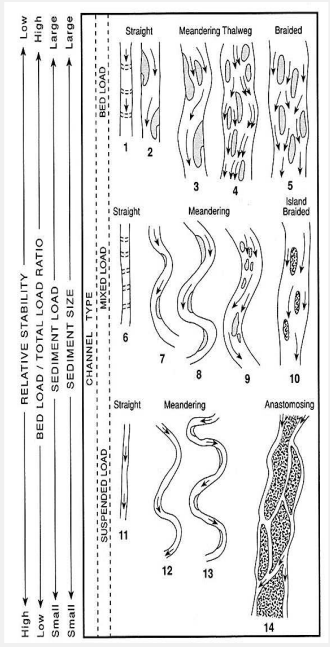


Table 4 Channel Zone
1. Headwater zone
2. Transfer zone
3. Deposition zone

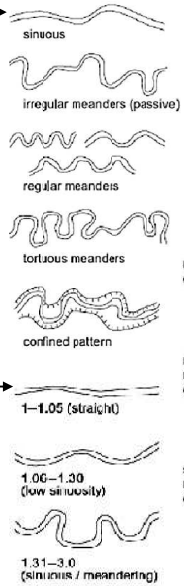
Table 5 Flow Type
1. Perennial
2. Intermittent
3. Ephemeral

Table 6 Dominant Vegetation Type
1. Trees
2. Shrubs
3. Grasses
4. Herbaceous

Table 7 Extent of Encroachment into Channel
1. None
2. Minimal
3. Moderate
4. Heavy
5. Extreme

Table 8 Type of Aquatic Vegetation
1. Rooted Emergent
2. Rooted Submergent
3. Rooted Floating
4. Free Floating Roots
5. Floating Algae
6. Attached Algae

Table 9 Type of Sinuosity
1. Sinuous
2. Irregular Meanders
3. Regular Meanders
4. Tortuous Meanders
5. Confined pattern (within valley)



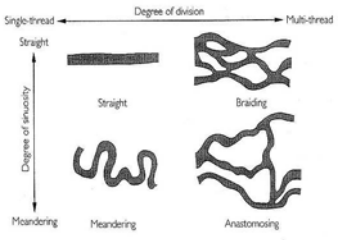
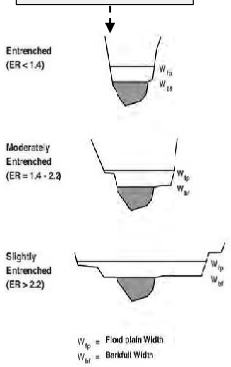


Table 10 Degree of Sinuosity
1. Straight (1 – 1.05)
2. Low sinuosity (1.06–1.30)
3. Meandering (1.31 - 3.0)

Table 11 Gradient
1. Low
2. Moderate
3. High

Table 12 Number of Channels
1. Single
2. Up to 3 (Wandering)
3. >3 (Braided)
4. >3 (Anastamosing or Anabranching)
5. Discontinuous or Absent

Table 13 Entrenchment
1. Low (>2.2)
2. Moderate (1.4 – 2.2)
3. High (<1.4)



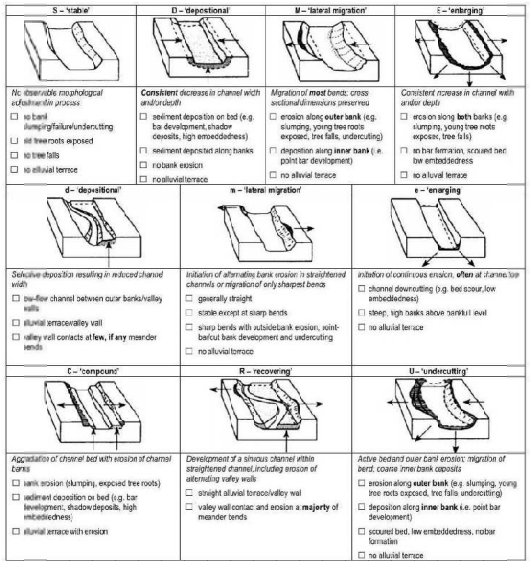


Table 14 Type of Bank Failure
1. Fluvial Entrainment (Hydraulic action)
2. Undercutting (Hydraulic action)
3. Slab Failure (Mass failure)
4. Parallel slide (Mass failure)
5. Fall/Sloughing (Mass failure)
6. Rotational slip and slump (Mass failure)

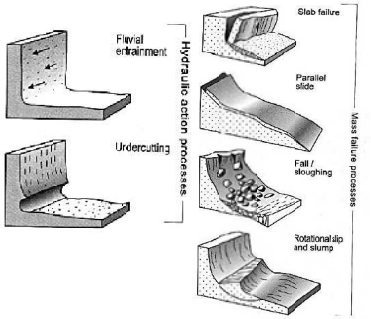


Table 15 Downs's Model of Channel Classification
S – Stable
D or d – Depositional
M or m – Lateral Migration
E or e – Enlarging
C – Compound
R – Recovering
U – Undercutting

Table 16 Odours
1. None
2. Fishy
3. Petroleum
4. Sewage
5. Chemical
6. Other

Table 17 Turbidity
1. Clear
2. Slightly turbid
3. Turbid
4. Opaque
5. Stained
6. Other

GEO | MORPHIX

General Site Characteristics

Project Code: 18049

Date:	June 1/2018	**Stream/Reach:**	14MC, Upstream
Weather:	Overcast, 25°C	**Location:**	Third Line / Wyecroft
Field Staff:	AB, BM²	**Watershed/Subwatershed:**	14 Mile Creek

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

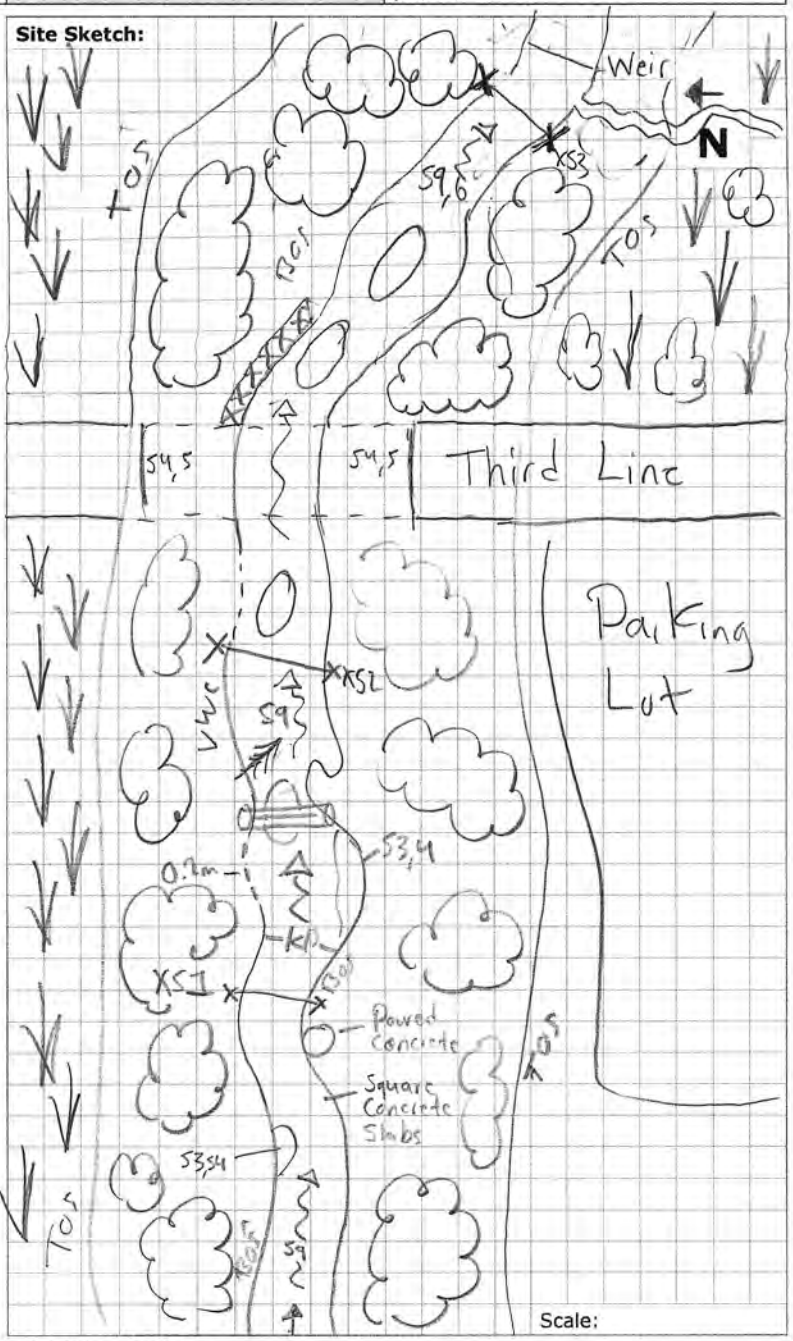
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes:

Completed by: AB Checked by: _____

GEO | MORPHIX

General Site Characteristics

Project Code: 18049

Date:	June 1, 2018	**Stream/Reach:**	14MC, DS
Weather:	Overcast 25°C	**Location:**	S. Service Rd & 3rd Line
Field Staff:	AB, BM	**Watershed/Subwatershed:**	14 Mile Creek

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

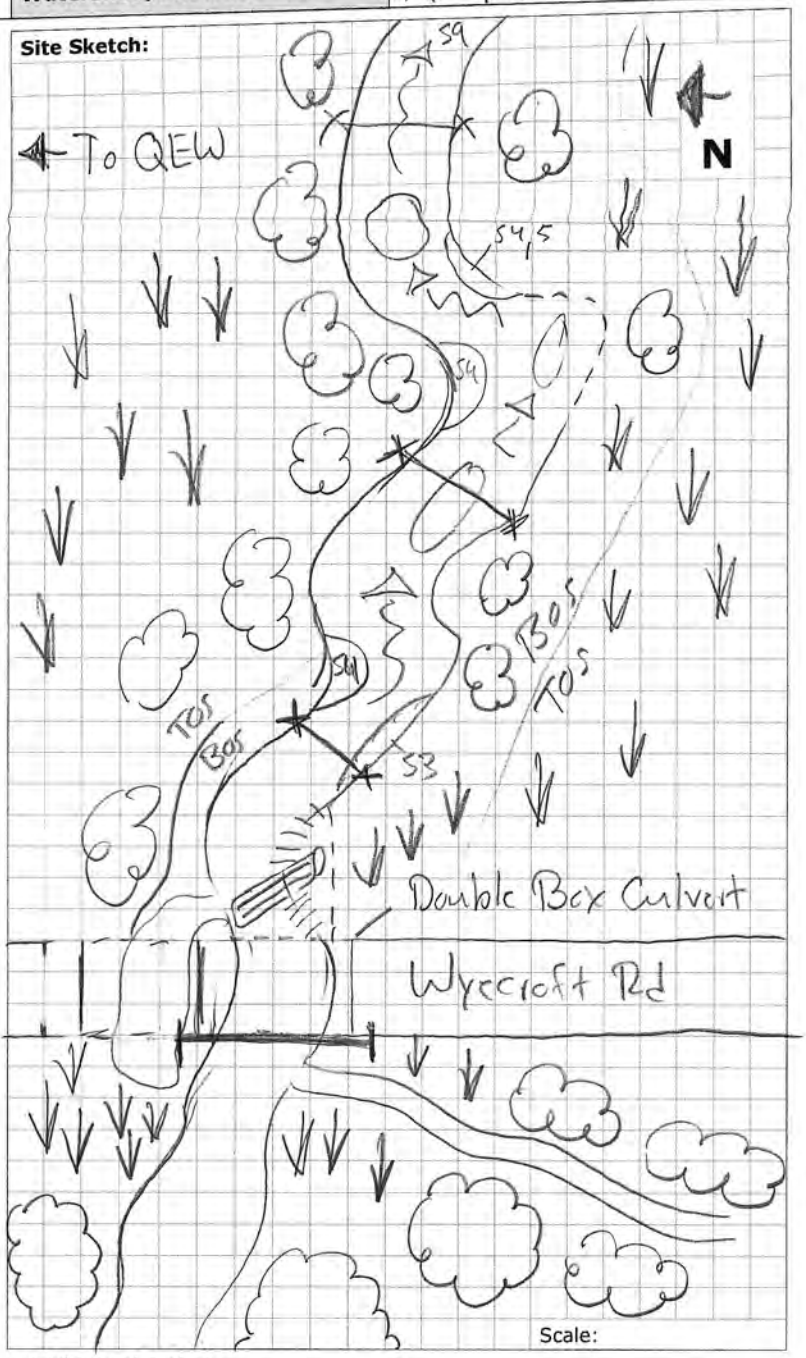
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes:

Completed by: AB Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: 18049

Date:	2018-06-01	**Stream/Reach:**	14MC-1
Weather:	25°C, Overcast	**Watershed/Subwatershed:**	14 Mile Creek
Field Staff:	AB, BM2	**Location:**	Third Line & S. Service Rd, Oakville

Process	No.	Geomorphological Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		/	0
	2	Coarse materials in riffles embedded		/	
	3	Siltation in pools		/	
	4	Medial bars		/	
	5	Accretion on point bars		/	
	6	Poor longitudinal sorting of bed materials		/	
	7	Deposition in the overbank zone		/	
		Sum of indices =	0	7	
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		/	0.571
	2	Exposed sanitary / storm sewer / pipeline / etc.			
	3	Elevated storm sewer outfall(s)			
	4	Undermined gabion baskets / concrete aprons / etc.		/	
	5	Scour pools downstream of culverts / storm sewer outlets			
	6	Cut face on bar forms		/	
	7	Head cutting due to knickpoint migration	/		
	8	Terrace cut through older bar material	/		
	9	Suspended armour layer visible in bank	/		
	10	Channel worn into undisturbed overburden / bedrock	/		
		Sum of indices =	4	3	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	/		0.571
	2	Occurrence of large organic debris		/	
	3	Exposed tree roots	/		
	4	Basal scour on inside meander bends		/	
	5	Basal scour on both sides of channel through riffle		/	
	6	Outflanked gabion baskets / concrete walls / etc.			
	7	Length of basal scour >50% through subject reach	/		
	8	Exposed length of previously buried pipe / cable / etc.			
	9	Fracture lines along top of bank	/		
	10	Exposed building foundation			
		Sum of indices =	4	3	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		/	0
	2	Single thread channel to multiple channel		/	
	3	Evolution of pool-riffle form to low bed relief form		/	
	4	Cut-off channel(s)		/	
	5	Formation of island(s)		/	
	6	Thalweg alignment out of phase with meander form		/	
	7	Bar forms poorly formed / reworked / removed		/	
		Sum of indices =	0	7	

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.28

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: AB Checked by: _____

Rapid Stream Assessment Technique

Project Code:

Date:	2018-06-01	**Stream/Reach:**	14MC-1
Weather:	25°C, Overcast	**Location:**	Third Line & S. Service Rd. W, Oakville
Field Staff:	AB, BM²	**Watershed/Subwatershed:**	14 Mile Creek

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Date:	June 1/2018	Reach:	14MC-1	Project Code:	18049

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☒ 5	☐ 6 ☐ 7

Total overall score (0–42) = 30	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: AB Checked by: _____

GEO | MORPHIX
Geomorphology Earth Science Observation

Reach Characteristics

Project Code/Phase: 18049

Date:	June 1, 2018	**Stream/Reach:**	14 Mile Creek Trib, US
Weather:	Overcast, 25°C	**Location:**	QEW, East of 3rd Line
Field staff:	AB, BM2	**Watershed/Subwatershed:**	14 Mile Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 7 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,2
Species: Deciduous

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths
- ☐ 1-4
- ☒ 4-10
- ☐ > 10

Age Class (yrs) :
- ☐ Immature (<5)
- ☒ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 0

Woody Debris
- ☑ Present in Cutbank
- ☐ Present in Channel
- ☐ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 4

Channel Characteristics

Sinuosity (Type) (Table 9): 2
Sinuosity (Degree) (Table 10): 2
Gradient (Table 11): 2
Number of Channels (Table 12): 1
Entrenchment (Table 13): 1
Type of Bank Failure (Table 14): 2
Downs's Classification (Table 15): m

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☑	☑	☐	☑	☐
Pool Substrate	☑	☐	☐	☐	☐	☑	☐
Bank Material	☑	☐	☐	☐	☐	☐	☐

Bankfull Width (m)	3.6	4	3.7	**Wetted Width (m)**	2.1	2.2	2.7
Bankfull Depth (m)	0.5	0.6	0.5	**Wetted Depth (m)**	0.13	0.18	0.25

Riffle/Pool Spacing (m): 20 | **% Riffles:** 20 | **% Pools:** 30 | **Meander Amplitude:** /

Pool Depth (m): 0.6 | **Riffle Length (m):** 5.7 | **Undercuts (m):** 0.2 | **Comments:** _____

Velocity (m/s): _____ | **Wiffle ball / ADV / Estimated** _____

Bank Angle
- ☐ 0 – 30
- ☒ 30 – 60
- ☒ 60 – 90
- ☒ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes:

Completed by: AB | Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 18049

Date:	June 1, 2018	**Stream/Reach:**	14 Mile Creek Trib, downstream
Weather:	Overcast, 25°C	**Location:**	5 Service Rd E of 3rd Line
Field staff:	AP, BM	**Watershed/Subwatershed:**	14 Mile Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): N/A | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 3
Species: _____

Coverage:
- ☐ None
- ☒ Fragmented
- ☐ Continuous

Channel widths:
- ☒ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☒ Immature (<5)
- ☐ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 6 | **Coverage of Reach (%):** 10

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☒ Not Present

Density of WD:
- ☒ Low
- ☐ Moderate
- ☐ High

WDI/50m: /

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity (Type) (Table 9): 1 | **Sinuosity (Degree)** (Table 10): 1 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 3 | **Type of Bank Failure** (Table 14): / | **Downs's Classification** (Table 15): /

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	N/A ☐	☐	☐	☐	☐	☐
Pool Substrate	☐	N/A ☐	☐	☐	☐	☐	☐
Bank Material	☒	N/A ☐	☐	☐	☐	☐	☐

	Bottom	Top	BF				
Bankfull Width (m)	3.25	8	4.3	**Wetted Width (m)**	3.1		
Bankfull Depth (m)		2	0.8	**Wetted Depth (m)**	0.15		

Riffle/Pool Spacing (m): / | **% Riffles:** 0 | **% Pools:** 0 | **Meander Amplitude:** /

Pool Depth (m): / | **Riffle Length (m):** / | **Undercuts (m):** /

Velocity (m/s): / / / **Wiffle ball / ADV / Estimated**

Bank Angle
- ☐ 0 – 30
- ☑ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments:

Notes: Concrete channel

Completed by: AB | Checked by: _____

GEO MORPHIX

General Site Characteristics

Project Code: 18049

Date:	June 7, 2018	**Stream/Reach:**	14 Mile Creek Tributary
Weather:	Overcast, 25°C	**Location:**	S Service Rd, E of 3rd Line
Field Staff:	AB, BM[2]	**Watershed/Subwatershed:**	14 Mile Creek

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

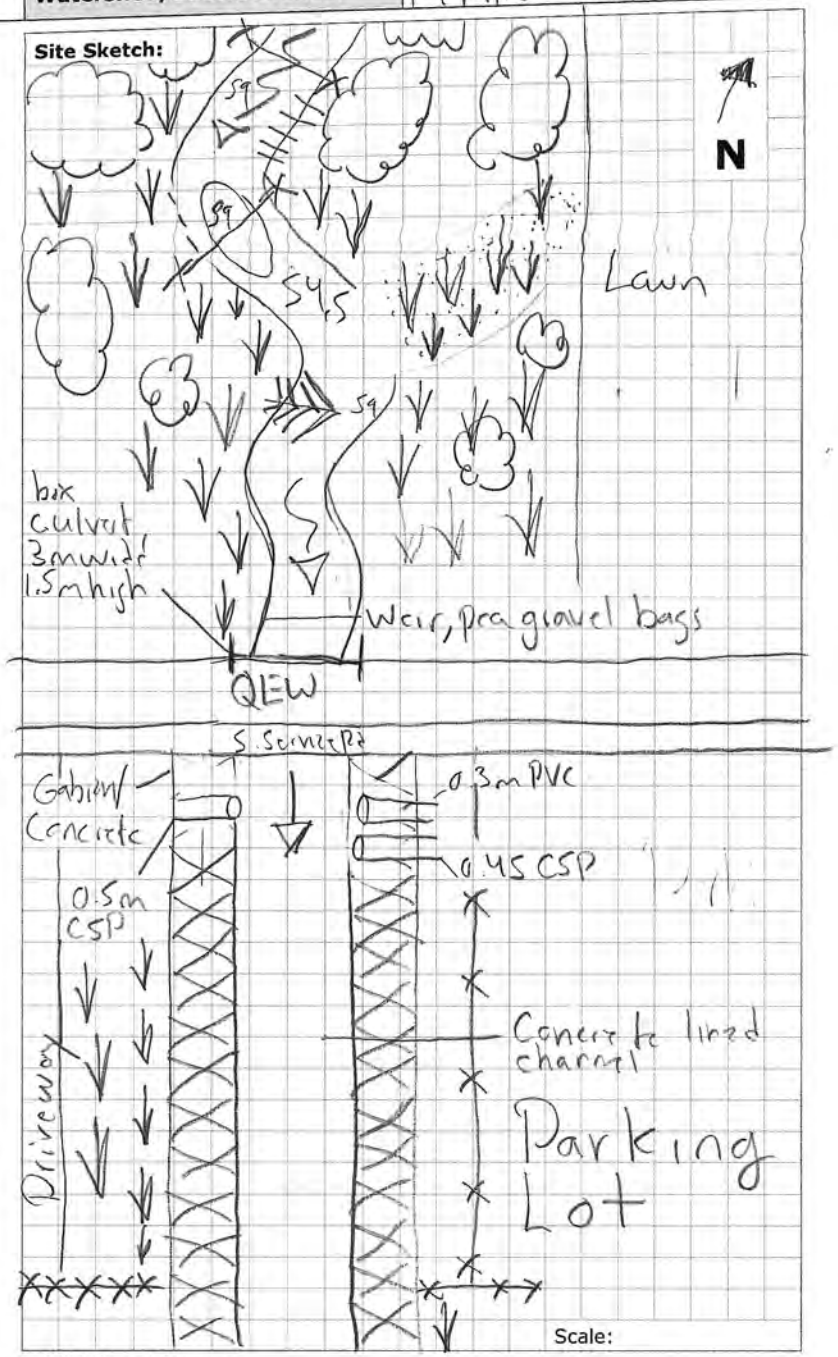
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes:

Completed by: AB Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: 18049

Date:	June 1, 2018	**Stream/Reach:**	14 Mile Creek trib. upstream
Weather:	Overcast, 25°C	**Watershed/Subwatershed:**	14 Mile Creek
Field Staff:	AB, BM²	**Location:**	QEW, E of 3rd Line

Process	Geomorphological Indicator		Present? Yes	Present? No	Factor Value
	No.	Description			
Evidence of Aggradation (AI)	1	Lobate bar		\	0.1
	2	Coarse materials in riffles embedded		\	
	3	Siltation in pools		\	
	4	Medial bars		\	
	5	Accretion on point bars		\	
	6	Poor longitudinal sorting of bed materials		\	
	7	Deposition in the overbank zone		\	
		Sum of indices =	0	7	
Evidence of Degradation (DI)	1	Exposed bridge footing(s)			0.333
	2	Exposed sanitary / storm sewer / pipeline / etc.			
	3	Elevated storm sewer outfall(s)			
	4	Undermined gabion baskets / concrete aprons / etc.			
	5	Scour pools downstream of culverts / storm sewer outlets		\	
	6	Cut face on bar forms		\	
	7	Head cutting due to knickpoint migration		\	
	8	Terrace cut through older bar material		\	
	9	Suspended armour layer visible in bank	\		
	10	Channel worn into undisturbed overburden / bedrock	\		
		Sum of indices =	2	4	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	\		0.143
	2	Occurrence of large organic debris		\	
	3	Exposed tree roots		\	
	4	Basal scour on inside meander bends		\	
	5	Basal scour on both sides of channel through riffle		\	
	6	Outflanked gabion baskets / concrete walls / etc.			
	7	Length of basal scour >50% through subject reach		\	
	8	Exposed length of previously buried pipe / cable / etc.			
	9	Fracture lines along top of bank		\	
	10	Exposed building foundation			
		Sum of indices =	1	6	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	0
	2	Single thread channel to multiple channel		\	
	3	Evolution of pool-riffle form to low bed relief form		\	
	4	Cut-off channel(s)		\	
	5	Formation of island(s)		\	
	6	Thalweg alignment out of phase with meander form		\	
	7	Bar forms poorly formed / reworked / removed		\	
		Sum of indices =	0	7	

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.119

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: AB Checked by: _____

Rapid Stream Assessment Technique

Project Code: 18049

Date:	June 1, 2018	**Stream/Reach:**	14MC Trib, upstream
Weather:	Overcast, 25°C	**Location:**	QEW, East of 3rd Line
Field Staff:	AB, BM2	**Watershed/Subwatershed:**	14 Mile Creek

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ **0** ☐ **1** ☐ **2**	☐ **3** ☐ **4** ☐ **5**	☐ **6** ☐ **7** ☐ **8**	☐ **9** ☐ **10** ☐ **11**
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ **0** ☐ **1** ☐ **2**	☐ **3** ☐ **4**	☐ **5** ☐ **6**	☐ **7** ☐ **8**

Date:	June 1/2018	Reach:	14MCTrib-US	Project Code:	18049

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☑ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☑ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☑ 5	☐ 6 ☐ 7

Total overall score (0–42) = 27	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: AB Checked by: _____

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 18049

Date:	June 1, 2018	**Stream/Reach:**	Taplow Creek
Weather:	Overcast, 25°C	**Location:**	4th Line & Wyecroft Rd
Field staff:	AB, BM	**Watershed/Subwatershed:**	McCraney Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): N/A | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☒ Groundwater | Evidence: Watercress

Riparian Vegetation

Dominant Type: (Table 6): 2,3
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☑ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 6 | **Coverage of Reach (%):** 5

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☑ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity (Type) (Table 9): /

Sinuosity (Degree) (Table 10): 1

Gradient (Table 11): 2

Number of Channels (Table 12): 1

Entrenchment (Table 13): N/A

Type of Bank Failure (Table 14): N/A

Downs's Classification (Table 15): N/A

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☐	☐	☐	☐	☐
Pool Substrate	☐	☐	☒	☐	☑ A	☐	☐
Bank Material	☐	☐	☐	☐	☐	☐	☐

Bank Material: Rock

Bankfull Width (m)	3.5	3	3.5	**Wetted Width (m)**	1.6	1.75	1.6
Bankfull Depth (m)	0.65	1	0.65	**Wetted Depth (m)**	0.09	0.08	0.09

Riffle/Pool Spacing (m): /
% Riffles: 0
% Pools: 0
Meander Amplitude:)

Pool Depth (m): 1
Riffle Length (m): /
Undercuts (m): /

Velocity (m/s): / / /
Wiffle ball / ADV / Estimated

Bank Angle
- ☐ 0 – 30
- ☑ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☑ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments: Buried channel

Notes:

Completed by: AB

Checked by: _____

GEO MORPHIX

General Site Characteristics

Project Code: 18049

Date:	June 1, 2018	**Stream/Reach:**	Taplow Creek
Weather:	Overcast, 25°C	**Location:**	S. Service Rd & Fourth Line
Field Staff:	AB, BM²	**Watershed/Subwatershed:**	McCraney Creek

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

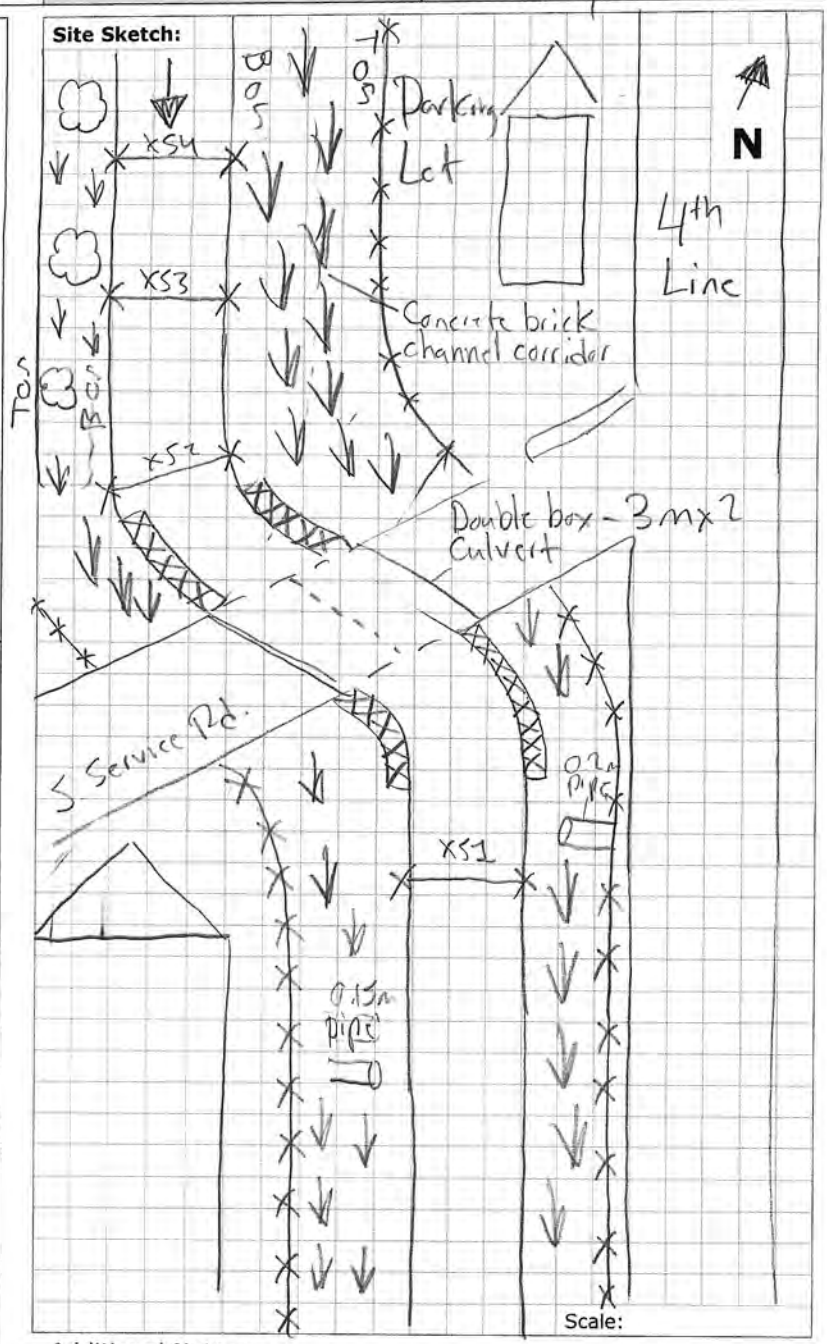
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes:

Completed by: _____ Checked by: _____

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 18049

Date:	June 1/2018	**Stream/Reach:**	Glen Oaks Creek
Weather:	25°C Overcast	**Location:**	Wycroft Rd, East of 4th Line
Field staff:	AB, BM²	**Watershed/Subwatershed:**	McCraney Creek
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,2
Species: _____

Coverage:
☐ None
☐ Fragmented
☒ Continuous

Channel widths
☒ 1-4
☐ 4-10
☐ > 10

Age Class (yrs):
☐ Immature (<5)
☒ Established (5-30)
☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): 5

Woody Debris
☒ Present in Cutbank
☐ Present in Channel
☐ Not Present

Density of WD:
☐ Low
☐ Moderate
☐ High

WDJ/50m:

Water Quality

Odour (Table 16): 5

Turbidity (Table 17): 4

Channel Characteristics

Sinuosity (Type) (Table 9): 1
Sinuosity (Degree) (Table 10): 1
Gradient (Table 11): 2
Number of Channels (Table 12): 1

Entrenchment (Table 13): 2
Type of Bank Failure (Table 14): 1
Downs's Classification (Table 15): 5

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☐	☒	☒	☐	☐
Pool Substrate	☒	☐	☐	☒	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☒

Bankfull Width (m)	2.9	4	3.5	**Wetted Width (m)**	1.8	2.3	1.3
Bankfull Depth (m)	0.8	0.7	0.8	**Wetted Depth (m)**	0.22	0.26	0.3

Riffle/Pool Spacing (m): 20 | **% Riffles:** 20 | **% Pools:** 20 | **Meander Amplitude:** 0

Pool Depth (m): 0.8 | **Riffle Length (m):** 6 | **Undercuts (m):** | **Comments:** _____

Velocity (m/s): | | | **Wiffle ball / ADV / Estimated** _____

Bank Angle
☐ 0 – 30
☒ 30 – 60
☒ 60 – 90
☐ Undercut

Bank Erosion
☐ < 5%
☒ 5 – 30%
☐ 30 – 60%
☐ 60 – 100%

Notes:

Completed by: AB | Checked by: _____

GEO | MORPHIX

General Site Characteristics

Project Code: 18049

Date:	June 1, 2018	**Stream/Reach:**	Glen Oaks Creek
Weather:	25°C, Overcast	**Location:**	Wyecroft Rd E of [illegible] Ln.
Field Staff:	AB, BM2	**Watershed/Subwatershed:**	McCraney Creek

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
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- Woody debris
- Station location
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Flow Type

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H9	Free fall

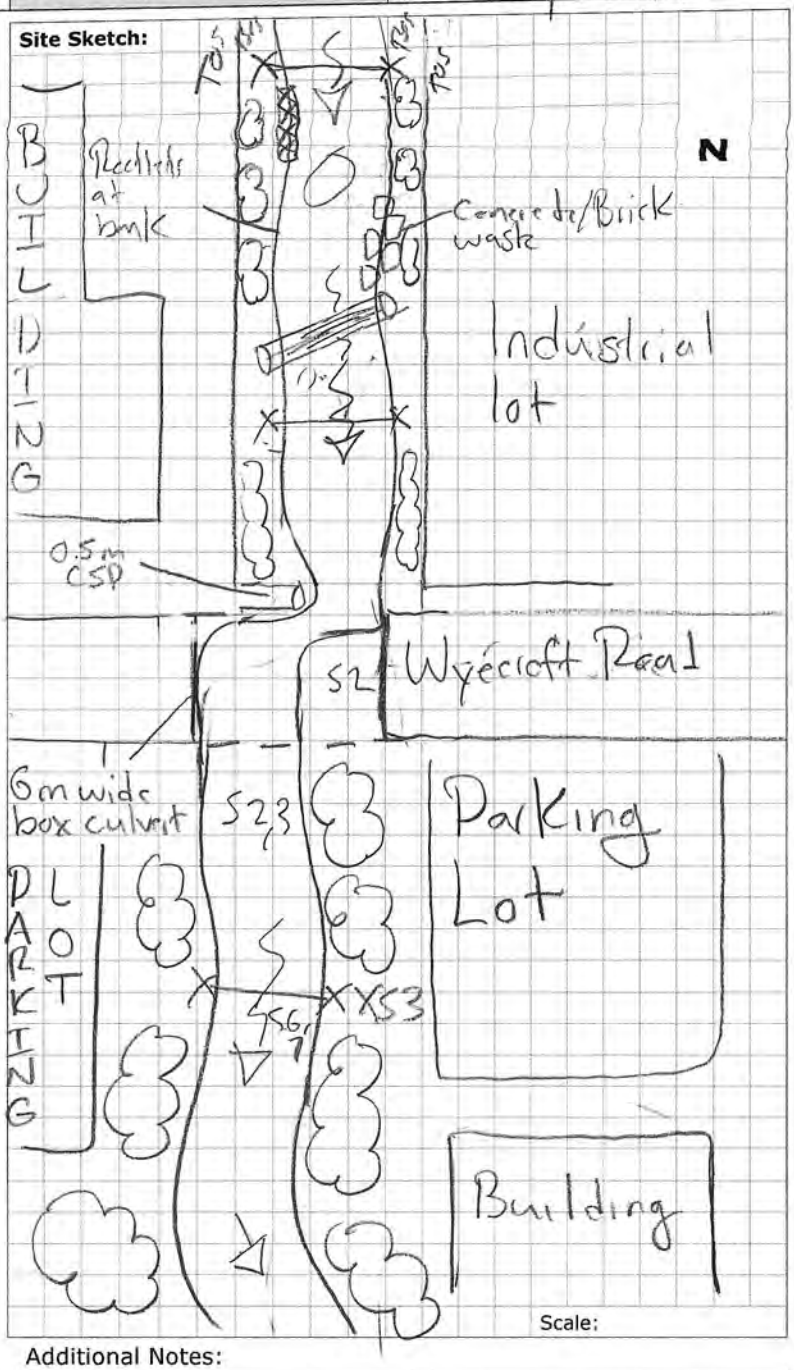
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

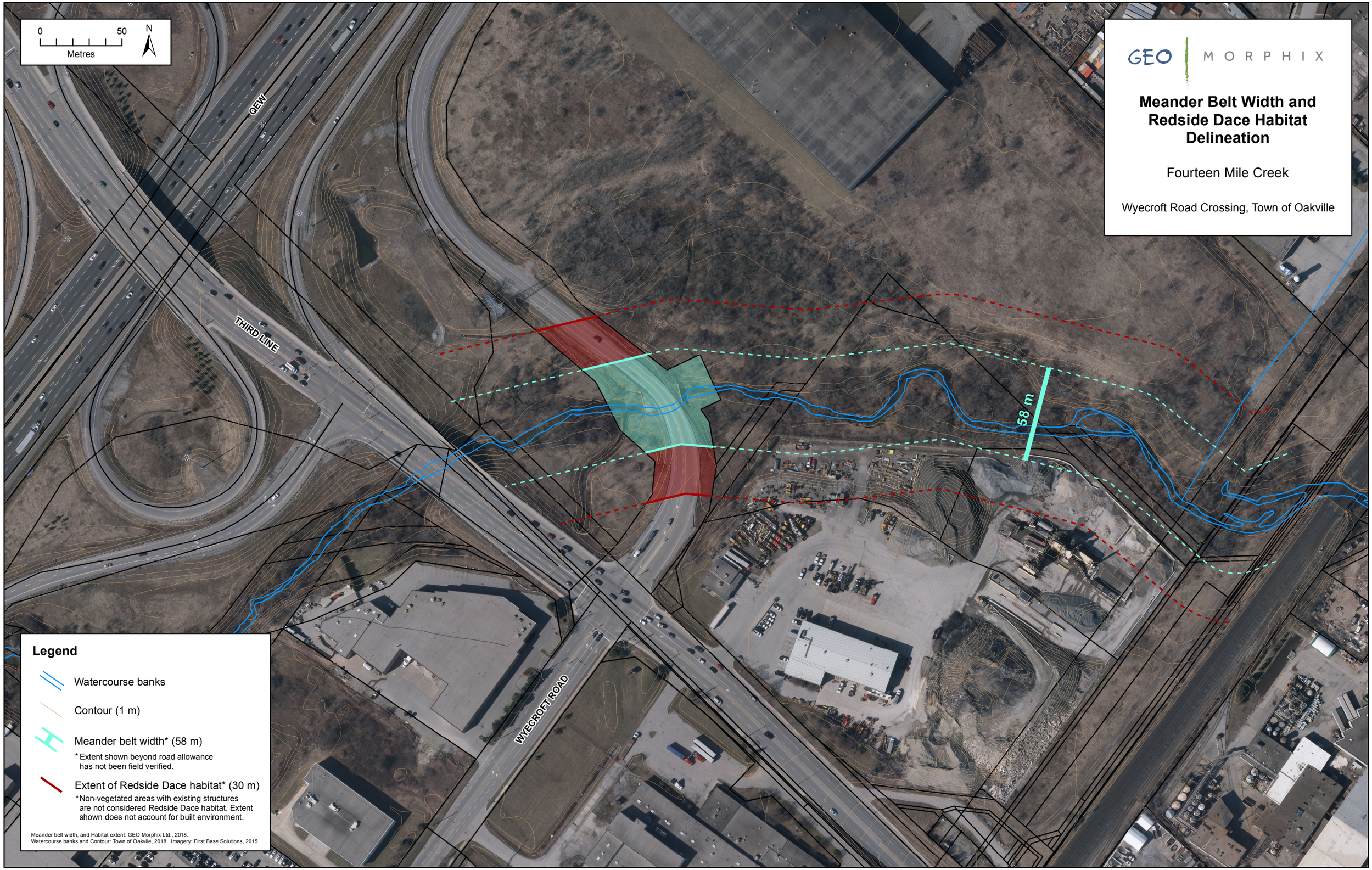
Site Sketch:



Additional Notes:

Completed by: AB Checked by: _____

Appendix D
Meander Belt Width Assessment



GEO MORPHIX

Meander Belt Width and Redside Dace Habitat Delineation

Fourteen Mile Creek

Wyecroft Road Crossing, Town of Oakville

Legend

- Watercourse banks
- Contour (1 m)
- Meander belt width* (58 m)
  - * Extent shown beyond road allowance has not been field verified.
- Extent of Redside Dace habitat* (30 m)
  - * Non-vegetated areas with existing structures are not considered Redside Dace habitat. Extent shown does not account for built environment.

Meander belt width, and Habitat extent: GEO Morphix Ltd., 2018.
Watercourse banks and Contour: Town of Oakvile, 2018. Imagery: First Base Solutions, 2015.