AECOM

Halton Region

Trafalgar Road (Regional Road 3) Improvements Class Environmental Assessment Study

Fluvial Geomorpholgy Assessment

Report

Halton Region

Trafalgar Road (Regional Road 3) Improvements Class Environmental Assessment Study

Fluvial Geomorphology Assessment

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Date:
April 6, 2015

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	C. Latimer	2014-07-31	Revised to include 'Minto' proposed creek realignment in 5.3.3
2	D. McParland	2014-12-19	Revised to include Conservation Halton's comments
3	S. Harmsworth	2015-04-06	Revised to include Conservation Halton and Halton Region comments

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Table of Contents

AECOM Halton Region Trafalgar Road (Regional Road 3) Improvements Class Environmental Assessment Study: Fluvial Geomorphology

List of Figures

List of Tables

Appendices

RPT_2015-04-06_Trafalgar Rd EA Fluv Geom_60119993.docx

1. Introduction

In 2009, Halton Region initiated a Class Environmental Assessment (Class EA) Study for road improvements along Trafalgar Road (Regional Road 3) from Cornwall Road to Highway 407, in the Town of Oakville. The purpose of this Study is address operational deficiencies along Trafalgar Road through a number of road improvement alternatives, including the long-term provision for Bus Rapid Transit (BRT).

In the study area, Trafalgar Road crosses both the Joshua Creek and Morrison Creek watersheds and includes eight watercourse crossings in addition to the Morrison-Wedgewood Diversion Channel. As part of the Class EA, a fluvial geomorphologic investigation was undertaken to review background reports, to conduct a scoped field investigation to gain insight into channel conditions and processes, to identify and evaluate alternatives, and to identify constraints and opportunities for enhancement. This report documents findings from the fluvial geomorphologic assessment that was focused specifically along the East Morrison Creek tributary in the vicinity of Trafalgar Road and Dundas Street East.

Figure 1.1 Study Area.

1.1 Study Area

The study area is located along Trafalgar Road (Highway 3) to the east of Sixth Line, between Highway 407 and Cornwall Road (just south of Queen Elizabeth Way). The area is generally low-lying. Land use along the road corridor consists of agriculture with homes to the north of Dundas Street East. To the south of Dundas Street East, the land on either side of Trafalgar Road has been subject to urban development that is situated around a Natural Heritage System that includes creek corridors (**Figure 1.1**).

Within the study area, Trafalgar Road crosses two subwatersheds under the jurisdiction of Conservation Halton: Morrison Creek Subwatershed and Joshua Creek Subwatershed. The majority of the road is within the Morrison Creek subwatershed. Both the East and West Branches of Morrison Creek are diverted north of QEW to Sixteen Mile Creek via the Morrison-Wedgewood Diversion Channel situated towards the south end of the study area (Figure 1.1)

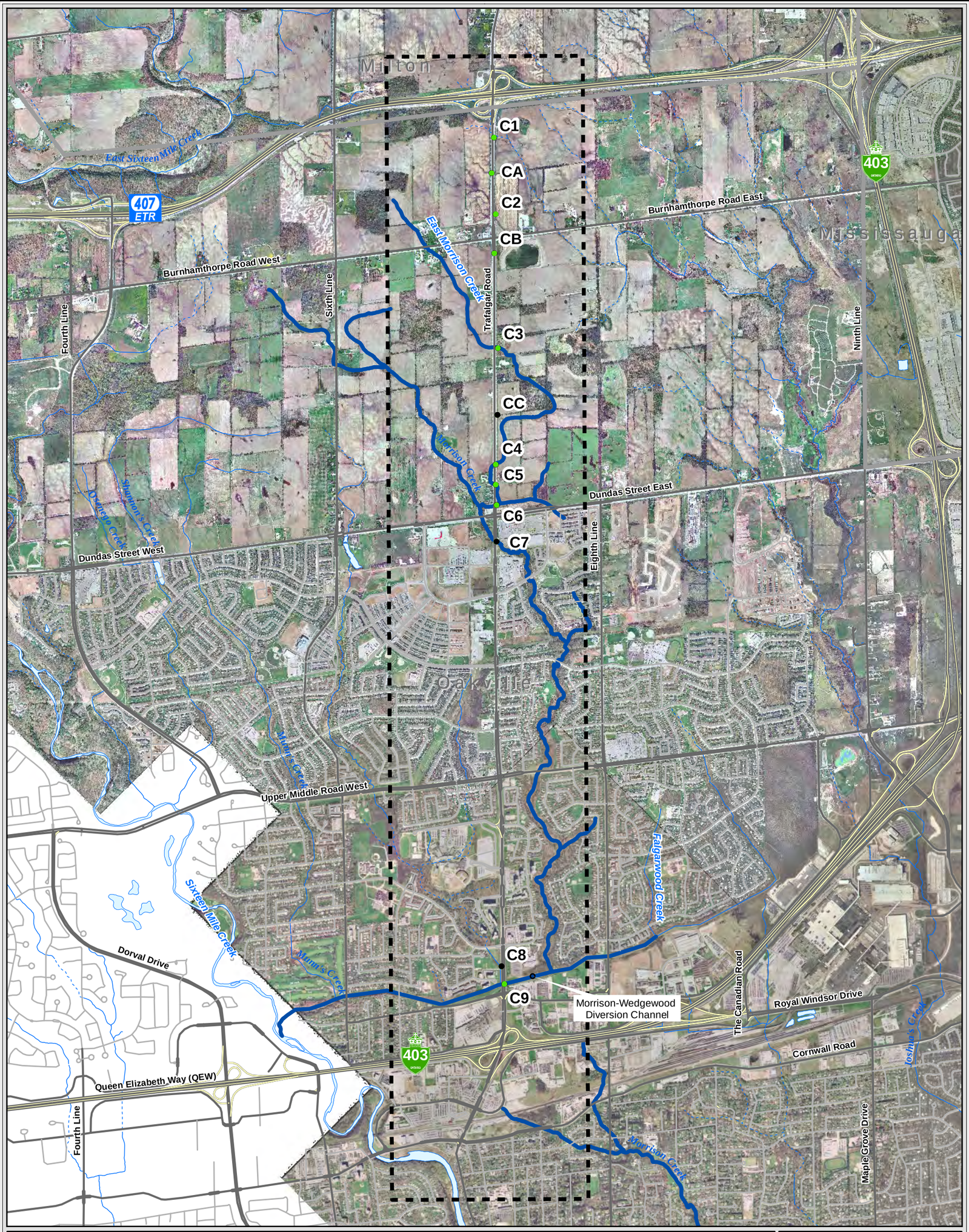
Trafalgar Road crosses two small headwater tributaries of Joshua Creek (Crossings 1 and 2; **Figure 1.2**). There are three crossings of the East Tributary of East Morrison Creek that are in close succession (i.e., within ~ 320 m; Crossing 3 – 6), followed by a crossing of the East Morrison Creek main branch (Crossing 7) less than 300 m down the road. The West Morrison Creek crossing occurs ~ 600 m north of the QEW (Crossing 8) on McCraney Street East and is diverted underground and outlets into the Morrison – Wedgewood Diversion channel. The final watercourse crossing within the study area is of the Morrison – Wedgewood Diversion (Crossing 9).

1.2 Objective

The objective of the Fluvial Geomorphic Assessment is to characterize the watercourses that are crossed within the study area, evaluate the future erosion risks to the road crossing structures and minimise adverse impacts on geomorphological processes. The assessment involves the following components:

- Complete review of available background information and previous studies
- Delineate reaches, based on previous studies, and available mapping
- Confirm reach boundaries and results of background assessment by completing field reconnaissance
- Establish channel characteristics within reaches and at the watercourse crossings
- Establish preliminary erosion hazard limits (i.e., Meander belt)
- Identify and evaluate alternatives for channel relocation in conjunction with proposed road widening north of the Dundas Street/Trafalgar Road intersection.

This assessment discusses two components, an assessment (referred to as the Combined Option) that discusses proposed options by adjacent developers (i.e., Dundas-Trafalgar Inc. “Minto” and Shieldbay Inc.) for channel modifications and/or relocations in combination with the proposed development, and another assessment which looks at options in the absence of adjacent development, The discussion on the Combined Option is included in **Sections 5** and **6** of this report.



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Legend

- Freeway
- Major Road
- Local Road
- Ramp
- MorrisonCreek
- Intermittent Stream
- Permanent Stream
- Waterbody
- Study Area
- Crossings
- Diversion Channel

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Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Study Area
Trafalgar Road, from Cornwall Avenue to Hwy 407

August 2013
60119993

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Figure 1.2

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2. Methodology

Observations along any watercourse should be placed in the context of its geomorphic system. This includes recognition that the form and function of watercourses are a result of the interaction between controlling (e.g., geology, flow) and modifying (e.g., vegetation) factors. Alteration in any one of these factors may cause a temporary or permanent channel response. In addition to considering the formative context of a watercourse, its position within the spatial hierarchy of the drainage network must also be examined. That is, channel conditions at a site or reach are affected by, and affect, other spatial units.

Insight into watercourse conditions and functions is best achieved by completing analyses at a range of spatial and temporal scales of analyses. Typically, this includes both desktop and field based study components. This section of the report provides an overview of the tasks that were undertaken to characterize the watercourses within the study area, in terms of their geomorphological form and function. Results of the analyses are presented in **Section 3**, which forms the basis for evaluating impacts from potential Trafalgar Road Improvements.

2.1 Desktop Assessment

The Desktop Assessment included review of all readily available materials relevant to the study area including previous study reports, mapping (physiography, Quaternary geology, and topography), historical aerial photographs, and hydrologic modelling. Findings from the assessments provided familiarity with the study area to focus the field investigation component (**Section 2.2**). A brief summary of the components of the desktop assessment is provided in this section, and results are discussed further in **Section 3**.

2.1.1 Background Review

In order to gain a comprehensive understanding of geomorphological character, it is important to build on previous investigations. Several reports concerning the watercourses within the study area were available and reviewed to extract relevant information. Mapping was also collected, including topography and geology, which was assessed alongside orthophotos, historic aerial photos, and Google Earth imagery.

A number of previous studies have been conducted in relation to the watercourses in the vicinity of Trafalgar Road which were reviewed as part of the assessment. The reports reviewed can be largely divided into two categories:

1) Studies to support new development and associated infrastructure between Highway 407 and Dundas Street East included:
    - Cosburn Patterson Wardman, 1995. East Morrison Creek Subwatershed Study
    - Town of Oakville, 2006. North Oakville Creeks Subwatershed Study (NOCSS). August 2006.
    - Town of Oakville, 2007. North Oakville Creek Subwatershed Study Addendum Figures. September 2007.
    - Town of Oakville, 2006. North Oakville Creek Subwatershed Study Implementation Report. August 2006.
    - Town of Oakville, 2008. North Oakville East Secondary Plan. Official Plan Amendment Number 272 to the Official Plan of The Corporation of the Town of Oakville.
    - AECOM, 2010. 2009 North Oakville Creek Monitoring – Results and Thermal Stability Analysis. January 2010.

    - Regional Municipality of Halton, 2010. New North Oakville Transportation Corridor and Crossing of Sixteen Mile Creek, Class Environmental Assessment Study - Environmental Study Report, report by AECOM, March 2010
    - AECOM, 2012 2011 North Oakville Creek Monitoring – Results and Thermal Stability Analysis, March 2012.

2) Erosion Assessment studies undertaken for the Town of Oakville concerning creeks downstream of Dundas Street East included:
    - Totten Sims Hubicki Associates (TSH), 2002. Town of Oakville Erosion Assessment Study 2001, Submitted to Town of Oakville, 2002.
    - Totten Sims Hubicki Associates (TSH), 2007. Town of Oakville Erosion Assessment Study, 2006, Submitted to Town of Oakville, May 2007.
    - AECOM Canada Ltd. (formerly TSH), 2009. Town of Oakville Erosion Assessment Study, 2008, Submitted to Town of Oakville, June 30, 2009.
    - AECOM, 2011. 2010 Creek Erosion Inventory and Assessment Study, Submitted to Town of Oakville, May, 2011.

2.1.2 Reach Delineation

Since observations of channel processes in proximity to Trafalgar Road should be placed within the context of a larger spatial unit, reaches were defined. Reaches are sections of channel that display homogeneity in features such as valley setting, underlying geology, channel pattern, riparian vegetation, hydrology, and surrounding land use. The channel within a reach shows similarity in natural channel characteristics (bed morphology, substrate materials, cross-section) and geomorphological processes.

Preliminary reach delineation is completed through desktop analysis of recent aerial imagery, and both geological, and topographic mapping. Reach breaks typically occur when there are obvious changes in hydrology (e.g., outfall or channel confluence), valley setting, land use, vegetation, or channel planform. Reach break locations are refined and verified during a reconnaissance level field investigation to ensure representativeness of channel processes, bed material, stream type and channel configuration along the entire reach length.

Previous reach delineations as documented in background reports were referenced and, where appropriate, replicated in this study. The characteristics of each reach are described fully in **Section 3.3**.

2.1.3 Historic Assessment

Historical assessments are used to identify changes to land use, channel planform (natural and/or anthropogenic change), and channel responses to watershed disturbances. Defining the area of previous floodplain occupation and quantification of erosion rates (if possible) informs the process of meander belt delineation. Review of historical airphotos thus informs understanding of existing conditions and can assist in the identification and evaluation of potential erosion hazards. Aerial photographs from 1934, 1961, 1985, and 2010 were geo-rectified and examined within a Geographical Information System (GIS). An historical assessment for the study areas was previously completed as part of the NOCSS (Town of Oakville, 2006). This study included a review of previous findings and a focussed historical assessment of the study area between Dundas Street and Burnhamthorpe Road.

2.2 Field Assessment

While desktop analyses provides a general description of channel characteristics and some insight into the controls and modifying influences affecting channel form, field reconnaissance is required to define the current overall condition of the channel (e.g. stable, stressed).

2.2.1 Reconnaissance Level Field Investigation

A field reconnaissance survey was undertaken to document geomorphological baseline conditions of the watercourses at each of the nine Trafalgar Road crossings in the study area (**Figure 1.2**). The reconnaissance level field assessment was intended to confirm reach boundaries and to document observations and general measurements of channel form, channel stability (i.e., including application of the Rapid Geomorphic Assessment, **Section 2.2.1),** riparian conditions, condition of engineering countermeasures in proximity to Trafalgar Road and to identify potential constraints and opportunities for the Trafalgar Road improvements.

These data provide for more detailed characterisation of the section of East Morrison Creek – East Tributary running immediately adjacent to Trafalgar Road, and of the existing conditions at the three crossings. These measurements are also used to inform any future natural channel design or realignment scenarios, and provide input for the sizing and orientation of any replacement crossing structures that may be required to accommodate road widening.

2.2.2 Rapid Geomorphic Assessment

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (1999) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Although certain limitations are inherent in this approach, it is a widely used method for assessing channel stability and is most applicable for watercourses situated within urban settings. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planform adjustment. Examples of these include, the presence of bar forms, exposed infrastructure, head cutting due to knick point migration, fallen or leaning trees and exposed tree roots, channel scour along the bank toes, transition of the channel from single thread to multiple threads, and cut-off channels. Overall, the index provides insight into whether the channel is stable/in regime, stressed/transitional, or in adjustment.

Results of the RGA for each reach and the implications are discussed further in **Section 3.3**.

2.2.3 Detailed field data collection

In addition to the rapid field reconnaissance, a detailed field investigation was completed to quantify channel parameters and enable an assessment of channel functions and processes. To date, the analyses have focused on the East Morrison Creek – East Tributary Crossings 4, 5 and 6 (**Figure 1.2**). Parameters measured during the field program included:

- Measurements of bankfull cross-sections at riffle, pool and transitional sections of the field site.
- A longitudinal profile survey of channel bottom and bankfull elevations to determine local energy gradients, including top-of-riffle, bottom-of-riffle, maximum depth and any obstructions to flow.
- Digital photography showing each of the field surveyed cross-sections and surrounding channel characteristics.
- Characterization of substrate and bank materials.
- Riparian vegetation assessments.

2.3 Meander Belt Assessment

The meander belt of a watercourse refers to the area that a meandering channel occupies now, or may be expected to occupy in the future on its floodplain. The area defined as the meander belt is commonly used as a planning tool by municipalities and conservation authorities to define the erosion hazard area. In future development scenarios, the meander belt is one component intended to define the width of the channel corridor and, where feasible, to define the span of new road crossings.

Delineation of the meander belt requires review of historical channel positions and observation of current channel behaviour and processes. The TRCA's *Belt Width Delineation Procedures* (2004) and the Ministry of Natural Resources and Forestry's (MNRF) *River and Stream Systems: Erosion Hazard Limit Technical Guide* (2002), describe generally accepted methods for meander belt assessment that are frequently used within the jurisdiction of Conservation Halton. Where channels have been previously straightened, then analyses are completed using surrogate reaches, if available, or rely on a suite of empirical analyses (e.g., Williams, 1986, Parish Geomorphic, 2004) to quantify a reasonable meander belt width based on parameters that may include drainage area, discharge, bankfull channel dimensions, channel slope, and median grainsize in order to define meander belt width. Comparison of the widths obtained through the application of various methods is often conducted to arrive at an appropriate meander belt width for a given reach.

A meander belt assessment was performed for a portion of the East Morrison Creek – East Tributary that is immediately north of Dundas Street East. Since the tributary had been previously straightened and no suitable surrogate reach was available, the TRCA (2004) map–based procedures could not be applied. Instead, a suite of empirical relations were applied to a range of field data to quantify the meander belt of this section of channel. AECOM typically applies a range of analyses since results often tend to converge on a small range, lending confidence to results. Results of the meander belt assessment are presented in **Section 4**.

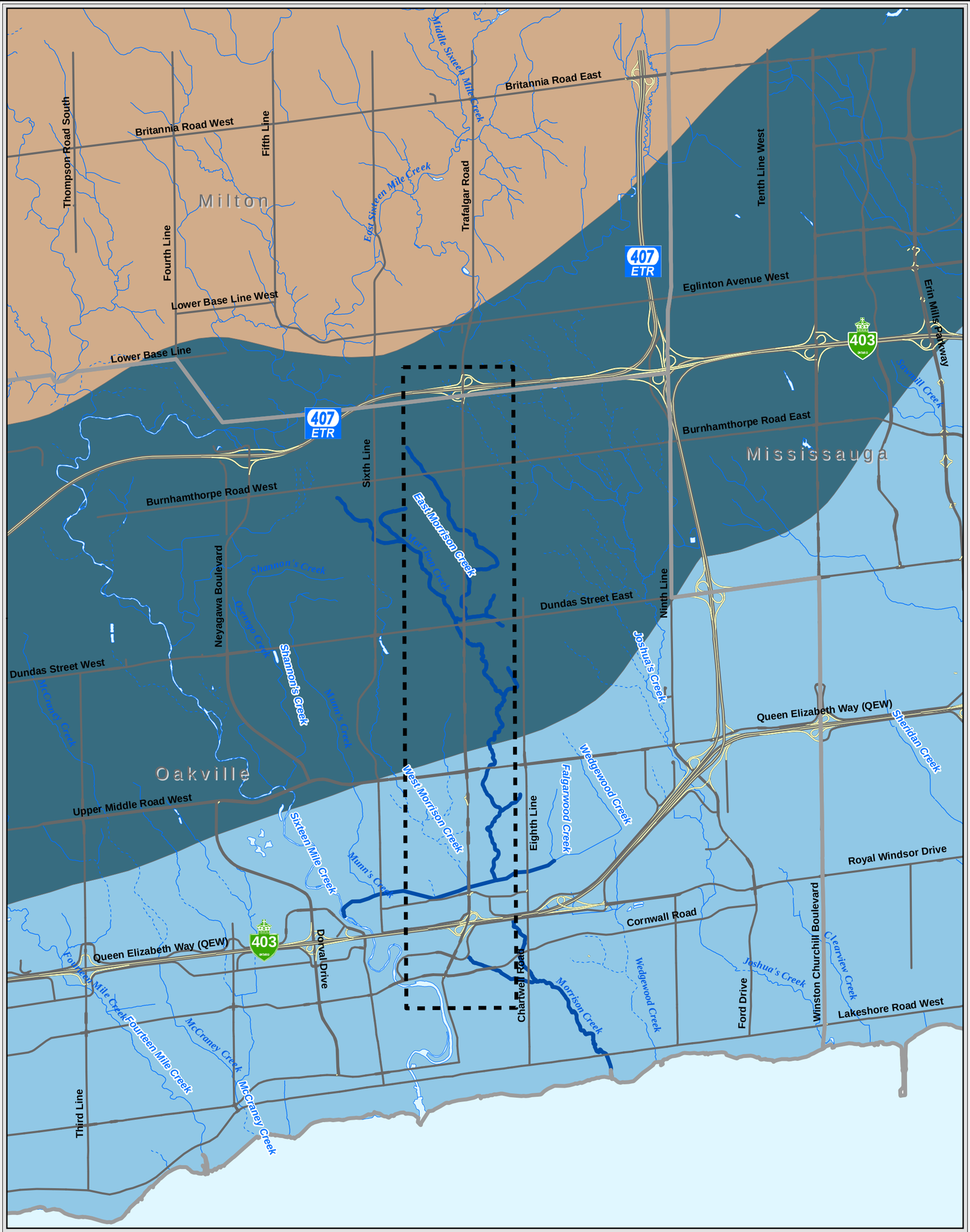
3. Results

3.1 Geology and Topography

Geology and topography are key controls of channel form and function. These characteristics influence the rate of channel migration and evolution, the rate of incision, the volume of sediment delivered to the watercourse, channel dimensions, and characteristics of bed morphology.

The study area is largely within the South Slope Physiographic Region of southern Ontario (Chapman and Putnam, 1984). The South Slope includes the strip of land between the former Lake Iroquois shoreline (**Figure 3.1**) to the south and the Peel Plain to the north. The ground surface rises gently upwards to the north (as a gently undulating till plain). North of Dundas Street East, the gentle slope continues until just north of Highway 407 where the Trafalgar Moraine is seen as a low ridge. The Trafalgar Moraine is the youngest moraine in the area (Karrow 1987).

As illustrated in **Figure 3.2**, Quaternary surficial geology deposits within the study area consists of three types: lacustrine and outwash sands (along the Lake Ontario shoreline); shale and dolomite bedrock (east-west along the QEW and extending northward along the creeks); and, Halton Till deposits in the upland areas north of the QEW, associated with the till plain and Trafalgar Moraine. The interbedded shale and dolomite bedrock are largely from the Queenston and Georgian Bay Formations. Queenston shale tends to be easily eroded into small sized materials that subsequently break down into the parent clays.



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Legend

- Freeway
- Expressway / Highway
- Major Road
- Local Road
- Ramp
- Study Area
- MorrisonCreek
- Waterbody
- Intermittent Stream
- Permanent Stream

Physiographic Regions

- South Slope
- Peel Plain
- Iroquois Plain

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Study Area Physiography

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Figure 3.1

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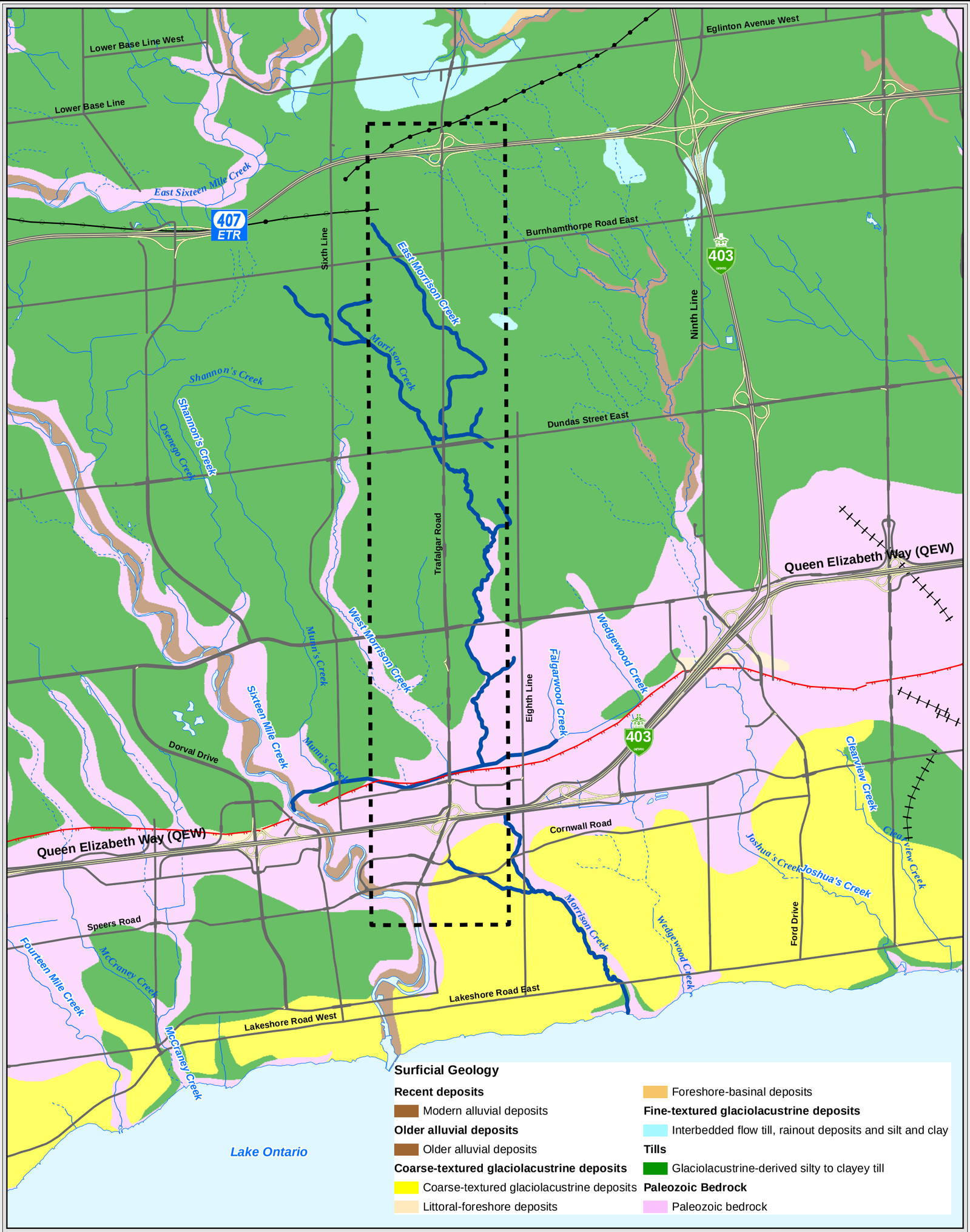

Legend

- Study Area
- Intermittent Stream
- Permanent Stream
- MorrisonCreek
- Waterbody

Surficial Geology Features

- Bluff (Iroquois Shoreline)
- End
- Moraine
- Popup (Bedrock Pressure Release Ridge)

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Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Study Area
Surficial Geology

August 2013
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Figure 3.2

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3.2 Historical Assessment

3.2.1 Land Use

While the northern portion of the study area remains predominantly agricultural, urban development has occurred south of Dundas Street East. A general overview of land use change has previously been provided as part of erosion assessment studies for the Town of Oakville (AECOM, 2011). In summary, the sequence of urbanization began around Sixteen Mile Creek and along the Lake Ontario shoreline and was more rapid east of Sixteen Mile Creek than west. North of the QEW, development has also occurred more rapidly east of Sixteen Mile Creek than west. Most recent developments have occurred south of Dundas Street East near Trafalgar Road (Morrison Creek, east and west branches) and around Third Line between Upper Middle Rd and Dundas Street East.

The NOCSS (Town of Oakville, 2006) includes a historical assessment undertaken over a 45 year time period, using aerial photographs taken in 1954, 1983, and 1999 (note that the study area included the whole North Oakville East area). The findings of this historical assessment indicate that land clearing for agricultural use took place prior to 1954, which, in the absence of proper management practices, generally increases the potential source of finer sediments and inhibits the development of stabilizing riparian vegetation. The study reports that residential development replaced the agricultural land in the area just south of Dundas Street East, around Shannon's Creek, Munn's Creek, and, to a lesser extent, West Morrison Creek, between 1983 and 1999.

Development of the area between Dundas Street East and Highway 407 is currently being planned under the North Oakville East Secondary Plan (Town of Oakville, 2008) involving the construction of urban centres, employment districts, and residential neighbourhoods which will replace the agricultural land that currently characterizes the area. The highest density development is to be located along Trafalgar Road in the Trafalgar Urban Core Area, outlined in the Plan as the area between Dundas Street East and Highway 407. Preservation of open spaces and of environmentally sensitive areas and valley lands is included as part of the plan.

3.2.2 Channel Change

The NOCSS (Town of Oakville, 2006) documents several changes to channel characteristics that occurred over the historical period of record associated with changes in land use:

> *"In general, most of the alterations to the channel network on the agricultural lands in the study area, south of Burnhamthorpe and north of Dundas, occurred prior to 1954. With the exception of the largest streams in the watersheds of Joshua's Creek and 16 Mile Creek, most of the streams and swales were treated as 'drains' and straightened for agricultural purposes prior to the 1954 coverage. Consequently, there was little observable change to the channel planform of the streams and swales on the agricultural lands..."*
>
> *"Just south of Dundas Street, the land use around Shannon's Creek, Munn's Creek and to a lesser extent West Morrison Creek has been converted from agricultural land to residential since 1983. The creeks themselves have been heavily modified to accommodate the land use change and are now generally 'engineered' channels."*

In this general context, a more focussed historic assessment was undertaken specific to East Morrison Creek's East Tributary along Trafalgar Road, upstream of Dundas Street East using the available historical aerial photography (Photographs used in the analysis are presented in **Appendix A**).

Findings from this assessment confirmed that there has been very little change in land use along this section of Trafalgar Road, with agriculture remaining the primary land use. Between 1961 and 2002 some of the farmland near (but primarily south of) the intersection of Dundas and Trafalgar was converted into commercial property.

In terms of channel planform change of East Morrison Creek – East Tributary, to the north of Dundas Street East, the following observations were made (see **Appendix A** for copy of historical photos and **Figure 3.3** for overlay of channel centreline):

- In **1934** a defined channel was not discernible along Trafalgar Road. A number of drainage networks are observable flowing through farmland; however, due to the resolution of the image it was not possible to clearly identify connectivity between them.
- The **1961** aerial photography clearly shows the channel form was straightened since 1934. Based on the findings of the NOCSS assessment, channelization must have taken place between 1934 and 1954. Upstream of the most upstream crossing, the channel form was also relatively straight around agricultural fields.
- The creek remained relatively stable between **1961 and 2002** with very little change in channel planform observable from aerial photography.

3.3 Existing Conditions

3.3.1 Background Characterization

Several of the background documents (i.e., mainly the NOCSS) that were reviewed in this study included fluvial geomorphic information and analytical results for the watercourses in the vicinity of Trafalgar Road between Highway 407 and Cornwall Road. Findings from the background documents are provided in this section, along with observations made during our reconnaissance level site investigation. The location of all crossings is illustrated on **Figure 1.2** and photos are in **Appendix B.**

Tributaries of Joshua Creek – Crossings 1 and 2

The two headwater tributaries of Joshua Creek that are crossed by Trafalgar Road, were not characterized as defined reaches in the Subwatershed Study (Town of Oakville, 2006), since these were classified as swales. The NOCSS (Town of Oakville, 2006) report differentiated between swales and headwater channels as follows:

- Swales are vegetated depressions without well-defined channel bed and banks. Where these dominate the headwaters, it can be expected that discharge is rarely high enough to erode sediment. The swales observed within the North Oakville study area were noted to be vegetation stabilized (Town of Oakville, 2006) – the vegetation retards the flow and the root matrix enhances the sediment's resistance to erosion. These systems are sensitive to land use changes that remove vegetation or increase the amount or intensity of discharge and may lead to increased channel definition (Town of Oakville, 2006).
- Defined headwater channels tend to be erosive, supplying sediment to downstream channels (Town of Oakville, 2006). They also tend to have storm-driven, flashy discharge regimes. Although each headwater channel provides only as small amount of sediment and water to the overall basin, as they are numerous, changes in their throughput of sediment and water produces cumulative effects through the watershed (Town of Oakville, 2006).

Recent field investigations, however, suggest that Joshua Creek is well defined east of Crossing 1, within an agricultural field.

East Morrison Creek – East Tributary (Crossings 3, 4, 5 and 6)

In the NOCSS (Town of Oakville, 2006), two reaches were defined along the East tributary of East Morrison Creek. Reach MOC-6, which ends approximately 110 m downstream of crossing C3, and Reach MOC-2, which flows under Trafalgar Road at Crossings 4, 5 and 6 (**Figure 3.4**). The East Morrison Creek Subwatershed Study (Cosburn Patterson Wardman, 1995) indicates that this section of creek is intermittent and does not support permanent baseflow. It further indicates that the channel maintains a ditched profile in the study area.

A summary of baseline characteristics documented for reach MOC-2, which extends from the downstream confluence with East Morrison Creek to approximately 1.1 km upstream (**Figure 3.4**), is contained in **Table 3.1**. Observations are based on field investigations undertaken in between April and July 2002. Similar information was not documented for reach MOC-6.

Table 3-1. Baseline Characteristics for Reach MOC-2[1]

Parameter	Value
Length (m)	1119.6
Gradient (%)	0.8
Sinuosity	1.01
RGA **RSAT**	11 (in regime) 22 (moderate)
Substrate Characteristics	Silt, sand, some cobbles. Poor bed morphology.
Bank Vegetation	Grasses and herbs
Sediment Supply / Transport	Aggradation: siltation in pools, overbank deposits
Channel Disturbance	Channel constructed along road
Channel Sensitivity **Rehabilitation Potential**	Moderate Medium
Meander Belt (m)	40

1: Town of Oakville (2006)

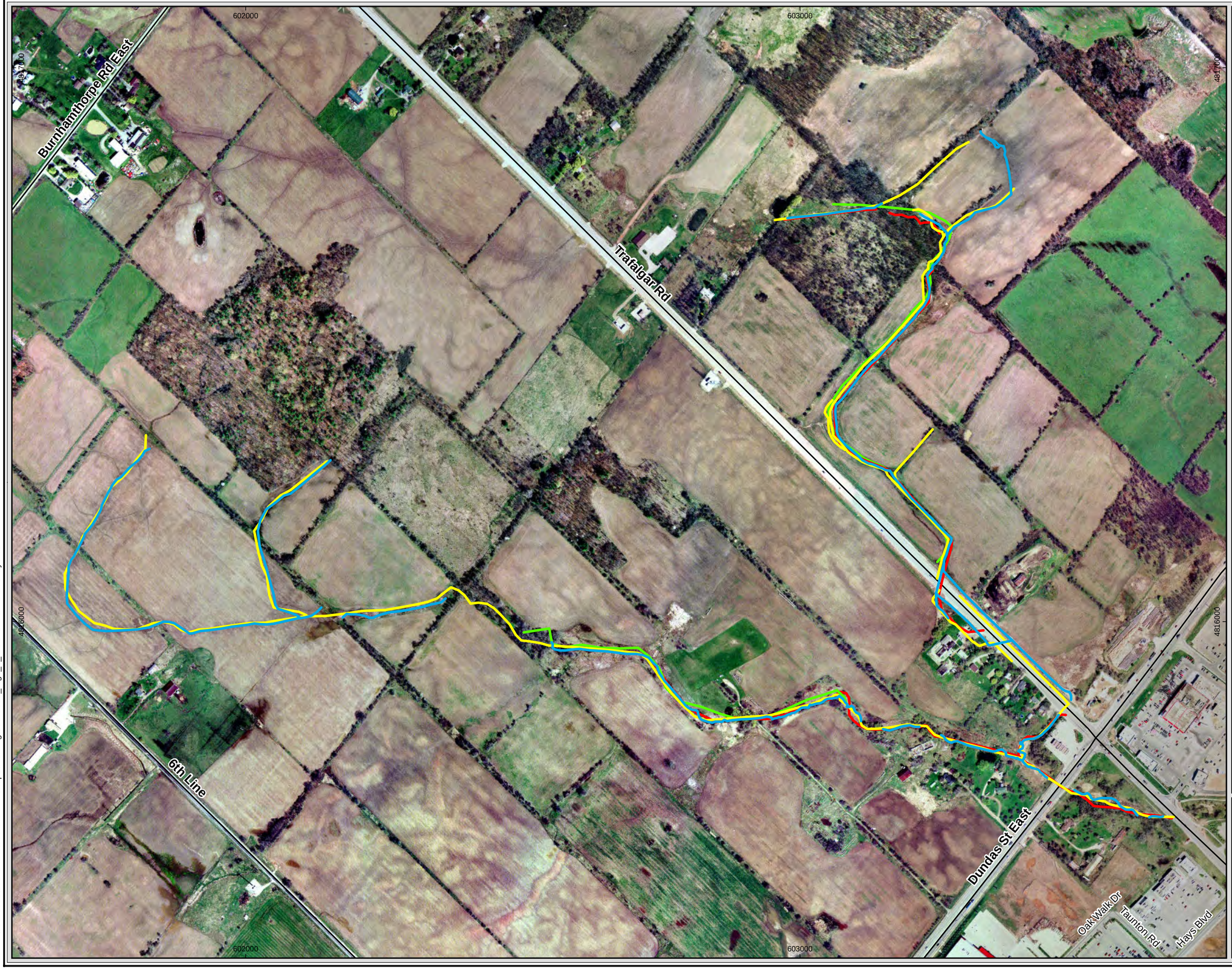
Based on the findings of the background review, gaps in documentation of existing conditions for the purpose of this study were identified, specifically as it relates to the section of East Morrison Creek's East Tributary near Dundas Road. The justification for undertaking further geomorphological assessment, in addition to that already undertaken for the NOCSS (Town of Oakville, 2006), is detailed in **Table 3.2**. Thus, to inform the Class EA, geomorphological understanding and characterization of Reach MOC-2 in particular where the channel flows alongside Trafalgar Road in the vicinity of Crossings 4-6 was undertaken.

Review of study area mapping revealed that the East Morrison Creek Tributary that flows between Crossings 4 and 6 is a first-order channel. Field observations confirmed that the general shape and function of the channel resembles that of a headwater channel and that the channel was confined to a ditch along the east end of Trafalgar. Five separate sub-reaches were defined using methods outlined in **Section 2.1.3** (**Figure 3.5** and **Figure 3.6**). Of the ~ 455 m length of channel that begins upstream of Crossing 4, and ends downstream of Crossing 6, ~ 253 m (i.e., 56%) of channel is enclosed either through culverts or under the parking lot of the former Oak Park Animal Hospital property.

A brief summary of the geomorphological characteristics of each reach gained from field observations is presented in **Table 3-3**, and photographs representing typical conditions are included on **Figure 3.4** and in **Appendix B**.

Table 3-2. Focus of Fluvial Geomorphic Assessment

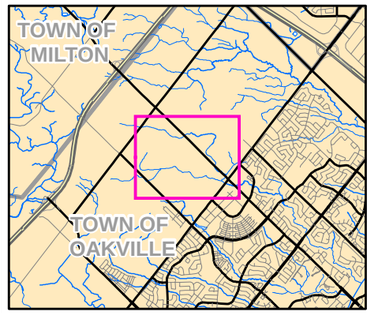
Watercourse	Crossing	Station	Inclusion in further assessment?	Justification
Joshua Creek Headwater 1	1	18+385	No	Not recognised as a defined channel in NOCSS or as a hydrological feature in the Secondary Plan.
Joshua Creek Headwater 2	2	17+750	No	Not recognised as a defined channel in NOCSS or as a hydrological feature in the Secondary Plan.
East Morrison Creek – East Tributary	3	16+725	No	Although Reach MOC-6 is identified as a high constraint reach in the NOCSS, both NOCSS and the Secondary Plan do not designate the area as a stream or hydrological feature since within NOCSS MOC-6 does not extend up to Crossing 3
	4	15+820	Yes, including upstream channel along road.	Reach MOC-2 is a medium constraint reach in the NOCSS and the Secondary Plan; proposed culvert replacement and extension
	5	15+665	Yes, including channel alongside road	Reach MOC-2 is a medium constraint reach in the NOCSS and the Secondary Plan; proposed culvert replacement and extension
	6	15+500	Yes, including channel alongside road	Reach MOC-2 is a medium constraint reach in the NOCSS and the Secondary Plan; proposed culvert replacement and extension
East Morrison Creek	7	15+228	Yes	Proposed culvert replacement and extension
West Morrison Creek	8	11+820	No	Culverted section under urban development
Morrison- Wedgewood Diversion	9	11+775	No	Concrete lined diversion channel



Legend

Stream Centreline

- 2002
- 1985
- 1961
- 1934



Basemapping from Ontario Ministry of Natural Resources
Orthophotography: 2002

N
W E
S

Metres

0 40 80 160 240 320

1:6,500

UTM Zone 17N, NAD 83

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

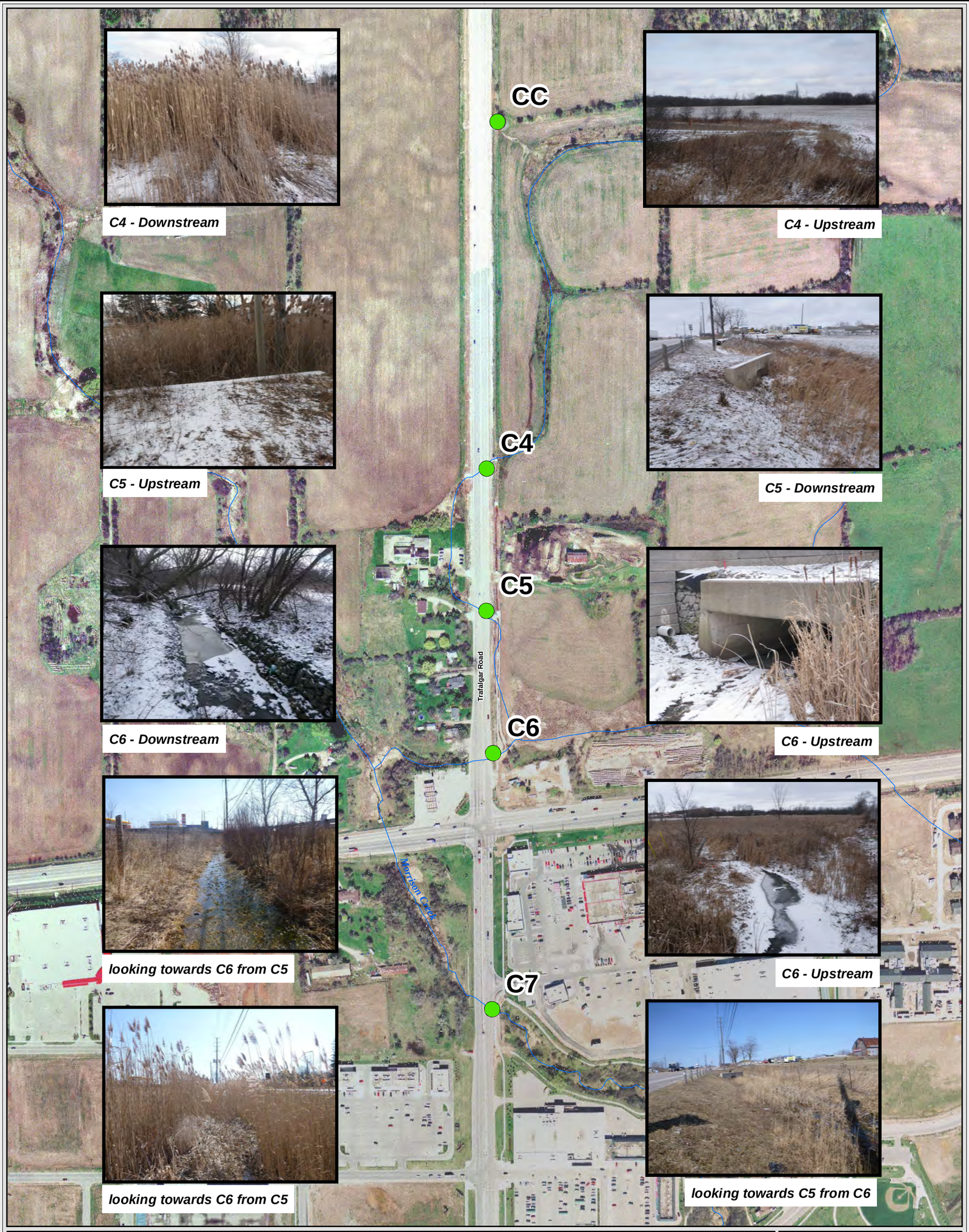
Historical Channel Overlay

August 2013
60119993

AECOM

Figure 3.3

Path: P:\60119993\000-CADD\050 GIS WIP\Maps\Working\60119993_Fig3_3_HistoricChannelOverlay.mxd



Legend

- Watercourse
- Crossings

m
0 25 50 100 150
1:4,000

UTM Zone 17N, NAD 83

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

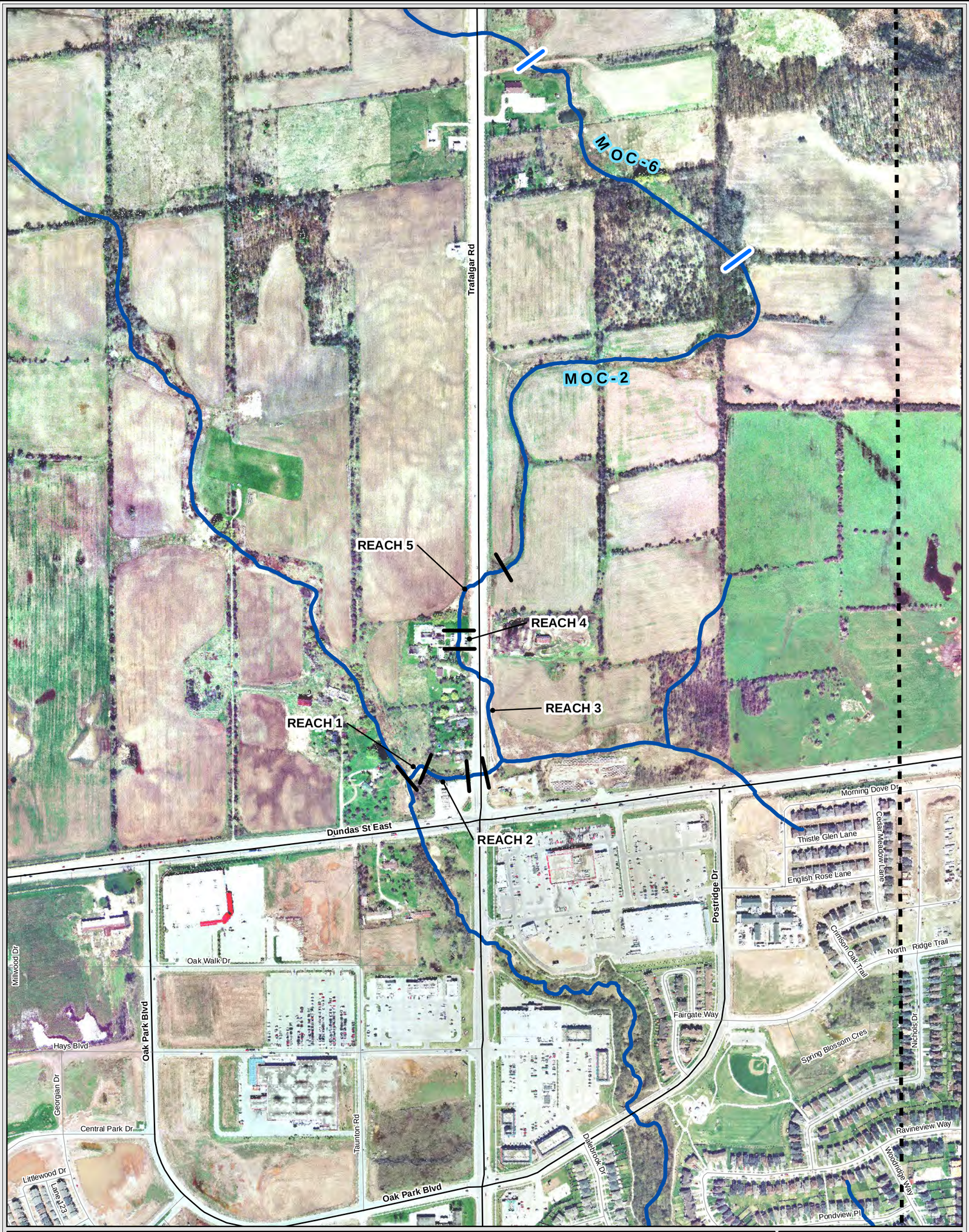
Study Area
Trafalgar Road
Crossings 4, 5, 6

August 2013
60119993

AECOM

Figure 3.4

Path: P:\60119993\000-CADD\050 GIS WIP\Maps\Working\60119993_Fig3_4_StudyAreaC456.mxd



Legend

- Study Area
- MorrisonCreek
- MOC-2 — NOCSS Reaches (Town of Oakville 2006)
- Reach 1 — Reach Breaks

Roads

- Major Road
- Local Road

m
0 25 50 100 150 200
1:6,000

UTM Zone 17N, NAD 83

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Reach Delineation

August 2013
60119993

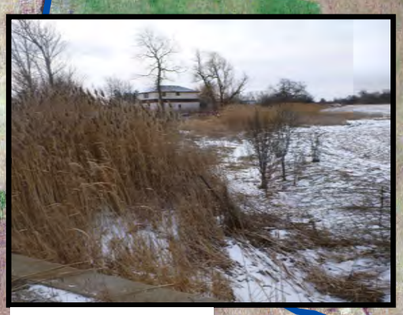
AECOM

Figure 3.5

Path: P:\60119993\000-CADD\050 GIS WIP\Maps\Working\60119993_Fig3_5_StreamReaches.mxd

C4 - West Side

C4 - Upstream



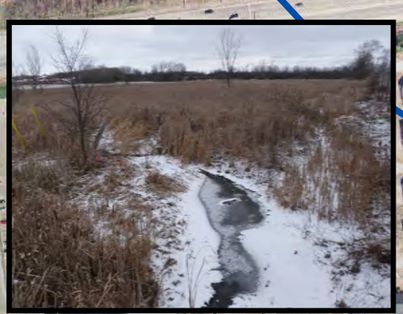
C5 - Downstream

C5 - Downstream

C6 - Downstream

C6 - Upstream

looking towards C6 from C5



C6 - Upstream

looking towards C6 from C5

looking towards C5 from C6

CC, ME-T3
Station 16+200
600mm CSP

Reach 5
Bankfull Width: 5.6m
Bankfull Depth: 0.26m

Former Oak Park
Pet Hospital Culvert
900mm CSP

C4 (ME-T3; Station 15+820)
Two 1000mm CSP Culverts
in Concrete Headwall

Reach 4
Buried Channel

Reach 3
Bankfull Width: 2.7m
Bankfull Depth: 0.25m

C5 (ME-T1; Station 15+665)
Span: 1800mm
Height: 1050m
Concrete Box Culvert

Trafalgar Road

C6 (ME-T1; Station 15+500
Span: 2400m
Height: 1520m
Concrete Box Culvert

Dundas Street East

Reach 2
Bankfull Width: 2.0m
Bankfull Depth: 0.60m

Reach 1
Bankfull Width: 1.2m
Bankfull Depth: 0.55m

ME-D2;
Span: 4270mm
Height: 2000mm
Concrete Box Culvert

C7 (03-1182510 CU01;
Station 15+225
Span: 3480mm
Height: 2210mm (with
gabion wingwalls) CSP

Legend

Morrison Creek

Crossings

Reach 1 — Reach Breaks

m
0 25 50 100 150
1:4,000

UTM Zone 17N, NAD 83

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Reach Delineation
Reach MOC-2
Crossings 4, 5 and 6

March 2015
60119993

AECOM

Figure 3.6

Path: P:\60119993\000-CADD\050 GIS WIP\Maps\Working\60119993_Fig3_6_ReachDelineation.mxd

Table 3-3. Overview of sub-reach characteristics

Sub-Reach	Length (m)	Description	Bankfull Channel Width	Bankfull Depth	Water depth
1	Confluence with main branch of East Morrison Creek (603402.036, 4815754.619) to base of ravine/valley (603408.771, 4815788.417)				
	50 m	The channel flows within well-defined banks and meanders across the floodplain in the bottom of the valley. Vegetation consists of grasses that have a fine and dense rooting network which serves as a controlling influence on channel form. Some vegetation has become established within the channel. Riffles and pools occur along the profile; pools tend to contain soft, mucky sediment accumulations and riffles tended to have firmer sediment. Bank materials consisted of clayey silt with very fine sand.	1.2 m	0.55 m	0.25 m
2	Base of ravine/valley (603408.771, 4815788.417) upstream to Trafalgar Road (behind Esso Station) Crossing 6 (603469.388, 4815827.706)				
	90 m	The creek enters this reach through a 2.4 m wide box culvert. The outlet of the culvert is oriented somewhat oblique to the channel, causing the flow trajectory to be directed into the gabion wall downstream of the outlet, rather than towards the open-channel. The reach is relatively straight and lined with gabions along approximately 23 m of its upstream length; corrosion, bulging, and scour around the gabion baskets were observed. The channel has incised through the valley wall and flanks the northern property line of the Esso Station. Channel banks are vegetated with trees with coarse and medium sized roots. Banks (silty clay with very fine sand) are not vegetated and show evidence of movement as indicated by bent tree trunks and exposed tree roots; some trees had fallen over the creek. Fragments of Queenston shale were observed in the channel banks. The bed morphology was poorly defined; bed materials consisted of scattered gabion stone and soft silty sediment.	2 m	0.6 m	0.15 m
3	From Crossing 6 (603487.910, 4815851.840) upstream to Oak Park Pet Hospital (603307.743, 4815964.655)				
	220 m	The channel occupies a ditch along the east side of Trafalgar Road and is often choked with standing grasses/reeds. Cobbles were observed along the bank toe; however bed materials consisted of fine mucky sediment. Bed morphology is poorly defined. The channel is well connected to the corridor. Extensive and dense occurrences of watercress were observed in the channel along the entire reach. At the downstream end, the channel bed consisted of round stone which had likely been placed during previous works associated with the east culvert of Trafalgar Road and/or works associated with the adjacent commercial property.	2.4 – 2.7 m	0.25 m	0.16 m
4	Former Oak Park Pet Hospital property parking lot (603307.743, 4815964.655 to 603287.538, 4815989.351)				
	50 m	Channel is enclosed through a 0.90 m diameter CSP under the Oak Park Pet Hospital parking lot.	n/a	n/a	n/a
5	From former Oak Park Pet Hospital property (603287.538, 4815989.351) upstream to upstream of Road Crossing 4 (603269.016, 4816114.513)				
	100 m	The channel is well defined and shows signs of historical straightening within the reach. Flow from the culvert is directed both through the linear roadside ditch and through a naturalized feature between the former Pet Hospital property culvert and the fence line near crossing 4. Bed materials consist of fine mucky sediment with isolated deposits of gravels and sand. Banks are vegetated with grasses, cattails and phragmites. Immediately upstream of Trafalgar Road, the channel was poorly defined and was generally choked by grasses and phragmites. The channel becomes situated within a well vegetated topographic depression upstream of the road right of way that was flanked by agricultural fields.	5.58 m	0.26 m	0.06 m

3.3.2 RGA Results

A Rapid Geomorphic Assessment (RGA) to assess channel stability was completed for all well-defined channel sections within the study area along the east branch of Morrison Creek (**Table 3.4**). Once the scoring was compiled, the overall index value was tabulated to gain insight into channel stability (see **Table 3-5.**). Results from the study area suggest that the watercourse that is parallel to Trafalgar Road between Crossings C4 and C6 (shown in **Figure 3.4**), are considered to be in regime. Although in regime, the channel has been highly impacted and is often conveyed through roadside ditches.

Downstream of Trafalgar Road, the creek is in adjustment and highly impacted by anthropogenic changes that have occurred along sub-reach 2.

Table 3-4. Rapid Geomorphic Assessment

Sub - Reach	RGA						
	Aggradation	Degradation	Widening	Planform Adjustment	Overall Stability	Interpretation	Dominant Process
1	0.29	0.20	0.57	0.29	0.34	In transition Moderately Sensitive	Widening
2	0.43	0.22	0.70	0.43	0.44	In Adjustment Most Sensitive	Widening
3, 5	0.17	0.00	0.00	0.00	0.04	In Regime Least Sensitive	Aggradation
4	n/a						

Table 3-5. RGA Classification

Factor Value	Classification	Interpretation
≤0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river meander propagation processes
0.21-0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics but the evidence of instability is frequent
≥0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is wide spread

3.3.3 Channel Conditions at Culvert/Bridge Crossings

As part of the reconnaissance level field investigation, field inspection of channel conditions was completed at each crossing (**Figure 1.2**). **Table 3.6** provides a summary of the observations made at each crossing and includes structure numbers (where known) of the culverts/bridges. Photos demonstrating channel conditions are in **Appendix B.**

Table 3-6. Channel Conditions at each Culvert Crossing (Figure 1.2)

Crossing	Structure	Station	Location	Existing Crossing dimensions	Watercourse	Reach	Channel Conditions
1			2.95 km N of Dundas Street, Adjacent to GO parking lot	0.70 m CSP (in disrepair)	Joshua Creek	JC – 10 Tributary (Town of Oakville 2006)	Relatively steep drainage ditches upstream of Trafalgar Road, flanking the GO Station parking lot and west side of road enters a driveway 0.70 m CSP before entering the Trafalgar Rd culvert on the road's west side. The Creek emerges into a drainage ditch, is conveyed through a driveway CSP (0.70 m) before entering a well-defined creek that appears to be controlled by topographic lows. Channel width is ~ 1 m.
2			2.35 km N of Dundas Street, North of Ren's Depot	1.4 m CSP	Joshua Creek	JC-9 Tributary (Town of Oakville 2006)	The creek/swale originates in an agricultural field and receives roadside drainage before entering the CSP. The relatively steep west drainage ditch shows evidence of channel bifurcation. Some sedimentation within the CSP was observed. Downstream of Trafalgar Road, the creek is vegetated and poorly defined; vegetation is situated directly at the culvert outlet. Channel width is ~ 2 m.
3			1.3 km N of Dundas Street, in the vicinity of a church	1.5 m CSP in concrete headwall	East Morrison Tributary	MOC-6 Tributary (Town of Oakville 2006)	The inlet and outlet of the culvert was hidden by dense in-channel vegetation. No well-defined channel was observed upstream of this culvert. Hydro poles are situated within the roadside ditch.
4		15+820	0.4 km N of Dundas Street; upstream Oak Park Pet Hospital	Two 1.0 m CSP culverts in concrete headwall	East Morrison Tributary	MOC-2 (Town of Oakville 2006)	Creek enters culvert from the east side of Trafalgar Road and splits into two channels (roadside ditch parallel to Trafalgar Road and a small watercourse feature oriented westward). The channel is vegetation controlled.
5	03-1182530 CU01	15+665	0.2 km N of Dundas Street, downstream of Oak Park Pet Hospital	Span 1.8 m, Height 1 m, concrete box culvert	East Morrison Tributary	MOC-2	Creek flows through a densely vegetated channel before entering the culvert's west side. Sedimentation occurs within the culvert. Dense vegetation occurs at the culvert outlet. A roadside ditch north of the culvert, along the east side of Trafalgar Road joins the channel at the culvert outlet. Channel width is not well defined.
6	03-1182530 CU02	15+500	0.1 km N of Dundas, behind the Esso gas station	Span 2.4 m, Height 1.4 m, concrete box culvert	East Morrison Tributary	MOC-2	Creek is conveyed through the east roadside drainage ditch before entering the concrete box culvert. Upstream of Trafalgar Road, the creek is in a well-vegetated channel. Downstream of Trafalgar Road, the creek is conveyed through a relatively steep gabion lined channel (gabions are corroding and in disrepair; including a ~ 0.3 m void under south gabions at the culvert outlet). Bed materials consist of gabion stones and small gravel (estimated D50 = 2.5 cm, D84 = 10 cm).
7	03-1182510 CU01	15+228	0.1 km S of Dundas E	3.5 m CSP	East Morrison	N/A	Creek is well-defined, bankfull width ranges from 1.6 – 2.3 m and bankfull depth is ~ 0.60 m. Channel is situated in a well vegetated valley which enhances bank material strength. Banks downstream of Trafalgar Road are eroding. Observed substrate appeared to consist of native materials. Corrosion of the bottom steel plate in the culvert noted in two locations.
8	03-1182320 CU01	11+820	0.6 km N of QEW, along McCraney Street East	3 m x 3.1 m concrete box culvert	West Morrison Creek	N/A	Flow is piped underground beginning at McCraney Street East.
9	13-1182340 BR01	11+775	Morrison Wedgewood Aqueduct	bridge	Morrison Wedgewood Diversion	N/A	Concrete lined channel.

3.3.4 Field Measurements

A scoped but detailed geomorphologic field survey was completed of East Morrison Creek – East Tributary from Crossing 6 to upstream of Crossing 4 (**Figure 3.4**). This field survey included a detailed profile of the channel bed configuration, detailed cross-sections, and bed material characterization (**Table 3.4**). Results from HEC-RAS modelling (AECOM, 2013) were used in conjunction with these field measurements to quantify basic channel parameters in order to gain insight into channel characteristics and processes.

Table 3-7. Results from Field Survey (See Figure 3.5)

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Location	Valley bottom, East Morrison Creek main branch floodplain	Narrow valley/ravine along the north end of the Esso Station to Crossing C6	Crossing C6 to former Oak Park Animal Hospital property	Former Oak Park Animal Hospital property parking area	Former Oak Park Animal Hospital property to upstream of Crossing C4
Slope (m/m)	0.00784	0.00295	0.00584	This reach represents the ~ 50 m of enclosed channel that is situated under the Oak Park Animal Hospital parking lot	0.0180
2-year flow (cm/s)	1.12	1.12	1.12		0.98
Average Bankfull Width (m)	1.63	1.85	3.81		5.58
Average Bankfull Depth (m)	0.27	0.17	0.22		0.26
Width:Depth Ratio (m/m)	6.13	10.77	21.27		22.02
Average Bankfull Area (m^2)	0.47	0.32	0.92		1.56
Average Wetted Width (m)	0.99	1.26	2.04		1.95
Average Water Depth (m)	0.29	0.13	0.11		0.06
Average Low-Flow Width:Depth Ratio (m/m)	3.78	15.72	30.09		111.79
Wetted Perimeter (m)	1.80	1.98	3.02		2.59
Bed Configuration	Riffle / Pool		Poorly defined		

4. Meander Belt Assessment

Within the NOCSS report (Town of Oakville, 2006), an estimate of the meander belt for all reaches within the North Oakville Study area was quantified. Reach MOC-2 (**Figure 3.5**) is in the direct area of interest along the East Morrison Creek – East Tributary. The meander belt was defined as 26 m within the NOCSS report (**Table 5.1**). Values reported in subwatershed studies are often completed on generalized data and thus should be re-examined during any detailed design stages that affect the creek corridor.

The lack of information regarding the historic channel planform (**Figure 3.3**) for Reach MOC-2 in the vicinity of sub-reaches 3 and 5; Crossings 4 to 6) required that data from a reference/surrogate reach be obtained. No suitable surrogate reaches were identified through the airphoto review. Instead, a suite of empirical relations were used to obtain estimates of the meander belt within the study area, based on measured channel parameters. The average meander belt value from all results presented in **Table 4.1** is 27.6 m.

Table 4-1. Overview of Meander Belt

Relation	Predicted Meander Belt Width
Annable (R^2 = 0.38)	34.83
TRCA Empirical relation accounting for change in flow	33.3
Williams (1986) based on bankfull area (R^2 = 0.62) + 20 % (NRCS manual TS14S)	20.5
Williams (1986) based on bankfull width (R^2 = 0.53) + 20 % (NRCS manual TS14S)	23.0
Chitale (1973)	18.3
NRCS manual TS14S	22.8
Vermont guidance document (8* bankfull width)	30.3
Piegay *et al.*. and Bravard *et al.*. (4 – 18 *bankfull width, or 10 * bankfull width on average)	38.0
Average	**27.6**

5. Geomorphological Constraints and Opportunities

5.1 Existing Recommendations from Background Review

When identifying constraints and opportunities for management of a watercourse, it is important to place a study area within the context of the overall drainage network. As outlined in **Section 2.1.1**, several studies have been completed that provide this larger spatial context and which thus serve as an appropriate basis for the current study. A summary of the recommendations contained within key background documents is provided in this chapter.

5.1.1 North Oakville Creeks Subwatershed Study (NOCSS) (Town of Oakville, 2006)

The NOCSS report included a comprehensive multidisciplinary (geomorphology, aquatic and terrestrial biology) baseline environmental characterization. Integration of results from each discipline was undertaken to develop a management strategy for all reaches.

As noted in **Section 3.3**, the study area includes reaches MOC-2 and MOC-6 as defined in the NOCSS. MOC-2 was classified as a 'blue stream' or medium constraint channel and MOC-6 is classified as a 'red stream' or high constraint channel. Medium Constraint streams were defined as "reaches where the current function is to be preserved". According to the Subwatershed Study, these streams still require preservation as a riparian corridor considering their environmental, geomorphologic, hydrologic, and hydrogeologic functions. It was judged, however that their function can still be preserved if the stream is either relocated or deepened, and, in most cases enhancements could be provided to improve the overall resiliency of the stream network and subwatershed. Any alteration, including lowering of the channel, establishing channel crossings, etc. is, of course, subject to acquiring approvals (DFO, HRCA, MNR, Town of Oakville).

The section of East Morrison Creek Tributary that flows between Crossings 4 and 6 was identified as a medium constraint stream corridor in the North Oakville East Secondary Plan (Town of Oakville, 2008), which requires that the stream be protected for hydrological and ecological reasons, but relocation or deepening of the channel is acceptable using natural channel design principals so long as Federal, Provincial, and Conservation Authority regulations are adhered to and the hydrologic and ecological function of the watercourse is maintained. This location is also associated with a Hydrological Feature "A" upstream of the section along the road, and a Hydrological Feature "B" just upstream of Crossing 6.

As a medium constraint channel, the general management recommendation allows for relocation of the stream and its corridor if the existing conditions are enhanced and an appropriately defined channel corridor is maintained.

Table 5.1 presents selected elements of the classification directly relevant to fluvial geomorphology as presented in the NOCSS report.

Table 5-1. Management strategies for reaches MOC-2 and MOC-6 - NOCSS[1]

Reach	Geomorphology Classification	Meander Belt Width (m)	Aquatic Habitat Classification	Aquatic habitat management	Overall Classification
MOC-2	Medium	26	Marginal habitat	Plant woody riparian vegetation to supplement existing herbaceous vegetation	Medium
MOC-6	High	42	Marginal habitat	Allow vegetative succession of woody vegetation to continue undisturbed	Medium

1: Town of Oakville, 2006

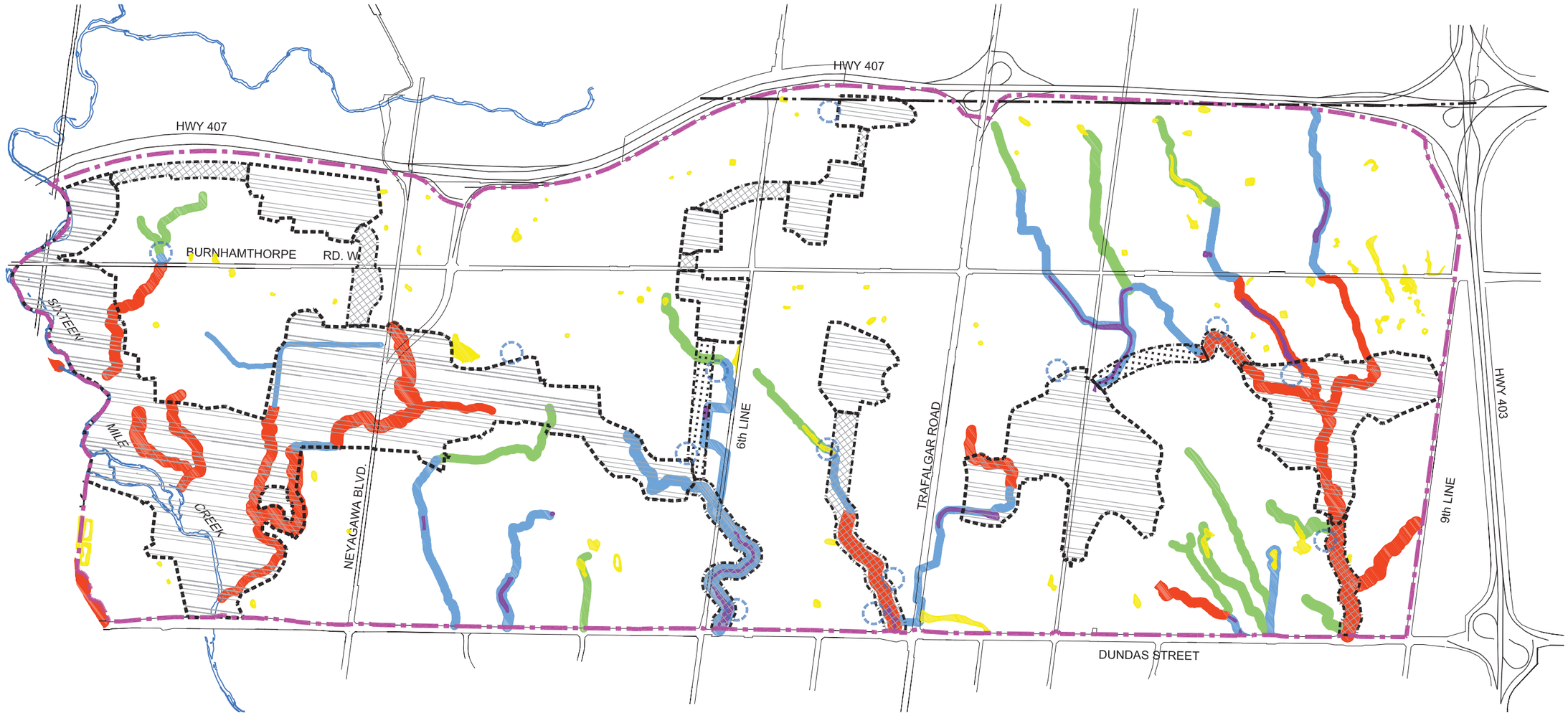
5.1.2 North Oakville East Secondary Plan (Town of Oakville, 2008)

The NOCSS Report was used to support the development of the North Oakville East Secondary Plan (NOESP). The key figure within the Secondary Plan in relation to stream management, is **Figure NOE3**, which illustrates the key components of the Natural Heritage and Open Space System. This figure is reproduced in this report and is shown on the following page.

In addition to the High and Medium Constraint Stream Corridor Areas, which require protection for hydrological and ecological reasons, a number of other hydrological features have been identified in North Oakville East. The other hydrological features identified on **Figure NOE3** include Hydrologic Features "A" and "B" and watercourses, with associated riparian lands, setbacks from top-of-bank and meander belts, located outside the Core and Linkage Preserve Areas and the High and Medium Constraint Stream Corridor Areas (Town of Oakville, 2008).

According to the NOESP (Town of Oakville, 2008):

- *"Where watercourses are designated as **"Low Constraint Stream Corridor Area"** on **Figure NOE3**, the streams do not need to be maintained, but the function of the watercourse must be maintained in accordance with the directions established in the North Oakville Creeks Subwatershed Study and Federal, Provincial and Conservation Authority regulations;*
- ***Other watercourses** do not need to be maintained, although stream density targets as established by the North Oakville Creeks Subwatershed Study must be met"*
- ***Hydrologic Features "A"** as designated on **Figure NOE3** form part of High Constraint and Medium Constraint Stream Corridor Areas and serve a key hydrological purpose. If a Medium Constraint Stream Corridor Area in which a Hydrologic Feature "A" is located is to be moved or rehabilitated, it is intended that the Hydrologic Feature "A" will be reconstructed in the relocated or rehabilitated stream corridor such that the form and function of the Hydrologic Feature "A" is retained or enhanced. The reconstruction of the Hydrologic Feature "A" shall be carefully considered through a detailed hydrological and hydrogeological assessment as part of the Environmental Implementation Report. This assessment will also include an evaluation of any ecological benefits of the Feature;*
- *"**Hydrologic Features "B"** may be relocated and consolidated with other wet features, wetlands or stormwater management ponds, provided the hydrologic function of the feature is maintained.*



LEGEND

- SECONDARY PLAN AREA BOUNDARY
- OAKVILLE / MILTON MUNICIPAL BOUNDARY
- CORE PRESERVE AREA
- CORE PRESERVE AREA
- LINKAGE PRESERVE AREA
- OPTIONAL LINKAGE PRESERVE AREA
- HIGH CONSTRAINT STREAM CORRIDORS
- MED. CONSTRAINT STREAM CORRIDORS

OTHER HYDROLOGICAL FEATURES

- LOW CONSTRAINT STREAM CORRIDORS
- HYDROLOGIC FEATURES "A"
- HYDROLOGIC FEATURES "B"

STORMWATER MANAGEMENT FACILITY

- CONCEPTUAL STORMWATER MANAGEMENT FACILITY LOCATIONS WHICH MAY ENCROACH IN NHS

Town of Oakville

North Oakville East of Sixteen Mile Creek Secondary Plan

FIGURE NOE 3

Natural Heritage Component of Natural Heritage and Open Space System including Other Hydrological Features

February 2008

500 300 100 750 metres
400 200 0

The reaches of Morrison Creek East Branch crossing Trafalgar Road remain classified as Medium Constraint, but are associated with a Hydrologic Feature "A" upstream of the crossings, and Hydrologic Feature "B" adjoining along the right hand bank at the most downstream crossing (see **Figure NOE3**).

5.2 Recommendations from Current Assessment

Results of field investigations from this study support the recommendations made in the NOCSS report. Specifically, since the East Morrison Creek Tributary functions as a straightened drainage ditch along much of its length within the study area, opportunities exist to re-establish a natural channel form. This could occur through design of a new drainage feature that incorporates some elements of natural channel morphology parallel to the road in conjunction with the proposed road widening, or through realignment of the channel into a corridor in conjunction with any future adjacent land development.

As noted in **Section 3.3.1**, of the ~ 455 m of channel length from upstream of Crossing 4 to downstream of Crossing 6, a total of ~253 m of channel is enclosed in road or parking lot culverts. Proposed widening of Trafalgar Road and required extension of the culverts for flood conveyance will require additional enclosure of the study area watercourses. The road widening will also encroach on the channel which is now mostly contained within a linear feature parallel to the road. Potential impacts from the proposed road widening are as follows:

- Increase in enclosed channel length - in addition to altering channel form, reducing floodplain access, and reducing natural sediment supply through the culvert, the natural environment may also be impacted (i.e., aquatic habitat, terrestrial linkage)
- Encroachment of wider road and associated embankment – this could oversteepen slopes and/or require the channel to be relocated to the east and west, within the new right-of-way due to erosion hazards
- Loss of headwater stream functions (floodplain access, floodplain water storage, sediment supply from overland sources.

Unless a crossing span is sufficiently wide and a defined channel is established within the crossing, the form and function of the channel are altered; hydraulic conditions within the culvert may also have implications for the channel immediately downstream. In addition, enclosure of a channel may contribute to other effects on the aquatic system (e.g., reduced contributions of organic materials, impediments to fish passage). Thus, it is generally recommended that the length of channel enclosure be minimized along any watercourse.

In conjunction with any proposed works, an opportunity may result which would enable enhancement of the natural channel form and functions of the watercourse. This could include the following:

a) Re-establish a functioning floodplain

- Creating a bankfull channel with better connectivity to a wider floodplain, or terrace, would allow the flows to overtop the banks during periods of high water levels. This excess water would then travel across the floodplain, dissipating energy across a much larger surface area. Vegetation would also decrease velocity, thus reducing erosion issues downstream.

b) Provide a low-flow channel

- Creating a low-flow channel will provide storage and refuge for aquatic organisms during drought conditions.

c) Re-establish a 'natural' meander planform

- Using reference reaches as an indication of channel planform prior to the influence of agricultural land use, it is obvious that historical ditching and straightening removed the natural meander planform of many reaches within the study area. This channelization effectively increased stream gradient and, consequently, the stream energy available to erode bed and banks. Where possible, the restoration of a more 'natural' meandering planform would decrease gradient and stream energy, thus facilitating a reduction in erosional processes along the network. In the context of the current study, establishment of a meandering watercourse would extend beyond the road right-of-way and thus require collaboration with adjacent landowners.

d) Re-establish riparian vegetation

- Re-establishing a healthy riparian vegetation community would increase bank stability in addition to creating shading and improving fish habitat along the creek. The provision of bank vegetation also provides a source of woody debris and organic matter for the stream, which aids in creating a more diverse morphology.

Review of site conditions in proximity to Crossing 7 (**Table 3.6**) suggests that, in conjunction with proposed road widening, replacement and widening of the existing culvert should be undertaken due to its corroded and failing condition. Further, observed erosion downstream of Trafalgar Road can be addressed in conjunction with proposed works at the culvert.

If no channel realignment/restoration work occurs (i.e. no channel alterations), the minimum crossings span required for the four crossings included in the detailed fluvial geomorphic assessment (C4 – C7) from a fluvial geomorphological is 3x the bankfull width. A span 3x the bankfull width will be able to accommodate future geomorphological processes and will mitigate upstream flooding caused by the limited capacity of existing culverts. Bankfull widths and recommended minimum crossings are listed in **Table 3-1**. For crossings that had a range of bankfull widths, the larger value was used for the purposes of calculating the span.

However, at the time channel realignment occurs, as is the preferred approach as proposed in Dundas-Trafalgar Incorporated and Shieldbay Incorporated (2012) (refer to **Section 5.3.3**), crossings spans from a fluvial geomorphological perspective have to be refined during detailed design according to channel dimensions, slope, planform, and boundary materials.

Table 5-2. Bankfull width and minimum crossings spans from a fluvial geomorphological perspective if no channel realignment or restoration work occurs

Crossing	Bankfull Width[1] (m)	Minimum Crossing Span (m)
C4	5.6	16.8
C5	2.4 - 2.7	8.1
C6	2.4 - 2.7	8.1
C7	1.6 - 2.3	6.9

1 – When a range of bankfull width was reported minimum crossing spans were calculated using the larger width

Note: The culvert size will be reassessed at the detailed design stage to ensure that substrate appropriate to the upstream And downstream reaches can be utilized. Furthermore, the culvert size will take into account aquatic habitat requirements and channel hydraulics.

5.3 Mitigation Opportunities

5.3.1 Alternative Identification

The proposed widening of Trafalgar Road will include replacement of crossing structures and extension to accommodate the increased channel width. Widening of the road and associated embankments would encroach on the watercourse that is situated within drainage ditches along both the east and west sides of Trafalgar Road, north

of Dundas Street East. As part of this assessment, four alternatives were identified to mitigate the effects of proposed Trafalgar Road widening on the Tributary of East Morrison Creek which would affect an ~ 400 m road length north of the Dundas/Trafalgar intersection.

The identified Alternatives 1 through 4 include the following (see **Table 5.2**):

1. No creek enhancements:
   - Replace and lengthen the three existing culverts (C4, C5 and C6)
2. Maintain general configuration and relocate creek into new ditches:
   - Replace and lengthen the three existing culverts
   - Establish new channel (with better defined morphology) in new ditches along the road
3. Establish creek on west side of Trafalgar Road:
   - Replace and lengthen the three existing culverts
   - Retain only Crossing C4 and tie-in channel to downstream of C6.
4. Establish creek on east side of Trafalgar Road:
   - Replace and lengthen the three existing culverts
   - Realign creek beginning at C4 to flow adjacent to Trafalgar Road. Retain only Crossing C6

For Alternatives 2 to 4, the realigned channel would be positioned to ensure the road is located outside of the erosion hazard limit as defined by Conservation Halton and Provincial Regulations and Guidelines. As a result of the relocation, the channel would increase in length and decrease in slope, with potential to have a negative impact on the channel's form and function. Loss of floodplain storage and conveyance for each alternative would be negligible and will be demonstrated during the detailed design stage.

5.3.2 Alternative Evaluation

Evaluation of the alternatives was undertaken from a geomorphologic perspective that included the following parameters (**Table 5.3**):

1. Potential impacts to floodplain function
   - ability to access floodplain during larger than bankfull flow conditions
2. Potential impact to headwater function
   - loss of flow attenuation and overland organic/sediment source
3. Potential Impacts to channel form and function
   - channel length
   - change in flow hydraulics and sediment conveyance
   - connectivity to existing hydrologic features
4. Natural hazards
   - erosion rates

In addition to the qualitative/theoretical evaluation, a quantitative assessment was also completed for each alternative, based on a geomorphological perspective. A comparison of the channel length between common reference points near Crossings C4 and C6 that could be asscciated with each alternative was completed. In the assessment, quantification of the open channel length was completed. The gain/loss of total and/or open channel length was made in comparison to Alternative 1. Results are presented in **Table 5.4.** Note that minimum culvert spans presented in **Table 5.2** only apply to the "No creek enhancement" alternative. For Alternatives 2 to 4, minimum culvert spans would need to be determined during detailed design.

Results of the assessment suggest that Alternative 4 is preferred from a geomorphologic perspective.

Determination of the actual preferred alternative should rely not only on the geomorphic considerations presented in **Tables 5.3** and **5.4**, but also consider implications from an aquatic habitat (e.g., loss of total channel length, change in open channel length etc.), terrestrial (linkage to natural features, continuous linkage along creek etc.), hydraulic (floodplain storage, flood elevations, crossing span etc.), and structures perspective (maintenance, cost of crossing structures etc.).

Alternative 1 has been identified as not feasible, as creek realignments must occur in conjunction with the road widening. This is supported by the increased risk to the public due to closer proximity of the roadway to the creek and anticipated increased use of the roadway located within the erosion hazard. For these reasons, Alternative 1 was eliminated as a possible option, but was still included in **Table 5-3** for comparison between alternatives.

For Alternative 2, 3, and 4, considerations regarding property ownership and future land use needs to be explored. Evaluation of the alternatives from other study team discipline perspectives should be completed as part of this Class EA Study.

Within the context of the NOCSS study (Oakville, 2006), implications of each of the alternatives should be evaluated which includes consideration of watercourse linkage to terrestrial features, and drainage density.

Table 5-3. Mitigation options and evaluation

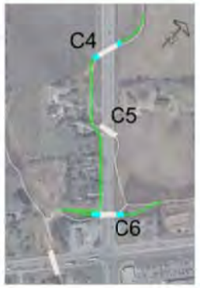
Evaluation Criteria	Alternative 1. No Creek Enhancements	Alternative 2. Maintain general configuration and relocate into new ditches	Alternative 3. Establish creek on west side of Trafalgar Rd.	Alternative 4. Establish creek on east side of Trafalgar Rd.
				
Potential impacts to floodplain function	• Potential for minor loss of floodplain function due to increased length of channel enclosure. • Potential opportunity to create overbank area in a wider culvert. • Widening of the roadway between the crossings has the potential for loss of floodplain function due to encroachment of the new roadway into the existing floodplain.	• Potential for minor loss of floodplain function due to increased length of channel enclosure. • Potential opportunity to create overbank area in a wider culvert.	• Potential for minor gain in floodplain function due to reduction in channel enclosure length. • Potential opportunity to create overbank area in a wider culvert.	• Potential for minor gain in floodplain function due to reduction in channel enclosure length. • Potential opportunity to create overbank area in a wider culvert.
Potential impact to headwater function	• Potential for loss of some headwater functions due to increased length of channel enclosure.	• Potential for minor loss of some headwater functions due to increased length of channel enclosure.	• Potential for minor gain of some headwater functions due to reduction in length of channel enclosure.	• Potential for minor gain of some headwater functions due to reduction in length of channel enclosure.

Table 5-3. Mitigation options and evaluation

Potential Impacts to channel form and function	• Potential opportunity to establish a defined channel with bed morphology in an open bottom culvert. • Potential to increase flood flow velocities due to culvert extension. • Widening of the roadway between the crossings has the potential to encroach into the channel itself where the watercourse runs parallel to the roadway.	• Potential opportunity to establish a defined channel with bed morphology in an open bottom culvert. • Potential opportunity to better define channel and provide diversity along profile and in cross-section. • Potential to reduce flood flow velocities in wider culvert.	• Reduce number of watercourse crossings • Potential opportunity to establish a defined channel with bed morphology in an open bottom culvert. • Potential loss of approximately 15 m in channel length • Potential opportunity to better define channel and provide diversity along profile and in cross-section • Potential to reduce flood flow velocities in wider culvert.	• Reduce number of watercourse crossings Potential opportunity to establish a defined channel with bed morphology in an open bottom culvert • Potential loss of approximately 63 m in channel length • Potential opportunity to better define channel and provide some lateral diversity along profile and in cross-section • Opportunity to maintain direct connectivity to existing hydrologic features.
Natural hazards	• Potential to increase erosion at culvert outlet due to increased flow velocity resulting from longer culvert. • There is potential to increase the risk to the roadway infrastructure due to the closer proximity of the widened road to the existing channel; as a result this could increase risk to the public	• No change in erosion potential	• Minor change in erosion potential due to shorter channel and increased channel slope	• Minor change in erosion potential due to shorter channel and increased channel slope
Preference	least	moderately	moderately	most

Table 5-4. Quantitative evaluation of mitigation options

Measure	1. No Creek Enhancements	2. Maintain general configuration and relocate into new ditches	3. Establish creek on west side of Trafalgar Rd.	4. Establish creek on east side of Trafalgar Rd.
No. of culverts	3	3	1	1
Channel length (m)	455	455	380	390
Proposed length of C4 (m)	80	80	80	0
Proposed length of C5 (m)	69	69	0	0
Proposed length of C6 (m)	49	49	49	49
Other enclosure length (i.e., Oak Park Pet Hospital) (m)	54	54	54	0
Current Enclosed Length (m)	170	170	170	170
Proposed Enclosed length (m)	253 (56%)	253 (56%)	183 (48%)	49 (13%)
Open length (m)	202	202	197	341
Gain/loss in total channel length (m)	0	0	-75	-65
Gain/loss in open channel length (m)	-83	-83	-47	121
Cost for channel works	$	$	$$	$$$
Preference	least	moderately	least	most

5.3.3 Dundas-Trafalgar Inc. (Minto) Proposed East Morrison Creek Realignment

Several proposed development projects located adjacent to Trafalgar Road are underway simultaneous to the completion of this Class EA Study. The Dundas-Trafalgar Inc. (Minto) and Shieldbay Inc. subdivision northeast of Dundas Street and Trafalgar Road is of specific importance to the Fluvial Geomorphological assessment because it includes the Tributary of East Morrison Creek.

The realignment of the east branch of East Morrison Creek was an opportunity proposed by Minto as a means to accommodate runoff and mitigate impacts to the creek resulting from the redevelopment of the above noted property. The East Branch EIR/FSS reports documenting the Minto proposed creek realignment design and associated impacts were reviewed in relation to the Trafalgar Road ROW and are documented in the *Trafalgar Road Corridor Improvements EA, Cornwall Road to Highway 407 Stormwater Management Report (2014).*

The Minto creek realignment proposal is the preferred alternative for the creek and is known as the 'Combination Option'. It is being carried forward to detailed design in advance of the Trafalgar Road proposed construction timeline for the ROW north of Dundas Street. The 'Combination Option' includes only two watercourse crossings for Trafalgar Road instead of the existing three culvert crossings. The East Morrison Creek Tributary would realign at Crossing C4 towards the west, where it would join the main branch of East Morrison Creek on the west side of Trafalgar Road, and upstream of the existing confluence. Crossing C6 would remain in place for the water features on the east side of Trafalgar Road.

6. Summary

A geomorphological assessment was completed for watercourses within the study area, including nine watercourse crossings. For a distance of approximately 420 m upstream of the Trafalgar Road and Dundas Street East intersection, a tributary of East Morrison Creek is situated adjacent to, and crosses three times under, Trafalgar Road. Given that this watercourse will be most directly affected by the proposed Trafalgar Road widening, it became the focus of this study.

Within the study area, the East Morrison Creek tributary is essentially defined as a first order headwater feature. The channel has been modified and it flows within a vegetated drainage ditch. The channel displays some evidence of a developing morphology. Within the NOCSS Report, this section of watercourse was defined as a medium constraint stream corridor whose current function is to be preserved. According to the NOCSS, the reach requires preservation as a riparian corridor considering its environmental, geomorphologic, hydrologic, and hydrogeologic functions, but these functions can still be preserved if the stream is either relocated or deepened, and enhancements could be provided to improve the overall resiliency of the stream network and subwatershed. Review of the meander belt width for the watercourse as initially presented within the NOCSS report (Town of Oakville, 2006) was completed and refined to a value of 27.6 m.

Four alternatives were identified for watercourse location/relocation in the context of proposed Trafalgar Road widening. These were evaluated according to geomorphic indicators to identify the preferred alternative to mitigate the impacts of the road widening. Results of the assessment indicate that, from a geomorphic perspective, relocation of the channel to the east of Trafalgar Road is preferred.

6.1 Summary of the Dundas-Trafalgar Inc. (Minto) Proposed East Morrison Creek Realignment

A realignment of the east branch of East Morrison Creek was proposed by Minto as a means to accommodate runoff and mitigate impacts to the creek resulting from the redevelopment of the land north of Dundas Street. The East Morrison Creek Tributary would realign at Crossing C4 towards the west, where it would join the main branch of East Morrison Creek on the west side of Trafalgar Road, and upstream of the existing confluence. Crossing C6 would remain in place for the water features on the east side of Trafalgar Road.

This alternative is the preferred alternative being carried forward to detailed design. The Region will continue to work with Minto, along with Conservation Halton and the Town of Oakville, through the detailed design of the culvert.

7. References

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Appendix A

Historical Aerial Photography

Basemap: from Ontario Ministry of Natural Resources
Additional Sources:
Ortho-Imagery: National Air Photo Library

1:6,000

0 30 60 120 180 240
Metres

NAD 1983 UTM Zone 17N

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Historical Aerial 1934

August 2013
60119993

AECOM

Path: D:\Projects\AECOM\60119993\GIS\Maps\Working\Appendix_Aerial_1934.mxd

Basemap: from Ontario Ministry of Natural Resources
Additional Sources:
Ortho-Imagery: National Air Photo Library

1:6,000

0 30 60 120 180 240
Metres

NAD 1983 UTM Zone 17N

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Historical Aerial 1961

August 2013
60119993

AECOM

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Basemap: from Ontario Ministry of Natural Resources
Additional Sources:
Ortho-Imagery: National Air Photo Library

1:6,000

0 30 60 120 180 240
Metres

NAD 1983 UTM Zone 17N

Halton Region
Trafalgar Road (Regional Road 3)
Improvements Class EA Study

Historical Aerial 1985

August 2013
60119993

AECOM

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Appendix B

Field Site photographs

AECOM

Photograph 1. **Joshua Creek Crossing C1. ↑**

Downstream of Trafalgar Road.
The channel exhibits bank scour within the agricultural field

Photograph 2. **Joshua Creek Crossing C1 ↑**

Upstream view on west side of Trafalgar Road. Steep channel flanks GO parking lot and comes into the roadside ditch from the west side

Photograph 3. Joshua Creek Headwater C2 ↑

Channel is not well defined

Photograph 4. Joshua Creek Headwater C2 ↑

No defined channel visible in landscape

Photograph 5. East Morrison Creek – East Tributary C3 ↑

Channel is choked with vegetation on east side of culvert

Photograph 6. East Morrison Creek – East Tributary C3 ↑

Channel is choked with vegetation on west side of culvert

Photograph 7. **East Morrison Creek – East Tributary C4 ↑**

Dense vegetation occurs in channel on east side of culvert

Photograph 8. **East Morrison Creek – East Tributary C4 ↑**

Channel is choked with vegetation on west side of culvert and exhibits a wide and shallow form. Definition increases in the downstream direction.

Photograph 9. **East Morrison Creek – East Tributary C4 ↑**

Upsteam view of tributary along east side of Trafalgar Road.

Photograph 10. **East Morrison Creek – East Tributary C5 ↑**

Dense vegetation occurs in channel on east side of culvert. Creek goes from west to east through culvert

Photograph 11. **East Morrison Creek – East Tributary C5 ↑**

West side of culvert, conveying flow to east side

Photograph 12. **East Morrison Creek – East Tributary C6 ↑**

Photograph 13. **East Morrison Creek – East Tributary C6 ↑**

Photograph 14. **East Morrison Creek – East Tributary C6 ↑**

Photograph 15. **East Morrison Creek C7 ↑**

Photograph 16. **East Morrison Creek C7 ↑**

Photograph 17. **East Morrison Creek C7 ↑**

Photograph 18. **West Morrison Creek C8 ↑**

West Morrison Creek enters a flow diversion channel under McCraney Street East

Photograph 19. **West Morrison Creek C8 ↑**

No channel exists within the valley downstream of McCraney Street East

Photograph 20. **Morrison Wedgewood Diversion C9 ↑**

East side of concrete lined diversion channel under Trafalgar Road, captures water from several tributaries and conveys this to Sixteen Mile Creek

Photograph 21. **Morrison Wedgewood Diversion C9 ↑**

Views looking toward west side of Trafalgar Road.