

**DATE** July 13, 2016**PROJECT No.** 1522372 (8000)**TO** Sonya Kapusin and Stephen Keen  
CIMA+**CC** James Francis and Chris Kellestine (Golder)**FROM** Christopher Davidson and Andrew Forbes**EMAIL** Andrew\_Forbes@golder.com;  
Christopher\_Davidson@golder.com**FLUVIAL GEOMORPHIC ASSESSMENT IN SUPPORT OF THE PORTAGE PARKWAY MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT STUDY, CITY OF VAUGHAN****1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) was retained by CIMA+ to complete a fluvial geomorphic assessment at Black Creek, located in the City of Vaughan, Ontario (Figure 1). The analyses were conducted to support a Municipal Class Environmental Assessment (EA) study in relation to the proposed extension and widening of Portage Parkway. The proposed development at Portage Parkway will include a stream crossing at Black Creek.

This technical memorandum outlines the results of the fluvial geomorphic assessment at Black Creek in the vicinity of the proposed development.

**1.1 Background**

Black Creek originates in the area north of Rutherford Road and flows in a mostly southern direction until it joins the Humber River at a location approximately 7 m upstream from the river outlet at Lake Ontario. The watershed of Black Creek is largely urbanized and in many cases the channel has been altered (e.g., re-aligned or hardened) relative to natural conditions.

An extension of Portage Parkway has been proposed from Jane Street to Creditstone Road (Figure 1). The project will also include the widening of Portage Parkway in the area to the west of Jane Street. The extension of Portage Parkway in particular will require a culvert crossing at Black Creek.

**1.2 Purpose and Scope**

The fluvial geomorphic assessment at Black Creek was completed in support of the Municipal Class EA for Portage Parkway. In addition, the assessment was carried out to assist with the design of the required culvert crossing. The following tasks were undertaken at Black Creek to address these objectives:

- Background review and field inspections to characterize channel morphology and assess bed and bank stability;
- Meander belt width assessment to determine the meander potential of the stream near the culvert crossing; and



- 100-year erosion assessment to determine the long-term erosion potential of the stream near the culvert crossing.

Each of these tasks is described in Section 2.0.

The following background information was reviewed to assist with the fluvial geomorphic assessment at Black Creek:

- *Black Creek Stormwater Optimization Study Municipal Class Environmental Assessment Master Plan Report (Phases 1 & 2)* that was prepared by AECOM in February 2012 for the City of Vaughan;
- *Humber River State of the Watershed Report – Fluvial Geomorphology* that was prepared by the Toronto Region Conservation Authority (TRCA) in 2008;
- HEC-RAS modelling for Black Creek that was prepared by TRCA in 2010;
- Topographic survey information that was collected and compiled by JD Barnes Ltd. in 2015 for CIMA+; and
- Aerial photography from 1946, 1960 and 1980 that was obtained from the National Air Photo Library, as well as a web based satellite image from 2013.

## 2.0 METHODOLOGY

### 2.1 Background Review and Field Inspections

A site visit was completed on July 8, 2015. This site visit included a walk over at Black Creek in the vicinity of the proposed stream crossing to assess channel morphology and identify any areas of instability. The walkover included a Rapid Geomorphic Assessment (RGA) and the collection of substrate samples (bed and bank) for grain size testing. In addition to the general field inspections, topographic channel surveys were completed at several locations (i.e., at the stream crossing, 100 m upstream of the crossing, and 75 m downstream of the crossing) to further assess characteristic channel geometry and build on the existing hydraulic model for the site.

The field data was used to inform the meander belt width assessment (Section 2.2) and 100-year erosion assessment (Section 2.3), as well as the hydraulic analyses (captured under a separate cover). The results of these studies were subsequently used to support the proposed design of the culvert crossing.

### 2.2 Meander Belt Assessment

A belt width assessment was conducted at Black Creek based on protocols developed by Toronto and Region Conservation Authority (TRCA, 2004). The belt width assessment included the following activities:

- Background preparation, comprising a detailed analysis of maps, historical aerial photographs and topographic survey, in order to delineate the study reach and examine historical land use and channel patterns;
- Field reconnaissance (described in Section 2.1) to evaluate current conditions and obtain measurements of channel geometry; and
- Delineation/quantification of the preliminary, existing and final meander belt widths to infer the stream corridor that the channel encompassed in the past and could potentially occupy in the future.

## 2.3 100-Year Erosion Assessment

A 100-year erosion assessment was conducted at the study reach of Black Creek in accordance with procedures outlined by Toronto and Region Conservation Authority (TRCA, 2007). The development of the 100-year erosion limit considered the average rate of channel migration in the vicinity of the proposed stream crossing and was based on similar activities described for the meander belt width assessment (Section 2.2), namely an analysis of historical aerial photographs and a field reconnaissance.

## 3.0 RESULTS

### 3.1 Background Review and Field Inspections

The background review and field assessment were targeted at the section of Black Creek that drains in the area east of Jane Street, noting that this portion of the stream is generally bounded by Macintosh Boulevard to the north and Highway 7 to the south (Figure 1). The watercourse drains to an inline pond (stormwater management facility) in the area that is located immediately downstream of the reach (i.e., northeast corner of Jane Street and Highway 7). To account for changes in geomorphologic characteristics along a watercourse, channels are typically separated into reaches that display similar physical characteristics and controls on channel morphology. Field observations, in combination with a review of available base mapping and air photographs, confirmed that the identified section of the watercourse comprised similar geological and biophysical controls, including gradient, local geology, degree of valley confinement, and vegetative control. As such, Black Creek was defined by a single reach, with a valley/corridor length of approximately 850 m and a gradient of approximately 0.3%. The limits of the stream reach were consistent with past geomorphic studies by AECOM (2012).

The key field observations at the study reach of Black Creek are summarized as follows:

- The channel included a defined bed and bank (refer to Photographs 1 through 3 in Attachment A), and was moderately entrenched in several sections (i.e., channel well-incised between steeply sloped banks).
- Channel planform was mostly straight (low sinuosity) and largely confined to an engineered stream valley.
- Bed morphology was largely absent (i.e., flat).
- Erosion and/or depositional features included:
  - Examples of sediment deposition along the bed; and
  - Instances of bank erosion (Photographs 4 and 5), recognizing however that the banks and riparian zones were for the most part well protected against erosion with a dense cover of vegetation.
- Channel geometry was rectangular to trapezoidal, noting that bankfull widths ranged from approximately 3.0 m to 5.0 m.
- Instream controls were largely absent.
- Substrate at the bed was dominated by medium sand with silt and clay, while substrate at the banks was characterized by mostly fines (clay and silt with some fine sand).
- Surface water flows were moderate and slightly turbid, recognizing that the field assessment was preceded by a moderate rainfall event (occurring on July 7, 2015).
- Channel margins (riparian areas) included a dense network of grasses, shrubs and trees.

The completed RGA form for the study reach is presented in Attachment B. The results of this assessment suggest that the study reach at Black Creek is generally stable, with some evidence of degradation.

The grain size distribution curves for the sampled substrate materials are provided in Attachment C. The results of this analysis were consistent with the field observations identified above.

## **3.2 Meander Belt Assessment**

### **3.2.1 Air Photograph Analysis**

The air photograph analysis (1946-2013) demonstrated that historic land use at the study reach and in the upstream catchment area was predominated by agriculture up until at least 1980. From there, the air photos/images showed that land use has transitioned to primarily urban development (mostly light industry).

Riparian vegetation within the area of investigation has been historically moderate in density, consisting of tree, shrub and grass cover. In some instances, this vegetation cover limited direct observation of features on the ground. Nevertheless, the watercourse at the study reach was visible on a fairly consistent basis in the air photograph pairs from 1960 and 1980, as well as in the 2013 web based satellite image. These photos/images were used to evaluate the general channel planform at Black Creek and related variations in channel patterns over time. The observed changes in the channel planform at the study reach are illustrated on Figure 1.

The channel at Black Creek appears to have been significantly altered (i.e., diverted and/or realigned) prior to 1960 and at one or more times after 1980, recognizing that, with few exceptions, the watercourse has historically exhibited low sinuosity. For this reason, the observed changes in channel patterns at the study reach are summarized below for the periods before and after 1980:

- From 1960 to 1980, the air photograph analysis showed that the channel followed a very similar pattern. The watercourse for the upper two-thirds of the reach included a relatively straight alignment and was oriented generally northwest to southeast or north to south. In comparison, the section of Black Creek in the lower third of the study reach was historically marked by a strong meandering pattern, noting two particularly prominent meander bends that were located in the area immediately downstream of the proposed stream crossing and that trended in a generally northeast to southwest direction. The results suggest that the upstream section of the reach was straightened before 1960 to accommodate agricultural practices, while the downstream section of the reach was left to adjust naturally. The meander belt axis at the study reach demonstrated no discernible shift prior to 1980.
- Under current conditions, the watercourse follows a mostly straight alignment for the full extent of the reach, albeit with a marked right angle bend at the upstream end of the reach and a broad sweeping bend in the central to downstream portion of the reach. The channel planform in 2013 has been noticeably altered relative to the channel patterns in 1960 and 1980, particularly at the upstream and downstream ends of the study reach (i.e., the channel at the upstream end is now oriented west to east before draining north to south, while the channel at the downstream end has been shifted to the east and no longer includes a meandering channel pattern – refer to Figure 1). In addition, the channel is now markedly confined to the surrounding stream valley relative to past conditions. Finally, two stormwater management ponds are now present at the downstream end of the reach (one of which is in line with the main channel, and the other drains to the main channel via a small tributary). The results suggest that the channel has been further straightened and realigned to accommodate urban development and associated stormwater management facilities.

### 3.2.2 Belt Width Calculations

Based on TRCA protocols, it is understood that portions of the channel planform that have been previously modified no longer represent the natural meander potential of a watercourse, meaning that these altered sections of the channel prevent reliable measurements of a meander belt width. To that end and in accordance with TRCA guidelines, the meander belt width for the study reach at Black Creek was determined based on the historic air photographs that recorded the position of the unaltered channel configuration. This meant that the belt width measurements were estimated using the section of the watercourse that is located immediately downstream of the proposed crossing location and that was characterized by a strong meandering pattern for the period between 1960 and 1980. The belt width calculations assumed no major changes to hydrology during this period, given that land use remained largely unchanged (for the duration of the air photo record and likely well before that).

The belt width estimates for the study reach at Black Creek are described below, recognizing that the assessment assumed long term changes in the hydrologic regime (i.e., flow duration and frequency) as a result of recent development in the upstream catchment:

- A preliminary meander belt width was measured to be approximately 59 m. This preliminary meander belt represents the measured width between the outer-most meander bends at the study reach (i.e., perpendicular to the established meander belt boundaries).
- The existing meander belt width was estimated to be approximately 63 m. The calculation of the existing belt width combines the preliminary meander belt width with the average bankfull width of the channel, as estimated in the field ( $59 \text{ m} + 4 \text{ m} = 63 \text{ m}$ ).
- The final meander belt width was estimated to be approximately 76 m. This final belt width combines the estimated existing belt width with a safety factor of 1.2 in order to account for anticipated changes in upstream hydrology and potential channel movement ( $63 \text{ m} * 1.2 = 76 \text{ m}$ ).

The final meander belt width of approximately 76 m was plotted on the 2013 web based satellite image (Figure 2); divided over the meander belt width axis to allow equal channel buffer on either side of the axis.

### 3.3 100-Year Erosion Limit

In accordance with TRCA protocols, the 100-year erosion limit at the study reach of Black Creek was assessed based on the average rate of channel migration in the vicinity of the proposed culvert crossing. Consistent with the approach used for the belt width calculation, the 100-year erosion assessment was determined using the historic air photographs from 1960 and 1980, recognizing that: (1) these air photographs captured the unaltered channel configuration (characterized by a prominent meandering pattern) in the area located immediately downstream of the proposed crossing; and (2) the channel alignment under current conditions includes relatively low sinuosity for the full extent of the reach (i.e., no prominent meander bends that could be used to estimate channel migration).

The average rate of channel migration was estimated at the following major meander bends based on the air photo record between 1960 and 1980:

- Meander Bend #1 (located approximately 80 m downstream of the proposed crossing) – average migration rate of 3 cm/yr.
- Meander Bend #2 (located approximately 120 m downstream of the proposed crossing) – average migration rate of 9 cm/yr.

Based on the historical analysis, the 100-year erosion limit was estimated to be approximately 22 m. This 100-year erosion limit was determined by extending the average rate of migration at the most active meander bend over a 100-year time span ( $0.09 \text{ m/yr} * 100 = 9 \text{ m}$ ), and then applying this distance to either side of the average width of the bankfull channel ( $9 \text{ m} * 2 + 4 \text{ m} = 22 \text{ m}$ ).

The 100-year erosion assessment that is described above does not fully meet the information requirements outlined in TRCA (2007), recognizing that the historical air photographs cover a period of 20 years rather than the minimum of 25 years. In light of this and for comparison purposes, the 100-year erosion limit was also assessed using an alternate method. This approach is based on the same set of TRCA procedures, but considers a multiple of the observed bankfull width under existing conditions.

For the alternate method, the 100-year erosion limit was estimated to be approximately 20 m. This 100-year erosion limit was determined by applying two times the bankfull channel width ( $4 \text{ m} * 2 = 8 \text{ m}$ ) to either side of the bankfull channel ( $8 \text{ m} * 2 + 4 \text{ m} = 20 \text{ m}$ ). As detailed in Table 1 below, the calculation is based on the understanding that applied shear stresses and flow velocities under bankfull conditions (assumed to represent the 2-year flow rate) are less than the permissible shear stresses and flow velocities for the observed substrate materials at the bed and bank.

**Table 1: Modelled Shear Stresses and Flow Velocities at Black Creek under Assumed Bankfull Flow Conditions**

Location	D <sub>50</sub> Grain Size (mm)	Permissible Velocity (m/s) <sup>(1)</sup>	Applied Velocity (m/s) <sup>(2)</sup>	Permissible Shear Stress (kg/m <sup>2</sup> ) <sup>(1)</sup>	Applied Shear Stress (kg/m <sup>2</sup> ) <sup>(2)</sup>
Bed	0.5	0.7	0.46	0.31	0.19
Bank	0.06	0.9 – 1.5		0.61 – 1.70	

**Notes:**

<sup>(1)</sup> Permissible shear stresses and velocities for the bed and bank materials were obtained from the Ministry of Transportation (MTO) Drainage Management Manual (MTO, 1997). The values correspond to medium sand for the bed and fine silt for the bank, which are generally consistent with observed substrate in the area of investigation.

<sup>(2)</sup> Cross-section average shear stresses and velocities were estimated based on a modelled flow rate of approximately 15 m<sup>3</sup>/s. The flow rate represents the 2-year return period event (assumed bankfull flow condition) and was obtained from the HEC-RAS modelling by TRCA.

Overall, the results of the alternate method for estimating the 100-year erosion limit were relatively consistent with the historical analysis.

## 4.0 SUMMARY AND CONCLUSIONS

A fluvial geomorphic assessment was completed at a study reach of Black Creek to support a Municipal Class Environmental Assessment (EA) study in relation to the proposed extension and widening of Portage Parkway. The key findings of the assessment are summarized below:

- The results of the field reconnaissance suggest that the channel is generally stable, noting the following observations:
  - the channel geometry was moderately entrenched in several sections (i.e., well-incised between steeply sloped banks);
  - the channel planform was largely confined to the surrounding stream valley; and

- the channel included instances of bank erosion in a number of locations, recognizing however that the banks and riparian zones were for the most part well protected against erosion with a dense cover of vegetation.
- Based on the desktop analysis, the meander belt width of the channel is approximately 76 m; and
- Based on the desktop analysis, the 100-year erosion limit of the channel ranges from approximately 20 to 22 m (using the results from the historical analysis and alternate approach).

According to TRCA protocols, crossing structures should be constructed outside of the meander belt width of a watercourse to the extent possible, or, alternatively, the features should be designed to match or exceed the 100-year erosion limit of the channel. However, for the study reach at Black Creek, it is recognized that spanning a crossing structure the length of the estimated belt width or 100-year erosion limit of the channel would be impractical and cost prohibitive. Furthermore, Golder is of the opinion that the estimated dimensions of the meander belt width and 100-year erosion limit for this particular study are overly conservative, with consideration of the following:

- The meander belt width and 100-year erosion limit are not directly representative of current conditions at the study reach, recognizing that:
  - the channel has been heavily altered over time relative to natural conditions;
  - the belt width and 100-year erosion calculations were estimated based on the historical air photographs from 1960 and 1980, noting that this approach was required to assess meander potential/migration at a formerly unaltered section of the channel configuration;
  - the channel has been further straightened and re-aligned relative to the period that was used to assess the belt width and 100-year erosion limit, noting that the meandering section of the channel configuration no longer exists; and
  - the channel is now largely confined to an engineered stream valley.
- The culvert crossing at Jane Street (i.e., upstream end of the study reach) includes a width of approximately 8 m;
- The proposed culvert at Portage Parkway will be designed to convey up to and including the 100-year flow event; hence, major flows will be directed to the channel and culvert, with limited opportunities to outflank the crossing feature and erode a separate flow path; and
- The air photograph analysis demonstrated that past instances of channel migration occurred at a relatively nominal rate, meaning that any required repairs or maintenance at the study reach could be readily accommodated within a reasonable timeframe.

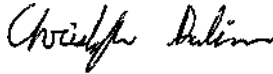
For the reasons identified above and from the standpoint of fluvial geomorphology, it is recommended that the proposed culvert at Portage Parkway include a width of at least 8 m. This suggested crossing dimension represents two (2) times the average bankfull width of the channel. The suggested span for the proposed culvert is expected to provide sufficient opportunities to maintain channel form and/or function (e.g., sediment transport and fish passage).

## 5.0 CLOSURE

We trust that this technical memorandum meets your needs at this time. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

**GOLDER ASSOCIATES LTD.**



Christopher Davidson, P.Eng.  
Water Resources Engineer



Andrew Forbes, M.Sc., P.Geo.  
Associate, Senior Geoscientist

TD/CD/AF/mp

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### **Attachments:**

Figure 1 – Historical Channel Patterns for Study Reach at Black Creek

Figure 2 – Estimated Meander Belt Width for Study Reach at Black Creek

Attachment A – Photographs

Attachment B – Results of Rapid Geomorphic Assessments

Attachment C – Grain Size Distribution Curves



## REFERENCES

AECOM. February 2012. Black Creek Stormwater Optimization Study Municipal Class Environmental Assessment Master Plan Report (Phases 1 & 2). Prepared for the City of Vaughan.

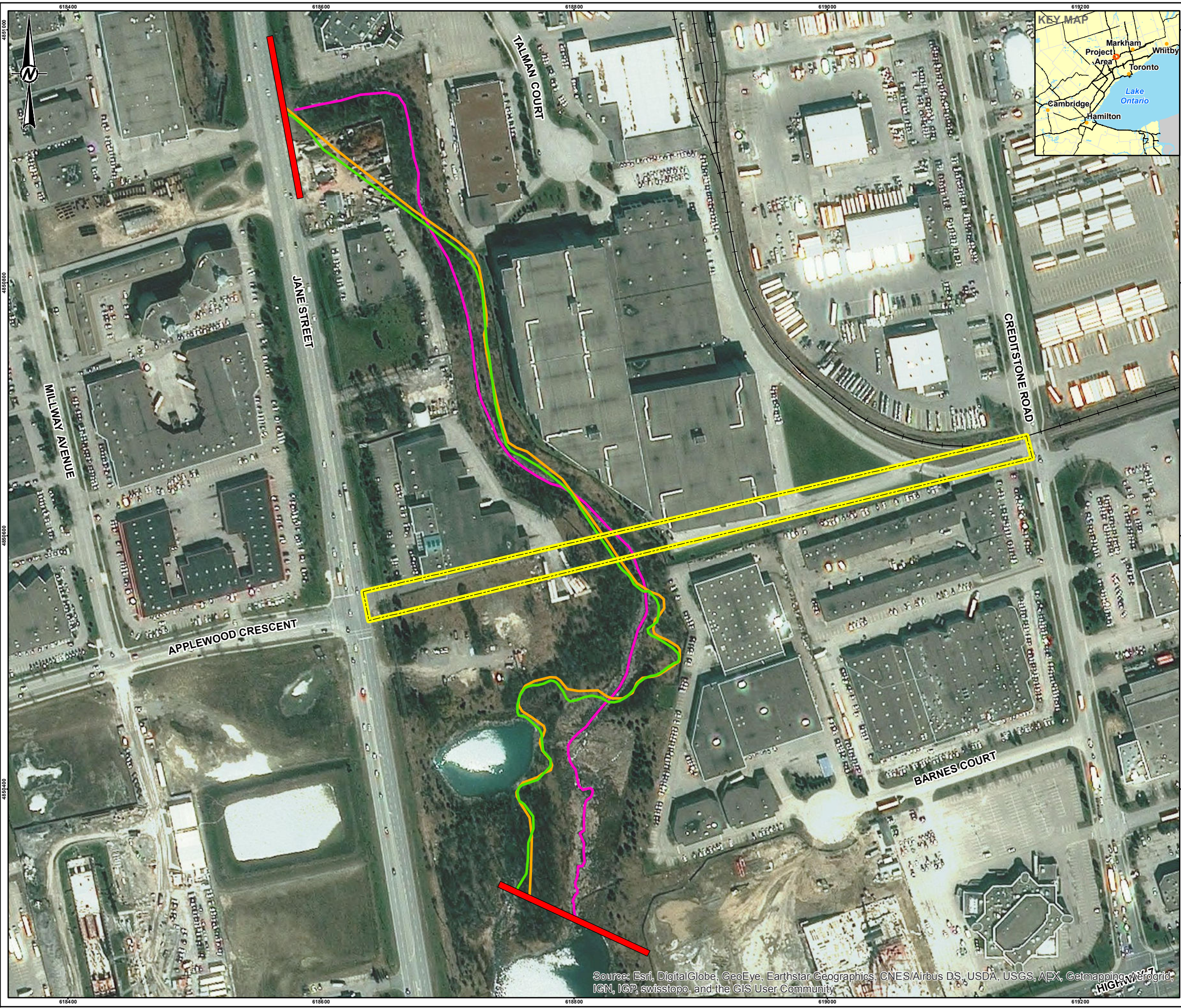
Ministry of Transportation Ontario. October 1997. MTO Drainage Management Manual.

TRCA [Toronto and Region Conservation Authority]. 2008. Humber River State of the Watershed Report – Fluvial Geomorphology.

TRCA [Toronto and Region Conservation Authority]. September 2007. Watercourse Crossing Design and Submission Requirements.

TRCA [Toronto and Region Conservation Authority]. 2004. Belt Width Delineation Procedures. Developed by Parish Geomorphic Ltd. for the Toronto and Region Conservation Authority.

# FIGURES



- LEGEND**
- Railway
  - Observed Channel Alignment in 1960 (Interpreted via Air Photography)
  - Observed Channel Alignment in 1980 (Interpreted via Air Photography)
  - Observed Channel Alignment in 2013 (Interpreted via Web-Based Satellite Imagery)
  - Reach Break
  - Approximate Area of Proposed Road Extension



**REFERENCE(S)**  
 BASE DATA - MNR LIO, OBTAINED 2015  
 PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM  
 ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2015  
 PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17

**CLIENT**  
 CITY OF VAUGHAN

**PROJECT**  
 PORTAGE PARKWAY ENVIRONMENTAL ASSESSMENT CITY OF VAUGHAN, ONTARIO

**TITLE**  
 HISTORICAL CHANNEL PATTERNS FOR STUDY REACH AT BLACK CREEK

CONSULTANT	YYYY-MM-DD	2015-08-27
DESIGNED	KD	
PREPARED	KD	
REVIEWED	TB	
APPROVED	AF	



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM 26mm



# Attachment A

## Photographs



## ATTACHMENT A Photographs



*Photograph 1: Black Creek near the proposed culvert crossing at Portage Parkway; view looking downstream on July 8, 2015.*



*Photograph 2: Black Creek at a location approximately 70 m upstream of the proposed culvert crossing at Portage Parkway; view looking upstream on July 8, 2015.*



*Photograph 3: Black Creek at a location approximately 80 m downstream of the proposed culvert crossing at Portage Parkway; view looking downstream on July 8, 2015.*



*Photograph 4: Elevated stormwater outfall at Black Creek; view at left bank of stream on July 8, 2015.*



*Photograph 5: Observed bank erosion at Black Creek; view at right bank of stream on July 8, 2015.*

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# Attachment B

## Results of Rapid Geomorphic Assessment

## RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: July 8, 2015

Location: Black Creek at Proposed Portage Parkway Crossing

Field Staff: TD/MLE

Project #: 1522372 (8000)

FORM/ PROCESS	GEOMORPHIC INDICATOR		PRESENT (YES) OR ABSENT (NO)	
	#	DESCRIPTION		
Evidence of Aggradation (AI)	1	Lobate bar		No
	2	Coarse material in riffles embedded		N/A
	3	Siltation in pools	Yes	
	4	Medial bars		No
	5	Accretion on point bars		No
	6	Poor longitudinal sorting of bed materials		No
	7	Deposition in the overbank zone		No
		<b>RATIO OF INDICES <sup>(1)</sup></b>		1/6 = 0.17
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A
	2	Exposed sanitary/storm sewer/pipeline/etc.		No
	3	Elevated storm sewer outfall(s)	Yes	
	4	Undermined gabion baskets/concrete aprons/etc.		No
	5	Scour pools d/s of culverts/stormsewer outlets		No
	6	Cut face on bar forms	Yes	
	7	Head cutting due to knick point migration		No
	8	Terrace cut through older bar material		No
	9	Suspended armor layer visible in bank		No
	10	Channel worn into undisturbed overburden/bedrock	Yes	
	<b>RATIO OF INDICES <sup>(1)</sup></b>		3/9 = 0.33	
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.		No
	2	Occurrence of large organic debris		No
	3	Exposed tree roots	Yes	
	4	Basal scour on inside meander bends		N/A
	5	Basal scour on both sides of channel through riffle		N/A
	6	Gabion baskets/concrete walls/etc. out flanked		N/A
	7	Length of basal scour > 50% through subject reach		No
	8	Exposed length of previously buried pipe/cable/etc.		No
	9	Fracture lines along top of bank		No
	10	Exposed building foundation		No
	<b>RATIO OF INDICES <sup>(1)</sup></b>		1/7 = 0.14	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		No
	2	Single thread channel to multiple channel		No
	3	Evolution of pool-riffle form to low bed relief form		No
	4	Cutoff channel(s)		No
	5	Formation of island(s)		No
	6	Thalweg alignment out of phase meander form		No
	7	Bar forms poorly formed/reworked/removed		No
	<b>RATIO OF INDICES <sup>(1)</sup></b>		0/7 = 0.00	
<b>STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4<sup>(2)</sup></b>			0.16 → In Regime	

Notes:

<sup>1</sup> Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices

<sup>2</sup> Stability Index or SI values inferred as follows: 0.20 or lower = In Regime; 0.21 to 0.40 = Transitional or Stressed; and 0.41 or higher = In Adjustment.

Sourced and adapted from: Ontario Ministry of the Environment, 2003. Stormwater Management Planning and Design Manual.

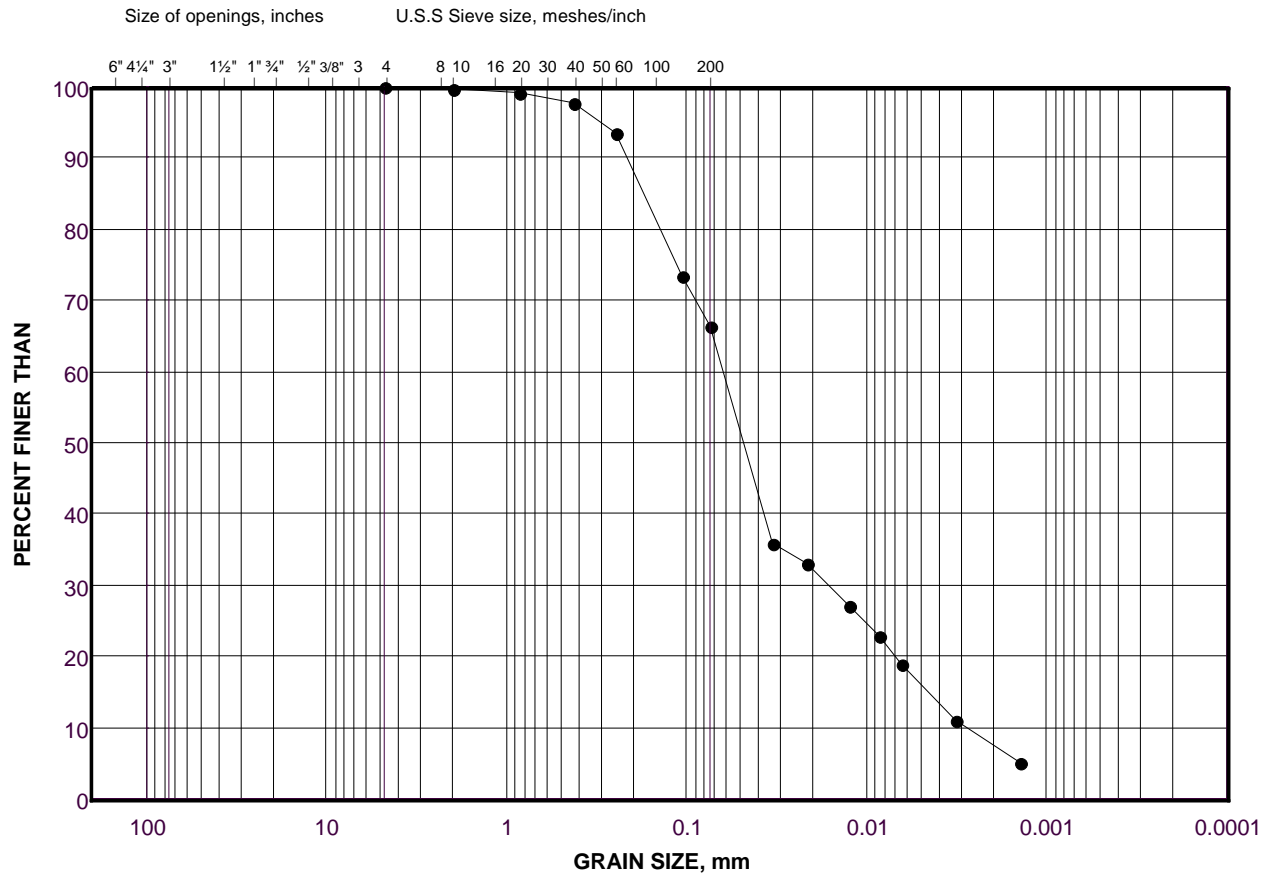


# Attachment C

## Grain Size Distribution Curves

# GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			
SIZE						

## LEGEND

SYMBOL



SAMPLE

BC-1 BANK

Project Number: 1522372

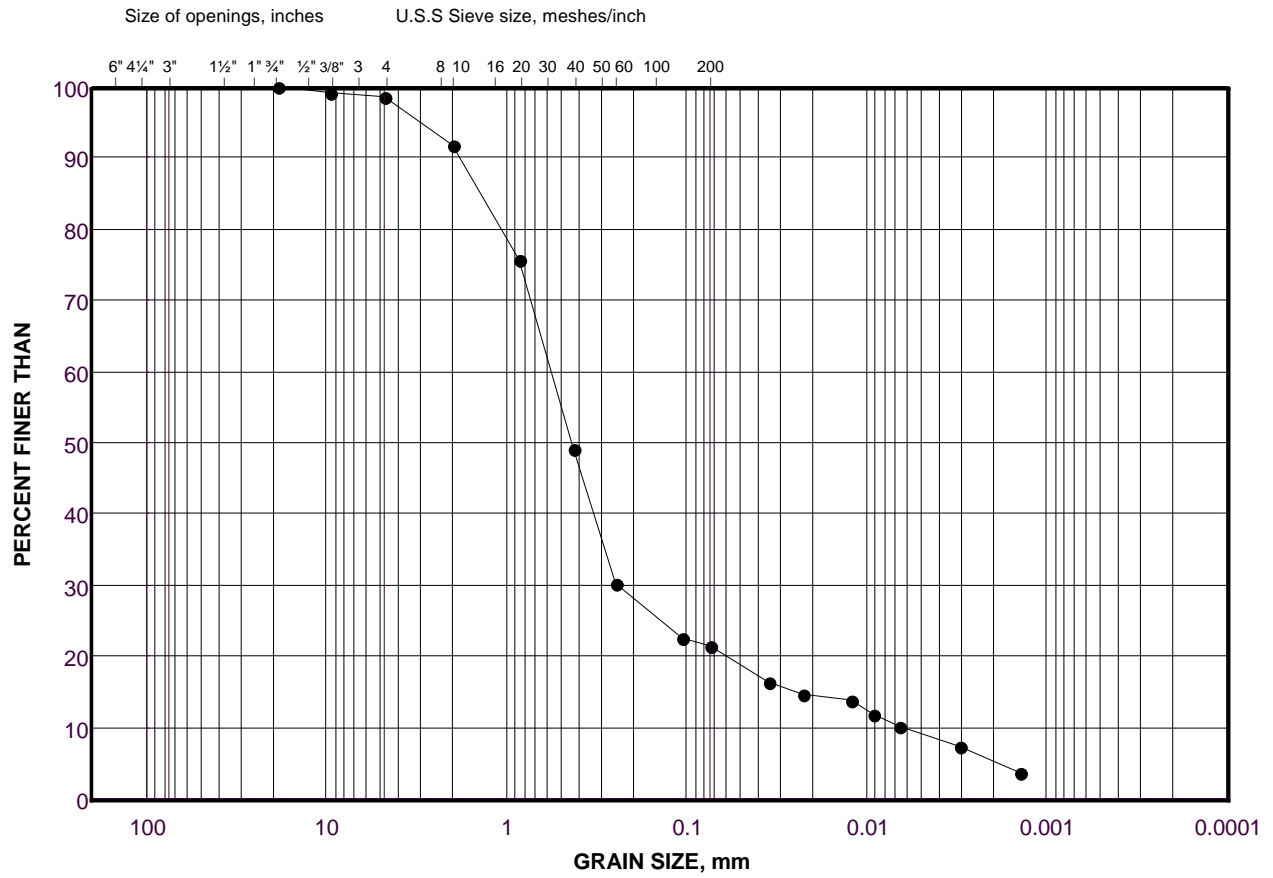
Checked By: AF

**Golder Associates**

Date: 17-Jul-15

# GRAIN SIZE DISTRIBUTION

FIGURE



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
	GRAVEL SIZE		SAND SIZE			
SIZE						

## LEGEND

SYMBOL



SAMPLE

BC-1 BED

Project Number: 1522372

Checked By: AF

**Golder Associates**

Date: 17-Jul-15