TECHNICAL MEMORANDUM

DATE September 23, 2019 **PROJECT No.** 1664178

TO Jaime Garcia (CIMA+)

CC Sandra McGaghran (Golder)

FROM Andrew Forbes and Justin Lim **EMAIL** aforbes@golder.com

FLUVIAL GEOMORPHIC ASSESSMENT IN SUPPORT OF THE SCHEDULE B MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT, ALBION VAUGHAN ROAD AND KING STREET EAST, TOWN OF CALEDON, ONTARIO

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by CIMA+ Inc. (CIMA) on behalf of the Regional Municipality of Peel (Peel Region) to complete a fluvial geomorphic assessment in support of the Schedule B Municipal Class Environmental Assessment (EA) for proposed roadway improvements at the intersection of Albion Vaughan Road and King Street East in the Town of Caledon, Ontario (Figure 1). This technical memorandum outlines the methods and results of the fluvial geomorphic assessment in the vicinity of the proposed development.

1.1 Background

Albion Vaughan Road (aligned north-south) and King Street East (aligned east-west) each represent a two lane collector road with dedicated left and right turning lanes. The intersection of the two roads has been targeted for improvements based on the *Peel Long Range Transportation Plan* (Region of Peel, 2012), *Peel Region's Road Characterization Study* (Region of Peel 2013), and *Peel 2041: Regional Official Plan Review* (Region of Peel, 2017), as well as the *Bolton Transportation Master Plan* (Town of Caledon, 2015). The roadway improvements will involve measures to increase the overall capacity of the road system in anticipation of growth within the local area, recognizing that the proposed road works are expected to extend beyond the intersection of these two roads to as far as 230 m to the east and 165 m to the west on King Street East, and 200 m to the south on Albion Vaughan Road (refer to Figure 1). Of note, Albion Vaughan Road to the north of the intersection with King Street East becomes Caledon King Townline, while King Street East to the east of the intersection becomes King Road; however, for practicality, the names Albion Vaughan Road and King Street East have been used herein to describe all sections of each respective roadway.

Residential housing and natural areas, specifically the Nashville Conservation Reserve that is managed by the Toronto and Region Conservation Authority (TRCA), represent the prominent land use in the areas adjacent to the roads. Other notable development features in the local area include the Bolton Camp (a recreation area that is also managed by the TRCA), Bolton Mill Park, and public schools (James Bolton Public School and Humberview Secondary School).

The proposed roadway improvements at the intersection of Albion Vaughan Road and King Street East include three watercourse crossings (Figure 1). One of these watercourse crossings is located at the Main Humber River (which flows generally west to east and is crossed by Albion Vaughan Road at a location approximately 200 m south of the intersection), while the other two crossings are located at Cold Creek (which flows generally southwest

to southeast and is bisected by Albion Vaughan Road at a location approximately 90 m north of the intersection, and by King Street East at a location approximately 40 m east of the intersection). Cold Creek represents a tributary to the Main Humber River, recognizing that the confluence of the channels is located to the immediate southeast of the intersection of Albion Vaughan Road and King Street East. The Main Humber River at Albion Vaughan Road is currently crossed by a multi-span bridge with a total span of approximately 32 m, while Cold Creek at Albion Vaughan Road and King Street East is crossed by single span bridges with total openings of 9 m and 13 m, respectively.

The headwaters of the Main Humber River originate in the areas of the Niagara Escarpment and the Oak Ridge Moraine – Dufferin and Simcoe Counties and Town of Caledon north of Mono Hills. The main branch of the river system flows for 126 km in a general northwest to southeast direction and ultimately drains to Lake Ontario at a location approximately 35 km downstream (as the crow flies) of the study area. The watershed of the Humber River includes a combination of mostly rural and urban land use (54% and 33%, respectively, of the total watershed area) (Toronto and Region Conservation, 2016).

1.2 Purpose and Scope

Modifications to the roadways at the intersection of Albion Vaughan Road and King Street East have the potential to influence channel conditions at Cold Creek and the Main Humber River. To that end, a fluvial geomorphic assessment was completed along defined ‘reach lengths’ (i.e., sections of the watercourse that include similar geomorphic characteristics and controls) to assess meander potential and channel stability. The results of the fluvial geomorphic assessments will be used to support the Class EA process, as well as to assist with the preliminary design of any modifications to the watercourse crossings (e.g., alterations or replacement of bridges or culverts).

The specific work scope involved the following tasks:

- Background review and field inspections at all reach lengths to characterize channel morphology and assess bed and bank stability (assuming that well defined channel conditions are applicable);
- Meander belt width assessment at select reach lengths to determine the meander potential of the stream in the vicinity of the roadway improvements; and
- 100-year erosion evaluation at select reach lengths to determine the long-term erosion potential of the stream in the vicinity of the roadway improvements.

Each of these tasks is described below in Section 2.0.

2.0 METHODOLOGY

2.1 Background Review and Field Inspections

The following background information was reviewed to assist with the fluvial geomorphic assessment for the roadways at the intersection of Albion Vaughan Road and King Street East:

- Aerial photography from 1951 and 1981 that was retrieved from the National Air Photo Library.
- Orthoimagery from 2016 that was obtained from Digital Globe.
- Topographic data (5 m contour lines in 2016) that was retrieved from the Ministry of Natural Resources’ Land Information Ontario database;

- Topographic data (1 m contour lines in 2011) that was retrieved from the York Region spatial data service; and
- Historical records of the founding of the Town of Bolton that were obtained from the Town of Caledon's 2009 Cultural Heritage Landscapes Inventory report.

In addition to the background review, a site visit was completed on August 9, 2017. The site reconnaissance included a walk-over at all relevant reach lengths of Cold Creek and the Main Humber River to assess channel morphology and to identify any areas of instability. Further to these general inspections, field activities at the reach lengths involved substrate sampling and Rapid Geomorphic Assessments (RGAs). The RGAs were completed along a 200 m reach; centered over each relevant crossing location.

The field data was used to inform the meander belt width and 100-year erosion assessments (Sections 2.2 and 2.3).

2.2 Meander Belt Assessment

A meander belt width assessment was conducted at select reach lengths of Cold Creek and the Main Humber River 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 and historical aerial photographs/orthoimagery from 1951, 1981, and 2016, in order to delineate the reach lengths and examine historical land use and channel patterns;
- Field reconnaissance at the identified reach lengths (described in Section 2.1) to evaluate current conditions and obtain measurements of channel geometry; and
- Delineation/quantification of meander belt widths at select reach lengths 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 select reach lengths of Cold Creek and the Main Humber River 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 existing watercourse crossings 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

To account for changes in fluvial geomorphologic characteristics along a channel, watercourses are typically separated into reaches that display similar physical characteristics and controls on channel morphology. With reference to Figures 2 and 3, field observations in combination with a review of available base mapping and air photographs identified a single reach length at both Cold Creek (described herein as CC-01) and the Main Humber River (HR-01). The delineation of the reach breaks for CC-01 and HR-01 (i.e., upstream and downstream boundaries of the reach length at each of the subject watercourses) were based on observed changes in channel confinement and hydrology. For CC-01, the upstream reach break is located in an area where the meander pattern

of the channel transitions from an unconfined condition to a mostly fully confined condition, while the downstream reach break is located at the downstream end of the watercourse (i.e., confluence point with the Main Humber River). In a fairly similar way, for HR-01, the upstream reach break is located in an area where the meander pattern of the channel transitions from fully confined to partially confined conditions, while the downstream reach break is located immediately downstream of the confluence with a prominent tributary (i.e., Cold Creek).

The key characteristics of the reach lengths at Cold Creek and the Main Humber River are outlined in Table 1 and Table 2. Photographs of the reach lengths are presented in Attachment A.

Table 1: Key Results from Background Review and Field Inspections at Cold Creek (CC-01)

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance
CC-01	- Medium sized permanent watercourse with well-defined channel (i.e., incised with visible bed and bank) that includes: - mostly alluvial controls; - low sinuosity at the upstream end of the reach (i.e., upstream of the King Street East crossing) and high sinuosity at the downstream end of the reach (i.e., downstream of the King Street East crossing); - limited bed morphology (flat) in most sections of the reach, although some riffle-pool sequences were noted upstream of the Albion Vaughan Road crossing; - wide range of side slopes (20º to 80º); - low to moderate entrenchment; and - a few examples of instream woody debris or overhanging trees. - Erosion and/or depositional features at the channel that include: - examples of sediment deposition along the bed (including the formation of mid-channel bars or islands in the area immediately downstream of the King Street East crossing); and - several instances of bank erosion (including undercutting of banks in the	6 to 17 m	- Fine sand at channel bed (D_{50} = 0.15 to 0.35 mm) - Silt to Fine sand at banks (D_{50} = 0.045 to 0.15 mm) - Instances of large gravels and cobbles were observed at the banks and/or bed of channel in a number of locations. This included the section of channel at and immediately upstream and downstream of the Albion Vaughan Road crossing.	- Riparian areas generally include a dense cover of grasses (manicured and wild/natural) and shrubs, noting that the upstream and downstream overbank zones support an increased number of larger/mature trees.	- The existing crossing structures at Albion Vaughan Road and King Street East include single span bridges with total openings of 9 m and 13 m, respectively. These bridges were shown to be in good condition, with little to no evidence of degradation. - Instances of channel hardening were noted in several locations. This included: - Cinder blocks (assumed to be used as a makeshift retaining wall) that were observed at the right bank of the channel at a location 75 m upstream of the Albion Vaughan Road crossing; and - Large boulder slabs that were observed at the left bank of the channel at a location 25 m upstream of the Albion Vaughan Road crossing. - A prominent meander pattern was observed downstream of the King Street East crossing. The channel at this location follows a broad sweeping shape (along a north-south axis – trending first toward the east and then to the west) for a full meander length before it joins the Main Humber River. The outer meander bend on the eastern side of the valley is located in close proximity to the valley wall (but remains unconfined), while the outer meander bend on the western side of valley is located immediately adjacent to Albion Vaughan Road (i.e., approximately 50 m section of channel was shown to be within 5 m of the road embankment). The banks of the channel at the outer meander bend on the western side of valley included large boulders and rootwad structures. It is assumed that these features form a vegetated buttress and were installed as part of a previous channel remediation/stabilization project.

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance
	area downstream of the King Street East crossing [specifically the outer meander bend on the western side of the valley]), recognizing however that the riparian zones and the upper portion of the banks were for the most part well protected against erosion with a dense cover of vegetation. - Existing channel pattern at the study reach supports a mostly fully confined condition (i.e., channel is fully confined at the upstream end of the reach, and, to a lesser extent, at the downstream end of the reach).				

Table 2: Key Results from Background Review and Field Inspections at the Main Humber River (HR-01)

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance
HR-01	- Large sized permanent watercourse with well-defined channel that includes: - mostly alluvial controls; - moderate sinuosity (i.e., channel planform is relatively straight in the vicinity of the existing bridge crossing at Albion Vaughan Road, but mostly meandering for all other sections of the reach).; - limited bed morphology (mostly flat);	12 to 19 m	- Coarse sand with gravels at channel bed (D_{50} = 4 mm) - Silty fine sand at banks (D_{50} = 0.08 mm)	- Riparian areas upstream and downstream of the existing bridge crossing at Albion Road generally include a dense cover of shrubs, grasses and small trees, noting that, at several residential properties that border the river, the riparian zone is	- The existing crossing structure at Albion Vaughan Road includes a multi-span bridge with a total span of approximately 32 m. This bridge was shown to be in good condition, with little to no evidence of degradation. - The reach length includes three other watercourse crossings at locations upstream of Albion Vaughan Road. These include (in order from upstream to downstream): Queen Street North, Humberlea Road, and King Street East.

Reach Length	General Description of Channel Morphology and/or Water Feature Conditions	Bankfull Width	Channel Substrate	Riparian Conditions	Additional Remarks from Background Review and Field Reconnaissance
	- wide range of side slopes (20º to 80º); - moderate entrenchment; and - a few examples of instream woody debris or overhanging trees. - Erosion and/or depositional features at the channel that include: - examples of sediment deposition along the bed; and - instances of bank erosion, recognizing however that the riparian zones and the upper portion of the banks were for the most part well protected against erosion with a dense cover of vegetation. - Existing channel pattern at the study reach supports partially confined conditions (i.e., channel is partially confined to the north side of the valley wall).			characterized by manicured grass.	

The completed RGA forms for CC-01 and HR-01 are presented in Attachment B, while grain size results for these reaches are presented in Attachment C. The results of the RGAs suggest that CC-01 is in a transitional state with evidence of aggradation and widening, while HR-01 is generally in-regime.

3.2 Meander Belt Assessment

3.2.1 Aerial Photography Analysis

A historical air photograph analysis was completed in support of the meander belt assessment, and relied on aerial photography and orthoimagery from 1951, 1981, and 2016. These photographs were used to evaluate changes in channel patterns and surrounding land use over time for the reach lengths Cold Creek and the Main Humber River (CC-01 and HR-01). The results of the historical air photograph analysis are illustrated on Figures 2 and 3, and described below.

The air photograph analysis (1951-2016) showed that historical land use in the vicinity of CC-01 and HR-01, as well as in the upstream catchment areas of these watercourses, was predominated by agriculture since at least 1951, noting that the Town of Bolton (centered around of the Main Humber River and founded in the 1800s) and Bolton Camp (a recreation area – located in the headwater area of Cold Creek and established in approximately 1922) were inherently present for the full duration of the air photo record. Between 1951 and present day, the air photos/images demonstrated that land use transitioned to primarily urban development. This included a marked increase in residential development in the Town of Bolton and surrounding areas, as well as the emergence of increased commercial and recreational land use. The urban development was also accompanied by roadway improvement projects in the vicinity of the intersection of Albion Vaughan Road and King Street East, including the construction of the west extension of King Street East prior to 1981, and the south extension of Albion Vaughan Road (to Highway 50) prior to 2016.

Riparian vegetation within the areas 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 channels at CC-01 and HR-01 were visible on a fairly consistent basis on all of the available aerial photography and orthoimagery.

The results of the historical air photo analysis demonstrated that channel patterns at CC-01 in the area upstream of the King Street East crossing have been characterized by low to moderate sinuosity for the duration of the air photo record, noting that the channel has included only minor adjustments over time (e.g., downstream shift/migration of the channel in a few locations). In comparison, the channel pattern downstream of the King Street East crossing was shown to be characterized by a prominent meander pattern. As described in Section 3.1, the channel at this location follows a broad sweeping shape (along a north-south axis – trending first toward the east and then to the west) for a full meander length before it joins the Main Humber River. A review of the historical air photos shows that the meander pattern downstream of the King Street East crossing has included marked examples of lateral and downstream migration over time. The outer meander bend on the eastern side of the valley has exhibited lateral migration toward the valley wall, especially prominent between 1951 and 1981, while the outer meander bend on the western side of valley has displayed downstream migration and rotation toward the Main Humber River (and, to a lesser extent, lateral migration toward Albion Vaughan Road). These observed patterns of channel migration are likely indicative of the location of the meander bends relative to the valley and local infrastructure, recognizing that the outer meander bend on the eastern side of the valley is largely unconfined (i.e., no visible constraint to adjust laterally), while the outer meander bend on the western side of the valley is located within 5 m of Albion Vaughan Road (i.e., potential constraint to lateral migration).

Channel conditions at HR-01 have been characterized by moderate sinuosity for the duration of the air photo record. These channel patterns have remained relatively unchanged between 1951 and present, noting only minor adjustments in a few locations (e.g., downstream or lateral migration of the channel in a few locations). As an exception, a discrete section of channel that runs adjacent to the Town of Bolton (and is centered over the watercourse crossing location at Humberlea Road) included a more pronounced shift in alignment between 1951 and 1981. This portion of channel appears to coincide with the location of the former mill that was historically operated in the Town of Bolton in the 1800s and early 1900s, and had been subsequently decommissioned/demolished in 1968. Although not apparent in the air photo record, a review of the historical documentation on the founding of the Town of Bolton suggest that the Main Humber River in the area of the former mill previously supported multiple channels with one or more inline ponds. It is possible that the river channel was altered between 1951 and 1981 (i.e., diverted or re-aligned) as part of the decommission of the mill and/or the construction of Humberlea Road.

3.2.2 Belt Width Calculations

The meander belt width estimates at Cold Creek (CC-01) and Humber River (HR-01) are illustrated on Figures 4 and 5, respectively, recognizing that the assessment assumed no major long term changes in the hydrologic regime (i.e., flow duration and frequency). A summary of the meander belt width estimates is provided below.

The meander belt width estimate for the study reach at CC-01 is summarized as follows:

- A preliminary meander belt width was measured to be approximately 110 m. This estimate of the preliminary belt width considered the following:
  - The meander pattern at the study reach was observed to be largely confined by valley walls along both sides of the planform. As such and in accordance with TRCA guidelines, the meander belt width was aligned with the average distance between the top and bottom of the valley walls for the full extent of the study reach. The available topographic data was used to infer the top of valley wall along both sides of the planform (estimated to be at an average elevation of roughly 210 to 215 m asl), recognizing that a detailed topographic survey should be completed to refine this estimate.
- The existing meander belt width was estimated to be approximately 122 m. The calculation of the existing belt width combines the preliminary meander belt width with the average bankfull width of the channel (12 m), as estimated in the field (e.g., 110 m + 12 m = 122 m).
- A final meander belt width was estimated to be approximately 134 m. This final belt width combines the estimated existing belt width with a safety factor of 1.1 in order to account for anticipated local changes in upstream hydrology and potential channel movement.

The meander belt width estimate for the study reach at HR-01 is summarized as follows:

- A preliminary meander belt width was measured to be approximately 200 m. This estimate of the preliminary belt width considered the following:
  - The channel at the study reach was observed to be partially confined along the left bank (north) side of the valley for the duration of the historical air photo analysis. As such and in accordance with TRCA guidelines, the meander belt width for the left bank side of the channel was aligned with the average distance between the top and bottom of the valley walls for the full extent of the study reach. The available topographic data was used to infer the top of valley wall along the left bank of the channel planform

(estimated to be at an average elevation of roughly 225 to 230 m asl), recognizing that a detailed topographic survey should be completed to refine this estimate. The meander belt width for the right bank (south) side of the channel was delineated based on the outer-most meander bends at the study reach.

  - The estimates of the preliminary belt width were shown to vary due to the irregular pattern/form of the right bank valley wall (refer to Figure 5).

- The existing meander belt width was estimated to be approximately 216 m. The calculation of the existing belt width combines the preliminary meander belt width with the average bankfull width of the channel (16 m), as estimated in the field (e.g., 200 m + 16 m = 216 m).
- A final meander belt width was estimated to be approximately 238 m. This final belt width combines the estimated existing belt width with a safety factor of 1.1 in order to account for anticipated local changes in upstream hydrology and potential channel movement.

3.3 100-Year Erosion Limit

In accordance with TRCA protocols, the 100-year erosion limit for the Cold Creek (CC-01) and the Main Humber River (HR-01) were assessed based on the average rate of channel migration at the relevant study reach. In general, the estimates considered all of the available photos/images (i.e., 1951, 1981, and 2016) and available topographic data.

The 100-year erosion limit at the reach length of the Cold Creek (CC-01) was assessed based on the average rate of channel migration at the following major meander bends:

- Meander Bend #1 (located upstream of the King Street East crossing) – average migration rate of 5 cm/yr.
- Meander Bend #2 (located upstream of the King Street East crossing) – average migration rate of 10 cm/yr.
- Meander Bend #3 (located downstream of the King Street East crossing at the outer meander bend on the eastern side of the valley wall) – average migration rate of 47 cm/yr.
- Meander Bend #4 (located downstream of the King Street East crossing at the outer meander bend on the eastern side of the valley wall) – average mitigation rate of 23 cm/yr.

Based on the historical analysis, the 100-year erosion limit at CC-01 was estimated to be approximately 106 m. This 100-year erosion limit was determined by extending the average rate of migration at the most active meander bend (Meander Bend #3 at CC-01) over a 100-year time span (0.47 m/yr * 100 = 47 m), and then applying this distance to either side of the average width of the bankfull channel (47 m * 2 + 12 m = 106 m).

The 100-year erosion limit at HR-01 was assessed based on the average rate of channel migration at the following major meander bends:

- Meander Bend #1 (located 730 m upstream from the bridge crossing at Albion Vaughan Road) – average migration rate of 32 cm/yr.
- Meander Bend #2 (located 660 m upstream from the bridge crossing at Albion Vaughan Road) – average migration rate of 24 cm/yr.

Based on the historical analysis, the 100-year erosion limit at HR-01 was estimated to be approximately 80 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 (0.32 m/yr *100 = 32 m), and then applying this distance to either side of the average width of the bankfull channel (32 m * 2 + 16 m = 80 m).

4.0 SUMMARY AND CONCLUSIONS

A fluvial geomorphic assessment was completed at study reaches of Cold Creek (CC-01) and the Main Humber River (HR-01) to support a Schedule B Municipal Class Environmental Assessment (EA) for proposed roadway improvements at the intersection of Albion Vaughan Road and King Street East in the Town of Caledon, Ontario. The key findings of the assessment are summarized below:

- The results of the field studies and historical air photo analysis at the reach lengths of Cold Creek (CC-01) and the Main Humber River (HR-01) suggest that the channel at CC-01 is transitional or stressed with evidence of aggradation and widening, while the channel at HR-01 is generally stable, noting the following observations:
  - The channel planform of HR-01 is relatively straight in the vicinity of the crossing location at Albion Vaughan Road and meandering in the areas upstream and downstream of the crossing, while the planform at CC-01 is similarly straight in the vicinity of the crossing locations at Albion Vaughan Road and King Street East, but variable in sinuosity in the areas upstream and downstream of the crossings (i.e. low sinuosity upstream of the King Street East crossing and high sinuosity downstream of the King Street East crossing);
  - The geometry of the channels at CC-01 and HR-01 is slightly to moderately entrenched (i.e., well-incised between banks with variable slopes), while the profile of the channels is in most cases flat;
  - The channels at CC-01 and HR-01 include instances of bank erosion and bed deposition in several locations, recognizing however that the banks and riparian zones are for the most part well protected against erosion with a dense cover of vegetation; and
  - With few exceptions, the channels at CC-01 and HR-01 have demonstrated only minor adjustments for the duration the historical air photo record; however, the prominent meander pattern that is located downstream of the King Street East crossing has included more substantial examples of lateral and downstream migration over time (i.e., the outer meander bend on the eastern side of the valley has exhibited lateral migration toward the valley wall, while the outer meander bend on the western side of valley has displayed downstream migration and rotation toward the Main Humber River, and, to a lesser extent, lateral migration toward Albion Vaughan Road).
- Based on the results of the desktop analysis, the meander belt width of the reach length of Cold Creek (CC-01) is approximately 134 m, while the meander belt width at the reach length of the Main Humber River (HR-01) is 238 m. In accordance with TRCA guidelines, the meander belt width for CC-01 and HR-01 was aligned with the average distance between the top and bottom of the valley walls for the full extent of the study reach (both sides of the valley for CC-01 [fully confined] and the north side of the valley only for the Main Humber River [partially confined]).
- Based on the results of the desktop analysis, the 100-year erosion limit at the reach lengths of Cold Creek (CC-01) and the Main Humber River (HR-01) is 106 m and 80 m, respectively.

It is understood that roadway improvements in the vicinity of the intersection of Albion Vaughan Road and King Street East will involve modifications of the existing crossing structures at Cold Creek (single span bridges at Albion Vaughan Road and King Street East with total openings of 9 m and 13 m, respectively) and the Main Humber River (multi-span bridge at Albion Vaughan Road with an approximate span of 32 m). More specifically, it is understood that the existing bridges at these crossing locations will be extended laterally to accommodate the planned road improvement works at and in the vicinity of the intersection of Albion Vaughan Road and King Street

East. 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 reaches at the Cold Creek (CC-01) and the Main Humber River (HR-01), 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, noting as well that the objective of the Class EA described herein relates to intersection improvements at Albion Vaughan Road and King Street East and not the upgrade or replacement of the structures in the general area. Furthermore, Golder is of the opinion that maintaining a crossing span less than the estimated dimensions of the meander belt width and 100-year erosion limit at CC-01 and HR-01 would be appropriate for this particular study, with consideration of the following:

- The channels of Cold Creek and the Main Humber River in the vicinity of the crossings at King Street East and/or Albion Vaughan Road are relatively straight and stable, noting that:
  - The channels at these crossing locations, and, for that matter, at locations immediately upstream and downstream of the crossing in the case of the Main Humber River, have shown limited evidence of movement over the period of the historical air photo record;
  - There is no evidence to suggest that meander bends located upstream of the crossings are at risk of encroaching on existing or future infrastructure at Albion Vaughan Road and King Street East (via lateral and/or downstream migration); and
  - Comparatively high rates of channel migration (e.g., 47 cm/year) were noted at the downstream end of Cold Creek (i.e., prominent meander pattern located downstream of King Street East that has exhibited notable lateral and downstream migration through the air photo record); however, these observed meander patterns and associated rates of channel change appear unique to this particular portion of the reach length, recognizing that the estimated rates of channel migration at locations upstream of King Street East were noticeably lower (i.e., on the order of 5 to 10 cm/yr).
- The valleys of the Cold Creek and Main Humber River crossings have been re-configured to accommodate the existing crossing structures, recognizing that the existing bridge spans and adjoining abutments are located well within the boundaries of the estimated belt width and 100-year erosion limit of the study reaches; and
- Any alterations to the existing crossing structures at the Cold Creek or the Main Humber River will be designed to convey up to and including the 100-year flow or Regional event; hence, major flows will be directed to the channel and crossing structure openings, with limited opportunities to outflank the crossing features and erode a separate flow path.

As mentioned above for Cold Creek, the prominent meander pattern that is located downstream of the King Street East crossing has included marked examples of lateral and downstream migration over time (i.e., the outer meander bend on the eastern side of the valley has exhibited lateral migration toward the valley wall, while the outer meander bend on the western side of valley has displayed downstream migration and rotation toward the Main Humber River, and, to a lesser extent, lateral migration toward Albion Vaughan Road). Field observations showed that the banks of the channel at the outer meander bend on the western side of valley included bank rehabilitation measures (i.e., large boulders and rootwad structures have been placed as part of a previous channel remediation/stabilization project); however, it is unclear if these rehabilitation measures have sufficiently mitigated the identified issues of channel instability. Information on the previous channel remediation/stabilization project

was not available at the time of reporting. To that end, any road improvements to Albion Vaughan Road in the area south of the intersection of King Street East will need to consider the observed channel conditions at Cold Creek in this area. Furthermore, any extension of the Albion Vaughan Road crossing structure at the Main Humber River should also consider the identified channel patterns, recognizing that the outer meander bend on the western side of valley is currently trending toward the existing crossing structure (based on the available air photo record). Monitoring and further investigation of the prominent meander pattern at Cold Creek is recommended to support any planning and design of future road improvement or maintenance activities at Albion Vaughan Road between King Street East and the watercourse crossing at the Main Humber River.

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,

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Figures:

Attachments:

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FIGURES

602750 602850 602950 603050 603150

4860292 4860192

CALEDON KING TOWNLINE SOUTH

KING ROAD

KING STREET EAST

COLD CREEK

COLD CREEK FLOW DIRECTION

ALBION VAUGHAN ROAD

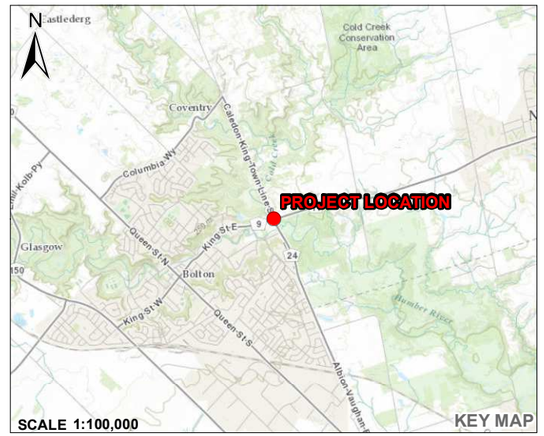
HUMBER RIVER (RIVIÈRE HUMBER)

HUMBER RIVER FLOW DIRECTION

OLD KING ROAD

LEGEND

- OBSERVED CHANNEL ALIGNMENT (2016)
- BRIDGE CROSSING
- FLOW DIRECTION



0 50 100

1:1,500 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2017
BASE IMAGERY - FIRST BASE SOLUTIONS, 2016
KEY MAP SOURCES: ESRI, HERE, DELORME, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
CIMA +

PROJECT
KING ALBION ROAD AND KING STREET EAST
TOWN OF CALEDON, REGION OF PEEL, ONTARIO

TITLE
SITE OVERVIEW AND FIELD OBSERVED REACH LENGTHS FOR COLD CREEK (CC-01) AND HUMBER RIVER (HR-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-10-16
DESIGNED	JT
PREPARED	JT
REVIEWED	JL
APPROVED	AF

PROJECT NO. 1664714 | CONTROL | REV. | FIGURE 1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
0 25mm

S:\Clients\Region_of_Peel\Caledon\99_PRO\1664714_Regional\Peel_Vaughan\KingEA\40_PROD\0006_Fluvial_Geomorph\Dwg\1664714-4006-C15-0001.mxd

602613 602713 602813 602913 603013 603113 603213

4860659 4860459 4860359 4860259 4860159 4860059

COLD CREEK

CALEDON KING TOWNLINE SOUTH

KING ROAD

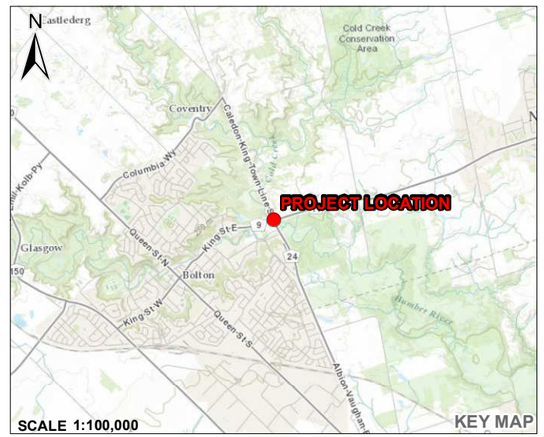
KING STREET EAST

ALBION VAUGHAN ROAD

HUMBER RIVER (RIVIÈRE HUMBER)

LEGEND

- OBSERVED CHANNEL ALIGNMENT (2016)
- OBSERVED CHANNEL ALIGNMENT (1981)
- INFERRED CHANNEL ALIGNMENT (1981)
- OBSERVED CHANNEL ALIGNMENT (1951)
- INFERRED CHANNEL ALIGNMENT (1951)
- BRIDGE CROSSING
- REACH BREAK



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1:2,000 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2017
BASE IMAGERY - FIRST BASE SOLUTIONS, 2016
KEY MAP SOURCES: ESRI, HERE, DELORME, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
CIMA +

PROJECT
KING ALBION ROAD AND KING STREET EAST
TOWN OF CALEDON, REGION OF PEEL, ONTARIO

TITLE
HISTORICAL CHANNEL PATTERNS FOR COLD CREEK (CC-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-10-16
DESIGNED	JT
PREPARED	JT
REVIEWED	JL
APPROVED	AF

PROJECT NO. 1664714 CONTROL REV. FIGURE **2**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
0 25mm

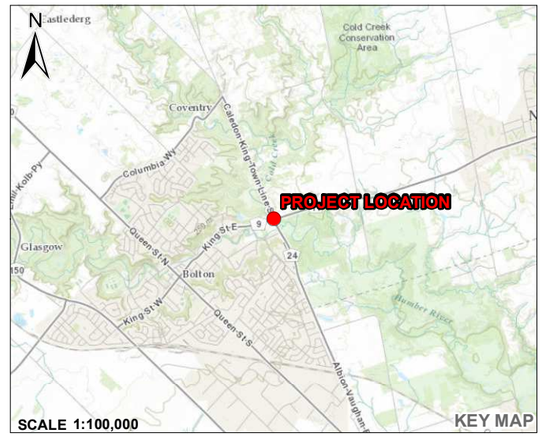
S:\Clients\Region_of_Peel\Caledon\99_PRO\1664714_Regional\Pref_Vaughan\KingEA\40_PROD\0006_Fluvial_Geomorph\dwg\1664714-40001-CC5-0002.mxd

600907 601907 602907

4859717

LEGEND

- OBSERVED CHANNEL ALIGNMENT (2016)
- OBSERVED CHANNEL ALIGNMENT (1981)
- INFERRED CHANNEL ALIGNMENT (1981)
- OBSERVED CHANNEL ALIGNMENT (1951)
- INFERRED CHANNEL ALIGNMENT (1951)
- BRIDGE CROSSING
- REACH BREAK
- WATERBODY
- WETLAND



0 250 500

1:7,500 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
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KEY MAP & BASE IMAGERY SOURCES: ESRI, HERE, DELORME, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
CIMA +

PROJECT
KING ALBION ROAD AND KING STREET EAST
TOWN OF CALEDON, REGION OF PEEL, ONTARIO

TITLE
HISTORICAL CHANNEL PATTERNS FOR HUMBER RIVER (HR-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-10-16
DESIGNED	JT
PREPARED	JT
REVIEWED	JL
APPROVED	AF

PROJECT NO. 1664714 CONTROL REV. FIGURE **3**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 0 25mm

S:\Clients\Region_of_Peel\Caledon\99_PRO\1664714_Region\of\Peel_VaughanKingEA\40_PROD\0006_Fluvial_Geomorph\dwg\1664714-A0001-c05-0003.mxd

602613 602713 602813 602913 603013 603113 603213

4860559 4860459 4860359 4860259 4860159 4860059

COLD CREEK

CALEDON/KING TOWNLINE SOUTH

KING ROAD

KING STREET EAST

ALBION VAUGHAN ROAD

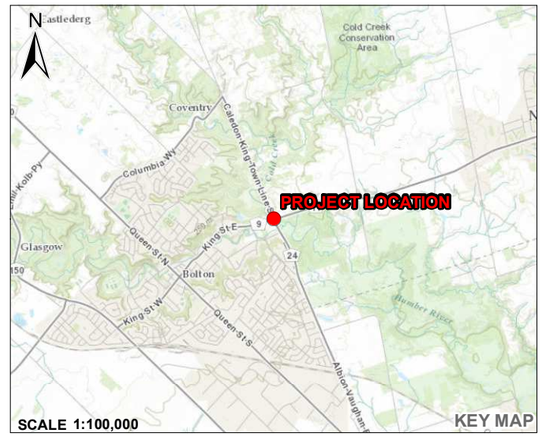
MEANDER BEND #1

MEANDER BEND #2

HUMBER RIVER (RIVIÈRE HUMBER)

LEGEND

- 1M CONTOUR ELEVATION
- OBSERVED CHANNEL ALIGNMENT (2016)
- OBSERVED CHANNEL ALIGNMENT (1981)
- INFERRED CHANNEL ALIGNMENT (1981)
- OBSERVED CHANNEL ALIGNMENT (1951)
- INFERRED CHANNEL ALIGNMENT (1951)
- MEANDER BELT AXIS (2016)
- BRIDGE CROSSING
- REACH BREAK
- ESTIMATED MEANDER BELT WIDTH



0 50 100

1:2,000 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016. REGION OF YORK
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2017
BASE IMAGERY - FIRST BASE SOLUTIONS, 2016
KEY MAP SOURCES: ESRI, HERE, DELORME, TOMTOM, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), SWISSTOPO, MAPMYINDIA, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
CIMA +

PROJECT
KING ALBION ROAD AND KING STREET EAST
TOWN OF CALEDON, REGION OF PEEL, ONTARIO

TITLE
MEANDER BEND LOCATIONS AND ESTIMATED MEANDER BELT WIDTH FOR COLD CREEK (CC-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-10-16
DESIGNED	JT
PREPARED	JT
REVIEWED	JL
APPROVED	AF

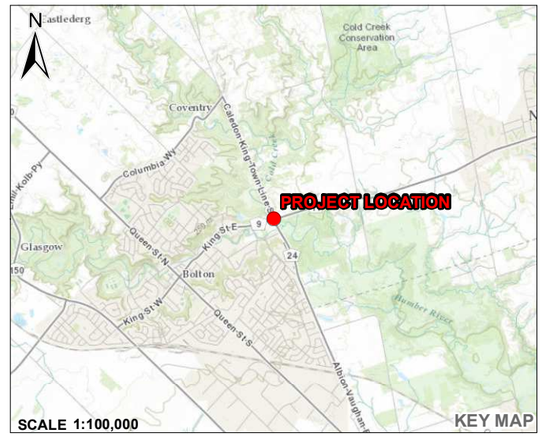
PROJECT NO. 1664714 CONTROL REV. FIGURE 4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
0 25mm

S:\Clients\Region_of_Peel\Caledon\99_PRO\11664714_RegionofPeel_VaughanKingEA\40_PROD\0006_Fluvial_Geomorph\Dwg\1664714-001-C5-0004.mxd

LEGEND

- 5M CONTOUR ELEVATION
- OBSERVED CHANNEL ALIGNMENT (2016)
- OBSERVED CHANNEL ALIGNMENT (1981)
- INFERRED CHANNEL ALIGNMENT (1981)
- OBSERVED CHANNEL ALIGNMENT (1951)
- INFERRED CHANNEL ALIGNMENT (1951)
- MEANDER BELT AXIS (2016)
- BRIDGE CROSSING
- REACH BREAK
- WATERBODY
- WETLAND



0 250 500

1:7,500 METRES

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
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PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
CIMA +

PROJECT
KING ALBION ROAD AND KING STREET EAST
TOWN OF CALEDON, REGION OF PEEL, ONTARIO

TITLE
MEANDER BEND LOCATIONS AND ESTIMATED MEANDER BELT WIDTH FOR HUMBER RIVER (HR-01)

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-10-16
DESIGNED	JT
PREPARED	JT
REVIEWED	JL
APPROVED	AF

PROJECT NO.	CONTROL	REV.	FIGURE
1664714			5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
0 25mm

S:\Clients\Region_of_Peel\Caledon\99_PRO\1664714_RegionofPeel_VaughanKingEA\40_PROD\0006_Fluvial_Geomorph\dwg\1664714-A001-C05-0005.mxd

ATTACHMENT A

Photographs

*Photograph 1: **Cold Creek (CC-01) at Albion Vaughan Road crossing**; looking upstream from the bridge at Albion Vaughan Road.*

*Photograph 2: **Cold Creek (CC-01) at Albion Vaughan Road crossing**; looking downstream from the bridge at Albion Vaughan Road.*

*Photograph 3: **Cold Creek (CC-01) 25 m upstream from Albion Vaughan Road crossing**; looking downstream at the bridge at Albion Vaughan Road.*

*Photograph 4: **Cold Creek (CC-01) 75 m upstream from Albion Vaughan Road crossing**; looking downstream.*

*Photograph 5: **Cold Creek (CC-01) 25 m downstream from Albion Vaughan Road crossing**; looking downstream.*

*Photograph 6: **Cold Creek (CC-01) at King Street East crossing**; looking upstream.*

*Photograph 7: **Cold Creek (CC-01) at King Street East crossing**; looking downstream from the bridge at King Street East.*

*Photograph 8: **Cold Creek (CC-01) at King Street East crossing**; looking upstream from the bridge at King Street East.*

*Photograph 9: **Cold Creek (CC-01) 25 m upstream from King Street East crossing**; looking upstream.*

*Photograph 10: **Cold Creek (CC-01) 75 m upstream from King Street East crossing (at the location of the Albion Vaughan Road crossing)**; looking downstream.*

*Photograph 11: **Cold Creek (CC-01) 25 m downstream from King Street East crossing**; looking downstream.*

*Photograph 12: **Cold Creek (CC-01) 75 m downstream from King Street East crossing**; looking downstream at the outer meander bend on the eastern side of the valley.*

*Photograph 13: **Cold Creek (CC-01) approx. 125 m downstream from King Street East crossing**; looking downstream at the outer meander bend on the western side of the valley.*

*Photograph 14: **Cold Creek (CC-01) approx. 150 m downstream from King Street East crossing**; looking downstream at left bank of the outer meander bend on the western side of the valley.*

*Photograph 15: **Cold Creek (CC-01) approx. 150 m downstream from King Street East crossing**; looking downstream at right bank of the outer meander bend on the western side of the valley.*

*Photograph 16: **Cold Creek (CC-01) approx. 150 m downstream from King Street East crossing**; looking upstream at the outer meander bend on the western side of the valley.*

*Photograph 17: **Cold Creek (CC-01) approx. 175 m downstream from King Street East crossing**; looking upstream at the outer meander bend on the western side of the valley.*

*Photograph 18: **Cold Creek (CC-01) approx. 225 m downstream from King Street East crossing**; looking upstream at at debris jam.*

*Photograph 19: **Humber River (HR-01) at Albion Vaughan Road crossing**; looking upstream from under the bridge at Albion Vaughan Road.*

*Photograph 20: **Humber River (HR-01) at Albion Vaughan Road crossing**; looking upstream from the bridge at Albion Vaughan Road.*

*Photograph 21: **Humber River (HR-01) 25 m upstream from Albion Vaughan Road crossing**; looking downstream at right bank.*

*Photograph 22: **Humber River (HR-01) 75 m upstream from Albion Vaughan Road crossing**; looking upstream.*

*Photograph 23: **Humber River (HR-01) 25 m downstream from Albion Vaughan Road crossing**; looking downstream.*

*Photograph 24: **Humber River (HR-01) 75 m downstream from Albion Vaughan Road crossing**; looking downstream.*

ATTACHMENT B

Results of Rapid Geomorphic Assessment

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 9-Aug-17 Location: Cold Creek

Field Staff: Brian Lingelbach, Colin Johnson Project #: 1664714

FORM/ PROCESS	GEOMORPHIC INDICATOR		PRESENT (YES) OR ABSENT (NO)	
	#	DESCRIPTION		
Evidence of Aggradation (AI)	1	Lobate bar		No
	2	Coarse material in riffles embedded	Yes	
	3	Siltation in pools		No
	4	Medial bars	Yes	
	5	Accretion on point bars		No
	6	Poor longitudinal sorting of bed materials	Yes	
	7	Deposition in the overbank zone		No
		RATIO OF INDICES [1]	3/7=0.42	
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		No
	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		No
	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		No
		RATIO OF INDICES [1]	1/10=0.1	
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	Yes	
	2	Occurrence of large organic debris	Yes	
	3	Exposed tree roots	Yes	
	4	Basal scour on inside meander bends		No
	5	Basal scour on both sides of channel through riffle		No
	6	Gabion baskets/concrete walls/etc. out flanked		No
	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	Yes	
	10	Exposed building foundation		No
		RATIO OF INDICES [1]	4/10=0.4	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(s)		No
	2	Single thread channel to multiple channel		No
	3	Evolution of pool-riffle form to low bed relief form	Yes	
	4	Cutoff channel(s)		No
	5	Formation of island(s)	Yes	
	6	Thalweg alignment out of phase meander form		No
	7	Bar forms poorly formed/reworked/removed		No
		RATIO OF INDICES [1]	2/7=0.28	
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4 [2]			0.3 -->Transitional	

Notes:

[1] Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices.

[2] 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 Enviroment, 2003. Stormwater Management Planning and Design Manual.*

RAPID GEOMORPHIC ASSESSMENT (RGA)

Date: 9-Aug-17 Location: Humber River

Field Staff: Brian Lingelbach, Colin Johnson Project #: 1664714

FORM/ PROCESS	GEOMORPHIC INDICATOR #	DESCRIPTION	PRESENT (YES) OR ABSENT (NO)	
Evidence of Aggradation (AI)	1	Lobate bar		No
	2	Coarse material in riffles embedded		No
	3	Siltation in pools		No
	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
		RATIO OF INDICES [1]	0/7=0	
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)		No
	4	Undermined gabion baskets/concrete aprons/etc.	N/A	
	5	Scour pools d/s of culverts/stormsewer outlets	N/A	
	6	Cut face on bar forms		No
	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		No
		RATIO OF INDICES [1]	0/10=0	
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	Yes	
	2	Occurrence of large organic debris	Yes	
	3	Exposed tree roots	Yes	
	4	Basal scour on inside meander bends		No
	5	Basal scour on both sides of channel through riffle		No
	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.	N/A	
	9	Fracture lines along top of bank	Yes	
	10	Exposed building foundation	N/A	
		RATIO OF INDICES [1]	4/10=0.4	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cute(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
		RATIO OF INDICES [1]	0/7=0	
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4 [2]			0.1 -->In Regime	

Notes:

[1] Ratio of Indices or Factor = Number of Indices Present / Total Number of Indices.

[2] 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.

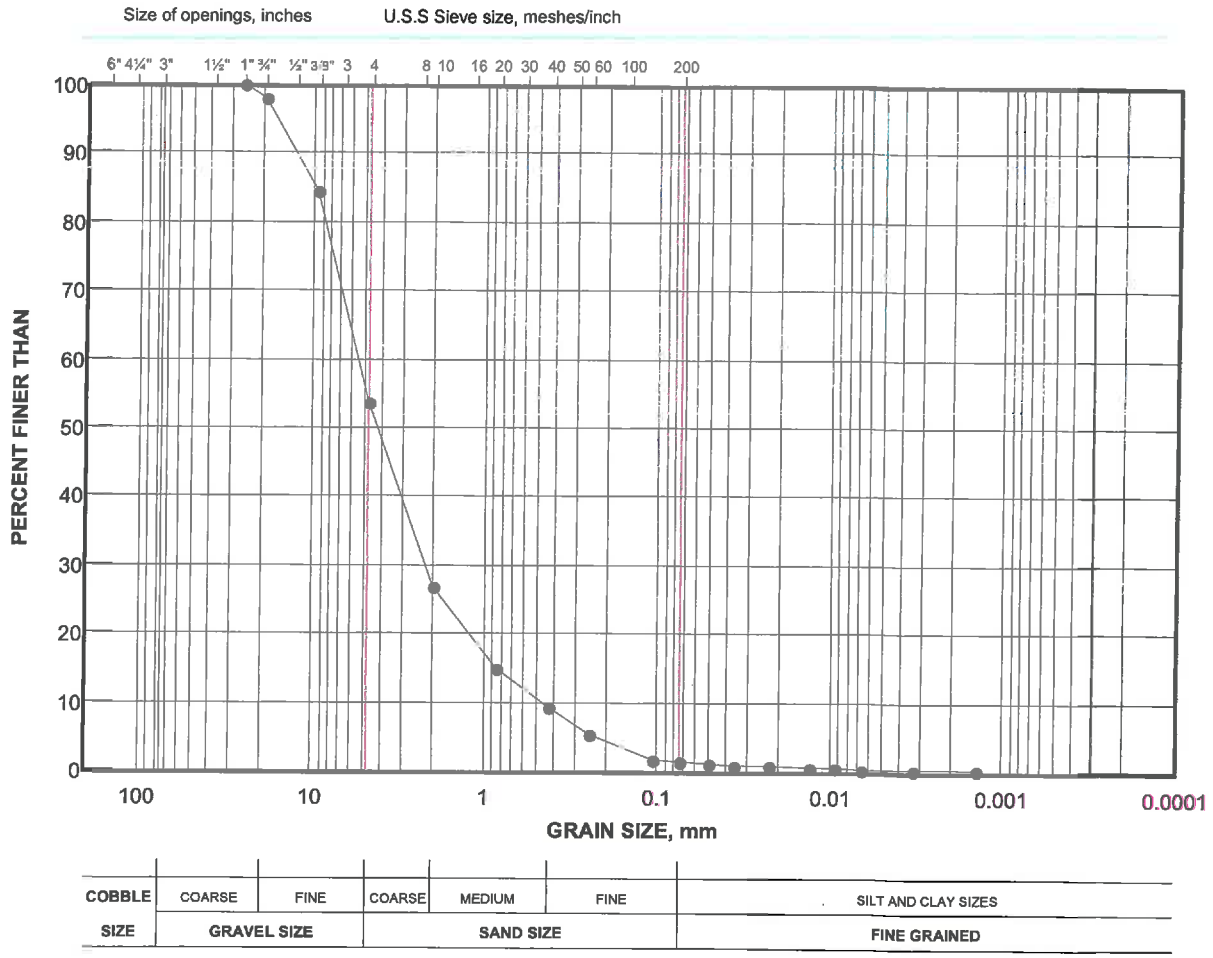
Sourced and adapted from: *Ontario Ministry of the Enviroment, 2003. Stormwater Management Planning and Design Manual.*

ATTACHMENT C

Grain Size Distribution Curves

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	Humber01A

Project Number: 1664714

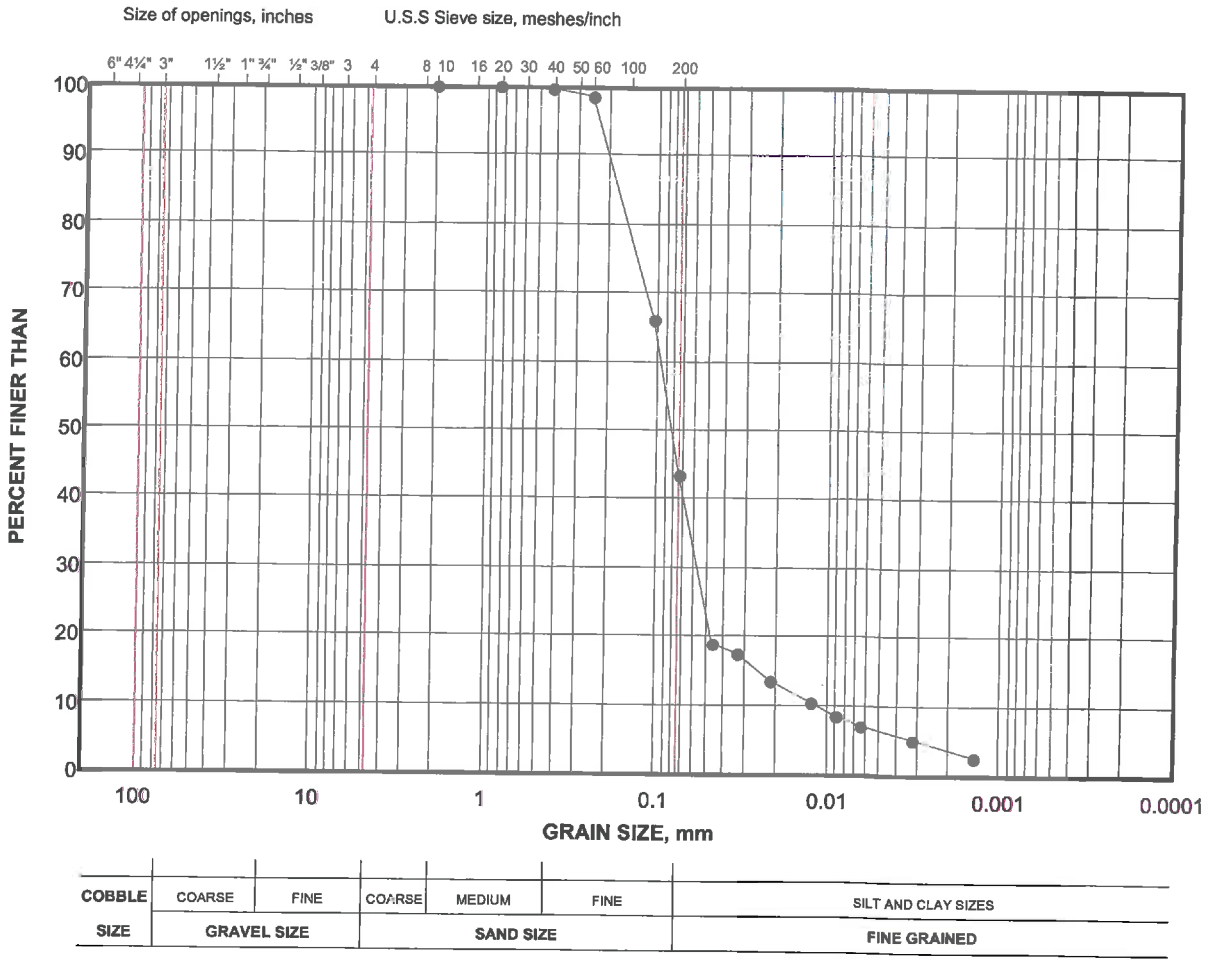
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	Humber01B

Project Number: 1664714

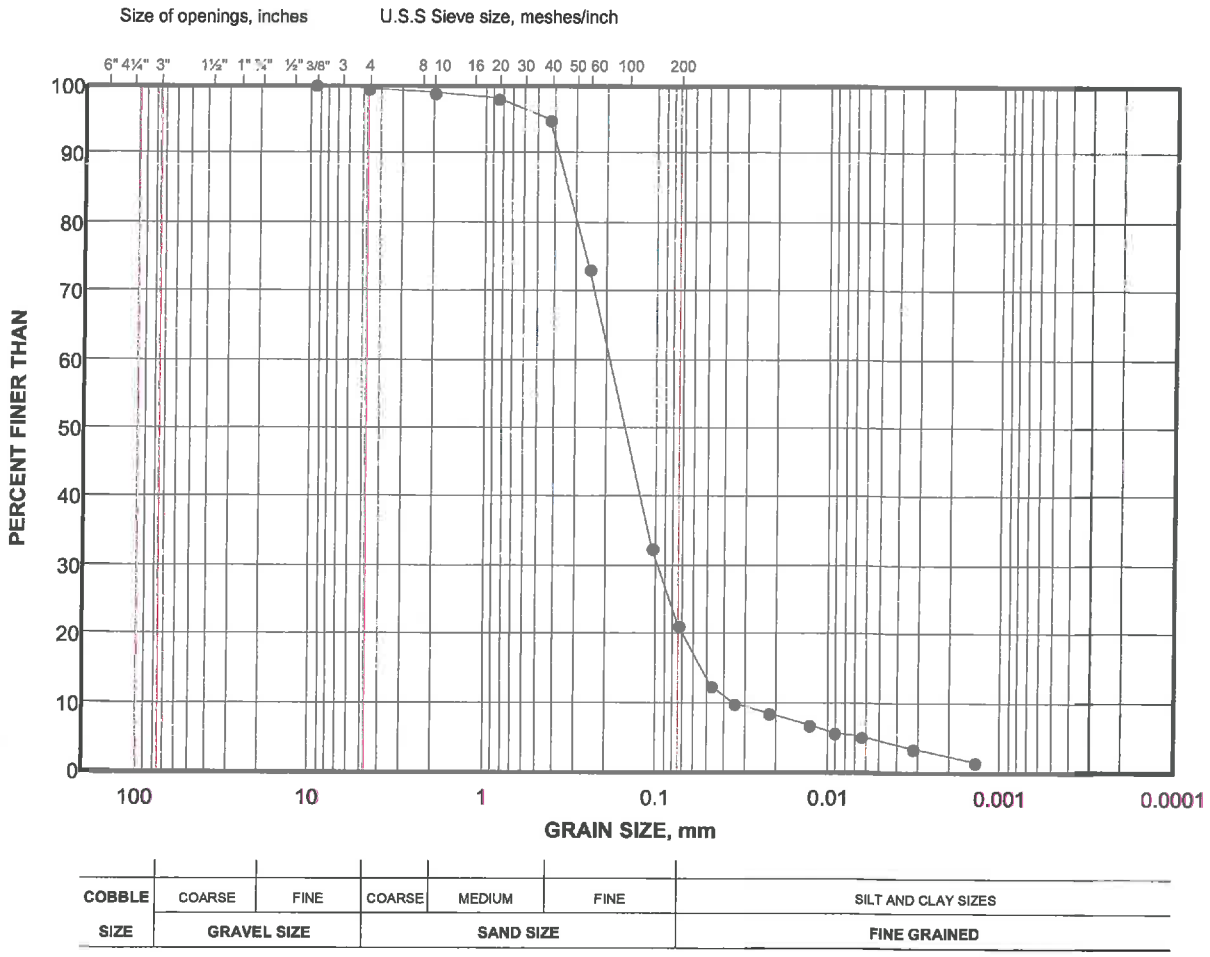
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC00A

Project Number: 1664714

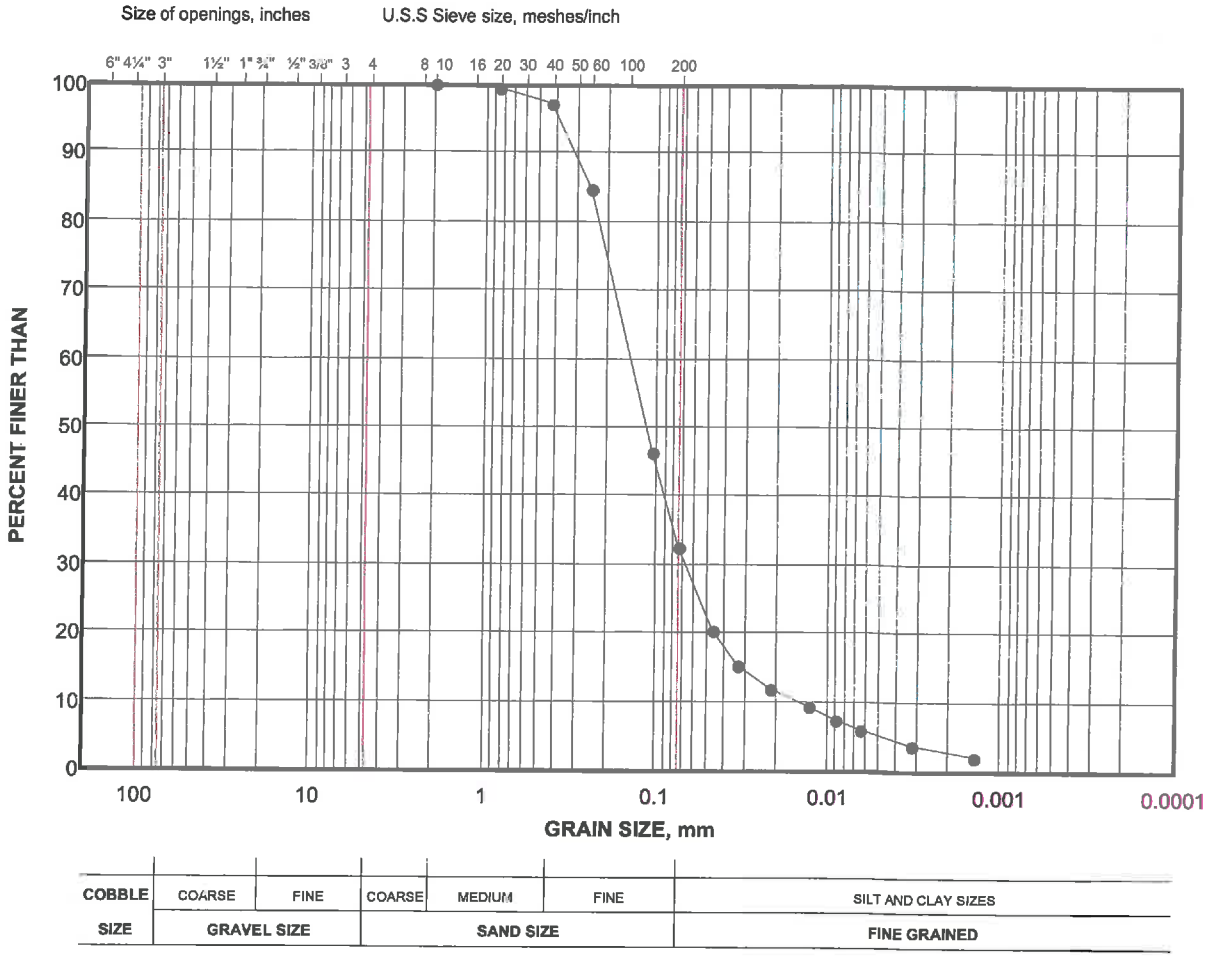
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC00B

Project Number: 1664714

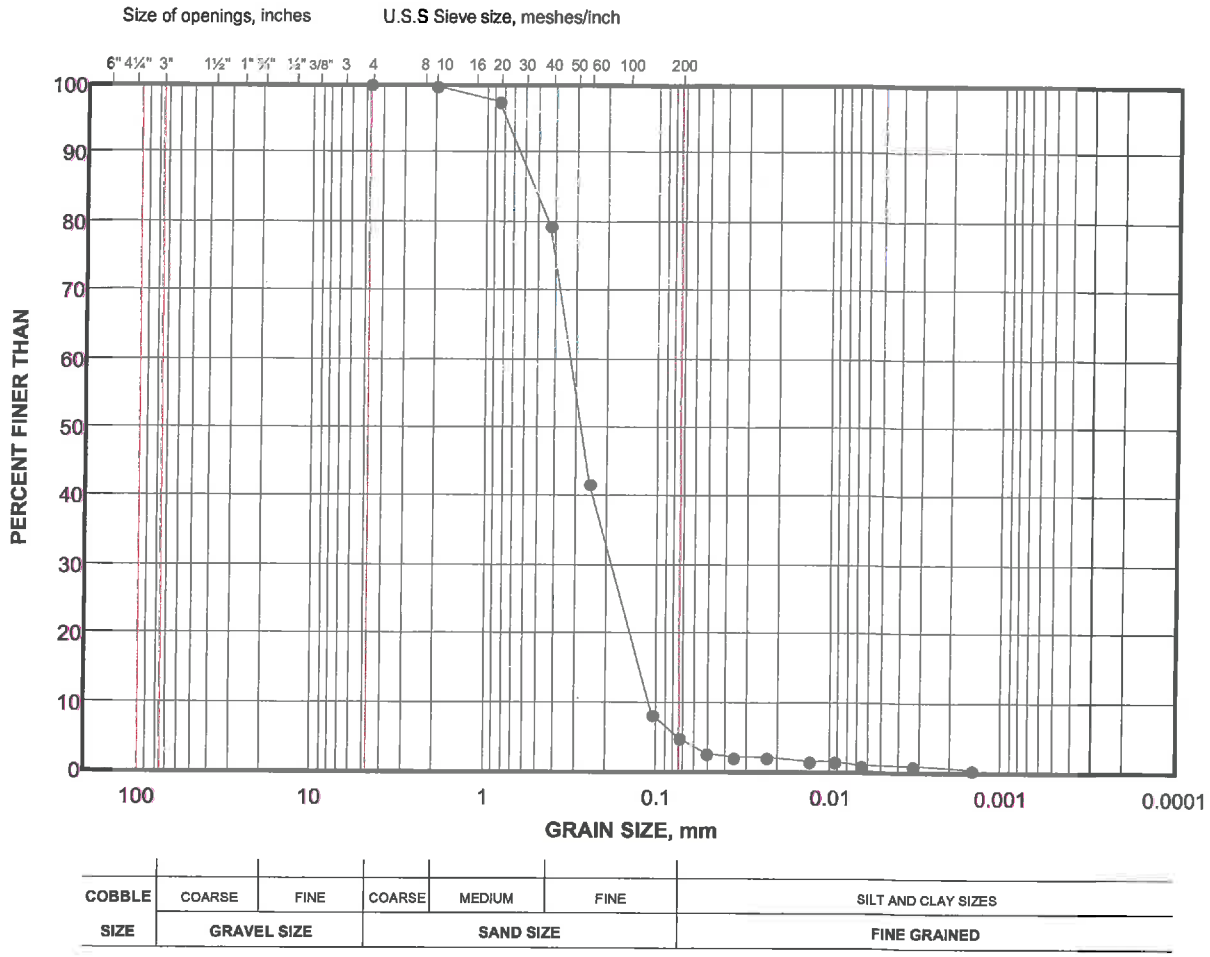
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC01A

Project Number: 1664714

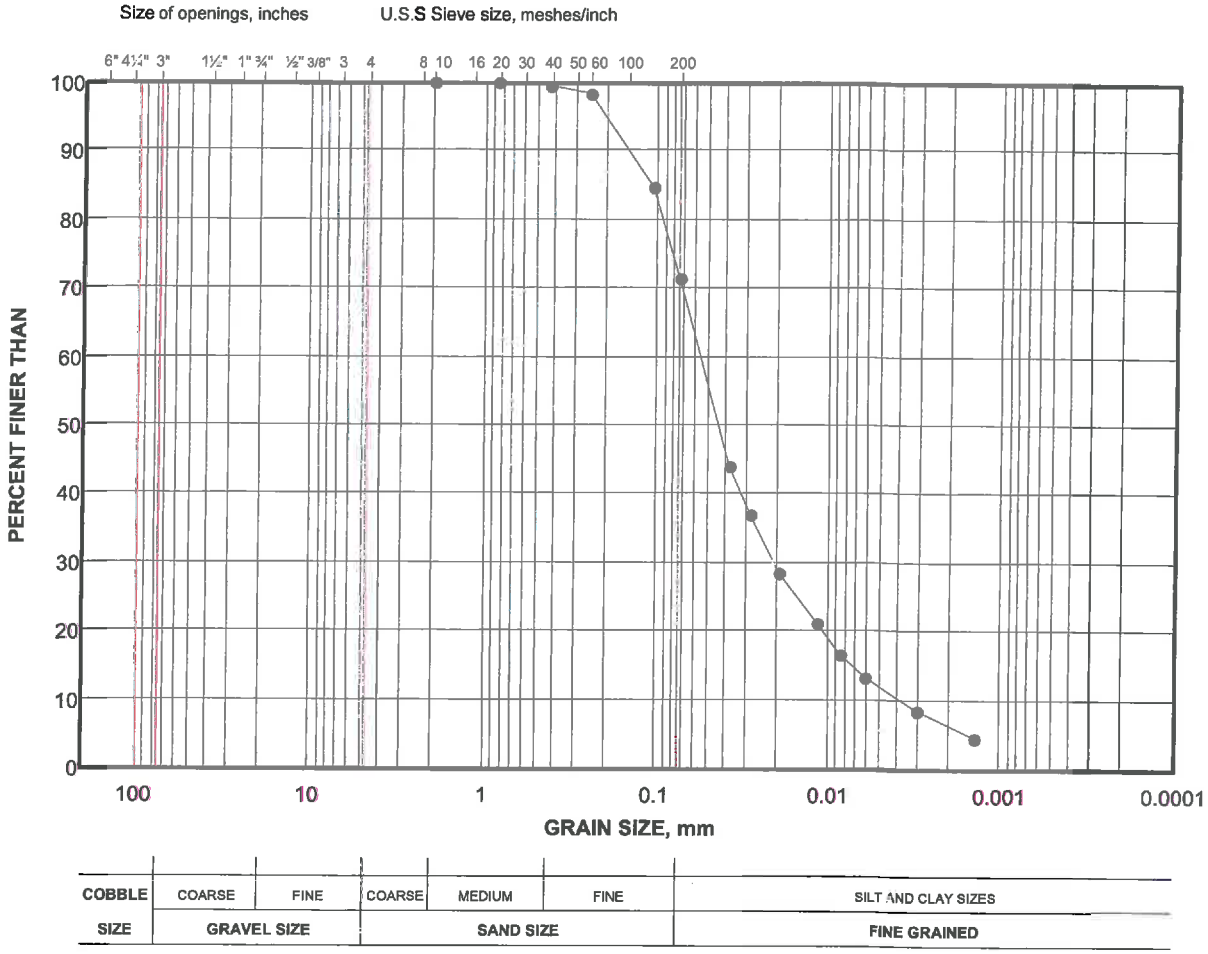
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC01B

Project Number: 1664714

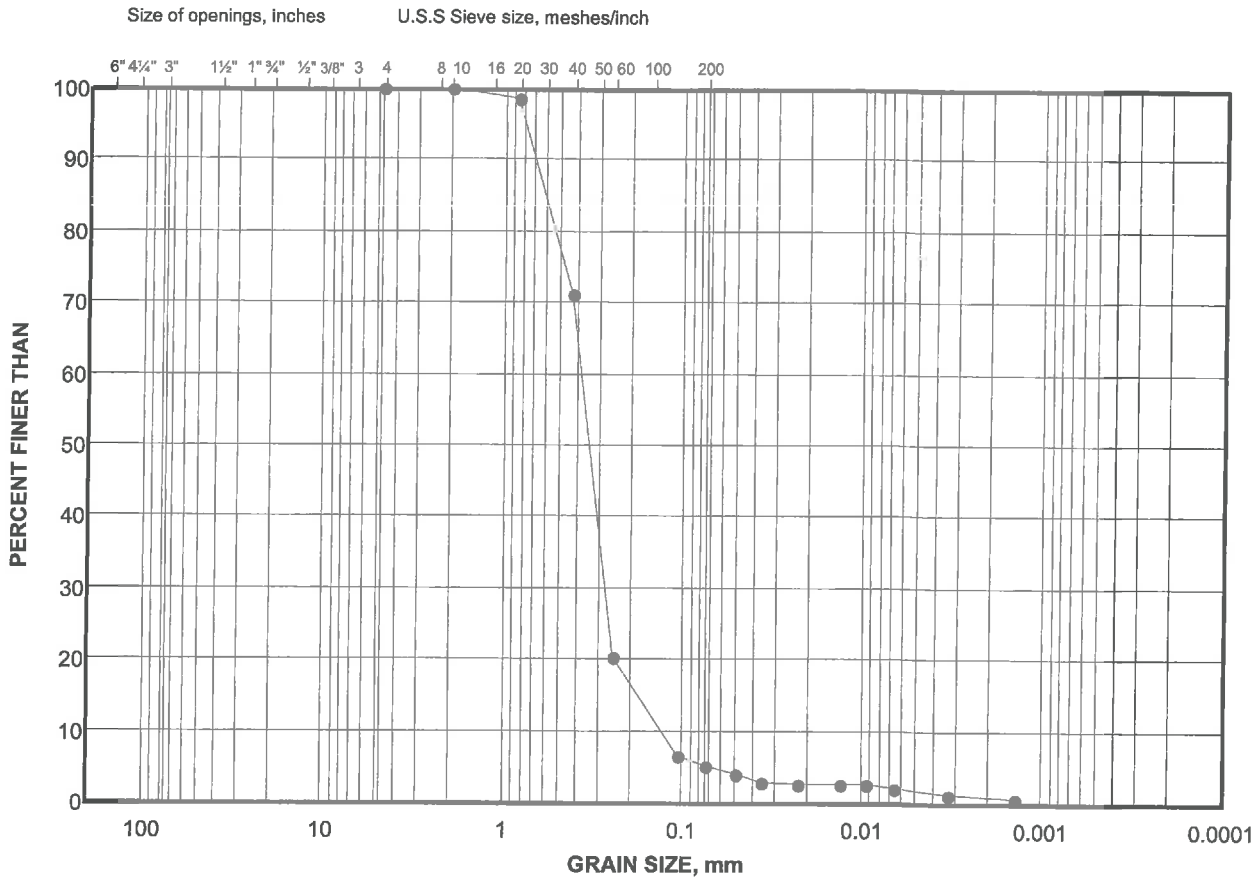
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC02A

Project Number: 1664714

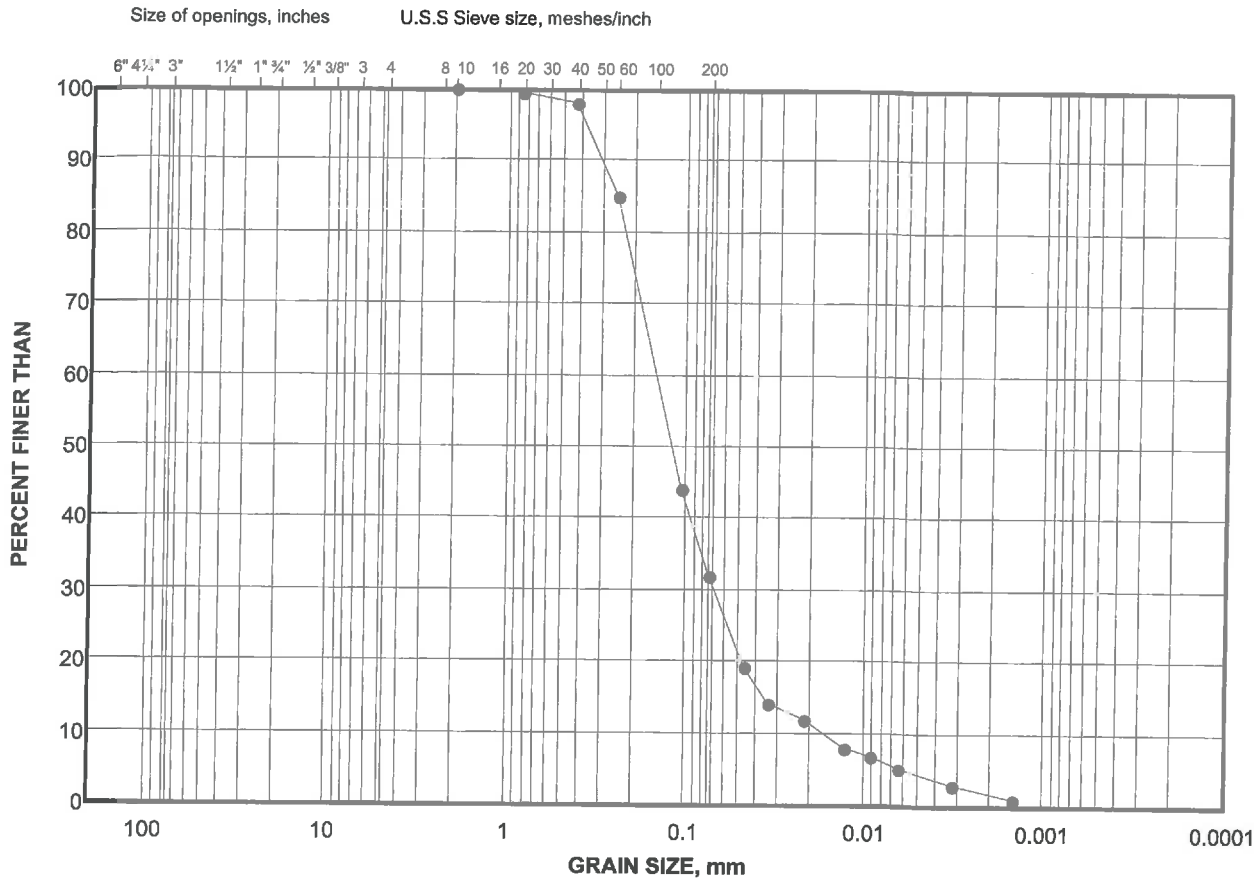
Checked By: _____

Golder Associates

Date: 24-Aug-17

GRAIN SIZE DISTRIBUTION

FIGURE



LEGEND

SYMBOL	SAMPLE
●	CC02B

Project Number: 1664714

Checked By: _____

Golder Associates

Date: 24-Aug-17