APPENDIX C
Fluvial Geomorphology Assessment

PRELIMINARY FLUVIAL GEOMORPHOLOGY ASSESSMENT OF LITTLE ETOBICOKE CREEK
DIXIE-DUNDAS FLOOD MITIGATION

Prepared for:
CITY OF MISSISSAUGA

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PRELIMINARY FLUVIAL GEOMORPHOLOGY ASSESSMENT OF LITTLE ETOBICOKE CREEK AT DIXIE-DUNDAS, MISSISSAUGA

Prepared for the City of Mississauga, August 2020

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1 INTRODUCTION

A preliminary fluvial geomorphology assessment was completed for Little Etobicoke Creek in Mississauga for the Dixie-Dundas flood mitigation project. The study area is centered on the Dixie Road bridge crossing and extends upstream (north) to Bloor Street and downstream (south) to Dundas Street East. Refer to Appendix A for a study area map. The City of Mississauga is seeking to manage spill from Little Etobicoke Creek to reduce flood risks and thereby protect existing properties and enable growth. In developing a flood remediation plan, Matrix is investigating the feasibility of alternatives including replacement of the Dixie Road bridge and capacity improvements within the creek. An understanding of existing creek form and function is critical to developing an appropriate remediation plan.

This report summarizes the preliminary fluvial geomorphology assessment that included these tasks:

- compilation and review of relevant background information including previously completed fluvial geomorphological reports for the Etobicoke Creek system
- desktop assessment of historical imagery and meander belt width analysis
- field visit (rapid assessments)
- identification of constraints and opportunities from a fluvial geomorphic perspective to inform the flood mitigation assessment
- recommendations for further analysis to be completed in subsequent project stages

2 STUDY AREA

2.1 Watershed

Little Etobicoke Creek is located within the Etobicoke Creek watershed (211 km^2) which has been identified to be highly urbanized and display degraded fluvial geomorphic conditions (TRCA 2010). The confluence of Little Etobicoke Creek with Etobicoke Creek is located approximately 1.2 km downstream of the fluvial geomorphic study limit.

Geology of the study area influences sediment input (volume and caliber), channel geometry, and the rate of channel change (e.g., migration and incision). In the study area, the creek runs through the Lake Iroquois Sand Plain physiographic region which comprises sand, silt, and clay deposits (Chapman and Putnam 2007) with sections of exposed or thinly drift-covered shale and dolostone. In channels with bedrock exposures, morphology can be influenced by the physical characteristics of the bedrock as well as the hydraulic and sediment transport characteristics of the river. In the case of Etobicoke Creek, exposed shale is subject to a combination of weathering and fluvial erosive forces and can present less resistance to erosion than a till formation. Siddiqui and Roberts (Siddiqui and Robert 2010) investigated the bedrock channel of Etobicoke Creek and found that rates of erosion and/or deposition can be significant during the snowmelt spring events. The investigators found that there was a greater loss of bed material over the study reach than was gained in several spots with bed lowering measured to be greater than 0.10 m in some locations, indicating that incision must be considered during the design process even when at sections with exposed bedrock.

2.2 Study Reaches

Reaches are lengths of channel that display similarity with respect to valley setting, planform, floodplain materials, and land use. Three reaches were delineated in the study area during initial desktop assessments and reach breaks were later confirmed during the site visit (Section 3.4). Refer to Appendix A for a study area map that includes the reach breaks.

- Reach 1 (R1) – 550 m of channel downstream of Bloor Street displaying moderate planform sinuosity set in a forested corridor.

- Reach 2 (R2) - approximately 920 m of channel that has been lined on both banks with armourstone blocks. For this study, the reach is further separated into R2a and R2b to facilitate a systematic evaluation of the subreaches.
  - R2a consists of 500 m of channel upstream of Dixie Road. The channel planform displays minor sinuosity along this reach at the upstream extent and is straight for the downstream-most 200 m.
  - R2b consists of 420 m of creek downstream of Dixie Road bridge. The channel displays two minor bends immediately downstream of the bridge before extending straight for 300 m.

- Reach 3 (R3) extends for 800 m downstream to Dundas Street East. The planform displays increased sinuosity compared to R2 and is set within a forested corridor with a mixture of natural boundary materials and constructed erosion countermeasures (both stable and failing).

3 BACKGROUND INFORMATION

3.1 Historic Assessment

Historic and current aerial imagery from 1954, 1966, 1975, 2000, and 2019 was reviewed to document historic changes in channel form and adjacent land use over time. The historical assessment revealed that between 1954 and 1966 the farmland around Dixie Road began developing into residential properties. Land development surrounding the creek increased heavily through 1975 and by the early 2000s, nearly all the land had been converted into industrial or residential land uses as currently exists. Several creek alterations are noted through the years:

- Between 1966 and 1975 erosion countermeasures were installed along R2a.
- In 1966, R2b is very sinuous, characterized by large meanders, but by 1975 was straightened.
- Between 1975 and 2000, R1 was realigned with symmetrical meanders and riffle/weir structures placed with relatively consistent spacing.

Available as-constructed drawings for linear infrastructure were reviewed for locations where the infrastructure crosses under the channel. At the upstream extent of R2a, an as-constructed drawing for the Hanlan Feedermain (MMM 1997) shows a 2,100 mm diameter concrete pressure watermain pipe crossing under the channel. The channel bed elevation shown in the drawing (121.5 m) is close to the current bed elevation obtained from the HEC-RAS model (approximately 121.67 m). There are notes included in the as-constructed drawing referring to a “Future Creek Reconstruction by MTRCA” and a proposed new channel is shown in plan and profile that is located north of where Little Etobicoke Creek was at the time. The proposed planform and rectangular cross-section of the “Future Creek Reconstruction” resemble the current configuration of the channel, however the MTRCA Creek Reconstruction plans appear to have also propose lowering the channel bed elevation (proposed MTRCA cross-section bed elevation of approximately 120.80 m) which likely did not occur. Overall, the channel bed elevation at the watermain crossing has remained consistent over the past two decades, representing approximately 2.3 m of cover over the infrastructure, the top of which is at an elevation of 119.2 m.

An as-recorded drawing for a 600 mm concrete pipe watermain replacement drawings (CH2M Hill 2016) at the Dixie Road bridge also shows a proposed 2,400 mm diameter feedermain, an existing 400 mm diameter watermain, a 900 mm diameter sanitary sewer, and utility conduit concrete structure crossing under the channel at this location. The profile shows the lowest bed elevation of the channel cross-section to be approximately 120.2 m which is comparable to the channel bed elevation in the current HEC-RAS model at that location. Notably, the top of the utility conduit concrete structure is at an elevation of 120.0 m and the top of the 900 mm sanitary sewer is at an approximate elevation of 119.5 m. Due to the minimal cover depths at this crossing location, maintenance of the channel bed stability is critical in order to limit damage to the underlying infrastructure.

Near the upstream extent of R3, an as-constructed drawing for a 450 mm sanitary sewer (R.E. Winter & Associates 1967) shows the sanitary crossing encased in concrete under Little Etobicoke Creek. The existing watercourse bed elevation shown in the drawing is approximately 118.7 m and the top of the sanitary sewer encasement is 118.4 m. Therefore, the sewer was constructed with only 0.3 m of cover. Infrastructure Hazard Monitoring Records (TRCA 2018) identified the encasement to be exposed in 2018 and noted other erosion issues at the crossing. Similar observations were noted during the current study (see Section 3.4). The exposed encasement and sanitary pipe is at risk of damage due to channel erosion and is a key constraint in the design area.

PARISH Geomorphic Ltd. (PARISH 2008) reports that Little Etobicoke Creek immediately upstream of Dundas Street (current study Reach R3) underwent restoration activities in 1999 including channel realignment, bioengineering of the west bank, enhancement of instream riffle features, flood protection measures for adjacent properties, and scour protection for the Dundas Street bridge.

3.2 Meander Belt Width

A meander belt width is delineated to characterize planform geometry and lateral extent of the channel, the meander belt is defined by tangential lines that are drawn along the outside bends of the laterally extreme meanders within the reach, following the meander axis. The Toronto and Region Conservation Authority (TRCA) delineation procedures (PARISH 2004) outline that when a watercourse has been previously altered from its natural planform and when the hydrologic regime of the watercourse has not been altered, the meander belt width should be based on original unaltered configuration; however, the form and condition of Little Etobicoke Creek in the study area is the result of both channel alterations and changes to the hydrologic regime meaning that the meander belt width of the original channel planform would not be representative of current conditions. As such, meander belt widths based on governing meanders of current planforms were measured, ranging from 24 m to 48 m, and are outlined in Table 1.

With extensive channel straightening and armouring, not only is it difficult to identify natural channel planform characteristics from aerial imagery, but historic migration rates are difficult to measure. The exercise is further challenged by dense vegetation concealing the channel in air photographs. In absence of historical erosion rates, a standard 20% factor of safety is applied to account for future migration and obtain the final meander belt width (100-year erosion limit).

TABLE 1 Meander Belt Width Measurements

Reach	Preliminary MBW (m)	FS (m)	Final MBW (m)
R1	41	8.2	49.2
R2a	32	6.4	38.4
R2b	24	4.8	28.8
R3	48	9.6	57.6

Note that the applicability of the factor of safety is potentially limited for R2a and R2b. It is highly unlikely that the channel will experience a measurable change in meander amplitude with the armouring currently in place and therefore there is low risk to adjacent properties from channel migration. Smaller-scale lateral adjustments are possible at locations where there is risk of bank treatment failure which can result in bank slumping and localized channel widening.

Re-establishment of historic meander characteristics or maintenance of current meander characteristics is not necessarily imperative for channel design of proposed works as their relation to the hydrologic/hydraulic properties of the creek is limited (i.e., the meander geometry did not establish naturally); however, opportunities to introduce channel meandering within the available footprint may be considered where possible to provide benefits such as mimicking natural energy dissipation processes and potentially enabling placement of more varied habitat elements in optimal locations (e.g., riffles on straight sections and pools on bends).

3.3 Previous Studies

Previous investigations in the study area have described the creek as displaying typical urban channel characteristics. As documented in the preceding section, the channel has changed both from direct alteration of form (e.g., channelization/armouring) and from modifications to the flow and sediment regimes as the watershed has urbanized. The result has been extensive erosion and degradation of the channel system. Some previous studies have employed standard protocols to characterize urban channels that include the Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT). The techniques document channel processes and stability/instability, and when repeated, may provide insight on how the channel is adjusting over time in response to a disturbance. Methodologies for both assessments are outlined in Appendix B.

A common way to characterize channels is by their bankfull dimensions. In stable alluvial channels, the bankfull channel area generally represents the maximum capacity of the channel before flow spills into the floodplain and is associated with the channel-forming discharge (bankfull discharge). Field indicators include obvious breaks or inflections in the cross-section profile, top elevation of point bar, and changes in vegetation. However, given the impacts of channelization, bankfull indicators are difficult to discern and field identifiers can be unreliable, particularly in armourstone-lined sections of the creek (i.e., limited sections of the channel have been formed based on natural processes). Secondly, the presence of exposed bedrock along the channel and applicability of relationships developed based on observations of purely alluvial channels must be considered. Mindful of these limitations, attempts to identify the bankfull elevation have been made in previous studies and for the current report.

3.3.1 Etobicoke and Mimico Creek Regional Monitoring

The TRCA initiated a long-term watershed monitoring program in 2001 that included ten monitoring sites in the Etobicoke Creek watershed. The results were presented in the Etobicoke and Mimico Creeks Watersheds Technical Report Update (TRCA 2010). Each site included the measurement of ten bankfull cross-sections, substrate (Wolman pebble count) and bank characterization, as well as a longitudinal profile of the channel bed morphology and identification of bankfull stage. A long-term monitoring station was established at each site including a control cross-section. Two sites (LE-1 and LE-2) were established in the upper reaches of Little Etobicoke Creek between Matheson Boulevard and Eglinton Avenue, south of Highway 401. Bankfull gradients were measured to rage between 0.56 to 0.73%. Average bankfull dimensions measured were a width of 3.9 m and a depth of 0.5 m. A median particle size of 0.6 mm was measured. Using the field measurements, a bankfull discharge was estimated to be 6.6 m^3/s. Over one year of monitoring (2007-2008), there was no change in cross-sectional area at the monitoring station on Little Etobicoke Creek; however, throughout the broader Etobicoke Creek watershed, ten sites showed cross-sectional change exceeding 5% between 2001 and 2008 with erosion occurring at half the sites and aggradation occurring at the other sites. This indicates a system in a state of active adjustment. It was reported that bedrock-controlled sites tend to be wider and shallower than other sites of comparable drainage area.

3.3.2 Little Etobicoke Creek Meander Belt Width and Erosion Assessment

PARISH completed fluvial geomorphic assessments immediately downstream of the study area extending from Dundas Street East south to the CP Rail crossing 550 m downstream. A first assessment was completed in 2007/2008 (PARISH 2008) and an update (confirmation) assessment of the same reach was completed in 2011 (PARISH 2011). The purpose of the assessments was to delineate the meander belt width/erosion hazard limits to enable development in the properties situated to the east and west of the creek corridor.

During field visits in 2007 and 2011, the creek was assessed to be in a state of transition (RGA score of 0.37 in both years) with the dominant geomorphic process being widening in 2007 and degradation in 2011. The creek was noted to be highly constrained and entrenched with undermined gabion baskets and concrete walls, and extensive basal scour. In places where bank protection was absent, banks were heavily eroded and undercut. The reach exhibited poor (RSAT Score of 15) and moderate (RSAT score of 23.5) stream health in 2007 and 2011, respectively, largely due to the degree of scour and lack of high-quality aquatic habitat.

Based on aerial imagery and topographic mapping, preliminary meander belt widths were determined for the channel configurations at the time of assessment. The determination of historical channel migration rates was not possible due to dense vegetation surrounding the creek. Additionally, due to channel realignment between 1978 and the early 2000s, migration rates would not be indicative of natural channel processes. In the straightened reach, aerial imagery was used to delineate a meander belt width of 33 m in 2007. The meander belt width was refined to 30 m in 2011 based on updated topographic mapping information. As it was not possible to measure channel migration rates, a standard 10% safety setback was applied to each side of the channel, resulting in a 100-year meander belt width (erosion hazard limit) of 36 m.

3.3.3 Little Etobicoke Creek at CP Rail – Galt M12.2 Technical Design Brief

PARISH (PARISH 2013) developed channel stabilization measures for a scour pool along Little Etobicoke Creek at the CP Rail crossing located approximately 550 m downstream of the current study area. A detailed geomorphic field investigation included identification of the bankfull channel dimensions based on field indicators. The measured bankfull cross-section widths ranged from 7.3 to 12.7 m and depths ranged between 0.5 to 1.1 m. Bankfull slope upstream and downstream of the crossing were measured to be 0.8% and 1.3%, respectively. Bed substrate was identified to primarily be in the gravel and cobble size range with occurrences of exposed bedrock. A bankfull discharge of 12 m^3/s was estimated using the survey information and used as the design discharge to develop channel design dimensions. A cascade-style design was developed to eliminate the existing scour pool, re-establish a stable bed profile to protect the existing crossing structure, and facilitate fish passage and migration. Based on an assessment of hydraulics with the proposed design configuration, a stone size distribution of approximately 400 to 800 mm was proposed to construct the cascade to ensure stability of the design.

3.4 Field Visit

Rapid field assessments were completed during a site walk on June 19, 2019. The study reaches between Bloor Street and Dundas Street East were assessed using the RGA method described in Appendix B, where applicable. Information on the fluvial geomorphic character of the channel upstream and downstream of the primary study area allows for a broader understanding of overall channel stability and constraints. A detailed fluvial geomorphic channel survey was not completed due to the understanding that the HEC-RAS model contains surveyed cross-sections with sufficient definition to complete high-level fluvial geomorphic entrainment analyses.

3.4.1 R1

In R1 Little Etobicoke Creek has a meandering planform and is bordered by mature trees and shrubs. Riffle-pool sequences have been constructed with riffles and vortex weir features comprised of large boulders up to 1 m in diameter. On outside bends, banks are armoured with riprap. Upstream-oriented rock vanes and rootwad treatments also integrated into the bank design. The bank treatments have been outflanked in numerous locations. Where riprap was not placed, bank erosion of native fine materials has occurred with vertical and undercut banks observed. Dense, near bank vegetation in the riparian zone is reduced due to the overhead tree canopy. There are several outfalls discharging to the creek along the reach, which have typically resulted in local scour at the outlet or along outlet channels.

Estimates of the bankfull channel dimensions included bankfull widths ranging between 8.5 to 12.5 m and bankfull depths ranging between 0.5 to 1.5 m. A reach profile slope of approximately 0.3% is measured in the HEC-RAS model. Throughout the reach, substrate near the riffles/ vortex weirs generally consisted of angular cobble/boulder-sized material 100 to 300 mm in diameter with interstitial sands and silts. At deep pools, sand and gravel typically lined the bottom of the channel. Bank armouring has been completed at several locations, particularly along the east bank, potentially to limit channel erosion toward infrastructure. Note that the alignment of a sanitary sewer adjacent to the channel is to be confirmed and will provide information on the existing setback from the channel. Stone sizes used to construct bank protection generally range between 100 to 1,000 mm. At the downstream extent of the reach the west bank appears to have recently been stabilized with boulders 500 to 1,250 mm in diameter. Large rock vanes were incorporated into the bank treatment.

The reach received an RGA score of 0.27, indicating a Transitional or Stressed reach. Widening was identified as the dominant geomorphic processes. Indicators of widening include steep vertical or undercut banks, leaning/fallen trees along the banks, and outflanked bank stabilization measures. Overall, there are signs of instability throughout the reach and the channel is adjusting with active (excessive) erosion noted. From a geomorphic process and habitat perspective, R1 stands out in presenting a more naturally functioning, albeit constructed, stream form and natural bank materials when compared to the armourstone-lined reaches downstream. R1 presents a variety of bedforms, velocities, widths, and depths and provides a source of sediment and nutrients to the channel.

It is understood that channel modifications will be limited to the reaches downstream of R1; however, it is beneficial to understand the success of a previous channel design and substrate that may be transported downstream (sediment transport) into the design reaches when considering channel modifications.

3.4.2 R2a

The reach break with R2a is delineated by the presence of large armourstone blocks installed along both sides of the channel. R2a is characterized by a straighter planform and there are two pedestrian bridge crossings along the reach. The armourstone blocks result in a confined, approximately 5 to 8 m wide rectangular channel with varying bank (armourstone) height. Blocks minimally measured 2 m long by 0.5 m high and 0.5 m wide; however, the dimensions are variable and are in some locations approximately 3 m long and 0.75 m high. Blocks are stacked nearly vertically 3 to 4 rows high. It appeared that the blocks sit on top of another layer or armourstone whose top elevation is approximately flush with the bed level. The “buried” row of armourstone protects against undermining and promotes structural integrity in the event of incision/downcutting.

The bed is also stabilized with armourstone blocks that are arranged as “cross rib” structures placed on the channel bed perpendicular to flow, and whose configuration promotes concertation of flows to the center of the channel at low flows. The armourstone block features are spaced strategically along the profile to maintain grade control. Between the armourstone blocks, bed materials consist of coarse angular gravel/cobble (100 to 200 mm diameter) stones with interstitial sands. During the site walk, it appeared that the step at each of the armourstone grade control features became increasingly pronounced nearer to the Dixie Road bridge. At the upstream extent of the reach, the gravel/cobbles between the armourstone features on the bed were essentially flush with the top of armourstone. Progressing downstream, there are minor drops at each of the features into deeper, more pool-like stretches of channel. A reach profile slope of approximately 0.5% is measured in the HEC-RAS model.

At the downstream extent of the subreach at Dixie Road bridge, there is a vast cobble/boulder deposit on the north side of the bridge that extends downstream where it becomes vegetated east of the bridge. Under the bridge, the low flow channel is concentrated along the south side of the bridge with interstitial gravel.

Most of the indicators associated with the RGA assessment are not applicable to R2a due to the extensive armouring and an RGA score is not presented for the reach. Overall, the reach was observed to be very stable, with few signs of erosion. Only minor settling of the armourstone block bank treatment was observed in a few select locations. As boundary materials appear largely immobile, there is minimal natural geomorphic processes occurring in the reach with no excessive erosion or deposition visible. It is possible that material transported to the reach from upstream in the system is simply flushed through during high flows. It did not appear that any of the minor steps associated with the grade control features would present a barrier to upstream fish passage. Due to the armourstone there is no vegetation directly on the channel banks, although above the armourstone blocks the valley is generally well vegetated and this is some overhanging trees providing shading to the creek.

3.4.3 R2b

Immediately downstream of the bridge there appears to be a concrete weir or pipe crossing the channel and could potentially be the concrete utility conduit structure identified in infrastructure constraint mapping as described in Section 3.1. Progressing downstream, the armourstone-lined style of channel described for R2a continues however channel width (approximately 8 to 10 m) is increased in the wider overall creek corridor. The armourstone bed control features are visible nearer the bridge; however, extending downstream armourstone is limited to the banks and the bed substrate ranges greatly with sections of exposed clay, silt/sand, gravel/cobbles (platey shale), boulder, and exposed bedrock noted. A reach profile slope of approximately 0.4% is measured in the HEC-RAS model. There is great difference in the stability of the vertical armourstone bank treatments between the two reaches, with numerous failures observed in R2b. There are a few possible reasons:

- Exposed bedrock was visible along the bed, therefore potentially the armourstone blocks could not be embedded as observed upstream, and any minor bedrock incision at the toe would result in shifting and loss of structural stability.

- Some sections of the armourstone walls were constructed of shale armourstone blocks which almost all failed (crumbled) or are near failure.

- Overtopping flows have resulted in erosion and potentially “piping” behind the blocks.

As with R2a, an RGA score was not assessed for the reach as it is lacking natural geomorphic processes. Overall, there are many bank treatments along the reach that are unstable providing opportunity for improvements and stabilization in this subreach.

3.4.4 R3

At the downstream extent of the armourstone blocks, channel sinuosity increases slightly, and natural bank materials are present. Bank erosion and eroded vertical banks are widespread. There are several woody debris jams present from fallen trees and trapped debris around which the channel generally widens out to around 12+ m. Channel widths and depth are variable along this section. Platey shale was observed along the bed at several locations. There is an exposed encased sanitary sewer crossing perpendicular to the channel and acts as a profile high point. Banks are eroded on both side of the channel at the crossing. There is a large bend approximately mid-reach along which the left bank has been stabilized with boulders and vegetation incorporated into the treatment that has established well. An outfall structure discharges to the bank in the middle of the treatment and has armourstone blocks at the outfall. Opposite the bank restoration, there is a large point bar costing of gravel- and cobble-sized platey shale. Downstream of the bank treatment, there are failing gabion baskets along the channel banks in various states of disrepair. There is a very narrow section confined by gabion baskets approximately 5 m wide and 2 m deep. At this location, riffle-run sequences are the dominant bed type throughout, consisting primarily of cobble- and boulder-sized (100 to 300 mm) angular material mixed with platey shale material and gravel interstitial material. The earlier background review revealed that this stretch is likely part of the channel restoration that occurred in approximately two decades ago. A reach profile slope of approximately 0.9% is measured in the HEC-RAS model. Bankfull dimensions in this reach are generally 10 to 13 m wide and 0.5 to 0.8 m deep. Toward Dundas Street East, there are sections with armourstone blocks lining the channel and a location where bank stabilization measures have failed with extensive erosion and bank failure observed.

R3 was assessed an RGA score of 0.27 indicating a Transitional or Stressed state. Widening was identified as the dominant geomorphic process. R3 presented both relatively stable and unstable sections, with some successful restoration/stabilization treatments constructed that contrasted with extensive widening where natural materials are present and failed gabion basket treatments.

4 OPPORTUNITIES AND CONSTRAINTS

The desktop and field assessments revealed varying channel form and stability along the study reaches of Little Etobicoke Creek. The upstream-most reach, R1, is a constructed channel design and displays natural cross-sectional form, a meandering planform and riffle-pool sequences. Although not completely destabilized, the channel was identified to be stressed and treatments installed as part of a previous channel design have been circumvented (outflanked) by the watercourse. There are natural fluvial geomorphic processes occurring in the reach, including erosion and deposition, that contrasts with R2 where the channel has been armoured with large armourstone blocks intended to be static/immobile. This is achieved in R2a which was identified to be stable but was less successful in R2b where channel treatments are failing at numerous locations. R3 is a mixture of stable designed sections and eroded natural and failed designed sections.

Channel modifications are likely to be limited to R2 and the upstream portion of R3 as part of flood mitigation activities and therefore opportunities to improve channel conditions are discussed for these reaches. Implementation of any channel modifications must also consider constraints that could limit the effectiveness of the modifications from a channel enhancement perspective. Universal considerations include:

- Proximity to buried infrastructure – sufficient depth or lateral distance to infrastructure is maintained or established (vertical and lateral erosion hazards are mitigated).
- Occurrences of exposed or shallow bedrock may limit channel deepening or installation of stable erosion countermeasures (bed and bank treatments).

- Stormwater outfalls must be incorporated into any modified or new bank treatments and must discharge to the creek in a stable manner.

- Maintain fish passage along the channel profile (connectivity) and improve aquatic habitat as is possible.

- If proposed works result in increased erosive forces downstream outside of the study area, monitoring of, and/or introduction of stabilization measures at locations with existing erosion issues may be warranted.

4.1 R2a

During the site visit, channel hardening was noted throughout the narrow, constrained corridor with minimal natural fluvial geomorphic form or function. We assume that limited corridor width precludes the option of constructing a fully meandering channel with natural stream features (e.g., riffles) and an accessible overbank/floodplain along this reach. A stable configuration currently exists and maintaining channel stability through this reach is a key consideration of any modifications. Stepped back armourstone walls may be considered as opposed to the current relatively high vertical walls; if the armourstone is stepped back on each side of the channel to create a wider section, or if the channel is deepened and increased velocities result, bed material must be sized appropriately to prevent entrainment during all flow events as it is likely not possible to design an alluvial channel in this constrained setting. The reach will act as a conduit to convey flows, sediment, and nutrients delivered from the watershed upstream to the downstream reaches.

If the channel base is to be widened, the new cross-section should concentrate flows at low flow (e.g., multi-stage cross-section) to maintain sufficient depth for aquatic organism passage in the low flow channel.

4.2 R2b

The channel treatments installed along R2b are less stable than upstream and this project provides opportunity to improve and stabilize channel conditions in this reach. The corridor along R2b is wider than R2a, potentially allowing for the introduction of sinuosity to the planform or the creation of a wider floodplain (by setting back armourstone walls a further distance from the channel) with an inset meandering low flow channel with natural stream features (dependent on sediment entrainment analysis).

Constraints noted specifically for this reach include an exposed infrastructure crossing at the downstream edge of the Dixie Road bridge that may constrain potential vertical adjustments, as well as the presence of exposed bedrock. The latter can create challenges in the design and implementation of stable channel features including bed features such as riffles, but also bank treatments.

4.3 R3

The upstream 200 m of R3 displays natural boundary materials but is highly eroded and may similarly benefit from stabilization works, including bank re-grading/restoration and profile modification. A key constraint is the exposed sanitary sewer crossing located 100 m downstream of the reach break with R2b. Extending further downstream, there is opportunity for local improvements along sections of the creek, such as gabion basket removal and replacement with a vegetated riprap treatment, for example. Existing channel treatments that are stable would ideally be maintained and newly introduced channel treatments should be designed in a manner that promotes consistency in channel form and continuity of channel processes.

5 SUMMARY AND NEXT STEPS

A general characterization of the fluvial geomorphology for Little Etobicoke Creek was completed in the study area between Bloor Street and Dundas Street East. A summary of existing reach conditions and opportunities is provided in Table 2.

TABLE 2 Reach Summaries

Reach	Characterization	Comments
R1	Constructed channel design with meandering planform and riffle-pool sequences. Design features include vortex weirs, riprap, rock vanes, and woody debris bank treatments.	Channel is adjusting in the reach (RGA score 0.27) as evidenced by outflanked bank treatments and extensive erosion in unarmoured sections. Reach not anticipated to be altered as part of the current assignment.
R2a	Armourstone-lined rectangular channel with armourstone grade control features along the bed. Limited natural fluvial geomorphic form or process.	Reach currently stable; maintaining channel stability is a key consideration of modifications in addition to maintain or improving fish passage/aquatic habitat conditions over existing conditions.
R2b	Armourstone-lined rectangular channel with armourstone grade control features along the bed. Exposed bedrock observed along reach.	Armourstone blocks lining the banks are failing at several locations; the wider overall corridor in this reach provides opportunity to re-construct the channel with stable bank treatments and incorporate natural stream features. Exposed bedrock may impose a constraint on the types of features that can be installed.
R3	Mixture of natural sections of channel and constructed design bed and bank treatments.	Channel is adjusting in the reach (RGA score 0.27) with highly eroded sections that may benefit from monitoring and/or stabilization works, including bank re-grading/ restoration and profile modifications, particularly if proposed works increase erosive forces downstream.

To facilitate assessment of design options, a variety of analyses can be completed based on the fluvial geomorphic information collected (e.g., bankfull estimations and sediment characterization) and using the HEC-RAS model. The hydraulics assessment will assess velocities and shear stress experienced in the channel at a range of flows. This exercise helps evaluate erosion sensitivity by comparing the boundary shear stress associated with modeled flows to the critical shear stress required to entrain sediment. Velocities and shear stress will be determined for existing and proposed configurations to assess:

- Substrate entrainment/transport to promote sediment continuity, ensuring a graded channel for which there is no excessive erosion or deposition and result in a self-maintaining channel.
- Bed and bank treatment stability (establish stable stone size and practicality of low flow channel configurations).
- Flow depth and velocities for fish passage and aquatic habitat opportunities.

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APPENDIX A
Study Area Map

Watercourse

Reach Break

1:6,000 metres

60 0 60 120

NAD 1983 UTM Zone 17N

Reference: Contains information licensed under the Open Government Licence – Ontario. Contains data obtained by Matrix Solutions Inc and the City of Missisauga

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

City of Mississauga
Dixie - Dundas

Reach Map

Date: Sept 2019	Project: 24603	Submitter: N. Cyples	Reviewer: M. Wojda

Appendix A

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APPENDIX B
Rapid Assessment Protocols

APPENDIX B

RAPID ASSESSMENT PROTOCOLS

1 RAPID GEOMORPHIC ASSESSMENT (MOE 2003)

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (MOE 2003) to assess channel reaches in urban channels. This qualitative technique is purely a presence/absence methodology designed to document evidence of channel instability such as exposed tree roots, undercut branches, etc. The various indicators are grouped into four categories indicating a specific geomorphic process:

- Aggradation
- Degradation
- Channel Widening
- Planimetric Form Adjustment

Over the course of the survey, the existing geomorphic conditions of each reach are noted and individual geomorphic indicators are documented. Upon completion of the field inspection, these indicators are tallied by category and used to calculate an overall reach stability index, which corresponds to one of three stability classes related to sensitivity to altered sediment and flow regimes:

- ≤0.20 In Regime or Stable (Least Sensitive)
- 0.21 to 0.40 Transitional or Stressed (Moderately Sensitive)
- ≥0.41 In Adjustment (Most Sensitive)

2 RAPID STREAM ASSESSMENT TECHNIQUE (GALLI 1996)

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). When compared with the RGA, the RSAT provides a more qualitative assessment of the overall health and functions of a reach in order to provide a quick assessment of stream conditions and the identification of restoration needs on a watershed scale. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- Channel Stability
- Erosion and Deposition
- Instream Habitat
- Water Quality
- Riparian Conditions
- Biological Indicators

Once a condition has been assigned a score, these scores are totaled to produce an overall rating that is based on a 50 point scoring system, divided into three classes:

- <20 Low
- 20-35 Moderate
- >35 High

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information does have relevance within a geomorphic context based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent stable, naturally functioning geomorphology as well (i.e., fish prefer a variety of physical conditions - pools provide resting areas while riffles provide feeding areas and contribute oxygen to the water - good riparian conditions provide shade and food - woody debris and overhanging banks provide shade). From a water quality perspective, the concentration of chemicals may not be a concern with respect to geomorphic conditions, but the turbidity of the stream can be an issue, as it implies active sediment transport and can contribute to substrate embeddedness.

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APPENDIX C
Site Photographs

Photograph 1: R1 view downstream of rock vortex weir outflanked on left bank

Photograph 2: R1 view of rock vortex weir

Photograph 3: R1 view of rootwad embedded in undercut channel bank

Photograph 4: R1 view downstream of outflanked bank treatments and eroded natural bank

Photograph 5: R2a view downstream of armourstone blocks lining channel and pedestrian bridge

Photograph 6: R2a view upstream of armourstone grade control feature

Photograph 7: R2a view downstream of armourstone grade control feature

Photograph 8: R2b view of armourstone on right bank and concrete feature on bed

Photograph 9: R2b view upstream of armourstone blocks in channel

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Photograph 11: R2b view downstream armourstone blocks on banks

Photograph 12: R2b failed armourstone treatment

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Photograph 15: R3 potential exposed pipe on bed of channel

Photograph 16: R3 view downstream of bank stabilization and armourstone at stormwater outfall

Photograph 18: R3 view downstream of failed gabion baskets on left bank

Photograph 19: R3 view downstream of channel stabilization design

FLUVIAL GEOMORPHOLOGY ASSESSMENT OF LITTLE ETOBICOKE CREEK
DUNDAS STREET BRIDGE ADDENDUM
DIXIE-DUNDAS FLOOD MITIGATION
MISSISSAUGA, ONTARIO

Prepared for:
CITY OF MISSISSAUGA

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FLUVIAL GEOMORPHOLOGY ASSESSMENT OF LITTLE ETOBICOKE CREEK

DUNDAS STREET BRIDGE ADDENDUM

DIXIE-DUNDAS FLOOD MITIGATION

MISSISSAUGA, ONTARIO

Prepared for the City of Mississauga, February 2022

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IN-TEXT TABLES

APPENDICES

1 INTRODUCTION

Matrix Solutions Inc. undertook an initial fluvial geomorphology assessment for Little Etobicoke Creek, located in Mississauga, Ontario, for the Dixie-Dundas Flood Mitigation Environmental Assessment (EA) project, with the final report submitted in August 2020 (Matrix 2020). The original study area for Little Etobicoke Creek was centered on the Dixie Road bridge crossing, extending upstream (north) to Bloor Street, and downstream (south) to Dundas Street East. The scope of the Dixie-Dundas Flood Mitigation EA project has since been extended downstream to also consider modification of the Dundas Street bridge, and as such, an additional fluvial geomorphology assessment was warranted to support the EA alternatives and evaluation (refer to Appendix A for the study area map).

The City of Mississauga (the City) is seeking to manage spill from Little Etobicoke Creek to reduce flood risks and thereby protect existing properties and enable growth. In developing a flood remediation plan, Matrix assessed the feasibility of alternatives, including replacement of the Dixie Road bridge and capacity improvements within the creek and is now investigating capacity improvements for the Dundas Street bridge. As creek erosion issues have been previously identified by the City for reaches both upstream and downstream of Dundas Steet, this addendum report has extended the fluvial geomorphology assessment further downstream and provides recommendations for erosion mitigation specifically to support the assessment of design options and flood mitigation alternatives being considered for the Dundas Street crossing.

This addendum report summarizes the extended fluvial geomorphology assessment including the following tasks:

- summarizing background information, desktop assessment of historical imagery and meander belt width analysis, and reach characterizations previously reported in the 2020 fluvial geomorphology assessment report (Matrix 2020) focused on Dixie Road
- documenting stream reach conditions extending downstream of Dundas Street, including rapid geomorphic assessments
- inventorying erosion sites based on field assessments of bank conditions, including the condition of existing erosion control works, the severity of bank erosion, and the associated risks of future erosion to adjacent infrastructure and/or property, public or private
- recommending erosion mitigation works that might further enhance creek conditions in the short term, contributing to the flood mitigation alternatives at the Dundas Street bridge
- recommending long-term creek management strategies that should be considered as part of future City planning and redevelopments in the study area

2 STUDY AREA

2.1 Watershed Context

Little Etobicoke Creek is located within the Etobicoke Creek watershed (drainage area ~211 km^2), which has been identified as highly urbanized and displays degraded fluvial geomorphic conditions (TRCA 2010). The confluence of Little Etobicoke Creek with Etobicoke Creek is located approximately 1.2 km downstream of Dundas Street. Within the Lake Iroquois Sand Plain physiographic region (Chapman and Putnam 2007), the channel of Little Etobicoke Creek transitions from a surface geology of dominantly fine-grained lake and glacial till deposits into valley reaches that have incised into the shales, limestones, and dolostones of the Georgian Bay Formation. The bedrock geology in the incised reaches is a source of platy-shaped limestone rocks that line the channel bed and makeup natural riffle features where native substrate is still available within the active channel. As such, these bedrock channels have some natural weathering, erosion, and degradation processes with native sediment regularly transported, especially during winter and spring snowmelt events (Siddiqui and Robert, 2010). The history of urban development within the watershed has modified the fluvial system both in terms of the hydrological inputs of stormwater runoff to the creek and previous erosion and flood mitigation measures within the channel and floodplain.

2.2 Study Reaches

Reaches are lengths of channel that display similarity with respect to valley setting, planform, floodplain materials, and land use. A total of five reaches were delineated for Little Etobicoke Creek within the study area from Bloor Street to the confluence with Etobicoke Creek. The initial desktop assessments and reach breaks were later confirmed during the field assessment (refer to Appendix A for a study area map that includes the reach breaks). This addendum report focuses on Reaches 3 and 4 upstream and downstream of Dundas Street, respectively. Reach 5, downstream of the study area, was also assessed for this report based on known issues from previous monitoring by the City and the recent history of erosion control works in the reach. Reaches 1 and 2 were revisited in the field for the current study, but the documented conditions are primarily based on the 2020 fluvial geomorphology report (Matrix 2020) for Dixie Road. The following reach descriptions are based on the initial desktop assessments, and additional details are provided based on the field assessments in Sections 3.1 and 4.

- Reach 1 (R1): 550 m of channel downstream of Bloor Street displaying moderate planform sinuosity set in a forested corridor.
- Reach 2 (R2): approximately 920 m of channel that has been lined on both banks with armourstone blocks. For this study, the reach is further separated into Reach 2a (R2a) and Reach 2b (R2b) to facilitate a systematic evaluation of the subreaches.

    - R2a consists of 500 m of channel upstream of Dixie Road. The channel planform follows the valley trend along this reach with a few bends upstream and a 200 m long straight section before crossing Dixie Road.
    - R2b consists of 420 m of creek downstream of Dixie Road bridge. The channel displays two minor bends immediately downstream of the bridge before extending straight for 300 m.
- Reach 3 (R3): extends for 800 m downstream to Dundas Street East. The planform displays increased sinuosity compared to R2 and is set within a forested corridor with a mixture of natural boundary materials and constructed erosion countermeasures (both stable and failing).
- Reach 4 (R4): extends approximately 550 m downstream of Dundas Street East to the Canadian Pacific Railway (CP) rail tracks. This reach displays slight sinuosity with an artificially straightened corridor containing a variety of bank hardening measures (e.g., gabion baskets, riprap, armourstone). Most of the reach is within a confined valley setting.
- Reach 5 (R5): extends approximately 565 m downstream of the CP rail tracks until the confluence with Etobicoke Creek. The channel planform displays moderate sinuosity in a wider floodplain with valley-wall contacts in a few locations locally confining the channel.

3 BACKGROUND INFORMATION

3.1 Fluvial Geomorphology Assessment for Dixie Road Bridge, 2019-2020

In August 2020, Matrix completed a fluvial geomorphic assessment on Little Etobicoke Creek from Bloor Street to Dundas Street East, within the City of Mississauga, as part of the Dixie-Dundas Flood Mitigation EA project (Matrix 2020). The purpose of the geomorphic assessment was to evaluate existing creek form and function and investigate the feasibility of alternatives, from a geomorphic perspective, to support the flood mitigation project. Alternatives included a variety of potential channel modifications to help mitigate flooding risks while also addressing erosion issues and rehabilitating the creek channel.

3.1.1 Historic Assessment

Three watercourse reaches (including two subreaches) were initially delineated as part of the 2020 fluvial geomorphology assessment (Matrix 2020): R1, R2a, R2b, and R3 (Appendix A). Historically, land use in the study area was primarily rural-agricultural until 1966, when farmland around Dixie Road began developing into residential properties. By 1975, land development surrounding the creek corridor had increased heavily and, by the early 2000s, nearly all the surrounding land use had been urbanized. Several creek alterations were noted historically, including the installation of erosion countermeasures along R2a between 1966 and 1975 as well as channel straightening during this time period. Additionally, between 1975 and 2000, R1 was realigned with symmetrical meanders and riffle/weir structures consistently spaced out. There were also several sewer and watermain crossings installed below the creek within the study area that contain minimal depths of cover and pose a key constraint on potential design alternatives.

3.1.2 Meander Belt Width Assessment

A meander belt width (MBW) was delineated for the study reaches based on governing meanders of the current channel planform. Within the study area, Little Etobicoke Creek has undergone historical channel alterations and changes to its hydrologic regime; therefore, the MBW was not derived from the historical channel planforms. Natural channel migration rates were difficult to quantify since most of the reaches have been historically straightened or hardened, preventing natural migration from occurring. In the absence of historical channel migration rates, a 20% factor of safety (FOS) was added to the preliminary MBW. MBW results are summarized in Table 1.

TABLE 1 Meander Belt Width Measurements from Matrix (2020) Report

Reach	Preliminary Meander Belt Width (m)	Factor of Safety (m)	Final Meander Belt Width (m)
R1	41	8.2	49.2
R2a	32	6.4	38.4
R2b	24	4.8	28.8
R3	48	9.6	57.6

Source: Matrix (2020)

3.1.3 Summary of 2019 Field Assessment in 2020 Fluvial Geomorphology Report

Matrix completed field assessments in June 2019 on the three reaches (including two subreaches), upstream and downstream of Dixie Road, using rapid geomorphic assessments to evaluate channel stability and stream health and observe existing geomorphic conditions to identify areas where the channel had been modified or hardened. A summary of the reaches assessed in the 2020 report is presented in Table 2.

TABLE 2 Reach Summaries from Matrix (2020) Report

Reach	Characterization	Comments
R1	Constructed channel design with meandering planform and riffle-pool sequences. Design features include vortex weirs, riprap, rock vanes, and woody debris bank treatments.	Channel is adjusting in the reach (Rapid Geomorphic Assessment [RGA] score 0.27) as evidenced by outflanked bank treatments and extensive erosion in unarmoured sections. Reach not anticipated to be altered as part of the current assignment.
R2a	Armourstone-lined rectangular channel with armourstone grade control features along the bed. Limited natural fluvial geomorphic form or process.	Reach currently stable; maintaining channel stability is a key consideration of modifications in addition to maintain or improving fish passage/aquatic habitat conditions over existing conditions.

Reach	Characterization	Comments
R2b	Armourstone-lined rectangular channel with armourstone grade control features along the bed. Exposed bedrock observed along reach.	Armourstone blocks lining the banks are failing at several locations; the wider overall corridor in this reach provides opportunity to reconstruct the channel with stable bank treatments and incorporate natural stream features. Exposed bedrock may impose a constraint on the types of features that can be installed.
R3	Mixture of natural sections of channel and constructed design bed and bank treatments.	Channel is adjusting in the reach (RGA score 0.27) with highly eroded sections that may benefit from monitoring and/or stabilization works, including bank regrading/ restoration and profile modifications, particularly if proposed works increase erosive forces downstream.

Source: Matrix (2020)

4 FIELD ASSESSMENT FOR DUNDAS STREET BRIDGE, 2021

Matrix completed a field assessment of Little Etobicoke Creek on June 23, 2021, to update existing conditions within the study area and extend the assessment downstream in support of the Dundas Street flood mitigation alternatives currently being considered. The updated field assessment included Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT) scores (Appendix B), bank condition and erosion site inventories, and general observations of the fluvial geomorphic conditions in the watercourse. Select field photographs for R3, R4, and R5 are provided in Appendix C from the June 2021 field assessment. Reach summaries are provided in Section 4.1, and the erosion site inventory is documented in Section 4.2.

4.1 Reach Summaries

4.1.1 Dixie Road Reaches (R1 and R2)

R1 was assessed in the 2020 report and was only partially revisited in 2021. Generally, R1 was viewed as an aged natural channel design with mature riparian trees in a well-vegetated riparian buffer, with the channel engineered and constructed as a sinuous riffle-pool system, including boulders and vortex weir features as riffle grade controls. Along channel bends, the outside banks were typically reinforced with large stone revetments, including riprap; however, in many locations the riffle and bank stone had been either outflanked or undercut, destabilizing the channel. There were several outfalls discharging to the creek along the reach, which have typically resulted in local scour at the outlet or along outlet channels. Estimates of the bankfull channel dimensions included bankfull widths ranging between 8.5 to 12.5 m, and bankfull depths ranging between 0.5 to 1.5 m. At the downstream extent of the reach, the west bank appears to have more recently been stabilized with boulders. The reach received an RGA score of 0.27, indicating a transitional or stressed state and an RSAT score of 32, indicating moderate stream health. Widening was identified as the dominant geomorphic process. Indicators of widening include steep vertical or undercut banks, leaning/fallen trees along the banks, and outflanked bank stabilization measures. Overall, there were signs of instability throughout the reach, and the channel appeared to be adjusting with active (excessive) erosion noted.

R2 was reassessed in 2021 to confirm existing conditions and to undertake the bank condition and erosion site inventories (Section 4.2; Appendix D, Figure D1). R2 was observed as an armourstone lined channel that has been divided into subreaches R2a and R2b upstream and downstream of the Dixie Road bridge, respectively. The channel in this reach has largely been straightened, including two pedestrian bridges in R2a, with channel bends generally following the trend of the valley corridor. The armourstone blocks have created a confined, approximately rectangular, channel increasing in width downstream from 5 to 10 m across, with varying bank (armourstone) heights typically ranging from 1.5 to 3 m high. The bed is also stabilized with armourstone blocks that are arranged as “cross rib” structures placed on the channel bed perpendicular to flow and with a configuration that concentrates base flows to the centre of the channel. The armourstone ribs are spaced systematically along the profile to maintain grade control, with angular riprap and gravel placed and/or deposited between the ribs.

Most of the indicators associated with the RGA assessment were not applicable to R2 due to the extensive armouring; therefore, an RGA score is not presented for the reach. RSAT scores for R2a and R2b were 34 and 32, respectively, indicating these reaches are of moderate stream health, where water quality contains the lowest stability ranking. Overall, Reach 2a was observed to be very stable, with very few signs of degradation in the erosion control structures. Only minor settling of the armourstone block structures on the banks was observed in a few select locations. Downstream of the Dixie Road bridge, in Reach 2b, there were more signs of instability, including local failures of the armourstone wall associated with vertical scour, and bedrock exposure that has undermined the foundation of the wall. Immediately downstream of the Dixie Road bridge there was a concrete encasement (watermain) crossing the channel that was slightly exposed but mostly embedded within the channel substrate. Armourstone blocks at that downstream limit of the reach have also fallen into the channel where there is evidence of scour at the tie-in between the walls and native bank materials. Despite some evidence of local scour and failures of the armourstone wall in R2b, R2 was considered to be stable overall, with erosion control structures still functioning as intended.

4.1.2 Dundas Street Reaches (R3 and R4)

R3, upstream of Dundas Street, was reassessed in 2021 to confirm existing conditions and to undertake the bank condition and erosion site inventories (Section 4.2; Appendix D, Figure D2). Downstream of the armourstone channel in R2, there was a 200 m section of predominantly natural, vegetated banks with evidence of localized bed scour, undercut banks, and large woody debris in the channel. In this section, the channel widened out to 12 to 15 m, with average bankfull depths of about 1 m, but still ranging from 0.5 to 1.5 m. As the channel approached a fairly sharp turn in the creek corridor to the south (i.e., the “elbow”), a number of erosion site issues were recorded related to an exposed sewer pipe crossing the channel bed and severe bank erosion along the south bank (Section 4.2). There was also an entrenched and eroding outfall channel in the floodplain on the north side draining from Taviton Court. As the creek corridor and channel turned south, the outer east bank was lined with a vegetated boulder and armourstone revetment in fair condition. The remaining 500 m of R3 to Dundas Street was characterized by assorted erosion control measures of varying ages and conditions. The documented erosion control measures included gabion baskets ranging from fair to poor to failed condition, evidence of riprap placement on the banks and deposited in the channel, and armourstone walls in fair to failed condition (Section 4.2). Platy shale and limestone were observed in the channel at several locations, indicating weathering and erosion of exposed bedrock in local sections of the bed. Mid reach, there was a very narrow section confined by gabion baskets approximately 5 m wide and 2 to 3 m deep. Local failures of erosion control materials and built ups of large woody debris had created occasional deep scour pools within the reach. R3 was assessed with an RGA score of 0.39, indicating a state of transitional or stressed, and an RSAT score of 28, indicating moderate stream health. There was evidence of both relatively stable and unstable sections, but this reach was considered to nearly be in adjustment. Widening was identified as the dominant geomorphic process, but evidence of degradation and aggradation were also present (Note: The RGA score increased from 0.27 in the 2020 report to 0.39 based on reassessment of degradation and aggradation indices).

R4, downstream of Dundas Street to the CP rail crossing, was assessed in 2021 to document existing conditions and to undertake the bank condition and erosion site inventories (Section 4.2; Appendix D, Figure D2). Immediately downstream of the Dundas Street bridge were amourstone wing walls, with riprap and armourstone-rib grade controls on the bed, all in relatively good condition. Downstream of the armourstone walls, the 550 m reach was characterized by assorted erosion control measures of varying ages and conditions, primarily including riprap and concrete debris along the banks and deposited within the channel as well as localized evidence of gabion baskets in poor condition, severely degraded, and/or buried. Extensive rock and large, woody debris in the channel were frequently associated with bars of sediment in the channel and localized scour pools. Local exposure of weathered bedrock was also observed, confirming the source of platy shale and limestone within the channel. Evidence of severe lateral bank erosion and valley slope instability was noted at a few locations within R4, indicating future risks to the adjacent properties (Section 4.2). R4 was assessed with an RGA score of 0.39, indicating a transitional or stressed state, and an RSAT score of 22, which is on the lower end of moderate stream health. Widening was identified as the dominant geomorphic process, but evidence of degradation and aggradation were also present.

4.1.3 Downstream of Study Area (R5)

R5, downstream of the CP rail crossing to the confluence with Etobicoke Creek, was assessed in 2021 to document existing conditions and to undertake the erosion site inventory (Section 4.2; Appendix D, Figure D3). More specifically, this reach was walked in June 2021 to document known erosion issues and erosion control measures downstream of the study area to provide further context in this report for the assessment of erosion mitigation options and flood mitigation alternatives being evaluated upstream. The first 140 m downstream of the CP rail crossing was lined with riprap, constructed prior to 2015, and was still in good condition. Continuing downstream where the channel and creek corridor turn to flow east, a combination of bank erosion controls (gabion baskets, boulders, and armourstone) and a concrete weir (~1 m drop) were assessed to be in fair to poor condition, with a sewer pipe known to be crossing under the weir (Section 4.2). The remaining 450 m to the confluence was characterized as a mostly natural channel in a relatively wide floodplain but constrained by locally exposed bedrock along the valley walls and local erosion control structures protecting maintenance holes and pipe crossings of the regional sanitary trunk sewer. Downstream of the concrete weir, the channel was on average wider and shallower compared to upstream reaches, with widths in the range of 15 to 18 m, and bankfull depths in the range of 0.5 to 0.9 m, deepening to greater than 1 m near the confluence. The exposure of weathered bedrock in the channel was recognized as the source of platy shale and limestone that dominated the bed materials. R5 was assessed with an RGA score of 0.45, indicating a state of in adjustment, and an RSAT score of 17, indicating low stream health. Widening and degradation were identified as the dominant geomorphic processes, with evidence of bar and chute formations also observed as indicators of aggradation and planform adjustment, respectively.

4.2 Erosion Site Inventory

As part of the fluvial geomorphic assessment completed in June 2021, bank condition and erosion site inventories were completed for Little Etobicoke Creek within the study area. More specifically, the conditions of existing erosion control works and natural banks were evaluated for R2, R3, and R4 upstream and downstream of the Dixie Road and Dundas Street crossings. Where erosion control works were observed to have failed or where banks appeared to be severely eroding in the vicinity of infrastructure and/or property, these locations were identified as erosion sites of relatively high, medium, or low risk. The bank scoring methodology is summarized in Section 4.2.1, the erosion sites are recorded in Section 4.2.2, and the erosion inventories for R2 through R5 are presented in Appendix D.

4.2.1 Methodology

A standardized bank scoring methodology was adapted for the current study, whereby the condition of existing erosion control works, or natural bank materials, are scored from 1 to 5, from good to failed conditions, respectively (i.e., 1 = good/stable; 2 = fair; 3 = poor; 4 = failing; 5 = failed, severely eroding). The bank condition scoring framework is presented in Figure 1, and criteria for scoring can be varied based on the classification of erosion control treatments and bank materials, including gabion baskets, rock revetments (i.e., riprap, boulder stone buttress), armourstone walls, and natural banks (i.e., alluvial soils, vegetation). Degradation and failure mechanisms of engineered structures (e.g., riprap, armourstone) typically include processes of undercutting and outflanking of materials around the erosion control structures or the general loss of structure or mass due to the movement of stones during high discharge events. Gabion baskets, specifically, have a variety of complex failure processes that can also be assessed to document the dominant mode of degradation or failure:

- wire corrosion, with stone loss from baskets, and associated loss of structure
- baskets undercut, with lost foundational support, and potential slumping

- baskets outflanked or leaning, with lost lateral support, and potential slumping or toppling
- baskets buried in soil, with general decay of structure, and often well rooted with vegetation

Bank condition scores are also assigned to native bank materials where engineered erosion control structures have not been placed or are no longer present. Native materials may include bedrock (i.e., shales and limestones within study area), alluvial sediments and soils (i.e., gravel, sand, loam), glacial tills (i.e., dominantly silt and clay), or other unconsolidated and fine-grained fill placed from local sources. Bank conditions are also scored on a scale of 1 to 5, from low angle and vegetated (score = 1) to near-vertical banks of exposed native materials with evidence of erosional processes in the channel (score = 5). An assessment of the erodibility of the native material is also factored into the bank condition score.

Given that the purpose of the current study is to support high-level flood mitigation alternatives, and complimentary erosion mitigation design options, bank conditions scores have been presented as averages and ranges over subreach scales in the mapping presented in Appendix D with examples in Appendix E. The same methodology can be applied at a higher resolution and at regular intervals for detailed risk assessment studies and focused monitoring programs of erosion control works.

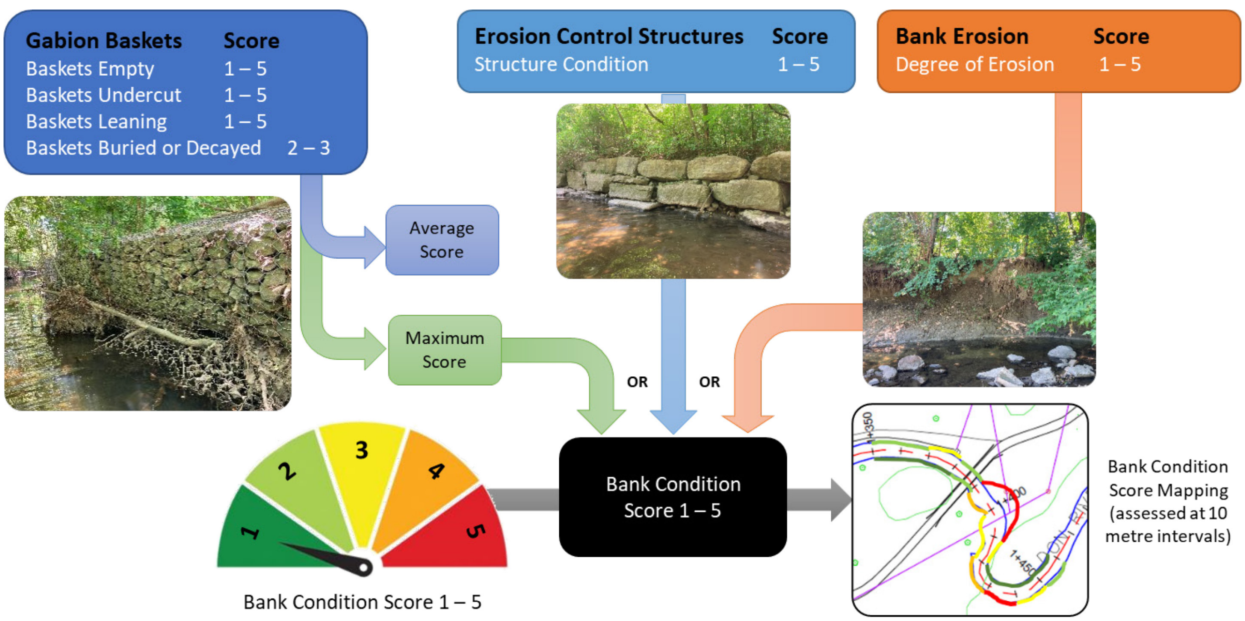

FIGURE 1 Erosion Control Structure and Bank Condition Scoring Framework (Examples Presented in Appendix E)

4.2.2 Erosion Sites

Erosion sites are defined based on the significance of the risk, the local bank condition scores, and the probability of damage. Collectively, these criteria can be integrated into a risk matrix to represent the well-established risk management approach of evaluating the severity of impacts and probability of negative outcomes. With respect to watercourse erosion hazards, the severity of impacts are assessed based the significance of the risk both in terms of what is at risk and how extensive the erosion damage might be (i.e., the size of the erosion site). Examples of both private and public risk types of generally increasing importance are trails, parks, yards, fence and property lines, parking lots, storm outfalls, major utilities (e.g., sewers), major transportation infrastructure (e.g., roads, bridges), building structures, etc. The probability of damage from erosion is assessed based on the bank conditions and context in the fluvial system, whereby naturally or artificially stable banks have a low probability of damage (scores of 1) and unvegetated, erodible bank materials with evidence of active erosion in the channel have a high probability of damage (scores of 5).

For the identification and priority classification of erosion sites on Little Etobicoke Creek within the study area, only sites with bank scores of 4 or 5 were selected where they were in close proximity to an observed risk. A total of nine erosion sites were identified within the study area, including R2 to R5, as presented in Table 3 and Appendix D. The two highest priority erosion sites are based on the close proximity of severe erosion conditions evident in the channel to infrastructure and property risks. Moderate- and low-priority erosion sites are those that are a greater distance from the infrastructure or property at risk and/or are situated in a section of channel with a lower probability or severity of erosion.

TABLE 3 Erosion Site Inventory for Little Etobicoke Creek within the Dixie-Dundas Study Area

Erosion Site (ES)	Description	Risks	Recommended Priority for Current Study
ES 2.1	Exposed concrete encasement for waterman crossing in channel	Watermain crossing	Moderate
ES 3.1	Exposed pipe crossing in channel	Sewer pipe crossing	High
ES 3.2	Severe bank erosion within 10 m of risk	Property line, parking lot	Moderate
ES 3.3	Unstable slope and failing riprap revetment at property line	Property line, parking lot	Moderate
ES 3.4	Severe bank erosion within 5 m of risk	Property line, parking lot	High
ES 4.1	Severe bank erosion and risk of slope instability within 20 m of risk	Property line, parking lot	Moderate
ES 4.2	Bank erosion in vicinity of risks	Property line, parking lot, sewer manhole	Low
ES 5.1	Vertical drop, concrete weir in poor condition over sewer crossing	Sewer pipe crossing	Moderate (offsite)
ES 5.2	Exposed trunk sewer crossing at failed rocky-ramp riffle	Trunk sewer pipe crossing	Moderate (offsite)

For ES 2.1, ES 3.1, and ES 3.2, it is expected that these risks will be addressed by the proposed floodplain regrading and channel rehabilitation alternative that has been selected for flood mitigation at Dixie Road. Erosion mitigation design options for ES 3.3, ES 3.4, and ES 4.1 can be considered as part of the preferred flood mitigation alternative selected for Dundas Street (Section 5.1). ES 4.2 is classified as low risk, and ES 5.1 and ES 5.2 are outside the study area; however, potential downstream impacts to existing erosion sites should be considered for the selected flood mitigation alternative and design options in future stages of the project.

5 RECOMMENDATIONS

5.1 Erosion Mitigation Recommendations

The recommendations generated from this fluvial geomorphology assessment addendum are specifically focused to support the assessment of design options and flood mitigation alternatives for the Dundas Street crossing. Appendix F, Figure F1 presents erosion mitigation concepts that will help to improve the existing conditions of Little Etobicoke Creek in the vicinity of Dundas Street and, in association with potential works, to increase the bridge's hydraulic capacity.

Based on the existing development constraints and property boundaries upstream and downstream of the Dundas Street crossing, additional erosion and flood mitigation options are limited, other than the alternative bridge spans being considered. A significant increase in the channel capacity upstream of the crossing is not possible in the short term; however, some minor conveyance increases may be achieved in conjunction with the opportunities to address erosion risks as identified in this study. Specifically, two erosion sites have been identified upstream within 200 m of Dundas Street (R3) where older erosion mitigation works have failed, and the adjacent properties at the top of the slope are at risk from future erosion and slope failure (ES 3.3 and ES 3.4; Appendix D, Figure D2). Given the limited space between the upland properties within the downstream sections of Reach 3, an armoured channel design is recommended to restore stable channel conditions in this section of the creek (Appendix F, Figure F1). The recommended design is similar to existing conditions upstream in R2; however, a critical aspect of the proposed design is the construction of armoured riffles to maintain the channel grades, which serve as foundations for the armourstone walls on both banks. The riffle grade control and embedded armourstone foundations below grade are key to maintain stability as observed in R2a and to minimize failures due to scour as observed in R2b. While armourstone channels are reasonable design solutions for confined urban channels, they do still require maintenance and/or replacement over the long term, and as such, it is preferable, if possible, to provide the creek channel a wider corridor as recommended in in Section 5.2.

Downstream of the Dundas Street crossing in R4, erosion mitigation measures may also be considered at ES 4.1 in the design options for the selected flood mitigation alternative. In addition, the selection of floodplain regrading downstream of the crossing—as part of the preferred flood mitigation alternative—would provide further opportunities to rehabilitate the degraded creek channel in this reach and address the erosion risks at ES 4.1 (Appendix F, Figure F1). Considering the slightly wider floodplain downstream in R4, softer approaches to channel restoration using smaller stone sizes and bioengineering with vegetation may be considered in a naturalized riffle-pool design and associated bank treatments.

5.2 Preferred Long-term Geomorphic Corridor

City planning for long-term redevelopment in the study area of Dixie-Dundas provides an opportunity to locally enhance the Little Etobicoke Creek corridor for a more sustainable and climate resilient approach to erosion and flood hazard management. Specifically, sections of the creek that have been historically straightened and narrowed can be rewidened in a similar “make room for the creek” concept as envisioned for the upstream floodplain regrading around the Dixie Road crossing. While recommendations for short-term erosion mitigation have been provided in Appendix F (in context of the flood mitigation study for Dundas Street) the concept of a preferable long-term geomorphic corridor is also presented for R3 given the potential for future redevelopments in the area. As a general concept, the recommendation is to ultimately provide the creek a corridor width of roughly 90 m within R3, upstream of Dundas Street, which includes a 60 m MBW in the valley bottom and an additional 30 m for valley side slopes (i.e., 15 m each side; note: a 57.6 m MBW is recommended for R3 in Table 1). The wider creek corridor would not only provide a sustainable and climate resilient buffer to manage erosion and flooding hazards, but it would also provide ecological benefits in the greenspace and recreational opportunities for the local community.

6 REFERENCES

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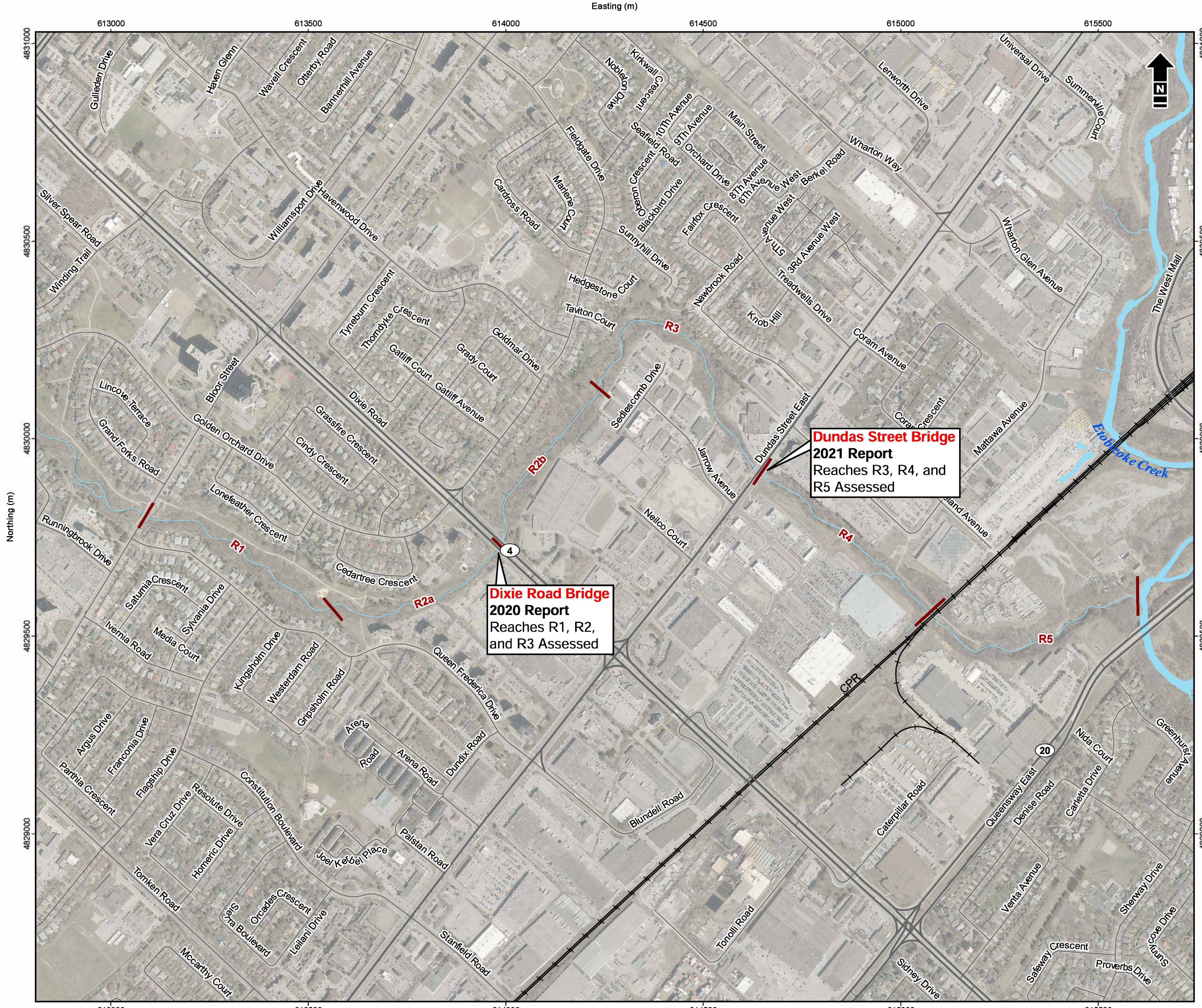
APPENDIX A
Study Area Map



Watercourse

Reach Break

1:10,000 metres

100 0 100 200

NAD 1983 UTM Zone 17N

Reference: Contains information licensed under the Open Government Licence – Ontario. Contains data obtained by Matrix Solutions Inc and the City of Missisauga

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City of Mississauga
Dixie - Dundas

Reach Map

Date:	Project:	Submitter:	Reviewer:
Sept 2019	24603	N. Cyples	M. Wojda

Appendix
A

APPENDIX B
Rapid Assessment Protocols

APPENDIX B

RAPID ASSESSMENT PROTOCOLS

1 RAPID GEOMORPHIC ASSESSMENT (MOE 2003)

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (currently the Ontario Ministry of the Environment, Conservation and Parks; MOE 2003) to assess channel reaches in urban channels. This qualitative technique is purely a presence/absence methodology designed to document evidence of channel instability such as exposed tree roots, undercut branches, etc. The various indicators are grouped into four categories indicating a specific geomorphic process:

- aggradation
- degradation
- channel widening
- planimetric form adjustment

Over the course of the survey, the existing geomorphic conditions of each reach are noted, and individual geomorphic indicators are documented. Upon completion of the field inspection, these indicators are tallied by category and used to calculate an overall reach stability index, which corresponds to one of three stability classes related to sensitivity to altered sediment and flow regimes:

- ≤0.20 in regime or stable (least sensitive)
- 0.21 to 0.40 transitional or stressed (moderately sensitive)
- ≥0.41 in adjustment (most sensitive)

2 RAPID STREAM ASSESSMENT TECHNIQUE (GALLI 1996)

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). When compared with the RGA, the RSAT provides a more qualitative assessment of the overall health and functions of a reach in order to provide a quick assessment of stream conditions and the identification of restoration needs on a watershed scale. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- channel stability
- erosion and deposition
- instream habitat
- water quality
- riparian conditions
- biological indicators

Once a condition has been assigned a score, these scores are totalled to produce an overall rating that is based on a 50-point scoring system, divided into three classes:

- <20 low
- 20 to 35 moderate
- >35 high

While the RSAT scores stream from a more biological and water quality perspective than the RGA, this information does have relevance within a geomorphic context based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent stable, naturally-functioning geomorphology as well (i.e., fish prefer a variety of physical conditions: pools provide resting areas while riffles provide feeding areas and contribute oxygen to the water, good riparian conditions provide shade and food, woody debris and overhanging banks provide shade). From a water quality perspective, the concentration of chemicals may not be a concern with respect to geomorphic conditions, but the turbidity of the stream can be an issue, as it implies active sediment transport and can contribute to substrate embeddedness.

REFERENCES

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APPENDIX C
Site Photographs for Reaches 3 to 5

Matrix Solutions Inc.
June 23, 2021

1. Reach R3 – Natural channel section downstream of Reach R2, with local undercutting of banks and some scour around large woody debris.

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June 23, 2021

2. Reach R3 – Looking upstream at exposed sanitary sewer crossing, south of Taviton Court.

Matrix Solutions Inc.
June 23, 2021

3. Reach R3 – Looking downstream at bank erosion and large channel bar near outfall channel south of Taviton Court

Matrix Solutions Inc.
June 23, 2021

4. Reach R3 – Looking downstream at boulder bank revetment on east bank.

Matrix Solutions Inc.
June 23, 2021

5. Reach R3 – Looking downstream at narrow channel confined by gabion baskets in poor to failing condition

Matrix Solutions Inc.
June 23, 2021

6. Reach R3 – Looking downstream at large accumulation of rip-rap and native limestone in channel

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June 23, 2021

7. Reach R3 – Looking downstream at scoured pool and rip-rap along the bank, with riffle and gravel bar in the background.

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8. Reach R3 – Looking upstream at west bank where armourstone toe transitions to rip-rap along bank

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June 23, 2021

9. Reach R3 – Upstream of Dundas Street; right bank (looking downstream) is vertical and actively eroding upstream of armourstone bank protection.

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10. Reach R3 – Looking downstream towards Dundas Street road crossing.

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11. Reach R3 – Outfall on right bank upstream of Dundas Street Crossing; toe of bank is lined with remnants of riprap.

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12. Reach R3 - ooking downstream through Dundas Street crossing.

Matrix Solutions Inc.
June 23, 2021

13. Reach R4 – Downstream end of Dundas Street crossing; both banks are well protected with armourstone blocks.

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14. Reach R4 – Looking downstream of road crossing; channel substrate is generally coarse and consist of platy bedrock or riprap.

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15. Reach R4 – Left bank (looking downstream) protected with gabion baskets – some of which are becoming undermined.

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16. Reach R4 – Vertical bank face with exposed clay and till layers across from cobble/boulder point bar.

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17. Reach R4 – Exposed bank face and abundant exposed tree roots within bank suggesting channel is widening.

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18. Reach R4 – Looking downstream – gravel/cobble point bar along right bank.

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19. Reach R4 – Outfall along left bank – bank was protected with gabion baskets that have since become undermined and material has washed into stream

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20. Reach R4 – Active bank erosion on right bank where gabion baskets stop.

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21. Reach R4 – Looking downstream toward railway crossing, channel bed still predominantly coarse substrate.

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22. Reach R4 – Looking downstream at railway crossing – there is a drop in channel profile of approximately 0.5 m

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June 23, 2021

23. Reach R4 - Right bank at railway crossing – concrete on channel bed and along right bank is cracking and beginning to fail.

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24. Reach R5 – Reach break downstream of railway; concrete weir over sewer crossing is cracking/eroding and will continue to crack/erode until pipe is exposed

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25. Reach R5 – Scour pool downstream of sewer crossing; slabs of concrete from railway have washed downstream.

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26. Reach R5 - Steep, eroding right bank with exposed tree roots and leaning trees; small pipe outlet at top of slope.

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June 23, 2021

27. Reach R5 – Vertical right bank with exposed bank face and layers of limestone – platy material has accumulated along toe of bank

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28. Reach R5 – Looking downstream towards trunk sewer crossing – active erosion is occurring around the sewer crossing causing it to become exposed

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June 23, 2021

29. Reach R5 – Overview of exposed trunk sewer crossing before confluence into Etobicoke Creek

APPENDIX D
Erosion Inventory and Bank Condition Scoring Map

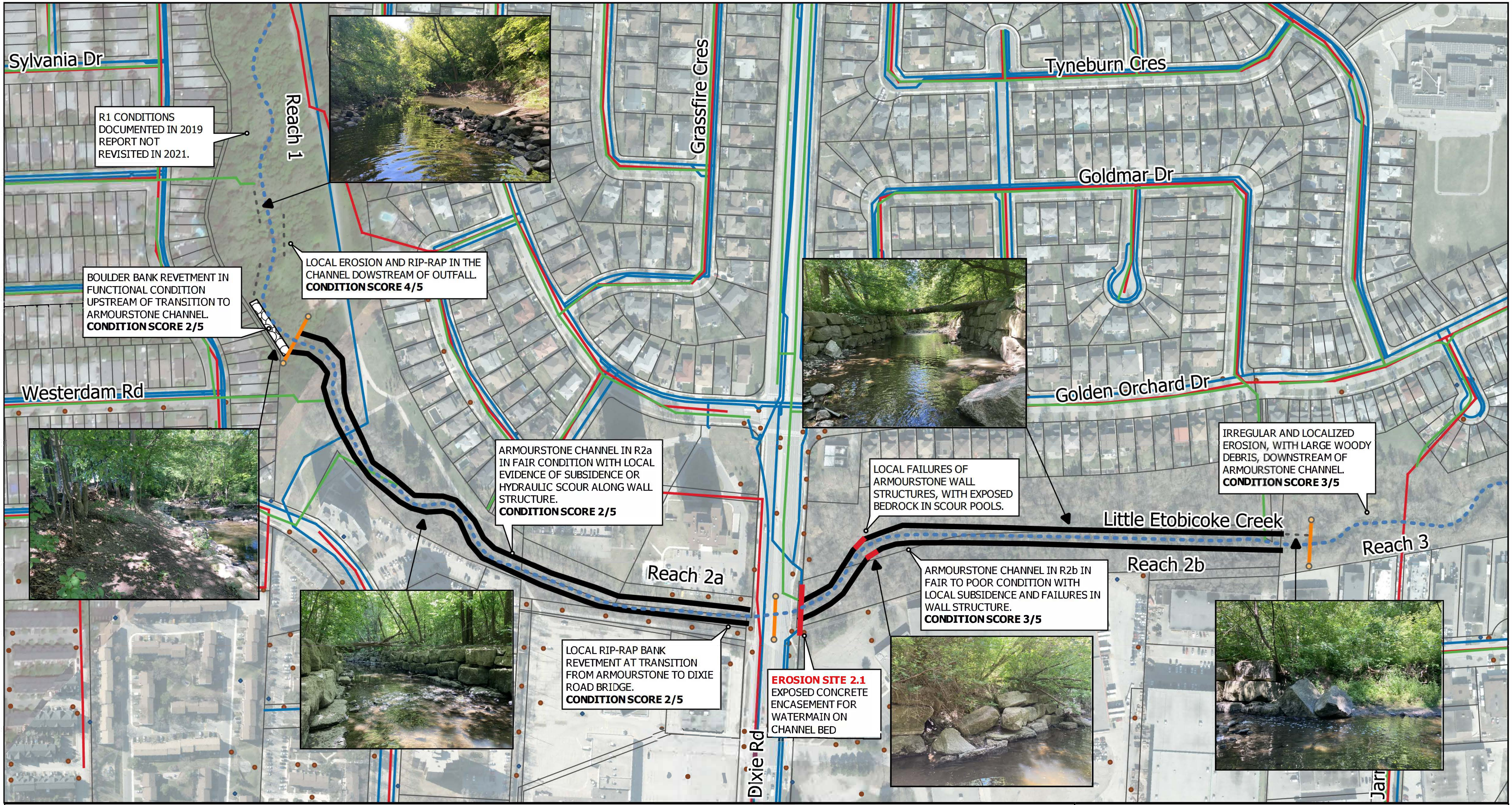

Figure Date: September 2, 2021

Note that the full extent of infrastructure is not fuly shown based on data availability.

Legend

- Armourstone
- Boulders/Rip-Rap
- Erosion_Site
- Minor/Variable Erosion
- Reach Breaks
- Watercourse
- Storm Sewer
- Sanitary Sewer
- Watermain
- Hydrant
- Utility Pole
- Property Boundaries

0 50 100 150 200 m

Scale 1:3000

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Dixie-Dundas Flood Mitigation
Fluvial Geomorphology Assessment Addendum

Project #: 24603

Erosion Inventory
Reach 2a and Reach 2b

msamson
rphilips

Figure D1

T:\24603 - Dixie-Dundas\531\05 Analysis\GIS\2021-05-26 - Infrastructure Constraints (Geomorph Scope Change)\Infrastructure Constraints.qgz|1 - R2 Erosion|pg1|2021-09-02

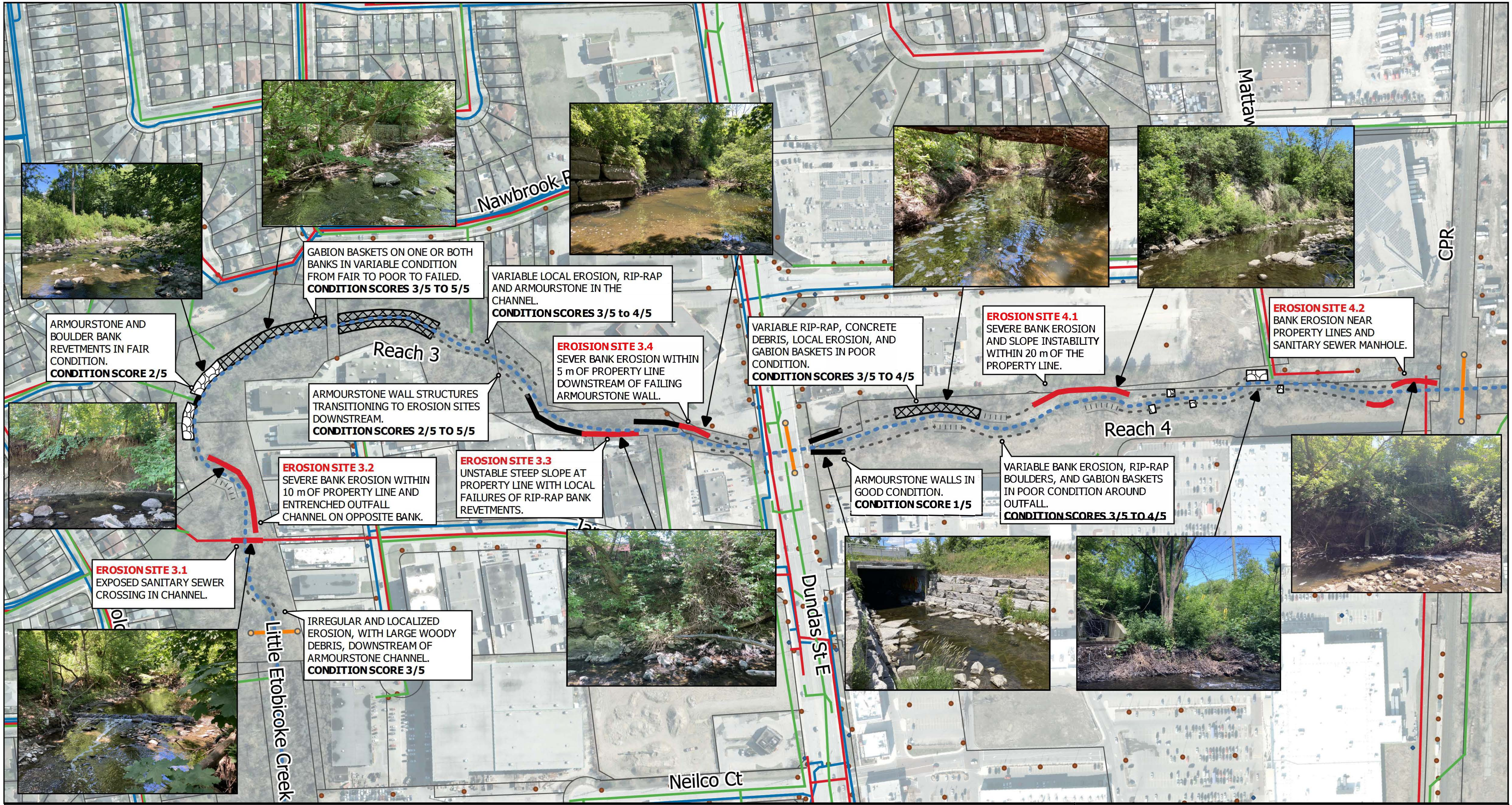

Figure Date: September 2, 2021

Note that the full extent of infrastructure is not fuly shown based on data availability.

Legend

- Armourstone
- Boulder/Rip-Rap
- Gabion Baskets
- Erosion Site
- Minor/Variable Erosion
- Bar
- Reach Breaks
- Watercourse
- Storm Sewer
- Sanitary Sewer
- Watermain
- Hydrant
- Utility Pole
- Property Boundaries

0 50 100 150 200 m

Scale 1:3000

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Fluvial Geomorphology Assessment Addendum

Project #: 24603

Erosion Inventory
Reach 3 and Reach 4

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rphilips

Figure D2

T:\24603 - Dixie-Dundas\531\05 Analysis\GIS\2021-05-26 - Infrastructure Constraints (Geomorph Scope Change)\Infrastructure Constraints.qgz|2 - R3 and R4 Erosion|pg1|2021-09-02

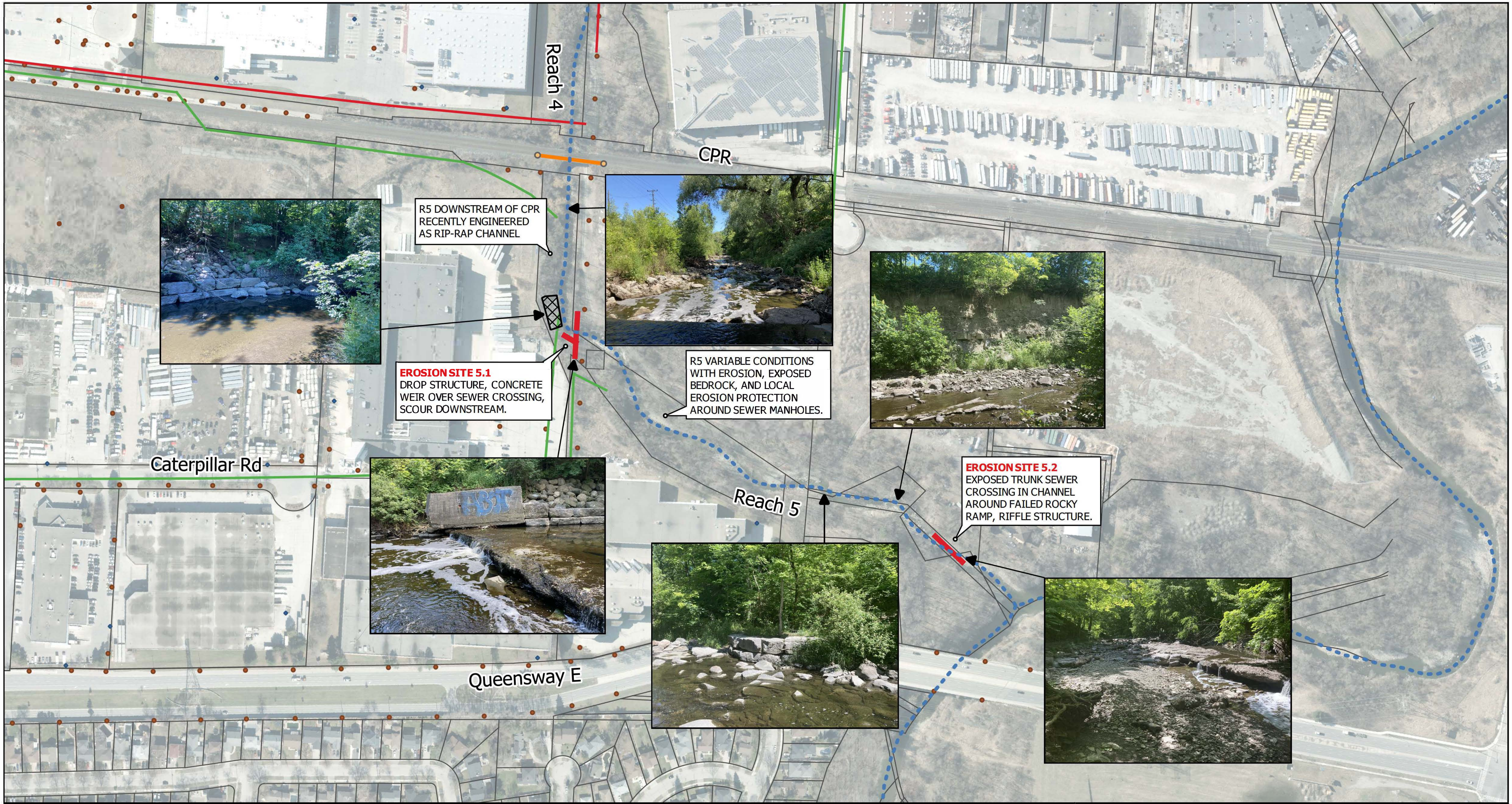

Figure Date: September 2, 2021

Note that the full extent of infrastructure is not fuly shown based on data availability.

Legend

- Boulder/Rip-Rap
- Gabion Baskets
- Erosion Site
- Reach Breaks
- Watercourse
- Storm Sewer
- Sanitary Sewer
- Watermain
- Hydrant
- Utility Pole
- Property Boundaries

0 50 100 150 200 m

Scale 1:3000

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Dixie-Dundas Flood Mitigation
Fluvial Geomorphology Assessment Addendum

Project #: 24603

Erosion Inventory
Reach 5

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Figure D3

T:\24603 - Dixie-Dundas\531\05 Analysis\GIS\2021-05-26 - Infrastructure Constraints (Geomorph Scope Change)\Infrastructure Constraints.qgz|3 - R5 Erosion|pg1|2021-09-02

APPENDIX E
Examples of Bank Conditions Scoring from Little Etobicoke Creek and Other Projects

City of Mississauga - Dixie-Dundas Flood Mitigation

Bank Condition Scoring Framework

Sub-reach averages and range presented in Appendix D

Gabion Baskets	Score
Baskets Empty	1 – 5
Baskets Undercut	1 – 5
Baskets Leaning	1 – 5
Baskets Buried or Decayed	2 – 3

Erosion Control Structures	Score
Structure Condition	1 – 5

Bank Erosion	Score
Degree of Erosion	1 – 5

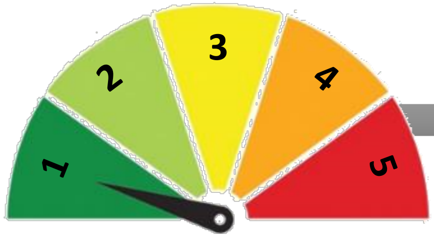
Average Score

Maximum Score

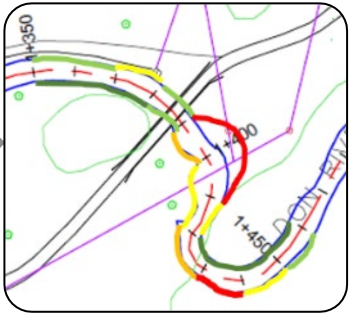
OR

OR

Bank Condition Score 1 – 5



Bank Condition Score 1 – 5



Bank Condition Score Mapping (assessed at 10 metre intervals)

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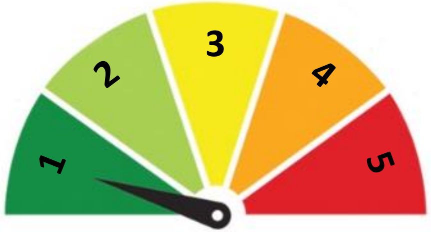
Condition of Erosion Control Structures: Amourstone, Rip-Rap, Round Stone Boulders



Condition of EC Structures

1 – Good (Amourstone)

2 – Fair (Armourstone)

3 – Poor (Armourstone Slump)

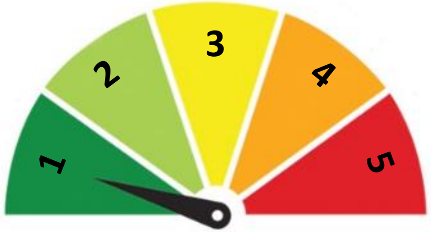
4 – Failure on Bank (Armourstone)

5 – Failure into Channel (Amourstone)

* Example not from study area

Overall Gabion Basket Condition:

General Score



Average or Maximum Score

1 – Good*

2 – Fair

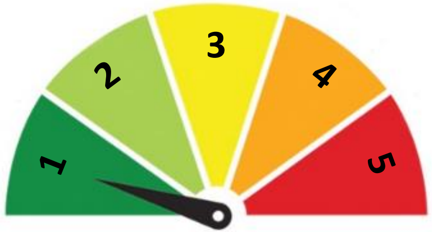
3 – Poor

4 – Slump or Topple on Bank

5 – Failure into Channel

Degree of Erosion

Bank Condition of Soft Native Material



Degree of Erosion

1 – Stable Bank

2 – Minor Bank Erosion

3 – Moderate Bank Erosion

4 – Major Bank Erosion

5 – Severe Bank Erosion

APPENDIX F
Erosion Mitigation Concept at Dundas Street

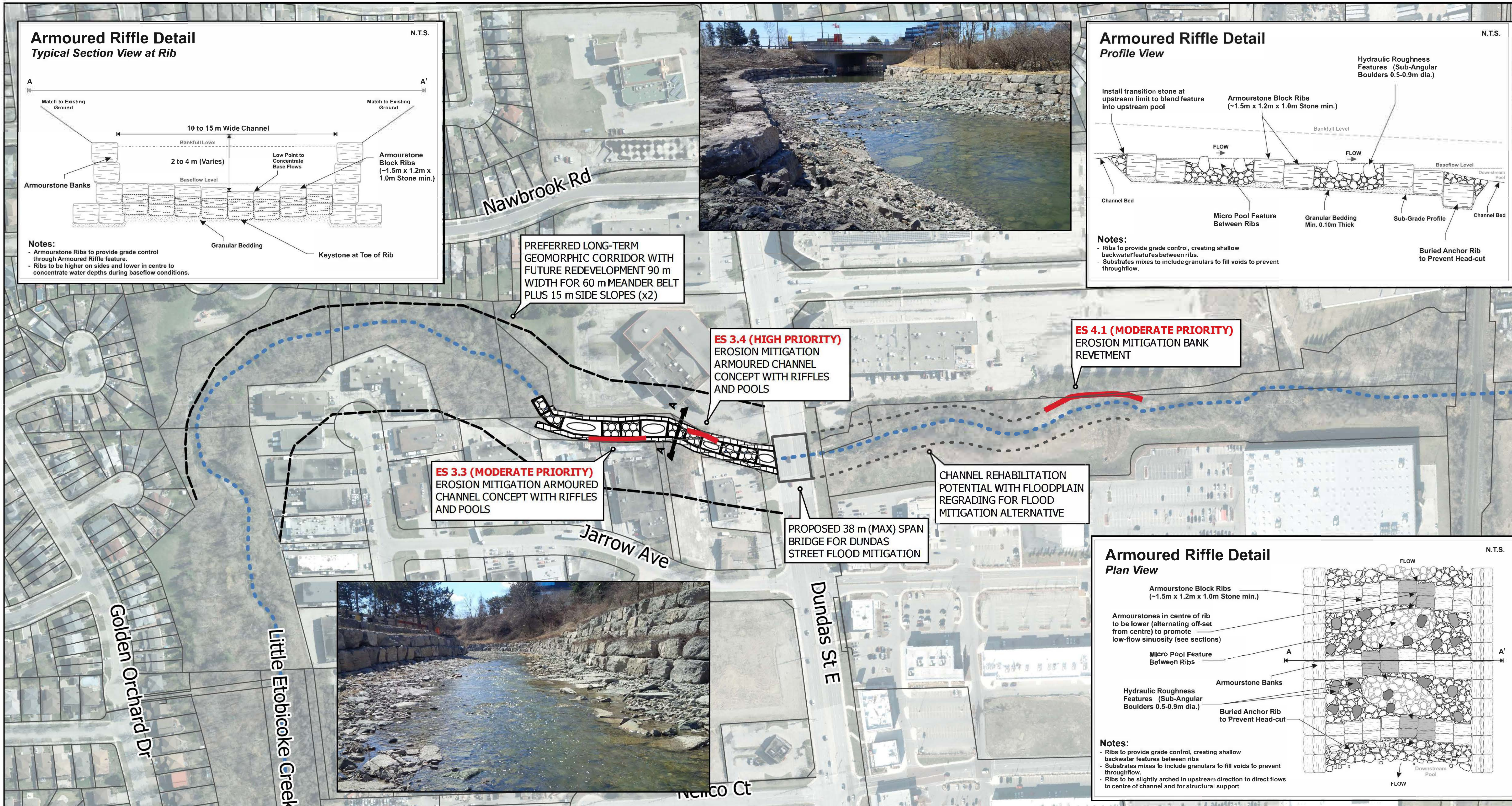


Figure Date: September 2, 2021

Note that the full extent of infrastructure is not fuly shown based on data availability.

Legend

- Armourstone
- Proposed Bridge Span
- Preferred Geomorphic Corridor
- Erosion Site
- Armoured Riffle and Pool
- Channel Rehabilitation
- Watercourse
- Property Boundaries

0 50 100 150 200 m

Scale 1:3000

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Dixie-Dundas Flood Mitigation
Fluvial Geomorphology Assessment Addendum

Project #: 24603

Erosion Mitigation Concept Dundas Street Crossing

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msamson
rphilips

Figure F1

T:\24603 - Dixie-Dundas\531\05 Analysis\GIS\2021-05-26 - Infrastructure Constraints (Geomorph Scope Change)\Infrastructure Constraints.qgz|4 - Preferred Long-term Geomorph Corridor|pg1|2021-09-02