Prepared for:

The City of Waterloo

CITY OF WATERLOO
Municipal Class Environmental Assessment
WATERCOURSE EROSION MASTER PLAN

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Table of Contents

List of Appendices

List of Figures

List of Tables

1 INTRODUCTION

Aquafor Beech Ltd. has been retained by the City of Waterloo to develop an Integrated Stormwater Management Master Plan (ISWM-MP) for the City under the Municipal Class Environmental Assessment process. This report presents the results of the Erosion Assessment component of the study, which includes a city-wide erosion inventory and identification of stream restoration opportunities. The Erosion Assessment is being completed as a separate and complete Watercourse Erosion Master Plan and its results will be integrated into the broader-ISWM-MP.

1.1 Purpose of Report

The purpose of this report is to document the 2017 creek field-walks and erosion inventory completed for the City of Waterloo to identify potential creek-based works as a sub-component of the Integrated Stormwater Management Master Plan. Specific tasks to be addressed in this report include:

1. Layout background information relevant to stream geomorphology and erosion within the City,
2. Document 2017 existing conditions for watercourses within the City based on creek walks and field data,
3. Outline the field and scoring methodology used to assess and classify erosion issues, and
4. Present the erosion assessment results in terms of stream restoration opportunities.

The technical field scoring methodology for erosion sites was developed in consultation with the project team and it assesses the levels of risk and environmental opportunity. The field scoring is intended to inform a first-order classification of erosion sites. Where mitigation of erosion is not urgent, erosion sites are to be considered as stream restoration opportunities to be integrated into a system-wide prioritization and implementation plan within the overall ISWM-MP. The erosion assessment, including identified erosion site and restoration reach opportunities, will also consider potential projects which align other proposed City works in regards to infrastructure rehabilitation and / or replacement.

1.2 Environmental Assessment Process

The Environmental Assessment Act was legislated by the Province of Ontario in 1980 to ensure that an Environmental Assessment is conducted prior to the onset of development and development related (servicing) projects. Depending on the individual project or Master Plan to be completed, there are different processes that municipalities must follow in order to meet Ontario's Environmental Assessment requirements.

This report provides a strategy for implementing a large number of projects of a similar nature with differences being primarily due to site specific conditions. For this reason, the Municipal Class Environmental Assessment Master Planning process, as described By the Municipal Engineers Association (2000, as amended 2007& 2011) will be followed.

Class Environmental Assessments (Class EA) are prepared for approval by the minister of the environment. A Class EA is an approved planning document that defines groups of projects and activities and the environmental assessment (EA) process which the proponent commits to for each

project undertaking. Provided the process is followed, projects and activities included under the Class EA do not require formal review and approval under the EA Act. In this fashion, the Class EA process expedites the environmental assessment of smaller recurring projects.

The Municipal Class Environmental Assessment Master Planning process to be followed is illustrated in **Figure 1-1**, and may involve up to five phases of assessment. These phases include:

- Phase 1: Establish the Problem or Opportunity
- Phase 2: Identify and Assess Alternative Solutions to the Problem, and Select a Preferred Alternative
- Phase 3: Identify and Assess Alternative Design Concepts for the Preferred Solution and Select a Preferred Design Concept.
- Phase 4: Prepare an Environmental Study Report
- Phase 5: Proceed with Design and Implementation.

Public and agency consultation is also an important and necessary component of the five phases.

In partial fulfillment of Ontario's Environmental Assessment requirements, a Master Plan must satisfy at least the first two (2) phases of the Class Environmental Assessment process. Depending on the type of Master Plan to be completed, Phases 3 and 4 may also be required.

The Municipal Engineers Association's Class EA document also classifies projects as Schedules A, A+, B, or C depending on their level of environmental impact and public concern. Any project identified in this Master Plan must be classified as to their level of complexity and potential level of environmental impact, which will in turn decide which Schedule process needs to be followed.

- **Schedule 'A'** projects generally consist of projects involving upgrades and routine maintenance; they do not have the potential for significant environmental impacts or need public input. Schedule 'A' projects are pre-approved without any further public consultation. Per Appendix I –Project Schedules of the Municipal Class Environmental Assessment (2000, as amended in 2007), Schedule 'A' watercourse projects include "replacing traditional materials in an existing watercourse or in slope stability works with material of equal or better properties, at substantially the same location and for the same purpose."

- **Schedule 'A+'** projects were introduced in 2007 by the Municipal Engineers Association. These projects are pre-approved; however, the public is to be advised prior to the project implementation. Per Appendix I –Project Schedules of the Municipal Class Environmental Assessment (2000, as amended in 2007), watercourse management projects that are pre-approved under Schedule A+ of the MEA includes to "retire a facility which would have been planned under Schedule A or Schedule A+ of the Municipal Class EA for its establishment"

- **Schedule 'B'** projects have more environmental impact and do have public implications. Examples would be "modifying existing water crossings for the purposes of flood control," or "works undertaken in a watercourse for the purpose of flood control or erosion control which may include bank or slope regrading, deepening the watercourse, relocation,

realignment or channelization of watercourse, revetment including soil bio-engineering techniques, or reconstruction of a weir or dam". Schedule 'B' projects require completion of Phases 1 and 2 of the Class EA process before proceeding to Phase 5, implementation.

- **Schedule 'C'** projects have the most major public and environmental impacts. Examples may include construction of a diversion channel, construction of new shore line works, or construction of new dam or weir in a watercourse. Schedule 'C' projects require completion of Phases 1 through 4 of the Class EA process before proceeding to Phase 5, implementation.

The Municipal Engineers Association's Class EA document also identifies four different approaches to completing Master Plans corresponding to different levels of assessment. Regardless of the approach selected, all Master Plans must follow at least the first two phases of the Class Environmental Assessment process.

- **Approach 1**, the most common approach, is to follow Phases 1 and 2 as defined above, then use the Master Plan as a basis for future investigations of site specific Schedule 'B' and 'C' projects. Any Schedule 'B' and 'C' projects that need specific Phase 2 work and Phases 3 and 4 work, usually have this Phase 2, 3 and 4 deferred until the actual project is implemented.

- **Approach 2**, is to complete all of the work necessary for Schedule 'B' site specific projects at the time they are identified. Using this approach, a municipality would identify everything it needed in the first five years and would complete all the site-specific work required, including public consultation to meet Class EA requirements. In such cases, the Master Plan has to be completed with enough detail so that the public in site-specific locations can be reasonably informed, and so that the approving government agencies (conservation authorities, Ministry of Natural Resources and Forestry, Federal Department of Fisheries and Oceans, Transportation Canada etc.) can be satisfied, in principal, that their concerns will be addressed before construction commences.

- **Approach 3**, is to complete the requirements of Schedule 'B' and Schedule 'C' at the Master Plan stage.

- **Approach 4**, is to integrate approvals under the EA and Planning Acts. For example, the preparation of new or amended Official Plans could be undertaken simultaneously with Master Plans for water, wastewater and transportation, and approval for both sought through the same process.

The Watercourse Erosion Master Plan was conducted in accordance with the requirements for Master Plans under Section 4, Approach #2 of the Municipal Engineers Association Municipal Class Environmental Assessment Act (October 2000, as amended in 2007 & 2011), which is an approved process under the Ontario Environmental Assessment Act. As part of the Class EA process evaluation of alternatives, assessment of the potential environmental effects and identification of mitigation measures for potential adverse impacts has been conducted and presented through public and agency consultations.

This Master Plan fulfills all of the Class EA requirements for Schedule A, A+, and B projects which can then proceed directly to detailed design and implementation (as required). The Master Plan also identifies any Schedule C projects for future studies (i.e. Phases 3 and 4).

Master Plans, by definition, are long range plans which integrate infrastructure for existing and future land use with environmental assessment planning principles. In the case of the Erosion Assessment MP, implementation is projected to occur over a period of 15 years. This MP concludes with a set of preferred alternatives which make up the recommended approach and, therefore, by its nature, the MP will limit the scope of alternatives which can be considered at the implementation stage. It is proper to revisit Master Plans on a 5-year basis to ensure conditions (environmental, social, financial, and technical) have remained unchanged. As such, if at the time of implementation, conditions have changed such that the preferred alternative cannot be implemented, an addendum may be prepared for the specific project. Amendments to the projects identified as part of the preferred alternatives can be made using the addendum procedures outlined in the Municipal Engineers Association Municipal Class Environmental Assessment Act document (October 2000, as amended in 2007 & 2011) and shall be posted for the required 30-day review period.

Prior to implementation, additional public consultation shall be undertaken in support of further work carried out for specific Schedule B projects. Additionally, integration across city departments is fundamental to a modern watercourse management approach and is essential for the City of Waterloo in the implementation of this MP to meet the project goals and objectives. In this regard, potential synergies with other City strategic plans, subwatershed studies, Master Plans, Secondary Plans, Environmental Assessments, and policies are considered essential.

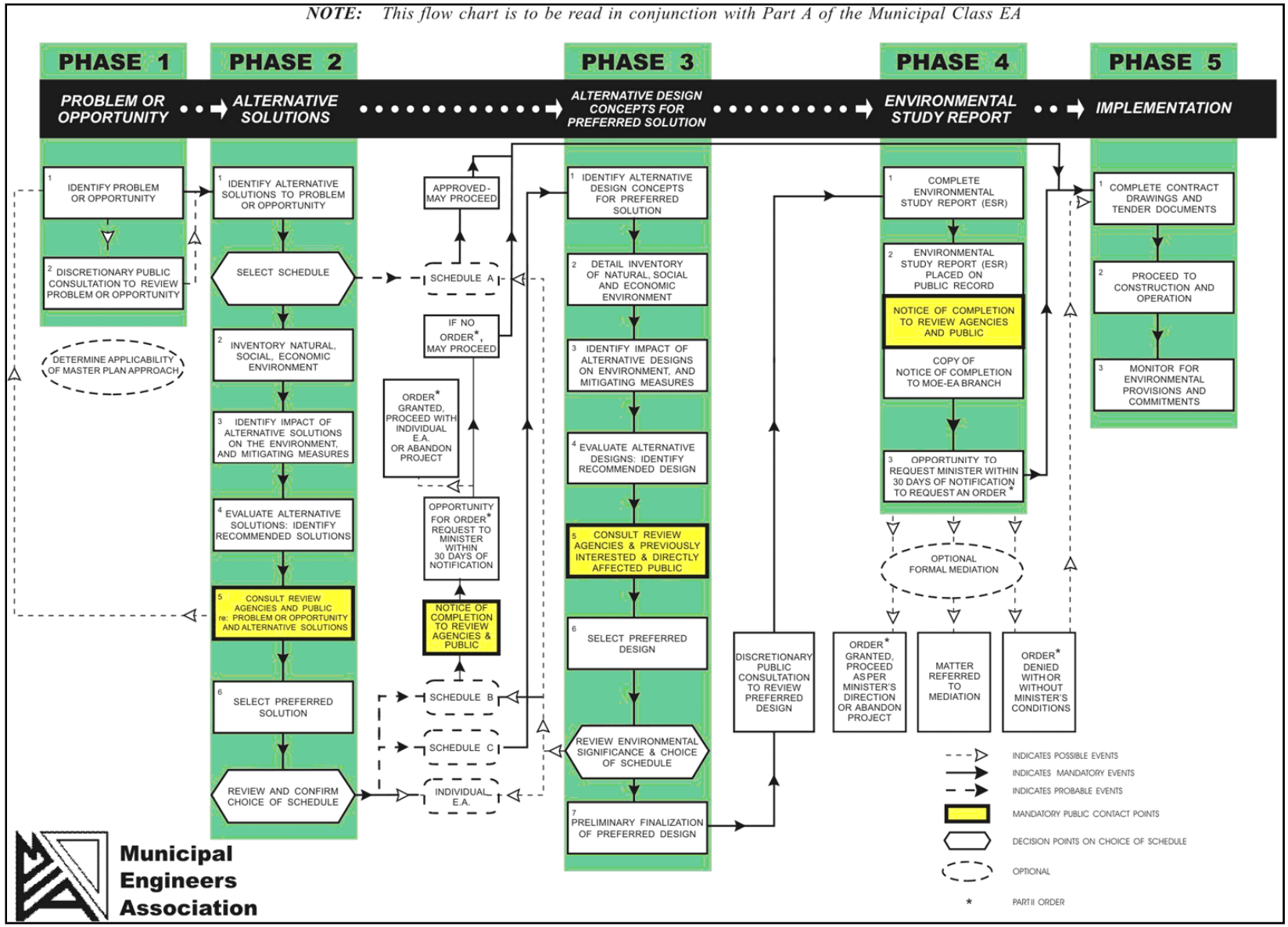

Figure 1-1: Municipal Class Environmental Assessment Planning and Design Process

1.3 Report Outline

This report covers Phases 1 and 2 of the Environmental Assessment process for the Watercourse Erosion Master Plan. The following provides a summary of the report components:

Section 1 – **Introduction:** A broad introduction to the purpose of the report and a description of the environmental assessment process.

Section 2 – **Background:** The available background information for the project, including previous studies, previous creek works, and concurrent environmental assessment studies.

Section 3 – **Phase 1: Identification of Problems and Opportunities:** An introduction to the tasks performed as part of Phase 1 of the Environmental Assessment process.

Section 4 – **Study Area:** A detailed description of the study area, including surface geology, drainage network and stream reaches, and an overview of the creeks.

Section 5 – **Methods:** The methodology of the geomorphic and erosion assessments of Phase 1 of the Environmental Assessment.

Section 6 – **Results:** The results of the geomorphic and erosion assessments of Phase 1 of the Environmental Assessment.

Section 7 – Opportunities: A variety of remediation alternatives for possible restoration works, their purpose, and the type of treatment they provide were outlined in this section.

Section 8 – Phase 2: Evaluation of Alternatives: This section outlines the tasks performed as part of Phase 2 of the Environmental Assessment process. This section also outlines the primary erosion issues within the site area and develops evaluation criteria to summarize the preferred alternative for each primary erosion issue.

Section 9 – Conceptual Design: For each of the primary erosion concerns, a conceptual design was developed for the preferred alternative. This section also includes a cost estimate, detailed design requirements, implementation measures, and monitoring requirements for each of the primary erosion issues.

Section 10 – Implementation Plan: Outlines the process required to implement the preferred alternatives.

Section 11 – Conclusions and Recommendations: The final conclusions and recommendations of Phase 1 and 2 of the Environmental Assessment process.

Section 12 – References: References used to complete the Erosion Assessment Master Plan.

2 BACKGROUND

2.1 Previous Studies

The City of Waterloo has previously undertaken inspections of municipal watercourses in 2002 (Parish Geomorphic Ltd. And Planning & Engineering Initiatives Ltd.) and 2013 (City of Waterloo). The 2013 report was provided to Aquafor at the onset of the current study and its methodology and findings are summarized in the ISWM-MP Existing Conditions Report (Aquafor Beech Ltd., 2019).

Overall, the assessment methodology used in the 2013 study was subjective to the individual assessors as no quantifiable metrics were used. As such, a new methodology was proposed for the current assessments. All sites identified for monitoring or remediation in the 2013 study were re-evaluated during the current creek walks and scored according to the new erosion site evaluation matrix.

2.2 Creek Works Undertaken Since 2002 Study

Since the 2002 study, the erosion control works have been undertaken by the City of Waterloo or are scheduled to be undertaken by the city on Cedar Creek, Clair Creek, Colonial Creek, Forwell Creek, Laurel Creek, and Maple Hill Creek. The location and date of the works is shown on **Figure 2-1**. While general programs are undertaken annually by the city for city-wide creek bank stabilization and sediment removal from creeks at crossing and culverts etc., individual erosion control or channel restoration are identified in in **Table 2-1**. A summary of the expected implementation year, cost, and approximate distance of creek affected, for these projects is shown in **Table 2-1**.

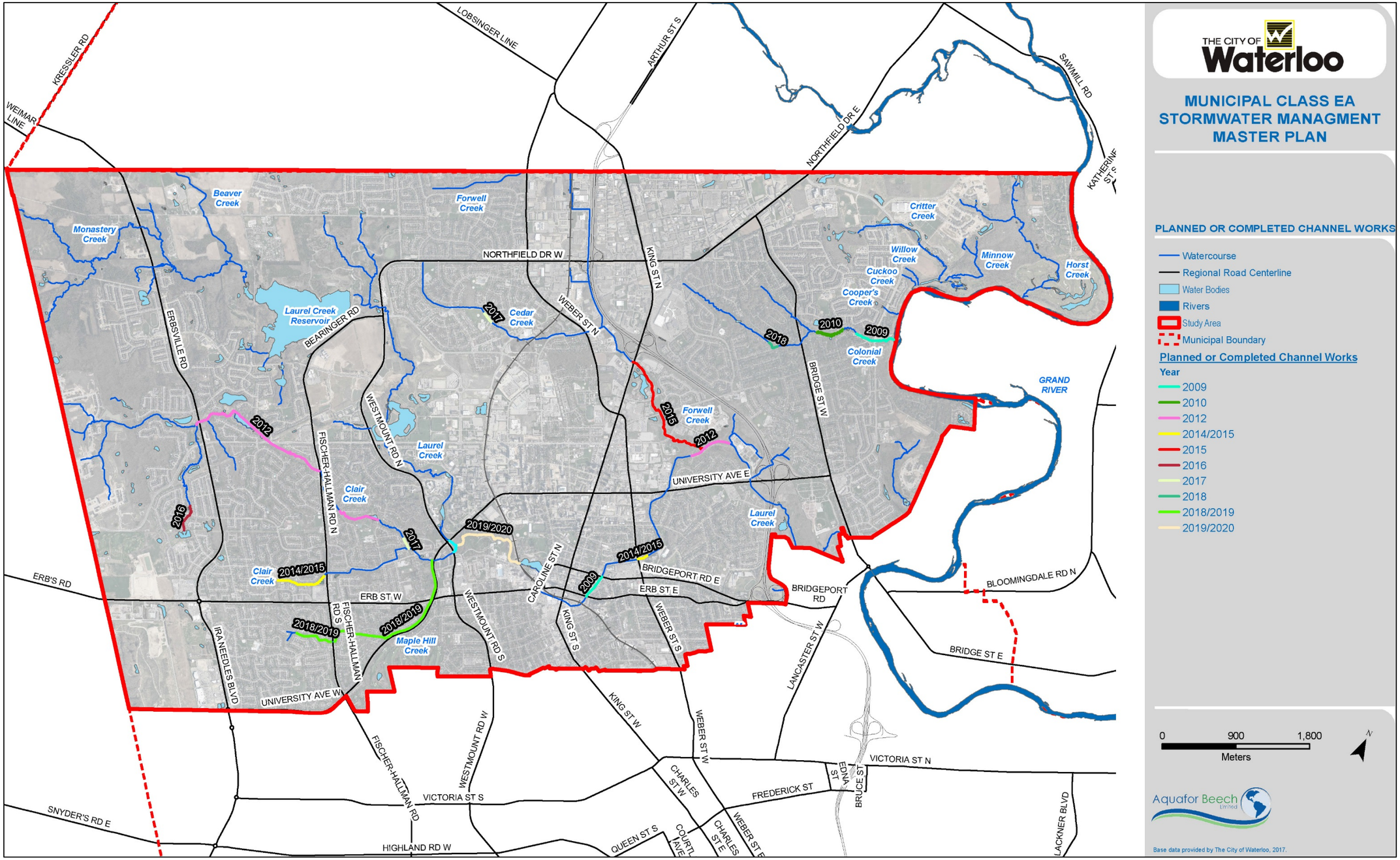

Figure 2-1: Location of Planned or Completed Channel Works within Waterloo

Table 2-1: Stormwater Management - Future Creek Works City-Wide (2018-2028)

Year	Asset Class	Project	Description	Total Cost ($ CAD)	Distance (metres)
2019-2028	Stormwater Management - Creek	Creek Bank Stabilization-City Wide	General city-wide program	765,220	n/a
2019-2028	Stormwater Management - Creek	Sediment Removal Creeks - City Wide	General city-wide program	353,400	-
2020	Stormwater Management - Creek	Bechtel Park Woodlot - Creek Rehabilitation	Design	30,000	140
2020	Stormwater Management - Creek	Bechtel Park Woodlot - Creek Rehabilitation	Construction	135,278	140
2019	Stormwater Management - Creek	Clair Creek North Reach 1	2019 Detailed Design	120,593	765
2020	Stormwater Management - Creek	Clair Creek North Reach 1	2020 Implementation	1,147,500	765
2022	Stormwater Management - Creek	Forwell Creek Industrial Lands	Year 1 - Functional Study	195,000	1,050
2023	Stormwater Management - Creek	Forwell Creek Industrial Lands	Year 2 - Design	150,000	1,050
2024	Stormwater Management - Creek	Forwell Creek Industrial Lands	Year 3 - Study Implementation	1,050,000	1,050
2025	Stormwater Management - Creek	Forwell Creek Industrial Lands	Year 4 - Study Implementation	1,050,000	1,050
2021	Stormwater Management - Creek	Keatsway Storm Bypass & Creek Bank Stabilization	Creek reconstruction	480,000	320
2025	Stormwater Management - Creek	Laurel Creek Channel Around Columbia Lake	Implementation	841,532	-
2027	Stormwater Management - Creek	Laurel Creek Rehabilitation - Reservoir to Erbsville Rd	2027 Class EA	250,000	1,050
2029	Stormwater Management - Creek	Laurel Creek Rehabilitation - Reservoir to Erbsville Rd	2029 Detailed Design	150,000	1,050
2030	Stormwater Management - Creek	Laurel Creek Rehabilitation - Reservoir to Erbsville Rd	2030 Implementation	1,575,000	1,050
2018	Stormwater Management - Creek	Laurel Creek Functional Study & Implementation - Regina to Weber	2018 Functional Study/EA	200,000	-

2019	Stormwater Management - Creek	Laurel Creek Functional Study & Implementation - Regina to Weber	2019 Detailed Design	100,000	-
2020	Stormwater Management - Creek	Laurel Creek Functional Study & Implementation - Regina to Weber	2020 Implementation (Erb To Bridgeport)	450,000	300
2021	Stormwater Management - Creek	Laurel Creek Functional Study & Implementation - Regina to Weber	2021 Implementation (Bridgeport to Weber)	825,000	550
2020	Stormwater Management - Creek	Laurel Creek Study Implementation - Hillside Park to HWY 85	2020 Various creek and natural environment restorations & enhancements	144,444	-
2021	Stormwater Management - Creek	Laurel Creek Study Implementation - Hillside Park to HWY 85	2021 Various creek and natural environment restorations & enhancements	337,037	-
2016/2017	Stormwater Management - Creek	Maple Hill Creek Rehabilitation- Westvale Pond to University Ave	2016/2017 - Functional Study/EA	232,500	775
2018	Stormwater Management - Creek	Maple Hill Creek Rehabilitation- Westvale Pond to University Ave	2018 - Detailed Design and Implementation	600,000	-
2018	Stormwater Management - Creek	Maple Hill Creek Rehabilitation- Westvale Pond to University Ave	2018 - Implementation	300,000	200
2019	Stormwater Management - Creek	Maple Hill Creek Rehabilitation- Westvale Pond to University Ave	2019 - Implementation	862,500	575
2024	Stormwater Management - Creek	Stormwater Management System Master Plan Implementation	2024 Implementation	534,188	-
2027	Stormwater Management - Creek	Stormwater Management System Master Plan Implementation	2027 Implementation	534,188	-
2028	Stormwater Management - Creek	Stormwater Management System Master Plan Implementation	2028 Implementation	534,188	-

2.3 Relevant Concurrent Environmental Assessment Studies

Concurrently with this study and the broader Integrated Stormwater Management Master Plan, the City of Waterloo has been undertaking Environmental Assessments on Maple Hill Creek and Waterloo Park, which cover erosion remediation works for the respective study areas. The City retained GHD to complete the Maple Hill Creek Rehabilitation EA and CH2M and Stantec to complete the Silver Lake and Laurel Creek Rehabilitation in Waterloo Park – EA Addendum. Descriptions of these projects are provided below.

Maple Hill Creek

Maple Hill Creek Rehabilitation Class Environmental Assessment was undertaken by GHD and included an assessment of the entire watercourse. The final project file includes the preferred alternative for each of the reaches along the creek. The preferred alternative is either local restoration or partial reach restoration depending on the issues to be addressed in the reach. The City is moving forward with the detailed design for the preferred alternatives followed by tendering and construction; as such, all priority issues identified in the Maple Hill Creek Rehabilitation Class EA will be addressed through this process.

Waterloo Park

The ***Silver Lake and Laurel Creek Rehabilitation in Waterloo Park – Environmental Assessment Addendum*** was undertaken by CH2M and Stantec with Stantec completing field walks of the reaches of Laurel Creek and Clair Creek running through Waterloo Park. The EA addendum identified erosion sites on these watercourses and the preferred alternative to address the issues. A project implementation plan proposes detailed design in 2018 and 2019 with construction in 2019 and 2020.

3 PHASE 1: IDENTIFICATION OF PROBLEMS AND OPPORTUNITIES

Identification of problems and opportunities is the first phase of the Environmental Assessment Process. Specific erosion problems were identified through field investigations of the City's Watercourses. Further details of these investigations and their findings are presented in the sections below. Subsequently, opportunities to remediate the erosion issues are presented.

4 STUDY AREA

In the City of Waterloo, over 74 km of stream systems flow through 15 distinct subwatersheds or catchment areas, all of which drain into the central segment of the Grand River watershed. (**Figure 4-1**). This segment of the Grand River includes all stream systems within Waterloo, Kitchener, and Cambridge, and is the most urbanized section of the watershed. Associated with urbanization are both direct and indirect factors of human activity on stream morphology. Direct impacts include changes of channel form, alignment, bank and bed materials, and instream structures (weirs, culverts, and dams), whereas indirect impacts relate primarily to changes in adjacent land use which can significantly influence the rate and method of water and sediment routing to a creek or river.

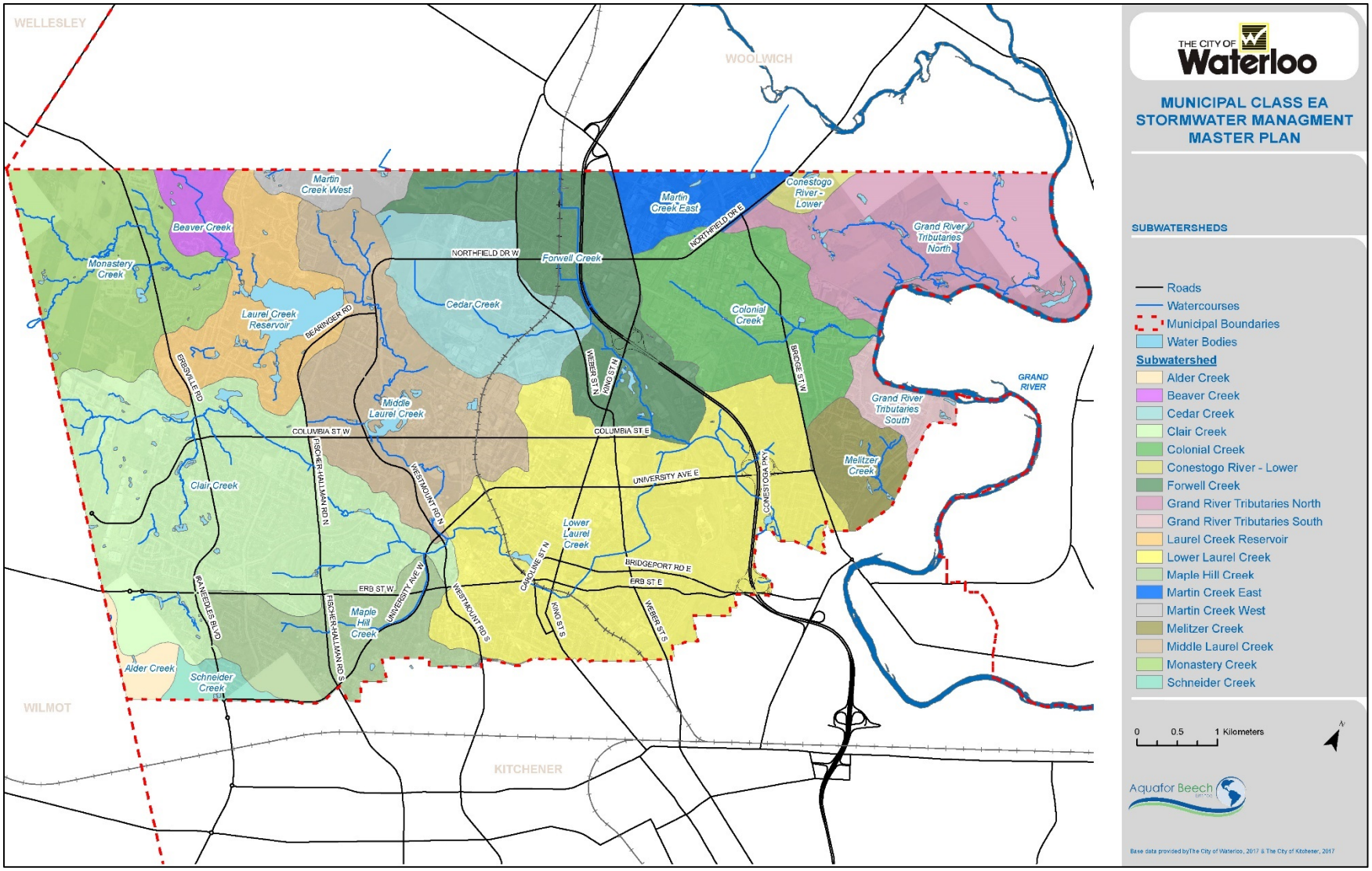

Figure 4-1: Study area and sub-watersheds

4.1 Surface Geology

Situated within a post-glacial geologic setting in southern Ontario, the surface geology of the study area is dominated by glacial sediments of variable texture, thickness, and depositional origin (**Figure 2-2**). Glacial tills (deposited by and under ice) within the City of Waterloo are a common surficial material in southern Ontario, but the study area is also underlain by significant deposits of ice-contact sands/gravels (including kames), lacustrine, and outwash materials (from melting ice, in lakes, and in streams beyond the glaciers, respectively). These glacial deposits, including the significant sources of sand and gravel, influence the geomorphology of the stream and river systems that are now cut into the post-glacial surfaces.

More specifically, the glacial landforms (i.e., the topographic features) influence the stream longitudinal profiles (and slopes / energy gradients) and the degree of valley confinement (i.e., how deep are the valleys cut into landscape). Further, the available glacial deposits supply sediments to the streams, influencing the texture and grain size distribution of the channel banks and bed materials. Collectively, these characteristics of the glacial surface geology play an important role in dictating the morphology and processes of the stream systems, representing the geologic template upon which the watercourses have evolved over millennia.

The surface geology characteristics (texture and stratigraphy) also strongly control the surface runoff patterns and hydrogeological connections between the catchments and the streams, with infiltration rates and hydraulic conductivity driving patterns and rates of groundwater and surface water flow. For example, the natural drainage density of streams within the sandy deposits of the Waterloo study area is lower (due to higher infiltration rates) as compared to clay-rich surface sediments that limit infiltration and increase runoff (e.g., glaciolacustrine plains of Brampton area).

Historical engineered modifications and restoration of stream channels within the Waterloo study area have imparted a coarse sediment texture to many stream systems stemming from infrastructure crossings, channel realignments, and previous erosion protection works. While these imported channel materials typically include cobble and boulder size stones (i.e., angular “rip-rap,” or rounded “field-stone”), natural supplies of cobble and gravel are also observed within Waterloo stream channels (e.g., Clair Creek), presumably sourced from the local moraine and outwash deposits. The availability of sand can be observed in Cedar Creek, with sandy gravel and sand-dominated channel bed materials are also common in other watercourses (e.g., Forwell and Laurel Creeks) where glacial sources of sand are most abundant.

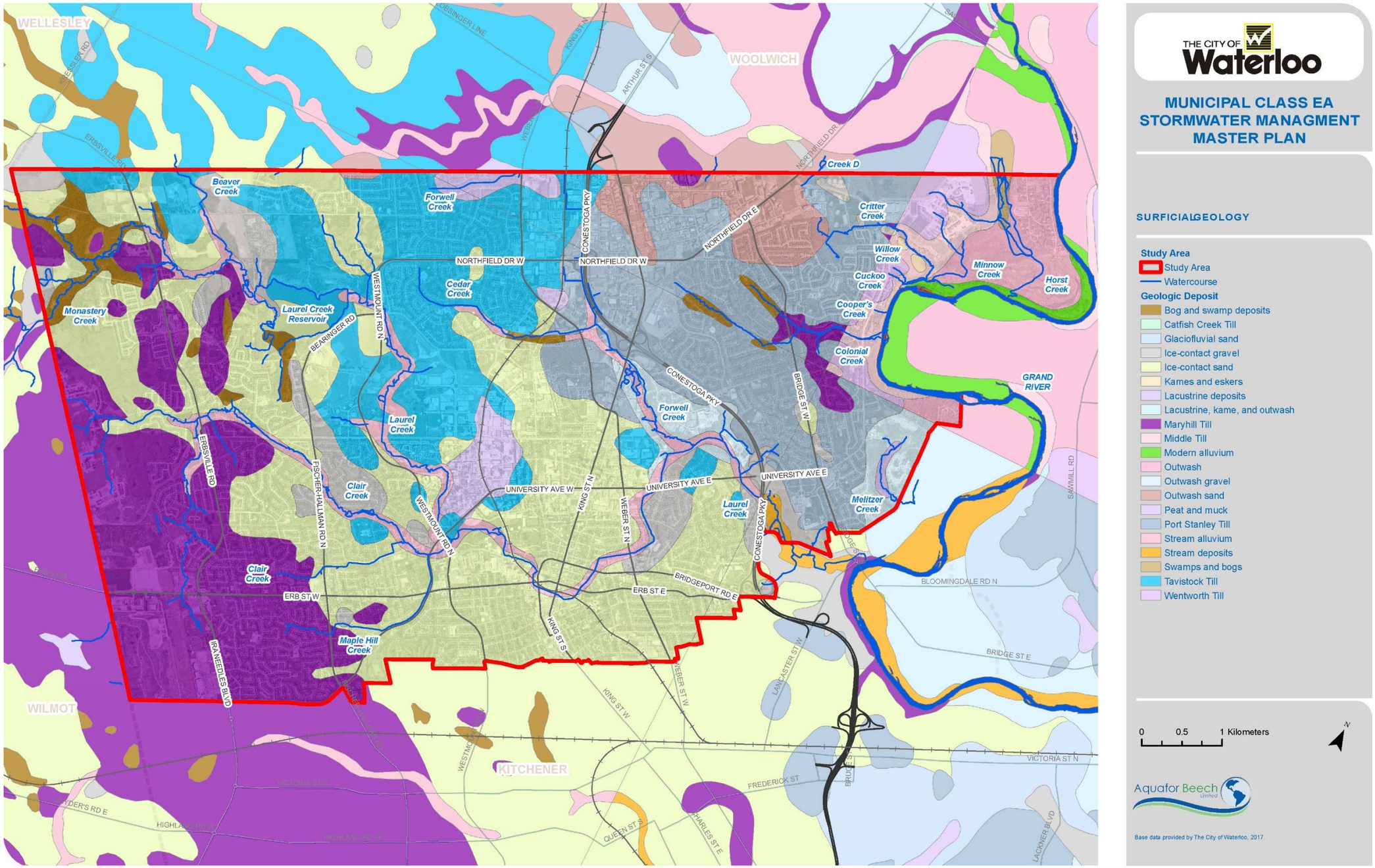

Figure 4-2: Surface Geology

4.2 Drainage Networks and Stream Reaches

The stream drainage networks within the City of Waterloo are centred around the main branch of the Grand River (**Figure 4-3**). The most significant tributary of the Grand River within Waterloo is Laurel Creek with a drainage area of about 2,400 ha. Laurel Creek tributaries include the Clair, Monastery, Beaver, Forwell, and Cedar Creeks. There are numerous other smaller tributaries of the Grand River within Waterloo, with the most notable being Colonial Creek. Areas at the north end of the City drain to the lower Conestogo River watershed which is, itself, a tributary of the Grand River.

Stream reaches had previously been identified by the City as part of the inspections of municipal watercourses in 2002 (Parish Geomorphic Ltd. and Planning & Engineering Initiatives Ltd.) and 2013 (City of Waterloo). Watercourse reaches are lengths of channel that display similar channel characteristics, functions, and processes and can be used as a guide for management objectives and restoration opportunities. Stream reaches are delineated by key factors that include hydrology, channel gradient, geology, valley setting, sinuosity, and riparian vegetation. The reach delineations were updated by Aquafor to better represent geomorphically significant changes in channel conditions. The reaches are shown in **Figure 4-3**.

The current assessment study was completed on a reach-basis, with erosion sites and geomorphic conditions summarized by reach.

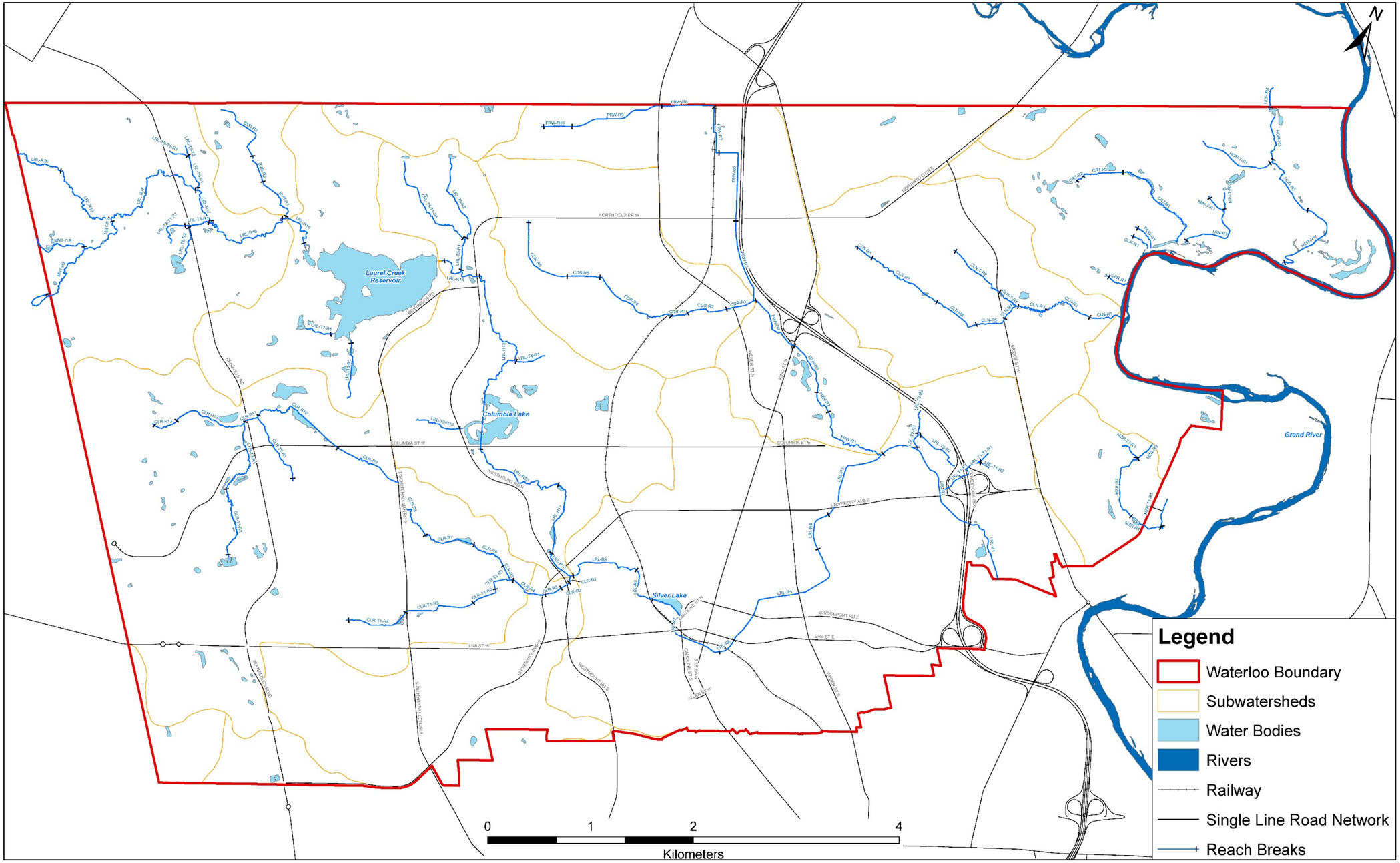

Figure 4-3: Study area Drainage Network and Stream Reaches

4.3 Overview of Creeks Assessed

The creek walks for the Waterloo Watercourse Erosion Master Plan covered about 40 km of watercourses within the City of Waterloo. Watercourses within the urbanized portions of the City were walked continuously from downstream to upstream while watercourses through natural settings were checked at road crossings. Watercourses on private property were omitted from the field walks. The extents of the field walks are shown in **Figure 4-4** while dates for field walks are included in **Table 4-1**.

It should be noted that Maple Hill Creek was not included in the field walks. The City retained GHD to undertake the *Maple Hill Creek Rehabilitation Class Environmental Assessment* and this study included an assessment of the entire watercourse and preferred alternatives for remediation of erosion sites.

Table 4-1: Summary of Watercourses and Reaches Assessed

Watercourse	Reaches	Date Assessed
Beaver Creek	BVR-R2	30-May-17
Cedar Creek	CDR-R1 to CDR-R6	16-May-17
Clair Creek	CLR-T2-R1	01-Jun-17
	CLR-R5 to CLR-R13	14-Jun-17
	CLR-T1-R3 CLR-T3-R1 to CLR-T3-R2	15-Jun-17
	CLR-R1 to CLR-R4 CLR-T1-R1 CLR-T1-R4	16-Jun-17
Colonial Creek	CNL-R1 to CNL-R8 CNL-T-R1 to CNL-T-R2	15-May-17
Cooper's Creek	CPR-R1	31-May-17
Critter Creek	CRT-R1	16-May-17
	CRT-R2 to CRT-R3	18-May-17
Cuckoo Creek	CCK-R1	16-May-17
Forwell Creek	FRW-R2 to FRW-R10	17-May-17
	FWL-R1	18-May-17
Horst Creek	HOR-R1	16-May-17
	HOR-T-R1	31-May-17
Laurel Creek	LRL-R3 to LRL-R5	18-May-17
	LRL-R6 to LRL-R10 LRL-T4-R1	19-May-17
	LRL-R11 to LRL-R14	30-May-17
	LRL-R1 to LRL-R2 LRL-T2-R1 LRL-T3-R1	31-May-17
	LRL-R16	01-Jun-17
Melitzer Creek	MZR-R1 MZR-R3	31-May-17
Minnow Creek	MIN-R1	16-May-17
	MIN-T-R1	31-May-17
Monastery Creek	MNT-R1 MNT-R2 MNT-T-R1	30-May-17
Willow Creek	WLW-R1	16-May-17

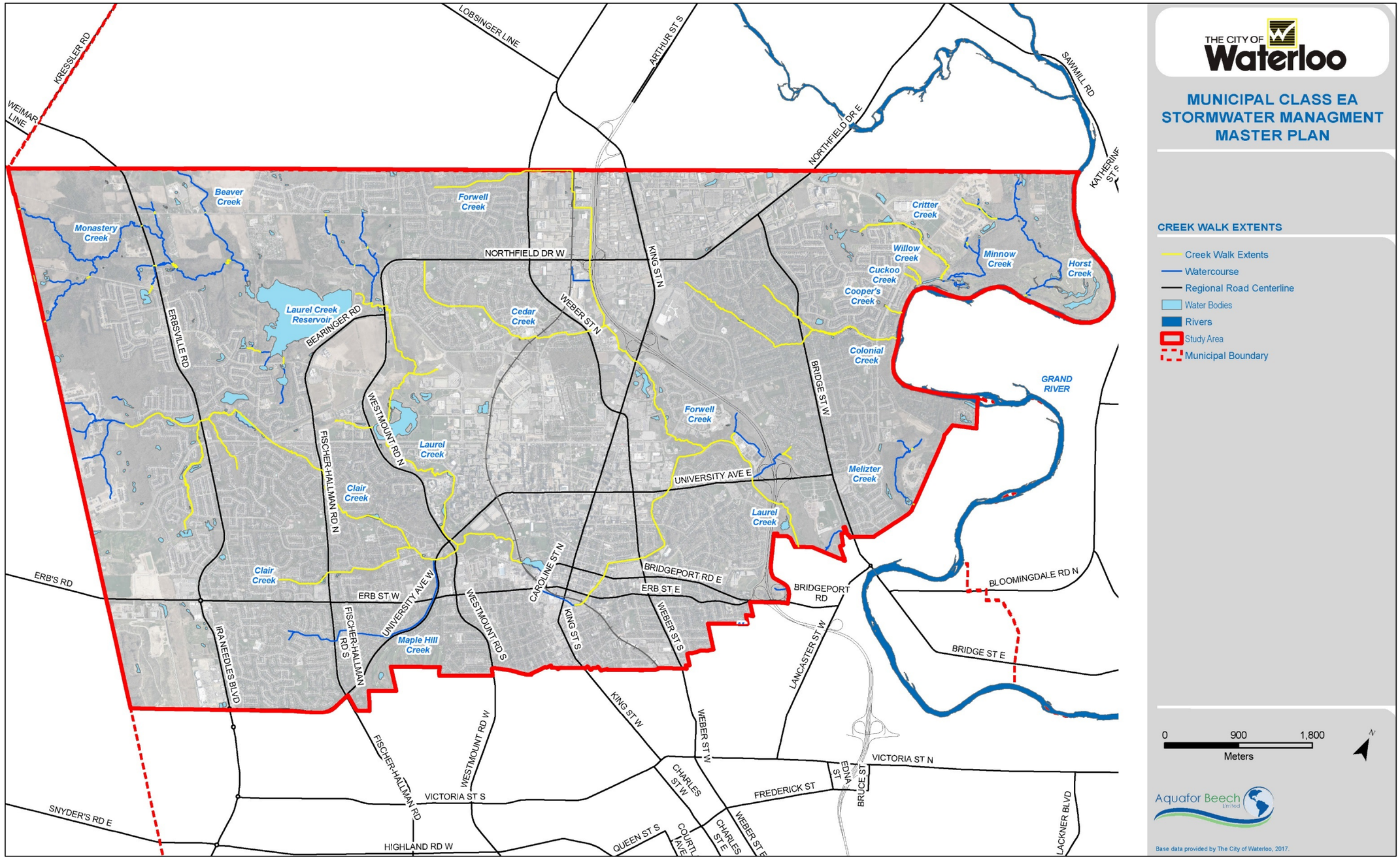

Figure 4-4: Extents of Creek Walks

5 METHODS

To complete the erosion inventory and assessment for watercourses within the City of Waterloo, all creeks were walked and visually assessed over the period of April to June 2017. Of the estimated 74 km of watercourses measured from the City's GIS mapping database, about 40 km were walked continuously. The balance of the watercourses was assessed by walking in-and-out from road crossings or were not accessed on as they were on private property.

During the creek field-walks, a number of tasks were completed by two staff members:

1. Geomorphic reach assessments, channel observations, and Rapid Geomorphic Assessments (RGAs),
2. Erosion site identification, characterization, and technical scoring,
3. Maintenance site identification, characterization, and technical scoring,
4. Stormwater outfall identification and assessment, with cross-referencing of erosion/maintenance sites, and
5. Photographic inventory collection for watercourse reach conditions, erosion sites, maintenance sites, and stormwater outfalls.

5.1 Geomorphic Assessment Methods

5.1.1 Geomorphic Stream Reaches

Geomorphic stream reaches are relatively uniform lengths of channel in terms of hydrology, slope, boundary materials, and vegetation that control dominant geomorphic processes and sediment transport dynamics. In other words, the physical channel processes and resulting stream morphology are relatively consistent over the length of the reach as compared to the differences between adjacent reaches. While, in practice, this requires that reaches be discretely divided by "reach breaks", in reality, reach changes may be abrupt or may transition gradually depending on changes in the controlling variables. For example, a sudden change in channel slope may cause an abrupt change in channel processes and thus represent a distinct reach break. In contrast, a gradual change in the boundary materials (increasing sand supply for example) would result in a gradual change in channel processes and the mapped reach break would only approximate the location of this transition.

As noted above, stream reaches had previously been identified by the City as part of the inspections of municipal watercourses in 2002 (Parish Geomorphic Ltd. and Planning & Engineering Initiatives Ltd.) and 2013 (City of Waterloo). The reach delineations were updated by Aquafor to better represent geomorphically significant changes in channel conditions and these updated reaches are shown in **Figure 4-3**.

5.1.2 Rapid Geomorphic Assessments

As a tool to help evaluate the existing geomorphic conditions within the channel, Rapid Geomorphic Assessments (RGA) (MOE, 2003) were completed for relevant reaches. The RGA protocol uses a series of visual indicators to determine whether the stream is stable or in adjustment, and is based on a percentage score. The stability of the channel is assessed by adjustments in slope and elevation, either an increase in elevation due to sediment deposition (i.e.,

aggradation) or a decrease in elevation due to bed erosion (i.e., degradation). Evidence of increases in bank-to-bank channel width (i.e., widening) and changes in the planform regime (planimetric form adjustment) are also part of the RGA method. **Figure 5-1** shows an example of how the RGA was completed in the field, and how the stability index was calculated (e.g., for reach CLR-R1 of Clair Creek, widening has the highest Factor Value and is therefore identified as the dominant process within the reach). The standard approach adopted for the Waterloo erosion inventory was to exclude indictors representing specific features not contained in the reach. For example, the "exposed bridge footings" indicator would be left blank and not included in the factor scoring if no bridges were contained within the reach. **Table 5-1** summarizes the stability classifications associated with the RGA stability index scores and detailed RGA results are provided in **Appendix A**. The RGA method is most appropriate for systems with natural or semi-natural alluvial boundaries that are capable of adjusting to flow changes in water and sediment. Therefore, engineered channels that have been completely stabilized (e.g., concrete, armourstone, or gabion basket channels) were not evaluated with an RGA.

Table 5-1: Rapid geomorphic assessment descriptions based on stability index values

Stability Index Value	Stability Class	Description
0 – 0.25	Stable	Channel morphology is within the expected range of variance for stable channels of similar type. Channels are in good condition with minor adjustments that do not impact the function of the watercourse.
0.25 – 0.40	Transitional	Channel morphology is within the expected range of variance but with evidence of stress. Significant channel adjustments have occurred and additional adjustment may occur.
0.40 – 1.0	In Adjustment	Metrics are outside of the expected range of variance for channels of similar type. Significant channel adjustments have occurred and are expected to continue.

Aquafor Beech Limited

Date 16-Jun-17

Reach CLR-R1

RAPID GEOMORPHIC ASSESSMENT

Watercourse: **Clair Creek**

Form/ Process	Geomorphic Indicator		Present		FactorValue
	no.	Description	No	Yes	
Evidence of Aggradation (AI)	1	Lobate bar	1		
	2	Coarse material in riffle embedded	1		
	3	Siltation in pools	1		
	4	Medial bars	1		
	5	Accretion on point bars		1	
	6	Poor longitudinal sorting of bed materials	1		0.14
	7	Deposition in overbank zone	1		
Evidence of Degradation (DI)	1	Exposed bridge footings	1		
	2	~~Exposed sanitary/storm sewer/pipeline etc~~			
	3	Elevated stormsewer outfall		1	
	4	undermined gabion basket/concrete apron/etc		1	
	5	Scour pools d/s of culverts/stormsewers		1	
	6	Cut face on bar forms	1		
	7	Head cutting due to knick point migration	1		
	8	Terrace cut through older bar material	1		
	9	Suspended armor layer visible in bank		1	0.44
	10	Channel worn into undisturbed overburden/bedrock	1		
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc		1	
	2	Occurrence of large organic debris		1	
	3	Exposed tree roots		1	
	4	Basal scour on inside meander bends		1	
	5	Basal scour on both sides of channel through riffle		1	
	6	Gabion baskets/concrete walls/armour stone etc. out flanked		1	
	7	Length of basal scour > 50% through subject reach		1	
	8	~~Exposed length of previously buried pipe/cable etc.~~			
	9	Fracture lines along top of bank	1		0.88
	10	~~Exposed building foundation~~			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	1		
	2	Evolution of single thread channel to multiple channel	1		
	3	Evolution of pool-riffle form to low bed relief form	1		
	4	Cutoff channel(s)	1		
	5	Formation of island(s)	1		
	6	Thalweg alignment out of phase with meander geometry	1		0.14
	7	Bar forms poorly formed/reworked/removed		1	
Stability Index (SI) = (AI+DI+WI+PI)/m				SI =	0.40

Figure 5-1: Example RGA Form for Clair Creek Reach CLR-R1

5.2 Erosion Assessment Methods

A comprehensive city-wide erosion inventory was completed to identify erosion hazards and public safety risks within the City of Waterloo. The erosion assessment involved identifying erosion sites, management issues, and maintenance issues. It also included identifying and cataloguing the stormwater outfalls in close proximity to the watercourses during the field walks. The purpose of the erosion assessment component is to identify stream restoration opportunities within the City. The results of the Watercourse Erosion Master Plan will be integrated with the other stormwater, infrastructure, and environmental management objectives to develop a broader Integrated Stormwater Management Master Plan (ISWM-MP) prioritization and implementation plan.

5.2.1 Erosion Site Identification and Scoring

Erosion sites (E) were identified as locations with erosional issues that pose a risk to surrounding infrastructure or public health that would require intervention to be mitigated. Furthermore, erosion sites were in some cases also identified as having an impact on the larger reach-scale health of the stream system. Erosion sites were visually identified in the field and locations were recorded on maps. The approximate extents of the erosion sites were measured, and photographs of the sites were taken and noted on mapping.

To standardize the erosion risk and environmental opportunity during the field assessments, a semi-quantitative technical scoring methodology was developed in consultation with the city project team. Each erosion site was given a score out of 100, with larger scores representing sites with high levels of erosion risk and/or higher degrees of environmental opportunity. **Table 5-2** and **Figure 5-2** summarize the technical scoring approach including the evaluation criteria of each scoring component. The erosion risk component included an erosion index of 35% (distance, extent, stress, and erodibility) and a public health and safety index of 35% (type of risk). The environmental opportunity component included opportunities to enhance riparian cover (15%) and opportunities to enhance aquatic habitat (15%). The total score out of 100 provides a semi-quantitative measure of risk and opportunity to guide subsequent decisions regarding stream restoration opportunities within the Master Plan. The final prioritization and implementation plan will be integrated with other stormwater, infrastructure, and environmental management objectives in the broader Integrated Stormwater Management Master Plan (ISWM-MP).

Table 5-2: Erosion site assessment evaluation criteria

Parameter	Definition	Evaluation Criteria			
Erosion Risk Component					
Erosion Index					
Distance	Distance from top of bank to resource type	In channel			15
		0 – 5 m			12
		5 – 10 m			10
		10 – 20 m			5
		20– 50 m			2
		> 50 m			0
Extent	The spatial area encompassed by the erosion site	> 301 m^2			10
		201 – 300 m^2			8
		101 – 200 m^2			6
		50 – 100 m^2			4
		1 – 50 m^2			2
Stress	Stream energy and flow regime.		Flow Regime		
		Stream Energy	Flashy	Transitional	Undeveloped
		High	5	4	3
		Moderate	4	3	2
		Low	3	2	1
Erodibility	Physical characteristics of bank materials	High			5
		Moderate			3
		Low			1
Public Health and Safety					
Type of Risk	Identified the type of infrastructure that was closest to the Erosion Site	Critical Infrastructure* (Buildings, Major Dams, Water or Gas Mains, Major Roads/Bridges, Sanitary Sewers and Maintenance Holes, Other Utilities)			35
		Minor Roads, Bridges and Paved Trails			25
		Public Property with Secondary Infrastructure (Public Parking, Minor Dams/Weirs, Active Park Lands, Trail Types 2-4, Other)			15
		Private Property with Secondary Infrastructure (Deck, Pool, Shed, Septic Bed, Other Permanent Structure)			10
		Open Space (Inactive)			0
		Total Erosion and Risk Component Score			/ 70
Environmental Opportunity Component					
Enhance Riparian Cover					
Riparian Buffer	Evaluation of the quality of the surrounding riparian cover	Sensitive			0
		High Quality (i.e. dense, mature, native)			5
		Moderate Quality			10
		Low Quality (i.e. no buffer)			15
Enhance Aquatic Habitat					
Existing Aquatic Habitat	General evaluation of the thermal regime of the system and evaluation of the quality of the channel bed to provided suitable habitat for fish or invertebrates		Habitat Quality		
		Thermal Regime/ Fish Community	High (i.e. Riffle-Pool, Natural Substrate)	Moderate (i.e. mixed)	Low (i.e. Engineered Channel)
		Coldwater / Intolerant	0	5	10
		Mixed / Moderately Tolerant	2	7	12
		Warmwater / Tolerant	5	10	15
		Total Environmental Opportunity Component Score			/ 30
		TOTAL EROSION ASSESSMENT SCORE			/ 100

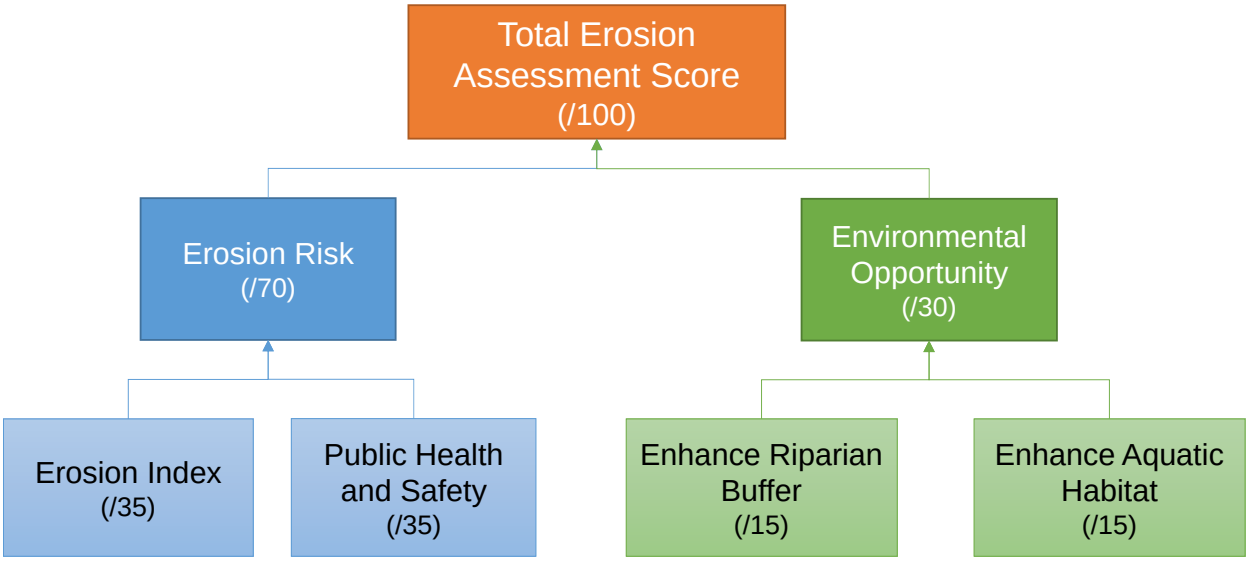

Figure 5-2: Schematic of the erosion assessment scoring identifying all evaluation categories

5.2.2 Maintenance Issues Identification and Cataloguing

During the creek walks, maintenance issues (MI) were identified as localized erosion, deposition, structural failures or disrepairs, or flow obstructions. The maintenance sites differ from the erosion sites in that the effects of the maintenance sites were very localized and/or associated with city infrastructure included within regular operations and maintenance responsibilities.

Maintenance issues were grouped under 10 categories. Descriptions of these categories and evaluation criteria are listed below in **Table 5-3**. Identified maintenance sites were scored using the scheme outlined in the table, with a higher score indicating that the maintenance issue is in a more degraded state, and a lower score indicating that the maintenance issue is minor. Not all types of maintenance issues were observed during the field walks and the number of maintenance issues varied between watercourses and between reaches.

During the creek walks maintenance issues were identified, mapped and given a unique identification code (ID code). The ID code is explained below:

Three letter watercourse acronym	–	**MI** (identifies that the code is for a maintenance issue, not an outfall)	**Two-digit number** (numbered from downstream to upstream on the subject watercourse)

As an example, CLR-MI01 is the downstream-most maintenance site identified on Clair Creek.

Table 5-3: Maintenance site assessment evaluation criteria

Code	Maintenance Issue	Method of Assessment	Score			
			1	2	3	Y/N
M1	**Visible chemical sheen on water**	If YES then contact City immediately, investigate and determine if spill response is required. Provide note for any visible sheen that may be organic along with a photo.				Y/N
M2	**Transient activity**	Evidence of unauthorized permanent or semi-permanent human occupancy near or along the banks of the watercourse (i.e. things such as anthropogenic shelters and human possessions)				Y/N
M3	**Unintended structures within 3 metres of the bank**	Inspector must be able to measure a 3m distance from both sides of the bank of the stream to answer this question. Note: this does not include engineered, intentional structures like bridges and culverts. What is the possible cause? (1) Is the resident encroaching? (2) Is the watercourse changing/degrading? (3) Is the property line adjacent to the bank intended or originally designed to be this close? (no action required)				Y/N
M4	**Beavers Activity**	Observed evidence of habitat structures (i.e., dams) which are/could cause flooding or erosional issues	Suspect presence	Residents/ structure found	Flooding/ backwatering concern	
M5	**Debris**	In channel, overhanging, or sunken debris	Minor obstruction	Significant obstruction	Complete channel obstruction	
M6	**Bank vegetation**	The bank should be 100% vegetated	Limited riparian width	Herbaceous only	Grass/bare ground	
M7	**Access road(s) general condition**	Issues identified on the access route to a creek	Minor defects	Major defects	Impassable	
M8	**Excessive sediment accumulation**	Locations of excessive sediment accumulation impacting channel processes				Y/N
M9	**Minor Erosion**	Small scale, local erosion or scour that has the potential to continue to erode and have a negative impact on the bank environment. This differs from an erosion site, in that this erosion can be addressed with small scale intervention by maintenance and operations staff.	Minor erosion/ scour	Moderate erosion/ scour	Major erosion/scour (causing risk)	
M10	**Outfall Maintenance**	Issues associated where storm sewer infrastructure outlets to the channel	Minor defects	Moderate defect	Major defect, asset no longer functioning as intended	

A geodatabase (ArcGIS) of all the maintenance sites was created and submitted to the City. The geodatabase included a mapped location for each maintenance site, and a series of attributes. General attributes include the river and reach where the maintenance sites were found, the observation date, a list of photograph(s) of the site, the maintenance site score, and specific comments about the maintenance site. Each of the maintenance sites were cross-referenced with the outfall inventory to integrate the data.

It is noted that external factors could alter the observed conditions of the maintenance sites, causing further degradation or reducing the risk/signification of the issue. As such, maintenance sites may require re-evaluation prior the initiation of maintenance or repair works.

5.2.3 Outfall Inventory

During the creek walks, stormwater outfalls that drain directly into the creek were assessed. The City provided Aquafor with base mapping including stormwater outfalls. Outfalls that appeared to be privately installed (i.e. draining private property only), where not included in the inventory.

The existing City outfall database was updated to cross-reference any maintenance issues located at outfalls. Where outfalls were not included in this database, the appropriate culvert in the gravity main database was identified and was updated to include a reference to the maintenance issue.

6 RESULTS

6.1 Geomorphic Assessment

During the field walks, the geomorphology of each watercourse was analyzed to characterize the stream system within the context of the erosion assessment. Erosion is a natural process and natural streams and rivers should be considered dynamic, allowing for gradual and long-term channel adjustments that may occasionally include more dramatic changes due to high magnitude flood events.

Sediment aggradation and degradation are processes that create and maintain geomorphic features within a river. However, changes within a watershed (such as deforestation or urbanization) can create an imbalance within these processes resulting in erosion that is unnatural, or unhealthy for the system. Therefore, completing a geomorphic assessment is important to identify the natural processes and areas of excessive erosion or sedimentation.

The geomorphic assessment consisted of field investigations for a total of 14 watercourses. The Grand River was not included within the field investigation. In addition to the RGAs completed on a reach-basis, typical channel characteristics were recorded. These characteristics included a general description of the existing channel conditions within each reach, the channel type (natural, concrete, rehabilitated, or restored), and observations regarding channel migration, riparian cover and aquatic habitat.

A summary of the representative geomorphic reaches within each of the watercourse is presented in **Appendix B**. For each system, a sub-catchment map is included to show the geographic location and the approximate watershed boundary. Average channel dimensions and RGA scores are included where relevant. A representative photograph of each reach is provided.

6.2 Erosion Assessment

6.2.1 Erosion Sites

A total of 36 erosion sites were identified during the field walks. Summary sheets for the erosion sites are presented in **Appendix C**. Each site was evaluated using the erosion site assessment scoring described above in **Table 5-2**. The sites and their evaluation are presented in **Table 6-2**. Sites have been ordered by priority, with the site with the highest score at the top of the table and the site with the lowest score at the bottom. The location of each site is shown in **Figure 6-1**.

The erosion sites are located in 6 watercourses with most of the sites being found in Clair Creek, Laurel Creek, and Forwell Creek. These creeks are the longest creeks within the City limits and are located within fully urbanized land uses (with the exception of the headwaters of Laurel Creek). A summary of sites by watercourse is presented in **Table 6-1**.

Erosion sites with scores of 85 of greater were categorized as “primary erosion issues” and those with scores less than 85 were categorized as “secondary erosion issues”. The primary erosion issues are those issues which the City should prioritize for restoration works and account for about 20% of the erosion sites. These primary erosion issues were assessed further during the evaluation of alternatives and preferred alternatives were determined for the implementation phase. The

secondary erosion issues should continue to be monitored to ensure that if their condition deteriorates further, they can be reassessed and re-evaluated to determine whether the observed changes have resulted in their becoming primary erosion issues.

Table 6-1: Summary of Erosion Sites by Watercourse

Watercourse	Number of Erosion Sites on Watercourse	Percentage of Erosion Sites on Watercourse
Cedar Creek	5	14%
Clair Creek	9	25%
Colonial Creek	2	6%
Cuckoo Creek	1	3%
Forwell Creek	8	22%
Laurel Creek	11	30%

Table 6-2: List of erosion sites identified during the 2017 field investigations

Erosion Category	Prioritized Ranking	Date	Watercourse	Site	Public Health & Safety Index	Erosion Index					Riparian Buffer Index	Aquatic Habitat Index	Total Score
					Type of Risk	Distance	Extent	Stream Energy & Flow Regime	Erodibility	TOTAL			
Primary Erosion Issue	1	18-May-17	Laurel Creek	LRL-E5	35	15	10	4	3	32	15	10	92
	2	16-May-17	Cedar Creek	CDR-E4	35	15	8	3	5	31	15	10	91
	3	18-May-17	Laurel Creek	LRL-E6	35	15	6	4	3	28	10	15	88
	4	17-May-17	Forwell Creek	FRW-E2	35	15	8	5	5	33	10	10	88
	5	19-May-17	Laurel Creek	LRL-E7	25	12	10	5	5	32	15	15	87
	6	16-May-17	Cedar Creek	CDR-E3	35	15	6	3	3	27	15	10	87
	7	16-Jun-17	Clair Creek	CLR-T1-E1	35	12	4	4	1	21	15	15	86
	8	14-Jun-17	Clair Creek	CLR-E4	35	12	6	4	3	25	10	15	85
Secondary Erosion Issue		31-May-17	Laurel Creek	LRL-E3	35	12	8	5	3	28	10	10	83
		16-Jun-17	Clair Creek	CLR-E1	35	12	4	4	3	23	15	10	83
		30-May-17	Laurel Creek	LRL-E10	35	12	2	4	3	21	15	10	81
		16-May-17	Cedar Creek	CDR-E1	35	12	8	3	3	26	10	10	81
		16-May-17	Cedar Creek	CDR-E2	35	12	4	3	5	24	15	5	79
		17-May-17	Forwell Creek	FRW-E4	25	12	8	4	5	29	10	15	79
		17-May-17	Forwell Creek	FRW-E1	35	12	4	4	3	23	10	10	78
		15-May-17	Colonial Creek	CLN-E1	35	12	2	5	3	22	10	10	77
		17-May-17	Forwell Creek	FRW-E5	15	15	4	4	5	28	15	15	73
		17-May-17	Forwell Creek	FRW-E3	35	5	4	4	3	16	10	10	71
		30-May-17	Laurel Creek	LRL-E9	35	15	2	4	5	26	5	5	71
		30-May-17	Laurel Creek	LRL-E11	35	15	2	2	5	24	5	5	69
		31-May-17	Laurel Creek	LRL-E2	35	5	4	4	5	18	5	10	68
		15-Jun-17	Clair Creek	CLR-T1-E2	15	15	4	4	5	28	10	15	68
		18-May-17	Laurel Creek	LRL-E4	15	12	4	4	3	23	15	15	68
		17-May-17	Forwell Creek	FRW-E6	10	10	8	4	5	27	15	15	67
		17-May-17	Forwell Creek	FRW-E7	10	12	2	3	5	22	15	15	62
		17-May-17	Forwell Creek	FRW-E8	10	12	6	3	5	26	15	10	61
		14-Jun-17	Clair Creek	CLR-E6	15	12	10	4	5	31	5	10	61
		16-May-17	Cedar Creek	CDR-E5	15	12	2	5	1	20	15	10	60
		31-May-17	Laurel Creek	LRL-E1	25	12	2	4	1	19	5	10	59
		14-Jun-17	Clair Creek	CLR-E3	10	15	2	4	3	24	15	10	59
		14-Jun-17	Clair Creek	CLR-E5	10	10	4	4	5	23	15	10	58
		16-Jun-17	Clair Creek	CLR-E2	10	12	6	4	3	25	10	10	55
		30-May-17	Laurel Creek	LRL-E8	10	12	2	5	3	22	10	10	52
		16-May-17	Cuckoo Creek	CCK-E1	10	5	10	5	3	23	5	10	48
		15-May-17	Colonial Creek	CLN-E2	10	12	4	4	5	25	5	5	45
		15-Jun-17	Clair Creek	CLR-T3-E1	0	5	2	4	3	14	10	5	29

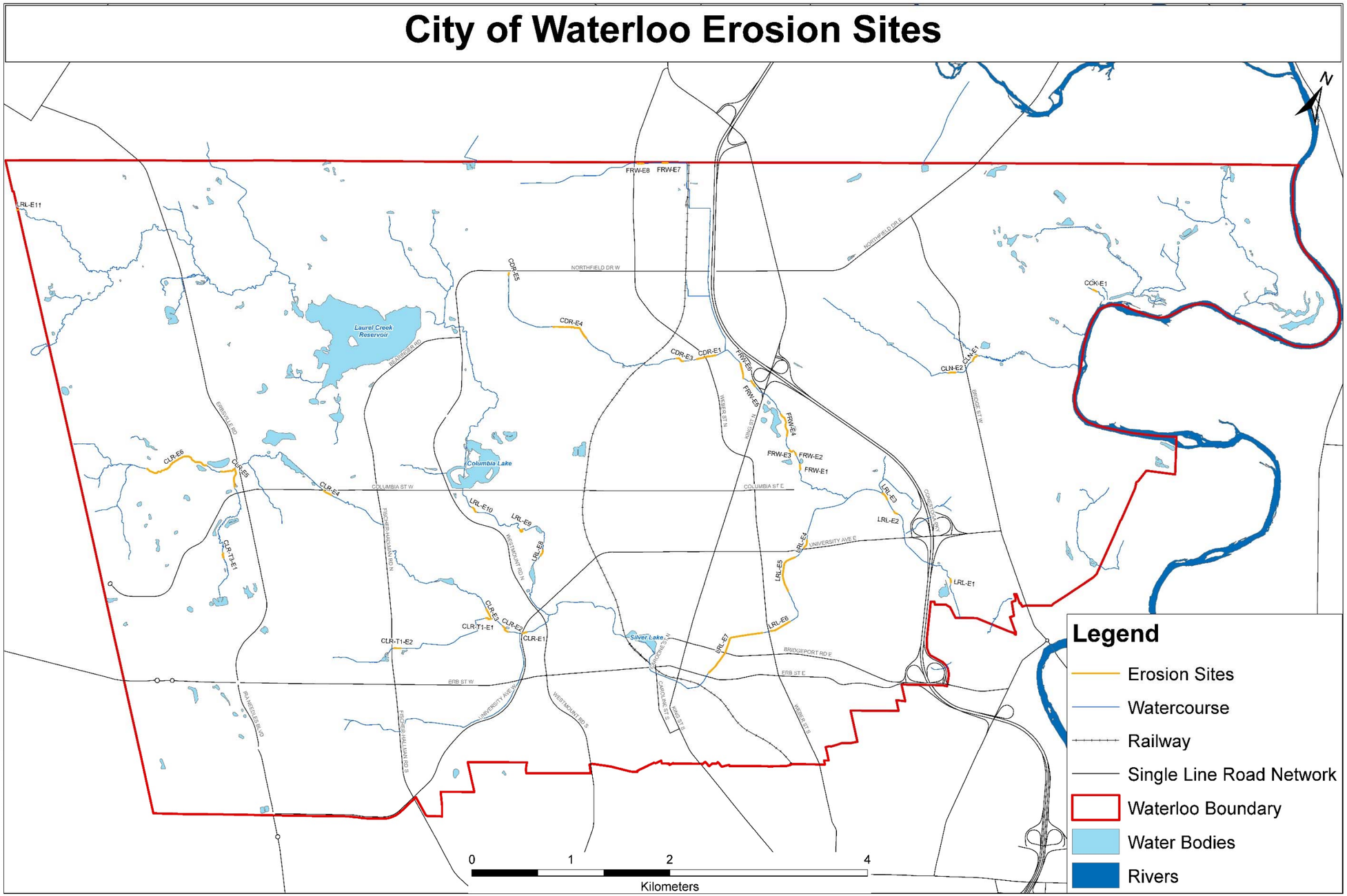

Figure 6-1: Locations of Primary Erosion Sites with the City of Waterloo

Waterloo Park

Most of the sites Aquafor identified in Waterloo Park were also identified by Stantec in the ***Silver Lake and Laurel Creek Rehabilitation in Waterloo Park – Environmental Assessment Addendum*** (2018). As noted in **Section 0**, the EA addendum identified the preferred alternative to address the erosion issues and included a project implementation plan which proposes detailed design in 2018 and 2019 with construction in 2019 and 2020. As such, the sites in Waterloo Park have been covered by a separate EA process and implementation of the preferred alternatives is planned.

One site within Waterloo Park which Aquafor identified, location "A" in **Figure 6-2** (bank erosion near soccer fields), was not included in the EA addendum. There is no immediate risk at this site; however, it is recommended that this site be monitored so that bank stability can be addressed prior to it posing a risk to the soccer fields.

Of the areas identified by Stantec, the preferred alternative includes repair to the failed outfall on Clair Creek, removal of the dam and gabion basket treatments, and removal of the weir. Although the erosion around the headwall for the culvert at University Avenue was identified in the Stantec report (location 1. in **Figure 6-2**), it was not included in works for the preferred alternative. As such, it is recommended that this site continue to be monitored for worsening conditions.

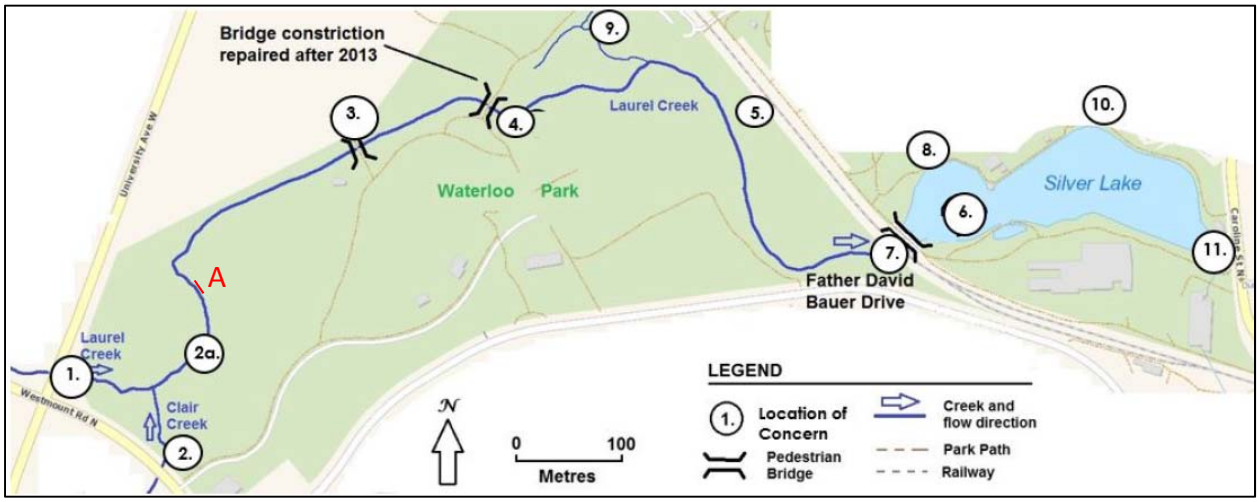

Figure 6-2: Areas of Concern Identified in the *Silver Lake and Laurel Creek Rehabilitation in Waterloo Park – Environmental Assessment Addendum*
Source: Appendix A4, CHM2 & Stantec (2018)

6.2.2 Maintenance Sites

The maintenance sites identified within the field were reviewed and tabulated into a database. A total of 82 maintenance sites were identified on 9 different creeks (see **Figure 6-3** to **Figure 6-7**). Each maintenance site was categorized and scored based on the evaluation form shown in **Table 5-3**. Seven (7) sites were assigned to 2 categories due to the issues encountered. A score was given for each of the maintenance sites identified.

A full inventory of the maintenance sites has been provided to the City in the form of a geodatabase which includes all the information about the site (i.e., date inspected, issue, evaluation score, photograph, etc.). It is noted that the maintenance sites are based on field observations from 2017 and the list does not represent management efforts or issues that have developed following these field observations. Furthermore, it is possible that new sites might require more immediate attention than those included on this list. This list should be used as a foundation to which future issues should be added.

A summary of the maintenance sites for each watercourse is provided below in **Table 6-3**. Almost half the maintenance sites are located in Laurel and Clair Creeks. This is expected as these are the longest creeks in the City and they traverse full-urbanized land use.

A summary of the types of maintenance issues is included in **Table 6-4**. Note that there is a total of 89 issues since 7 maintenance sites had 2 issues. The majority of the maintenance issues are defects associated with storm sewer outfalls (42%) or debris accumulation (31%). For defects associated with storm sewer outfalls, either part of the outfall structure required maintenance (pipe, apron, headwall, or drainage channel), or the area that required maintenance contained an outfall (although the outfall condition may be acceptable).

Table 6-3: Summary of Maintenance Sites by Watercourse

Watercourse	Number of Maintenance Sites on Watercourse	Percentage of Maintenance Sites on Watercourse
Beaver Creek	1	1%
Cedar Creek	10	12%
Colonial Creek	11	13%
Clair Creek	20	24%
Critter Creek	1	1%
Forwell Creek	10	12%
Laurel Creek	25	30%
Monastery Creek	3	4%
Melitzer Creek	1	1%

Table 6-4: Summary of Maintenance Sites by Category

Maintenance Code	Maintenance Issue	Number of Issues	Percentage of Issues
M1	Visible chemical sheen on water	0	0%
M2	Transient activity	1	1%
M3	Unintended structures within 3 metres of the bank	1	1%
M4	Beaver Activity	0	0%
M5	Debris	28	31%
M6	Bank Vegetation	7	8%
M7	Access road(s) general condition	1	1%
M8	Excessive sediment accumulation	11	12%
M9	Localized Erosion	3	3%
M10	Defects associated with storm sewer outfalls	37	42%

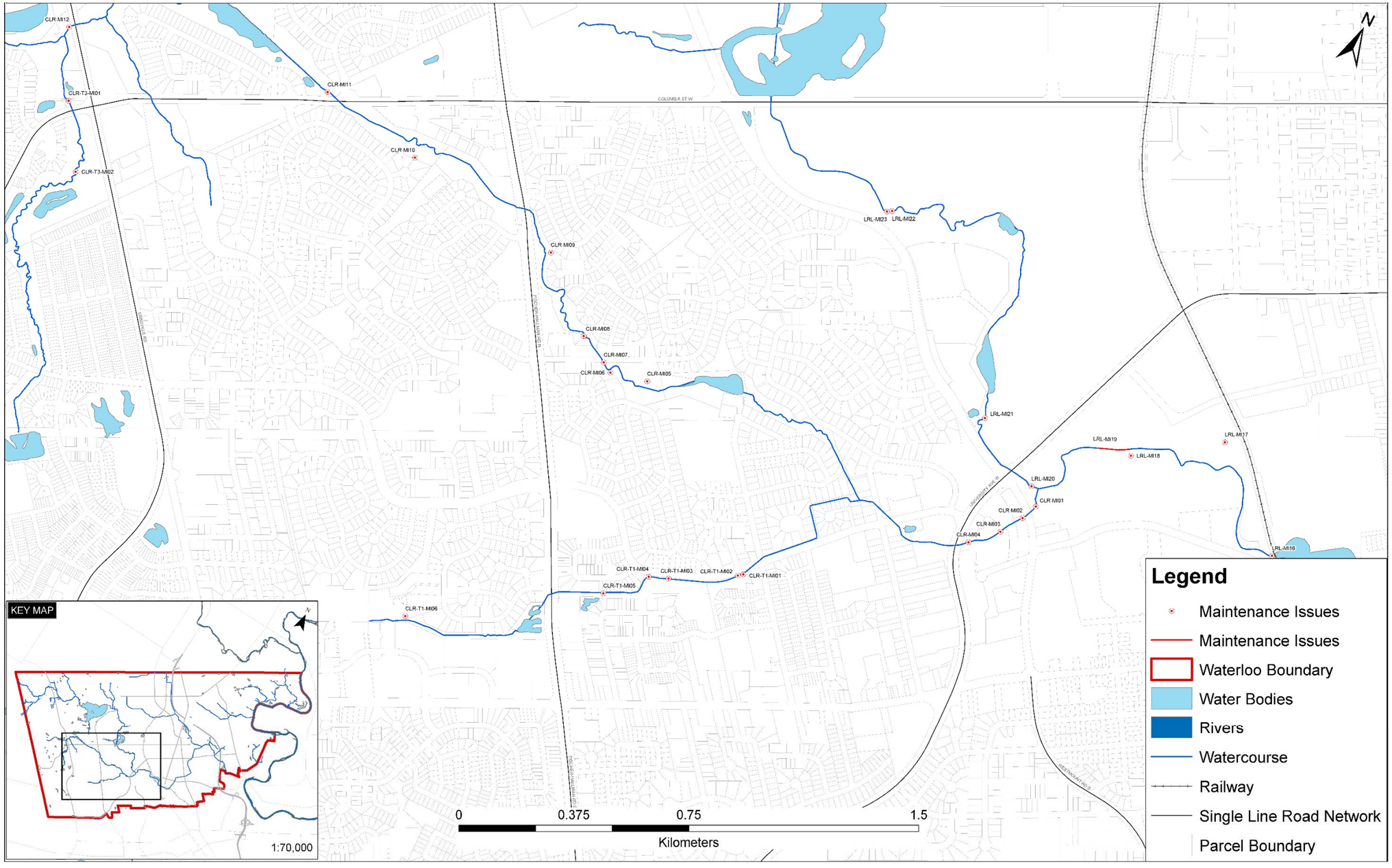

Figure 6-3: Maintenance Sites

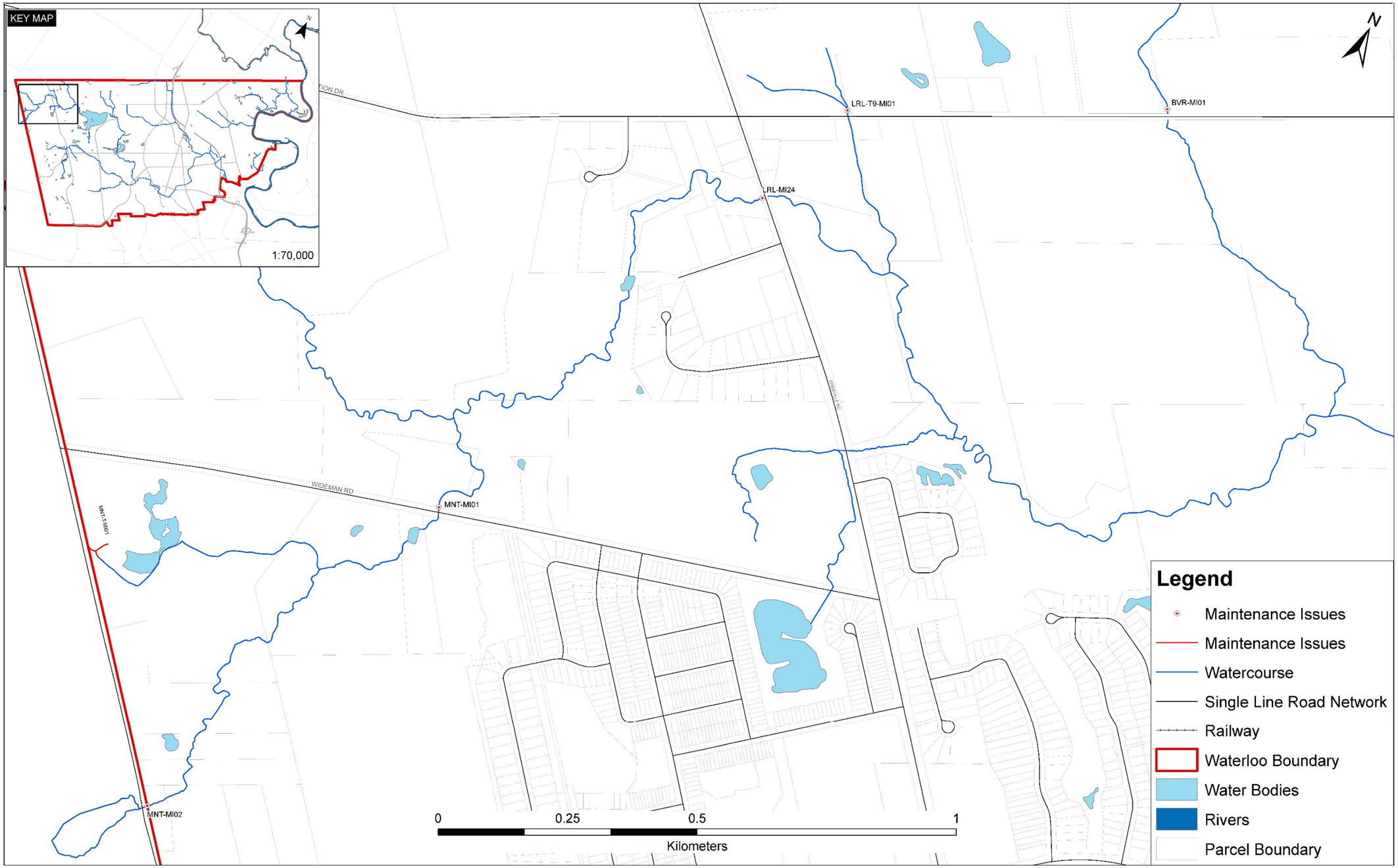

Figure 6-4: Maintenance Sites

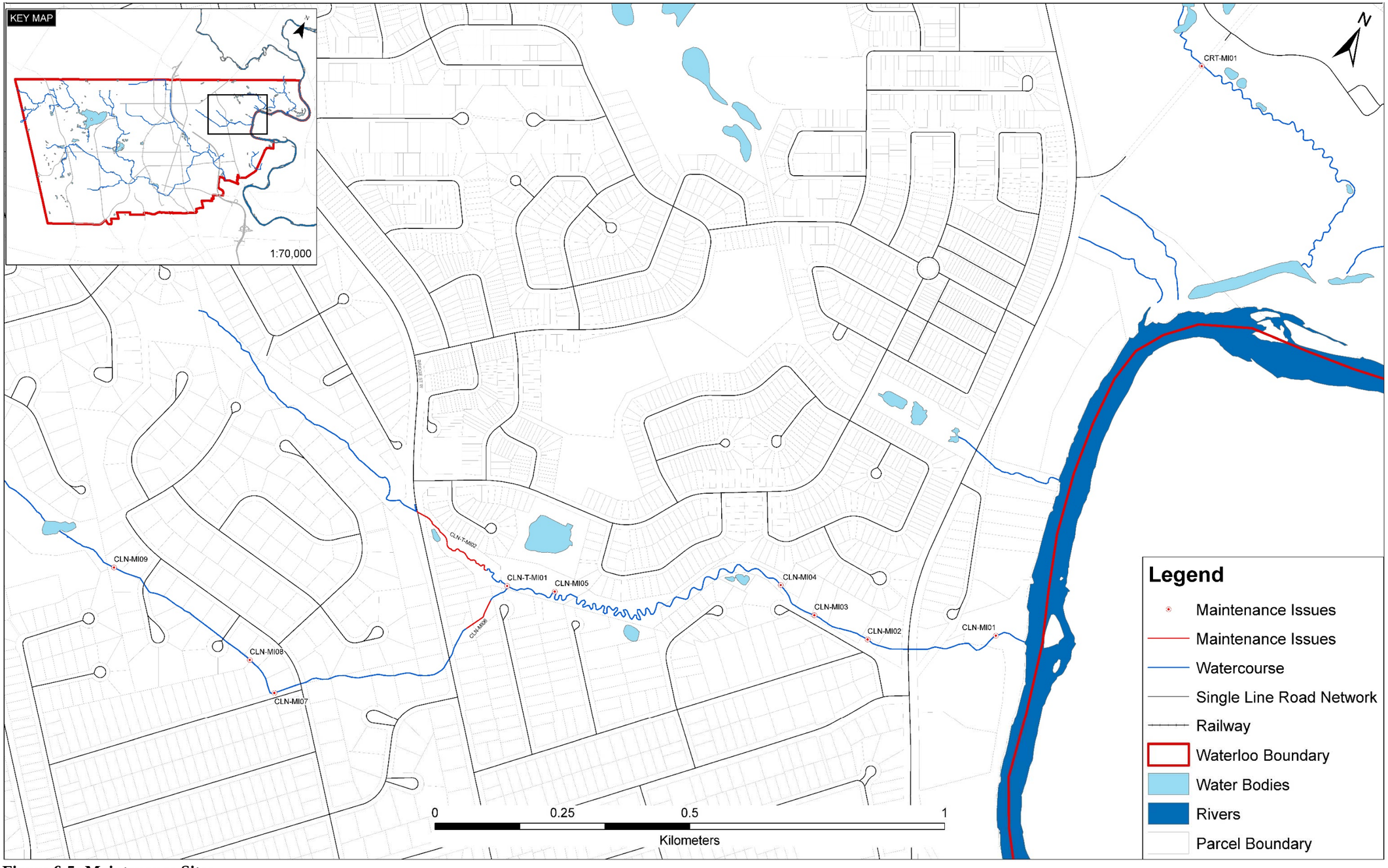

Figure 6-5: Maintenance Sites

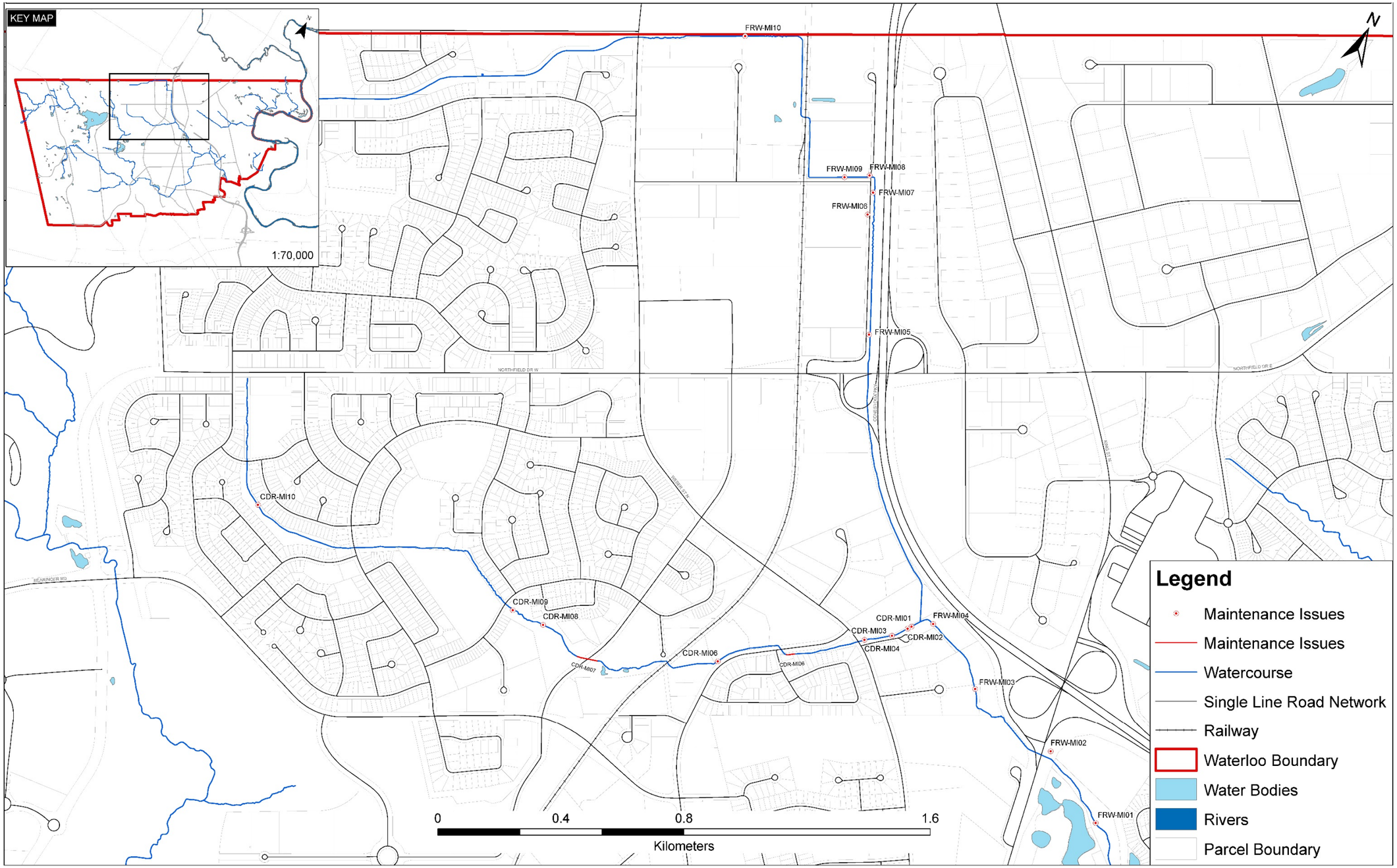

Figure 6-6: Maintenance Sites

Figure 6-7: Maintenance Sites

6.2.3 Outfall Inventory

An updated outfall database and gravity main database (for outfalls which were not included in the outfall database) was provided to the City. The update to the database consisted of cross-referencing any maintenance issues located at outfalls.

7 OPPORTUNITIES

7.1 Erosion Remediation

A variety of remediation alternatives are available to address the erosion concerns identified in this study. The alternatives range from reach-based solutions to local restoration works. A variety of restoration works are available from soft techniques, such as bioengineering, to harder techniques, such as roundstone or armourstone bank and/or bed treatments. The appropriate remediation method for each erosion site will depend on a number of factors including space, landownership, channel boundary conditions, hydraulics, and cost.

The following sub-sections provide examples of possible restoration works, their purpose, and the type of treatment they involve. The approaches outlined are examples of remediation that will promote channel stability and/or habitat, and can reduce the risk to public health and safety caused by threats to, or degradation of, City infrastructure. Preferred remediation alternatives are determined subsequently during the evaluation of the alternatives.

7.1.1 Armourstone Wall Protection

Armourstone wall protection consists of a free-standing stone structure with large blocks of stone layered vertically and offset from one another. The geotextile material and free-draining gravel placed behind the stone prevent soil movement into or through the stones and allow water to drain. These structures can be used within reaches which experience lateral channel adjustment, have highly erodible banks, or a step bank grade and where space is constrained such that natural planform adjustment is not possible. The armourstone walls protect the bank toe and bank face and are able to withstand high design velocities (approximately 5.0 m/s).

7.1.2 Vegetated Rock Buttress

Vegetated rock buttresses are used to minimize erosion and can also improve habitat within the restoration area. The treatment consists of layers of large roundstone with mixture of smaller roundstone and soil between them. The face of the buttress is planted with potted stock within the soil-roundstone portions. The sizing of the large roundstone used in these structures is designed to accommodate site-specific velocities and shear stresses. Once the vegetation establishes, its roots further stabilize the bank while the branches and leaves provide habitat and increase the bank roughness under high flows thereby reducing watercourse velocities.

7.1.3 Live Crib Wall

Live crib walls are used for slope and stream bank protection. These structures consist of a hollow, box-like framework of untreated logs or timbers filled with rip rap and alternating layers of soil and live branch cuttings. They can be used to protect banks against toe scour and undermining. Immediate protection is provided by the log framework and long-term durability is provided by the live branch cuttings. Crib walls should not be used where the channel bed is severely eroded or where undercutting is likely; as well, high banks (greater than 3 m in height) should be avoided due to the fact that crib walls cannot resist large lateral earth stresses (Heaton et al., 2002).

7.1.4 Live Staking

Live staking involves the insertion of live, woody, rootable plant cuttings into stream banks to encourage vegetative growth. This vegetation establishes a root mass which helps to bind, stabilize, and reinforces the stream bank. Live stakes can slow water velocities, trap sediment, and control erosion. Live staking is only considered to be a preventative measure and should be applied where it is desirable to slow further erosion. However, this method can be used in conjunction with other restoration techniques such as vegetated rock buttresses. Live stakes should be planted on streams with low to moderate flow fluctuations and where sufficient sunlight exists.

7.1.5 Rib Structures

Rib structures are used to provide grade control in watercourses with channel bed degradation. They may also be used to maintain the bed grade where infrastructure crosses under the channel. Ribs structures are typically composed of large key stones which are sized to ensure they are stable under high flow conditions within the watercourse. Additional well-graded material is placed around the key stones. Aquatic habitat may be enhanced by stepping the key stones in cross-section to create a low flow channel across the rib structures.

7.1.6 Deflectors

Stream deflectors are structures which limit channel width and accelerate normal flows through the constricted section. They can be used in over-widened watercourses to provide a narrower, deeper low-flow channel. Deflectors are typically constructed of rock and logs and can be used singly or in series. Deflectors can be used to direct base flow away from channel banks and, under certain conditions, can create scour pools which will enhance fish habitat. Deflectors should not be used in unstable streams and they are ineffective in bedrock channels. As well, deflectors should not be used in reaches which exceed a gradient of 3% or in channels with large sediment and/or debris loads.

7.1.7 Terraced Floodplain

A terraced floodplain can help to reduce channel erosion capacity for higher-flow events by allowing flows to spill out of the channel. Additional width and higher surface roughness in the floodplain achieve the reductions in the watercourse velocities and shear stresses. Construction of a terraced floodplain would only be possible in areas with open space available adjacent to the channel. As such, the applicability of this technique is limited in constrained urban areas.

7.1.8 Channel Realignment

Channel realignment can be used where the existing channel location poses a risk to infrastructure or property. Realigning the planform of the channel can increase the lateral distance between the channel and the item of concern thereby reducing the risk. However, the availability of adjacent space limits the applicability of this technique. As well, initial terrestrial habitat impacts may be high depending on the required vegetation clearing and removal for the new channel alignment.

7.2 Additional Opportunities

In addition to the rehabilitation of erosion, opportunities not directly related to individual erosion sites were also identified during the field walks. These opportunities included establishment of

vegetative buffers and landowner education. Implementation of these opportunities can help to reduce future erosion and flooding-related impacts within watercourses and improve overall watershed health.

In some areas, manicured lawns were found adjacent to the channel. In other areas, plant diversity within the riparian zone was limited as was the width of the buffer. Increasing the width, as well as the variety and diversity of native plant species within the riparian buffer will provide cover and habitat for fish, insects, and invertebrates along the watercourse. Deep-rooted vegetation planted along the banks will also help to stabilize the creek banks, which in turn will help to limit bank erosion. Landowner education regarding these benefits will be needed to encourage owners to plant native species and establish a healthy riparian buffer on their properties. Resident education will also be needed in areas where the Town may decide to establish improved riparian buffers in parks. An understanding of the benefits may help residents to adjust to the new look of the parks.

Another opportunity for landowner education exists with respect to the disposal of yard waste. Piles of discarded yard waste were found in numerous locations in watercourse corridors throughout the City. Disposal of yard waste into watercourse corridors can cause debris jams within the channel and impact flow conveyance, which could potentially cause channel erosion and flooding and may place city infrastructure and private property at risk. Due to the observed widespread nature of this issue, it is recommended that the City implement a program of landowner education on this matter. The program should also emphasize the fact that the Region of Waterloo provides a bi-weekly curb-side yard waste removal service from April to November at no additional cost to residents (Region of Waterloo, 2018). Acceptable items for yard waste collection include branches, leaves, pine cones, plants, pruning from bushes and hedges, grass edging, weeds, other compostable yard waste, and pumpkins. Additional information can be obtained from the Region of Waterloo website.

8 PHASE 2: EVALUATION OF ALTERNATIVES

8.1 Primary Erosion Issues

As described in Section 6.2.1, 8 sites were identified as primary erosion issues. A description of each site is provided below while additional details and photographs are included in the erosion site summary sheets in **Appendix C**.

8.1.1 Laurel Creek, Site LRL-E5

A concrete conduit, approximately 2.5 m in width, is exposed to varying degrees on the channel bed between University Avenue and Marshal Street. The sides of conduit are also exposed in some areas. Utilities have been investigated through City of Waterloo records and through a planning request to Ontario One Call. No utilities were identified in the location of the observed conduit.

An additional erosion issue was identified within this site at the private road crossing upstream of University Avenue East. Gabion headwalls are failing, with baskets leaning and emptying. Possible piping was noted along the right abutment/culvert wall. On the road deck, cracks were observed in the curb and asphalt.

Figure 8-1: Exposed concrete conduit on channel bed at LRL-E5

8.1.2 Cedar Creek, Site CDR-E4

Erosion concerns were identified at 4 locations between Glen Forest Boulevard and Cedarbrae Avenue. The concerns consist of risk to 3 sanitary maintenance holes and a failing gabion bank treatment posing a risk to private property.

Figure 8-2: Sanitary maintenance hole in creek at CDR-E4

8.1.3 Laurel Creek, Site LRL-E6

Downstream of Weber Street, near-vertical bank erosion was observed on the right bank with a maintenance hole located within about 4 m of the top of bank. A second maintenance is located downstream behind a failing crib wall. A private storm outfall is located at the upstream end of the site and protrudes into the flow, likely contributing to bank scour. Closer to Weber Street, exposed concrete was observed on the channel bed and is likely a sanitary sewer encasement. Armourstone walls are located on either side of channel in this area.

Figure 8-3: Exposed concrete on channel bed at LRL-E6

8.1.4 Forwell Creek, Site FRW-E2

The culverts and headwall for the Forwell Creek Road recreational trail crossing are in very poor condition. The gabion baskets are slumping and the corrugated steel pipe (CSP) culverts are deforming and highly corroded. There appear to have been maintenance works on the culverts but the condition of the culverts has continued to degrade. A recreational trail, a sanitary sewer, a

natural gas pipeline, and hydro lines cross the creek in this location. Material has been lost from the sides of the trail and gravel restoration works have continued to erode.

Figure 8-4: Failing, undermined culverts on downstream side of Forwell Creek Road crossing at FRW-E2

8.1.5 Laurel Creek, Site LRL-E7

Erosion concerns were identified from Erb Street East to Weber Street with near-vertical bank erosion occurring on both sides of channel. A recreation trail and sanitary sewer run along the left bank and the eroding bank is within 1 m of the trail in some areas. Private property is located on the top of the right bank with erosion posing a risk to a fire hydrant, parking lot, loading area, and structures. Numerous storm outfalls are in poor repair. Concrete rubble and yard waste dumping on the bank was noted at the upstream end of the site.

Figure 8-5: Undermining of paved loading area on private property at LRL-E7

8.1.6 Cedar Creek, Site CDR-E3

On the downstream side of the Albert Street crossing, the left side of the culvert is collapsing. The gabion baskets over the culvert are also failing in this area and the sidewalk above is cracked. On the upstream side of Albert Street, a gabion weir is failing with scour occurring downstream of the weir. The base layer of the gabion treatments is failing, as is the concrete lining on the bed.

Figure 8-6: Downstream end of failing culvert under Albert Street at CDR-E3

8.1.7 Clair Creek Tributary 1, Site CLR-T1-E1

Gabion basket bank treatments are failing at the first house upstream of McDougall Road. The gabions are located on the south side of the creek and the building is located within 5m of the top of bank.

Figure 8-7: Failing gabion baskets with building located within 5 m of the top of bank at CLR-T1-E1

8.1.8 Clair Creek, Site CLR-E4

This site extends from Columbia Street downstream to 2 storm sewer outfalls on the channel banks. At Columbia Street, 2 corrugated steel pipe culverts convey flows under the road and the CSP on the east appears to be deformed. From Columbia Street downstream, gabion basket bank treatments are in varying states of failure and a pile of rip rap has developed in this area, likely sourced from the failed gabion baskets. A sanitary sewer crosses under the creek in the vicinity of the downstream storm sewer outfalls.

Figure 8-8: Failed gabion basket treatment and exposed storm sewer outfall at CLR-E4

8.2 Development of Alternatives

A series of alternatives was developed to address erosion concerns for the primary erosion issues. These alternatives are described below with specifics dependant on each particular site.

- **Alternative 1: Do Nothing** – This alternative involves leaving the site as it is and allowing erosive processes to continue within the watercourse corridor. Maintenance will have to be undertaken to address damage to infrastructure caused by the continued erosion as the damage occurs.
- **Alternative 2: Local Works** – This alternative consists of localized channel bank and/or bed work to address erosion issues at the site.
- **Alternative 3: Full Channel Restoration** – This alternative consists of a reach-based approach to address erosion issues at the site.
- **Alternative 4: Removal of Risk** – This alternative consists of moving the infrastructure at risk and allowing channel processes to continue at the site.

8.3 Evaluation Criteria

As part of the Municipal Class Environmental Assessment process, each alternative must be evaluated based on a set of environmental/physical, social, and economic criteria. A set of criteria was developed specific to erosion issues. These evaluation criteria are described in **Table 8-1**.

Table 8-1: Evaluation Criteria

Evaluation Criteria	Description
Physical/Natural Environment	
Impacts to Aquatic Habitat	Ranks how the changes impact fish habitat, including substrate, overhanging vegetation, turbidity, and passage/connectivity
Impacts to Terrestrial Habitat	Ranks how the changes impact terrestrial habitat, including loss of vegetation and corridor connectivity
Potential to Reduce Erosion of Public Lands	Ranks how the alternative impacts erosion risks to public lands
Potential to Reduce Erosion of Private Lands	Ranks how the alternative impacts erosion risks to private lands
Potential to Reduce Stream Bank and Stream Bed Erosion	Ranks how the alternative impacts erosion or stream bed and banks
Integration with Existing Infrastructure	Ranks how the alternative impacts existing infrastructure in the vicinity of the site
Integration with Existing Environment	Ranks how the alternatives impact the existing environment around the site
Social/Cultural Environment	
Aesthetics / Recreation	Ranks how the alternative impacts the aesthetics of the creek corridor and how the alternative impacts recreational use of the corridor
Compatibility with Adjacent Land Use	Ranks the impacts of the alternative on the adjacent properties
Community Disruption	Ranks the degree to which the surrounding community will be impacted by the alternative
Public Health and Safety	Ranks the degree to which the alternative protects public health and safety
Economic Environment	
Construction Costs	Ranks the construction cost associated with the alternative relative to other alternatives
Operation and Maintenance Costs	Ranks the upkeep costs associated with the alternative relative to other alternatives
Technical/Engineering Considerations	
Ease of Implementation	Ranks ease of implementing the alternative
Agency Acceptance	Ranks the likelihood that regulation authorities will support the alternative
Technical Feasibility	Ranks the degree of difficulty for the detailed design for the alternative

8.4 Evaluation of Alternatives

Using the criteria described in Section 8.3, each of the alternatives was evaluated for each of the primary erosion issues. The detailed evaluation matrices are included in **Appendix D**. The following table summarizes the preferred alternatives at each site.

Table 8-2: Summary of Preferred Alternatives

Primary Erosion Issue Site Number	Preferred Remediation Alternative
LRL-E5	Removal of risk
CDR-E4	Full channel restoration
LRL-E6	Full channel restoration
FRW-E2	Local works
LRL-E7	Full channel restoration
CDR-E3	Local works
CLR-T1-E1	Full channel restoration
CLR-E4	Full channel restoration

8.5 Public Consultation

A Public Information Centre (PIC) was held on October 30, 2018 5:00 p.m. to 7:00 p.m.at the Waterloo Memorial Recreation Complex, Bauer Room #202, located at 101 Father David Bauer Drive, Waterloo, Ontario. The PIC was extensively advertised by the City of Waterloo within the Waterloo Chronicle in advance of the PIC as well as on City websites, City message boards within community and recreation centers and City Hall as well as the City's social media feeds.

A series of posters was presented, which outlined the study background, problems, opportunities, alternatives, and preliminary alternative evaluation. The PIC was attended by approximately 10 people with 2 formally signing in. In addition, formal comments were received from five local and provincial agencies, as well as utilities.

In general, attendees were in support of the preliminary preferred alternative and expressed interest in learning more about the project outcomes and their timelines.

9 CONCEPTUAL DESIGN

9.1 Conceptual Design

For each of the primary erosion concerns, conceptual designs were developed for the preferred alternative. The conceptual designs are described below and conceptual design drawings are included following the descriptions below.

9.1.1 Laurel Creek, Site LRL-E5

The City of Waterloo completed an extensive review of record drawings and consultation with technical staff. The reason for the concrete conduit within the channel was not determined. An Ontario One Call planning locates request was also completed and none of the infrastructure identified from this request matched the location of the concrete conduit in the channel. Prior to removing the concrete conduit, exploratory field tests should be conducted to determine what it is and whether it is still in use.

Assuming that the concrete conduit is no longer in use, the preferred alternative at this site is the removal of the risk. The concrete conduit would be removed from the channel and bed and bank restoration works would be completed. Aquatic and terrestrial habitat features should be included where feasible. A geotechnical investigation may be required at the detailed design stage.

The private bridge structure should be assessed for structural condition and replaced as required. At a minimum, the failing gabion basket abutments should be replaced as part of the above channel bank restoration works.

9.1.2 Cedar Creek, Site CDR-E4

The preferred alternative at this site is full channel restoration. A geomorphic assessment should be completed at the onset of the detailed design to inform the restoration works. Consideration to channel sediment transport processes should be given to assess the impacts of potential bank treatments. During the detailed design, consideration should be given to moving the trail away from the creek, where possible, and using vegetated treatments where space is available. The detailed design must also provide protection to buried sanitary sewer infrastructure.

A geotechnical investigation should be undertaken at the onset of the project to inform the design of armourstone walls, where required by space constraints.

9.1.3 Laurel Creek, Site LRL-E6

The preferred alternative at this site is full channel restoration. Bank protection is required downstream of the existing armourstone wall to protect the sanitary sewer line and maintenance holes. The existing protruding outfall will be retrofitted into the bank protection. Bed restoration works (i.e. grade control) will be undertaken to protect the existing sanitary sewer crossing which is currently exposed. During the detailed design, implications of the bed works on the upstream flow gauging station must be identified and addressed. A geotechnical investigation will also be required at the detailed design stage.

9.1.4 Forwell Creek, Site FRW-E2

The preferred alternative at this site is local works. A hydraulic assessment should be undertaken to determine the appropriate sizing for the culvert replacement. Additionally, a geotechnical investigation should be undertaken at the onset of the project to inform the culvert replacement design. Since a recreational trail, a sanitary sewer, a natural gas pipeline, and hydro lines cross the creek in this location, the utility owners should be contacted at the start of the project. Utility requirements should be identified and incorporated into the design for the culvert replacement.

9.1.5 Laurel Creek, Site LRL-E7

The preferred alternative at this site is full channel restoration. Due to the confined nature of the channel at this site, it is expected that armourstone walls will be required. Grade control on the channel bed will be included at the sanitary sewer crossing and elsewhere, as required, to protect the base of the armourstone wall from undermining. Vegetation plantings at the top of the armourstone wall should be included where space permits.

To inform the detailed design, a geotechnical investigation will be required at the onset of the project.

9.1.6 Cedar Creek, Site CDR-E3

The preferred alternative at this site is local works. A hydraulic assessment of the culvert should be performed to determine the appropriate sizing for a new culvert. A geotechnical investigation should also be completed at the onset of the project to inform the culvert and bank treatment designs. The existing culvert and gabion baskets will be removed and replaced. It is expected that armourstone walls will be required to replace the gabion baskets given the confined nature of the creek corridor. The existing gabion weir will be replaced with riffle grade control which will incorporate fish passage.

9.1.7 Clair Creek Tributary 1, Site CLR-T1-E1

The preferred alternative at this site is full channel restoration. The existing gabion baskets will be removed and replaced with armourstone walls. Due to the confined nature of the corridor in this area, it is expected that softer channel restoration measures will not be feasible. A geotechnical investigation will be required at the onset of the project to inform the armourstone wall design and assess the potential construction impacts to the adjacent building.

9.1.8 Clair Creek, Site CLR-E4

The preferred alternative at this site is full channel restoration. The existing gabion baskets would be removed and replaced with armourstone walls and/or vegetated buttresses depending on the space available. The storm sewer headwalls will be restored and grade control will be required on the channel bed to protect the sanitary sewer crossing. The culvert condition at Columbia Street West should be assessed and replaced if required.

To inform the detailed design, a geotechnical investigation will be required at the onset of the project.

9.2 Cost Estimate

Based on the primary list of erosion sites and restoration reach opportunities, $9.2 – $13.0 million in stream restoration projects are estimated.

The eight (8) primary stream restoration opportunities represent the key projects to be considered by the City. For each of the sites, preliminary alternative solutions were evaluated using baseline information and a list of evaluation criteria. Scoring of the criteria produced a preferred alternative based on the highest score, which was then developed into a conceptual design. Cost estimates for engineering services (i.e., design, background studies such as geotechnical investigations) and construction costs for each of the preferred alternatives was estimated for each of the preferred alternatives for each site.

The estimated range of costs for the conceptual designs are presented in **Section 9.1** and **Appendix D,** which includes the costs for construction, engineering design and approval and contingency (15%). Cost estimates are exclusive of HST.

A summary of the evaluation of the primary opportunities is presented below in **Table 9.1.**

Table 9.1: Estimated Cost ($) Summary of Stream System Opportunities

Watercourse	Reach ID	Erosion ID	Primary Classification	Risk	Preferred Alternative(s)	EA Schedule	Estimated Range in Costs for Preferred Alternative [1]
Laurel Creek	R4 (Marshall St to Marsland Dr N)	LRL-E5	Erosion Site	Sanitary maintenance holes	Removal of Risk (& Local Works)	B	$1,100,000 - $1,600,000 [2]
Cedar Creek	R4 (Rec. trail to LRT crossing)	CDR-E4	Erosion Site	Sanitary maintenance holes	Full Channel Restoration	B	$1,600,000 - $2,200,000
Laurel Creek	R5 (Erb St to Marshall St)	LRL-E6	Erosion Site	Sanitary sewer and maintenance hole	Full Channel Restoration	B	$1,200,000 - $1,600,000
Forwell Creek	R2 (Blue Springs Dr to Forwell Creek Rd)	FRW-E2	Erosion Site	Culverts and headwall	Local Works	B	$500,000 - $600,000 [3]
Laurel Creek	R5 (Erb St to Marshall St)	LRL-E7	Erosion Site	Recreation trail, sanitary sewer run, private property	Full Channel Restoration	B	$2,500,000 - $3,800,000
Cedar Creek	R2 (Pedestrian crossing to drainage channel)	CDR-E3	Erosion Site	Culvert and gabion weir	Local Works	B	$800,000 - $1,100,000 [3]
Clair Creek Tributary 1	T1-R1 (Keats Way to confluence)	CLR-T1-E1	Erosion Site	Gabion and private residence	Full Channel Restoration	B	$1,100,000 - $1,600,000 [4]
Clair Creek	R9 (Columbia St W to Craigleith Dr)	CLR-E4	Erosion Site	Storm sewer outfalls, sanitary sewer, culvert	Full Channel Restoration	B	$400,000 - $500,000

Notes:
1. Cost estimate range includes costs for construction, engineering design and approval (15%), and contingency (15%), but is exclusive of HST.
2. Bridge repair for a private crossing at LRL-E5 upstream of University Drive East is not included, estimated to be between $250 – 500 K.
3. Erosion sites FRW-E2 and CDR-E3 include culvert replacements and associated crossing repairs estimated in the range of $200 – 300 K.
4. City to consider additional hydraulic study at erosion site CLR-T1-E1 to investigate flow diversion options through storm sewer for alleviating future flood and erosion risks. Study costs are estimated at $50– 75K.

10 IMPLEMENTATION PLAN

The following section describes the necessary next steps to complete detailed design, the various implementation measures to be considered at the detailed design and implementation stages, as well as monitoring requirements.

10.1 Detailed Design Requirements

The current study provides conceptual designs for the preferred alternatives to address erosion concerns at the primary erosion sites. The next step in the process is to undertake detailed design for each of the preferred alternatives. At the detailed design stage, the following items will need to be addressed:

Species at Risk – The protection of Species at Risk (SAR) in Ontario is dictated primarily by the Ontario Endangered Species Act (ESA) (2007). In addition to the ESA, aquatic SAR in Ontario are protected under the federal Species at Risk Act (SARA). A scientific body known as the Committee on the Status of Species at Risk in Ontario is tasked with identifying threats to species in Ontario and classifying those deemed at risk as extirpated, endangered, threatened or special concern. Endangered and threatened species receive recovery strategies, which offer science-based recommendations that aid in their protection and future recovery. These species are also protected from being killed, harmed or harassed (s. 9) and receive habitat protection (s. 10). Alternatively, special concern species receive management plans rather than recovery strategies and are not subject to species or habitat protection.

Species-at-Risk (SAR) are defined as species listed as Endangered, Threatened, or of Special Concern by the Committee on the Status of Species at Risk in Ontario (COSSARO). Species of conservation concern (SOCC) are defined as species listed as Endangered, Threatened, or of Species Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); species with Global Ranks of G1-G3; species with Sub- National/Provincial ranks of S1-S3; and species with a local significant species ranking, as applicable.

The status of SAR and other SOCC, as well as their habitats, are routinely updated. As such, the status SAR and SOCC (i.e. Endangered, Threatened, Special Concern, S-ranked, and local-ranked species) should be reviewed at subsequent project stages to reflect the most up-to-date species designations. A SAR and SOCC screening exercise should be completed at detailed design to identify the location of SAR and SOCC and their habitats, and to avoid contravention of the ESA (2007), the federal Migratory Birds Convention Act (1994), which protects the nests of most breeding bird species in Ontario, the Provincial Policy Statement (2014), and local official plans. Additionally, a SAR and SOCC screening exercise should be conducted prior to construction.

Restoration Planting Plan – Vegetative restoration plans must be developed at each site, specifying native species to be used to restore channel banks, the floodplain, staging areas, and the access route associated with the detailed design. The plans must include compensation for trees removed for construction in accordance with ratios prescribed by the City of Waterloo and Grand River Conservation Authority. The restoration plans will aid in the restoration of the ecological function of the erosion sites, including functions as a linkage and as wildlife habitat.

Grand River Conservation Authority Permit – Permits for works associated with the erosion sites remediation will be required from Grand River Conservation Authority in accordance with Ontario Regulation 150/06. For each site, a design package will need to be submitted to GRCA with the design drawings, a design brief, and hydraulic model files. Scheduling of the project should allow for review of the submission by GRCA and revisions to the design and resubmission following receipt of comments from GRCA.

DFO Request for Review – Once the detailed design has been prepared for the channel works at each site, a request for review under the Fisheries Act should be submitted to DFO. Since channel work below the high-water mark will be required, these projects cannot be exempted from review based on the DFO's self-assessment process.

Utilities – All utility locations must be confirmed at the detailed design and daylighting of the utilities should be undertaken if insufficient information is available to confirm the elevation of all utilities.

10.2 Implementation Measures

For each individual project, the following measures must be considered at the detailed design and implementation stages.

Construction Staging, Erosion and Sediment Control Measures – Appropriate plans are to be included within the detailed design packages, based on consultations with the City and Grand River Conservation Authority. The construction access route and staging areas are to be finalized for each detailed design, and a restoration plan will be required to ensure that the access route and staging area are replanted and restored in accordance with GRCA's requirements.

Construction Timing – Construction works must adhere to the fisheries windows mandated by the Ministry of Natural Resources and Forestry (see Error! Reference source not found.). For cold water watercourses, in-water works may only occur between July 1 and September 15. For warm water watercourse, in-water works may only occur between July 1 and March 31.

Table 10-1: Thermal Regime for Waterloo Watercourses

Creek	Thermal Regime
Beaver Creek	Cold
Cedar Creek	Warm
Clair Creek	Warm
Colonial Creek	Warm
Cooper's Creek	Warm
Critter Creek	Warm
Cuckoo Creek	Warm
Forwell Creek	Warm
Horst Creek	Warm
Laurel Creek	Warm
Maple Hill	Warm
Melitzer Creek	Cold
Minnow Creek	Warm

Monastery Creek	Cold
Willow Creek	Warm

Source: MNRF (2017)

Tree Protection – Tree protection fencing following the requirements of the City of Waterloo and GRCA must be installed. Tree protection fencing should be erected to protect trees along all construction access routes and work areas. Fencing should consist of posts or t-bars with filter cloth affixed to page wire fencing. Tree protection fencing should be located at a minimum distance of 1 m from the dripline of potentially affected trees. Maintaining the minimum 1 m distance separation may not be possible in some areas. In such cases, fencing should be located as far as possible from the tree.

Environmental Approvals and Permitting – In addition to approvals by the City's works and parks departments, applications will be required for permits from GRCA under Ontario Regulation 150/06 (Development, Interference with Wetlands and Alterations to Shorelines and Watercourses), and, if applicable, MECP under the Species at Risk Act. Approval from the MNRF is required for a fish collection permit (fish rescue).

As well, works must consider the Provincial Policy Statement regarding water (Policies 2.2.1 and 2.2.2) which states that "planning authorities shall protect, improve or restore the quality and quantity of water" and that "site alteration shall be restricted in or near sensitive surface water features and sensitive ground water features". To comply with the Provincial Policy Statement, channel works should be completed in the dry to protect water quality, and downstream base flows should be provided during construction to protect water quantity. It should also be noted that no sensitive surface water or groundwater features were identified during the field assessments.

Tendering, Construction Administration, and Supervision – The design engineering consultant may be retained to provide all of these services. However, as a minimum, the design engineering consultant should provide input to the tender document, specifically the special provisions, and should provide at least part-time construction supervision. The consultant may also be asked to provide recommendations for qualified stream construction contractors for consideration within the City's tender process.

10.3 Monitoring Requirements

For channel restoration projects, conservation authorities typically require a commitment to post-construction monitoring for a period of 3 years following construction as a part of the permitting agreement. Detailed as-built surveys and drawings should also be completed immediately following construction by the contractor and/or stream restoration consultant. The specific details and length of monitoring required for the restoration works will be developed by the channel restoration consultant in consultation with the City, GRCA, and/or DFO during the permitting process. Typical monitoring tasks are described below.

<u>Pre-Construction and During Construction</u>

- Field inspections conducted periodically before and during construction to document and photograph site conditions associated with the channel construction process.

- Field inspections conducted at least once prior to construction and weekly during the construction period.
- Photographs collected from the same vantage point to allow for time series comparison.

Immediately Post-Construction

- Site inspection including monitoring channel stability during the stabilization period.
- As-built survey of the completed culvert and channel works (plan, profile, and cross-sections) to verify implementation of design within reasonable tolerances.
- Drawings prepared for the as-built survey for inclusion in the first monitoring report.

Post-Construction Monitoring

- Post-construction monitoring for channel form and vegetation in years 1, 2, and 3 post-construction.
- Monitoring site visits, typically 1 per monitoring year in the late spring/early summer, including monitoring of intended channel functions and restoration works. (Additional inspections after large storms to be completed by the City.)
- Monitoring reports (3) submitted to stakeholders and regulatory agencies in January of each year following monitoring activities. Reports to include field assessment of channel form and restoration including the following items:
    - Planform (bank stability and treatments and tie-ins, years 1-3 post-construction);
    - Profile (upstream and downstream culvert tie-ins years 1-3 post-construction);
    - Cross-section (flow concentration and width adjustments, years 1-3 post-construction);
    - Planting success (including bank and slope treatments, years 1-3 and 5 post-construction);
    - Photographic inventory and map to document observations (years 1-3 post-construction); and
    - Recommendations for any required mitigation measures (channel works, years 1-3 post-construction and vegetation, years 1-3 and 5 post-construction).

Adaptive management responses related to restoration works should include replacement/repair of failed restoration measures identified through monitoring.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Environmental Assessment Process

This study was undertaken as a Master Plan under the Municipal Class Environmental Assessment process. Phases 1 and 2 of the planning and design process were addressed in this study. Implementation of the preferred alternative can proceed under Phase 5 of the Municipal Class EA process.

11.2 Conclusions

Consistent with the recommended approach as outlined within this report, the following conclusions have been developed:

1. Primary erosion issues should be addressed through remediation measures identified in this study. The conceptual designs for each of the primary erosion issues have been developed and the implementation plan should be followed to take these sites through the detailed design and construction stages.

2. Secondary erosion issues should be monitored annually and following large storm events. The conditions at the site should be compared to exiting conditions as described in this report. Should the condition at any of the sites deteriorate, the site should be re-evaluated according to the methodology used in this study. The new score should be used to determine whether the site has become a primary erosion issue and should be added to the priority list of sites for restoration.

11.3 Recommendations

Consistent with the recommended approach as outlined within this report, the following study recommendations for the consideration by the City of Waterloo are as follows:

1. That Council approve the City of Waterloo Watercourse Erosion Master Plan together with the Preferred Alternatives as detailed within.

2. That City staff be directed to file the report with the Ministry of the Environment and Climate Change for the 30-day public review period as required by the *Environmental Assessment Act.*

3. That City staff be directed to revise the Capital Budget to reflect and permit the implementation of the Preferred Alternatives as detailed within.

4. That staff be directed to integrate the Master Plan report, its recommendations and preferred alternatives into the broader City of Waterloo Integrated Stormwater Management Master Plan.

5. That the City of Waterloo develop specific policies and programs for landowner education:
    a. for the establishment of vegetative buffers to reduce the area of manicured lawns adjacent to the channel and to maximize plant diversity within the riparian zone and the width of the buffer
    b. with respect to the disposal of yard waste within and adjacent to the City's watercourses. Disposal of yard waste into watercourse corridors can cause debris jams within the channel and impact flow conveyance, which could potentially cause channel erosion and flooding and may place city infrastructure and private property at risk.

6. That the City explore the development and implementation of a city-wide policy in regards to undertaking watercourse restoration or repair works within private property.

7. That the City, in the future, explore the opportunity to collaborate and partner with the City of Kitchener on their Habitat Banking Agreement with DFO. The identified primary erosion issues and associated preferred alternatives would likely qualify for Habitat Banking consideration under the City of Kitchener's current program.

12 REFERENCES

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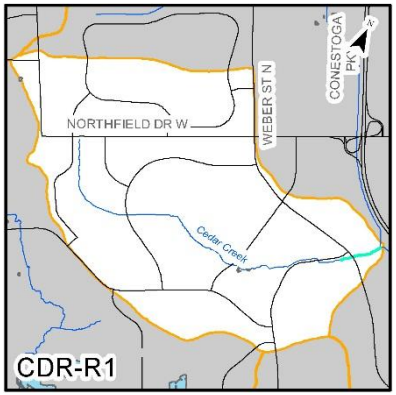
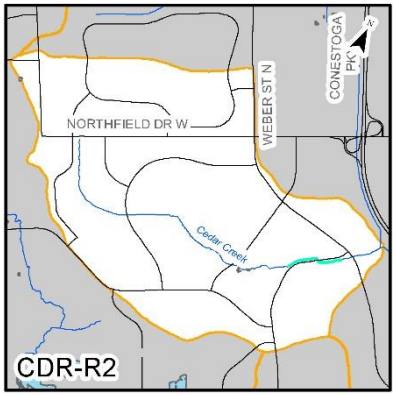
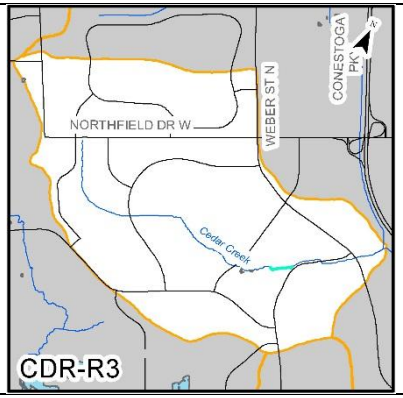
Appendix A – Rapid Geomorphic Assessments

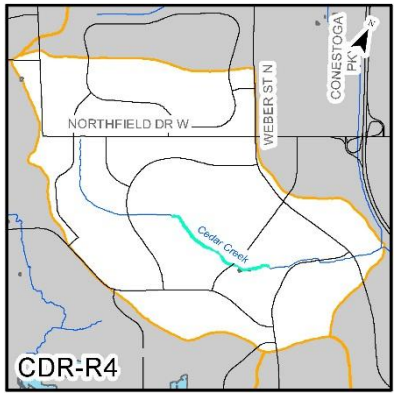
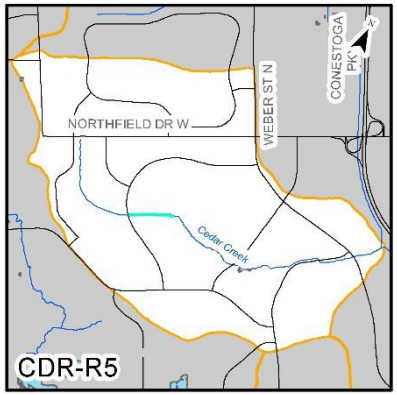
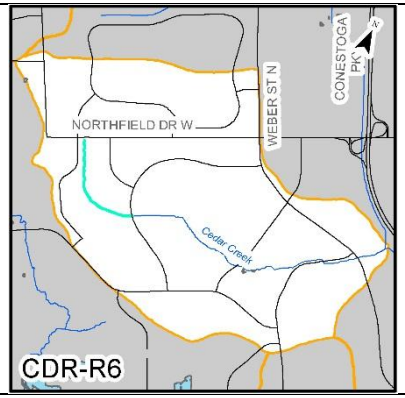
Form/ Process		Geomorphic Indicator	Cedar	Clair											Colonial						
	no.	Description	CDR-R3	CLR-R1	CLR-R3	CLR-R4	CLR-R6	CLR-R7	CLR-R8	CLR-R9	CLR-R10	CLR-R12	CLR-R13	CLR-T3-R1	CLR-T3-R2	CLN-R1	CLN-R2	CLN-R3	CLN-R5	CLN-R7	CLN-T-R1	CLN-T-R2
Evidence of Aggradation (AI)	1	Lobate bar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
	2	Coarse material in riffle embedded	0	0	0	1	1	1	1	0	0	0	0	0.5	0	0	1	1	0	1	0
	3	Siltation in pools	0.5	0	1	1	0	1	1	1	1	0	1	0.5	0	0	0	1	1	1	1
	4	Medial bars	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1
	5	Accretion on point bars	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	6	Poor longitudinal sorting of bed materials	0	0	0.5	0	1	1	0	1	N/A	1	1	0	1	0	0	0	1	0	1	0
	7	Deposition in overbank zone	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	1	0	1
		SCORE	0.36	0.14	0.36	0.29	0.43	0.50	0.43	0.43	0.17	0.14	0.29	0.14	0.14	0.14	0.14	0.29	0.57	0.57	0.43	0.57
Evidence of Degradation (DI)	1	Exposed bridge footings	0	0	0	0	0	N/a	N/A	N/A	0	0	0	0	0	1	1	N/A	1	N/A	N/A	0
	2	Exposed sanitary/storm sewer/pipeline etc	N/A	N/A	N/A	N/A	0	N/a	0	0	N/A	N/A	N/A	0	N/A	0	N/A	0	N/A	N/A	N/A	0
	3	Elevated stormsewer outfall	N/A	1	N/A	1	0	1	1	0	N/A	N/A	N/A	N/A	0	0	N/A	N/A	1	N/A	N/A	N/A
	4	undermined gabion basket/concrete apron/etc	0	1	1	1	0	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1	N/A	N/A	N/A
	5	Scour pools d/s of culverts/stormsewers	0	1	0	1	0	0	1	0	0	N/A	N/A	0	0	0	0	N/A	0	0	0	0
	6	Cut face on bar forms	N/A	0	0	0	0	0	0	N/A	0	0	0	0	0	0	0	0	0	0	0	0
	7	Head cutting due to knick point migration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	Terrace cut through older bar material	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
	9	Suspended armor layer visible in bank	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0
	10	Channel worn into undisturbed overburden/bedrock	0	0	1	0	0	1	1	1	1	1	1	0	1	1	0	0	1	0	1	0
		SCORE	0.00	0.44	0.25	0.33	0.00	0.25	0.33	0.13	0.14	0.50	0.50	0.00	0.25	0.22	0.13	0.17	0.44	0.00	0.17	0.00
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc	1	1	1	1	1	1	1	0	0	1	1	0	N/A	0	0	0	1	1	N/A	1
	2	Occurrence of large organic debris	1	1	0	1	1	1	1	1	0	1	0	0	N/A	1	0	1	1	1	0	1
	3	Exposed tree roots	1	1	1	1	0.5	1	1	1	0	1	1	0	N/A	1	1	0	1	1	N/A	0
	4	Basal scour on inside meander bends	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0
	5	Basal scour on both sides of channel through riffle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0
	6	Gabion baskets/concrete walls/armour stone etc. out flanked	N/A	1	0	1	1	N/A	0	0	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
	7	Length of basal scour > 50% through subject reach	0	1	0	1	0	0	1	1	0	1	1	0	0	0	0	0	0	0	1	0
	8	Exposed length of previously buried pipe/cable etc.	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0	N/A	N/A	N/A	0
	9	Fracture lines along top of bank	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1	1	0	1	0
	10	Exposed building foundation	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		SCORE	0.57	0.88	0.56	0.88	0.50	0.57	0.75	0.63	0.14	1.00	0.75	0.14	0.50	0.38	0.43	0.38	0.71	0.43	0.60	0.22
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	1	1	1
	2	Evolution of single thread channel to multiple channel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	Evolution of pool-riffle form to low bed relief form	0	0	1	1	1	1	1	1	N/A	0	0	0	0	N/A	0	0	0	0	0	0.5
	4	Cutoff channel(s)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	Formation of island(s)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	6	Thalweg alignment out of phase with meander geometry	1	0	1	1	1	0	1	1	0	1	1	0	0	0	0	0	1	0.5	0	1
	7	Bar forms poorly formed/reworked/removed	1	1	1	1	1	1	1	1	1	1	1	1	1	N/A	N/A	N/A	1	0	1	0
		SCORE	0.29	0.14	0.43	0.43	0.57	0.43	0.57	0.43	0.17	0.29	0.29	0.14	0.14	0.20	0.00	0.17	0.29	0.21	0.43	0.36
		Stability Index (SI) = (AI+DI+WI+PI)/m	0.30	0.40	0.40	0.48	0.38	0.44	0.52	0.40	0.15	0.48	0.46	0.11	0.26	0.24	0.17	0.25	0.50	0.30	0.41	0.29

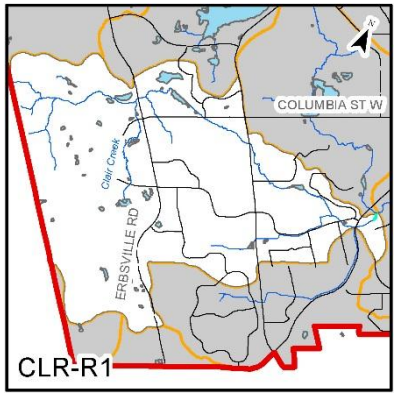
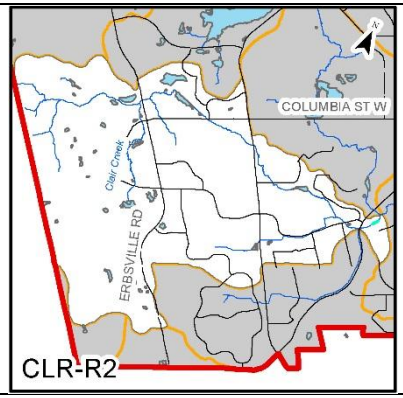
Form/ Process		Geomorphic Indicator	Critter	Cuckoo	Forwell		Laurel							Willow
	no.	Description	CRT-R1	CCK-R1	FRW-R1	FRW-R2	LRL-R2	LRL-R3	LRL-R8	LRL-R9	LRL-R11	LRL-R12	LRL-R13	WLW-R1
Evidence of Aggradation (AI)	1	Lobate bar	0	0	1	0	0	0	1	0	0	0	0	0
	2	Coarse material in riffle embedded	0	0	0.5	0	1	1	1	0	1	1	1	0
	3	Siltation in pools	0	0	0	0	0	1	1	0.5	1	1	0	0
	4	Medial bars	0	0	1	1	0	0	1	1	0	0	0	0
	5	Accretion on point bars	0	0	1	0	0	0	0	0	0	0	0	0
	6	Poor longitudinal sorting of bed materials	0	0	1	1	1	0	1	0	0	1	1	0
	7	Deposition in overbank zone	0	0	0	0	0	0	1	0	0	0	0	0
		SCORE	0.00	0.00	0.64	0.29	0.29	0.29	0.86	0.21	0.29	0.43	0.29	0.00
Evidence of Degradation (DI)	1	Exposed bridge footings	0	N/A	0	0	1	0	0	0	0	0	0	N/A
	2	Exposed sanitary/storm sewer/pipeline etc	0	N/A	N/A	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A
	3	Elevated stormsewer outfall	N/A	N/A	N/A	N/A	1	1	0	0	0	0	0	N/A
	4	undermined gabion basket/concrete apron/etc	N/A	N/A	0	N/A	1	0	0	0	0	0	N/A	N/A
	5	Scour pools d/s of culverts/stormsewers	1	1	0	1	1	0	0	1	0	1	0	0
	6	Cut face on bar forms	0	0	1	0	0	N/A	0	0	0	0	0	N/A
	7	Head cutting due to knick point migration	0	1	0	0	0	0	0	0	0	0	0	1
	8	Terrace cut through older bar material	0	0	1	0	0	0	0	0	0	0	0	N/A
	9	Suspended armor layer visible in bank	0	1	1	1	1	1	0	0	0	0	0	1
	10	Channel worn into undisturbed overburden/bedrock	1	1	1	1	0	1	0	1	1	1	1	1
		SCORE	0.25	0.67	0.50	0.38	0.50	0.44	0.00	0.22	0.11	0.22	0.13	0.75
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc	0	1	0	1	1	1	1	1	0	1	0.5	1
	2	Occurrence of large organic debris	0	1	0	1	1	0.5	1	1	0.5	1	0	1
	3	Exposed tree roots	0	0.5	1	1	1	1	0	1	1	1	1	0.5
	4	Basal scour on inside meander bends	0	0	0	1	1	1	1	1	1	0	0	0
	5	Basal scour on both sides of channel through riffle	0	0	1	1	1	1	1	1	0	0	1	0
	6	Gabion baskets/concrete walls/armour stone etc. out flanked	N/A	N/A	0	N/A	1	0	0	0	0	0	N/A	N/A
	7	Length of basal scour > 50% through subject reach	0	0	0	1	1	1	1	1	0	0	0	0
	8	Exposed length of previously buried pipe/cable etc.	N/A	N/A	N/A	0	0	0	N/A	N/A	N/A	1	N/A	N/A
	9	Fracture lines along top of bank	0	1	1	1	1	0	0	1	0	0.5	0	1
	10	Exposed building foundation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.5	0	N/A	N/A
		SCORE	0.00	0.50	0.38	0.88	0.89	0.61	0.63	0.88	0.33	0.45	0.36	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)	0	0	0	0	0	0	0	0	0	0	0	0
	2	Evolution of single thread channel to multiple channel	0	0	0	0	0	0	0	0	0	0	0	0
	3	Evolution of pool-riffle form to low bed relief form	0	1	1	1	0	1	1	1	0	1	1	1
	4	Cutoff channel(s)	0	0	0	0	0	0	0	1	0	0	0	0
	5	Formation of island(s)	0	0	0	1	0	0	1	1	0	0	0	0
	6	Thalweg alignment out of phase with meander geometry	0	1	1	1	1	0	1	1	0.5	1	1	1
	7	Bar forms poorly formed/reworked/removed	0	0	1	1	1	1	1	1	1	1	1	0.5
		SCORE	0.00	0.29	0.43	0.57	0.29	0.29	0.57	0.71	0.21	0.43	0.43	0.36
		Stability Index (SI) = (AI+DI+WI+PI)/m	0.06	0.36	0.49	0.53	0.49	0.41	0.51	0.51	0.24	0.38	0.30	0.40

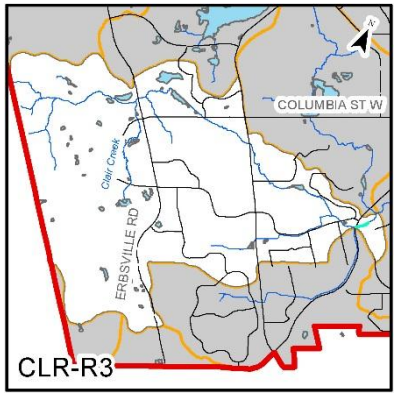
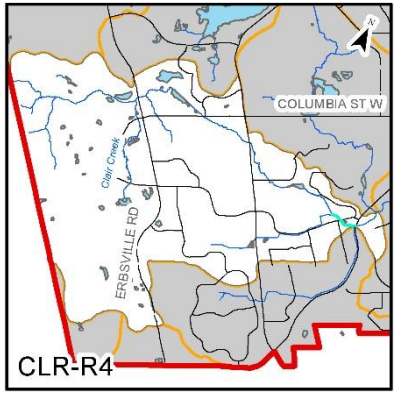
Appendix B – Reach Summaries

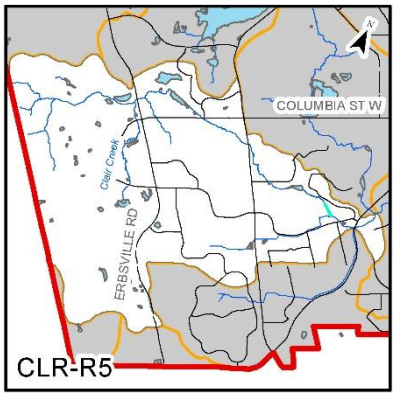
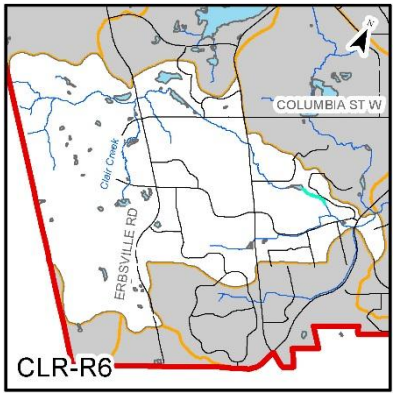
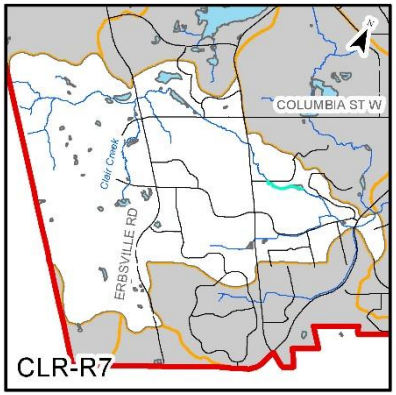
Table B1: Reach Summaries

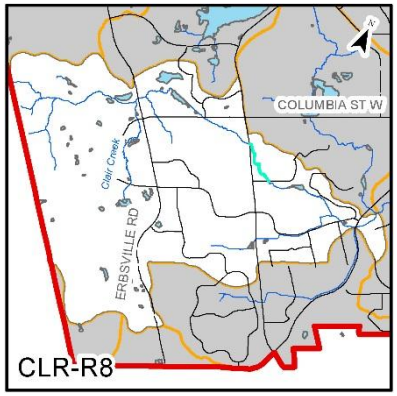
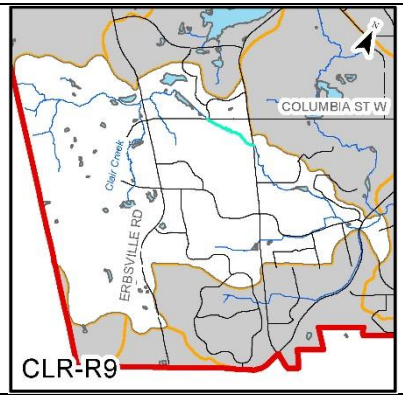
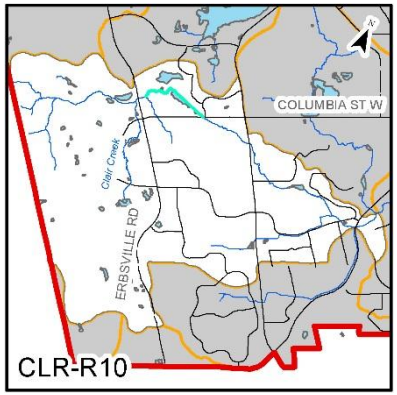
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Cedar Creek **CDR-R1** Upstream Limit: Confluence with drainage channel Downstream Limit: Confluence with Forwell Creek	Straightened, entrenched, trapezoidal channel with gabion treatments. Sand deposits likely from road sand and upstream bank erosion.	Average Channel Dimensions Width ~ 4 m Depth ~ 0.7 m RGA Results N/A		
Cedar Creek **CDR-R2** Upstream Limit: Pedestrian crossing at trail Downstream Limit: Confluence with drainage channel	Straightened and entrenched channelized with gabions on banks. Sand deposits throughout.	Average Channel Dimensions Width ~ 4 m Corridor Depth ~ 3 m RGA Results N/A		
Cedar Creek **CDR-R3** Upstream Limit: LRT crossing Downstream Limit: Recreational trail crossing	Alluvial, mildly-entrenched channel with limited pool-riffle form. Bed composed mainly of sand with some larger material. Leaning trees on banks.	Average Channel Dimensions Width ~ 3 m Depth ~ 0.8 m RGA Results Dominant Process: Widening SI: 0.30 (Transitional)		

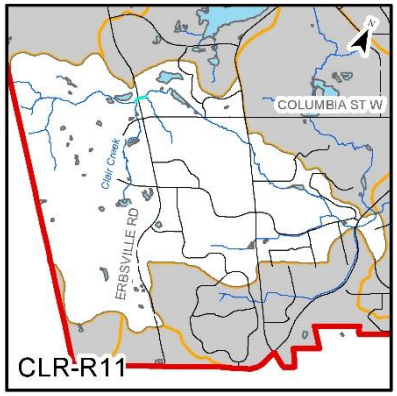
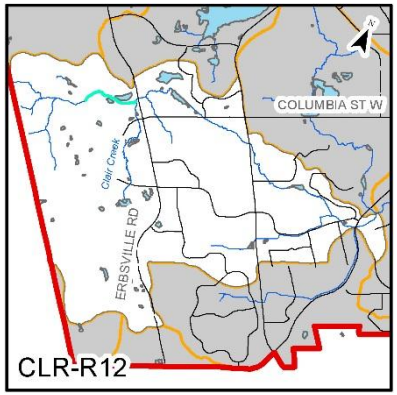
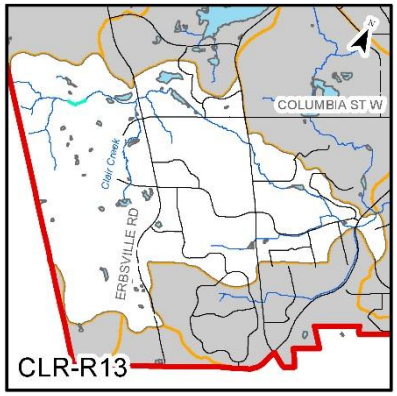
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Cedar Creek **CDR-R4** Upstream Limit: Recreational trail crossing to Park Lawn Place Downstream Limit: LRT crossing	Straightened, entrenched channel with intermittent gabion baskets, armourstone. Large woody jams present. Bed material is mainly sand and silt.	Average Channel Dimensions Width ~ 2–3.5 m Depth ~ 0.5–1 m RGA Results N/A		
Cedar Creek **CDR-R5** Upstream Limit: Glen Forest Boulevard Downstream Limit: Recreational trail crossing to Park Lawn Place	Straightened, entrenched and over-widened channel. Bed material ranges from silt to cobbles with some coarser material on riffles.	Average Channel Dimensions Width ~ 5 m Depth ~ 0.4 m RGA Results N/A		
Cedar Creek **CDR-R6** Upstream Limit: Northfield Dr. Downstream Limit: Glen Forest Boulevard	Straightened, entrenched channel in narrow corridor developing limited meandering form. Intermittent gabion treatments. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 2 m Depth ~ 0.5 m RGA Results N/A		

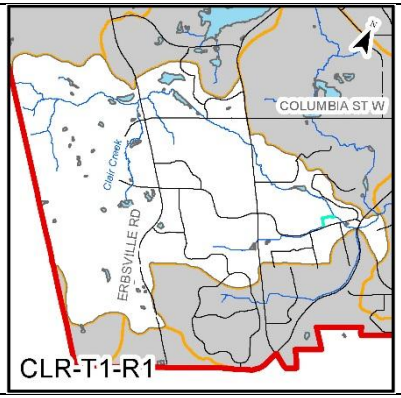
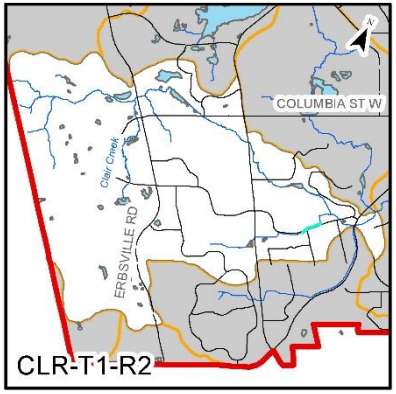
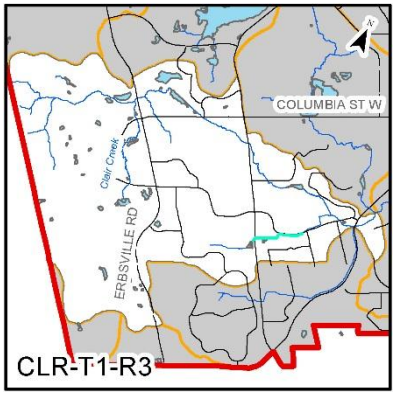
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-R1** Upstream Limit: Westmount Rd. N. Downstream Limit: Confluence with Laurel Creek	Entrenched, alluvial channel in forested corridor. Intermittent gabion treatments and toe scour throughout. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 4–6 m Depth ~ 1.2 m RGA Results Dominant Process: Widening SI: 0.40 (Transitional)		
Clair Creek **CLR-R2** Upstream Limit: Private Road Downstream Limit: Westmount Rd. N.	Concrete trapezoidal channel with vegetation establishing in concrete joints. Accumulated sediment at toe of concrete.	Average Channel Dimensions Width ~ 5 m Depth ~ 0.8 m RGA Results N/A		

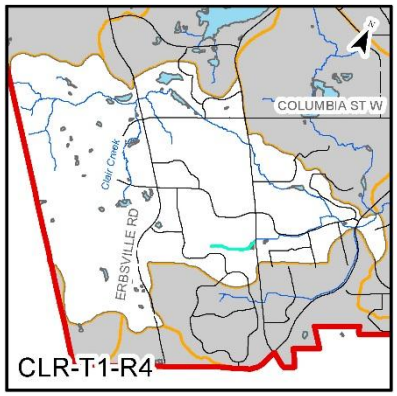
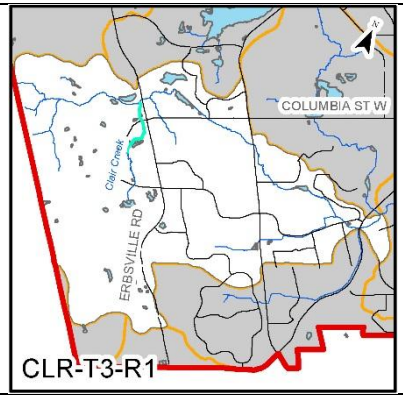
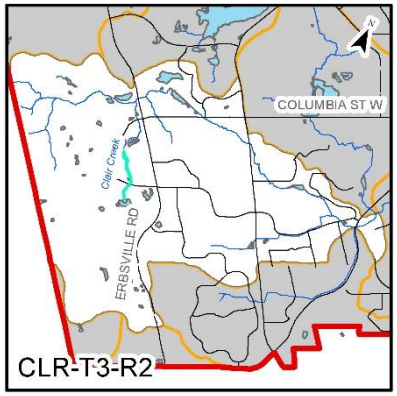
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-R3** Upstream Limit: University Ave. Downstream Limit: Private Road	Constructed, entrenched channel in narrow corridor with townhouses at top of slope/edge of corridor. Willow roots are providing grade control and stabilizing banks. Armourstone walls are present with boulders placed at toe. Bed material ranges from clay to boulders.	Average Channel Dimensions Width ~ 4–5 m Depth ~ 0.5–0.8 m RGA Results Dominant Process: Widening SI: 0.40 (Transitional)		
Clair Creek **CLR-R4** Upstream Limit: Confluence with Tributary 1 Downstream Limit: University Ave.	Channel with rectangular cross section, vegetated banks, floodplain connection, and toe scour throughout. Rip rap, gabion, and concrete treatments present. Bed material ranges from silt to boulders.	Average Channel Dimensions Width ~ 4–5 m Depth ~ 0.6–0.8 m RGA Results Dominant Process: Widening SI: 0.48 (In adjustment)		

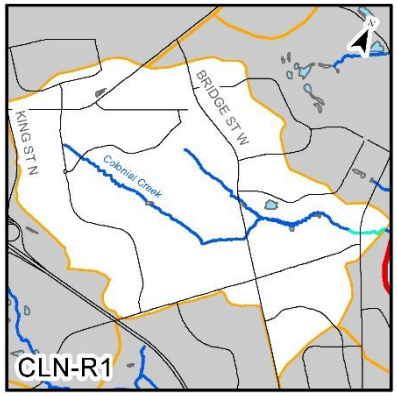
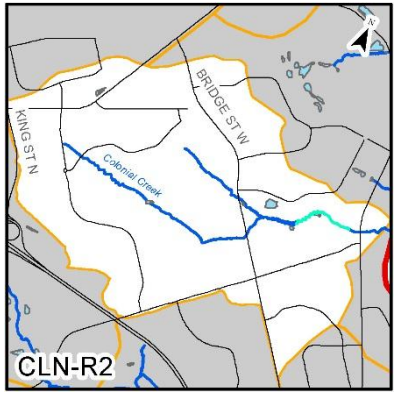
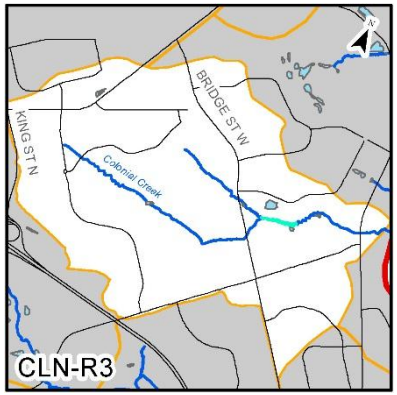
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-R5** Upstream Limit: End of straightened reach Downstream Limit: Confluence with Tributary 1	Confined, straightened, mildly entrenched trapezoidal channel with hardened banks (gabion baskets, concrete, and roundstone). Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 3–4 m Depth ~ 0.6–0.8 m RGA Results N/A		
Clair Creek **CLR-R6** Upstream Limit: Clair Lake Downstream Limit: Beginning of straightened reach	Meandering, alluvial channel with some riffle-pool form and good floodplain access. Rip-rap and gabion treatments are present intermittently. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 4 m Depth ~ 0.6 m RGA Results Dominant Process: Planform adjustment SI: 0.38 (Transitional)		
Clair Creek **CLR-R7** Upstream Limit: Craigleith Dr. Downstream Limit: Clair Lake	Alluvial channel with good floodplain access and some wetland areas. Large woody debris jams and deposition throughout. Gabion treatments present intermittently. Bed material ranges from clay to cobbles.	Average Channel Dimensions Width ~ 4 m Depth ~ 0.4 m RGA Results Dominant Process: Widening SI: 0.44 (In adjustment)		

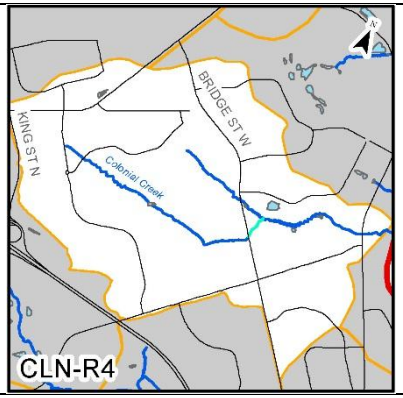
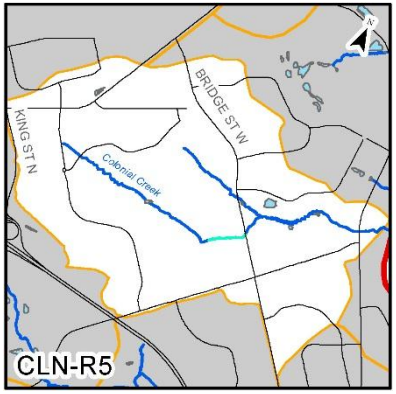
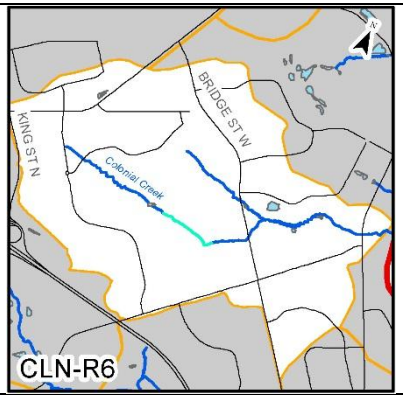
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-R8** Upstream Limit: Fischer-Hallman Rd. Downstream Limit: Craigleith Dr.	Most of reach appears to have been previously straightened. Channel is mildly entrenched with clay exposed on bed. Gabion treatments present. Bed material ranges from clay to cobbles.	Average Channel Dimensions Width ~ 3–3.5 m Depth ~ 1–1.2 m RGA Results Dominant Process: Widening SI: 0.52 (In adjustment)		
Clair Creek **CLR-R9** Upstream Limit: Columbia St. W. Downstream Limit: Craigleith Dr.	Straightened alluvial channel with toe scour throughout the vegetated corridor. Channel is connected to floodplain. Bed is silty with roundstone.	Average Channel Dimensions Width ~ 2–3 m Depth ~ 0.3–0.5 m RGA Results Dominant Process: Widening SI: 0.40 (Transitional)		
Clair Creek **CLR-R10** Upstream Limit: Confluence with Tributary 2 Downstream Limit: Columbia St. W.	Constructed meandering channel with roundstone riffles. Pools extend into clay in some areas. Banks have vegetative control where roundstone is not present. Channel is well connected to the floodplain. Bed material ranges from clay to cobbles.	Average Channel Dimensions Width ~ 2–2.5 m Depth ~ 0.4–0.5 m RGA Results Dominant Process: Aggradation & planform adjustment SI: 0.15 (Stable)		

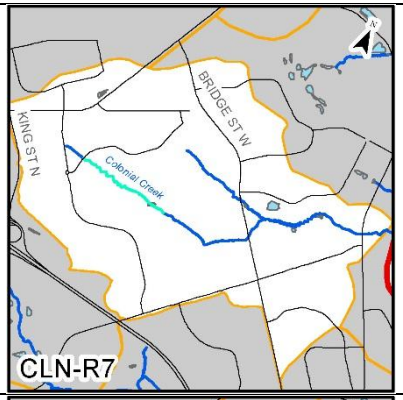
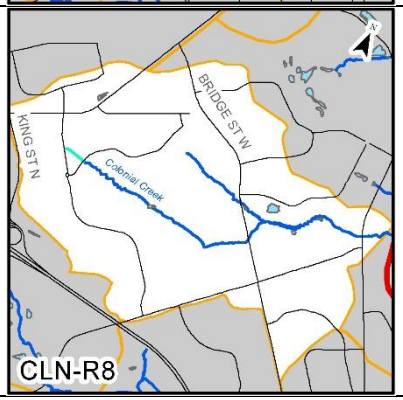
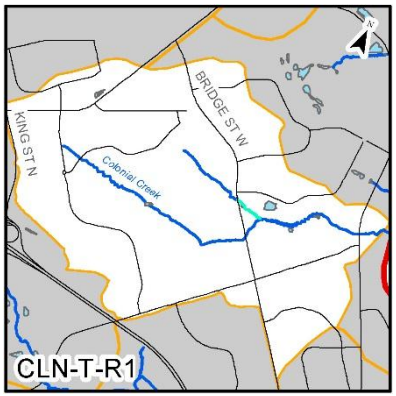
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-R11** Upstream Limit: Confluence with Tributary 3 Downstream Limit: Confluence with Tributary 2	Constructed and straightened channel with roundstone riffles and rip-rap and armourstone treatments. Channel is connected to the floodplain. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 3–4 m Depth ~ 0.4 m RGA Results N/A		
Clair Creek **CLR-R12** Upstream Limit: Mature forest Downstream Limit: Confluence with Tributary 3	Straightened, entrenched channel with roundstone control. Channel appears to be over-widened from stormwater flows. Large woody debris jams and sediment deposits were present throughout. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 3-5 m Depth ~ 0.5 m RGA Results Dominant Process: Widening SI: 0.48 (In adjustment)		
Clair Creek **CLR-R13** Upstream Limit: SWMFs Downstream Limit: Mature forest	Over-widened, entrenched channel with urbanized cross sections flowing through mature forest. Armourstone treatments were present. Bed material ranges from silt to boulders with roundstone.	Average Channel Dimensions Width ~ 4–12 m Depth ~ 1–3 m RGA Results Dominant Process: Widening SI: 0.46 (In adjustment)		

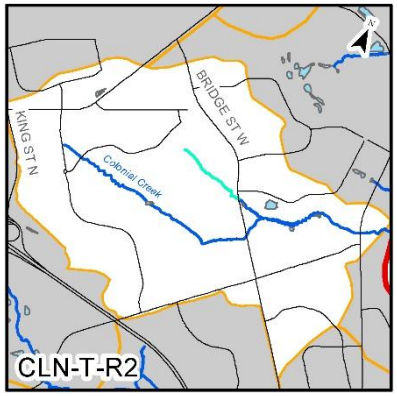
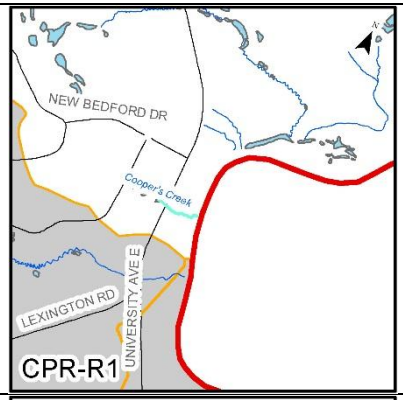
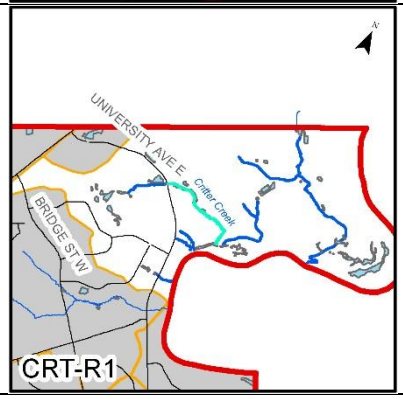
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-T1-R1** Upstream Limit: Keats Way and Keats Walk Downstream Limit: Confluence	Engineered channel with gabion baskets. Channel is confined and entrenched. Bed material ranges from silt to boulders.	Average Channel Dimensions Width ~ 4 m Depth ~ 0.8 m RGA Results N/A		
Clair Creek **CLR-T1-R2** Upstream Limit: Keats Way and Keats Walk Downstream Limit: Keats Way and Glenburn Dr.	Piped channel.	N/A		
Clair Creek **CLR-T1-R3** Upstream Limit: Fischer-Hallman Rd. Downstream Limit: Keats Way and Glenburn Dr.	Engineered channel with gabion baskets and broken concrete toe. Channel is entrenched. Bed material consists of fines with organics and gravel.	Average Channel Dimensions Width ~ 2–2.5 m Depth ~ 0.3–0.5 m RGA Results N/A		

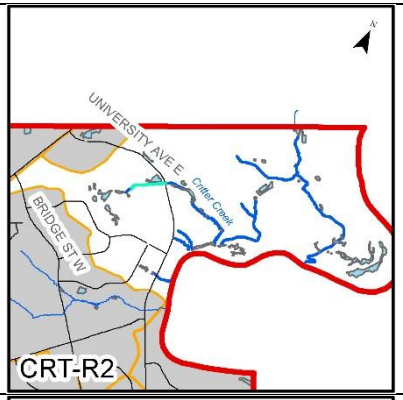
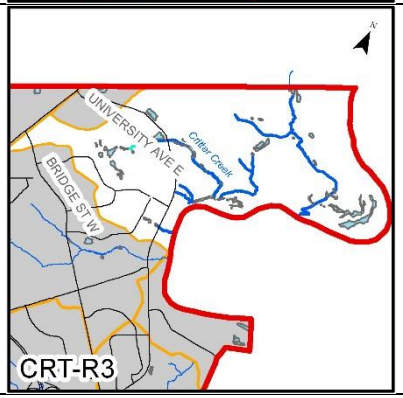
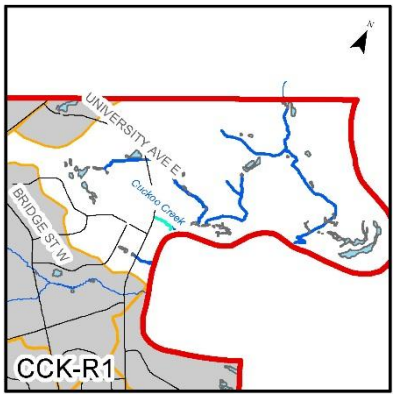
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Clair Creek **CLR-T1-R4** Upstream Limit: SWMF Downstream Limit: Fischer-Hallman Rd.	Roundstone-lined, rock-controlled ditch with some meandering. Channel is well connected to the floodplain. Some minor erosion observed. Tree roots are maintaining stability in intermittent grass lined sections.	Average Channel Dimensions Width ~ 1.2 m Depth ~ 0.4 m RGA Results N/A		
Clair Creek **CLR-T3-R1** Upstream Limit: Hydro corridor Downstream Limit: Confluence with main branch	Constructed channel with meandering planform and roundstone and vegetation control. Channel is well connected to floodplain. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 1–1.5 m Depth ~ 0.3–0.5 m RGA Results Dominant Process: Stable/regime SI: 0.11 (Stable)		
Clair Creek **CLR-T3-R2** Upstream Limit: Brandenburg SWMF Downstream Limit: Hydro corridor	Constructed channel in grassed corridor. Bed material clay with constructed roundstone riffles. Upstream portion appears to be recently constructed and vegetation establishment is limited. Channel is well connected to the floodplain.	Average Channel Dimensions Width ~ 0.5–1 m Depth ~ 0.3–0.5 m RGA Results Dominant Process: Widening SI: 0.26 (Transitional)		

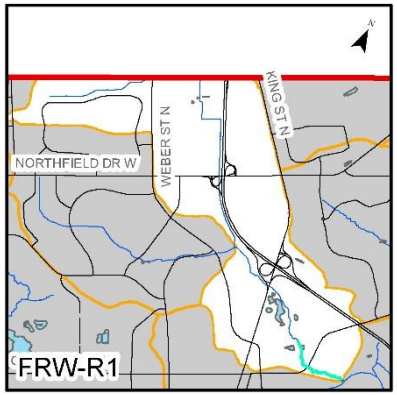
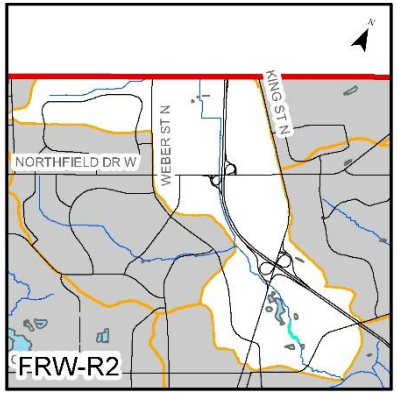
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Colonial Creek **CLN-R1** Upstream Limit: West-most driveway culvert on Malabar Dr. Downstream Limit: Grand River	Step-pool boulder lined constructed channel with moderate bank erosion throughout. Well connected to floodplain. Bed material ranges from gravel to boulders.	Average Channel Dimensions Width ~ 2.5–3 m Depth ~ 0.5 m RGA Results Dominant Process: Widening SI: 0.24 (Stable)		
Colonial Creek **CLN-R2** Upstream Limit: Confluence with SWM channel Downstream Limit: West-most driveway culvert on Malabar Dr.	Constructed u-shaped channel with roundstone riffles and herbaceous vegetation and willows on banks. Well connected to floodplain. Bed material ranges from sand to boulders.	Average Channel Dimensions Width ~ 1.5 m Depth ~ 0.6 m RGA Results Dominant Process: Widening SI: 0.17 (Stable)		
Colonial Creek **CLN-R3** Upstream Limit: Confluence with Tributary Downstream Limit: Confluence with SWM channel	Vegetation controlled, u-shaped channel with willows on banks. Large woody debris jams from yard waste. Well connection to floodplain. Bed material ranges from silt to boulders	Average Channel Dimensions Width ~ 1.5–2 m Depth ~ 0.5–0.7 m RGA Results Dominant Process: Widening SI: 0.25 (Stable)		

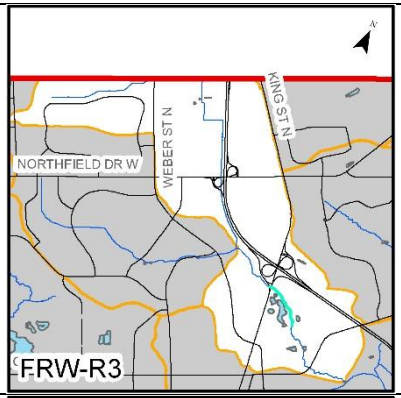
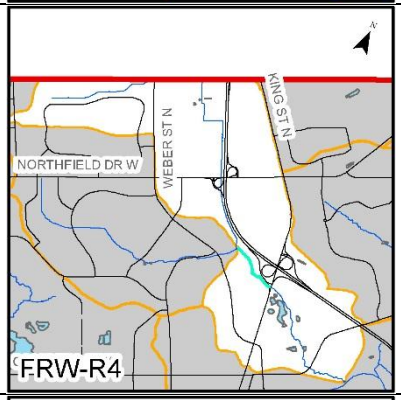
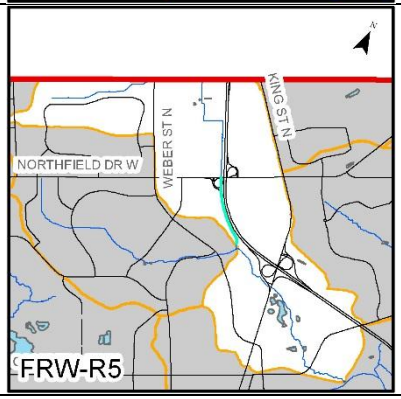
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Colonial Creek **CLN-R4** Upstream Limit: Bridge St. Downstream Limit: Confluence with Tributary	Engineered channel with gabions on the bed and banks. Bed material ranges from silt to gravel. The channel is connected to the floodplain.	Average Channel Dimensions Width ~ 1–2 m Depth ~ 0.4–0.7 m RGA Results N/A		
Colonial Creek **CLN-R5** Upstream Limit: Lee Ave. Downstream Limit: Bridge St.	Over-widened alluvial channel with steep banks and well-defined pools and riffles. System has good riparian cover and is slightly entrenched. Bed material ranges from clay to cobbles.	Average Channel Dimensions Width ~ 3–4 m Depth ~ 1.2 m RGA Results Dominant Process: Degradation and widening SI: 0.50 (In adjustment)		
Colonial Creek **CLN-R6** Upstream Limit: Anndale Park Downstream Limit: Lee Ave.	Engineered channel with various gabion treatments. System is channelized and entrenched. Bed material ranges from silt to gravel.	Average Channel Dimensions Width ~ 1.5–5 m Depth ~ 1–2 m RGA Results N/A		

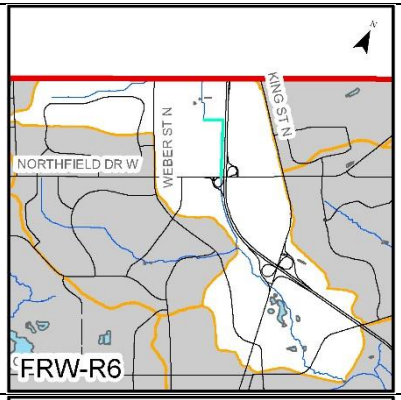
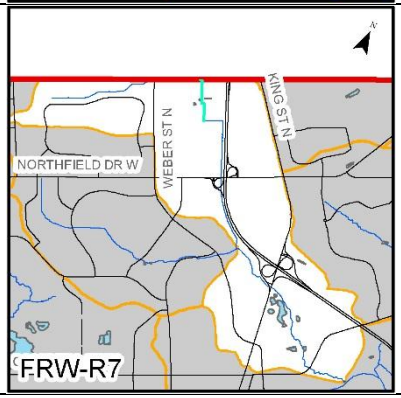
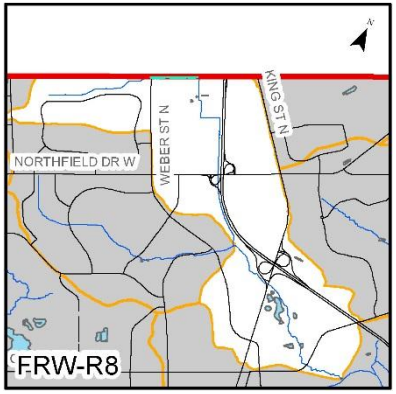
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Colonial Creek **CLN-R7** Upstream Limit: Old Abbey Downstream Limit: Anndale Park	Wide and shallow alluvial channel through a wooded corridor. Leaning cedars on banks. Well connected to floodplain. Reach has fine organic bed material.	Average Channel Dimensions Width ~ 2–2.5 m Depth ~ 0.3 m RGA Results Dominant Process: Aggradation SI: 0.30 (Transitional)		
Colonial Creek **CLN-R8** Upstream Limit: Davenport Rd. Downstream Limit: Old Abbey Rd.	Concrete trapezoidal channel with rails on bed.	Average Channel Dimensions Width ~ 3 m Depth ~ 0.5 m RGA Results N/A		
Tributary to Colonial Creek **CLN-T-R1** Upstream Limit: Bridge St. Downstream Limit: Confluence with main branch	Vegetation controlled, meandering channel with lots of erosion and a well-connected floodplain. Bank vegetation is limited (mostly grass and some stumps) and the channel appears to be constructed. Bed material is silt to cobbles.	Average Channel Dimensions Width ~ 0.5–1.2 m Depth ~ 0.5–0.6 m RGA Results Dominant Process: Aggradation, widening and planform adjustment SI: 0.41 (In adjustment)		

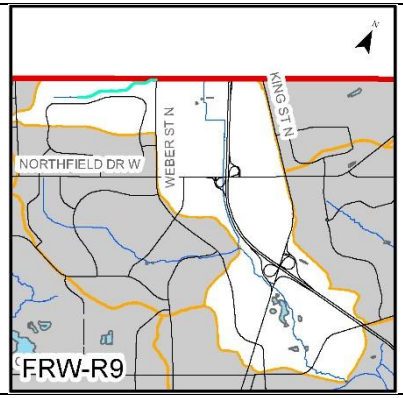
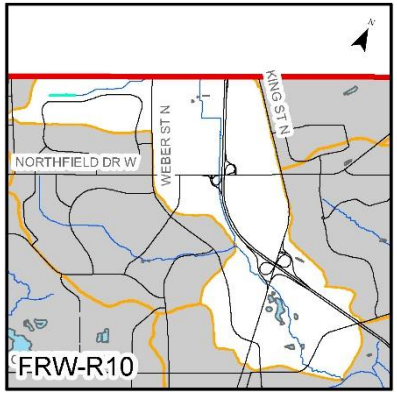
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Tributary to Colonial Creek **CLN-T-R2** Upstream Limit: STM outfall from Parkridge Crt. Downstream Limit: Bridge St.	Vegetation controlled, u-shaped, low gradient, meandering channel with lots of large woody debris and a well-connected floodplain. Silt and sand on bed.	Average Channel Dimensions Width ~ 0.5–2 m Depth ~ 0.3 m RGA Results Dominant Process: Aggradation SI: 0.29 (Transitional)		
Cooper's Creek **CPR-R1** Upstream Limit: University Ave. Downstream Limit: Grand River	Steep, incised channel originating at storm outfall. Bed material ranges from fines to boulders.	Average Channel Dimensions Width < 1 m Depth ~ 0.4 m RGA Results N/A		
Critter Creek **CRT-R1** Upstream Limit: University Ave. Downstream Limit: Confluence with Minnow Creek	Vegetation-controlled channel with meandering planform and pool-riffle sequence. Well connected to floodplain. Channel has a cobble-gravel bed and is cut into clay in some areas.	Average Channel Dimensions Width ~ 1 m Depth ~ 0.3 m RGA Results Dominant Process: Degradation SI: 0.06 (Stable)		

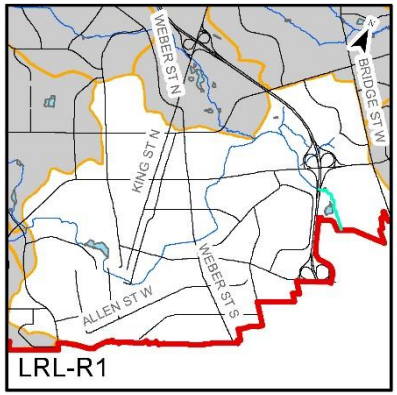
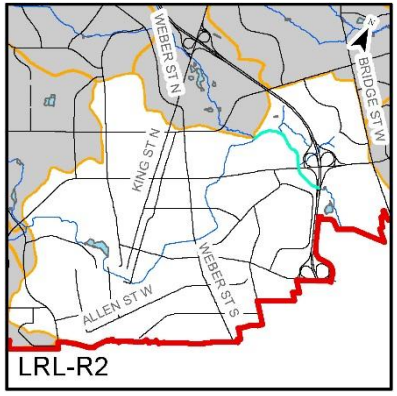
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Critter Creek **CRT-R2** Upstream Limit: Pedestrian crossing Downstream Limit: University Ave.	Constructed channel with meandering planform. Well connected to floodplain. Roundstone on channel bed.	Average Channel Dimensions Width ~ 0.5 m Depth ~ 0.2 m RGA Results N/A		
Critter Creek **CRT-R3** Upstream Limit: Wetlands Downstream Limit: Recreational trail crossing	U-shaped constructed channel with fine organic bed material. Well connected to floodplain.	Average Channel Dimensions Width ~ 1.8 m Depth ~ 0.5 m RGA Results N/A		
Cuckoo Creek **CCK-R1** Upstream Limit: STM outfall from University Ave. drainage Downstream Limit: Confluence with Minnow Creek	Alluvial channel in narrow valley with steep valley walls. The channel is entrenched with erosion throughout. Channel appears to be adjusting to an altered flow regime and is entrenched. Bed material ranges from sand to boulders.	Average Channel Dimensions Low flow width ~ 0.5 m Low flow depth ~ 0.05 m RGA Results Dominant Process: Degradation SI: 0.36 (Transitional)		

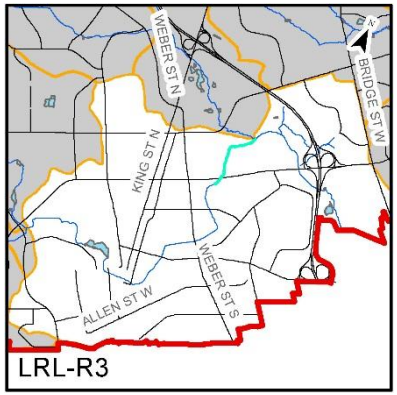
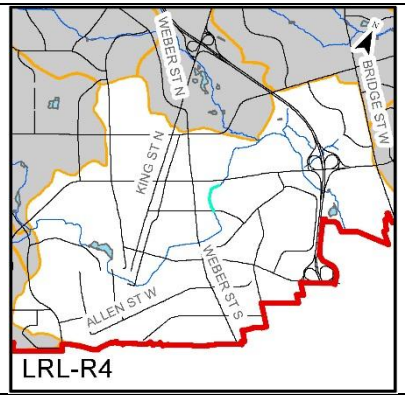
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Forwell Creek **FRW-R1** Upstream Limit: Forwell Creek Rd. Downstream Limit: Confluence with Laurel Creek	Meandering channel with pool-riffle form. Engineered treatments throughout (crib walls, woody bank treatments, and boulder riffles). Bed material ranges from silt to boulders with some deposition of roundstone from upstream throughout reach. and mostly grasses on banks.	Average Channel Dimensions Width ~ 6 m Depth ~ 1 m RGA Results Dominant Process: Aggradation SI: 0.49 (In adjustment)		
Forwell Creek **FRW-R2** Upstream Limit: Blue Springs Dr. Downstream Limit: Forwell Creek Rd.	Channel appears to have been previously straightened and is redeveloping meandering form. Basal scour present throughout and Channel is mildly entrenched. Bed material ranges from silt to boulders with inputs of roundstone from upstream reach.	Average Channel Dimensions Width ~ 6 m Depth ~ 1.2 m RGA Results Dominant Process: Widening SI: 0.53 (In adjustment)		

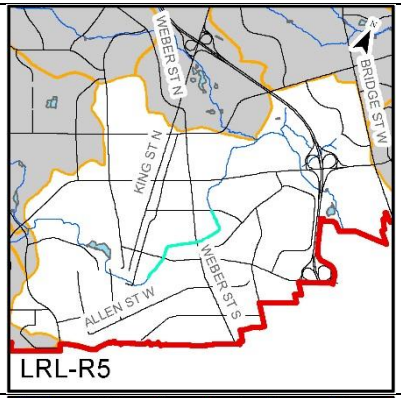
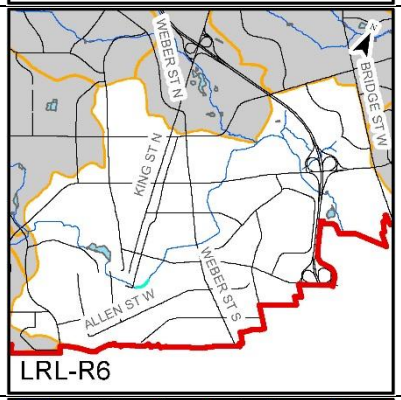
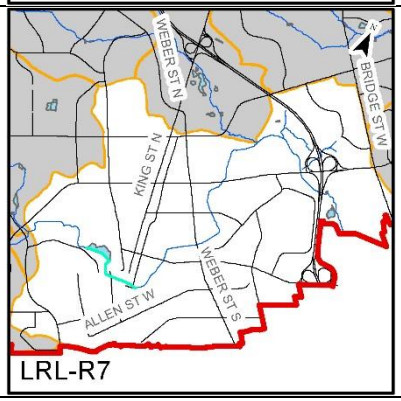
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Forwell Creek **FRW-R3** Upstream Limit: King St. N. Downstream Limit: Blue Springs Dr.	Engineered channel with roundstone and vegetated silt sock treatments in poor condition. Channel is connected to floodplain with bed material ranging from silt to boulders.	Average Channel Dimensions Width ~ 5.5 m Depth ~ 1.2 m RGA Results N/A		
Forwell Creek **FRW-R4** Upstream Limit: Confluence with Cedar Creek Downstream Limit: King St. N.	Entrenched, straightened channel. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 2 m Depth ~ 0.7 m RGA Results N/A		
Forwell Creek **FRW-R5** Upstream Limit: Northfield Dr. Downstream Limit: Confluence with Cedar Creek	Straightened, entrenched channel running adjacent to Conestoga Parkway. Bed material mainly sand and silt.	Average Channel Dimensions Width ~ 1–1.5 m Depth ~ 0.7 m RGA Results N/A		

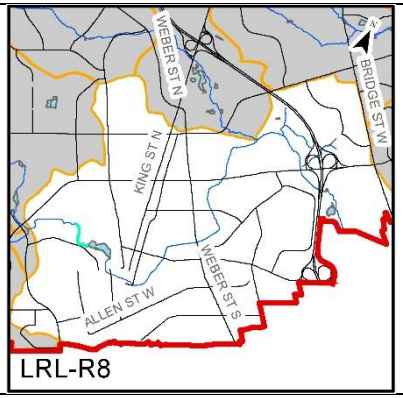
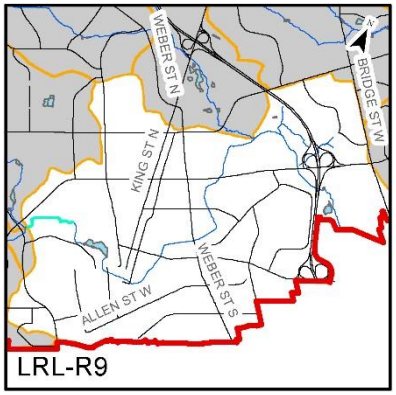
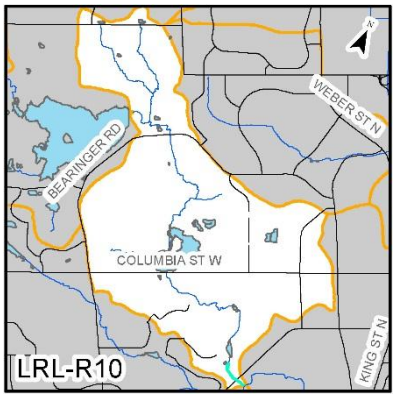
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Forwell Creek **FRW-R6** Upstream Limit: Railway at Randall Dr. Downstream Limit: Northfield Dr.	Straightened, entrenched channel running adjacent to Conestoga Parkway. Steep banks with some slumping. Bed material sandy with limited bedforms.	Average Channel Dimensions Width ~ 2.2 m Depth ~ 0.5 m RGA Results N/A		
Forwell Creek **FRW-R7** Upstream Limit: SWMF outlet Downstream Limit: Railway at Randall Dr.	Straightened, entrenched channel with silty bed and limited bedforms. Engineered bank treatments consist of gabion baskets.	Average Channel Dimensions Width ~ 1.2–1.5 m Depth ~ 0.3 m RGA Results N/A		
Forwell Creek **FRW-R8** Upstream Limit: Weber St. Downstream Limit: SWMF outlet	Straightened, u-shaped, vegetation-controlled channel starting to develop limited meandering. Connected to floodplain. Bed material ranges from silt to gravel with some coarser material.	Average Channel Dimensions Width ~ 1 m Depth ~ 0.6 m RGA Results N/A		

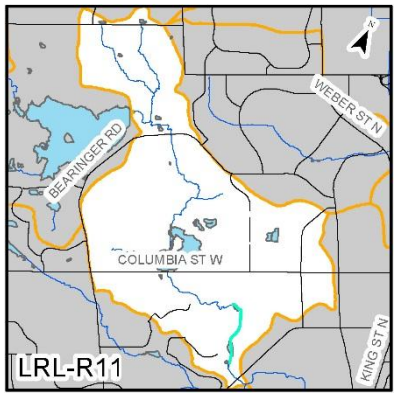
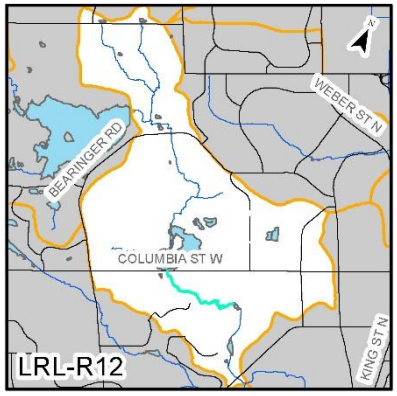
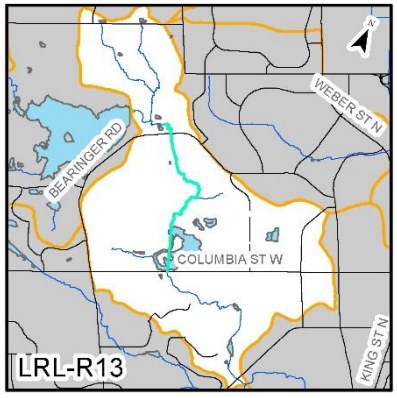
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Forwell Creek **FRW-R9** Upstream Limit: Recreational trail crossing Downstream Limit: Weber St.	Straightened concrete channel. Well connected to floodplain.	Average Channel Dimensions Width ~ 2 m Depth ~ 0.2 m RGA Results N/A		
Forwell Creek **FRW-R10** Upstream Limit: Storm outfall from Waterbury Lane Downstream Limit: Recreational trail crossing	Low gradient, straightened channel contained in trapezoidal corridor. Connected to floodplain.	Average Channel Dimensions Width <1 m Depth <0.1 m RGA Results N/A		

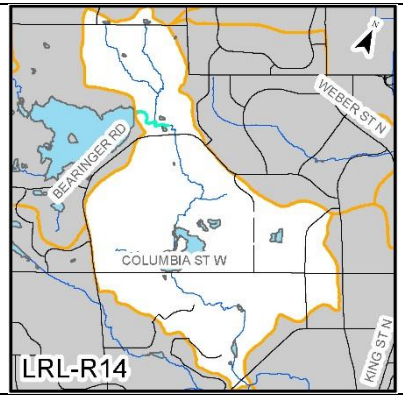
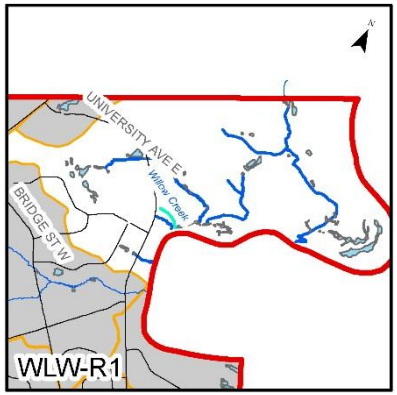
Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R1** Upstream Limit: Conestoga Parkway Downstream Limit: City Limit	Constructed channel with crib walls, ribs/veins, and gabions throughout. Sanitary sewer runs parallel to creek and wetlands are present on right overbank. There is terrace development within the channel but floodplain access is limited. Bed material ranges from silt to boulders.	Average Channel Dimensions Width ~ 8–10 m Depth ~ 0.7–1.0 m RGA Results Dominant Process: SI: N/A		
Laurel Creek **LRL-R2** Upstream Limit: Confluence Downstream Limit: Conestoga Parkway	Semi-alluvial structural channel with some constructed weirs and rip-rap and gabion treatments. A trail separates the trapezoidal, entrenched channel and a wetland area. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 8 m Depth 1.5 m RGA Results Dominant Process: Degradation and Widening SI: 0.49 (In adjustment)		

Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R3** Upstream Limit: Village on the Green Downstream Limit: Confluence with Forwell Creek	Alluvial channel containing runs with shallow pools and having limited meandering form. A lot of basal scour and some gabion and armourstone treatments were observed. Channel is connected to the floodplain. Bed material is comprised of silt to boulders with sand deposits.	Average Channel Dimensions Width ~ 8 m Depth ~ 1.5 m RGA Results Dominant Process: Widening SI: 0.41 (In adjustment)		
Laurel Creek **LRL-R4** Upstream Limit: Marshall St. Downstream Limit: Village on the Green	The entrenched creek is in a trapezoidal corridor with gabion treatments on both sides of the upstream section. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 10 m Depth ~ 1 m RGA Results N/A		

Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R5** Upstream Limit: Erb St. Downstream Limit: Marshall St.	Structural channel with limited riffle-pool form and limited floodplain access. The channel flows through a confined corridor. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 10 m Depth ~ 1.6 m RGA Results N/A		
Laurel Creek **LRL-R6** Upstream Limit: Regina St. Downstream Limit: Erb St.	Concrete, rectangular channel.	Average Channel Dimensions Width ~ 8 m Depth ~ 1 m RGA Results N/A		
Laurel Creek **LRL-R7** Upstream Limit: Silver Lake Downstream Limit: Regina St.	Piped channel.	N/A		

Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R8** Upstream Limit: Confluence with tributary Downstream Limit: Silver Lake	Alluvial, meandering channel that is backwatered by Silver Lake. Some basal scour observed. Bed is silty and channel is well connected to floodplain.	Average Channel Dimensions Width ~ 8 m Depth ~ 0.6 m RGA Results Dominant Process: Aggradation SI: 0.51 (In adjustment)		
Laurel Creek **LRL-R9** Upstream Limit: Confluence with Clair Creek Downstream Limit: Confluence with tributary	Alluvial, low-gradient channel with many straightened sections and gabion treatments. Floodplain access ranges from well-connected to mildly entrenched. Some bank scour was observed. Bed material ranges from silt to gravel.	Average Channel Dimensions Width ~ 8 m Depth ~ 1 m RGA Results Dominant Process: Widening SI: 0.51 (In adjustment)		
Laurel Creek **LRL-R10** Upstream Limit: Weir at Conrad Grebel Downstream Limit: Confluence with Clair Creek	Constructed, confined channel running parallel to Westmount Rd. N. Bed material is sand to cobbles.	Average Channel Dimensions Width ~ 7 m Depth ~ 1 m RGA Results N/A		

Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R11** Upstream Limit: Upstream end of pond at UW Health Services Downstream Limit: Weir at Conrad Grebel	Semi-alluvial structural channel with steep, well-vegetated banks. Local gabion and armourstone treatments. Channel is connected to the floodplain.	Average Channel Dimensions Width ~ 5 m Depth ~ 0.7 m RGA Results Dominant Process: Widening SI: 0.24 (Stable)		
Laurel Creek **LRL-R12** Upstream Limit: Columbia St. Downstream Limit: Upstream end of pond at UW Health Services	Alluvial, low gradient channel with some channelized sections with gabion and armourstone treatments. Channel is well connected to floodplain. Bed material ranges from silt to cobbles.	Average Channel Dimensions Width ~ 5 m Depth ~ 0.4 m RGA Results Dominant Process: Widening SI: 0.38 (Transitional)		
Laurel Creek **LRL-R13** Upstream Limit: Westmount Rd. N. Downstream Limit: Columbia St.	Alluvial channel with meandering form. Bed material ranges from clay to boulders with coarser material occurring on the riffles. The channel is well connected to the floodplain.	Average Channel Dimensions Width ~ 5–7 m Depth ~ 0.6 m RGA Results Dominant Process: Planform adjustment SI: 0.30 (Transitional)		

Reach	Summary	Channel Characteristics	Representative Photograph	Key Map
Laurel Creek **LRL-R14** Upstream Limit: Laurel Reservoir Downstream Limit: Westmount Rd. N.	Alluvial channel with bed material ranging from silt to cobbles.	Average Channel Dimensions Width ~ 4–5 m Depth ~ 0.5 m RGA Results N/A		
Willow Creek **WLW-R1** Upstream Limit: Fire Station at University Ave. Downstream Limit: Confluence with Minnow Creek	Alluvial channel in narrow valley with steep valley walls. Leaning and fallen trees present throughout. Channel appears to be adjusting to an altered flow regime and is entrenched. Bed material ranges from sand to boulders.	Average Channel Dimensions Low flow width ~ 0.5 m Low flow depth ~ 0.05 m RGA Results Dominant Process: Degradation SI: 0.40 (Transitional)		

Appendix C – Erosion Site Summary Sheets

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CDR-E1		**Date:**	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cedar Creek	CDR-R1	3393-96, 3401-03, 3405		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ❑ Valley Wall		
4m	0.7m			

Observations Upstream
Weber Street

Observations Downstream
Confluence with Forwell Creek

Site Description
The MH incorporated into gabion bank is at risk due to failed gabions . Toe is rotted out of all gabions.
The headwalls are failing on the upstream side of Weber Street. Gabions are slumped & eroded from behind (road runoff). The sidewalk is also cracked due to the loss of material under it and behind the headwall.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial	✓	✓	Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	
Park/Open Space	✓ Small riparian		Trees (Occasional)	✓	✓
Other		✓ Road	Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
☒ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	(8)
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	(3)	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

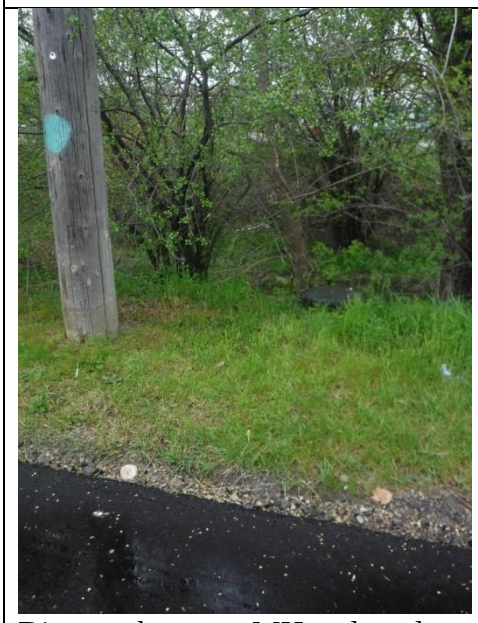
Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
(Coldwater / Intolerant)	0	5	(10)	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**26**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	81

Photos of Erosion Site

MH behind failing gabion basket treatment

MH behind failing gabion basket treatment



Distance between MH and road

View of MH from above

 Failing headwall on upstream side of Weber Street	 Outflanked and leaning headwall
 Outflanked gabion basket headwall	 Cracks in sidewalk and road behind headwall

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CDR-E2		**Date:**	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cedar Creek	CDR-R1	3406, 3408, 3409, 3411-12		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
4 m	Corridor depth = 3 m	30m	3m	

Observations Upstream
Trapezoidal channel

Observations Downstream
Weber Street

Site Description
Debris jam appears to have been recently removed. Immediately upstream, the right bank is scoured adjacent to the sanitary sewer and it is expected that bank erosion will continue in this direction. The bank is currently bare and a tree on the opposite bank appears to be deflecting flows towards the eroded bare bank. Flows from the upstream storm sewer are likely contributing to erosion.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential		✓	None		
Commercial			Grass		✓
Industrial			Herbaceous	✓	
Institutional			Shrubs	✓	
Park/Open Space			Trees (Occasional)	✓	✓
Other	✓ Road		Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**24**
Aquatic Habitat	**5**
Riparian Buffer	**15**
TOTAL	79

Photos of Erosion Site

Remains of debris jam with eroded bank

Compost bins encroaching on creek corridor

Storm sewer outfall and tree deflecting flow to opposite bank

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CDR-E3		**Date:**	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cedar Creek	CDR-R2	3421-31, 3432		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
4m	0.5m	10m	3m	

Observations Upstream
Weber Street

Observations Downstream
Channelized creek with trapezoidal cross-section

Site Description
On the downstream side of the Albert Street crossing, the left side of the culvert is collapsing. The gabion baskets over the culvert are also failing in this area and the sidewalk above is cracked. The issue may be related to road drainage. Boreholes were observed in this area suggesting work may be underway.
On the upstream side of Albert Street, a gabion weir is failing with scour occurring downstream of the weir. The base layer of the gabion treatments is failing and as is the concrete lining on the bed.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential		✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs	✓	
Park/Open Space			Trees (Occasional)		✓
Other	✓ Road		Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
❑ Water or Gas Main
☒ Major Roads/Bridges
❑ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**27**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	87

Photos of Erosion Site

Condition of culvert on downstream side of Albert Street

Sidewalk cracked on downstream side of Albert Street

Detail of condition of collapsing culvert on downstream side of Albert Street

Failing concrete and gabion basket weir on upstream side of Albert Street

Failing gabion basket weir

Culvert on upstream side of Albert Street

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Erosion Site	CDR-E4		**Date:**	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cedar Creek	CDR-R4 & CDR-R5	Location 1: 3479-3482 Location 2: 3483-87	Location 3: 3488-91 Location 4 3498-3500	
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m)	☒ Bank ❑ Valley Wall	
2.5-3m	0.6-1m	Location 1: 10m Location 2: 30m Location 3: 20m Location 4: 10m	0.6m (2m to path) 1.5m (gabion height) 1m 4 m	

Observations Upstream
Glen Forest Boulevard

Observations Downstream
Cedarbrae Avenue

Site Description

Note: locations are numbered from downstream to upstream within the erosion site.

Location 1: There is a sanitary MH in the creek with bank scour upstream of the MH. A large tree stump was observed at the base of the MH. Recent bank work upstream of the MH was observed consisting of roundstone around a PVC storm sewer outfall. Works may have been completed to protect the trail from the eroding bank.

Location 2: A gabion treatment on an outside bend is failing. Private property is located behind the gabion treatment. Trees growing in front and behind the gabions are providing some stabilization to the failing treatment. A sanitary sewer MH is located on the opposite side of the creek at least 4 m from the top of bank and does not appear to be at risk at present.

Location 3: The right bank is eroding towards a sanitary sewer MH. The bank material appears to be sandy and a large slump has developed. A rill has also developed from surface runoff towards the MH. On the opposite bank, shrubs in front of a storm sewer appear to be blocking flows. Upstream, banks were steep and trees were observed to be leaning over the creek.

Location 4: A sanitary sewer MH is located within 1 m of the top of bank. Roots from a dead ash tree are holding the bank at present. The creek is entrenched in this area and bank erosion is likely once the ash tree is lost. There may be an opportunity to realign the creek away from the MH.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓		None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees (Occasional)	✓	✓
Other		✓ Trail, MH	Other		

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**31**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	**91**

Photos of Erosion Site

Location 1 – Roundstone and storm sewer outfall upstream of exposed MH

Location 1 – Scoured bank immediately upstream of MH


Location 1 – MH with stump of tree at base


Location 2 – Failing gabion basket treatment on left bank

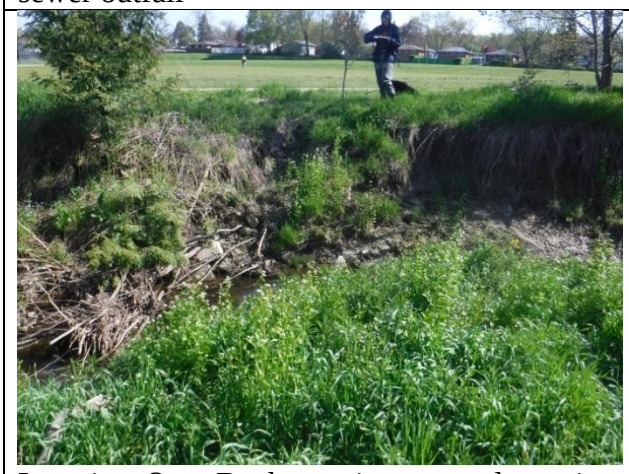

Location 2 – Emptying gabion baskets


Location 2 – Failing gabion baskets on left bank


Location 2 – MH on inside of bend

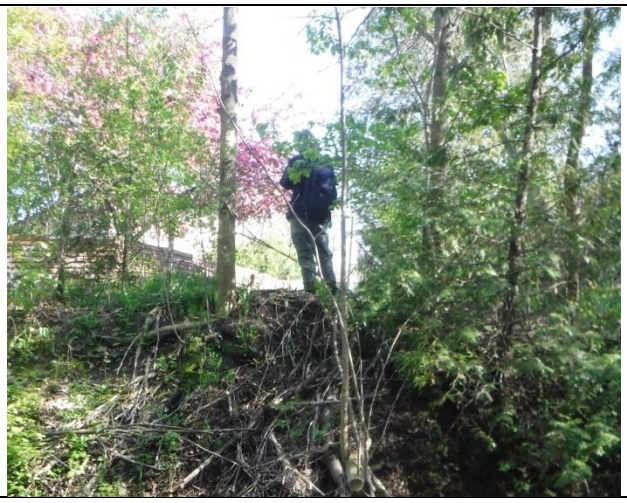
Location 3 – Shrubs blocking flows from storm sewer outfall

Location 3 – Storm sewer outfall



Location 3 – Bank erosion towards sanitary sewer MH

Location 4 – MH behind ash tree at top of bank



 Location 4 – Channel is entrenched in this area	Location 4 – Eroded bank at MH. Staff standing on MH for reference with ash to left of staff.

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CDR-E5		**Date:**	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cedar Creek	CDR-R6	3528-30		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
2.5m	0.4m	5m		

Observations Upstream
Storm sewer outlet from Northfield Drive

Observations Downstream
Creek in channelized corridor

Site Description
The gabion baskets for the headwall Northfield Drive are slumping and emptying. Upstream of Northfield Drive, the creek is piped.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential		✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs		
Park/Open Space	✓		Trees (Occasional)	✓	✓
Other	✓ School		Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive) & Priv Property	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ☒ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**15**
Erosion Index	**20**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	**60**

Photos of Erosion Site

Gabion basket headwalls are slumping and emptying

Condition of gabion baskets on left bank

Condition of gabion baskets on right bank

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Erosion Site	CCK-E1		Date:	May 16, 2017
Watercourse	Reach number	Photo Numbers		
Cuckoo Creek	CCK-R1	3341-59		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
N/A	N/A			

Observations Upstream
Storm sewer outfall

Observations Downstream
Confluence with Critter Creek/Minnow Creek

Site Description
An alteration in the flow regime in this creek from the storm sewer outfall at the upstream end of the reach has resulted in down-cutting and bank/valley wall erosion. A garage is located at the top of slope and erosion poses a risk to the garage in the long term.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential	✓		None		
Commercial			Grass		
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space		✓	Trees	✓	✓
Other		Private Prop	Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ☒ Septic Bed
- ☒ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**23**
Aquatic Habitat	**10**
Riparian Buffer	**5**
TOTAL	48

Photos of Erosion Site

Valley wall erosion with leaning and fallen trees

Bank erosion with garage at top of slope in background

Leaning and fallen trees in the valley

Bank erosion near storm sewer outfall

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLN-E1		**Date:**	May 15, 2017
Watercourse	Reach number	Photo Numbers		
Colonial Creek	CLN-R4	3344-53		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
3m	1.2m	20m	1.2m	

Observation Upstream
Gabion basket bank treatments

Observations Downstream
Confluence with triburary

Site Description
The right bank is eroding towards the sanitary sewer MH. The bank is steep and there is exposed clay on the channel, suggesting downcutting. The MH cover is located about 0.7 m from the top of bank. Manicured lawn extends to the top of bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass		✓
Industrial			Herbaceous		
Institutional			Shrubs	✓	
Park/Open Space			Trees	✓	
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
☒ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

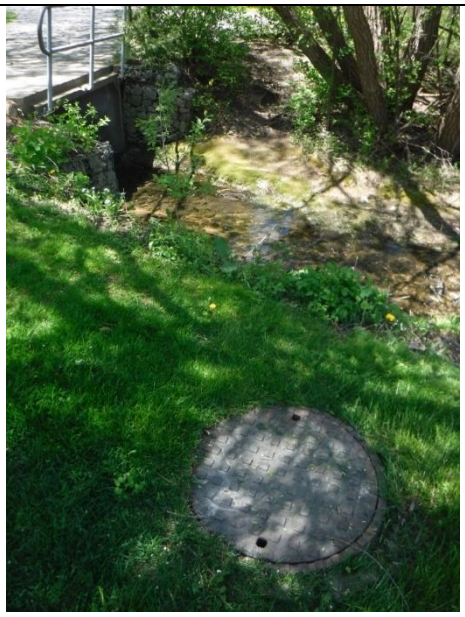
Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

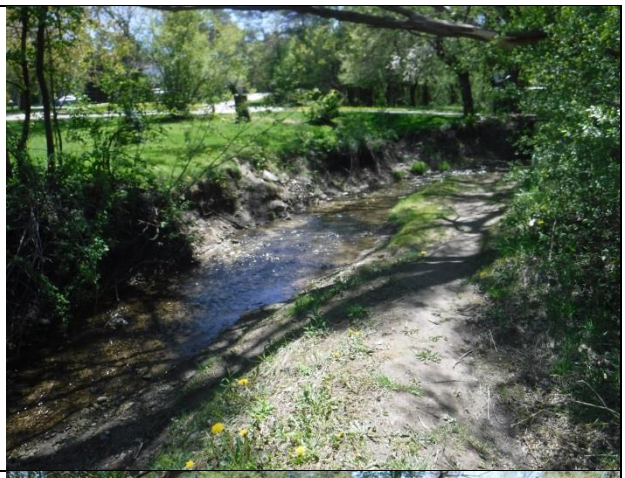
TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**22**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	77

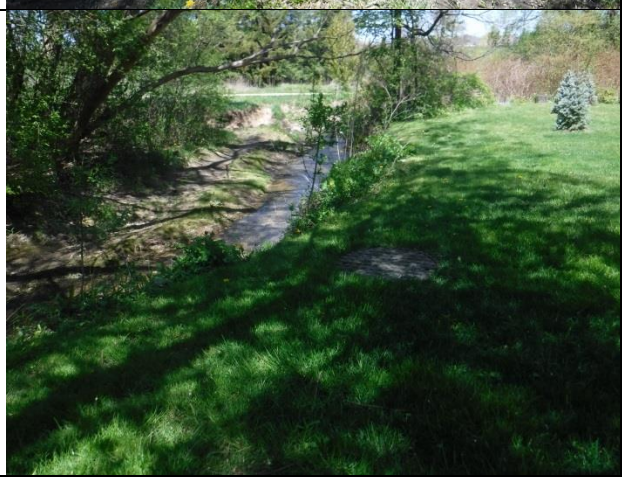
Photos of Erosion Site



MH in bank

Steep, eroded bank with MH in grass at top



THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLN-E2		**Date:**	May 15, 2017
Watercourse	Reach number	Photo Numbers		
Colonial Creek	CLN-R5	232-247		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
4m	1.2m	50m	12m	

Observations Upstream
Perched outfall

Observations Downstream
Adjusting planform (formerly straightened)

Site Description
Bank erosion was observed in an entrenched section of the channel. Bank erosion has caused the undermining and failure of a fence post. A private bank treatment was observed to be in poor condition on the left bank and a perched storm sewer outfall was observed on the right bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space			Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ☒ Shed
- ☒ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**25**
Aquatic Habitat	**5**
Riparian Buffer	**5**
TOTAL	45

Photos of Erosion Site

Undermined and leaning fence post

Undermined and leaning fence post

Failed private bank treatment

Perched storm sewer outfall

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E1		**Date:**	June16, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R3	5083-5101		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
4-5m	0.5-0.8m	30m	2.5m	

Observations Upstream
University Ave

Observations Downstream
Private crossing

Site Description
Vertical bank erosion poses a threat to a private parking lot at the top of bank. Failed asphalt from the parking lot was observed on the bank slope. A buried MH on the slope is becoming exposed but maybe abandoned since its top has been paved over. Upstream, privately constructed concrete slab and block walls are present on the banks.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass		
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space			Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure (parking lot)

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	(4)
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	(15)

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	(10)	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**23**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	83

Photos of Erosion Site

Bank erosion immediately adjacent to private parking lot

Exposed MH at top of bank with asphalt covering a portion of the lid

Bank erosion adjacent to parking lot with top of bank and exposed MH in foreground

Bank erosion

Failing privately constructed concrete slab and concrete block bank treatments

Bank toe erosion

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E2		**Date:**	June 16, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R4	5122-5134		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
4-5m	0.8m	~100m 1.5m		

Observations Upstream
Keats Way Culvert

Observations Downstream
Creek through forest

Site Description
Failed bank treatments on private property (cinder blocks, roundstone/boulders, gabion baskets, concrete bed). A scour pool has developed the large boulders treatments upstream of the second pedestrian bridge. The second house south of Keats Way is within 5-10 m of the top of bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs		
Park/Open Space			Trees		
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ☒ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**25**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	55

Photos of Erosion Site

Pedestrian bridge and failing concrete block bank treatment

Failing boulder bank treatment

Failed gabion basket treatments

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E3		**Date:**	June 14, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R5	4605-4624		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
3-4m	0.6-0.8m	80 m	~0.8m	

Observations Upstream
Creek corridor upstream of Coleridge Drive

Observations Downstream
Confluence with tributary

Site Description
Concrete and log bank treatments on both sides of the creek are failing and are likely causing conveyance issue. MH in gabions are at risk for infiltration/inflow.
Note: Site has since been repaired by City but MH should still be inspected for I/I.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	
Industrial			Herbaceous	✓	✓
Institutional			Shrubs		✓
Park/Open Space			Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**24**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	59

Photos of Erosion Site

 Failing concrete bank treatments may be causing conveyance issues	 MH in creek

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E4		**Date:**	June 14, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R9	4777-4792		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
~3m	0.5m	40m Gabion height ~3m		

Observations Upstream
Columbia Street

Observations Downstream
Channel in vegetated corridor

Site Description
Gabion basket bank treatments are in varying states of failure extending from Columbia Street downstream to 2 storm sewer outfalls. A pile of rip rap has developed in this area. A sanitary sewer crosses under the creek in the vicinity of the storm sewer outfalls. At Columbia Street, 2 CSPs convey flows under the road. The CSP on the east appears to be deformed.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass		
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ☒ Major Roads/Bridges
- ☒ Sanitary Sewer
- ☒ Other Utilities (storm sewer)

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**25**
Aquatic Habitat	**15**
Riparian Buffer	**10**
TOTAL	85

Photos of Erosion Site

Rip rap with failed gabion baskets and storm outfall in backgrounds

Failed gabions over storm sewer outfall

Gabions around second outfall with energy dissipater gabion block in centre of channel upstream

Gabion basket headwall at Columbia Street with lower baskets emptying. Note deformation of culvert on right side of photo.

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Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E5		**Date:**	June 14, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R12 & CLR-T3-R1	4832-39		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m)	☒ Bank ❑ Valley Wall	
~1m	0.5m	50m	1m ~ 1.2m	

Observations Upstream
Sani crossing (not exposed)

Observations Downstream
Confluence

Site Description
Bank slumping and erosion throughout site likely due to lack of riparian buffer. Grass has been mowed to top of bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs		
Park/Open Space			Trees		
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ☒Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**23**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	58

Photos of Erosion Site

Manicured lawn to top of bank with bank erosion throughout channel

Eroded and slumping banks

Manicured lawn to top of bank with bank slumping and eroding

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Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-E6		**Date:**	June 14, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-R12 & CLR-R13	4870		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
2 - 12m	0.4m	Long 3m		

Observations Upstream
Stormwater management facilities

Observations Downstream
Pedestrian crossing

Site Description
Extensive effects of urbanization observed in reaches CLR-R12 & CLR-R13 include: over-widening, entrenchment, down-cutting, and fallen trees. No immediate risks were identified but forest and aquatic habitats are being degraded. Upstream development is on-going so conditions are likely to deteriorate further.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**15**
Erosion Index	**31**
Aquatic Habitat	**10**
Riparian Buffer	**5**
TOTAL	61

Photos of Erosion Site

Entrenched channel with falling and leaning trees

Over-widened channel

Entrenched channel with steep, eroded bank

Armourstone weirs downstream of stormwater management facility outfalls

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Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-T1-E1		**Date:**	June 16, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-T1-R1	4597-4601		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
3-4m	0.6m	50m	0.8m ~ 1.5m	

Observations Upstream
Confined channel with gabions in decent condition

Observations Downstream
Culvert for Keats Way

Site Description
Gabion basket bank treatments are failing at the first house upstream of McDougall Road. The gabions are located on the south side of the creek and the building is located within 5m of the top of bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs		
Park/Open Space			Trees	✓	
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
☒ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
❑ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	(4)
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	(1)

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	(15)

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
(Warmwater / Tolerant)	5	10	(15)	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**21**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	86

Photos of Erosion Site

House located within 5 m of the top of bank

Failing gabion baskets

Failing gabion baskets

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-T1-E2		**Date:**	June 15, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-T1-R3	5023-34		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
2m	0.4m	25m	Slope 1.5m ~ 2m	

Observations Upstream
Fischer Hallman Road North

Observations Downstream
Gabion-basket-lined channel, garbage dumping in rear yard

Site Description
Gabion basket bed and bank treatments are failing with rock emptying from baskets and filter cloth exposed. Debris accumulation is occurring within the channel. Consideration should be given to replacing treatments within the entire reach when addressing this erosion site.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space			Trees	min	min
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ☒ Other (gabion baskets)

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

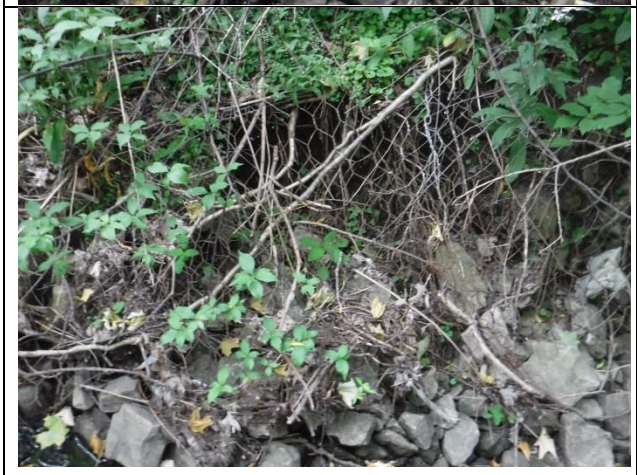
Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

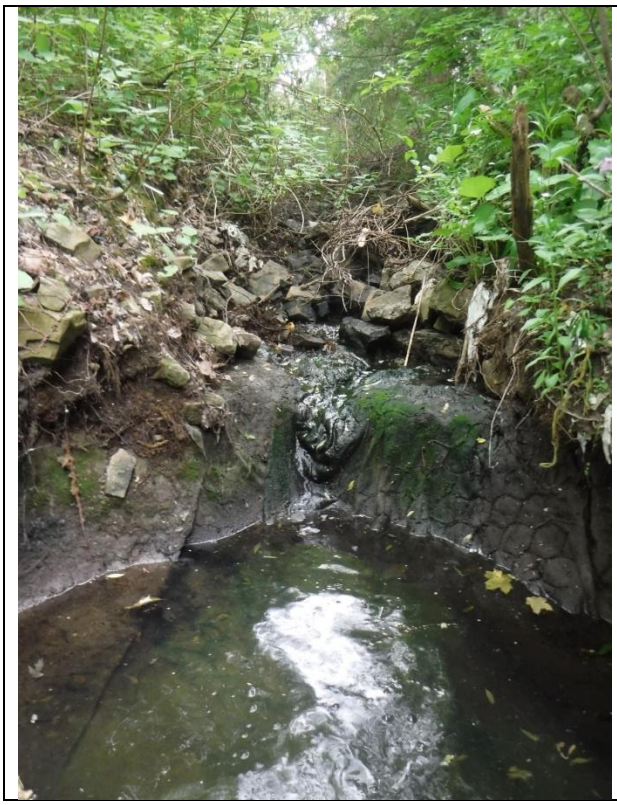
Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**15**
Erosion Index	**28**
Aquatic Habitat	**15**
Riparian Buffer	**10**
TOTAL	68

Photos of Erosion Site



Empty gabion baskets



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Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	CLR-T3-E1		**Date:**	June 15, 2017
Watercourse	Reach number	Photo Numbers		
Clair Creek	CLR-T3-R2	4934-42		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
1 - 2m	0.3 - 0.4m	15m	4m ~ 5m	

Observations Upstream
Grassed corridor

Observations Downstream
Hydro corridor

Site Description
Creek contact at toe of valley is causing slope erosion. Rear yards are located within 10 m of the top of the slope. Bank vegetation is mainly herbaceous with some dogwoods. In addressing this erosion site, consideration should be given to moving the creek away from the toe of the slope.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees		
Other			Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	(0)

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	(5)
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	(2)

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	(High)	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
(Warmwater / Tolerant)	(5)	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**0**
Erosion Index	**14**
Aquatic Habitat	**5**
Riparian Buffer	**10**
TOTAL	29

Photos of Erosion Site

Toe of slope erosion with houses at top of slope in background

Toe erosion at creek contact with valley wall.

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E1		**Date:**	May 18, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R1	3741-46		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
6m	1m	60m	1m	

Observations Upstream
E8

Observations Downstream
Creek in open corridor

Site Description
The left bank is eroding towards the sanitary sewer (of unknown depth) and a stormwater management facility. The SWMF is located less than 5 m from the top of bank. A sanitary sewer MH was observed to be about 3 m from the top of bank.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous		✓
Institutional			Shrubs	✓	✓
Park/Open Space		✓	Trees	✓	✓
Other	✓ SWMF		Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

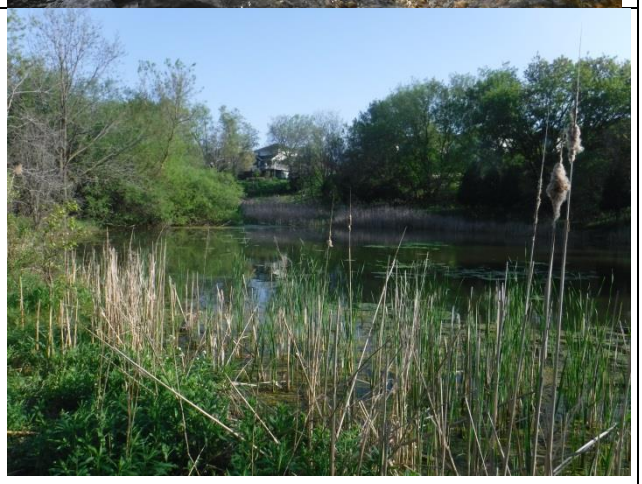
Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**23**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	78

Photos of Erosion Site

Bank erosion

Creek on left side of photo and SWMF on right side



THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E2		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R2	403-425		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ❑ Valley Wall		
6m	1.2m	20m		

Observations Upstream
Site FRW-E7

Observations Downstream
Creek in wooded corridor

Site Description
The culverts and headwall for the Forwell Creek Road recreational trail crossing are in very poor condition. The gabion baskets are slumping and the CSP culverts are deforming and rotting out. There appears to have been maintenance works on the culverts, but the condition of the culverts has continued to degrade. A recreational trail, a sanitary sewer, a natural gas pipeline, and hydro lines cross the creek in this location. Material has been lost from the sides of the trail, and gravel restoration works have continued to erode.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential		✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓ Trail		Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
☒ Water or Gas Main
❑ Major Roads/Bridges
☒ Sanitary Sewer
☒ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**33**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	88

Photos of Erosion Site

Upstream face of culverts

Upstream face of culverts

Shearing at joints in culvert

Downstream face of culverts

Downstream face of culverts

Downstream face of culverts

Failing gabion baskets

Embankment erosion

Marker for natural gas pipeline crossing creek

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E3		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R2	398-402		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ☒ Valley Wall		
6m	1.2m	70m	1.2m	4m

Observations Upstream
Blue Springs' Drive

Observations Downstream
Forwell Creek Road

Site Description
Bank erosion on the outside bends poses a risk to the sanitary sewer line and to private property. The sanitary sewer appears to be within 5 to 10 m of the 4-m high, near-vertical, eroding bank. The building on the private property is about 30 m back from the top of bank.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓ Priv Prop		Trees	✓	✓
Other		✓ Trail	Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	(5)
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	(4)
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	(10)	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**16**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	71

Photos of Erosion Site

Bank erosion towards sanitary sewer

Bank erosion towards sanitary sewer

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E4		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R3	3705-09, 3710, 3725-30		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
5.5m	1m	170 m	1 - 1.5m	

Observations Upstream
King Street North

Observations Downstream
Blue Springs Drive

Site Description
Roundstone bank treatments are failing and bank is eroding and near vertical in areas. Vegetation on top of bank is mainly herbaceous. Bank erosion poses a risk to the recreational trail, the sanitary sewer, and a stormwater management pond.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass		
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	(25)
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	(8)
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	(5)
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**25**
Erosion Index	**29**
Aquatic Habitat	**15**
Riparian Buffer	**10**
TOTAL	79

Photos of Erosion Site

Roundstone is failing and bank is near vertical and eroding towards the path

Roundstone bank treatment is slumping and vegetation on bank is primarily herbaceous

Roundstone bank treatment is failing

Roundstone treatment with herbaceous vegetation on bank

Slumping roundstone with eroding bank downstream

Bank erosion between roundstone treatments with trail in background

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Erosion Site	FRW-E5		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R4	3677-3686		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
2.5m	0.7m	75m + 3m		

Observations Upstream
Construction debris (site FRW-E7)

Observations Downstream
King St N

Site Description
Erosion on the left bank poses a risk to a hydro pole and fence. Guy wires for the hydro pole are in the creek. Fence posts are exposed and undermined. A sanitary sewer crossing is present in this area although it was not exposed. The depth of sanitary sewer should be confirmed.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs		✓
Park/Open Space		✓ Priv Prop	Trees		✓
Other	✓ Lamp for parkway		Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ☒ Other (fence and guy wires)

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**15**
Erosion Index	**28**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	73

Photos of Erosion Site

	
Undermining of fence posts	Guy wires in channel. Sanitary sewer crosses under creek.

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Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E6		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R4	3668-70, 3688-3689 382-385		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
2m	0.7m	125m	4m	

Observations Upstream
Private culvert

Observations Downstream
Straightened channel and erosion site FRW-E6

Site Description
Masonry debris dumping has been occurring and is spilling into the creek. Potential encroachment onto MTO lands is noted. There is minimal vegetation on the bank and some bank erosion is occurring towards private property with a shed at risk.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial		✓	Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓		Trees		✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ☒ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure (storage area)

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**27**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	67

Photos of Erosion Site

Construction debris dumping on bank

Construction debris dumping on bank

Bank erosion towards shed in background

Bank erosion towards private property

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E7		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R8	3589 - 92		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
1.5m	0.5m	40m	2.5m	

Observations Upstream
Straightened creek

Observations Downstream
Outfall from Conrad Place

Site Description
The creek is eroding towards the parking lot with an erosion scar adjacent to the areas containing the dumpsters. Ash trees on the bank are dying.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial	✓		Grass	✓	✓
Industrial		✓	Herbaceous	✓	
Institutional			Shrubs	✓	
Park/Open Space			Trees	✓	✓ Ash
Other	✓ SWMF		Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure (parking)

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**22**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	62

Photos of Erosion Site

 Bank erosion towards parking lot and dumpsters	 Bank erosion towards parking lot and dumpsters

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	FRW-E8		**Date:**	May 17, 2017
Watercourse	Reach number	Photo Numbers		
Forwell Creek	FRW-R8	3595 - 3606		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
1.5m	0.4m	~100m 2.5m		

Observations Upstream
Straightened channel

Observations Downstream
Weber Street

Site Description
Channel banks are slumping on the outside of meander bends and the fence is undermined where runoff enters the creek from the adjacent paved surface. A gabion weir has failed. Bank erosion poses a risk to the garden centre on the top of bank.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial	✓	✓	Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs		
Park/Open Space			Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ☒ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure (fence)

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m²	10
201-300 m²	8
101-200 m²	6
50-100 m²	4
1-50 m²	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**26**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	61

Photos of Erosion Site

Bank erosion and slumping adjacent to garden centre lot

Undermining of fence

Undermining of fence where storage area runoff enters the creek

Failed gabion weir on bed

Bank slumping adjacent to garden centre lot

Looking downstream at bank adjacent to garden centre

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E1		**Date:**	May 31, 2017
Watercourse	Reach number	Photo Numbers		
Laurel	LRL-R1	4249-58		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
10m	0.8m	15m	1.5m at bridge	

Observations Upstream
Island

Observations Downstream
Armourstone ribs

Site Description
Gabion basket bank projection is failing on both banks at a pedestrian crossing. The gabions are outflanked, slumping, and emptying. There is a crib wall on the left bank immediately downstream of the bridge. The crib wall is in poor condition but the vegetation within the crib well is well established.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓	✓	Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**25**
Erosion Index	**19**
Aquatic Habitat	**10**
Riparian Buffer	**5**
TOTAL	**59**

Photos of Erosion Site

Gabions outflanked

Gabions emptying at toe

Gabions outflanked

Crib wall in poor condition but vegetation well established

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Erosion Site	LRL-E2		Date:	May 31, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R2	4189-4196		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
~8m	~1.2-1.5m	70m ~6-7m		

Observations Upstream
Erosion site LRL-E3

Observations Downstream
University Avenue

Site Description
Old concrete abutments are outflanked and are likely undermined. Further downstream, an erosion scar approximately 7 m in height, was observed to have groundwater seeps throughout the bank. A recreational trail and sanitary sewer are located at the top of bank.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space		✓	Trees (Occasional)	✓	✓
Other	✓ WWTP		Other	✓ WWTP	

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
❑ Sanitary Sewer
☒ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	35
Erosion Index	18
Aquatic Habitat	10
Riparian Buffer	5
TOTAL	68

Photos of Erosion Site


Outflanked old concrete abutment


Outflanked old concrete abutment


Erosion scar


Erosion scar

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E3		**Date:**	May 31, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R2	4160-65, 4169, 4172-79		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
8m	1.2m	70m	3m	

Observations Upstream
Creek in trapezoidal channel

Observations Downstream
Erosion site LRL-E2

Site Description
A leaning, and potentially undermined, concrete wall is located on the left bank adjacent to the WWTP. Two (2) storm sewer outfalls are located within the concrete wall. Erosion on the right bank has resulted in a near-vertical bank. A MH is located on the right bank but is set back at least 5 m. Two (2) sanitary sewers cross under the creek in this location, but were not observed to be exposed.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space		✓	Trees (Occasional)	✓	✓
Other	✓ WWTP		Other	✓ WWTP	

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
☒ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
❑ Sanitary Sewer
☒ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**28**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	**83**

Photos of Erosion Site


Leaning concrete wall with storm sewer outfall


Outflanked downstream end of leaning concrete wall


Storm sewer outfall in concrete wall


Storm sewer outfall in concrete wall


Outflanked downstream end of concrete wall


Near-vertical bank opposite concrete wall

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E4		**Date:**	May 18, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R3	3815-3823		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
10m	1.2m	15m	1.5-1.8m	

Observations Upstream
University Avenue

Observations Downstream
Creek beside recreational trail

Site Description
The gabion baskets on the left bank at the downstream end of the armourstone wall are emptying and slumping. The right bank has no riparian planting, and the storm sewer outfall channel on this bank is causing erosion. There are gabion baskets on right bank as well with failure of the mesh at the toe. A sediment fence on the right bank was observed, and was assumed to have been left from previous construction works.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential		✓	None		
Commercial	✓		Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs		
Park/Open Space			Trees (Occasional)	✓	
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	(15)
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ☒ Active Park Land
- ❑ Trail Type 2-4
- ☒ Other (bank treatment)

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	(4)
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

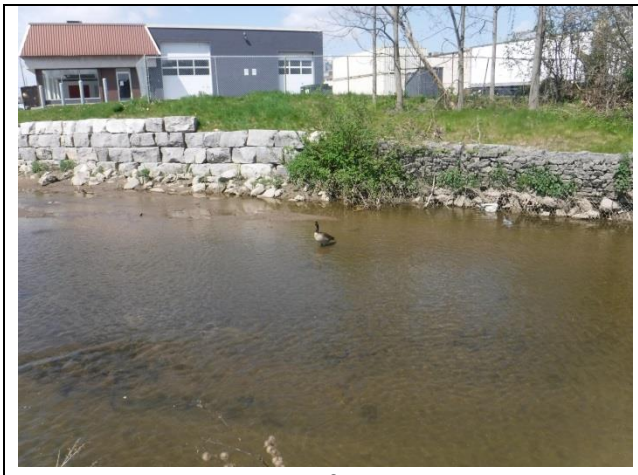
Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	(15)

Aquatic Habitat Index

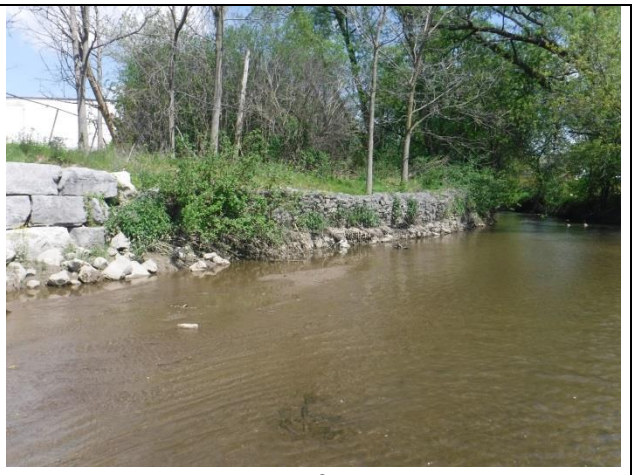
Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	(15)	

TOTAL SCORE / 100	
Public Health & Safety	**15**
Erosion Index	**23**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	**68**

Photos of Erosion Site



Failing gabions at end of armourstone wall



Failing gabions at end of armourstone wall

Bank erosion on right bank

Bank erosion associated with storm sewer outfall

Failing gabion toe on right bank

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E5		**Date:**	May 18, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R4	3829-3860, 437-439		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m)	☒ Bank	☒ Valley Wall
10m	1.5m	150m	1.5m	4 m

Observations Upstream
Marshall Street

Observations Downstream
University Avenue

Site Description
At the private road crossing upstream of University Avenue East, gabion headwalls are failing and possible piping was noted along the right abutment/culvert wall. The gabion baskets are leaning and emptying. On the road deck, cracks were observed in the curb and asphalt.

A concrete conduit, approximately 2.5 m in width, was exposed to varying degrees on the channel bed between University Avenue and Marshall Street. The sides of conduit are exposed in some areas. Planning locates were requested through Ontario One Call and no utilities identified in the planning locates ran along the length of the creek.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential		✓	None		
Commercial	✓		Grass	✓	✓
Industrial			Herbaceous		
Institutional			Shrubs	✓	✓
Park/Open Space			Trees (Occasional)	✓	
Other			Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ☒ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	(15)
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	(10)
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	(15)

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	(10)	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**32**
Aquatic Habitat	**10**
Riparian Buffer	**15**
TOTAL	**92**

Photos of Erosion Site

Failing gabion basket abutments

Cracks in curb and asphalt on bridge deck

Exposed concrete on channel bed

Exposed concrete on channel bed

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E6		**Date:**	May 19, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R5	453-5, 461-8, 469-478		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ☒ Valley Wall		
10m	1.6m	70 m	1.6m	~4-5m

Observations Upstream
Weber Street & Water Survey of Canada gauge

Observations Downstream
Creek confined to corridor

Site Description
Near vertical erosion was observed on the right bank with a MH located on the slope within about 4 m of the top of bank. A second MH was located downstream behind a failing crib wall. A private storm outfall is located at the upstream end of the site and protrudes into the flow, likely contributing to bank scour.
Exposed concrete was observed on the channel bed and is likely a sanitary sewer encasement. Armourstone walls are located on either side of channel in this area.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓	✓	None		
Commercial			Grass		✓
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓		Trees (Occasional)		✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	(35)
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	(15)
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	(6)
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	(4)	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

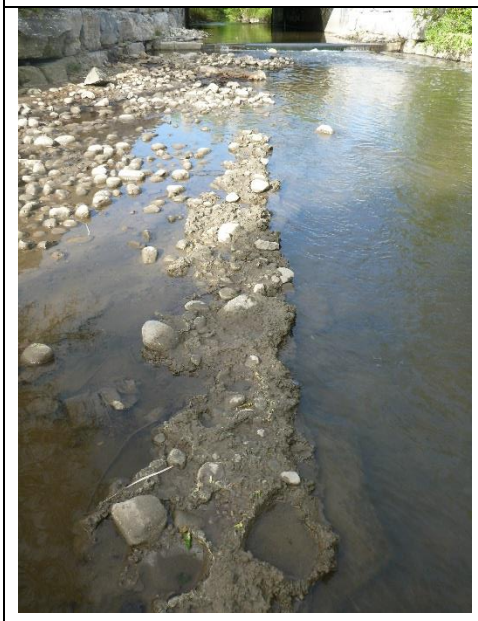
Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	(15)	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**28**
Aquatic Habitat	**15**
Riparian Buffer	**10**
TOTAL	**88**

Photos of Erosion Site

Near vertical bank erosion in front of MH. Failing private outfall.

Exposed concrete on bed



Exposed concrete on bed

Exposed concrete on bed

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E7		**Date:**	May 19, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R5	483-505, 518-546		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ❑ Bank ☒ Valley Wall		
9m	1-1.5m	350m	3-4m	

Observations Upstream
Erb Street East

Observations Downstream
Weber Street

Site Description
Near-vertical bank erosion is occurring on both sides of channel. A recreation trail and sanitary sewer run along the left bank. The eroding bank is within 1 m of the trail in some areas. Private property is located on the top of the right bank with erosion posing a risk to a fire hydrant, parking lot, loading area, and structures. Numerous storm outfalls are in poor repair. Concrete rubble and yard waste dumping on the bank was noted at the upstream end of the site. Erosion works should be addressed on a reach-scale extending from Erb Street East to Weber Street.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential	✓		None		
Commercial		✓	Grass	✓	
Industrial			Herbaceous	✓	✓
Institutional			Shrubs	✓	✓
Park/Open Space	✓ trail		Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
☒ Water or Gas Main
❑ Major Roads/Bridges
☒ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
☒ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

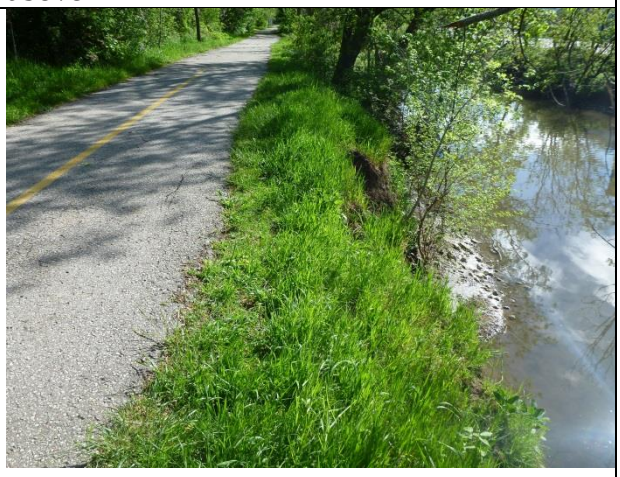
TOTAL SCORE / 100	
Public Health & Safety	**25**
Erosion Index	**32**
Aquatic Habitat	**15**
Riparian Buffer	**15**
TOTAL	**87**

Photos of Erosion Site

Bank erosion adjacent to paved loading area

Storm outfall on eroded bank with loading area above

Undermining of loading area pavement



Near vertical bank erosion putting trail at risk

Storm sewer outfall in poor condition

Concrete debris on toe of bank

Near vertical bank erosion adjacent to trail

Erosion upstream of roundstone treatment

Existing treatment around storm outfall

Rock riffle at upstream end of site with right bank erosion adjacent to private property

Structures on private property at top of bank

Bank erosion adjacent to trail

Storm outfall in poor repair

Storm outfall in poor repair

Top of eroding bank in close proximity to trail

Failing gabions on slope adjacent to trail

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E8		**Date:**	May 30, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R11	3919-3926		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
5m	1m	10m	1m	

Observations Upstream
Riffle

Observations Downstream
Pond

Site Description
The top of bank is located within 1 m of a structure beside the Ring Road on the University of Waterloo campus. The bank is well-vegetated but there is some erosion and undermining of the vegetation. A beaver was observed in the creek in this area.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	
Industrial			Herbaceous		✓
Institutional	✓	✓	Shrubs	✓	✓
Park/Open Space			Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	(10)
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ☒ Shed
- ❑ Septic Bed
- ☒ Other Permanent Structure (pump house)

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	(12)
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	(2)

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	(5)	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	(3)
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	(10)
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
(Warmwater / Tolerant)	5	(10)	15	

TOTAL SCORE / 100	
Public Health & Safety	**10**
Erosion Index	**22**
Aquatic Habitat	**10**
Riparian Buffer	**10**
TOTAL	**52**

Photos of Erosion Site

Top of bank within 1 m of structure

Bank erosion and undermining of vegetation

Eroding bank with structure in background

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E9		**Date:**	May 30, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R12	3944-3952		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
5m	0.6m	15m	1.2m	

Observations Upstream
Channel in vegetated corridor

Observations Downstream
Channel in vegetated corridor

Site Description
A MH is exposed on the right bank of the channel at an outside bend. The banks in this area are forested. Approximately 50% of the circumference of the chimney is exposed. There may be infiltration occurring at joints in the MH structure.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial			Grass		
Industrial			Herbaceous	✓	✓
Institutional	✓	✓	Shrubs	✓	✓
Park/Open Space			Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ☒ Sanitary Sewer
- ❑ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

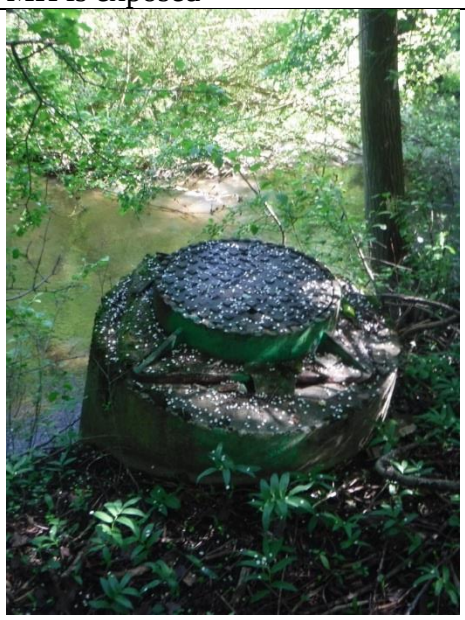
TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**26**
Aquatic Habitat	**5**
Riparian Buffer	**5**
TOTAL	**71**

Photos of Erosion Site

MH in bank on outside bend

Approximately half the circumference of the MH is exposed

Infiltration may be occurring in joints and cracks in the concrete



View of the MH from bank

View of the top of the MH

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Erosion Site	LRL-E10		Date:	May 30, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek	LRL-R12	3972-81		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
4-5m	1m	30m	3m	

Observations Upstream
Steep riffle

Observations Downstream
Cross walk for University of Waterloo residence (REV)

Site Description
Gabion baskets line the banks upstream and downstream of the crossing for the University of Waterloo residence, Ron Eydt Village (REV). Some of the gabions are in poor condition with lower baskets emptying and some slumping. Upstream of the gabions, the right bank is eroding. A sanitary sewer MH and a fire hydrant are located behind the top of bank.

Land Use	Left Bank	Right Bank	Riparian Vegetation	Left Bank	Right Bank
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional	✓	✓	Shrubs		
Park/Open Space			Trees (Occasional)		
Other			Other		

Public Health and Safety Index

Type of Risk	Score /35
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
❑ Buildings
❑ Major Dams
❑ Water or Gas Main
❑ Major Roads/Bridges
☒ Sanitary Sewer
❑ Other Utilities

Public Secondary Infrastructure
❑ Public Parking
❑ Minor Dam/Weir
❑ Active Park Land
❑ Trail Type 2-4
❑ Other

Private Secondary Infrastructure
❑ Deck ❑ Pool ❑ Shed
❑ Septic Bed
❑ Other Permanent Structure

Erosion Index

Distance	Score
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	Score
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	Flow Regime		
	Flashy	Transitional	Undeveloped
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	Score
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	Score
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	Quality of Habitat			Stream IDs
	High	Moderate	Low	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

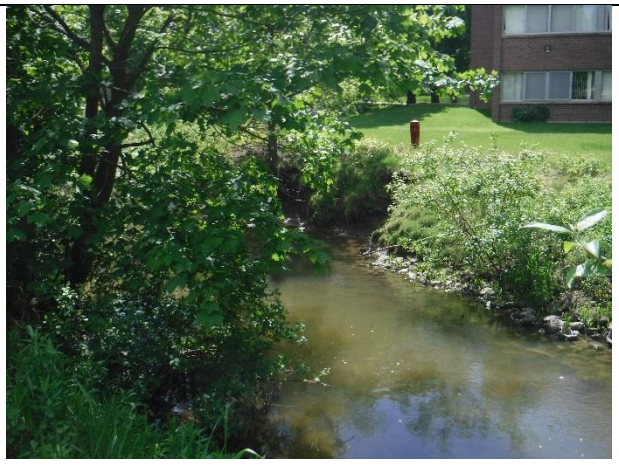
TOTAL SCORE / 100	
Public Health & Safety	35
Erosion Index	21
Aquatic Habitat	10
Riparian Buffer	15
TOTAL	81

Photos of Erosion Site

Emptying gabion baskets downstream of crossing for University of Waterloo residence (REV)

Bank erosion upstream of gabions on right bank

Sanitary sewer MH behind eroding bank



Fire hydrant behind eroding bank

THE CITY OF Waterloo

Waterloo Erosion Assessment
Erosion Site Summary Sheet

Aquafor Beech Limited

Erosion Site	LRL-E11		**Date:**	May 30, 2017
Watercourse	Reach number	Photo Numbers		
Laurel Creek		4109-4117		
Bankfull W (m)	Bankfull D (m)	Site Length (m) and Height (m) ☒ Bank ❑ Valley Wall		
2m	0.4m	5m	0.4m	

Observations Upstream
Wilmot Line

Observations Downstream
Creek within forested corridor

Site Description
An exposed conduit was observed on the channel bed immediately downstream of Wilmot Line. A second conduit may have been exposed downstream. A sign on the bank indicated buried communications cables. The creek does not appear to be downcutting significantly in this area.

Land Use	**Left Bank**	**Right Bank**	**Riparian Vegetation**	**Left Bank**	**Right Bank**
Residential			None		
Commercial			Grass	✓	✓
Industrial			Herbaceous	✓	✓
Institutional	✓	✓	Shrubs	✓	✓
Park/Open Space			Trees (Occasional)	✓	✓
Other			Other		

Public Health and Safety Index

Type of Risk	**Score /35**
Critical Infrastructure	35
Minor Roads/Bridge/ Paved Trail	25
Public Property with 2nd Infrastructure	15
Private Property with 2nd Infrastructure	10
Open Space (Inactive)	0

Critical Infrastructure
- ❑ Buildings
- ❑ Major Dams
- ❑ Water or Gas Main
- ❑ Major Roads/Bridges
- ❑ Sanitary Sewer
- ☒ Other Utilities

Public Secondary Infrastructure
- ❑ Public Parking
- ❑ Minor Dam/Weir
- ❑ Active Park Land
- ❑ Trail Type 2-4
- ❑ Other

Private Secondary Infrastructure
- ❑ Deck ❑ Pool ❑ Shed
- ❑ Septic Bed
- ❑ Other Permanent Structure

Erosion Index

Distance	**Score**
In channel	15
0 – 5 m	12
5 – 10 m	10
10 – 20 m	5
20 – 50 m	2
> 50 m	0

Extent	**Score**
>301m^2	10
201-300 m^2	8
101-200 m^2	6
50-100 m^2	4
1-50 m^2	2

Stream Energy	**Flow Regime**		
	Flashy	**Transitional**	**Undeveloped**
High	5	4	3
Moderate	4	3	2
Low	3	2	1

Erodibility	**Score**
High	5
Moderate	3
Low	1

Riparian Buffer Index

Riparian	**Score**
Sensitive	0
High Quality	5
Moderate	10
Low Quality	15

Aquatic Habitat Index

Thermal Regime / Fish Comm.	**Quality of Habitat**			**Stream IDs**
	High	**Moderate**	**Low**	
Coldwater / Intolerant	0	5	10	
Mixed / Moderately Tolerant	2	7	12	
Warmwater / Tolerant	5	10	15	

TOTAL SCORE / 100	
Public Health & Safety	**35**
Erosion Index	**24**
Aquatic Habitat	**5**
Riparian Buffer	**5**
TOTAL	**69**

Photos of Erosion Site

Looking downstream from culvert at Wilmot Line

Exposed conduit on channel bed

Exposed conduit on channel bed

Location of second conduit

Sign indicating buried communication cables

Appendix D: Evaluation of Alternatives

Table D1: Evaluation Matrix for Erosion Site LRL-E5

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	3	No change	-	N/A	3	Concrete bed not exposed, construction impacts	4	Concrete bed removed, construction impacts
Impacts to Terrestrial Habitat	3	No change, continued loss of vegetation at failing abutments	-	N/A	4	Construction impacts, long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	-	N/A	3	Potential for bank treatments, limited space if conduit to be buried	4	Potential for bank treatments
Potential to Reduce Erosion of Private Lands	1	No reduction	-	N/A	3	Potential for bank treatments, limited space if conduit to be buried	4	Potential for bank treatments
Potential to Reduce Stream Bank and Stream Bed Erosion	3	Existing concrete prevents bed erosion	-	N/A	3	Potential to protect bed but limited space if conduit to be buried	5	Flexibility with bed since conduit removed
Integration with Existing Infrastructure	5	No change	-	N/A	5	No other infrastructure on creek bed	5	No other infrastructure on creek bed
Integration with Existing Environment	5	No change	-	N/A	1	Challenging to raise channel bed to protect conduit	5	More flexibility in channel with conduit removed
Score	**3.00**		**0.00**		**3.14**		**4.43**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Concrete bed not aesthetically appealing	-	N/A	4	Potential for vegetation enhancement, channel bed constrained due to conduit	5	Potential for vegetation and channel bed enhancements
Compatibility with Adjacent Land Use	5	No impact	-	N/A	2	Raising bed to protect conduit may be challenging with floodlines	5	Flexibility with channel since conduit removed
Community Disruption	4	Impact for any maintenance work on bridge	-	N/A	1	Construction noise and dust	1	Construction noise and dust
Public Health and Safety	2	Does not address risk at bridge and from exposed infrastructure	-	N/A	4	Protects infrastructure	5	Removes infrastructure risk
Score	**3.00**		**0.00**		**2.75**		**4.00**	
Economic Environment								
Construction Costs	5	None	-	N/A	2	Costs associated with bridge, bed and bank works	1	Costs associated with bridge, bed and banks works, and removal of conduit
Operation and Maintenance Costs	3	Bridge may require maintenance	-	N/A	3	Maintenance required to continue to protect infrastructure	5	Minimal maintenance
Score	**4.00**		**0.00**		**2.50**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	-	N/A	2	Limited space and potential to impact floodlines negatively	3	Limited space
Agency Acceptance	3	No impact to ecology but concrete is not removed	-	N/A	2	Dependent upon impacts to flooding	5	Removal of concrete increases potential for improvements to aquatic habitat
Technical Feasibility	5	No works involved	-	N/A	2	Limited space and potential to impact floodlines negatively	5	Space to design channel restoration
Score	**4.33**		**0.00**		**2.00**		**4.33**	
Total Score	**3.58**		**0.00**		**2.60**		**3.94**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D2: Evaluation Matrix for Erosion Site CDR-E4

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	3	No change, continued sediment inputs at eroding banks	4	Construction impacts, restoration of bare banks	4	Construction impacts, potential for long-term improvements	5	Construction impacts, potential for long-term improvements and softer bed and bank treatments
Impacts to Terrestrial Habitat	3	No change, continued loss of vegetation at failing banks	3	Construction impacts, localized long-term improvements from plantings	3	Construction impacts, long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Addresses existing erosion and future erosion between treatments	5	Potential for bank treatments and widening of channel corridor
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Addresses existing erosion and future erosion between treatments	1	Private lands would need to be purchased for trail and sanitary sewer relocation
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Addresses existing erosion and future erosion between treatments	5	More flexibility with alignment since sanitary sewer relocated
Integration with Existing Infrastructure	1	Risks to infrastructure remain	4	Protects infrastructure in areas of concern, does not prevent future risk between treatments	5	Protects sanitary sewer and trail	1	Sanitary sewer and trail would need to be relocated
Integration with Existing Environment	3	Continued loss of bank material and vegetation	4	Works within existing corridor	4	Works within existing corridor	5	More flexibility in channel with infrastructure relocated
Score	**1.86**		**3.43**		**4.29**		**3.71**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Risk to recreational trail remains, failing bank visible from trail	4	Localized improvements, no prevention of future issues between treatments	5	Protection of trail and enhanced banks	5	Potential for vegetation and channel bed enhancements
Compatibility with Adjacent Land Use	1	Risks to infrastructure and private property remain	5	Protects adjacent land use	5	Protects adjacent land use	1	Would need to purchase adjacent land for sanitary sewer and trail relocation
Community Disruption	3	Recreational trail may need to be diverted or closed	3	Construction noise and dust, shorter duration than full channel restoration	2	Construction noise and dust	1	Construction noise and dust, land use changes
Public Health and Safety	3	Risk to trail and sanitary sewer	4	Addresses immediate risk but does not prevent future risk between treatments	5	Protects recreational trail, sanitary sewer, and private property	5	Removes infrastructure risk
Score	**2.00**		**4.00**		**4.25**		**3.00**	
Economic Environment								
Construction Costs	5	None	4	Lower cost than full channel restoration	3	Bed and bank works required throughout	1	High costs to relocate sanitary sewer and trail and purchase property
Operation and Maintenance Costs	1	Maintenance required as banks continue to erode into trail and sanitary sewer	3	Long-term maintenance work required on treatments and future work between treatments	4	Long-term maintenance of treatments required	5	Minimal maintenance
Score	**3.00**		**3.50**		**3.50**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along existing recreational trail	4	Access available along existing recreational trail	1	Extensive work required to relocated sanitary sewer and trail, purchase of private property required
Agency Acceptance	1	Risk to infrastructure not addressed	4	Addresses risks to infrastructure	4	Addresses risk to infrastructure	5	Could allow for more natural corridor
Technical Feasibility	5	No works involved	5	Bed and banks works possible	5	Bed and banks works possible	2	Difficult to relocated sanitary sewer
Score	**3.67**		**4.33**		**4.33**		**2.67**	
Total Score	**2.63**		**3.82**		**4.09**		**3.10**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D3: Evaluation Matrix for Erosion Site LRL-E6

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	2	No change, continued sediment load from bare banks	3	Construction impacts, localized reduction in sediment loading	4	Construction impacts, potential for long-term improvements	4	Construction impacts, potential for long-term improvements
Impacts to Terrestrial Habitat	3	No change, continued loss of vegetation due to bank erosion	3	Construction impacts, localized long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Potential for bank treatments	5	Potential for softer bank treatments
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Potential for bank treatments	4	Some private lands would need to be purchased for relocating sanitary sewer
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Bed and bank treatments possible, corridor width limited	5	More flexibility for channel bed and bank treatments
Integration with Existing Infrastructure	1	Risks to infrastructure remain	4	Protects infrastructure in areas of concern, does not prevent future risk between treatments	5	Protection of sanitary sewer possible	1	All infrastructure would need to be removed
Integration with Existing Environment	3	Continued loss of bank material and vegetation	4	Works within existing corridor	4	Works within existing corridor	5	More flexibility in channel with sanitary sewer removed
Score	**1.71**		**3.29**		**4.43**		**4.00**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Exposed sanitary sewer remains on bed, storm sewer extends into flow	3	Localized improvements, no prevention of future issues between treatments	4	Consistency in bank treatments	5	Potential for vegetation and channel bed enhancements, loss of recreational trail
Compatibility with Adjacent Land Use	1	Risks to infrastructure and private property remain	5	Protects adjacent land use	5	Protects adjacent land use	1	Would need to purchase adjacent land to relocate sanitary sewer
Community Disruption	5	No works involved	3	Construction noise and dust, shorter duration than full channel restoration	2	Construction noise and dust	1	Construction noise and dust, loss of private property
Public Health and Safety	1	Risks to infrastructure remain	4	Addresses immediate risk but does not prevent future risk between treatments	5	Protects sanitary sewer and private property	5	Removes infrastructure risk
Score	**2.00**		**3.75**		**4.00**		**3.00**	
Economic Environment								
Construction Costs	5	None	4	Lower cost than full channel restoration	3	Bed and bank works required throughout	1	High costs to purchase private property and relocate sanitary sewer
Operation and Maintenance Costs	1	Maintenance required as banks continue to erode into trail and private property	3	Long-term maintenance work required on treatments and future work between treatments	4	Long-term maintenance of bed and bank treatments required	5	Minimal maintenance
Score	**3.00**		**3.50**		**3.50**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along existing recreational trail	4	Access available along existing recreational trail	1	Difficult to remove/relocate infrastructure and purchase properties
Agency Acceptance	2	Risk to sanitary sewer not addressed, continued sediment loading from bare banks	4	Addresses risk to sanitary sewer and sediment loading from bare banks	4	Addresses risk to sanitary sewer and sediment loading from bare banks	5	Addresses risks, could allow for softer bank treatments
Technical Feasibility	5	No works involved	5	Bed and banks works possible	5	Bed and banks works possible	5	Feasible to relocate sanitary sewer
Score	**4.00**		**4.33**		**4.33**		**3.67**	
Total Score	**2.68**		**3.72**		**4.07**		**3.42**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D4: Evaluation Matrix for Erosion Site FRW-E2

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	1	No fish passage through culverts, continued riprap inputs	3	Construction impacts, potential to provide fish passage through new culvert	-	N/A	5	Construction impacts, long-term reconnection of corridor
Impacts to Terrestrial Habitat	2	Loss of vegetation as embankment continues to erode	4	Construction impacts, long-term improvements from plantings	-	N/A	5	Construction impacts, long-term reconnection of corridor
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Replacement of crossing allows for bank protection	-	N/A	5	Removal of risks
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Replacement of crossing allows for bank protection	-	N/A	5	Removal of risks
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Replacement of crossing allows for bank protection	-	N/A	5	Removal of risks
Integration with Existing Infrastructure	1	Risk to infrastructure remains	4	Protects existing infrastructure	-	N/A	1	Existing infrastrucutre would need to be relocated
Integration with Existing Environment	3	Continued inputs of riprap from failing gabions	4	Works within existing corridor	-	N/A	5	Allows for reconnection of creek corridor
Score	**1.43**		**3.43**		**0.00**		**4.43**	
Social/Cultural Environment								
Aesthetics / Recreation	3	Poor aesthetics due to failing conditions, potential for trail closure	5	Continued connection of trails, improved channel aesthetics	-	N/A	3	Loss of creek crossing, improved channel aesthetics
Compatibility with Adjacent Land Use	3	Potential for trail closure	5	Continued connection of trails	-	N/A	1	Loss of trail connection
Community Disruption	3	Potential for trail closure	3	Construction impacts, trail connection maintained	-	N/A	1	Construction noise and dust and loss of trail connection
Public Health and Safety	1	Risk to infrastructure remains	5	Removes infrastructure risk	-	N/A	5	Removes infrastructure risk
Score	**2.50**		**4.50**		**0.00**		**2.50**	
Economic Environment								
Construction Costs	5	None	4	Much lower cost to replace culverts than to relocate utilities	-	N/A	1	High costs associated with relocating all utilities
Operation and Maintenance Costs	1	Maintenance or emergency works required as structure deteriorates	4	Long-term maintenance work required on crossing	-	N/A	5	Minimal maintenance
Score	**3.00**		**4.00**		**0.00**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along Forwell Creek Rd.	-	N/A	1	Difficult to relocate all utilities
Agency Acceptance	1	Does not address risks to infrastructure	4	Addresses risks to infrastructure	-	N/A	5	Addresses risk to infrastructure and reconnects creek corridor
Technical Feasibility	5	No works involved	5	Replacement of culverts possible	-	N/A	1	Difficult to relocate all utilities
Score	**3.67**		**4.33**		**0.00**		**2.33**	
Total Score	**2.65**		**4.07**		**0.00**		**3.07**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D5: Evaluation Matrix for Erosion Site LRL-E7

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	1	No change, possible entry of concrete and asphalt into channel	2	Construction impacts, prevention of concrete and asphalt entry into channel	3	Construction impacts, potential for long-term improvements	4	Construction impacts, potential for long-term improvements
Impacts to Terrestrial Habitat	2	No change, continued loss of vegetation at failing abutments	2	Construction impacts, localized long-term improvements from plantings	3	Construction impacts, long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Bank treatments to prevent loss of land	5	Potential for bank treatments and floodplain development
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	5	Bank treatments to prevent loss of land	1	Private lands would need to be purchased for space
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Bed and bank treatments possible, corridor width limited	5	Flexibility with bed since conduit removed
Integration with Existing Infrastructure	1	Risks to infrastructure remain	4	Protects infrastructure in areas of concern, does not prevent future risk between treatments	5	Protection of sanitary sewer possible	1	All infrastructure would need to be removed
Integration with Existing Environment	3	Continued loss of bank material and vegetation	4	Works within existing corridor	4	Works within existing corridor	5	More flexibility in channel with conduit removed
Score	**1.43**		**3.00**		**4.14**		**3.57**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Risk to recreational trail remains	3	Localized improvements, no prevention of future issues between treatments	5	Protection of trail and enhanced banks	3	Potential for vegetation and channel bed enhancements, loss of recreational trail
Compatibility with Adjacent Land Use	1	Risks to infrastructure and private property remain	5	Protects adjacent land use	5	Protects adjacent land use	1	Would need to purchase adjacent land
Community Disruption	1	Recreational trail becomes unsafe	3	Construction noise and dust, shorter duration than full channel restoration	2	Construction noise and dust	1	Construction noise and dust, loss of recreational trail, land use changes
Public Health and Safety	1	Recreational trail becomes unsafe	4	Addresses immediate risk but does not prevent future risk between treatments	5	Protects recreational trail, sanitary sewer, and private property	5	Removes infrastructure risk
Score	**1.00**		**3.75**		**4.25**		**2.50**	
Economic Environment								
Construction Costs	5	None	3	Lower cost than full channel restoration	2	Bed and bank works required throughout	1	High costs to remove trail, purchase private property, and relocate sanitary sewer
Operation and Maintenance Costs	1	Maintenance required as banks continue to erode into trail and private property	3	Long-term maintenance work required on treatments and future work between treatments	4	Long-term maintenance of bed and bank treatments required	5	Minimal maintenance
Score	**3.00**		**3.00**		**3.00**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along existing recreational trail	4	Access available along existing recreational trail	1	Difficult to remove/relocate infrastructure and purchase properties
Agency Acceptance	2	Risk to sanitary sewer not addressed, potential for asphalt and concrete to enter creek	4	Addresses risk to sanitary sewer and prevents entry of asphalt and concrete into channel	4	Addresses risk to sanitary sewer and prevents entry of asphalt and concrete into channel	5	Could allow for more natural corridor
Technical Feasibility	5	No works involved	5	Bed and banks works possible	5	Bed and banks works possible	1	No good option for relocating sewer
Score	**4.00**		**4.33**		**4.33**		**2.33**	
Total Score	**2.36**		**3.52**		**3.93**		**2.85**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D6: Evaluation Matrix for Erosion Site CDR-E3

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	1	No fish over existing weir, continued riprap inputs	3	Construction impacts, potential to provide upstream fish passage	-	N/A	-	N/A
Impacts to Terrestrial Habitat	2	Loss of vegetation as gabions continue to slump	4	Construction impacts, long-term improvements from plantings	-	N/A	-	N/A
Potential to Reduce Erosion of Public Lands	1	No reduction	5	Replacement of crossing allows for bank protection	-	N/A	-	N/A
Potential to Reduce Erosion of Private Lands	1	No reduction	5	Replacement of crossing allows for bank protection	-	N/A	-	N/A
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	5	Replacement of crossing allows for bank and bed protection	-	N/A	-	N/A
Integration with Existing Infrastructure	1	Risk to infrastructure remains	5	Protects existing infrastructure	-	N/A	-	N/A
Integration with Existing Environment	3	Continued inputs of riprap from failing gabions	5	Works within existing corridor	-	N/A	-	N/A
Score	**1.43**		**4.57**		**0.00**		**0.00**	
Social/Cultural Environment								
Aesthetics / Recreation	3	Poor aesthetics due to failing conditions, potential for road closure with further culvert deterioration	5	Continued connection of Albert St., improved channel aesthetics	-	N/A	-	N/A
Compatibility with Adjacent Land Use	3	Potential for road closure with continued culvert deterioration	5	Continued connection of Albert St.	-	N/A	-	N/A
Community Disruption	3	Potential for trail closure	3	Construction impacts, trail connection maintained	-	N/A	-	N/A
Public Health and Safety	1	Risk to public remains	5	Removes risk to public	-	N/A	-	N/A
Score	**2.50**		**4.50**		**0.00**		**0.00**	
Economic Environment								
Construction Costs	5	None	3	Cost to replace structure	-	N/A	-	N/A
Operation and Maintenance Costs	1	Maintenance or emergency works required as structure deteriorates	4	Long-term maintenance work required on crossing	-	N/A	-	N/A
Score	**3.00**		**3.50**		**0.00**		**0.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along Forwell Creek Rd.	-	N/A	-	N/A
Agency Acceptance	1	Does not address risks that culvert will fail	4	Addresses risk of culvert failure	-	N/A	-	N/A
Technical Feasibility	5	No works involved	5	Replacement of culverts possible	-	N/A	-	N/A
Score	**3.67**		**4.33**		**0.00**		**0.00**	
Total Score	**2.65**		**4.23**		**0.00**		**0.00**	

5 = Alternative ranks high compared to other alternatives

1 = Alternative ranks low compared to other alternatives

Table D7: Evaluation Matrix for Erosion Site CLR-T1-E1

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	1	No change, riprap and failed gabions remain in channel	3	Construction impacts, removal of riprap, potential for long-term improvements through localized bed works	4	Construction impacts, removal of riprap, potential for long-term improvements through comprehensive bed works	5	Construction impacts, potential for long-term improvements
Impacts to Terrestrial Habitat	3	No change, existing vegetation is mostly manicured	3	Construction impacts, localized long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings	5	Construction impacts, long-term improvements from more extensive plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Addresses existing erosion, does not prevent future failures where gabions are currently in good condition	4	Addresses bank erosion	5	Potential for softer bank treatments
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion where gabions are currently in good condition	4	Addresses bank erosion	5	Potential for softer bank treatments
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Addresses existing erosion, does not prevent future erosion where gabions are currently in good condition	4	Addresses bank erosion	5	More flexibility for channel bed and bank treatments
Integration with Existing Infrastructure	1	Risk to building remains	4	Protects infrastructure in areas of concern, does not prevent future risk where gabions are currently in good condition	5	Protects building	1	Building would need to be removed
Integration with Existing Environment	3	Continued riprap entry into channel and degradation of banks	4	Works within existing corridor	4	Works within existing corridor	5	More flexibility in channel with building removed
Score	**1.57**		**3.29**		**4.14**		**4.43**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Failed treatments and riprap in channel remain	3	Localized improvements, no prevention of future issues between repaired areas	4	Consistency in bank treatments	5	Potential for vegetation and channel enhancements
Compatibility with Adjacent Land Use	1	Risk to building remains	5	Protects adjacent land use	5	Protects adjacent land use	4	Impacts 1 property which would need to be purchased
Community Disruption	5	No works involved	3	Construction noise and dust, shorter duration than full channel restoration	2	Construction noise and dust	1	More extensive construction noise and dust due to building demolition
Public Health and Safety	1	Risk remains to trail, storm outfalls, and sanitary sewer crossing	4	Protects building but does not prevent future risk of remaining gabion failure	5	Protects building	5	Removes risk to building
Score	**2.00**		**3.75**		**4.00**		**3.75**	
Economic Environment								
Construction Costs	5	None	4	Lower cost than full channel restoration	3	Bed and bank works required throughout	1	High cost to purchase property and demolish house
Operation and Maintenance Costs	1	Maintenance required as treatments continue to degrade	3	Long-term maintenance work required on treatments and future work between treatments	4	Long-term maintenance of treatments required	5	Minimal maintenance
Score	**3.00**		**3.50**		**3.50**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access from McDougall Rd.	4	Access from McDougall Rd.	1	Owner may not want to sell house
Agency Acceptance	1	Risk to building not addressed, continued riprap in channel	4	Addresses risk to building and loss of riprap into channel	4	Addresses risk to building and loss of riprap into channel	5	Addresses risks, could allow for more natural channel features
Technical Feasibility	5	No works involved	5	Bed and banks works possible	5	Bed and banks works possible	5	Feasible to purchase house
Score	**3.67**		**4.33**		**4.33**		**3.67**	
Total Score	**2.56**		**3.72**		**3.99**		**3.71**	

5 = Alternative ranks high compared to other alternatives

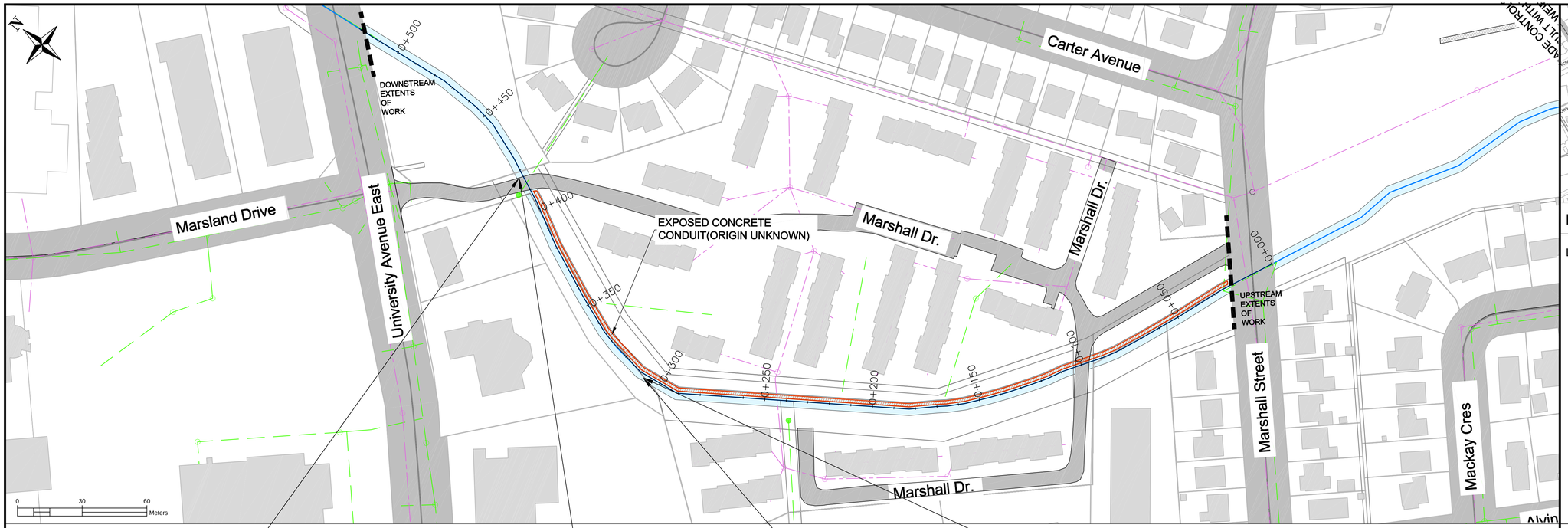
1 = Alternative ranks low compared to other alternatives

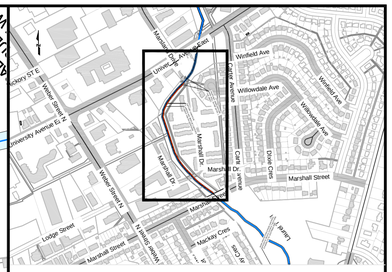
Table D8: Evaluation Matrix for Erosion Site CLR-E4

Evaluation Criteria	Alt 1: Do Nothing		Alt 2: Local Works		Alt 3: Full Channel Restoration		Alt 4: Removal of Risk	
Physical/Natural Environment								
Impacts to Aquatic Habitat	1	No change, riprap piles remain in channel	3	Construction impacts, removal of riprap, potential for long-term improvements through localized bed works	4	Construction impacts, removal of riprap, potential for long-term improvements through comprehensive bed works	5	Construction impacts, potential for long-term improvements
Impacts to Terrestrial Habitat	3	No change, potential loss of vegetation due to bank protection degradation	3	Construction impacts, localized long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings	4	Construction impacts, long-term improvements from plantings
Potential to Reduce Erosion of Public Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Potential for bank treatments	5	Potential for softer bank treatments
Potential to Reduce Erosion of Private Lands	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Potential for bank treatments	5	Potential for softer bank treatments
Potential to Reduce Stream Bank and Stream Bed Erosion	1	No reduction	3	Addresses existing erosion, does not prevent future erosion between treatments	4	Bed and bank treatments possible	5	More flexibility for channel bed and bank treatments
Integration with Existing Infrastructure	1	Risks to infrastructure remain	4	Protects infrastructure in areas of concern, does not prevent future risk between treatments	5	Protection of sanitary sewer possible	1	All infrastructure would need to be removed
Integration with Existing Environment	3	Continued loss of bank material and vegetation	4	Works within existing corridor	4	Works within existing corridor	5	More flexibility in channel with sanitary sewer removed
Score	**1.57**		**3.29**		**4.14**		**4.29**	
Social/Cultural Environment								
Aesthetics / Recreation	1	Recreation trail risk remains, treatments in disrepair and riprap piles in channel	3	Localized improvements, no prevention of future issues between treatments	4	Consistency in bank treatments	5	Potential for vegetation and channel bed enhancements
Compatibility with Adjacent Land Use	1	Risks to trail and sanitary sewer remain	5	Protects adjacent land use	5	Protects adjacent land use	5	Protects adjacent land use
Community Disruption	5	No works involved	3	Construction noise and dust, shorter duration than full channel restoration	2	Construction noise and dust	1	Construction noise and dust, traffic impacts on Columbia St. W.
Public Health and Safety	1	Risk remains to trail, storm outfalls, and sanitary sewer crossing	4	Addresses immediate risk but does not prevent future risk between treatments	5	Protects sanitary sewer and trail	5	Removes infrastructure risk
Score	**2.00**		**3.75**		**4.00**		**4.00**	
Economic Environment								
Construction Costs	5	None	4	Lower cost than full channel restoration	3	Bed and bank works required throughout	1	High costs to relocate sanitary sewer
Operation and Maintenance Costs	1	Maintenance required as treatments continue to degrade	3	Long-term maintenance work required on treatments and future work between treatments	4	Long-term maintenance of bed and bank treatments required	5	Minimal maintenance
Score	**3.00**		**3.50**		**3.50**		**3.00**	
Technical/Engineering Considerations								
Ease of Implementation	5	Nothing to implement	4	Access available along existing recreational trail	4	Access available along existing recreational trail	1	Difficult to relocate sanitary sewer (impacts to Columbia St. W.)
Agency Acceptance	1	Risk to sanitary sewer and trail not addressed, riprap in channel	4	Addresses risk to sanitary sewer and trail and removes riprap	4	Addresses risk to sanitary sewer and trail and removes riprap	5	Addresses risks, could allow for softer bank treatments
Technical Feasibility	5	No works involved	5	Bed and banks works possible	5	Bed and banks works possible	3	Tie-in to gravity sewer may require extensive work
Score	**3.67**		**4.33**		**4.33**		**3.00**	
Total Score	**2.56**		**3.72**		**3.99**		**3.57**	

5 = Alternative ranks high compared to other alternatives
1 = Alternative ranks low compared to other alternatives

Appendix E: Conceptual Designs





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE

Site Description:

At the private road crossing upstream of University Avenue East, gabion headwalls are failing and possible piping was noted along the right abutment/culvert wall. The gabion baskets are leaning and emptying. On the road deck, cracks were observed in the curb and asphalt.

A concrete conduit, approximately 2.5 m in width, was exposed to varying degrees on the channel bed between University Avenue and Marshal Street. The sides of conduit are exposed in some areas. Planning locates were requested through Ontario One Call and no utilities identified in the planning locates ran along the length of the creek.

CRACKS IN CURB AND ASPHALT ON BRIDGE DECK

FAILING GABION BASKET ABUTMENTS

EXPOSED CONCRETE ON CHANNEL BED

EXPOSED CONCRETE ON CHANNEL BED

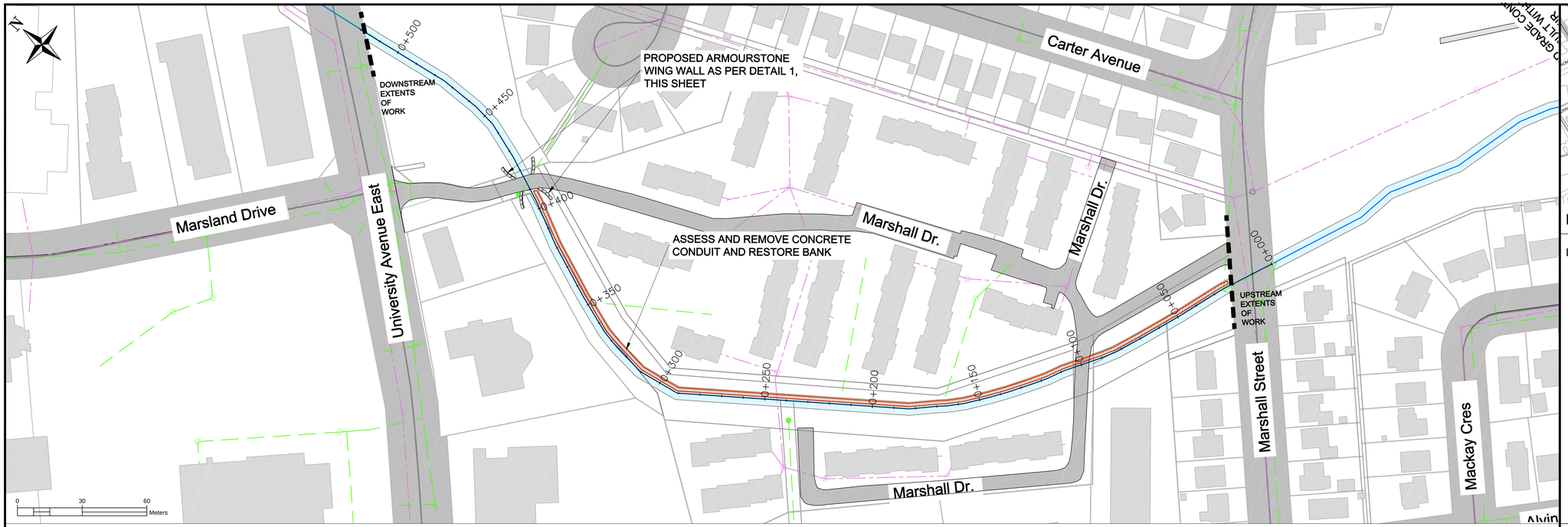
THE CITY OF Waterloo

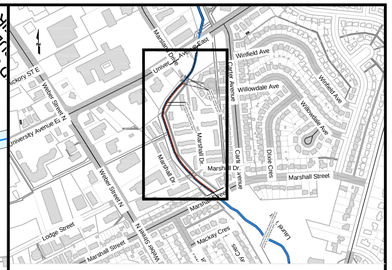
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE LRL - E5

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



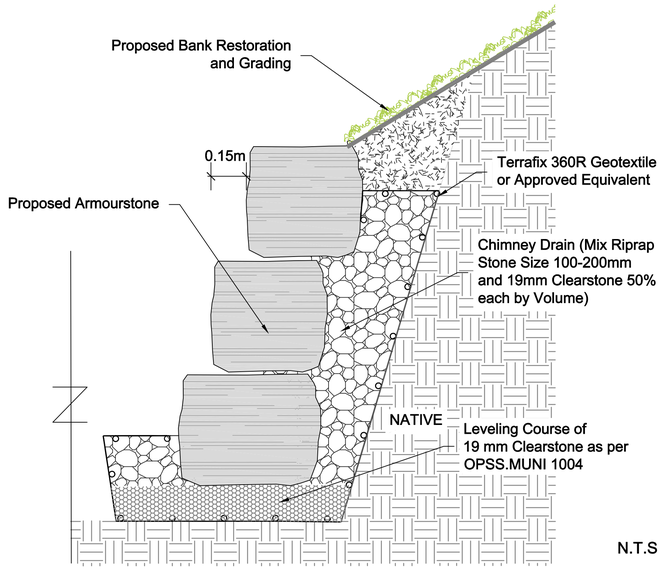


DRAFT - NOT FOR CONSTRUCTION

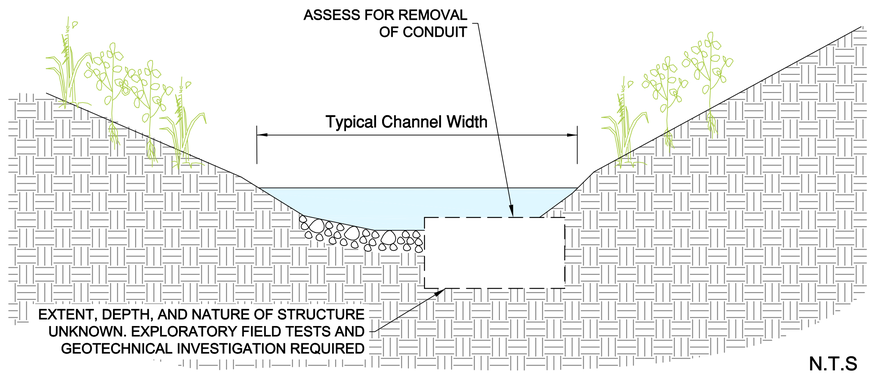
LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE

DETAIL 1 - TYPICAL ARMOURSTONE WING WALL



DETAIL 2 - TYPICAL CROSS SECTION



Conceptual Design:

The City of Waterloo completed an extensive review of record drawings and consultation with technical staff. The reason for the concrete conduit within the channel was not determined. An Ontario One Call planning locates request was also completed and none of the infrastructure identified from this request matched the location of the concrete conduit in the channel. Prior to removing the concrete conduit, exploratory field tests should be conducted to determine what it is and whether it is still in use.

Assuming that the concrete conduit is no longer in use, the preferred alternative at this site is the removal of the risk. The concrete conduit would be removed from the channel and bed and bank restoration works would be completed. Aquatic and terrestrial habitat features should be included where feasible. A geotechnical investigation may be required at the detailed design stage.

The private bridge structure should be assessed for structural condition and replaced as required. At a minimum, the failing gabion basket abutments should be replaced as part of the above channel bank restoration works.

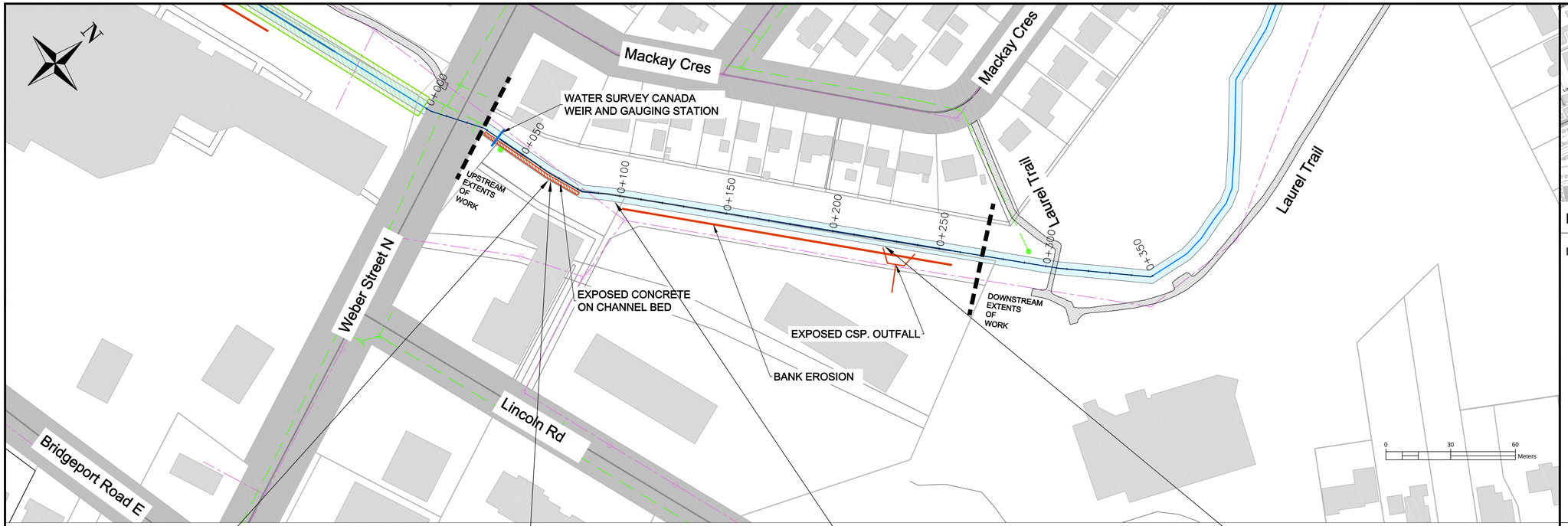
THE CITY OF Waterloo

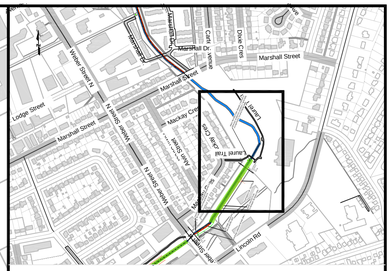
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE LRL - E5

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

EXPOSED CONCRETE ON BED

EXPOSED CONCRETE ON BED

EXPOSED CONCRETE ON BED

NEAR VERTICAL BANK EROSION IN FRONT
OF MH. FAILING PRIVATE OUTFALL.

Site Description:

Near vertical erosion was observed on the right bank with a MH located on the slope within about 4 m of the top of bank. A second MH was located downstream behind a failing crib wall. A private storm outfall is located at the upstream end of the site and protrudes into the flow, likely contributing to bank scour.

Exposed concrete was observed on the channel bed and is likely a sanitary sewer encasement. Armourstone walls are located on either side of channel in this area.

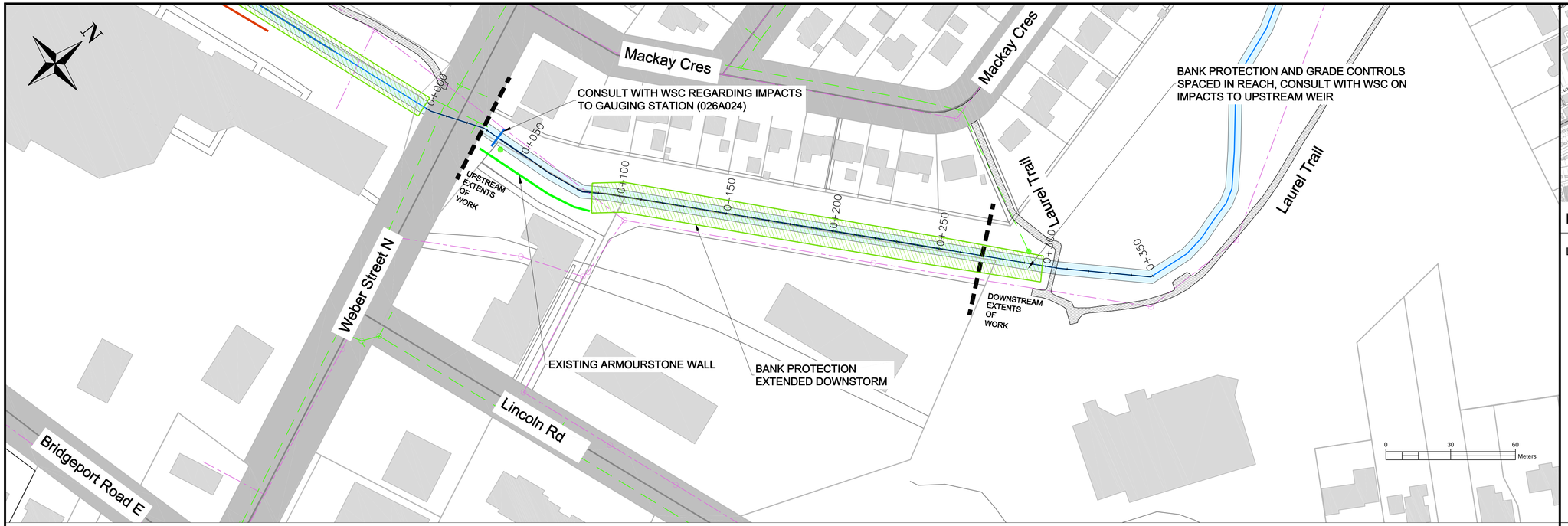
THE CITY OF Waterloo

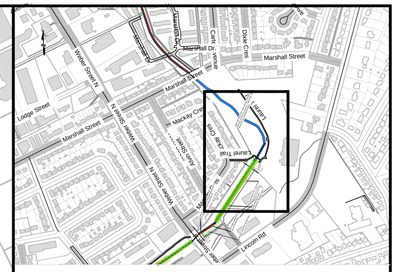
CITY OF WATERLOO
INFRASTRUCTURE AND
ENVIRONMENTAL SERVICES

SITE LRL - E6

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



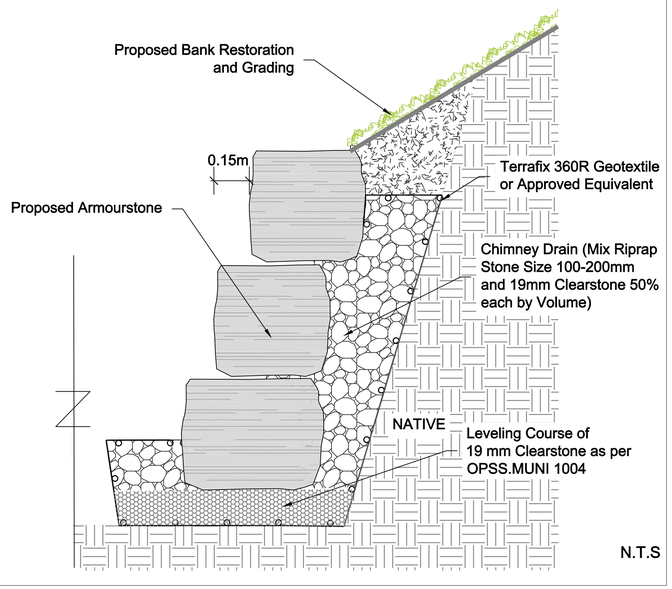


DRAFT - NOT FOR CONSTRUCTION

LEGEND

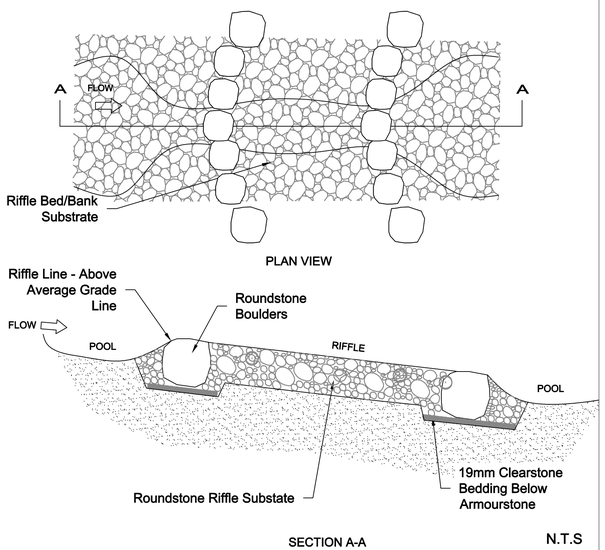
- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

DETAIL 1 - TYPICAL ARMOURSTONE WING WALL



N.T.S

DETAIL 2 - TYPICAL GRADE CONTROL STRUCTURE



N.T.S

DETAIL 3 - SITE SPECIFIC CONSIDERATIONS

Conceptual Design:

The preferred alternative at this site is full channel restoration. Bank protection is required downstream of the existing armourstone wall to protect the sanitary sewer line and maintenance holes. The existing protruding outfall will be retrofitted into the bank protection. Bed restoration works (i.e. grade control) will be undertaken to protect the existing sanitary sewer crossing which is currently exposed. During the detailed design, implications of the bed works on the upstream flow gauging station must be identified and addressed. A geotechnical investigation will also be required at the detailed design stage.

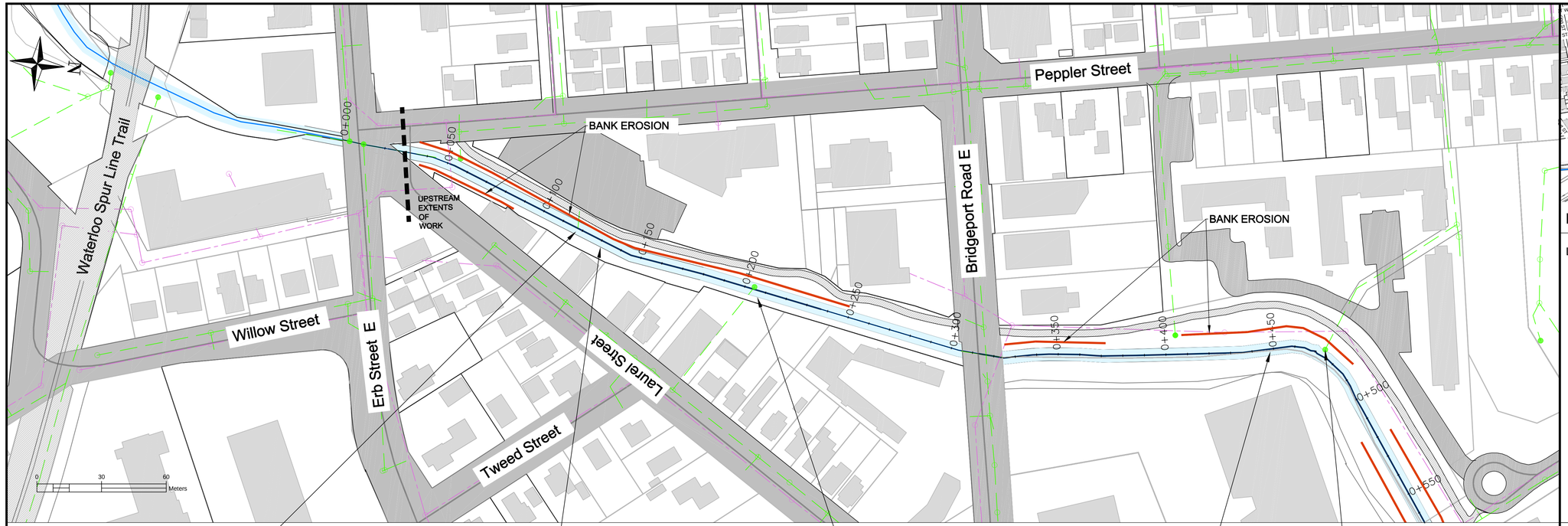
THE CITY OF Waterloo

CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE LRL - E6

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

STORM OUTFALL IN POOR REPAIR

STORM OUTFALL IN POOR REPAIR

CONCRETE DEBRIS ON TOE OF BANK

STORM OUTFALL IN POOR CONDITION

EROSION UPSTREAM OF ROUNDSTONE TREATMENT

Site Description:

Near-vertical bank erosion is occurring on both sides of channel. A recreation trail and sanitary sewer run along the left bank. The eroding bank is within 1 m of the trail in some areas. Private property is located on the top of the right bank with erosion posing a risk to a fire hydrant, parking lot, loading area, and structures.

Numerous storm outfalls are in poor repair. Concrete rubble and yard waste dumping on the bank was noted at the upstream end of the site.

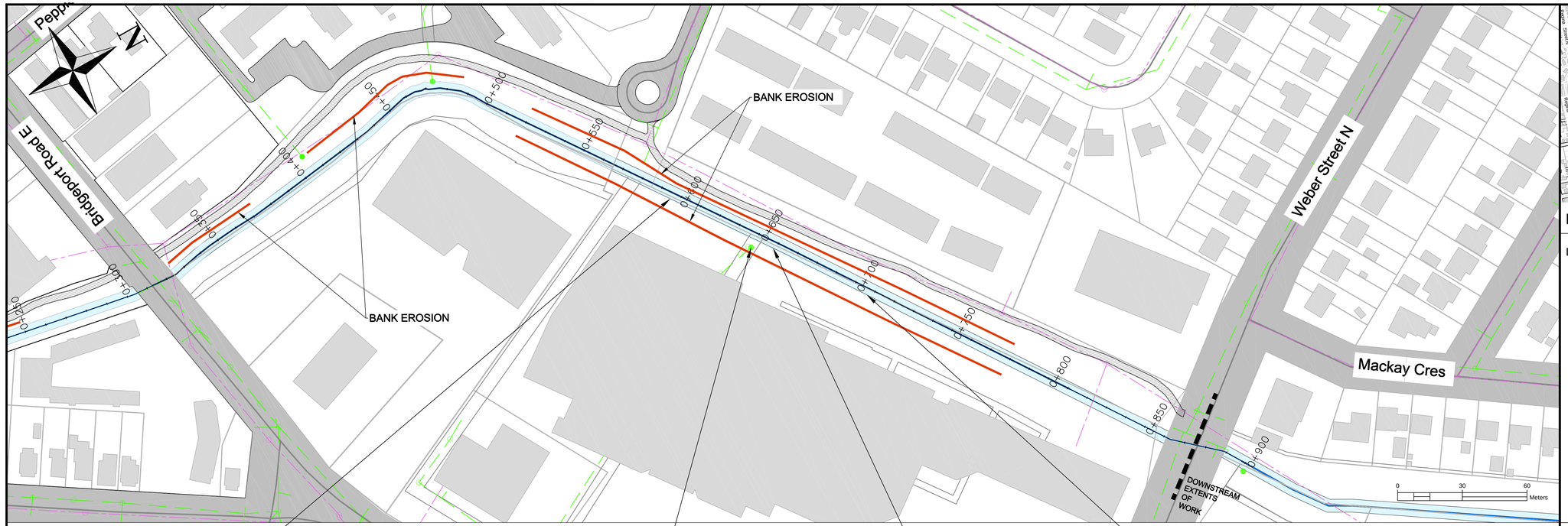
THE CITY OF Waterloo

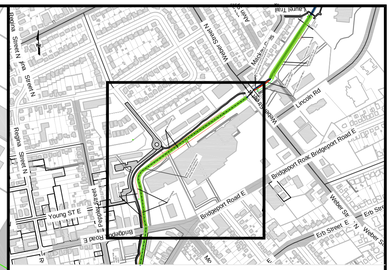
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE LRL - E7

EXISTING CONDITIONS - 1

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

UNDERMINING OF LOADING AREA PAVEMENT

NEAR VERTICAL BANK EROSION PUTTING TRAIL AT RISK

STORM OUTFALL ON ERODED BANK WITH LOADING AREA ABOVE

BANK EROSION ADJACENT TO PAVED LOADING AREA

Site Description:

Near-vertical bank erosion is occurring on both sides of channel. A recreation trail and sanitary sewer run along the left bank. The eroding bank is within 1 m of the trail in some areas. Private property is located on the top of the right bank with erosion posing a risk to a fire hydrant, parking lot, loading area, and structures.

Numerous storm outfalls are in poor repair. Concrete rubble and yard waste dumping on the bank was noted at the upstream end of the site.

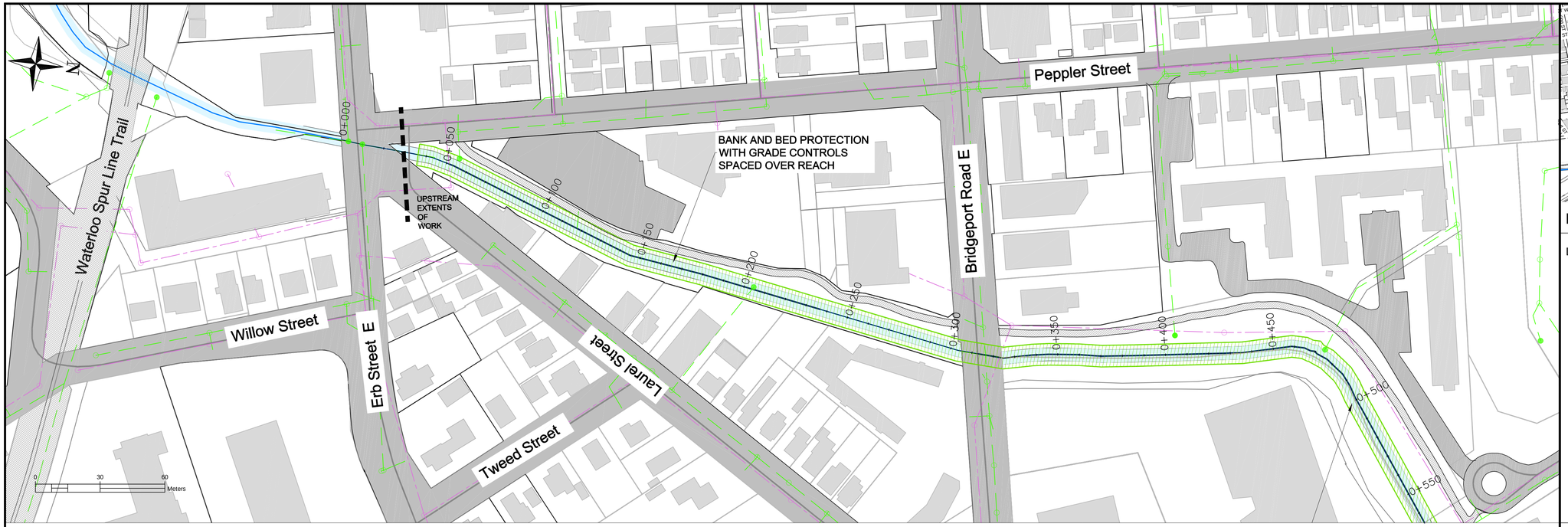
THE CITY OF Waterloo

CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE LRL - E7

EXISTING CONDITIONS - 2

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



DRAFT - NOT FOR CONSTRUCTION

LEGEND

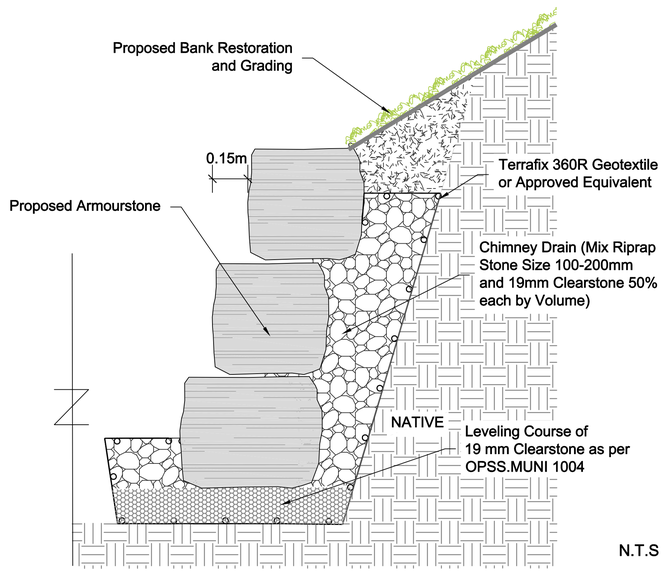
- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Conceptual Design:

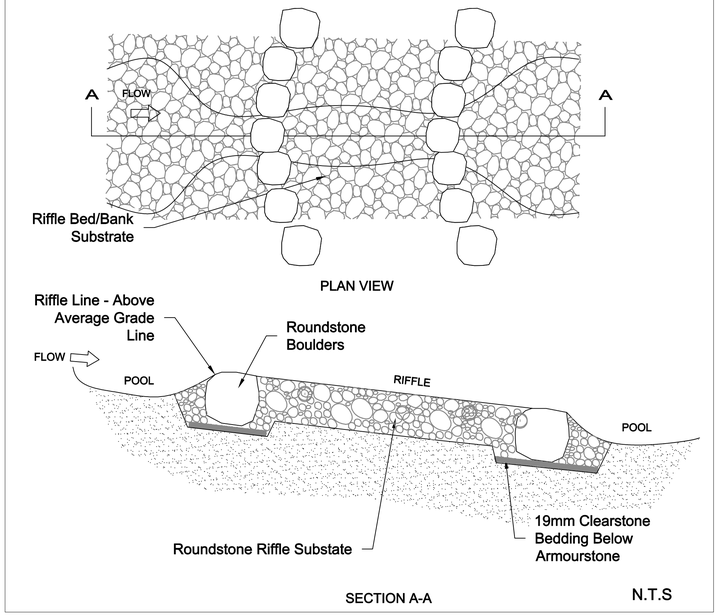
The preferred alternative at this site is full channel restoration. Due to the confined nature of the channel at this site, it is expected that armourstone walls will be required. Grade control on the channel bed will be included at the sanitary sewer crossing and elsewhere, as required, to protect the base of the armourstone wall from undermining. Vegetation plantings at the top of the armourstone wall should be included where space permits.

To inform the detailed design, a geotechnical investigation will be required at the onset of the project.

DETAIL 1 - TYPICAL ARMOURSTONE WING WALL



DETAIL 2 - TYPICAL GRADE CONTROL STRUCTURE



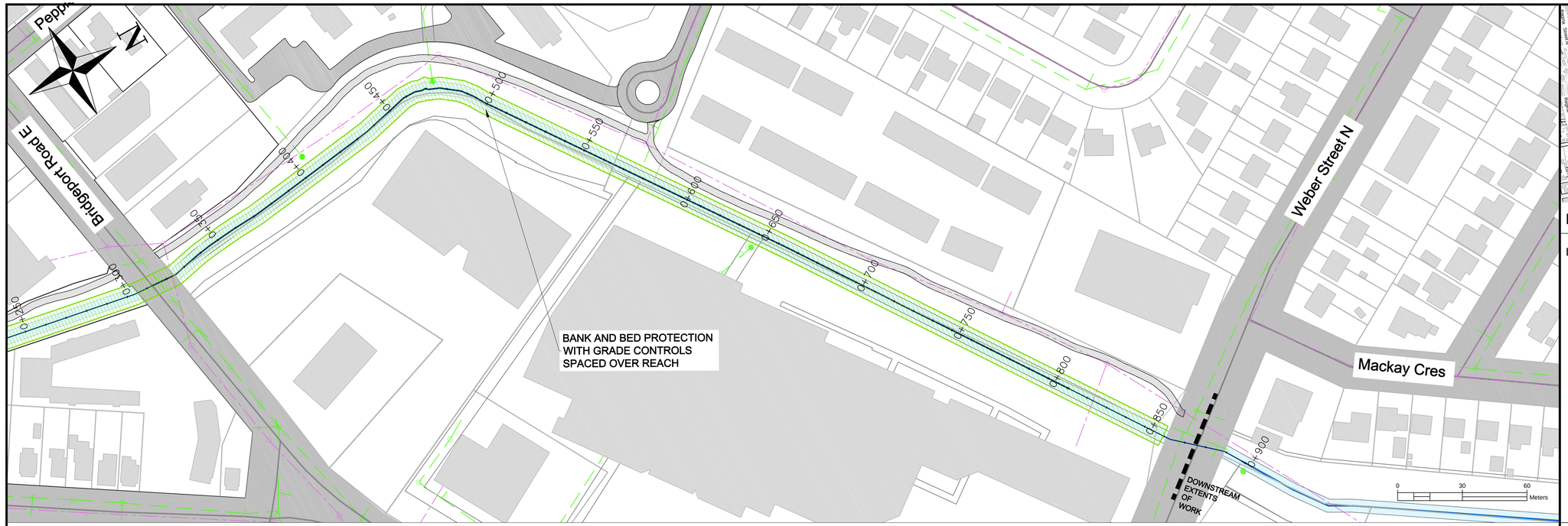
THE CITY OF Waterloo

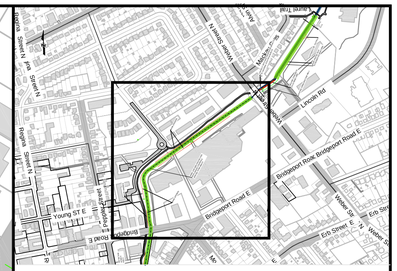
CITY OF WATERLOO
INFRASTRUCTURE AND
ENVIRONMENTAL SERVICES

SITE LRL - E7

PROPOSED CONDITIONS - 1

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



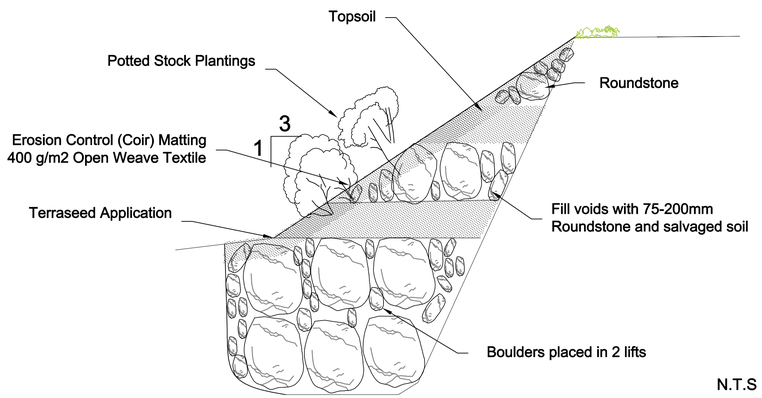


DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

DETAIL 3 - VEGETATED BUTTRESS DETAIL

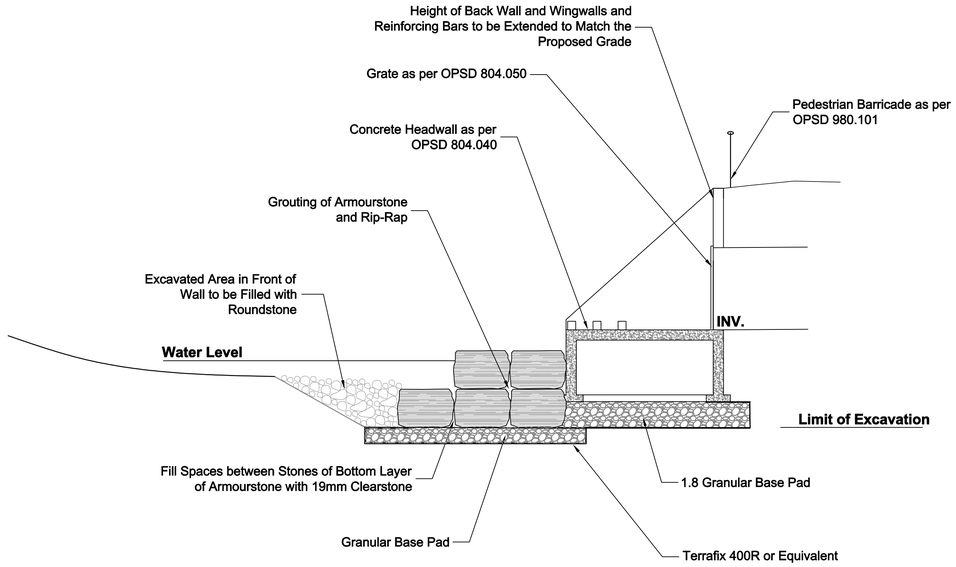


N.T.S

NOTE:

300MM TOPSOIL SHOULD BE PLACED BETWEEN LIFTS TO CREATE ROOT ZONE FOR VEGETATION GROWTH.

DETAIL 4 - OUTFALL RESTORATION DETAIL



Conceptual Design:

The preferred alternative at this site is full channel restoration. Due to the confined nature of the channel at this site, it is expected that armourstone walls will be required. Grade control on the channel bed will be included at the sanitary sewer crossing and elsewhere, as required, to protect the base of the armourstone wall from undermining. Vegetation plantings at the top of the armourstone wall should be included where space permits.

To inform the detailed design, a geotechnical investigation will be required at the onset of the project.

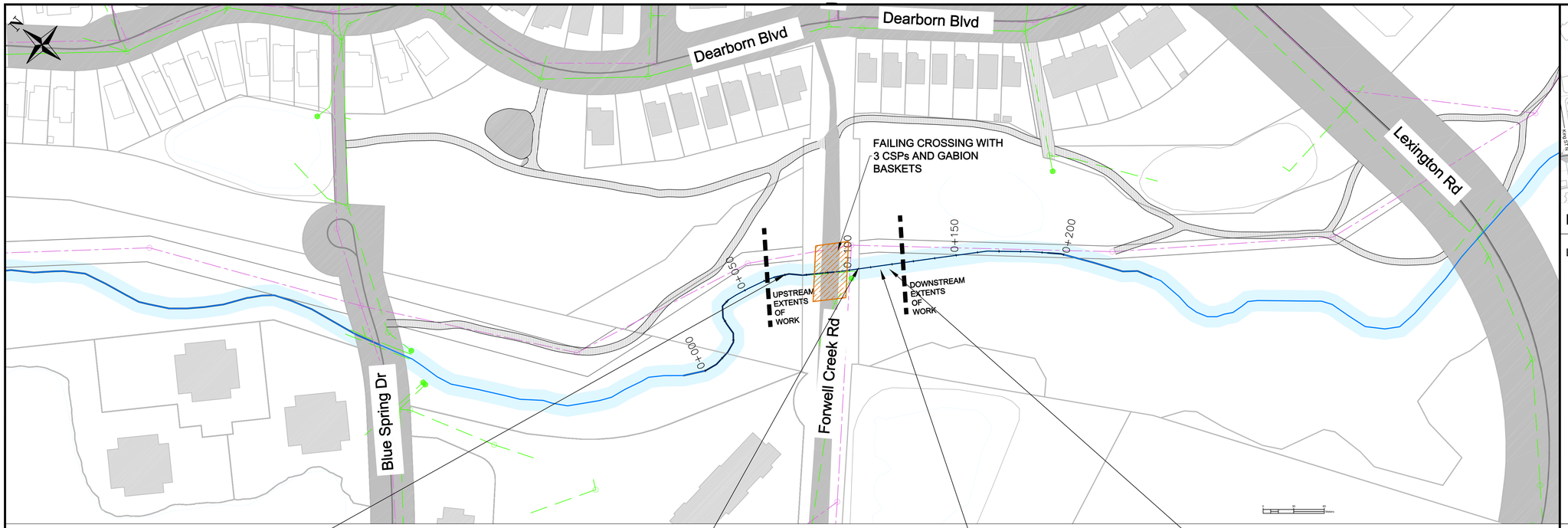
THE CITY OF Waterloo

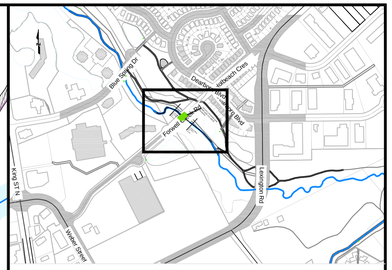
CITY OF WATERLOO
INFRASTRUCTURE AND
ENVIRONMENTAL SERVICES

SITE LRL - E7

PROPOSED CONDITIONS - 2

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

UPSTREAM FACE OF CULVERTS

EMBANKMENT EROSION

DOWNSTREAM FACE OF CULVERTS

DOWNSTREAM FACE OF CULVERTS

Site Description:

The culverts and headwall for the Forwell Creek Road recreational trail crossing are in very poor condition. The gabion baskets are slumping and the CSP culverts are deforming and rotting out. There appear to have been maintenance works on the culverts but the condition of the culverts has continued to degrade. A recreational trail, a sanitary sewer, a natural gas pipeline, and hydro lines cross the creek in this location. Material has been lost from the sides of the trail and gravel restoration works have continued to erode.

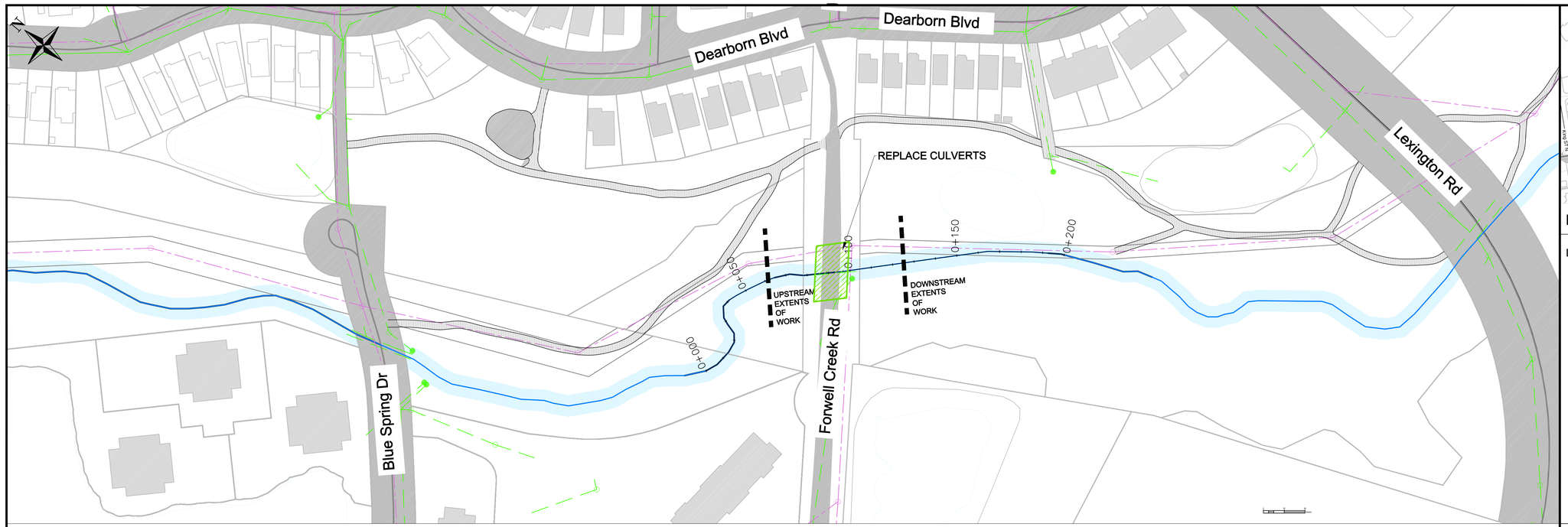
THE CITY OF Waterloo

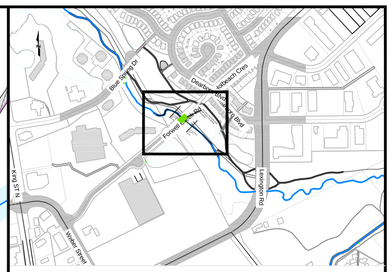
CITY OF WATERLOO
INFRASTRUCTURE AND
ENVIRONMENTAL SERVICES

SITE FRW - E2

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089



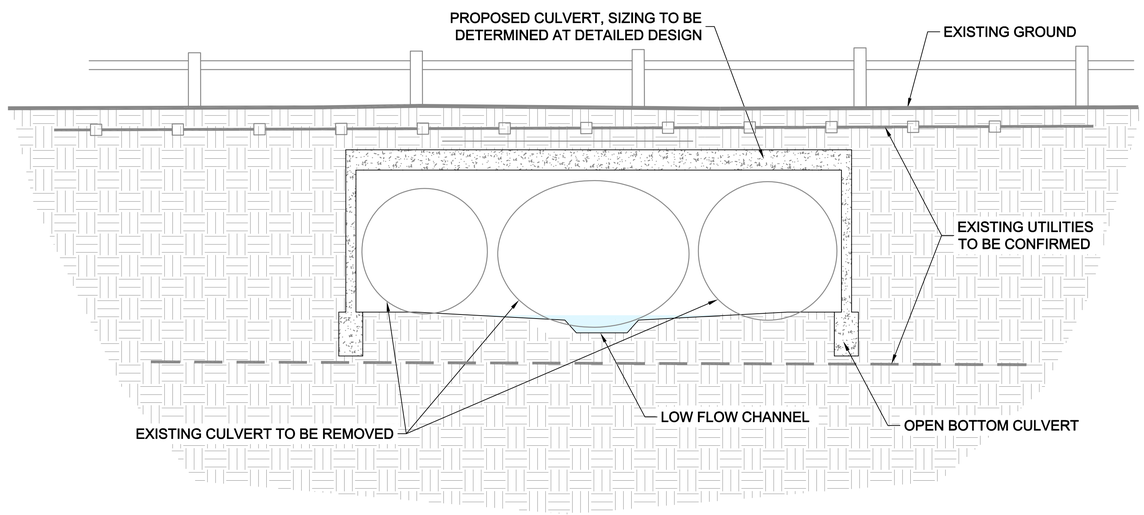


DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

DETAIL 1 - TYPICAL CULVERT REPLACEMENT DETAIL



Conceptual Design:

The preferred alternative at this site is local works. A hydraulic assessment should be undertaken to determine the appropriate sizing for the culvert replacement. Additionally, a geotechnical investigation should be undertaken at the onset of the project to inform the culvert replacement design. Since a recreational trail, a sanitary sewer, a natural gas pipeline, and hydro lines cross the creek in this location, the utility owners should be contacted at the start of the project. Utility requirements should be identified and incorporated into the design for the culvert replacement.

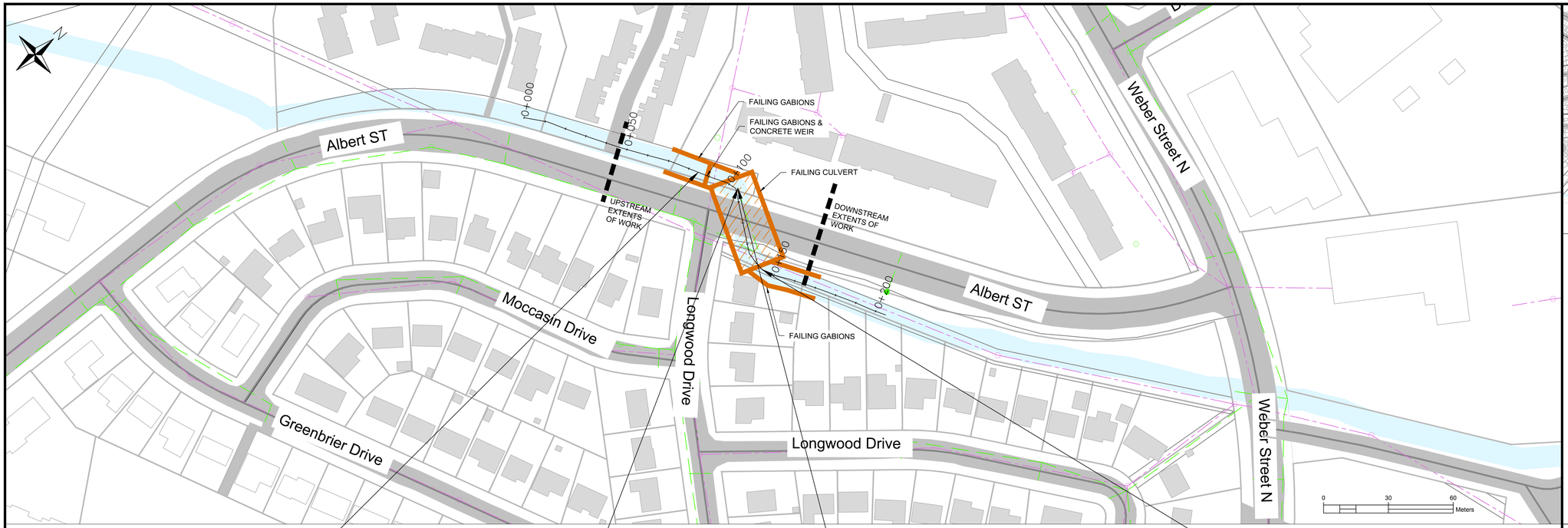
THE CITY OF Waterloo

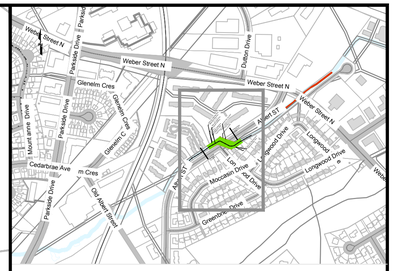
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE FRW - E2

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

FAILING GABION BASKET WEIR

FAILING CONCRETE AND GABION BASKET WEIR ON UPSTREAM SIDE OF ALBERT STREET

CULVERT ON UPSTREAM SIDE OF ALBERT STREET

CONDITION OF CULVERT ON DOWNSTREAM SIDE OF ALBERT STREET

Site Description:

On the downstream side of the Albert Street crossing, the left side of the culvert is collapsing. The gabion baskets over the culvert are also failing in this area and the sidewalk above is cracked. The issue may be related to road drainage. Boreholes were observed in this area suggesting work may be underway.

On the upstream side of Albert Street, a gabion weir is failing with scour occurring downstream of the weir. The base layer of the gabion treatments is failing and as is the concrete lining on the bed.

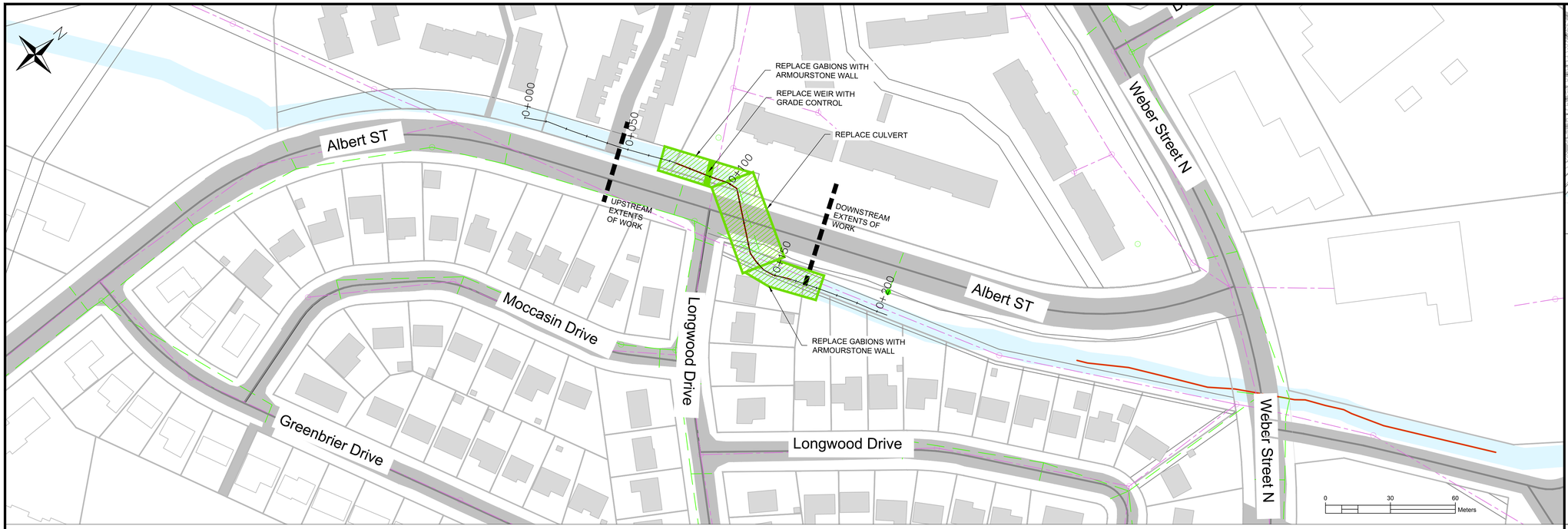
THE CITY OF Waterloo

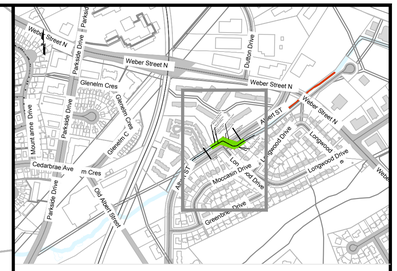
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CDR - E3

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

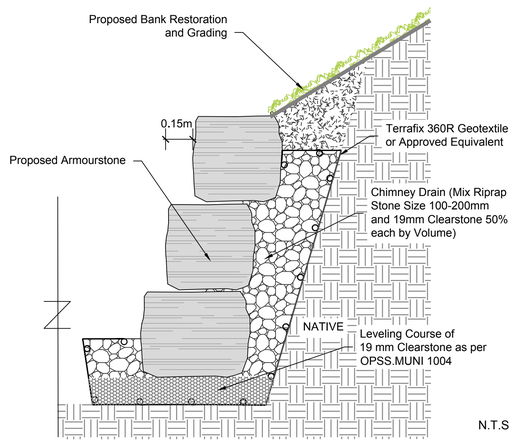
LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Conceptual Design:

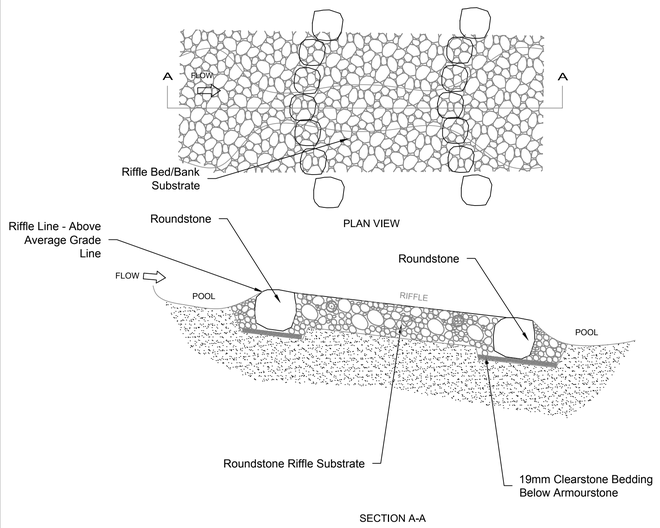
The preferred alternative at this site is local works. A hydraulic assessment of the culvert should be performed to determine the appropriate sizing for a new culvert. A geotechnical investigation should also be completed at the onset of the project to inform the culvert and bank treatment designs. The existing culvert and gabion baskets will be removed and replaced. It is expected that armourstone walls will be required to replace the gabion baskets given the confined nature of the creek corridor. The existing gabion weir will be replaced with riffle grade control which will incorporate fish passage.

DETAIL 1 - TYPICAL ARMOURSTONE RETAINING WALL

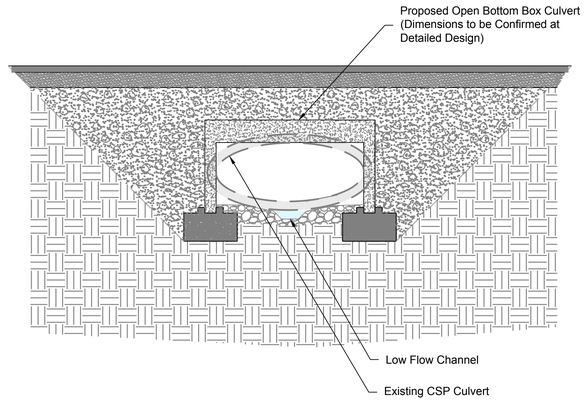


N.T.S

DETAIL 2 - TYPICAL GRADE CONTROL STRUCTURE



DETAIL 3 - TYPICAL OPEN BOX CULVERT



N.T.S

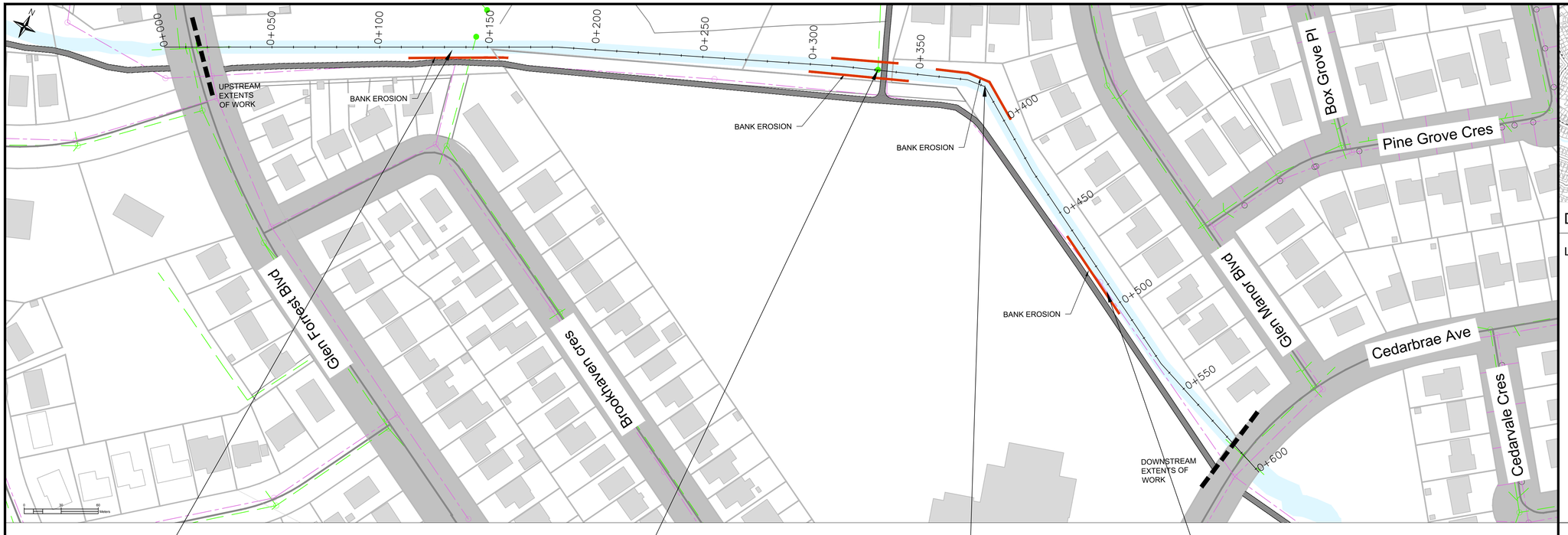
THE CITY OF Waterloo

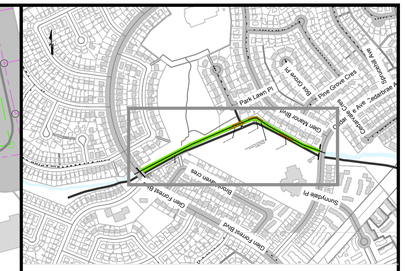
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CDR - E3

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

LOCATION 4 - ERODED BANK AT MH.

LOCATION 3 - STORM SEWER OUTFALL

LOCATION 2 - FAILING GABION BASKETS ON LEFT BANK

LOCATION 1 - SCOURED BANK IMMEDIATELY UPSTREAM OF MH

Site Description:

Location 1: There is a sanitary MH in the creek with bank scour upstream of the MH. A large tree stump was observed at the base of the MH. Recent bank work upstream of the MH was observed consisting of roundstone around a PVC storm sewer outfall. Works may have been completed to protect the trail from the eroding bank.

Location 2: A gabion treatment on an outside bend is failing. Private property is located behind the gabion treatment. Trees growing in front and behind the gabions are providing some stabilization to the failing treatment. A sanitary sewer MH is located on the opposite side of the creek at least 4 m from the top of bank and does not appear to be at risk at present.

Location 3: The right bank is eroding towards a sanitary sewer MH. The bank material appears to be sandy and a large slump has developed. A rill has also developed from surface runoff towards the MH. On the opposite bank, shrubs in front of a storm sewer appear to be blocking flows. Upstream, banks were steep and trees were observed to be leaning over the creek.

Location 4: A sanitary sewer MH is located within 1 m of the top of bank. Roots from a dead ash tree are holding the bank at present. The creek is entrenched in this area and bank erosion is likely once the ash tree is lost. There may be an opportunity to realign the creek away from the MH.

Note: locations are numbered from downstream to upstream within the erosion site.

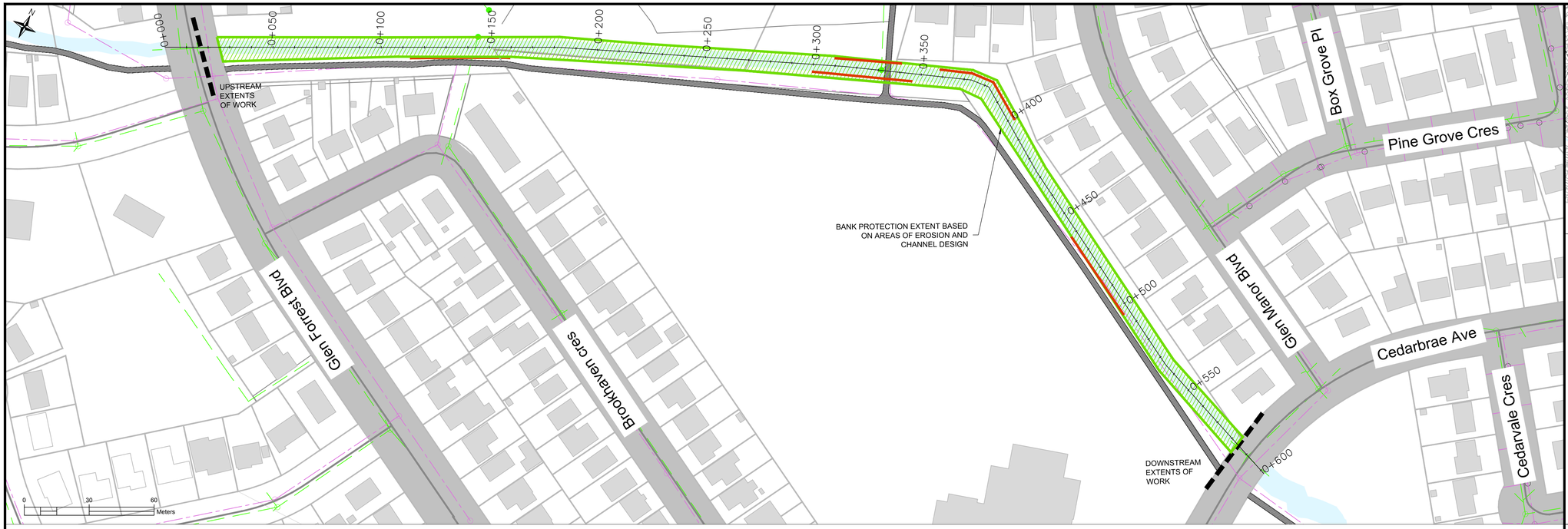
THE CITY OF Waterloo

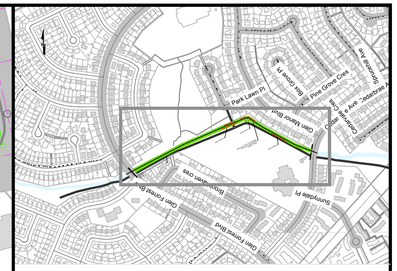
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CDR - E4

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

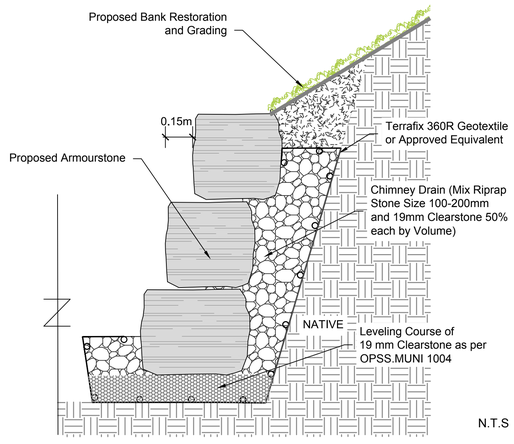
LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

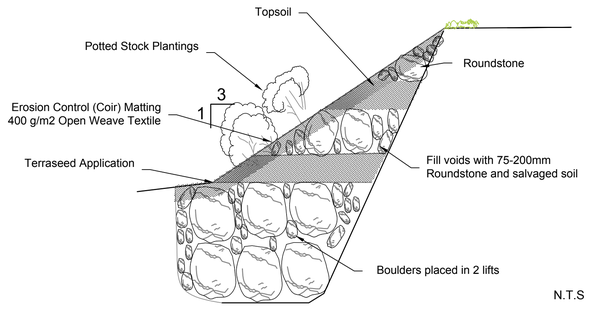
Conceptual Design:

The preferred alternative at this site is full channel restoration. A geomorphic assessment should be completed at the onset of the detailed design to inform the restoration works. Consideration to channel sediment transport processes should be given to assess the impacts of potential bank treatments. During the detailed design, consideration should be given to moving the trail away from the creek, where possible, and using vegetated treatments where space is available. The detailed design must also provide protection to buried sanitary sewer infrastructure.

DETAIL 1 - TYPICAL ARMOURSTONE RETAINING WALL



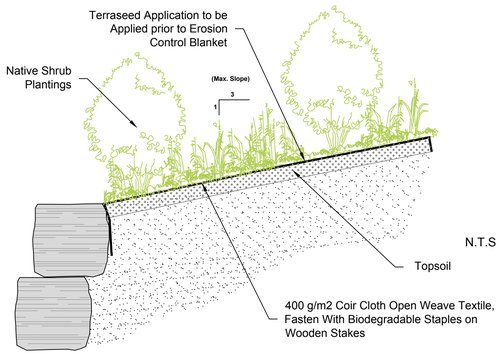
DETAIL 2 - TYPICAL VEGETATED BUTTRESS DETAIL



NOTE:

300MM TOPSOIL SHOULD BE PLACED BETWEEN LIFTS TO CREATE ROOT ZONE FOR VEGETATION GROWTH.

DETAIL 3 - TYPICAL BANK RESTORATION AND GRADING



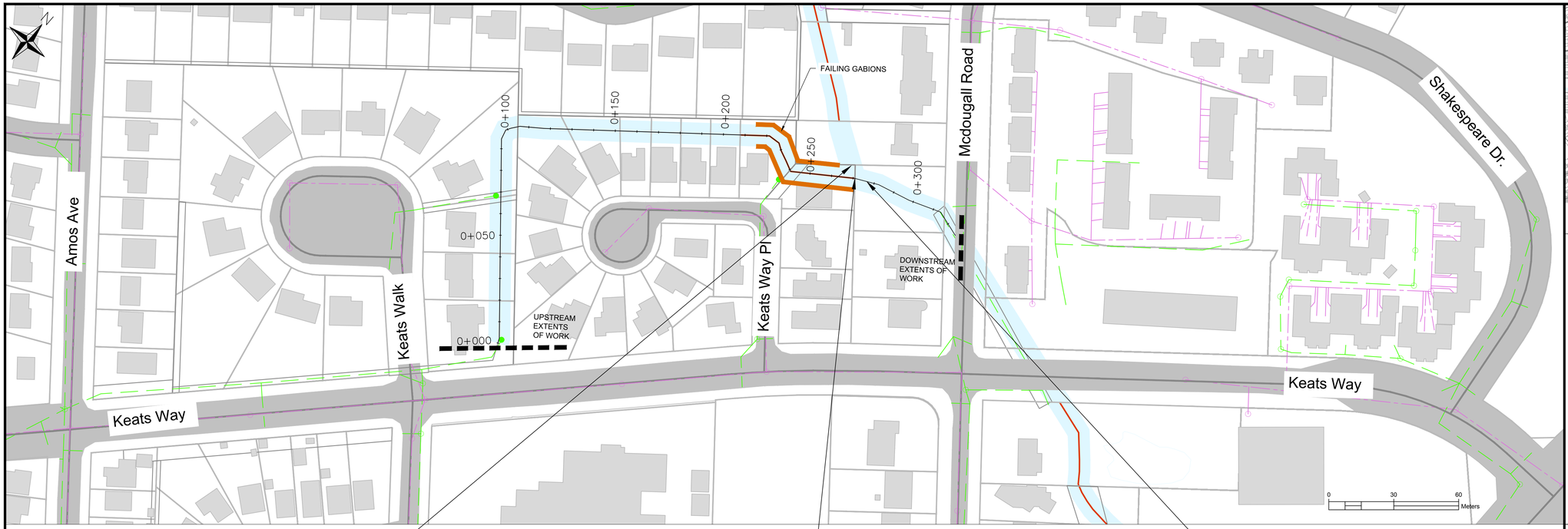
THE CITY OF Waterloo

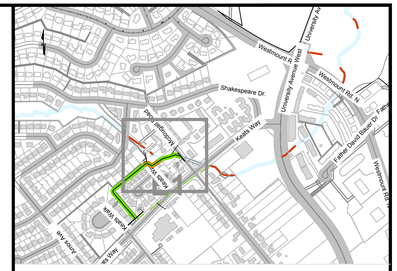
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CDR - E4

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave.,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Site Description:

Gabion basket bank treatments are failing behind 116 Keats Way Place. The gabions are located on the south side of the creek and the building is located within 5m of the top of bank.

HOUSE LOCATED WITHIN 5 M OF THE TOP OF BANK

FAILING GABION BASKETS

FAILING GABION BASKETS

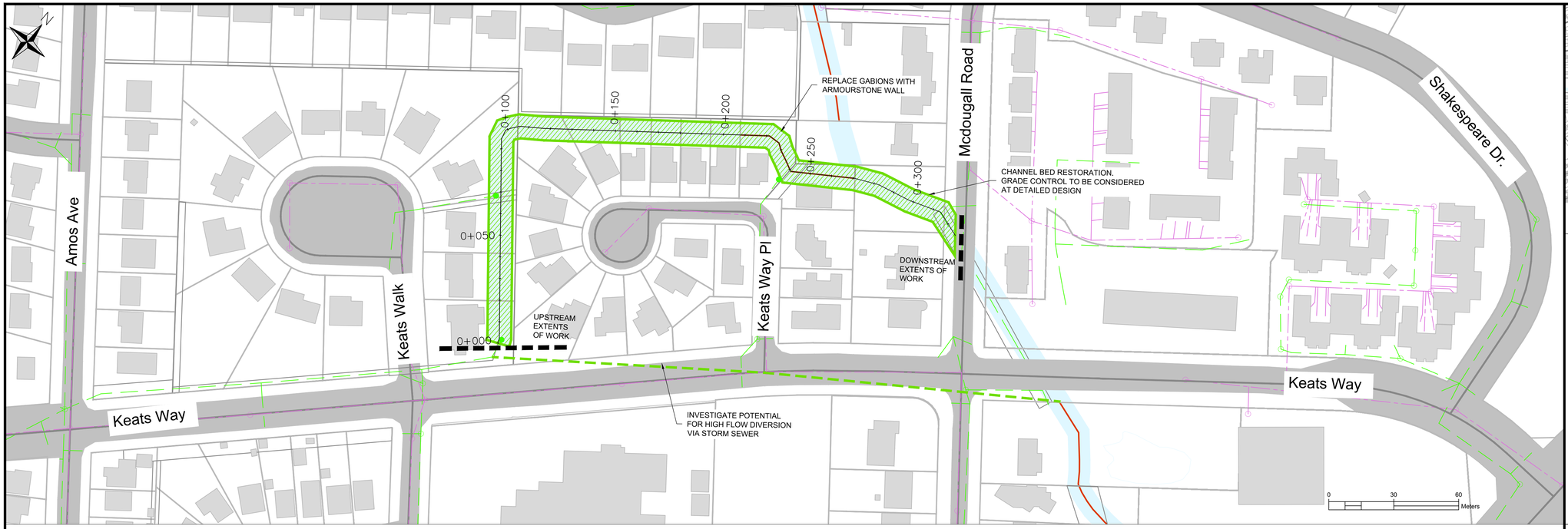
THE CITY OF Waterloo

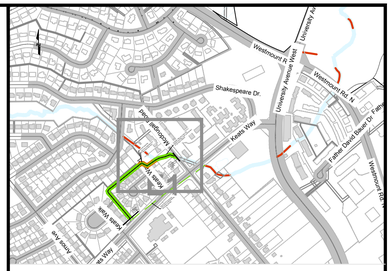
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CLR - T1-E1

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

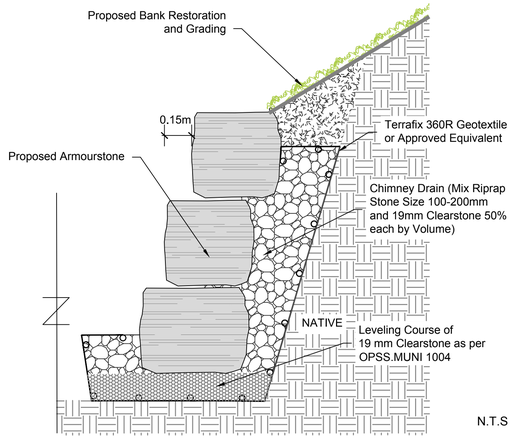
- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Conceptual Design:

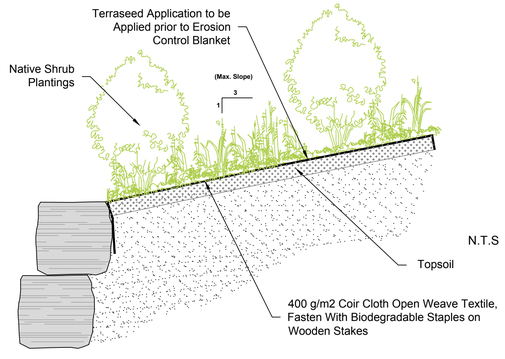
The preferred alternative at this site is full channel restoration. The existing gabion baskets will be removed and replaced with armourstone walls. Due to the confined nature of the corridor in this area, it is expected that softer channel restoration measures will not be feasible. A geotechnical investigation will be required at the onset of the project to inform the armourstone wall design and assess the potential construction impacts to the adjacent building.

Additionally, a high flow diversion via storm sewer may be investigated.

DETAIL 1 - TYPICAL ARMOURSTONE RETAINING WALL



DETAIL 3 - TYPICAL BANK RESTORATION AND GRADING



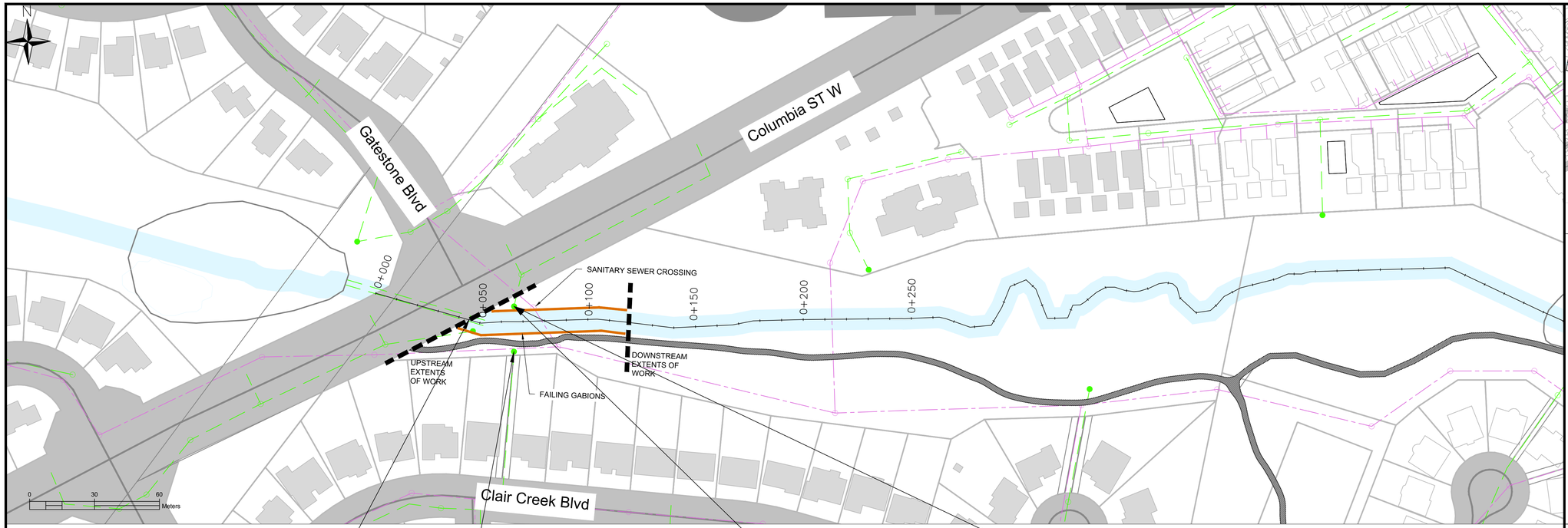
THE CITY OF Waterloo

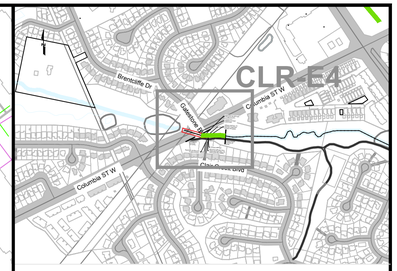
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CLR - T1-E1

PROPOSED CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Site Description:

Gabion basket bank treatments are in varying states of failure extending from Columbia Street downstream to 2 storm sewer outfalls. A pile of rip rap has developed in this area. A sanitary sewer crosses under the creek in the vicinity of the storm sewer outfalls. At Columbia Street, 2 CSPs convey flows under the road. The CSP on the east appears to be deformed.

GABION BASKET HEADWALL AT COLUMBIA STREET WITH LOWER BASKETS EMPTYING

GABIONS AROUND SECOND OUTFALL WITH ENERGY DISSIPATER GABION BLOCK IN CENTRE OF CHANNEL UPSTREAM

RIP RAP WITH FAILED GABION BASKETS AND STORM OUTFALL IN BACKGROUNDS

FAILED GABIONS OVER STORM SEWER OUTFALL

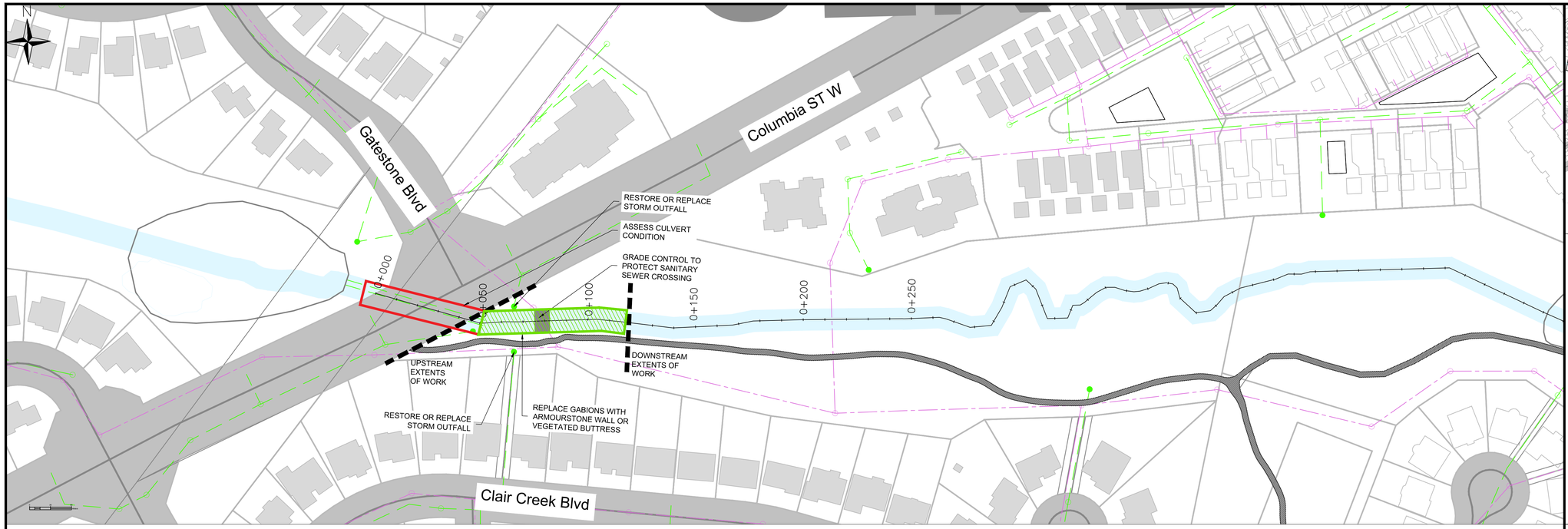
THE CITY OF Waterloo

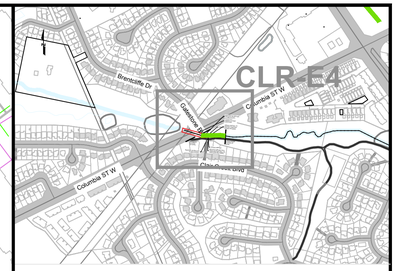
CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CLR - E4

EXISTING CONDITIONS

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave.
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089





DRAFT - NOT FOR CONSTRUCTION

LEGEND

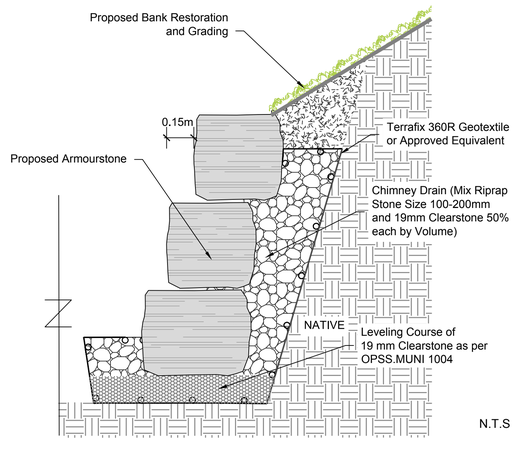
- SANITARY SEWER
- STORM SEWER
- STORM MAINTENANCE HOLE
- SANITARY MAINTENANCE HOLE
- STORM OUTFALL
- PROPERTY LINE
- EXISTING TRAIL

Conceptual Design:

The preferred alternative at this site is full channel restoration. The existing gabion baskets would be removed and replaced with armourstone walls and/or vegetated buttresses depending on the space available. The storm sewer headwalls will be restored and grade control will be required on the channel bed to protect the sanitary sewer crossing. The culvert condition at Columbia Street West should be assessed and replaced if required.

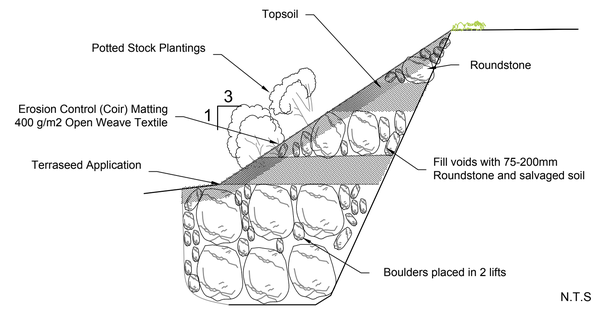
To inform the detailed design, a geotechnical investigation will be required at the onset of the project.

DETAIL 1 - TYPICAL ARMOURSTONE RETAINING WALL



N.T.S

DETAIL 2 - TYPICAL VEGETATED BUTTRESS DETAIL

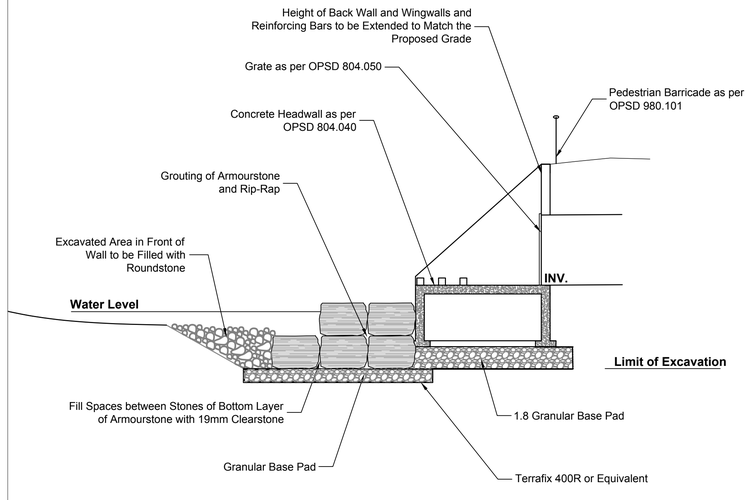


N.T.S

NOTE:

300MM TOPSOIL SHOULD BE PLACED BETWEEN LIFTS TO CREATE ROOT ZONE FOR VEGETATION GROWTH.

DETAIL 3 - TYPICAL OUTFALL RESTORATION DETAIL



THE CITY OF Waterloo

CITY OF WATERLOO
INFRASTRUCTURE AND ENVIRONMENTAL SERVICES

SITE CLR - E4

PROPOSED CONDITIONS

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