Yellow Creek Geomorphic Systems Master Plan

Municipal Class Environmental Assessment

City of Toronto

20 February 2025

→ The Power of Commitment

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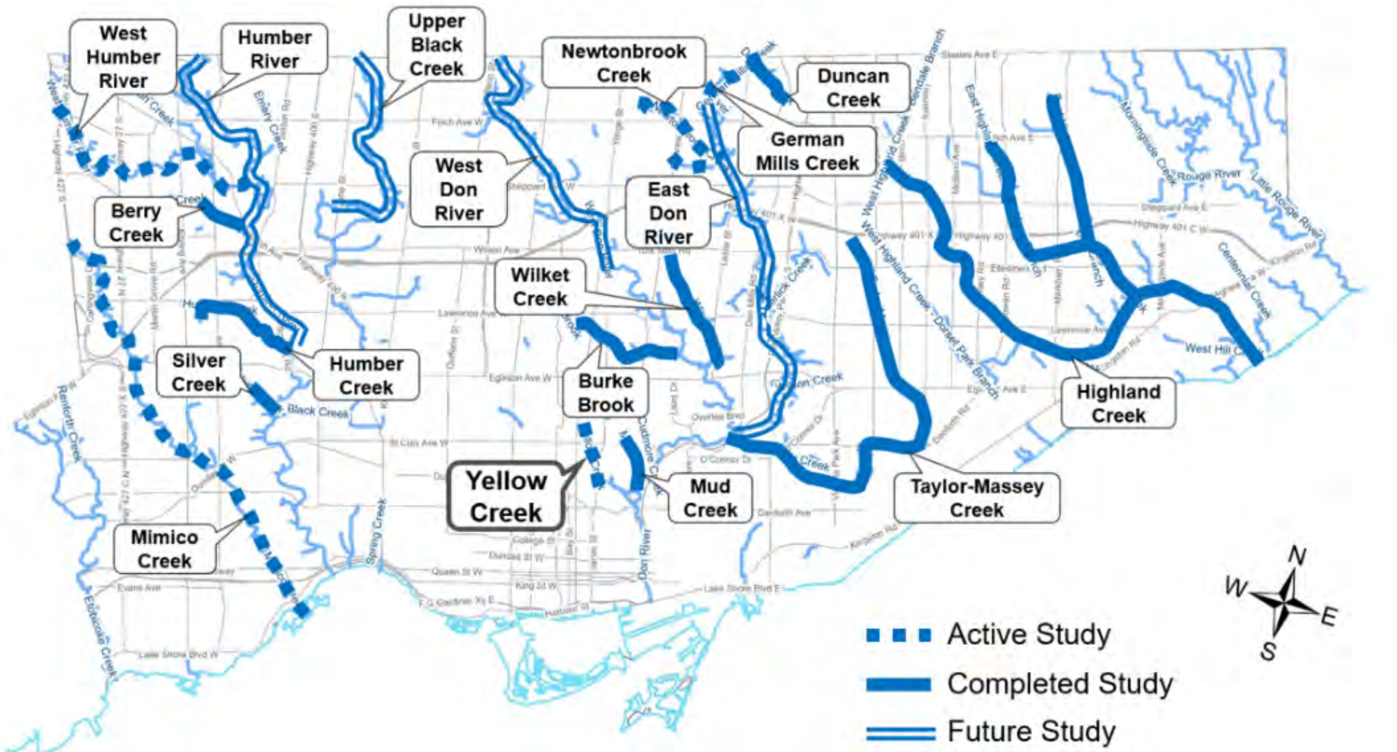
Executive Summary

Introduction

The City of Toronto (City) initiated the Yellow Creek Geomorphic Systems Master Plan (YCGSMP) Municipal Class Environmental Assessment (MCEA) in 2020, as one of five ongoing GSMPs across the City, to identify and assess water and storm sewer infrastructure in Yellow Creek that is at risk of erosion from high flows due to storms and snow melt runoff (Project).



Watercourse studies across the City of Toronto

The Study Area for this Project includes the 1.3 km aboveground reach of Yellow Creek within the Vale of Avoca between Mount Pleasant Cemetery and the downstream inlet structure upstream of the crossing of Mount Pleasant Road. At-risk Toronto Water infrastructure within the Study Area includes: six stormwater outfalls with associated storm sewer pipes, one channel inlet at the downstream limit of the watercourse, one stormwater/reservoir discharge outfall, one watermain crossing, and one watermain adjacent to the watercourse within 5 metres of the bank.

Local urbanization of the land surrounding the remnant open waters of Yellow Creek occurred in the early 1900's. The upstream stormwater pipe network that discharges to Yellow Creek's open channel from underneath Mt Pleasant Cemetery was in place by 1960. Full urbanization of the Yellow Creek subwatershed by the 1960's has significantly increased stormwater runoff to Yellow Creek and transformed the creek into a flashy, runoff dominated watercourse. Anecdotal evidence suggests that quarried block walls along Yellow Creek were constructed in the early 1900's as an initial effort at armouring the channel. Rapid runoff following storm events has led to significant erosion along the channel bed and banks of Yellow Creek, causing the early 1900's erosion control structures to fail particularly in the upper reaches and to be replaced by gabion basket protection in the early 1970s. The degradation / failure of these bank lining structures particularly in the upper reaches of Yellow Creek continues, and place Toronto Water infrastructure within the valley at-risk of exposure and damage in the present era. Recognizing that climate change may result in increased frequency and severity of storm events, it is imperative to develop an understanding of the erosive conditions and risks within and near the watercourse and develop plans to minimize the impact of the erosive forces on infrastructure.

The purpose of the Yellow Creek Geomorphic Systems YCGSMP is to

- Identify concerns related to erosion that may damage the City's water and storm sewer infrastructure.
- Develop solutions that protect the City's water and storm sewer infrastructure from excessive erosion processes within the stream.
- Improve stream functions, such as increasing stream bank stability, reducing erosion, enhancing stormwater conveyance, and improving habitats.

Historical Context

Yellow Creek has been known as both Rosedale Brook and Silver/Sylvan Creek in the past. Development of this area began in the 1880s when an iron bridge was built to connect the area to Yonge Street and encourage settlement (ASI, 2018). This bridge was replaced with the existing St. Clair Viaduct by 1924.

Postcard dated early 1900s shows historic Yellow Creek pedestrian bridge
Source: Yellow Creek Below Summerhilll Gardens Channel Repairs
(https://trca.ca/conservation/erosion-risk-management/restore/yellow-creek/)

Photos of Yellow Creek in the 1880's show a natural channel, whereas photographs from the 1900's portray the quarried block walls that we can still see today. Initial streambank stabilization efforts likely followed the meandering form of the original natural creek. The grouted quarried stone walls, spillways lined with rounded stone imbedded in concrete, and stone wall abutments at a pedestrian crossing bridge have an aesthetic character, but vastly altered Yellow Creek. As City development continued, the headwaters and downstream portion of Yellow Creek to its confluence with the Lower Don River were piped underground.

The rail crossing towards the downstream limit of the Study Area was established prior to 1939 and is present in all available aerial imagery. Prior to 1949 there were a number of residential developments surrounding Yellow Creek; however intensive urbanization of the surrounding area appeared to begin between 1954 and 1967 when many high-rise buildings were erected to the west of the Study Area and the number of residential properties significantly expanded. A small portion of the Mount Pleasant Cemetery expanded into the Study Area beginning in 1967 (TRCA, 2018). Channel stabilization works were implemented by the City in the early 1970s to mitigate erosion that was causing damage to infrastructure and private property. The works spanned the length of the current Study Area and consisted of stepped gabion basket revetments, riprap revetments and armourstone walls, instream boulder treatments, timber crib walls, and cemented riprap spillways.

Today, the creek headwaters flow southeast within the City’s storm sewer network before daylighting at a stormwater outfall downstream of the Mount Pleasant Cemetery, approximately 300 m northwest of the St Clair Avenue bridge. The Creek then flows approximately southeast for 1,275 m through the Vale of Avoca ravine and David A. Balfour Park (the Study Area), before entering a stormwater inlet 170 m south of the CP Rail crossing. From there the Creek is conveyed underground by a 2700-mm x 2550-mm box culvert for approximately 1,650 m before flowing into an open outfall channel to the Lower Don River.

Pedestrian bridge, grouted quarried stone walls and instream boulder treatments observed in 2020

The lands surrounding the remnant open waters of Yellow Creek were serviced initially by water supply from Lake Ontario and a combined sewer system. As-built drawings indicate installation of the combined sewer system around 1908 and 1910 to service the building of houses for residential use. The oldest storm outfall discharging into Yellow Creek was installed in 1924 which corresponds to the time period of the combined sewer installation. Other outlets were installed more recently in approximately 1965 and 1966. The mid 1960s represents the timeframe when significant areas of the combined sewer service area had road sewers installed to function as separated storm sewers to separate storm and sanitary sewers.

The current state of Yellow Creek is highly armoured. There are relatively short unarmoured sections within the middle of the Study Area, however bank erosion in these sections is notable. Localized erosion in the Creek over the past 50 years has damaged many of these former stabilization works to the extent that many gabion basket revetments, armourstone walls and stormwater outfalls have been outflanked and now lie within the channel. Addtionally, concrete aprons have been undermined exposing pedestrian bridge abutments and threatening Toronto Water infrastructure. Most of the relatively newer gabion basket bank treatments in the upper section of the creek have failed or are failing. However, quarried stone walls from the early 1900s are still intact over significant stretches of Yellow Creek, especially in the downstream sections of Yellow Creek.

The flow capacity of the existing North Inlet structure was sufficient to convey between the 10 and 25-year flow events. Therefore, significant flows would be contributed from the other stormwater outlets and through overland flow. The Yellow Creek Outlet structure will convey greater than the 100-year event without backwater impacts.

A formalized paved trail runs through the Yellow Creek valley corridor, also referred to as the Vale of Avoca. The trail runs parallel to the Creek on the west side, south of St. Clair Avenue, before crossing to the east side of the Creek at a mid-point in the watercourse. The trail is extensively used for public recreation and connects to the Mud Creek and Don Valley trail systems.

Master Plan

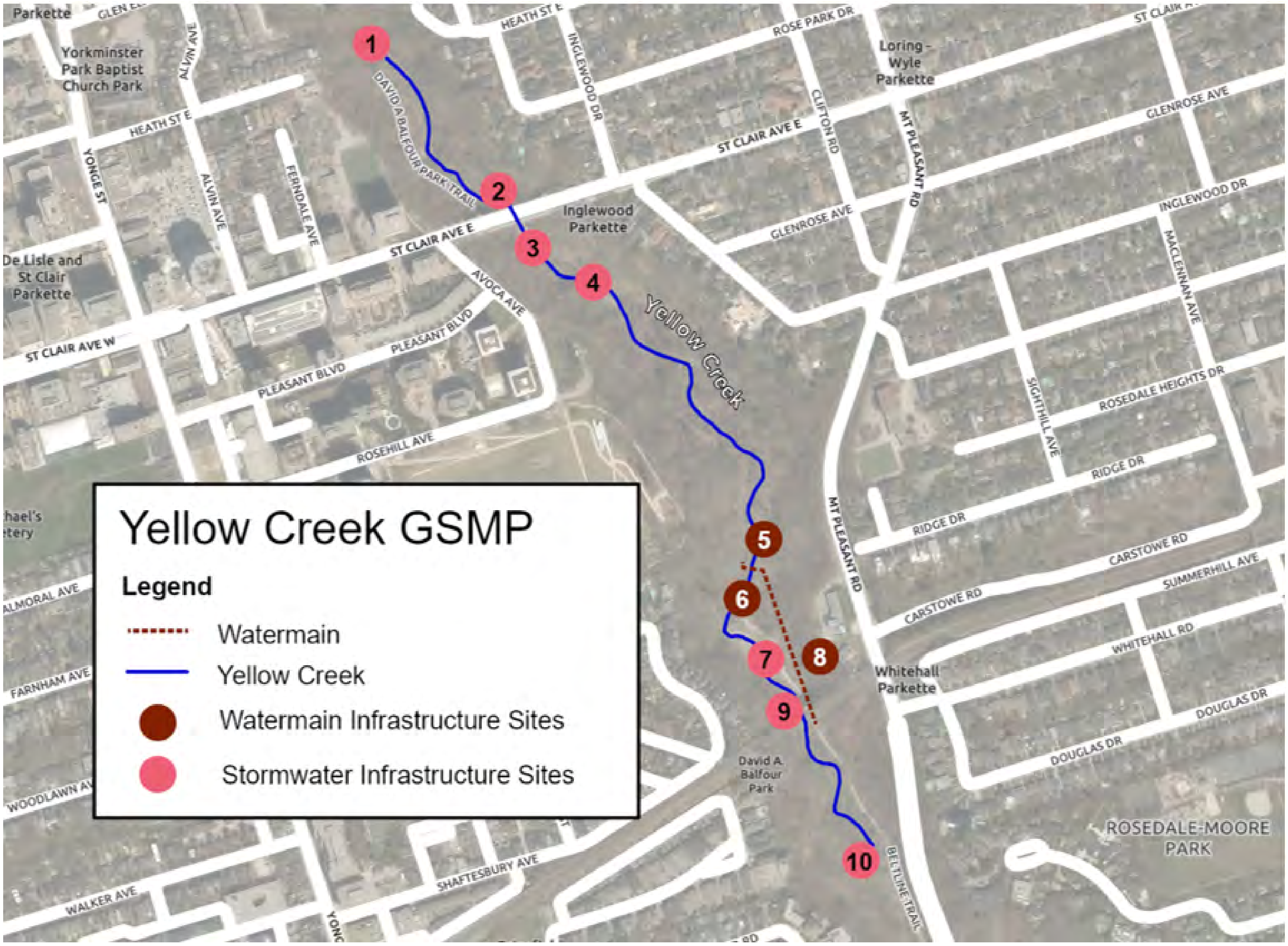
The YCGSMP is a long-range plan that examines the Creek rehabilitation needs within the geographic area with respect to protecting Toronto Water infrastructure and provides a framework and vision for recommended improvements. The YCGSMP project was carried out in accordance with the requirements of the MCEA (Municipal Engineers Association, October 2000 [as amended in 2007, 2011, 2015 and 2023]) following Approach #2 or "master plan approach" where the level of investigation, consultation, and documentation are sufficient to fulfill the requirements for Schedule B projects. This approach integrates infrastructure requirements or municipal works with environmental assessment planning principles. Master Plans document the long-term infrastructure needs for an area that can range from a local area, like the Yellow Creek channel, to an entire municipality. The Master Plan outlines an integrated plan guiding subsequent infrastructure projects or municipal works based on a holistic view of the area.

The YCGSMP has progressed through the following steps, consistent with the MCEA process, and the Adaptive Management of Stream Corridors in Ontario (2001) guideline:

1. Issue assessment
2. Problem confirmation and assessment
3. Past and future trends/disturbances to the Study Area
4. Assessment of channel response
5. Present stream functions
6. Forecast of ultimate configuration of Yellow Creek
7. Feasibility of intervention to protect Toronto Water infrastructure
8. Define and evaluate alternative solutions
9. Selection of the preferred solution

Study Conclusions Concerning State of the Creek, Risk to Toronto Water Infrastructure, and Prioritization of Intervention

Yellow Creek has been extensively modified in conjunction with the urbanization of the city over the last 130 years. The high level of urbanization and the lack of stormwater management (SWM) controls in the watershed is reflected in the rapid response of flows in the Creek to rainfall, which has resulted in frequent overtopping of the banks and high stream power, relative to other less urbanized areas. Historic channel alterations and fragmentation from the Don River Valley have resulted in extirpation of the Yellow Creek fish community within the Study Area. The surrounding forested river valley does have the potential to provide habitat to a number of terrestrial species at risk (SAR), as well as trees that are highly valued by the public.



Toronto Water At-Risk Infrastructure Sites 1 to 10 within the Study Area

The assessment of the existing conditions within Yellow Creek concluded that channel widening, lateral migration and degradation would continue within the Study Area without intervention, and these processes in the long-term would result in further damage to Toronto Water infrastructure, high total suspended solids (TSS)/bedload contributions to downstream Toronto Water treatment facilities, as well as risks to slope stability and public trails, loss of valley trees, and impacts to private property.

Within the Study Area, at-risk Toronto Water infrastructure was subdivided into Sites 1 to 10 for site-specific evaluation of erosion risk. Site 4, the storm outfall south of St Clair Avenue, was considered to be a high-moderate risk. This ranking was due to the fact that erosion has put the storm sewer outfall at risk; erosion by the stream channel against the valley wall within the sub-reach were notable; and the sub-reach was overall considered to be in poor condition. The remaining sites were identified as low or moderate risk.

The consequence of failure was then evaluated based on the type of infrastructure at the Site, potential impacts to downstream water quality of the watercourse in the event of infrastructure failure and impacts to the downstream ecosystem. The focus of the evaluation was on the potential failure of Toronto Water infrastructure, however secondary consideration was given to potential impacts to park infrastructure and private property. Site 8/9 was ranked highest with respect to consequence of failure. Should failure occur, it would impact a large watermain, a CPR bridge on private property, and an outfall.

The level of risk and the consequences of failure were then combined for each site in a Conceptual Risk Register. It was noted that there was no sanitary sewer infrastructure at risk within the YCGSMP Study Area. Failure of sanitary sewers versus storm or watermain infrastructure would inherently carry a much higher consequence of failure. As such, high priority rankings are generally reserved for exposed sanitary sewer crossings that are found in other watercourses across the City (City of Toronto Staff report dated June 8 2023 "**The Vale of Avoca/Yellow Creek – 2023 Update and Next Steps**" available at https://www.toronto.ca/legdocs/mmis/2023/ie/bgrd/backgroundfile-237424.pdf). This larger City-wide view was factored into the priority ranking of the Yellow Creek implementation plan.

Feasibility of Intervention

On a watershed or subwatershed scale, potential solutions would include the reduction of peak flows and associated energy within the system through implementation of stormwater management techniques designed to reduce stormwater runoff. Measures such as stormwater detention ponds are difficult to implement in the Yellow Creek area, which is already in a densely urbanized state. Other measures, such as disconnecting downspouts, installing rain barrels, exfiltration systems, etc., would not be sufficient to address the issue alone.

As Yellow Creek within the Study Area has already been highly altered with hard bank stabilization structures, many of which are in a degraded state due to age and may be further influencing erosion within the creek, direct intervention is warranted through local protection works and/or sub-reach scale works.

Problem/Opportunity Statement

Through the MECA process, the problem/opportunity statement for the Yellow Creek study area was developed as follows:

> "Full urbanization of the Yellow Creek subwatershed over 50 years ago, has significantly increased stormwater runoff to Yellow Creek and transformed the creek into a flashy, runoff dominated watercourse. The banks of the creek were historically lined with quarried rock structures in the early 1900's and several stretches were replaced with gabion structures in the early 1970's, especially in the upper reaches of Yellow Creek. Rapid runoff following storm events has led to localized erosion along the channel bed and banks of Yellow Creek, particularly in the upper section of the Study Area, causing most of the existing gabion basket erosion control structures to fail or to be at risk of failing, placing Toronto Water infrastructure within the valley at-risk of exposure and damage. Recognizing that climate change may result in increased frequency and severity of storm events, it is imperative to develop an understanding of the erosive conditions and risks within and near the watercourse and develop plans to minimize the impact of the erosive forces on infrastructure. The purpose of the Yellow Creek Geomorphic Systems Master Plan is to identify improvements to Yellow Creek that will protect Toronto Water infrastructure while minimizing riparian ecosystem impacts and enhancing aquatic habitat, taking into consideration climate change adaptation."

Evaluation of Alternative Solutions

At-risk Toronto Water infrastructure Sites 1 to 10 were considered for site-specific potential solutions. Site 1was subsequently eliminated from further consideration due to its inclusion in upcoming planned works by the Toronto Region Conservation Authority (TRCA). Site 3 was eliminated from further consideration since it was recently repaired by the City.

Three alternative solutions were considered per Site as part of Phase 2 of the MCEA process for the Project: Do-Nothing, Local Works and Protection, and Sub-Reach Based Works. The following briefly describes each of the three alternative solutions:

1. Alternative Solution No.1: Do Nothing - The existing Toronto Water infrastructure would remain in its present location and no bank/bed protection works would be installed with this alternative. As a result, no actions would be undertaken to improve the conditions of the channel bed and banks surrounding the Sites within the Project limits. Although Alternative Solution No. 1 would not address the problem/opportunity statement, it was included as part of the Project because the MCEA states that the "Do Nothing" alternative should be considered by a proponent, like the City, in all projects because it provides a benchmark against which the benefits/consequences of the other alternatives can be measured.
2. Alternative Solution No.2: Local Works and Protection – Single phase construction over a short section of channel subject to priority and budget availability.
3. Alternative Solution No.3: Sub-Reach Based Works – Single or multiple phase construction over a long section of channel subject to priority and budget availability.

A comparative evaluation was undertaken of the alternative solutions taking the environment into consideration to identify a recommended solution for each of the sites based on the application of criteria. The evaluation criteria were developed based on the problem / opportunity statement, existing environmental conditions, and the range of alternatives being considered.

Each evaluation criterion was connected to a particular aspect of the environment (e.g., natural) as defined in the *Environmental Assessment* (*EA) Act* because the description of the effects of each alternative on the environment is required by the EA process. In addition, criteria were included for assessing the technical and financial aspects of the alternative solutions. One or more indicators were developed for each criterion to identify how the potential environmental effects were to be measured for each criterion.

Preferred Solution(s)

The preferred solution for Sites 2, 4, 5/6, 7, 8/9, and 10 is Alternative 3 – Sub-Reach Based Works based on the comparative evaluation carried out. Alternative 3 has the following advantages:

- Reduces the existing risks of damage and failure to Toronto Water infrastructure and mitigates existing erosion on a reach scale.
- Minimizes bed and bank erosion and reduces TSS to the greatest extent, thereby mitigating impacts to the proposed Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridge's Bay Treatment Plant.
- Establishes a long-term geomorphically stable bankfull channel that is adaptive to the potential impacts of climate change.
- Long-term benefits to both terrestrial and aquatic habitat.
- Stabilization of the watercourse and valley wall contacts benefits park infrastructure and private property.
- Anticipated high positive acceptance from community.
- Maximizes the cost and resource effectiveness through completing large scale restoration works under one contract and permit.

Implementation

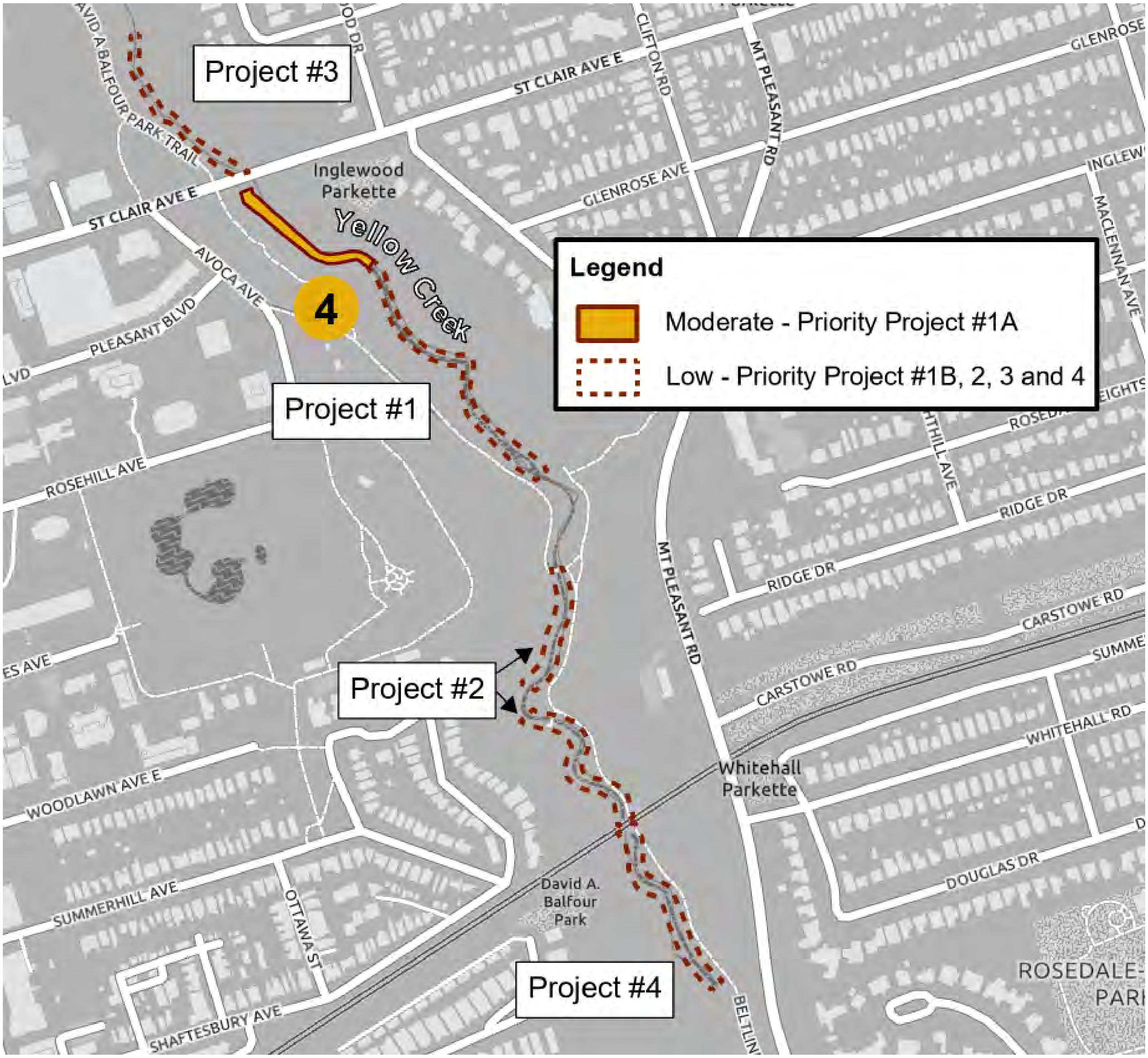
Since undertakings carried out by municipalities can vary in their environmental impact, the undertakings are classified as exempt, eligible for screening, B, and C within the MCEA with each classification having different requirements. The preferred solutions of the YCGSMP fall within the exempt and Schedule B project classifications.

Sites 5/6, 7 and 8/9 fall within the exempt category. The proposed natural channel design works will take place within sub-reaches that are entirely, or almost entirely, currently lined with existing bank stabilization measures such as gabion, armourstone or quarried rock wall. These materials will be replaced with similar or better stabilization measures. The existing path of the watercourse will be maintained. Exempt projects are exempt from the EA Act and can proceed directly to the implementation stage.

Sites 2 and 4 fall within the Schedule B category as the proposed works require some channel realignment, backfill of the existing channel, and/or works on more substantially unarmoured banks. The YCGSMP Schedule B Sites can be approved as part of this master planning process and can proceed to the implementation stage following the issuance of a Notice of Completion by the City, filing of the Master Plan report, and completion of the 30-day public comment period and subsequent 30-day Ministry of the Environment, Conservation and Parks review period.

Toronto Water Infrastructure Sites have been prioritized for construction based on the geomorphic risk to the infrastructure and the consequence of failure. The Sites were then further divided into projects based on their prioritization and geographic proximity to each other. Sites 2 and 4 are likely to be accessed from the Avoca Avenue trail entrance and via the watercourse, whereas Sites 5/6, 7, and 8/9 are to be accessed via the trail from Mount Pleasant Road. Based on the risk assessment and evaluation of alternatives, improvements to the Creek in segments greater than 150 m are recommended, resulting in four separate sub-reach projects. Project groupings for undertaking construction are as follows:

- Project 1A – Site 4 Local Works and Protection (moderate priority)
- Project 1B – Site 4 Sub-Reach Based Works (low priority)
- Project 2 – Sites 5, 6, 7, 8, 9 Sub-Reach Based Works (low priority)
- Project 3 – Site 2 Sub-Reach Based Works (low priority)
- Project 4 – Site 10 Sub-Reach Based Works (low priority)

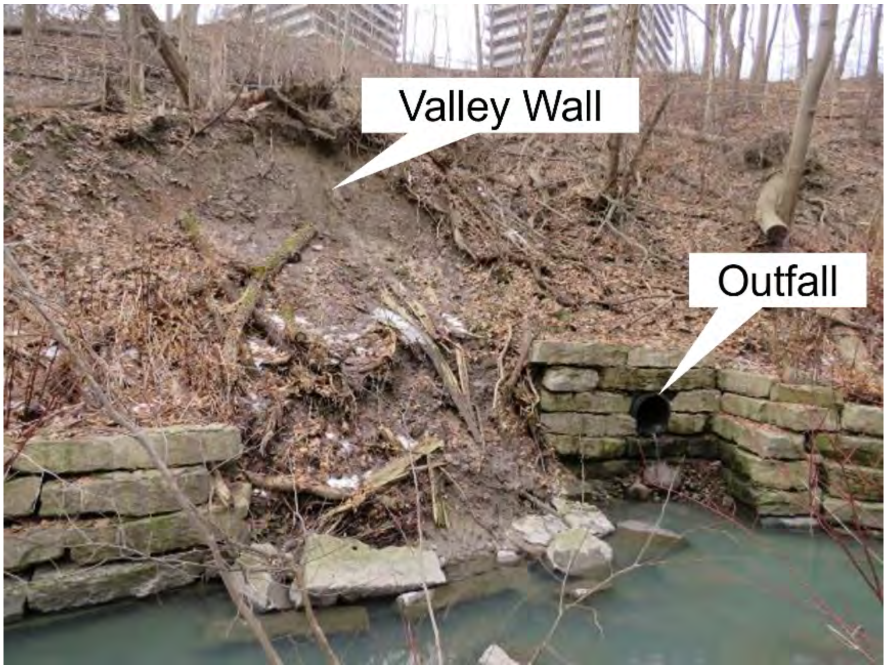


Recommended Projects based on YCGSMP Prioritization for Implementation

Project 1 involves channel engineering works for approximately 340 m of watercourse. The Project has been divided into Project 1A and Project 1B to reflect the higher priority need of the Site 4 storm sewer outfall. Project 1A consists of an 85 m section of creek and will involve the retrofit of the storm sewer outfall at Site 4 and provide a local realignment to protect the outfall. Project 1B consists of a 255 m length of creek and will involve the removal of the failed concrete spillway at the historic sawmill site.

Project 2 will address priority Sites 5, 6, 7, 8 and 9. Channel engineering works would address a 245 m length of channel. Engineered natural channel design would protect the storm sewer outfall and watermain infrastructure. Channel alteration will require that the upstream pedestrian bridge be replaced. Banks would be lowered to reconnect Yellow Creek to the floodplain.

Watercourse stability issues at Sites 7, 8 and 9 are anticipated to largely be addressed by Toronto Region Conservation Authority (TRCA) in the near future. Therefore, it is recommended that long-term observation of erosion at Toronto Water Infrastructure sites be implemented, as well as on-going communication with TRCA for these sites, with no further stream rehabilitation works planned. Sites 5/6 are also recommended for long-term observation, with proposed works taking place in the 10-to-20-year timeframe because most of the existing sub-reaches are armoured.



Project 1A would focus on the retrofit of the storm sewer outfall at Site 4 and local channel realignment

Project 3 involves channel engineering works over approximately 170 m of watercourse. Engineered natural channel design and the retrofit of the storm sewer outfall at Site 2 will be completed. The creek work proposed at the northern limit in Project 3 overlaps with private property. TRCA is undertaking a separate MCEA Study to address conditions at Site 1 and is in communication with the City. Therefore, the YCGSMP does not propose any works at Site 1, upstream of the identified Project 3 limits.

Project 4 involves channel engineering works to address a 180 m length of creek. The proposed work includes the retrofit of the storm sewer inlet to update the trash rack intake structure at Site 10. Streambanks would be lowered and regraded to reconnect Yellow Creek to its floodplain.

The following site groupings are expected to share similar access routes: Sites 2 and 4 and Sites 5/6, 7, 8/9, and 10.

Within Yellow Creek, Project 1A (Site 4) is recommended to be prioritized for restoration works out of the YCGSMP Sites. However, when considering other sites on a City-wide basis, it is anticipated that it is of a Moderate Priority, with works to take place in approximately 5 to 10 years' time. Project 1B, Project 2 (Sites 5/6, 7, 8/9), Project 3 (Site 2) and Project 4 (Site 10) are recommended to be addressed in the low priority timeframe of 10 to 20 years' time, separated into sub-projects based on geographic proximity. The Yellow Creek block wall lines most of the Yellow Creek Study Area and is currently in generally good condition. The City of Toronto intends to monitor the condition of this block wall. Deteriorating conditions will be used as an indicator for when low-priority projects will need to be considered for implementation in the long-term.

Adaptive management principles may dictate that the prioritization of the Sites could vary in the future if future storm events or slope instability concerns alter the conditions. In addition, the City may need to implement construction of the sub-reach work in phases due to needed reprioritization in the City-wide construction program owing to changing conditions due to weather events, emergency work requirements and/or capital funding constraints. Therefore, it is recommended that the sites be visually re-assessed on a 2 to 3-year rotation basis to ensure consistency with the implementation plan and Toronto Water priorities. This periodic field inventory would assess the Toronto Water infrastructure as well as the extent of channel erosion within the Study Area to determine if new erosion may pose a new risk to public health and safety.

Study Conclusions

YCGSMP's key conclusions concerning the present state of the geomorphic system, ecological habitat and risk to Toronto Water infrastructure within the Yellow Creek Study Area include:

– Yellow Creek has undergone drastic human-made alterations within the past century and current flashy, extreme stormwater flows continue to alter the landscape and damage existing bank stabilization structures, most notably in Reach 1 and 2 of the Study Area.
– Direct fish habitat within Yellow Creek is no longer present due to historic channel alterations and underground piping of the system through storm water pipes, however the surrounding valley provides potential habitat to many species, including SAR, and contains mature trees and recreational hiking opportunities that are highly valued by the surrounding community.
– A thorough detailed assessment of geomorphic processes active within each of the four reaches of Yellow Creek was conducted, along with an analysis of risks to bank protection measures and is provided in Section 7.
– A total of 1093 m, or 87% of the Yellow Creek channel through the Study Area had existing bank protection, in varying states of repair. The quarried rock walls have been present for approximately 100 years and long sections remained in fair condition, particularly evident through Reaches 3 and 4 where a meandering pattern was maintained when the walls were installed. This is unique since stabilization of creek banks within the City of Toronto in the past typically involved first straightening the watercourse first before stabilizing.
– Geomorphic adjustments observed within the Yellow Creek Study Area included channel widening, lateral migration and degradation, most evident within Reaches 1 and 2 where existing bank protection was failing (71%) or had failed (60%). Notable rapid creek bank erosion into the valley wall was occurring at an outside bank in Reach 2 near the remains of a historic sawmill. These adjustments are anticipated to continue without direct intervention, putting Toronto Water infrastructure and private property at varying degrees of risk.
– The preferred solutions have been prioritized for construction based on a review of erosion risk and an assessment of the consequences of failure associated with the Toronto Water Infrastructure sites and have been divided into four (4) Project groupings. Since there is no at-risk sanitary infrastructure within the Yellow Creek Study Area, there were no sites evaluated as high-risk. Sanitary at-risk sites within the city will need to be prioritized for construction ahead of the high-moderate Site 4.
– Phased implementation of sub-reach-based works are the preferred solution for all evaluated Sites, with Project 1A (Site 4) evaluated as the highest priority for rehabilitation works. Relatively hard bank protection measures using large armourstone are prescribed to withstand the demonstrated strong stormwater flows that the Yellow Creek system experiences, however restoration and protection of the surrounding riparian area is anticipated to result in maintaining and/or improving the natural habitat of the valley and enjoyment by the public. Project 1A (Site 4) is recommended to be prioritized for restoration works out of the YCGSMP Sites. However, when considering other sites on a City-wide

basis, it is anticipated that it is of Moderate Priority, with works to take place in approximately 5 to 10 years' time. Project 1B, Project 2 (Sites 5/6, 7, 8/9), Project 3 (Site 2) and Project 4 (Site 10) are recommended to be addressed in the low priority timeframe of 10 to 20 years' time, separated into sub-projects based on geographic proximity.

– Intact quarried block wall circa 1900 lines significant portions of Reaches 3 and 4. The City intends to monitor the condition of this block wall. Deteriorating conditions will be used as an indicator for when low-priority projects will need to be considered for implementation in the long-term.

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Scope and Limitations

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The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

1. Introduction

This report documents the Yellow Creek Geomorphic Systems Master Plan (YCGSMP) undertaken in accordance with Municipal Class Environmental Assessment (MCEA) by the City of Toronto (City). This is one of five ongoing GSMPs across the City being carried out to identify and assess water and storm sewer infrastructure that is at risk of erosion from high flows due to storms and snow melt runoff. The Yellow Creek subwatershed has fully urbanized over the last 50 years significantly increasing stormwater runoff to the Creek and transforming it into a flashy, runoff dominated watercourse. As a result, rapid runoff following storm events has led to significant erosion along the channel bed and banks of Yellow Creek, causing existing erosion control structures to fail and placing Toronto Water infrastructure within the valley at-risk of exposure and damage.

The Study Area for this Project includes the 1.3 km aboveground reach of Yellow Creek within the Vale of Avoca between Mount Pleasant Cemetery and the crossing at Mount Pleasant Road (**Figure 1**). At-risk Toronto Water infrastructure within the Study Area includes six stormwater outfalls with associated storm sewers, one channel inlet at the downstream limit of the watercourse, one stormwater/reservoir discharge outfall, one watermain crossing, and one watermain adjacent to the channel within 5 metres of the bank. Recognizing that climate change may result in increased frequency and severity of storm events, it is imperative to develop an understanding of the erosive conditions and risks within and near the watercourse and develop plans to minimize the impact of the erosive forces on infrastructure.

As a result, the City initiated the YCGSMP with the following purposes in mind:

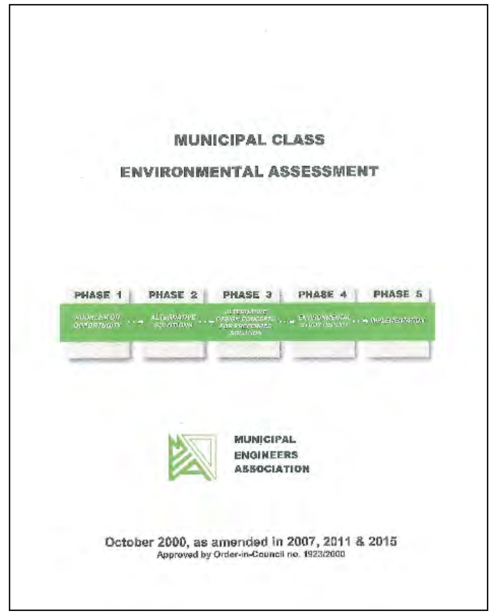
– To identify concerns related to erosion that may damage the City's water and storm sewer infrastructure.
– To develop solutions that protect the City's water and storm sewer infrastructure from excessive erosion processes within the stream.
– To improve stream functions, such as increasing stream bank stability, reducing erosion, enhancing stormwater conveyance, and improving habitats.

As mentioned, the Project was carried out in accordance with the requirements of the MCEA following Approach #2 or a "master plan approach" where the level of investigation, consultation, and documentation are sufficient to fulfill the requirements for Schedule B projects. In addition, the methodologies from the Ministry of Natural Resources and Forestry (MNRF) *Adaptive Management of Stream Corridors* (2002) protocol consisting of nine steps were integrated within the context of the MCEA for the Project (**Section 2**). With this context in mind, **Section 3** documents the assessment of issues and confirmation of the problem (Steps 1 and 2). Next, the past and future trends and disturbance for Yellow Creek are documented in **Section 4** as part of Step 3. In terms of Step 4, two rapid assessment tools, a Rapid Geomorphic Assessment and a Rapid Stream Assessment Technique, were used to assess the watercourse as described in **Section 5**.

The present stream function of Yellow Creek in the Study area (Step 5) is detailed in **Section 6**. Step 6 (Forecast Ultimate Confirmation) is documented in **Section 7**. **Section 8** describes the feasibility of intervention (Step 7). Following this, alternative solutions for the at-risk Toronto Water Infrastructure sites with the Study Area are defined and evaluated in **Section 9** as per Step 8. The preferred solution and its proposed implementation is detailed as part of completing Step 9 in **Section 10**.

Figure 1 Site Location Map

2. Municipal Class Environmental Assessment Process



The Yellow Creek Geomorphic Systems Master Plan (YCGSMP) Project is being carried out in accordance with the requirements of the Municipal Class Environmental Assessment (MCEA) (Municipal Engineers Association, October 2000 [as amended in 2007, 2011, 2015 and 2023]). In Ontario, there are two types of environmental assessment (EA) and approval processes for municipal projects to follow prior to being implemented in order to meet the requirements of the *Environmental Assessment Act* (*EA Act*):

– Individual EAs (Part II of the *EA Act*) – those projects for which a Terms of Reference and an individual EA are carried out and submitted to the Minister of the Environment, Conservation and Parks (Minister) for review and approval.
– Class EAs (Part II.1 of the *EA Act*) – those projects that are approved subject to compliance with an approved Class EA process with respect to a class of undertakings. Provided the approved process is followed, a proponent has complied with Section 13 (3)(a) of the *EA Act*.

Thus, the MCEA provides an approved process whereby specified municipal infrastructure projects can be planned, designed, constructed, operated, maintained, rehabilitated, and retired without having to obtain project-specific approval under the *EA Act*.

Five Phase Municipal Class EA Process

The approved MCEA process consists of five planning and design phases. The five phases are briefly summarized as follows:

– **Phase 1** – Identify the problem or opportunity.
– **Phase 2** – Identify alternative solutions to address the problem or opportunity and establish the preferred solution taking into account the existing environment and review agency and public input.
– **Phase 3** – Examine alternative methods for implementing the preferred solution and determine the preferred implementation method, taking into account the existing environment and additional review agency and public input.
– **Phase 4** – Document the preceding phases in an Environmental Study Report (ESR) and make it available for scrutiny by review agencies and the public.
– **Phase 5** – Complete contract drawings and documents and proceed to construct the preferred method for implementing the preferred solution.

Four Project Classifications

Since projects vary in their potential for adverse environmental effects, they are classified in the MCEA in terms of schedules. An amendment to the MCEA schedule classification was made in March 2023. The current schedules are briefly summarized in **Table 1**.

Table 1 Project Schedule Descriptions and Requirements

Municipal Class EA Schedule	Project Description	Municipal Class EA Requirements
Exempt (formerly Schedule A/A+)	Limited in scale Minimal adverse environmental effects Primarily municipal maintenance and operational activities	Exempt from the *Environmental Assessment Act*
Schedule B projects	Potential for some adverse environmental effects Primarily improvements and minor expansions to existing facilities	Phases 1 and 2 Consult with review agencies and the public Project File Report
Schedule C projects	Potential for significant adverse environmental effects Construction of new facilities and major expansions to existing facilities	Phases 1 to 4 Consult with review agencies and the public Environmental Study Report

Figure 2 illustrates the five phases of the MCEA planning and design process within the context of the preceding four project classifications or schedules.

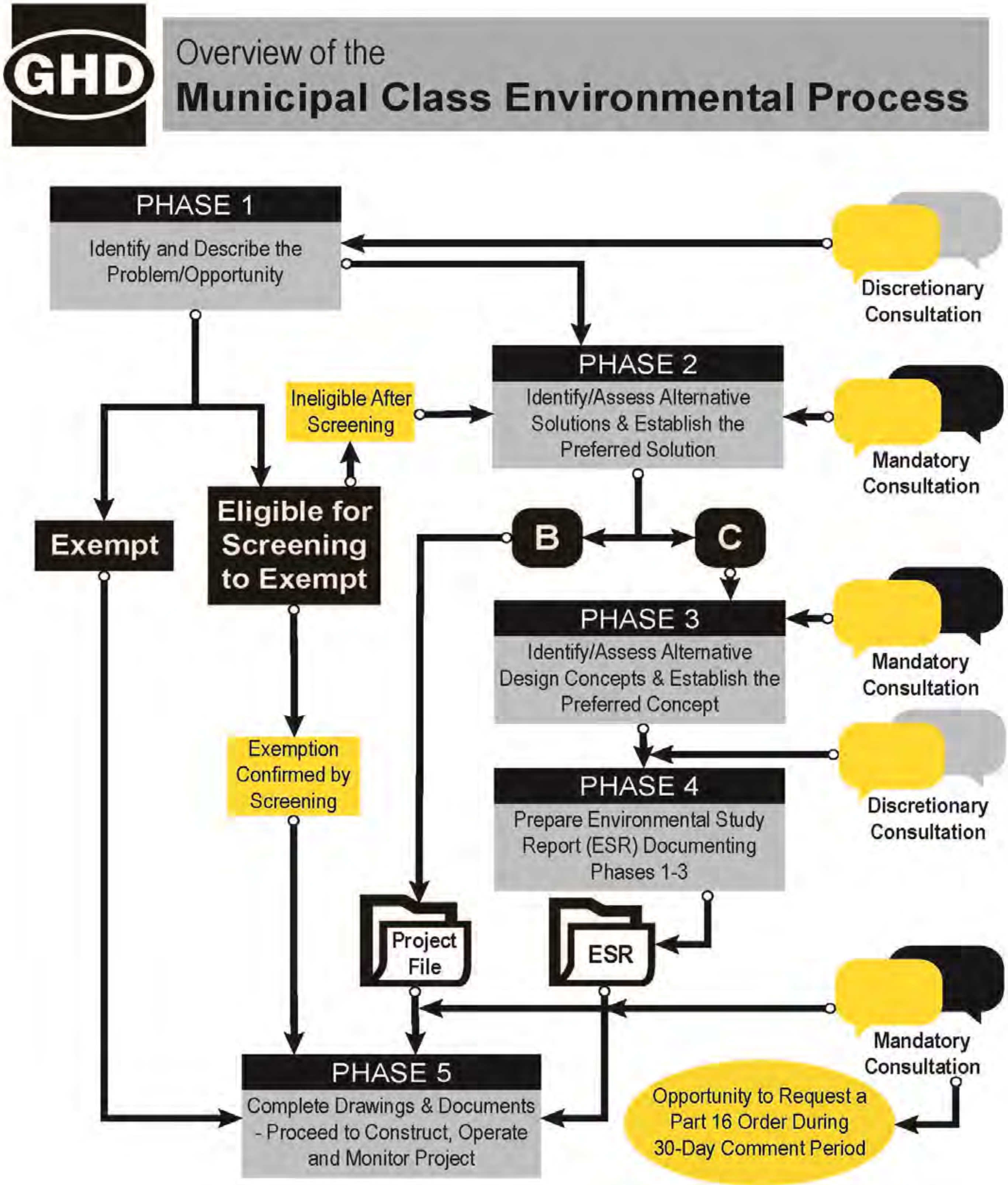


Figure 2 Overview of the Municipal Class Environmental Assessment Process

Project Implementation – Schedule Specific

A person or party involved in either a Schedule B or C project may request that the Minister make a Section 16 Order request on the grounds that the order may prevent, mitigate or remedy adverse impacts on the existing Indigenous and treaty rights of the Indigenous peoples of Canada. A Section 16 Order may require the proponent of a project going through a Class EA process to:

1. Submit an application for approval of the project before they proceed. This is generally referred to as an Individual Environmental Assessment.
2. Meet further conditions in addition to the conditions in the Class EA. This could include requirements for further study, monitoring, or consultation.

The person or party can make this request if they feel that their concerns raised cannot be resolved in discussion with the proponent by the end of the mandatory 30 calendar day comment period.

In addition, the Minister may issue an order on his or her own initiative within the 30 calendar days after the conclusion of the mandatory 30 calendar day comment period. Therefore, a proponent can only implement Schedule B and C projects if there are no outstanding "Section 16 Order" requests.

2.1 Yellow Creek Geomorphic Systems Master Plan Class EA

As stated, the City is carrying out the YCGSMP based on a "master plan approach", as set out in Section A.2.7 of the MCEA, which integrates infrastructure requirements or municipal works with environmental assessment planning principles. Master Plans document the long-term infrastructure needs for an area that can range from a local area, like the Yellow Creek channel, to an entire municipality. Taking a holistic view of an area, the Master Plan outlines an integrated plan guiding subsequent infrastructure projects or municipal works in the area.

The MCEA contains four different approaches for integrating the Master Plan with the MCEA requirements. The City has utilized Approach #2 for the YCGSMP where the level of investigation, consultation, and documentation are sufficient to fulfill the requirements for Schedule B projects.

As a result, the following MCEA planning phases were completed for this Project:

- **Phase 1: Problem or Opportunity**
  - Step 1: Identify the problem or opportunity
- **Phase 2: Alternative Solutions**
  - Step 2: Identify alternative solutions to the problem or opportunity
  - Step 3: Carry out an inventory of the environment
  - Step 4: Identify the potential impacts of the alternative solutions on the environment and any measures needed to mitigate those impacts
  - Step 5: Carry out a comparative evaluation of the alternative solutions and identify a recommended solution
  - Step 6: Notify and consult with review agencies and the public by carrying out mandatory consultation
  - Step 7: Determine the preferred solution based on the comparative evaluation and feedback received

Phase 1 and Phase 2 have been documented in this Master Plan which will be available for the mandatory 30 calendar day comment period. In order to initiate the comment period, the City will issue a Notice of Project Completion to those consulted as part of the Project.

2.2 Adaptive Management Approach

The Project utilized a system-based restoration strategy consistent with the Adaptive Stream Corridor Management Approach advocated by the Ministry of Natural Resources (MNRF) (**Error! Reference source not found.**). Adaptive management is essentially a process by which scientifically driven decisions are put forward in a management plan context, and information gained through implementation of the plan is then used to refine and improve the original decisions, in a positive feedback loop.

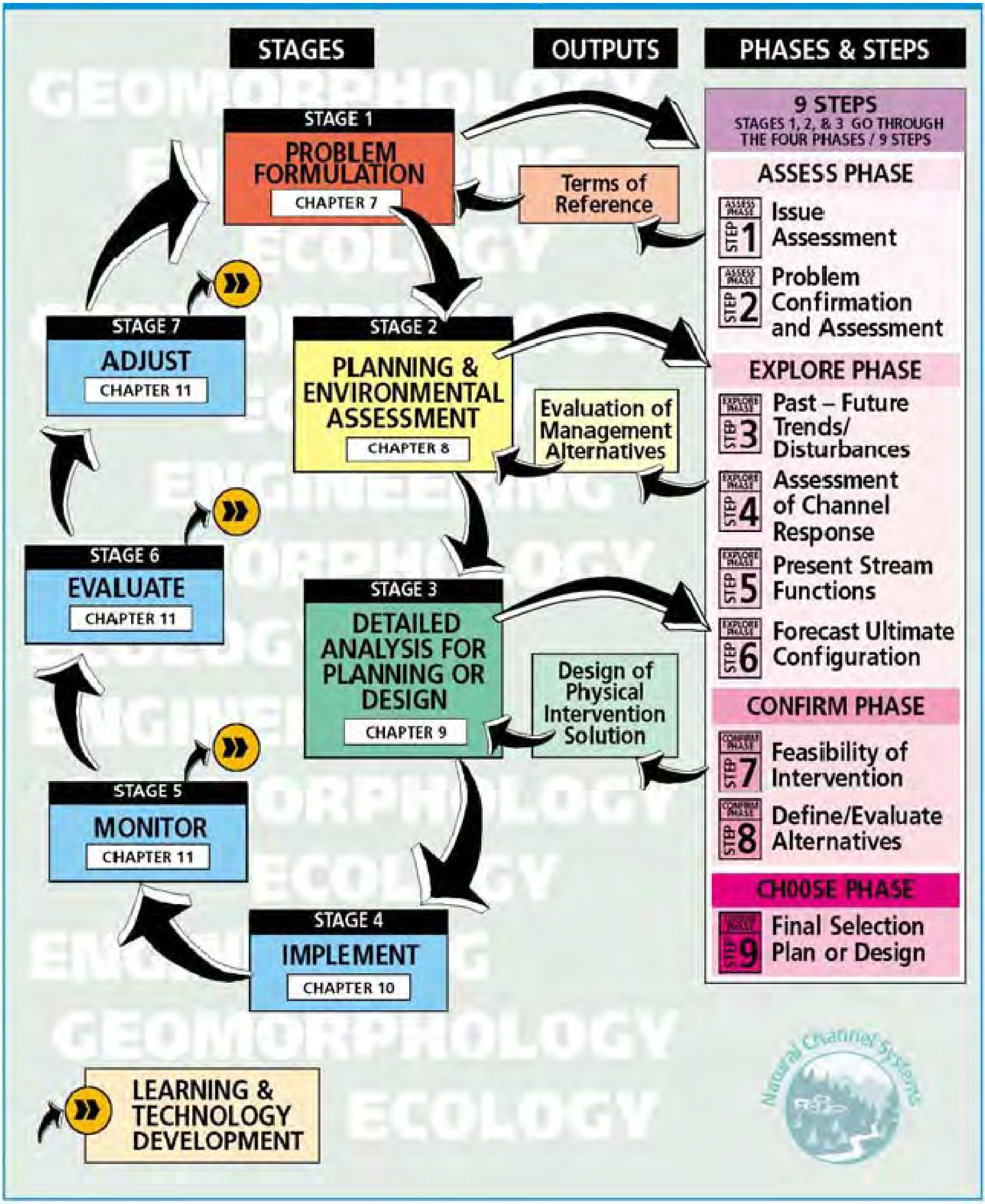


Figure 3 MNRF Adaptive Management Stream Corridor Management Process

The first six steps of the nine-step process assess and confirm past and future trends within the corridor, examine channel response and stream function, and consider future conditions within a given planning time frame. This baseline information provides the context needed to evaluate the feasibility of various restoration solutions and allows alternatives to be defined and assessed. The GSMP Phase 1: Issue Assessment and Problem Confirmation and Phase 2: Development of Alternative Solutions will address the first six steps.

Steps 7 to 9 focus on providing site specific management solutions at a conceptual level, for areas identified as opportunities for enhancement or where potential risk due to channel processes are identified. This will form the basis of the GSMP Phase 3: Define and Evaluate Alternative Solutions and Phase 4: Selection of Preferred Solutions.

Adaptive management assumes that there will always be some level of uncertainty with respect to long-term impacts, even with a substantial mitigation framework in place. An adaptive management framework, therefore, attempts to account for this uncertainty by providing a flexible system through which potential and possibly unexpected impacts can be identified, assessed, and mitigated. Thus, monitoring is a key component of the adaptive management framework. The development of baseline data allows triggers, even if rudimentary, to be developed which are integrated into the overall environmental monitoring program. If the triggers are exceeded the potential impacts can be reviewed and the flexible mitigation plan can be adapted to limit the observed impacts.

Table 2 lists the requirements associated with the MCEA Schedule B process and the Adaptive Management Stream Corridor Management Process and how they are integrated within the YCGSMP approach. The steps from MNRF's Adaptive Stream Corridor Management Process are used as the framework in documenting the YCGSMP.

Table 2 Yellow Creek Geomorphic Systems Master Plan – Overview of Applicable Processes

Municipal Class Environmental Assessment Schedule B Process	Ministry of Natural Resources and Forestry Adaptive Stream Corridor Management Process	Yellow Creek Geomorphic Systems Master Plan
Phase 1: Problem/Opportunity (discretionary public consultation) Step 1: Identify the problem or opportunity	Step 1: Issue Assessment Step 2: Problem Confirmation and Assessment	GSMP Phase 1: Issue Assessment and Problem Confirmation
Phase 2: Identify/Assess Alternative Solutions & Establish the preferred solution (mandatory public consultation) Step 1: Identify alternative solutions to the problem or opportunity Step 2: Carry out an inventory of the environment Step 3: Identify the potential impacts of the alternative solutions on the environment and any measures needed to mitigate those impacts Step 4: Carry out a comparative evaluation of the alternative solutions and identify a recommended solution	Step 3: Past – Future Trends/Disturbances Step 4: Assessment of Channel Response Step 5: Present Stream Functions Step 6: Forecast Ultimate Configuration	GSMP Phase 2: Development of Alternative Solutions
	Step 7: Feasibility of Intervention Step 8: Define/ Evaluate Alternatives	GSMP Phase 3: Define and Evaluate Alternative Solutions
	Step 9: Final Selection Plan or Design	GSMP Phase 4: Selection of Preferred Solution(s)

Municipal Class Environmental Assessment Schedule B Process	Ministry of Natural Resources and Forestry Adaptive Stream Corridor Management Process	Yellow Creek Geomorphic Systems Master Plan
Step 5: Notify and consult with review agencies and the public by carrying out mandatory consultation Step 6: Determine the preferred solution based on the comparative evaluation and feedback received		
Project File Report (mandatory public consultation)		Master Plan Report

3. Steps 1 and 2 – Issue Assessment and Problem Confirmation

3.1 Problem/Opportunity Statement

As part of the EA process, the problem/opportunity statement is a clear statement of the problem or opportunity being addressed, documenting factors which lead to the conclusion that an improvement or change is needed. Alternative solutions (Phase 2) are reasonable and feasible solutions to address the problem or opportunity. Taking into consideration the problems and opportunities identified by the City in RFP #9117-19-7169 and at the February 20, 2020, start-up meeting, below is the problem/opportunity statement for this EA:

> "Full urbanization of the Yellow Creek subwatershed over 50 years ago, has significantly increased stormwater runoff to Yellow Creek and transformed the creek into a flashy, runoff dominated watercourse. The banks of the creek were historically lined with quarried rock structures in the early 1900's and several stretches were replaced with gabion structures in the early 1970's, especially in the upper reaches of Yellow Creek. Rapid runoff following storm events has led to localized erosion along the channel bed and banks of Yellow Creek, particularly in the upper section of the Study Area, causing most of the existing gabion basket erosion control structures to fail or to be at risk of failing, placing Toronto Water infrastructure within the valley at-risk of exposure and damage. Recognizing that climate change may result in increased frequency and severity of storm events, it is imperative to develop an understanding of the erosive conditions and risks within and near the watercourse and develop plans to minimize the impact of the erosive forces on infrastructure. The purpose of the Yellow Creek Geomorphic Systems Master Plan is to identify improvements to

Yellow Creek that will protect Toronto Water infrastructure while minimizing riparian ecosystem impacts and enhancing aquatic habitat, taking into consideration climate change adaptation."

3.2 Background Review

3.2.1 Available Data

Additional data and information compiled in support of this project are summarized below in **Table 3**. This report assumes that the as-built drawings provided for stormwater infrastructure within the Study Area are accurate and representative of the structure locations and elevations.

Table 3 Background Information

Item	Background Information Summary
City of Toronto Utility Maps and Engineering Drawings[1]	
1	Digital Map Owners Group (DMOG) Utility Mapping (dwg format)
2	Engineering Drawings for Channel Works, Sewers, Watermains, Road Works, Bridge and Rail Crossings
3	Access to City's DCAD Sewer and Water Supply Mapping Database
4	St Clair Outfall As-Built
5	St Clair Bridge As-Built
6	1998 Yellow Creek proposed repairs drawings
City of Toronto Open Data Catalogue - Web Map Services[2]	
6	Orthorectified Aerial Imagery
7	Historic Aerial Imagery
8	Aerial LiDAR - Hillshade
TRCA GIS/Ecology Data[3]	
9	ELC
10	Flora and Fauna
11	Regulation Limit
12	Physiography
13	Surficial Geology
14	Natural Cover
15	Riparian Habitat
16	Subwatersheds
17	Watersheds

[1] Source: Engineering Drawings, Engineering and Construction Services (**engdrawings@toronto.ca**)
[2] Source: **https://open.toronto.ca/dataset/web-map-services/**
[3] Source: TRCA Information Technology and Records Management (**olusola.obembe@trca.ca**)

Item	Background Information Summary
18	Property
19	Trails
20	Don River Fisheries Data
21	Don River Water Quality
TRCA Hydrology/ Hydraulics[4]	
22	TRCA Yellow Creek Estimated HEC-RAS Model
23	Don River Hydrology Update Report (AECOM, 2018)
24	Don River Hydrologic PCSWMM Model
TRCA Ongoing Projects[5]	
25	Yellow Creek Interim Channel Works - Existing Conditions Survey
26	Yellow Creek Below Summerhill Gardens Emergency Works - Existing Conditions Survey
27	Yellow Creek Below Summerhill Gardens Emergency Works - As Built Survey
28	Turbidity and Water Level Monitoring Data During Construction
Previous Studies[6]	
29	Forty Steps to a New Don (Don Watershed Task Force, 1994)
30	Wet Weather Flow Management Plan (City of Toronto, 2003)
31	Don River Watershed Plan: Aquatic System (TRCA, 2009)
32	Don River Watershed Plan: Beyond Forty Steps (TRCA, 2009)
33	Geotechnical Slope Stability and Erosion Risk Assessment Yellow Creek near Heath Street East, Toronto (GeoTerre, 2017)
34	30-36 Rose Park Geotechnical Investigation (Terraprobe, 2018)
MNRF Information Request[7]	
35	Species at Risk (SAR) Preliminary Screening
36	NHIC Database Screening

3.2.2 Watershed Setting and Site History

The greater Don River watershed drains approximately 360 km^2 of highly urbanized land use, and is characterized by limited sediment supply, poor water quality and highly peaked flood events. 96 percent of the watershed is urbanized and approximately 35 percent consists of impervious surfaces which lack drainage and contribute to overland flow and runoff. The headwaters of the Don River, along the south slope of the Oak Ridges Moraine, split into two branches, the East and West Don Rivers, which join

[4] Source: TRCA Water Resources (**michael.jones@trca.ca**)
[5] Source: TRCA Engineering Projects (**jaya.soora@trca.ca**)
[6] Source: Miscellaneous
[7] Source: Ontario Ministry of Natural Resources and Forestry (MNRF) (**jeff.andersen@ontario.ca**)

downstream to form the Lower Don River. Yellow Creek is a tributary to the Lower Don River and is located within subcatchment 46B of the Don watershed, which drains an area of 10.25 km^2 (TRCA, 2009c).

Yellow Creek has been known as both Rosedale Brook and Silver/Sylvan Creek in the past. Yellow Creek's headwaters begin in the Downsview area. The upstream reaches of the creek were piped underground through the expansion and densification of the City of Toronto over the past century. The creek headwaters flow southeast within the City of Toronto storm sewer network before daylighting at a stormwater outfall downstream of the Mount Pleasant Cemetery, approximately 300 m northwest of the St Clair Avenue bridge. The creek then flows approximately southeast for 1275 m through the Vale of Avoca ravine and David A. Balfour Park, before entering a stormwater inlet 170 m south of the CP Rail crossing. From there the creek is conveyed underground by a 2700-mm x 2550-mm box culvert for approximately 1650 m before flowing into an open outfall channel to the Lower Don River.

Development of this area began in the 1880s when an iron bridge was built to connect the area to Yonge Street and encourage settlement in the area (ASI, 2018). This bridge was replaced with the existing St. Clair Viaduct by 1924. The rail crossing towards the downstream limit of the Study Area was established prior to 1939 and is present in all available aerial imagery. Prior to 1949 there were a number of residential developments surrounding Yellow Creek; however, intensive urbanization of the surrounding area appeared to begin between 1954 and 1967 when many high-rise buildings were erected to the west of the Study Area and the number of residential properties significantly expanded. A small portion of the Mount Pleasant Cemetery expanded into the Study Area by 1978; however, construction for this expansion appeared to begin around 1967 (TRCA, 2018).

Yellow Creek has been extensively modified in conjunction with the urbanization of the City of Toronto over the last 100 years. Channel stabilization works were implemented by the City in the early 1970s to mitigate erosion that was causing damage to infrastructure and private property. The works spanned the length of the current Study Area and consisted of stepped gabion basket revetments, riprap revetments and armourstone walls, instream boulder treatments, timber crib walls, and cemented riprap spillways. Severe erosion in the creek over the past 50 years has damaged these former stabilization works to the extent that many gabion basket revetments, armourstone walls and stormwater outfalls have been completely outflanked and now lie within the channel. Addtionally, concrete aprons have been undermined entirely exposing bridge abutments and threatening Toronto Water infrastructure. There are currently two ongoing TRCA projects and one completed City of Toronto project within the Study Area. These are further described in **Section 3.2.4**.

A formalized paved trail runs through the Yellow Creek valley corridor, also referred to as the Vale of Avoca. The trail runs parallel to the creek on the west side, south of St. Clair Avenue, before crossing to the east side of the creek at a mid-point in the watercourse. The trail is extensively used for public recreation and connects to Mud Creek and Don Valley trail systems.

3.2.3 Previous Studies

A number of studies have been undertaken over the last 20 years concerning the Don River watershed and Yellow Creek. The reports include recommendations for actions to improve the watershed and watercourse and have been reviewed and summarized in order to provide background information for the YCGSMP study.

3.2.3.1 Forty Steps to a New Don (Don Watershed Task Force, 1994)

Forty Steps to a New Don was a report assembled by the Don Watershed Task Force and formally endorsed by TRCA that detailed forty specific steps for regenerating the watershed, seven detailed subwatershed regeneration plans and six conceptual sites. This plan focused on water quality protection, naturalization and habitat improvements, increasing public access to natural areas within the watershed, community development, and growth partnerships.

3.2.3.2 Wet Weather Flow Management Master Plan (City of Toronto, 2003)

The Wet Weather Flow Management Master Plan (WWFMMP) was governed by the principle that rainwater is a resource and should be managed on a watershed basis with a natural systems approach applied to stormwater management (City of Toronto, 2003). There were four main categories that are emphasized for this plan: water quality, water quantity, natural areas and wildlife, and sewer systems.

The water quality goals outlined in the plan are to meet the guidelines for water and sediment quality, eliminate toxics through pollution prevention, improve water quality in rivers and the lake for body contact recreation, and improve aesthetics. The water quantity goals were to preserve and re-establish a natural hydrologic cycle, reduce erosion impacts on habitats and private properties, and eliminate or minimize threats to life and property from flooding. Within the natural areas and wildlife section, the primary objectives were to protect, enhance, and restore natural features and functions, achieve healthy aquatic communities, and reduce fish contamination. Finally, the goals of the sewer system category were to eliminate sanitary sewage discharge, reduce infiltration and inflow to sanitary sewers, and reduce basement flooding. The objectives of the WWFMMP will be considered when developing conceptual alternatives for high priority sites.

3.2.3.3 Don River Watershed Plan: Aquatic System (TRCA, 2009a)

In 2009, TRCA released a report on the current watershed conditions of the Don River aquatic habitat and fish community (TRCA, 2009a). Previously, 23 fixed monitoring stations were established in the Don River. One of these stations was in close proximity to the confluence of Yellow Creek and the Don River (Station DN001WM). There were 21 fish species present in the Don between 2002 and 2005, 17 of which were native. Six native species were present at the majority of stations through the fish collection records: longnose dace (*Rhinichthys cataractae*), blacknose dace (*Rhinichthys atratulus*), white sucker (*Catostomus commersoni*), creek chub (*Semotilus atromaculatus*), fathead minnow (*Pimephales promelas*), and bluntnose minnow (*Pimephales notatus*). Redside dace (*Clinostomus elongates*), an endangered species, as well as mottled sculpin (*Cottus bairdi*) and American brook lamprey (*Lampetra rostrata*), both sensitive species, have been identified within the Don River but were limited to reaches in the Upper East Don River. The watershed received an F (fail) rating for both fish community and benthic invertebrates as fish health was observed to be poor and all observed stations were 'potentially impaired' and dominated by pollution tolerant families of benthic invertebrates.

3.2.3.4 Don River Watershed Plan: Beyond Forty Steps (TRCA, 2009b)

TRCA released an updated watershed plan in 2009 in the publication "Beyond Forty Steps" (TRCA, 2009b). This plan was a revised version of the Forty Steps to a New Don based on the results of ongoing monitoring and research within the watershed. The overall objective of the plan was wet weather flow management and restoration of a balanced flow regime to the Don River to mitigate ongoing flooding and erosion, poor water quality, and deteriorating aquatic and terrestrial habitats. The plan outlined three strategic plans:

1. We must build, re-build and retrofit our communities to restore water balance and improve the sustainability of the urban model.
2. We must regenerate the aquatic and terrestrial landscapes.
3. We must engage the attention, enthusiasm and support of the people of the Don.

Key issues were identified for each subsection of the watershed report card. The need for effective stormwater management controls in the urbanized areas of the watershed was identified as a key concern given the potential for increased frequency and severity of climate change-induced storm events. Poor water quality in the watershed is attributed to the lack of stormwater controls, construction activities, road salting, and former landfills. The watershed was characterized by low biodiversity of all aquatic species and poor in-stream habitat conditions. In-stream barriers to fish passage was identified as a key concern for the aquatic system. The current quality and quantity of terrestrial natural cover was identified as inadequate to support biodiversity and ecosystem functions. GHD will consider the updated strategic plan and key issues when developing conceptual plans for high priority sites.

3.2.3.5 Geotechnical Slope Stability and Erosion Risk Assessment Yellow Creek near Heath Street East, Toronto, Ontario (GeoTerre, 2017)

In 2017, GeoTerre completed a geotechnical slope stability and erosion risk assessment for TRCA along the east slope of Yellow Creek near Heath Street East (GeoTerre, 2017). The slope at the site was 26 m in height at the time with an upper incline of approximately 1H:1.2V. The inclination reduced towards Yellow Creek. The report found native materials had been replaced with fill materials above 120 m elevation in close proximity to Yellow Creek. The material was hypothesized to be backfill from a previously downcut watercourse that fed into Yellow Creek from the east. The dominant water table at the site was at an elevation of approximately 121 m near Yellow Creek. The minimum Factor of Safety (FOS) and Long-Term Stable Slope Crest (LTSSC) were calculated for the following properties: 3, 5, and 7 Heath Crescent; 78, 79, 89, 95, and 99 Heath Street East; 94 Heath Street East; and 6 Rose Park Crescent. The values ranged from 1.24 to 1.72 depending on the slope inclinations. Buildings at 7 Heath Crescent, 78 Heath Street East, and 95 Heath Street East were within the LTSSC at the time of investigation.

3.2.3.6 30-36 Rose Park Geotechnical Investigation (Terraprobe, 2018)

Terraprobe was retained by TRCA in 2018 to complete a geotechnical investigation and slope stability and erosion risk assessments for the properties at 30, 32, and 36 Rose Park Crescent. Slope failures, property damage and debris in the creek were observed at the site following a large rainfall event. One deep borehole and four shallow boreholes were advanced at the site to identify deep stratigraphy, native soil and the depth of fill material at the site. Earth fill was found up to depths of 1.5 to 6.1 m below the existing ground elevation. The fill was loosely compacted with sandy silt to gravelly sand materials. A sandy silt glacial till was identified below the earth fill layer followed by dense sand 6.1 m below the existing ground elevation. The dense sand was underlain by a hard clay and silt till. The site has a gully that runs through Rose Park Crescent to the watercourse. Failure of the upstream section of the gully was thought to be causing the slope instability at this site. Toe instability was not linked to the observed slope failure. The LTSSC was within the property at 30 Rose Park Crescent. Terraprobe recommended the use of rubble fill buttress or a lagging wall to stabilize the slope.

3.2.3.7 Don River Hydrology Update (AECOM, 2018)

AECOM was retained by TRCA in 2018 to update the Don River hydrology model and update design flow estimates for various design storm events (AECOM, 2018). The update included updating the model with the most recent and thorough topographic data, land use and cover and soil information, completing the model on the PCSWMM platform, a calibration and validation processes, and model simulations to define Regional Storm flows for both existing and future land use. At the time, the Don River watershed contained: 109 stormwater management ponds, the G Ross Lord dam, 128 major road crossings, and 896 subcatchments. The updated model was found to provide suitable estimates for design events of 2-year through 350-year return periods and for the Regulatory event (Hurricane Hazel). No return period is typically ascribed to Hurricane Hazel-generated flows since hydrology models uses the full 48-hour rainfall hyetograph for Hazel, whereas the 5-100-year storms use a 12 hour AES type rainfall distribution. However, for a watershed the size of the Don River, the Hurricane Hazel return period can be estimated to be equivalent to a 1 in 500-year flood.

3.2.4 Current and Ongoing Studies

3.2.4.1 Yellow Creek Outfall (GHD, 2019)

The City of Toronto retained GHD in 2018 to address the failure of a 1,350-mm storm sewer outfall to Yellow Creek, a tributary to the Don River, just downstream of St. Clair Avenue East in Toronto (GHD, 2019). A storm on August 19, 2005, caused the collapse of the first section of concrete pipe. Since the initial storm, the bank material surrounding the failed outfall had been scoured, and the headwall apron, as well as a second section of the storm sewer outfall, had collapsed. The collapsed outfall was causing a disturbance to the stream system, and continued erosion posed a hazard to the public, since an unofficial pedestrian trail travelled along the steep terrain near the eroding banks. A detailed design was generated for the removal and replacement of the outfall at the location of the failed outfall. Construction for the works began in 2020 and was substantially completed in early 2021. The post-construction monitoring program will conclude in 2024.

The banks of Yellow Creek in the vicinity of the outfall were subsequently stabilized by installing vegetated rock buttresses. The implemented design included two vortex rock weirs downstream of the outfall. The vortex rock weirs provide grade control and prevent migration of downstream bed degradation upstream to the outfall. The vortex rock weirs consisted of two rows of armourstone providing mutual support to each other to remain stable in high flows. The weirs were curved to direct flows toward the centre of the watercourse and away from the banks downstream of the weirs. The weirs provide variations in flow depth and velocity to improve aquatic habitat diversity. Gaps between the individual stone of the weir allow passage of small fish during low flows. The weirs were also sloped downwards toward the centre of the channel to provide defined low flow capacity.

The outfall repair further included a 45° bend to better transition the outfall discharge to the watercourse. A concrete headwall was constructed to hold the outfall pipe in place and to allow for secure attachment of the safety grate, however this headwall was masked by natural armourstone to meet City of Toronto requirements.

3.2.4.2 Yellow Creek Below Summerhill Gardens Emergency Works (TRCA, 2024a)

In 2019, TRCA initiated emergency works to address significant toe erosion for a 90-metre section of Yellow Creek near Summerhill Gardens (TRCA, 2024a). A retaining wall within the creek was undermined and exposed, leading to erosion at the toe of slope under elevated flow conditions. The erosion caused slope failure that impacted one of the pedestrian trails through the valley and created a public safety concern. The scope of work included removing an abandoned footbridge and an outflanked/undermined stone & mortar wall and realigning the overflow channel away from the base of the coincident slope to mitigate the risk of slope failure precipitated by toe erosion. The existing channel was backfilled, graded, and planted, and the bed of the new realigned channel is stabilized by a riffle-pool sequence. Armourstone and boulders were used to harden the toe of the coincident slope, and a vegetated rip rap buttress was constructed towards the downstream end of the work area. Construction was substantially completed the work and demobilized at the end of April 2020. Urban Forestry Renewal completed restorative tree and shrub planting in the impacted area in Fall 2020. The newly constructed channel showed signs of rapid adjustment, evidenced by a headcut/knickpoint migrating upstream through the exposed till, and prematurely failing bank treatments. TRCA initiated a design for repair of the failing works in 2023. Construction of the remediation works will begin in 2024.

3.2.4.3 Yellow Creek Interim Channel Works (TRCA, 2024b)

In 2019, TRCA initiated interim channel works to complete conceptual and detailed design work for a section of channel from a source outfall behind 95 Heath Street East downstream to approximately behind 14/16 Rose Park Crescent. The planning process for this project followed the Class Environmental Assessment for Remedial Flood and Erosion Control Projects (Class EA), and the design incorporated stabilization measures for the slope near Heath Street East and a section of Yellow Creek. In 2024, TRCA will obtain all necessary permits and approvals for the proposed channel work; complete detailed designs for the erosion control and slope stabilization based on the preferred alternative solution identified in the Class EA; and aims to begin channel construction in late fall. The chosen rehabilitation option includes realignment of Yellow Creek, stabilization of the slope near 95 Heath Street East using soil nailing, and replacement of the staircase on public lands. Yellow Creek would be realigned implementing a natural riffle-pool sequence from the concrete box culvert near Mount Pleasant Cemetery downstream to 14 Rose Park Crescent.

3.2.5 Geology

The underlying geology influences the rate of channel change (e.g., migration), sediment input (amount and type), and channel geometry. Local surficial geology is comprised mostly of glacial till deposits (sandy silt to sand) and some river deposits (sand and gravel) (Sharpe et al. 1997). The glacial till deposits are known as Newmarket/Northern Till, and are comprised of greater than 5 percent pebbles, with silty sand to sandy silt diamicton. Sandy and silty interbeds with thickness ranging from 1 to 5 m are present throughout the glacial till deposits.

The Ontario geotechnical borehole database was also used to investigate the surficial geology within the Study Area (Ministry of Energy, 2012). There were multiple boreholes collected within the Study Area. Borehole 654011 was drilled to a depth of 6.4 m in 1971 at the upstream extent of the creek. The upper 3 m of the borehole was fill, underlain by dense sand, gravel, and silt from 3 to 3.8 m, followed by dense silt and sand to the base of the borehole. In 1971, a borehole was drilled 6.6 m deep at the downstream limit of the creek (Borehole ID: 654082). The top 1.4 m of the borehole was fill material underlain by loose sand, organic material and silt to 2.6 m depth. The remainder of the borehole was composed of dense sand. The borehole material is all relatively fine grained and easily erodible. The existing channel banks are comprised of this more easily erodible materials, contributing to the decreased channel stability along the banks. In areas with increased bank erosion, any bank protection works should aim to protect the banks from exposure of the native erodible material to reduce the rate of future channel widening.

3.2.6 Climate

Climate, precipitation in particular, provides the energy for the system and directly influences basin hydrology and rates of channel erosion. Average precipitation was calculated from climate normals (1981 to 2010) recorded at the Toronto Weather Station (Station ID 6158350), which is located approximately 3 km southwest of the northern extent of the Study Area. Precipitation averaged 66 mm in winter months (November to February, inclusive), and 73 mm in the summer months (July and August, inclusive) (Environment Canada, 2020). The precipitation averages do not significantly vary across the Greater Toronto Area and are discussed to provide some context for the typical precipitation range for these systems. As with most watercourses in southern Ontario, the highest instream flows usually occur during snowmelt (i.e., freshet) and, in particular, rain-on-snow events. While the longest duration of high flows typically occurs during freshet, the increase over the summer months is likely a result of convective thunderstorms.

3.2.7 Historical Land Use

A Stage 1 Archaeological Assessment documenting historical land use was completed within the YCGSMP Study Area by Archaeological Services Inc. (ASI) and is provided in **Appendix A**. The study determined that two previously registered archaeological sites are located within one km of the Study Area. It was also determined that parts of the Study Area do exhibit archaeological potential and will require a Stage 2 assessment by test pit survey at five-metre intervals prior to any construction disturbance to these areas. In addition, all Mount Pleasant Cemetery lands must be avoided. The remainder of the Study Area does not retain archaeological potential due to deep and extensive land disturbance or slopes in excess of 20 degrees.

3.2.8 Aquatic Environment

Data sources including TRCA sampling data, historic and recent Ministry of Natural Resources and Forestry (MNRF) Aquatic Resource Area (ARA) data, records from the Ontario Stream Assessment Protocol (OSAP) database and DFO Species at Risk (SAR) mapping were searched for existing data on Yellow Creek.

No MNRF ARA fish community data was available directly within Yellow Creek; however, the watercourse was listed as "warm water" based on water temperature data, with the potential for "cold water restoration". One TRCA sampling station from 1949 recorded the presence of blacknose dace, bluntnose minnow, creek chub and fathead minnow. This data is considered to be outdated due to alterations and impacts to the Yellow Creek system over subsequent decades. The lack of a daylighted channel from the Don River to upstream of Mount Pleasant Road severely impacts fish migration into Yellow Creek and use of habitat within the watercourse.

On the recent Yellow Creek Outfall project (GHD, 2019), correspondence with TRCA indicated that TRCA believed there was no longer any fish in Yellow Creek within the Study Area extent and did not recommend any in-water work timing restrictions for that project.

DFO Species at Risk (SAR) mapping was also consulted. There were no federal aquatic SAR or critical habitat within Yellow Creek.

3.2.9 Terrestrial Environment

Yellow Creek occurs within a fully urbanized subwatershed comprised of woodland with numerous wetlands. Yellow Creek is predominantly fed by stormwater runoff, as such the rapid onset of high flows has led to the severe erosion of the creek banks and beds in many locations.

The Yellow Creek Study Area does not directly contain an Area of Natural and Scientific Interest (ANSI) for earth science.

3.2.10 Species at Risk

GHD evaluated the potential for SAR to occur within the Study Area through a combination of secondary source review, agency consultation, and field investigations. The full evaluation can be found in **Appendix B**. This list is current as of February 23, 2024. There were 12 SAR identified through the background review with a moderate or high potential to occur within the Study Area based on available habitat. Eight of these species receive protection in this Study Area under either the Endangered Species Act (*ESA)* or Species at Risk Act (*SARA)*.

Table 4 SAR Species Potentially within Study Area that Receive Protection under ESA/SARA

SAR Potentially Found in the Study Area
Chimney swift
Wood thrush
Barn swallow
Red-headed woodpecker
Tri-coloured bat
Little brown myotis
Northern myotis
Butternut

Field visits, and possible studies, would be necessary to confirm the presence/absence of SAR or their habitats within or adjacent to any areas where future works are planned.

3.3 Existing Channel Characterization

3.3.1 Reach Delineation

Reaches are homogenous sections of channel with regard to form and function and can therefore, be expected to behave consistently along their length to changes in hydrology and sediment inputs, as well as to other modifying factors. Reach delineation was based on changes in channel planform and active geomorphological processes, which are directly related to local surficial geology, gradient, hydrology, land use, and riparian vegetation (Montgomery et al, 1997; Richards et al, 1997). Reach analysis was completed utilizing historical aerial photographs and surficial geology mapping. Field verification of reach extents was then undertaken by GHD, with modifications made where required. A total of four reaches were delineated for Yellow Creek. Reach breaks were located at significant grade changes corresponding to the three crossings within the Study Area, the St. Clair Avenue East bridge crossing, the pedestrian trail bridge crossing, and the CP Rail bridge crossing. The reaches are delineated on **Figure 1**.

Existing channel conditions were investigated based on available background information and site reconnaissance. Photo documentation of each reach is provided below. Note that the convention when referring to a left or right bank is based on an individual facing downstream.

3.3.2 Reach 1

Reach 1 spans 275 m from the Yellow Creek source outfall to the St Clair Ave bridge. **Table 5** provides a summary of existing reach conditions and photographs taken in May 2020. **Figure 4** maps existing conditions, infrastructure, issues, and constraints.

Table 5 Reach YC-1 Existing Conditions

Reach 1	
Upstream Boundary	Yellow Creek Source Outfall (0+000)
Downstream Boundary	St Clair Bridge (0+275)
Channel Length	275 m
Reach Map	
Channel Conditions (from US to DS)	The entire reach has been hardened with gabion baskets and stacked armourstone walls, which are in varying states of failure (0+000) Concrete apron downstream of source outfall has been undermined and partially collapsed. 30 cm CSP outlets on left bank (Photo 1.1)

Reach 1	
	(0+000 to 0+090) Downstream of source outfall the channel is narrow and lined with gabion baskets on both banks. The gabion baskets have been undermined and outflanked, and are slumping into the creek (Photo 1.2 and 1.3) (0+090 to 0+140) Channel widens, and gabion baskets are stable on both banks, but show signs of degradation and undermining (Photo 1.4) (0+140 to 0+175) Creek has abandoned historical armourstone channel and migrated into west valley wall, undercutting bank, causing tree falls and threatening the adjacent trail system (Photo 1.5) (0+175 to 0+205) Channel narrows and is lined with gabion baskets on both banks. Gabion is undermined throughout and slumping into channel (Photo 1.6) (0+205) Stormwater outfall OF3862313685 on right bank. Headwall structure and armourstone bank protection have been outflanked and now lie within the banks of the creek (Photo 1.7) (0+205 to 0+275) Banks are lined with gabion baskets and stacked armourstone, both of which are stable but are undermined and show signs of degradation (Photo 1.8). Some armourstone has collapsed into creek. Large erosion scar on left bank immediately downstream of gabion treatment and upstream of St Clair bridge (Photo 1.9) (0+275) Banks are lined with armourstone and shale tile through St Clair bridge crossing (Photo 1.10) (0+275) Slope failure and debris slide on east bank originating from 32 Rose Park Crescent (Photo 1.10)
Toronto Water Assets	– Yellow Creek Source Outfall asset ID OF3882413570 – Stormwater Outfall asset ID OF3862313685
Constraints	– Site access – Extensive hardening of channel – Steep, unstable ravine slopes – Large, mature trees throughout riparian area – Public usage and adjacent informal pedestrian trail

Photographs	
 **Photo 1.1** Source outfall, facing south. Failed concrete apron and failed gabion bank treatments. CSP outlet on left bank.	 **Photo 1.2** Facing north. Outlet of Yellow Creek at the upstream limit of the aboveground portion of the creek. Gabion baskets failing along both banks.
 **Photo 1.3** Facing south. Undermined and outflanked gabion baskets failing along both banks.	 **Photo 1.4** Facing north. Gabion baskets stable on both banks.
 **Photo 1.5** Facing south. Historical armourstone channel visible in left side of photo. Creek migrating west into valley wall resulting in severe scour and loss of mature trees.	 **Photo 1.6** Facing south. Collapsed gabion on right bank due to undermining and scour behind the wall.

Photographs	
 **Photo 1.7** Facing south. Outflanked stormwater outfall OF3862313685 on right bank. Evidence of scour on bank above outfall.	 **Photo 1.8** Facing south. Gabion baskets on both banks are stable but shows signs of degradation.
 **Photo 1.9** Facing south. Large erosion scar on left bank downstream of gabion.	 **Photo 1.10** Facing south. Armourstone and shale tile line banks through St Clair bridge crossing. Debris from slope failure visible in left side of photo.

Figure 4 Reach 1 Existing Conditions

3.3.3 Reach 2

Reach 2 spans 500 m from the St Clair bridge to a wooden pedestrian crossing downstream. **Table 6** provides a summary of existing reach conditions and photographs taken in May 2020. **Figure 5** maps existing conditions, infrastructure, issues, and constraints.

Table 6 Reach YC-2 Existing Conditions

Reach 2	
Upstream Boundary	St Clair Bridge (0+275)
Downstream Boundary	Pedestrian Crossing (0+795)
Channel Length	520 m

Reach 2	
Reach Map	
Channel Conditions (from US to DS)	The upper reach is hardened with gabion baskets and stacked armourstone. The lower reach is primarily hardened with armourstone, however creek has abandoned or widened beyond historical channel in many locations (0+295) Failed stormwater outfall OF3857613765 immediately downstream of St Clair Ave bridge on left bank. Outfall has been undermined and pipe segments collapsed into the creek. Large erosion scar behind pipe (Photo 2.1) (0+310 to 0+390) Downstream of St Clair Ave the channel narrows with gabion baskets and stacked armourstone on the right and left banks, respectively. The bank treatments are undermined and failing throughout. Gabion baskets are slumped into channel on right bank with evidence of scour behind gabion. Armourstone wall is partially outflanked on left bank (Photo 2.2) (0+370) Stormwater outfall OF3851713800 on right bank. Headwall and stacked armourstone walls upstream and downstream are failing (Photo 2.3). Slope failure behind the outfall has exposed a sewer pipe and is putting the associated maintenance hole at risk (Photo 2.4) (0+380) Large erosion scar immediately downstream of OF3851713800 on the right bank (Photo 2.3). (0+390 to 0+470) Channel widens forming a large cobble bar between the main east channel and a flood flow channel to the west. Main channel is migrating east into valley wall resulting in collapse of gabion on left bank (Photo 2.5 and 2.6) (0+470 to 0+570) Channel narrows and is hardened with gabion baskets along right bank, followed by stacked armourstone walls along both banks and a failed concrete

Reach 2	
	apron bed. The gabion baskets are undermined and slumping into channel (Photo 2.7). The stacked armourstone walls are outflanked and falling into the channel (Photo 2.8) (0+570) Site of historical sawmill and spillway. Channel has outflanked the concrete weir and spillway and is migrating into the east valley wall. The scour has resulting in a 4 m high erosion scar which is threatening the adjacent pedestrian trail. Significant large woody debris has accumulated in the scour pool (Photo 2.9) (0+570 to 0+660) Creek widens significantly beyond historical armourstone banks, leaving outflanked armourstone in the middle of the channel (Photo 2.10) (0+660 to 0+710) The only unarmoured section of channel in Yellow Creek - representative of natural channel form with wide banks and good floodplain connectivity (Photo 2.11) (0+710 to 0+795) Channel narrows and is lined on both banks with stacked armourstone walls. Armourstone is generally stable with the exception of two locations where there is evidence of scour behind the wall and some displaced armourstone. The creek bed is intermittently lined with concrete, boulders, cobble, and gravel (Photo 2.12 and 2.13) (0+795) Wooden pedestrian crossing. Narrow abutments constrict flow through crossing. Stone abutments are undermined at toe
Toronto Water Assets	– Stormwater Outfall asset ID OF3857613765 – Stormwater Outfall asset ID OF3851713800 – Maintenance Hole asset ID MH3850413796
Constraints	– Site access – Extensive hardening of channel – Steep, unstable ravine slopes – Large, mature trees throughout riparian area – Public usage and adjacent informal pedestrian trail

Photographs	
 **Photo 2.1** Facing south. Failed stormwater outfall on left bank.	 **Photo 2.2** Facing south. Collapsed gabion on right bank and partially outflanked armourstone wall on left bank.

Photographs	
 **Photo 2.3** Facing west. Stormwater outfall on right bank with failing headwall and surrounding armourstone walls. Slope failure behind outfall. Large downstream erosion scars on the right bank.	 **Photo 2.4** Facing west. Storm sewer pipe connecting to maintenance hole is exposed due to loss of material associated with slope failure.
 **Photo 2.5** Facing south. Flood flow channel and cobble bar visible in right side of photo. Creek migrating east into valley wall resulting in collapse of gabion on east bank.	 **Photo 2.6** Facing north. Flood flow channel and cobble bar visible in left side of photo. Creek migrating east into valley wall resulting in collapse of gabion on east bank.
 **Photo 2.7** Facing south. Undermined and slumping gabion baskets on right bank.	 **Photo 2.8** Facing south. Outflanked armourstone wall and failed concrete bed.

Photographs

Photo 2.9 Facing east. Outflanked concrete spillway in the foreground and large erosion scour in the background.

Photo 2.10 Facing south. Channel has widened beyond historical banks, leaving armourstone in the middle of channel.

Photo 2.11 Facing northwest. Unarmoured section of channel.

Photo 2.12 Facing east. Concrete bed embedded with roundstone. Evidence of scour behind armourstone wall on right bank.

Photo 2.13 Facing south. Armourstone lined banks with evidence of scour behind wall on left bank.

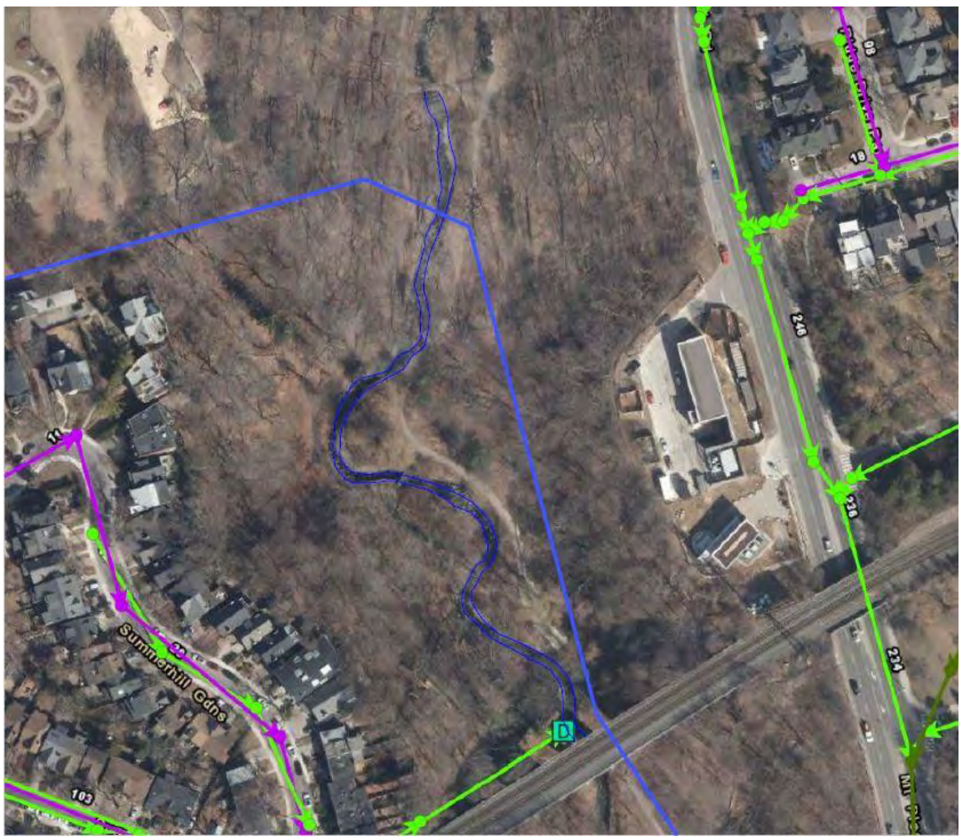
Photo 2.14 Facing south. Wooden pedestrian crossing. Abutments on both banks are undermined.

Figure 5 Reach 2 Existing Conditions

3.3.4 Reach 3

Reach 3 spans 290 m from the wooden pedestrian bridge crossing to the CP rail crossing. **Table 7** provides a summary of existing reach conditions and photographs taken in May 2020. **Figure 6** maps existing conditions, infrastructure, issues, and constraints.

Table 7 Reach YC-3 Existing Conditions

Reach 3	
Upstream Boundary	Pedestrian Crossing (0+795)
Downstream Boundary	CP Rail Crossing (1+075)
Channel Length	280 m
Reach Map	
Channel Conditions (from US to DS)	The upper reach is narrow and hardened in place with vertical armourstone walls. The lower reach was recently realigned and restored as part of the TRCA Summerhill Gardens Emergency Works (0+795 to 0+850) Narrow channel lined with grouted armourstone and concrete apron embedded with roundstone downstream of pedestrian crossing. Apron shows signs of degradation and is undermined at downstream extent (Photo 3.1) (0+810) Erosion and exposure of geowebbing beneath trail on right overbank. Erosion appears to be caused by overland runoff from pedestrian trail (Photo 3.2)

Reach 3	
	(0+825) Rosehill Reservoir Discharge Outfall OF800169 on right bank. Outfall and armourstone walls upstream and downstream appear stable (Photo 3.3) (0+840) Watermain LN1012177 crosses beneath channel. Grouted armourstone walls appear stable, however concrete bed at toe of left bank is undermined and downcutting (Photo 3.4) (0+850 to 0+940) Narrow channel lined with grouted armourstone. Armourstone is generally stable with the exception of three locations where the walls have collapsed into creek. The creek bed is intermittently lined with boulders, cobble, and gravel (Photo 3.5 and 3.6) (0+940 to 1+055) Realigned and restored channel as part of the TRCA Summerhill Gardens Emergency Works (completed spring 2020). The upstream banks are lined with vegetated stone buttress, and the downstream banks are lined with stacked armourstone walls. The newly constructed channel shows signs of rapid adjustment, evidenced by a headcut/knickpoint migrating upstream through the exposed till (Photo 3.7), and prematurely failing bank treatments (Photo 3.8) (0+1000) Two stormwater outfalls (asset ID's unknown) originating from the Rosehill Pumping Station were directed to a new outfall location and discharge channel into the re-aligned creek (Photo 3.9) (1+065) Stormwater outfall OF3801714062 on right bank. Outfall pipe is embedded in armourstone wall. Armourstone upstream and downstream of outfall appears stable (Photo 3.10) (1+075) CP Railway Bridge crossing. Banks are lined with grouted armourstone walls and bed is lined with concrete apron. Apron shows signs of degradation and cracking (Photo 3.11 and 3.12)
Toronto Water Assets	– Rosehill Reservoir Discharge Outfall OF800169 – Watermain Crossing asset ID LN1012177 – Two Rosehill Pumping Station Storm Outfalls (asset IDs unknown) – Stormwater Outfall asset ID OF3801714062
Constraints	– Site access – Extensive hardening of channel – Recently restored Summerhill Gardens works show signs of failure – Steep, unstable ravine slopes – Large, mature trees throughout riparian area – Public usage and adjacent informal pedestrian trail

Photographs

Photo 3.1 Facing south. Concrete apron spillway downstream of pedestrian crossing.

Photo 3.2 Facing west. Erosion and exposed geowebbing on right overbank.

Photo 3.3 Facing south. Rosehill reservoir discharge outfall OF800169 on right bank.

Photo 3.4 Facing south. Watermain crossing location.

Photo 3.5 Facing south. Armourstone lined banks with failure on left bank.

Photo 3.6 Facing south. Armourstone lined banks with failure on left bank.

Photographs	
 **Photo 3.7** Facing north. Headcut/knickpoint migrating upstream through the exposed till.	 **Photo 3.8** Facing south. Failing armourstone wall on left bank.
 **Photo 3.9** Facing east. Rosehill pumping station storm outfall channel, 2023.	 **Photo 3.10** **Facing** downstream. Erosion on left bank. Stormwater outfall channel connects to main channel at red arrow.
 **Photo 3.11** Facing south. CP railway bridge crossing.	 **Photo 3.12** Facing north. CP railway bridge crossing.

Figure 6 Reach 3 Existing Conditions

3.3.5 Reach 4

Reach 4 spans 185 m from the CP rail crossing to the downstream channel inlet which conveys the creek underground. **Table 8** provides a summary of existing reach conditions and photographs taken in May 2020. **Figure 7** maps existing conditions, infrastructure, issues, and constraints.

Table 8 Reach YC-4 Existing Conditions

Reach 4	
Upstream Boundary	CP Rail Crossing (1+075)
Downstream Boundary	Channel Inlet (1+270)
Channel Length	185 m
Reach Map	
Channel Conditions (from US to DS)	The entire reach is hardened in place with grouted armourstone walls, which are in varying condition (1+075 to 1+150) Narrow channel lined with grouted armourstone downstream of CP rail crossing. Armourstone walls appear to be stable with the exception of two locations where there is evidence of erosion behind walls and displaced armourstone (Photo 4.1 and 4.2) (1+150 to 1+220) Narrow channel lined with grouted armourstone. Armourstone walls are failing in multiple locations (Photo 4.3 and 4.4)

Reach 4	
	(1+220) Concrete grade control apron embedded with stone. Apron appears stable but is likely contributing to downstream erosion. Armourstone wall is undermined at downstream extent (Photo 4.5) (1+220 to 1+270) Narrow channel lined with grouted armourstone. Armourstone is failing throughout with evidence of erosion behind walls (Photo 4.6 and 4.7) (1+270) Downstream channel inlet structure conveys creek underground. Headwall structure and armourstone in immediate vicinity of inlet appear stable, however armourstone on right bank upstream is compromised and leaning into channel. Debris has been noted to accumulate on trash grate, limiting flow capacity. A CSP outlet on right bank conveys overland flow from a swale to the west (Photo 4.8)
Toronto Water Assets	– Watermain adjacent to channel asset ID LN1012177 – Stormwater Inlet asset ID SL1466936
Constraints	– Site access off of Mt Pleasant Rd – Extensive hardening of channel – Steep, unstable ravine slopes – Large, mature trees throughout riparian area – Public usage and adjacent informal pedestrian trail

Photographs

Photo 4.1 Facing south. Armourstone lined banks with displaced armourstones on left bank.

Photo 4.2 Facing east. Armourstone lined banks with erosion behind wall on right bank.

Photo 4.3 Facing south. Armourstone lined banks with failure on left bank.

Photo 4.4 Facing south. Armourstone lined banks with failure on right bank.

Photographs	
 **Photo 4.5** Facing south. Concrete grade control apron.	 **Photo 4.6** Facing south. Armourstone lined banks with failure on left bank.
 **Photo 4.7** Facing south. Armourstone lined banks with failure on right bank.	 **Photo 4.8** Facing south. Downstream inlet structure. CSP culvert conveying overland flow on right bank.

Figure 7 Reach 4 Existing Conditions

3.4 Existing Hydraulic Model

TRCA provided the Estimated HEC-RAS model developed by TRCA Engineering Projects staff for the Summerhill Gardens and Interim Channel Works sites. Preliminary review of the model suggests the following:

1. The HEC-RAS model utilizes up to date Don River (2018) hydrology.
2. The model is 'Estimated' and not 'Engineered', and therefore not accepted for the plotting of Regulatory Floodplain Map Sheets under Ontario Reg. 166/06. Since the YCGSMP scope of work does not include updates to Regulatory Floodplain Map Sheets, this will not impact the project.
3. The model cross sections in the Estimated model are a combination of topographic survey and LiDAR digital elevation model (DEM) data. The creek bed is represented by the topographic survey data, and the overbank floodplain by the LiDAR data. GHD will verify and refine the channel geometry based on up-to-date topographic survey data.
4. The Estimated model contains the single pedestrian crossing over Yellow Creek, but not the larger St Clair Avenue or CP rail crossings. These larger structures do not infringe on the floodplain and are not

expected to impact flow. GHD will verify and refine crossing and hydraulic structure geometry as necessary.

Upon review, the TRCA Estimated HEC-RAS model includes all relevant hydraulic data required for the fulfilment of the project scope and is suitable for use in this project.

3.5 Infrastructure Assessment

Based on the preliminary background review, the initial estimate of at-risk Toronto Water infrastructure within the Study Area includes: six stormwater outfalls with associated storm sewer pipes, one channel inlet at the downstream limit of the watercourse, one reservoir discharge outfall, one watermain crossing, and one watermain adjacent to the channel within 5 metres of the bank. These ten sites are outlined below. The Site IDs, YCGSMP IDs, and City Asset IDs are shown in **Table 9** and illustrated in **Figures 4 to 7** above.

Table 9 Infrastructure Identification

Site ID	YCGSMP Structure ID	Identified At-Risk Structure ID	Type of Structure
Site 1	YC-OF1	OF3882413570	Outfall
Site 2	YC-OF2	OF3862313685	Outfall
	YC-MH1	MH3861413680	Maintenance Hole
Site 3	YC-OF3	OF3857613765	Outfall
	YC-MH2	MH3858113777	Maintenance Hole
Site 4	YC-OF4	OF3851713800	Outfall
	YC-MH3	MH3850413796	Maintenance Hole
Site 5	YC-OO1	OF800169	Rosehill Reservoir Discharge Outfall
Site 6	YC-WM1	LN1012177	Watermain
Site 7	YC-OF5	Asset ID Unknown	Outfall
	YC-OF6	Asset ID Unknown	Outfall
Site 8	YC-OF7	OF3801714062	Outfall
Site 9	YC-WM2	LN1012177	Watermain
Site 10	YC-CB1	CB3786114151	Inlet Catchbasin

3.5.1 Site 1: Watercourse Source Outfall

This 1800 mm outfall is owned by Toronto Water with an asset ID of OF3882413570. This outfall conveys the buried creek into the Vale of Avoca and is the upstream limit of the aboveground portion of Yellow Creek. Potential solutions at this site include: scour pool or stepped grade controls to dissipate high energy flows as they exit the outfall; and restoration of failing bed and banks downstream of the outfall with appropriate integrated bed and bank treatments. We understand this area falls within the project area of ongoing TRCA projects and will require coordination with TRCA.

3.5.2 Site 2: Stormwater Outfall Upstream of St. Clair Avenue East

This outfall is owned by Toronto Water with an asset ID of OF3862313685. The 525 mm outfall was established in 1966. Potential solutions at this site include: replace existing stormwater outfall with new outfall set back from the banks with associated outfall channel and scour pool to dissipate high energy flows as they enter the creek; restore outfall and direct flow away from banks and towards centre of the channel using in-stream vortex rock weirs or rootwads/rock vanes protruding from bank treatments; or minor channel realignment to relocate the channel away from Toronto Water infrastructure.

3.5.3 Site 3: Stormwater Outfall Immediately Downstream of St. Clair Avenue East Crossing

This outfall is owned by Toronto Water with an asset ID of OF3857613765. The 1350 mm outfall was established in 1977. This outfall was replaced, with associated stream works constructed, in late 2020 to early 2021.

3.5.4 Site 4: Stormwater Outfall Downstream of St. Clair Avenue East

This 600 mm outfall is owned by Toronto Water with an asset ID of OF3851713800. The outfall was established in 1965 and is located at the toe of a steep valley wall with evidence of slope failure. Potential solutions at this site include: replace existing stormwater outfall with new outfall set back from the banks with associated outfall channel and scour pool to dissipate high energy flows as they enter the creek; restore outfall and direct flow away from banks and towards centre of channel using in-stream vortex rock weirs or rootwads/rock vanes protruding from bank treatments; or significant realignment to move the channel away from the outfall and the steep valley wall contact.

3.5.5 Site 5: Rosehill Reservoir Discharge Outfall

This 1500 mm x 2500 mm outfall is owned by the City of Toronto and is used to drain drinking water from the Rosehill Reservoir during cleaning once every 5 to 10 years and for local stormwater drainage from David A. Balfour Park. Correspondence with City staff indicates that flow from the outfall is controlled, and temporary erosion control can be put in place during draining to mitigate scour. The outfall is located on an inside meander bend where deposition has formed a vegetated point bar. A small discharge channel has cut through the point bar from the outlet, indicating relatively recent discharge from the reservoir. Armourstone walls upstream and downstream of the outfall are stable and show no signs of significant erosion. Due to the stability of the existing outfall, conceptual stream restoration designs should keep the channel alignment similar at this location and the outlet in place as it is now.

3.5.6 Site 6: Watermain Crossing

A watermain crosses through the channel roughly 175 m upstream of the CP rail crossing and directly downstream of the Rosehill Reservoir Discharge Outfall. The watermain is owned by Toronto Water, constructed in 1966, with an asset ID of LN1012177. The banks are currently hardened with grouted armourstone walls at this location. The armourstone appears to be stable however the concrete bed appears to have been undermined and is downcutting. Potential solutions for watermain infrastructure protection include installation of integrated armourstone bed and bank treatments or vegetated rock buttresses along the banks; or rebuilding sections of bed above the crossing with a focus on fish habitat creation and grade control treatments such as rocky ramps, cascade pool features and vortex rock weirs.

Installation of rocky ramps over the watermain will protect them from erosion and enable fish passage. Use of grade control structures could provide opportunities to reduce stream power and diversify depth through the reaches, which would further improve aquatic habitat. Existing stone material from previous channel bed and bank treatments could be reused, where possible.

3.5.7 Site 7: Rosehill Pumping Station Stormwater Outfalls

Two stormwater outfalls (asset ID's unknown) originating from the Rosehill Pumping Station were directed to a new outfall location and discharge channel into the re-aligned Yellow Creek channel as part of the TRCA Summerhill Gardens Restoration Works. Rapid change is currently occurring in this area due to failure of portions of the recent channel works. The evolving site condition will be monitored and TRCA will be consulted to learn of any corrective works they may have planned.

3.5.8 Site 8: Stormwater Outfall at CP Rail Crossing

This outfall is owned by Toronto Water with an asset ID of OF3801714062. The 300 mm outfall was established in 1925. Armourstone banks upstream and downstream of the outfall appear stable. Potential solutions at this site include: replace existing stormwater outfall with new outfall set back from the banks with associated outfall channel and scour pool to dissipate high energy flows as they enter the creek; restore outfall and direct flow away from banks and towards centre of channel using in-stream vortex rock weirs or rootwads/rock vanes protruding from bank treatments; or minor channel realignment to relocate the channel away from Toronto Water infrastructure. Note that channel realignment at this site will be restricted by the CP rail crossing and may not be a viable alternative.

3.5.9 Site 9: Watermain Parallel to Channel

The watermain lies within 5 m of the creek immediately upstream of the CP Rail crossing. Any lateral migration or widening could potentially expose the watermain in the future. Potential solutions for this site include: bank protection such as armourstone bank treatments and/or vegetated rock buttresses; or minor channel realignment to relocate the channel away from Toronto Water infrastructure. Existing stone material from previous channel bank treatments could be reused, where possible. Note that channel realignment at this site will be restricted by the CP rail crossing and may not be a viable alternative.

3.5.10 Site 10: Downstream Channel Inlet

The downstream stormwater inlet is located approximately 170 m south of the CP Rail crossing and conveys the creek underground by a 2700-mm x 2550-mm box culvert for approximately 1650 m. The inlet is owned by Toronto Water with an asset ID of SL1466936. Erosion and bank failures were noted immediately upstream of the inlet. Potential solutions for this site could involve alterations to the configuration of the inlet structure, bed and bank erosion control upstream, or creation of a larger channel area to contain flows and prevent backwater erosion and outflanking.

3.5.11 Bank Condition Assessment

In conjunction with the assessment of individual Toronto Water Infrastructures Sites, a detailed bank condition assessment was conducted within the Study Area by GHD in 2023. The purpose of the bank condition assessment was to identify the type of bank protection (if present) and the condition of the structure or natural slope within the Study Area, to prioritize future bank protection repairs or replacements.

GHD completed the bank condition assessment on November 20th, 2023. Full details of the assessment are provided in a Technical Memorandum included in **Appendix C.**

The bank type and condition were assessed every 20 m along the centerline of the channel (**Note:** Due to channel sinuosity the bank length in each section varies slightly from 20 m). There were five bank types found within the study area: gabion baskets, quarry block walls, vegetated buttresses, rip rap revetments, and natural banks. The channel bank conditions were scored from 1 to 5, where 1 is Good, 2 is Fair, 3 is Poor, 4 is Failing, and 5 is Failed. When scoring the conditions of bank treatments, 3 major criteria were considered: undermining of the structure, loss/displacement of material, and slumping of the structure. For natural banks, the 3 major criteria were: undercutting of the banks, degree of scouring, and degree of slumping/overhanging.

Gabion baskets, quarry blocks walls, vegetated rock buttresses, rip rap revetments, and natural banks composed approximately 19%, 61%, 5%, 2%, and 13% of the creek, respectively. The prominent bank type in reach 1 was gabion baskets, covering 61% of the reach. In reaches 2 and 3, quarry block walls were the prominent bank type, covering 58% and 80% of these reaches, respectively. Reach 4 was composed only of quarried block walls on the banks of the whole reach.

Most gabion baskets in the study area had failed, with major loss of material, severe slumping, and severe undermining. Quarried block walls were generally in less than fair condition, however there were significant sections where the block wall was in good condition particularly in Reach 4 where the block walls were constructed to the natural channel meander form. Vegetated rock buttresses were frequently in fair condition, featuring only 10 to 20% of the material displaced, consistent slope, and good vegetation growth securing the structure. Rip rap revetments were the least common bank type with only two occurrences, one in poor condition, and the other failed. Lastly, natural banks were primarily in moderate condition featuring moderate scouring, some exposed roots and parent material, and slight overhanging or slumping.

Approximately 54% of all banks suffered from severe erosion and were failing or had failed. Approximately 29% of all banks were in moderate condition, while 17% of banks were in good or fair condition. The percentage of gabion baskets, quarry block walls, vegetated rock buttresses, and rip rap revetments in critical condition (failed or failing) were 79%, 51%, 33%, and 50%, respectively. Most of reach 1 and 2 were failing or had failed (71% and 60%, respectively), while less than half of the banks assessed in reach 3 and 4 were failing or had failed (37% and 38%, respectively).

The bank condition assessment revealed that most of the gabion basket and many of the quarry block wall bank treatments were failing (4) or have failed (5). Reaches 1 and 2 had the highest percentage of failed and failing banks as 71% and 60% of the banks, respectively, were failing or had failed. This corresponds to approximately 400 m and 600 m of failing or failed banks in Reaches 1 and 2, respectively. The main exceptions to this were sections of the channel with quarry block walls in good condition in Reach 3 and Reach 4.

3.6 Potential Constraints Based on Site History

There are multiple constraints based on the site history that will impact the alternative solutions proposed to address infrastructure at-risk within the Study Area. The trail network within the Vale of Avoca is heavily utilized by the public and public engagement is important throughout the YCGSMP project. Steep, unstable ravine slopes are present throughout the length of the near field project limits and will need to be considered when developing the alternative solutions for infrastructure at-risk. Construction access is a major constraint at the site, as evidenced during the Yellow Creek outfall replacement project, detailed in **Section 3.2.4.1**. Consideration of construction access will be incorporated into the evaluation of alternative solutions. TRCA presently has two ongoing projects within the Study Area. Integration with upstream and downstream projects will require coordination with TRCA. Sites will also need to be prioritized within the Study Area, as well as against other projects within the City of Toronto. Existing bank protection, such as the historic quarried rock walls, remain in relatively good condition in the lower reaches of the Study Area (Reach 3 and 4), while more degradation of the gabion basket protection has been observed in Reach 1 and the upstream portion of Reach 2.

4. Step 3 – Past-Future Trends / Disturbances

4.1 Historical Assessment

4.1.1 Historical Bank Locations

To complete the historical assessment, aerial photographs from 1965, 1978, 2005, and 2015 were compared to a 2018 aerial photograph. Historical aerials were obtained through the City of Toronto Web Map Services, and the 2005, 2015, and 2018 images were obtained from Google Earth Pro. The aerials were georeferenced to the 2018 image and bank locations were traced where visible. The results are provided in **Appendix D and H**. The historical bank locations will be discussed by reach. A detailed hazard assessment was performed using the historical aerial tracings to quantify rates of channel planform adjustments throughout the Study Area. The methodology and results are outlined in **Section 7.1.** In 1972 multiple channel works were implemented by the City throughout Yellow Creek. A description of these works based on the as-built drawings is included in **Section 4.1.3.1.**

Reach 1

There is evidence of planform adjustment and width changes throughout the reach. Reach 1 was not visible in the 1965 aerial, so all observations are based on the 1978, 2005, 2015, and 2018 imagery. The channel was narrowed and straightened between 1978 and 2005. Channel stabilization works (gabion baskets) were implemented by the City in the 1970's, as discussed in **Section 4.1.3.14.1.3.2**, and the changes in width are attributed to artificial works and channel realignment as opposed to natural channel evolution. Between 2005 and 2015, the channel widened in the downstream portions but remained narrow upstream. These changes are attributed to outflanking of the bank protection structures. Minimal change has occurred between 2015 and 2018 with the exception of minor widening at the upstream limits and minor lateral migration towards the downstream limit of the reach. As observed by GHD in the 2023 bank condition assessment (**Appendix C Figure 2-1**), the majority of Reach 1 banks have been armoured by gabion baskets that are currently in a poor to failed condition. Collapse of the gabion banks has allowed for watercourse widening.

Reach 2

Reach 2 has experienced the most significant planform adjustments and channel width changes since 1965. The adjustments have continued in recent years, as opposed to the other reaches where large planform adjustments primarily occurred from 1965 to 1978 and from 1978 to 2005. These changes are not related to natural channel evolution but rather to artificial stabilization structures implemented by the City during this period. Since 2005, the channel has widened, and planform adjustment has occurred. The widening is attributed to the failure and outflanking of many artificial bank protection measures, as the majority of the reach is armoured. The largest meander migration has occurred at the valley wall contact mid-reach. The meander at this location has continued to migrate to the east since 1978. Additional planform adjustments have occurred between 2015 and 2018, largely related to outflanking of bank protection measures and debris jams due to fallen trees or displaced armourstone. The majority of Reach 2 consisted of a combination of early 1900's quarried rock wall and gabion basket bank protection. The upstream two-thirds of Reach 2 stream bank/bank protection structure was found to be in a failing or failed state, with better conditions found towards the downstream extent of the reach. In general failure of the gabion banks and quarried block walls has led to widening of the watercourse though outflanking of the failed structures.

Reach 3

Reach 3 was largely armoured by quarried rock walls along both banks in the early 1900's. The quarried block walls appear to have been constructed along the existing 'natural' planform of the watercourse. This is fairly unique to Yellow Creek since most watercourses within Toronto were first straightened and then armoured. Moderate planform adjustment occurred between 1965 and 1978. The adjustments primarily occurred immediately downstream of the pedestrian crossing and upstream of the CP Rail crossing. Intensive urbanization of the area surrounding Yellow Creek began between 1954 and 1967 and resulting increases in overland flow/runoff would have created channel instability and likely caused planimetric form adjustments to modify channel gradient and dissipate stream power. Since 1978, the channel has undergone minor variations in width but has not experienced significant planform adjustment. Channel bank repair works were implemented by the City in the early 1970's, in addition to earlier rock walls, and the artificial bank treatments have limited planform adjustment since 1978. Minor changes in width or planform could be related to minor outflanking of the structures. The majority of Reach 3 consisted of quarried rock wall bank protection in fair to good condition as observed in the 2023 bank condition assessment (**Appendix C Figure 2-3**),

Reach 4

Reach 4 was largely armoured by quarried rock walls along both banks in the early 1900's. The block walls follow a meandering pattern which was likely the existing path of the creek. This is a novel approach to creek stabilization, as noted in Reach 3, since creeks were normally straightened and then armoured in Toronto urban areas. This reach has experienced minor historical variations but no significant planform adjustments. Between 1965 and 1978 the channel migrated to the west but has had no major planform changes since 1978. Bank repairs works were implemented by the City in the early 1970's, and the artificial bank treatments have limited planform adjustment since 1978. The channel width in Reach 4 has remained relatively constant since 1965. The majority of Reach 4 consisted of quarried rock wall bank protection in fair to good condition as observed in the 2023 bank condition assessment (**Appendix C Figure 2-4**),

4.1.2 Historical Sinuosity

Sinuosity was calculated for each historical aerial based on the comparison of channel centreline distance to channel straight-line distance of the aboveground portion of the creek. The results are summarized for each reach in **Table 10**. There has been minimal change in sinuosity since 1978, after the majority of the channel bank treatments were introduced. The channel armouring confined the channel and limited lateral migration causing the sinuosity to remain relatively constant since 1978.

Table 10 Sinuosity of Historic Channels

Year	Centreline Distance (m)	Straight-line Distance (m)	Sinuosity
1965[8]	-	-	-
1978	1269.84	1080.76	1.175
2005	1259.29	1080.76	1.165
2015	1262.15	1080.76	1.168
2018	1263.08	1080.76	1.169

4.1.3 Previous Channel Works

The majority of the channel banks through Yellow Creek have been armoured either with gabion baskets, armourstone walls, or rip rap retaining walls. Previous work on the channel bed has been completed and portions of the channel have concrete beds with embedded boulders, armourstone steps, or rock weirs. Previous works have also included channel planform adjustments, including channel widening and realignment.

4.1.3.1 Early 1900s Bank Works with Quarried Stone

An initial effort at armouring the channel occurred in the early 1900s. Quarried rock walls were constructed along much of the Yellow Creek channel banks through the Study Area. These walls have survived to present day, most notably in Reach 3 and Reach 4 of the Study Area.

The upstream stormwater pipe network that discharges to Yellow Creek's open channel from underneath Mt Pleasant Cemetery was in place by 1960. Full urbanization of the Yellow Creek subwatershed by the 1960's has significantly increased stormwater runoff to Yellow Creek and transformed the creek into a flashy, runoff dominated watercourse. Rapid runoff following storm events has led to significant erosion along the channel bed and banks of Yellow Creek, causing the early 1900's erosion control structures to fail particularly in the upper reaches and to be replaced by gabion basket protection in the early 1970s.

However, an estimated 61% of the Study Area remains armoured by the historic quarried rock walls, with 58% of Reach 2, 80% of Reach 3 and all of Reach 4 consisting of this style of bank protection in 2023 (**Appendix C**). It was estimated that 51% of the remaining rock walls were in a critical condition (failed or failing), but it was further noted that the Reach 3 and Reach 4 walls were in fair to good condition and appeared to have persisted in a better state than the 1970's gabion baskets (**Appendix C**). The longevity of the quarried block walls could be due to their construction along the likely existing meandering pattern of the watercourse. For example, straight watercourses often fail due to the tendency of the watercourse to initial meandering. The meandering planform at this location may have been more in equilibrium with the hydraulic forces.

4.1.3.2 1972 Channel Works

In 1972 multiple channel works were implemented by the City throughout Yellow Creek. The works will be discussed by reach and are based on the City's as-built drawings (City of Toronto, 1972).

[8] Tree cover limited bank tracings through many sections of the channel so this aerial is not accurate for sinuosity calculations

Reach 1

Immediately downstream of the upstream-most outfall (OF3882413570), a three-tier stepped gabion retaining wall was added as bank protection to the right bank while boulders were added to the left bank. Boulders were added to the outer banks of many of the meanders in Reach 1. Upstream of the outfall upstream of the St. Clair Avenue East bridge, OF3862313685, a three-tier stepped gabion retaining wall was added to the right bank and a four-tier stepped gabion retaining wall was added to the left bank. The four-tier stepped gabion retaining wall terminated at Outfall OF3862313685 and the three-tier stepped gabion retaining wall transitioned to a small armourstone retaining wall which continued along the right bank until the St. Clair Avenue East bridge crossing. Boulders were added to both banks under the St. Clair Avenue East bridge crossing.

Reach 2

A small armourstone retaining wall structure was constructed along the left bank at the upstream limit of Reach 2 and stepped gabion retaining wall was implemented along the right bank. The stepped gabion retaining wall transitioned from three-tier to four-tier immediately upstream of outfall OF3851713800. The creek banks in this location were realigned slightly to widen the watercourse downstream of the outfall. A vegetated island was present downstream of the outfall and the bank protection measures transitioned on both banks at the upstream limit of the island. The left bank transitioned from a rip rap retaining wall to a stepped gabion retaining wall while the right bank transitioned from a stepped gabion retaining wall to a rip rap retaining wall. The vegetated island was to be surrounded by a rip rap retaining wall. Further downstream the left bank protection terminated but the rip rap retaining wall continued along the right bank with one minor gap where the channel lacked any bank protection.

At the existing valley wall contact, a small armourstone retaining wall was constructed along the outer bend of the meander while the inner bend (right bank) was left unprotected. The existing stone spillway was repaired by setting rip rap stones in concrete and a rock weir was added approximately 30 feet downstream of the spillway. A small armourstone retaining wall was added to the right bank. Approximately 60 feet downstream of the rock weir, a stepped gabion retaining wall was added to the left bank while the rip rap retaining wall continued along the right bank. The creek banks were cut back to widen the channel. The channel downstream of these measures was left natural with no added bank protection until the downstream-most meander of Reach 2 where a check dam was constructed with a rip rap retaining wall along both banks. At the time of the 1972 works, armourstone walls were already in place along both banks immediately upstream of the pedestrian bridge crossing marking the downstream limit of the reach.

Reach 3

At the upstream limit of the reach, small armourstone retaining walls were constructed on both banks and were to be cemented in place. Boulders were added to the channel bed to form rock weirs. A dense bed of boulders was constructed at the outlet of the storm sewer towards the upstream limit of the reach. At the time of construction, the right bank of the reach had an existing rip rap retaining wall which was to be repaired. The left bank was unprotected except for some minor rip rap retaining walls that were constructed along the outer banks of meanders. A downstream pedestrian wooden bridge crossing was present in 1972, and boulder rock weirs were added as well as rip rap retaining walls cemented in place. Downstream of the rock weirs, the right bank protection ended and a rip rap retaining wall was constructed along the outer left bank of the downstream most-meander. No works were added to the remainder of the reach immediately upstream of the CP Rail crossing.

Reach 4

At the upstream limit of the reach, under the CP Rail crossing, rip rap retaining walls were added to both banks using materials from the pre-existing stone blocks. The rip rap retaining walls were to be constructed along both banks through the entire reach except for a small segment mid-reach, after the first meander, where the banks were left unprotected. Upstream of the inlet, a new check dam was constructed and the channel immediately upstream of the inlet was widened. Boulders were added to bed on the left and right sides of the inlet.

4.1.4 Yellow Creek Below Summerhill Gardens Emergency Works

TRCA completed channel works immediately upstream of the CP Rail crossing in early 2020 that included channel realignment, bank protection, and grade control (TRCA, 2020). The works involved significant channel realignment towards the west, where previously the channel had outflanked the bank protection and relocated to the east. The as-built drawings were provided by TRCA, although the conditions in this segment of the creek have been rapidly evolving. The condition of the TRCA emergency works were inspected on April 8th, April 14th, and April 16th, 2020. In the period of a week between observations, portions of the constructed banks were observed to have failed with displaced armourstone along the banks and bed of the creek. Additionally, a knickpoint had formed that began headcutting and exposing the underlying till. These concerns have been flagged to TRCA and we understand TRCA will be monitoring the site and determining mitigation measures.

5. Step 4 – Assessment of Channel Response

5.1 Rapid Geomorphic Assessment

Existing conditions were characterized for Yellow Creek on April 1, 2020. The Study Area was divided into four reaches, as discussed in **Section 3.3**, with Reach 1 extending from Mount Pleasant Cemetery to the St. Clair Avenue East Bridge, Reach 2 extending from downstream of the St. Clair Avenue East Bridge to the pedestrian crossing, Reach 3 extending from the pedestrian crossing to the CP Rail crossing, and Reach 4 from downstream of the CP Rail Crossing to where the creek enters an underground conduit downstream of the CP Railway.

Two rapid assessment tools, a Rapid Geomorphic Assessment (RGA) and a Rapid Stream Assessment Technique (RSAT) were used to assess the watercourse (MOE, 2003; Galli, 1996). The RGA documents observed indicators of channel instability by quantifying observations using an index that identifies channel sensitivity. Sensitivity is based on evidence of aggradation, degradation, channel widening and planimetric form adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21 to 0.40) or in adjustment (score >0.41).

The classifications resulting from the assessment are defined as:

- **In regime -** The watercourse form is adjusted to the flow and sediments conveyed by the system.
- **In transition/stress -** The watercourse is showing signs of form adjustment in response to changes in the flow and/or **sediment** conveyed by the system.
- **In adjustment -** The **watercourse** form is actively undergoing adjustment as a result of changes in the flow and/or sediment conveyed by the system.

The RSAT offers a slightly different approach by using an index to quantify overall stream health and includes the consideration of biological indicators. Observations concerning channel stability, channel scouring/sediment deposition, physical instream habitat, water quality, and riparian habitat conditions are used in an index to produce values that indicate whether the channel is in poor (<13), fair (13 to 24), good (25 to 34), or excellent (35 to 42) condition.

The Downs (1995) classification system was also used as an indicator of morphological adjustment. This classification scheme categorizes channels based on adjustment processes and changes in channel form. For example, streams are characterized as stable, laterally migrating, enlarging, undercutting, aggrading, or recovering (**Figure 8**). A photographic inventory of site conditions at the time of survey was compiled as part of the field assessment and is provided in **Section 3.3.** Field observations and rapid assessment results are shown in **Table 11** and **Table 12,** respectively. Notes identifying the key differentials between reaches are listed in **Table 12**. The channel geometry, including average bankfull width and depths, and substrate classification for each reach are discussed in more detailed within **Sections 6.2**.

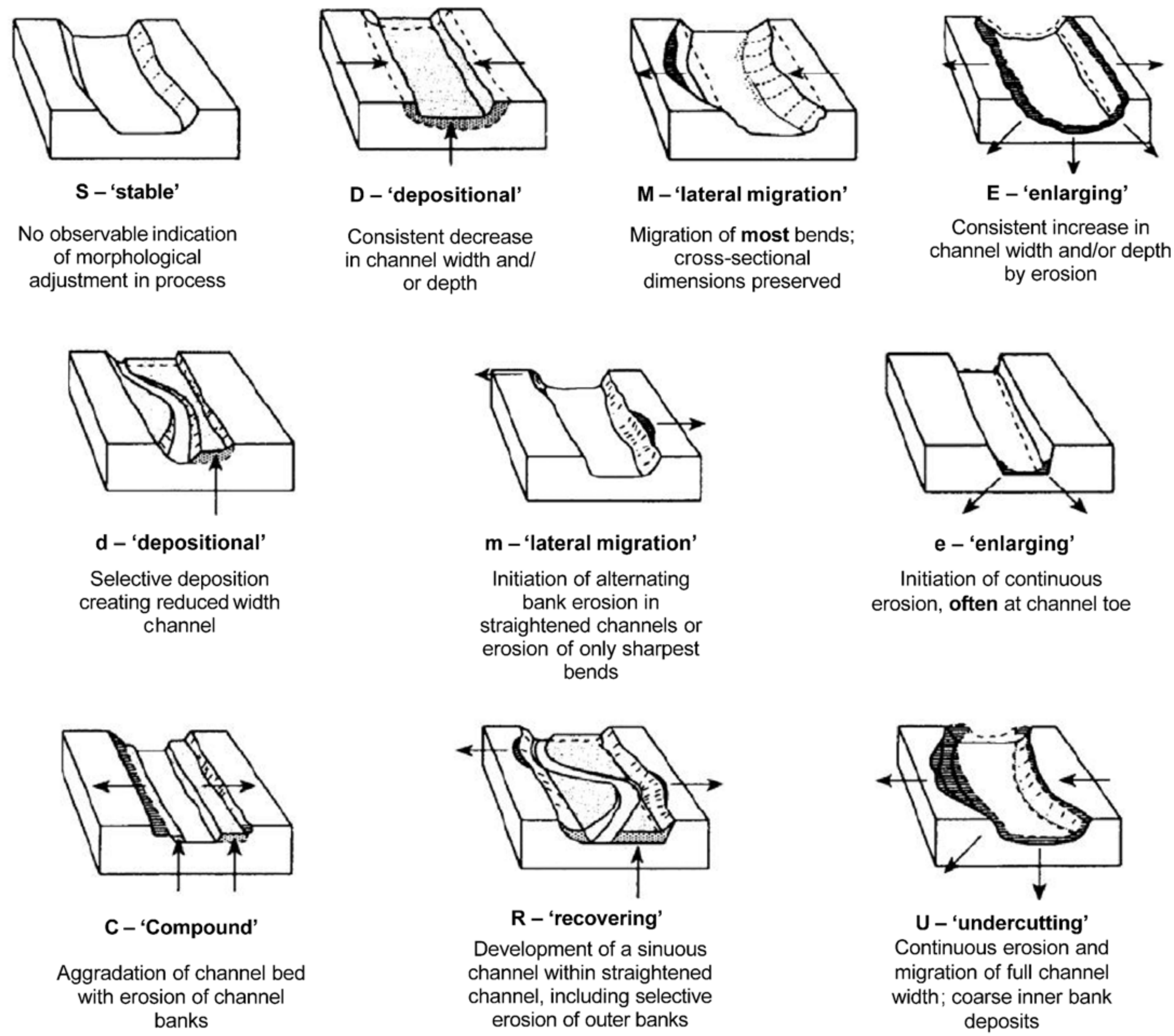


Figure 8 Channel Classification Based on Trends and Types of Morphological Change (Downs, 1995).

Reach 1

The upstream reach was characterized as a confined, well-defined watercourse. The riparian buffer zone was continuous and greater than 5 channel widths wide throughout its length. Mature forest and trails comprised the land use within the creek corridor, while a cemetery with medium density tree cover was located north of the reach and high-density residential land use surrounded the creek valley. The riparian community was dominated by trees and shrubs.

Watercourse sinuosity was low, while gradient and entrenchment were high. Bank angles ranged from 60 to 90º, with some undercuts present, and 60 to 100% bank erosion was observed. Bank failure was comprised of slump/rotational and mass failure. Undercuts ranged from 0.5 to 0.7 m, and bank materials consisted of clay/silt and sand. Channel bed morphology consisted of riffles, pools, and plane bed at a ratio of 2:1:1. Riffle bankfull widths ranged from 4.5 to 6 m and riffle bankfull depths ranged from 0.5 to 1 m. Pool bankfull widths ranged from 6.4 to 8.3 m, and pool bankfull depths ranged from 0.8 to 1.3 m. Riffle substrate was generally comprised of gravel to boulder sized materials, while pool substrate size distribution was dominated by clay/silt and sand with some cobble and boulder sized material also present. The larger materials within the pools were sourced from failed gabions and other artificial bank armouring present within the reach. There was minimal vegetation encroachment into the stream, with only attached algae observed within the watercourse. Evidence of disturbance included failed gabion and other debris from artificial bank armouring and fallen trees in the channel.

Reach 1 scored 0.62 on the RGA, characterizing it as being in a state of adjustment. The dominant mode of adjustment observed during field assessment was widening, while evidence of degradation was also prominent. Evidence of widening included fallen and leaning trees; large organic debris; exposed tree roots; basal scour throughout the reach; failed gabion baskets; outflanked armourstone banks; exposed pipe; and fracture lines along the top of the bank. Evidence of degradation included scour pools downstream of outfalls; undermined gabion; elevated storm sewer outfalls; exposed pipe; terrace cut through older bar material; and a suspended armour layer visible in the banks. A score of 15.5 was achieved on the RSAT, indicating 'fair' ecological health. The main features limiting the ranking included water quality, physical in-stream habitat, and channel stability.

The Down's (1995) model characterized the reach as 'M' – 'lateral migration' and 'E' – enlarging. Evidence of these adjustment modes included erosion along some outer banks with deposition on the inner bank, no alluvial terrace, and erosion along both banks in some locations.

Reach 2

Reach 2 was characterized as a confined, well-defined watercourse. Both informal and paved pedestrian trails were noted within the creek corridor. The creek valley land use was primarily roads, parkland, and residential properties. The riparian buffer zone was continuous, greater than 5 channel widths throughout its length, and dominated by established and mature trees and shrubs.

Watercourse sinuosity was low, while gradient and entrenchment were high. Bank angles ranged from 60 to 90º, with some undercut banks present and 60 to 100% bank erosion observed. Bank failure was comprised of slump/rotational and mass failure. A large valley wall contact was observed within the reach. Undercuts ranged from 0.3 to 1 m, and bank materials consisted of clay/silt and sand. Channel bed morphology consisted of riffles, pools, and plane bed at a ratio of 2:1:1. Riffle bankfull widths ranged from 6.8 to 8 m, while riffle bankfull depths ranged from 0.4 to 0.5 m. Pool bankfull widths ranged from 10 to 12.2 m, and pool bankfull depths ranged from 1 to 1.6 m. Riffle substrate was generally comprised of gravel and cobble, with some boulder sized material. The majority of the materials within the channel in this reach were previously gabion or armourstones. The pool substrate was dominated by clay/silt and sand sized material with some cobble and boulders. The water quality was turbid, and a sewage odour was present at the time of assessment. Evidence of channel disturbance included failed gabion, outflanked armourstone banks, undercut gabion retaining walls, large organic debris in the watercourse, and exposed lengths of previously buried pipe.

Reach 2 scored 0.62 on the RGA, characterizing it as being in a state of adjustment. The dominant mode of adjustment was widening, while evidence of degradation was also prominent. Evidence of widening included fallen and leaning trees; large organic debris; exposed tree roots; basal scour throughout the reach; failed gabion baskets; outflanked armourstone banks and gabion retaining walls; exposed pipe; and fracture lines along the top of the bank. Evidence of degradation included exposed bridge footings; exposed storm sewer/pipe; elevated storm sewer outfall; undermined gabion; scour pools downstream of culverts/outfalls; head cutting due to knickpoint migration; terrace cut through older bar material; suspended armour layer visible in the bank; and exposed till. A score of 17 was achieved on the RSAT, indicating 'fair' ecological health. Water quality, channel scouring, and channel stability were all limiting factors.

The Down's (1995) model characterized the reach as 'M' – 'lateral migration' and 'E' – enlarging, similar to Reach 1. Evidence of these adjustment modes included erosion along some outer banks with deposition on the inner bank, no alluvial terrace, and erosion along both banks in some locations.

Reach 3

Reach 3 was characterized as a confined, well-defined watercourse. The riparian buffer zone was continuous, greater than 5 channel widths throughout its length, and dominated by established and mature trees and shrubs. Paved and informal pedestrian footpaths were noted within the creek corridor, while roads, parkland, and residential land use surrounded the creek valley.

Reach 3 had low sinuosity with a high gradient and entrenchment. Significant bank erosion was observed with 60 to 100% of the banks showing signs of erosion. Some channel banks within the reach were undercut by 0.3 to 1 m and bank angles ranged from 60 to 90º. Bank failure was comprised of slump/rotational and mass failure. The bank materials consisted of clay/silt and sand. Channel bed morphology consisted of riffles, pools, and plane bed at a ratio of 2:1:1. Pool bankfull widths ranged from 6.1 to 6.5 m, and pool bankfull depths ranged from 1 to 1.2 m. Riffle bankfull widths ranged from 3.6 to 4.1 m, while riffle bankfull depths ranged from 0.6 to 0.8 m. Riffle substrate was generally comprised of gravel and cobble, with some boulder sized material; while pool substrate was dominated by clay/silt and sand sized material with some cobble and boulders. The water quality was slightly turbid. Evidence of channel disturbance included an undermined concrete channel bed, outflanked bank armouring, large organic debris in the watercourse, displaced armourstone from bank protection works, and headcutting due to knickpoint migration.

Reach 3 scored 0.53 on the RGA, characterizing it as being in a state of adjustment. The dominant mode of adjustment was widening, while evidence of degradation was also prominent. Evidence of widening included large organic debris; fallen trees; exposed tree roots; basal scour throughout the reach; outflanked armourstone banks; and fracture lines along the top of the bank. Evidence of degradation included undermined previous concrete channel bed; scour pools downstream of culverts/outfalls; head cutting due to knickpoint migration; terrace cut through older bar material; suspended armour layer visible in the bank; and exposed till. A score of 18 was achieved on the RSAT, indicating 'fair' ecological health. Water quality, channel scouring, and channel stability were all limiting factors.

The Down's (1995) model characterized the reach as 'M' – 'lateral migration' and 'E' – enlarging, similar to Reaches 1 and 2. Evidence of these adjustment modes included erosion along some outer banks with deposition on the inner bank, no alluvial terrace, and erosion along both banks in some locations.

Reach 4

Reach 4 was characterized as a confined, well defined watercourse. Paved and informal pedestrian footpaths were noted adjacent to the creek, while roads, parkland, and residential land use surrounded the creek valley. The riparian buffer zone was continuous, greater than 5 channel widths throughout its length, and dominated by established and mature trees and shrubs.

The channel gradient and entrenchment in Reach 4 were both high, while the watercourse sinuosity was low. Undercut banks were observed and bank angles ranged from 60 to 90º. Undercuts ranged from 0.3 to 0.5 m and bank materials consisted of clay/silt and sand. Channel bed morphology consisted of riffles, pools, and plane bed at a ratio of 2:1:1. Riffle substrate was generally comprised of gravel and cobble, with some boulder sized material; while pool substrate was dominated by clay/silt and sand sized material with some cobble and boulders. The water was turbid at the time of assessment. Evidence of channel disturbance included failed armourstone banks, outflanked bank armouring, and large organic debris in the watercourse.

Reach 4 scored 0.53 on the RGA, characterizing it as being in a state of adjustment. The dominant mode of adjustment was widening, while evidence of degradation was also prominent. Evidence of widening included fallen and leaning trees; large organic debris; exposed tree roots; basal scour throughout the reach; outflanked armourstone banks; and fracture lines along the top of the bank. Evidence of degradation included exposed bridge footings; scour pools downstream of the bridge crossing; head cutting due to knickpoint migration; and exposed till. A score of 18 was achieved on the RSAT, indicating 'fair' ecological health. Water quality, channel scouring, and channel stability were all limiting factors.

The Down's (1995) model characterized the reach as 'M' – 'lateral migration' and 'E' – enlarging, similar to the other reaches in Yellow Creek. Evidence of these adjustment modes included erosion along some outer banks with deposition on the inner bank, no alluvial terrace, and erosion along both banks in some locations.

Table 11 General Reach Characteristics

Reach	Bankfull Width (m)	Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Riffle	Pool		
1	4.5 to 9	0.5 to 1.3	Gravel – boulder	Clay/silt and sand	Trees, shrubs	Steep, high banks with high stacked gabion bank protection. Majority of the banks were exhibited signs of bank failure with undermined and slumping gabion.
2	6.8 to 13	0.4 to 1.6	Gravel – boulder	Clay/silt and sand	Trees, shrubs	Failing valley wall contacts. This reach has the only unarmoured and migrating meander bend. There are some sections within the reach with low entrenchment and a well-connected floodplain.

Reach	Bankfull Width (m)	Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Riffle	Pool		
3	3.6 to 6.5	0.6 to 1.2	Gravel – boulder	Clay/silt and sand	Trees, shrubs	This reach was narrow with a high gradient. Failing concrete bed protection and signs of degradation and knickpoint formation.
4	4.9 to 6.9	0.7 to 1.3	Gravel – boulder	Clay/silt and sand	Trees, shrubs	Armourstone walls along both banks throughout the reach. Armoured channel has a meandering pattern. Armourstone is varying states throughout reach.

Table 12 Rapid Assessment Summary

Reach	RGA			RSAT			Downs Classification
	Score	Condition	Dominant form of Adjustment	Score	Condition	Limiting Factor	
1	0.62	In Adjustment	Widening, Degradation	15.5	Fair	Channel Stability and Water Quality	'M' – 'lateral migration' and 'E' – 'enlarging'
2	0.62	In Adjustment	Widening, Degradation	17	Fair	Channel Stability and Water Quality	'M' – 'lateral migration' and 'E' – 'enlarging'
3	0.53	In Adjustment	Widening, Degradation	18	Fair	Channel Stability and Water Quality	'M' – 'lateral migration' and 'E' – 'enlarging'
4	0.53	In Adjustment	Widening, Degradation	18	Fair	Channel Stability and Water Quality	'M' – 'lateral migration' and 'E' – 'enlarging'

6. Step 5 – Present Stream Function

6.1 Hydrology and Hydraulics

6.1.1 Hydrology

The Don River Hydrology Update report and PCSWMM model were reviewed to evaluate flows in each reach of Yellow Creek (AECOM, 2018). The latest model includes design flow estimates for various design storm events, including the regulatory flood (Hurricane Hazel). Yellow Creek falls within the Lower Don subwatershed. The high level of urbanization and the lack of SWM controls in the watershed is reflected in the rapid response of flows in the creek to rainfall, which has resulted in frequent overtopping of the banks and high stream power, relative to other less urbanized areas.

Flows for typical design storms are shown in **Table 13**.

Table 13 Yellow Creek Design Flows

Flow Event	Annual Probability of Exceedance (%)	Flow Rate (m^3/s)
2-Year	50	8.19
5-Year	20	17.76
10-Year	10	23.78
25-Year	4	30.99
50-Year	2	38.49
100-Year	1	45.4
Regional	-	139.97

6.1.2 Hydraulics

A hydraulic analysis for Reaches 1 to 4 of Yellow Creek was completed using the Hydrologic Engineering Centre River Analysis System (HEC-RAS) hydraulic model, which was used to conduct a one dimensional steady flow analysis for a range of storm events. The existing Yellow Creek HEC-RAS model (YellowCreekUpdate.prj) was provided by the TRCA. The 2-Year, 5-Year, 10-Year, 25-Year, 50-Year, 100-Year and Regional Storm Events were modelled for each reach. Flows for these storms were extracted from the Don River Hydrology update. Summaries of average channel velocity, shear stress and unit stream power through each reach is provided in the following sections and a detailed summary of hydraulic parameters is provided in **Appendix E.** Definitions of relevant hydraulic parameters are provided in **Table 14**.

Critical shear stresses capable of mobilizing typical bed and bank treatments used in natural channel designs are summarized in **Table 15**.

In accordance with best practices for site specific hydraulic modelling, Manning's '*n*' roughness coefficients were reviewed and verified for the overbank floodplain and low-flow channel based on the US Geological Survey Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (USGS, 1989).

Table 14 **Hydraulic Output Variables**

Variable Name	Units	Description
Flow Rate	m^3/s	Total flow in cross section
Min Channel Elev	m	Minimum main channel elevation
Water Surface Elev	m	Calculated water surface from energy equation
Energy Grade Slope	m/m	Slope of the energy grade line. Equivalent to channel slope in uniform flow
Velocity Chnl	m/s	Average velocity of flow in main channel
Shear Chnl	N/m^2	Shear stress in main channel
Unit Stream Power	N/ms	Mean available power supply to the column of fluid over unit bed area. Product of river discharge, slope, and weight of water divided by the flow width (Bagnold 1966). $\omega = \frac{pgQS}{W}$ Where: ω = Unit stream power p = Density of water (1000 kg/m^3) g = Acceleration due to gravity (9.8 $m/s^{2)}$ Q = River discharge (m^3/s) S = Energy grade slope (m/m) W = Flow width (m)
Max Chnl Depth	m	Maximum main channel depth
Top Width Chnl	m	Top width of the main channel
Flow Area	m^2	Total area of cross section active flow
Froude # Chnl	-	Froude number for the main channel. Non-dimensional ratio of the inertial force to the gravitational force $Fr = \frac{V}{\sqrt{gD}}$ Where: Fr = Froude number V = Average velocity g = Acceleration due to gravity D = Hydraulic Depth When: Fr = 1, critical flow, Fr > 1, supercritical flow (fast / rapid flow), Fr < 1, subcritical flow (slow / tranquil flow)

Table 15 Critical Shear Stress for Typical Bed and Bank Treatments

Treatment	Critical Shear Stress (N/m^2)[9]
500 to 600 mm Boulders	324 to 388
1 to 2 Tonne Armourstone	583 to 728

6.1.2.1 Steady vs Unsteady Flow Simulations

The U.S. Army Corps of Engineers HEC-RAS hydraulic model can perform steady flow, and unsteady flow simulations. The steady flow component flow is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction and contraction/expansion. The momentum equation is applied in situations where the water surface profile is rapidly varied. These situations include hydraulic jumps, hydraulics of bridges, and evaluating profiles at river confluences. The unsteady flow component solves the full, dynamic, 1-D Saint Venant Equation using an implicit, finite difference method.

Under steady flow, the user specifies the discharge at the upstream boundary, and stage at the downstream boundary. The steady flow model proceeds to calculate stages throughout the interior points, while keeping the discharge constant for each storm event.

Under unsteady flow, the user inputs an inflow hydrograph at the upstream boundary and a rating curve at the downstream boundary. The flood wave is routed through the model and translated to varying stage at interior points over time. That is, the stage at a given cross section varies over the course of a given flood hydrograph.

Unsteady models are particularly useful for routing flows through storage structures and detention basins, such as dams and stormwater management facilities, where details regarding flood wave attenuation are critical. For the purposes of this assignment a steady state model was utilized since no storage or detention features exist within Yellow Creek.

However, for larger flood events modelled in steady state, it is practical to consider the real-world runoff event, which will ramp up from low flow to the peak and back down to the low flow over the course of the storm hydrograph. Larger events such as the 100-year and Regional storms will encounter the same hydraulic conditions seen in lesser events as flow in the channel increases over time. In some instances, the peak flow velocities during the 100-year or Regional event may be lower than those during more common events due to site specific geometry. Flow durations during larger events are also typically longer, subjecting the channel to elongated periods of high-power stream flows. The reader should consider these factors when interpreting the following steady state modelling results.

6.1.2.2 Reach 1

Locations of cross sections through Reach 1 are shown in **Figure 9** (4169 through 3314). A summary of average channel velocity, shear stress and unit stream power through the near field limits of Reach 1 is provided in **Table 16**, and a detailed summary of hydraulic parameters is provided in **Appendix E.**

[9] Miller (1977) with Shield's Parameter of 0.045

Figure 9 **Location of Cross-sections throughout Reach 1 (HEC-RAS 5.0.7)**

Table 16 Existing Conditions Channel Velocities and Shear Stresses Summary for Reach 1

Storm Event	Flow Rate (m^3/s)	Existing Channel Velocities[10] (m/s)	Existing Channel Shear Stress[11] (N/m^2)	Existing Unit Stream Power[12] (N/ms)
2	7.99	1.87	66.01	174.37
5	17.16	2.30	86.38	278.05
10	22.91	2.50	97.94	344.14
25	29.71	2.71	110.56	421.51
50	36.97	2.85	118.89	483.61
100	43.67	2.99	127.36	545.06
Regional	134.41	4.31	229.91	1457.56

6.1.2.3 Reach 2

Locations of cross sections through Reach 2 are shown in **Figure 10** (3220 through 1601). A summary of average channel velocity, shear stress and unit stream power through the near field limits of Reach 2 is provided in **Table 17**, and a detailed summary of hydraulic parameters is provided in **Appendix E.**

[10] Based on average channel velocity and shear stress observed within the reach
[11] Based on average channel velocity and shear stress observed within the reach
[12] Average unit stream power in main channel

Figure 10 **Location of Cross-sections throughout Reach 2 (HEC-RAS 5.0.7)**

Table 17 Existing conditions Channel Velocities and Shear Stresses Summary for Reach 2

Storm Event	Flow Rate (m^3/s)	Existing Channel Velocities[13] (m/s)	Existing Channel Shear Stress[14] (N/m^2)	Existing Unit Stream Power[15] (N/ms)
2	7.99	1.99	74.35	192.87
5	17.16	2.33	90.07	271.07
10	22.91	2.49	99.02	323.23
25	29.71	2.68	110.02	385.23
50	36.97	2.85	120.12	448.16
100	43.67	2.99	127.65	496.91
Regional	134.41	4.04	184.27	896.59

6.1.2.4 Reach 3

Locations of cross sections through Reach 3 are shown in **Figure 11** (1572 through 656). A summary of average channel velocity, shear stress and stream power through the near field limits of Reach 3 is provided in **Table 18**, and a detailed summary of hydraulic parameters is provided in **Appendix E.**

[13] Based on average channel velocity and shear stress observed within the reach
[14] Based on average channel velocity and shear stress observed within the reach
[15] Average unit stream power in main channel

Figure 11 **Location of Cross-sections throughout Reach 3 (HEC-RAS 5.0.7)**

Table 18 Existing Hydraulic Conditions Summary for Reach 3

Storm Event	Flow Rate (m^3/s)	Existing Channel Velocities[16] (m/s)	Existing Channel Shear Stress[17] (N/m^2)	Existing Unit Stream Power[18] (N/ms)
2	7.99	2.30	98.26	308.06
5	17.16	2.89	145.43	607.33
10	22.91	3.01	154.53	701.81
25	29.71	3.17	163.12	776.13
50	36.97	3.30	170.75	840.98
100	43.67	3.36	171.56	860.42
Regional	134.41	3.99	193.53	1049.34

6.1.2.5 Reach 4

Locations of cross sections along Reach 4 are shown in **Figure 12** (563 through 3). A summary of average channel velocity, shear stress and stream power through the near field limits of Reach 4 is provided in **Table 19,** and a detailed summary of hydraulic parameters is provided in **Appendix E.**

[16] Based on average channel velocity and shear stress observed within the reach
[17] Based on average channel velocity and shear stress observed within the reach
[18] Average unit stream power in main channel

Figure 12 Location of Cross-sections throughout Reach 4 (HEC-RAS 5.0.7)

Table 19 Existing Hydraulic Conditions Summary for Reach 4

Storm Event	Flow Rate (m^3/s)	Existing Channel Velocities[19] (m/s)	Existing Channel Shear Stress[20] (N/m^2)	Existing Unit Stream Power[21] (N/ms)
2	8.19	2.31	90.33	263.82
5	17.76	2.79	115.00	400.22
10	23.78	3.00	125.70	464.61
25	30.99	3.18	135.03	525.66
50	38.49	3.41	148.80	606.13
100	45.4	3.57	158.70	671.10
Regional	139.97	4.21	186.28	980.16

6.1.2.6 Hydraulic Risk Rating

A hydraulic risk rating was determined based on the average 100-year unit stream power for each reach. Unit stream power characterizes the driving force available for sediment transport, and is defined as the product of flow, slope and the weight of water divided by flow width (Bagnold, 1966).

$$\omega = \frac{\rho g Q S}{W}$$

Where:
ω = Unit stream power
ρ = Density of water (1000 kg/m^3)
g = Acceleration due to gravity (9.8 m/$s^{2)}$
Q = River discharge (m^3/s)
S = Energy grade slope (m/m)
W = Flow width (m)

This metric incorporates the direct hydraulic forces within the channel and the magnitude of flow. Large volumes of flow can transport significant quantities of debris, trees and root wads which can contribute to infrastructure damage.

Each reach was assigned a hydraulic risk rating based on its average unit stream power in order to inform the prioritization process. The hydraulic risks are shown in **Table 20.** For each reach, the hydraulic risk rating is evaluated on a scale using the numbers 1, 2, 3, and 4 where a higher value is related to the highest hydraulic score and a lower value is related to a lower hydraulic score. The highest score is considered to be at the greatest risk due to hydraulic forces. The highest hydraulic risk occurs in Reach 3 and the lowest in Reach 2.

[19] Based on average channel velocity and shear stress observed within the reach
[20] Based on average channel velocity and shear stress observed within the reach
[21] Average unit stream power in main channel

Table 20 Hydraulic Risk Summary

Reach	100-Year Flow Rate (m^3/s)	Average Channel Velocity (m/s)	Average Channel Shear Stress (N/m^2)	Average Unit Stream Power (N/ms)	Hydraulic Risk Rating
3	43.67	3.36	171.56	860.42	**4**
4	45.4	3.57	158.70	671.10	**3**
1	43.67	2.99	127.36	545.06	**2**
2	43.67	2.99	127.65	496.91	**1**

6.2 Detailed Geomorphic Assessment

A detailed geomorphic assessment was completed on the only un-armoured section of Yellow Creek, located in Reach 2. The assessment consisted of a topographic survey of the longitudinal profile and four cross sections, pebble counts to characterize the creek bed, and observations of bank material and angle, and root density and depth. The assessment will be used to provide reference channel parameters for proposed channel works.

The detailed assessment summaries are provided in **Appendix F**. Bankfull discharge and velocity were calculated from these observations, and the results are summarized in **Table 21**. Bankfull discharge is the maximum amount of flow the watercourse can carry without overflowing on to the floodplain. The frequency of occurrence of the bankfull flow varies from stream to stream and typically occurs from a few times each year to once every few years. Streams in Southern Ontario normally experience bankfull flow once every year or two. Bankfull discharge and velocity were determined using the Manning's approach based on the channel dimensions and gradient. The D_{50} is the median grain size and the D_{84} is representative of the larger grain sizes present. Flow competencies for D_{50} and D_{84} grain sizes represent the velocities required to entrain these sizes of material.

Note that determination of bankfull dimensions was approximate given the extensive past modification to the watercourse, the lack of naturally evolving banks, and the poor distinction between the watercourse and the floodplain. The calculated bankfull flow should be distinguished from the 2-Year storm event provided in **Section 6.1.1**. The 2-Year storm event of 8.19 m^3/s was provided by TRCA based on the updated Don Hydrology model. The bankfull discharge provided in **Table 21** was determined based on field observations of watercourse characteristics, whereas the discharge for specific return period storm events are typically estimated using a hydrologic model which considers rainfall data and characteristics of the catchment rather than the morphology of the watercourse itself.

Table 21 Detailed Assessment Summary

Channel Parameter	Value
Measured	
Average bankfull width (m)	12.2
Average bankfull depth (m)	0.6
Channel bankfull gradient (%)	2.27
Channel bed gradient (%)	1.90

Channel Parameter	Value
D_{50} (mm)	18
D_{84} (mm)	120
Manning's 'n'-value	0.04
Computed	
Bankfull discharge (m^3/s)	18.56
Bankfull velocity (m/s)	2.48
Tractive force at bankfull (N/m^2)	114
Flow competency for D_{50} (m/s)[22]	0.7
Flow competency for D_{84} (m/s)[23]	1.6

6.2.1 Channel Geometry

The channel geometry of Yellow Creek was analyzed based on the results from the detailed geomorphic assessment, and additional cross sections collected at armoured sections of the channel. An armoured section from each reach of the channel was analyzed along with the un-armoured channel in the following locations:

1. Armoured channel upstream of St. Clair Avenue East bridge crossing (Reach 1)
2. Armoured channel downstream of St. Clair Avenue East bridge crossing (Reach 2)
3. Un-armoured channel (Reach 2)
4. Armoured channel downstream of pedestrian bridge crossing (Reach 3)
5. Armoured channel at CP Rail Crossing (Reach 4)

A summary of the bankfull characteristics is presented in **Table 22**, including bankfull velocity and discharge which were modeled using Manning's approach.

Bankfull widths were the greatest within the un-armoured sections of channel. The channel at these locations has been subject to significant widening and downcutting due to the lack of channel armouring and ease of transport of the silt sized bank materials. The bankfull width of the channel was the smallest within the armoured channel downstream of the pedestrian bridge crossing as the bed and bank treatments in this section of channel restricted channel widening and downcutting. The more horizontally constrained sections of channel have elevated bankfull depths relative to the rest of the channel due to the prevalence of downcutting since channel widening is restricted by the armoured banks.

The width/depth ratio within the channel was the greatest towards the upstream limit of the Study Area where channel widths were the greatest. As the channel flowed downstream the width was reduced and the dominant form of adjustment transitioned from widening to downcutting with increases in bankfull depth. The change from a wider channel at the upstream end of the reach to a higher gradient, more entrenched channel at the downstream end of the reach was due to the addition of bank and bed treatments restricting channel planform adjustment.

[22] Komar, 1987
[23] Komar, 1987

Table 22 Bankfull Channel Characteristics

Location	Average Bankfull Width (m)	Average Bankfull Depth (m)	Width/Depth Ratio	Local Bankfull Gradient (%)	Manning's	Local Bankfull Velocity (m/s)	Local Bankfull Discharge (m^3/s)
Armoured Channel US of St. Clair Ave. E	8.6	1.1	8.18	2.16	0.04	3.83	35.18
Armoured Channel DS of St. Clair Ave. E	7.2	2.0	5.23	1.46	0.04	3.76	37.52
Un-Armoured Channel	12.2	0.6	20.31	1.82	0.04	2.43	18.17
Armoured Channel DS of Pedestrian Crossing	9.8	0.8	12.4	1.80	0.04	2.86	22.05
Armoured Channel at CP Rail Crossing	8.8	1.2	7.6	1.35	0.04	3.04	19.29

Entrenchment ratios were calculated based on the cross-sectional dimensions collected during the detailed geomorphic survey (**Table 23**). The entrenchment ratio is equal to the flood-prone width (the width at two times the bankfull elevation) divided by the bankfull width.

A channel with a wide, well-developed floodplain has a larger entrenchment ratio, while an incised, confined channel has an entrenchment ratio closer to 1. An entrenchment ratio of 1.0 to 1.4 indicates that the channel is 'entrenched'. Entrenchment ratios of 1.41 to 2.2 represent 'moderate entrenchment' and entrenchment ratios greater than 2.2 indicate 'minimal entrenchment' (Rosgen, 1994). Most of the cross-sections measured in Yellow Creek are classified as "minimally entrenched" to 'moderately entrenched'. The most entrenched cross sections occur in Reaches 1 and 3 due to the presence of high, vertical armourstone walls while the upstream portion of Reach 2 is less entrenched with greater floodplain connectivity along the left bank.

Table 23 Entrenchment Ratios

Location	Cross Section	Bankfull Width (m)	Flood Prone Width (m)	Entrenchment Ratio (m)	Entrenchment Classification
Armoured Channel US of St. Clair Ave. E	1	8.43	15.12	1.79	Moderately Entrenched
	2	9.01	22.21	2.46	Minimal Entrenchment

Location	Cross Section	Bankfull Width (m)	Flood Prone Width (m)	Entrenchment Ratio (m)	Entrenchment Classification
	3	8.47	12.13	1.43	Entrenched
Armoured Channel DS of St. Clair Ave. E	1	7.89	27.56	3.49	Minimal Entrenchment
	2	6.91	21.64	3.13	Minimal Entrenchment
	3	6.8	18.13	2.67	Minimal Entrenchment
Un-Armoured Channel	1	14.55	26.65	1.83	Moderately Entrenched
	2	13.62	36.52	2.68	Minimal Entrenchment
Armoured Channel DS of Pedestrian Crossing	1	9.76	14.13	1.45	Entrenched
Armoured Channel at CP Rail Crossing	1	4.94	13.21	2.67	Minimal Entrenchment
	2	6.87	15.56	2.26	Minimal Entrenchment

6.2.2 Substrate Characterization

Modified Wolman (1954) pebble counts were conducted at four (4) cross sections in the non-armoured reference reach. **Table 24** outlines the D_{10}, D_{50} and D_{84} at each of the non-armoured cross sections.

Table 24 Sediment Characteristics

Cross Section	Morphology	D_{10} (mm)	D_{50} (mm)	D_{84} (mm)
1	Run	< 1	16	74
2	Riffle	< 1	11.5	70
3	Run	1.4	25	125
4	Run	1.2	16	110

The channel is generally characterized by abundant sediment sources due to the ongoing erosion of the ravine walls and the transport of sandy material from the large valley wall contact present in Reach 2. Exposure of non-alluvial tills also occurs locally but is more common along the downstream sections of Yellow Creek, notably at the knickpoint in Reach 3. In general, bed composition is characterized by abundant silt, gravel, and cobble, which form lobate and point bars throughout the channel.

Coarse armourstone, boulder sized materials, and gabion were displaced throughout the channel from failed previous bank treatments. Armourstone and boulder sized material from previous bed and bank treatments was observed within natural cross sections indicating the erosive power of storm flows within the channel. Storm flows within the channel have the potential to mobilize both native channel materials and larger bank and bed treatment materials.

6.2.3 Geomorphic Sensitivity

Geomorphic sensitivity is evaluated through assessments of areas of potential erosion concern and calculation of erosion thresholds. Erosion thresholds determine the magnitude of flows required to potentially entrain and transport sediment in the channel. Furthermore, erosion thresholds provide a tool with which to evaluate potential reduction in erosion within a channel under different conceptual flow management plans. Erosion assessments include the following tasks:

– Review of background information, including previous existing conditions reports, detailed geomorphic surveys and historic aerial photographs.
– Evaluation of channel reaches using historic background information, where available, to quantify channel migration, if possible.
– Summary of field data and various analyses to determine erosion thresholds. Multiple analytical methods (both critical shear and threshold velocity models) are applied to the data to define threshold flows for the bed and banks of the sensitive reaches. The model results are examined for convergence, appropriateness, and compatibility with field observations.

Rapid assessments for this study included measurements of channel and bank characteristics and bankfull flow conditions. The detailed geomorphic assessment was used to quantify the bankfull cross-sectional dimensions of the non-armoured sections of the channel (e.g., bankfull depth and width). A modified Wolman (1954) pebble count was used to roughly characterize the channel bed substrate materials at un-armoured locations. The long profile survey was consulted to calculate a local grade. From these observations, erosion thresholds and bankfull discharge were modelled. The bankfull characteristics from these measurements were presented previously in **Table 21.** Erosion threshold variables are presented in **Table 25**.

The threshold analysis was first completed for the D_{10} grain size, which represents the finer fraction of the particle distribution and can be used to determine a flushing flow, which removes fines from a riffle feature. The threshold calculations are completed for each individual cross-section and the average D_{10} value for all natural cross sections was 1 mm. The threshold discharge based on the D_{10} was approximately 0.002 m^3/s using Van Rijn (1984). This is <1% of the un-armoured bankfull discharge indicating transport of D_{10} grain size occurs during most flows.

The threshold analysis was then completed for the D_{50} grain size. The median grain size value over all four (4) non-armoured cross sections was 18 mm, characterized by medium pebble sized material. It is noted that a wide range of material was present and varied between more natural sections with exposed till and the armoured sections of channel with large armourstone and boulders. The threshold discharge based on the median grain size was approximately 0.450 m^3/s using Komar (1987). This is ~2.2% of the average unarmoured bankfull discharge indicating transport of the median grain size also occurs during frequent flows.

The threshold analysis was also completed for the D_{84} grain size, which is representative of the larger material in the system. The average D_{84} value was 88 mm, characterized by a medium cobble material. The larger cobble material is often found at riffle features which act as grade control. The results can therefore serve as an indication of the discharge that would alter in-stream structures. Again, using Komar (1987), threshold discharge for the D_{84} clast size was 5.159 m^3/s, which is 25% of the average bankfull discharge.

The threshold discharge is limited by the shear stress resistance of the bed and bank material so an erosion threshold discharge for the banks was also calculated. In a typical cross section, 75% of the bed shear stress acts on the channel banks (Chow, 1959). Given the dominance of fine sediment, a critical bank shear stress of 5 N/m^2 was used based on values in Chow (1959). The threshold discharge for bank material was 0.019 m^3/s, which is <1% of the average bankfull discharge.

Table 25 Erosion Threshold Data for D_{10}, D_{50}, and D_{84}

Cross Section	D-Value	Grain size (mm)	Depths (m)	Threshold Discharge (m^3/s)
Average for Natural Channel (XS 1 - 4)	D_{10}	1	0.015	0.002
	D_{50}	18	0.204	0.450
	D_{84}	88	0.568	5.159
	Bank	-	0.056	0.019

The erosion threshold analysis indicates the system has the potential to transport sediment across a broad distribution. The D84, which is representative of the coarse fraction of the non-armoured channel, has the potential to be mobilized at only 25 percent of the estimated bankfull discharge. Based on the erosion threshold results, it appears that the Yellow Creek urbanized flow regime can easily mobilize the entire natural grain size distribution and has an excess transport capacity.

6.2.3.1 Armoured Channel

The sensitivity of the system was further investigated by estimating the probability of failure of the bed and bank treatments in armoured sections of the channel. Maximum shear stresses for different flow events from the Yellow Creek HEC-RAS model were used to determine the potential for failure of bed and bank treatments throughout Yellow Creek (**Table 26**). Critical shear stresses for the observed bed and bank treatments are listed in **Table 27**. The most common bed and bank treatments consisted of 1 to 2 tonne armourstone retaining walls, gabion retaining walls and large boulder retaining walls. The probability of occurrence for each flow event for a given time period are given in **Table 28**. This information was used to estimate the probability that a bank treatment will fail in a given period of time.

It can be seen that boulder bed and bank treatments could be compromised by flows with return periods less than the 2-year event. This result is supported by observations in the field, where major failure and displacement of boulder treatments was evident throughout the channel, specifically at grade changes where velocity and shear stresses are greatest.

Shear stresses capable of displacing 1 to 2 tonne armourstone may occur during the 10-year flow event and greater. A 10-year flow event has a 41 percent probability of occurring in the next 5 years. In most of the channel the existing armourstone has been compromised by undermining or outflanking, exposing the highly erodible bedding material. Specific locations are described in more detail in **Section 3.3**. In these cases, the underlying material can easily be mobilized by a 2-year flow event. A 2-year flow event has a 97% chance of occurring in the next 5 years. This suggests that once a section of armourstone has been partially compromised, the surrounding armourstone treatment is likely to fail soon after. Observations of change in historic channel aerial photographs have revealed that once armourstone is undermined and begins to collapse, total collapse and failure of the entire bed and bank treatment can occur rapidly. Once this occurs, the treatment is beyond repair and the entire channel will likely require rehabilitation.

Table 26 Existing Shear Stress Summary

Storm Event	Existing Channel Shear Stress (N/m²)[24]			
	Reach 1	Reach 2	Reach 3	Reach 4
2	323.93	365.8	356.02	246.09
5	378.36	390.58	573.34	287.42
10	405.04	419.14	616.48	299.91
25	434.19	458.32	610.19	308.74
50	461.88	503.51	646.66	319.89
100	489.19	528.52	668.99	334.73

Table 27 Critical Velocities for Bed and Bank Treatments

Treatment	Critical Shear Stress (N/m²)[25]
500 to 600 mm Boulders	324 to 388
1 to 2 Tonne Armourstone	583 to 728

[24] Based on peak shear stress observed within each reach
[25] Miller (1977) with Shield's Parameter of 0.045

Table 28 Probability of Occurrence for Flow Events over Different Time Spans

Return Period	Probability of Occurrence in 1-Year (%)	Probability of Occurrence in 2-Years (%)	Probability of Occurrence in 5-Years (%)	Probability of Occurrence in 10-Years (%)	Probability of Occurrence in 25-Years (%)	Probability of Occurrence in 50-Years (%)	Probability of Occurrence in 100-Years (%)
2	50	75	97	100	100	100	100
5	20	36	67	89	100	100	100
10	10	19	41	65	93	99	100
25	4	8	18	34	64	87	98
50	2	4	10	18	40	64	87
100	1	2	5	10	22	39	63

6.2.4 Stormwater Flow Capacity

A flow capacity assessment was completed to provide supplemental information on the condition of Yellow Creek to aid in future prioritization of works within the valley. The purpose of the flow capacity analysis was to determine the size of storm events that could be conveyed through the upstream source culverts and the downstream outlet structure within the Study Area to better understand the hydrology and hydraulics of the system. Full details of this analysis are provided in a Technical Memorandum included in **Appendix C**.

Yellow Creek originates at a large box culvert to the south of Mount Pleasant Cemetery. The creek is an open channel for 1256 m before going back underground in an inlet south of the rail crossing. There are additional stormwater outlets within the system ranging from 300 mm diameter to 1350 mm diameter.

The flow capacity of the existing North Inlet structure was estimated as 27.2 m^3/s, which was sufficient to convey between the 10 and 25-year flow events. Therefore, significant flows would be contributed from the other stormwater outlets and through overland flow. The next largest outlet at Site 3 was estimated to convey 8.4 m^3/s at full capacity (GHD, 2019), which in combination with the North Inlet structure accounts for flows nearly as high as the 50-year event.

The Yellow Creek Outlet structure capacity was estimated as 61.6 m^3/s, which will convey greater than the 100-year event without backwater impacts.

6.3 Terrestrial Habitat

Terrestrial habitat assessments were completed to support the YCGSMP. GHD characterized the existing ecological conditions in the Study Area and completed the SARA, ESA and ANSI Environmental Inventory Analysis, Wildlife Inventory Analysis, and Vegetation Inventory Analysis. The results are included within **Appendix G**. The primary terrestrial constraints relate to the Environmentally Significant Area of the valleyland and its vegetation communities, as well as the potential presence of SAR (i.e. bats) that may roost in mature trees. Mitigation of impacts through implementation of Best Management Practices should be incorporated into conceptual and detailed designs at later stages of the project.

6.4 Aquatic Habitat

6.4.1 Physical Habitat Assessment

The full length of Yellow Creek within the Study Area was walked on June 15, 2020, to capture an up-to-date understanding of potential aquatic habitat potential. In addition to the channel dimensions, gradient, and substrate descriptions observed as part of the geomorphic assessment, additional features and impacts were noted with respect to fish habitat. The main issues noted within the reach were multiple barriers to fish passage, heavily armoured streambanks and failing bank protection measures; and impacts due to stormwater discharge.

Barriers to Fish Movement

Location of barriers, or potential barriers, to fish passage are shown on **Figures 4 to 7**, and photographs are provided in **Table 29** below.

Table 29 Potential Barriers to Fish Movement within Yellow Creek

Barrier	Photo
FB-1: The underground portion of Yellow Creek beginning just upstream of Mount Pleasant Road to an open outfall channel to the Lower Don River would prevent fish from the Don River from accessing the Study Area. The inlet structure also in itself presents a barrier to fish due to its grade, velocity, and long shallow flow over a concrete slab.	
FB-2: Approximately 50 m upstream of where Yellow Creek goes underground, a concrete grade control apron embedded with stone was noted. Large rocks were embedded in the concrete to provide a natural appearance and dispersion of flow; however, the steeper grade of this feature could prevent fish passage.	
FB-3: A concrete lined section of the channel under the railway bridge, with shallow uniform flow across the slab of 0.01 to 0.07 m in depth, would present a potential barrier to fish passage under low flow conditions.	

Barrier	Photo
FB-4: At the time of the aquatic habitat assessment, a knickpoint at an armourstone step within the TRCA interim channel works had created a 0.8 m vertical drop that would restrict fish migration upstream of this location. Note that this location is constantly changing due to significant erosion and transport of bed and bank material.	
FB-5: A series of concrete steps 0.15 m to 0.23 m in height, in combination with a concrete grade control apron embedded with rock, create a barrier to fish passage at the pedestrian bridge crossing.	
FB-6: Approximately 100 m upstream of the pedestrian bridge, a third concrete grade control apron embedded with rock and steeper grade create a potential barrier to fish movement.	

Barrier	Photo
FB-7: The source outfall at the upstream extent of the reach has two vertical drops of approximately 0.8 m in height that would prevent fish migration upstream of this point, however all upstream habitat has been piped underground.	

Streambank Armouring

The streambanks of Yellow Creek through the Study Area have almost entirely been armoured by armourstone, concrete blocks or gabion baskets in order to protect against erosion. However, over time the high, flashy stormwater flows have damaged these measures in numerous locations along the extent of the channel. In many locations, failed bank protection has resulted in:

- Armourstone blocks in the channel
- Armourstone/gabion outflanked due to channel movement leaving the degraded walls crossing within the channel itself
- Flow forced through very narrow sections, as bank protections have fallen inwards, further confining the flow path

The concrete lined, rock embedded ramps both upstream and downstream of the pedestrian bridge crossing were also noted to have undermining of the associated armourstone wall. These locations currently have deep undercuts under the ledge of concrete that is now visible in the channel. The undercuts themselves could provide beneficial cover for fish, however the destabilized bank presents a greater hazard.

Storm Water and Riparian Impacts

All headwaters upstream of the Study Area have been piped underground and diverted into the City's storm water system, out-letting at the upstream extent of the study reach. In addition, six outfall pipes of varying sizes were noted discharging to Yellow Creek within the assessed reach. These factors, combined with the high percentage of surrounding impervious surfaces result in high, flashy storm water flows within the creek. The armoured banks further confine the powerful flows, preventing natural energy dissipation when the water would overtop its banks and disperse on the surrounding floodplain. Where bank protection was degraded or missing, erosion was usually observed. Water quality conditions following storm events have generally appeared to be quite turbid. Results to be presented at the conclusion of the water quality monitoring program.

While the length of Yellow Creek within the Study Area is generally surrounded by a narrow greenway of forest, resulting in canopy cover ranging between 30 to 60%, bank armouring has also resulted in a lack of direct streamside vegetation. The bank vegetation is located vertically higher, limiting the potential for overhanging or in-stream vegetation or woody debris cover. Japanese knotweed, a highly invasive, non-native plant was found to infest almost the full length of the channel. In-stream vegetation was limited to filamentous algae growing on the larger rocks.

Positive Habitat Features

Despite the many obvious impacts to Yellow Creek, physical in-stream habitat had potential to provide acceptable fish habitat. There was a good mixture of riffle and pool habitat diversity, with gravel/cobble riffles and several deep pools. Pools ranged in depth from 0.3 m to up to 1 m deep, although the deeper pools were generally associated with failing bank protection works.

In-stream cover opportunities were provided by approximately 5% undercuts (concrete toe undercut, as opposed to bank undercut); 15% boulders/fallen armourstone blocks; 60% cobble; and 5% in-stream woody debris.

Iron staining was noted at one location within the reach. Iron staining indicates groundwater discharge. This was observed approximately 20 m upstream of the rail bridge.

6.4.2 2020 Electrofishing Survey

On August 28, 2020 an electrofishing survey was conducted within a representative reach following the OSAP protocol for standard single pass survey. The reach was located upstream of where the study reach is piped underground, and downstream of any other physical barriers within the study reach. The sampled reach was 55.5 m in length, an average of 4.2 m wide. A catch per unit effort of 1.9 electrofishing seconds per metre squared was expended. No fish were captured or seen. In addition, no incidental fish sightings have occurred during any GHD site visit during the course of this project. The sampling results, combined with site observations and historic records, indicate that it is unlikely that fish are currently present within Yellow Creek in the daylighted section between Mt Pleasant Road and Mount Pleasant Cemetery.

6.4.3 2020 Benthic Invertebrate Survey

On August 28, 2020 a benthic invertebrate sample was collected within the same OSAP site extent as the electrofishing survey described in **Section 6.4.2.** Two riffles and one pool were sampled via the travelling kick-and-sweep method. The sample was preserved in 70% isopropanol and sent to a benthic laboratory for identification of individuals to the lowest possible taxonomic level. The results of the sampling and data analysis are summarized in **Table 30** below.

Table 30 Summary of the Benthic Aggregate Analysis

Site	Index				
	Species Richness	HBI (0 to 10)	EPT (%)	EPT: Chironomids	Oligochaetes (%)
Riffle 1	23 – Slightly Impacted	6.59 – Moderately Impacted	38.59	0.98	13.46
Pool	20 – Slightly Impacted	7.17 – Moderately Impacted	42.86	0.82	1.28
Riffle 2	18 – Moderately Impacted	5.84 – Slightly Impacted	69.19	3.27	0.07

Site	Index				
	Species Richness	HBI (0 to 10)	EPT (%)	EPT: Chironomids	Oligochaetes (%)
Average	20 – Slightly Impacted	6.53 – Moderately Impacted	50.21	1.69	4.94

Species richness, a measure of the diversity of species present in each sample, was relatively comparable between the three samples, with an average of 20 species. This indicates an average water quality assessment of "slightly impacted" (Mackie, 2001). However, this metric does not take into account the sensitivity to pollution of each species.

The Hilsenhoff Biotic Index (HBI) provides a measure of water quality based upon the particular invertebrates found in the channel relative to their tolerance to pollution. HBI scores range from 0 to 10, with higher values indicating poor water quality. An average of the three Yellow Creek benthic samples indicated "moderately impacted" water quality.

As another measure, Ephemeroptera, Plecoptera and Tricoptera species (collectively EPT) are indicators of healthy aquatic systems as they have narrow tolerances to pollution and thrive in areas with abundant oxygen and cool temperatures. They may also provide information about species richness since they represent all feeding groups (predators, scrapers, collectors, and shredders). As such, they may indicate impairment if one or more feeding groups is missing. A higher percent EPT also demonstrates beneficial food inputs for the fish community. Percent EPT at Yellow Creek indicated moderate to high presence of these more sensitive species, with an average of 50% of Ephemeroptera and Tricoptera organisms in the three samples. There were no Plecoptera species present, however all feeding groups were represented.

Additional calculations, such as EPT: Chironomids, provide an indication of abundance of pollution sensitive to pollution tolerant individuals within a sample. These values ranged greatly between the three samples and were therefore less conclusive.

A calculation of percent Oligochaetes indicates a degree of organic pollution, and an increase in this measure over time can show notable changes within the ecosystem. This metric also varied between the three samples; however, Oligochaetes generally represented a smaller percentage of the samples at this point in time.

6.5 Built and Socio-Economic Environment

6.5.1 Existing Land Uses

The Study Area for this project includes the aboveground reach of Yellow Creek within the Vale of Avoca from just south of the Mount Pleasant Cemetery to the piped watercourse crossing at Mount Pleasant Road, illustrated in **Figure 1**. The Study Area is a steeply sloped, forested valley with both formal and informal recreational trails. Two crossings intersect the Study Area, the St. Clair Avenue East Road crossing towards the northern limit and a CP rail line crossing towards the southern limit. Mount Pleasant Road runs parallel to the watercourse just outside of the southeastern limits of the Study Area. Mount Pleasant Cemetery is present immediately north of the Study Area but is not within the Study Area limits of the YCGSMP. Immediately to the northeast of the valley, outside of the Study Area, are residential properties along Rose Park Crescent and Inglewood Drive. Northwest of the Study Area, the land use is primarily commercial and southwest of the Study Area residential properties are present along both

Summerhill Gardens and Mathersfield Drive. Between the western residential and commercial properties is David A. Balfour Park, part of which is within the Study Area limits.

The existing land uses correspond well to the designated land uses based on the official land use plans (City of Toronto, 2019). The majority of the Study Area is designated as Natural Area land use according to the City of Toronto Official Land Use Plan (2019), with a narrow utility corridor towards the southern limit of the Study Area associated with the CP rail crossing. Parks land use, associated with the David A. Balfour Park, is designated to the west of the Study Area. Neighbourhoods, Apartment Neighbourhoods, Mixed Use Areas, and Open Space Areas (associated with Mount Pleasant Cemetery) bound the Study Area but are not included within the Study Area limits of the YCGSMP.

6.5.2 Recreational Trails

A formalized paved trail runs through the Yellow Creek valley corridor, also referred to as the Vale of Avoca. The trail runs parallel to the creek on the west side, south of St. Clair Avenue East, before crossing to the east side of the creek at a mid-point in the watercourse. North of St. Clair Avenue East, there is an informal mud trail that runs parallel to the watercourse. The trail is extensively used for public recreation and connects to both the Mud Creek and Don Valley trail systems.

6.5.3 Water and Wastewater Infrastructure

Toronto Water Infrastructure exists within the Study Area and includes six stormwater outfalls with associated storm sewer pipes, one channel inlet at the downstream limit of the watercourse, one reservoir discharge outfall, one watermain crossing, and one watermain adjacent to the channel within 5 metres of the bank. Additional details regarding Toronto Water infrastructure are provided in **Section 3.5**.

6.5.4 Utilities

A Sub-Surface Utility Engineering (SUE) Investigation to quality level "C" was completed by multiVIEW to identify the presence and approximate location of underground utilities by surveying visible above ground utility features. No utilities, aside from the infrastructure discussed in **Section 3.5**, were identified.

6.6 Cultural Environment

Portions of the Study Area, the extent of which is described in **Section 1** and shown in **Figure 1**, exhibit archaeological potential based on a Stage One Archaeological Assessment (AA) Study completed as part of the MCEA process (ASI, 2020). Further, a post-1960s addition to Mount Pleasant Cemetery is located adjacent to the Study Area, which must be avoided. In addition, there are two properties located within the Study Area, highlighted in **Figure 5**, which are included in the Municipal Heritage Register as Listed or Designated under the *Ontario Heritage Act*: 120 Inglewood Drive and 122 Inglewood Drive. The Stage One AA Study report and mapped areas of archaeological potential are included as **Appendix A**.

7. Step 6 – Forecast Ultimate Configuration

7.1 Channel Planform Adjustment

A GIS-based modelling exercise that incorporated results from our desktop historical aerial analysis and field assessments was executed to identify and characterize risk to Toronto Water Infrastructure. Historical bank locations from 1965, 1978, 2005, 2015 and 2018 were georeferenced, traced and overlaid on 2018 aerial imagery. Sections of the channel were identified for further analysis based on proximity to Toronto Water Infrastructure and degree of channel migration over the 1965 to 2015 period. Historic rates of lateral migration and channel widening were investigated at a number of transects through Yellow Creek, shown in **Figure H.1** in **Appendix H**.

Note, possible transect locations to assess channel widening and lateral migration were limited as much of Yellow Creek through the Study Area had existing bank protection, either in the form of gabion baskets, quarried rock wall, riprap revetment or vegetated rock buttress. Short sections of natural bank were situated sporadically through the Study Area, mainly in Reach 1 and 2, and were estimated to account for 13% or 162 m of the 1256 m Study Area length. Channel widening was calculated at Transect D (See **Figures G.2** in **Appendix H**), located within a relatively straight section of Reach 2 where both banks were in a natural state. This transect was close to midway between St Clair Avenue East and the CP Railway crossing. Lateral migration was monitored on unarmoured outer bends at Transects A (Reach 1), B and C (Reach 2).

7.1.1 Channel Widening

Channel widths were calculated at one transect based on the available aerial images (**Table 31**). Channel width changes are shown in **Figures H.2** in **Appendix H**. Channel widening was calculated in the same location as the detailed assessment, in the unarmoured section of Reach 2, to conservatively represent the rate of change expected in the absence of armouring. The average rate of change at this transect was 0.08 m/yr. The recent increase in the rate of change for the channel width at this transect may be linked to the fallen tree and debris accumulation within the center of the channel, directing stream flow into the channel banks.

Table 31 Channel Widths

Transect	Year	Width (m)	Average Rate of Change (m/yr)
D	1978	8.24	-
	2015	9.16	0.025
	2018	9.55	0.130

Channel widening could potentially threaten YC-OF1, YC-CB1, and YC-OO1 if the existing channel armouring and bank protection were to fail. If the channel were to widen beyond the existing channel width at each site, the Toronto Water infrastructure could be outflanked. The gabion baskets surrounding YC-OF1 have been undermined and outflanked and are slumping into the creek. If the gabion bank protection were to fail, YC-OF1 would be at-risk due to channel widening. The existing armourstone bank protection surrounding YC-OO1 is in good condition and there is low risk of these structures failing and causing damage to Toronto Water infrastructure. The outfall is located on an inside meander bend where deposition has formed a vegetated point bar. There is minimal risk of damage to this structure. At YC-CB1, the headwall structure and armourstone in the immediate vicinity of inlet appear stable, however the armourstone on right bank upstream is compromised and leaning into the channel. If the remainder of the armourstone were to fail and be displaced, the YC-CB1 infrastructure would be at-risk due to channel widening.

Widening was mainly occurring in Reaches 1 and 2 where the banks had failed. The bank condition assessment (**Appendix C**), evaluated that Reaches 1 and 2 had the highest percentage of failed and failing banks as 71% and 60% of the banks, respectively, were failing or had failed. This corresponds to approximately 400 m and 600 m of failing or failed banks in Reaches 1 and 2, respectively. In comparison, less than half of the banks assessed in Reach 3 and 4 were failing or had failed (37% and 38%, respectively). The stable banks in these Reaches were generally the quarried block walls.

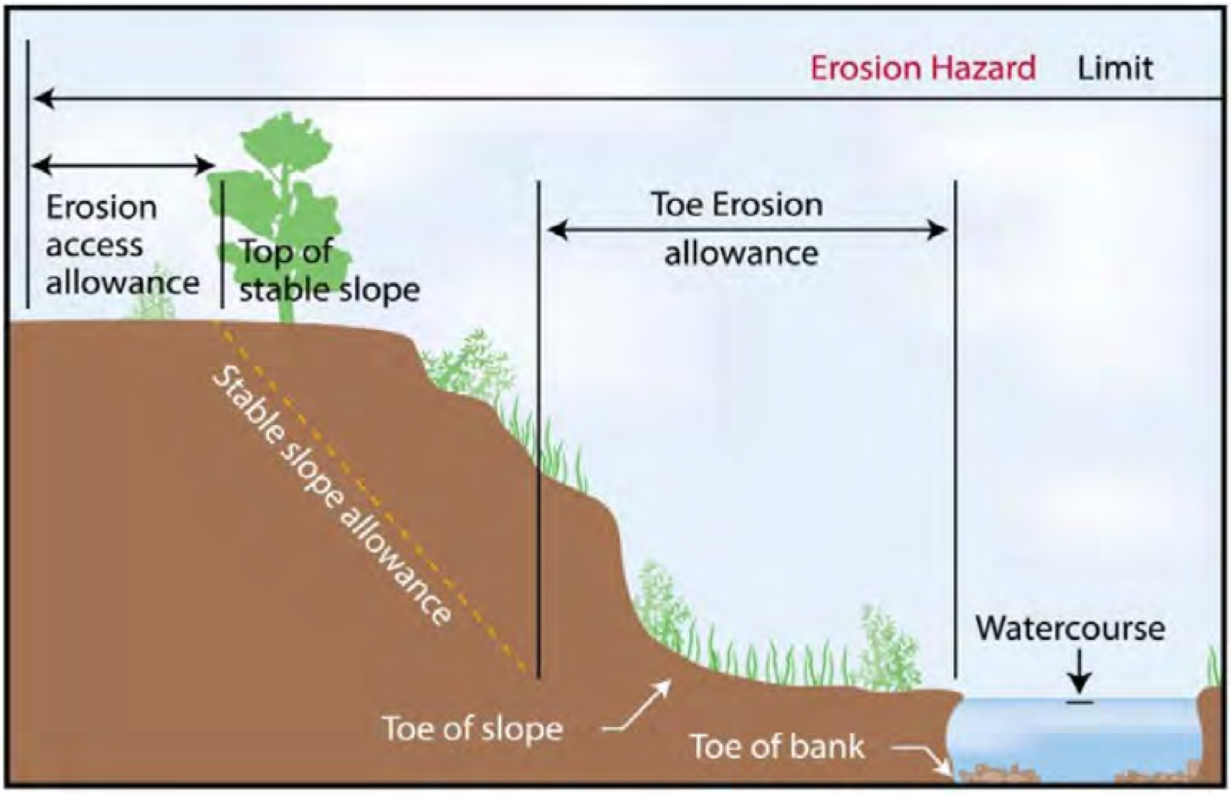
7.1.2 Lateral Bank Migration

Three transects were selected to investigate outer bank migration. Transect A intersects the meander bend immediately upstream of the St. Clair Avenue East crossing showing migration towards sewer infrastructure YC-OF2. Transect B intersects the meander bend immediately downstream of the St. Clair Avenue East crossing showing migration towards sewer infrastructure YC-OF4. Transect C intersects the valley wall contact within Reach 2. Transects and results of the lateral migration analyses are outlined in **Figures H.3, H.4,** and **H.5** in **Appendix H**.

Outer bank migration was investigated through comparison of the bank coordinates along the transects extracted for each year using the aerial tracings. At each transect, some of the aerial images were not used due to extensive tracing gaps in the area of interest. Movement of the outer bank between each aerial record is shown in **Table 32**, along with an average migration rate over the 1965 to 2018 period for each transect. The top of bank was used for Transect A as it was distinguishable in the aerial imagery; however, the toe of bank was used for Transects B and C since the top of slope was difficult to distinguish in many of the aerials. The outer bank could only be distinguished within the 1978 aerial for Transect A and only the 1978 and 2018 aerials for Transect C, so the existing condition survey data was used for comparison. The migration rate at transects A and B are slow due to the armouring present at these sites. These migration rates do not represent the natural channel migration rates. Migration of the transects between 1978 and 2005 is primarily attributed to artificial stabilization structures implemented by the City during this period as opposed to natural channel evolution. More recent migration of the banks is attributed to degrading and outflanking of the bank protection measures. Once the armouring fails, the migration rates will be much higher, likely close to the rates seen at Transect C. The migration rate at Transect C (the valley wall contact) is the highest and can be attributed to the lack of channel armouring along the outer bend of this meander. Transect C is a conservative estimate of future meander migration rates if bank protection were to fail at the other channel meanders. The Down's (1995) model characterized all of the reaches as 'M' – 'lateral migration' and 'e' – 'enlarging, which is likely occurring on a creek-wide scale and causing the migration rates at all meanders to increase over the most recent period as the bank protection measures fail and are outflanked/undermined.

Table 32 Meander Outer Bank Migration Rates

Transect	Migration Rate (m/yr)				Average
	1978 to 2005	2005 to 2015	2015 to 2018	2018 to 2020	
Transect A	0.049[26]	-	-	-	0.049
Transect B	0.060	0.036	0.130	-	0.075
Transect C	0.26	-	-	0.53[27]	0.39



Hazard land requirement for a stable slope used in land use planning; (City of Toronto, 2014)

Erosion hazard limits are defined in Ontario by MNRF (2002) for confined and unconfined systems. A confined system is where the watercourse is within a larger defined valley that restricts migration of the watercourse. The confined hazard limit is defined by the valley wall slope stability and the toe erosion allowance. This hazard delineation method is also endorsed by the City of Toronto (City of Toronto, 2014).

The hazard limits were determined for Transects A, B and C using the measured lateral migration rate of the channel at each location, as further described below. Development or infrastructure within the hazard limits are to be avoided to avoid future risks cause by erosion.

Hazard limits for Transects B, and C were determined based on MNRF (2002) recommendations for confined systems as the valley walls restrict lateral migration. Hazard limits in confined systems are based on slope stability and potential for toe erosion. The stable slope allowance is determined by projecting the long-term stable slope inclination from the slope toe. Based on MNRF (2002) guidelines, in the absence of

[26] Change between 1978 aerial tracing and 2020 GHD survey due to lack of coverage in recent aerials
[27] Change between 2018 aerial tracing and 2019 TRCA survey

a geotechnical investigation, a conservative stable slope allowance estimate was calculated using a horizontal allowance equivalent to three times the height of the slope at each transect, creating a 3:1 (Horizontal:Vertical) stable slope inclination. A geotechnical study may result in narrowing of the hazard limits. The potential for future toe erosion at each Transect location was determined based on the average outer bank migration rate at each transect.

Erosion hazard limits were determined for transects B and C based on the combined stable slope allowance and projected 10-year, 25-year and long-term (100-year) toe erosion setback. Transect A was not directly in contact with the valley walls, so the current migration rates were used to project future meander movement in the next 10, 25, and 50 years at this transect. These limits are identified in **Figure H.3, H.4,** and **H.5** in **Appendix H.** Note that the hazard limits shown for Transects A and B were based on the current rates given there is still channel bank armouring providing a degree of protection at these locations. Once this protection fails, the migration rate will increase to a level similar to that measured at Transect C. Note that a 6 m access allowance is normally added to the erosion hazard limits as recommended by MNRF (2002), this has not been added to these figures.

At Transect A, there is moderate short-term risk of YC-OF2 being outflanked and the pipe leading to YC-OF2 being exposed. If the existing bank treatments were to fail at Transect B, there is high short-term risk that YC-OF4 would be outflanked and both YC-MH3 and the pipe leading to YC-OF4 would be exposed. Based on the stable top of slope projections, there is risk to Avoca Avenue as well. At Transect C, based on the current migration rates, there is little short-term risk to infrastructure; however there appears to be long-term risk to private properties along Inglewood Drive. Bank protection structures surrounding YC-OF5 and YC-OF6 were recently constructed by TRCA so these outfalls are not considered at-risk currently. At YC-OF7 and YC-WM2, the bank treatments appear stable and there is minimal current risk to the Toronto Water infrastructure.

7.1.3 Channel Incision

The quantity of channel cover above the watermain, located just downstream of the Rosehill Reservoir outfall in Reach 3, relative to the 1966 as-built drawings was calculated based on the existing pipe obvert and channel invert. Rates of change were calculated based on the changes in cover between years. The existing channel cover and results of the channel incision analysis are summarized in **Table 33** and shown on **Figure H.6** in **Appendix H**. The as-built cover is shown on **Figure H.6** for the area immediately surrounding the watermain, the upstream and downstream elevations are not indicated on the as-built drawing. Note that annual rates of change are not consistent and could be greater or less than this average value based on annual channel flow and the intensity and duration of storm flow events. The 1966 to 2020 rate of channel incision suggest that the watermain will be exposed in greater than 50 years, which underestimates the expected time until exposure. The rate of channel incision after the installation of the watermain was likely influenced and reduced by the presence of the concrete bed protection, which is currently undermined and failing. Channel incision rates may have increased in recent years as this protection has begun to fail and collapse and the time until exposure may be underestimated. The current rate of channel incision was examined in more detail through the short-term monitoring program completed in conjunction with the YCGSMP study. The results of this monitoring program supported a relatively low rate of erosion within the Study Area, with the exception of two of the short-term monitoring locations. These locations were located mid-way in Reach 1 and mid-way in Reach 2. Existing quarried rock walls within the Study Area remained stable through the monitoring period.

Table 33 Summary of Channel Incision for Watermain Crossing

Crossing	Year	Depth of Cover Over Pipe Crown (m)	Average Rate of Change Relative to 1966 (m/yr)	Time Until Exposure (years)
1	1966	1.59	-	-
	2020	0.93	0.012[28]	77.5 (similar rate was found during the short-term erosion monitoring: 1 to 2 cm in 1.5 years)

7.2 Meander Belt Width

MNRF (2002) natural hazard guidelines state that watercourses are classified as either confined systems or unconfined systems in order to apply the most appropriate erosion hazard limit determination methodology. Unconfined systems are those where the meander belt width is able to fully develop. Confined systems are those where the valley walls restrict the lateral migration of the watercourse. Hazard limits in confined systems are based on slope stability and potential for toe erosion. Hazard limits in unconfined systems are defined by the meander belt width. Yellow Creek was classified as a confined system as valley walls and steep ravine slopes limit watercourse migration over the floodplain; therefore, the meander belt width is not an accurate representation of the geomorphic hazards within the Study Area; however the meander belt width was still delineated for the Study Area following TRCA meander belt width guidelines (2004) and empirical models. It is estimated to determine the necessary space required to support a naturally meandering watercourse.

7.2.1 Aerial Photograph Meander Belt Width Calculations

Procedure 3 within the TRCA guidelines (2004) states that if the meander belt width is greater than 50 m, the meander belt width is equivalent to the meander amplitude identified within aerial images plus a 20% buffer in locations where the hydraulic regime may change in the future. Given the extensive channel armouring that has prevented natural meanders from developing, the TRCA Procedure 3 results do not accurately represent the natural meander amplitudes that would evolve in the absence of armouring. The meanders appear to have been hardened based on the existing meanders at the time of channel protection works (majority were completed in 1972); however, flows have changed since then, and meander amplitudes would be larger in the absence of armouring.

TRCA Procedure 3 states that if the meander amplitude is less than 50 m in a location where the hydraulic regime may change in the future, the MBW is delineated based on the sum of the meander amplitude, a 5% buffer, the 100-year migration distance, and the 100 year shift in meander belt location within the floodplain. The meander belt axis (centre of the MBW) was not observed to have shifted within the available aerial images. In areas where the meander belt width is between 40 and 60 m, the TRCA meander belt width guidelines suggest that the meander belt width should be calculated using both the formula for meander belt widths greater than 50 m and the formula for meander belt widths less than 50 m, with the final meander belt width being the most conservative of the two.

Procedure 3 of the TRCA guidelines was used to determine final meander belt width by measuring the meander amplitude in available aerial photographs. The meander amplitudes are illustrated in

[28] Rate of channel incision underestimates potential rate of future change as existing bed protection is failing

Figures H.7-H.10 in Appendix H and represent the maximum meander belt amplitudes visible for each reach within all of the historical imagery (1965 to 2018). The meander belt amplitudes within Reaches 1, 2, 3, and 4 were 41 m, 49 m, 41.5 m, and 37 m, respectively. The meander belt amplitude for Reach 2 (49 m) was used for all of the reaches to provide a conservative meander belt width estimate.

The rates of migration were calculated at one unarmoured transect (Transect C) within Yellow Creek, illustrated in **Figure H.5** in **Appendix H**, the rates of migration are summarized in **Table 32** above. Based on the average bank migration rate within Transect C, a conservative rate of change within unarmoured meanders of Yellow Creek is 0.39 m/year. A migration rate of 0.39 m/year was used for all four reaches to ensure the final MBW estimate was conservative. The 100-year migration distance for all reaches is 39 m. The final meander belt widths for the two methods are summarized in **Table 34**. The meander belt width calculated using the formula for meander belt width less than 50 m wide was more conservative than that calculated with the formula for meander belt widths greater than 50 m and was used for the final TRCA Procedure 3 meander belt width estimates in **Table 34.** Note that given the extensive channel armouring that has prevented natural meanders from developing, the meanders delineated using the aerial imagery do not accurately represent how the meander belt width would evolve in the absence of armouring.

Table 34 TRCA Procedure 3 Meander Belt Width Estimates

TRCA Procedure 3 Approach	Meander Amplitude (m)	Buffer (m)	100-Year Migration Distance (m)	Meander Belt Width (m)
MBW < 50 m (MBW = amplitude*1.05 + 100-yr migration distance)	49	3	39	91
MBW > 50 m (MBW = amplitude*1.2)	49	10	N/A	59

7.2.2 Empirical Meander Belt Width Estimates

Three empirical techniques were also used: the Williams (1986) model; Ward (2001) model; and TRCA (2004) model. Bankfull channel width and flow, as determined from the detailed geomorphic assessment (**Section 6.2**), and an approximate drainage area obtained from the Ontario Flow Assessment Tool were used for these analyses.

The Williams (1984) model that was utilized is defined as:

$$B_w = 4.3 * W_b^{\ 1.12}$$

where B_w is meander belt width and W_b is bankfull width. A 20% buffer has also been added in **Table 35.**

The Ward (2001) model is defined as:

$$B_w = (6 * W_b^{\ 1.12})*1.2$$

where W_b and B_w are defined in feet. A 20% buffer has been added in **Table 35**.

Meander belt widths were also calculated using the TRCA (2004) model. This model defines belt width based on a regression equation using stream power and drainage area:

$$B_w = -14.827 + 8.319\ \ln(\Omega * DA) + S$$

where:

B_w = meander belt width (m)
Ω = stream power, γQs (W)
γ = specific weight of water (9806 kg m^{-2} s^{-2})
Q = Calculated 2 yr. flow discharge (m s^{-1})
s = slope
DA = drainage area
S = standard error (8.63)

Table 35 summarizes the meander belt widths determined for the four (4) reaches of Yellow Creek employing various methodologies. Note that a 6 m access allowance is normally added to the meander belt width as recommended by MNRF (2001). Due to the confined nature of the watercourse the meander belt width does not effectively describe the geomorphic hazards due to partial restriction of channel migration within the floodplain as a result of nearby valley walls. The average meander belt width was calculated for each reach. The average meander belt width for each reach within Yellow Creek is illustrated on **Figure H.11** in **Appendix H**. Based on the average meander belt width for each reach, a natural meandering channel would not fit within the floodplain between the toe of the valley walls in most of the valley. A natural meandering channel would overlap the existing trail system and pose an increased risk to some adjacent residential properties.

Table 35 Meander Belt Width

Reach	Model	Meander belt Width (m)
Reach 1	TRCA Procedure 3 – Aerial Imagery	91
	Williams Model	45
	Williams Model with 20% buffer	58
	Ward Model	77
	Ward Model with 20% buffer	93
	TRCA Model	81
	Average (all methods)	73
Reach 2	TRCA Procedure 3	91
	Williams Model	61
	Williams Model with 20% buffer	73
	Ward Model	98
	Ward Model with 20% buffer	117
	TRCA Model	78
	Average (all methods)	85

Reach	Model	Meander belt Width (m)
Reach 3	TRCA Procedure 3	91
	Williams Model	56
	Williams Model with 20% buffer	67
	Ward Model	90
	Ward Model with 20% buffer	108
	TRCA Model	78
	Average (all methods)	80
Reach 4	TRCA Procedure 3	91
	Williams Model	49
	Williams Model with 20% buffer	59
	Ward Model	79
	Ward Model with 20% buffer	95
	TRCA Model	78
	Average (all methods)	74

7.3 Climate Change Assessment

A climate change assessment has been completed and results are presented in the Climate Change Assessment memorandum in **Appendix I**. This assessment evaluated the sensitivity of the watercourse to climate change and included a risk analysis on the watershed to examine how the hydrological and fluvial systems will respond to future climate, based on climate change factors.

This assessment established that hydraulic forces in the Yellow Creek channel will increase in the coming decades due to increases in rainfall resulting from climate change. These increases should be considered in the context of sizing natural channel design features. Shear stresses in the future climate scenario are capable of mobilizing material up to 14% larger than material mobilized under existing climactic conditions. Typically, a minimum safety factor of 1.2 times the critical stone size is applied for channel applications. Given the expected increases in shear stress due to climate change, it is recommended that a minimum factor of safety of 1.4 times the critical stone size be applied for design features in the Yellow Creek channel if existing climate hydraulic parameters are used in the conceptual and detailed design.

In addition, GHD found through a separate design project within Reach 3, that maximum velocities estimated using a 2-D hydraulic model were much higher than those estimated using a 1-D hydraulic model. This was due to the steep channel gradient and lack of floodplain connectivity at the assessment location. It is recommended that 2-D hydraulic modelling is used to guide design works within steeper sections of Yellow Creek where the flow velocities would be relatively high and difficult to predict with 1-D hydraulic models.

7.4 Erosion Hazards

The existing erosion hazards within the Yellow Creek GSMP Study Area were assessed and the results are summarized in **Table 36**. The sites are illustrated in **Figure H.12** in **Appendix H**. The features at risk and type of erosion for each erosion hazard were identified, along with any toe erosion for all valley wall contact (VWC) erosion types. Slope stability assessments were recommended for all VWCs with toe erosion.

Table 36 Yellow Creek Erosion Hazards

Erosion Hazard ID	Type of Erosion	Toe Erosion Along Valley Wall Contact (VWC)?	Feature(s) At-Risk	Recommendation to Address Risk
YC-EH1[29]	N/A	N/A	N/A	N/A
YC-EH2	Creek Bank	N/A	Pedestrian trail	Monitor Creek Bank Erosion
YC-EH3	Creek Bank	N/A	Toronto Water Infrastructure; Pedestrian trail	Toronto Water Infrastructure Addressed Under YCGSMP (Site 2); Monitor Creek Bank Erosion
YC-EH4	Creek Bank Erosion – Potential for Long-Term Impact to Valley Wall	No	St. Clair Avenue East Road Crossing	Monitor Creek Bank Erosion
YC-EH5[30]	N/A	N/A	N/A	N/A
YC-EH6	VWC	Yes	Toronto Water Infrastructure; Tableland; Pedestrian Trail	Toronto Water Infrastructure Assessed Under YCGSMP (Site 4); Slope Stability Assessment for Tableland and Pedestrian Trail Risk
YC-EH7	VWC	Yes	Tableland	Slope Stability Assessment
YC-EH8	VWC	Yes	Tableland; Pedestrian Trail	Slope Stability Assessment
YC-EH9	VWC	Yes	Tableland	Slope Stability Assessment
YC-EH10	Creek Bank	N/A	Pedestrian Trail	Monitor Creek Bank Erosion
YC-EH11	Creek Bank	N/A	Pedestrian Bridge; Pedestrian Trail	Works to Repair Bridge and Channel Banks

[29] Assessed by the Yellow Creek Near Heath Street East Erosion Control and Slope Stabilization Project Currently Being Completed by TRCA
[30] Erosion Repaired Under City of Toronto Yellow Creek St. Clair Outfall Repair Project

Erosion Hazard ID	Type of Erosion	Toe Erosion Along Valley Wall Contact (VWC)?	Feature(s) At-Risk	Recommendation to Address Risk
YC-EH12	Channel Bed Incision	N/A	Toronto Water Infrastructure	Assessed Under YCGSMP (Sites 5/6)
YC-EH13	Creek Bank	N/A	Toronto Water Infrastructure; Pedestrian Trail	Toronto Water Infrastructure Assessed Under YCGSMP (Site 7); Monitor Creek Bank Erosion
YC-EH14	Creek Bank	N/A	Toronto Water Infrastructure; Pedestrian Trail	Toronto Water Infrastructure Assessed Under YCGSMP (Sites 8/9); Monitor Creek Bank Erosion
YC-EH15	VWC	No	Tableland	Monitor for Toe Erosion
YC-EH16	Creek Bank	N/A	Pedestrian Trail	Monitor Creek Bank Erosion
YC-EH17	Creek Bank	N/A	Toronto Water Infrastructure; Pedestrian Trail	Toronto Water Infrastructure Assessed Under YCGSMP (Site 10); Monitor Creek Bank Erosion

Note that the hazard assessment completed for the YCGSMP was focused on hazards to Toronto Water infrastructure; however, it is clear that hazards extend to the surrounding tableland, pedestrian trail system, and pedestrian bridge. We recommend that a full erosion hazard study be completed to assess hazards to the tableland. The timing of the study would depend on other existing erosion hazard priorities across the City. This erosion hazard study should include determination of the slope stability and location of the stable top of slope. Existing hazards to the pedestrian trail as a result of bank erosion should be monitored.

7.5 Infrastructure Erosion Site Prioritization

The erosion risk to all infrastructure within the Study Area was evaluated and prioritized based on the current condition of the infrastructure and the lateral planform adjustment and vertical incision of the channel at each respective location. The erosion risk for all identified hazard areas were prioritized based on imminent/high (0 to 5 years), moderate (6 to 10 years) and low (11 to 25 years) risk. A summary of risk prioritization for all structures is provided in **Table 37.**

Table 37 Erosion Risk Summary

Site Number	YCGSMP ID	Identified At-Risk Structure ID	Type of Structure	Dominant Erosion Process	Erosion Risk
Site 1	YC-OF1	OF3882413570	Outfall	Channel Widening	Moderate

Site Number	YCGSMP ID	Identified At-Risk Structure ID	Type of Structure	Dominant Erosion Process	Erosion Risk
Site 2	YC-OF2	OF3862313685	Outfall	Lateral Migration	Moderate
	YC-MH1	MH3861413680	Maintenance Hole	Lateral Migration	Low
Site 3	YC-OF3	OF3857613765	Outfall	Lateral Migration	Repaired in 2021
	YC-MH2	MH3858113777	Maintenance Hole	Lateral Migration	Repaired in 2021
Site 4	YC-OF4	OF3851713800	Outfall	Lateral Migration	High
	YC-MH3	MH3850413796	Maintenance Hole	Lateral Migration	Moderate
Site 5	YC-OO1	OF800169	Rosehill Reservoir Discharge Outfall	Channel Widening	Low
Site 6	YC-WM1	LN1012177	Watermain	Channel Incision	Moderate
Site 7	YC-OF5	Asset ID Unknown	Outfall	Lateral Migration	Low
	YC-OF6	Asset ID Unknown	Outfall	Lateral Migration	Low
Site 8	YC-WM2	LN1012177	Watermain	Lateral Migration	Moderate
Site 9	YC-OF7	OF3801714062	Outfall	Lateral Migration	Low
Site 10	YC-CB1	CB3786114151	Inlet Catch basin	Channel Widening	Moderate

Based on the above analysis, lateral migration of the channel threatens YC-OF2, YC-OF3, YC-OF4, YC-MH2, YC-MH3, and YC-WM2, channel widening threatens YC-OF1 and YC-CB1, and channel incision threatens YC-WM1. These at-risk Toronto Water structures are within Sites 1, 2, 3, 4, 6, 8 and 10. Site 3 was repaired in 2021.

The consequence of failure was evaluated based on the type of infrastructure at the Site, potential impacts to downstream water quality of the watercourse in the event of infrastructure failure and impacts to the downstream ecosystem. The focus of the evaluation was on the potential failure of Toronto Water infrastructure, however secondary consideration was given to potential impacts to park infrastructure and private property.

A summary is provided in **Table 38.** For each Site, the criteria were ranked from lowest (1) to highest (6). The highest average rank is considered to be the greatest priority for implementation of the preferred sub-reach solutions. Site 1 was not included in this assessment since it is being addressed in a separate study by TRCA. Site 3 was not included since it was subsequently repaired in 2021. Sites 5 and 6 as well as Sites 8 and 9 were bundled together due to their proximity since any work at the sites would logically include both sites.

Table 38 Prioritization Ranking Based on Consequences of Toronto Water Infrastructure Failure

Objective	Comments	Site 2	Site 4	Site 5/6	Site 7	Site 8/9	Site 10
Current condition (visual)	Current state of Toronto Water infrastructure at the site. Based on quantity of Toronto Water Infrastructure exposed and visual level of exposure	5	6	4	1	2	3
Potential for damage due to geomorphic processes	Erosion Risk to Toronto Water infrastructure. Based on hazard assessment	4	6	5	1	2	3
TSS/bedload impacts to Toronto Water's New (under construction) Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridge's Bay Treatment Plant's (ABTP) new physical-chemical plant, when completed in the late 2030s	Degree of negative impact to downstream water treatment facilities due to ongoing erosion and increased TSS in water column.	5	6	4	3	1	2
Habitat concerns raised by infrastructure failure	Degree of risk was based on a scenario where the erosion and degradation of infrastructure were to continue to failure at each Site, impacting aquatic habitat and loss of trees due to erosion at each Site.	4	6	5	1	2	3
Likelihood of Catastrophic Failure	Likelihood that Toronto Water infrastructure will fail, considering historic watercourse changes, encasement thicknesses, and channel morphology	5	6	4	1	2	3
Impacts to infrastructure and property	Impacts to Toronto Water infrastructure and residents, including secondary impacts to part infrastructure and private property, if Toronto Water Infrastructure failed.	3	4	5	1	6	2

Ranking	Site 2	Site 4	Site 5/6	Site 7	Site 8/9	Site 10
Average	4.3	5.7	4.5	1.3	2.5	2.7
Consequence Of Failure Rank	3	1	2	6	5	4

The erosion risk from **Table 37** and the consequences of failure from **Table 38** were then used in a Conceptual Risk Register, as per the following example (**Table 39**) to determine the priority for restoration.

Table 39 Conceptual Risk Register Matrix

	Lesser Geomorphic Risk	Moderate Geomorphic Risk	Greater Geomorphic Risk
Lesser Consequence of Failure	Low Priority	Low Priority	Moderate Priority
Moderate Consequence of Failure	Low Priority	Medium Priority	High-Moderate Priority
Greater Consequence of Failure	Moderate Priority	High-Moderate Priority	High Priority

The following Risk Register was then determined for Yellow Creek based on both the risk of failure (erosion risk) and the consequences of failure (**Table 40**). The results and site locations are shown in Figure 13.

Table 40 Conceptual Risk Register Matrix for Yellow Creek

	Lesser Erosion Risk	Moderate Erosion Risk	Greater Erosion Risk
Lesser Consequence of Failure	Site 7	Site 8/9 Site 10	no sites
Moderate Consequence of Failure	no sites	Site 2 Site 5/6	no sites
Greater Consequence of Failure	no sites	Site 4	no sites

It was noted that there was no sanitary sewer infrastructure at risk within the YCGSMP Study Area. Failure of sanitary sewers versus storm or watermain infrastructure would inherently carry a much higher consequence of failure. As such, high priority rankings are generally reserved for exposed sanitary sewer crossings that are found in other watercourses across the city. This larger city-wide view was factored into the priority ranking of the Yellow Creek evaluation.

Figure 13 Site Prioritization Based on Erosion Risk to Structure and Consequence of Failure

7.6 Short-Term Erosion Monitoring

As part of the YCGSMP process, which has been developed over several years, short-term erosion monitoring of Yellow Creek was essential to ensure that the priority list was updated, if necessary, as site conditions evolved, maintenance needs were met, and to document successful and unsuccessful restoration approaches. A Short-Term Erosion Monitoring Program was developed in consultation with City of Toronto and implemented concurrently with the development of the YCGSMP. This program involved the following:

- Bi-annual survey of six (6) monumented cross-sections of Yellow Creek within the Study Area between April 2020 and June 2022, with monumented photographs taken upon each visit. Comparisons of channel morphology between each monitoring event were made to determine if the channel was undergoing significant alterations from baseline conditions during this time frame that would affect YCGSMP planning decisions.
- Repetition of a rapid geomorphic assessment in each of the four (4) reaches within the Study Area in July 2021 and June 2023, with comparisons made to the baseline assessment conditions to determine if the types of systematic changes within Yellow Creek were changing over time.
- Monitoring of flow in 2020 and 2021 at one (1) location within the Study Area over a range of flow conditions in order to develop a stage-discharge curve that would estimate the discharge within Yellow Creek based on water depth.
- Water quality sampling at six (6) monitoring locations during three (3) “wet” and three (3) “dry” weather events to determine baseline water quality conditions within the Study Area and at the outlet to the Don River, with respect to total suspended solids (TSS), turbidity, pH, conductivity, dissolved oxygen and water temperature.

Full details of these monitoring tasks and results are provided in individual memos included as **Appendix J**. Key conclusions included:

- Bank erosion and degradation were ongoing processes within Yellow Creek, however rates of change were relatively low except for known erosion at the outside bend of cross-section 4 (M4, Reach 2) and significant erosion of the right bank at cross section 1 (M1, Reach 1). Overall, the results of the monitoring supported the findings of the hazard assessment completed in Phase 2 of the YCGSMP. Existing quarried block walls at the monitoring sites remained stable through the monitoring period.
- All four (4) Study Area reaches were considered to be “In Adjustment” with the dominant form of adjustment remaining ”Widening” and “Degradation” throughout the monitoring period. “Channel Stability” was considered to be the limiting factor throughout the Study Area and did not differ from the baseline assessment results.
- A stage-discharge curve complements the short-term erosion modelling to estimate magnitude of discharge within the Study Area based on water depth. It was noted that water levels increase rapidly with rain events due to runoff contributions from the surrounding urban watershed.
- Water quality measurements indicated varying levels of TSS, turbidity and conductivity due to upstream land use; and periodic low dissolved oxygen levels were at times unsupportive of aquatic life. These conditions would limit the quality of aquatic habitat that could be potentially restored in Yellow Creek for fish, unless larger watershed impacts were addressed that are beyond the scope of this YCGSMP. Currently, it is believed that there are no fish populations within the Study Area.

8. Step 7 – Feasibility of Intervention

The assessment of the existing conditions within Yellow Creek concluded that channel widening, lateral migration and degradation would continue within the Study Area without intervention, and these processes in the long-term would result in further damage to Toronto Water infrastructure, high TSS/bedload contributions to proposed downstream Toronto Water treatment facilities, as well as risks to slope stability and public trails, loss of valley trees, and impacts to private property.

On a watershed or subwatershed scale, potential solutions would include the reduction of peak flows and associated energy within the system through implementation of stormwater management techniques designed to reduce stormwater runoff. Measures such as stormwater detention ponds are difficult to implement in the Yellow Creek area because of its densely urbanized state. Other measures, such as disconnecting downspouts, installing rain barrels, exfiltration systems, etc., would not be sufficient to address the problems alone. For similar reasons, the Wet Weather Flow Master Plan of 2003 (D'Andrea, et al, 2004) concluded that direct intervention in each creek and river of Toronto is needed to address the impacts of urbanization within Toronto.

As Yellow Creek within the Study Area has already been highly altered with hard bank stabilization structures, most of which are in a degraded state due to age and may be further influencing erosion within the creek, direct intervention is warranted through local protection works and/or sub-reach based works. These alternatives are further discussed in **Section 9**.

Removal and relocation of existing infrastructure from within the Yellow Creek natural system was considered by City of Toronto and deemed to be not realistically feasible or desirable. Toronto Water's YCGSMP is a state of good repair project designed to protect Toronto Water underground piped-like assets where stream erosional processes cause excessive risk to these assets. There are no sanitary sewers in Yellow Creek, only a transmission main crossing and a few storm sewer outfalls.

In regards to the transmission main risk from stream erosion processes, three alternatives for the YCGSMP were evaluated: (i) null option, (ii) local works, and (iii) sub-reach scale works. As a part of sub-reach scale works, either channel works, or a combination of channel works and transmission main works, were examined. There are no plans over the next 20 years to relocate or replace the Rosehill Reservoir/Yellow Creek transmission main. Given the YCGSMP reflects an approximate 20-year planning horizon, the City has reviewed plans for the Rosehill Reservoir/Yellow Creek transmission main. Toronto Water can advise that any potential future works on this system will likely involve rehabilitation with lining techniques, to extend the asset life for another 50 plus years. In addition, there are not currently any defined projects which would require expansion of the transmission main capacity that would be triggered by population growth. Accordingly, Toronto Water can advise that the valley-based Rosehill Reservoir/Yellow Creek transmission main is essentially staying where it is for this current planning horizon.

Storm sewer risk from stream erosion processes was also evaluated. The major erosion risk to storm sewers is stream erosion at outfalls or erosion caused by the segmenting of pipes connected to the storm outfall. Toronto has approximately 3600 Toronto Water outfalls over its 63,000 ha with an average storm sewer catchment area of 24 ha. Removal of storm sewers and outfalls from the stream corridor, defined as a warm water corridor of 10 m on either side of Yellow Creek's centerline, is not advised.

For example, a significant number of outfalls discharge at the top of tablelands, or part way down the valley wall or ravine slope and cause significant erosion downstream of the outfall. This erosion is caused by concentrated flow and leads to significant downcutting of the intermittent channel and causes water quality degradation in the receiving waters due to the increased total suspended solids (TSS) loadings to the creek or river. One method of mitigating this erosion is by installing a storm pipe from the discharge point to the receiving waterbody – which is in contrast with the idea of removing sewers from the stream corridor. Another alternative is to install a "natural channel" to mitigate the erosion, however, that calls for repeated interventions on steep slopes to address erosion in the future years that may require rehabilitation every 10 to 15 years.

It is City staff's observation that having a storm outfall discharging close to the creek provides an overall greater benefit to reducing erosion from concentrated flow from storm sewers. To mitigate the effects of storm pipe discharges, the City's modified design practice is twofold (i) to attempt to angle the discharge at a 45 to 30 degree angle to the direction of creek flow, (ii) use armourstone as a head wall where feasible, rather than a concrete structure, and (iii) build a rock based drop structure and short flow channel to the creek to dissipate concentrated flow energy from the pipe discharge. Given the City's as built condition is largely outfalls at the creek channel, the City is not, in its GSMPs, exploring universal reconstruction of outfalls to be outside of the creek corridor. Rather, the City is simply attempting to return priority storm outfalls, that have been impacted by stream erosion processes, like channel incision. causing outfall downcutting and undermining, or bend migration and bank erosion causing outfall channel erosion, to a state of good repair.

9. Step 8 – Define and Evaluate Alternative Solutions

In context of the Problem/Opportunity Statement developed in **Section 3.1**, three alternative solutions were considered as part of Phase 2 of the MCEA process for the Project: Do-Nothing, Site Based Works, and Sub-Reach Based Works. The following briefly describes each of the three alternative solutions:

1. Alternative Solution No.1: Do Nothing - The existing Toronto Water infrastructure would remain in its present location and no bank/bed protection works would be installed with Alternative Solution No.1. As a result, no actions would be undertaken to improve the conditions of the channel bed and banks surrounding the Sites within the Project limits. Although Alternative Solution No.1 would not address the problem/opportunity statement, it was included as part of the Project because the MCEA states that the "Do Nothing" alternative should be considered by a proponent, like the City, in all projects because it provides a benchmark against which the benefits/consequences of the other alternatives can be measured.
2. Alternative Solution No.2: Local Works and Protection – Single phase construction over a short section of channel subject to priority and budget availability.
3. Alternative Solution No.3: Sub-Reach Based Works – Single or multiple phase construction over a long section of channel subject to priority and budget availability.

9.1 Development of the Alternative Solutions for the At-Risk Toronto Water Infrastructure Sites

There are ten at-risk Toronto Water infrastructure sites within the Project area including six stormwater outfalls with associated storm sewers, one channel inlet at the downstream limit of the watercourse, one stormwater/reservoir discharge outlet, one watermain crossing, and one watermain adjacent to the channel within five metres of the bank.

Table 41 outlines the ten sites including their Site IDs, YCGSMP IDs, City Asset IDs and Alternative Solution summaries and **Figure 13** illustrates their locations.

Table 41 Descriptions of the At-Risk Toronto Water Infrastructure Sites

Site ID	YCGSMP Structure ID	Identified At-Risk Structure ID	Considered as part of MCEA Phase 2	Alternative Solution No.2 Local Works and Protection	Alternative Solution No.3 Sub-Reach Based Works
Site 1	YC-OF1	OF3882413570	No	Not Applicable (NA)	NA
Site 2	YC-OF2, YC-MH1	OF3862313685, MH3861413680	Yes	Storm outfall retrofit; local bank protection, along the west bank surrounding the outfall Length: 50 m	Engineered natural channel design; storm outfall retrofit Length: 170 m Both channel banks and bed
Site 3	YC-OF3, YC-MH2	OF3857613765, MH3858113777	No	NA	NA
Site 4	YC-OF4, YC-MH3	OF3851713800, MH3850413796	Yes	Channel to be realigned to the east away from outlet and unstable bank on west side of creek; storm outfall retrofit Length: 85 m	Engineered natural channel, realigned to the east away from storm outlet; storm outfall retrofit; removal of failed concrete spillway at historic sawmill site Length: 340 m Both channel banks and bed
Site 5, Site 6	YC-OO1, YC-WM1	Asset ID Unknown, LN1012177	Yes –Site 5 and Site 6 bundled for evaluation of alternatives	Channel bed rehabilitation immediately surrounding the watermain crossing with minor channel bank works at Site 5 and no bank works at Site 6; backfill and restore erosion scar Length: 35 m	Engineered natural channel design; replace pedestrian bridge; backfill and restore erosion scar Length: 105 m Both channel banks and bed
Site 7	YC-OF5, YC-OF6	Asset IDs Unknown	Yes	Bank treatment on east bank immediately upstream of the outfall channel confluence with Yellow Creek Length: 25 m	Engineered natural channel design, including stormwater outlet channel Length: 95 m Both channel banks and bed

Site ID	YCGSMP Structure ID	Identified At-Risk Structure ID	Considered as part of MCEA Phase 2	Alternative Solution No.2 Local Works and Protection	Alternative Solution No.3 Sub-Reach Based Works
Site 8, Site 9	YC-WM2, YC-OF7	LN1012177, OF3801714062	Yes –Site 8 and Site 9 bundled for evaluation of alternatives	Replacement or repair of the existing bank protection along the east bank to protect against channel migration towards the adjacent watermain Length: 25 m	Engineered channel design; lower banks and regrade floodplain Length: 45 m Both channel banks and bed
Site 10	YC-CB1	CB3786114151	Yes	Bank protection along both banks approximately 40 m upstream of the channel inlet; remove existing concrete apron, tie-in drainage swale Length: 50	Engineered natural channel design; lower banks and regrade floodplain; retrofit trash rack intake structure; tie-in drainage swale Length: 180 Both channel banks and bed

Site 1 is an 1,800 mm outfall owned by Toronto Water that conveys the buried creek into the Vale of Avoca and is the upstream limit of the aboveground portion of Yellow Creek. Since this area falls within the project area of a TRCA led Class EA, Site 1 was not considered further as part of this Project. Likewise, Site 3 is a 1,350 mm outfall also owned by Toronto Water, which was established in 1977. The outfall was repaired in 2020; and as a result, it was no longer considered part of the Project. With the remaining eight sites in mind, the following briefly describes the three alternative solutions specifically developed for the sites (four individual and two bundled) that were considered as part of MCEA Phase 2 for the Project. For context, remediation objectives and constraints specific to each site are provided as part of developing the site-specific alternative solutions.

9.1.1 Site 2: Stormwater Outfall Upstream of St. Clair Avenue East

Site 2 is a 525 mm outfall owned by Toronto Water, which was established in 1966. The objectives of the remediation solutions and constraints at Site 2 are as follows:

Solution Objectives	Constraints
– Reduction in geomorphic risk to stormwater infrastructure and associated maintenance holes and protection from exposure and failure – Mitigate TSS/bedload impacts to Toronto Water’s Don River and Central Waterfront System’s Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant.	– Limited realignment potential due to adjacent pedestrian trail and valley wall contacts – Limited construction access points nearby to gain access to the valley floor – Existing bank protection structures adjacent to the Site

Solution Objectives	Constraints
– Enhancement of geomorphic function by the removal of failing bank protection structures and stabilization of channel banks with alternative solutions – Improvement of structural integrity and function of stormwater outfall – Protection of existing pedestrian pathway – Improvement of terrestrial and aquatic environments as a secondary benefit – Maintenance/improvement of channel functions including hydraulic function and sediment transport	– Heavily utilized public trail system adjacent to the watercourse – Sub-reach works would infringe on private property boundaries to the east

Alternative No.1: Do Nothing

The headwall structure and armourstone bank protection would remain outflanked and within the banks of the Creek with the Do Nothing alternative. Consequently, the risk of exposure and failure of the outfall, stormwater pipe, and maintenance hole would remain.

Alternative No.2: Local Works and Protection

The local works and protection alternative for Site 2 would involve local bank protection, armourstone walls or vegetated buttress, along the right bank surrounding the outfall. The bank protection measures would tie into the upstream and downstream gabion bank protection along the right bank. The existing channel planform (shape) would be maintained, and the banks would be armoured in their existing locations. The outlet would be setback from the Creek for further protection of the outlet and dissipation of the flows before they enter the watercourse. The discharge angle would be altered to approximately a 45-degree angle to align with the direction of stream flow.

Alternative No.3: Sub-Reach Based Works

The sub-reach based works alternative for Site 2 would involve bank protection, armourstone walls or vegetated buttress, along both the left and right banks of the channel spanning from the downstream limit of the TRCA led Class EA, to the upstream limit of the recently completed construction at Site 3. The alternative would involve grade control along the channel bed to limit channel downcutting surrounding the outfall. The existing channel planform (shape) would be maintained, and the banks would be armoured in their existing locations. The existing high gabion wall at the upstream end of the design limits could be stabilized by raising the bed and protecting the toe of the gabions. The sub-reach based work limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution. This alternative would require disturbance into private property.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 for Site 2.

9.1.2 Site 4: Stormwater Outfall Downstream of St. Clair Avenue East

This 600 mm outfall is owned by Toronto Water with an asset ID of OF3851713800. The outfall was established in 1965 and is located at the toe of a steep valley wall with evidence of slope failure. The objectives of the remediation solutions and constraints at Site 4 are as follows:

Solution Objectives	Constraints
– Reduction in geomorphic risk to Toronto Water stormwater outfall, pipe, and associated maintenance hole – Mitigate TSS/bedload impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant. – Enhancement of geomorphic function by the removal of failing bank protection structures and stabilization of channel banks with alternative solutions – Improvement of structural integrity and function of stormwater outfall – Address valley slope instability upslope and downstream of the outfall – Tie-in bank protection measures with recently completed work on Site 3 – Protect public health and safety by protecting the existing pedestrian pathway, as the failing slope puts the pathway at risk – Improvement of terrestrial and aquatic environments as a secondary benefit – Maintenance/improvement of channel functions including hydraulic function and sediment transport	– Limited realignment potential due to adjacent official pedestrian trail to the west of the channel and valley wall contacts; however floodplain space to east of channel could accommodate some channel realignment away from the outfall – Limited construction access points nearby to gain access to the valley floor – Existing bank protection structures adjacent to the Site – Heavily utilized public trail system adjacent to the watercourse – Steep valley wall contact along the right bank downstream of the outfall with potential slope instability concerns

Alternative No.1: Do Nothing

The outfall headwall and armourstone walls will continue to fail and the slope failure behind the outfall will continue causing additional exposure of the stormwater pipe. The erosion upslope and downstream of the outfall will continue and may result in complete failure of the outfall, stormwater pipe, and maintenance hole. This ongoing erosion poses risks to public safety on the adjacent pedestrian trail and potential risk of slope failure which may impact the tableland.

Alternative No.2: Local Works and Protection

The local works and protection alternative involves realignment of the channel immediately surrounding the outfall to the east with the construction of a short outfall channel to connect flow from the outfall with Yellow Creek. Realignment of the channel would shift the watercourse away from the existing slope instability along the right bank and remove the existing valley wall contact along the western slope. The failing bank protection would be removed, and the previous channel area would be backfilled. Bank protection would be constructed along both banks of the outfall channel and realigned creek and would extend from the downstream limit of the recently constructed bank protection at Site 3 to the downstream cutoff point bar. The bank protection would tie in with existing upstream and downstream bank protection at the limits of the proposed works.

Alternative No.3: Sub-Reach Based Works

The sub-reach based works alternative includes the Local Works and Protection alternative and expands on the rehabilitation aspect. Alternative No.3 involves realignment of the channel immediately surrounding the outfall to the east with the construction of a short outfall channel to connect flow from the outfall with Yellow Creek watercourse. Realignment of the channel would shift the watercourse away from the existing slope instability along the right bank and remove the existing valley wall contact along the western slope. The failing bank protection would be removed, and the previous channel area would be backfilled. Bank protection would be constructed along both banks and would extend from the downstream limit of the recently constructed bank protection at Site 3 to downstream of the historic sawmill and large valley wall contact. The bank protection would tie in with existing upstream and downstream bank protection at the limits of the works. The sub-reach based work limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution. The downstream extent extends beyond the limit of what would be strictly required to stabilize the channel for protection of the outfall, but it will provide additional stability to the channel and valley by addressing additional valley wall contacts and the associated hazards.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 for Site 4.

9.1.3 Sites 5/6: Rosehill Reservoir Discharge Outlet and Watermain Crossing

This 1500 mm x 2500 mm outlet is owned by the City and is used to drain drinking water from the Rosehill Reservoir during cleaning once every 5 to 10 years and for local stormwater drainage from David A. Balfour Park. Correspondence with City staff indicates that flow from the outlet is controlled, and temporary erosion control can be put in place during draining to mitigate scour. The outlet is located on an inside meander bend where deposition has formed a vegetated point bar. A small discharge channel has cut through the point bar from the outlet indicating relatively recent discharge from the reservoir. Armourstone walls upstream and downstream of the outlet are stable and show no signs of significant erosion. Due to the stability of the existing outlet, conceptual stream restoration designs should keep the channel alignment similar at this location and the outlet in place as it is now.

A watermain crosses through the channel approximately 175 m upstream of the CP rail crossing and directly downstream of the Rosehill Reservoir Discharge Outlet. The watermain is owned by Toronto Water, constructed in 1966, with an asset ID of LN1012177. The banks are currently hardened with grouted armourstone walls at this location and there was a previously installed concrete channel bed. The armourstone appears to be stable, however the concrete bed was undermined and downcutting.

The objectives of the remediation solutions and constraints at Sites 5/6 are as follows:

Solution Objectives	Constraints
– Maintenance of structural integrity and function of reservoir outlet – Protection of existing pedestrian pathway – Maintenance/improvement of channel functions including hydraulic function and sediment transport – Reduction of geomorphic risk to watermain crossing – Mitigate TSS/bedload impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant. – Removal failed channel bed protection – Maintenance or improvement of existing channel bank protection measures – Reduction of incision (downcutting) through the creation of stable channel bed morphology and the installation of grade control measures – Fish habitat creation and improvement of aquatic habitat	– Limited realignment potential due to proximity of adjacent pedestrian trail – Protection of existing armourstone bank structures surrounding the Site – Heavily utilized public trail system adjacent to the watercourse – Steep channel gradient – Replacement of the pedestrian bridge with a larger structure would be a key component to the sub-reach based works but would be costly.

Alternative No.1: Do Nothing

The outfall would remain in the armourstone wall along the right bank and would continue to drain drinking water from the Rosehill Reservoir during cleaning once every 5 to 10 years and local stormwater from David A. Balfour Park. The channel incision (downcutting) will continue and the risk to the watermain would increase. Continued channel incision could result in undermining of the channel bank protection measures and affect Site 5 and the upstream pedestrian crossing.

Alternative No.2: Local Works and Protection

The local works and protection alternative would involve channel bed rehabilitation immediately surrounding the watermain crossing with no channel bank works at Site 6. The channel bed rehabilitation would involve building up the channel bed elevation to reduce the risk of exposure of the watermain from channel downcutting. Minor works are proposed above the bank upstream of Site 5 to protect the bank from damage due to flood flows around the pedestrian bridge.

Alternative No.3: Sub-Reach Based Works

The Sub-Reach Based Works alternative would involve restoration of the channel bed surrounding the watermain crossing and channel bank works downstream of the watermain crossing. The bank protection upstream of the watermain crossing was observed to be in good condition and any bank protection constructed would tie into the existing upstream protection. The bank protection would ensure the length of the existing watermain crossing does not increase as a result of channel migration or widening. The bed protection would involve the removal of the existing concrete apron where it is failing and the introduction of grade control measures.

The existing channel planform would be maintained, and the banks would be armoured in their existing locations. The channel would be widened though the pedestrian crossing to reduce overbank flow around the crossing. The pedestrian crossing would need to be replaced with a longer bridge, which would be a costly endeavour. The sub-reach based works limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 at Sites 5/6.

9.1.4 Site 7: Rosehill Pumping Station Stormwater Outfalls

Two Toronto Water stormwater outfalls (asset ID's unknown) originating from the Rosehill Pumping Station were directed to a new outfall location and discharge channel into the re-aligned Yellow Creek channel as part of the TRCA Summerhill Gardens Restoration Works. Rapid change is currently occurring in this area due to failure of portions of the recent channel works. The objectives of the remediation solutions and constraints at Site 7 are as follows:

Solution Objectives	Constraints
– Stabilization of channel banks and bed to reduce risk to stormwater outfalls – Maintenance/improvement of channel functions including hydraulic function and sediment transport – Mitigate TSS/bedload impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant. – Protection of adjacent pedestrian pathway	– Heavily utilized public trail system adjacent to the watercourse – CP Railway property constraints immediately south of the Site – Limited realignment potential due to adjacent pedestrian trail – Existing bank and bed protection upstream and downstream of the Site

Alternative No.1: Do Nothing

The bank protection upstream of the stormwater outfalls would continue to erode and threaten the confluence with the outfall channel.

Alternative No.2: Local Works and Protection

The local works and protection alternative would consist of the installation of bank protection along the left immediately upstream of the outfall channel confluence with Yellow Creek. The bank protection would consist of either vegetated buttress or an armourstone wall. The existing channel planform would be maintained and the bank would be stabilized in the existing location.

Alternative No.3: Sub-Reach Based Works

The sub-reach based work alternative would involve more extensive bank protection treatment along both banks of Yellow Creek both upstream and downstream of the outfall channel confluence. The works would tie into the Sites 8/9 alternative as well as the existing bank protection upstream. Channel bed grade control would be introduced to address the knickpoint forming upstream of the stormwater outfall channel. The existing channel planform would be maintained, and the banks would be stabilized at their existing location. The sub-reach based work limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 for Site 7.

9.1.5 Sites 8/9: Watermain Parallel to Channel and Stormwater Outfall at CP Rail Crossing

The watermain discussed in **Section 9.1.3** lies within 5 m of the creek immediately upstream of the CP Rail crossing. Additionally, immediately upstream of the CP Rail crossing is a 300 mm Toronto Water outfall, asset ID OF3801714062, that was constructed in 1925 outlets along the right bank. Armourstone banks upstream and downstream of the outfall appear stable. Any lateral migration or widening could potentially expose the watermain in the future. The objectives of the remediation solutions and constraints at Sites 8/9 are as follows:

Solution Objectives	Constraints
– Reduction of geomorphic risk to watermain running parallel to the watercourse – Mitigate TSS/bedload impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant. – Protection of existing pedestrian pathway – Maintenance/improvement of channel functions including hydraulic function and sediment transport – Maintenance of existing outfall and channel functions surrounding Site 9 – Maintenance of structural integrity and function of stormwater outfall	– Heavily utilized public trail system adjacent to the watercourse – CP Railway property constraints immediately south of the Site – Limited realignment potential due to adjacent pedestrian trail and CP Railway crossing – Impacts of construction on adjacent infrastructure – Existing bank and bed protection upstream and downstream of the Site

Alternative No.1: Do Nothing

The damaged armourstone wall on the left bank will remain and continued erosion and displacement may cause the wall to fail, leading to increased risk of exposure to the adjacent watermain. The outfall would remain within the existing armourstone wall.

Alternative No.2: Local Works and Protection

The local works and protection would involve the replacement or repair of the existing bank protection along the left bank to protect against channel migration towards the adjacent watermain. The bank protection structure would be either a vegetated buttress or armourstone wall. The remaining bank protection measures would remain, and the newly installed measures would tie into any existing structures. The existing channel planform would be maintained, and the bank would be stabilized in the existing location. This alternative would involve works on private CP Railway property.

Alternative No.3: Sub-Reach Based Works

The sub-reach based works alternative involves installation of bank protection measures along both banks from the downstream extent of the Site 7 works to the upstream limit of the CP Rail bridge piers. The existing channel platform would be maintained, and the banks would be stabilized in their existing locations. The sub-reach based works limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution. This alternative would involve works on private CP Railway property.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 for Sites 8/9.

9.1.6 Site 10: Downstream Channel Inlet

The downstream stormwater inlet is located approximately 170 m south of the CP Rail crossing and conveys the Creek underground by a 2700-mm x 2550-mm box culvert for approximately 1,650 m. The inlet is owned by Toronto Water with an asset ID of SL1466936. Erosion and bank failures were noted immediately upstream of the inlet. There is an upstream pointing culvert on the right bank adjacent to the inlet structure that should be included within any remediation designs. During high flow conditions and back-up at the inlet. this culvert has the potential to direct flow onto the floodplain at high velocity causing erosion. The objectives of the remediation solutions and constraints at Site 10 are listed as follows:

Solution Objectives	Constraints
– Reduction in geomorphic risk to Toronto Water infrastructure – Mitigate TSS/bedload impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant. – Enhancement of geomorphic function by the removal of failing bank protection structures – Improvement of structural integrity and function of channel inlet – Reduction in risk of erosion along floodplain from culvert structure on right bank – Protection of existing informal pedestrian pathway – Improvement of terrestrial and aquatic environments as a secondary benefit – Maintenance/improvement of channel functions including hydraulic function and sediment transport	– Heavily utilized public trail system adjacent to the watercourse – Limited realignment potential due to adjacent pedestrian trail – Existing bank and bed protection upstream of the Site – Bank erosion due to drainage culvert along right bank

Alternative No.1: Do Nothing

The armourstone bank protection would continue to be displaced and erosion of the channel banks would continue. Continued erosion of the upstream banks may cause the inlet to be outflanked and damaged leading to erosion to the area downstream of the inlet, erosion of the adjacent floodplain, and reduced channel stability. Ongoing erosion poses risks to public safety on the adjacent pedestrian trail.

Alternative No.2: Local Works and Protection

The local works and protection alternative includes bank protection along both banks approximately 40 m upstream of the channel inlet. The channel inlet would remain in the existing orientation, as would the drainage outlet along the right bank. The existing channel planform would be maintained, and the banks would be armoured in their existing locations.

Alternative No.3: Sub-Reach Based Works

The sub-reach based works alternative includes bank protection through the entirety of Reach 4. The channel inlet would remain in the existing orientation, as would the drainage outlet along the right bank. The existing channel platform would be maintained; however, the channel would be widened, and the height of the banks would be reduced to improve floodplain connection. The sub-reach based work limits were determined to provide overall channel stability to provide a longer lasting infrastructure protection solution and added value in preventing long term valley wall contact impacts on the west bank and trail erosion on the east bank.

Appendix K provides the conceptual designs prepared for Alternative Nos. 2 and 3 for Stie 10.

9.2 Comparative Evaluation of the Alternative Solutions

A comparative evaluation was undertaken of the alternative solutions taking the environment into consideration to identify a recommended solution for each of the sites based on the application of criteria. The evaluation criteria were developed based on the problem / opportunity statement, existing environmental conditions, and the range of alternatives being considered.

Each evaluation criterion was connected to a particular aspect of the environment (e.g., physical and natural environment, etc.) as defined in the *EA Act* because the description of the effects of each alternative on the environment is required by the EA process. In addition, criteria were included for assessing the technical and cost aspects of the alternative solutions. Next, one or more indicators were developed for each of them to identify how the potential environmental effects were to be measured for each criterion. **Table 42** lists the evaluation criteria and their respective indicators by category.

Table 42 Alternative Solutions Evaluation Criteria

Category	Evaluation Criteria	Indicator
Toronto Water Infrastructure Risk	Risk Reduction	Ability to reduce the risk to Toronto Water infrastructure caused by watercourse erosion.
	Bed and Bank Erosion	Ability to minimize bed and bank erosion to reduce small and large solids, such as total suspended solids (TSS) and bedload, from flowing into Toronto Water's new (under construction) Don River and Central Waterfront System's Coxwell Bypass Tunnel and the Ashbridges Bay Treatment Plant when completed in the late 2030s.
Physical and Natural Environment	Geomorphic Form & Function	Ability to improve geomorphic stability and physical components of watercourse function; including reducing rate of erosion and loss of public and private lands
	Slope Stability	Ability to improve slope stability of known, or potential, valley wall erosion
	Aquatic Habitat (Water-based Habitat)	Ability to improve the habitat of water species, including benthic invertebrates, by promoting the sustainability of water species habitat features and functions and limiting their temporary, or permanent, loss based on type, such as provincially significant wetland, locally significant wetland and watercourse.
	Water Quality	Ability to improve surface water quality through erosion reduction and floodplain connectivity.

Category	Evaluation Criteria	Indicator
	Groundwater	Ability to improve groundwater resources through floodplain connectivity
	Terrestrial Habitat (Land-based Habitat)	Ability to improve the habitat of land species by promoting the sustainability of land species habitat through improved ecosystem connectivity, diversity and limiting temporary, or permanent, habitat loss.
	Terrestrial Vegetation (Land-based vegetation)	Ability to limit disturbance to existing vegetation in woodlots and natural heritage features including Environmentally Significant Areas, Areas of Natural and Scientific Interest, wildlife corridors and others.
	Flood Hazard	Ability of alternative to meet legislated criteria for flooding and reduce adverse impacts of flooding in an urban environment
	Species at Risk	Ability to improve the environment and habitat for species at risk, potentially affected temporarily or permanently.
	Climate Change	Ability to adapt to, and be resilient to, climate change
Social and Cultural Environment	Long-term Impacts to Private Property	Potential to positively or negatively impact private property in the long-term.
	Short-term Impacts to Community	Ability to limit short-term negative impacts, such as erosion damage, closures and noise, on the community. Impacts relate to doing nothing or during construction.
	Long-term Impacts to Community	Ability to produce long-term positive impacts, such as improved environment, amenities and aesthetics, on the community. Impacts relate to doing nothing or following construction.
	Cultural Heritage	Ability to protect built heritage resources, cultural heritage landscapes and archaeological resources
Economic Environment	Capital Costs	Relative capital costs for implementing the alternative solution
	Lifecycle Cost Consideration	Ability to limit long-term recurring costs of multiple interventions to address chronic erosion issues over the span of fifty years.
	Cost Efficiency	Ability to maximise improvements and outcomes measuring the financial cost of multiple local improvements against the financial cost of completing improvements as a single initiative. Includes the cost of mitigating environmental and social disturbances and the ability of Toronto Water to partner and share costs with other infrastructure owners experiencing risk.
Technical and Engineering Considerations	Regulatory Agency Acceptance	Ability to satisfy the standards and guidelines of regulatory agencies such as the City of Toronto, including Urban Forestry, Toronto Region Conservation Authority, Department of Fisheries and Oceans and Provincial Ministries.
	Resource Allocation	Ability to maximise improvements and outcomes by considering the need and availability of technical resources required for multiple local improvements, against the resources needed to complete

Category	Evaluation Criteria	Indicator
		City-wide improvements at the same time with consideration for engineering, permitting and administration. Includes the ability to reduce engineering, permitting and administration services to free up resources for other priority work, maximising improvements and outcomes.
	Natural Infrastructure Opportunity	Ability to improve the ecosystem, using enhanced engineering solutions, in keeping with the Government of Canada's natural and hybrid infrastructure initiative.

Following the development of evaluation criteria and indicators, they were applied to each of the three alternative solutions on an individual site basis to identify potential environmental effects. Next, the alternative solutions were comparatively evaluated using the Reasoned Argument or "Trade-off" approach based on the results of applying the evaluation criteria and indicators, which is summarized as follows:

– Step 1: Identify Criterion Rankings Based on Effects - First, the effects identified for each alternative by criterion were compared to one another to identify a criterion ranking by alternative (e.g., Most Preferred, More Preferred, Less Preferred or Least Preferred). If the corresponding effects of a criterion were the same for two or more alternatives, then they were ranked equally and the word "tied" was added to the criterion ranking (e.g., Tied for Most Preferred).
– Step 2: Identify Category Rankings Based on Criterion Rankings - The criterion rankings identified through the preceding step were considered collectively to assign an alternative ranking (e.g., Most Preferred, More Preferred, Less Preferred or Least Preferred [includes Ties]) by individual category (e.g., Physical and Natural Environmental, Social and Cultural Environment, Economic Environmental, etc.). The City developed a quantitative weighting for each of preference levels as outlined in **Table 42**. In the situations where a category has more than one evaluation criterion, then all the evaluation criterion rankings were considered collectively to identify an alternative ranking for the category. A weighted scale, **Table 43**, for each of the evaluation categories was developed to avoid one category outweighing the others in the overall comparison.
– Step 3: Identify Overall Recommendation Based on Category Rankings - Following the identification of category rankings, an overall recommendation was assigned to the alternative with the greatest weighted score out of 100 (**Table 44**), reflective of the greatest number of top placed category rankings (e.g., more "Most Preferred" and "More Preferred" rankings) among the three alternatives considered, thus providing the highest number of advantages and the least number of disadvantages overall.

Table 43 Scoring Scale

Preference Level	Score
Least Preferred	1
Less Preferred	2
More Preferred	3
Most Preferred	4

Table 44 Weighting for Evaluation of Alternatives

Category	Weighting Factor	Maximum Points for Category
Toronto Water Infrastructure	0.2	20
Physical and Natural Environment	0.2	20
Social and Cultural Environment	0.2	20
Economic Environment	0.2	20
Technical and Engineering Considerations	0.2	20
Total	**1**	**100**

The preceding comparative evaluation approach was divided into two separate sets of tables. The criterion rankings based on effects, Step 1 in the preceding approach, are summarized for each Site (2, 4, 5/6, 7, 8/9, and 10) in individual tables in **Appendix L**. The scores, category rankings, and recommended solution, Steps 2 and 3 in the preceding approach, are also documented in **Appendix L**, immediately following each of the Step 1 tables for each Site.

9.3 Alternative Solution Summary

The following tables provide a summary of the advantages and disadvantages of each alternative per Site and identify the most preferred solution starting with Site 2 and ending with Site 10. For all Sites, Alternative Solution No. 3 – Sub-Reach Based Works was identified as the most preferred based on the comparative evaluation.

Table 45 Site 2 Evaluation Summary

Item	Alternative Solution No. 1 – Do Nothing	Alternative Solution No. 2 – Local Works and Protection	Alternative Solution No. 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost.	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Some reduction in TSS and bedload to downstream systems. ✓ Improved local geomorphic stability, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ The continued loss of trees due to erosion reduced and localized restoration allows for the establishment of native trees. ✓ Lower capital costs and lowest lifecycle costs.	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Most effective option in reducing TSS and bedload entering downstream systems as both identified and future erosion would be addressed. ✓ Improved reach-scale geomorphic and slope stability, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Potential to increase flow capacity and reduce flood impacts. ✓ The continued loss of trees due to erosion reduced and restoration allows for a stable channel and establishment of native trees over reach. ✓ Provides connectivity with upstream TRCA restoration works.
Disadvantages	– Does not address risk to 535 mm outfall owned by Toronto Water – Future cost to respond to emergency infrastructure failures – Existing degraded geomorphic and ecological conditions remain/continue to deteriorate	– Minor impact to flood levels – Local portions of trail system may be closed – Independent improvements would require repeated permitting, administration and engineering fees	– Limited increase in protection over Alternative 2 – Broader short-term construction impacts – Highest capital and lifecycle costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs
Evaluation	Least Preferred	More Preferred	**Most Preferred**

Table 46 Site 4 Evaluation Summary

Item	Alternative 1 – Do Nothing	Alternative 2 – Local Works and Protection	Alternative 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost.	✓ Infrastructure protected, reducing risk of failure or damage ✓ Some reduction in TSS and bedload to downstream systems ✓ Improved local slope stability through mitigation of toe erosion along the valley wall contact adjacent to Avoca Avenue. ✓ Localized improvements to aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources ✓ The continued loss of trees due to erosion reduced and localized restoration allows for the establishment of native trees. ✓ Lower capital costs and lowest lifecycle costs	✓ Infrastructure protected, reducing risk of failure or damage ✓ Most effective option in addressing TSS and bedload entering downstream systems as both identified and future erosion would be addressed. ✓ Improved reach-scale slope stability through mitigation of reach scale bank erosion and toe erosion at valley wall contacts adjacent to Avoca Avenue, the pedestrian trail entering from Avoca Avenue and properties on Inglewood Drive adjacent to the remains of historic sawmill bank erosion. ✓ Improved reach-scale geomorphic and slope stability, aquatic habitat, floodplain connectivity, surface water and groundwater resources. ✓ The continued loss of trees due to erosion reduced and restoration allows for a stable channel and establishment of native trees over reach.
Disadvantages	– Does not address risks to Toronto Water stormwater outfall, pipe, and associated maintenance hole. – Future cost to respond to emergency infrastructure failures. – Existing degraded geomorphic and ecological conditions remain/continue to deteriorate. – Closure of trail. – Potential long-term risk to 120 and 122 Inglewood Drive.	– Independent improvements would require repeated permitting, administration and engineering fees – Localized trail closures – Potential long-term risk to 120 and 122 Inglewood Drive	– Limited increase in protection over Alternative 2 – Broader short-term construction impacts – Highest capital and lifecycle costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs
Evaluation	Least Preferred	More Preferred	**Most Preferred**

Table 47 Site 5/6 Evaluation Summary

Item	Alternative 1 – Do Nothing	Alternative 2 – Local Works and Protection	Alternative 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost	✓ Infrastructure protected, reducing risk of failure or damage. Improved local geomorphic stability. Establishment of a more natural bed to cover the exposed till and concrete bed. ✓ Some reduction in TSS and bedload to downstream systems. ✓ Improved local geomorphic stability, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ The continued loss of trees due to erosion reduced and localized restoration allows for the establishment of native trees. ✓ Lower capital costs	✓ Infrastructure protected, reducing risk of failure or damage. Re-establishment of a geomorphically stable bankfull channel and increased connection to the floodplain. Elimination of the bridge pinch point and establishment of more natural bed cover. ✓ Most effective option in addressing TSS and bedload entering downstream systems as both identified and future erosion addressed. ✓ Improved reach-scale geomorphic stability, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources ✓ The continued loss of trees due to erosion reduced and restoration allows for the establishment of native trees over reach. ✓ Moderate impact to flood levels due to increase in channel bed elevation, however potential to reduce flooding through increased flow capacity and widened crossing.
Disadvantages	– Does not address risks to reservoir outlet infrastructure. – Future cost to respond to emergency infrastructure failures. – Existing degraded geomorphic and ecological conditions remain/continue to deteriorate. – Continual erosion and overbank flow around the pedestrian crossing poses a risk to the bridge and safety of public trail users; eventual trail closure.	– Potential local increase in flood levels and impacts of flooding due to raising of the channel bed. – Reduced erosion, however continued overbank flow around pedestrian bridge and potential safety risk to public trail users. – Localized long-term trail closures – Independent improvements would require repeated permitting, administration and engineering fees.	– Limited increase in protection over Alternative 2 – Broader short-term construction impacts – Highest capital costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs
Evaluation	Least Preferred	More Preferred	**Most Preferred**

Table 48 Site 7 Evaluation Summary

Item	Alternative 1 – Do Nothing	Alternative 2 – Local Works and Protection	Alternative 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Some reduction in TSS and bedload to downstream systems. ✓ Improved local geomorphic stability, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ The continued loss of trees due to erosion reduced and localized restoration allows for the establishment of native trees. ✓ Lower capital costs	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Most effective option in addressing TSS and bedload entering downstream systems as identified and future erosion would be addressed. ✓ Improved reach-scale geomorphic, aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Reduced likelihood of valley wall erosion to the south. The continued loss of trees due to erosion reduced and restoration allows for the establishment of native trees over reach. ✓ Moderate impact to flood levels due to increase in channel bed elevation, however potential to reduce flooding through increased flow capacity and widened crossing. ✓ Multiple improvements under one scope. Extends upstream and downstream from local Site to address multiple concerns and reduce engineering, permitting, administration, and mobilization resources through constructing Sites 7 and 8/9 together.
Disadvantages	– Does not address risks to Rosehill Pumping Station stormwater outfalls. – Future cost to respond to emergency infrastructure failures. – Existing degraded geomorphic and ecological conditions remain/continue to deteriorate. – Continued channel downcutting worsens floodplain connectivity in long-term. – Trail closure – Highest lifecycle costs due to emergency maintenance and rehabilitation requirements.	– Toe protection will not reduce the likelihood of potential future valley wall erosion to the south. – Potential local increase in flood levels and impacts of flooding due to raising of the channel bed. – Localized long-term trail closures – Independent improvements would require repeated permitting, administration and engineering fees.	– Negligible increase in protection over Alternative 2. – Broader short-term construction impacts – Highest capital costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs
Evaluation	Least Preferred	More Preferred	**Most Preferred**

Table 49 Site 8/9 Evaluation Summary

Item	Alternative 1 – Do Nothing	Alternative 2 – Local Works and Protection	Alternative 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost.	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Some reduction in TSS and bedload to downstream systems. ✓ Improved local geomorphic stability; opportunity to establish a bioengineered bank to replace the vertical stone wall. Toe protection results in reduced potential for future valley wall erosion. ✓ Improved aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Lower capital costs.	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Most effective option in addressing TSS and bedload entering downstream systems as both identified and future erosion addressed. ✓ Improved reach-scale geomorphic stability; opportunity to establish a bioengineered bank to replace the vertical stone wall over a longer section of creek. ✓ Improved reach-scale aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Potential to reduce adverse flood impacts through an increased flow capacity. ✓ Multiple improvements under one scope. Extends upstream and downstream from local Site to address multiple concerns and reduce engineering, permitting, administration, and mobilization resources through constructing Sites 7 and 8/9 together.
Disadvantages	– Does not address risks to watermain running parallel to watercourse. – Future cost to respond to emergency infrastructure failures. – Existing geomorphic and ecological conditions remain/continue to deteriorate; failing bank protection continues to limit stream function. – Potential for future valley wall erosion due to continued erosion. – Trail closure – Highest lifecycle costs due to more frequent emergency maintenance and rehabilitation requirements.	– Protects local portion of trail, however other reach scale portions of trail may be closed. – Potential need to intervene and address erosion issues on a local scale in long-term. Independent improvements would require repeated permitting, administration and engineering fees.	– Negligible increase in protection over Alternative 2 – Broader short-term construction impacts – Highest capital costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs
Evaluation	Least Preferred	More Preferred	**Most Preferred**

Table 50 Site 10 Evaluation Summary

Item	Alternative 1 – Do Nothing	Alternative 2 – Local Works and Protection	Alternative 3 – Sub-Reach Based Works
Advantages	✓ No immediate construction cost	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Some reduction in TSS and bedload to downstream systems. ✓ Improved local geomorphic stability; opportunity to replace vertical stone walls with bioengineered bank treatment and improve local geomorphic stability. ✓ Improved local aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Lower capital costs and lowest lifecycle costs	✓ Infrastructure protected, reducing risk of failure or damage. ✓ Most effective option in addressing TSS and bedload entering downstream systems as identified and future erosion addressed. ✓ Re-establishment of a geomorphically stable bankfull channel and increased connection to the floodplain. Establishment of bioengeering bank treatments and more natural bed material. Improved reach-scale geomorphic stability. ✓ Improved toe protection and stability to mitigate reach scale bank erosion and potential valley wall contacts. ✓ Improved reach-scale aquatic and terrestrial habitat, floodplain connectivity, surface water and groundwater resources. ✓ Multiple improvements under one scope. Extends upstream and downstream from local Site and eliminates the need for repeated permitting, administration and engineering resources.
Disadvantages	– Does not address risks to downstream stormwater inlet. – Future cost to respond to emergency infrastructure failures. – Existing geomorphic and ecological conditions remain/continue to degrade; continued displacement of existing bank protection and long term migration of the channel may eventually impact stability of valley wall. – Trail closure. – 2nd lowest lifecycle costs due to frequent emergency maintenance and rehabilitation requirements.	– Improved toe protection locally but potential valley wall contacts are not mitigated. – Local trail remains open, but portions of reach-scale trail to potentially close. – Potential need to intervene and address erosion issues on a local scale in long-term; repeated permitting, administration and engineering fees. – Independent improvements would require repeated permitting, administration and engineering fees.	– Negligible increase in protection over Alternative 2. – Broader short-term construction impacts. – Highest capital costs; large initial cost to construct, however limited need to intervene and address erosion issues long-term with repeated permitting, administration and engineering resources costs.
Evaluation	Least Preferred	More Preferred	**Most Preferred**

9.4 Public Consultation

Consultation is a requirement of the Municipal Class Environmental Assessment Process. Through consultation, interested and potentially affected parties are informed about the problem and opportunities, the study process, alternative solutions and study recommendations. There is an opportunity for interested and potentially affected parties to share knowledge of the local environment and provide feedback on preliminary recommendations before decisions are finalized. For the YCGSMP the City provided information on the study purpose, the study area, study details and process, including evaluation criteria and recommended solutions and facilitated opportunities for feedback.

Details of the public consultation are provided in **Appendix M** and described further below.

9.4.1 Project Contact List

Consultation included outreach and communication with members of the public, community groups, potentially impacted properties, Indigenous First Nations, public review agencies and utilities. An initial contact list was developed at the study onset and updated at each stage to account for organisational changes, correspondence received, meeting participants and those who requested to receive direct communication. Refer to Appendix M which provides lists of the groups that were contacted.

9.4.1.1 Indigenous First Nations

Consultation with First Nations by the project team is by delegated authority through the Provincial Ministry of Environment, Conservation and Parks (MECP). The following list of First Nations with potential interest in the Yellow Creek Study was identified by the MECP:

- Mississaugas of the Credit First Nation
- Haudenosaunee Confederacy Chiefs Council
- Huron Nation of Wendat (archaeological interests)
- Six Nations of the Grand River

9.4.2 Notification

Notification was provided at two stages: at the commencement of the study and in advance of public consultation on the recommended solutions.

The Notice of Commencement for the study was issued in January 2021. The notice was sent via email to Indigenous First Nations, Agencies and Utilities and community groups. The notice was distributed via Canada Post to 8,107 residential and business properties in the study area. A copy of the notice is provided in Appendix M.

A Public Consultation Notice was issued the week of November 13, 2023, at the onset of the public consultation period. The notice provided information about the study details, recommended alternatives, and opportunities for feedback including details on how to participate in the virtual public meeting. The notice was shared and distributed through a variety of communication platforms, including:

- The project website, toronto.ca/YellowCreek, was updated to include public consultation materials and a link to the feedback survey
- Notices were sent via Canada Post direct mail to 11,360 addresses in the study area

– Email was circulated to community groups including 28 residents' associations, community groups, organizations, institutions and elected officials
– Email was circulated to 63 government agencies and utility companies
– Direct email was sent to First Nations identified by the MECP

Individual letters were sent via addressed mail to 2 private properties that are potentially impacted by the recommended projects.

9.4.3 Consultation Activities

Consultation took place between November 13, 2023, and December 17, 2023, and included a virtual public meeting, a meeting with interested community groups and follow-up communication with Indigenous Treaty Partners, Agencies and Utilities. There were opportunities to provide feedback during meetings, through an online survey, via email or by phone.

Summary of participation:

– Virtual public event: 51 participants
– Meeting with community groups: 10 participants
– Twelve comment submissions received from the public via telephone and email
– 145 completed survey responses

9.4.3.1 Feedback during Public Consultation

There were no specific concerns raised with the recommended solutions. Concerns related to the recommended solutions were with respect to the presented timelines for implementation. The estimated timelines presented are high level to allow for city-wide prioritization, across several creek restoration studies. The highest priority are exposed sanitary sewers. As there are no sanitary sewers in Yellow Creek, the highest priority project in Yellow Creek is anticipated for medium-term implementation (5 to 10 years). The concern is that conditions in Yellow Creek may become worse in the interim limiting use of the creek and trail by the public.

Concerns were also raised regarding the overall scope of the study which focused on protecting water infrastructure at risk of damage form erosion. The trails along Yellow Creek are used by the community for leisure and to connect residents living on the east side of the creek to the school and shops on the west side of the creek. Many people who provided feedback were concerned about the impact of erosion on the ravine slope, trails, stairs and bridges surrounding Yellow Creek and wanted the study to address these impacts as well.

Appendix M contains the complete Public Consultation Report along with copies of public notices, consultation materials, correspondence with Agencies and Utilities, correspondence with First Nations and comment tracking from the public.

First Nations Feedback

The City received feedback from Six Nations of the Grand River requesting soft infrastructure be used along the creek bed and to be included in continued communication during the detailed design stage.

The Mississaugas of the Credit Frist Nations requested capacity funding for review of the Stage one Archaeology Assessment report.

No other First Nations provided comment.

Agencies and Utilities Feedback

The City received feedback from

- Canadian Pacific and Kansas City Southern (CPKC)
- Network Locates
- Metro Fibrewerx
- Bell
- Environmental Assessment Program, Ontario Region, Transportation Canada
- TRCA
- Hydro One

Feedback focused on utility locates. See details in Appendix M-4

Community Groups and Public Feedback

The City received feedback from community groups and members of the public. Appendix M includes the complete Public Consultation Report.

In summary, there were no specific concerns with respect to the recommended projects for creek restoration in Yellow Creek. However, there is great concern for increasing erosion along the creek and the impact of erosion on the trails and ravine slopes.

Concerns were raised with respect to implementation timeframes for the recommended projects, which are anticipated to be implemented in the medium term (5 to 10 years) to long-term (over 10 years) and will be prioritized city-wide following the completion of several GSMPs across the city.

Feedback beyond the scope of the study focused on the need for trail improvements, the prevalence of invasive plant species in Yellow Creek, and the overall need for maintenance of water infrastructure city-wide.

Feedback from Impacted Properties

Two properties were identified as intersecting with a recommended project. Communication with property owners provided advance notice that access to the property may be sought at a future stage.

Access to Canadian Pacific Kansas City railway land can be arranged by contacting their access agreement department. We did not receive feedback from the private residential property.

Further details are provided in Appendix M-6.

10. Step 9 - Preferred Solution and Implementation

The preferred solution for Sites 2, 4, 5/6, 7, 8/9, and 10 is Alternative 3 – Sub-Reach Based Works based on the comparative evaluation carried out. Alternative 3 – Sub-Reach Based Works is the preferred solution because it is ranked as "most preferred" (1st or 1st [tied]) or "more preferred (2nd [tied]) in the majority of the categories. As a result, Alternative 3 has the following advantages:

- Reduces the existing risks of damage and failure to Toronto Water infrastructure and mitigates existing erosion on a reach scale.
- Minimizes bed and bank erosion and reduces TSS to the greatest extent, thereby mitigating impacts to Toronto Water's Don River and Central Waterfront System's Coxwell Bypass Tunnel and the proposed Ashbridge's Bay Treatment Plant's (ABTP) new Physical – Chemical Plant which will be built on the ABTP landform nearing completion in 2024.
- Establishes a long-term geomorphically stable bankfull channel that is adaptive to the impacts of climate change.
- Long-term benefits to both terrestrial and aquatic habitat.
- Stabilizing of the watercourse and valley wall contacts benefits park infrastructure and private property.
- Positive long-term impacts to the community with anticipated high positive acceptance from community.
- Maximizes the cost and resource effectiveness through completing large scale restoration works under one contract and permit.

10.1 MCEA Project Classification

Since projects carried out by municipalities can vary in their environmental impact, the MCEA classifies them as exempt, eligible for screening, Schedule B, and Schedule C with each classification having different requirements. As a result, MCEA Appendix 1 (Municipal Engineers Association, March 2023) was reviewed having regard for the preferred solutions identified for the Sites, and it was determined that either the Exempt or Schedule B classification was appropriate as follows:

Exempt

- Replace 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.
- Reconstruct an existing dam weir at the same location and for the same purpose, use and capacity.

The preferred solutions for Sites 5/6, 7 and 8/9 are classified as Exempt. The proposed natural channel design works will take place within sub-reaches entirely, or almost entirely, currently lined with existing bank stabilization measures such as gabion, armourstone or quarried rock wall. These materials will be replaced with similar or better stabilization measures. The existing path of the watercourse will be maintained. These projects are exempt under the EA Act; and as a result, from further MCEA phases and can proceed directly to the implementation stage.

Schedule B

- Works undertaken in a watercourse for the purposes 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
  - Reconstruction of a weir or dam
- Construction of spillway facilities at existing outfalls for erosion or sedimentation control.

- Construct a fishway or fish ladder in a natural watercourse, expressly for the purpose of providing a fishway.
- Reconstruct existing weir or dam at the same location where the purpose, use and/or capacity are changed.
- Removal of an existing weir or dam.
- Enclose a watercourse in a storm sewer.

The preferred solutions for Sites 2 and 4 are classified as Schedule B projects because the proposed works require some channel realignment, backfill of the existing channel, and/or works on more substantially unarmoured banks. The Schedule B preferred solutions for Sites 2 and 4 can receive *EA Act* approval through the YCGSMP and can proceed to the implementation stage following the issuance of a Notice of Completion by the City, filing of the Master Plan report, and completion of the 30-day public comment period and subsequent 30-day Ministry of the Environment, Conservation and Parks review period.

10.2 Recommended Prioritization Sequence

The preferred solutions have been prioritized for construction based on a review of erosion risk and an assessment of the consequences of failure associated with the Toronto Water Infrastructure sites. Since there is no at-risk sanitary infrastructure within the Yellow Creek Study Area, there were no sites evaluated as high-risk. Sanitary at-risk sites within the city will need to be prioritized for construction ahead of / over the high-moderate Site 4 identified in the YCGSMP.

Based on the risk assessment and the preferred solutions, improvements to Yellow Creek in segments greater than 150 m are recommended as four separate sub-reach projects (**Figure 14**). Project groupings for implementation/construction are as follows:

- Project 1A – Site 4 Local Works and Protection (moderate priority)
- Project 1B – Site 4 Sub-Reach Based Works (low priority)
- Project 2 – Sites 5, 6, 7, 8, 9 Sub-Reach Based Works (low priority)
- Project 3 – Site 2 Sub-Reach Based Works (low priority)
- Project 4 – Site 10 Sub-Reach Based Works (low priority)

Project 1 involves channel engineering works for approximately 340 m of channel. It has been divided into Project 1A and Project 1B to reflect the higher priority need of the Site 4 storm sewer outfall. Project 1A consists of an 85 m section of creek and would involve the retrofit of the storm sewer outfall at Site 4 and provide a local realignment to protect the outfall. Project 1B consists of a 255 m length of creek and would involve the removal of the failed concrete spillway at the historic sawmill site.

Project 2 would address priority Sites 5, 6, 7, 8 and 9. Channel engineering works would address a 245 m length of channel. Engineered natural channel design would protect the storm sewer outfall and watermain infrastructure. Channel alteration would require that the upstream pedestrian bridge be replaced. Banks would be lowered to reconnect Yellow Creek to the floodplain.

Watercourse stability issues at Sites 7, 8 and 9 are anticipated to largely be addressed by TRCA in the near future. Therefore, it is recommended that no further stream works be undertaken for these sites presently. Instead, it is recommended that the City undertake long-term observation of the Toronto Water Infrastructure at this location and maintain on-going communication with TRCA. Sites 5/6 are also recommended for long-term observation, with the proposed works taking place in the 10-to-20-year timeframe because most of the existing sub-reaches are armoured.

Project 3 involves channel engineering works over approximately 170 m of the Creek. Engineered natural channel design and the retrofit of the storm sewer outfall at Site 2 would be completed. The Creek work proposed at the northern limit in Project 3 overlaps with private property. TRCA is undertaking a separate Class EA to address conditions at Site 1 and is in communication with the City. Therefore, the YCGSMP does not propose any works at Site 1, upstream of the identified Project 3 limits.

Project 4 involves channel engineering works to address a 180 m length of creek. The proposed work includes the retrofit of the storm sewer inlet to update the trash rack intake structure at Site 10. Streambanks would be lowered and regraded to reconnect Yellow Creek to its floodplain.

The following site groupings are expected to share similar access routes: Sites 2 and 4 and Sites 5/6, 7, 8/9, and 10. Sites 2 and 4 are likely to be accessed from the Avoca Avenue trail entrance and via the watercourse, while Sites 5/6, 7, 8/9 and 10 would be accessed via the trail from Mount Pleasant Road.

Within Yellow Creek, Project 1A (Site 4) is recommended to be prioritized for restoration works out of the YCGSMP Sites. However, when considering other sites on a City-wide basis, it is anticipated that it is of Moderate Priority, with works to take place in approximately 5 to 10 years' time. Project 1B, Project 2 (Sites 5/6, 7, 8/9), Project 3 (Site 2) and Project 4 (Site 10) are recommended to be addressed in the low priority timeframe of 10 to 20 years' time, separated into sub-projects based on geographic proximity. The Yellow Creek quarried block wall lines most of the Yellow Creek Study Area and is currently in generally good to fair condition. The City intends to monitor the condition of this block wall. Deteriorating conditions will be used as an indicator for when low-priority projects will need to be considered for implementation in the long-term.

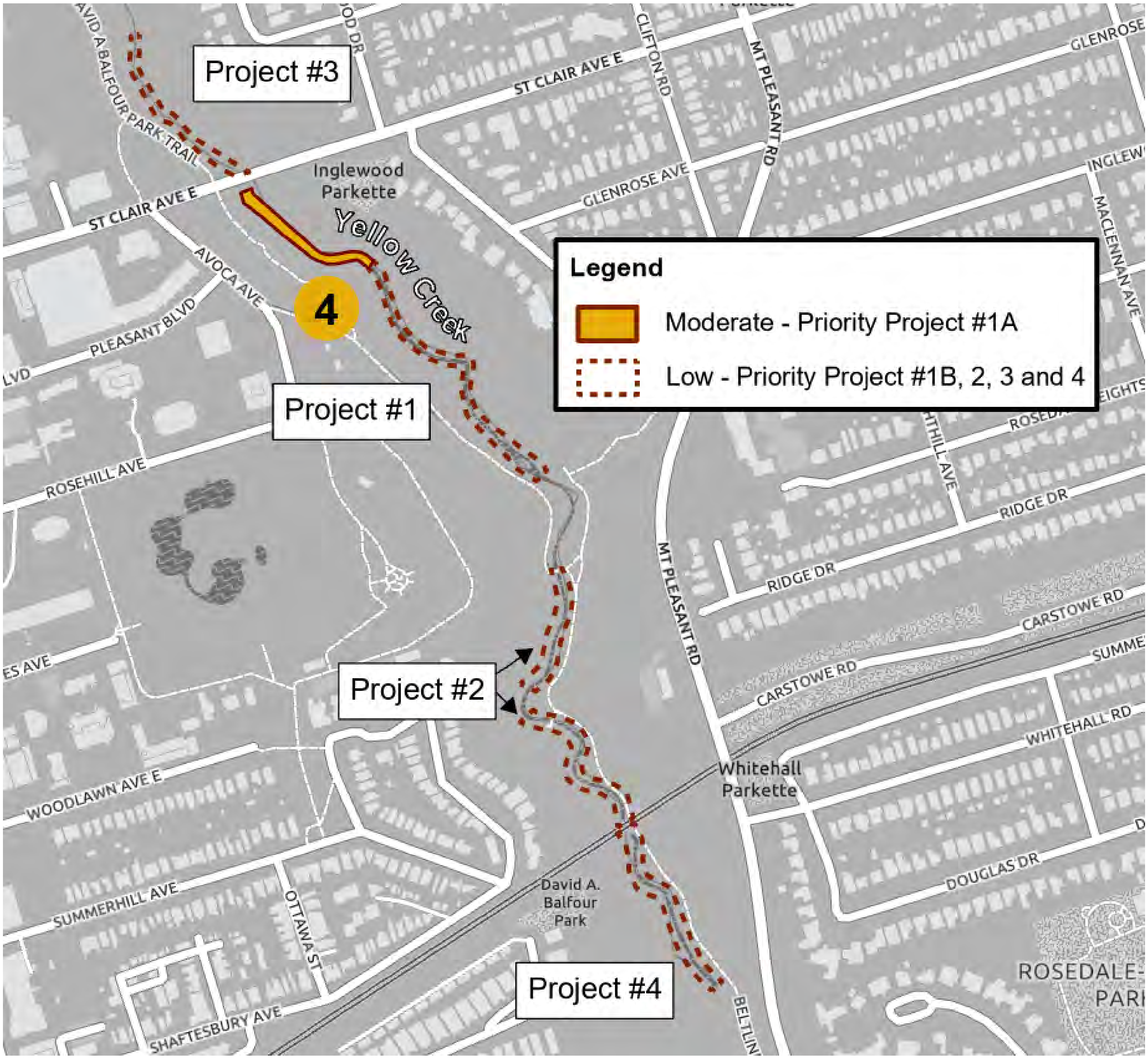


Figure 14 Recommended Projects based on Prioritization for Implementation – Site 4 shown

10.2.1 Conceptual Design Detail Overview

Project details are to be confirmed at the preliminary and detailed design stages, however conceptual natural channel design features may include the following bed and/or bank treatments.

10.2.1.1 Bed Treatments

Pools/Riffles

The channel should be designed to be spatially complex with respect to morphology and hydraulics. Riffle and pool sequences would allow for limited natural in-stream energy dissipation thereby reducing erosive energy. This morphology would also offer an enhanced fish habitat, in the event of future reintroduction to the reach.

The watercourse naturalization design would include alternating riffle and pool sequences within a bankfull channel, sized to contain the effective or channel-forming discharge. This discharge is considered to be the flow that has the greatest influence with respect to shaping channel morphology and is roughly equivalent to the 1.5 to 2 year return flow in Southern Ontario.

Riffles invariably have a higher grade than the bankfull channel, and therefore should be comprised of bed materials that are sufficiently large to be generally stable up to bankfull flows. This conceptual design includes stone ribs within the riffles to provide additional support during high flows. Pools are deeper sections of channel where energy is dissipated as flows exit the riffles.

Aquatic habitat would be improved through the establishment of woody riparian plantings. Trees and shrubs would provide cover and organic inputs, as well as improve erosion protection and overbank roughness. The riffle-pool channel morphology would enhance aquatic habitat by providing water aeration through riffles, and relatively quiescent flows and lower water temperatures in pools. Additionally, the pool sections provide refuge during high flow events.

Cascade/Pools

Cascade/pool features are often used in steeper gradient areas or where there is a need to raise the channel bed to prevent continued downstream downcutting. The cascade sequence would be a steeper gradient with a series of small steps interspersed with pools that could be navigable by fish. The cascades would be constructed of hydraulically sized stone and provide enhanced bed protection and grade control to prevent channel downcutting.

Vortex Rock Weir

The vortex rock weirs are intended to provide grade control and prevent migration of downstream bed degradation. The vortex rock weirs would provide backwater stabilization for the bed material and prevent local bed downcutting.

The conceptual vortex rock weir design consists of three rows of hydraulically sized boulders or armourstone providing mutual support to each other to remain stable in high flows. The weirs would be curved to direct flows toward the centre of the watercourse and away from the banks downstream of the weirs. The weirs would provide variations in flow depth and velocity to improve aquatic habitat diversity. Gaps between the individual stone of the weir would allow passage of small fish during low flows. The weirs would also slope downwards toward the centre of the channel to provide defined low flow capacity. Construction of the vortex weirs with three rows of boulder/armourstone, proper arrangement, and extension of the weirs into the streambanks and bank treatments, should be incorporated to ensure their longevity.

10.2.1.2 Bank Treatments

Multiple bank treatments are presented below and can be chosen based upon further hydraulic modelling at the detailed design stage.

Vegetated Rock Buttress, with/without Armourstone Toe

A possible bank treatment would involve the installation of a vegetated rock buttress, a soil bioengineering technique, that can also include a more substantial armourstone toe for additional stability. This treatment would mot likely be applied on the outer meander bends. This bioengineering treatment would involve the installation of a combination of rocks and vegetation that provide bank protection even at steep angles. Vegetated rock buttress treatment has a small footprint and offers longer-term stability, as it is a harder bank treatment compared to vegetation-only stabilization. A vegetated rock buttress is more robust than that of a typical stone bank treatment since it is constructed in lifts, with placement of individual stone and incorporation of shrub plantings between the lifts. Individual placement of the large stones provides mutual protection from entrainment and greater stability than randomly placed stone. Buttress stone would be sized to be hydraulically stable through a range of flows. Armourstone toe protection can be incorporated where high flows warrant additional protection. Proposed imported clean fill overlain by topsoil would match existing grade.

Significant benefits of this type of treatment are the habitat features and soil matrix within the buttress, which allow for the development of aquatic microhabitats (velocity refugia, stream shading, and vegetated/structured bank overhangs).

Armourstone Wall

If warranted by significantly high velocity flows modelled at the detailed design stage, an armourstone wall bank treatment may be employed. The larger armourstone would increase stability of the treatment. The armourstone wall allows for a near vertical slope to reduce the footprint of the works, and the height of the treatment can be adjusted by varying the number of armourstone layers. Native plantings at the top of the armourstone wall would assist in creating a more natural appearance to the structure and providing shading to the watercourse.

10.3 Construction Cost Estimate

Approximate total construction cost estimates for the preferred solutions (Projects 1A, 1B, 2, 3 and 4) are provided in **Table 51**. Cost estimates are for construction only and do not include detailed design, permitting, contract administration, construction inspection or post construction monitoring.

Table 51 Approximate Total Construction Cost Estimates for the Preferred Solutions by Project

Project	Watercourse Length (m)	Cost per length of watercourse ($/m)	Mobilization/Demobilization, Access Route, Restoration ($)	Total Construction Cost Estimate ($)
1A	85	10,000	300,000	1,150,000
1B	255	10,000	400,000	2,950,000
2	245	10,000	400,000	2,850,000
3	170	10,000	350,000	2,050,000
4	180	10,000	350,000	2,150,000

10.4 Interim Monitoring Plan and Adaptive Management

Implementation is anticipated to be completed in a phased approach over a 20-year period. As such, conditions within the channel will continue to evolve and deteriorate. Prioritization or urgency of the Sites may change following the impacts of significant storm events. Therefore, it is recommended that the sites be visually re-assessed periodically to ensure consistency with the implementation plan and Toronto Water priorities. The City of Toronto erosion inspection program involves inspection for damage to / risk to Toronto Water Infrastructure sites once every two to four years caused by creek bank erosion, creek bend migration, or channel incision. TRCA undertake inspections related to glacial valley wall stability and particularly focus on risk to private property and associated structures at the crest of slope, including risk to public health and safety. It is recommended that combination of these approaches is used for Yellow Creek where the general stability of the quarried block wall is inspected as well as the erosion of the valley wall. The erosion monitoring sites used in the Short-Term Monitoring (**Appendix J**) should be periodically assessed for lateral migration or degradation of bank protection structures every 2 to 3 years.

Adaptive management principles may dictate that the prioritization could vary in the future if future storm events or slope instability concerns alter the conditions, and create a risk to Toronto Water infrastructure, or to public health and safety. In addition, the City may need to implement construction of the sub-reach work in phases due to needed reprioritization in the City-wide construction program owing to changing conditions due to weather events, emergency work requirements, and/or capital funding constraints.

10.5 Agency Review and Permitting

As the detailed design is developed for each Project, the following regulatory approvals or permits are anticipated to be required for each prior to construction.

10.5.1 Municipal

Ravine and Natural Feature Protection (RNFP)

An RNFP permit will be required as construction activities within each Site could result in injury, destruction, or removal of protected trees. The impacts to trees will need to be determined by an arborist during detailed design in concert with ongoing consultation with Toronto Parks.

10.5.2 Provincial

Toronto and Region Conservation Authority (TRCA)

Yellow Creek and surrounding lands are regulated by TRCA. Therefore, a permit under Ontario Regulation 166/06 for the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses will be required for implementation of each of the preferred alternatives.

Detailed designs will need to address, but not limited to, the following topics of concern to obtain TRCA approval:

- How the hydrologic function of the identified wetland communities in the project area will be maintained. Future phases of the study must demonstrate that wetland hydrology and vegetation will be maintained.
- Ensure that there will be no impacts on flooding, erosion or slope instability to upstream, downstream or adjacent properties in future stages.
- Options that avoid or minimize impacts to the natural environment need to be considered and the area of natural system occupied for construction disturbance needs to be minimized to the extent feasible.

Ministry of Environment, Conservation and Parks (MECP)

The MECP is responsible for implementing the *Endangered Species Act (ESA), 2007)*. During the YCGSMP MCEA process, 30 Species at Risk (SAR) were identified as potentially occurring in the Study Area, with 12 SAR identified as having a moderate or high potential to occur within the Study Area based on available habitat (**Appendix B**). Eight of these species receive protection in this Study Area under either the *ESA* or Species at Risk Act (*SARA)*. These species are chimney swift (*Chaetura pelagica*), red-headed woodpecker (*Malenerpes erythrocephalus*), wood thrush (*Hylocichla mustelina*), barn swallow (*Hirundo rustica*), little brown myotis (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), tri-coloured bat (*Perimyotis subflavus*), and butternut (*Juglans cinerea*). Field visits, and possible studies, would be necessary to confirm the presence/absence of SAR or their habitats within or adjacent to any areas where the proposed works are planned. In particular, impacts to butternut, SAR bats, and red-headed woodpecker would need to be ruled out based on the tree impacts determined during detailed design for each Project.

Measures intended to avoid/mitigate impacts to SAR should be included in the detailed designs. Communication with the MECP early in the design process is recommended. MECP would then determine if impacts to SAR have been avoided through the proposed measures or if further permitting under the ESA would be required.

10.5.3 Federal

Department of Fisheries and Oceans, Canada (DFO)

Fish and fish habitat is protected under the *Fisheries Act* (1985) is managed by DFO. On August 28, 2019, changes were made to the *Fisheries Act*. These changes include new protections for fish and fish habitat in the form of standards, codes of practice, and guidelines for projects in and near water. These provide guidance on how to avoid and mitigate impacts to fish and fish habitat and comply with the *Fisheries Act* to avoid causing the death of a fish or harmful alteration, disruption, or destruction of fish habitat from the proposed work, undertaking or activity.

As it has been previously accepted that Yellow Creek no longer contains fish and the underground geographic separation of the YCGSMP to downstream habitat is substantial, DFO formal review will likely not be required of the proposed works. This preliminary determination should be revisited by a qualified aquatic ecologist when detailed design information is available for each Site.

11. Study Conclusions

YCGSMP’s key conclusions concerning the present state of the geomorphic system, ecological habitat and risk to Toronto Water infrastructure within the Yellow Creek Study Area include:

1. Yellow Creek has undergone drastic human-made alterations within the past century and current flashy, extreme stormwater flows continue to alter the landscape and damage existing bank stabilization structures, most notably in Reach 1 and 2 of the Study Area.
2. Direct fish habitat within Yellow Creek is no longer present due to historic channel alterations and underground piping of the system through storm water pipes, however the surrounding valley provides potential habitat to many species, including SAR, and contains mature trees and recreational hiking opportunities that are highly valued by the surrounding community.
3. A thorough detailed assessment of geomorphic processes active within each of the four reaches of Yellow Creek was conducted, along with an analysis of risks to bank protection measures and is provided in Section 7.
4. A total of 1093 m, or 87% of the Yellow Creek channel through the Study Area had existing bank protection, in varying states of repair. The quarried rock walls have been present for approximately 100 years and long sections remained in fair condition, particularly evident through Reaches 3 and 4 where

a meandering pattern was maintained when the walls were installed. This is unique since stabilization of creek banks within the City of Toronto in the past typically involved first straightening the watercourse first before stabilizing.

5. Geomorphic adjustments observed within the Yellow Creek Study Area included channel widening, lateral migration and degradation, most evident within Reaches 1 and 2 where existing bank protection was failing (71%) or had failed (60%). Notable rapid creek bank erosion into the valley wall was occurring at an outside bank in Reach 2 near the remains of a historic sawmill. These adjustments are anticipated to continue without direct intervention, putting Toronto Water infrastructure and private property at varying degrees of risk.
6. The preferred solutions have been prioritized for construction based on a review of erosion risk and an assessment of the consequences of failure associated with the Toronto Water Infrastructure sites and have been divided into four (4) Project groupings. Since there is no at-risk sanitary infrastructure within the Yellow Creek Study Area, there were no sites evaluated as high-risk. Sanitary at-risk sites within the city will need to be prioritized for construction ahead of the high-moderate Site 4.
7. Phased implementation of Sub-Reach Based Works are the preferred solution for all evaluated Sites, with Project 1A (Site 4) evaluated as the highest priority for rehabilitation works. Relatively hard bank protection measures using large armourstone are prescribed to withstand the demonstrated strong stormwater flows that the Yellow Creek system experiences, however restoration and protection of the surrounding riparian area is anticipated to result in maintaining and/or improving the natural habitat of the valley and enjoyment by the public. Project 1A (Site 4) is recommended to be prioritized for restoration works out of the YCGSMP Sites. However, when considering other sites on a City-wide basis, it is anticipated that it is of Moderate Priority, with works to take place in approximately 5 to 10 years' time. Project 1B, Project 2 (Sites 5/6, 7, 8/9), Project 3 (Site 2) and Project 4 (Site 10) are recommended to be addressed in the low priority timeframe of 10 to 20 years' time, separated into sub-projects based on geographic proximity.
8. Intact quarried block wall circa 1900 lines significant portions of Reaches 3 and 4. The City intends to monitor the condition of this block wall. Deteriorating conditions will be used as an indicator for when low-priority projects will need to be considered for implementation in the long-term.

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Ontario Butterfly Atlas. **https://www.ontarioinsects.org/atlas/**

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