PUBLIC WORKS

BRANEIDA STORMWATER MANAGEMENT FACILITY RETROFIT AND DOWNSTREAM CHANNEL REMEDIATION MUNICIPAL CLASS ENVIRONMENTAL ASSESSMENT

MARCH 2021

VOLUME 1: DRAFT PROJECT FILE REPORT

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description

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Executive Summary

The City of Brantford has retained Ecosystem Recovery Inc. (ERI) to complete a Schedule “B” Municipal Class Environmental Assessment for proposed retrofits to the existing Braneida Industrial Stormwater Management Facility (SWMF). The existing SWMF does not meet current standards and does not have an Environmental Compliance Approval (ECA) in place. The objective of this project is to develop alternative designs and select the preferred alternative for the retrofit of the existing SWMF in compliance with current provincial standards.

The public consultation process for this project was to issue a Notice of Commencement, hold a Public Information Centre, and post the Project File Report for public review before final approval from the City of Brantford.

A fluvial geomorphological assessment was completed that involved an analysis of historical aerial photos and a field assessment to observe processes that may influence the SWMF design, photographic inventory of channel conditions, and data collection to enable quantification of channel dimensions and substrate materials. A hydrogeomorphic assessment was completed to examine existing hydraulic conditions including channel capacity, floodplain connectivity, stream power, shear stress, and sediment entrainment. The channel has been previously modified which has caused incision into underlying clay, increasing entrenchment in the downstream direction, and corresponding high energy that remains within the channel. It is expected that these processes are likely to continue as the watercourse adjusts to the modified conditions. An erosion threshold analysis and summary of geomorphic process is also included.

Existing and future drainage patterns are outlined, including catchment areas and imperviousness. This informed the hydrologic model, which was built using Visual OTTHYMO. Both existing conditions and the ultimate development scenario were modelled. The hydraulic conditions of the site were modelled using HEC-RAS, the results of which were also used to inform the geomorphic analysis.

An Environmental Impact Study (EIS) was completed for the study area. Five locally rare vegetation species were recorded within the study area and should be avoided where possible, including meadow horsetail (*Equisetum pratense*), marsh horsetail (*Equisetum palustre*), tamarack (*Larix laricina*), poke milkweed (*Asclepias exaltata*), and pearly everlasting (*Anaphalis margariacea*). An opportunity exists within the study area limits to improve the overall native species composition through the removal of invasive and non-native species and replacement with native tree, shrubs, and herbaceous species along Garden Avenue Tributary. There is also an opportunity to create additional fish habitat and increase fish passage through the removal of barriers to fish movement and have the SWMF as an open water feature. The intent of restoration is not to create habitat for wildlife and fish species within the SWMF, but a large open water feature will likely be used by amphibians, reptiles, fish, and bird species.

A draft Stage 1 archaeological assessment has been conducted for the Braneida SWMF by Timmins Martelle Heritage Consultants. The only location within the study area that retains archaeological potential is the first potential easement. The rest of the study area, including easements 2 through 7, the SWMF facility, and the watercourse downstream of the SWMF no longer retain archaeological potential due to either previous disturbance or previous assessment, and no further assessment is required. A Cultural Heritage Assessment found that the subject property does not meet the criteria for known or potential cultural heritage value.

Alternative development for the SWMF was based on current stormwater management practices. The design criteria that must be achieved include improvements in water quality, improvements in erosion criteria using natural channel design concepts for the downstream channel remediation, demonstrate that the post-retrofit peak flow rates do not exceed the existing conditions, and provision of maintenance and operation easements.

Alternative solutions were developed for the three main aspects of the project including the location of easements, the SWMF retrofit, and the downstream channel remediation.

Five potential easement locations were evaluated, including 132 Adams Boulevard, 112 Adams Boulevard, 90 Adams Boulevard, 66 Adams Boulevard, and 66 Adams Boulevard (from Bury Court). The evaluation criteria categories included land use, natural environment, design requirements, and the availability of a willing host. The easement at 90 Adams Boulevard was selected as the preferred alternative, subject to the willingness of the existing landowners to provide the required easement.

Three retrofit alternatives were evaluated for the SWMF, including do nothing, retrofit the existing SWMF within the existing SWM block, and retrofit the existing SWMF and expand the existing SWM block. The evaluation criteria categories included public health and safety, technical, environmental, heritage and archaeological resources, socio-economic, cost, and constructability. The draft preferred alternative is to retrofit the existing SWMF within the current footprint.

Four alternatives were considered for the downstream channel remediation, including do nothing, channel bed/profile enhancements, channel capacity/floodplain connectivity, and channel realignment. The evaluation criteria categories included technical, natural environment, socio-economic, cost, and constructability. The preferred alternative is a hybrid of Alternative 2 and 3, to provide channel bed/profile enhancements and increase channel capacity and floodplain connectivity.

The works are scheduled to be completed in spring to summer 2021, including detailed design and permitting, tendering and construction plan preparations, and construction and completion of the project works. An easement will be required to access the SWMF for construction and long-term operation and maintenance of the facility. The preliminary cost estimate is $1,309,000 for the SWMF retrofit and $253,000 for the channel restoration, resulting in a total project cost of $1,562,000. Relevant permits and approvals will be required prior to construction.

1 Introduction

The City of Brantford has retained Ecosystem Recovery Inc. (ERI) to complete a Schedule “B” Municipal Class Environment Assessment (Municipal Class EA), for proposed retrofits to the existing Braneida Industrial Stormwater Management Facility (SWMF). Refer to **Figure 1** in **Appendix A** for a map of the study area.

The existing Braneida Industrial SWMF was constructed in the 1990s and does not meet current MOE water quality and quantity control standards. Furthermore, there is no Environmental Compliance Approval (ECA) (formerly Certificate of Approval (C of A)) in place.

The goal of the Municipal Class EA will be to evaluate and consider the sizing of the existing SWMF based on current stormwater management practices and provincial standards. An overall drainage review of the storm catchments will be completed, and a design report prepared for the reconstruction of the existing SWMF. The ultimate objective on completion of the Municipal Class EA will be to obtain the necessary approvals and permits for the retrofit of the existing SWMF for water quality, erosion and quantity controls in compliance with current provincial standards.

1.1 Background Studies

Background studies have been reviewed and the relevant details have been captured and summarized in the following sections.

1.1.1 Braneida - Industrial Park VII

Braneida Industrial Park, City of Brantford, Stormwater Drainage Plan, Philips Planning and Engineering Limited, dated June 1990.

This report provided the drainage area characteristics for the Braneida SWMF under existing and anticipated developed conditions, as well as detailed design information associated with the proposed and subsequently constructed SWMF.

The facility was designed to provide post to pre-development peak flow attenuation for the 2-year through 100-year return period events. In addition, the facility was designed to retain the first 10 mm of run-off for water quality improvement, consistent with the GRCA policy at the time.

The outlet structure was designed with low-level control provided by twin 200 mm diameter drains and a concrete rectangular weir. The 200 mm diameter drains provide a restricted outlet for the stormwater quality portion discharged over 40 to 45 hours. The concrete weir was designed to attenuate flows to pre-development levels for the 2-year to 100-year return period events.

Flows are conveyed via a terrafix block lined transition channel to twin 2.0 m diameter CSP culverts under a former railway embankment. Flows in excess of the 100-year design to Regional event flow through a terrafix block lined emergency spill way to the transition channel.

1.1.2 Braneida Industrial Park - VII Hydrology Update

Braneida Industrial Park - VII Hydrology Update, Philips Planning and Engineering, July 6, 1990

This letter report provides an update to the drainage characteristics of certain portions of the land upstream of the Braneida SWMF. Some of the previously assumed drainage areas were larger than originally assumed.

As such it was recommended that these upstream areas be controlled on-site to pre-development release rates in order to maintain functionality of the Braneida SWMF.

1.1.3 Brantford Power Center

Brantford Power Center Stormwater Management Report, Sernas Associates, June 2009

This report was prepared for Brantford Power Center Commercial development located on Henry Street at the northeast corner of the Wayne Gretzky Parkway and Henry Street intersection. The report provides detailed design information associated with the proposed commercial development of the land, with respect to on-site stormwater management controls for quantity control and a retrofit of the existing Braneida SWMF for quality control.

On-site controls are required to attenuate post-development peak flows to pre-development levels for the 2-year to 100-year events for the contributing drainage area. The on-site controls were proposed to be provided with rooftop, underground, and parking lot storage.

Retrofits to the existing SWMF were proposed to convert the existing dry facility to a wet pond. The proposed retrofits included: excavating a permanent pool, regrading the pond side slopes, constructing a forebay berm, and modifying the existing outlet control structure.

1.1.4 Brant Trade Industrial Park – Letter of Intent

Brant Trade Industrial Park Inc, Letter of Intent to Implement Compensation, Mitigation and Monitoring Measures for the Harmful Alteration, Disruption (HADD) of Fish Habitat, Stantec, June 2009

This report outlines the compensation plan and Fisheries Act Authorization associated with the Brant Trade Industrial Park Inc development east of Tim Hortons along Henry Street, refer to **Figure 1**. The development approval permitted the enclosure of a portion of remnant channel subject to compensation works in the tributary downstream of the Braneida SWMF.

1.1.5 Brant Trade Industrial Park Inc. Channel Design Brief

Brant Trade Industrial Park Inc. Channel Design Brief: Tributary to Fairchild Creek, Stantec, June 2009

This report outlines the nature of the proposed channel improvements as compensation to the proposed watercourse enclosures for the Brant Trade Industrial Park development; refer to **Figure 1**. The improvements will commence 40 m downstream from the twin culverts under the railway embankment and extend for a length of approximately 215 m to the confluence of two wetland channels. The constructed channel will exhibit natural bed morphology that utilizes pools and riffles and stable substrate material.

The downstream watercourse is divided into reaches that have been surveyed and channel characteristics are provided. The channel enhancements are designed based on measuring the stable channel reach (FT-6) and designing the channel to convey a future 2-year flow of 0.81 m^3/s from the Braneida SWMF following completion of the proposed retrofits to provide water quality and erosion control.

1.1.6 Villarboit Development Inc

Villarboit Development Inc, "Stormwater Management Report, John Towle Associates Limited Consulting Engineers, September 2012

This report was prepared for the Brant Trade Industrial development located on Henry Street at the intersection of Wayne Gretzky Parkway and Henry Street (Lowes and Brantford Power Center). The strategy is proposed to meet the intent of the recommendations contained in the Sernas June 2009 report described above. The report provides detailed design information associated with the proposed commercial development with respect to water and wastewater servicing and stormwater management.

The 100-year post development flow is to be attenuated to 2-year pre-development flow. Stormwater calculations from Lowes and Brantford Power Center have been prepared for two discharge locations, the North Area and the South Area

1.1.7 Kylin Development Inc

Kylin Development Inc, 225 Henry Street Industrial Development Stormwater Management Report exp, September 2018

This report outlines the proposed stormwater management strategy to develop 225 Henry Street. The site is approximately 74.40 ha comprising 43.20 ha of existing industrial development and 31.20 ha of proposed industrial development, refer to **Figure 1** in **Appendix A**. The stormwater management strategy incorporates the following:

- Stormwater from Lowes and Brantford Power Center with controls as described above; and,
- Quantity and quality control provided in a proposed stormwater management pond;
- Best Management Practices (BMPs) on each development block to achieve a maximum allowable release rate of 0.13 m^3/s/ha.

Prior to approval of construction an assessment of the receiving waterbody up to 500 meters downstream from the limits of subdivision. The assessment will demonstrate that the proposed development and modifications to the existing stormwater management scheme will not impair or exacerbate current conditions downstream or provide suitable mitigation options and implementation either through onsite or offsite modification to the satisfaction of GRCA and the City of Brantford.

2 Environmental Assessment Process

2.1 Ontario's Environmental Assessment Act

The Braneida Stormwater Management Facility Proposed Retrofits project is subject to the provisions of Ontario's *Environmental Assessment Act*. The Act requires that an environmental assessment of any major public sector project that has the potential for significant environmental effects be undertaken prior to implementation to determine the ecological, cultural, economic, and social impact of the project.

The Act exists to "provide for the protection, conservation, and wise management of Ontario's environment". The act mandates clear terms of reference, focused assessment hearings, ongoing consultation with all parties involved — including public consultation — and, if necessary, referral to mediation for decision. Environmental assessment is a key part of the planning process and must be completed before decisions are made to proceed on a project.

To comply with the requirements of the Act, two types of environmental assessment processes can be applied to projects:

1. **Individual Environmental Assessment** (under Part II of the Act): This process includes the development of a project-specific Terms of Reference that is submitted for review and approval to the Minister of the Environment. This process is typically applied to large, unique, or complex projects that do not have precedents that demonstrate a predictable and manageable environmental impact.
2. **Class Environmental Assessment**: This process applies to routine projects that have predictable and manageable environmental effects and follow a Terms of Reference that has been previously approved for certain types of projects. Provided that the approved Class EA process is followed, the project will comply with Section 13(3) a, Part II.1 of the *Environmental Assessment Act*.

2.2 Municipal Class Environmental Assessment

The Braneida Stormwater Management Facility project falls under the Class Environmental Assessment process as a project with predictable and manageable environmental impacts and will be carried out under the Terms of Reference established in the Municipal Class Environmental Assessment document, prepared by the Ontario Municipal Engineers Association in June 2000 (as amended in 2011).

Error! Reference source not found. **2** in Error! Reference source not found. illustrates the Municipal Class EA Process for the planning and design of projects, which is divided into five phases. These fives phases are described in **Table 2-1**.

Table 2-1. Description of the Five Phases of the Municipal Class Environmental Assessment Process

Phase 1	Identify the problem (deficiency) or opportunity
Phase 2	Identify alternative solutions to address the problem or opportunity by taking into consideration the existing environment and establish the preferred solution considering public and review agency input.
Phase 3	Examine alternative methods of implementing the preferred solution, based upon the existing environment, public and review agency input, anticipated environmental effects and methods of minimizing negative effects and maximizing positive effects.

Phase 4	Document, in an Environmental Study Report, a summary of the rationale, and the planning, design and consultation process of the project as established through the above Phases and make such documentation available for scrutiny by review agencies and the public.
Phase 5	Implementation. Complete contract drawings and documents and proceed to construction and operation; monitor construction for adherence to environmental provisions and commitments. Where special conditions dictate, also monitor the operation of the completed facilities.

The Municipal Class EA applies to municipal infrastructure projects including roads, water, wastewater and stormwater projects. There are several classifications of projects under the Class EA process, known as schedules, based on their potential environmental impact:

- **Schedule "A"** projects generally include normal or emergency operational and maintenance activities, where environmental effects are minimal. Only Phase 1 of the Class EA process must be completed prior to these projects being implemented.
- **Schedule "A+"** projects were introduced in 2007 and include an additional consultation component wherein the public is to be advised prior to the implementation of a Schedule "A" project.
- **Schedule "B"** projects generally include improvements and minor expansions to existing facilities, where there is the potential for some adverse environmental impacts. The first two phases of the Class EA process are completed for these projects, including the preparation and submission for public review of a Project File, prior to implementation.
- **Schedule "C"** projects generally include the construction of new facilities and major expansions to existing facilities and have the potential for significant environmental impact. The complete Class EA process is undertaken for these projects prior to implementation, including the production of an Environmental Study Report.

The Braneida Stormwater Management Facility study is being completed under Schedule "B" of the Municipal Class EA process, as the project is likely to involve improvements to existing facilities with an anticipated benefit to stormwater control and the downstream environment. The project will involve a public consultation component of the study, as specified under the description of a Schedule "B" project in the MEA document.

2.3 Public Review and Next Steps

This Project File Report is available for public review and comment for a 30 business day period. Placing the Project File Report for public review completes the planning stage of the project. A public notice (Notice of Completion) was published to announce commencement of the review period. Due to the COVID-19 restrictions and closure of public facilities, hard copies of the Project File Report will not be available at the City of Brantford offices.

If, after reviewing this report, you have questions or concerns regarding specific projects recommended through the Master Plan, please follow this procedure:

1. Contact Nahed Ghbn at the address below to discuss your questions or concerns:

Nahed Ghbn, PMP, P.Eng.
Senior Project Manager, Water Resources
Engineering Services – Public Works Commission
City of Brantford
City Hall, 100 Wellington Square, Brantford, N3T 2M2

Mailing Address: P.O. Box 818, Brantford, N3T 5R7
Phone: 519-759-4150   Fax: 519-752-6775
Email: nghbn@brantford.ca

2. If your concerns remain, the City of Brantford will attempt to resolve the concerns as best it can. If there are outstanding concerns regarding potential adverse impacts to constitutionally protected Aboriginal treaty rights, you may request the Minister of the Environment, Conservation and Parks (MECP), formerly MOECC, to issue an order requiring the Municipality to comply with Part II of the EAA before proceeding with the specific projects associated with the issue(s). This is called a Part II Order request.

A Part II Order may only be requested if there are outstanding concerns that a project may adversely impact constitutionally protected Aboriginal and treaty rights.

In addition, the Minister may issue an order on his or her own initiative within a specified time period. The Director will issue a Notice of Proposed Order to the proponent if the Minister is considering an order for the project within 30 days after the conclusion of the comment period on the Notice of Completion. At this time, the Director may request additional information from the proponent. Once the requested information has been received, the Minister will have 30 days within which to make a decision or impose conditions on the project.

This means the City cannot proceed with the project until at least 30 days after the end of the comment period provided for in the Notice of Completion. Further, the proponent may not proceed after this time if:

- a Part II Order request has been submitted to the Ministry regarding potential adverse impacts to constitutionally protected Aboriginal and treaty rights, or
- the Director has issued a Notice of Proposed Order regarding the project.

3. After reviewing the Part II Order request and the relevant project detail, the Minister may make one of the following decisions:

- Deny the request;
- Deny the request with conditions;
- Refer the matter to mediation; or
- Issue a Part II Order whereby the City will be required to prepare a Terms of Reference and a project-specific EA for the undertaking.

Part II Order requests regarding potential adverse impacts to constitutionally protected Aboriginal and treaty rights must be submitted in writing to the Minister of the Environment, Conservation and Parks. The request must be sent to the following address within the 30-day review period:

Minister Jeff Yurek
Ministry of the Environment, Conservation and Parks
777 Bay Street, 5th Floor
Toronto, ON M7A 2J3
minister.mecp@ontario.ca

and

Director, Environmental Assessment Branch
Ministry of the Environment, Conservation and Parks
135 St. Clair Avenue West, 1st Floor
Toronto, ON M4V 1P5
EABDirector@ontario.ca

If no Part II Order requests are received, the City may proceed with detailed design and construction of the recommended projects as presented in this report.

Information will be collected in accordance with the Municipal Freedom of Information and Protection of Privacy Act. All comments, with the exception of personal information, will become part of the public record.

2.4 Consultation Process

The consultation approach taken with this Schedule B project was to issue a Notice of Commencement, hold a Public Information Centre (PIC) and have the Project File Report screened to the public for a 30 day period before final approval from the City of Brantford. All public consultation materials and records are included within **Appendix B**.

2.4.1 Notice of Commencement and Public Information Centre

A Notice of Commencement was sent to indigenous groups and neighbouring landowners within the Braneida industrial subdivision by City of Brantford staff and was also advertised in the City of Brantford Civic News and Turtle Island News in late November 2020. The Notice was also emailed to a contact list of relevant agencies, included in **Appendix B**.

A Public Information Centre (PIC) was hosted virtually by ERI and the City for the public to watch, and was posted on the City of Brantford website on November 30, 2020. The video was viewed 34 times. The public was invited to provide feedback to the City and ERI, and the full comments can be found attached with the Notice of Commencement and PIC boards in **Appendix B**. Public feedback was incorporated into the evaluation of alternatives and selection of a preferred alternative.

2.4.2 Notice of Completion

A Notice of Completion was sent to stakeholders and published on the City of Brantford website. The Notice of Completion is included in **Appendix B**.

3 Existing Conditions

This section of the report summarizes the existing conditions related to the surrounding environment. The information will be used to scope further technical studies, confirm and update the design considerations, potential environmental impacts and mitigating measures for the evaluation of stormwater retrofit alternatives.

3.1 Physiography and Surficial Geology

The physiography of an area refers to spatial groupings of similar landscape characteristics (i.e., landforms, rock or sediment type) that have a common geologic or evolutionary history. The physiography of a region is intrinsically linked to the topography of the landscape and the geomorphic influences acting upon it. Landscape characteristics exert an important influence on watercourse form and function. The topography of the area will determine the gradient of the watercourse. The profile of a watercourse represents the historical evolution of the stream system within the physiographic and geologic contexts.

The study area is located within the Norfolk Sand Plain physiographic region. The region is characterized by coarse sands and silts that are associated with deltaic sediment deposited into Glacial Lakes Whittlesey and Warren by glacial meltwaters from the Grand River as the glaciers receded from the area (Chapman and Putnam, 1984; 2007). The sand lies over portions of the Galt Moraine and is bisected by river valleys. The sediment allows for greater infiltration and groundwater movement (MacVeigh et al., 2016).

Surficial geology, also referred to as Quaternary geology, describes the material that was deposited, and the depositional features that formed, during the last glaciation which ended approximately 10,000 years ago. The boundary materials (bed and banks) of a watercourse are determined by the local surficial geology and upstream sediment contributions. The two primary surficial geology units that comprise the study area include that of modern alluvium and fine-texture glaciolacustrine deposits (clay) (OGS, 2010). Fine-textured glaciolacustrine deposits are present upstream of the existing pedestrian bridge within the study area. These deposits are primarily of silt and clay, with minor sand and gravel deposits, and may be massive to well-laminated.

Erosion of clay materials is influenced less by hydraulic stress than by chemical weathering processes and are prone to long term channel bed lowering when this material is exposed on the channel bed. The unit is characterized as consisting of ‘tight’ soils with low permeability and is poorly drained; the area is dominated by surface runoff with very little infiltration to groundwater (MacVeigh et al., 2016).

Downstream of the pedestrian bridge, modern alluvium is present, which consists of clay, silt, sand, gravel, and may contain organic materials. This material can generally be reworked by flows that are conveyed through the channel. The alluvium is generally a thin layer that is situated on the underlying clay into which the channel has incised. Field investigations indicated incision into clay along the majority of the watercourse within the study area. Excess flow above the threshold of sediment mobility could result in a response to channel form and function.

3.2 Fluvial Geomorphology

The Braneida SWMF outlets to a watercourse that conveys flow to the Garden Avenue Tributary of Fairchild Creek. A geomorphological assessment of the tributary was previously completed by Stantec (2009).

Drainage and erosion problems were previously identified in the Garden Avenue Tributary of Fairchild Creek downstream of Garden Avenue (K Smart Associates LTD, March 2012). In response, the City, in collaboration with Brant County, completed work on the Garden Avenue Municipal Drain (i.e., downstream of Garden Avenue) to address identified erosion and stream deterioration.

Within the current study area, Stantec (2009) indicated that the channel likely does not have capacity to accommodate additional flows (e.g., due to upstream development) and that the channel is at risk of deterioration. In response, Stantec (2009) recommended that channel improvements should be undertaken downstream of the Braneida SWMF, commencing 40 m downstream from the twin culverts under the railway embankment and extending for a length of approximately 215 m to the confluence of two wetland channels. The GRCA has also identified creek erosion and capacity concerns in this area.

Existing geomorphic conditions and an understanding of channel functions within the tributary, within the context of the current study, were established through field investigations and hydrogeomorphic analyses. The following sections summarize the findings from these investigations.

3.2.1 Historical Assessment

A sequence of historical air photos was obtained from the National Air Photo Library (1964, 1982 and 2006) (**Appendix C – Attachment 1**). Review of aerial photography provides insight into changes that have occurred within the watershed, to the drainage network, and within the immediate study area. A summary of key observations is provided in **Table 3-1** and a historic channel overlay is shown in **Table 3-1**.

Table 3-1: Overview of Historical Changes Within Study Area.

Image year	Key observations
1964	The study area is comprised entirely of agricultural lands (fields). An agricultural watercourse crossing is located at the existing pedestrian bridge crossing. The watercourse through the study area appears to have been dredged, with smooth and relatively straight banks through the agricultural fields. A tributary is present where the existing SWM facility is located, extending northwest from the watercourse confluence. The channel continues to Adams Boulevard as an open watercourse, with headwater drainage features extending from the agricultural lands into the tributary.
1982	The study area remains in similar conditions to that of 1964. The study area is entirely agricultural lands (fields). The tributary and headwater drainage features remain connected to the watercourse from the adjacent lands. The channel has developed in planform since 1964, with a secondary meandering pattern developed on the previously dredged or altered channel planform.
2006	Development has occurred along Adams Boulevard and further upstream within the watershed. The SWM facility has been constructed within the study area. Reach 3 has been straightened and modified to accommodate the SWM facility. Downstream of the SWM facility, the channel exhibits a similar planform or footprint to current conditions. The channel has continued to meander within the larger channel footprint or primary meandering pattern. Some headwater features extending from the surrounding lands of the tributary have been removed as development has progressed.

Braneida SWM Facility

Figure 3.1
Historical Analysis

Legend

- 2019 Watercourse
- 2019 Headwater Drainage Feature
- 1982 Watercourse
- 1982 Headwater Drainage Feature
- 1964 Watercourse
- 1964 Headwater Drainage Feature

ecosystem recovery inc. PROFESSIONAL ENGINEERS

0 50 100 200
Meters

NAD 1983 UTM 17N | 1:4,000

Project: 1839 Braneida SWM
Date: 2020/01

Data Sources: Ecosystem Recovery Inc., 2020:

3.2.2 Geomorphic Assessment

A reconnaissance level field assessment was completed in October 2019. The field assessment documented:

- Observations of channel form and processes which may influence the design of the SWM facility;
- Specific areas for inclusion in the topographic site survey;
- A photographic inventory of channel conditions; and,
- Data collection to enable quantification of channel dimensions and substrate materials as a basis for geomorphological analyses.

Through the field reconnaissance and subsequent data analyses, it became apparent that there was spatial variability with respect to channel conditions and processes within the study area. Three reaches were defined to enable spatial organization of data and observations, to facilitate analyses, and to provide baseline understanding to inform the identification and selection of potential alternatives (**Figure 3.3**).

Reach boundaries were determined primarily by a change in boundary material, and/or observed geomorphic processes (**Figure 3.3**). An overview of sub-reach characteristics and conditions, including discussion of channel bed profile (**Figure 3.6**) and cross-sectional features (**Table 3-2**), is provided below. A photographic inventory of the watercourse from a geomorphic perspective is included in **Appendix C (Attachment 2)**.

<u>Reach 1:</u>

Reach 1 is a defined section of channel which extends from the tributary confluence to 286 m upstream (**Figure 3.3**). Overhanging vegetation (i.e., herbaceous, grasses, shrubs) is abundant throughout the reach. The channel demonstrates an incised setting, with increased incision exhibited in the downstream direction as reflected in the presence of a smaller cross-section developing within the larger and deeper cross-section, as seen in **Figure 3.2** and reflected in the profile **(Figure 3.6)**. The dimensions of the inset bankfull cross-section (i.e., associated with the channel forming flows) are smaller than the larger channel cross-section dimensions (**Table 3-2**). The larger channel dimensions within the reach are generally double the bankfull cross-section dimensions. Vertical banks are present within the smaller inset cross-section, while the larger channel cross-section exhibits more gently sloping channel banks to the table lands surrounding the watercourse.

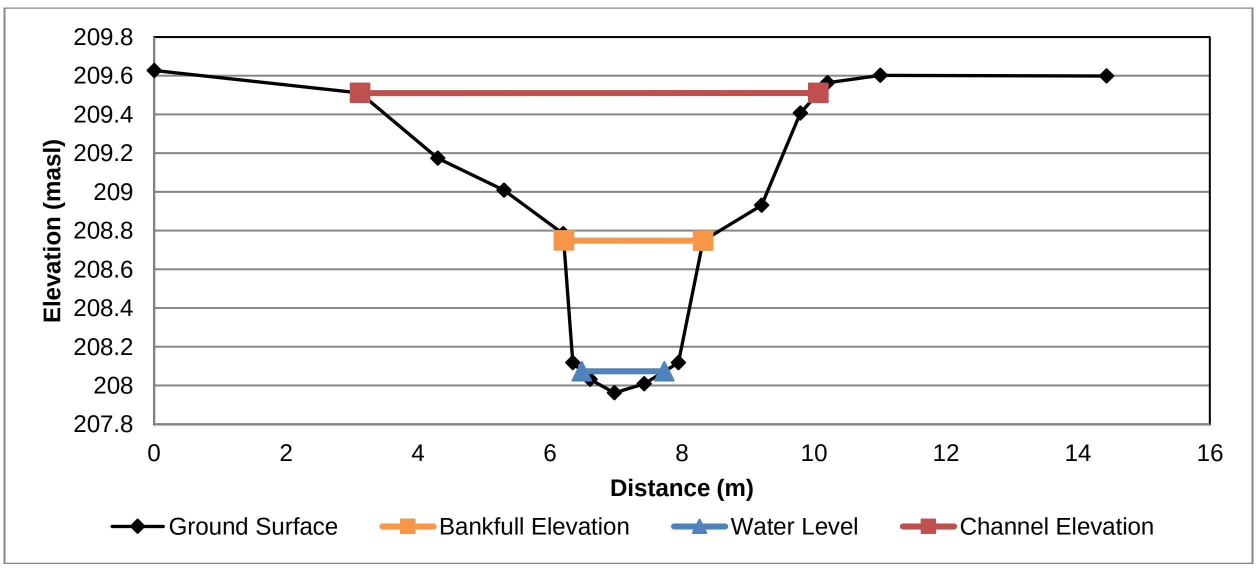
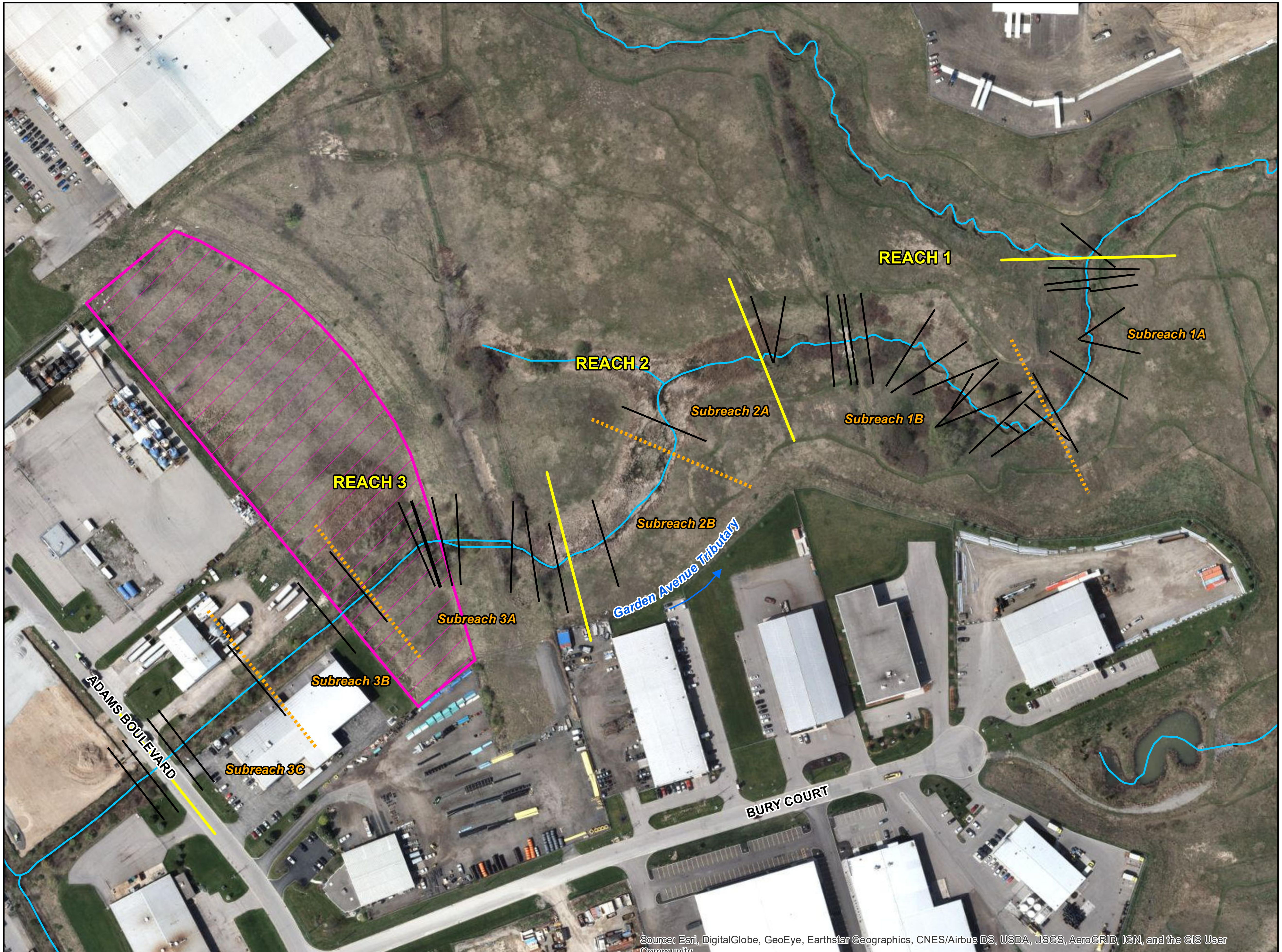


Figure 3.2. Reach 1 typical cross-section.



Braneida SWM Facility

Figure 3.3
Reach Breaks

Legend

- Reach Break
- Subreach Break
- Cross-section Location
- Watercourse
- Braneida SWM Facility

ecosystem recovery inc.
PROFESSIONAL ENGINEERS

0 25 50 100
Meters

NAD 1983 UTM 17N | 1:2,000

Project: 1839 Braneida SWM
Date: 2020/01

N W E S

Data Sources: Ecosystem Recovery Inc., 2020:

Document Path: E:\1839 - Braneida SWM Pond\5 - GIS\01 MXD\1839_GeomorphReachBreaks_20200123.mxd

Vegetated blocks of slumped bank materials were observed within the channel, suggesting ongoing erosion along the channel banks. Vegetation plantings (i.e., small trees) along the watercourse demonstrate exposed tree roots in the channel banks, further indicating active and ongoing erosion within the reach. Bare erosion scars and undercut banks are visible along the length of the reach.

The upstream limit of Reach 1 is located approximately 46 m upstream of the pedestrian bridge that crosses the channel; a knickpoint is present within the channel profile in this area. Erosion protection (erosion blanket, stakes, concrete blocks) surrounding the pedestrian bridge crossing is in disrepair or has failed. The upstream portion of the reach demonstrates less incision within the channel cross-section and profile than the downstream lengths of the reach.

The watercourse demonstrates a form of compound meandering planform through the reach, in that a smaller or secondary meander pattern has developed on the larger or primary meander pattern. This secondary planform is developing within the footprint of the incised channel, as the watercourse meanders through the larger channel setting. Point bar formations within the watercourse are indicative of planform development.

The channel bed primarily consisted of exposed clay, which varied in saturation or stiffness. The exposure of clay along the channel bed has resulted in sculpted undulations along the bed profile, which mimic the presence of pool-riffle formations within the watercourse. The presence of knickpoints within the channel profile suggest ongoing adjustment within the reach (**Figure 3.6**). The channel gradients established for Subreaches 1A and 1B are 0.94% and 0.46%, respectively.

Local areas of gravel (small to medium sized gravel) and sand deposition have occurred within the reach. Some of the gravel-sized materials are composed of fragmented clay materials, which are less dense and more readily transported when compared to lithic gravel substrate.

Reach 2:

Reach 2 extends 171 m upstream from Reach 1. Reach 2 is characterized primarily as a wetland feature where the watercourse is poorly defined (**Figure 3.3**). The tributary splits into multiple channels through the reach (see **Figure 3.4**), with poorly defined banks and vegetation dominating the feature. These small channels ranged in width and depth from 0.8 – 2.5 m and 0.1 – 0.3 m, respectively. The extent of the wetland varies from approximately 15 – 34 m in width (**Table 3-2**). The combination of a gentle slope (0.31%) through the reach and a knickpoint formation (influenced by bed resistance created by the vegetation rooting network, **Figure 3.6**) allows for pooling or backwatering behind drops within the channel profile. The channel bed is dominated by saturated clay-silt and organic materials that has deposited within the vegetation-dominated reach.

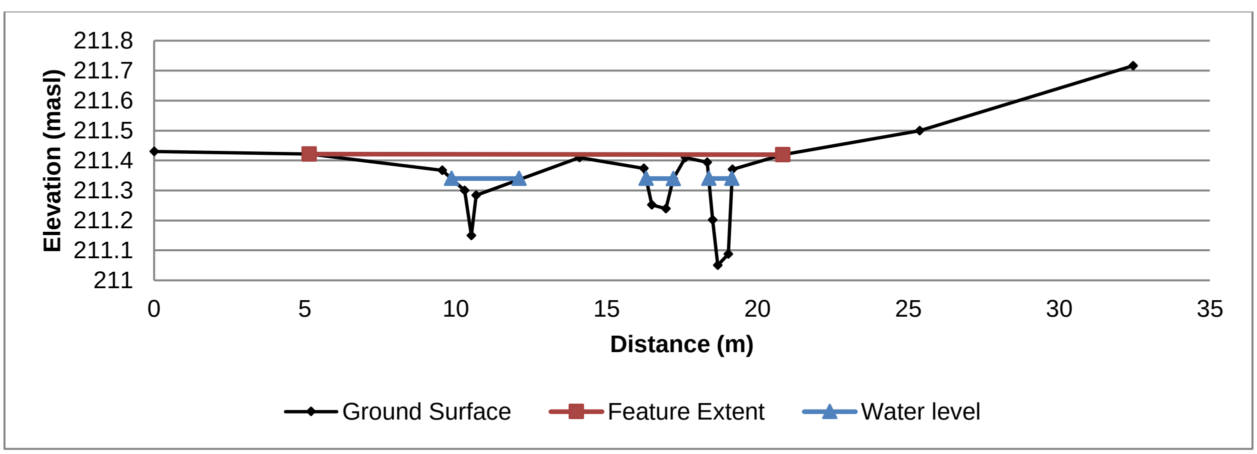


Figure 3.4. Reach 2 cross-section.

Reach 3:

Reach 3 extends approximately 262 m upstream from the wetland feature (Reach 2) to Adams Boulevard (**Figure 3.3**). In the downstream section, the reach traverses the SWM facility embankment, through the SWM facility, into a defined channel setting. From Adams Boulevard, the channel is well defined (Subreach 3C), exhibiting evidence of cross-sectional and channel bed profile alterations.

Between Adams Boulevard to the SWM facility inlet (Subreach 3B), the channel is lined with cabled concrete and is inset within a storm conveyance channel, as demonstrated in **Figure 3.5**. Riparian vegetation surrounding the channel is primarily shrubs and trees, with some grasses established within the watercourse. Subreach 3B (**Figure 3.6**) through the reach demonstrates the greatest average channel bed gradient of the study area, measured at 1.77%.

Continuing downstream through the SWM facility (Subreach 3A), a low flow channel is defined within a wetland feature. A concrete weir delimits the downstream boundary of the SWM facility. The weir causes backwatered conditions in the upstream channel. Vegetation is present through the feature (grasses), with shrubs and trees comprising the relatively narrow riparian zone surrounding the watercourse.

The channel continues downstream to the SWM facility embankment, where two (2) CSP culverts convey the low flow channels to the downstream reaches. Here, the channel bed is lined with cabled concrete and the average channel bed gradient through the subreach is 0.33% (**Figure 3.6**).

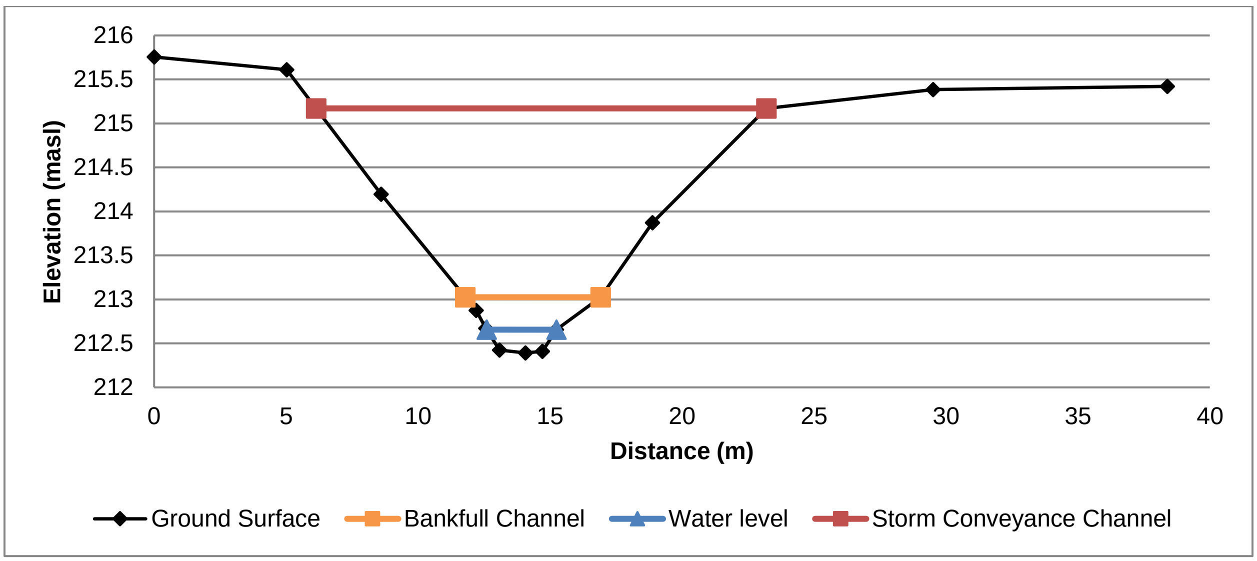


Figure 3.5. Reach 3 typical cross-section.

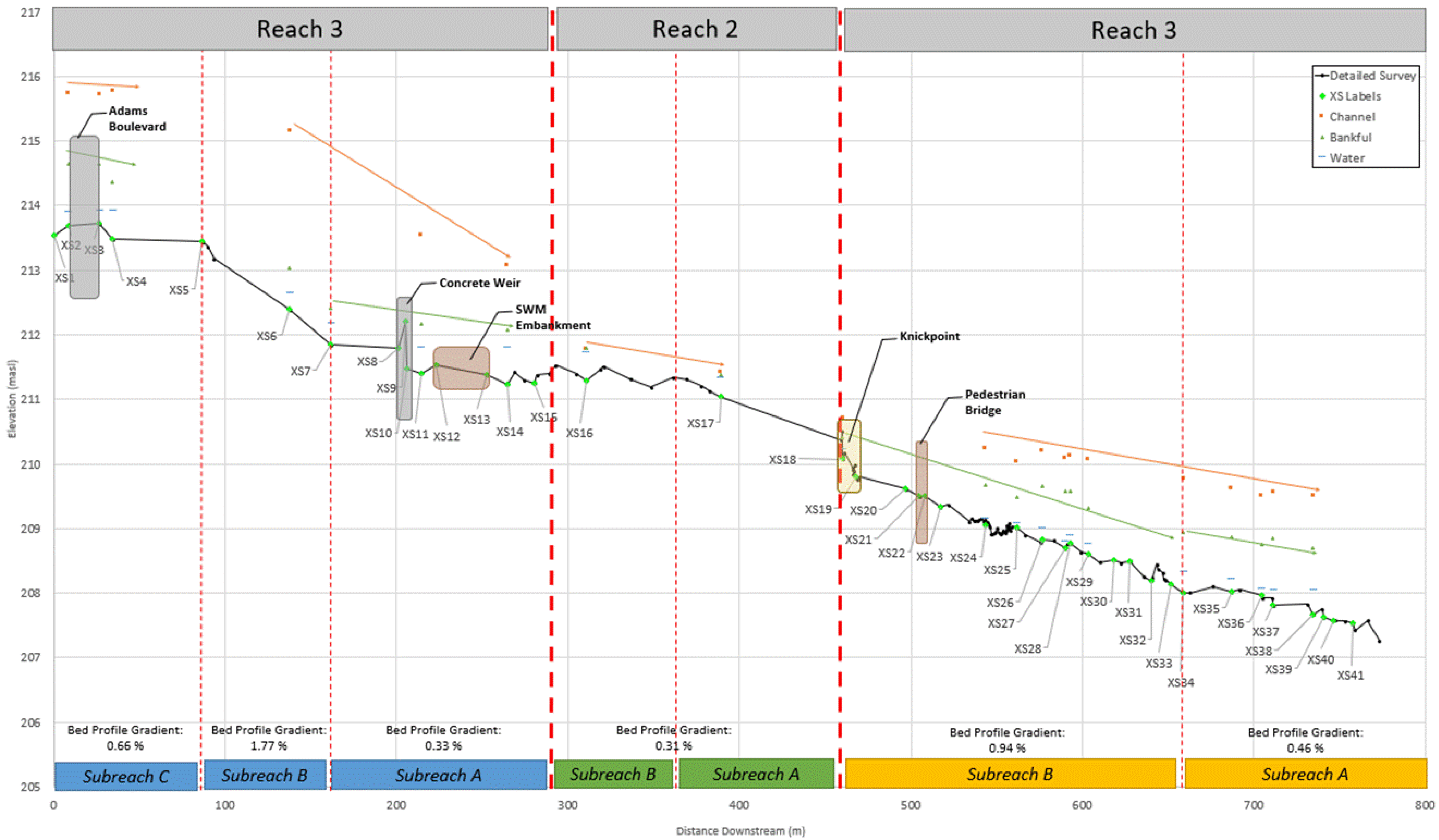


Figure 3.6. Channel bed profile from Adams Boulevard to tributary confluence.

Table 3-2. Cross-Sectional Parameters.

Reach	Reach 1			Reach 3		
Average Grade (%)	0.46 – 0.94%			0.66%		
	Min	**Max**	**Avg**	**Min**	**Max**	**Avg**
Bankfull Dimensions						
Bankfull Width (m)	2.01	4.19	3.09	5.13	8.66	6.88
Max. Bankfull Depth (m)	0.71	1.04	0.85	0.63	0.96	0.77
Avg. Bankfull Depth (m)	0.43	0.62	0.52	0.31	0.79	0.51
Bankfull Channel Area (m^2)	1.06	1.81	1.56	1.06	6.04	3.22
Bankfull Width: Depth Ratio (m/m)	3.38	9.73	6.20	9.72	19.68	14.16
Bankfull Channel Perimeter (m)	2.87	5.26	4.10	2.87	9.49	6.74
Hydraulic Radius (m)	0.31	0.43	0.38	0.25	0.67	0.42
Average Shear Stress (N/m^2)	19.44	48.70	34.90	19.90	51.01	33.47
Unit Stream Power (W/m^2)	35.45	82.59	57.35	40.97	61.87	50.27
Channel Dimensions						
Channel Width (m)	5.84	10.68	7.37	17.07	34.10	24.87
Max. Channel Depth (m)	1.36	1.84	1.55	1.84	2.78	2.19
Avg. Channel Depth (m)	0.62	1.03	0.73	0.86	1.47	1.07
Channel Area (m^2)	3.60	7.42	5.39	21.87	31.98	25.49
Channel Width: Depth Ratio (m/m)	6.89	15.37	10.28	11.62	36.36	25.03
Channel Perimeter (m)	5.59	14.66	9.31	18.49	36.49	25.65
Hydraulic Radius (m)	0.51	0.66	0.60	0.77	1.35	1.05
Substrate			**Size (mm)**			
D5			5			
D10			6			
D16			10			
D25			10			
D35			12			
D50			15			
D65			20			
D75			20			
D84			25			
D90			30			
D95			40			

3.2.3 Hydrogeomorphic Conditions

A hydraulic model of the study area was developed and used as a basis for the hydrogeomorphic assessment, refer to **Section 6.1.5** for modelling details. Since the intent of the analyses was to examine existing hydraulic conditions, the existing (rather than future) flows were used for the assessment. Results of the assessment are discussed below.

<u>Channel Capacity</u>

The flow events that are contained in the cross-sections, and those that begin to access the floodplain, were examined in the HEC-RAS model. Results (**Table 3-3**) indicated that the estimated bankfull flow (approximately 60% of the 2 year event) was contained within the cross-section in Reach 1 (i.e., within the inset channel), and the majority of Reach 3. The bankfull flow approached the bank elevation or spilled onto the adjacent floodplain locally within Reach 3 and within Reach 2.

Flows up to the Regional Storm were contained within the upstream portions of Reach 3. Generally, the flow capacity of the channel increases in Reach 1 in the downstream direction, with flows up to the 100-year storm contained within the overall channel cross-section. This confirms the notion that the tributary is incised into the landscape

<u>Floodplain Connectivity</u>

The connectivity of the channel to the floodplain determines whether flood flow energy remains largely focused within the channel cross-section or becomes dissipated on the floodplain. The assessment of floodplain connectivity thus provides insight into which flow events tend to remain within the channel cross-section and those which flow events spill onto the floodplain. Examining channel and floodplain interactions is especially relevant in urban systems where an increase in water depth and energy conditions within the creek can increase erosive conditions beyond a threshold of tolerance.

Entrenchment ratio, as defined by Rosgen (1994) is the ratio of the flood width at twice the bankfull depth (approximately equivalent to the 50-year flood event) to the bankfull width. Rosgen (1994) suggests that when the ratio is < 1.1, then flows are 'entrenched' and remain within the cross-section; ratios 1.2 – 1.4 indicate moderate entrenchment, and ratios larger than 1.4 indicate partial entrenchment. Review of **Table 3-3** reveals that the entrenchment ratio is variable through the study area. Overall, the study area is considered to be entrenched, which indicates that the channel and larger flows are vertically contained within the existing floodplain setting. This is expected given site observations.

<u>Stream Power, Shear Stress, and Sediment Entrainment</u>

Stream power refers to the rate of energy dissipation against the bed and banks of a watercourse per unit length of channel and provides indication of the potential for channel flows to perform geomorphic work. Geomorphic work refers to the transport or deposition of sediment and to overall processes of channel widening, incision or aggradation. Stream power is calculated as the product of the specific weight of water, discharge, and channel slope. Specific stream power refers to stream power per unit width of channel.

Various classification schemes exist that correlate stream type with stream power and are thus indicative of the processes occurring within the channel and the sediment load and supply characteristics necessary to sustain the stream type. The Nanson and Croke (1992) classification scheme has discretized channels into high, medium, and low energy systems. High values of stream power commonly correspond with steep, straight channels. Low stream power typically occurs in broad alluvial floodplains.

When the stream power of flows is in proximity to a threshold number associated with a change in stream type, then adjustment in channel form from one type to another may occur. If the boundary materials and sediment supply are insufficient to sustain the new channel type, then instability will result. Such instability may occur when there are changes in discharge (e.g., from uncontrolled stormwater runoff) or changes in slope (e.g., channel straightening).

Review of **Table 3-3** indicates that the stream power of the estimated bankfull flow is generally low in Reach 3, with higher values calculated for Reach 1 and locally in Reach 2. These higher values coincide with locations where the flow capacity conveyed through the channel cross-section is larger than bankfull; this may suggest that the high stream energy within the channel contributes to downcutting. The stream power values are within the naturally occurring range associated with meandering and braided type channels as per established stream power classifications (Brookes (1988), Nanson and Croke (1992)), which is considered appropriate for the system.

The shear stresses exerted on the channel bed demonstrate similar trends as the stream power.

The grain sizes that are, theoretically, entrainable during estimated bankfull flows range from 0.01 – 0.09 m in Reach 1, and 0.001 – 0.07 m in Reach 3, with an overall average of 0.03 m throughout the study area (**Table 3-3**). These ranges correspond to stone that is larger than the measured D84 of the substrate gradation in Reach 1 (**Table 3-2**); this finding supports the observation of localized and shallow alluvial cover on the clay and also suggests that excess energy is available for sediment transport. It follows that, within the entrenched channel, the potential size of entrainable sediment increases and exceeds the D95 of observed substrate materials.

Summary

The hydrogeomorphic conditions of the watercourse through the area provide insight as to the forms, functions, and processes occurring within the tributary. The channel has been previously modified (i.e., straightening, SWM facility integration), and exhibits evidence which suggest the system is currently responding to previous changes in hydrology and channel realignment. Such evidence includes the incision of the channel into underlying clay, the increasing entrenchment in the downstream direction, and corresponding high energy that remains within the channel cross-section which is available for sediment transport due to the lack of floodplain connectivity. These processes are likely to continue as the watercourse continues to adjust to the modified conditions, until a state of equilibrium may be achieved. The continuation of the existing channel conditions and processes are expected to include further erosion and channel incision, and cross-section/valley evolution.

Table 3-3. Hydraulic Parameters and Potential Sediment Mobility During 60% of the 2 Year Flow Event.

HEC Stn	Sub-reach	Flow Event Capacity of Section	60% of 2-year flow	Velocity (m/s)	Froude	Unit Stream Power (W/m)	Estimated Stream Type	Shear stress (N/m²)	Grain Entrainable (m)	Grain Transportable (m)	Entrenchment Ratio (Q50:Q bf)
REACH 3											
764	C	Regional	in channel	0.52	0.27	2.32	Straight / Meander	4.48	0.006	0.008	0.92
755	C	Regional	in channel	0.51	0.23	2.04	Straight / Meander	4.02	0.005	0.008	1.03
Adams Boulevard Culvert											
737	C	Regional	in channel	0.6	0.3	3.53	Straight / Meander	5.88	0.007	0.011	0.82
729	C	Regional	in channel	0.7	0.37	5.89	Straight / Meander	8.38	0.010	0.016	0.72
677	B	Regional	in channel	1.52	1	69.35	Braided / Meander	45.49	0.056	0.084	0.73
626	B	Regional	in channel	1.82	0.94	103.57	Braided / Meander	56.87	0.070	0.125	43.35
602	B	< Bankfull	overtop	0.08	0.03	0.01	Straight / Meander	0.1	0.000	0.000	0.71
563	A	< Bankfull	overtop	0.25	0.1	0.22	Straight / Meander	0.89	0.001	0.002	0.08
Concrete Weir											
549	A	100 year	in channel	0.46	0.17	1.32	Straight / Meander	2.87	0.004	0.006	0.95
543	A	100 year	in channel	0.44	0.21	1.39	Straight / Meander	3.12	0.004	0.006	1.00
540	A	100 year	in channel	0.45	0.21	1.43	Straight / Meander	3.15	0.004	0.006	0.63
SWM Facility Culverts											
511	A	5 year	in channel	0.6	0.26	3.35	Straight / Meander	5.57	0.007	0.011	1.41
498	A	5 year	in channel	0.65	0.25	3.98	Straight / Meander	6.1	0.008	0.013	3.18
483	A	< Bankfull	overtop	0.87	0.39	10.57	Meander	12.11	0.015	0.025	0.99
REACH 2											
453	B	< Bankfull	overtop	1.34	0.77	45.11	Braided / Meander	33.74	0.042	0.064	1.32
378	B	< Bankfull	overtop	0.32	0.25	1.21	Straight / Meander	3.75	0.005	0.003	0.11
295	A	5 year	in channel	1.7	1	154.62	Braided / Meander	90.93	0.112	0.108	0.59
287	A	5 year	in channel	1.68	0.75	83.5	Braided / Meander	49.61	0.061	0.105	1.06
REACH 1											
257	B	25 year	in channel	1.6	0.72	68.92	Braided / Meander	42.99	0.053	0.094	1.27

HEC Stn	Sub-reach	Flow Event Capacity of Section	60% of 2-year flow	Velocity (m/s)	Froude	Unit Stream Power (W/m)	Estimated Stream Type	Shear stress (N/m²)	Grain Entrainable (m)	Grain Transportable (m)	Entrenchment Ratio (Q50:Q bf)
249	B	25 year	in channel	1.26	0.57	32.44	Meander	25.77	0.032	0.056	1.01
246	B	25 year	in channel	1.32	0.61	39.24	Meander	29.73	0.037	0.062	0.95
237	B	10 year	in channel	1.38	0.63	42.77	Meander	31.1	0.038	0.068	0.82
211	B	10 year	in channel	1.28	0.51	33.3	Meander	26.09	0.032	0.058	1.10
194	B	5 year	in channel	1.58	0.74	67.36	Braided / Meander	42.7	0.053	0.092	2.51
180	B	5 year	in channel	0.8	0.36	8.04	Meander	10.04	0.012	0.021	0.64
166	B	25 year	in channel	1.09	0.38	18.05	Meander	16.55	0.020	0.041	0.64
163	B	50 year	in channel	1.87	0.96	117.54	Braided / Meander	62.92	0.078	0.132	1.19
153	B	25 year	in channel	1.24	0.48	29.37	Meander	23.67	0.029	0.054	0.72
139	B	10 year	in channel	2.01	1	148.78	Braided / Meander	74.05	0.091	0.155	1.98
129	B	25 year	in channel	0.97	0.47	15.01	Meander	15.51	0.019	0.032	0.87
116	B	5 year	in channel	1.27	0.53	32.9	Meander	25.98	0.032	0.057	1.21
104	B	10 year	in channel	1.2	0.48	27.01	Meander	22.49	0.028	0.050	0.64
96	A	25 year	in channel	1.22	0.42	27.27	Meander	22.43	0.028	0.052	1.39
68	A	25 year	in channel	0.92	0.33	11.26	Meander	12.29	0.015	0.028	0.70
51	A	50 year	in channel	1.27	0.48	32.03	Meander	25.14	0.031	0.057	1.27
45	A	50 year	in channel	1.18	0.58	28.53	Meander	24.24	0.030	0.049	1.02
20	A	50 year	in channel	1.03	0.48	18.48	Meander	17.92	0.022	0.036	0.66
11	A	100 year	in channel	1.94	1	132.22	Braided / Meander	68.16	0.084	0.143	0.90
5	A	100 year	in channel	2.02	1.01	143.91	Braided / Meander	71.19	0.088	0.156	0.00

3.2.4 Erosion Threshold Analysis

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport channel bed and/or bank materials and, in turn, inform erosion reduction strategies and flow management plans.

Erosion thresholds are typically defined for the most sensitive reach within the zone of influence from the SWM facility. Quantification of an erosion threshold considers material type and characteristics of both bed and bank materials; the cross-sectional configuration determines the distribution of flow and is therefore considered in the calculation of the thresholds value.

The permissible shear stress necessary to entrain, and permissible velocity necessary to transport, sediment was determined with reference to established tables and charts. As the dominant channel process within the system has been identified as downcutting and incision, the underlying clay materials, in which the channel has already eroded into, was determined as the target of the erosion threshold analyses. The substrate gradation of the alluvial cover on the clay was also considered in the calculation since maintaining alluvial cover protects the underlying clay from mobilization.

The critical shear of the gravel bed materials measured in the channel was defined as 12.15 N/m^2 for the D50, and 20.25 N/m^2 for the D84 (**Table 3-4**) based on consideration of overloose boundary condition for alluvial substrate. The critical shear values correspond to the lower limit of coarse gravel, as demonstrated in **Table 3-6**. Based on the critical shear stress analysis for the gravel bed materials within the watercourse, the associated critical discharge was 0.03 and 0.11 m^3/s for the D50 and D84 scenarios, respectively. Although this scenario satisfies the critical shear conditions, it does not consider the velocity required for active sediment transport.

As the channel is primarily clay-bedded, the standard critical shear stress and permissible velocity values for clay materials were also consulted in reference to standard tables and charts. The permissible shear stress for clay materials (**Table 3-6**) correspond to the upper and lower limits of the D50 and D84 substrate gradation within the Reach 1 watercourse. Based on the reference values for clay materials, a conservative critical velocity value of 0.92 m/s was identified (i.e., as per Fischenich (2001). The critical discharge that would satisfy both the critical shear stress and permissible velocity condition of the exposed/underlying clay was determined through an iterative analysis approach, resulting in a minimum critical discharge rate of 0.27 m^3/s (**Table 3-5**).

Table 3-4. Critical Shear Stress Conditions and Corresponding Critical Discharge.

	D50	D84
Grain Size (m)	0.015	0.025
Critical Shear Stress (N/m^2)	12.15	20.25
Maximum Depth (to attain critical shear) (m)	0.13	0.22
Average Discharge (m^3/s)	0.03	0.11
Minimum Discharge (m^3/s)	0.02	0.08
Average Velocity (m/s)	0.41	0.61
Unit Stream Power (W/m^2)	2.23	6.04
Entrainable Grain Size (m)	0.01	0.03

Table 3-5. Permissible Velocity Conditions and Corresponding Critical Discharge.

Parameter	Value
Velocity (m/s)	0.92
Average Discharge (m^3/s)	0.36
Minimum Discharge(m^3/s)	0.27
Maximum Shear (N/m^2)	38.21
Unit Stream Power (W/m^2)	17.56
Entrainable Grain Size (m)	0.05

Table 3-6. Critical Shear Stress and Permissible Velocity Values Based on Soil Type.

Source	Soils	Permissible Shear		Permissible Velocity	
		Minimum	Maximum	Minimum	Maximum
Fischenich (2001)	Stiff clay	12.45		0.92	1.37
	Gravel/cobble (0.025)	15.80		0.76	1.53
MNR (2002)	Firm clay	3.59	7.18	0.76	1.07
	Stiff clay	12.45	22.02	1.14	1.53
	Coarse gravel	14.36	32.08	1.22	1.83
Chow (1959)	Stiff clay	12.45	22.02	1.14	1.52
	Coarse gravel	14.36	32.08	1.22	1.83

3.2.5 Geomorphic Processes

Geomorphic understanding of the watercourse through the study area was gained through completing a review of background documents, a field investigation, and data analyses. A summary of geomorphic processes that affect channel stability and erosion is provided in this section.

The historical changes within the watercourse, which indicates channel incision over time, suggests adjustment has previously occurred within the watercourse, and based on observations from field investigations and analyses, is still ongoing within the system.

The profile of all watercourses tends to exhibit a concave up configuration and is adjusted (or works to adjust) to a downstream base level control point. Base level control points are elevation points along the channel, and typically occur at the mouth of the watercourse. The elevation of this point either does not change, or changes very gradually (e.g., lower lake levels over time). In the study area, the presence of knickpoints along the bed profile (Reach 1 and 2) suggest channel adjustment to a base level control point (i.e., tributary confluence at downstream limit of study area).

Review of the potential channel capacity through the study area indicates that the estimated bankfull flows, as well as the larger range of flows, are largely contained within the channel cross-section in Reach 1 and 3, while flows readily overtop the banks in Reach 2 and spread into the wetland feature that coincides with this reach.

An increase in flow volume and frequency will elicit a channel response. In general, there is a lag time between onset of change and initiation of channel response. The amount of time required for the channel to adjust to a change in flow regime is a function of boundary materials, magnitude and timing of change, and pre-existing stability of the channel. As a generalization, channels situated within sandy materials may take up to 25 years to adjust to watershed urbanization; whereas channels with cohesive clay boundaries may take 50 years to adjust to watershed urbanization (Aquafor, 2011). The watercourse demonstrates evidence of channel response, through incision, bank erosion, and planform development; however, as the channel has yet to reach a state of equilibrium, further response is anticipated. The watercourse is considered to be sensitive to receiving additional flows.

Erosion threshold analysis were completed for the sensitive portion of the watercourse (Reach 1) by identifying the critical shear and permissible velocity required to entrain and transport alluvial sediment within the channel or the exposed/underlying clay, in consultation to previously established standards. Based on these analyses, the critical discharge of clay is estimated to be approximately 0.27 m^3/s; movement of the alluvial cover occurs during lower flows.

3.3 Drainage Patterns

The study area is located within the Fairchild Creek subwatershed which is a tributary to the Grand River. The existing and future drainage patterns within the study area are outlined below.

3.3.1 Existing Drainage Pattern

The study area contains industrial development and open lands that have generally been cleared of forested areas. Existing storm drainage infrastructure is comprised of ditches, storm sewers, and culverts.

Drainage patterns within the study area were determined using topographic data from the Ministry of Natural Resources and Forestry (MNRF) LiDAR Digital Terrain Model (2016-2018). Additional on-site reconnaissance was completed by ERI staff to confirm drainage conditions. The drainage catchments were delineated and named in **Figure 3** and **Figure 4** in **Appendix A** in a manner which was consistent with that depicted in the Kylin Developments Report (2017) where possible.

Drainage is generally directed from west to the east towards the existing Braneida SWMF. Stormwater from the existing catchments is collected into two main branches of the stormwater conveyance channel, which confluences just west of Adams Boulevard and drains into the Braneida SWMF. Under existing conditions, the northwest corner of the study area (catchment 104) drains into a tributary north of the study area and is not treated by the Braneida SWMF.

Stormwater from the Lowes and Brantford Power Center are attenuated on-site, as described in **Section 1.1**. **Figure 3** illustrates the existing minor system catchments, and **Figure 4** illustrates the existing major system catchments within the study area; both figures are found within **Appendix A**.

The existing system catchment properties for both major and minor flows are outlined in **Table 3-7.**

Table 3-7. Existing Conditions Catchment Areas and Imperviousness (Major and Minor Flows)

Catchment	Area (ha)	Imperviousness (%)
Braneida SWMF 'Uncontrolled' Catchments		
101 – 103, 140 - 152	126.4	64.7
On-Site Controls (Lowes and Brantford Power Center)		
1001 - 1003	12.4	90.1

3.3.2 Future Drainage Pattern

The remaining open space areas are designated for future industrial development. Development approval has been issued for the proposed Kylin Development of these lands, refer to **Section 2** for details. The Kylin Development proposed stormwater management strategy includes on-site controls and a stormwater management facility (Kylin SWMF).

Under future proposed conditions, an additional SWMF would be constructed (catchment 318) within the study area, where the newly developed areas would drain to and be treated prior to draining to the Braneida SWMF.

The future conditions increase the impervious land areas in developed catchments, as well as provide an increase in the total catchment area due to the inclusion of previously external catchment areas (catchments 302 through 304, previously catchment 104 under existing conditions). **Figure 5** illustrates the future minor system catchments and **Figure 6** illustrates the future major system catchments within the study area. These figures are found in **Appendix A**.

The future system catchment properties for both major and minor flows are outlined in **Table 3-8**. The catchment areas which drain towards the Kylin SWMF before being conveyed to the Braneida SWMF and the catchments which drain directly towards the Braneida SWMF have been shown separately.

Table 3-8. Future Conditions Catchment Areas and Imperviousness (Major and Minor Flows)

Catchment	Area (ha)	Imperviousness (%)
Kylin SWMF		
301 - 332	74.4	91.5
Braneida SWMF		
140-152, 346	70.6	70.0
Braneida SWMF (Total)		
140-152, 301 – 332, 346	145	81.0
On-Site Controls (Lowes and Brantford Power Center)		
1001 - 1003	12.4	90.1

Best Management Practices (BPMs) were proposed on each development block within the Kylin SWMF catchment to achieve a maximum allowable release rate of 0.13 $m^3/s/ha$.

3.4 Hydrologic Conditions

3.4.1 Hydrologic Model Selection

To provide a design context for the proposed rehabilitation and enhancements to the Braneida SWMF, a hydraulic model was built using Visual OTTHYMO (VO). VO is an industry accepted single event hydrologic model used to simulate hydrographs by modelling rainfall, infiltration, runoff and conveyance routing through a watershed. As previously noted, the existing Braneida SWMF is situated downstream and in series with the Kylin development SWMF. A Visual OTTHYMO (VO) model has been developed for the proposed Kylin development SWM report (225 Henry Street Industrial Development, exp, September 2018) and has been used to inform the ERI VO model developed for the Braneida catchment area. The Braneida and Kylin catchment areas have been verified and expanded to incorporate all catchments which ultimately direct drainage to the Braneida SWMF.

3.4.2 Design Storm Selection

The City of Brantford Intensity-Duration-Frequency (IDF) values are outlined in **Table 3-9** and were used for storm flow analysis. IDF rainfall data was used to generate 4-hour Chicago design storm distributions for the 2, 5, 10, 25, 50 and 100-year return period design storm events. The 25 mm - 4-hour design storm was added to the analysis and the Regulatory storm event was represented by Hurricane Hazel.

Table 3-9. Chicago Storm Properties

Storm Return Period	IDF Chicago Parameter		
	A	B	C
2-year	743	6.0	0.7989
5-year	1593	11.0	0.8789
10-year	2221	12.0	0.9080
25-year	3158	15.0	0.9355
50-year	3886	16.0	0.9495
100-year	4688	17.0	0.9624

3.4.3 Soils

Information on the underlying soils can be found in **Section 3.7**. Soils were observed to be predominately silty-clay and clayey-silt with occasional seams of sand and silt. Based on the information provided in the Pinchin and Exp geotechnical and hydrogeological reports, ERI has established a CN value of 74 for the undeveloped catchment areas. CN value of 74 represents silty clay as the predominant soil type with seams of interbedded with silt and sandy seams, and a ground cover of pasture for undeveloped areas.

3.4.4 Predevelopment Conditions (Greenfield)

A predevelopment VO model has been developed to determine flows generated under 'greenfield' conditions. Greenfield conditions reflect the historical land use before any development has occurred. These conditions can be described as each catchment having good condition pasture cover over C type soils with a CN value of 74.

The historical conditions VO model was informed by the Phillips catchment extents (101 - 108) as verified. **Table 3-10** provides a summary of the catchment Nashyd command inputs for the pre-development conditions. The VO model schematic and catchment extents can be found within **Appendix D**.

Table 3-10. Pre-Development – Nashyd Input

Catchment Number	Area	IA	TP	CN	SMIN
	(ha)	(mm)	(hrs)		
101	9.5	3	0.4	74	3
102	14.0	3	0.5	74	2
103	6.0	3	0.4	74	3
104	16.4	3	0.4	74	3
105	37.2	3	0.7	74	0.8
106	8.4	3	0.3	74	1
107	25.2	3	0.7	74	0.7
108	22.6	3	0.6	74	0.9

Table 3-11. Pre-Development Flow Rates at Braneida SWMF Inlet Location

Design Storm	Predevelopment Flow Rate (m^3/s) Inlet Location of Existing SWMF	
	Phillips 1990 Existing	ERI State of Nature
25mm-4hr	-	0.53
2	1.56	1.51
5	2.66	3.12
10	3.83	4.47
25	5.05	6.38
50	7.03	8.04
100	7.65	9.82
Hazel	15.60	14.22

Differences between the 1990 Phillips model and the ERI VO model approach are noted and explained below:

Channel Routing

The channel characteristics for routing runoff from upstream catchment areas has been adjusted to correspond with field measured cross-sections and satellite-measured flow lengths, as summarized in **Table 3-12**.

Table 3-12. Predevelopment Drainage Channel Routing Characteristics

Routed Channel Characteristics			
VO Channel ID	Upstream Connection	Channel Length (m)	Channel Slope (%)
46	NasHyd 108	800	0.7
47	AddHyd: 16	540	1.3
48	NasHyd 107	335	0.9
49	AddHyd: 13	380	1.1
50	AddHyd: 10	270	1.0

SCS Curve Numbers

CN values for undeveloped lands were updated from 71 (used within the Kylin VO model) to 74. Geotechnical background review and analysis summarized in **Section 3.7** demonstrates that the underlying soils predominately consist of tightly packed silt and clay with occasional sandy or silty seams, which is generally reflective of a C type soil with a CN value of 74 for good condition grass and pasture cover. A CN value of 71 is more reflective of BC soils predominately consisting of medium textured loam (MTO Drainage Management Manual), which were not seen through any geotechnical background reviewed by ERI.

3.4.4.1 Existing Conditions

An existing conditions VO model has been developed to determine flows generated under conditions which reflect the current day land use at the time that this report is published. The existing conditions VO model was informed by the proposed Kylin development VO model schematic (exp, September 2018) as verified and updated, where applicable.

Differences between the Kylin development VO model and the ERI VO model are noted and explained below:

SCS Curve Numbers

Same changes were applied as described above in **Section 3.4.4**.

Catchment Areas

Catchment areas 141 through 154 were added to the model to reflect areas outside of the Kylin SWMF catchment area which will drain to the Braneida SWMF, as shown on **Figures 3 – 6** in **Appendix A**.

Channel Routing

Flows generated by catchment areas downstream of the Kylin SWMF location and outside of the Kylin SWMF catchment area are conveyed to the Braneida SWMF by drainage channels which were surveyed by ERI in summer 2019. These channels were added to the VO model and used to route the flows as they were conveyed to the Braneida SWMF with the characteristics shown in **Table 3-12**.

Table 3-13. Existing Conditions Drainage Channel Routing Characteristics

Routed Channel Characteristics			
VO Channel ID	**Upstream Connection**	**Channel Length (m)**	**Channel Slope (%)**
30	NasHyd: 101	250	0.2
31	AddHyd: 201	250	0.2
32	AddHyd: 558	600	0.2
33	AddHyd: 552	80	0.2
34	AddHyd: 550	500	0.2
35	AddHyd: 2002	500	0.2
36	AddHyd: 554	140	1.0

Initial Abstraction (IA)

Initial abstraction values for any impervious areas were raised to 2 mm (MOE SWMP-DM, 2003).

Time to Peak (TP)

Time to peak for catchments within the Kylin SWMF were set to a default value recommended in VO of 0.2. The time to peak values applied in the ERI model for catchments outside of the Kylin development were individually derived using the average of the SCS, Airport and Uplands methods for calculating time of concentration and time to peak.

Existing Condition and Designed Condition Rating Curves

During the field inspection carried out by ERI staff, the outlets of the Braneida SWMF were found to be clogged with woody debris and sediment. This resulted in the weir outlet acting as the primary flow control for the SWMF, which eliminated the active storage volume of 13,700 m^3 which should have been in place according to the Phillips design report. The loss of this active storage volume resulted in much higher flows leaving the facility throughout the different design storms in the existing condition scenario. The rating curves used in the model for the designed SWM pond function and actual SWM pond function can be seen below in **Table 3-14**.

Table 3-15 and **Table 3-16** provide summaries of the catchment NasHyd and StandHyd command inputs for the existing conditions, respectively. VO model schematic and catchment extents can be found within **Appendix E**.

Table 3-14. Design vs Actual Rating Curve for Existing Conditions Braneida SWMF

Phillips Design		Existing Condition (Clogged Outlet Orifice)	
Storage (ha*m)	Discharge (m³/s)	Storage (ha*m)	Discharge (m³/s)
0	0	0	0
1.37	0.14	0.61	0.72
1.98	0.89	1.64	3.15
3.01	3.36	2.70	6.52
4.07	6.76	3.18	8.33
4.55	8.36	3.73	17.07
5.10	17.07	-	-

Table 3-15. Existing Conditions – Nashyd Input

Catchment Number	Area (ha)	IA (mm)	TP (hrs)	CN
102	7.82	5	0.4	74
103	8.44	5	0.4	74
104	16.77	5	0.2	74
105	0.97	5	0.2	74
1420	5.3	5	0.2	74
154	7.12	5	0.2	74

Table 3-16. Existing Conditions – StandHyd Input

Catchment Number	Area	XIMP	TIMP	C	Pervious				Impervious			
					IA	Slope	Length	Manning's n	IA	Slope	Length	Manning's n
	(ha)	(%)	(%)		(mm)	(%)	(m)		(mm)	(%)	(m)	
1001	0.99	0.5	0.5	0.55	5	2.0	40	0.25	2	1.0	40	0.015
1002	5.94	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
1003	5.69	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
140	3.1	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
141	0.5	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
142	8.5	0.40	0.40	0.54	5	2.0	40	0.25	2	1.0	40	0.015
143	6.3	0.50	0.50	0.60	5	2.0	40	0.25	2	1.0	40	0.015
144	9.9	0.60	0.60	0.66	5	2.0	40	0.25	2	1.0	40	0.015
145	12.7	0.90	0.90	0.84	5	2.0	40	0.25	2	1.0	40	0.015
146	9.5	0.90	0.90	0.84	5	2.0	40	0.25	2	1.0	40	0.015
147	2.3	0.80	0.80	0.78	5	2.0	40	0.25	2	1.0	40	0.015
148	1.7	0.90	0.90	0.89	5	2.0	40	0.25	2	1.0	40	0.015
149	0.9	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
150	3.2	0.80	0.80	0.80	5	2.0	40	0.25	2	1.0	40	0.015
151	9.4	0.66	0.65	0.70	5	2.0	40	0.25	2	1.0	40	0.015
152	2.2	0.80	0.80	0.30	5	2.0	40	0.25	2	1.0	40	0.015
153	9.1	0.80	0.80	0.80	5	2.0	40	0.25	2	1.0	40	0.015
154	7.1	0.93	0.93	0.30	5	2.0	40	0.25	2	1.0	40	0.015

Existing stormwater management controls are incorporated on three properties: Lowes (catchment 1002), the area west of Lowes (catchment 1001) and the Brantford Power Center (catchment 1003). Stormwater management for these properties is in the form of rating curves integrated within the VO model.

Table 3-17 outlines the existing SWM properties and their respective rating curves.

Table 3-17. Existing Stormwater Management

Catchments 1001, 1002		Catchment 1003	
Storage (ha*m)	Discharge (m^3/s)	Storage (ha*m)	Discharge (m^3/s)
0	0	0	0
0.250	0.813	0.083	0.157

As described above, two existing conditions cases have been modelled and reviewed as a part of this analysis: the actual condition of the SWMF and the designed condition of the SWMF. The results of those models are summarized in **Table 3-18**.

Table 3-18. Existing Condition Flow Rates at SWMF Outlet

Design Storm	Existing Conditions Flow Rate (m^3/s)	
	Outlet of Existing SWMF	
	Phillips Designed ERI Model	Clogged Orifice/Actual ERI Model
25 mm - 4 hr	0.597	1.515
2	1.561	2.722
5	2.991	4.543
10	4.215	5.857
25	5.925	7.739
50	7.324	10.784
100	9.625	14.095
Hazel	15.049	15.113

The loss of extended detention storage is evident in the outflow quantities, with the actual existing condition having 25 mm – 4-hour event flows approximately the same as the designed condition 2-year flows. This means that as the facility is functioning today, flows are an average of 63% higher than how the facility was designed to function in the original Phillips design report.

3.4.4.2 Ultimate Development Scenario

An ultimate development scenario VO model has been created to determine flows which reflect the catchment conditions after the Kylin SWMF has been constructed, the Kylin catchment has been built out completely and the Braneida SWMF has had the preferred alterative retrofit works completed. The ultimate development scenario VO model was informed by the proposed Kylin development VO model schematic (exp, September 2018) as verified and updated, where applicable.

Differences between the Kylin development VO model and the ERI VO model are noted and explained below:

SCS Curve Numbers

Same changes were applied as described above in **Section 3.4.4**.

Catchment Areas

Catchment areas 303 through 332 upstream of the Kylin SWMF and catchment areas 141 through 154 were added to the model as shown on **Figures 5 – 6** in **Appendix A**.

Channel Routing

Flows generated by catchment areas downstream of the Kylin SWMF and outside of the Kylin SWMF catchment area are conveyed to the Braneida SWMF by drainage channels which were surveyed by ERI in summer 2019. These channels were added to the VO model and used to route the flows as they were conveyed to the Braneida SWMF with the characteristics shown in **Table 3-19**.

Table 3-19. Ultimate Conditions Drainage Channel Routing Characteristics

Routed Channel Characteristics			
VO Channel ID	**Upstream Connection**	**Channel Length (m)**	**Channel Slope (%)**
31	RouteReservoir: 413	250	0.2
32	AddHyd: 550	600	0.2
33	AddHyd: 552	100	0.2
36	AddHyd: 554	140	1.0
701	DuHyd: 605	200	0.05
702	AddHyd: 535	100	0.05

Initial Abstraction (IA)

Initial abstraction values for any impervious areas were raised to 2 mm (MOE SWMP-DM, 2003).

Time to Peak (TP)

Time to peak for catchments within the Kylin SWMF were set to a default value recommended in VO of 0.2. The time to peak values applied in the ERI model for catchments outside of the Kylin development were individually derived using the average of the SCS, Airport and Uplands methods for calculating time of concentration and time to peak.

3.5 Hydraulic Conditions

3.5.1 Model Development

The tributary which flows through the Braneida SWM Pond and joins the Garden Avenue tributary will be referred to as the Braneida Tributary for this study. The reach that was included in the study stretched from the channel upstream of the Adams Boulevard culvert for approximately 765 m downstream to the confluence between the Braneida tributary and the Garden Avenue tributary to Fairchild Creek.

A detailed survey was completed by ERI field staff complete with both profiles and cross sections of the Braneida Tributary. Field staff were also able to capture details for the existing outlet of the SWMF culvert(s) and weir controls which was built into the HEC-RAS model.

LiDAR data from the MNRF Digital Terrain Model (2016-2018) was integrated with the HEC-RAS model to fill in any gaps not captured by the field survey.

3.5.2 Flow Data

Flow data was derived through the development of hydrologic models described in **Section 6.1.4.**

3.5.3 Boundary Conditions

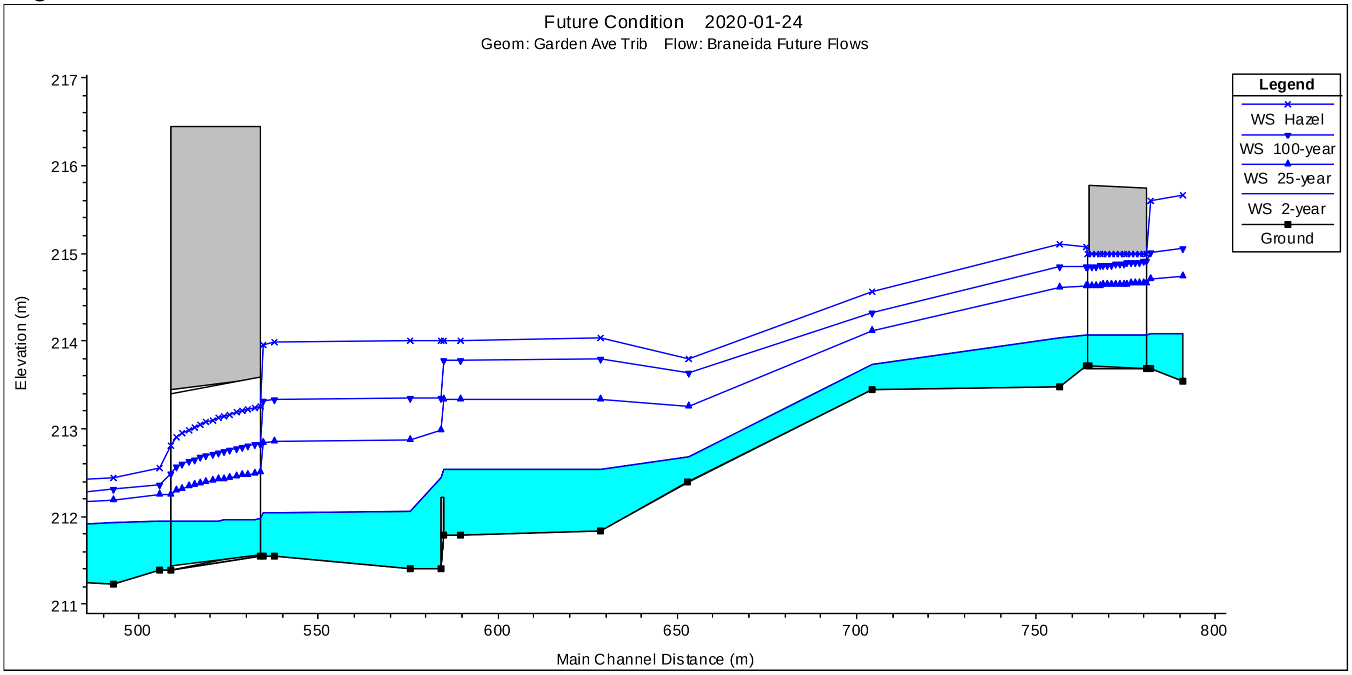
Boundary conditions for the reach of the Braneida Tributary connecting to Fairchild Creek were set as:

- tailwater depth at low flow bank elevation for the 2-year flow,
- normal depth with a channel slope of 0.5% for:
  - the 5-year to the Regulatory flows of the downstream boundary, and;
  - each flow scenario of the upstream boundary.

The GRCA Fairchild Creek HEC-RAS model was reviewed to help establish tailwater conditions for the ERI constructed Braneida Tributary model. The most upstream reach of the Fairchild Creek model ends just upstream of the Garden Avenue culvert crossing, which is still approximately 540 m downstream of the downstream end of the Braneida Tributary HEC-RAS model created for the Creek rehabilitation design. The most upstream reach of the Fairchild Creek is too far from the study area to reasonably use to set the downstream boundary conditions. The GRCA Fairchild Creek model was used as a relative check to confirm that using the bank-full water elevation during the 2-year and the normal depth for the 5 through 100-year and Hurricane Hazel flows was a reasonable approach.

Figure 3.7. HEC-RAS Model Geometry with Lidar Integration – Braneida Tributary

Figure 3.8. HEC-RAS Model Profile – Adams Boulevard to Culverts Downstream of SWMF



3.5.4 Cross-Sections

Cross section locations were determined by ERI's field staff in consultation with senior design staff to be spaced to represent control structures, obstructions, flood storage and geomorphic relevant features of the reach of the Braneida Tributary. Control structures and obstructions were captured with cross-sections taken immediately upstream and downstream.

3.5.5 Lidar and Survey Integration

The LiDAR data proved to be a valuable tool in calibrating and extending the reach and overbank information within the study area. The LiDAR data was also used to confirm the surveyed characteristics of the reach.

In areas where the LiDAR information and surveyed data were found to be notably different, the surveyed elevations were given preference. The surveyed top of bank elevation would frequently be between 0.20 and 0.50 m higher than the LiDAR top of bank and the overbanks from the LiDAR extended further than the overbanks of the surveyed cross-section. In these cases the overbanks of the Lidar would be adjusted to match the surveyed top of bank; i.e. if the left bank was surveyed at 0.20 m higher than the LiDAR top of bank, that whole left bank of LiDAR elevation points would be shifted 0.20 m higher for the model cross-section. This allowed the model to capture a full cross-section width to store higher flow scenarios in the floodplain.

The tie-in points for the surveyed data were MH10A and MH11A as identified on the as-constructed Plan and Profile drawing of Adams Boulevard (Philips Planning and Engineering, 1990). The as-constructed top of MH was very close to the same elevation for MH11A when compared to the surveyed value, but the surveyed value for MH10A was 0.14 m lower than the as-constructed elevation.

The Lidar measured elevations for MH10A and MH11A were both 0.40 m higher than the surveyed elevations.

The elevation differences measured for MH10A and MH11A are summarized below:

Table 3-20. Comparison of Lidar and Surveyed Elevations

Name	GIS ID	As-built Z	Lidar Z	Trimble GPS Survey Z	Trimble Vertical Precision
MH 10A	2	216.481	215.94	216.337	0.02524
MH 11A	3	215.702	215.29	215.697	0.02235

3.5.6 Hydraulics Results

Once the hydraulic results tables were printed, they were shared with the geomorphic team members within ERI and used to complete geomorphic analysis found in **Section 3.2.2**.

3.6 Natural Environment

A complete Environmental Impact Study (EIS) can be found in **Appendix F**.

The subject lands are approximately 20 ha in size and are bounded to the west by Adam’s Boulevard, to the north by Highway 403, to the northeast by Abbott Court and to the south by several industrial buildings. The study area is located entirely within the Grand River Conservation Authority regulation limits.

Detailed field investigations were completed during the spring, summer, and fall of 2019 and 2020 for the subject lands and surrounding 120 m study area buffer. These investigations identified the existing natural heritage, aquatic and terrestrial habitat features present within the study area. Field surveys were conducted during the appropriate field seasons to confirm relevant habitat features and species presence. Incidental wildlife observations were collected during all site visits.

A desktop natural heritage review was completed prior completing field investigations to understand the general wildlife conditions and potential for Species at Risk (SAR) to occur within the study area. Sources reviewed included:

- Natural Heritage Information Centre (NHIC);
- Grand River Conservation Authority mapping and data;
- Land Information Ontario open data (MNRF, 2020);
- DFO’s Aquatic Species at Risk Mapping (2019);
- Municipal Official Plans;
- Ontario Breeding Bird Atlas (OBBA; Birds Canada et al., 2020);
- Ontario Butterfly Atlas (Toronto Entomologists’ Association, 2020);
- Ontario Herpetofaunal Atlas (Ontario Nature, 2019);
- Ontario Mammal Atlas (Dobbyn, 1994);
- eBird (the Cornell lab of Ornithology, 2020); and
- iNaturalist (California Academy of Sciences and National Geographic, 2020).

3.6.1 Aquatic Habitat

A detailed aquatic habitat assessment was conducted on Reaches 1 - 5 of the Garden Avenue tributary to characterize aquatic features in the study area. The following information was documented during the aquatic habitat assessment:

- Substrate type and composition
- Riparian and aquatic vegetation
- Potential fish habitat or presence of fish
- Water temperature
- Flow conditions
- Adjacent lands (vegetation community type, riparian habitat, canopy cover, land use, etc.)
- Channel morphology

- Instream habitat and cover

The five aquatic habitat assessment reaches were identified and assessed on August 14, 2020. The existing condition of this tributary varied across the reaches, but common traits of the channel include large evidence of downcutting, near vertical creek banks, large areas of erosion, low water levels, and low flow velocities and heavily vegetated top of banks. Minnows were also observed in most reaches.

Reaches 1, 4, and 5 were very uniform to each other. These reaches were relatively natural in form and function and were generally a meandering tributary with high vertical banks, narrow channel, large areas of erosion, low wetted widths, and water depth and substrates which varied between hard pan clay, sand, and gravel. As the assessment was completed during low flow conditions, portions of the channel were dry, and smaller pools of stagnant water exist, but throughout the majority of the channel low water levels of low flow velocities exist. Little instream vegetation was present within the channel, and top of bank vegetation did provide minor shading to the channel. Historical alteration to the channel as part of previous restoration efforts existed in the form of occasional riffle and pool features, which were stable. Multiple pedestrian walking bridges are also present within these reaches. Meadow and thicket vegetation communities surround the tributary within these reaches.

Reach 2 is a unique aquatic habitat assessment reach compared to the others as it is functioning more as a wetland feature with the main flow path meandering through the middle of the wetland. Water velocities within this reach were low, and sometime stagnant within the wetland. The surrounding vegetation communities are a cattail marsh and a phragmites dominated marsh. Recent disturbance to the cattail marsh by heavy equipment has removed most of the cattail vegetation and altered the substrate and flow path of the watercourse. Large areas of pooled water exist and water meanders through the low-lying areas of the wetland to connect to the downstream channel. Typically, dense emergent vegetation would be present, but due to disturbance, was not what would be typically be found within this community. Within the phragmites wetland the channel formed a small, narrow channel with low banks that are relatively stable, with only minor areas of erosion. Water velocities are low in the channel and water was flowing clear at the time of assessment. Occasional minnows were observed. The emergent vegetation provided strong shading to the creek.

Reach 3 originates at a concrete box culvert and flows east under Adams Boulevard down a cable concrete channel, which is overgrown with root systems from surrounding thicket habitat, which narrows the flow path of the channel. After this the channel widens near the SWMF and high evidence of deposition is present with deep, easily disturbed sediment. The water is slowed by a concrete weir, which acts as a barrier to fish movement. This portion of the tributary is heavily shaded by thicket and forest habitat on the edge of the banks. Emergent vegetation of cattail and phragmites is also present. Downstream of the weir cable concrete again lines the channel, overlaid with a fine layer of sediment until the watercourse flows through two large, corrugated steel culverts and into Reach 2. Minnows were observed within Reach 3, but multiple fish passage barriers exist including the weir and the narrow width and steep grade of the cable concrete section of the channel.

In general, evidence of impacts from the surrounding industrial lands exists within the aquatic environment in the form of debris and garbage being present occasionally within the watercourse and present on its banks. Occasional use of this habitat by vehicles and machinery is also present for hydro related maintenance activities.

3.6.2 Terrestrial Habitat

Vegetation

Eight vegetation communities were delineated by ERI ecologists on June 24, June 30, and August 19. These included a dry-moist old field meadow (CUM1-1), mineral cultural thicket (CUT1), dry-moist old field meadow and mineral cultural thicket (CUM1-1/CUT1), narrow-leaved sedge graminoid meadow marsh (MAM2-5), mineral meadow marsh (MAM2), cattail mineral shallow marsh (MAS2-1), willow mineral thicket swamp (SWT2-2), and fresh-moist lowland deciduous forest (FOD7). A total of 116 species were observed within the study area during ERI field investigations. Of these, 65 were native and 51 were non-native species including six sensitive species and 5 regionally rare species. Overall, the Floristic Quality Index (FQI) value of the study area is 29.77 with a mean Coefficient of Conservatism (CC) value of 3.69. The relatively high FQI value is likely skewed by the few species with a high CC sensitivity ranking. The mean CC value suggests that most species observed are common of disturbed sites. Overall, 51% of the species observed had the lowest CC sensitivity ranking of 0-3, followed by 38% with a moderate CC sensitivity ranking of 4-6, 9% with a high sensitivity ranking of 7-8 and only 2% in the highest CC sensitivity ranking of 9-10. This suggests that the sites are dominated by common plant species of low sensitivities. A full list of species, detailed description of each community and representative photographs can be found in **Appendix F**.

Wildlife

Two breeding bird surveys were completed on May 22 and June 30, 2020 according to Ontario Breeding Bird Atlas protocols. In total, 45 bird species were observed. Two Species at Risk (barn swallow (*Hirundo rustica*) and bank swallow (*Riparia riparia*)) were observed foraging or flyovers and did not display any evidence of breeding withing the study area. See **Appendix F** for a full list of wildlife species within the study area.

Three reptiles and amphibians were observed by ERI during field investigations including green frog *(Lithobates clamitans*), northern leopard frog (*Lithobates pipiens*) and spring peeper (*Pseudacris crucifer*). Additionally, a predated turtle nest was observed on private property directly adjacent to the SWMF.

Four mammal species were observed as incidental observations during site visits including white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), coyote (*Canis latrans*), and northern racoon (*Procyon lotor).*

Species at Risk and Species of Conservation Concern

A habitat screening was completed to determine the potential occurrence of SAR within the study area. For this screening, SAR are defined as species that are listed as either Threatened (THR) or Endangered (END) under the Endangered Species Act (ESA). Individual species, as well as their habitat, are protected in Ontario. Species listed as Special Concern (SC) under the ESA receive protection under the Provincial Policy Statement (PPS) and their habitat is considered Significant Wildlife Habitat (SWH). Species listed under SARA are only protected on federal land, as part of projects that are otherwise being permitted by a federal agency. This includes aquatic SAR; however, no aquatic SAR have been identified within the study area, but NHIC mapping did identify greater redhorse (*Moxostoma valenciennesi*), which is defined as an S3 species within the vicinity of the study area. SARA also requires consideration for any migratory bird listed on Schedule 1 where critical habitat has been identified; however, should the species also be listed under ESA and provides equal or greater protection, the ESA take precedence.

20 SAR were identified as potentially occurring within the study area during the background review. This number was refined based on habitat assessments, targeted wildlife surveys, and ELC surveys. This resulted in three confirmed species within the study area and one species with candidate habitat within the study area, these species are presented below. The full screening can be found in **Appendix F**.

Confirmed SAR

Barn Swallow (THR) – Barn swallow is listed as Threatened provincially and federally. It is typically found within close proximity to humans, buildings, building cup-shaped mud nests also most exclusively on human made structures such as culverts, under bridges and in barns. They prefer unpainted, rough-cut wood, as opposed to smooth surfaces. Construction activities may be subject to the MBCA (CWS, 2013), though it is not anticipated that human made structures will be affected by the proposed works.

Bank Swallow (THR) – Bank swallow is listed as Threatened both provincially and federally. Bank swallows form burrows in the side of vertical faces such as cliffs, riverbanks, road cuts or soil stockpiles. Breeding sites are typically formed close to aerial foraging areas such as grasslands, meadows, pastures, and cropland. The study area contains suitable meadow habitat, and one individual was observed flying overhead during a breeding bird survey.

Monarch (SC) – Species can typically be found in open or disturbed habitats such as roadsides, fields, wetlands, prairies, and open forests with the presence of an abundance of milkweed. Any recommended planting lists will include milkweed species.

Candidate SAR

Snapping Turtle (SC) – Snapping turtle is listed as Special Concern provincially and federally. They are found in a variety of habitats like shallow wetlands, slow moving water, ponds, river edges and slow streams. The study area contains suitable habitat for snapping turtle, but no overwintering habitat.

3.6.3 Summary and Recommendations

The existing natural environment and its features should be considered as part of the restoration design. Avoidance of any sensitive species and the previously outlined SAR found during field surveys must be undertaken. Proper contractor practice, implementing erosion and sediment controls, following provincial guideline and policy for wildlife protection, and having a wildlife management protocol are an important feature of the construction and restoration effort.

Regionally Rare Species – Consideration should be given to the relocation of locally rare vegetation where feasible, or the inclusion of the species into proposed seed mixes. Five locally rare vegetation species were recorded within the study area and should be avoided where possible. These include meadow horsetail (*Equisetum pratense*), marsh horsetail (*Equisetum palustre*), tamarack (*Larix laricina*), poke milkweed (*Asclepias exaltata*), and pearly everlasting (*Anaphalis margariacea*).

Restoration & Invasive Species Management - An opportunity exists within the study area limits to improve the overall native species composition through the removal of invasive and non-native species and replacement with native tree, shrubs, and herbaceous species along Garden Avenue Tributary. There is also an opportunity to create additional fish habitat and increase fish passage through the removal of barriers to fish movement and have the SWMF as an open water feature. The intent of restoration is not to create habitat for wildlife and fish species within the SWMF, but a large open water feature will likely be used by amphibians, reptiles, fish, and bird species.

3.7 Geotechnical / Soils

3.7.1 Grand River Conservation Authority (GRCA) Grand River Information Network (GRIN) Mapping

GRCA GRIN online GIS mapping identifies the underlying soils in the catchment area as predominantly clay with some sandy areas downstream of the SWMF surrounding the Creek. The figure titled 'Braneida GRCA Soils' in **Appendix G** illustrates the GRCA GRIN Mapping results.

3.7.2 2019 Pinchin Geotechnical Investigation

ERI retained Pinchin Ltd. (Pinchin) to complete a geotechnical investigation in the areas of the Braneida Park SWMF. The geotechnical investigation was published in July 2019 and can be found in **Appendix G** of this report. Pinchin's geotechnical work comprised of four boreholes and four test pits within the SWMF property limits and two boreholes were utilized as monitoring wells following their drilling.

Test pits were excavated to a depth of 3.0 m below ground surface (mbgs), and the soil stratigraphy was generally consistent with what was observed in the boreholes with variable thickness of topsoil, underlain by native silt to the maximum test pit depth.

Table 3-21. Test Pit Observation Summary from 2019 Pinchin Geotechnical Investigation

Test Pit No.	Topsoil Thickness (mm)	Notes
TP1	500	- No groundwater observed during and upon completion of test pit excavation - Test pit caved to 2.1 mbgs approximately 140 minutes after completion of excavation and no groundwater was observed at that time
TP2	700	- No groundwater observed during and upon completion of test pit excavation - Surface water infiltration as observed approximately 75 minutes after completion of excavation, with 200 mm of water measured at the base of the excavation. The west side wall was beginning to cave at that time - The test pit caved to 1.9 mbgs approximately 85 minutes after completion of excavation - 50 to 100 mm of water was measured at the base of the excavation approximately 130 minutes after completion of excavation
TP3	400	- The ground surface between TP2 and TP3 was saturated and soft - No groundwater observed during and upon completion of test pit excavation - No groundwater infiltration observed approximately 60 minutes after completion of excavation - Surface water infiltration was observed approximately 120 minutes after completion of excavation, with 50 to 100 mm of water measured at the base of the excavation. The side walls were beginning to cave at this time.
TP4	400	- No groundwater observed during and upon completion of test pit excavation - Infiltration of water from wet seams at approximately 1.8 mbgs to 3.0 mbgs was observed approximately 55 minutes after completion of excavation, with 50 to 100 mm of water measured at the base of the excavation. - No additional water measured at the vase of the excavation approximately 115 minutes after completion of excavation.

Monitoring wells were installed, and groundwater levels were measured during drilling in May 2019. Pinchin observed that the groundwater is perched above the relatively impermeable silt deposits, with both monitoring wells observing water levels above grade. While this groundwater is perched, the Pinchin report states that the groundwater inflow can be controlled using a gravity dewatering system and it is not expected that dewatering volumes will trigger an EASR or PTTW. Observed groundwater conditions in the two monitoring wells are summarized below in **Table 3-22**.

Table 3-22. Groundwater Conditions Observed During 2019 Pinchin Geotechnical Investigation

Borehole No.	Date	Water Elevation (masl)
BH2	May 10, 2019	213.99
BH4	May 10, 2019	213.31

Based on the results of Pinchin's geotechnical investigation soil conditions in the SWMF area of the site can be generally described as clayey silt with trace to some sand. At the time of drilling completion, the groundwater was perched above a relatively impermeable silt deposit and in the saturated seams within the silt deposits.

Infiltration rates of the underlying soils were lower than recommended for infiltration infrastructure by the Low Impact Development Stormwater Management Planning and Design Guide (CVC, 2010). Recommendation specifics for potential SWMF liner installations were detailed and will be referred to during final design of the preferred alternative.

3.7.3 Exp Reports

Geotechnical and hydrogeological investigations of the Brant Business Park were completed by Exp in August and April of 2018, respectively.

The geotechnical report consisted of analysis based on four boreholes located within the limits of the eventual SWMF location for the Kylin development. The predominant soil found on site was silty clay which was found at each borehole site in depths ranging from 0.3 to 4.1 m below grade.

The hydrogeological investigation involved drilling and installing nine monitoring wells spaced throughout the proposed development area. Hydraulic conductivity testing was completed in each of the nine monitoring wells and the soil formation screened was generally a mix of clayey silt to silty clay.

The hydrogeological report also referenced a past Exp geotechnical report (2017) and included a total of 22 boreholes placed throughout the development lands. These borehole logs were used to create cross-sections illustrating the soils encountered. These logs and cross-sections can be found in **Appendix G**. Generally, the logs and figures show interbedded soils consisting of clayey silt, sandy silt, silty sand, silt and silty clay. Each of the soils encountered was observed in a moist to saturated state.

3.8 Archaeology

A draft Stage 1 archaeological assessment has been conducted for the Braneida SWMF by Timmins Martelle Heritage Consultants, October 2019. The Stage 1 background study included a review of current land use, historic and modern maps, registered archaeological sites and previous archaeological studies, past settlement history for the area and a consideration of topographic and physiographic features, soils and drainage. According to the map-based review and background research, potential for the discovery of archaeological sites is indicated by the proximity (within 300 m) to:

- A watercourse (tributaries of Fairchild Creek);
- Previously identified archaeological sites (AgHb-229, AgHb-232, AgHb-234, AgHb-235 and AgHb-236); and
- The area is depicted as having archaeological potential in the City of Brantford Archaeological Master Plan.

As the Project area was in proximity to features signalling archaeological potential, a Stage 1 property inspection was conducted to evaluate the current conditions of the Project area and evaluate integrity. Based on the Stage 1 background research and property inspection the following recommendations are made:

The lawn area within Potential Easement 1 of the Project Area is not obviously disturbed and retains archaeological potential. This area would require Stage 2 survey. As these lands are non-ploughable, the Stage 2 survey should consist of a standard test pit survey at a 5 m transect interval, in keeping with provincial standards. Potential easement locations 2 through 7 are completely disturbed. As such, no longer retains archaeological potential and no further assessment work is required.

The SWMF is completely disturbed. As such, it no longer retains archaeological potential and no further assessment work is required.

The watercourse downstream of the SWMF has been subject to assessment and no longer retains archaeological potential and no further assessment work is required.

These recommendations are subject to the conditions laid out in Section 7.0 of the Timmins and Martell report and to the Ministry of Tourism, Culture and Sport's review and acceptance of this report into the provincial register.

3.9 Built Heritage

A draft Cultural Heritage Assessment (CHA) was prepared by Timmins Martelle Heritage Consultants, October 2019. The CHA followed the Ministry of Tourism, Culture and Sport's (MTCS) checklist entitled, "Criteria for Evaluating Potential for Built Heritage Resources and Cultural Heritage Landscapes." The purpose of the checklist is to determine if a property/properties or project area is a recognized heritage property and/or may be of cultural heritage value.

If a property meets any of the MTCS screening criteria, and a Statement of Cultural Heritage Value has not previously been prepared, then a Cultural Heritage Evaluation Report may be required. If the property is determined to be of cultural heritage value and alteration or development is proposed, a Heritage Impact Assessment will be required to identify and mitigate potential heritage impacts.

The CHA found that the Subject Property does not meet any of the MTCS screening criteria for known or potential cultural heritage value. No further heritage studies are recommended.

4 Stormwater Strategy Overview

4.1 Design Basis

Stormwater management (SWM) is required to mitigate the effects of urbanization on the hydrological cycle, including increased runoff and decreased infiltration of rain and snowmelt. Without proper stormwater management, reduced base flow, degradation of water quality, and increased flooding and erosion can lead to reduced diversity of aquatic life, fewer opportunities for human uses of water resources, and loss of property and human life (MOE, 2003).

The design basis of alternative development for the SWMF will be based upon current stormwater management practices. Design guidelines found within the Stormwater Management Planning and Design Manual (MOE, 2003) and local municipal design standards will be applied to the stormwater management strategy, as applicable.

Relevant standards and design guidelines used in the development of the stormwater management strategy include:

- Stormwater Management Planning and Design Manual (MOE 2003);
- Storm Sewers Design and Construction Manual Linear Municipal Infrastructure (City of Brantford 2017); and,
- Master Servicing Plan (MSP) for water, Sanitary and Stormwater Services (City of Brantford 2014).

4.2 Stormwater Management Objectives

Stormwater management objectives have been defined for the proposed Braneida SWMF retrofit include water quality, erosion control, water quantity, and LID. These are further described in the following sections.

4.2.1 Water Quality Control

Contaminants, such as oil, grease, metals, pesticides, fertilizers, winter salt and sediment tend to build up on surfaces in urbanized areas. These pollutants come from sources such as pavement deterioration, tire and brake pad wear, vehicle emissions, spills, construction and road maintenance.

The preferred SWM strategy will target satisfying the MOE Enhanced quality control criteria of providing a minimum 80% Total Suspended Solids (TSS) removal efficiency. However, this may not be practical, the actual TSS removal efficiency is to be determined to be the highest achievable level of quality control based on the balance of the evaluation criteria.

In Section 3.3.2 of the MOE Stormwater Management Planning and Design Manual (2003), it is clarified that when there are two stormwater management facilities in series, the second facility only needs to accommodate a detention storage volume for water quality control in accordance with the upstream catchment areas that have not been treated by the upstream stormwater management facility. Therefore, the calculations for the Braneida pond retrofit were completed considering only the areas designated to be uncaptured and untreated by the proposed pond in the Kylin development plans. However, the MOE Manual also specifies that the active storage area may be doubled from 40 m^3/ha to 80 m^3/ha to compensate for the increased water quantities and anticipated increase in overflows. This is also reflected in the estimation of the required storage volumes for the Braneida pond.

4.2.2 Water Quantity Control

Typically, the increase in direct runoff as a result of uncontrolled development (i.e., increased impervious areas) combined with rapid storm conveyance systems, results in increased peak flows. The potential impacts of increased peak flows include flooding and increased risks to life and property.

The SWM strategy must demonstrate that the post retrofit peak flow rates do not exceed the corresponding existing peak flow rates for the 1 in 2-year, 1 in 5-year, 1 in 10-year, 1 in 25-year, 1 in 50-year and the 1 in 100-year design storm events.

The SWMF will be designed to convey the Regional storm event safely without causing erosion issues or raising upstream flood levels.

4.2.3 Erosion and Sediment Control

Sediment and erosion control are integral components of stormwater management, which aims to ensure that post development stormwater flows are controlled and released in such a manner that existing downstream receiving watercourse or channel erosion is not exacerbated by land use change.

Natural creek systems regularly see flows that entrain and transport sediment; this is part of the natural process that maintains creek form. However, issues arise when changes in the watershed's hydrology results in an increase in the frequency or period of erosive events, or a cumulative increase in the quantity of flow that can entrain and transport sediment (CVC, 2010).

The preferred SWM strategy will incorporate extended detention storage of post construction 25 mm, 4-hour Chicago storm reducing the peak flow to a rate which reduces further incision and erosion of the downstream tributary.

The strategy must demonstrate improvements in erosion criteria over existing conditions and be consistent with the natural channel design concepts for the proposed downstream channel remediation project.

4.3 Low Impact Development

Low Impact Development (LID) assists in maintaining and improving natural systems, providing resiliency in stormwater infrastructure and contribute to climate change adaption and mitigation strategies. LID is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater.

Both the City and the GRCA have expressed the desire to utilize Low Impact Development (LID) features to aide in the management of stormwater runoff. Development within the Braneida SWMF catchment since 2009 has incorporated site controls (Sernas, 2009). The proposed development Kylin proposes site controls (Exp 2018). The following LID opportunities have been incorporated into development within the existing Braneida SWMF catchment:

- Brant Power: on-site controls provided with rooftop, underground, and parking lot storage;
- Kylin Development: Quantity and quality control provided in a proposed stormwater management pond; and
- Kylin Development: Best Management Practices (BPMs) on each development block to achieve a maximum allowable release rate of 0.13 $m^3/s/ha$.

As such, LID measures or BMPs are part of all of the SWM strategy alternatives.

4.4 Climate Change and Infrastructure Resiliency

The preferred SWM strategy will incorporate climate change and infrastructure resiliency. The implementation of LID, BMPs along with the strategic optimization of the existing Braneida SWMF will promote resiliency in the ultimate drainage system and reduce potential climate change related events such as droughts or intense precipitation.

The consideration of climate change and infrastructure resiliency has been incorporated using extreme event modeling, up to and including Hurricane Hazel. Freeboard and the capacity of existing and proposed SWM infrastructure are evaluated and optimized through the preferred solution.

This approach provides a reasonable and practical means to assess and increase the resiliency of SWM infrastructure for extreme intense weather events.

4.5 Maintenance and Operation Easements

Maintenance and operation easements are to be identified and recommended as part of the preferred retrofit. Easements are required to ensure the City can properly install and maintain the stormwater management facility and/or access roads. Required easement widths are dependent on the nature, extent and location of proposed SWM improvements.

4.6 Braneida Stormwater Management Facility Retrofit Design Criteria Summary

The following SWM design criteria must be achieved:

- Demonstrate improvements in water quality;
- Demonstrate improvements in erosion criteria over existing conditions that are consistent with natural channel design concepts for the proposed downstream channel remediation project;
- Demonstrate that the post retrofit peak flow rates do not exceed the corresponding existing peak flow rates for the 1 in 2-year, 1 in 5-year, 1 in 10-year, 1 in 25-year, 1 in 50-year and the 1 in 100-year design storm events; and
- Provision of maintenance and operation easements.

The following SWM design criteria have been adopted as preferred targets, however their achievement may not be practical, and the preferred performance is to be determined based on the balance of the evaluation criteria:

- MOE Enhanced quality control criteria of providing a minimum 80% Total Suspended Solids (TSS) removal efficiency;
- Extended detention storage of post construction 25 mm, 4-hour Chicago storm, based on results of the geomorphic assessment of downstream erosion thresholds to prevent further incision and erosion of the downstream tributary; and
- Post retrofit peak flow rates do not exceed the corresponding existing peak flow rates for the 1 in 2-year, 1 in 5-year, 1 in 10-year, 1 in 25-year, 1 in 50-year and the 1 in 100-year design storm events; and
- Safe conveyance of Hurricane Hazel peak flow rates.

5 Identification and Evaluation of Alternative Solutions

5.1 Braneida Stormwater Management Facility Easement

5.1.1 Easement Requirements

An asphalt pathway is required to access the Braneida SWMF to undertake operational and maintenance activities. The pathway would be located within an easement over private property. Based on the City of Brantford Design and Construction Manual, Linear Municipal Infrastructure Standards, Roads and Transportation (Section 13) standard for multi-use pathways and OPSD 502.010 for access lanes the pathway would be 3.0 m wide.

If the existing surface treatment is asphalt it would need to be inspected by the City to ensure that it meets minimum pavement strength requirements. If the existing surface is grassed a new asphalt path would be installed. Maintenance and repair of the asphalt path would be the responsibility of the City.

A minimum 5.0 m easement width to contain the access path is recommended in order to allow access by construction equipment. All easement access paths on **Figure 7** in **Appendix A** are shown as 10 m wide.

The City will require the easement to be free from obstructions and accessible from the adjacent street year-round. A locked gate to access the SWMF block would be placed at end of the easement to prevent public access.

5.1.2 Alternative Easement Locations

A total of five potential easement locations have been evaluated, as shown in **Figure 7** in **Appendix A**. Photographs of the potential easement locations are provided from Google Street View in Error! Reference source not found.**H**. The locations are:

- Easement 1: 132 Adams Boulevard;
- Easement 2: 112 Adams Boulevard;
- Easement 3: 90 Adams Boulevard;
- Easement 4: 66 Adams Boulevard; and
- Easement 5: 66 Adams Boulevard (from Bury Court).

5.1.3 Evaluation of Alternative Easement Locations

The criteria used for the evaluation of alternative locations are outlined in **Table 5-1**.

Table 5-1. Evaluation Criteria for Alternative Easement Locations

Criteria	Indicator
Land Use	• Potential for damage to existing property improvements (pavement, landscaping). • Potential to impact on existing businesses day to day operations (fencing, parking, storage, gates). • Presence of utilities and overhead power.
Natural Environment	• Potential to impact terrestrial and aquatic environment including habitat and tree removal.
Design Requirements	• Proximity to the stormwater management facility. • Ease of grade transitions to stormwater management facility. • Opportunity to coordinate access for future stream rehabilitation works within the downstream tributary.
Willing Host	• The City of Brantford investigated the availability of lands for an easement and the willingness of landowners to provide easement access

An assessment of each alternative easement location was completed. In the evaluation, trade-offs were considered between the advantages and disadvantages of each alternative to address the requirement for access with the least environmental effects and least impacts to existing land users. Weights were assigned to each category in a manner which emphasized willing host, and balanced criteria of land use, natural environment, and design requirements. For each of the alternative solutions, a weighted sum was calculated to determine the relative ranking of the alternative solutions and identify a preferred alternative solution. The evaluation is provided with symbology in **Table 5-2**.

Table 5-2. Evaluation of Alternative Easement Locations and Relative Ranking of Alternative Locations

	Potential Easement Location				
Criterion	132 Adams Blvd (1)	112 Adams Blvd (2)	90 Adams Blvd (3)	66 Adams Blvd (4)	66 Adams Blvd from Bury Ct (5)
Land use (20%)	- Vacant - Grass - No fence	- Business - Paved - Parking - Fencing	- Business - Gravel - Parking - No fence	- Business - Paved - Storage - Fence	- Business - Gravel - Storage - Fencing - Adjacent to hydro corridor
	●	○	◐	○	◔
Natural Environment (20%)	- No trees - No aquatic	- No trees - No aquatic	- No trees - No aquatic	- No trees - No aquatic	- No trees - No aquatic
	●	●	●	●	●
Design Requirements (20%)	- Flat grade - Good access to SWMF - Furthest from downstream tributary	- Flat grade - Good access to SWMF - Ok access to downstream tributary	- Flat grade - Steeper access to SWMF - Ok access to downstream tributary	- Flat grade - Good access to SWMF - Good access to downstream tributary	- Flat grade - Ok access to SWMF - Good access to downstream tributary
	◕	◕	◐	●	◐
Willing Host (40%)	- No indication that the landowner is a willing host	- No indication that the landowner is a willing host	- Landowner indicated willingness to allow easement	- No indication that the landowner is a willing host	- No indication that the landowner is a willing host
	○	○	●	○	○
Overall Ranking	◐ **2**	◐ **4**	◕ **1**	◐ **3**	◔ **5**

5.1.4 Preferred Easement Locations

The ranking of potential easements which may provide access to the existing Braneida SWMF and future channel remediation area with minimal disturbance to private properties and business operations, in order of preference, are:

1. Easement 3: 90 Adams Boulevard;
2. Easement 1: 132 Adams Boulevard;
3. Easement 4: 66 Adams Boulevard;
4. Easement 2: 112 Adams Boulevard; and
5. Easement 5: 66 Adams Boulevard (from Bury Court).

A feasible access can be provided from each of the alternative locations, the final preferred alternative will be subject to the willingness of the existing landowners to provide the required easement.

5.2 Braneida Stormwater Management Facility Retrofit

5.2.1 Retrofit Alternatives

5.2.1.1 Alternative 1: Do Nothing

This option is a baseline for comparison. Under this option, there would be no implementation of retrofit stormwater quantity, quality, or erosion controls to the existing Braneida SWMF.

Refer to **Figure 8** in **Appendix A** for an illustration of the existing facility.

5.2.1.2 Alternative 2: Retrofit Existing Braneida SWMF Within Existing SWM Block

The current arrangement results in the flow path through the facility being unable effectively access the available storage. The flow path through the facility is also minimized to be the closest path between the inlet and outlet. A potential retrofit to the existing SWMF could include implementation of the following:

- A permanent pool to provide water quality;
- A forebay to improve maintenance frequency of the main cell;
- Access roads and easement;
- Multi-stage outlet with erosion control and quantity control that is active during frequent storm events; and
- Separation of the inlet and outlet structures to increase the flow path and residence time in the SWMF.

Refer to **Figure 9** in **Appendix A** for an illustration of Alternative 2.

<u>Water Quality</u>

A summary of the water quality criteria achieved by Alternative 2 is provided in **Table 5-3**. The water quality control criteria of enhanced treatment is readily achieved.

Table 5-3. Summary of Water Quality Criteria Achieved Within the Existing SWMF Facility Area

Item	Required Amount	Provided Amount
Total Contributing Drainage Area (ha)	70.6	
Total Imperviousness (%)	70.0	
From Table 3.2 of MOE Manual (2003)		
Quality Control Volume (m^3/ha)	225	343.6
Total volume (m^3)	15,885	24,261
Permanent Pool Volume (m^3/ha)	145	181.3
Permanent Pool volume (m^3)	10,237	12,800
Extended detention Volume (m^3/ha)	80	162.3
Extended detention Volume (m^3)	5,648	11,461

<u>Erosion Control</u>

A summary of the erosion control criteria achieved by Alternative 2 is provided in **Table 5-4**. The erosion control criteria of extended detention of the 25 mm storm volume is readily achieved and is calculated through the ultimate development condition SWMF location inflows in the VO hydrologic modelling.

Table 5-4. Erosion Control Criteria Achieved Within the Existing SWMF Facility Area from VO Output

Item	Required	Provided
Total Contributing Drainage Area (ha)	70.6	
Alternative 2 - 25 mm storm extended detention volume (m^3)	11,461	11,461
Existing extended detention (Phillips designed)		13,700**

* refer to **Appendix D** catchment characteristics for run-off coefficient calculations.
** Phillips 1990, current clogged orifice condition results in an available extended detention volume of 0

Quantity Control

A summary of the quantity control criteria achieved by Alternative 2 is provided in **Table 5-5**. Additional active storage volume of 11,461 m^3 is available for a total active storage depth of 2.3 m of quantity control which is greater than existing.

Table 5-5. Quantity Control Criteria Achieved Within the Existing SWMF Facility Area

Item	Volume (m^3)
Existing Braneida SWMF Quantity Control Volume (212.20 m – 213.75 m)	31,752*
Alternative 2 Quantity Control Volume (211.90 m – 214.50 m)	47,080

* Phillips 1990

5.2.1.3 Alternative 3: Retrofit Existing Braneida SWMF and Expand Existing SWMF Block

This option will consider retrofits to the constructed Braneida SWMF, as per Alternative 2 with works proposed beyond the existing SWMF block. Refer to **Figure 10** in **Appendix A** for an illustration of Alternative 3.

Water Quality

A summary of the water quality criteria achieved by Alternative 2 is provided in **Table 5-6**. The water quality control criteria of enhanced treatment is readily achieved.

Table 5-6. Summary of Water Quality Criteria Achieved Within the Existing SWMF Facility Area

Item	Required Amount	Provided Amount
Total Contributing Drainage Area (ha)	70.6	
Total Imperviousness (%)	70	
From Table 3.2 of MOE Manual (2003)		
Quality Control Volume (m^3/ha)	225	633
Total volume (m^3)	15,885	44,690
Permanent Pool Volume (m^3/ha)	145	355.4
Permanent Pool volume (m^3)	10,237	25,090
Extended detention Volume (m^3/ha)	80	277.6
Extended detention Volume (m^3)	5,648	19,600

Erosion Control

A summary of the erosion control criteria achieved by Alternative 3 is provided in **Table 5-7**. The erosion control criteria of extended detention of the 25 mm storm volume is readily achieved and is calculated through the ultimate development condition SWMF location inflows in the VO hydrologic modelling

Table 5-7. Erosion Control Criteria Achieved Within the Existing SWMF Facility Area

Item	Required	Provided
Total Contributing Drainage Area (ha)	70.6	
Weighted Run-off Coefficient	0.70	
Alternative 3 - 25 mm storm extended detention volume (m^3)	11,461	19,600
Existing extended detention		13,700*

* Phillips 1990, current clogged orifice condition results in an available extended detention volume of 0

Quantity Control

A summary of the quantity control criteria achieved by Alternative 3 is provided in **Table 5-8**. Additional active storage volume of 17,620 m^3 is available for total active storage depth of 2.3 m is available for quantity control which is greater than existing.

Table 5-8. Quantity Control Criteria Achieved Within the Existing SWMF Facility Area

Item	Volume (m^3)
Existing Braneida SWMF Quantity Control Volume (212.20 m – 213.75 m)	31,752*
Alternative 3 Quantity Control Volume (212.50 m – 214.80 m)	47,372

* Phillips 1990

5.2.2 Evaluation of Retrofit Alternative Solutions

Evaluation Criteria

The evaluation of the alternative solution was done by first identifying the key categories of importance of the project. This includes the categories shown in **Table 5-9**, including Public Health and Safety, Technical, Environmental, etc. Within each of these categories, an additional set of criteria were identified on which the project should be evaluated for its beneficial impacts, and mitigation of adverse risk factors. These criteria are set based on the nature of the project and the potential impacts the project may have on the adjacent businesses and landowners, the environment, the impacts on the public and cultural resources, and the actual costs and constructability of the alternatives. Collectively, these criteria provide a comprehensive and balanced approach to evaluate the alternatives from the collective perspectives of the public, the relevant agencies, First Nations, and other relevant stakeholders to the project.

The criteria used to evaluate the alternative solutions are described in further detail in **Table 5-9**.

Table 5-9. Criteria for the Evaluation of the Braneida SWMF Alternative Solutions

Category	Subcategory
Public Health and Safety	• Protection of residents from downstream flooding • Protection of adjacent landowners from backwater flooding
Technical	• Water quality control enhancements resulting from stormwater management measures • Erosion enhancements resulting from stormwater management measures. • Water quantity control enhancements resulting from stormwater management measures • Implementation of best management practices
Environmental	• Impact on fish habitat • Impact on vegetation • Impact on terrestrial habitat
Archaeological and Heritage Resources	• Disturbance of heritage resources • Disturbance of archaeological resources
Socio-Economic	• Temporary construction impacts (access, noise, dust, vibration) • Property Requirements (area required, access, flooding) including temporary and permanent easements • Potential to integrate trails and enhance multi-use trail network
Cost	• Construction costs • Operation and Maintenance costs
Constructability	• Design implementation and access • Constructability • Maintenance requirements • Impact to existing utilities

<u>Alternative Evaluation</u>

A detailed assessment of each alternative storm water management retrofits was completed. In the evaluation approach, trade-offs consider the advantages and disadvantages of each alternative to address the problem/opportunity statement with the least environmental effects and the most technical benefits, which forms the rationale for the identification of the preferred alternative.

The evaluation of the three alternative solutions was done within each item in the subcategory on a scale of 0 to 4, with 0 representing the least desirable outcome and 4 the most desirable outcome. The weights were assigned to each category and subcategory in a manner which emphasized Public Health and Safety, and balanced criteria of cost, technical merit, environmental impacts, and other impacts. For each of the alternative solutions, a weighted sum was calculated to determine the relative ranking of the alternative solutions and identify a preferred alternative solution.

This evaluation is presented in summary format with symbology in **Table 5-10**. The detailed numerical evaluation of the alternative solutions is provided in **Table 5-11**.

Table 5-10. Summary of the Alternative Solution Evaluation Results

Criteria	Alternative 1 (Do Nothing)	Alternative 2 (Retrofit Existing Facility)	Alternative 3 (Expand Existing Facility)
Public Health and Safety (25%)	○	◕	●
Technical (10%)	○	◕	◕
Environmental (15%)	◕	◕	○
Heritage and Archaeological Resources (10%)	●	◕	○
Socio-economic (15%)	◕	◕	◔
Cost (15%)	◕	◑	○
Constructability (10%)	●	◕	◑
Overall Score	◑	●	◔

Table 5-11. Alternative Solutions Detailed Evaluation Matrix

Criteria	Weight (%)	Alternative 1 (Do Nothing)	Alternative 2 (Retrofit Existing Facility)	Alternative 3 (Expand Existing Facility)	Description
Public Health and Safety (25%)		**0.0**	**3.0**	**4.0**	
Protection of residents from downstream flooding	12.5	0.0	3.0	4.0	Protection of residents from increased risk of downstream flooding
Protection of adjacent landowners from backwater flooding	12.5	0.0	3.0	4.0	Protection of adjacent landowners from increased risk of backwater flooding
Technical (10%)		**0.0**	**3.6**	**4.0**	
Water quality enhancements	2.5	0.0	3.5	4.0	Water quality control enhancements resulting from stormwater management measures
Erosion enhancements	2.5	0.0	3.5	4.0	Erosion enhancements resulting from stormwater management measures
Water quantity control enhancements	2.5	0.0	3.5	4.0	Water quantity control enhancements resulting from stormwater management measures
Implementation of best management practices	2.5	4.0	4.0	4.0	Implementation of best management practices
Environmental (15%)		**3.7**	**3.7**	**0.7**	
Impact on fish habitat	5.0	3.0	3.0	2.0	Measure the impact on fish and other aquatic species and aquatic habitat
Impact on vegetation	5.0	4.0	4.0	0.0	Measure the impact on vegetation on the slope and in surrounding project site
Impact on terrestrial habitat	5.0	4.0	4.0	0.0	Measure the impact on terrestrial habitat and terrestrial species
Heritage and Archaeological Resources (10%)		**4.0**	**3.0**	**0.0**	
Disturbance of heritage resources	5.0	4.0	3.0	0.0	Measure the disturbance of built and cultural heritage landscapes
Disturbance of potential archaeological resources	5.0	4.0	3.0	0.0	Measure the disturbance of archaeological resources on site
Socio-economic (15%)		**3.3**	**3.3**	**1.3**	
Temporary construction impacts	5.0	4.0	2.0	0.0	Temporary construction impacts to adjacent properties, including access, noise, dust, vibration, etc.
Property requirements	5.0	4.0	4.0	0.0	Property requirements including area required, access, flooding, temporary and permanent easements
Integration of trails	5.0	2.0	4.0	4.0	Potential to integrate trails and enhance multi-use trail network
Cost (15%)		**3.7**	**2.0**	**0.7**	
Construction costs	10.0	4.0	2.0	0.0	Relative measure of the initial construction costs
Operation and Maintenance costs	5.0	3.0	2.0	2.0	Relative measure of the ongoing operation and maintenance costs following construction
Constructability (10%)		**4.0**	**3.3**	**2.5**	
Design implementation and access	2.0	4.0	3.0	2.0	Feasibility of the project implementation, including construction access
Constructability	3.0	4.0	3.0	1.0	Overall technical constructability of the alternative
Maintenance Requirements	2.0	4.0	3.0	3.0	Measure of the ongoing maintenance requirements following construction
Impact to existing utilities	3.0	4.0	4.0	4.0	Impact of the construction and maintenance to existing utilities in the study area
Overall Score		**2.40**	**3.09**	**2.05**	

5.2.3 Draft Retrofit Preferred Alternative

The evaluation of the alternative solutions provided in **Table 5-11** indicates that the preferred alternative solution is Alternative 2, the retrofit of the existing SWMF within the current footprint. The criteria used in the evaluation of the preferred alternative are described in **Table 5-9**.

The calculations provided in **Section 5.2** with respect to the contributing catchment areas and water volumes required for water quality treatment with a wet pond, as well as detention of water with respect to erosion in the downstream system and flood concerns, indicate that the existing facility footprint is sufficient to provide enhanced water quality treatment and removal of suspended solids.

It is anticipated that an expansion of the existing facility's footprint in order to accommodate a greater storage volume and treatment is both not required to meet desired treatment targets and may incur undesired environmental impacts with the additional disruption of the adjacent areas. Therefore, Alternative 2 scores higher than Alternative 3, which is reflected n the evaluation. The Do Nothing Alternative (Alternative 1) also scores lower than the retrofit alternative, as the existing SWMF does not adequately meet the needs for water quality treatment, erosion control, and flood management.

5.3 Downstream Channel Remediation

The Stantec (2009) report recommended channel realignment for the portion of the Garden Avenue Tributary that extends from the twin culverts to 215 m downstream, ending near the confluence of the two wetland tributary channels. Stantec (2009) indicates that the proposed channel realignment was intended to compensate for the loss of open channel length that would occur with future planned development and channel enclosure. Stantec (2009) indicates that this section of channel is currently situated within a broad cattail marsh where it bifurcates, becomes less defined and flows diffusely through the cattail marsh; the section of channel is considered to include poor aquatic habitat and be restrictive to fish passage.

Through the assessments completed for the current study, it was agreed that fish passage may be restricted through the marsh during periods of low flow. The proposed Stantec channel realignment would allow for a defined channel be exist but, in doing so, would alter characteristics of the adjacent marsh area; this may inadvertently result in the further invasion of phragmites into the area.

Instead of completing channel remediation work in the marsh, results of the current study suggest that addressing the incised and entrenched channel that occurs downstream of the trail crossing to the Garden Avenue Tributary confluence with a second tributary (~ 300 m downstream) would be more advantageous. That is, the marsh will be able to attenuate flows whereas within the downstream channel, continued incision into the till channel bed materials and erosion of the banks will contribute to a degradation of aquatic habitat. Upstream regression of knickpoints will place the marsh at risk in the future.

5.3.1 Channel Remediation Considerations

The ongoing Municipal Class EA for the existing Braneida Stormwater Management Facility provides an opportunity to enhance the downstream watercourse through remediation. The proposed watercourse remediation also provides an opportunity to optimize erosion control enhancements within the stormwater management facility retrofit.

Based on the assessment of existing geomorphic conditions, the following considerations have been identified for the channel remediation works:

- **Floodplain connectivity and channel capacity:** it is beneficial to reconnect the Reach 1 channel to the floodplain, reducing the existing channel capacity to reduce entrenchment and to mitigate ongoing incision within the channel.
- **Flow management:** manage proposed flows from the SWM facility retrofit to reduce erosion potential as identified through the erosion threshold analysis.

- **Channel form and function:** decrease high energy conditions (i.e., effective shear stress on channel boundary) existing within the channel to reduce further erosion and incision; Improve natural channel form and function to the adjusting system; reduce the positive feedback cycle of bed erosion/incision/entrenchment by protecting the till bed.

5.3.2 Channel Remediation Alternatives

Alternative 1: Do Nothing

The 'Do Nothing' alternative provides a baseline for comparison where no action would be taken to address the identified erosion concerns within the channel. This alternative is always considered in an Environmental Assessment in order to assess the impact of taking no action to address the issues under evaluation. Under this alternative, ongoing channel processes would continue, resulting in continual channel adjustment (i.e., incision and erosion) within the study area.

The 'Do Nothing' alternative will result in no impacts to the natural environment within the study area related to construction activity or site alteration. Although this alternative protects the natural environment from modifications related to channel remediation works, impacts to the natural environment remain from continued erosion and channel adjustment (i.e., loss of trees and vegetation surrounding the watercourse through bank erosion and incision). Continued incision into the till materials will further entrench the channel and concentrate larger flows within the channel cross-section rather than spilling onto the floodplain.

The cost of implementing Alternative 1 is low.

Alternative 2: Channel Bed/Profile Enhancements

The local restoration alternative would address sensitive areas of the channel through the study area. The alternative would involve the protection of the clay channel bed, thus, mitigating further incision of the channel. Means of protection may include providing in-channel cover, feeding the channel with granular sediment, and providing bed cover such as the incorporation of large woody debris or boulders (i.e., keystones to the stone matrix) to retain upstream sediment cover.

The alternative would maintain the existing footprint of the channel. Impacts to the terrestrial natural environment will result at the locations of construction access where the removal of vegetation will likely be required. However, these impacts will be temporary, as access points will be re-vegetated using native vegetation upon completion of the work. This alternative would allow for enhancement opportunities to the terrestrial and aquatic natural environments.

Implementation of this alternative will not completely halt ongoing channel adjustment (incision). Continued downcutting and widening (i.e., cross-section enlargement and bank failure) of the channel may continue to occur in the future, resulting in further erosion issues downstream of the SWM facility, and sediment loading to the overall Garden Avenue tributary system.

The cost of implementing Alternative 2 is considered to be moderate in comparison to the other alternatives. A continued need for monitoring activity, in the future, would occur.

Alternative 3: Channel Capacity/Floodplain Connectivity

Alternative 3 includes increasing the channel capacity and/or floodplain connectivity within the incised section of the watercourse in the study area. Reconnecting the channel to the floodplain will allow the energy associated with larger flows to be dissipated onto the floodplain, reducing energy pressures within the channel cross-section. Specific channel modifications that may be undertaken include increasing cross-sectional area within the overbank area, where feasible, to reduce hydraulic stresses and stream power on the bed and bank materials. An increased cross-sectional capacity could also increase in-stream storage potential during periods of higher flow.

Impacts to the natural environment from local channel modifications are expected to be greater than the potential impacts resulting from Alternative 2; however, the impacts of enhancing floodplain connectivity are still anticipated to be relatively localized. Similar to Alternative 2, impacts to the terrestrial natural environment will result at the locations of construction access, and in locations where vegetation will likely be required (e.g., channel widening, enhanced floodplain connectivity). This alternative would allow for enhancement opportunities to the terrestrial natural environment.

The cost of implementing Alternative 3 is considered to be moderately high.

Alternative 4: Channel Realignment

In the proposed channel realignment alternative, the watercourse through the study area would be re-aligned. The cross-sectional configuration would be enlarged to increase the flow capacity of the channel and reduce flow energy associated with more frequent flows, as well as larger storms. Modification of the channel bed profile would be undertaken to conform to the natural occurring patterns within the channel. The channel design would be developed based on natural design principles and promote natural channel functions while reducing erosion potential. This alternative will address all identified erosion issues and erosion mechanisms. The focus would be on reducing flow energy and increasing floodplain connectivity.

Through detailed design, the footprint of the channel realignment, and configuration of the proposed profile and cross-section will be determined; the intent of the channel realignment is to minimize impact to the natural environment while supporting channel function, and to avoid any increase in erosion risk within the downstream length of channel. Reducing future potential incision of the channel bed should be considered in the design (e.g., protecting the underlying till). Consideration of the trail system location through the study area will be required during detailed design.

Impacts to natural environment from this alternative are expected to be the greatest of all the proposed alternatives. Temporary impacts to the terrestrial natural environment will result at the locations of construction and proposed channel alignment due to the required removal of vegetation. These areas can be restored once construction is complete, providing opportunity for enhancement.

The cost of implementing Alternative 3 is considered to be the highest of all alternatives.

5.3.3 Evaluation of Channel Remediation Alternatives

The criteria used for the evaluation of the alternative solutions for channel remediation are outlined in **Table 5-12**.

Table 5-12. Evaluation Criteria for Alternative Channel Remediation Solutions.

Technical	• Protection from erosion • Impacts to river stability and flood risk
Natural Environment	• Impact on vegetation and terrestrial habitat
Socio-Economic	• Temporary construction impacts (access, noise, dust, vibration)
Cost	• Construction costs • Operation and Maintenance costs
Constructability	• Design implementation and access • Constructability • Maintenance / monitoring requirements

An assessment of each alternative for downstream (Reach 1) channel remediation was completed. In the evaluation, the advantages and disadvantages of each alternative in regards to the considerations and the evaluation criteria for channel remediation were assessed. This evaluation forms the rational for the ranking of channel remediation alternatives. Weights were assigned to each category in a manner which emphasized willing host, and balanced criteria of land use, natural environment, and design requirements. For each of the alternative solutions, a weighted sum was calculated to determine the relative ranking of the alternative solutions and identify a preferred alternative solution. This evaluation is presented with symbology in **Table 5-13.**

Table 5-13. Evaluation Criteria for Alternative Channel Remediation and Relative Ranking of Alternatives

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Technical (30%)	• No erosion protection • Channel instability continues	• Some erosion protection along channel bed • Increased river stability • No implications for flood risk	• Erosion reduced with increased channel capacity • Increased river stability • Reduced flood risk	• Erosion reduced with increased channel capacity • Increased river stability • Reduced flood risk
	○	◐	●	●
Environmental (20%)	• No construction impact of vegetation	• Temporary construction impacts to vegetation • Opportunity for enhancement at locations of construction access	• Temporary construction impacts to vegetation • Opportunity for enhancement at widened channel sections	• Temporary construction impacts to vegetation • Permanent impacts to vegetation along new alignment • Opportunity for enhancement
	◐	◕	◕	◔
Socio-Economic (15%)	• No construction impacts	• Minor construction impacts	• Minor construction impacts	• Major construction impacts
	●	◕	◕	○
Cost (20%)	• No construction cost • No immediate maintenance costs	• Moderate construction costs • Moderate maintenance costs	• Moderate construction costs • Moderate maintenance costs	• High construction costs • Low maintenance costs
	◕	◐	◐	◔
Construct-ability (15%)	• No construction • No maintenance / monitoring	• Simple design implementation and access • Maintenance and monitoring required	• Moderate design implementation and access • Maintenance and monitoring required	• Complex design implementation and access • Maintenance and monitoring required
	◔	◐	◐	○
Overall Ranking	◐ **3**	◐ **2**	◕ **1**	◐ **4**

5.3.4 Preferred Channel Remediation Alternative

The evaluation ranking of potential channel remediation solutions, based on the evaluation criteria as described in **Table 5-13**, in order of preference, are:

1. Alternative 3: Channel Capacity/Floodplain Connectivity
2. Alternative 2: Channel Bed/Profile Enhancements
3. Alternative 1: Do Nothing
4. Alternative 4: Channel Realignment

The evaluation of the alternative solutions provided in **Table 5-13** indicates that the preferred alternative solution is a hybrid of Alternative 2 and 3, to provide channel bed/profile enhancements and increase channel capacity and floodplain connectivity. The combined benefits of the alternatives, as well as the minimal negativities, based on the evaluation criteria, condones a hybrid approach to the channel remediation.

The hybrid alternative merges elements of Alternatives 2 and 3 wherein channel processes and erosion concerns are considered while minimizing the footprint of proposed works. Channel modifications would focus primarily on enhancing channel form to manage flow energy through channel widening and providing stability through channel bed enhancements.

6 Preferred Alternative

6.1 Preferred Strategy Concept Design

6.1.1 SWM Pond Design Summary

The design basis, SWM objectives and design criteria summaries are found in **Section 4** of this report. Preliminary modelling and design calculations have been completed and are provided in **Appendix I** to provide a proof of concept. A concept design is included in **Appendix J**. **Table 6-1** provides a summary of key design features for the proposed SWM retrofit design **Table 2-1**.

The proposed SWMF includes the following components:

- One sediment forebay;
- One permanent pool main cell;
- Inlet controls to reduce sediment resuspension;
- An extended detention control outlet structure; and,
- A high flow/emergency overflow control outlet weir.

Table 6-1. Preferred SWM Pond Alternative 2 Design Details

General	Pond Characteristics
Wet Pond Stormwater Management Facility	Enhanced Quality Control
Total Contributing Area	145 ha
Total Contributing Area Requiring Quality Controls (Downstream of Kylin SWM Facility)	70.6 ha
Imperviousness (of whole drainage area downstream of Kylin facility)	70.0 %
Bottom Elevation	210.9 m
Storage	
Unit Area Storage Volume Requirements per SWMP-DG (MOE, 2003)	225 m^3/ha
Required Total Volume	15,885 m^3
Provided Total Volume	25,495 m^3
Permanent Pool	
Required Permanent Pool Volume	10,237 m^3
Provided Permanent Pool Volume	12,800 m^3
Permanent Pool Elevation	211.90 m
Extended Detention/Erosion Control	
Minimum Required Volume per MOE SWMMP (80 m^3/ha)	5,648 m^3
Minimum Required Volume per 25 mm storm	11,461 m^3
Provided Extended Detention Volume	11,461 m^3
Approximate Drawdown time for 90% of Erosion Control Volume	89 hours
Approximate Drawdown time for 70% of Erosion Control Volume	48 hours
Peak Release Rate for Extended Detention/Erosion Control	0.26 m^3/s
Outlet Controls	
1800 mm dia. Outlet Control Maintenance Hole	
Orifice Diameter	370 mm
Orifice Elevation	211.90 m
Weir 1 Length (concrete weir)	5.20 m
Weir 1 Elevation	212.64 m
Weir 2 Length (trapezoidal overland weir)	5.20 m
Weir 2 Elevation	214.00 m

6.1.2 Water Quantity Control

Water quantity control is provided through attenuating outflows to the Phillips 1990 SWM Report design intent for the 2-year through 100-year storm events and providing an erosion control flow attenuating flow to be less than the erosion control threshold determined through the geomorphic analysis completed earlier within the report.

Quantity control is provided through a multi-staged outlet with a low-flow orifice and two higher-flow weirs which provide quantity controls enabling the rating curve in **Table 6-2** which results in the post-rehabilitation flows shown in **Table 6-5**.

Erosion control flow rates are much lower than both the existing condition and the predevelopment flows. Drawdown is designed to be longer due to the sensitive nature of the downstream receiving system. Efforts have been made to ensure that the majority of erosion control storage available within 48 hours of the peak outflow time. This design decision was made to allow for a controlled low-flow release peak flow rate of 0.26 m^3/s during the 25 mm – 4 hour storm event to prevent further incision and erosion of the downstream tributary. The exceedance in drawdown time is less of a concern than the flow rate in the receiving tributary for long-term impact on the receiving watercourse. Further fluvial geomorphologic background analysis and justification can be found within **Section 3.2**.

6.1.3 Water Quality Control

Water quality control will be achieved through implementation of the designed permanent pool volume capable of providing enhanced (80% long-term TSS removal) treatment. To achieve the enhanced level of treatment a total permanent volume of 10,237 m^3 is required with an associated extended detention/erosion control volume of 11,461 m^3. The rehabilitation design provides a permanent pool volume of 12,800 m^3 and an extended detention/erosion control volume of 11,461 m^3.

Typical extended detention volume is 40 m^3/ha, but in this case since the SWM pond is designed in series with an upstream SWM pond, so an extra extended detention volume calculation of 80 m^3/ha will be used as recommended in the MOE SWMP-DM (2003). The SWM Facility catchment area and imperviousness are reflective of the portions of the total catchment area which do not drain into the Kylin SWM Pond before draining to the design pond.

The forebay has been sized to meet and exceed MOE design criteria. Extra storage volume has been provided to decrease the required cleanout frequency. The forebay has been designed to have flows up to the 25 mm – 4 hour design storm directed to it. In larger intensity storm events, the inlet flows will be conveyed over a 25 m paved weir at elevation 214.35 into the main cell of the pond to avoid higher flows from resuspending accumulated sediment in the forebay. The 25 m overflow weir into the main cell has been designed to prevent any tailwater from encroaching onto any adjacent lots in the upstream drainage channel.

6.1.4 Hydrology

Retrofit Design Condition Rating Curve

As explained above, the current condition of the Braneida SWMF has an active storage volume deficit of 13,700 m^3 compared to design specifications in the Phillips design report. The loss of this active storage volume resulted in much higher flow rates leaving the facility throughout the different design storms in the existing condition scenario. SWM attenuation and control principles were applied to the preferred alternative design, and the resulting rating curve applied to the VO model can be seen below.

Table 6-3 and **Table 6-4** provide summaries of the catchment NasHyd and StandHyd command inputs for the ultimate development scenario, respectively. Catchment areas upstream of the Kylin SWMF have the same areas and schematic connections with updates to their characteristics (CN values, initial abstractions) noted above. The VO model schematic and catchment extents can be found within **Appendix E**.

Table 6-2. Design Rating Curve for Braneida SWMF

Preferred Alternative Design			
Discharge (m^3/s)	Storage (ha*m)	Discharge (m^3/s)	Storage (ha*m)
0	0	2.62	2.79
0.05	0.31	3.05	2.99
0.12	0.64	3.50	3.18
0.16	0.97	5.13	3.38
0.24	1.32	7.75	3.59
0.62	1.67	11.03	3.79
1.17	2.03	14.85	4.00
1.85	2.41	19.13	4.21

Table 6-3. Ultimate Development Condition – Nashyd Input

Catchment Number	Area	IA	TP	CN
	(ha)	(mm)	(hrs)	
105	0.97	5	0.2	74
154	7.12	5	0.2	74

Table 6-4. Ultimate Development Condition – StandHyd Input

Catchment Number	Area	XIMP	TIMP	C	Pervious				Impervious			
					IA	Slope	Length	Manning's n	IA	Slope	Length	Manning's n
	(ha)	(%)	(%)		(mm)	(%)	(m)		(mm)	(%)	(m)	
1001	0.99	0.5	0.5	0.55	5	2.0	40	0.25	2	1.0	40	0.015
1002	5.94	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
1003	5.69	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
140	3.1	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
141	0.5	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
142	8.5	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
1420	5.3	0.93	0.93	0.85	5	2.0	40	0.25	2	1.0	40	0.015
143	6.3	0.50	0.50	0.60	5	2.0	40	0.25	2	1.0	40	0.015
144	9.9	0.60	0.60	0.66	5	2.0	40	0.25	2	1.0	40	0.015
145	12.7	0.90	0.90	0.84	5	2.0	40	0.25	2	1.0	40	0.015
146	9.5	0.90	0.90	0.84	5	2.0	40	0.25	2	1.0	40	0.015
147	2.3	0.80	0.80	0.78	5	2.0	40	0.25	2	1.0	40	0.015
148	1.7	0.90	0.90	0.89	5	2.0	40	0.25	2	1.0	40	0.015
149	0.9	0.99	0.99	0.89	5	2.0	40	0.25	2	1.0	40	0.015
150	3.2	0.80	0.80	0.80	5	2.0	40	0.25	2	1.0	40	0.015
151	9.4	0.66	0.65	0.70	5	2.0	40	0.25	2	1.0	40	0.015
152	2.2	0.80	0.80	0.30	5	2.0	40	0.25	2	1.0	40	0.015
153	9.1	0.80	0.80	0.80	5	2.0	40	0.25	2	1.0	40	0.015
154	7.1	0.93	0.93	0.30	5	2.0	40	0.25	2	1.0	40	0.015

Existing stormwater management controls are incorporated on three properties: Lowes (catchment 1002), the area west of Lowes (catchment 1001) and the Brantford Power Center (catchment 1003) as detailed in **Section 3.4.4.1**.

The results of the preferred alternative SWM attenuation compared to the existing condition model is summarized in **Table 3-18**.

Table 6-5. Flow Rates at SWMF Outlet

Design Storm	Flow Rate (m^3/s)		
	Outlet of Existing SWMF		
	Phillips Design ERI Model	Clogged Orifice/Actual ERI Model	Preferred Alternative Design
25 mm – 4 hr	0.60	1.52	0.21
2	1.56	2.72	0.79
5	2.99	4.54	1.95
10	4.22	5.86	2.90
25	5.93	7.74	4.78
50	7.32	10.78	6.70
100	9.63	14.10	9.62
Hazel	15.05	15.11	16.07

6.1.5 Hydraulics

The impact on upstream and downstream hydraulics was considered throughout the development of the preferred alternative design. A HEC-RAS model was created and used to determine upstream and downstream conveyance capacities to ensure that the preferred alternative SWMF design would not cause tailwater flooding upstream of the SWMF and that the receiving watercourse has the conveyance capacity to pass all SWMF outflows without causing tailwater flooding in the SWMF.

As mentioned in **Section 6.1.3**, the upstream inlet to the SWMF has been designed with an overflow bypass of the forebay allowing major storm events to pass straight into the main SWMF cell without causing resuspension of solids in the forebay or tailwater flooding in the conveyance channel leading towards the SWMF.

The twin culverts downstream of the SWMF will be removed during the SWMF rehabilitation construction phase to eliminate the potential for the culverts to limit the outflow capacity of the SWMF. The location of the culverts will be rehabilitated with a rock lined channel and overbank storage appropriate for conveyance of the Regulatory storm event.

6.1.6 Creek Restoration

The preferred alternative for the creek restoration involves two aspects: channel bed and profile enhancements, and an increase in channel capacity and floodplain connectivity. These enhancements to the channel form will help manage flow energy through channel widening and provide stability through channel bed enhancements. A concept design is included in **Appendix J**.

Channel bed and profile enhancements included in the concept design consist of protection of the clay bed to mitigate further incision of the channel. This is done through the provision of in-channel cover, feeding the channel with granular sediment, and providing bed cover including large woody debris or boulders. The channel capacity and floodplain connectivity in the incised section of the channel will also be increased. This will result in stream energy from higher flows being dissipated into the floodplain. This will be accomplished by increasing the cross-sectional area within the overbank area to reduce hydraulic stresses and stream, as well as increase stream storage potential during high flows.

7 Implementation and Timing

The City of Brantford has scheduled the works for the Braneida SWMF Retrofit to be completed in spring to summer 2021 and has accounted for the rehabilitation of the SWMF and creek within its capital budget.

The proposed project implementation timeline is summarized, by phase, below:

Phase 1 Detailed design and permitting of the preferred alternatives. (Winter 2020)

Phase 2 Tendering and construction plan preparations. (Spring – Summer 2021)

Phase 3 Construction and completion of project works. (Summer 2021)

7.1 Property Requirements

The property requirements for the SWMF will require the City of Brantford to acquire a legal easement in favour of the City on the property of 90 Adams Boulevard, in the approximate location shown on **Figure 7** in **Appendix A**. The easement will provide access to the SWMF for construction and long-term operation and maintenance of the facility.

7.2 Costs

The preliminary costs for the preferred alternative solutions have been estimated based upon the professional experience in recent contracts and tenders completed by ERI. The estimated costs to implement the preferred alternatives are summarized below in **Table 7-1.**

Table 7-1. Cost Estimates for Preferred Alternatives

SWMF Restoration	
Site Preparation	$95,000
Removals	$50,000
Pond Works	$785,000
Storm Sewer and Appurtenances	$110,000
Landscaping	$100,000
Miscellaneous	$50,000
Sub-total	$1,190,000
Contingency (10%)	$119,000
Total (excl. HST)	**$1,309,000**
Creek Restoration	
Site Preparation	$20,000
Channel Works	$150,000
Landscaping	$40,000
Miscellaneous	$20,000
Sub-total	$230,000
Contingency	$23,000
Total (excl. HST)	**$253,000**
Total SWM Pond & Channel Restoration (excl. HST)	**$1,562,000**

8 Permits and Approvals

8.1 Ontario Ministry of Environment, Conservation and Parks (MECP)

An Environmental Compliance Approval (ECA) will be required from the MECP for the rehabilitated SWMF. Guidance and consultation with the MECP will also be required in dealing with construction works near and within the SWMF and creek.

8.2 Grand River Conservation Authority (GRCA)

Both the SWMF and the Braneida tributary to Fairchild Creek exist within GRCA identified floodplain, which is considered a regulated area. A permit application form will need to be completed, submitted, and accepted by the GRCA prior to the initiation of construction works for the SWMF and creek rehabilitation. No negative impacts to onsite wetlands are anticipated as a result of the proposed retrofit. Where wetland communities are in proximity to the proposed works, appropriate mitigation measures will be implemented reducing the risk of negative impacts.

8.3 Ontario Ministry of Natural Resources and Forestry (MNRF)

Guidance and consultation from the MNRF will be required where trees are proposed to be removed for construction. An Overall Benefit Permit may be required to undertake tree removal or disturbance of habitat. An application for a Wildlife Scientific Collectors Authorization shall be obtained from the MNRF for the duration of the construction project by a qualified individual. Any works within potential overwintering habitat of amphibian or reptile habitat will require a wildlife rescue performed prior to the hibernation period (early October to the end of May (timing is seasonally dependant)) and permitting and authorization obtained from MNRF.

8.4 Fisheries and Oceans Canada (DFO)

The amount of proposed works within a watercourse and at an elevation lower than the high-water mark for creek works warrants a request for project review with the DFO. The request for review only involves review of the creek works within the Braneida tributary to Fairchild Creek. The proposed works within the SWMF is not a part of the watercourse and has a weir at the downstream outlet which prevents fish migration upstream of the SWMF outlet. A DFO Request for Review has been submitted and a response permit (20-HCAA-02198) was received from DFO. A copy of the permit is including in the EIS in **Appendix F**. All works will adhere to the permitting requirements. Any in-water works shall comply with the DFO Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (March 15 to July 15).

9 Conclusions and Recommendations

The existing Braneida SWM facility is not providing the stormwater quality control required by the MOE SWM Planning and Design Guidelines. The erosion control function of the existing Braneida SWM facility is ineffective and the downstream receiving system is experiencing ongoing erosion challenges. The tributary through the study area has been previously modified, identified through the historic analysis of the study area, and exhibits evidence of previous and current channel adjustment. The watercourse, which is a clay-dominated system, is incised, particularly through the downstream reach (Reach 1). Hydrogeomorphic analyses indicated that the existing channel flows, including bankfull flows and larger storms, are mainly contained within the channel cross-section through reaches which exhibit a defined channel (Reaches 1 and 3). The areas of channel incision correspond to the high energy conditions that remain within the channel cross-section due to lack of floodplain connectivity. These processes are likely to remain within the system as the watercourse continues to adjust, resulting in further erosion and incision downstream.

Through an erosion threshold analysis, which examined the critical shear stress and velocity values associated with the gravel substrate and clay bed materials identified within the channel, the critical discharge target for the SWM facility retrofit was determined to be 0.26 m^3/s. This critical discharge target will ensure that the ongoing incision and erosion in the downstream reaches of the tributary are reduced through flow management.

Alternative solutions were developed for the three main aspects of the project including the location of easements, the SWMF retrofit, and the downstream channel remediation.

Five potential easement locations were evaluated, including 132 Adams Boulevard, 112 Adams Boulevard, 90 Adams Boulevard, 66 Adams Boulevard, and 66 Adams Boulevard (from Bury Court). The evaluation criteria categories included land use, natural environment, design requirements, and the availability of a willing host. The easement at 90 Adams Boulevard was selected as the preferred alternative, subject to the willingness of the existing landowners to provide the required easement.

Three retrofit alternatives were evaluated for the SWMF, including do nothing, retrofit the existing SWMF within the existing SWM block, and retrofit the existing SWMF and expand the existing SWM block. The evaluation criteria categories included public health and safety, technical, environmental, heritage and archaeological resources, socio-economic, cost, and constructability. The draft preferred alternative is to retrofit the existing SWMF within the current footprint while adding in a permanent pool to provide enhanced quality control. The design will prevent further incision of erosion of the downstream tributary for the 25 mm – 4 hour design storm. The retrofitted facility will match or lower post-development flows relative to predevelopment flows for the 2-year through 100-year storm events.

The twin 2000 mm diameter culverts located immediately downstream of the Braneida SWMF should be removed and replaced with rock lined channel and overbanks capable of conveying the flows associated with the Regional storm event. Current buildout conditions downstream of Kylin SWMF and upstream of the Braneida SWMF are considered as the ultimate buildout scenario for the hydrologic and SWM calculations. Any further intensification/increased impervious areas on upstream sites are recommended to require SWM calculations proving either: (1) the on-site controls will match predevelopment or (2) the pond capacity and outflows will not be significantly impacted (acceptance to the discretion of the City of Brantford and GRCA).

Four alternatives were considered for the downstream channel remediation, including do nothing, channel bed/profile enhancements, channel capacity/floodplain connectivity, and channel realignment. The evaluation criteria categories included technical, natural environment, socio-economic, cost, and constructability. The preferred alternative is a hybrid of Alternative 2 and 3, to provide channel bed/profile enhancements and increase channel capacity and floodplain connectivity. Targeted creek rehabilitation is recommended to prevent knickpoints from further regression by protecting the till bed and managing the change in elevation through a naturalized cascade or step pool bed configuration. The enhancements will include integrating habitat elements such as large woody as well as an increase in channel capacity and floodplain connectivity by increasing the cross-sectional area within the overbank area.

The works are scheduled to be completed in spring to summer 2021, including detailed design and permitting, tendering and construction plan preparations, and construction and completion of the project works. An easement will be required to access the SWMF for construction and long-term operation and maintenance of the facility. The preliminary cost estimate is $1,309,000 for the SWMF retrofit and $253,000 for the channel restoration, resulting in a total project cost of $1,562,000. Relevant permits and approvals will be required prior to construction.

10 References

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