Aquafor Beech Limited

Prepared for:
City of Brantford

North Brantford and Tutela Heights Subwatershed Study Update

Phase 2 and 3 Report

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1 Introduction

The City of Brantford is a rapidly growing population center located by the Grand River, west of the City of Hamilton. With a 2021 census population of 104,688, it is politically separate with a municipal government of its own that is fully independent of Brant County's municipal government. The North Brantford and Tutela Heights Subwatersheds are located within the 2,720 hectares annexed from the County of Brant Boundary Adjustment Lands in 2017.

The new City of Brantford Official Plan – Envisioning Our City: 2051 – expanded the City's Settlement Area by designating approximately 900 hectares of urban land uses. The settlement area expansion includes almost 400 hectares for new Employment Areas and 500 hectares for Community Areas, which gives a total of 525 hectares of Employment Areas and 730 hectares of Community Areas within the Boundary Adjustment Lands. The North Brantford and Tutela Heights Subwatershed Study is the beginning of a multi-staged approach to fully characterize, evaluate, and implement recommendations for this subwatershed.

This document constitutes **Phases 2 and 3 of the North Brantford and Tutela Heights Subwatershed Study (SWS)**, which updates the hydrologic and floodplain models; finalizes constraints mapping; identifies protective measures to protect, enhance or restore environmental features and functions; formulates alternative subwatershed management strategies; evaluates these strategies based on a range of environmental, social and cost considerations, together with stakeholder input; and selects a recommended subwatershed strategy from among the alternatives.

The Subwatershed Study will take an environment-first approach, fulfill the requirements of the Brantford Official Plan (OP) and also inform the preparation of block plans by guiding development in a manner that respects the local natural heritage system, natural hazards and supports long-term environmental sustainability.

1.1 Study Area and Land Uses

The Study Area for this subwatershed study encompasses two geographical areas within the City of Brantford; i.e., the North Brantford lands and Tutela Heights subwatersheds. Each of these subwatersheds has primary, secondary and tertiary Study Areas, which are described in **Sections 1.1.1** and **1.1.2,** respectively. However, efforts have been focused on the portions of the watersheds that fall within the primary Study Area, shown outlined in red on **Figure 1-1**.

Existing land use within the North Brantford and Tutela Heights subwatersheds is mainly rural in character and includes existing agricultural, residential, and highway commercial land uses. The Grand River is found at the Northeastern boundary of Tutela Heights subwatershed.

1.1.1 North Brantford

The North Brantford lands are located north of Powerline Road and Paris Road along the north side of the city, and east of Garden Avenue to the municipal boundary between the City of

Brantford and the County of Brant, with an approximate area of 2,123 hectares. Historically, the land use within the North Brantford Subwatershed was predominately agricultural with some forest and wetlands. Presently, the westernmost and easternmost portions of the subwatershed are designated primarily for Employment purposes, with the rest of them for Core Natural Areas. Meanwhile, the central part of the North Brantford Subwatershed is mainly planned for residential purposes, south of Core Natural Areas along Jones Creek and a large portion of rural area within the subwatershed.

The Primary Study Area for the North Brantford Area is roughly 2,123 hectares, including the lands east of Garden Avenue. Approximately 2,100 hectares of municipal Boundary Adjustment Lands obtained from the County of Brant in the North Brantford Area is the Secondary Study Area. The Tertiary Study Areas include lands of great significance to the subwatershed study, which are outside of the municipal boundary, including the catchment areas of Jones Creek and Fairchild Creek and their tributaries.

1.1.2 Tutela Heights

Tutela Heights subwatershed is bounded generally by Mt. Pleasant Road, Tutela Heights Road, and Phelps Road.

In the Tutela Heights area, the Primary Study Area is roughly 581 hectares, which is also the actual Boundary Adjustment Lands in Tutela Heights, and includes the same lands as the Secondary Study Area. The Tertiary Study Area is defined as the lands that form catchments of the tributaries to the Grand River, namely Phelps Creek.

Historically, the land use within the Tutela Heights Subwatershed was predominately agricultural with some forest and wetlands. Presently, community areas, rural areas and core natural areas comprise the whole subwatershed. No employment land use is designated within this area.

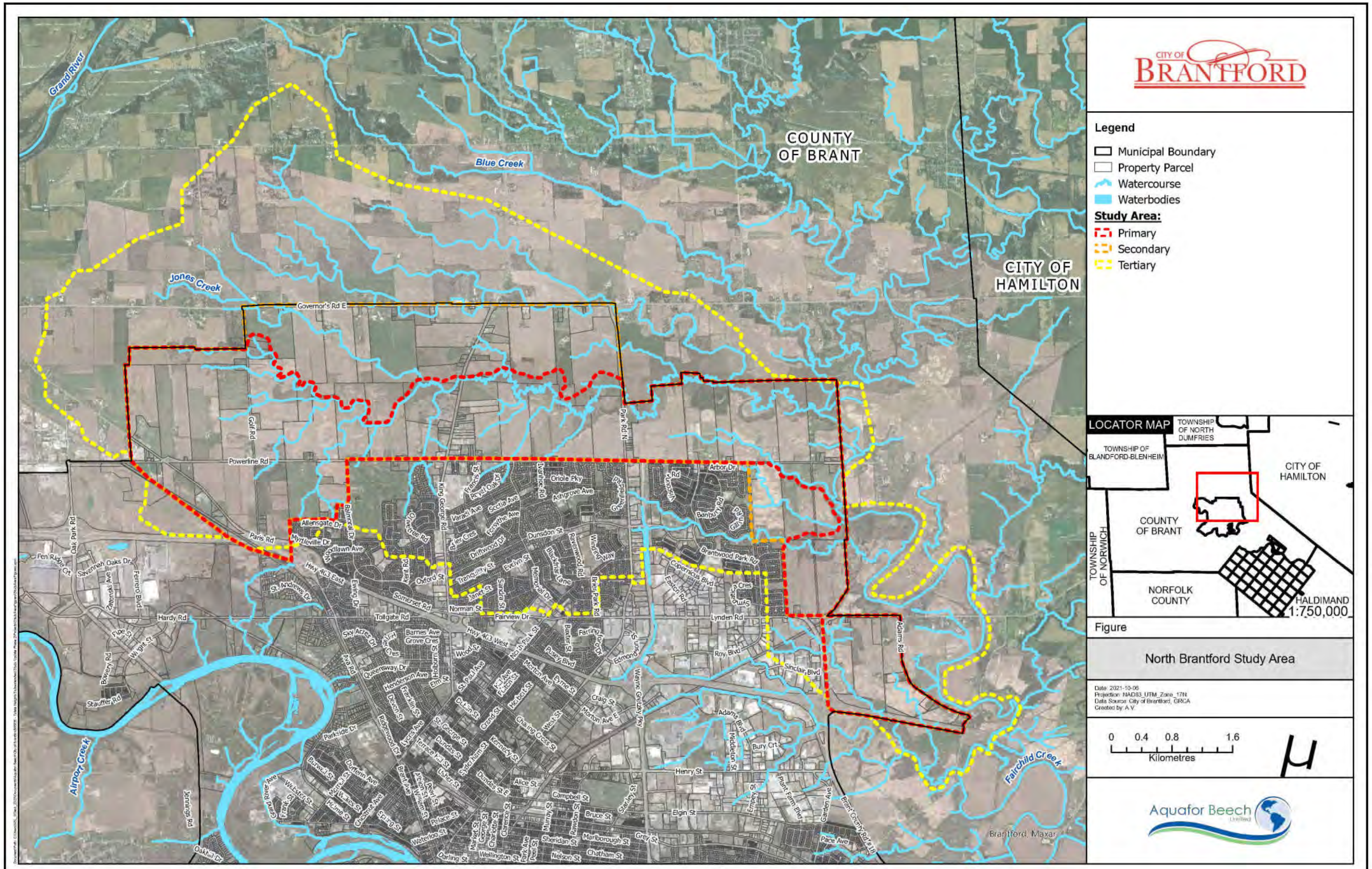


Figure 1-1: Study Area

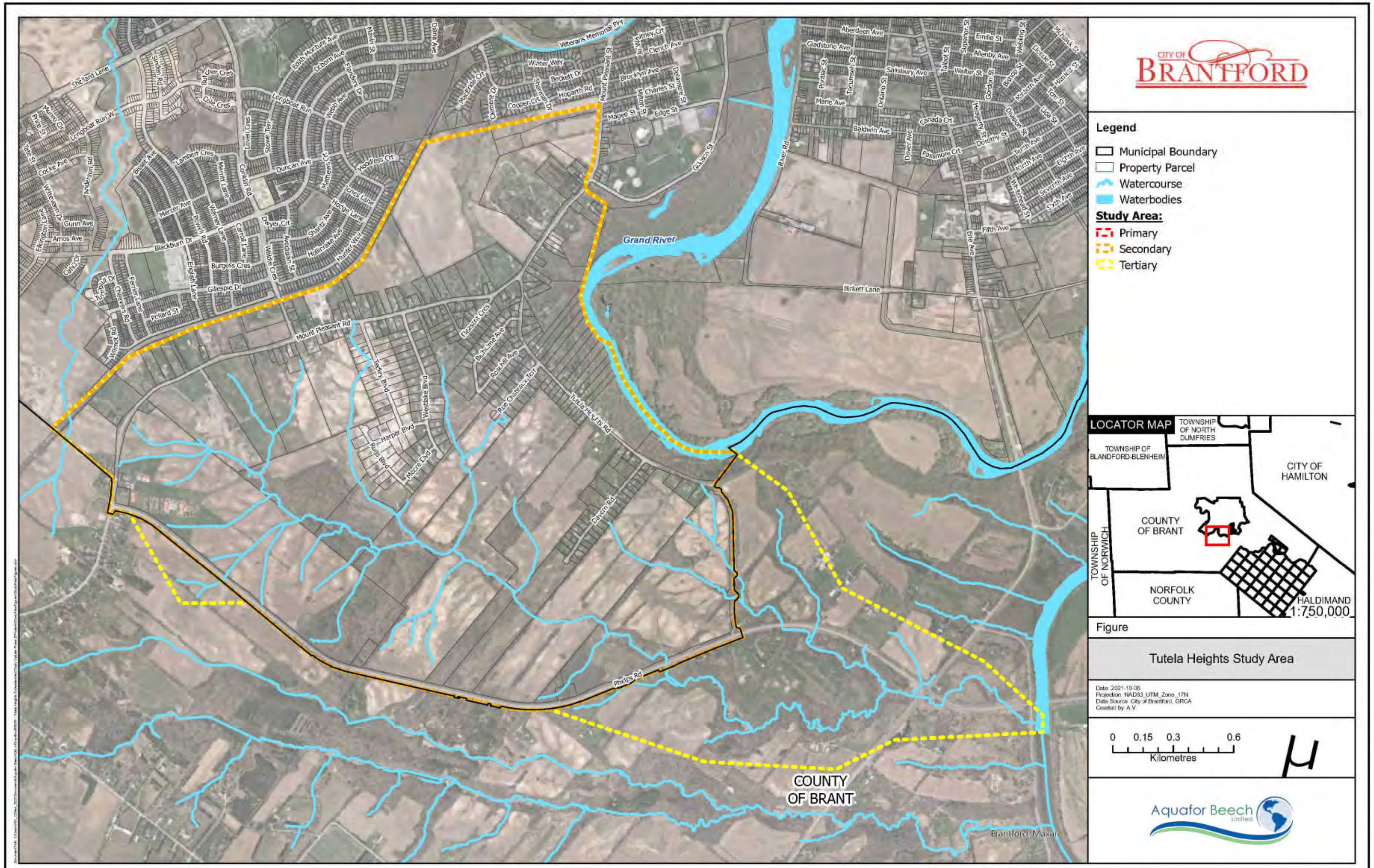


Figure 1-1 (cont'd)

1.2 Subwatershed Study Goals, Objectives, and Phasing

The overall goal of this Subwatershed Study may be defined as follows:

> "**Development of a management plan that allows sustainable urban growth, while ensuring maximum benefits to the natural and human environments on a watershed basis.**" – Watershed Planning in Ontario

The Subwatershed Study is undertaken in three phases. The objectives of this study are summarized below, according to the three study phases. **This report has been prepared to present the results for Phases 2 and 3 of the process.**

Phase 1: Subwatershed Characterization

- Identify and evaluate the location, extent, significance, and sensitivity of the existing natural features of the study area, together with their potential interrelationship with other natural features;
- Identify sensitive areas and natural hazard lands, together with recommend buffers, and select preliminary management practices for these lands; and
- Develop preliminary constraints and opportunities mapping to identify developable and non-developable lands which will inform the development and update of Secondary Plans within the Study Area.

Phase 2: Subwatershed Management Strategies

- Identify potential land use impacts to natural features and functions (Impact Assessment);
- Identify protective measures (best management practices, or BMPs) that, when implemented, will protect, enhance or restore environmental features and functions;
- Formulate alternative subwatershed management strategies;
- Evaluate each strategy, based on a range of environmental, social and cost considerations, together with stakeholder input; and
- Select from among the alternatives a recommended subwatershed strategy (or plan).

Phase 3: Implementation and Monitoring Plans

- Develop an Implementation Plan to ensure the long-term integrity of the Recommended Plan, including the identification of issues and areas where further detailed studies may be required at the draft plan of subdivision stage of the planning process, including the identification of issues and areas where further detailed studies may be required at the block plan or draft plan of subdivision stage of the planning process;
- Identify any future recommended monitoring studies or contingency plans; and
- Integrate the Subwatershed Study findings with Municipal Official Plan Policy and ongoing Block Plans.

1.3 Class Environmental Assessment (EA) Process

This Subwatershed Study is being conducted as a Municipal Class Environmental Assessment (Class EA). One public meeting is being held.

The relationship between the components of the Subwatershed Study process and the Class EA process is depicted in **Figure 1-2**.

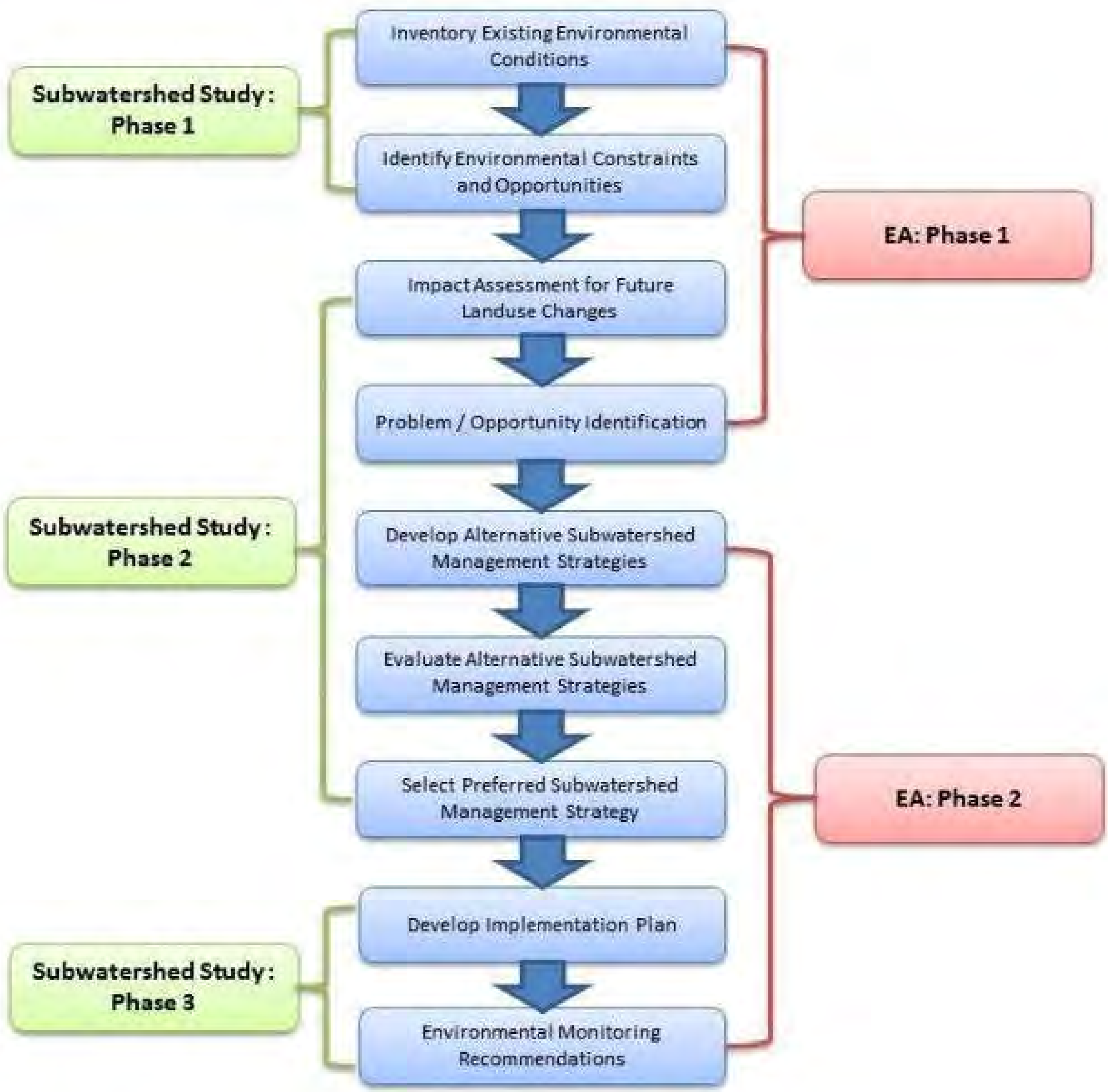


Figure 1-2: Subwatershed Study & Environmental Assessment Study Process

1.4 Block Plan Process within North Brantford and Tutela Heights

The City of Brantford Official Plan – Envisioning Our City: 2051 expanded the City's Settlement Area by approximately 900 hectares for urban land uses, in which nearly 400 hectares are designated as new Employment Areas and up to 500 hectares of the expansion lands are planned for community/ residential areas. The land uses and Block Plan areas for the North Brantford and Tutela Heights are shown in **Figure 1-3**.

The City of Brantford envisions to achieve a population of 165,000 residents and 80,000 jobs by the year 2051. To ensure the comprehensive and balanced growth of the City, the OP also requires the preparation of Block Plans for Community Areas in the lands annexed from the County of Brant. There are five (5) block plan areas within the North Brantford Subwatershed, i.e., Powerline West, Powerline Central, Powerline East, Balmoral and Lynden Garden. Similarly, three (3) residential areas were delineated in Tutela Heights Subwatershed. These Block Plans are to be prepared prior to the submission of development applications: Tutela Heights West, Tutela Heights South and Tutela Heights East. Lastly, the industrial lands will not be required to follow a comprehensive block planning process, but will still be required to follow the Subwatershed Study.

The outcomes of the North Brantford and Tutela Heights Subwatershed Study will include, but not be limited to, constraints mapping and a Stormwater Management Strategy. All Block Plans must comply with the outcomes of this Subwatershed Study.

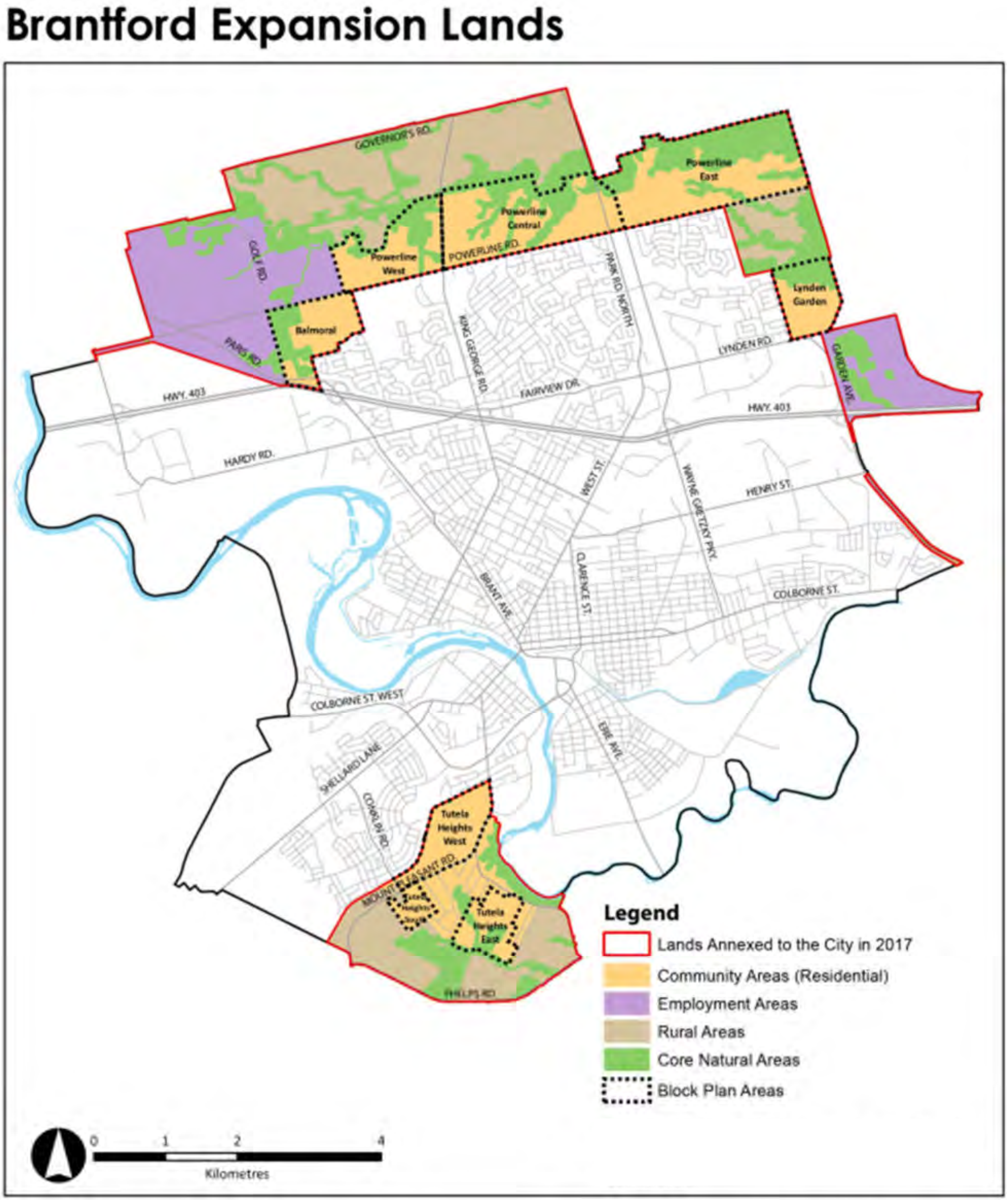


Figure 1-3 Land Uses and Block Plan Areas in the North Branford and Tutela Heights Subwatersheds (based on the City of Brantford Official Plan – Envisioning Our City: 2051)

2 Subwatershed Planning – Master Plan

The process of Subwatershed Planning has evolved over the last 20-30 years (**Figure 2-1**). The typical Subwatershed Plan of the 1980s, which was commonly termed "Master Drainage Plan", was primarily concerned with two issues: flooding and erosion. In the latter part of the 1980s, the plan evolved and typically dealt with the above issues as well as water quality and occasionally aquatic resources.

Subwatershed Plans have continued to evolve and now deal with numerous inter-related environmental issues including:

- surface water flooding, erosion, and water quality;
- groundwater quantity and quality;
- water budget (groundwater recharge, baseflows and peak flows);
- terrestrial and aquatic habitat;
- wetlands and woodlands, including woodlots and forests;
- Species at Risk;
- environmentally sensitive areas; and
- recreation and aesthetics.

Furthermore, the plans are ecosystem-based, with the potential interaction between each of the environmental features being strongly considered.

Integration of the Land Use Planning Process with Water Resource Management Planning has also evolved over the last 20-30 years. Whereas the historic practice in the mid-eighties involved the development of Official, Secondary and Draft Plans with nominal consideration of environmental consequences; present practice considers the two planning processes in unison.

As a result of ongoing updated policies, this Subwatershed-wide Master Plan becomes an integral part of the overall planning process to provide a solid foundation related to the environmental features that will be protected, enhanced, or restored under present conditions, and as land use changes occur.

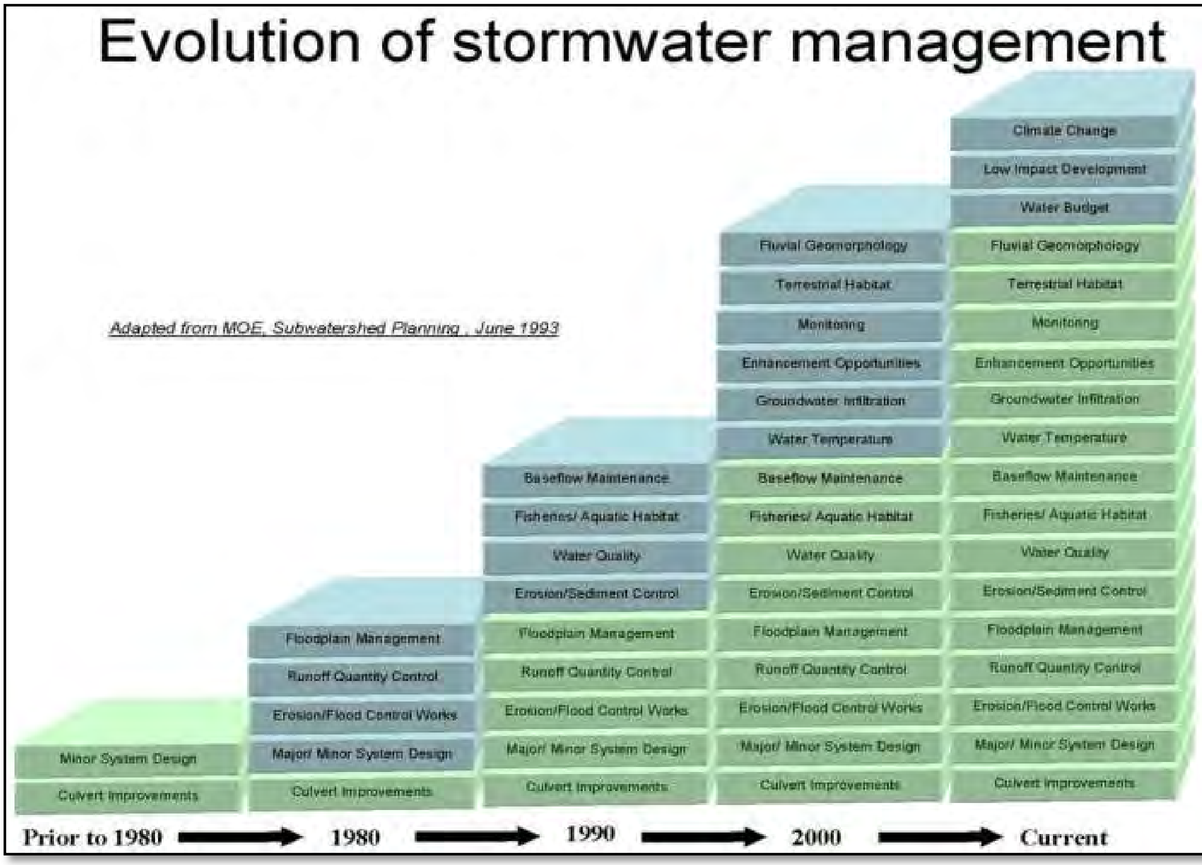


Figure 2-1: The Evolution of Stormwater Management in Ontario (adapted from MECP, 1993)

2.1 Provincial Stormwater Guidance Manuals

The "state-of-the-art" in stormwater management has been evolving rapidly. The MECP's 2003 Stormwater Management Planning and Design Manual (SWMPDM) provides an integrated approach to stormwater management that has been utilized across the province since its publication. The SWMPDM incorporates water quantity and erosion considerations. It also provides technical and procedural guidance for the planning, design, and review of stormwater management practices. The focus of the manual was broadened to incorporate the current multi-objective approach to stormwater facility planning to address targets related to hazards, water quality, fish habitat and recreation. Fundamental stormwater management objectives included in the 2003 SWMPDM include:

- Groundwater and baseflow characteristics are preserved;
- Water quality will be protected;
- Watercourses will not undergo undesirable and costly geomorphic change;
- There will not be any increase in flood damage potential; and ultimately,
- That an appropriate diversity of aquatic life and opportunities for human uses will be maintained.

A central theme of the SWMPDM is the application of a "treatment train", a term that is used to describe the combination of controls – source, conveyance and end-of-pipe controls - usually required in an overall stormwater management strategy to ensure that objectives are achieved. The SWMPDM states that:

> "the recommended strategy for stormwater management is to provide an integrated **treatment train approach** to water management that is premised on providing control at the lot level and in conveyance (to the extent feasible) followed by end-of-pipe controls. This combination of controls is the only means of **meeting the multiple criteria for water balance, water quality, erosion control and water quantity**."

The 2003 SWMPDM remains the go-to reference material for end-of-pipe stormwater management criteria and design requirements for wet ponds, constructed wetlands, hybrid wet pond/wetland systems, dry ponds and centralized infiltration facilities.

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. It is now understood that to effectively mitigate the impacts from urbanization, stormwater strategies must include a means to **reduce runoff volume** with the objective of maintaining the pre-development water balance. To meet the multiple objectives of stormwater management on a broad-scale, it is expected that a combination of source, conveyance and end of pipe controls will be required within Ontario's stormwater systems, an approach that has been supported by GRCA and the Municipality. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a LID Stormwater Management Guidance Manual. The draft manual outlines a Runoff Volume Control Target (RVC_T) to be used for new development; similar targets have since been implemented in the Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA).

3 Existing Subwatershed Conditions

The **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report** included an investigation of the subwatershed's existing conditions, including stream morphology, erosion, surface water quality, sediment quality, hydrogeology, aquatic ecology, terrestrial ecology, hydrology, stormwater infrastructure, and flooding.

The results from the Phase 1 Update identified areas to be protected from development, as well as opportunities for restoration and enhancement. As such, the priorities within the Phase 2 and Phase 3 investigations are to identify alternatives to enable development to proceed within the study area, considering best protection and enhancement of the subwatersheds.

Due to laboratory reporting periods, sediment loading to Jones Creek could not be evaluated during the Phase 1 Update report. As such, these results are presented below.

3.1.1 Sediment Loading into Fairchild Creek

The sediment regime within the creeks that drain the agricultural lands to the north and east of the study area were sampled for bedload composition and suspended sediment concentrations (**Figure 3-1**). Bedload samples were collected from the channel substrate using a dredge at low flow, while suspended sediment concentrations were recorded at the time of water quality testing during dry conditions. The purpose of this analysis was to determine the sediment flux from Jones Creek to Fairchild Creek. This analysis will review the existing conditions and serve as a baseline for future development related impacts to the watershed.

Four (4) bedload samples were collected with a manual dredge and processed at ALS Laboratories. The full report is presented in **Appendix A**. A summary of the sample analysis is presented here in terms of the grainsize collected. This is reported as the percentile of grains that are of the reported diameter or smaller. For example, the D_{50} represents the median grainsize, meaning that the value reported for the D_{50} means that ½ the grains (50%) are of that diameter or smaller, 10% of the grains are of the diameter equal to the D_{10} or smaller and all grains in the sample are equal to or smaller than the D_{100}.

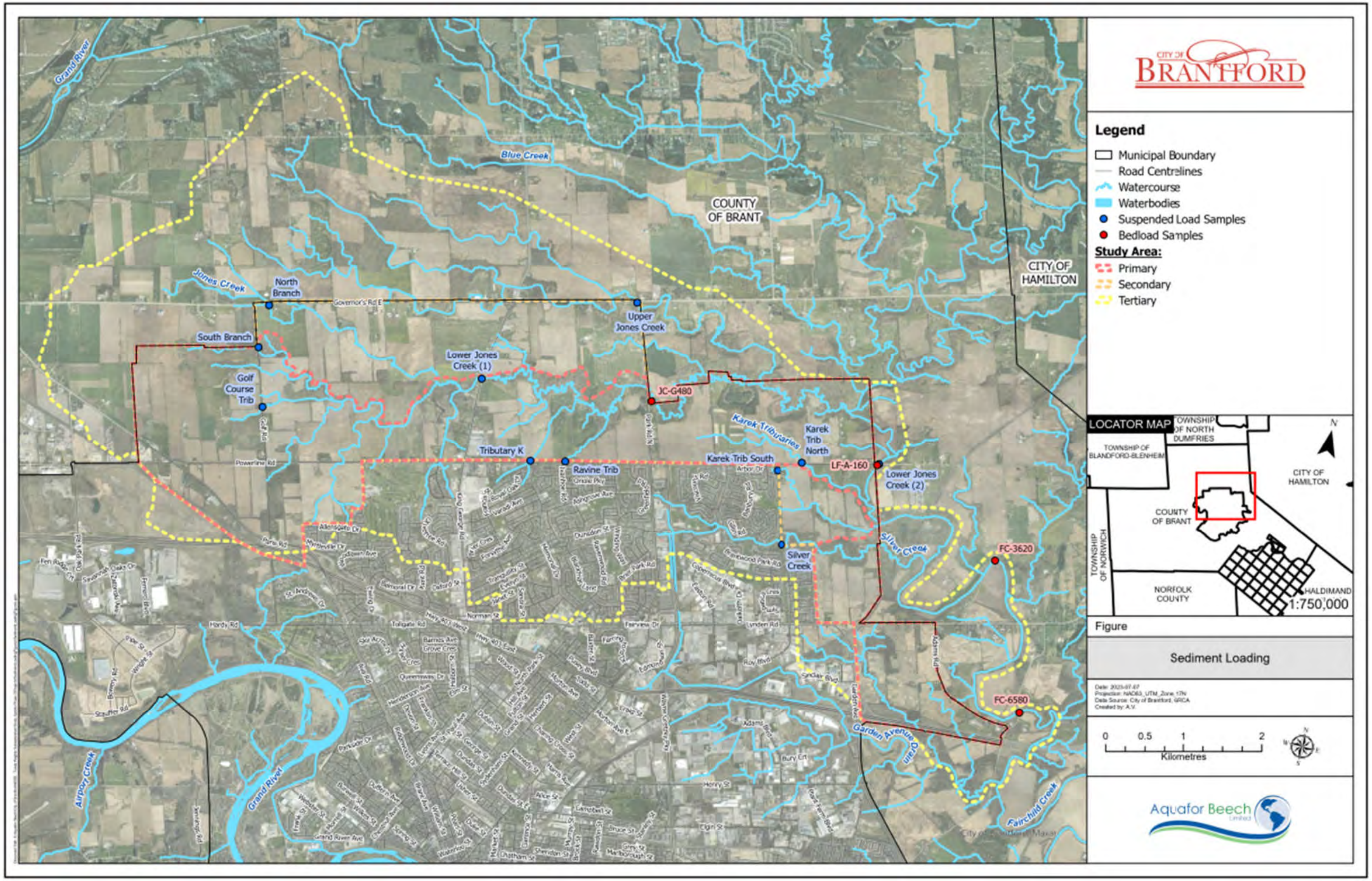


Figure 3-1: Location of Bedload and Suspended Sediment Samples

The most upstream Sample is JC-G480 which is representative of the Upper Jones Creek main channel. The Upper Jones Creek substrate is composed mainly of silt to fine sand (**Figure 3-2**). This sediment is derived from the local bank material and surrounding agricultural land use. The lack of riparian buffers and sediment control measures has contributed to a high fraction of silt and clay material in these headwaters.

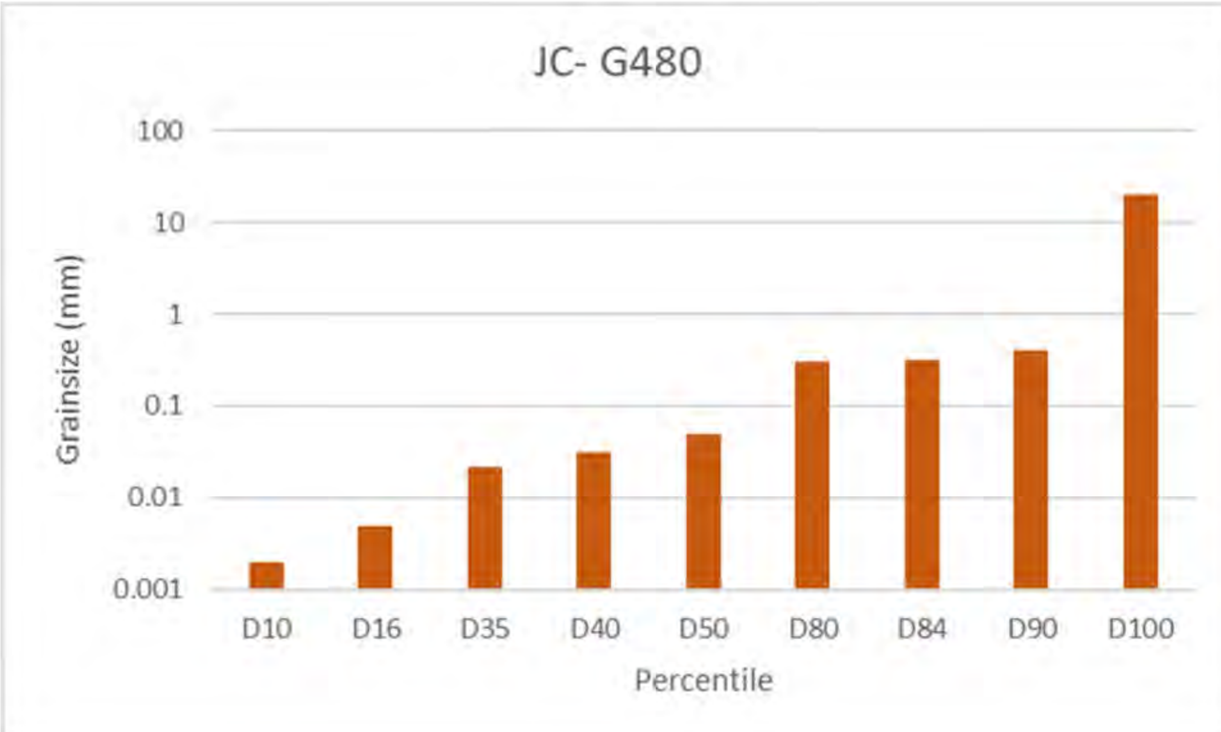


Figure 3-2: Grainsize Distribution of the Upper Jones Creek Bedload

Further downstream, Sample LF-A 160 (**Figure 3-3**) was taken from the Lower Jones main channel. This bedload has an increased fraction of silt material than the Upper Jones Creek substrate, however coarser gravel material is also present, despite the lower velocities recorded in the lower reaches due to backwater conditions. The dominance of silt material is a result of those factors associated with the Upper Jones Creek sediment regime, namely; agricultural runoff.

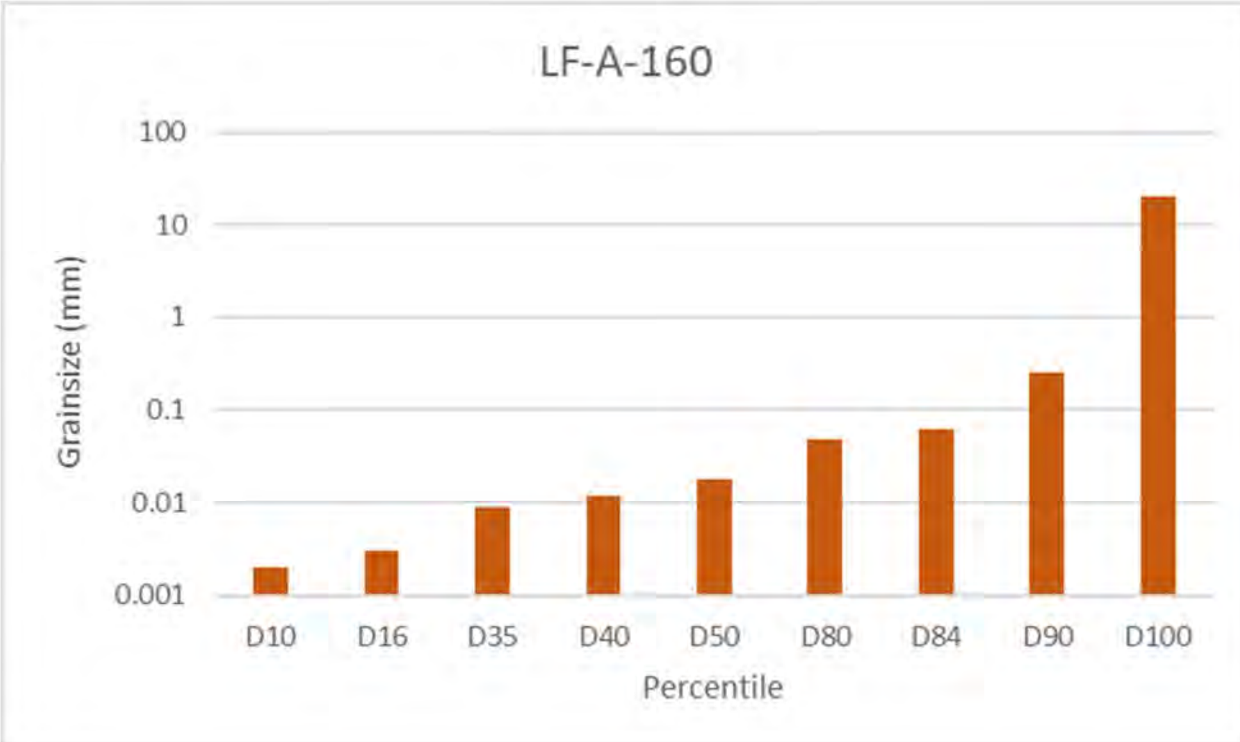


Figure 3-3: Grainsize Distribution of the Lower Jones Creek Bedload

The Fairchild Creek bedload (**Figure 3-4**) is nearly identical to the Jones Creek sediment load, in terms of range and sorting. The dominant sediment is silt, with a higher fraction of gravel sized material than the Lower Jones Creek bedload. Velocities were not evaluated for Fairchild Creek as a part of this study, however increases in meander amplitude and sinuosity relative to Jones Creek suggest a gentler gradient, and therefore the topography favors a smaller grainsize.

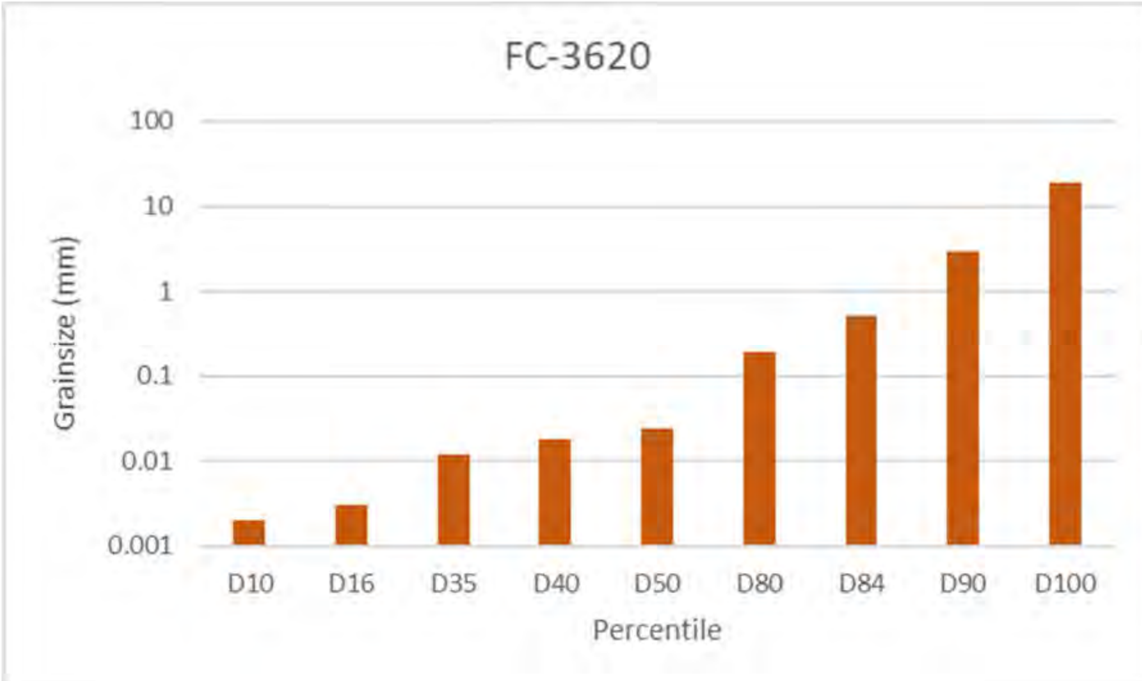


Figure 3-4: Grainsize Distribution of the Fairchild Creek Bedload

Sample FC-6580 (**Figure 3-5**) was taken nearly three (3) kilometers downstream from Sample FC-3620, in Fairchild Creek. This sample was meant to be representative of the Fairchild Creek sediment regime, without the direct and immediate influence of the Jones Creek sediment input. The inherent sediment regime of Fairchild Creek is mud (silt and clay) dominant.

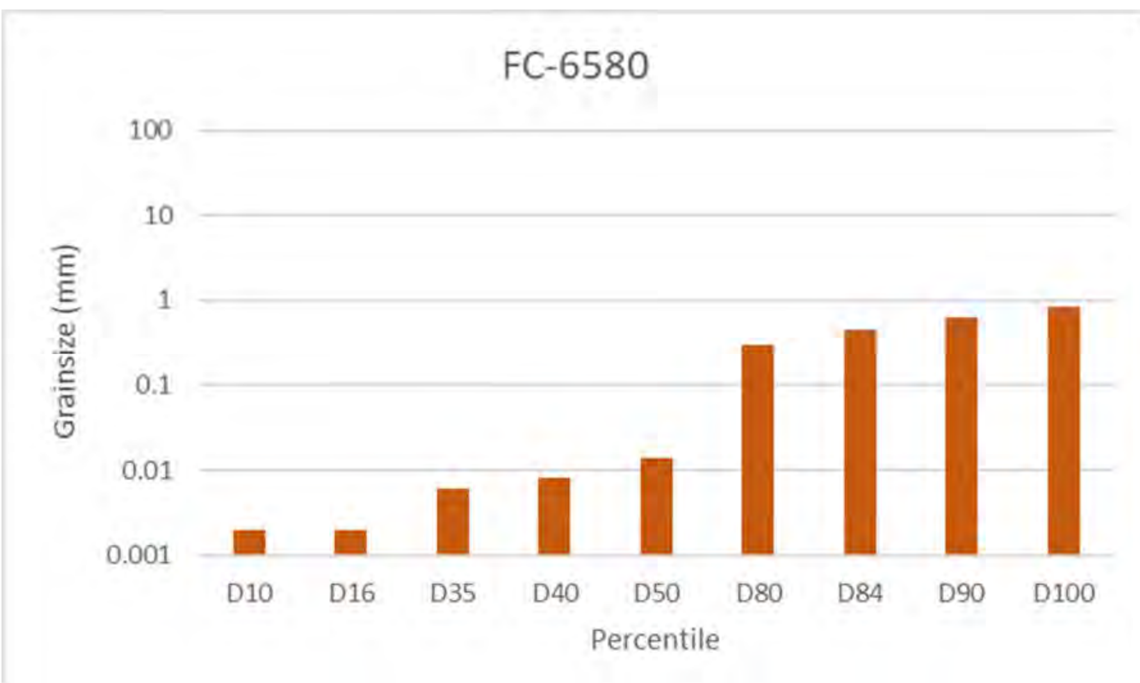


Figure 3-5: Grainsize Distribution of the Lower Fairchild Creek Bedload

With a clay fraction of approximately 15 to 20% in Jones Creek, and an assumed background clay fraction of over 30% in Fairchild, high level estimates suggest that Jones Creek may contribute as much as half the bedload sediment flux into Fairchild Creek downstream of the confluence.

Suspended sediment values taken at water quality sites (**Figure 3-1**) show that, while Jones Creek suspended load input at low flow is elevated in the Lower Jones Creek reaches, the sediment concentration from Silver Creek is nearly three (3) times as high, likely due to its steeper gradient and steep valley setting. A summary of the suspended sediment loadings by watercourse is presented in **Figure 3-6**.

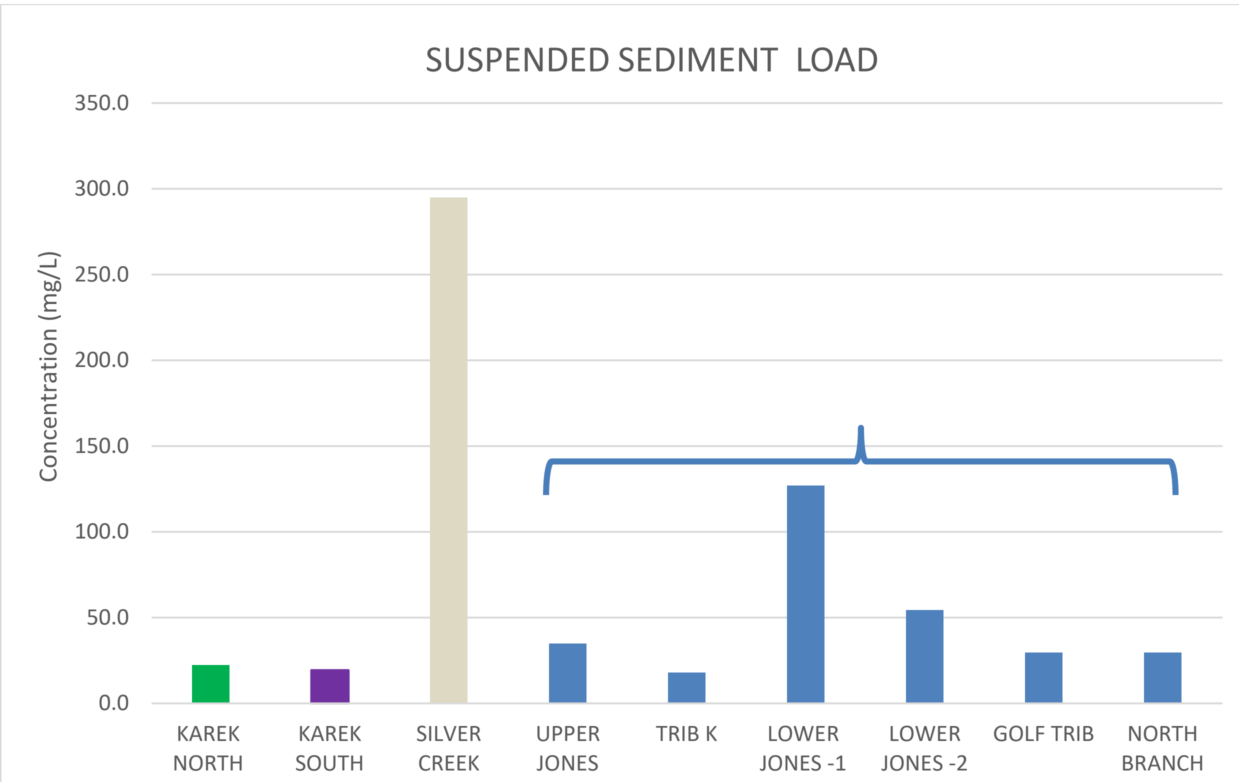


Figure 3-6: Suspended Sediment Concentrations

A summary of all sediment concentrations and bedload grainsize percentiles is presented in **Table 3.1**.

Table 3.1: Sediment Loading Values by Watercourse

SAMPLE	WATERCOURSE	SUSPEND LOAD		BED LOAD										
		Sample location	Suspended Solids	Sample ID	sample location	D_{10}	D_{16}	D_{35}	D_{40}	D_{50}	D_{80}	D_{84}	D_{90}	D_{100}
Lowest Detection Limit			3.0			0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Units			mg/L			mm	mm	mm	mm	mm	mm	mm	mm	mm
KAREK NORTH	North Karek Creek	At Powerline Rd	22.2	not sampled		-	-	-	-	-	-	-	-	-
KAREK SOUTH	South Karek Creek	At Powerline Rd	19.4	not sampled		-	-	-	-	-	-	-	-	-
SILVER CREEK	Silver Creek	In Friendship Park south of Ludlow Cres	295	not sampled		-	-	-	-	-	-	-	-	-
UPPER JONES	Jones Creek Tributary	Tributary at Governor's Rd and Park Rd	34.6	not sampled		-	-	-	-	-	-	-	-	-
TRIB K	Jones Creek Tributary	At Powerline Rd	17.8	not sampled		-	-	-	-	-	-	-	-	-
LOWER JONES -1	Jones Creek	King George Rd between Governor's Rd and Powerline Rd	127	JC- G480	Park Rd between Governor's Rd and Powerline Rd	0.002	0.005	0.022	0.031	0.049	0.3	0.31	0.4	20
LOWER JONES -2	Jones Creek	At Powerline Rd	54.5	LF-A-160	At Powerline Rd	0.002	0.003	0.009	0.012	0.018	0.049	0.063	0.25	20
GOLF TRIB	Jones Creek Tributary	At Golf Rd	29.6	not sampled		-	-	-	-	-	-	-	-	-
NORTH BRANCH	Jones Creek Tributary	At Governor's Rd	29.6	not sampled		-	-	-	-	-	-	-	-	-
UPPER FAIRCHILD	Fairchild Creek	not sampled	-	FC-3620	At McMillan Rd	0.002	0.003	0.012	0.018	0.024	0.19	0.51	3	19
LOWER FAIRCHILD	Fairchild Creek	not sampled	-	FC-6580	Fairchild CreekJohnson Rd	0.002	0.002	0.006	0.008	0.014	0.3	0.45	0.62	0.85

4 Future Subwatershed Conditions

Future conditions were developed based on the City of Brantford Official Plan – Envisioning Our City: 2051, which provides future land use conditions. The future conditions also account for the constraints to development that were delineated as part of the **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report**. The subcatchments that were delineated during the Phase 1 study were modified, as needed, to account for anticipated changes associated with future development. **Figure 4-1** presents the future proposed land use.

Within North Brantford, future development will largely be residential, with employment areas on the east and west sides of the City. Within Tutela Heights, future development will be entirely residential.

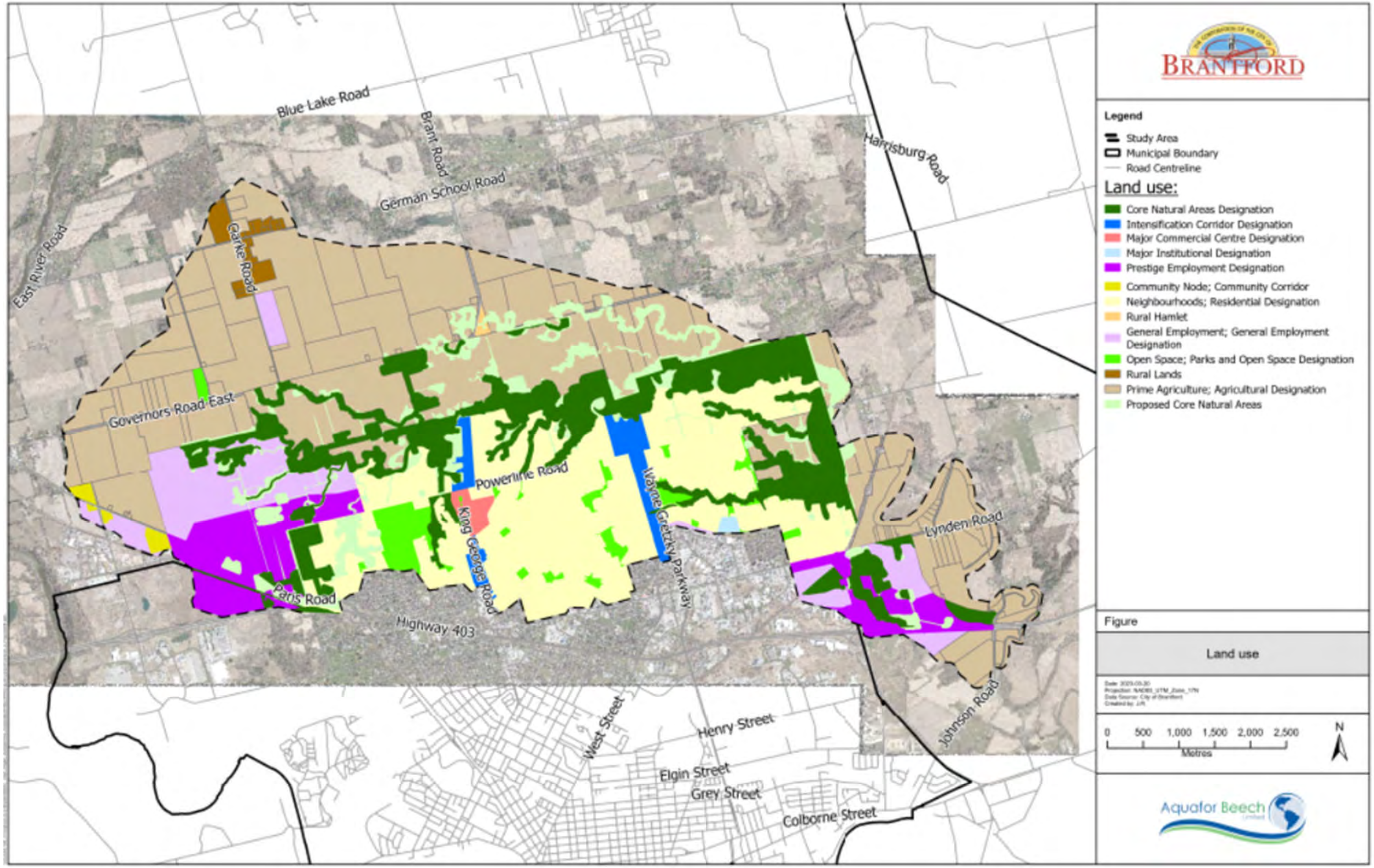


Figure 4-1: Proposed Land Use

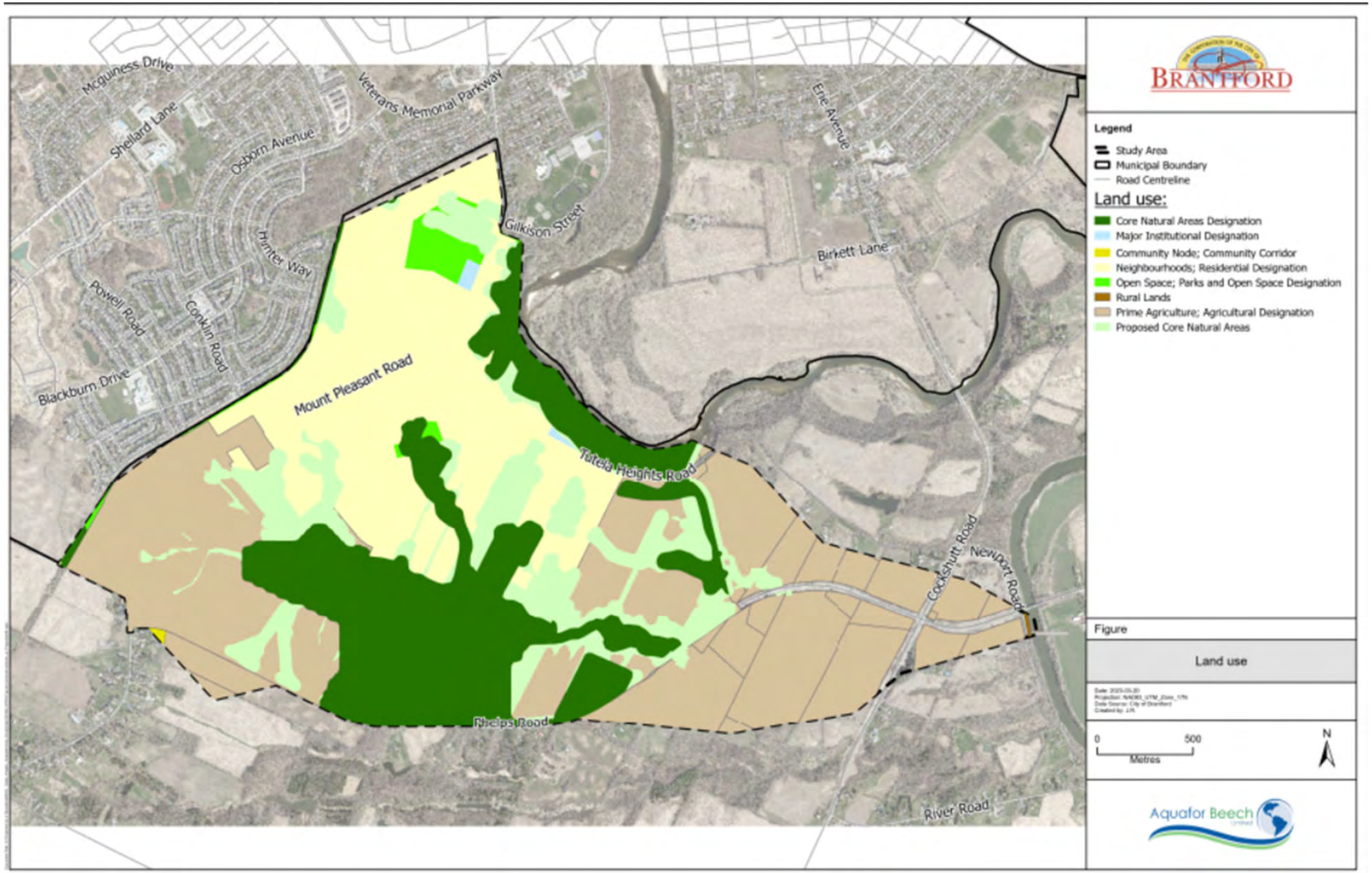


Figure 4-1 cont.

4.1 Potential Impacts Associated with Land Use Changes

4.1.1 Potential Stormwater Impacts

This section provides a brief overview of the general stormwater impacts which are directly associated with changes to the hydrologic regime due to urban development. This includes impacts to:

- the overall hydrologic cycle or water balance;
- water quality;
- stream erosion; and
- flooding.

Note that, in addition to the direct impacts noted above, stormwater impacts from urban development can also have a significant effect on many other natural resources including aquatic and terrestrial communities and their habitat.

4.1.1.1 Potential Impact to Groundwater and Water Balance

Significant Groundwater Recharge Areas (SGRAs) are defined as areas where the rate of groundwater recharge exceeds the watershed's annual rate of recharge by a factor of 1.15 or more. They are also referred to as High Volume Recharge Areas (HVRAs). These areas are recognized as provincially significant for groundwater protection. Areas of significant groundwater recharge were identified in the **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report** While there are limited shallow aquifer resources within the North Brantford and Tutela Heights study areas, there are high recharge areas and significant aquifer resources west and south of the North Brantford area. Recharge in these neighbouring areas likely supply the deeper overburden and bedrock aquifers that underly the study area. The model indicates that there are some recharge fed stream reaches in the western portion of the study area. There were no significant recharge areas or shallow groundwater resources in the Tutela Heights study area.

Without controls, the impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface water runoff instead (**Figure 4-2**). This alteration to the water budget, in turn, can contribute to increased rates of flooding, erosion, and pollutant loadings, having a negative impact to the surrounding natural heritage features. The corresponding reduction in groundwater levels can also result in reduced supplies of clean, cool baseflows to area streams, thereby negatively impacting downstream aquatic communities. As such, mitigating the impacts to the overall site and feature-based water balances is a requirement of development approval.

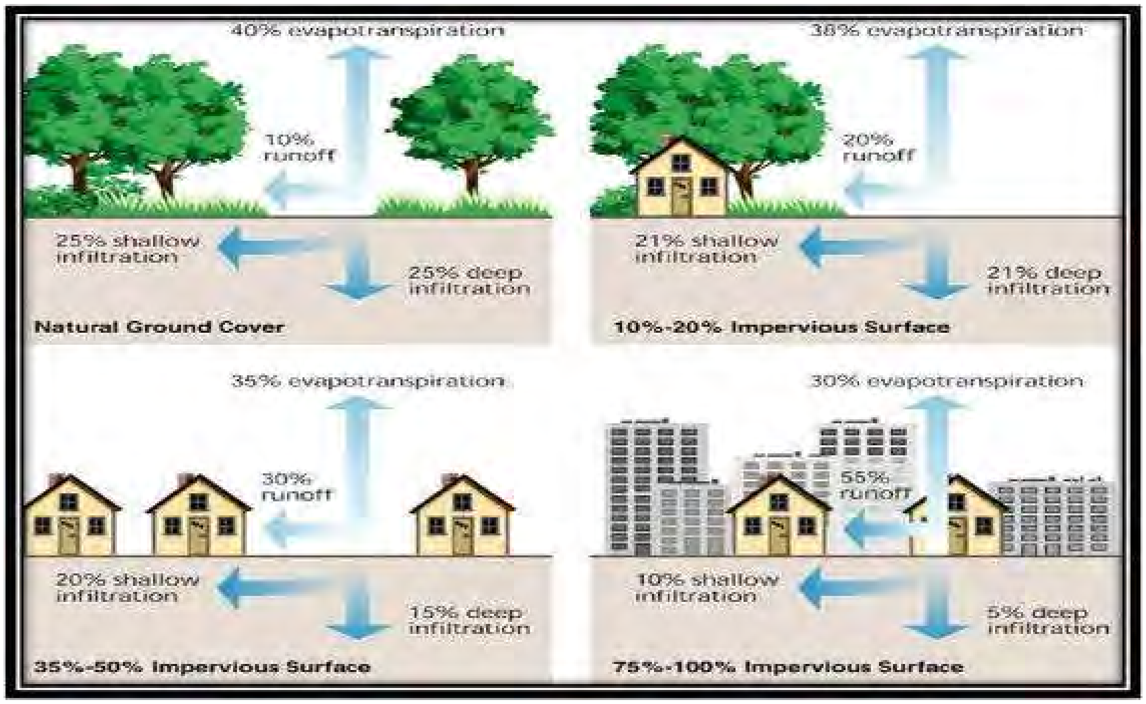


Figure 4-2: **Example of General Water Budget Impacts Due to Development**

4.1.1.2 Potential Impact to Water Quality

The protection of surface water quality within the study area is a key objective. Water quality has a strong influence on the health of fish and other aquatic communities, and also determines the suitability of water for drinking, recreation, fishing, wildlife and general aesthetics.

Stormwater runoff from urban sources typically contains elevated levels of contaminants such as sediment (i.e., suspended solids), nutrients (e.g., phosphorous, etc.), metals (e.g., copper, lead, zinc, etc.), and bacteria. Therefore, without controls, future urban development will result in increased pollutant loadings to the area streams. This, in turn, can contribute to degraded aquatic habitat and increased health risks associated with various recreation activities (**Figure 4-3**).

Figure 4-3: **Water Quality Impacts**

4.1.1.3 Flood and Erosion Impacts

With urbanization there is a typical hydrologic response from the developed land. This generally involves an increase in peak flow rates and runoff volumes, and a decrease in the time-to-peak flow. These effects commonly occur with increased impervious surface areas and improved stormwater drainage systems which are typical of the change from rural to urban land use. The increased runoff volumes and flow rates can result in increased rates of erosion and flooding (**Figure 4-4**).

Figure 4-4: **Examples of Flooding and Erosion Impacts**

4.1.2 Potential Terrestrial and Aquatic Ecological Impacts

This section provides a preliminary discussion of impacts to the natural environment resulting from land use changes and urban development. Additional discussion specific to the study area is provided in later sections of this report.

Natural heritage features within the study area were identified and discussed in detail in the North Brantford and Tutela Heights Subwatershed Study Phase 1 report. Direct, negative impacts to the identified ecological features and functions may be generally attributed to two categories: direct loss of features or functions (e.g., due to removal of vegetation, channelization or piping of watercourses, changes to water chemistry due to stormwater/wastewater input, etc.); and fragmentation or isolation of retained natural areas due to the creation of barriers (e.g., roads) which limit movement and dispersal of species using those areas. Indirect negative impacts may also occur where land use changes adjacent to natural areas bring an increase in noise, light, or human activity that affects species' behaviour (e.g., vocalization). There is also the potential for positive impacts to occur in locations where naturalization or restoration efforts are carried out.

Preservation of natural cover on the landscape is crucial for maintaining the health and functionality of a watershed, as natural cover provides wildlife habitat, supports water quality and flood control, and contributes to air quality and carbon sequestration. Both the North Brantford and Tutela Heights study areas have already experienced a high degree of clearing and development with additional intensive development proposed throughout. Phase 1 of the SWS identified features and areas which met the criteria for inclusion in the City's Natural

Heritage System; these features have been carried forward as environmental constraints and must have an appropriate buffers and setbacks applied in keeping with the requirements of the City of Brantford's OP and any additional applicable requirements (e.g., recommendations of this SWS). Features which did not meet the minimum requirement for inclusion in the NHS are not protected features per existing policies and regulations, but their removal would still represent a loss of natural cover on the landscape. Retention of these features in parklands, stormwater management blocks, or other similar features wherever possible is recommended. If these features/areas are proposed for removal, ecological offsetting is strongly recommended at the site plan or similar stage of proposed development to ensure no net loss of natural cover, and may be required as a condition of site plan approval where impacts to or removal of natural features or areas are proposed.

Land use changes can create barriers to ecological processes (e.g., wildlife movement, seed dispersal) where previously such barriers did not exist. Roads, in particular, act as barriers to wildlife movement and often result in wildlife mortality due to collisions with vehicles. Where new roads are proposed in the study area, it is first and preferentially recommended that these be sited such that they do not encroach on natural heritage features. Where siting of roads cannot avoid impacting natural areas or potential linkages, it is recommended that measures are incorporated to facilitate wildlife movement – e.g., oversized drainage culverts with a terrestrial 'bench' to allow wildlife passage, or dedicated wildlife tunnels separate from the drainage culverts, with the associated exclusion fencing placed along habitat boundaries to direct wildlife to the crossing locations. Existing aquatic culverts may be retrofitted or replaced during redevelopment to provide similar wildlife crossing considerations as well as to remove barriers to fish passage and improve aquatic habitat. In all cases, the culvert design process should ensure appropriate sizing and siting to allow for water flow, fish passage, and terrestrial wildlife movement.

Further discussion related to natural heritage and related requirements is provided in **Sections 7.2** and **8.4.2**.

5 Alternative Stormwater Strategies

Three potential stormwater management control approaches were considered as part of the process, and are described in the subsequent sections below:

1. Do Nothing
2. Traditional (Conventional) Stormwater Management
3. Traditional Stormwater Management and Low Impact Development (LID)

5.1 Do Nothing Approach

This scenario illustrates the impacts if no stormwater management is applied. For this study, the "Do Nothing" approach refers to not providing any form of water quantity control for new development within the Expansion Lands. Development using this approach would cause significant environmental and ecological degradation, contravene municipal, provincial and federal policy, as well as fail to meet the study purpose.

5.2 Traditional (Conventional) Stormwater Management

The traditional stormwater management approach involves establishing an end-of-pipe stormwater management facility (i.e., a wet pond or hybrid wetland-wet pond) within each new development area. For new development areas, siting and preliminary design of the stormwater management facility would be undertaken as part of the Block Plan process. It is most technically and economically feasible to place stormwater management facilities at site locations that are conducive to gravity drainage without excessive land grading. Stormwater management facilities typically discharge to natural drainage features (creeks, rivers, wetlands and lakes) or engineered conveyance structures such as ditches, swales, channels or pipes.

Wet ponds or hybrid wetland-wet ponds use active storage detention and elongated flow paths through the facility to settle suspended sediments and associated pollutants. Both facility types require a forebay for pre-treatment and easier maintenance. While both facilities can be designed to meet MECP's enhanced level of water quality treatment corresponding to a long-term sediment removal efficiency of 80%, the wetland component of a hybrid design provides enhanced biological removal during the summer months.

Figure 5-1: A wet pond SWM facility provides water quality treatment via the settlement of suspended pollutants and flood control via the temporary detention and peak flow reduction

5.3 Traditional Stormwater Management and LID Approach

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff volume 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. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows. The key principles for Low Impact Development Design are to "soak it up or slow it down":

1. **Use existing natural systems as the integrating framework for planning;**
   - Consider regional and watershed scale contexts, objectives and targets;
   - Look for stormwater management opportunities and constraints at watershed/subwatershed and neighbourhood scales;
   - Identify and protect environmentally sensitive resources; and,
   - Restore, enhance, and expand natural areas.
2. **Focus on runoff prevention**
   - Minimize impervious cover through innovative site design strategies and application of permeable surfaces;
   - Incorporate green roofs and rainwater harvesting systems in building designs;
   - Drain roofs to pervious areas with amended topsoil or stormwater infiltration practices; and,
   - Preserve existing trees and design landscaping to create urban tree canopies.
3. **Treat stormwater as close to the source area as possible**
   - Utilize decentralized source and conveyance stormwater management practices as part of the treatment train approach;
   - Flatten slopes, lengthen overland flow paths, and maximize sheet flow; and,

- Maintain natural flow paths by utilizing open drainage (e.g., swales).

4. **Create multifunctional landscapes**
   - Integrate stormwater management facilities into other elements of the development to conserve developable land;
   - Utilize facilities that provide filtration, peak flow attenuation, infiltration and water conservation benefits;
   - Design landscaping to absorb runoff, decrease need for irrigation, urban heat island effect and enhance site aesthetics.

LID stormwater management practices used together with conventional stormwater management as part of an overall holistic treatment train approach have been shown to better meet stormwater management targets and objectives, provide better performance, are more cost effective, have lower maintenance burdens, and are more protective during extreme storms than conventional stormwater practices alone. The underlying concept is that each LID stormwater management and traditional practice within the treatment train provides successive storage, attenuation and water quality benefits.

Figure 5-2 illustrates the generalized impact of a holistic approach to stormwater management on the four (4) primary and most common stormwater management objectives when LID and conventional stormwater management solutions are used.

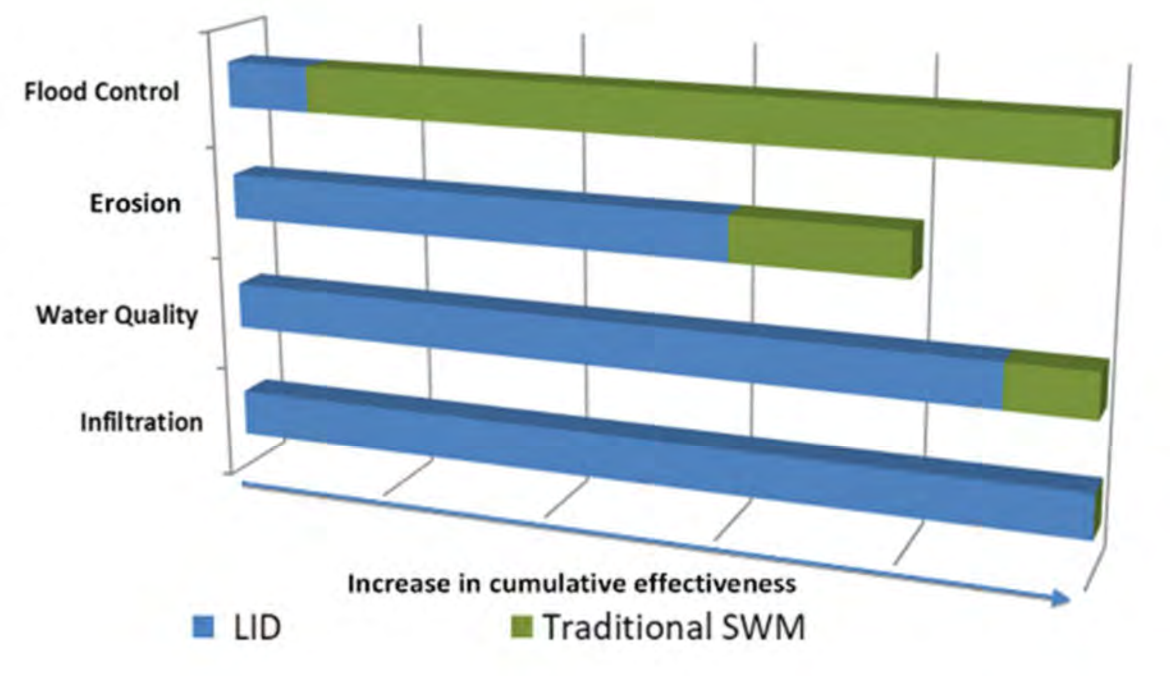


Figure 5-2: The Rationale for the Traditional Stormwater Management and LID Approach

Additional site-specific field studies (e.g. meander belt analysis, slope stability analysis, wetland boundary delineation) may be required to address any remaining data and information gaps pertaining to natural hazards within the North Brantford and Tutela Heights study areas, in accordance with GRCA policy. The GRCA is to confirm whether they will accept quantity and/or quality control volume reductions for LID measures constructed within the catchment of a SWM pond.

In this strategy, LIDs are incorporated into new development areas to provide water quality control via runoff volume reductions and filtration. Where these LIDs can treat the runoff generated from the 90th percentile event, the end of pipe facilities can be designed to provide water quantity control only. For these catchment scenarios, a dry stormwater management pond and/or multi-use flood storage facility may be feasible. In new development areas where LIDs can treat only a portion of the runoff, the end-of-pipe facilities will need to provide a volume of water quality storage.

The traditional (conventional) stormwater management and LID approach can be developed in a way that fosters complete corridors wherever possible throughout the study subwatersheds, whereby stormwater management features are integrated with natural heritage, open space and recreational opportunities. This involves properly integrating green infrastructure with consideration for passive, ecologically supportive land uses adjacent to creek and tributary corridors. The complete corridor approach is a proactive way to protect, maintain, rehabilitate and/or restore critical ecological function. Properly implemented, a complete corridor provides continuous natural area and enhanced ecological connectivity for the movement of water, wildlife and people.

5.3.1 Low Impact Development (LID) Approach

In October 2022, a meeting was held with the City to discuss the use of LIDs, and to confirm the City's acceptance of various LID measures for different land uses. Both the City of Brantford and GRCA accept the use of LIDs for stormwater management. Pending GRCA confirmation, LID measures will be accepted to meet design criteria associated with water quality, erosion control, or water balance, but not for quantity control. However, LIDs on residential lots are not accepted for meeting water quality, erosion control, or water balance criteria because homeowners frequently modify their properties and there is no guarantee of the facility's longevity. Slides from this presentation are included as **Appendix B.**

To provide water quality, water balance, and erosion targets, LID practices will be integrated on municipal property (road ROWs, parks, municipal buildings, etc.) and on private property (commercial, institutional and industrial (ICI) properties). This approach requires performance verification and a maintenance framework to be approved by GRCA.

Low Impact Development stormwater management practices that are accepted to meet design criteria associated with water quality, erosion control or water balance are listed in **Table 5.1,** including their general classification.

Table 5.1: LID Stormwater Management Practices

<table>
<tr><th>LID BMP</th><th>Notes</th></tr>
<tr><td>Soakaways, Infiltration Trenches and Perforated Pipe Systems (including pervious catch basins)</td><td rowspan="2">Suitable for use within the road right-of-way or on public and private (ICI) sites to control runoff at the source</td></tr>
<tr><td>Bioretention/ Bioswales (a.k.a rain gardens)</td></tr>
<tr><td>Rain water harvesting</td><td rowspan="2">Suitable for use on public and private (ICI) sites to control runoff at the source</td></tr>
<tr><td>Permeable Pavements</td></tr>
</table>

In addition to the LID BMPs listed in **Table 5.1**, the use of scarified subsoil, amended topsoil, and extra topsoil depth on yards is recommended on all sites to reduce post-development runoff volume, but these amendments will not be accepted to meet water quality, erosion control or water balance criteria.

Specific types of LID practices that are generally appropriate for different land uses are listed in **Table 5.2**.

Table 5.2: Municipal LID Applicability by Land Use

<table>
<tr><th colspan="2">Land Use</th><th>Single Family Residential</th><th>Multi-Family (Medium Density)</th><th>Multi-Family (High Density)</th><th>Industrial, Commercial & Institutional</th></tr>
<tr><td colspan="2">Soil Amendments</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td rowspan="3">Perforated Pipe (PP)</td><td>PP as Storm Sewer</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Parallel PP (“3rd Pipe”)</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Grassed Swale PP System</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Permeable Pavements</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Bioretention, Bioswales and Enhanced Swales</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Soakaway Pits, Infiltration Trenches and Chambers</td><td></td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Green Roofs</td><td></td><td></td><td>✓</td><td>✓</td></tr>
<tr><td colspan="2">Rainwater Harvesting</td><td></td><td></td><td>✓</td><td>✓</td></tr>
</table>

5.3.1.1 LID Approach for Municipal ROW

LID SWM practices that would be incorporated into an overall municipal stormwater management approach include:

Soil Amendments - Compost amendments are tilled or mixed into existing soils thereby enhancing or restoring soil properties by reversing the loss of organic matter and compaction (**Figure 5-3)**. They also are used to make Hydrologic Group C and D soils suitable for on-site stormwater BMPs such as downspout disconnection, filter strips, and grass channels etc. Soil amendments benefits include increased infiltration, stormwater storage in the soil matrix, survival rate of new plantings, root growth and stabilization against erosion, improved overall plant/tree health and decreased need for irrigation and fertilization of landscaping. Amended soils are suitable for any pervious area where soils have been or will be compacted by the grading and construction process. While soil amendments will never be used solely to meet stormwater management objectives, they are effective in reducing the overall runoff volume, will contribute to a lower peak discharge, and can help improve water quality by reducing contaminant loads. Soil amendments can be applied on private property and do not require ongoing maintenance activities.

Perforated Pipe Systems - Perforated pipe systems, also called exfiltration systems, can be thought of as long infiltration trenches that can be designed for both conveyance and infiltration of stormwater runoff (**Figure 5-3)**. They are underground stormwater systems composed of perforated pipes installed in gently sloping granular stone beds lined with geotextile fabric that allows infiltration of runoff into the granular bed and underlying native soil. Perforated pipe systems can be used in place of almost any conventional storm sewer pipes where topography, water table depth, and runoff quality conditions are suitable. They are capable of handling runoff from roofs, walkways, parking lots, and roads. For road applications, these systems can be located within boulevard areas or beneath the roadway surface itself. There are three configurations of perforated pipe systems that are feasible within residential road rights-of-way. The first is a perforated pipe system that functions as the minor system conveyance. The second is a perforated pipe that runs parallel and discharges to the conventional storm sewer. Because the conventional storm sewer meets conveyance requirements, the parallel pipe (also known as a "3rd pipe system") can be sized to infiltrate smaller volumes. This configuration is shown in the associated figure and is consistent with the PCSWMM modeling approach used for this study. The third configuration is a catchbasin lead to either a perforated or solid pipe that conveys flows to an infiltration chamber within the municipal ROW. There are also perforated pipes available up to 1200mm in diameter that can be used instead of a solid walled storm sewer to promote infiltration.

Soakaway Pits, Infiltration Trenches and Chambers - Soakaways, infiltration trenches and chambers can be used to reduce runoff volume and maintain or enhance recharge (**Figure 5-3)**. Most surface areas can be directed to infiltration practices without pre-treatment. Roads and parking lots should be provided with pre-treatment devices to prevent clogging and extend their lifecycle.

These practices are also known as infiltration galleries, trench drains and / or dry wells, and are excavations in the native soil that are lined with geotextile fabric and filled with clean granular stone. They are typically designed to accept runoff from a relatively clean water source such as a roof or pedestrian area. Where possible, they should be installed where native soils allow for infiltration; however, like other infiltration techniques, underdrains can be installed where poorly drained soils are present. These practices can be designed in a broad range of shapes and sizes.

Infiltration chambers are a variant that use prefabricated modular plastic or concrete structures (as opposed to only aggerates) installed over a granular base to provide maximum void space (up to 90%) and provide structural support. These systems provide more storage capacity than equivalently sized soakaways and have minimal footprints. Infiltration chambers are ideal for heavily urbanized sites because they can be installed below parking lots or other impervious surfaces. Infiltration chambers have also been successfully installed below recreational fields and public urban courtyards. They can be designed in many configurations to suit site constraints.

Figure 5-3: Example LID Practices from Top Left to Right: Soil Amendment (Mississauga, ON), Exfiltration System (Etobicoke ON); Exfiltration System (Guelph, ON); Perforated Pipe (Toronto, ON)

Bioretention, Bioswales and Enhanced Grass Swales - As a stormwater filtration and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. The primary component of the practice is the bioretention soil media (**Figure 5-4**). This component is comprised of specific ratio of sand, fines and organic material. Another important element of bioretention practices is vegetation, which can be either grass or a more elaborate planting arrangement such as an ornamental garden.

Bioretention can be integrated into a diverse range of landscapes including as roadside practices, open space, and as part of parking lots and landscaped areas a perimeter control. Perimeter controls are placed adjacent to the impermeable surface (i.e. parking lot) typically at the low point where it can efficiently collect runoff. Bioretention practices are commonly referred to as “rain gardens”. Depending on the native soil infiltration rate and site constraints, bioretention practices may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (commonly called a biofilter) where infiltration is not desired or where contaminated soils are encountered.

Bioswales are similar to bioretention cells. They include a filter media bed, gravel storage layer and optional underdrain components. The main difference is that bioswales are also designed to provide linear conveyance via their swale-like surface geometry and slope. Pre-treatment and rock check dams are often included in the design. In general, bioswales are open channels designed to convey, treat and attenuate stormwater runoff. Vegetation or aggregate material on the surface of the swale slows the runoff water to allow sedimentation, filtration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil. Bioswales may be planted with grasses or have more elaborate landscaping. They are implemented to provide water quality treatment and water balance benefits beyond those of a conventional ditch. Bioswales are sloped to provide conveyance, but due to their permeable soil media and gravel, surface flows are only expected during intense rainfall events. Bioswales are the most commonly applied LID as part of complete streets and parking lots.

Enhanced grass swales (also referred to as enhanced vegetated swales) are vegetated open channels designed to convey, treat and attenuate stormwater runoff. Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs. Enhanced grass swales are not capable of providing the same water balance and water quality benefits as dry swales, as they lack the engineered soil media and storage capacity of that best management practice (**Figure 5-4**).

Figure 5-4: Example LID Practices from Top Left to Right: Bioretention (Toronto, ON); Bioretention (Bostwick Community Centre, London, ON); Grass Swale (Mississauga, ON)

5.3.1.2 LID Approach for Private Property

The BMPs already described above (Soil Amendments, Perforated Pipe, Permeable Pavements, Bioretention & Bioswales, Enhanced Swales, and Soakaway Pits, and Infiltration Trenches and Chambers) are suitable for municipal ROW and on private property. The following BMPs are suitable only for private property.

Rainwater Harvesting - Rainwater harvesting is the process of intercepting, conveying and storing rainwater for future use. Harvesting rainwater for domestic purposes has been practiced in rural Ontario for well over a century. Roof runoff is the ideal source for this practice due to the large surface area and minimal exposure to contaminants. Rainwater harvesting not only reduces the volume of runoff that is conveyed offsite, but also reduces the onsite usage of potable water for irrigation and associated costs (**Figure 5-5**).

Rainwater harvesting systems convey runoff to a storage tank or cistern. Prefabricated storage units can range in size from simple rain barrels that tie into downspouts to precast concrete tanks capable of storing tens of thousands of litres or more from much larger catchment areas. Cisterns can be located inside a building or outside.

Rainwater that is collected in a cistern can be used for non-potable indoor or outdoor uses. Sufficient pre-treatment options include gravity filtration or first flush diversion. The irrigation of landscaped areas and washing of site features and vehicles are common uses of harvested rainwater. The 2017 Ontario Building Code explicitly allows the use of harvested rainwater for toilet and urinal flushing (See Section 7.1.5.3 of the Code).

Permeable Pavements - Permeable pavement is a collective term that describes LID BMPs that can be used in place of conventional asphalt or concrete pavement (**Figure 5-5**). These alternatives contain pore spaces or joints that allow stormwater to pass through to a stone base for infiltration into underlying native soil or temporarily detained for flood control purposes. Typical types of permeable pavement include:

- pervious concrete;
- porous asphalt;
- permeable interlocking concrete pavers (PICP) (i.e., block pavers);
- plastic or concrete grid systems (i.e., grid pavers or grass pavers); and
- rubberized granular surfaces, bricks and pads.

Permeable Pavements can be implemented as sidewalks, driveways, multi-use pathways, on-street (lay-by) parking, alleyways, road shoulders and even minor or local roadways themselves but are most commonly applied in parking lots. When implemented within a parking lot, permeable pavement can be implemented as:

- Full permeable pavement parking surface (drive lanes and parking stalls); and
- Partial permeable pavement parking surface where permeable pavement is strategically constructed within the parking stall areas only and the central drive-lanes remain as conventional asphalt. In this manner, the permeable pavement systems can accept runoff from impervious areas (i.e., drive lanes).

An ongoing maintenance plan is required for permeable pavements, to ensure clogging of void space does not occur.

Figure 5-5: Example LID Practices from Left to Right: Green Roof (Portland, OR); Rainwater Harvesting (Portland OR); Permeable Pavements (London, ON)

6 Evaluation of the Stormwater Strategies

Three (3) alternative stormwater strategies were identified in **Section 5** to address the potential impacts associated with future development (as outlined in **Section 4.1**). **Section 6.1** describes the criteria used to evaluate these strategies; **Section 6.2** describes the modeling results to be used in the evaluation criteria; followed by the evaluation (**Section 6.3**) and selection of the preferred alternative (**Section 6.4**).

6.1 Criteria Description

Three (3) alternative stormwater management strategies were identified in **Section 5**. In order to evaluate these solutions identified in the previous sections, four general categories of criteria have been developed. The categories include Physical and Natural Environment; Social, Economic and Cultural Environment; Technical; and Financial. The detailed list of criteria for each category together with the measures for assigning scores presented in **Table 6.1** through **Table 6.4**. The evaluation of the alternatives based on these criteria would form the basis and justification for the selection of the preferred alternative(s).

Section 6.2 describes the modeling associated with each alternative to enable the evaluation of alternatives in **Section 6.3** and the identification of the preferred alternative in **Section 6.4.**

Table 6.1: Description of Physical and Natural Environment Evaluation Criteria

Criteria	Description of Criteria	Measures for Assigning Scores
Water Quality Treatment	Potential to improve water quality based on existing water quality conditions and ability to provide Enhanced water quality as per the MECP requirements	Scoring ranges from 4 if the alternative exceeds an estimated 100% of the required water quality control as per MECP requirements, to zero if no water quality treatment is provided. Interim scores are provided based on the percentage of the required water quality control that is provided
Flood Mitigation	Potential to reduce impact of new development on peak flows associated with both urban and riverine flooding such that the 2-year through 100-year post-development flows are less than or equal to the predevelopment flows, and that the post-development uncontrolled flows are less than the existing regulatory floodlines	Scoring ranges from 4 if the alternative reduces flood potential, to 0 if the alternative has the potential to increase flooding. Interim scores are provided based on the percentage of increase in flooding

Criteria	Description of Criteria	Measures for Assigning Scores
Erosion Mitigation	Potential to maintain existing fluvial geomorphic regime or improve erosion conditions within watercourses	Scoring ranges from 4 if the alternative reduces erosion potential, to 0 if the alternative has the potential to significantly increase erosion potential. Interim scores are provided based on the percentage of increase in erosion potential
Water Balance	Potential to meet a water balance within the subwatershed area that is consistent with a natural catchment area lacking anthropogenic impervious surfaces	Scoring ranges from 4 if the alternative improves existing (pre-development) hydrologic cycle, to 0 if the alternative significantly alters the cycle. Interim scores are provided based on relative impact to cycle.
Thermal Impacts	Potential to maintain cooler water temperatures discharged into streams to sustain coolwater habitat. Impervious surfaces, such as roads and rooftops, can reach very high temperatures, especially during the summer months, and this heat is transferred to stormwater running over it.	Scoring ranges from 4 if the alternative reduces thermal impacts, to 0 if the alternative has the potential to significantly increase temperatures in discharged water. Interim scores are provided based on the relative thermal impact
Aquatic Habitat	Potential to mitigate any negative effects of development on the aquatic habitat or improve habitat and aquatic ecosystem diversity	Scoring ranges from 4 if the alternative improves existing aquatic habitat, to 0 if the alternative has the potential to significantly degrade existing habitat. Interim scores are provided based on the relative impact to habitat
Terrestrial Habitat	Potential to mitigate any negative effects of development on the terrestrial habitat or improve habitat and terrestrial ecosystem diversity	Scoring ranges from 4 if the alternative improves existing terrestrial habitat, to 0 if the alternative has the potential to significantly degrade existing habitat. Interim scores are provided based on the relative impact to habitat

Table 6.2: Description of Social Environment Evaluation Criteria

Criteria	Description of Criteria	Measures for Assigning Scores
Aesthetics / Recreation	Potential for the alternative to become an asset to the community by integrating and improving the existing site activities (walking/jogging, cycling, biking and hiking) and/or improve the site aesthetics	Scoring ranges from 4 if the alternative has a high potential to integrate into existing activities and/or improve aesthetics, to 0 if there is minimal potential and/or existing site uses will be lost to the community
Impact on existing and proposed development	Potential for the alternative to integrate with the adjacent land uses (existing and future)	Scoring ranges from 4 if the alternative has a high potential to integrate with adjacent land uses, to 0 if there is minimal potential
Potential benefit to the community and public acceptance	Potential for the alternative to be accepted by the public	Scoring ranges from 4 if the alternative has a high potential to be accepted by the public, to 0 if there is minimal potential

Table 6.3: Description of Technical Environment Evaluation Criteria

Criteria	Description of Criteria	Measures for Assigning Scores
Level of Service and proven effectiveness	Potential for the alternative to meet the City's specified level of service, and whether the alternative has been previously proven to achieve this level	Scoring ranges from 4 if the alternative has a high potential to effectively meet the City's level of service, to 0 if has a low potential
Regulatory agency acceptance	The willingness of representative agencies (Municipal, Provincial, Federal, Conservation Authority) to accept the proposed alternative based on relevant policy constraints.	Scoring ranges from 4 if the alternative has a high potential to be accepted by the agencies, to 0 if the proposed alternative will not be accepted
Impact on existing infrastructure	Potential for the alternative to be integrated into existing infrastructure, and to minimize the need to replace existing infrastructure	Scoring ranges from 4 if the alternative can be integrated into existing infrastructure without needing upgrades or replacements, to 0 if the proposed alternative will require high levels of infrastructure replacement
Constructability	The relative ease with which the proposed alternative can be implemented taking into consideration approvals, public consultation requirements (adjacent landowner acceptance) and length of time to implement (construction time).	Scoring ranges from 4 if the alternative can be implemented with ease, to 0 if the proposed alternative will encounter difficulties with constructability
Maintenance requirements	Ease for the alternative's maintenance requirements to be integrated into the City's existing maintenance program	Scoring ranges from 4 if the alternative can be easily integrated into the City's existing maintenance program, to 0 if the alternative will require significant extra maintenance work

Table 6.4: Description of Economic Environment Evaluation Criteria

Criteria	Description of Criteria	Measures for Assigning Scores
Construction Costs	The relative estimated cost as compared to the other alternatives	Scoring ranges from 4 if the relative cost, based on the identified factors is the lowest, to 0 if the relative cost is the highest
Long Term Operation and Maintenance Costs	The relative cost of operation and maintenance for the proposed alternative based on factors such as access/egress, sediment drying capability, ongoing general maintenance to associated infrastructure and overall maintenance frequency and intensity	Scoring ranges from 4 if the relative operation and maintenance costs for the alternative is the lowest as compared to the other alternative, to 0 if the alternative results in the highest operation and maintenance cost
Land Requirements	The area of land that will be required for the implementation of the alternative	Scoring ranges from 4 if the alternative can be implemented with minimal land requirements, to 0 if the alternative requires large areas of land
Infrastructure Protection	Potential for the proposed alternative to protect existing or future infrastructure including streams, outfalls, storm sewers watercourse crossings	Scoring ranges from 4 if the alternative is the most effective at protecting existing and proposed infrastructure thereby reducing risk, to 0 if existing/proposed infrastructure is most susceptible
Potential to increase private property values	Potential for alternative to increase or decrease private property values	Scoring ranges from 4 if the alternative increases overall property value, to 0 if the alternative reduces values

6.2 Modeling Results

6.2.1 Flood Control

The PCSWMM model developed in the **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report** was updated to account for any changes within each subwatershed. Land use was updated based on the future land use (**Section 3**). **Appendix C** describes the model updates.

Flows at key locations (**Figure 6-1**) are presented in **Table 6.5** and **Table 6.6** to show existing conditions, future uncontrolled conditions, and future conditions with stormwater ponds. End-of-pipe SWM facilities were modelled wherever development is proposed and were placed near the outlets of subcatchments. The drainage area for each facility was defined based on the updated subcatchments, while pond sizing was obtained by varying the storage volumes per hectare until both of the following conditions were met:

1. Post-development flows at key nodes throughout the watershed from the 2-year through 100-year events were less than or equal to the 2-100 year existing flows; and
2. Uncontrolled flows were less than the existing regulatory flows, where the regulatory flow is defined as the larger of the 100-year or Regional flow.

The objective of the assessment for the first condition is to define storage volumes for proposed development such that peak flows within the watercourses do not increase as a result of development. The assessment was carried out using land use information which was available at the time of undertaking the study. The storage volumes will need to be updated once further work is completed through the Block Plan process, which will modify parameters such as percent impervious, drainage area and patterns, and location of stormwater facilities.

The first condition was met in both subwatersheds when ponds were designed with a storage volume of 450 m^3/ha for residential areas and 750 m^3/ha for industrial/business areas. Storage volumes will also be required to maintain pre-development stream flows where diversions are approved by GRCA.

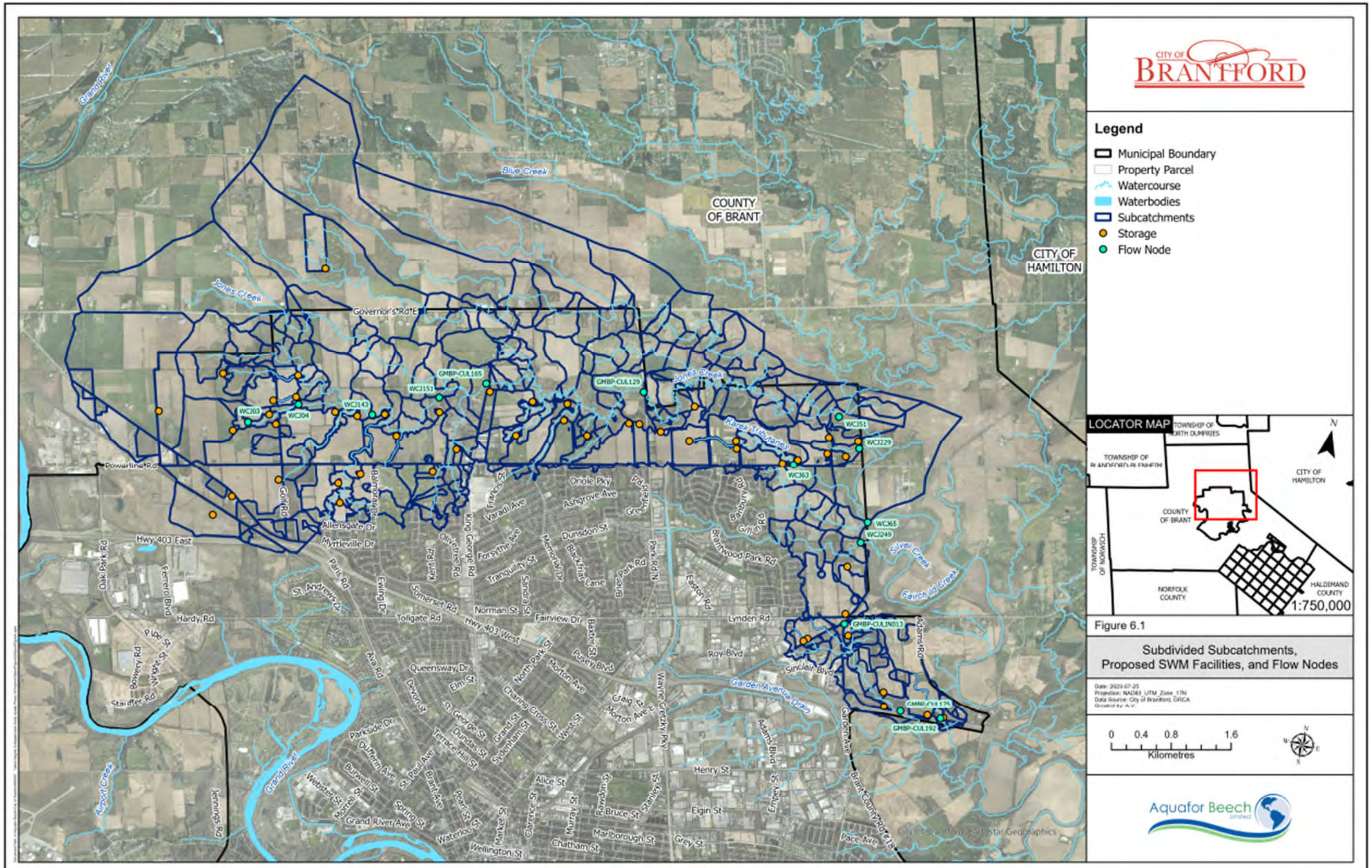


Figure 6-1: Subdivided Subcatchments, Proposed SWM Facilities, and Flow Nodes

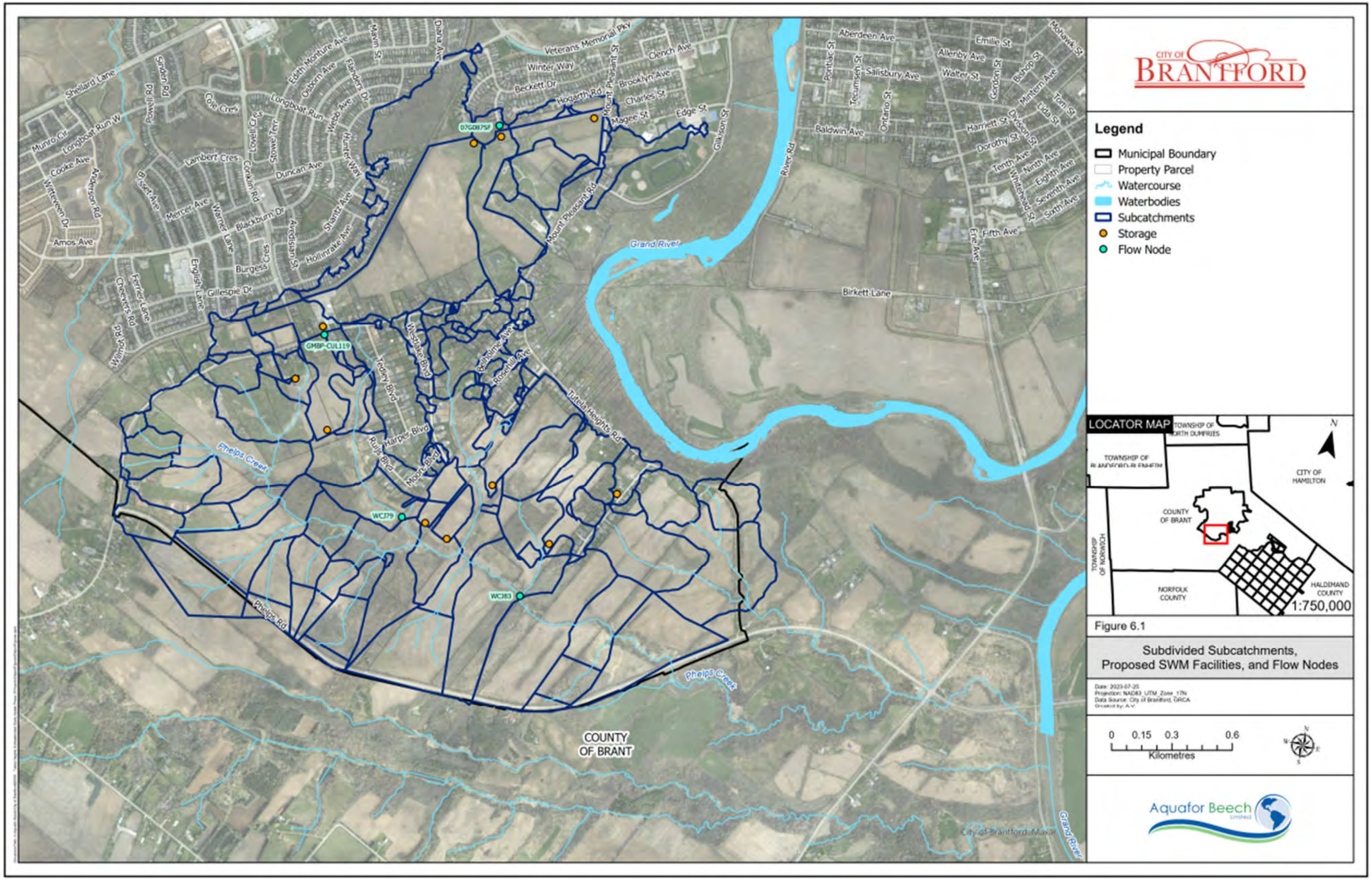


Figure 6-1 cont.

Table 6.5: Summary of Estimated Flood Flows – Regional Event (m^3/s)

Flow Node	Existing	Future (Uncontrolled)	Future (Traditional)	Future (Traditional + LID)
WCJ03	5.43	6.96	1.54	0.86
WCJ04	14.79	18.68	6.19	4.40
WCJ143	57.65	62.68	36.00	31.53
WCJ151	76.46	81.90	49.00	42.98
GMBP-CUL165	105.61	108.16	82.41	76.70
GMBP-CUL129	104.51	106.62	94.89	93.03
WCJ63	11.12	13.06	4.75	4.06
WCJ229	5.13	5.71	2.70	2.38
WCJ249	44.90	45.12	44.26	44.14
WCJ51	272.99	273.95	271.03	270.23
WCJ65	288.77	287.69	284.94	283.11
GMBP-CULIN013	5.75	6.98	1.24	1.06
GMBP-CUL175	23.37	25.29	16.20	14.93
GMBP-CUL192	7.55	9.95	3.74	2.57
07G087SF	7.52	9.00	2.59	2.43
GMBP-CUL119	0.95	2.13	0.28	0.23
WCJ79	5.13	5.47	4.02	3.91
WCJ83	37.05	37.48	33.72	33.30

Table 6.6: Summary of Estimated Flood Flows – 100-year Event (m^3/s)

Flow Node	Existing	Future (Uncontrolled)	Future (Traditional)	Future (Traditional + LID)
WCJ03	2.91	6.52	1.05	0.80
WCJ04	8.05	17.04	3.42	2.62
WCJ143	23.17	40.32	17.51	13.56
WCJ151	25.04	40.99	19.40	16.16
GMBP-CUL165	38.95	54.94	31.93	28.25
GMBP-CUL129	41.37	57.54	35.18	31.73
WCJ63	6.84	11.42	2.19	1.71
WCJ229	3.71	5.10	1.50	1.06
WCJ249	33.53	33.69	33.46	33.34
WCJ51	51.94	55.66	50.70	50.30
WCJ65	60.31	60.63	57.97	57.22
GMBP-CULIN013	3.38	6.13	0.52	0.50
GMBP-CUL175	11.77	17.21	8.09	6.99
GMBP-CUL192	4.23	8.83	2.45	2.05
07G087SF	5.91	8.36	1.46	1.20
GMBP-CUL119	0.67	1.88	0.20	0.16
WCJ79	3.98	4.66	2.92	2.81
WCJ83	22.59	24.07	19.68	18.93

Table 6.7:Summary of Estimated Flood Flows – 29 mm Event (m^3/s)

Flow Node	Existing	Future (Uncontrolled)	Future (LID)
WCJ03	0.09	1.74	0.05
WCJ04	0.26	4.28	0.15
WCJ143	0.59	6.64	0.55
WCJ151	0.51	5.85	0.53
GMBP-CUL165	1.32	4.07	1.28
GMBP-CUL129	1.39	4.32	1.27
WCJ63	0.29	1.86	0.06
WCJ229	0.14	0.92	0.05
WCJ249	5.03	5.09	5.03
WCJ51	1.65	4.57	1.54
WCJ65	1.58	4.57	1.53
GMBP-CULIN013	0.18	1.02	0.02
GMBP-CUL175	0.60	1.69	0.53
GMBP-CUL192	0.26	2.13	0.13
07G087SF	0.18	1.32	0.05
GMBP-CUL119	0.03	0.36	0.00
WCJ79	0.39	0.65	0.27
WCJ83	1.09	1.52	0.94

Detailed hydrologic and hydraulic modelling outputs have been provided in **Appendix C**.

The Future Uncontrolled floodlines in comparison with the GRCA Phase 1 floodlines can be seen in **Figure 6-2**. The future uncontrolled Regional event exceeds the future uncontrolled 100-year event throughout the study area, and is therefore the governing storm. Furthermore, at all locations except for WCJ65, the future uncontrolled Regional flows exceed the existing conditions Regional flows.

In accordance with discussions with the GRCA, tributaries with drainage areas under 1 km2 (100 ha) have been removed from Future Uncontrolled floodplain mapping. Areas located within the tertiary study area and beyond the current model boundary may need to be integrated into the existing GRCA floodplain mapping, where deemed necessary or appropriate.

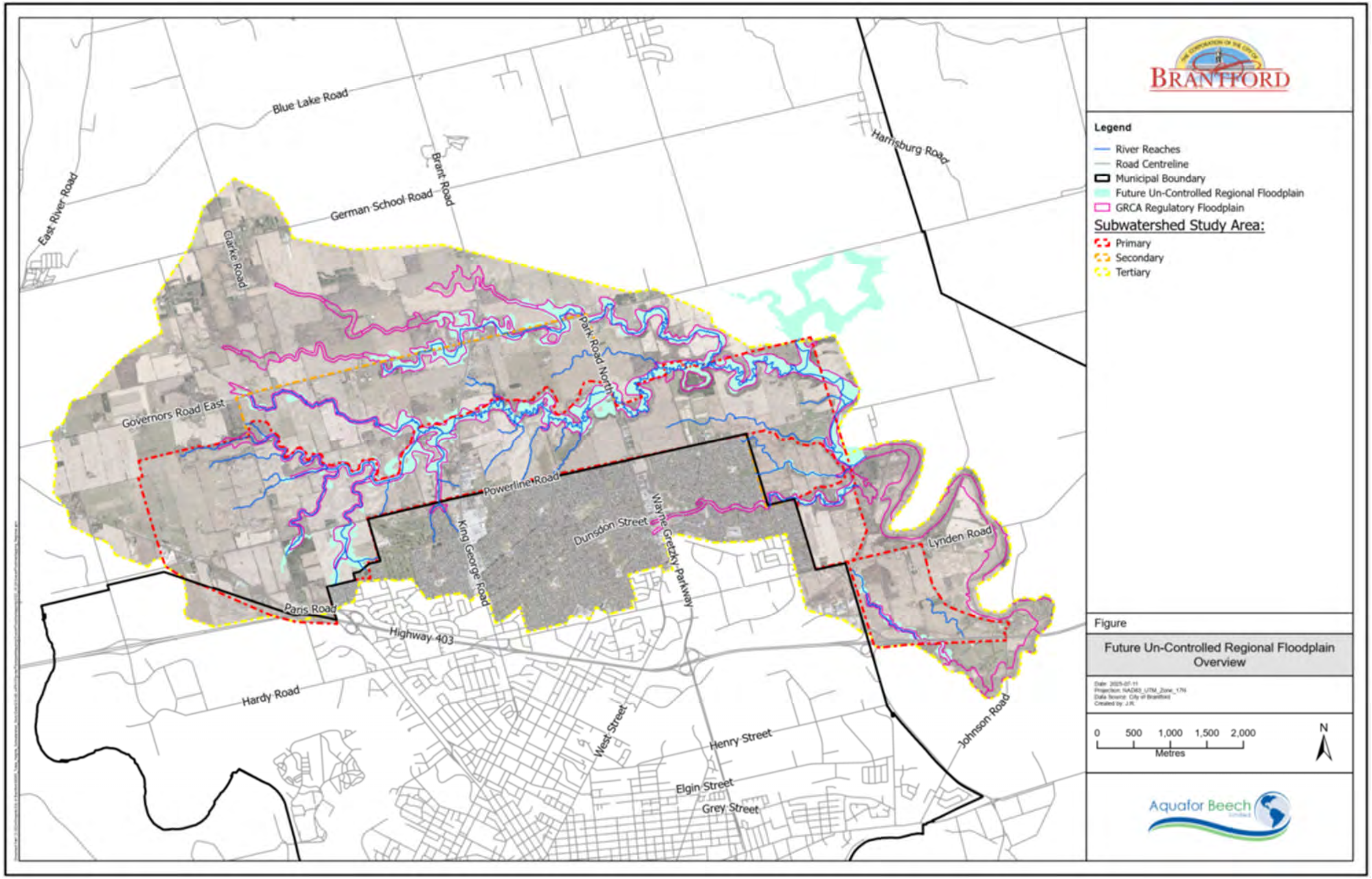


Figure 6-2: Existing and Future Uncontrolled Regional Floodlines

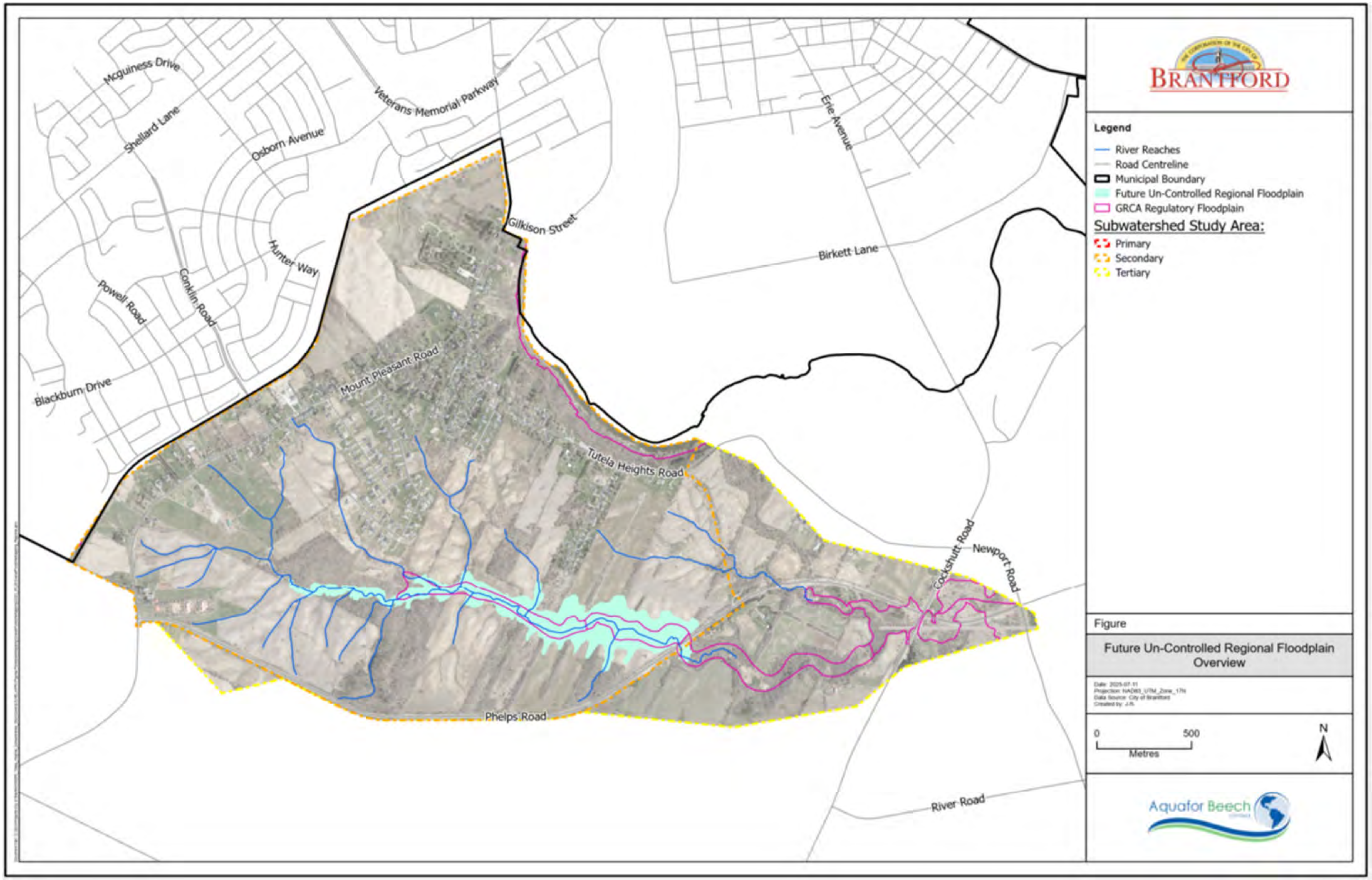


Figure 6-2 cont.

6.2.1.1 Watercourse Crossing Capacity

Analyzing the water surface elevation profile of creeks, it was determined that culverts may be creating a backwater effect. The structures in the study areas were reviewed to identify the possibility of upgrading the culvert structures.

Golf Rd Culvert 1, Golf Rd Culvert 3 and Park Rd N Culvert 1 are crossings creating a backwater effect due to the undersized hydraulic structures for study areas. For Phelps Creek in Future Uncontrolled Condition, HW 18 Culvert 1 would have over 30 cm flood water over top from 50-year event, and HW 18 Culvert 2 would have over 30 cm flood water over top from 100-year event. For Jones Creek, Park Rd N Culvert 1 was damaged at the time of field survey and can plan to be upgraded to reduce upstream flood impact for the smaller storms than the 50-year storm return period.

Results suggest the Traditional SWM with LID scenario would reduce the future uncontrolled water level where the future land use changes. For the reaches where future land use remains the same as existing condition, the future uncontrolled flows are equal to existing flows and the water levels are the same.

In conclusion, the Traditional SWM with LID alternative estimated floodlines show a smaller extent compared to the future uncontrolled scenario, and would be smaller than the existing Phase 1 floodline for North Brantford and Tutela Height study areas.

The road overtopping under future uncontrolled conditions results are presented in **Table 6.8**.

Table 6.8: Roadway Flooding Status in North Brantford and Tutela Height Subwatershed

Structure Name	River	Reach	Roadway Crossing	Type	Shape	Road Elev (m)	Difference between WES and Road Elevation (m)													
							2-year		5-year		10-year		25-year		50-year		100-year		Regional	
							Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID	Fut. Unc.	Trad+LID
HW 18 Culvert 1	Phelps_Trib1	Phelps_Trib1	Highway 18	Culvert	Circular	206.81	-2.92	-2.99	-2.57	-2.65	-2.22	-2.35	-1.09	-1.6	-0.05	-0.64	1.22	0.47	1.65	1.62
HW 18 Culvert 2	Phelps	Phelps-2	Highway 18	Culvert	Circular	209.88	-3.89	-4.22	-2.47	-3.37	-1.12	-2.27	0.13	-0.94	0.23	0.08	0.3	0.2	0.48	0.44
Powerline Rd Culvert 1	Jones_Trib9	Jones_Trib9-S3	Powerline Rd	Culvert	Circular	232.24	0.08	-2.51	0.12	-2.41	0.13	-2.34	0.15	-1.97	0.17	-1.63	0.19	-1.22	0.23	0.07
Powerline Rd Culvert 2	Jones_Trib9	Jones_Trib9_S2	Powerline Rd	Culvert	Circular	231.47	-4.9	-5.45	-4.7	-5.36	-4.52	-5.26	-4.03	-5.07	-3.21	-4.92	-2.2	-4.77	0.09	-2.01
Powerline Rd Culvert 3	Jones_Trib8	Jones_Trib8-2	Powerline Rd	Culvert	Circular	224.77	-2.05	-2.1	-1.76	-1.81	-1.51	-1.57	-1.08	-1.18	-0.45	-0.65	0.05	0.01	0.21	0.21
Powerline Rd Culvert 4	Karek	Karek	Powerline Rd	Culvert	Circular	212.19	-1.34	-3.47	0.1	-3.34	0.16	-3.24	0.23	-3.2	0.26	-3.1	0.3	-2.77	0.34	-1.36
Powerline Rd Bridge 5	Fairchild	Fairchild-3	Powerline Rd	Bridge	Box	203.78	-5.17	-5.53	-4.76	-5.05	-4.47	-4.79	-4.17	-4.36	-3.92	-4.02	-3.63	-3.71	-1.33	-1.36
HW 99 Culvert 8	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	215.49	-3.47	-3.53	-3.11	-3.2	-2.84	-2.92	-2.42	-2.54	-2.06	-2.21	-1.7	-1.85	0.7	0.68
HW 99 Culvert 6	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	218.21	-4.33	-4.41	-3.92	-4.03	-3.61	-3.71	-3.13	-3.27	-2.74	-2.91	-2.37	-2.53	0.55	0.54
Park Rd N Culvert 1	Jones_Trib2	Jones_Trib2	Park Rd N	Culvert	Circular	220.97	0.06	0.06	0.09	0.09	0.11	0.11	0.13	0.13	0.15	0.15	0.16	0.16	0.19	0.19
Golf Rd Culvert 3	Jones_Trib9	Jones_Trib9-W1-1	Golf Rd	Culvert	Circular	238.47	0.15	-2.45	0.23	-2.34	0.27	-2.26	0.32	-2.05	0.35	-1.74	0.38	-1.51	0.4	-1.07
Golf Rd Culvert 2	Jones_Trib9	Jones_Trib9-W2	Golf Rd	Culvert	Circular	231.82	-1.74	-1.74	-1.49	-1.49	-1.27	-1.27	-0.79	-0.79	-0.32	-0.32	0.04	0.04	0.1	0.1
Golf Rd Culvert 1	Jones_Trib9	Jones_Trib9-1	Golf Rd	Culvert	Circular	232.05	0.13	0.05	0.18	0.09	0.2	0.11	0.23	0.14	0.24	0.16	0.26	0.18	0.31	0.26
HW 24 Culvert 2	Jones	Jones-8	King George Rd	Culvert	Box	219.13	-1.8	-2.72	-1.22	-2.2	-0.57	-1.97	0.17	-1.65	0.3	-1.17	0.39	-0.62	0.75	0.58
HW 24 Culvert 1	Jones_Trib1	Jones_Trib1	King George Rd	Culvert	Box	221.72	-1.78	-2.01	-1.51	-1.68	-1.32	-1.41	-0.91	-1.12	-0.56	-0.81	-0.25	-0.47	0.61	0.6
Lauchlin Culvert	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	224.02	-3.21	-3.49	-3.05	-3.27	-2.85	-3.08	-2.49	-2.85	-2.04	-2.51	-1.45	-2.04	0.29	0.29
Charlton Culvert	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	220.48	-2.17	-2.37	-1.82	-1.99	-1.59	-1.68	-1.2	-1.36	-0.83	-1.09	-0.43	-0.72	0.54	0.52
Batson Bridge	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	218.37	-2.54	-2.66	-2.12	-2.29	-1.79	-1.95	-0.96	-1.32	-0.05	-0.6	0.16	0.09	0.66	0.66
Kitchen Culvert	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	215.77	-3.37	-3.46	-2.94	-3.05	-2.63	-2.73	-2.17	-2.3	-1.72	-1.93	-1.22	-1.45	1.31	1.28
Governors Rd E Culvert 2	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	223.65	-1.11	-1.39	-0.98	-1.28	-0.81	-1.14	-0.53	-0.85	-0.17	-0.59	0.23	-0.27	0.71	0.67
Batson Culvert	Jones	Jones-3	Park Rd N	Culvert	Box	212	-3.04	-3.83	-2.63	-3.58	-1.96	-3.24	-0.92	-2.76	0.35	-2.25	0.62	-1.64	1.17	1.07
Governors Rd E Culvert 1	Jones_Trib1	Jones_Trib1	Governors Rd E	Culvert	Box	223.64	-2.19	-2.48	-2	-2.28	-1.86	-2.1	-1.53	-1.86	-1.04	-1.56	-0.21	-1.09	0.68	0.67

Green	Not overtopped
Orange	Less than 0.3m water depth
Red	Greater than 0.3 m water depth

6.2.2 Water Quality

An Enhanced level of protection is required throughout the Expansion Lands. To achieve this level of control, LID measures are prioritized for achieving the water quality criteria, followed by stormwater management facilities and then manufactured treatment devices. The MECP's Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA) accepts control of the 90th percentile storm event (29 mm) to achieve Enhanced water quality treatment, as presented in **Figure 6-3**, where the Runoff Volume Control Target (RVCT) corresponds to the runoff generated from the regionally specific 90th percentile rainfall event.

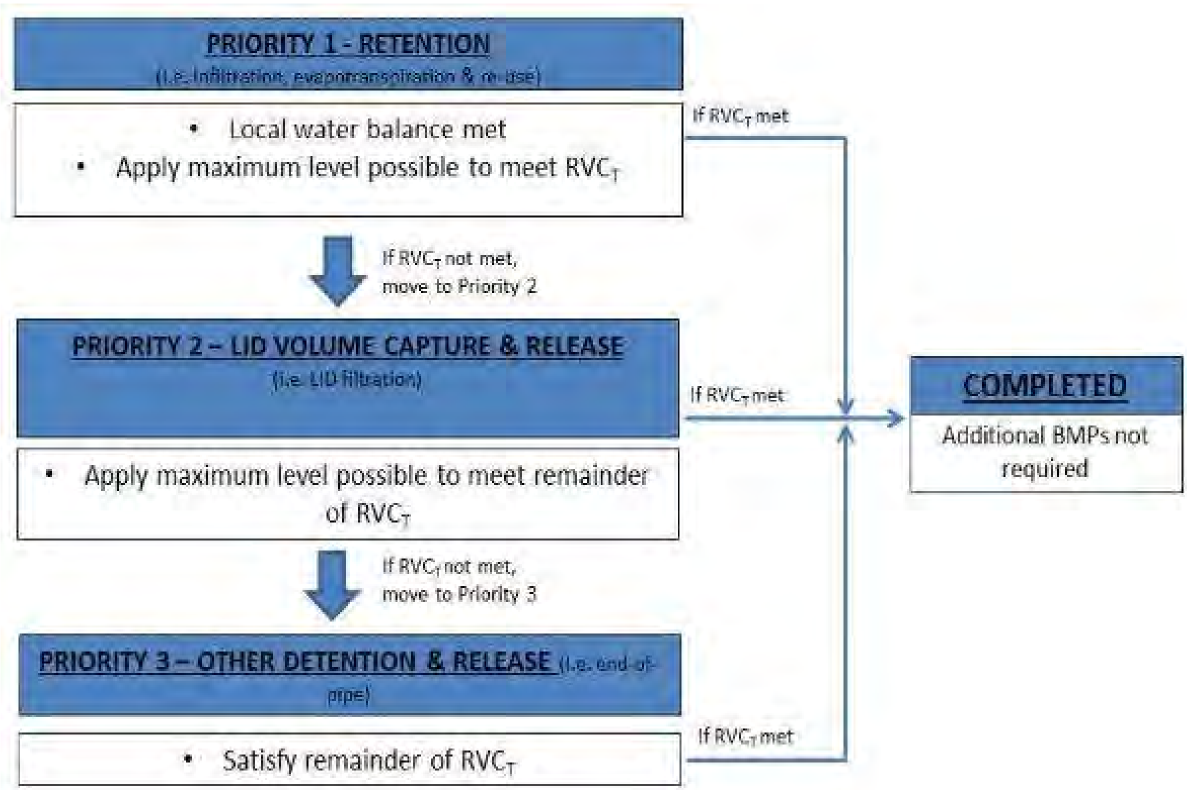


Figure 6-3: The runoff control hierarchy from the MECP's LID Stormwater Management Guidance Manual

LID measures were therefore modeled throughout the new developments. The PCSWMM model assumed an infiltration trench system is implemented for all proposed land uses. Treatment of the 29 mm event throughout both subwatersheds was feasible using LIDs, so the use of stormwater management facilities or manufactured treatment devices was not necessary to achieve an Enhanced level of treatment. The runoff volumes for typical subcatchments associated with the 29 mm event are presented in **Table 6.9.** The full table of runoff volumes for typical subcatchments associated with the 29 mm event can be found in **Appendix C**.

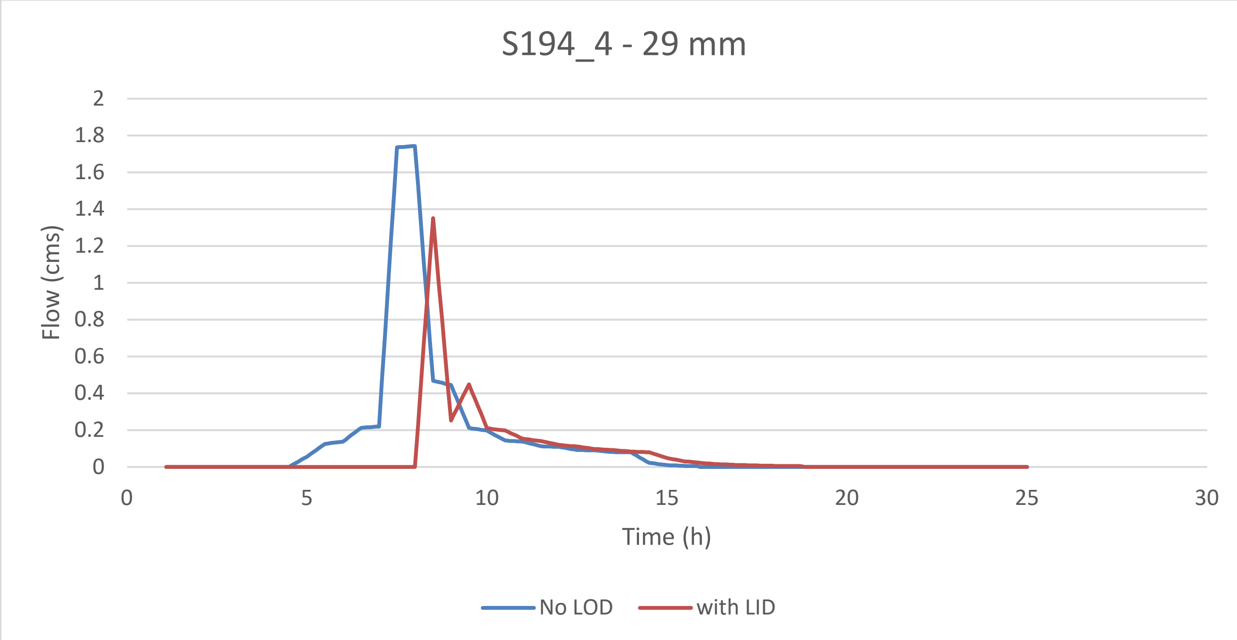
Table 6.9: Required 29 mm Runoff Volumes in Typical Subcatchments

Subcatchment	Land Use	29 mm (12 Hour SCS) Runoff Equivalent Depth (mm)	29 mm (12 Hour SCS) Runoff Volume (m^3)
S194_4	Employment	24.49	11580
S199	Residential	16.27	3170
S205	Residential	16.36	4090
S195	Employment	24.42	1750
S233	Residential	15.34	6120

Flows at two catchments, S194_4 and S199, are presented in **Table 6.10**, **Figure 6-4** and **Figure 6-5** to illustrate the performance of LID measures during the 29 mm and 2 year events. The locations for S194_4 and S199 can be found in **Figure 6-6**. With the implementation of LIDs controlling the 29 mm event, peak flows during the 29 mm event drop significantly. LID implementation also delays the peak flow, which is typically more in line with what is observed in a less developed watershed.

Table 6.10: Flows at S194_4 and S199 with LID Measures During 29 mm and 2-Year Events

		29mm		2-Year	
		Flow (m^3/s)	Runoff (mm)	Flow (m^3/s)	Runoff (mm)
S194_4	**Uncontrolled**	1.74	24.49	2.96	40.58
	LID Only	1.35	13.21	2.79	29.32
S199	**Uncontrolled**	0.48	16.27	0.75	26.22
	LID Only	0.15	5.81	0.79	16.01



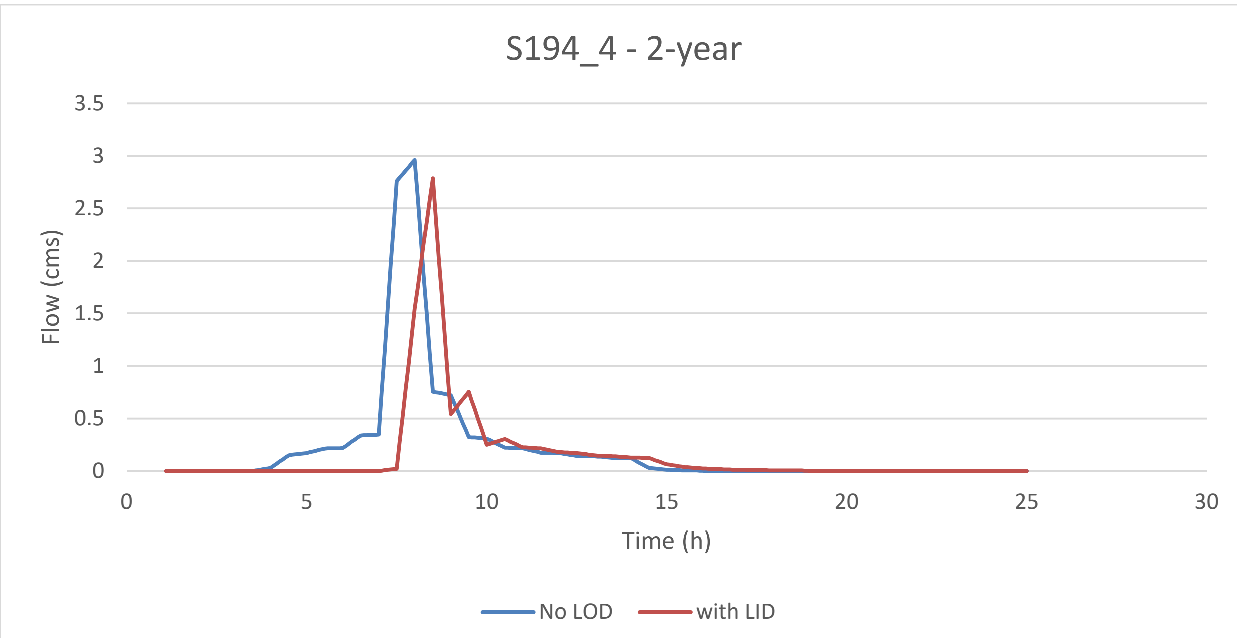
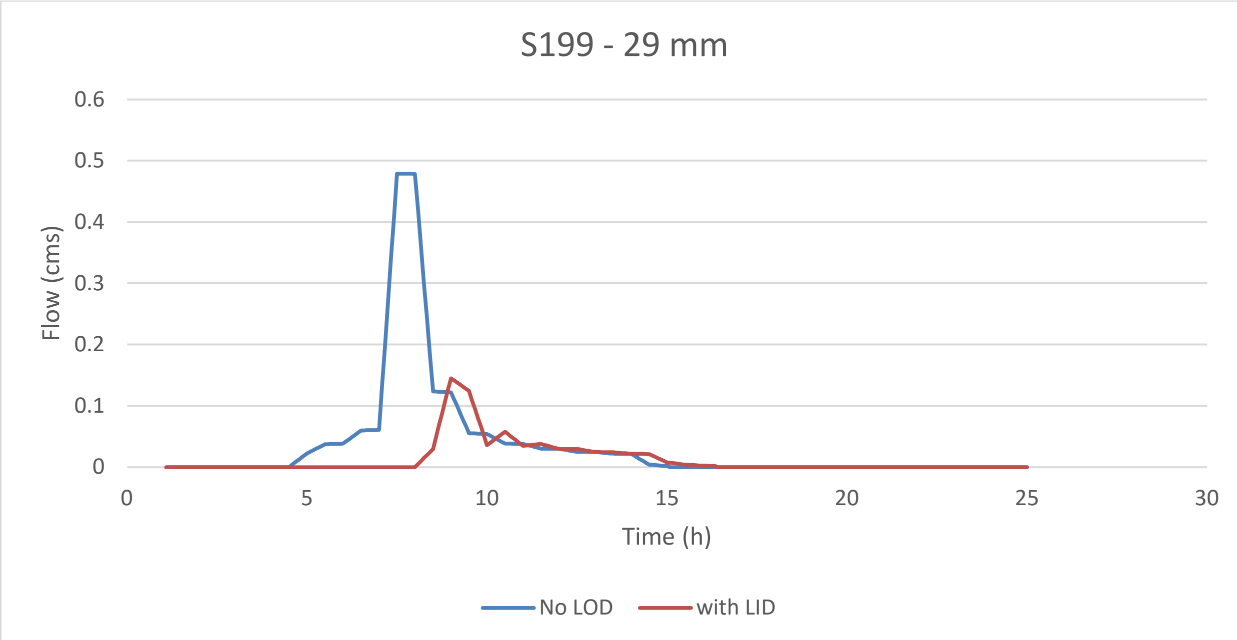


Figure 6-4: Flows at S194_4 with LID Measures Implemented



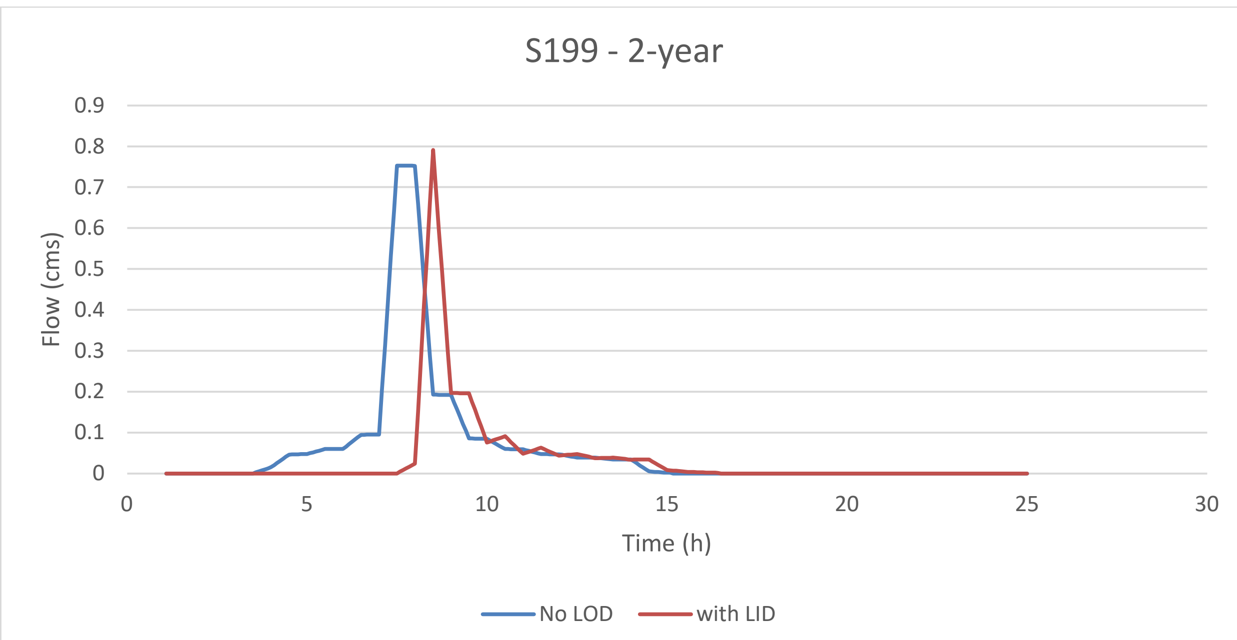


Figure 6-5: Flows at S199 with LID Measures Implemented

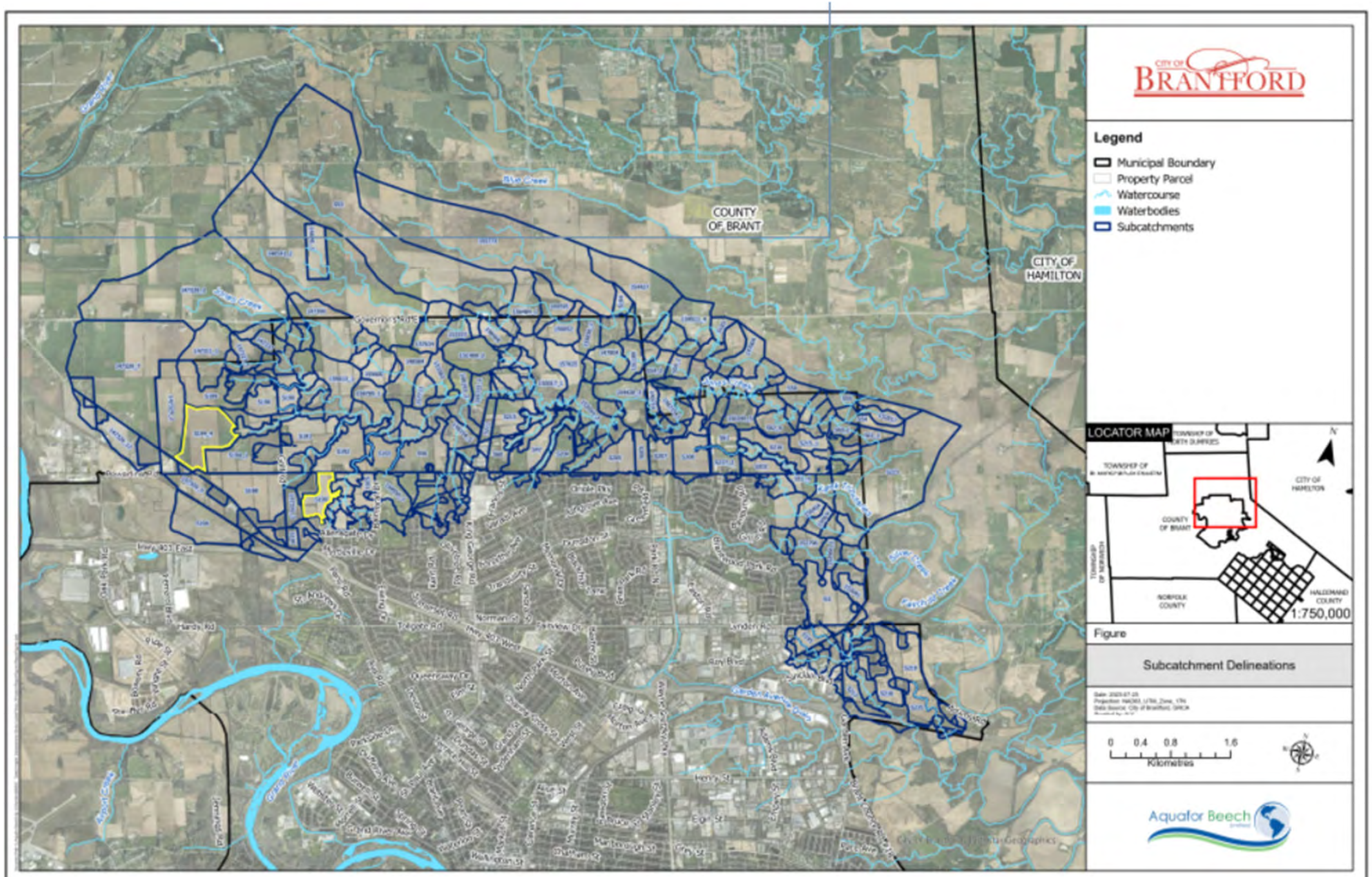


Figure 6-6: Subcatchment Locations for S194_4 and S199

6.2.3 Erosion Control

Erosion potential within the study area was determined to be as high as 15 m/100 years as part of the geomorphic assessments completed as part of the **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report**. A number of assessed reaches throughout the study area were determined to be in a state of geomorphic adjustment, or transitioning to said state. In order to protect against increased rates of erosion, and thus unstable channel adjustments, stormwater management facilities, including LIDs, will be a necessary part of future development to prevent increased peak flow rates and increased durations of critical discharge exceedance.

As access to Phelps Creek was not provided by landowners, future studies that have access will need to examine the site-specific erosion potential and the impacts of discharge exceedances prior to future development. Erosion thresholds and cross-sectional geometry will determine risk assessment, infrastructure requirements and development limits in this catchment.

A minimum of a 29 mm rainfall event is required to be captured, retained, or detained from all new and/or fully reconstructed impervious surfaces. The first priority is retention of the full volume from the 29 mm event through infiltration, evapotranspiration, reuse, bioretention, etc. If this is not feasible, then volume reduction to the maximum extent practical, as demonstrated through supporting documentation, is required with a minimum of 5 mm. The remaining runoff volume must then be detained on site and released over 24 to 48 hours.

As presented in **Section 6.2.2,** control of the runoff from the 29 mm event is possible using LID measures. The LID measures were able to reduce the Future Uncontrolled peak flow during the 29 mm event to be equivalent or below the Existing peak flow at most node locations (**Table 6.11**). Runoff volumes are presented in **Table 6.9**.

Table 6.11: Peak Flow (m^3/s) during the 29 mm 12-hour SCS Storm

Node	Existing Peak Flow	Future Uncontrolled Peak Flow	With LID Measures
WCJ03	0.09	1.74	0.05
WCJ04	0.26	4.28	0.15
WCJ143	0.59	6.64	0.55
WCJ151	0.51	5.85	0.53
GMBP-CUL165	1.32	4.07	1.28
GMBP-CUL129	1.39	4.32	1.27
WCJ63	0.29	1.86	0.06
WCJ229	0.14	0.92	0.05
WCJ249	5.03	5.09	5.03
WCJ51	1.65	4.57	1.54
WCJ65	1.58	4.57	1.53
GMBP-CULIN013	0.18	1.02	0.02
GMBP-CUL175	0.60	1.69	0.53
GMBP-CUL192	0.26	2.13	0.13
07G087SF	0.18	1.32	0.05
GMBP-CUL119	0.03	0.36	0.00
WCJ79	0.39	0.65	0.27
WCJ83	1.09	1.52	0.94

6.2.4 Water Balance

The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff. For the North Brantford and Tutela Height Subwatersheds, the Thorthwaite and Mather method was used to estimate existing infiltration values on a yearly basis.

The hydrologic cycle is a complex process and its natural components are dependent on many factors (e.g., soils, topography, vegetation, geology, climate). Any change to these natural factors will result in a change to the hydrologic cycle. The water budget analysis is a comprehensive examination of the hydrological cycle based on the following expression:

Precipitation (P) = Evapotranspiration (ET) + Runoff (R) + Infiltration (I)

Evapotranspiration (ET) was calculated according to the Thornthwaite and Mather model (Thornthwaite and Mather, 1957) which uses an accounting procedure to analyze the allocation of water among various components of hydrologic system. This was completed based on weather data from 2013-2023 using the Brantford Airport and Brantford MOE weather stations. Years with data gaps were supplemented by the nearest Environment Canada weather station at Hamilton Airport. Other assumptions are summarized in **Table 6.12.**

Table 6.12: Thornthwaite and Mather Inputs

	North Brantford		Tutela Heights	
	Existing	Future	Existing	Future
Runoff Factor	0.46	0.49	0.46	0.47
Soil-Moisture-Storage-Capacity	214	149	208	166
Percent Impervious	3%	38%	7%	17%
Direct Runoff Factor	5%			
Latitude	44°			
Rain Temperature Threshold	3.3°C			
Snow Temperature Threshold	-10°C			
Maximum Melt Rate	0.51			

The computed evapotranspiration values were then used to estimate annual and monthly water surplus. The results of the water budget analysis highlight the importance of infiltration and evapotranspiration in the natural hydrological cycle (i.e., predevelopment) of the study area (**Table 6.13**).

Table 6.13: Water Budget

Water Budget Component	North Brantford		Tutela Heights	
	Existing	Future	Existing	Future
Annual Precipitation (mm/yr)	782			
Actual ET (mm/yr)	544	368	522	471
Water Surplus (mm/yr)	238	414	260	311
Runoff (mm/yr)	120	340	147	209
Infiltration (mm/yr)	119	74	113	102

6.2.4.1 Annual Infiltration

The Thornthwaite and Mather calculations estimate an annual pre-development infiltration rate of between 113 and 119 mm/year for Tutela Heights and North Brantford, respectively. Given that there are approximately 40 rainfall events per year, the average infiltration rate per event is relatively modest (approximately 3 mm per event). The actual values on a site-by-site basis will vary depending on soil type, slopes, vegetation cover and depth to water table.

The above recharge targets can be achieved by incorporating appropriate LID source and conveyance control measures as outlined in **Section 5**, together with the requirements to meet the Water Quality targets as noted in **Section 6.2.2**. Collectively, the LID measures should ensure that post-development infiltration rates equal or exceed pre-development levels. Monitoring has shown that, for soils of a similar nature, infiltration of up to 10 mm per event is possible.

The Phase 1 Update included six (6) Guelph permeameter infiltration tests, which found hydraulic conductivity rates ranging from 1.05×10^{-5} cm/s to 2.22×10^{-5} cm/s. This converts to infiltration rates of 25 mm/hr to 31 mm/hr following the approach outlined by the LID Stormwater Management Planning and Design Guide Appendix C (CVC and TRCA, 2010).

6.2.5 Thermal Mitigation

Aquatic investigations by Aquafor as part of the **North Brantford and Tutela Heights Subwatershed Study Phase 1 Update** found that most of the watercourses in the study area demonstrated a cool-warmwater thermal regime, outside of the North Branch of Jones Creek which supports coldwater habitat. The use of LID measures effectively reduces stormwater temperature. Conversely, conventional wet ponds provide an opportunity for standing water to increase in temperature. Best management practices can be followed in the design of wet ponds to reduce temperature impacts.

6.3 Evaluation of Alternatives

Section 6.2 describes the modeling results, which were used in combination with professional knowledge to evaluate the three alternatives. Results are tallied in **Table 6.14**. The following should be noted:

- A score of ● indicates that the alternative scores high in satisfying the evaluation criteria
- A score of ○ indicates the alternative scores low in relation to the criteria.

Table 6.14: Evaluation Results

Evaluation Criteria	Do Nothing	Conventional SWM Strategy	Combined Conventional & LID
1. Physical and Natural Environment	○	◑	●
Water Quality Treatment	○	◕	●
Flood Mitigation	○	●	●
Erosion Mitigation	○	◑	●
Water Balance	○	○	◕
Thermal Impacts	○	◑	◕
Aquatic Habitat	○	◑	●
Terrestrial Habitat	○	◕	◕
2. Social Environment	○	◕	●
Aesthetics/Recreation	◔	◕	●
Impact on existing and proposed development	○	●	●
Potential benefit to the community and public acceptance	○	◕	●
3. Technical Environment	◑	◕	●
Level of service and proven effectiveness	○	◕	●
Regulatory agency acceptance	○	◕	●
Impact on existing infrastructure	○	◕	●
Constructability	●	◕	◕
Maintenance requirements	●	◑	◑

Evaluation Criteria	Do Nothing	Conventional SWM Strategy	Combined Conventional & LID
4. Economic Environment	◔	◑	◑
Construction costs	●	◑	◔
Long term operation and maintenance costs	○	◕	◔
Land requirements	●	○	◑
Infrastructure protection	○	◕	●
Potential to increase private property values	○	◑	◕
Total Normalized Score for Stormwater Management Alternative	◔	◑	◕

6.4 Preferred Alternative

As shown in **Table 6.14**, the preferred alternative consists of LID source and conveyance controls combined with end-of-pipe facility controls. This approach scored the highest across the physical and natural environment, social environment, and technical environment categories. In the economic category it scored similarly to the conventional SWM approach, as a result of lower scores associated with capital cost and long-term O&M, although it did provide the highest level of infrastructure protection.

In terms of stormwater management objectives, the use of LID source controls as part of this strategy would provide water balance, water quality, and erosion benefits. The end-of-pipe controls would provide further water quality, erosion, and flood control benefits. These benefits, together with the stream restoration component of the strategy, would have a positive impact on the aquatic and terrestrial habitat of the study area.

In all locations, the future uncontrolled Regional event exceeds the future uncontrolled 100-year event and is therefore the governing storm. Furthermore, at 16 of the 18 flow locations, the future uncontrolled Regional flows exceed the existing conditions Regional flows. It is Aquafor's understanding that GRCA will not consider SWM facilities to be in place when assessing the Regional storm. As such, GRCA has accepted the future uncontrolled Regional flows as the Regulatory flows within the study area.

6.4.1 Costs of Preferred Alternative

Unit cost estimates for the preferred alternative were estimated based on implementation of similar projects within the Greater Toronto and Hamilton Area:

- LID: $400 per linear metre

- Dry Ponds: $175 per cubic metre of pond volume

6.5 Potential Impacts Associated with Climate Change

Climate change has the potential to alter rainfall patterns in Ontario as more moisture in a warmer atmosphere is expected to cause an increase in extreme weather events and result in less climate predictability from year-to-year. A change in the intensity and/or frequency of rainfall events can have both acute and long-term effects on stream flow and municipal stormwater management. Rainfall events that produce a larger volume of water than the design flow can result in many complications. If a sufficient outlet or emergency overflow is not provided, large volumes of water can cause surcharging of the storm sewer systems, resulting in flooding in upstream urban areas.

Several tools have been developed by climate scientists and statisticians to project future intensity-duration-frequency (IDF) relationships for rainfall events in Ontario. The IDF_CC Tool 6.5 was developed through the Western University and the Institute for Catastrophic Loss Reduction. This tool was designed as a simple and generic decision support system to generate local IDF curve information that accounts for the possible impacts of climate change. It applies a user-friendly GIS interface and provides precipitation accumulation depths for a variety of return periods (1:2, 1:5, 1:10, 1:25, 1:50 and 1:100 years) and durations (5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours), and allows users to generate IDF curve information based on historical data, as well as future climate conditions that can inform infrastructure decisions. The IDF_CC tool stores data associated with 700 Environment and Climate Change Canada operated rain stations from across Canada. The IDF_CC tool allows users to select multiple future greenhouse gas concentration scenarios and apply results from an ensemble of Global Circulation Models (GCMs) that simulate various climate conditions to local rainfall data.

The IDF_CC Tool 6.5 was used to generate IDF curves for the Brantford Airport station under four climate change scenarios from 2035-2065 using the “all models ensemble” raw GCMs model selection default. The projections included SSP1.26, SSP2.45, SSP3.70, and SSP5.85. Higher SSP numbers correspond to more severe climate change severity.

The 5-year storm (minor system) and 100-year storm (major system) were estimated for all four projections and compared with the existing storm, as provided in the City’s Linear Municipal Infrastructure Standards for Storm Sewers (2023). The rainfall depth associated with each rain event is presented in **Table 6.15** and **Table 6.16**, where cells highlighted in orange indicate an increase in rainfall depth due to climate change.

Under most scenarios, the existing IDF curve is more conservative than the climate change predictions. It is only during long-duration rain events where the existing IDF curve is less conservative, and the model indicates an increase in rainfall depth. The greatest increase in rainfall depth is associated with the 24-hour 100-year event under SSP3.70, which was projected to be 10.8% greater than the existing IDF curve. It is therefore recommended that the effects of climate change be considered by using the IDF projection results to 2050 as a sensitivity analysis during the design of stormwater infrastructure (IDF interpolation equations are provided in **Appendix D**). This sensitivity analysis is recommended, but not required, by the Subwatershed Study. This recommendation may be implemented at the City's discretion.

Table 6.15: Rainfall Depth (mm) for the 5-Year Storm to 2050

	Existing	SSP1.26	SSP2.45	SSP3.70	SSP5.85
5 min	11.61	11.04	11.16	11.28	11.5
10 min	18.28	16.18	16.35	16.53	16.76
15 min	22.73	19.55	19.69	19.99	20.34
30 min	30.45	25.89	26	26.37	27.02
1 h	37.60	31.79	31.91	32.35	33.16
2 h	43.80	40	40.44	40.88	41.7
6 h	52.80	51.16	51.37	52.08	53.39
12 h	57.60	57.45	57.6	58.42	59.85
24 h	64.80	66.99	67.17	68.14	69.82

* orange cells indicate a projected increase in rainfall depth due to climate change

Table 6.16: Rainfall Depth (mm) for the 100-Year Storm to 2050

	Existing	SSP1.26	SSP2.45	SSP3.70	SSP5.85
5 min	19.95	14.91	14.96	15.54	15.4
10 min	32.75	20.23	20.1	20.69	20.75
15 min	41.73	26.04	26.08	26.92	26.78
30 min	57.65	42.68	44.08	46.38	45.63
1 h	71.70	51.06	52.4	55.39	54.5
2 h	82.40	53.43	53.55	55.71	55.22
6 h	93.00	81.88	84.94	89.3	88.14
12 h	98.40	89.12	91.6	97.28	96.42
24 h	100.80	102.77	107.13	111.7	111.12

* orange cells indicate a projected increase in rainfall depth due to climate change

7 Description of the Recommended Plan

This section will summarize the overall Management Strategy for the expansion lands in consideration of the preceding sections. **Section 3** outlined the proposed land uses, while **Sections 5** and **6** identified alternative stormwater strategies and selected a preferred approach. The discussion in this section will focus on targets and appropriate measures related to stormwater management (surface water), erosion, natural heritage, and groundwater.

7.1 Stormwater Management (Surface Water)

Changes in land use, including the conversion of rural lands to urban development alters the water balance as pervious surfaces are converted to impervious surfaces, infiltration characteristics of the soils are altered, and vegetation is removed. When rural lands are urbanized, porous soils are replaced with impervious materials such as concrete and asphalt which yield high runoff during precipitation events. Consequently, land use change can lead to a significant and sometimes radical alteration in the watershed hydrology and water quality.

In order to mitigate the impact of urbanization of the expansion lands, stormwater management in the form of source, conveyance and end-of-pipe facilities will need to provide:

- Water quality treatment consistent with MECP "enhanced" level quality control;
- Infiltration opportunities to maintain pre-development water balance characteristics and support Significant Groundwater Recharge Areas (SGRAs);
- Detention of peak flows to mitigate flooding in critical reaches of study area watercourses; and
- Erosion controls to ensure critical erosion thresholds are not exceeded.

The Runoff Volume Control Target (RVC_T) corresponds to the runoff generated from the regionally specific 90th percentile rainfall event, which is approximately a 29 mm event in Brantford. The runoff generated from a 29 mm rainfall event should be controlled using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are preferred. The control hierarchy is shown below in **Figure 7-1**.

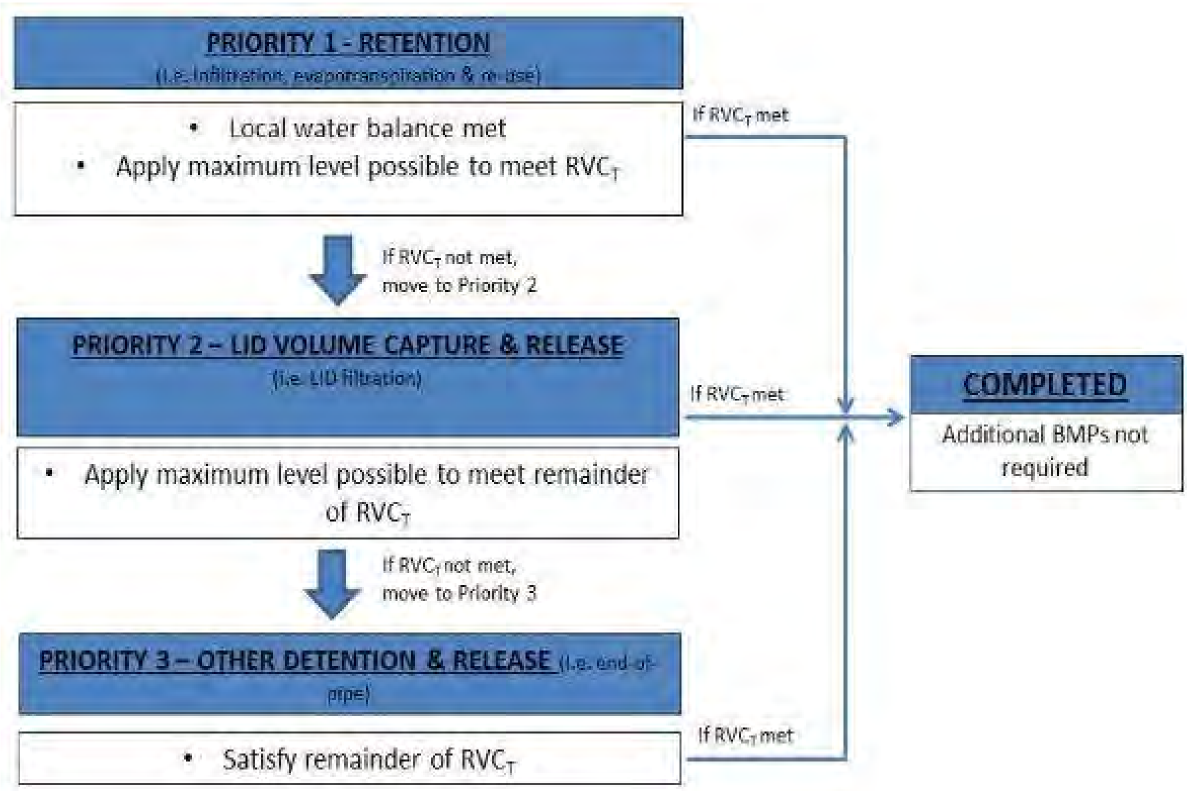


Figure 7-1: The runoff control hierarchy from the MECP's LID Stormwater Management Guidance Manual

7.1.1 Flood Control

This section will address the flood control strategy for up to the 100-year and Regional storms to ensure that proposed development does not increase flows within the creeks or their tributaries. The following criteria must be achieved:

1. Post-development flows from the 2-year through 100-year events are less than or equal to the 2-100 year existing flows; and
2. Uncontrolled flows are less than the existing Regulatory flows, where the Regulatory flow is defined as the larger of the 100-year or Regional flow.

Since post-development flows exceeded existing flows, stormwater detention ponds are necessary. The required detention can be provided within the end-of-pipe stormwater ponds as recommended as part of the preferred stormwater strategy. This consists of municipal dry ponds which were placed near the outlets of the subcatchments; pond placement can be revised as needed during the Block Plan process for areas identified in schedule 2 of the OP, or outside of that, plans of subdivision.

The list of the proposed ponds and stormwater control facilities and their storage volumes are presented in **Table 7.1** based on the locations identified in **Figure 6-1**. Ponds were designed with a storage volume of 450 m^3/ha for residential areas and 750 m^3/ha for industrial/business areas. Storage volumes will also be required to maintain pre-development stream flows where diversions are approved by GRCA. The assumed footprint of each facility is also provided, using an average facility depth of 2m. The proposed storage volumes and footprints are preliminary and need to be confirmed through the design process. In addition, these ponds must be designed to ensure that the post-development flow rates at key flow nodes (**Figure 6-1**) are controlled to the pre-development flow rates.

Table 7.1: Summary of Conceptual Municipal Stormwater Management Ponds

Expansion Lands	Pond Name	Subwatershed	Drainage Area (ha)	Storage Volume (m^3)	Assumed Footprint (ha)
North Brantford	P147329_2	Jones Creek	40.45	30337	2.83
	P147359_5	Jones Creek	24.77	18575	1.73
	P148194_3	Jones Creek	2.07	933	0.15
	P148541_1	Jones Creek	20.25	15191	1.42
	P185	Jones Creek	4.20	1888	0.29
	P188	Jones Creek	48.15	36110	3.37
	P189	Jones Creek	28.15	21110	1.97
	P190	Jones Creek	7.85	5885	0.55
	P191	Jones Creek	33.68	25258	2.36
	P192	Jones Creek	27.95	20966	1.96
	P193	Jones Creek	17.54	7892	1.23
	P194	Jones Creek	40.11	30081	2.81
	P194_1	Jones Creek	35.63	26723	2.49
	P194_3	Jones Creek	9.02	6765	0.63
	P194_4	Jones Creek	47.28	35460	3.31
	P198	Jones Creek	15.01	11256	1.05
	P199	Jones Creek	19.51	8779	1.37
	P200	Jones Creek	5.27	2370	0.37
	P201	Jones Creek	10.94	4921	0.77
	P202	Jones Creek	11.36	5111	0.80
	P203	Jones Creek	3.13	1408	0.22
	P204	Jones Creek	15.37	6916	1.08

Expansion Lands	Pond Name	Subwatershed	Drainage Area (ha)	Storage Volume (m^3)	Assumed Footprint (ha)
	P205	Jones Creek	25.01	11255	1.75
	P206	Jones Creek	9.71	7284	0.68
	P207	Jones Creek	14.56	10921	1.02
	P208	Jones Creek	23.90	10755	1.67
	P209	Jones Creek	6.29	2830	0.44
	P210	Jones Creek	7.85	5885	0.55
	P211	Jones Creek	7.93	5946	0.55
	P213	Jones Creek	3.86	1739	0.27
	P214	Jones Creek	6.33	2848	0.44
	P215	Jones Creek	20.86	9385	1.46
	P215_1	Jones Creek	11.84	5327	0.83
	P215_2	Jones Creek	8.61	3872	0.60
	P216	Jones Creek	19.08	8584	1.34
	P237_2	Jones Creek	11.81	5313	0.83
	P47	Jones Creek	23.60	10622	1.65
	P56	Jones Creek	31.44	14150	2.20
	P59	Jones Creek	4.59	2065	0.32
	P60	Jones Creek	12.63	5684	0.88
	P61	Jones Creek	12.58	5662	0.88
	P153041	Silver Creek	9.09	4091	0.64
	P195	Alexander Drain	7.16	5372	0.50
	P217	Alexander Drain	12.03	9024	0.84
	P218	Alexander Drain	15.30	11473	1.07
	P219	Alexander Drain	39.99	29991	2.80
	P220	Alexander Drain	2.93	2197	0.21
	P224	Alexander Drain	2.47	1851	0.17
	P235	Alexander Drain	14.04	10526	0.98
	P51	Alexander Drain	40.79	18357	3.67
Tutela Heights	P196	Phelps Creek	10.14	4565	0.71
	P197	Phelps Creek	3.73	1678	0.26

Expansion Lands	Pond Name	Subwatershed	Drainage Area (ha)	Storage Volume (m^3)	Assumed Footprint (ha)
	P212	Phelps Creek	7.17	3224	0.50
	P226	Phelps Creek	11.53	5189	0.81
	P227	Phelps Creek	3.56	1603	0.25
	P228	Phelps Creek	2.74	1232	0.19
	P229	Phelps Creek	7.47	3364	0.52
	P230	Phelps Creek	1.09	490	0.08
	P232	Phelps Creek	13.89	6250	0.97
	P233	Phelps Creek	39.90	17955	2.79
	P234	Phelps Creek	5.30	2383	0.48

7.1.2 Water Quality

Following the approach outlined in **Figure 7-1**, it is recommended that new development areas maintain a water quality target that will not vary and will remain as control of the runoff generated from a 29 mm event using infiltration LID measures as a first priority, followed by filtration measures if full infiltration is not feasible. This approach is aligned with the requirements of the MECP CLI ECA, which prioritizes LID measures to achieve an Enhanced level of treatment. An Enhanced level of treatment corresponds to a long-term load reduction of total suspended solids of 80%.

Achieving control of the 29 mm event is possible through infiltration, with **Table 7.2** presenting the equivalent runoff volume within each subcatchment (**Figure 6-6**). However, local conditions may indicate that infiltration of the full 29 mm is not feasible; see **Section 7.1.2.1** for discussion of site-specific factors. If any of these factors apply to a specific site, then LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes should be considered. If using these techniques to treat the full 29 mm is still not feasible, then the use of stormwater management facilities (eg. Wet ponds, wetlands, or hybrid ponds) or manufactured treatment devices (eg. Oil and grit separators) are permitted. Regardless of the method used to achieve the water quality criteria, SWM quantity controls to control peak flows will still be required at the end-of-pipe.

Table 7.2: Runoff Volumes

Subcatchment	29 mm (12 Hr SCS) Runoff Equivalent Depth (mm)	29 mm (12 Hr SCS) Runoff Volume (m^3)
147329_2	24.85	10050
147329_6	24.85	1410
147359_2	25.24	420

Subcatchment	29 mm (12 Hr SCS) Runoff Equivalent Depth (mm)	29 mm (12 Hr SCS) Runoff Volume (m^3)
147359_5	23.54	5830
148175_2	18.71	320
148194_3	16.24	340
148541_1	23.36	4730
153041	15.78	1430
153845_9	18.26	140
S185	16.23	680
S186	14.32	630
S187	15.99	630
S188	35.12	16910
S189	24.16	6800
S190	25.05	1970
S191	23.64	7960
S192	24.46	6840
S193	17.19	3010
S194	24.36	9770
S194_1	23.87	8500
S194_3	22.34	2020
S194_4	24.49	11580
S195	24.42	1750
S196	16.45	1670
S197	13.65	510
S198	23.94	3590
S199	16.27	3170
S200	16.21	850
S201	16.4	1790
S202	16.92	1920
S203	16.53	520
S204	16.29	2500
S205	16.36	4090
S206	24.69	2400
S207	24.89	3620
S208	16.7	3990
S209	17	1070
S210	24.89	1950
S211	23.9	1890
S212	16.58	1190
S213	18.2	700
S214	17.02	1080
S215	17.8	3710

Subcatchment	29 mm (12 Hr SCS) Runoff Equivalent Depth (mm)	29 mm (12 Hr SCS) Runoff Volume (m^3)
S215_1	17.97	2130
S215_2	18.03	1550
S216	18.28	3490
S217	25.17	3030
S218	25.81	3950
S219	26.28	10510
S220	25.5	750
S222	24.41	800
S224	24.42	600
S226	18.03	2080
S227	18.8	670
S228	18.66	510
S229	18.48	1380
S230	18.67	200
S232	19.12	2660
S233	15.34	6120
S234	17.14	910
S235	24.06	3380
S237_2	17.48	2060
S36	25.03	390
S36_6	16.26	1110
S36_8	32.13	470
S47	16.35	3860
S51	16.12	6580
S56	16.33	5130
S59	17.04	780
S60	17.04	2150
S61	17.61	2220

7.1.2.1 Site-Specific Factors Limiting Use of LIDs

The use of infiltration LID measures may be limited by site-specific factors. These factors may include, but are not limited to:

- Shallow bedrock;
- High groundwater;
- Zoning, setbacks or other land-use requirements;
- Property or infrastructure restrictions;
- Poor soils (low infiltration rates, highly compacted, contaminated); or
- Highly vulnerable aquifer.

In addition to these factors, the presence of high-risk site activities within the catchment area may also restrict the use of LIDs. For all sites, infiltration practices should not accept runoff from drainage areas within the site which are associated with higher risks such as fueling stations, waste disposal areas, vehicle washing stations, salt storage areas, stockpiling areas and shipping and receiving areas. A complete list of high-risk site activities based on O.Reg. 153/04 (Records of Site Condition) and O.Reg. 287/07 (Clean Water Act) is provided in **Table 7.3**. These regulations provide guidance for protecting soil and water from contamination. This prohibition includes the use of flexible liners and or gated/ closeable inlets to prevent infiltration of runoff due to the potential for punctures and or winter by-pass, respectively. Should 'permanent' and 'hardened' impermeable closed bottom structure be used (i.e., plastic or concrete tanks, vaults, or chambers), explicit approval from the City of Brantford shall be obtained.

Instead of infiltration-based stormwater practices, pollution prevention practices in the form of administrative and engineering controls should be applied in these areas, followed by treatment using conventional stormwater management controls such as ponds, wetlands and hybrid facilities as well as hydrodynamic separators (OGS units) and/or membrane or media filtration units.

Table 7.3 identifies individual high-risk site activities based on O.Reg. 153/04 and O.Reg. 287/07. High-risk site activities are defined as those with the potential for high levels of contamination such as hydrocarbons, metals, organic and inorganic compounds, sediments and chlorides. At this scale of study, it is impossible to predict the long-term site-specific activities of individual sites; however, **Table 7.3** can be used a screening framework for identifying portions of each site where additional focus and review is needed to where LIDs should be discouraged, due to risk associated with the specific uses.

Drainage areas containing a site with high-risk activities (**Table 7.3**) will generally be discouraged from incorporating LID techniques that utilize infiltration as its primary function within the identified catchment because of the associated risk to groundwater contamination. However, high-risk site activities do not preclude the use of those LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes. Additionally, the infiltration of rainwater from catchments that are isolated from the respective high-risk site activities such as rainwater emanating from rooftops, employee parking facilities or directly falling on permeable surfaces is generally considered relatively 'clean' and should not be excluded from infiltration.

While the application of road salt is identified in **Table 7.3** due to its inclusion in O.Reg. 287/07 as a Prescribed Drinking Water Threat, the need for winter maintenance of roads and parking surfaces, including the application of de-icers, is recognized due to safety and liability concerns. However, there is also the need to target impervious surfaces with infiltration-based LIDs in order to meet infiltration targets and sustain critical surface water – groundwater connections. To balance these needs, it is recommended that:

1) Infiltration practices are recommended for Local Roads only. Local roads typically have less intensive winter deicer application as a result of lower usage and posted speed limits; and
2) A Salt Management Plan must be completed for the subject property for paved surfaces between 200 to 2000 m^2. Infiltration practices are discouraged for runoff originating from paved surfaces in excess of 2000 m^2 the facility is not used during winter months or an appropriate engineering solution is implemented to the satisfaction of City staff.

7.1.2.2 Additional Water Quality Best Practices

In addition to providing water quality treatment, the reduction of pollutant loading through the implementation of best management practices is recommended. Recommendations include:

- Residents:
    - Reducing the use of fertilizer and pesticides on lawns and gardens;
    - Pick up and dispose of litter and pet waste in a timely manner;
    - Manage yard waste so that grass clippings and leaves stay out of the street;
    - If residents wash their car at home, make sure they do so on the grass instead of in the driveway, and use phosphorus-free detergents;
    - Promote native landscaping to reduce turfgrass. If planting grass, keep a thick cover at least 8 cm tall to reduce soil erosion; and
    - Do not leave uncovered soil exposed to the elements – stabilize it using grass or native vegetation.
- City of Brantford:
    - Practice good sanitary sewer maintenance to ensure the system doesn’t leak;
    - Reduce the use of fertilizer and pesticides, and ensure vegetative debris doesn’t enter storm sewer systems;
    - Implement broader City-wide initiatives to prevent pesticide use by residents;
    - Reduce turfgrass cover and use native vegetation where feasible;
    - Control waste-generating wildlife such as geese;
    - Remove debris from storm sewer system, especially inlets and catch basins;
    - Manage exposed soil to prevent wind or water erosion; and
    - Maintain vehicles to prevent pollutant releases.

Table 7.3: High-Risk Site Activities Which Preclude the Use of Infiltration-Based LID BMPs Within the Contributing Catchment Area

Potentially Contaminating Activities (O.Reg 153/04 Table 2)		
• Acid and Alkali Manufacturing, Processing and Bulk Storage • Adhesives and Resins Manufacturing, Processing and Bulk Storage • Airstrips and Hangars Operation • Antifreeze and De-icing Manufacturing and Bulk Storage • Asphalt and Bitumen Manufacturing • Battery Manufacturing, Recycling and Bulk Storage • Boat Manufacturing • Chemical Manufacturing, Processing and Bulk Storage • Coal Gasification • Commercial Autobody Shops • Commercial Trucking and Container Terminals • Concrete, Cement and Lime Manufacturing • Cosmetics Manufacturing, Processing and Bulk Storage • Crude Oil Refining, Processing and Bulk Storage • Discharge of Brine related to oil and gas production • Drum and Barrel and Tank Reconditioning and Recycling • Dye Manufacturing, Processing and Bulk Storage • Electricity Generation, Transformation and Power Stations • Electronic and Computer Equipment Manufacturing • Explosives and Ammunition Manufacturing, Production and Bulk Storage • Explosives and Firing Range • Fertilizer Manufacturing, Processing and Bulk Storage	• Fire Retardant Manufacturing, Processing and Bulk Storage • Fire Training • Flocculants Manufacturing, Processing and Bulk Storage • Foam and Expanded Foam Manufacturing and Processing • Garages and Maintenance and Repair of Railcars, Marine Vehicles and Aviation Vehicles • Gasoline and Associated Products Storage in Fixed Tanks • Glass Manufacturing • Importation of Fill Material of Unknown Quality • Ink Manufacturing, Processing and Bulk Storage • Iron and Steel Manufacturing and Processing • Metal Treatment, Coating, Plating and Finishing • Metal Fabrication • Mining, Smelting and Refining; Ore Processing; Tailings Storage • Oil Production • Operation of Dry-Cleaning Equipment (where chemicals are used) • Ordnance Use • Paints Manufacturing, Processing and Bulk Storage • Pesticides (including Herbicides, Fungicides and Anti-Fouling Agents) Manufacturing, Processing, Bulk Storage and Large-Scale Applications • Petroleum-derived Gas Refining, Manufacturing, Processing and Bulk Storage • Pharmaceutical Manufacturing and Processing	• Plastics (including Fibreglass) Manufacturing and Processing • Port Activities, including Operation and Maintenance of Wharves and Docks • Pulp, Paper and Paperboard Manufacturing and Processing • Rail Yards, Tracks and Spurs • Rubber Manufacturing and Processing • Salt Manufacturing, Processing and Bulk Storage • Salvage Yard, including automobile wrecking • Soap and Detergent Manufacturing, Processing and Bulk Storage • Solvent Manufacturing, Processing and Bulk Storage • Storage, maintenance, fuelling and repair of equipment, vehicles, and material used to maintain transportation systems • Tannery • Textile Manufacturing and Processing • Transformer Manufacturing, Processing and Use • Sewage Treatment and Sewage Holding Facilities • Vehicles and Associated Parts Manufacturing • Waste Disposal and Waste Management, including thermal treatment, landfilling and transfer of waste, other than use of biosoils as soil conditioners • Wood Treating and Preservative Facility and Bulk Storage of Treated and Preserved Wood Products
Prescribed Drinking Water Threats (O.Reg. 287/07)		
• The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act. • The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage. • The application of agricultural source material to land. • The storage of agricultural source material. • The management of agricultural source material. • The application of non-agricultural source material to land. • The handling and storage of non-agricultural source material.	• The application of commercial fertilizer to land. • The handling and storage of commercial fertilizer. • The application of pesticide to land. • The handling and storage of pesticide. • The application of road salt.[1] • The handling and storage of road salt. • The storage of snow. • The handling and storage of fuel. • The handling and storage of a dense non-aqueous phase liquid. • The handling and storage of an organic solvent.	• The management of runoff that contains chemicals used in the de-icing of aircraft. • An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body. • An activity that reduces the recharge of an aquifer. • The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. • The establishment and operation of a liquid hydrocarbon pipeline. O. Reg. 385/08, s. 3; O. Reg. 206/18, s. 1.
Other Threats		
• Anthropogenically contaminated soils that have not been fully remediated		

1 Although salt is included as a Prescribed Drinking Water Threat, it is being managed through restrictions to infiltration in high-risk areas and through City and Private Salt Management Plans, and therefore does not automatically prohibit infiltration.

7.1.3 Water Balance

The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead.

Pre-development groundwater recharge estimates (see **Section 6.2.4**) provide an annual infiltration rate of approximately 113 and 119 mm/year for Tutela Heights and North Brantford, respectively. Given that there are approximately 40 rainfall events per year the average infiltration rate per event is relatively modest (approximately 3 mm per event). The actual values on a site by site basis will vary depending on soil type, slopes, vegetation cover and depth to water table.

The above recharge targets can be achieved by incorporating appropriate LID source and conveyance control measures as outlined in **Section 5** together with the requirements to meet the Water Quality targets as noted in **Section 7.1.2** above. Collectively the LID measures should ensure that post-development infiltration rates equal or exceed pre-development levels. The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead.

Significant Groundwater Recharge Areas (SGRAs) will require additional attention to ensure pre-development recharge rates are maintained (see **Section 7.4**).

Site-scale and/or catchment-scale water balance assessments will be required to help guide the development of stormwater management and functional servicing plans at the block plan or subdivision stage.

7.1.4 Thermal Mitigation

Aquatic investigations by Aquafor as part of the **North Brantford and Tutela Heights Subwatershed Study Phase 1 Update** found that most of the watercourses in the study area demonstrated a cool-warmwater thermal regime, outside of the North Branch of Jones Creek which supports coldwater habitat.

Since the use of LID measures reduces stormwater temperature, it is expected that the implementation of the recommended stormwater strategy will adequately cool stormwater temperatures. The proposed SWM facilities will also be dry ponds without a permanent pool that can impact temperatures in receiving watercourses. However, if it is deemed technically not feasible to achieve the water quality target using LID measures, and a wet end-of-pipe stormwater facility is required, this facility should be designed with best management practices. The latest thermal mitigation technologies should be considered in addition to more common practices which include, but are not limited to (STEP, no date):

- Bottom draw outlets;
- Cooling trenches;

- Subsurface trench outlets;
- Shading of permanent pool, outfall channel, and paved surfaces throughout the catchment;
- Improved pond design (e.g., location, orientation, length-to-width ratio, planted berms); and
- Use of facilities without a permanent pool.

7.2 Natural Heritage

This section provides an overview and summary of natural heritage considerations and policy requirements that were discussed previously in the Phase 1 SWS report, with additional discussion provided as appropriate related to the proposed land use plan and future requirements.

7.2.1 Application of NHS Criteria

The City of Brantford's OP, Section 5.6, defines the policies applicable to the Natural Heritage System (NHS) and the components that are included in that system. Specific to this analysis, the NHS is defined as comprising the following components:

- The **Core Natural Areas** designation, which includes the environmental features themselves plus an associated 30-metre buffer, plus portions of the NHS for the Growth Plan for the Greater Golden Horseshoe (key natural heritage features and key hydrologic features) which are located within Brantford.

- The **Adjacent Lands** overlay, which is based on an approximate 90 m setback from the boundary of the Core Natural Areas designation and which is intended to act as a trigger for the completion of an EIS. Adjacent Lands may have ecological and hydrological functions or linkages that are important to the long-term health of the features and functions of the Natural Heritage System.

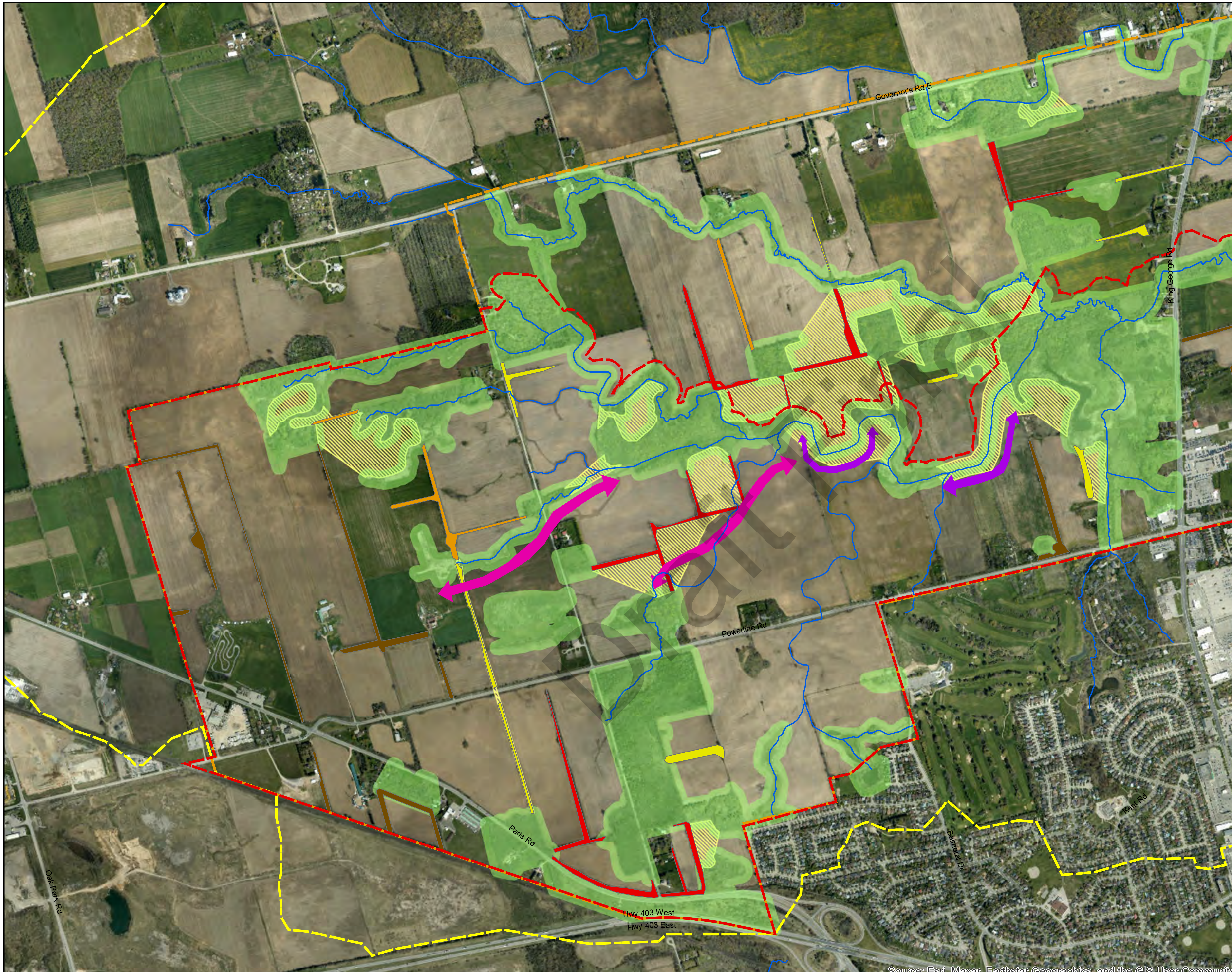
- The Growth Plan NHS defined by A Place To Grow: Growth Plan for the Greater Golden Horseshoe (Government of Ontario, 2020) which includes key hydrologic features (permanent streams; intermittent streams; inland lakes and their littoral zones; seepage areas and springs; and wetlands) and key natural heritage features (habitat of endangered species and threatened species; fish habitat; wetlands; life science areas of natural and scientific interest [ANSIs], significant valleylands, significant woodlands; significant wildlife habitat [including habitat of special concern species]; sand barrens, savannahs, and tallgrass prairies; and alvars).

Many of the defined key natural heritage features under the Growth Plan overlap with components of the City's Core Natural Areas, with the exception of aquatic features and fish habitat which will be discussed in the context of the provincial Growth Plan NHS.

Further to the above, the City's Core Natural Areas designation includes the following:

- Provincially significant wetlands;
- Provincially significant woodlands (i.e., woodlands >4 ha in size, excluding actively managed woodlots for forestry or agriculture);
- Significant wildlife habitat attributes and functions, including habitat for SAR and rare plant communities such as prairie, savannah, and oak woodland;
- Significant areas of natural and scientific interest (ANSI)
- Hazard lands;
- Other natural heritage features (i.e., woodlands that are less than 4 ha, locally significant wetlands, treed slopes, and cultural habitat features);
- Enhancement/restoration areas; and
- Additional Key Natural Heritage Features and Key Hydrologic Features (as appropriate).

Features meeting the above criteria for inclusion in the NHS were identified through field investigations and review of existing data during Phase 1 of the SWS, and the results are illustrated on **Figure 7-2**.



THE CORPORATION OF THE CITY OF BRANTFORD

Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Growth Plan Natural Heritage
- Watercourse
- Functional Linkages (ABL,
- Functional Linkages (Plan B,
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Vegetation Protection Zone
- Enhancement/Restoration
- Significant Valley Boundary

Figure 7.3 (1 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
Author: KB
Projection: UTM_Zone_17N
Source: City of Burlington, Plan B Natural Heritage, LIO

0 450 900
Metres

N

Aquafor Beech Limited

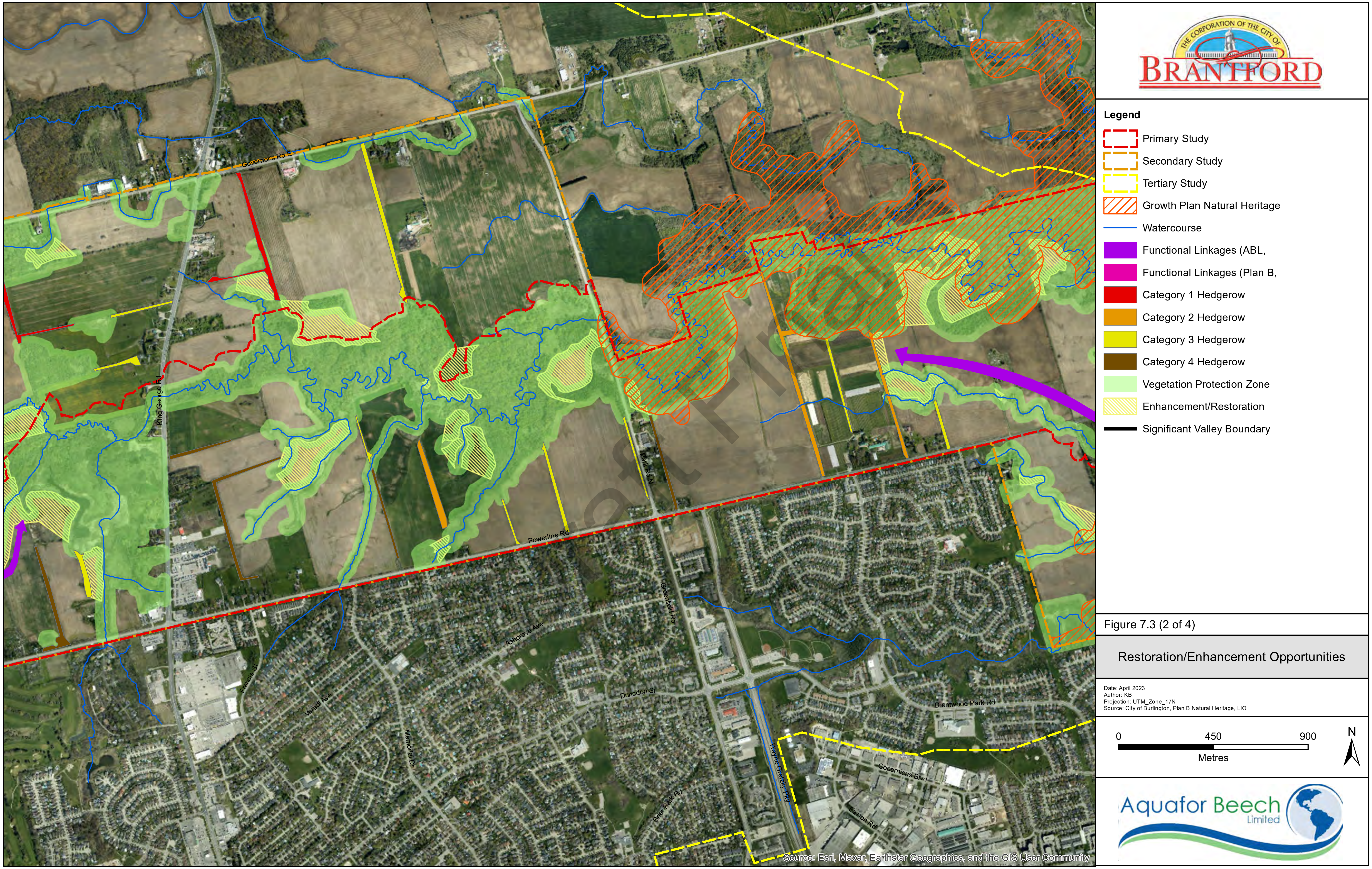
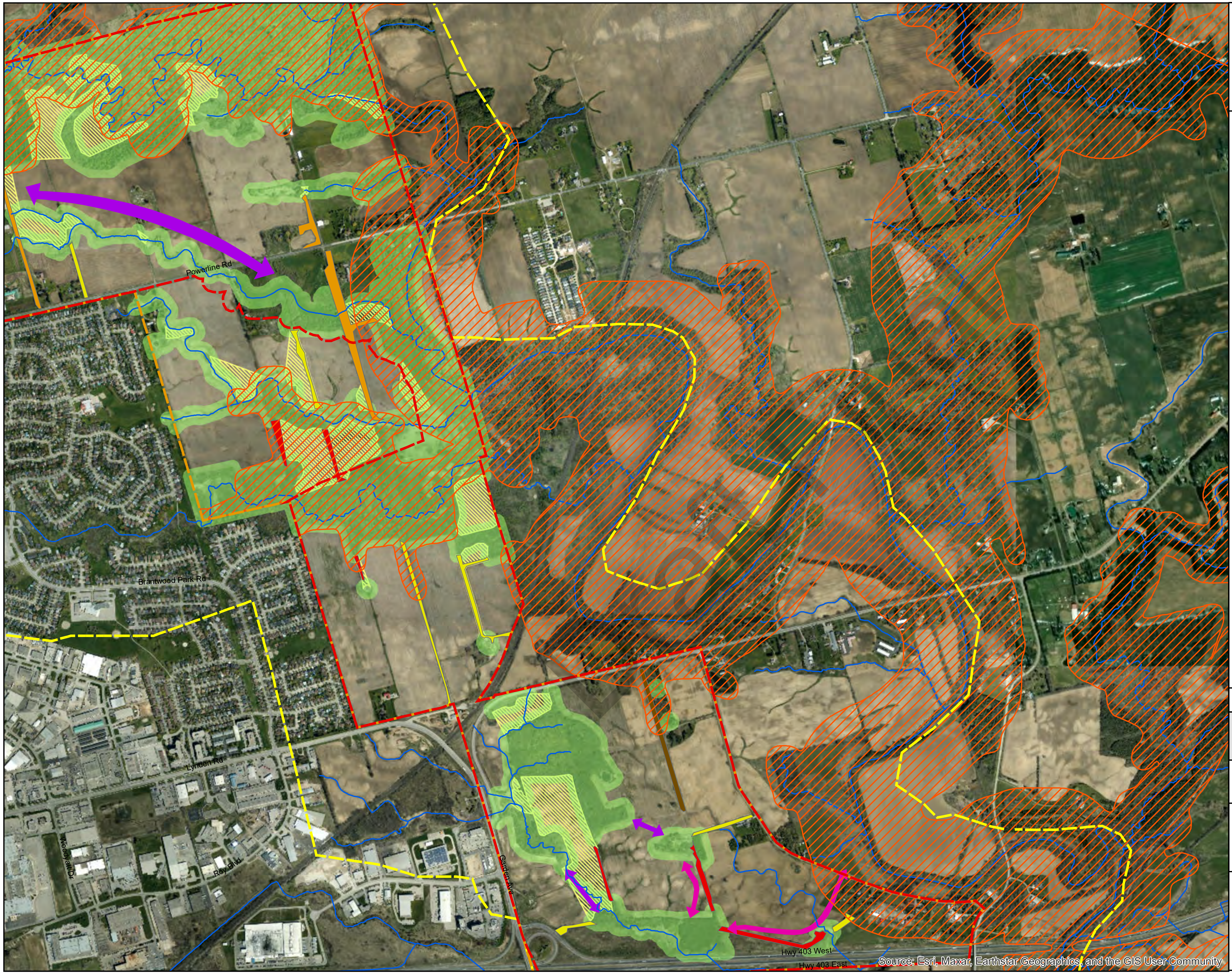


Figure 7.3 (2 of 4)

Restoration/Enhancement Opportunities



BRANTFORD
THE CORPORATION OF THE CITY OF

Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Growth Plan Natural Heritage
- Watercourse
- Functional Linkages (ABL,
- Functional Linkages (Plan B,
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Vegetation Protection Zone
- Enhancement/Restoration
- Significant Valley Boundary

Figure7.3 (3 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
Author: KB
Projection: UTM_Zone_17N
Source: City of Burlington, Plan B Natural Heritage, LIO

0 450 900
Metres
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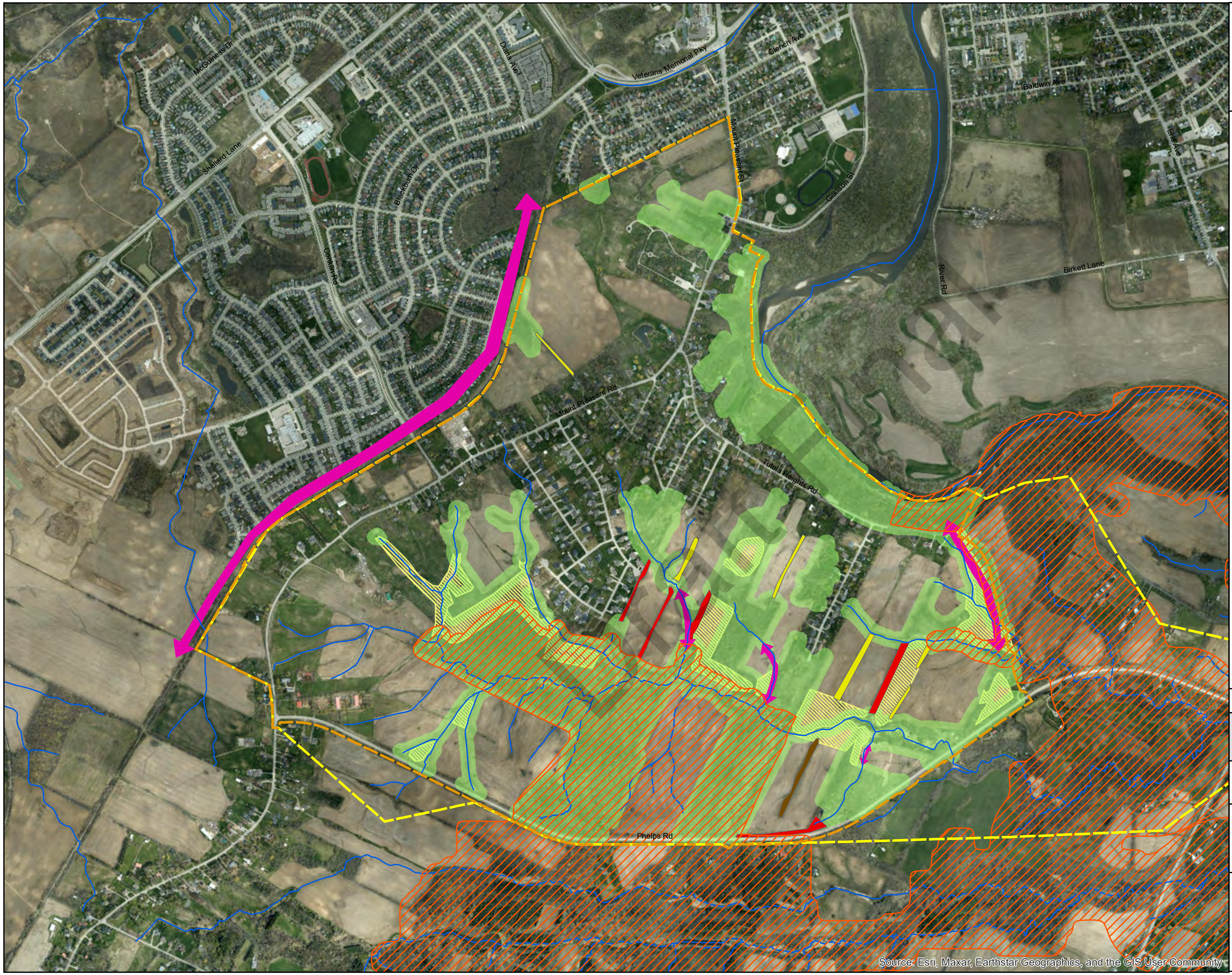
Limited



Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Growth Plan Natural Heritage
- Watercourse
- Functional Linkages (ABL,
- Functional Linkages (Plan B,
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Vegetation Protection Zone
- Enhancement/Restoration
- Significant Valley Boundary

Figure 7.3 (4 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
Author: KB
Projection: UTM_Zone_17N
Source: City of Burlington, Plan B Natural Heritage, LIO

0 450 900
Metres

N

7.2.2 Vegetation Protection Zones/Buffers

The City's Core Natural Areas designation includes a 30 m vegetation protection zone from the identified features to protect their ecological and hydrological functions. The City's OP indicates that 30 m is generally accepted as the minimum requirement but that it may be adjusted as a result of further analysis carried out in an EIS. Allowances may be made for municipal infrastructure such as roads, public trails, and SWM facilities provided grading is restricted to the outer third of the buffer zone. Local catchments, or contributing drainage areas, could be a basis for development setbacks from significant wetlands and cold-water fish habitat.

7.2.3 Enhancement and Restoration Opportunities

The City's Official Plan policies and requirements support the principle of enhancement and restoration of ecological features and functions, stating that "*it is the intent of this Plan to ensure that the biodiversity, ecological function and connectivity of the Natural Heritage System is protected, maintained, restored or, where possible, enhanced for the long-term, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features*". "Enhancement/restoration areas" are included as a component of the Core Natural Areas designation. Opportunities to improve the existing NHS should be reviewed and developed at the site-specific assessment stage and should be considered in keeping with the following factors:

- **Size**: Larger patches of habitat are generally more valuable than smaller. Opportunities to increase the size of existing patches of natural cover (e.g., by designating open space or establishing parks adjacent to existing natural areas) should therefore be considered.
- **Shape**: Habitat patches which are compact (i.e., those which have less 'edge' per area) are generally more valuable than those which are linear or elongated. Edges are often associated with effects such as greater establishment of introduced and invasive plant species, increased rates of predation, increased noise disturbance, and changes to microclimate. Opportunities to fill in gaps and reduce the edge to interior ratio of natural heritage patches should therefore be considered.
- **Complexity**: Natural areas with a high diversity of vegetation communities, microhabitats, and topographical features often support a wider variety of species (and a greater proportion of rare species) than those which are more uniform. Opportunities to increase the diversity of habitat across the landscape (e.g., by planting restoration areas with a variety of native species, by creating sloughs or pit/mound topography in restoration areas, or by conserving successional meadows and thickets in addition to forests) should therefore be considered.
- **Connectivity**: Fragmentation of natural areas by development can lead to the isolation of habitat patches and the wildlife they support, limiting dispersal of individuals and reducing genetic variability within the population. Opportunities to maintain and improve existing connections between natural areas (e.g., by completing riparian planting along ephemeral watercourses and HDFs, or by widening and enhancing

canopy cover along hedgerows) and to create new connections where they are currently lacking should therefore be considered.

Restoration and/or enhancement of a site may be done either actively (i.e., by planting or seeding native vegetation, potentially accompanied by grading to create specific topography or features such as constructed wetlands) or passively (i.e., by ceasing management and allowing vegetation to colonize according to the in-situ seed bank). Active restoration is a more costly and labour-intensive approach, but it offers opportunities for community involvement (e.g., tree planting days) and can accelerate a site to a more advanced stage of succession (i.e., promote forest development through tree and shrub planting). It is also more likely to achieve a target vegetation community or species diversity target; passively allowing succession to occur is more likely to allow colonization of a site by non-native and/or invasive species. Active restoration is likely to be a component of any required ecological offsetting plan or compensation strategy related to impacts of proposed development; the need for and scope of such a plan would be identified through the development application process (i.e., addressed as a component of a site-specific EIS or equivalent study) and would need to be developed in consultation with the City and GRCA.

Opportunities for restoration and enhancement within the study area, as mapped on **Figure 7-3**, were generally identified in three categories: infill areas adjacent to or between existing NHS components; stream corridor restoration; and restoration of buffers.

NHS Infill

The maps provided illustrate multiple locations where cleared or highly disturbed land (mainly fields currently in use for agriculture) are fully or nearly surrounded on all sides by the identified NHS. These locations may be undevelopable due to a lack of access and are therefore ideal candidates for restoration in order to improve the size and shape of the existing NHS patches.

This ‘infill’-type restoration would be particularly valuable in the North Brantford portion of the study area along the Jones Creek corridor to establish a pocket of forest interior habitat which is currently missing from the landscape. In the Tutela Heights study area, many of the existing natural features are long and narrow, and therefore filling gaps between two proximal patches will dramatically widen the linkage corridor.

Stream Corridor and Riparian Restoration

Restoration and enhancement of riparian zones along watercourses and HDFs is also recommended; well-vegetated riparian zones provide shade, cover, and food sources for in-stream wildlife, help control water temperature, and allow the filtration/settling of suspended sediment in runoff before it reaches a watercourse channel. Riparian restoration would be particularly effective along the tributaries connecting Jones Creek to the urban area as well as along the tributaries extending off Phelps Creek that provide the majority of the connectivity in the Tutela Heights study area. Other restoration opportunities include the removal of any barriers to fish movement.

VPZ/Buffer Restoration
Restoration of the identified VPZs around eligible components of the NHS would provide a benefit to the NHS as a whole and increase the effectiveness of the buffering function the VPZs were established to provide. Restoration of VPZs should not, however, be considered as a component of ecological offsetting, if such is required, since the naturalization of VPZs is a pre-existing requirement.

Compatible land uses or low-impact development (e.g., LIDs) may be allowed within VPZs, but should not compromise the ability of the VPZ to provide the necessary buffering function to the NHS feature around which it was established.

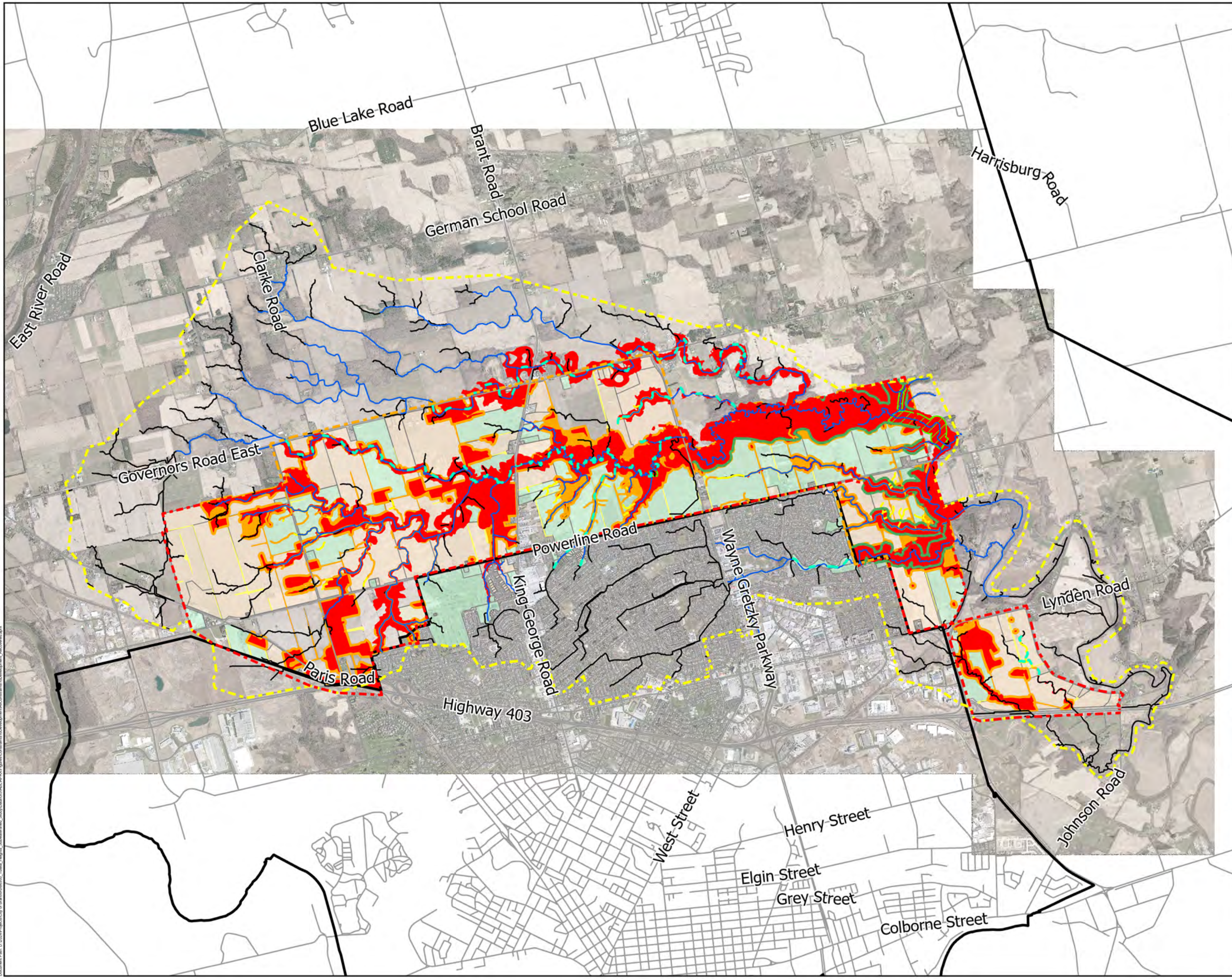
Linkages
Hedgerows were evaluated in this study with regard to the linkage function that they provide; linkages are important ecological features that promote the diversity and spread of plants and animals on the landscape, and the restoration or enhancement of these features can have a positive net impact on the adjacent core features. Where linkages/hedgerows have been identified by this study, is important to note that in many cases it is the linkage *function* that is important, and that some modification of the *feature* itself may be allowed (if supported by EIS or equivalent study) so long as any important functions are maintained or replicated elsewhere. Future site-specific assessments (e.g., EIS) shall review and address linkages in the study area (including but not limited to or restricted by those hedgerow linkages identified in this SWS) and ensure that habitats are not fragmented or isolated by future site alteration or development.

The spatial, aesthetic, and biophysical characteristics of each identified hedgerow within the study area was assessed in the field, as detailed in the Phase 1 SWS report. Hedgerows have not been identified as a major component of connectivity and linkage throughout the watershed, but a few hedgerows have been characterized as Category 1 or 2, indicating that they have, or potentially have, high value for connectivity in the subwatershed area, or that they contain significant or protected species (e.g., Butternut) that warrant retention. Based on these characteristics, management recommendations or enhancement opportunities may exist to further increase their value as linkage corridors within the NHS. Hedgerows that are Category 3 (containing other valuable attributes unrelated to connectivity or linkage) may be also considered for integration based on the presence of mature or specimen trees or wildlife habitat, where adjacent land uses allow (e.g., where parklands can be integrated).

In general, management or linkage enhancement recommendations for high value hedgerows (e.g., Category 1 and 2) include the removal of invasive species and native species planting to widen existing corridors or bridge existing tree gaps. It is recommended that dead/dying ash also be replaced with native trees.

Compensation
Features where areas may meet NHS criteria but are isolated or of lower quality/function and therefore could be reviewed related to proposed development if supported by an EIS and if

suitable compensation/offsetting is also proposed to ensure no net negative impact. Proposed restoration/enhancement in keeping with the above must be considered wherever ecological offsetting or compensation is required related to anticipated impacts of development. The minimum goal for offsetting/compensation should be no net loss of natural cover or ecological function within the subwatershed. Compensation/mitigation measures to offset any loss of the required VPZ and its function is also required. Compensation/mitigation should preferentially be applied to the affected feature and not 'offsite' (e.g., additional planting area connected to a woodland with reduced VPZ, as opposed to planting in an isolated park some distance away). Further, planting of vegetation within the minimum VPZ is not eligible to propose as compensation since, as stated above, the VPZ is already intended to actively "be restored with native, self-sustaining vegetation". Restoration of the VPZ is therefore considered the baseline requirement, to which additional compensation measures must be added where required.



THE CORPORATION OF THE CITY OF BRANTFORD

Legend

- Municipal Boundary
- No Private Property Access Granted
- Private Property Access Granted
- Long-Term Stable Slope Offset
- Meander Belt Assessment Required
- Road Centreline
- Watercourse (GRCA)
- Future HDF Studies Required
- Stable Slope Constraint

Subwatershed Study Area:

- Primary
- Secondary
- Tertiary

Tier Constraints to Development:

- High Constraint
- Moderate Constraint
- Low Constraint
- High Constraint HDF
- Moderate Constraint HDF
- Low Constraint HDF

Figure

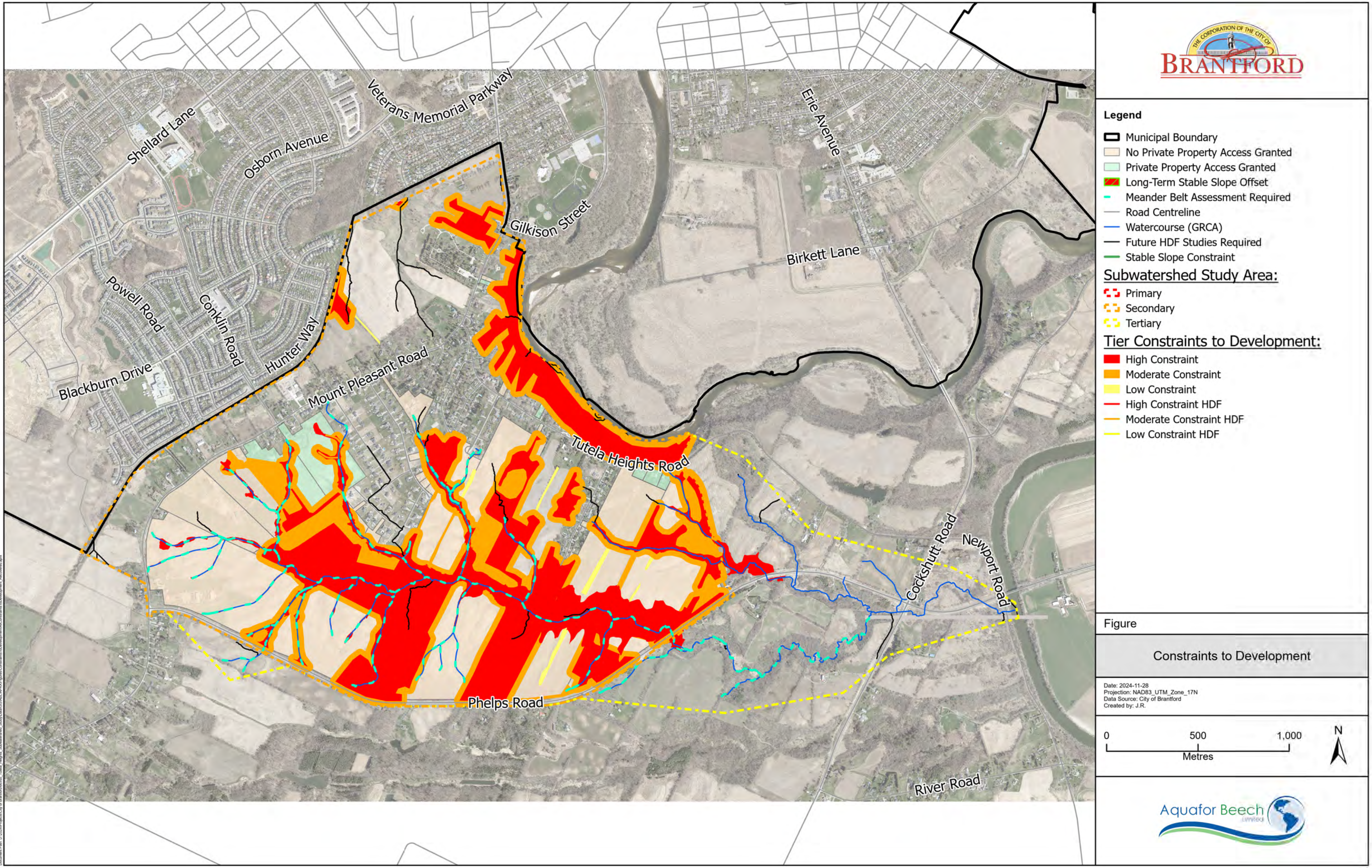
Constraints to Development

Date: 2024-11-28
Projection: NAD83_UTM_Zone_17N
Data Source: City of Brantford
Created by: J.R.

0 500 1,000 1,500 2,000 2,500
Metres

N

Aquafor Beech Limited



Veterans Memorial Parkway
Shellard Lane
Osborn Avenue
Gilkison Street
Erie Avenue
Birkett Lane
Powell Road
Conklin Road
Hunter Way
Blackburn Drive
Mount Pleasant Road
Tutela Heights Road
Cockshutt Road
Newport Road
Phelps Road
River Road
THE CORPORATION OF THE CITY OF
BRANTFORD
Legend
Municipal Boundary
No Private Property Access Granted
Private Property Access Granted
Long-Term Stable Slope Offset
Meander Belt Assessment Required
Road Centreline
Watercourse (GRCA)
Future HDF Studies Required
Stable Slope Constraint
Subwatershed Study Area:
Primary
Secondary
Tertiary
Tier Constraints to Development:
High Constraint
Moderate Constraint
Low Constraint
High Constraint HDF
Moderate Constraint HDF
Low Constraint HDF
Figure
Constraints to Development
Date: 2024-11-28
Projection: NAD83_UTM_Zone_17N
Data Source: City of Brantford
Created by: J.R.
0
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Aquafor Beech Limited

7.2.4 Headwater Drainage Features

Headwater Drainage Features (HDFs) are important in maintaining primary and secondary inputs to surface water, groundwater, and fish habitat. HDFs within the Study Area were previously defined as a part of the Phase 1 program, but were not assessed as a part of the **North Brantford and Tutela Heights Subwatershed Study: Phase 1 Update Report** due to timing and access constraints. A desktop analysis was completed to build upon the management recommendations made as a part of Phase 1 and to further identify potential features within the study area. HDFs on lands not accessed during either phase of this study will have to be assessed as part of a future study to address the potential management implications displayed below in **Table 7.4**.

HDFs with a "Protection" management recommendation are to be retained and protected in situ. As these features within the Study Area were documented to provide indirect fish habitat, "Protection" HDFs should therefore be treated as *fish habitat and key hydrologic features*, which are protected as part of the Municipal NHS, with appropriate VPZs applied.

Table 7.4: Summary of HDF Management Implications

Management Implications	HDF Classification			
	Protection	Conservation	Mitigation	No Management Required
Must remain open	Yes	Yes	Yes	n/a
Relocate using Natural Channel Design	Not permitted, enhancement only	May be considered, not preferred	Natural Channel Design not required[1]	n/a
Maintain or replicate groundwater or wetlands	Maintain or enhance	Maintain or replicate, restore if possible	n/a	n/a
Maintain hydroperiod	Yes	Yes	Yes	n/a
Direct connection to downstream	Yes	Yes	Yes	n/a
Replicate function through enhanced lot conveyance control	n/a	n/a	Replicate using bioswales, LID, vegetated swales or constructed wetlands	n/a

[1]Unless the management recommendations call for the restoration of lost function or enhancement and creation of fish habitat.

HDFs with a "Conservation" or "Mitigation" classification also provide indirect fish habitat within the study area and would, per Brantford's OP, qualify for protection as Key Hydrologic Features where located outside of the Settlement Area. However, the Management Recommendations provided in the HDF Guidelines indicate that these features can be relocated or replicated within certain guidelines/requirements. To rectify this apparent conflict between municipal policy regarding fish habitat and the management recommendations of the HDF Guidelines, this study recommends the following approach: proposed development or land-use change should consider HDFs first using the Management Recommendations, as these were developed specific to HDFs and account for the preservation of important features and functions associated with these features. Relocation or replication of "Conservation" or "Mitigation" HDFs may therefore be proposed in keeping with the Management Recommendations.

However, once any proposed relocation of a "Conservation" HDF is completed as part of a new development, the new channel would then need to have the Key Hydrologic Feature designation applied and all associated setbacks and VPZs would need to be observed for the new alignment. For "Mitigation" HDFs where function is to be replicated through LIDs or similar, NHS designation would not apply but an EIS or other appropriate study would need to be completed to ensure no net loss of function to downstream systems (i.e., maintenance of indirect fish habitat function would need to be demonstrated).

Please note that other considerations (e.g., flood hazard limits, wetland vegetation communities) may also apply to HDFs.

7.3 Identification of Constraints to Development

The natural heritage features and hydrologically sensitive features discussed in the preceding subsections were considered in concert with natural hazards in order to identify constraints to future development. Constraints were classified as High, Moderate, or Low, where:

- **High** was applied to areas where development intrusion is generally not allowed (although specific exceptions may be applicable to flood hazard constraints) - these areas have been carried forward as 'Environmental Protection Area' or similar designation on the proposed land use plans;
- **Moderate** was applied to areas requiring further study to fully define natural heritage features or determine the appropriate level of protection, or where some development intrusion or modification of features may be allowed if supported by a scoped Environmental Impact Study, Geotechnical Slope Stability Study, or other appropriate study. These areas have been carried forward as 'Environmental Protection Area' or similar designation on the proposed land use plans; and
- **Low** was applied to features or areas for which municipal policy does not preclude development intrusion, but which represent natural cover on the landscape and therefore may be associated with ecological offsetting requirements (as previously touched on in **Section 4.1.2**) or to which other requirements may apply. Such features are generally recommended for incorporation into site-level plans where possible (e.g.,

parks or SWM blocks, preservation of individual specimen trees, alignment with rear lot lines or trail routes, etc.).

Features which were included in the above-listed categories are illustrated on **Figure 7-4** and include:

High Constraint

- Natural Hazards (regulatory flood line; slope hazard and long-term stable slope setback; GRCA slow erosion and river valley slopes)
- Confirmed Natural Heritage System components (provincially significant wetlands; woodlands >4 ha in size; provincially significant valleylands; "other natural features" as defined by the City's OP; watercourses; HDFs with "protection" management recommendation)

Moderate Constraint

- Natural Heritage System components requiring confirmation or further analysis via further site-specific study (significant wildlife habitat; Species at Risk habitat; enhancement and restoration areas, including linkages; HDFs with "conservation" or "mitigation" management recommendation)

Low Constraint

- Natural features not eligible for inclusion in the NHS (e.g., Category 3 or 4 hedgerows)

The above information and the mapping shown in **Figure 7-4** were key deliverables of Phase 1 Update of this SWS, and provided a basis for the land uses developed in the Secondary Plans. As the SWS is a landscape-scale study, natural heritage features were not field-delineated and surveyed. It is the intention that site-level studies such as an EIS (see **Section 8.4.2**) may confirm and/or refine the boundaries of features at a later date (e.g., by staking and surveying the dripline of a woodland or a wetland boundary). Staking and surveying of wetland boundaries must be done in consultation with the GRCA. Note that **Figure 7-4** also indicates which properties did not grant access for field investigations, and therefore will require additional study, as outlined in the Phase 1 Update.

7.3.1 Erosion Hazards for Development Constraints

The erosion hazard assessment was mapped with all known geomorphic erosion hazards, including those reaches that need to fulfill the requirement of a meander belt assessment at the block planning stage. **Figure 7-4** shows the stable slope hazard limit with respect to confined watercourses and the reaches requiring meander belt assessment. Where access was not provided to assess the watercourse, the assumption of a channelized watercourse was made in all cases, thereby requiring a meander belt assessment, whereas the presence of an HDF would preclude this requirement. Stable slope offset requirements may in turn be reduced with appropriate geotechnical evaluation of a reduced stable slope from the 3:1 ratio used in this analysis.

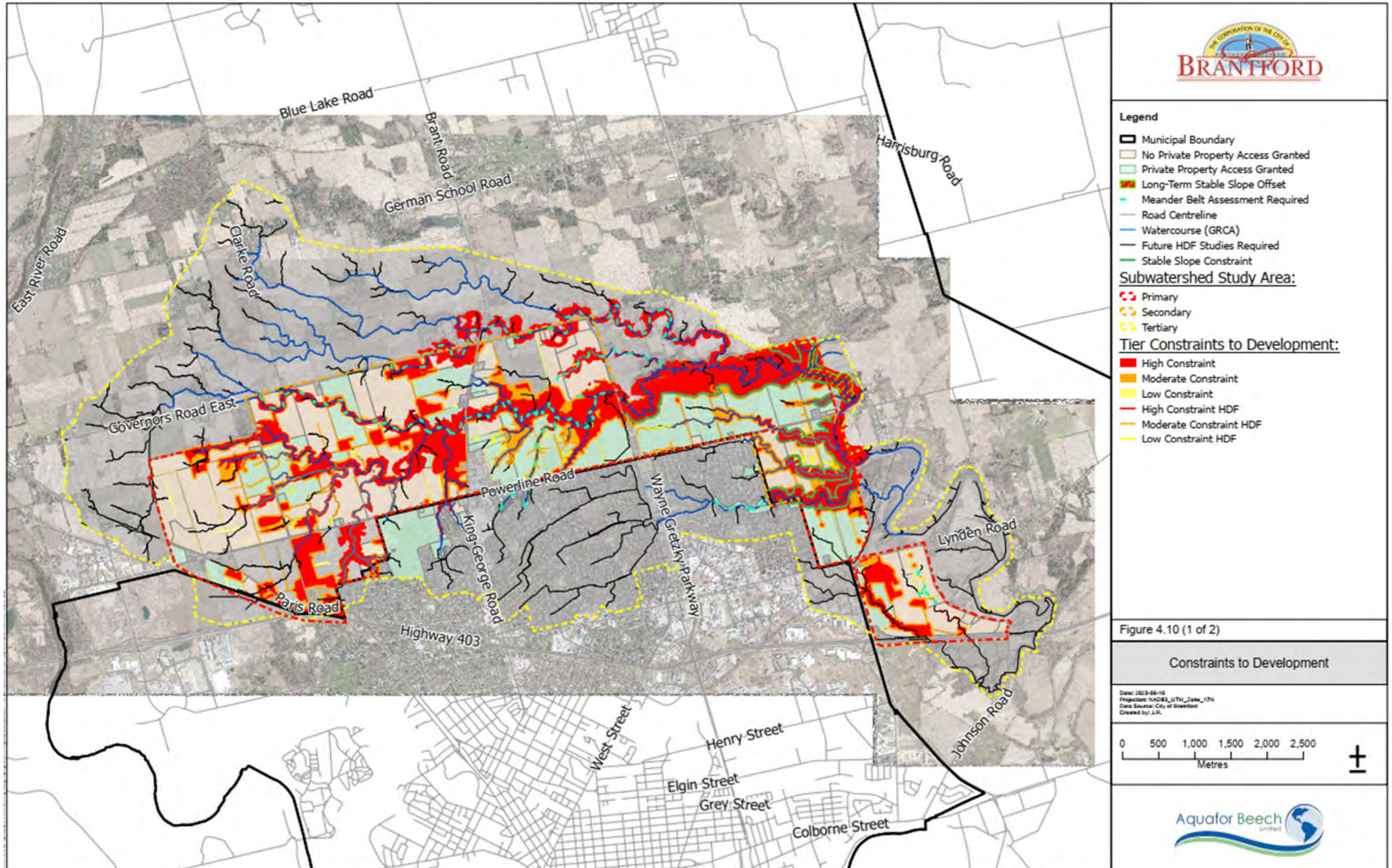

Figure 7-4: Development Constraints, Stable Slope Offsets and Meander Belt Requirements

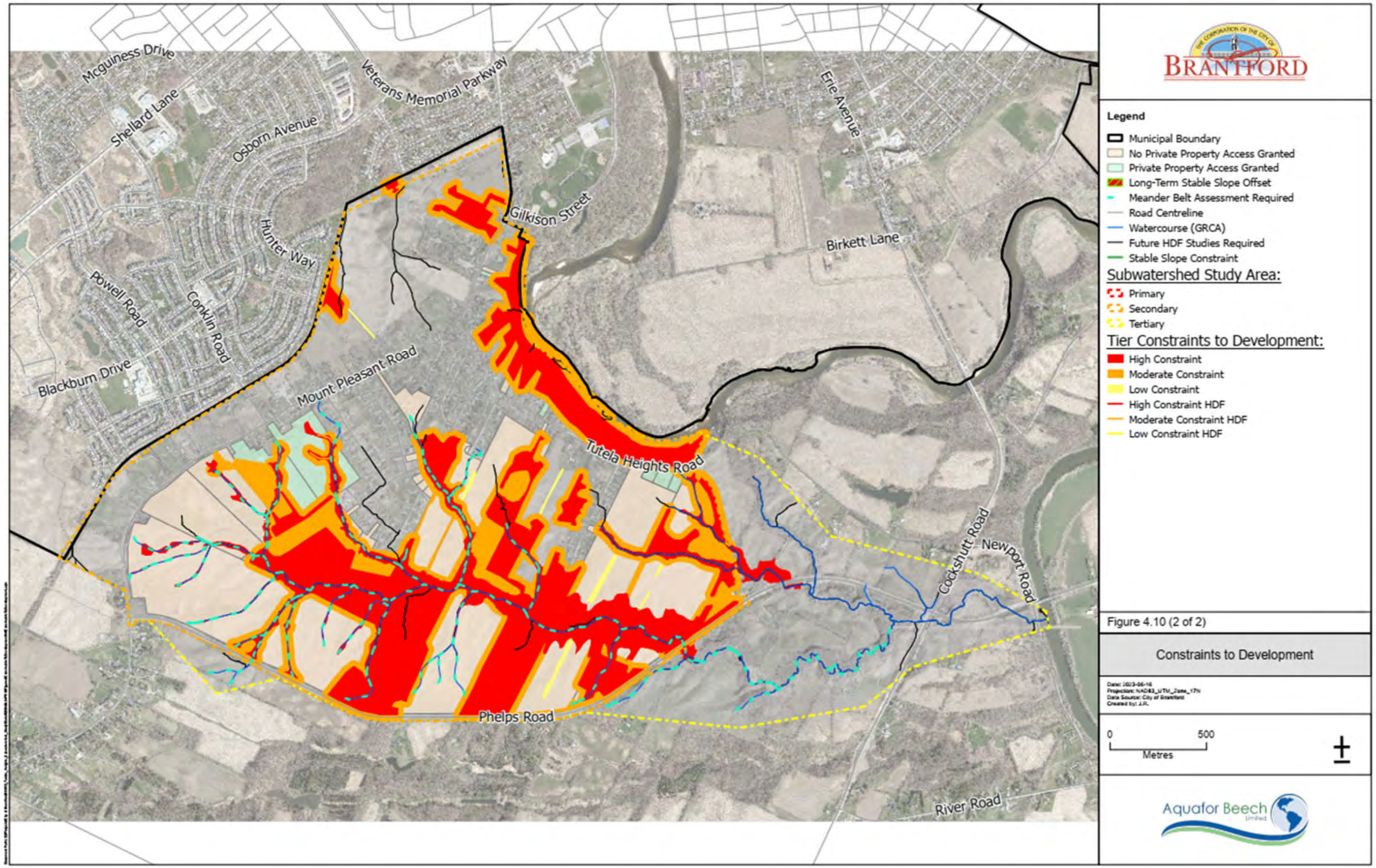

Figure 7-4 (cont'd)

7.4 Groundwater Strategy

Any areas of high groundwater recharge within the Study Area should be maintained to preserve of infiltration and to maintain groundwater flows towards wetlands and watercourses. An opportunity exists within the Study Area to develop an urbanization strategy which preserves groundwater recharge via the use of strategically located source and conveyance controls which take advantage of local infiltration capacities.

While there are limited shallow aquifer resources within the North Brantford and Tutela Heights study areas, there are high recharge areas and significant aquifer resources west and south of the North Brantford area. Recharge in these neighbouring areas likely supply the deeper overburden and bedrock aquifers that underly the study area. There ware no significant recharge areas or shallow groundwater resources in the Tutela Heights study area.

Land development in the western portion of the North Brantford secondary study area should preserve the high groundwater recharge, as it is expected that the high recharge in that area supports both the aquifers and the headwater tributaries. The model indicates that there are some recharge fed stream reaches in the western portion of the study area.

Zones of shallow depth to water table primarily occur in the riparian areas near the streams. Development is unlikely to encroach on those areas and will not likely affect those water table conditions. It is important to note that the number of shallow wells used to estimate this surface can be limited, so the known well locations used to estimate the water table are posted as circles on the map. Areas of shallow groundwater may be of a concern during development, for both construction and implementation of effective LID measures. To further illustrate the shallow areas, a second map is attached highlighting areas where the water table may be less than 3 m in depth (**Figure 7-5**). However, local hydrogeological investigations will be needed to identify the seasonally high groundwater level as part of the detailed design process for LID measures.

7.4.1 Significant Groundwater Recharge Area

Significant Groundwater Recharge Areas (SGRAs) are defined as areas where the rate of groundwater recharge exceeds the watershed's annual rate of recharge by a factor of 1.15 or more. They are also referred to as High Volume Recharge Areas (HVRAs). These areas are recognized provincially as significant for groundwater protection. SGRAs throughout the study area are shown in **Figure 7-6**. The results generally follow surficial geology mapping of the more permeable materials but also account for reduced groundwater recharge in urban areas. These results can be used to identify areas for groundwater protection.

7.4.2 Submission Requirements

A water budget is to be submitted to the City and GRCA as part of the stormwater management submission. Infiltration rates should be measured in situ using a Guelph permeameter, and post-development infiltration rates should match pre-development rates on an annual basis.

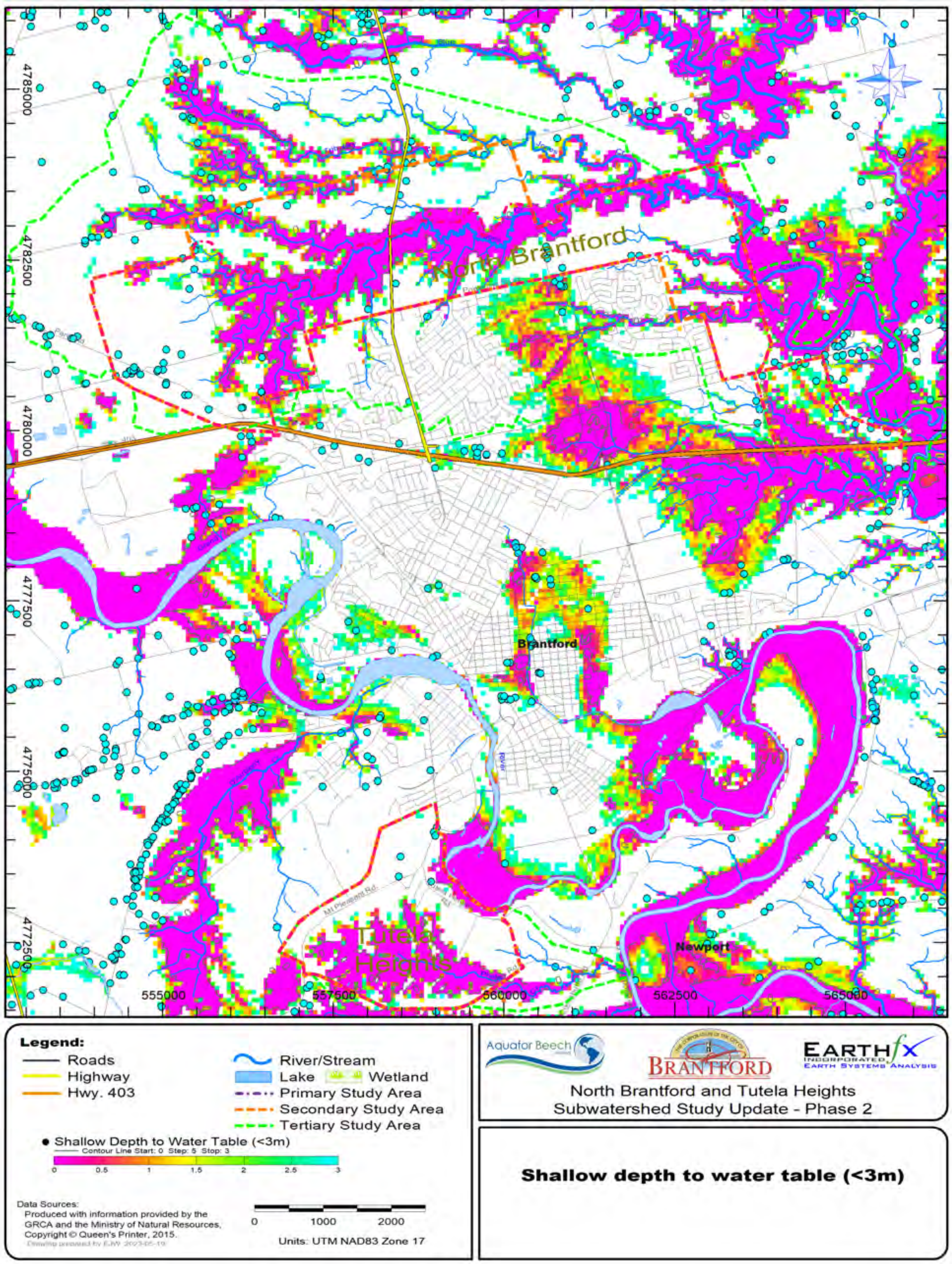

Figure 7-5: Areas of shallow depth to water table (<3m)

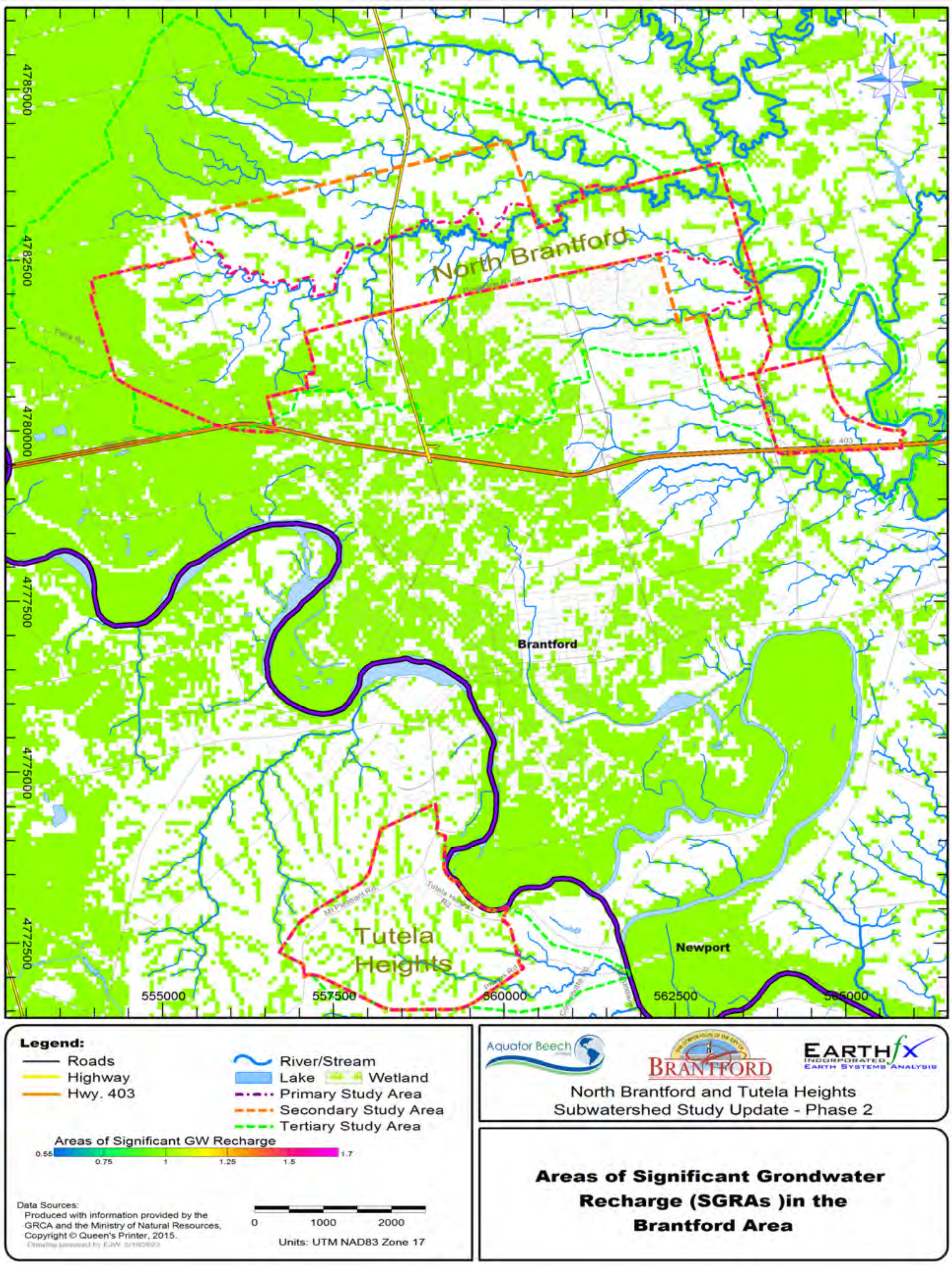

Figure 7-6: Areas of significant groundwater recharge

8 Implementation

8.1 Introduction to Implementation Strategy

The preceding sections have summarized the investigations, inventories, and analyses used to define existing environmental conditions, future impacts, and recommended management measures for the North Brantford and Tutela Heights Expansion Lands. The recommended measures include actions to address stormwater management requirements plus protection of the natural heritage system and associated ecological features, together with groundwater resources.

In terms of the land development and environmental planning process, the role of the North Brantford and Tutela Heights Subwatershed Study is to provide a framework and broad-scale guidance to the next level of planning and design study as urban development proceeds. As such, the focus of this chapter is to provide guidance for the future work required to implement the recommendations. This includes direction with respect to future studies, timing/phasing of the works, policy/design guidance, and approvals.

8.2 Stormwater Management Controls

Stormwater management controls consist of the recommended works required to mitigate the impacts from proposed future development. This includes:

- End-of-pipe stormwater ponds for flood control; and
- Low Impact Development (LID) source control techniques to meet water quality, water balance and erosion requirements.

The PCSWMM model was used to define flows for existing and proposed development conditions. **Table 7.1** of this document summarizes the names, type, drainage area and flood storage requirements for each of the proposed facilities. The location of the proposed facilities is shown in **Figure 4-1**.

Sections 7.1.1 through **7.1.4** of the report outline the requirements for water quality, water balance, erosion control and thermal mitigation. As noted, the primary driver is to control the runoff generated from a 29 mm rainfall event, using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are to be implemented. Where the LID approach is utilized and the runoff volume from the full 29 mm event is controlled, end-of-pipe SWM facilities may be designed without the water quality component. The approach to meeting stormwater management targets is outlined in **Table 8.1**.

Table 8.1: Approach to Meeting SWM Targets

Target Category	Target	Approach	Notes
Flood Control	Peak flow rates from the 1:2-year to 1:100-year events must be controlled to pre-development levels. Post-development peak flow rates from the Regulatory storm must be below Existing Regulatory peak flow rates	End-of-Pipe SWM facilities in the form of Dry detention ponds.	Where the future Regional flows exceed the existing Regional flows, GRCA to confirm approach.
Water Quality	Preferred Target: Capture and retain runoff resulting from the 29 mm rainfall event using infiltration-based LIDs.	Infiltration-based Low Impact Development Practices located on private property and municipal property, following the runoff control hierarchy (**Figure 7-1)**.	
Stream Erosion Control	Runoff from a 29 mm rainfall event must be retained on site through infiltration, evapotranspiration, reuse, bio-retention, etc. to the maximum extent practical with a minimum of 5 mm	Site-level Low Impact Development practices (See **Section 5.3.1**)	Where site-level LIDs cannot meet the 29 mm retention target, any remaining runoff volume from the 29 mm event must be detained on site for 24 to 48 hours.

Target Category	Target	Approach	Notes
Water Balance	Match pre-development annual infiltration volume in all stormwater catchments.	Infiltration-based Low Impact Development Practices located on private property and municipal property. A site-specific water budget will need to be completed as part of the stormwater management submission	This target is to be refined via in-situ infiltration testing (see **Section 8.4.1**). It was calculated in **Section 6.2.4** that an average infiltration target across the study area of approximately 3 mm per rainfall event would be sufficient to maintain pre-development water balance. Within SGRAs the target will be higher.
Thermal Mitigation	Cool runoff as appropriate for a coolwater receiver.	Use of Low Impact Development and dry stormwater ponds.	

All stormwater management facilities must be designed to meet the design requirements set out by GRCA in addition to the MECP Stormwater Management Planning and Design Manual (SWMPDM) which provides technical and procedural guidance for the planning, design, and review of stormwater management practices. SWM facilities must also comply with the City of Brantford CLI ECA.

8.2.1 Low Impact Development

A meeting was held with the City of Brantford to discuss the type of LID measures that are suitable for different land uses. These acceptable LID measures are described in **Section 5.3** for different land uses, with a summary table provided in **Table 8.2**.

In Ontario, the Toronto Region Conservation Authority (TRCA), Credit Valley Conservation (CVC) and Lake Simcoe Conservation Authority (LSRCA) are supporting a Wiki-based “living design manual” on the Sustainable Technologies website. This is a key resource for consultants as well as the public with respect to general information and design considerations surrounding LID systems.

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a LID Stormwater Management Guidance Manual. The draft manual outlines a Runoff Volume Control Target (RVC_T) to be used for new development, and should be referred to for additional design guidance.

The use of LIDs may be constrained by site-specific conditions, as outlined in **Section 7.1.2.1**. If any of these factors apply to a specific site, then LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes should be considered. If control of the full 29 mm is still not feasible through the use of LID measures, then the use of stormwater management facilities (e.g., wet ponds, wetlands, or hybrid ponds) or manufactured treatment devices (e.g., oil and grit separators) are permitted. Regardless of the method used to achieve the water quality criteria, SWM quantity controls to control peak flows will still be required at the end-of-pipe. It is recommended that in-situ infiltration testing be completed early in the development process to ensure ideal locations for LIDs are considered during the formation of draft plans.

Additionally, the use of scarified subsoil, amended topsoil, and extra topsoil depth on yards is recommended on all sites to reduce post-development runoff volume, but these amendments will not be accepted to meet the above stormwater targets.

Recommended types of LID practices that are generally appropriate for different land uses are listed in **Table 8.2**.

Table 8.2: Municipal LID Applicability by Land Use

Land Use		Single Family Residential	Multi-Family (Medium Density)	Multi-Family (High Density)	Industrial, Commercial & Institutional
Soil Amendments		☑	☑	☑	☑
Perforated Pipe (PP)	PP as Storm Sewer	☑	☑	☑	☑
	Parallel PP ("3rd Pipe")	☑	☑	☑	☑
	Grassed Swale PP System	☑	☑	☑	☑
Soakaway Pits, Infiltration Trenches and Chambers			☑	☑	☑
Permeable Pavements			☑	☑	☑
Bioretention, Bioswales and Enhanced Swales			☑	☑	☑
Rainwater Harvesting				☑	☑

8.2.2 SWM Facility Maintenance

Regardless of the type of stormwater management infrastructure that is in place, maintenance, rehabilitation, and replacement is necessary to maintain the intended level of service to the public. SWM ponds may require sediment dredging and disposal at a recurring interval dependent on loading rate and facility design. LID operation and maintenance varies with practice. For perforated pipes, very little maintenance is required. For bioswales and bioretention facilities, the O&M is similar to that of municipal gardens which require weeding and mulching occasionally (or mowing if the low maintenance turf option is preferred).

8.2.3 Site-Specific Water Budget

A site-specific water budget is required to be submitted as part of the stormwater management submission. The site-specific water budget should be completed per the 2003 SWMPDM requirements and the 2013 Conservation Authority Guidelines for Hydrogeological Assessment Submissions (Cuddy et al., 2013).

8.3 Monitoring Program

It is recommended that a water quality monitoring program be developed, taking an Adaptive Management Approach (AMA) and span pre-construction, construction and post-construction phases. This approach will allow for adjustments to monitoring sites, parameters and protocols to be made over time, as gaps are identified in order to optimize the program. The monitoring program will likely require extensive coordination and collaboration through annual monitoring meetings among representatives of GRCA, the City, the development community and their consulting teams. Specific monitoring details would be defined in an EIS or similar study.

8.3.1 Geomorphology

Continual geomorphic monitoring of targeted tributaries is recommended to examine the effects of development on rates of erosion and/or aggradation. A monitoring program will include repeat cross section and longitudinal profile surveys in order to establish baseline conditions and continue to monitor land use changes within the study area, to ensure that natural rates of erosion and aggradation are neither increased nor decreased beyond what is considered natural variance. Change exceedances from repeated surveys that are 30% from baseline will be identified and considered as effects from anthropogenic activities such as development and/or climate change. Such exceedances will be discussed and analyzed.

Cross Section Surveys

- Three to six monitoring cross sections will be established at each monitoring sites in detailed mapping for each site. The extents of the cross sections are to be demarcated by installing rebar stakes on both banks at, or above, the bankfull elevation. During monitoring events, cross section depths are to be sequentially measured laterally between the two stakes using a total station.

Longitudinal Profile

- A survey of the channel thalweg will capture any adjustments to the longitudinal gradient of the channel that may occur in the future. This aspect will be completed in unison with the cross-section surveys using a total station, and included survey points recorded at approximately 0.5 - 1 m increments along the channel thalweg. The longitudinal surveys span approximately the distance between the upstream- and downstream-most cross sections at each site – a distance that is subject to the geometry of the targeted tributary.

Due to accessibility limitations, the ongoing monitoring from 2020 Subwatershed Phase 1 consisted of two (2) out of the four (4) monitoring locations on Jones Creek. The two sites are Trib K and Jones 2. In addition to the two (2) sites, additional targeted tributaries will be selected for geomorphic monitoring. The location of additional monitoring sites were chosen based on four factors: presence of active erosion, accessibility, location of tributary, and ease of access.

Tributaries with active erosion identified in the Phase 1 SWS were all considered to be monitored. However, not all tributaries are accessible as some areas are city owned and some are private or inaccessible. Therefore, tributaries on city owned and accessible lands were selected as potential monitoring sites to ensure uninterrupted monitoring is possible. Furthermore, the location of the tributary was then considered, such that in the case that there was more than one candidate within the same watercourse, the preference was given to tributaries that are more downstream. The reason for this is that monitoring the downstream end can yield information regarding the response of the watercourse to changes occurring upstream. Lastly, the ease of access of the tributaries were considered, as carrying survey equipment can be strenuous and can negatively impact scheduling and budget. Therefore, tributaries that are in relatively close proximity to major roads were given priority.

Seen in **Table 8.3** below is a summary of the selected sites based on the rationale explained above. The table highlights the tributaries with active erosion that are city owned or accessible. In bold are the reaches that are selected and ultimately proposed for future geomorphic monitoring.

Table 8.3: Tributaries with Active Erosion, Their Accessibility and Proposed Monitoring Locations

Channel Reach	Accessibility	
	City Owned	Accessible
JC TRIB K-1A	X	
***JC TRIB K-1B**	**X**	
SC		X
SC-E	X	
JC-I	X	
JC-S		X
JC-H	X	
JC-R		X
JC-K	X	
***LF-A**		**X**
***SC-B**	**X**	
SC-C	X	
SC-D	X	
JC-J	X	
JC-L	X	
***JC-Q**		**X**

* Proposed monitoring location

The list of proposed monitoring sites, including the ongoing monitoring sites from the 2020 Phase 1 SWS are:

- Trib K – ongoing monitoring site; iron bars to be re-installed using Aquafor's survey files
- Jones 2 – ongoing monitoring site with established iron bars
- New monitoring locations:
    - JC TRIB K-1B
    - LF-A

- SC-B
- JC-Q

Specific monitoring locations within the four new reaches have not been identified. Establishing new monitoring sites anywhere in the subject reach is acceptable provided:

1. A continuous 60m reach is accessible for monitoring for the channel profile;
2. A minimum of three cross-sections per site should be established, and should extend beyond the tops of banks into the floodplain. The three cross-sections should include:
   a. One cross-section through a pool;
   b. One cross-section through a riffle; and
   c. One cross-section at the apex of a cut bank.

If there is no riffle, pool or cut bank morphology, then three equally spaced sections should be implemented at each monitoring site. Monumented survey bars should be installed at all locations, so that the survey can be repeated. Total station or GPS survey will provide the level of consistency and accuracy required for such monitoring. Survey points should be digitized in CAD or GIS and provided as a digital file for referencing.

8.4 Future Studies

This Subwatershed Study also lays the groundwork for future studies. Additional studies will be required as follows:

8.4.1 Stormwater and Groundwater

While the North Brantford and Tutela Heights Subwatershed Study has provided significant information on the proposed development lands, additional studies will be required. Notes and assumptions to be carried forward through all future studies:

- Note: Any modifications made to the proposed land uses and boundaries after the completion of the Subwatershed Study will require updates to the PCSWMM and HEC-RAS models to account for these changes.
- Note: Approximate sizing of all stormwater ponds has also been completed, using 450 m^3/ha and 750 m^3/ha for industrial/business areas to meet pre-development peak flows.
- Note: The LID strategy was outlined in **Section 7.1.2** to **7.1.4**, and includes control of the runoff from the 29 mm storm using infiltration practices preferentially, followed by filtration measures and/or reuse. A minimum of the runoff volume of 5 mm shall be retained on site if it is not possible achieve the full volume due to the factors outlined in **Section 7.1.2.1**.
- Note: Future stormwater management, functional servicing, dewatering, and erosion and sediment control plans will need to consider local physiography and soil conditions within individual stormwater catchments and clearly demonstrate that there will no negative or adverse impacts on flooding or erosion.

Additional study requirements include:

- Block Planning Areas and Plans of Subdivision:
  - The Block Plan must follow all requirements outlined by GRCA and the City. Additional requirements may be subsequently identified by the City.
  - Studies that weren't completed during the Subwatershed Study will need to be completed through the Block Plan process (see Phase 1 Update report for list of studies).
- Functional Servicing Report
  - Top of bank staking/slope stability analysis
  - Minor and major flow routes identified, and capacities verified
  - Preliminary sizing for SWM Facility
  - SWM outfall locations (may require site walk with approval agencies)
  - LID siting, footprints, soils and infiltration values, and preliminary sizing. Define the types of LID techniques that are to be incorporated into the future urban landscape to meet the targets identified in **Table 8.1** over the respective study areas. Infiltration rates should be measured in situ using test pits and/or boreholes, and post-development infiltration rates should match pre-development rates on an annual basis. In–situ infiltration testing characterizes the field saturated hydraulic properties of the existing native material on-site. On-site infiltration testing using industry standard methodologies (e.g., Guelph Permeameter) to determine the in-situ field saturated hydraulic conductivity infiltration rates and the design infiltration rate per the LID Stormwater Planning and Design Guide is recommended (https://wiki.sustainabletechnologies.ca/wiki). Field testing should be performed within the approximate location and invert of proposed LID practices.
  - Other requirements as may be outlined by the City
- Stormwater Management Report
  - Note: Location planning and design of future stormwater management ponds should take into account adjacent developments within a catchment, rather than on a site-by-site basis, in order to identify opportunities to minimize the overall number of facilities by providing larger, more efficient centralized ponds. The centralized ponds would provide benefits to both the development proponent and the City through savings in land and lower future maintenance requirements. From a land use perspective, ponds are 'green infrastructure' that contribute to the urban fabric and can contribute as a connective element in the overall pathways system.
  - As the developments proceed, proposed watercourse crossings will need to be sized based on the Regulatory floodlines. The impact of the proposed watercourse crossings will also have to be incorporated into the Hec-Ras model to define the impact on adjacent upstream lands. In some cases, it may be

necessary to oversize structures in order to preserve lands that are proposed for development and to protect existing lands. In addition, these crossings must ensure that at any time of year, the free movement of water and the passage of fish may not be blocked or otherwise impeded up and down stream of the crossing, with the exception of a temporary blockage due to water crossing construction/removal activities. In most cases, clear-span bridges or open bottom culverts are preferred with appropriate span to accommodate natural channel migration. All in-water construction and removal activities must abide by the appropriate fisheries in-water timing windows in order to avoid disrupting sensitive fish life stages.

  - None of the requirements for a Stormwater Management Brief have been completed yet. This stage of planning builds upon the preliminary work at the functional design level in order to finalize the drainage and stormwater pond designs. This report will require:
    - Detailed SWMF design
    - Detailed LID design
    - Other requirements as may be outlined by the City

- Other
  - Hydrogeologic Assessment - Field testing, through the installation of boreholes and monitoring wells, will be used to verify soil and groundwater conditions including any constraints associated with high or perched groundwater. As part of a complete field program soil samples should be collected as part of geotechnical and/or hydrogeological investigations in order to characterize the soil properties.
  - Erosion and Sediment Control Plan

8.4.2 Environmental Impact Studies

The need for an EIS is triggered by any proposed development or site alteration within the NHS (i.e., within or affecting the features themselves or the identified Adjacent Lands overlay). The general purpose of an EIS is to characterize the natural heritage features and functions affected by the proposal, evaluate the potential impacts of the proposed works, and detail mitigation measures to be applied during or post-construction. An EIS in support of a development proposal would need to demonstrate that *"there will be no negative impacts on any natural heritage features, or their ecological and hydrological functions"*, in keeping with all applicable City and GRCA policies and guidelines.

Phase 1 of this SWS characterized the NHS on a high level using existing information and field investigations. As such, it is understood that the information presented in this SWS may be appropriate to confirm, refine, or update via additional investigations at a later date. A site-specific study such as an EIS is expected to assess specific locations in far greater detail than was capable for the SWS, such that site-level features and functions are fully understood and potential impacts may be identified and evaluated. The scope of an EIS should be confirmed in advance via pre-consultation with the City and any appropriate reviewing agencies (e.g., GRCA) through the preparation and submission of a Terms of Reference (ToR), such that the necessary tasks are established at the outset and all required components are identified and included. Anticipated components of an EIS scope of work include:

- Vegetation community assessment via Ecological Land Classification;
- Single- or multi-season botanical inventory, depending on complexity of site and the habitat present (e.g., multi-season including spring botanical is appropriate on sites containing forests that support spring ephemeral wildflowers);
- Breeding bird surveys;
- Amphibian calling surveys for sites containing wetland habitat;
- Updated SAR screening, plus targeted SAR field surveys if required to confirm presence/absence of species or habitat (e.g., structures to be reviewed for Barn Swallow nesting; treed areas to be subject to bat roosting habitat assessment; wooded areas to be surveyed for Butternut or Black Ash; etc.);
- Updated Significant Wildlife Habitat assessment, plus targeted field surveys if required to confirm the applicability of noted SWH criteria;
- Wetland and woodland boundary delineation via field assessment and on-site staking/survey, in consultation with City and GRCA staff as appropriate;
- Updated or revised wetland evaluation per the Ontario Wetland Evaluation System protocol (MNRF, 2022);
- Headwater Drainage Feature Assessment for features identified during desktop analysis completed in Phase 1 of the SWS;
- Analysis of appropriate buffer widths specific to identified natural heritage features; and
- Review and confirmation of identified restoration/enhancement opportunities, or proposal of alternative opportunities based on the results of site-specific assessments.

An EIS is typically focused on natural heritage concerns, but may also be required to incorporate the results of other assessments (e.g., geomorphological) where appropriate to the site.

8.5 Permits and Approvals

8.5.1 Ontario Endangered Species Act

The Ontario Ministry of the Environment, Conservation, and Parks (MECP) is responsible for the administration of the *Endangered Species Act* (ESA), under which Species at Risk (SAR) and their habitat receive protection in Ontario. As the list and rankings of SAR in the province is always being updated with new information, future studies (e.g., EIS) will be required to include an updated screening and assessment for SAR and SAR habitat within their study area. This process is expected to include consultation with the MECP or the provincial Natural Heritage Information Center (NHIC), if required to confirm the identity or location of particular species records.

Projects which will potentially impact Endangered or Threatened species are required to undertake additional requirements under the ESA, potentially including a Notice of Activity and Mitigation Plan if the project qualifies under one of the regulatory exemptions detailed under O.Reg. 242/08, or an Information Gathering Form (IGF) with possible follow-up Avoidance Alternatives Form (AAF) and Overall Benefit Permit application if the proposed works do not qualify for an exemption.

One Endangered species (Butternut), three Threatened species (Bobolink, Eastern Meadowlark, and Barn Swallow) and three Special Concern species (Eastern Wood-pewee, Wood Thrush, and Monarch) were identified in the study area in the Phase 1 SWS. SAR bats are also expected to be present in treed portions of the study area, as these species are still relatively ubiquitous in suitable habitat despite their decline. Other species were identified in the Phase 1 SWs report on a preliminary basis due to past occurrence records in the vicinity and the suitability of habitat features. Presence/absence and habitat extent for these species and any other applicable species under current SAR legislation at the time will need to be confirmed on subject properties via a site-specific EIS or equivalent study.

8.5.2 Fisheries Act: Department of Fisheries and Oceans Canada Regulatory Review

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. Many watercourses and aquatic features within the study area fit this definition and therefore, the *Fisheries Act* applies to works conducted in or near water in many cases. However, review of the *Fisheries Act* and the site-specific aquatic resources should be reviewed on a site-by-site basis to determine if the Act applies to the aquatic resource.

Upon completion of the detailed design for any works in or near water protected under the Act, the works should be cross-referenced with the DFO “Projects Near Water” online service to determine if a request for regulatory review under the federal *Fisheries Act* is required (Fisheries and Oceans Canada, 2020). Using field investigations, background information and correspondence with regulatory bodies, the site-specific study area shall be examined to determine if the potential to contain fish at any time during any given year, or that a certain connection to waterbodies that do support fish at any time during any given year, is demonstrated. Following the guidance of the DFO, the need for a request for regulatory review by Fisheries and Oceans Canada will be determined. It is recommended that a proponent exercise the measures listed by Fisheries and Oceans Canada to avoid contravention with the Federal *Fisheries Act* and exercise due diligence by further mitigating accidental death of fish and the harmful alteration, disruption or destruction of fish habitat.

As discussed above and as outlined in the federal *Fisheries Act*, the proponent is to exercise mitigation measures to avoid contravention with the Act and exercise due diligence by further mitigating accidental death of fish and the harmful alteration, disruption or destruction of fish habitat. As such, any proposed works being undertaken within and/or adjacent to the watercourse features identified as a part of this or future studies that are protected under the Fisheries Act, construction should be undertaken such that the construction timing will be limited to outside of the critical life stages of the fish community listed for the specific watercourse. As both spring and fall spawning fish species are present within the study area, the In-water Work Timing Window Guideline (MNRF, 2013) is restricted based on the reproduction requirements of these species and should be determined prior to any in-water works in consultation with the DFO, MNRF and GRCA.

9 References

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