Bronte Creek Watershed – Structure Survey

Study Report

FHIMP Project: ON22-035

Prepared by:

CONSERVATION HALTON

Version 1.0
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BRONTE CREEK WATERSHED – STRUCTURE SURVEY

STUDY REPORT

AUTHORS

Nathan Plato, EIT
Water Resources Engineering Technologist

Jeff Lee
Water Resources Analyst

REVIEWED BY

Amy Mayes, P.Eng.
Program Manager, Flood Hazard Mapping

CONTRIBUTORS

Name	Job Title	Role
Victor Toth	GIS Technician, Floodplain Mapping	Survey & GIS

DISCLAIMER

This project received funds from the Flood Hazard Identification and Mapping Program (FHIMP). Regardless of this funding, the views expressed in this report do not necessarily reflect those of the Province of Ontario or Natural Resources Canada.

VERSION

Version	Date	Description
0.5.1	January, 2024	Internal Draft
1.0	February, 2024	Study Report

EXECUTIVE SUMMARY

Conservation Halton (CH) compiled data for 428 watercourse crossing structures situated on public, private, and controlled access lands within the Bronte Creek watershed. This information was gathered through an extensive field program involving measurements, surveys, and data recording, encompassing details considered essential for coding crossing structures into a planned future hydraulic model for the Bronte Creek watershed. Information gathered included:

- Crossing dimensions, shape, configuration, and materials,
- Survey of upstream and downstream inverts, obverts, abutments, channel cross sections, and
- Photographs and sketches of each crossing.

In total, 709 watercourse crossing structures were initially identified within the study area through a desktop exercise. Structures that were deemed to have no or limited impact on flood depths and flood extents under the extreme flood events which define the regulatory flood hazard were screened out through a two-tiered process. 430 crossing structures were deemed as important to include within future modelling of the flood hazard, with respect to their impact on regulatory flood depths and extents. This report documents CH's understanding of these structures.

Of these 430 crossing structures, 292 are located on publicly accessible lands, 105 are on private lands, and 33 are within controlled access highway and rail corridors.

CH surveyed 290 out of the 292 public crossing structures. The remaining two crossings were under construction at the time of the survey and will be surveyed in the future.

For the 105 private watercourse crossing structures, permissions were requested to access private properties to conduct measurements. CH obtained permissions for and surveyed 42 crossing structures. The remaining 63 crossing structures were estimated using several data sources including design reports, drawings, orthophotography, and LiDAR elevation data. These crossings will be surveyed in the future if access permissions are granted.

CH enlisted the services of Water's Edge Environmental Solutions Team Ltd. (Water's Edge) to acquire permits and survey 33 watercourse crossing structures within controlled access corridors (including Ontario Provincial Highways 401, 403, and 6; Guelph Junction Railway; Canadian Pacific Railway - Galt and Hamilton subdivisions; and Canadian National Railway - Halton Subdivision).

Watercourse crossing structures can have large impacts on flood depths and extents along river and stream systems. These surveys play a crucial role in ensuring that forthcoming updates to flood hazard mapping within the Bronte Creek watershed can make use of the most current and accurate information available. Updated flood hazard mapping is an important tool that supports community planning, land use and regulatory decision making, prioritizing flood mitigation works and/or infrastructure renewal, emergency planning and response, and flood forecasting and warning.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AEP	Annual Exceedance Probability
CH	Conservation Halton
CN	Canadian National Railway
CPKC	Canadian Pacific Railway
FHIMP	Flood Hazard Identification and Mapping Program
GJR	Guelph Junction Railway
GNSS	Global Navigation Satellite System
MTO	Ontario Ministry of Transportation
NRCan	Natural Resources Canada
NVA	Non-vegetated Vertical Accuracy
O.Reg. 162/06	Ontario Regulation 162/06
OMNR	Ontario Ministry of Natural Resources
RMSE	Root Mean Square Error
Water's Edge	Water's Edge Environmental Solutions Team LTD.

1. INTRODUCTION

Conservation Halton (CH) collected data associated with watercourse crossings to support a future flood hazard mapping update within the Bronte Creek watershed. This dataset represents a key element supporting the flood hazard mapping process, as watercourse crossing structures can have localized but significant impacts on the hydraulics of a watercourse. It is therefore important to represent them as accurately as possible within hydraulic models of river and stream systems.

This project involves the identification, collection, and documentation of data associated with hydraulically significant crossing structures on watercourses regulated by CH under Ontario Regulation 162/06 (O.Reg. 162/06) within the Bronte Creek watershed. This includes the collection of field information associated with each crossing – including dimensions, shape and configuration, materials, channel cross sections, photos, as well as a survey of relevant components such as the upstream and downstream invert, obvert and abutments, among other items.

This project received matching funds from the Government of Canada through the Flood Hazard Identification and Mapping Program (FHIMP) which is a component of Canada's National Adaptation Strategy. The FHIMP is led by Natural Resources Canada (NRCan), in partnership with Environment and Climate Change Canada and Public Safety Canada and provides funding to Provincial and Territorial governments. Notwithstanding this funding, the views expressed in this report do not necessarily reflect those of the Province of Ontario or NRCan.

2. STUDY AREA

The Bronte Creek watershed covers an area of 315 km^2 and encompasses portions of the Region of Halton (including the City of Burlington and Towns of Oakville and Milton), City of Hamilton, and Township of Puslinch (which is located within Wellington County). The watershed drainage area is predominantly rural, with around 47% made up of fields, agricultural land, and open water, and another 37% comprising of forested land. The remaining 16% consists of developed areas, including transportation networks, rural settlement areas within the above listed communities (including Morriston, Moffat, Mountsberg, Freelton, Strabane, Carlisle, Kilbride, Cedar Springs, Lowville, Mount Nemo, and Zimmerman) as well as portions of urban Burlington, Milton, and Oakville.

The watershed drains to Lake Ontario through a drainage network that includes more than 350 km of watercourses. The watershed's eleven subwatersheds can be generally divided into the Upper Bronte Creek (i.e., the Upper Main Branch, Strabane, Mountsberg, and Flamboro subwatersheds) which terminates at the brow of the Niagara Escarpment, and the Lower Bronte Creek (i.e., the Lower Main Branch, Kilbride, Willoughby, Limestone, Lowville, Indian and Mount Nemo subwatersheds) which flows from the Niagara Escarpment to its outlet at Lake Ontario in the Town of Oakville. Figure 1 shows the subwatersheds within the Bronte Creek watershed.

Key transportation routes which cross the study area include Provincial Highways 401, 6 and 403/QEW, Highway 407, Campbellville Road, Carlisle Road, Guelph Line, Burloak Drive, Dundas Street, Bronte Road, and Rebecca Street, the Guelph Junction Railway (GJR), the Canadian Pacific Railway (CPKC) Galt and Hamilton subdivisions, the Canadian National Railway (CN) Halton subdivision, and the GO Transit rail line.

More than 700 watercourse crossing structures were identified within the study area through a desktop exercise. While many of the watercourse crossing structures are located on public lands, others are located on private property, and more than 30 are in public or private controlled access corridors, including the corridors associated with the three Provincial Highways (HWY 401, HWY 6, and HWY 403/QEW) which are managed by the Ontario Ministry of Transportation (MTO), Canadian Pacific Railway (CPKC), Canadian National Railway (CN), and Guelph Junction Railway (GJR).

Figure 2 shows an overview of the crossing structures located on Bronte Creek and its tributaries. Detailed maps which show the exact location of each surveyed and estimated crossing are available in Appendix B.

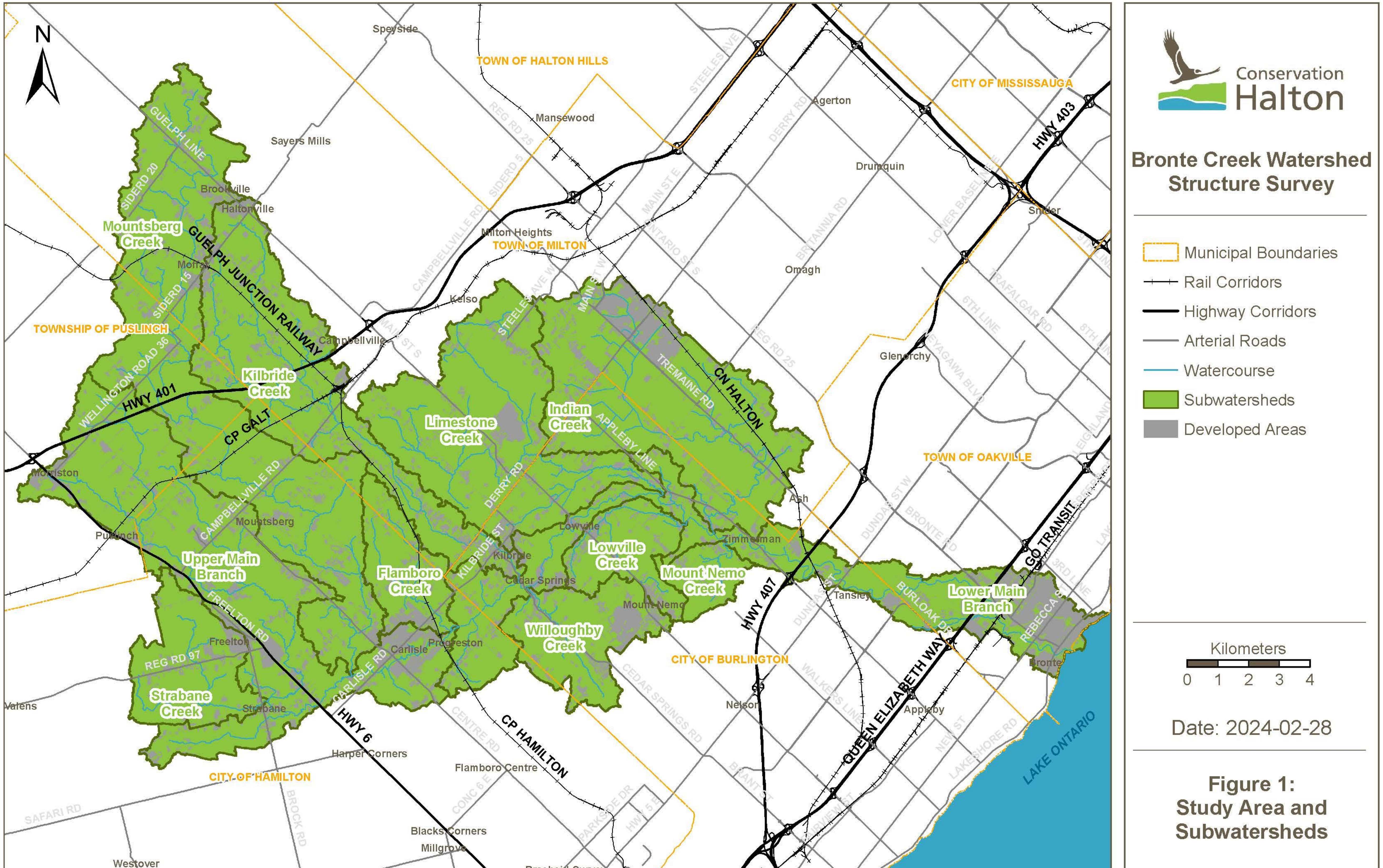

Figure 1: Study Area and Subwatersheds

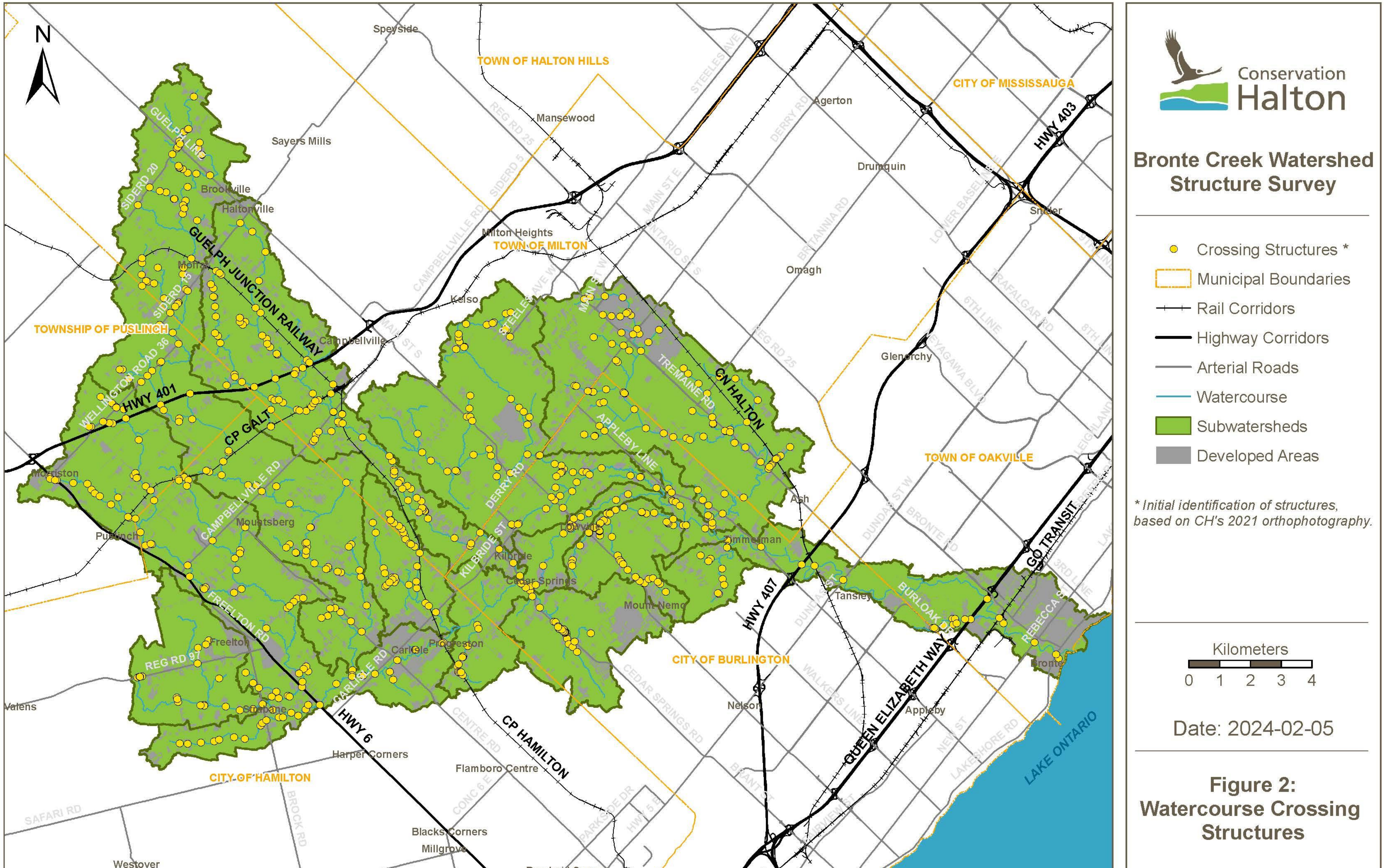

Figure 2: Watercourse Crossing Structures

3. BACKGROUND INFORMATION

3.1 Terminology

The following terms are used throughout the report and should be interpreted in the following manner:

Public crossing: Watercourse crossings located on lands which are accessible to the public without requiring special permissions (e.g., municipally owned roads).

Private crossing: Watercourse crossings located on privately owned lands which are inaccessible without express permission from the landowner.

Controlled access crossing: Watercourse crossings which, whether publicly or privately owned, are barred from access unless specific permits have been granted by the agency in question (e.g., rail corridors, provincial highways).

Watercourse: Watercourses are regulated by Conservation Halton under O.Reg. 162/06. These watercourses will in most cases align with the study extents for the riverine floodplain component of any future flood hazard mapping updates.

Regulatory Flood: The greater of the flood events generated by the Hurricane Hazel Flood Event Standard storm, and the 100-year Flood Event Standard storm, as outlined in O.Reg. 162/06.

Regulatory Storm: The storm which generates the Regulatory Flood; either the Hurricane Hazel Flood Event Standard storm, or the 100-year Flood Event Standard storm, as outlined in O.Reg. 162/06.

Hydraulically Significant: Watercourse crossing structures which, under Regulatory Flood conditions, and through the two-tiered screening procedure outlined in Section 4.1.3 of this report, meet any of the following criteria:

- The presence of the crossing embankment results in a water surface elevation change greater than or equal to 0.1m;
- There is potential for flooding to impact a building;
- The presence of the crossing embankment results in visually identifiable differences in the flood hazard limit on adjacent properties; or
- Results indicate a significant lateral expansion of the flood hazard limit.

Hydraulically Insignificant: Watercourse crossing structures which, under Regulatory Flood conditions, and through the two-tiered screening procedure outlined in Section 4.1.3 of this report, have no or limited impact on flood depths and extents.

3.2 Preliminary Data Sources

Remote data sources including orthophotography and LiDAR-derived elevation data were used in the initial identification of watercourse crossing locations within the study area. CH’s 2021 orthophotography was used for visual inspection along all watercourses within the study area.

CH’s 2018 LiDAR-derived bare earth digital elevation model was used to delineate the drainage network. This dataset was also used in the development of a hydraulic model to screen private crossings for hydraulic significance, as well as to estimate crossing structure parameters for private crossings where permissions to enter and survey were not granted by the landowners. The dataset uses the CGVD2013 vertical datum, which is the same vertical datum which has been used for the survey of structures conducted during this project. The *Survey Control and Accuracy Report* [1], prepared by Airborne Imaging for CH in August 2018, reports a Vertical Accuracy (2σ or 95%) of 0.066m on smooth hard surfaces. This vertical accuracy meets the recommended minimum accuracies for the Level 1 Risk level for Ontario (Non-vegetated Vertical Accuracy (NVA) – 95% Confidence Level ≤ 19.6 cm) as per the Ontario Ministry of Natural Resources’ (OMNR) *Technical Bulletin – Flood Hazards: Data Survey and Mapping Specifications* [2] as well as recommended accuracies for the High flood risk category (Non-vegetated Vertical Accuracy (NVA) – 95% confidence level of 10-15 cm) as per NRCan’s *Federal Airborne LiDAR Data Acquisition Guideline* [3].

4 METHODOLOGY

The project has the following components:

a) Establishment of Data Structures
b) Crossing Data Collection and Field Survey - Outside Controlled Access Corridors
c) Crossing Data Collection and Field Survey - Within Controlled Access Corridors
d) Estimates for Inaccessible Crossings

The following sections summarize the general methodology for each component.

4.1 Establishment of Data Structures

4.1.1 Geodatabase Design

A geodatabase was designed to facilitate the collection of hydraulic structure data supporting field data acquisition through an ESRI field maps application (Version 23.2.3). The geodatabase comprises a geometry point file visually representing the location of the structures slated for inventory in addition to tables housing specific details related to the type of structure. The geodatabase also documents general channel information for the upstream and downstream aspects of the crossing.

A comprehensive overview of the geodatabase tables, as well as a visual representation of the geodatabase structure and interconnections between its tables, are provided in Appendix A. Each table is accompanied by detailed information on its column data types, description and constraints.

4.1.2 Watercourse Crossing Structure Naming Convention

A watercourse crossing naming convention was developed to be consistent with future crossing inventory and flood hazard mapping initiatives at CH. Crossings were grouped by watershed and subwatershed, and numbered sequentially, starting at the subwatershed outlet, and ascending in an upstream direction. All identified structures (including structures that were later determined to be hydraulically insignificant relative to the regulatory flood) were included when the structure naming convention was established. This naming convention enables quick and intuitive identification of the watercourse crossing in question. Table 1 shows the naming convention that was used for the project.

Table 1: Watercourse Crossing Structure Naming Convention

Watershed	Subwatershed	Prefix	Example Crossing ID
Bronte Creek	Flamboro Creek	BR_FL	BR_FL_1
Bronte Creek	Indian Creek	BR_IN	BR_IN_1
Bronte Creek	Kilbride Creek	BR_KL	BR_KL_1
Bronte Creek	Limestone Creek	BR_LIM	BR_LIM_1
Bronte Creek	Lower Main Branch	BR_LMB	BR_LMB_1
Bronte Creek	Lowville Creek	BR_LOW	BR_LOW_1
Bronte Creek	Mount Nemo Creek	BR_MN	BR_MN_1
Bronte Creek	Mountsberg Creek	BR_MB	BR_MB_1
Bronte Creek	Strabane Creek	BR_SC	BR_SC_1
Bronte Creek	Willoughby Creek	BR_WC	BR_WC_1
Bronte Creek	Upper Main Branch	BR_UMB	BR_UMB_1

4.1.3 Screening for Hydraulic Significance

More than 700 watercourse crossing structures were identified within historic flood hazard areas along the regulated portions of Bronte Creek and its tributaries. These were identified using a combination of orthophotography, LiDAR-derived topographic surface, and CH's watercourse and drainage lines data. To prioritize resources, structures that would have no or limited hydraulic significance for the purposes of the future flood hazard mapping initiative were screened out through a two-tiered process.

Primary screening involved a desktop exercise relying solely on orthophotography and the LiDAR-derived topographic surface, where the following structures were removed from the study:

- Structures not crossing watercourses to be studied,
- Structures that do not present a constriction of flow (e.g., a bridge crossing that spans the valley where the low chord is located above the regulatory flood),

- Temporary structures (e.g., small wooden footbridges), and
- Select pedestrian bridges and private driveways where the bridge deck spans the channel and is thin enough that the LiDAR has penetrated through the deck and captured the channel below.

In the above cases, embankments associated with the bridge abutments will still be represented in they hydraulic model via the LiDAR-derived topographic surface and model cross-sections.

Unless screened out by primary screening, public road crossings on watercourses were assumed to be hydraulically significant and, site conditions permitting, were surveyed.

A secondary screening process was conducted for crossings located on private lands. To survey watercourse crossings on private lands, permission to enter and survey must be granted by each property owner. Given differences in design standards associated with public and private crossings, many of these crossings cause only a minimal constriction for flood flows and are not anticipated to be hydraulically significant under extreme flood events such as the 1:100 year or 1% Annual Exceedance Probability (AEP) and the Regional Storm, which define the extent of the regulatory flood hazard. At this stage of the study, CH prioritized collection of private watercourse crossing structures of hydraulic significance under the regulatory flood hazard.

Secondary screening involved a preliminary hydraulic analysis, to measure the potential range of impacts the crossing embankment could have on upstream water surface elevations, buildings, and the extent of the flood hazard limit on adjacent properties. The process involved generating a high-level model with two scenarios – one scenario that included the embankment associated with a crossing, and one scenario that excluded the embankment.

Crossings were deemed to have hydraulic significance under the Regulatory Storm for watershed scale modelling if the preliminary hydraulic analysis demonstrated they met any of the following criteria:

- The presence of the crossing embankment results in a water surface elevation change greater than or equal to 0.1m;
- There is potential for flooding to impact a building;
- The presence of the crossing embankment results in visually identifiable differences in the flood hazard limit on adjacent properties; or
- Results indicate a significant lateral expansion of the flood hazard limit.

The secondary screening process is documented in Appendix D.

4.1.4 Permission to Enter for Private Properties

To survey hydraulically significant crossings on private property, permission to enter and survey was required from each landowner. Letters requesting permission to enter, and survey were sent by mail to all private landowners where a hydraulically significant watercourse crossing was identified on their property. The letter template that was used to request permission to enter is included in Appendix E. Should additional permissions be obtained during later study phases, CH will coordinate further survey at that time.

4.2 Crossing Data Collection and Field Survey – Public and Private

Between May 4th and November 3rd, 2023, CH completed a comprehensive field program consisting of field measurements, survey, and data recording (photos, sketches, etc.). A total of 332 structures were surveyed, consisting of 290 publicly owned and 42 privately owned structures. The NAD83 / UTM zone 17N (EPSG:26917) projected coordinate system and the CGVD2013 (EPSG:6647) height reference system were used for the survey.

Survey of 33 additional structures within controlled access corridors was also completed from October 2023 to February 2024 and is discussed in Sections 4.3 and 5.3.

4.2.1 Survey Procedures and Quality Control Measures

The survey of the structures was conducted with a rigorous approach to ensure the accuracy and reliability of the collected data. The following equipment and RTK corrections method were employed.

Sokkia GCX2 Antenna: The Sokkia GXC2 antenna was used for precise Global Position System measurements. The antenna was configured to access satellite signals from the GPS, GLONASS, and BeiDou satellite constellation.

SHC5000 Controller (Tablet): The SHC5000 Controller, functioning as a tablet, served as the user interface for controlling the GPS equipment and collecting survey data. Its user-friendly interface facilitated efficient data acquisition in the field.

Magnet Field GPS Software: The surveying process was streamlined with the use of the Magnet Field GPS software, which allowed for real-time data collection and management.

Base Station Correction: To enhance the accuracy of GPS data, a base station installed at CH's Mountsberg Park was used for real-time Global Navigation Satellite System (GNSS) correction. The base station is part of the Topcon Live Network.

Vertical Tolerance: All measurements were taken with reference to the CGVD2013 vertical datum, with minimum vertical accuracies following the recommended range for Flood Risk Level 1 in Ontario as outlined in OMNRF's *Technical Bulletin – Flood Hazards: Data Survey and Mapping Specifications* [2] as well as recommended accuracies for the High flood risk category (Non-vegetated Vertical Accuracy (NVA) – 95% confidence level of 10-15 cm) as per NRCan's Canada's *Federal Airborne LiDAR Data Acquisition Guideline* [3].

4.2.2 GPS Measurements

Spot Elevations

To streamline the recording and categorization of spot elevations during the GPS survey, a comprehensive coding system was established. This system assigns unique codes to specific elevation points, allowing for efficient data management and retrieval. Table 2 illustrates the key elements of this coding system, which was applied throughout the survey.

Table 2: Survey Spot Elevation Codes and Description

Code	Description
BRA	Bridge - Abutment
BRP	Bridge - Pier
GRD	Ground
FEN	Fence
CUT	Culvert - Top
ARM	Armourstone
HWL	Headwall
ROC	Road - Curb
CRB	Creek - Bottom
CUI	Culvert - Invert
CUO	Culvert - Obvert
GUR	Guard Rail
ROD	Road
BRT	Bridge - Top
BRR	Bridge - Railing
BRS	Bridge - Soffit
CAB	Catch Basin
WWL	Wingwall
CRW	Creek - Water Surface
GAB	Gabion
BCM	Benchmark
RWL	Retaining Wall

Road measurements - At each crossing location, spot elevations were taken at the following locations on the road (Figure 3). Road crest at the road centerline, in line with the axis of the crossing (J), the top of the guardrail (G), the top of the sidewalk (H), and the edge of pavement/bottom edge of the sidewalk (I).

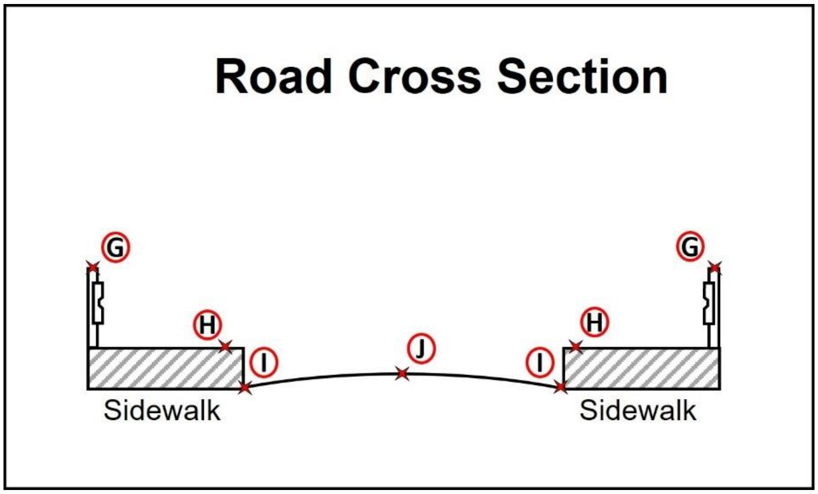

Figure 3: Locations for Spot Elevation Measurement at Roads

Culverts – For circular and arch culverts, measurements were taken at the obvert (A), and invert (B). The ground elevation was also collected if the culvert was perched (C). For box culverts, measurements were taken at the top of the culvert inner wall edge at both sides of the culvert (E and D). The invert (B) and obvert (F) were surveyed in the middle of the culvert (Figure 4). Note: Refer to Section 4.2.4 for summary of additional data collected through field measurement.

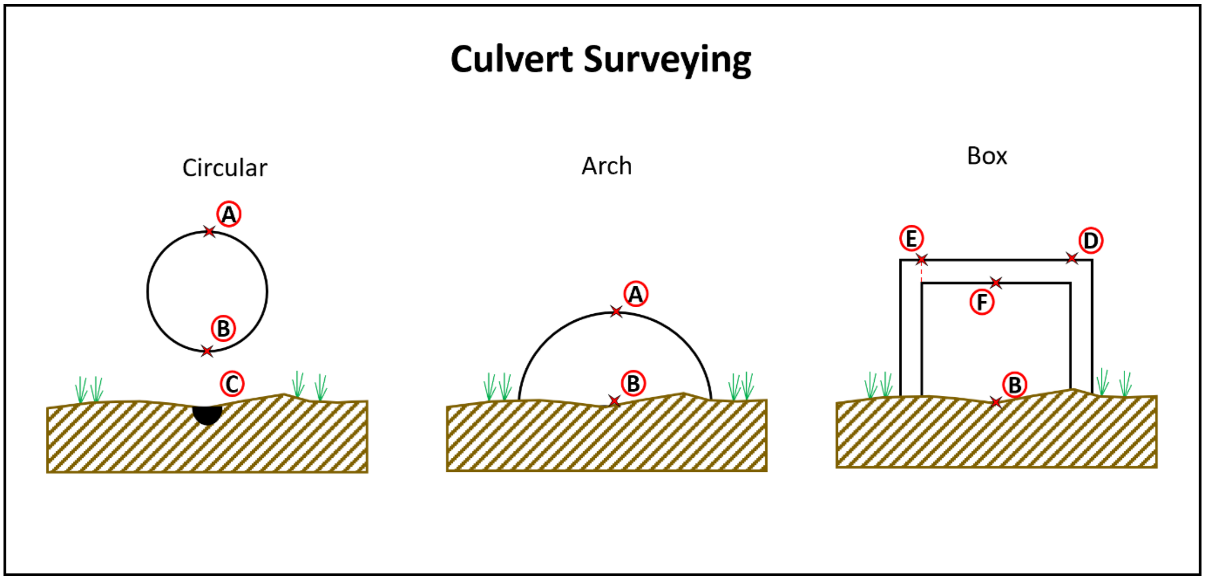

Figure 4: Location for Spot Elevation Measurement at Culverts

Bridges – Both sides of the bridge opening were surveyed from the bridge deck (A and B). Where possible, low chord elevation was recorded (D). Bridge railing (C) and road guardrail (G) were recorded (Figure 5). Additional bridge data was collected through field measurement, as described in Section 4.2.4.

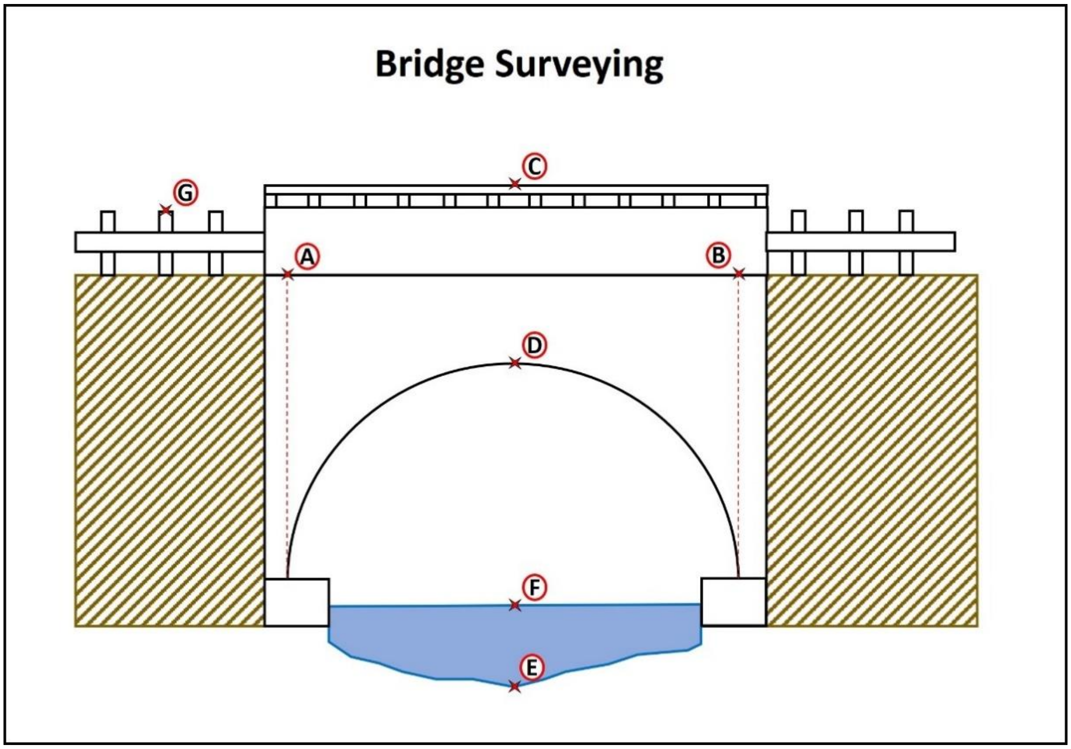

Figure 5: Location for Spot Elevations at Bridges

When present, pier locations were recorded with the GPS by peering over the bridge railing to locate pier footing, or locating expansion joints between adjacent bridge sections where expansion joints lined up with pier locations.

Water surface and creek bottom - in the presence of flow, water surface elevations and creek bottom elevations were recorded on both the upstream and downstream sides of the crossing.

Cross Sections

Whenever feasible, cross-section surveys were conducted on the upstream and downstream sides of the crossing, following a left-to-right direction as one looks downstream. Cross sections were oriented perpendicular to the slope grade, encompassing the whole floodplain. They were positioned to capture significant inflection points in the elevation profile to ensure an accurate representation of the topography of the top of the valley, valley walls, valley floor, and bankfull channel within the surveyed area (Figures 6 and 7).

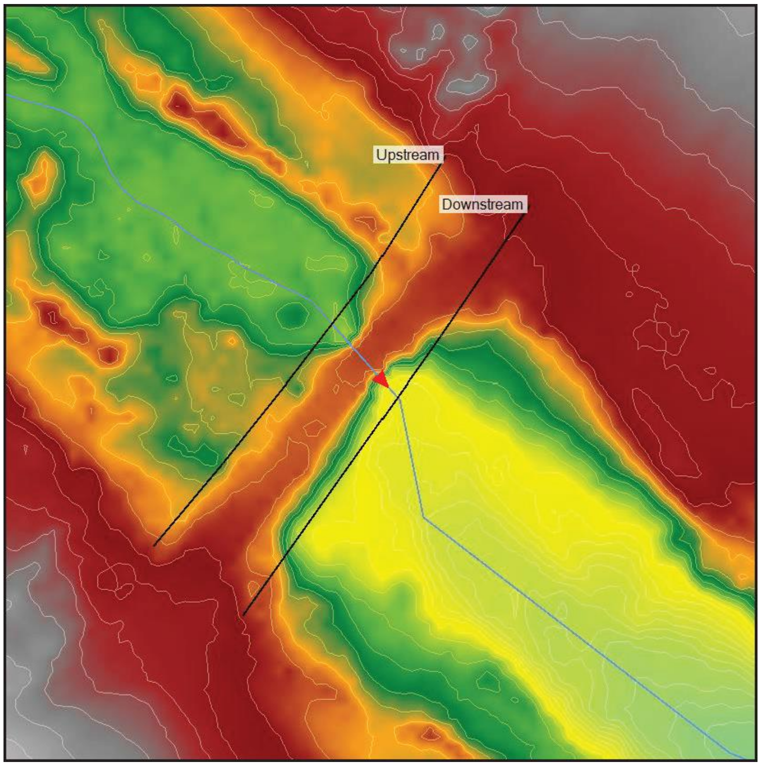

Figure 6: Aerial Perspective of Survey Cross-Sections

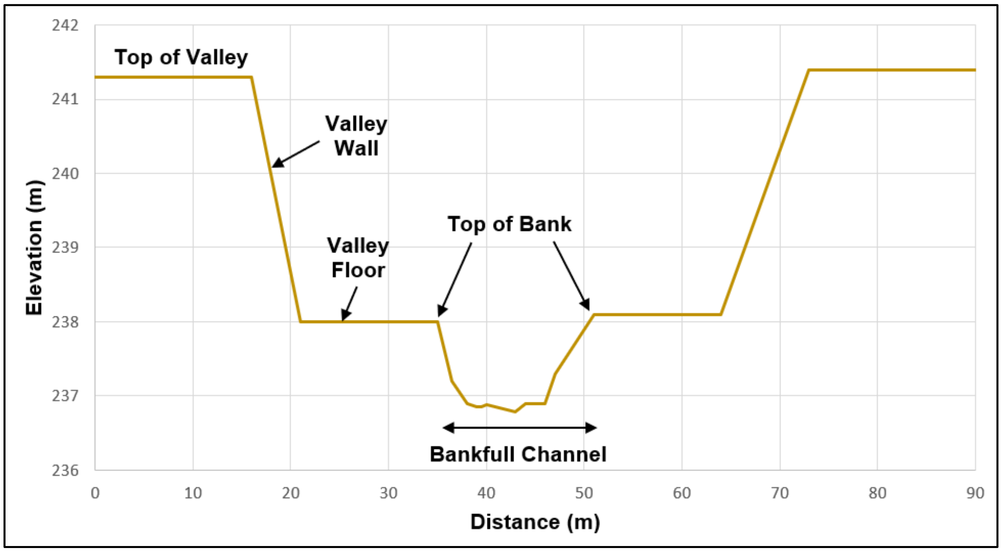

Figure 7: Typical Cross-Section Elevation Profile of a Floodplain Area

4.2.3 GPS Survey Vertical Accuracy Assessment

As part of the comprehensive geospatial data collection and quality assurance effort, surveys were conducted on a total of 12 benchmarks in the vicinity of the study area. Figure 8 shows the location of surveyed benchmarks. The measurement of geodetic benchmarks was integrated into the GPS survey to assess the accuracy and reliability of geospatial data collection efforts. The vertical accuracy of our GPS survey data was accomplished using Root Mean Square Error (RMSE) as a key performance metric.

Vertical accuracy is the measure of the positional accuracy of the surveyed data with respect to a vertical datum. At 95% confidence, vertical accuracy is defined as follows:

VA_z 95% = 1.96 x $RMSE_z$

Where:

$$RMSE_z = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i(Survey) - x_i(Benchmark))^2}$$

$x_i(Survey)$ = set of survey points being evaluated
$x_i(Benchmark)$ = corresponding benchmark points that are used to compare the survey elevation points at that geographic location
n = the number of checkpoints.

Table 3 below presents the published and surveyed elevations, calculated residuals, RMSE, and vertical accuracy at a 95% confidence level. At a 95% confidence level, the vertical accuracy of 6.1 cm indicates that the collected elevation data conforms to the highest vertical accuracy requirements outlined by NRCan's Canada's *Federal Airborne LiDAR Data Acquisition Guideline* [3] ($RMSE_z$ 5.0 – 7.5 cm and 1.96* $RMSE_z$ 10-15cm) and the OMNRF's *Technical Bulletin – Flood Hazards: Data Survey and Mapping Specifications* [2] (≤ 10 cm $RMSE_z$ and ≤ 19.6cm 1.96* $RMSE_z$) for floodplain mapping in the high flood risk category (Flood Risk Level 1).

Table 3: Vertical Accuracy Assessment

Benchmark ID	Network	Published Elevation (m)	Surveyed Elevation (m)	Residual (m)
0011975U088	COSINE	280.359	280.350	0.009
0011975U105	COSINE	255.205	255.160	0.045
00819828159	COSINE	206.160	206.123	0.037
75U097	PCN	301.630	301.593	0.037
76D000	PCN	299.806	299.800	0.006
2012-09	Town of Milton	188.397	188.416	-0.019
Unknown-1	Town of Milton	322.093	322.070	0.023
2014-01	Town of Milton	210.640	210.656	-0.016
2016-02	Town of Milton	194.708	194.709	-0.001
86	City of Burlington	167.764	167.710	0.054
444	City of Burlington	160.807	160.757	0.05
0011975U237	COSINE	290.226	290.239	-0.013
$RMSE_z$ (Vertical Root Mean Square Error)				0.031
Standard Deviation (σ)				0.027
VAz 95% (Vertical Accuracy at 95% Confidence level)				0.061

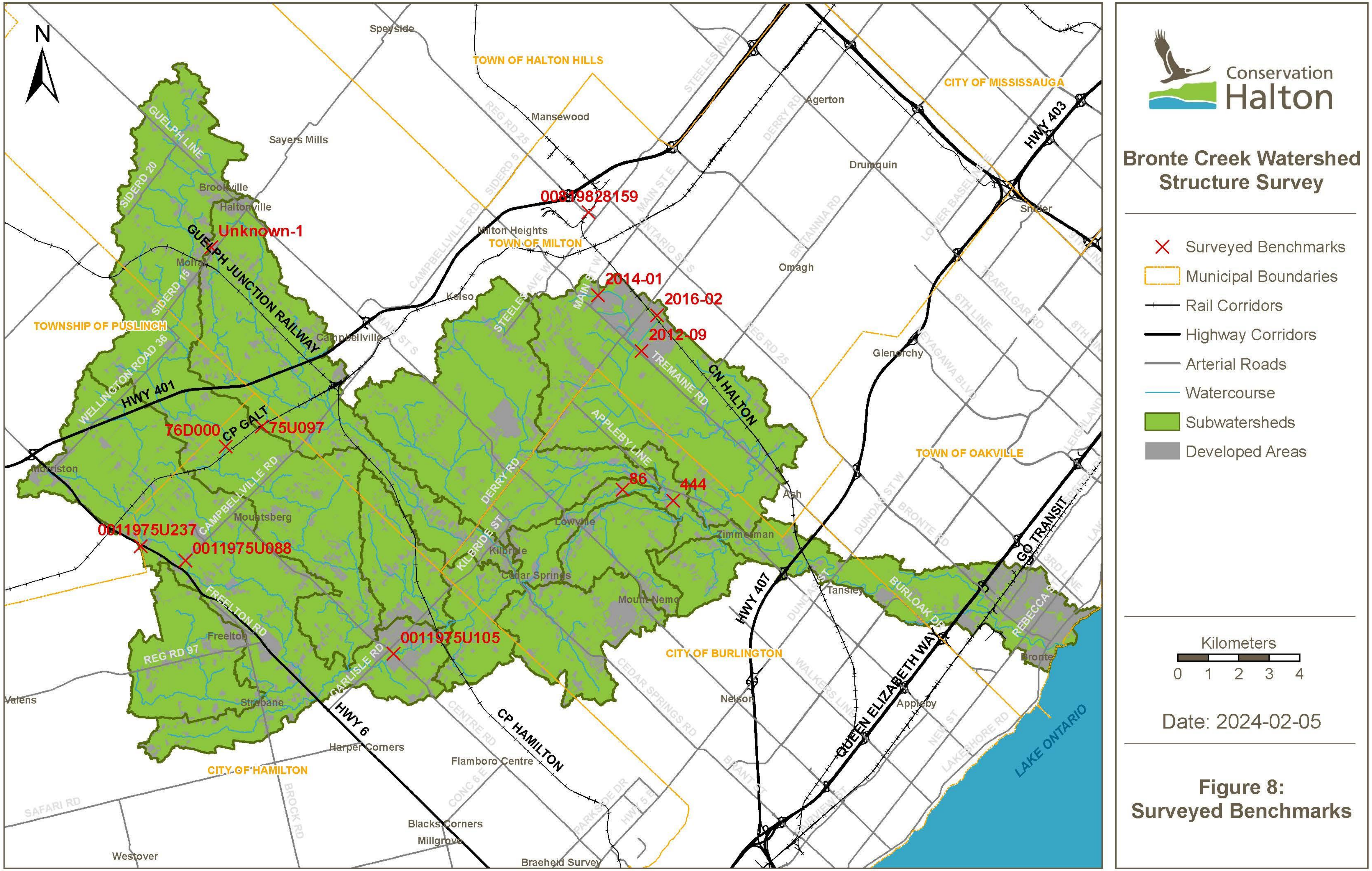

Figure 8: Surveyed Benchmarks

4.2.4 Structure Field Measurements

Throughout the survey process, field measurements and documentation were undertaken for culverts and bridges located within the project area. All length and height measurements were consistently recorded in metres (m) while angles were recorded in degrees.

Crossing Site Measurements

When applicable, field estimates were made for the wing wall position in relation to the watercourse centerline and watercourse skew angle associated with the inlet opening (Figure 9). These field estimates were subsequently confirmed using GIS, through a combination of LiDAR data and aerial photography. Road deck width was determined in a GIS using aerial photography. Measurements for both guardrail and sidewalk height and water depth were obtained through a combination of manual field measurements and GPS technology.

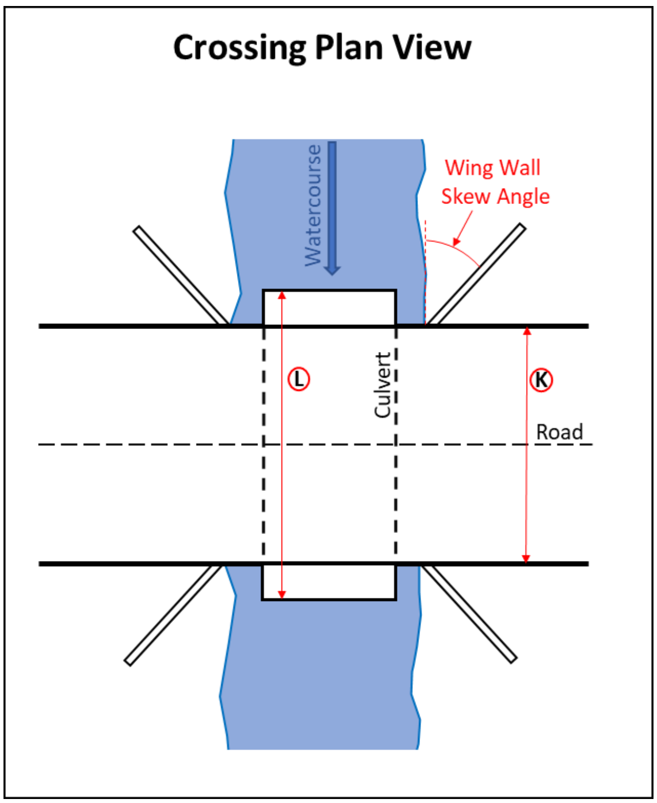

Figure 9: Typical Crossing Plan View

Culvert Measurements

Culvert lengths were obtained through a combination of GIS and GPS technology. Additionally, measurements were taken for culvert height (A), width (B), culvert wall thickness (C and D), distance between barrels (H) in cases where multiple barrels were present, and sediment height (I) within the culvert (Figure 10). These measurements were acquired using a combination of tape measurements and GPS technology.

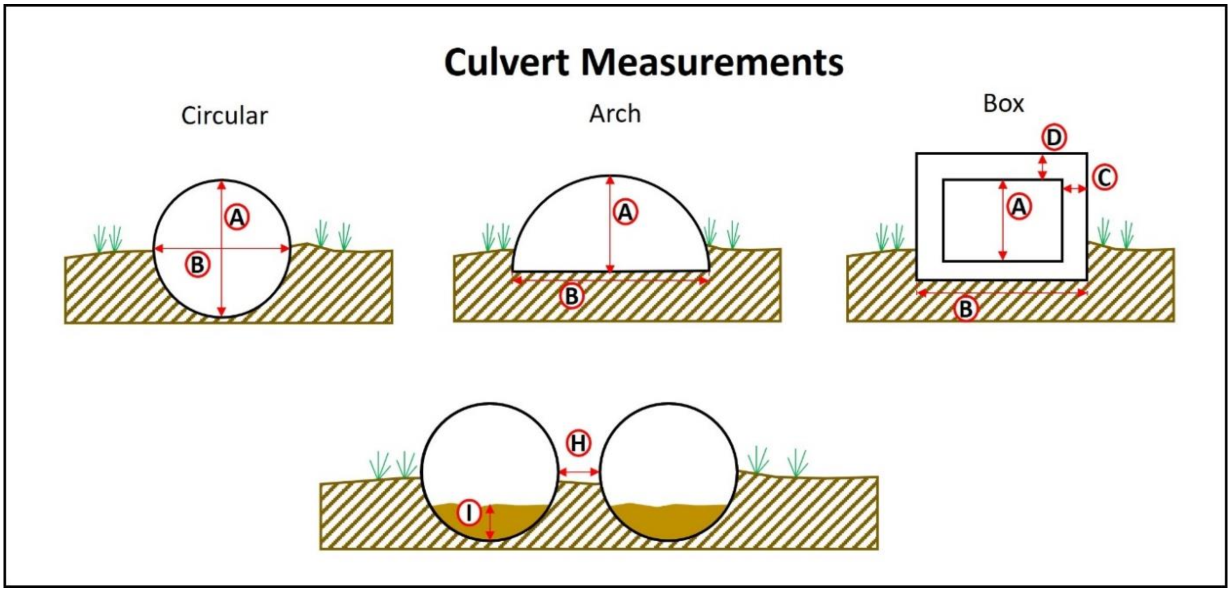

Figure 10: Culvert Measurement Parameters

Bridge Measurements

Measurements were collected for various bridge attributes, including opening width (B), total height (A + C), soffit depth (D), railing height (E), and overall length (F) (Figure 11). Additionally, in cases where applicable, data was gathered regarding the number of piers, pier width (H) and pier footing dimensions (I) (Figure 12). These measurements were acquired through a combination of tape measurements, GPS technology, and GIS measurements employing aerial photography.

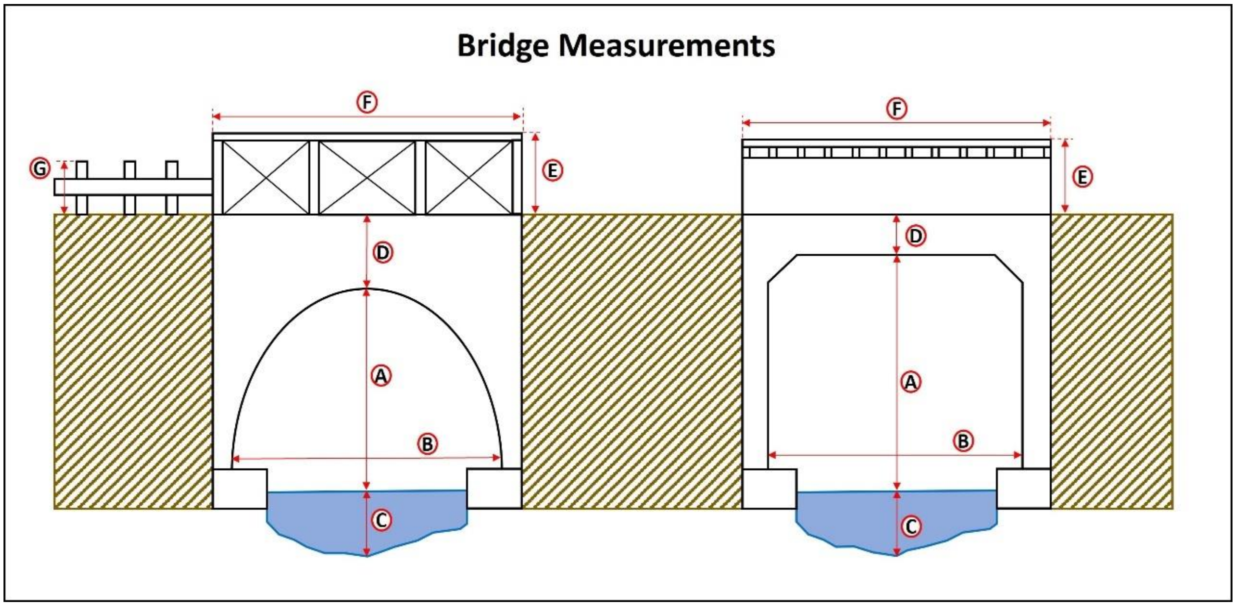

Figure 11: Bridge Measurement Parameters (no Piers)

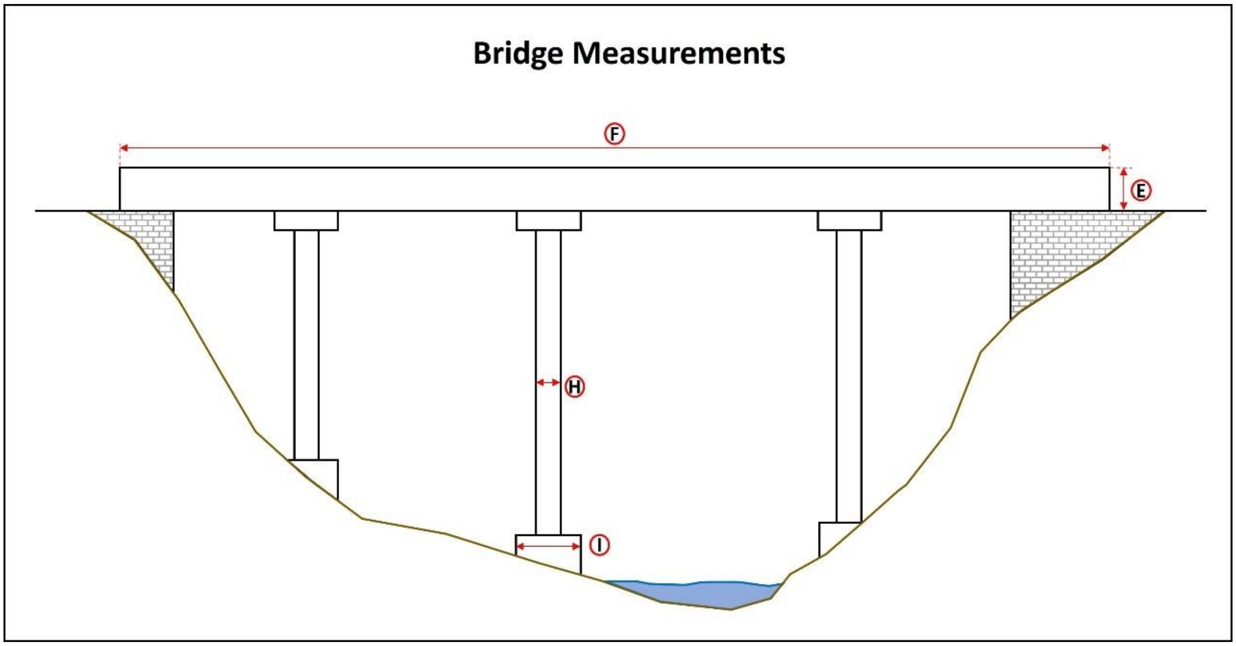

Figure 12: Bridge Measurement Parameters (with Piers)

Geodatabase and Documentation

Besides the above-discussed attributes, a range of attributes related to the crossing structures were recorded. These attributes included the crossing footing type, culvert material, culvert shape, inlet type, the number of barrels, and bridge railing type.

On the upstream and downstream faces of the crossing, additional documentation included recording the presence of flow, scour pools, bank erosion, and stream bed material.

High-resolution photographs were taken for the inlet and outlet sections of the culvert and bridges. These photographs captured views looking towards and away from the inlet and outlet. They will be used to support future engineering decisions related to crossing structure representation in the hydraulic model.

Hand-drawn sketches were created to illustrate the upstream and downstream faces of each crossing. These sketches offer a visual portrayal of key hydraulic elements, including features such as scour pools, debris accumulation, or erosion patterns. They serve as a valuable complement to the photographic documentation, providing an alternate perspective, particularly in locations where heavy vegetation obscures the view of the inlet and/or outlet.

All measurements, observations, and documentation gathered during the survey process have been organized and stored within a comprehensive data management system.

PDF exports of the resulting inventory sheets for each watercourse crossing structure are included in Appendix C.

4.3 Crossing Data Collection and Field Survey – Controlled Access

Water's Edge Environmental Solutions Team LTD. (Water's Edge) was retained by CH to obtain all necessary approvals and survey 35 watercourse crossing structures within the following controlled access corridors:

- Provincial Highways:
  - HWY 6
  - HWY 401
  - HWY 403/QEW
- Guelph Junction Railway (GJR)
- Canadian Pacific Railway (CPKC)
- Canadian National Railway (CN)

Upon field investigation, two of the 35 watercourse crossing structures were found to no longer exist, leaving 33 crossings to survey. In addition to the 33 watercourse crossing structures in the Water's Edge field program, 4 crossings were flagged as hydraulically insignificant for the purposes of this study, as bridge embankments are well defined within LiDAR elevation data, and bridge soffit elevations far exceed anticipated Regulatory flood elevations. These crossings include the crossings of the Lower Main Branch by HWY 407 (BR_LMB_13), the major crossing of HWY 403/QEW (BR_LMB_10), CN rail immediately south of HWY 407 (BR_LMB_12) and the GO Transit tracks south of HWY 403/QEW (BR_LMB_5). While detailed field survey was not required at these crossings, it is anticipated that as-built drawings will be collected during later study phases to assist in incorporating these crossings within the hydraulic models for the purpose of model readability. As such, the status of these crossings has been labeled as "Pending" in the crossing location maps in Appendix B.

The methodology for data collection and field survey at the 33 watercourse crossings within controlled access corridors is detailed in the final report by Water's Edge, which is provided in Appendix G. This methodology generally follows CH's approach as outlined in Section 4.2.

Water's Edge's survey data was collected in the NAD83(CSRS)v7/UTM zone 17N projection (EPSG:22717), and applied the CGVD2013 height reference system.

Non-vegetated vertical accuracy was found to be $RMSE_Z$ = 4.1cm, equating to +/- 8.1cm at 95% confidence level. This accuracy level corresponds to criteria for Ontario Risk Level 1.

4.4 Estimates for Inaccessible Crossings

Where private watercourse crossings have been deemed hydraulically significant, but permissions were not granted to survey the crossing structure, crossings were estimated using a combination of data sources. Estimates were made on the following basis, per the order of precedence detailed below:

1. Data identified in CH's permit files taken from:
    - As-constructed drawings; or
    - Design reports or drawings.

2. Crossing details included in CH's existing hydraulic modeling studies, or

3. Remote data sources including:
    - Site photographs,
    - Visual observation from an accessible off-site location,
    - Measurements and conveyance capacity associated with measured upstream and downstream crossings for similar crossing types,
    - Current orthophotography, and/or
    - Current LiDAR elevation data.

4. Design standards, including:
    - Assumed minimum depth of fill (culverts), typically using the minimum height of fill specified by the Ontario Provincial Standards – Volume 3 – Division 800 drawings,
    - Assumed bridge deck thickness (bridges) on a case-by-case basis.

Wherever possible this data was cross-referenced against recent orthophoto data to ensure that the drawings and photographs are representative of the current watercourse crossing structure. When abstracting data from the drawings or models consideration was given to the coordinate system and vertical datum to ensure an accurate conversion to the project coordinate system and vertical datum.

Assumptions made regarding comparisons to measured upstream and downstream crossings and minimum depth of fill were considered in conjunction with all available data sources (e.g., orthophotos, LiDAR-derived elevation data of the embankment height and stream bed, etc.). Where existing data sources did not clearly indicate the likely crossing configuration, care was taken to avoid over-estimating conveyance.

Crossing Inventory sheets were completed for all estimated crossings. In the "*Additional Field Notes / Sketch"* field, the following information was included:

- Clear statement that the crossing has been estimated,
- Explicit reference to all data sources and assumptions used to support the estimate, and
- The following notes:
    - During the hydraulic modeling stage, a sensitivity analysis assessing the impact of this structure on upstream water surface elevations should be considered.
    - Crossing estimate to be re-assessed on the basis of any additional information sources that may become available.

5 RESULTS

The project results are presented in the following categories:

a) Survey of Public Watercourse Crossing Structures
b) Survey of Private Watercourse Crossing Structures
c) Survey of Crossings within Controlled Access Corridors
d) Summary of Results

5.1 Survey of Public Watercourse Crossing Structures

Primary screening for hydraulic significance was conducted prior to the survey of public watercourse crossing structures. Of the 297 public crossing structures identified during desktop analysis, five structures were found to be hydraulically insignificant and/or could not be located in the field (e.g., were confirmed in the field to be temporary structures, or were washed out or removed), and two more were inaccessible as they were under construction. Dundas Street at Bronte Creek (BR_LMB_11) and Bergamot Avenue at a tributary of Indian Creek (BR_IN_36) will be surveyed once constructed. Surveys were completed for the remaining 290 publicly owned watercourse crossing structures. Table 4 shows the number of surveyed public watercourse crossings, broken down by subwatershed, ownership, and crossing type. Figure 13 shows the location of surveyed public watercourse crossing structures. Detailed location maps which include the Crossing ID are included in Appendix B. The resulting watercourse crossing inventory sheets are provided in Appendix C.

Table 4: Public Watercourse Crossing Structures - Survey Summary

Subwatershed	Local Municipality	Surveyed Structures	
		Bridge	Culvert
Lower Main Branch	Town of Oakville	2	10
	City of Burlington	10	6
	City of Hamilton	0	3
Mount Nemo Creek	City of Burlington	0	3
Indian Creek	Town of Milton	3	39
	City of Burlington	0	8
Lowville Creek	City of Burlington	1	16
Limestone Creek	City of Burlington	1	12
	Town of Milton	0	11
Willoughby Creek	City of Burlington	0	12
Kilbride Creek	City of Burlington	0	5
	Town of Milton	0	23
	City of Hamilton	0	1
	Township of Puslinch	0	5
Flamboro Creek	City of Hamilton	0	8
	Town of Milton	0	3
Upper Main Branch	City of Hamilton	7	25
	Township of Puslinch	0	15
Mountsberg Creek	City of Hamilton	5	9
	Township of Puslinch	0	10
	Town of Milton	1	22
Strabane Creek	Hamilton	3	11
Total:		33	257

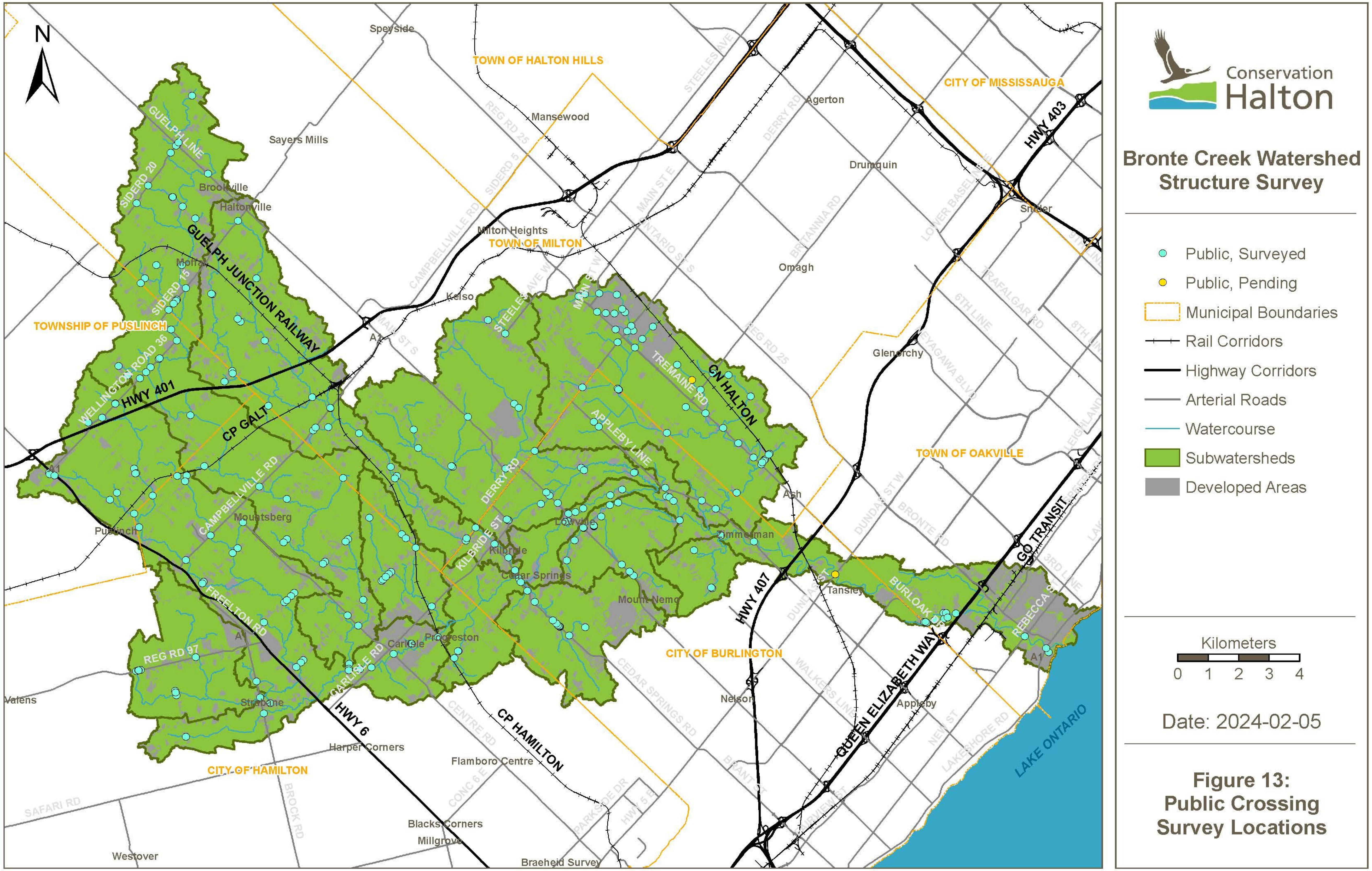

Figure 13: Public Crossing Survey Locations

5.2 Survey of Private Watercourse Crossing Structures

Prior to the survey of watercourse crossing structures on private lands, primary and secondary screening for hydraulic significance was conducted, in addition to requesting permission to enter for each property.

Of the initial 375 private structures, 106 were removed through primary screening for hydraulic significance. Another 164 crossings were removed through secondary screening, leaving 105 structures to be surveyed. Figure 14 shows the location of hydraulically significant and insignificant private crossing structures.

On August 9th, 2023, letters requesting permission to enter and survey were mailed to all private properties with hydraulically significant watercourse crossings. CH received responses and permissions to survey 33 of these structures. CH surveyed these structures, and surveyed another 9 structures located on CH-owned lands. The remaining 63 hydraulically significant watercourse crossings on private lands were estimated as per Section 4.4 of this report. Figure 15 shows the location of the surveyed and estimated private watercourse crossing structures deemed to be hydraulically significant. Table 5 shows a summary of the private crossing structures, broken down by subwatershed, local municipality, and crossing status. Appendix F contains tables which detail the data sources used to estimate opening dimensions for each of the estimated crossings. Detailed location maps which include the Crossing ID can be viewed in Appendix B.

Table 5: Private Watercourse Crossing Structures - Survey Summary

Subwatershed	Local Municipality	Private Structures		
		Insignificant	Surveyed	Estimated
Lower Main Branch	Town of Oakville	1	0	0
	City of Burlington	8	0	0
	City of Hamilton	5	0	2
Mount Nemo Creek	City of Burlington	4	0	3
Indian Creek	Town of Milton	19	0	2
	City of Burlington	18	0	0
Lowville Creek	City of Burlington	22	9	8
Limestone Creek	City of Burlington	16	2	2
	Town of Milton	12	14	5
Willoughby Creek	City of Burlington	10	1	6
Kilbride Creek	City of Burlington	0	0	0
	Town of Milton	41	7	7
	City of Hamilton	0	1	0
	Township of Puslinch	0	0	0
Flamboro Creek	City of Hamilton	8	0	3
	Town of Milton	2	5	7
Upper Main Branch	City of Hamilton	31	1	8
	Township of Puslinch	14	0	3
Mountsberg Creek	City of Hamilton	21	0	4
	Township of Puslinch	4	0	1
	Town of Milton	25	2	1
Strabane Creek	Hamilton	9	0	1
Totals:		270	42	63

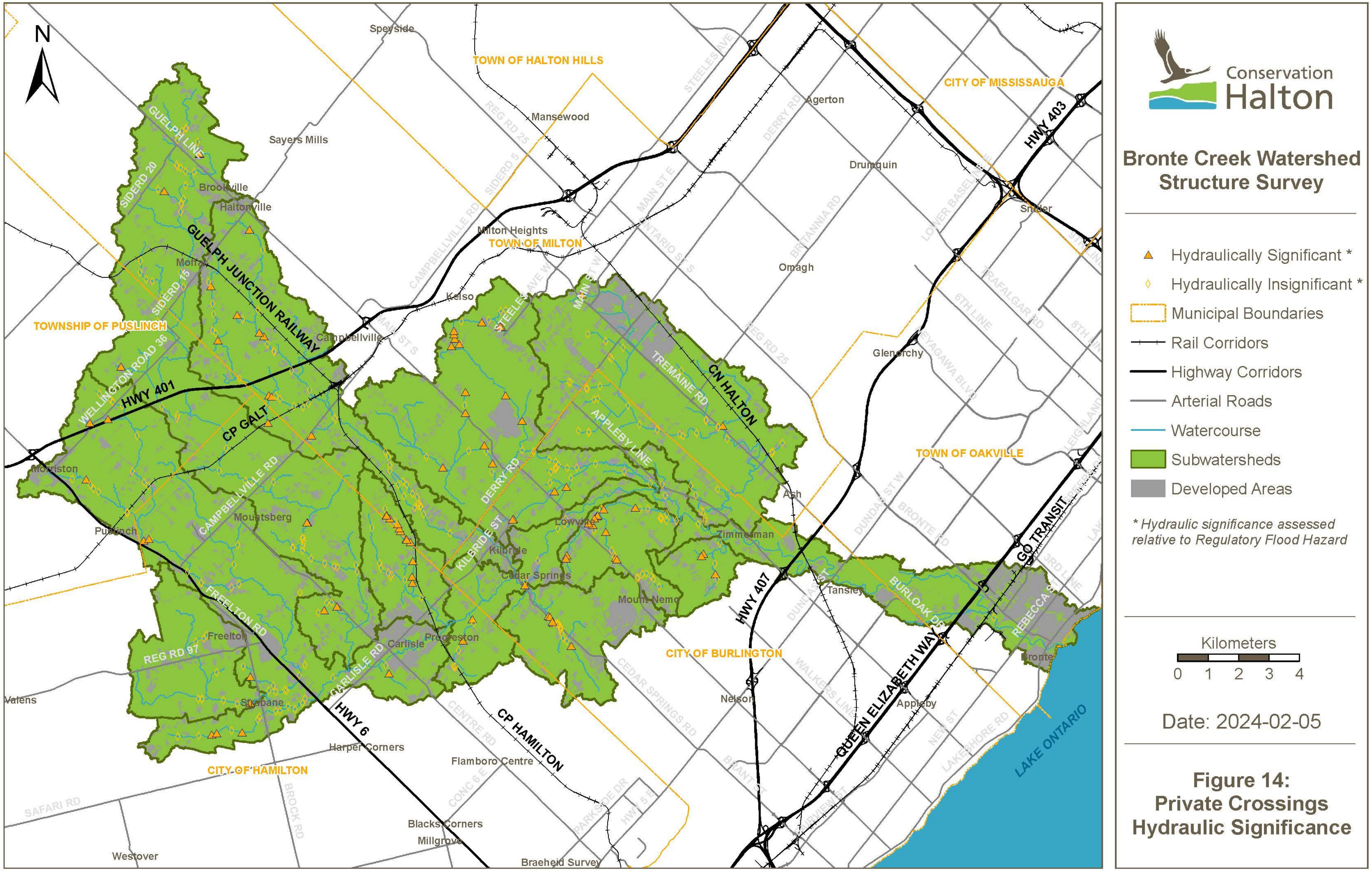

Figure 14: Private Crossings Hydraulic Significance

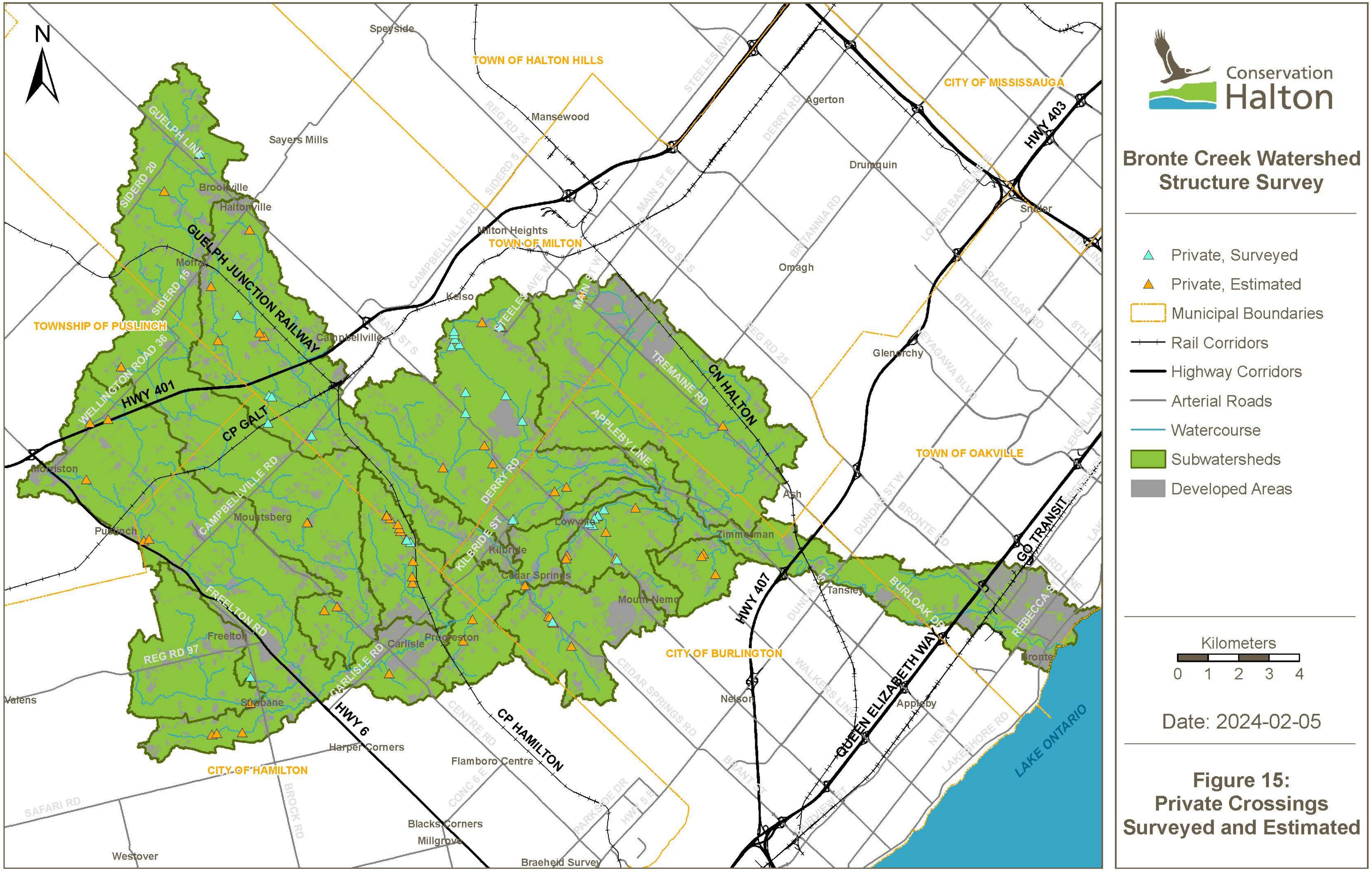

Figure 15: Private Crossings Surveyed and Estimated

Estimates were established for 63 hydraulically significant but inaccessible watercourse crossing structures, per the methodology outlined in Section 4.4. Table 6 summarizes the general distribution and supporting information sources applied for estimated crossing structures. Inventory sheets were created for each estimated crossing and are included with the surveyed crossing inventory sheets in Appendix C. All estimated crossings and specific supporting data sources are clearly identified in the *"Additional Field Notes / Sketch"* field of the inventory sheet. Tables which document the data sources used for each estimated crossing are included in Appendix F.

Table 6: Estimated Watercourse Crossing Structures

Subwatershed	Local Municipality	Estimated Structures - By Data Source	
		Remote data only	Available reports
Lower Main Branch	Town of Oakville	0	0
	City of Burlington	0	0
	City of Hamilton	2	0
Mount Nemo Creek	City of Burlington	2	1
Indian Creek	Town of Milton	2	0
	City of Burlington	0	0
Lowville Creek	City of Burlington	3	5
Limestone Creek	City of Burlington	2	0
	Town of Milton	5	0
Willoughby Creek	City of Burlington	5	1
Kilbride Creek	City of Burlington	0	0
	Town of Milton	3	4
	City of Hamilton	0	0
	Township of Puslinch	0	0
Flamboro Creek	City of Hamilton	1	2
	Town of Milton	3	4
Upper Main Branch	City of Hamilton	7	1
	Township of Puslinch	2	1
Mountsberg Creek	City of Hamilton	2	2
	Township of Puslinch	1	0
	Town of Milton	1	0
Strabane Creek	Hamilton	1	0
Totals:		42	21

5.3 Survey of Crossings within Controlled Access Corridors

Within controlled access corridors, there are a total of 39 watercourse crossings that cross watercourses within the Bronte Creek watershed. Of these 39, four were removed through preliminary screening for hydraulic significance. The locations for these crossings have been maintained in the database. These crossings include the crossings of the Lower Main Branch by HWY 407 (BR_LMB_13), the major crossing of HWY 403/QEW (BR_LMB_10), CN rail immediately south of HWY 407 (BR_LMB_12) and the GO Transit tracks south of HWY 403/QEW (BR_LMB_5). These four crossings function as prominent landmarks and will assist with model readability; as such it is intended to estimate these crossings based on as-constructed drawings and incorporate them into the hydraulic model as future stages of the project advance.

CH retained *Water's Edge Environmental Solutions Team LTD (Water's Edge),* as a consultant to secure approvals and survey the remaining 35 watercourse crossings within controlled access corridors, which included those associated with HWY 401, HWY 6, HWY 403/QEW, CN Railway, CPKC Railway, and GJR. These surveys were conducted in the fall of 2023 and winter of 2024.

Upon field investigation, two of the 35 crossings were found to no longer exist, leaving 33 to be surveyed. Figure 16 shows the location of these crossings. The report by *Water's Edge* which details the survey of these crossings is included in Appendix G. Detailed location maps which include the Crossing ID can be seen in Appendix B. Inventory sheets for these crossings are provided in Appendix C.

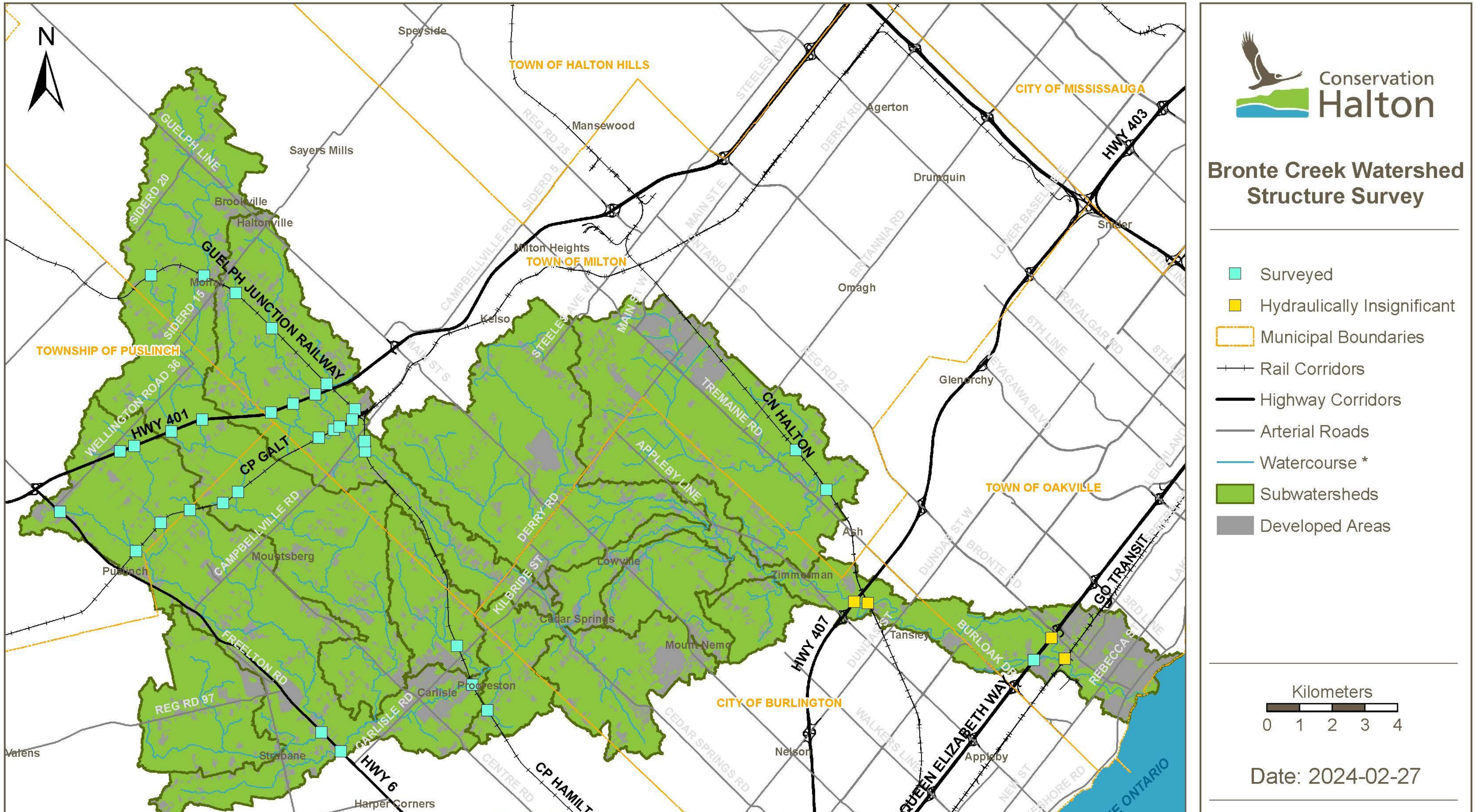

Figure 16: Controlled Access Crossings

5.4 Summary of Results

Table 7 and Figure 17 provide a summary of all surveyed and estimated crossing structures. Detailed location maps and watercourse crossing inventory sheets can be seen in Appendix B and C respectively, while Appendix H includes tables which summarize key structure details for all measured and estimated crossings.

Table 7: Summary of Surveyed and Estimated Watercourse Crossing Structures

Subwatershed	Local Municipality	Surveyed			Estimated
		Public	Private	Controlled Access	Private
Lower Main Branch	Town of Oakville	12	0	1	0
	City of Burlington	16	0	0	0
	City of Hamilton	3	0	1	2
Mount Nemo Creek	City of Burlington	3	0	0	3
Indian Creek	Town of Milton	42	0	2	2
	City of Burlington	8	0	0	0
Lowville Creek	City of Burlington	17	9	0	8
Limestone Creek	City of Burlington	13	2	0	2
	Town of Milton	11	14	0	5
Willoughby Creek	City of Burlington	12	1	0	6
Kilbride Creek	City of Burlington	5	0	0	0
	Town of Milton	23	7	13	7
	City of Hamilton	1	1	0	0
	Township of Puslinch	5	0	0	0
Flamboro Creek	City of Hamilton	8	0	1	3
	Town of Milton	3	5	0	7
Upper Main Branch	City of Hamilton	32	1	4	8
	Township of Puslinch	15	0	5	3
Mountsberg Creek	City of Hamilton	14	0	2	4
	Township of Puslinch	10	0	2	1
	Town of Milton	23	2	2	1
Strabane Creek	Hamilton	14	0	0	1
Totals:		290	42	33	63
Total:		428			

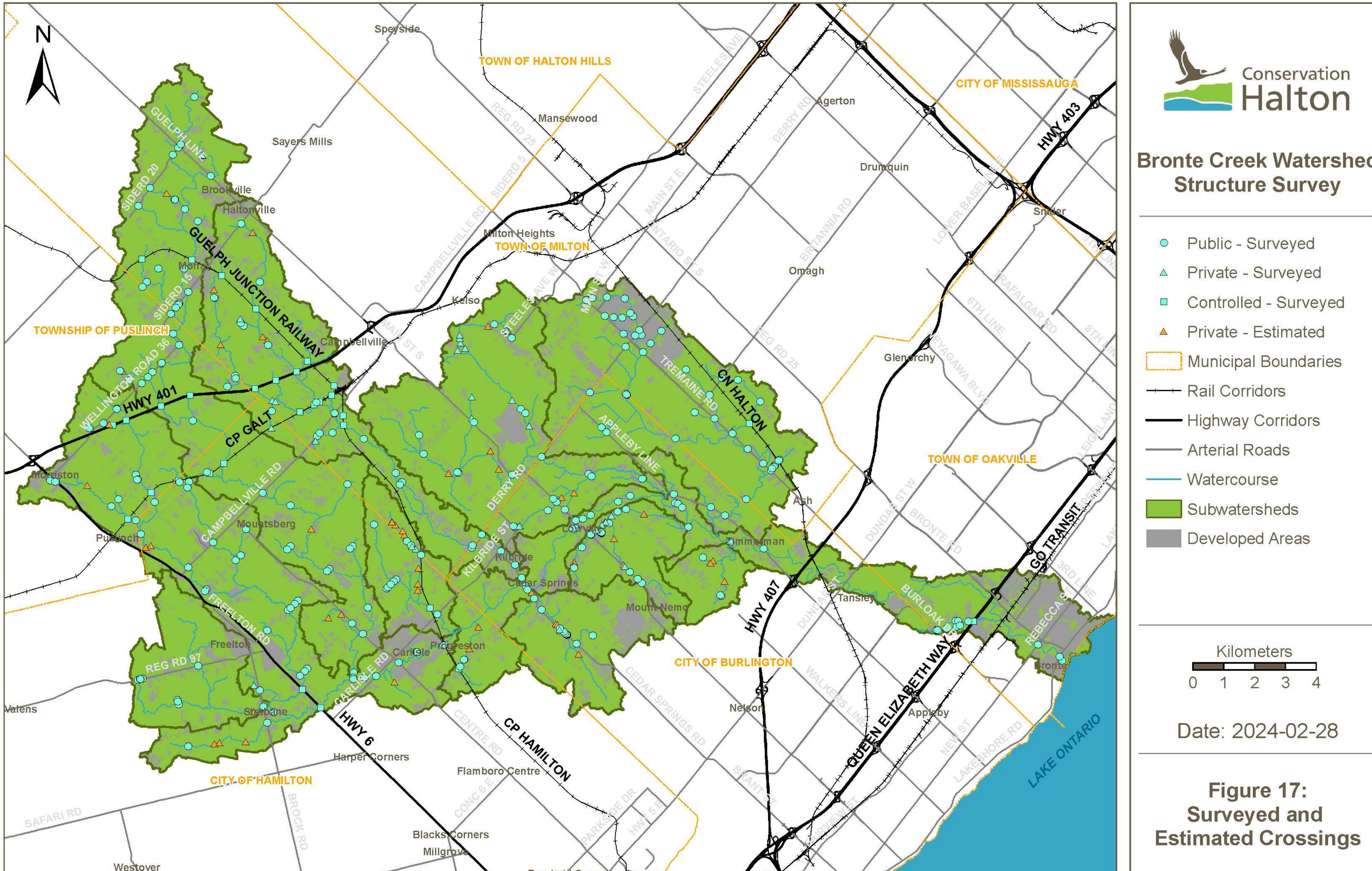

Figure 17: Surveyed and Estimated Crossings

6 CONCLUSIONS AND RECOMMENDATIONS

Conservation Halton (CH) gathered information related to 428 hydraulically significant watercourse crossings located on public, private, and controlled access lands within the Bronte Creek watershed. The data encompassed various details such as dimensions, shape, configuration, materials, channel cross sections, and accompanying photographs. Additionally, a comprehensive survey was conducted, covering essential components like upstream and downstream inverts, obverts, abutments, and other pertinent elements necessary for coding the crossing structures into upcoming hydraulic models for the stream system.

Watercourse crossing structures can have large impacts on flood depths and extents along river and stream systems. These surveys play a crucial role in ensuring that forthcoming updates to flood hazard mapping within the Bronte Creek watershed can make use of the most current and accurate information available. Updated flood hazard mapping is an important tool that supports community planning, land use and regulatory decision making, prioritizing flood mitigation works and/or infrastructure renewal, emergency planning and response, and flood forecasting and warning.

The following items are recommended for future consideration:

- That as-constructed drawings be obtained, and where timelines allow, a survey be conducted for BR_LMB_11 (Bronte Creek at Dundas) and BR_IN_36 (tributary of Indian Creek at Bergamot Ave) following construction.
- That as-constructed drawings be obtained for BR_LMB_10 (Bronte Creek at HWY 403), BR_LMB_13 (Bronte Creek at HWY 407), BR_LMB_12 (CN rail south of HWY 407) and BR_LMB_5 (GO Transit tracks south of HWY 403/QEW) for readability purposes within the future hydraulic models.
- That at the hydraulic modelling stage, photographs and drawings collected separate from this study be used to evaluate the hydraulic impact of seven inline dam structures on Bronte Creek and its tributaries.
- That at the hydraulic modelling stage, a methodology be developed to represent embankment terrain data associated with crossings deemed to have no or limited hydraulic significance under the extreme flood events which define the extent of the regulatory flood hazard.

- That further efforts be undertaken throughout the flood hazard mapping process to obtain permissions to survey hydraulically significant watercourse crossings which have been estimated. These crossings were estimated due to the inability to secure permissions at the present time.
- That at the hydraulic modeling stage, a sensitivity analysis be conducted to evaluate the impact of all remaining estimated watercourse crossing structures on resulting water surface elevations.

7 REFERENCES

[1] “Conservation Halton 2018 Lidar Survey Control and Accuracy Report,” Airborne Imaging, Calgary, Alberta, Canada, August 2018.

[2] “Technical Bulletin – Flooding Hazards: Data Survey and Mapping Specifications,” Ontario Ministry of Natural Resources and Forestry, Ontario, Canada, Version 1.0, December, 2023. Available: https://ero.ontario.ca/notice/019-4706

[3] “Federal Airborne LiDAR Data Acquisition Guideline,” Natural Resources Canada, Canada, Version 3.1, 2022. Available: https://doi.org/10.4095/330330