

## Appendix C2 - Fluvial Geomorphology Report



**Stage 2 ION Light Rail Transit  
Fluvial Geomorphic Assessment of the Preferred Route  
Region of Waterloo**

Prepared for:  
**WSP CANADA INC.**

Prepared by:  
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**Fluvial Geomorphic Assessment of the Preferred Route**  
**Region of Waterloo**

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**Disclaimer**

We certify that this report is accurate and complete and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but is not guaranteed. We have exercised reasonable skill, care, and diligence in assessing the information obtained during the preparation of this report.

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# 1 Introduction

Matrix Solutions Inc. was retained by WSP Canada Inc., to complete a fluvial geomorphological assessment of the proposed Stage 2 ION Light Rail Transit (LRT) Preferred Route which extends from Kitchener to Cambridge. The Preferred Route crosses the Grand River, Speed River, and Freeport Creek, a tributary to the Grand River. This fluvial geomorphic assessment was conducted to evaluate the chosen alignment developed as part of the pre-planning phase of the Transit Project Assessment Process for the Region of Waterloo.

## 1.1 Objective

The objective of this fluvial geomorphic assessment is to provide input to the functional design of the Preferred Route and bridge crossings. The following scope of work was undertaken in the completion of the assessment herein:

- reviewing available materials (previous studies, mapping, and historical aerial photographs)
- determining the planform migration (meander belt width and 100-year erosion rate) on a reach basis to inform design
- conducting high-level geomorphic assessments of each proposed crossing location; these assessments were completed to determine existing geomorphic conditions, delineate reach boundaries, document evidence of active erosion and fluvial processes, and confirm desktop results
- providing geomorphic considerations for crossing structures at proposed crossing locations

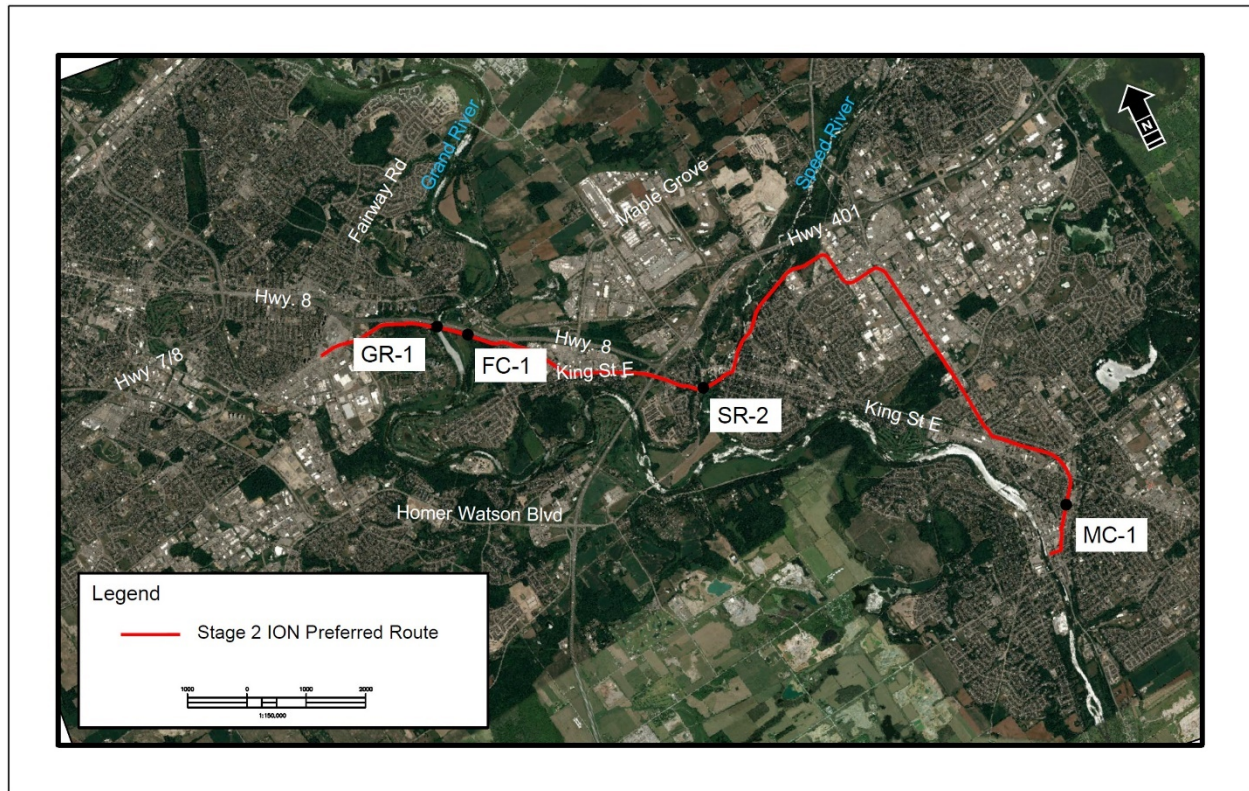
## 1.2 Study Area

The Preferred Route for Stage 2 ION was developed through an evaluation process which compared numerous route alternatives within the study area. The Preferred Route, which was endorsed by Regional Council in June 2019, is shown on Figure 1. The Preferred Route extends the Stage 1 ION alignment from the existing Fairway station (located at Fairview Park Mall in Kitchener) southerly to downtown Cambridge, with the southern terminal station located on Bruce Street at Water Street.

The watercourse crossings assessed by Matrix Solutions Inc. for the Preferred Route are as follows:

- Grand River Reach - GR-1 and Freeport Creek - FC-1 downstream of Highway 8
- Speed River Reach - SR-2 downstream of King Street
- Mill Creek Reach - MC-1 between Beverly Street and Shade Street

These crossings are indicated on Figure 1.



**Figure 1 Stage 2 ION - Preferred Route and Associated Watercourse Crossing Locations**

## 2 Background Review

A background review was undertaken to build on the current understanding of the watersheds and site characteristics that may influence the preferred crossing locations. The review was also completed to identify any disturbances to the watercourses that may have impacted channel dynamics.

### 2.1 Physiography and Soils

The following figures provide a general overview of the physiography and soils around the study area, which are outlined in more detail in the ensuing subsections (Figures 2 and 3).

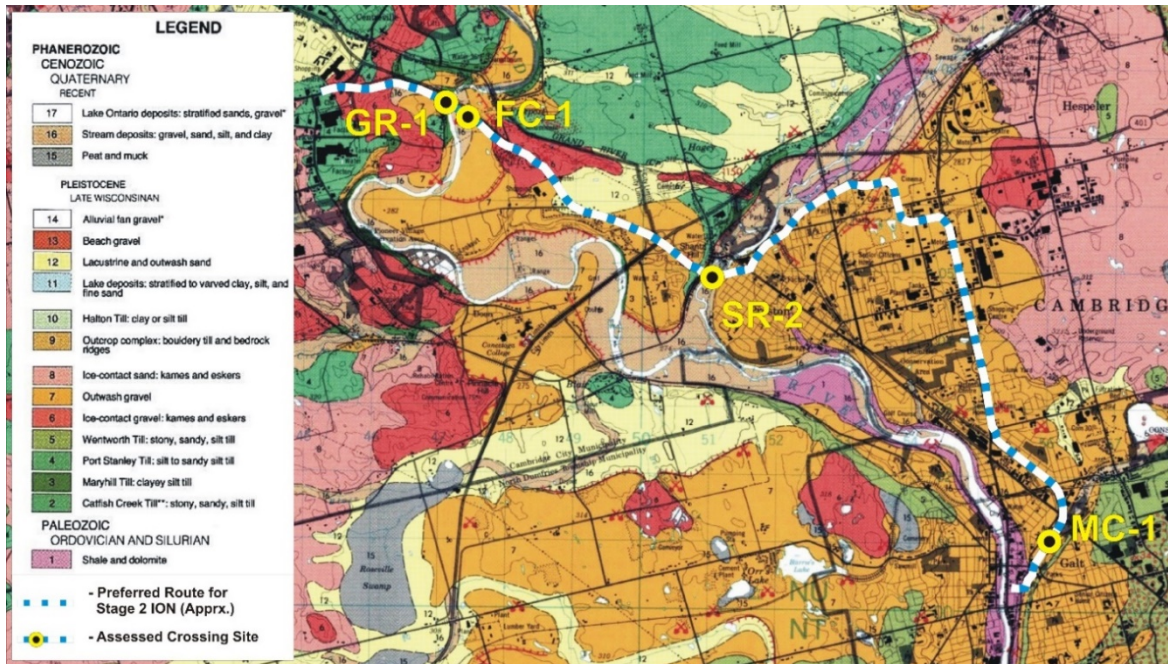


Figure 2 Physiography of Study Area, Modified from “Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario” (Karrow 1987)

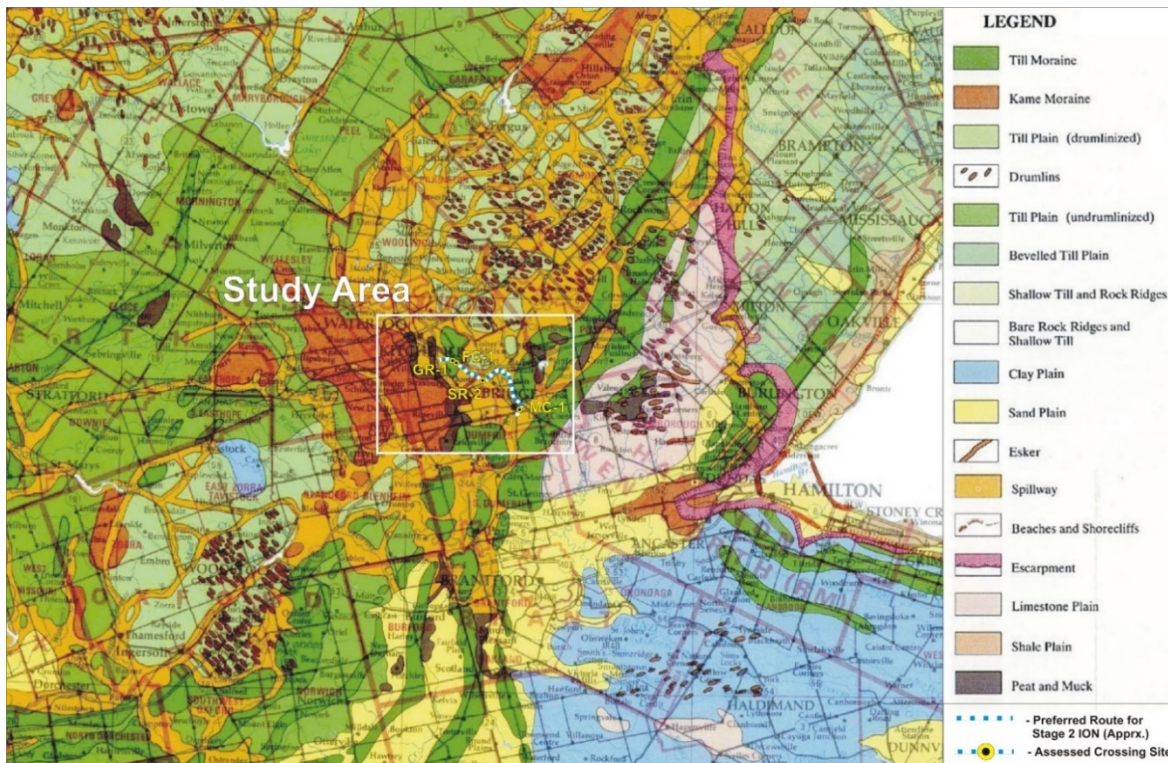


Figure 3 Soils of Study Area, Modified from “The Soils of Waterloo County” (Presant and Wicklund 1971)

### **2.1.1 Grand River - GR-1 and Freeport Creek - FC-1**

The predominant Paleozoic geology along the Grand River Reach GR-1 is the Salina Formation in the Upper Silurian, a bedrock band composed of dolomite, shale, gypsum, and salt (Liberty et al. 1976). The Grand River north of the Speed River confluence has large meanders over unconsolidated soils. South of the confluence it straightens through a predominantly bedrock channel (Presant and Wicklund 1971). At the proposed crossing, coarse and medium loams formed on alluvial deposits. Surficial stream deposits (coarse and medium loams including gravel, sand, silt, and clay) are underlain by outwash gravel (Maryhill Till and Catfish Creek Till).

The geology around Freeport Creek Reach FC-1 includes Port Stanley Till, lacustrine and outwash sand, and ice-contact gravels. Topography is gently sloping, with good drainage through surficial coarse and medium soils overlying medium till deposits (Presant and Wicklund 1971). The Freeport Esker, a geological ridge comprised sand and gravel deposited at the base of glaciers, is located between Highway 8 and the Canadian Pacific Railway and is an Earth Science Area of Natural and Scientific Interest.

### **2.1.2 Speed River - SR-2**

Near the Speed River confluence with the Grand River the Paleozoic geology is composed of the Guelph Formation of Middle and Lower Silurian age comprised dolomite. Surficial materials include recent stream deposits and outwash gravels. The gradient of the Speed River is between 0.1 and 0.3% through the study area reach. Through Reach SR-2 where the Preferred Route is proposed, the Speed River contains well-drained coarse and medium loams on alluvial deposits (Presant and Wicklund 1971).

### **2.1.3 Mill Creek - MC-1**

The north bank of the Grand River near the Mill Creek confluence is composed of Paleozoic shale and dolomite and Pleistocene outwash gravels. Soils containing organic deposits and sand surround Mill Creek Reach MC-1.

## **2.2 Previous Studies, Land Use, and Historical Planform Changes**

### **2.2.1 Grand River - GR-1**

The Grand River watershed has a catchment area of 6,800 km<sup>2</sup> and has seen changes in land use from forest to agricultural and urban, resulting in hydrological changes (Wong and Boyd 2014). As a result, events of greater extremes have been observed, including flash floods and prolonged drought, with impacts to sediment transport including increased sedimentation and

over-widening of channels. Additionally, dams throughout the watershed have altered flows, water depths, and temperature, resulting in ecological impacts. At a monitoring site approximately 6 km downstream of the study area near Doon, frequent bed mobilizing flows averaging 187 m<sup>3</sup>/s were observed between 1984 and 2012 (Wong and Boyd 2014).

The former Grand River Railway, part of the Toronto to Sarnia Canadian Pacific Railway line on the Waterloo subdivision, crosses the Grand River connecting Kitchener and Cambridge. Approximately 30 m downstream of this crossing is a concrete bowstring arch bridge carrying King Street across the Grand River, built in 1926 with seven spans, having a total length of 160.1 × 11 m wide (Benjamin et al. 2013). Another 650 m downstream of King Street, and immediately upstream of the Stage 2 ION Preferred Route is the Highway 8 crossing of the Grand River. Land use along the outside bends is predominantly low-density residential with a forested fringe along the riparian zone, while the floodplain on the inside of meander bends is undeveloped with meadow and forests.

### **2.2.2 Freeport Creek - FC-1**

The Freeport Creek subwatershed has a catchment area of 4.01 km<sup>2</sup> and is largely bounded by Allendale Road to the north, Fountain Street North to the east, and Highway 8 to the south, draining west into the Grand River (Aquafor Beech 2013a). The headwaters of Freeport Creek originate to the west of Maple Grove Road. Adjacent land uses are industrial, commercial, and institutional including École Secondaire Catholique Père-René-de-Galinée and the Challenger Motor Freight Inc. property. The creek flows west between these properties, then south for 1.2 km before entering a stormwater management area, Pond 130 (Aquafor Beech 2013a). The creek discharges flows southwesterly through forest and agricultural lands for 700 m, then passes through a residential area for 500 m. Water flows under the Canadian Pacific Railway line and King Street East, and through the former Grand Valley Garden Village property, then under Highway 8, through the proposed crossing location of the Stage 2 ION Preferred Route and into the Grand River.

A study conducted by Aquafor Beech Ltd. (Aquafor Beech 2013a) measured the slope between the former Grand Valley Garden Village property and the Canadian Pacific Railway line at 1.88%, with a Rapid Geomorphic Assessment score of 0.16, suggesting a stable channel with degradation and minor planimetric form adjustment taking place. Bankfull width averaged 1.4 m, with an average bankfull depth of 0.35 m. From the residential properties to the Canadian Pacific Railway line, the slope was 0.96%, with a Rapid Geomorphic Assessment score of 0.10, indicating it was stable, with slight degradation, widening, and planimetric form adjustment.

The rapid assessment work conducted by Matrix Solutions Inc. in 2015 confirmed that from the Canadian Pacific Railway line to the Grand River has been historically channelized and is bounded by commercial and industrial facilities upstream of the Highway 8 crossing. This channelizing has resulted in a channel with reduced natural function that is currently in a state of limited adjustment, with the exception of several undersized crossing structures. Refer to Section 3.2.2 for additional discussion.

### **2.2.3 Speed River - SR-2**

In 2007, this area of the Speed River was assessed by PARISH Geomorphic Ltd. (PARISH 2007) as part of a study by the Grand River Conservation Authority regarding water quality and instream flow targets. During this study, the Speed River was divided into reaches of similar geomorphologic characteristics, which were subsequently subjected to detailed field data collection, including cross-section and longitudinal profile surveys, and bed sediment sampling. A 1 km reach (SR-2) which is crossed by the Preferred Route stretches immediately downstream of a tri-channel braided section downstream of King Street East to the last meander bend before the channel straightens and confluences with the Grand River at an average slope of 0.1%. A cross-section immediately downstream of the braided portion had a bankfull width of 30.5 m and a bankfull depth of 2.75 m, with commercial land use on the right bank, and residential and parkland on the left bank.

### **2.2.4 Mill Creek - MC-1**

Mill Creek originates in the Township of Puslinch and flows to the City of Cambridge, passing through Shade's Mills Conservation Area and a dam-controlled reservoir, before flowing through downtown Cambridge and into the Grand River. The creek was altered, with the construction of riffle-pool sequences and a uniform meander pattern with adjacent vernal pools through Soper Park, followed by a straightened, hardened section as it enters central Cambridge before being piped near the Grand River confluence.

### 3 Reach Characterization

Study reaches were identified for the four watercourse crossings of the Preferred Route using available aerial photography, topographic mapping, current and historical watercourse planforms, and surficial geology. Final reach delineations were adjusted based on the field investigation. Reaches are lengths of channel that display similarity with respect to valley setting, planform, floodplain materials, and land use/cover. Reach length will vary with channel scale since the morphology of low-order watercourses will vary over a smaller distance than those of higher-order watercourses. At the reach scale, the characteristics of the watercourse corridor impose a direct influence on channel form, function, and processes.

#### 3.1 Rapid Assessment Methods

##### 3.1.1 Rapid Geomorphic Assessment

The Rapid Geomorphic Assessment was designed by the Ontario Ministry of the Environment (MOE 2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planimetric adjustment. Examples of these include the presence of bar forms, exposed infrastructure, fallen, or leaning trees and exposed tree roots, channel scour along the bank toe, transition of the channel from single thread to multiple thread, and cut-off channels. Overall, the index produces values that indicate whether a channel is stable/in regime (score  $\leq 0.20$ ), stressed/transitional (score 0.21 to 0.40), or adjusting (score  $\geq 0.40$ ). Table 1 provides explanations of the various classifications.

**Table 1 Rapid Geomorphic Assessment Classification**

Factor Value	Classification	Interpretation
$\leq 0.20$	Stable or In Regime (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics; evidence of instability is isolated or associated with normal river meander propagation processes
0.21 to 0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent
$\geq 0.41$	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is widespread

### **3.1.2 Rapid Stream Assessment Technique**

The Rapid Stream Assessment Technique (Galli 1996) provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories: channel stability, erosion and deposition, in-stream habitat, water quality, riparian conditions, and biological indicators. Scores are divided into three classes: low (<20), moderate (20 to 35), and high (>35).

While the Rapid Stream Assessment Technique scores streams from a more biological and water quality perspective than the Rapid Geomorphic Assessment, this information is also relevant within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (e.g., fish prefer a variety of physical conditions: pools provide resting areas while riffles provide feeding areas and contribute oxygen to the water; good riparian conditions provide shade and food; and woody debris and overhanging banks provide shade). Additionally, the Rapid Stream Assessment Technique approach includes semi-quantitative measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

### **3.1.3 Rapid Assessment Results**

Field reconnaissance was completed to confirm site reaches and perform a Rapid Geomorphic Assessment and the Rapid Stream Assessment Technique on December 2 and 3, 2015, with relevant site photographs provided in Appendix A. The watercourse for each proposed crossing within the study area was assessed on a reach scale basis as summarized in Table 2.

**Table 2 Rapid Geomorphic Assessment and Rapid Stream Assessment Technique Summary**

Reach/ Watercourse	Factor Value				Stability Index	Condition	Rapid Stream Assessment Technique Score
	Aggradation	Degradation	Widening	Planimetric Adjustment			
Grand River - GR-1	0.33	0	0.38	0.14	0.21	Transitional	32
Freeport Creek - FC-1	0.11	0.14	0.13	0.29	0.17	In Regime	24
Speed River - SR-2	0.22	0.14	0.13	0	0.12	In Regime	30
Mill Creek - MC-1	0	0.43	0.5	0	0.23	Transitional	17

## 3.2 Watercourse Existing Conditions Assessment

Existing conditions summarized in the following sections were based on field data and observations collected on December 2 and 3, 2015.

### 3.2.1 Grand River - GR-1

The Preferred Route for Stage 2 ION crosses the Grand River in Kitchener parallel to Highway 8 on the south side. On December 2, 2015, a Rapid Geomorphic Assessment was conducted for a 2 km reach of the Grand River from Allendale Road to 500 m downstream of Highway 8 (Figure 4). The Grand River exhibits large-amplitude sinuosity throughout the study reach as a result of being an alluvial channel with a low longitudinal gradient. At the bend upstream of the proposed crossing, valley wall contact was observed on the left bank along the outside bend, with erosion along the toe of slope and bank slumping/failure. At the bend downstream of the Canadian Pacific Railway crossing, valley wall contact is present on the right bank with minimal erosion.

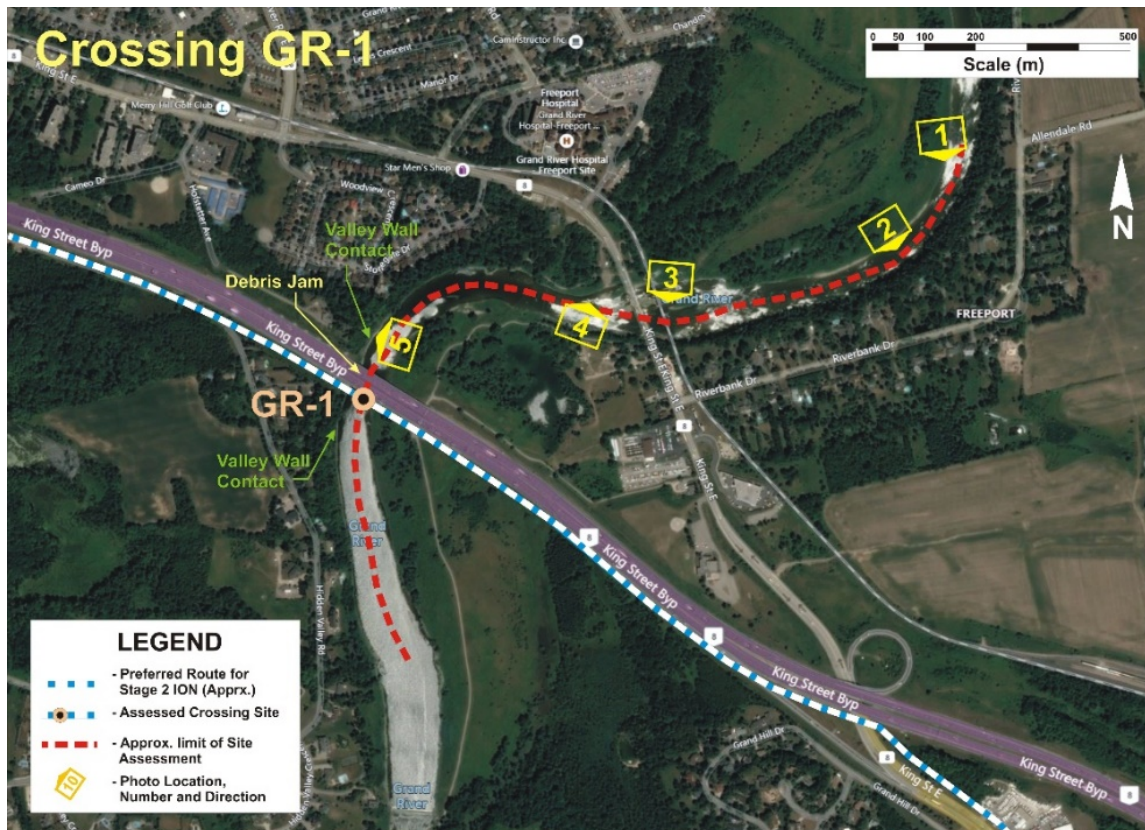


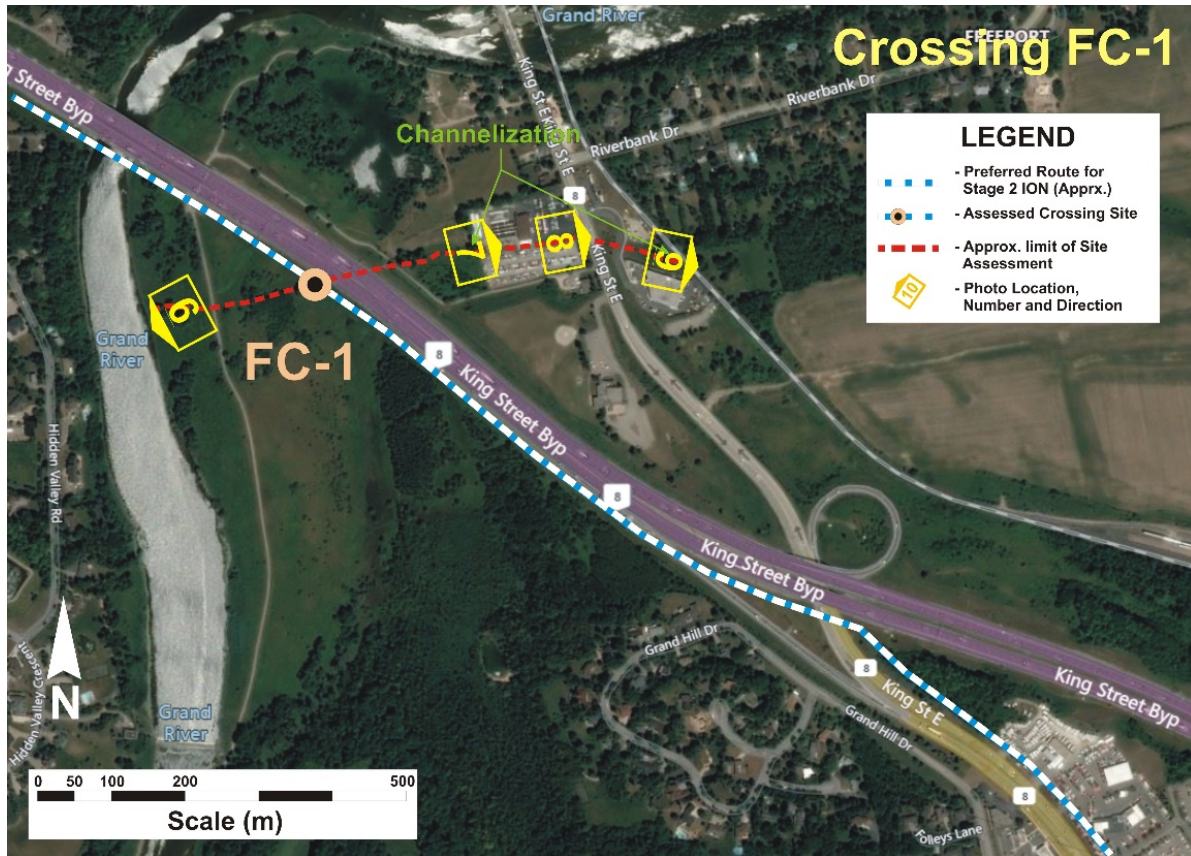
Figure 4 Site Map Depicting the Approximate Field Assessment Limits and Photograph Locations for GR-1

Bankfull widths through the reach ranged from 64 to 122 m, with wetted widths between 55 m and 112 m. Banks comprised coarse-fine sands, silt and clay, with grasses, and shrubs. At the King Street crossing, a debris jam along the right bank is causing a flow diversion and forcing water toward the right pier. The diversion has resulted in localized scour and erosion at the toe of the right pier.

The Grand River Reach GR-1 was assigned a Rapid Stream Assessment Technique score of 32 and a Rapid Geomorphic Assessment score of 0.21, indicating it is of moderate health and is transitional in terms of stability. Widening and aggradation were observed as the dominant geomorphic processes.

### **3.2.2 Freeport Creek - FC-1**

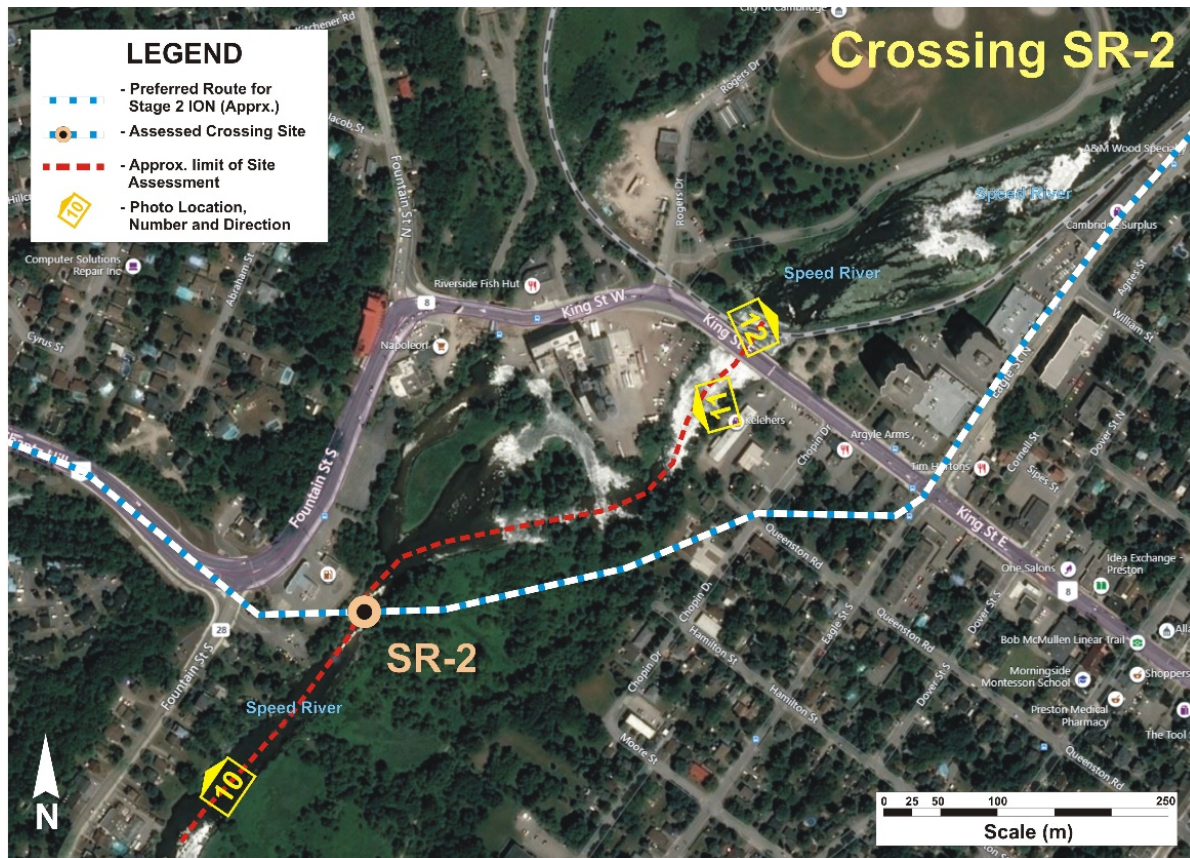
The Preferred Route for Stage 2 ION crosses Freeport Creek near its confluence with the Grand River parallel and downstream to Highway 8. Freeport Creek Reach FC-1 was assessed from the confluence of the Grand River to King Street East on December 3, 2015 (Figure 5) and was found to have low to moderate sinuosity. Downstream of Highway 8, watercress was present; the growth of this plant generally indicates groundwater supply to the creek. Bed material consisted of exposed clay and medium sand deposits located near a road drainage inlet. Between Highway 8 and the Canadian Pacific Railway line through the former Grand Valley Garden Village property, the channel had previously been straightened and hardened, with evidence of bank erosion and outflanking of the culvert. Bankfull widths ranged from 1.2 to 2.0 m, with bankfull depths of 0.5 m. Wetted widths ranged from 0.63 to 0.85 m, with wetted depths of 0.11 to 0.21 m. Bed materials included medium-sand deposits, exposed clay, and cobble substrate. This reach of Freeport Creek was assigned a Rapid Stream Assessment Technique score of 24, suggesting the creek is of moderate health, and a Rapid Geomorphic Assessment score of 0.17, suggesting the creek is in regime in terms of its stability. Planimetric form adjustment was determined to be the dominant geomorphic process.



**Figure 5 Site Map Depicting the Approximate Field Assessment Limits and Photograph Locations for FC-1**

### 3.2.3 Speed River - SR-2

The Preferred Route for Stage 2 ION extends easterly on a dedicated alignment from the intersection of Shantz Hill Road and Fountain Street across the Speed River (Figure 6). The channel then runs parallel to the Speed River before diverging and connecting with Eagle Street. The reach has a low sinuosity and a low gradient (0.9%). The narrowest channel section is at the proposed crossing location, with a bankfull width of 30.5 m, a bankfull depth of 2.75 m, and a wetted width of 26 m. No Rapid Geomorphic Assessment or Rapid Stream Assessment Technique was conducted for the reach; however, some erosion was observed along the east bank where concrete blocks have been placed as protection. Greater erosion and undercutting occur at the meander further downstream.

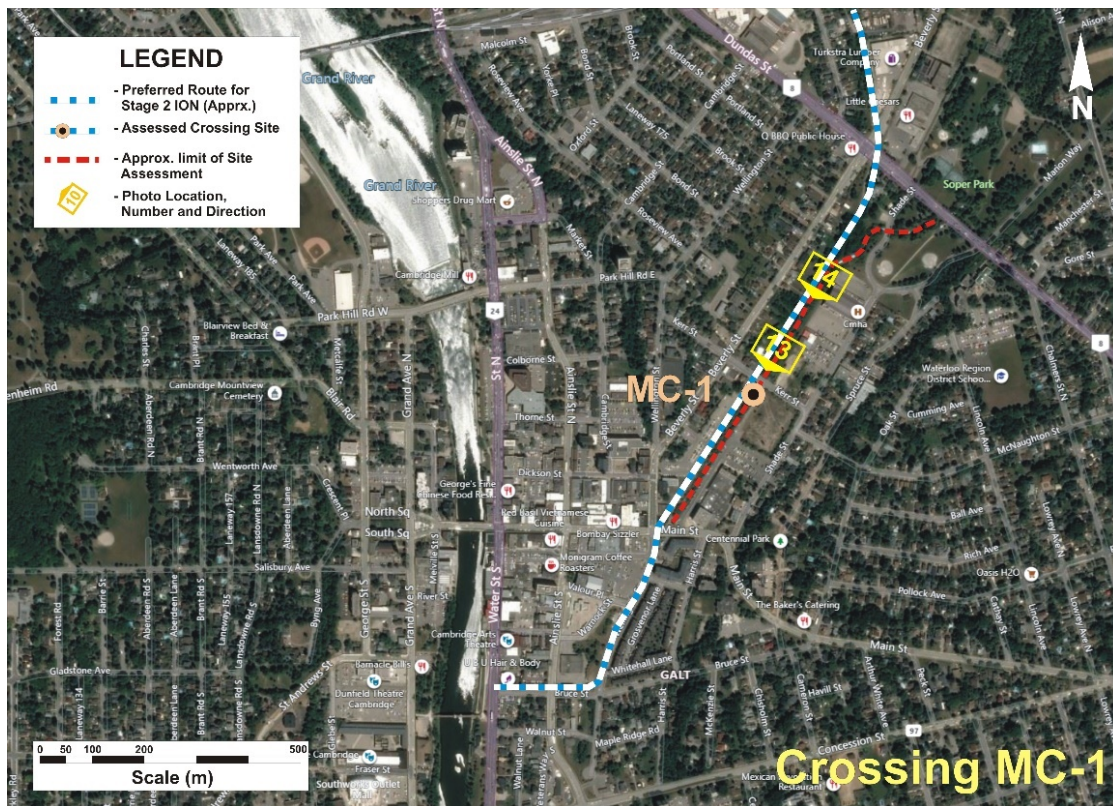


**Figure 6 Site Map Depicting the Approximate Field Assessment Limits and Photograph Locations for SR-2**

### 3.2.4 Mill Creek - MC-1

Mill Creek was investigated in South Cambridge to consider impacts associated with the proximity of the Preferred Alignment for Stage 2 ION on the west side of the channel; the Preferred Route is located adjacent to Mill Creek but does not cross it. The creek was assessed between Dundas Street North and Main Street before it enters a culvert that runs under downtown Cambridge and, ultimately, discharges into the Grand River (Figure 7). The creek has been heavily altered through Soper Park north and south of Dundas Street North where vernal pools and exaggerated meanders appear to have been constructed, and along Beverley Street where it has been armoured and straightened. The steep banks (approximately 2 m in height) and bed are often lined with interlock paving stones, and gabion baskets that are eroding and failing in places. The bankfull width and depth was uniformly 10 m wide and 1 m deep, with a wetted width and depth of 5 to 7 m and 0.5 to 0.6 m, respectively. Fallen and leaning trees, exposed clay within the bed, and organic debris jams are evident, indicating that widening and degradation are the dominant geomorphic processes within the channel. This reach of Mill

Creek was assigned a Rapid Stream Assessment Technique of 17 and Rapid Geomorphic Assessment of 0.232, suggesting the creek is of low health and transitional in terms of stability.



**Figure 7** Site Map Depicting the Approximate Field Assessment Limits and Photograph Locations for MC-1

## 4 Meander Belt Width and 100-year Erosion Rate Analysis

Streams and rivers are dynamic features that change their configuration and position within a floodplain by means of meander evolution, development, and migration processes. When meanders change shape and position, the associated erosion and deposition that enable these changes to occur can cause loss or damage to property or infrastructure. Therefore, when development or other human activities are contemplated near a watercourse, it is desirable to designate a corridor that is intended to contain all the natural meander and migration tendencies of the channel. Outside of this corridor, it is assumed that private property and structures will be safe from the erosion potential of the watercourse. The space that a meandering watercourse occupies on its floodplain, within which all associated natural channel processes occur, is commonly referred to as the meander belt.

The Belt Width Delineation Procedure is applicable to confined and unconfined systems and follows a process-based methodology to determine the meander belt width based on background information, historical data (including aerial photography), degree of valley confinement, and channel planform (PARISH 2004). Based on available mapping and historical aerial photographs, a preliminary belt width was delineated for the study reaches. Historical aerial photographs from 1945, 1955, and 1963 (University of Waterloo 2016), where available, were reviewed and compared with recent digital orthoimagery from 2014 (Regional Municipality of Waterloo 2014) to document changes in channel planform and process.

Braided rivers are atypical of eastern Ontario systems and require additional consideration when delineating hazard allowances. Unconfined braided systems are often dynamic and highly mobile. The Speed River is braided in several locations through the study site due to various factors, including steep gradients and changes in surficial geology. For the purposes of this study, aerial photographs, an assessment of the level/age of vegetation found on islands, and observations made during the field investigation were used as indicators of the stability of the channel through braided reaches. Overall, the Speed River is highly stable in braided areas. A study by Leopold and Wolman (1957) suggested that rivers with braided patterns may be as close to quasi-equilibrium as rivers possessing meandering or other patterns. This is the case with the Speed River, where significant vegetation growth (mature trees) are present, little planform adjustment (since 1963 aerial photographs were taken) can be discerned, and observations made indicate a high level of channel stability.

Ideally, a proposed crossing structure would span the meander belt width of its channel. From a geomorphic perspective, a maximized span is desirable as it minimizes long-term risk and maintenance associated with channel migration. This alternative is typically cost-prohibitive, especially in larger rivers such as the Grand River and Speed River through the reaches studied as part of the current work. As such, no meander belt width analysis was completed for these larger channels as part of this report.

Typically, aerial photograph analysis also supports the quantification of the 100-year erosion rate. From a geomorphic perspective, the 100-year erosion rate generally represents the erosion setback to be applied to either side of the meander belt width to account for bank erosion and channel migration over time. Depending on the availability of and quality of aerial photographs, migration of certain reaches could not be quantified near the study area. In these cases, an erosion setback of 10% was applied to each bank to allow for future bank erosion. Results from this analysis, including preliminary corridor width, erosion setback, and final meander belt width are provided in Table 3.

## 4.1 Meander Belt Width Methods

### 4.1.1 100-year Migration Rate

Historical migration rates are a useful indicator of planform adjustment and provide a means of quantifying the rate of channel widening or bank erosion over time. The 100-year migration rate also generally represents the erosion setback applied to the preliminary meander belt corridor.

Channel migration rates and channel planform adjustment were assessed for the governing meander bends within the reach. The changes in channel bank position over time is measured on sequential aerial photographs, where distances between the banks from known points can be measured and used to estimate the lateral migration of banks.

### 4.1.2 Empirical Analysis

Meander belt widths can be determined or verified using empirical relations based on channel parameters measured in the field. The following equations (Table 3) provide an estimate of meander belt width dimensions based on measurements of average bankfull width. These relations are based on measurements of real watercourses; however, the transferability to watercourses that are situated within southern Ontario is limited due to differences in hydrologic regime, drainage area, and general controlling factors. When compared to the standard “*Belt Width Delineation Procedure*” (PARISH 2004), the empirical relationships can help establish the appropriateness of the results. In situations where a discernible preliminary meander belt width cannot be delineated, empirical methods provide an alternative.

**Table 3 Meander Belt Empirical Analysis**

Source	Equation
Williams (1986) - width (m)	4.3 (Average bankfull width) <sup>1.12</sup>
Ward et al. (2002) - width (ft)	4.8 (Average bankfull width) <sup>1.08</sup>
Lorenz et al. (1985) - width (m)	7.53 (Average bankfull width) <sup>1.01</sup>

Bankfull channel dimensions measured during the field assessment were used as input parameters for the empirical analyses, producing estimated preliminary belt widths. Final belt widths had a 10% factor of safety applied and were produced based on traditional mapping methods.

## 4.2 Meander Belt Width Results

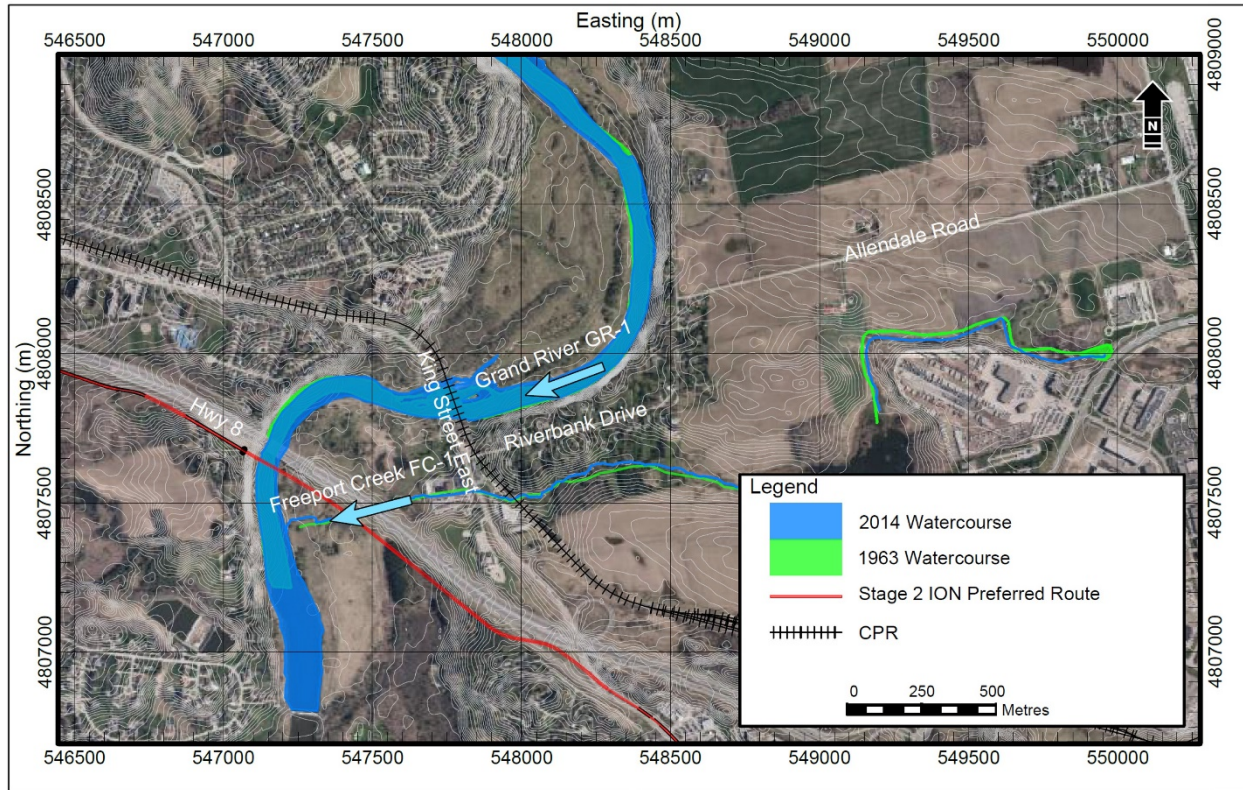
A summary of the results, including preliminary corridor width, erosion setback, and final meander belt width are provided in Table 4. The approach and description of the migration of each subject reach is provided in following sections and are a summary of Matrix Solutions Inc. (2016) findings.

**Table 4 Meander Belt Width Parameters for Stage 2 ION Preferred Route**

Reach	Preliminary Meander Belt Width (m)	Erosion Setback (m) (10% or 100 year Erosion Rate)	Final Meander Belt Width (m)
Freeport Creek - FC-1	16	1.6	19
Mill Creek - MC-1	56	5.6	67

### 4.2.1 Grand River - GR-1

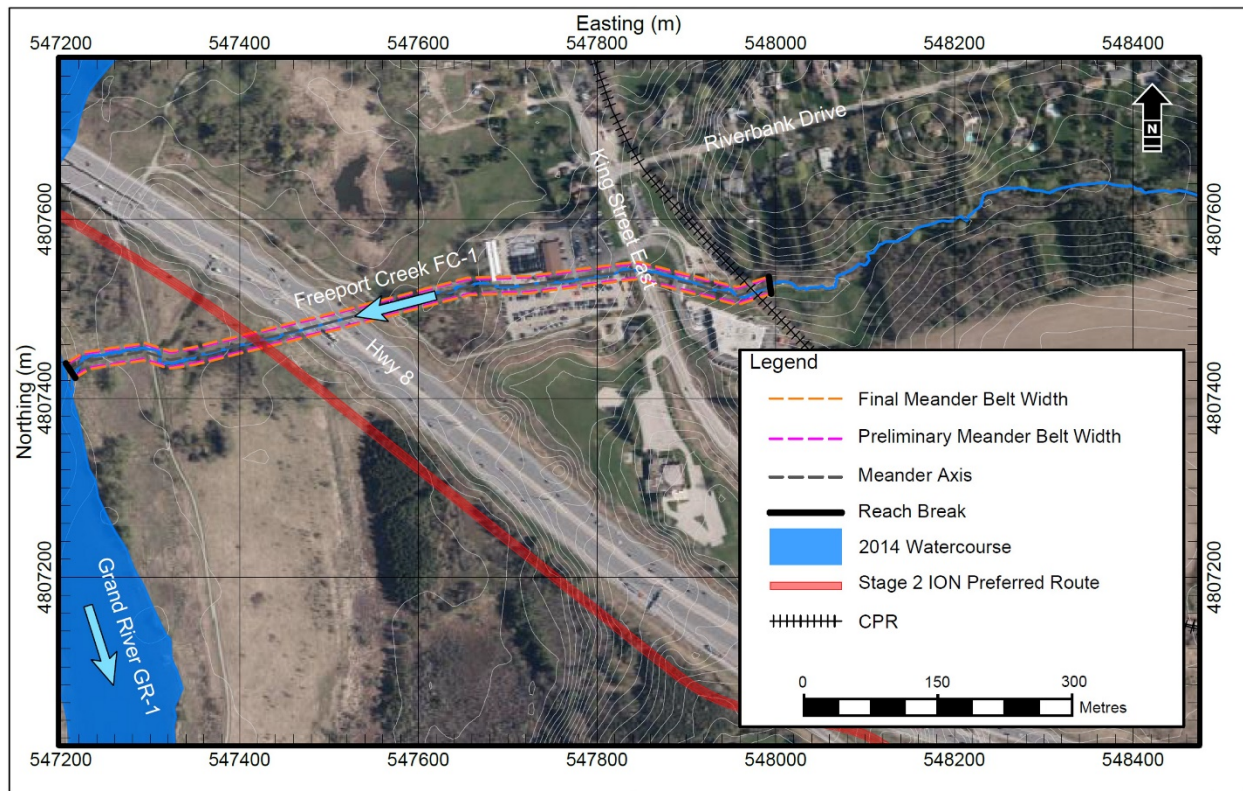
The Grand River through GR-1 is a confined watercourse, with valley wall contact at the apex of meanders. The meander axis did not exhibit significant changes between 1963 and 2014 as seen in the aerial photograph comparison provided on Figure 8. A 100-year erosion rate of 23 m was measured between 1963 and 2014 at the two meanders immediately upstream and downstream of the alternatives. Currently, the average slope of the outside bend valley wall is approximately 1H:1V. Because of the span of the existing local bridges crossing the Grand River (King Street East and Canadian Pacific Rail) compared to the total meander belt width of the channel, a meander belt width was not deemed appropriate as part of this assessment, and a more focused discussion is provided as part of the bridge crossing conceptual alternatives section.



**Figure 8 Grand River Reach - GR-1**

### 4.2.2 Freeport Creek- FC-1

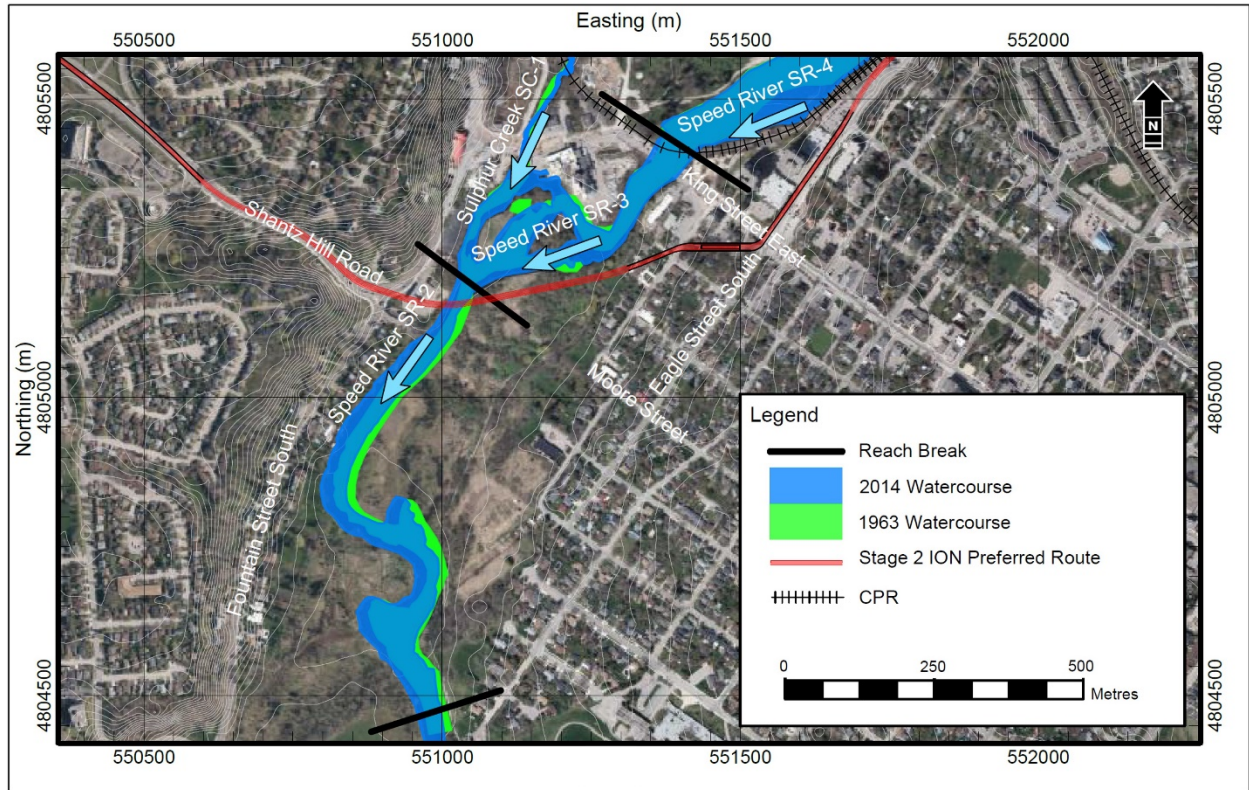
Freeport Creek Reach FC-1 near the Grand River confluence has historically been straightened and, as a result, shows no discernible meandering pattern. As such, the portion upstream of the Canadian Pacific Railway line behind the residential lands was analyzed as a surrogate reach. This location exhibits similar meandering patterns between 1945 and 2014, suggesting the natural form of the channel has not been altered. A preliminary meander belt width of 16 m was measured for the surrogate reach and compared to the empirical formula, using bankfull measurement of FC-1, which yielded an average of 12 m (Lorenz et al. 1985, Ward et al. 2002, Williams 1986). The preliminary belt width determined from an evaluation of the surrogate reach was chosen as more representative of the planimetric form adjustment processes observed in the study reach, a safety factor of 10% was applied to each side of the preliminary width, yielding a final meander belt width of 19 m for Reach FC-1 (Figure 9).



**Figure 9 Freepoint Creek Reach - FC-1 Meander Belt Width**

### 4.2.3 Speed River - SR-2

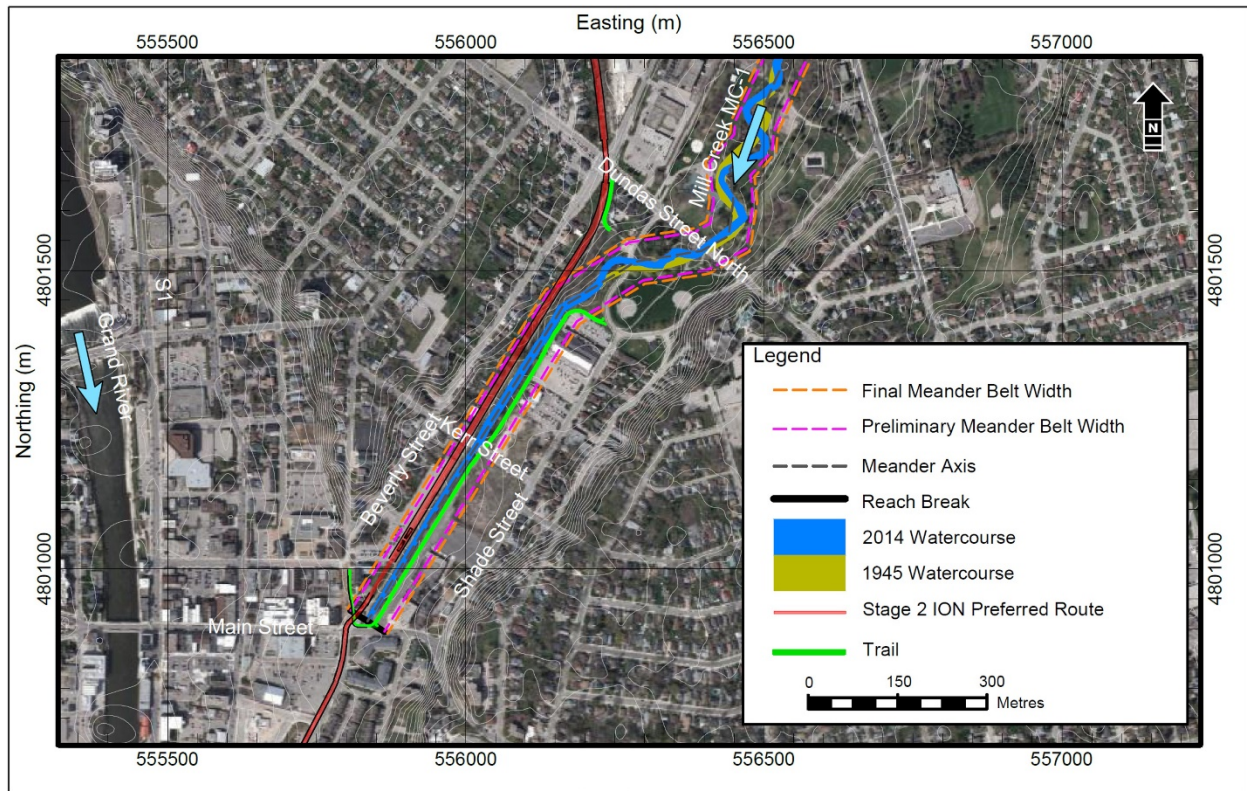
The Speed River downstream of the Riverside Dam within Reach SR-2 had an approximate 100-year erosion rate of 19 m based on aerial photographs between 1963 and 2013 (Figure 10). Future changes to the Riverside Dam may result in changes to the flow regime and geomorphological processes could change and would require further investigation (Amec Foster Wheeler 2018, the City of Cambridge and AMEC 2013). A detailed discussion of the bridge crossing conceptual alternative is provided in Section 5 of this report.



**Figure 10** Speed River Reach - SR-2

#### 4.2.4 Mill Creek - MC-1

Historical changes including grading and channelization have reduced the natural hydrologic regime of Mill Creek. A preliminary meander belt width of 66 m was determined using an average of various empirical formula methods (Lorenz et al. 1985, Ward et al. 2002, Williams 1986). Applying a 10% factor of safety resulted in a 79 m final meander belt width (Figure 11). Because the Preferred Route does not cross Mill Creek, this analysis was used to inform a discussion of hazards in Section 5 of this report.



**Figure 11** Mill Creek Reach - MC-1 Meander Belt Width

## 5 Alternative Crossing Analysis

To provide insight toward structure sizing for watercourse crossings, a risk-based procedure is typically applied. The procedure used in the current study considers five main parameters including valley setting, overall channel stability, meander belt width, bankfull width, and the 100-year migration rate. The consideration of these risk factors allows for an evaluation of a proposed watercourse crossing based on spatial and temporal scales to determine the appropriateness of crossing structure location and size.

- Valley Setting:** Watercourses with wide, flat floodplains and with low valley and channel slopes tend to migrate laterally across the floodplain over time. Watercourses that are confined in narrow, well-defined valleys are less likely to erode laterally but are more susceptible to down-cutting and channel widening, particularly where there are changes to upstream land use.
- Channel Stability:** The Rapid Geomorphic Assessment score provides an indication of the overall stability of the channel. Channels that are unstable tend to be actively adjusting and thus more sensitive to the possible effects of a proposed crossing.

- **Meander Belt Width:** The meander belt width represents the maximum expression of the meander pattern within a channel reach. Therefore, this width/corridor covers the lateral area where the channel could potentially occupy over time. This value is often used by regulatory agencies for corridor delineation associated with natural hazards. The use of the meander belt width for structure sizing has been established as a criterion by some regulatory agencies and is a highly conservative approach.
- **Bankfull Width:** Based on field observations and aerial photographs for larger river systems, the bankfull width of the channel is often used to provide recommendations related to crossing design when a full meander belt width span is cost-prohibitive or in cases where flood elevations and/or hydraulic considerations are negatively impacted. Often a three times bankfull width span is considered adequate and conservative. If design constraints are more significant or in larger river systems, a single bankfull width span is proposed with an erosion allowance.
- **100-year Migration Rates:** Using historical aerial photographs, migration rates may be quantified (where possible) for each crossing location. A higher migration rate indicates a more unstable system with higher risk. An estimate of the 100-year erosion rate of a channel is often used as an erosion buffer. In areas where migration rates cannot be estimated due to tree cover, poor aerial imagery, etc., 10% of the meander belt width is often used as an erosion allowance.

## 5.1 Results and Recommendations

### 5.1.1 Grand River - GR-1

The Preferred Route for Stage 2 ION crosses the Grand River Reach - GR-1 parallel to the existing Highway 8 bridge. This reach of the Grand River exhibits large meanders confined by steep valley walls, which are met at meander apexes. No discernible longitudinal migration rate of meanders through the valley could be observed by comparing historical aerial photographs. Some lateral migration of the channel was observed at various locations throughout the study reach during the field investigation causing widening and localized scour at some of the existing piers at various bridges (Canadian Pacific Railway existing bridge for example).

In the case of the Grand River, a meander belt width or bankfull width span is cost-prohibitive and is deemed unnecessary given the low rate of channel adjustment. The average bankfull width of the channel is approximately 93 m for the subject reach and existing structures have multiple piers which extend into the channel bottom. The valley setting appears to be the

primary limiting factor of pier placement and spacing. The proximity to the existing Highway 8 crossing structure further reduces the likelihood of significant localized channel migration.

A 100-year erosion rate of 23 m was measured through the study reach, which can be considered as an erosive hazard allowance from the top of bank for consideration in crossing design. Bridge design considerations should include minimizing the number of piers and mitigating potential scour at pier footings. The alignment of the piers between bridges should be positioned to reduce the impacts to flow paths within the river system.

### 5.1.2 Freeport Creek - FC-1

South of the Grand River, the Preferred Route crosses Freeport Creek Reach - FC-1 south of Highway 8. This reach of Freeport Creek is within the Grand River floodplain and is not confined; however, several culverts throughout the reach constrain geomorphic processes (from upstream to downstream; Aquafor Beech 2013a, 2013b):

- Canadian Pacific Railway: 0.9 m diameter twin corrugated steel pipes; one culvert is used as overflow
- Honda Motor Company driveway east of King Street East: 2.4 m span by 1.8 m rise concrete box culvert
- King Street East: 1.5 m diameter concrete pipe culvert
- Former Grand Valley Garden Village property driveway: 450 mm twin corrugated steel pipes
- Hydro access road downstream of the former Grand Valley Garden Village property: 1.2 m diameter culvert
- Highway 8: 1.4 m span by 1 m rise open-bottom box culvert

The meander belt width along Freeport Creek Reach - FC-1 was determined to be 19 m which is likely cost-prohibitive and could have an impact on road and flood elevations. Having been historically straightened, there is evidence of planimetric form adjustment. Bankfull widths ranged from 1.2 to 2.0 m. A three times bankfull width, 6.0 m span, is recommended and would allow for future channel adjustment.

For context of channel processes occurring through the study reach, there are current erosion issues and outflanking around an existing culvert. The culvert under the Canadian Pacific Railway line has previously been identified as being in disrepair and a barrier to fish passage (Aquafor Beech 2013b). It is expected that at existing crossings, maintenance and local protection measures will be necessary to address channel adjustments, although these are not

included in the Stage 2 ION LRT project. However, these observations suggest that existing crossings are undersized and that any proposed crossings associated with the Stage 2 ION LRT consider future channel adjustments into span widths. This will ensure long-term stability and to allow for a degree of natural channel adjustment.

### 5.1.3 Speed River - SR-2

The Speed River through SR-2 is confined within its valley with a steep valley wall and valley wall contact along the right bank at the crossing of the Stage 2 ION Preferred Route. The Preferred Route then runs parallel to the Speed River downstream of stable river braiding across the floodplain.

As with the Grand River, spanning the meander belt width is cost-prohibitive and deemed to be unnecessary given the stability of the Speed River and number of features that control flows and water levels, including the Riverside Dam. The Speed River along Reach SR-2 has a low sinuosity and a low gradient (0.9%) and is experiencing lateral migration toward the right bank, with evidence of erosion. This erosion toward the right bank is considered the greatest hazard to this crossing location and may require stabilization works depending on crossing design. Reach SR-2 had an approximate 100-year erosion rate of 19 m which should be considered as an erosion hazard allowance to the top of bank.

Formations consistent with historical braiding at the downstream portion of the reach suggest planimetric changes could occur but, under existing conditions, the channel is narrow and straight at the preferred crossing location.

Applying a three times bankfull width to the span of the crossing structure would result in a crossing span of 91.5 m, which is likely cost-prohibitive. The consideration of a bankfull width of the channel with a 19 m hazard allowance applied would require a span of approximately 68.5 m. Existing crossings include piers that extend into the river bottom. Bridge design considerations should include minimizing the number of piers and mitigating potential scour at pier footings.

Additional considerations may be required in a future design phase for Stage 2 ION based on the outcome of proposed improvements to Riverside Dam, as changes to the flow regime could alter geomorphic processes through Reach SR-2 (Amec Foster Wheeler 2018, the City of Cambridge and AMEC 2013).

#### 5.1.4 Mill Creek - MC-1

Mill Creek has been straightened along the Preferred Route and runs parallel to Beverly Street and Shad Street. There is no open channel crossing at this location; the Stage 2 ION Preferred Route does not cross Mill Creek but is located immediately adjacent to it. The existing channel is armoured to protect adjacent properties and infrastructure; however, the meander belt width delineated as part of this study suggests that the Stage 2 ION Preferred Route is within the natural hazard allowance. Maintaining the existing channel alignment (i.e., channel armouring) will be necessary to limit channel migration.

## 6 Conclusions

WSP Canada Inc. retained Matrix Solutions Inc. to complete a fluvial geomorphological assessment of the Stage 2 ION Preferred Route at its crossings of the Grand River, the Speed River, and two tributary channels to inform the Transit Project Assessment Process for the Region of Waterloo. The objective of the fluvial geomorphic assessment was to provide input into the design basis/criteria that will assist in the development of bridge crossing conceptual alternatives. As part of this work, a background review of relevant documents and aerial mapping, field observations, and geomorphic analyses were used to provide geomorphic recommendations for each alternative crossing location.

The crossings of the Grand River, Freeport Creek and Mill Creek will require new structures that run parallel to existing crossings (Highway 8 and Beverly Street). At these locations, consideration is given for the impact of the geomorphology of the channel on the crossing structures, and vice versa. Delineated meander belt width limits, bankfull widths, and erosion hazard allowances show the potential hazard of meandering channels on crossing locations and were used to provide high level recommendations at the preliminary design level. The Grand and the Speed rivers require consideration for bankfull widths and erosion hazard allowances while the crossing of Freeport Creek should consider a three times bankfull width approach to allow channel future channel migration and minimize maintenance.

Additional analysis will be required in future phases to reassess the implications on watercourses as key decisions are made. This will include the future of the Riverside Dam, which could have implications for the Speed River on downstream reaches, especially given the braiding nature of the system.

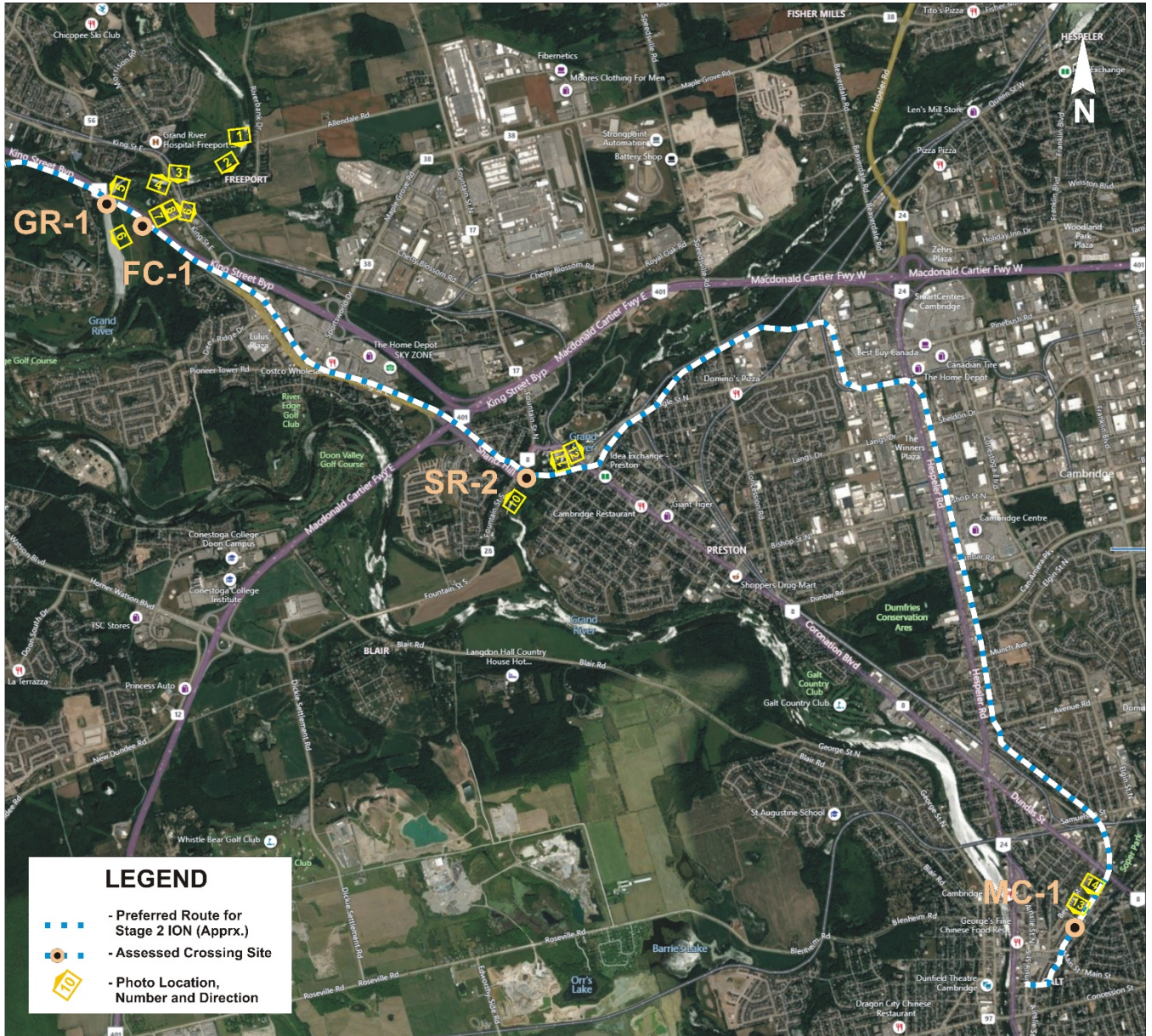
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# Appendix A

## Site Photographs



Key Plan – Location and direction of photos presented below in Appendix A.



*Matrix Supplied –  
December 2, 2015*

1. Grand River Reach GR-1 near Allendale Road, facing downstream along outer bend (south).



*Matrix Supplied –  
December 2, 2015*

2. Grand River Reach GR-1 downstream of Allendale Road. Valley wall contact experiencing erosion along left outer bend facing downstream (southeast).



*Matrix Supplied –  
December 2, 2015*

3. CPR spanning the Grand River Reach GR-1 facing left bank.



*Matrix Supplied–  
December 2, 2015*

4. CPR spanning the Grand River Reach GR-1 facing right bank.



*Matrix Supplied –  
December 2, 2015*

5. Highway 8 spanning Grand River Reach GR-1 towards right bank (northwest).



*Matrix Supplied–  
December 2, 2015*

6. Freeport Creek Reach FC-1, facing downstream, near the confluence with the Grand River (southwest).



*Matrix Supplied –  
December 2, 2015*

7. Freeport Creek Reach FC-1 through channelized Grand Valley Garden Village property facing upstream (east).



*Matrix Supplied –  
December 2, 2015*

8. Freeport Creek Reach FC-1 flowing through twin corrugated steel pipes under Grand Valley Garden Village property driveway in foreground and concrete culvert in background under King Street East, facing upstream (east).



*Matrix Supplied –  
December 2, 2015*

9. Freeport Creek Reach FC-1 between King Street East concrete culvert and box culvert Honda driveway.



*Matrix Supplied –  
December 3, 2015*

10. Speed River Reach SR-2 facing scoured and armoured right bank at outfall.



*Matrix Supplied –  
December 3, 2015*

11. Speed River Reach SR-2 facing downstream from below King Street East adjacent to P&H Flour Mill.



*Matrix Supplied –  
December 3, 2015*

12. Speed River Reach SR-2 facing upstream from King Street East over existing rail line and Riverside Dam.



*Matrix Supplied –  
December 3, 2015*

13. Mill Creek Reach MC-1 facing downstream, north of Kerr Street (southwest).



*Matrix Supplied –  
December 3, 2015*

14. Mill Creek Reach MC-1 facing downstream, north of Kerr Street; tiles are lining the bed and banks through the reach (southwest).