# WILLBAND CREEK ISMP

**APPENDICES**

October 18, 2019

URBAN systems · GeoADVICE · DILLON CONSULTING · THURBER ENGINEERING LTD. · plan for 200K · ABBOTSFORD

# APPENDIX A

Issues Identification - City of Abbotsford

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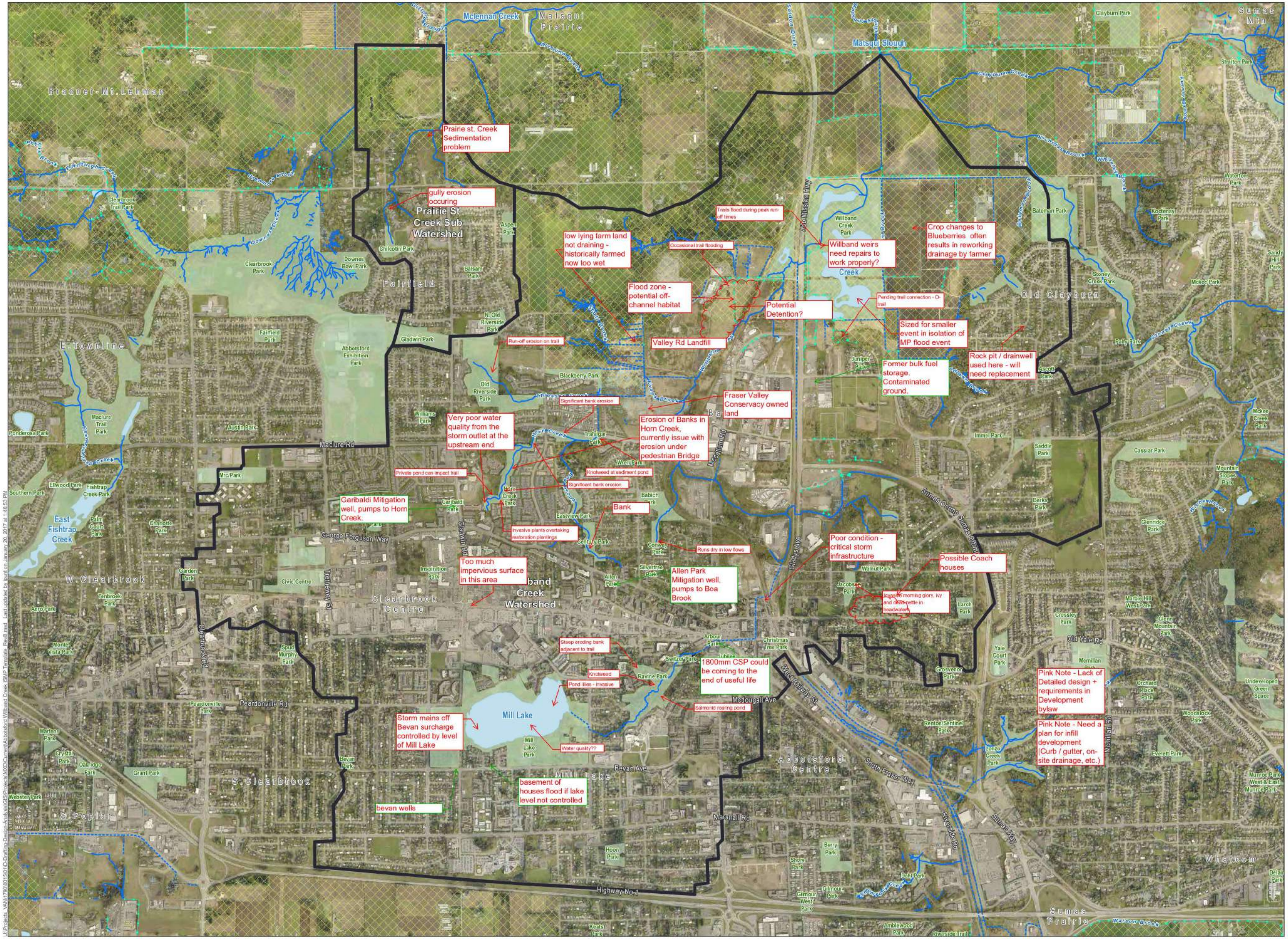



ABBOTSFORD

# Willband Creek Integrated Storm Water Management Plan

## Study Area

Legend

- Willband Creek Watershed
- Lake
- Marsh
- Natural Watercourse
- Channelized Watercourse
- Ditch
- Park
- Agricultural Land Reserve

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100 200 300 400 500 Meters

N

Coordinate System: NAD 1983 UTM Zone 10N

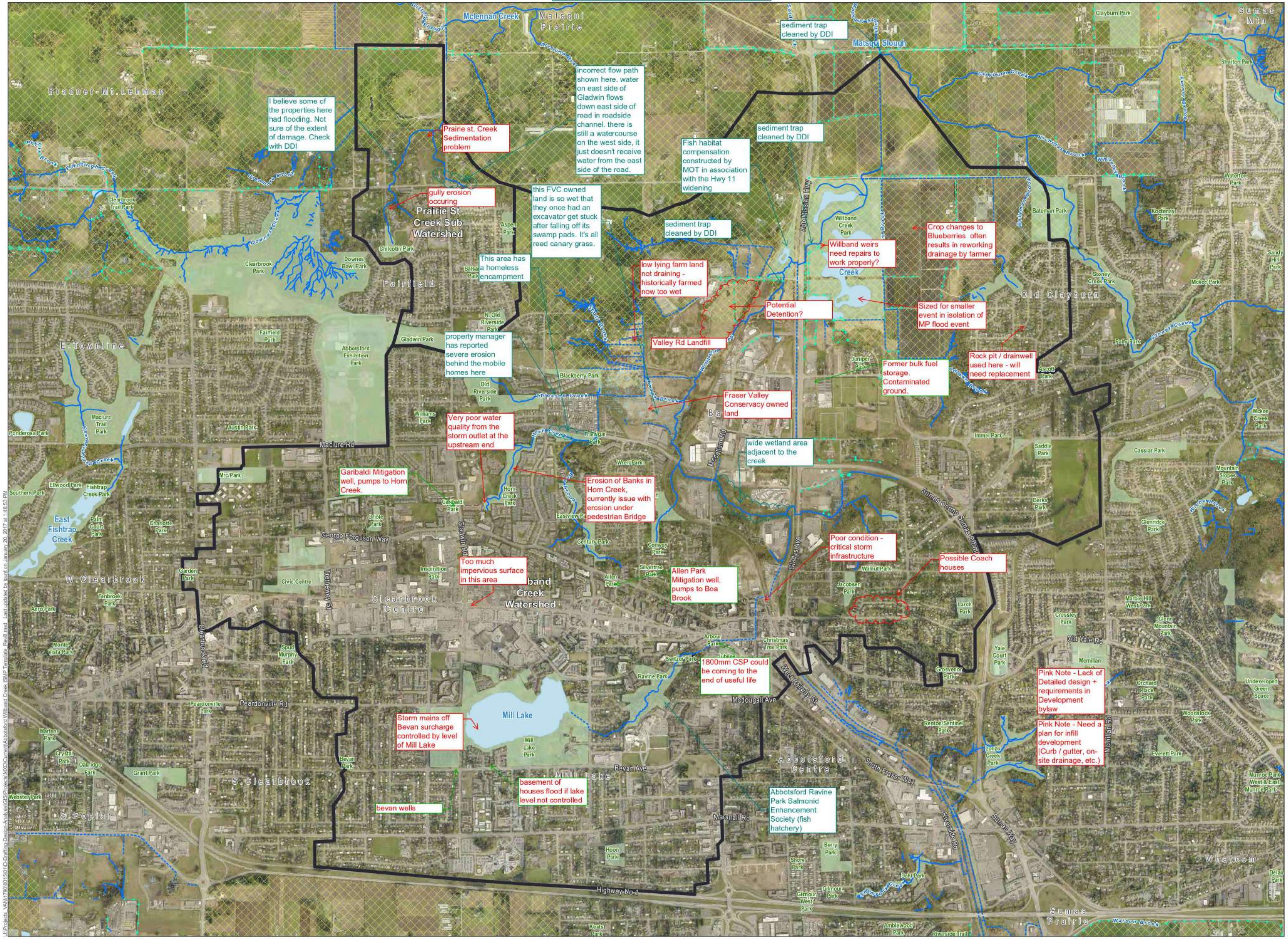
Scale: 1:11,058

Data Sources: Data provided by the City of Abbotsford (2016).

| | |
|---|---|
| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | B |
| Date: | 2017 / 1 / 20 |

URBAN systems

the map was created using the stream data available on our x drive, but this is missing some of the SHIM data that's been collected in the last few years. I believe this was sent to the consultant though.(?)




**ABBOTSFORD**

Willband Creek Integrated Storm Water Management Plan

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0 50 100 200 300 400 500 Metres

N

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| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | B |
| Date: | 2017 / 1 / 20 |

URBAN systems

# APPENDIX B

Watercourse Classification

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Stream Classification Description

| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Setback: Vegetation Category 1 | Setback: Vegetation Category 2 | Setback: Vegetation Category 3 | Description | Methodology |
|---|---|---|---|---|---|---|---|---|---|---|
| | | red | A | | Red (A) | 30m | Greater of: (1) existing width, (2) potential width[1], or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Watercourses with fish[2] presence at some point in the year. Permanence is unknown (i.e. water supply can be permanent [i.e. flow for >6 months] or non-permanent [i.e.flow for <6 months]). | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction[3] OR reach with gradient >25%[4] |
| | | red | A | P (Permanent) | Red (A) - P | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply. | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction OR reach with gradient >25%<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | red-dotted | A | NP (Non-permanent) | Red (A) - NP | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Watercourses with non-permanent (i.e. flow for <6 months) water supply that dry up in the summer months. Inhabited by fish during the over-wintering period. | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction OR reach with gradient >25%<br>• Non-permanence classification is based on site visits over multiple years |
| | | red double line | A | OW (Overwintering. Wet year round) | Red (A) - OW | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round. | • Salmonid presence is based on recorded observations and an analysis of obstructions.<br>• Water quality monitoring is conducted during the summer over multiple years. Extended periods of high temperatures and low dissolved oxygen preclude fish presence. |
| | | red-dashed | A | CD (Constructed Ditch) | Red (A) - CD | 5-10m (as per RAR) | 5-10m (as per RAR) | 5-10m (as per RAR) | Constructed ditches that contain salmonids. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are fed by surface runoff rather than groundwater, and consequently can dry up quickly after a rain event. The RAR provides specific setbacks for these types of watercourses. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• If groundwater seepages/springs are found, then it's a channelized A |
| | | orange | UFH (Unclassified Fish Habitat) | | Orange (UFH) | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Watercourses with unknown classification that we know have fish habitat value (i.e. are either red or yellow), versus watercourses with unknown classification that may be class C. Example: a natural reach upstream of a natural obstruction that prevents anadromous fish access. Resident trout may exist upstream of the obstruction. In this case, property owners should default to red-coded or undertake an assessment for fish presence. | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.) |

| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Setback | | | Description | Methodology |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Vegetation Category 1 | Vegetation Category 2 | Vegetation Category 3 | | |
| | | orange | UFH (Unclassified Fish Habitat) | P (Permanent) | Orange (UFH) - P | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Permanent watercourses (i.e. flow for >6 months) with unknown classification that we know have fish habitat value (i.e. are either red or yellow). | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.)<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | orange-dotted | UFH (Unclassified Fish Habitat) | NP (Non-permanent) | Orange (UFH) - NP | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Non-permanent watercourses (i.e. flow for <6 months) with unknown classification that we know have fish habitat value (i.e. are either red or yellow). | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.)<br>• Non-permanence classification is based on site visits over multiple years |
| | | yellow | B | | Yellow (B) | 30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown (i.e. water supply can be permanent [i.e. year-round] or non-permanent [i.e. ephemeral]), so setbacks default to permanent values. | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or a reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e. too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.) |
| | | yellow | B | P (Permanent) | Yellow (B) - P | 30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Water supply is permanent (i.e. year-round). | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e .too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.), AND<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | yellow-dotted | B | NP (Non-permanent) | Yellow (B) -NP | 15-30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Water supply is non-permanent (i.e. ephemeral). | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e .too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.) OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND all upstream reaches completely and simultaneously dry up during the summer (i.e. with no remnant pools to provide refuge), AND<br>• Non-permanence classification is based on site visits over multiple years |

| | | | | | | Setback | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Vegetation Category 1 | Vegetation Category 2 | Vegetation Category 3 | Description | Methodology |
| | | green | C | | Green (C) | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m[6]<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc. |
| | | green | C | P (Permanent) | Green (C) - P | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Permanently flowing (i.e. >6 months) constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc.<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | green-dotted | C | NP (Non-permanent) | Green (C) - NP | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Non-permanent (i.e. < 6 months) constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. Based on observations over multiple years, these ditches are known to dry up seasonally. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m5<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc.<br>• Non-permanence classification is based on site visits over multiple years |
| | | green double line | C | WSA - Not Fish Habitat | WSA - NFH | none | none | none | Watercourses that are not connected via surface flow to fish habitat. | watercourse connectivity must be assessed during saturated conditions immediately following a significant rainfall event |

| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Setback: Vegetation Category 1 | Setback: Vegetation Category 2 | Setback: Vegetation Category 3 | Description | Methodology |
|---|---|---|---|---|---|---|---|---|---|---|
| | | blue | U | | Unknown (U) | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Watercourses for which the approximate location is known but insufficient information precludes classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | |
| | | blue | U | P (Permanent) | Unknown (U) - P | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Permanently flowing (i.e. >6 months) watercourses for which the approximate location is known but insufficient information precludes further classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | • Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | blue-dotted | U | NP (Non-permanent) | Unknown (U) - NP | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Non-permanent (i.e. flow <6 months) watercourses for which the approximate location is known but insufficient information precludes further classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | • Non-permanence classification is based on site visits over multiple years |

1 Potential width = width from the top of bank to the edge of an existing permanent structure, as defined by the RAR

2 Fish = includes salmonids, game fish, and regionally significant fish

3 Obstruction = impassible conditions or barriers where no reasonable potential for fish presence can be expected include:

- Natural impassable barriers such as falls or steep cascades that are too high even in high flow periods for fish of any life stage to jump.
- Human made permanent barriers that cannot be reasonably modified to allow fish passage; e.g., large weirs or dams, or extensive enclosed or channelized reaches.

4 The Fish Stream Identification Guidebook identifies 20% as the gradient that leads to a designation as a non-fish stream, however, 25% is utilized in order to provide room for measurement error

5 Fish sampling done in accordance with the methods identified in the Fish Stream Identification Guidebook

6 As per the Fish Stream Identification Guidebook

NOTES:

1 Unless noted, all watercourses are assumed to be fed by groundwater seepages/springs, rather than just surface runoff.

2. Vegetation Category based on the City of Abbotsford's Streamside Protection Bylaw (which is the same as the RAR Simple Assessment):

| Vegetation Category: | Existing or potential streamside vegetation conditions |
|---|---|
| 1 | continuous areas >30m or discontinuous but occasionally >30m to 50m |
| 2 | narrow but continuous areas =15m or discontinuous but occasionally >15m to 30m |
| 3 | very narrow but continuous areas up to 5m or discontinuous but occasionally >5m to 15m |

3. The City will adopt coding that was reviewed and accepted by DFO, as long as there is no new information that would change the accepted classification.

## APPENDIX C

Environmental Assessment Report

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CITY OF ABBOTSFORD

# Willband Creek Integrated Stormwater Management Plan

## Existing Environmental Conditions

December 2018 – 16-3437

December 17, 2018

DILLON CONSULTING

3820 Cessna Drive
Suite 510
Richmond, BC
Canada
V7B 0A2
Telephone
604.278.7847
Fax
604.278.7894

City of Abbotsford
32315 South Fraser Way
Abbotsford, BC
V2T 1W7

Attention: Mr. Tony Seibert, P.Eng.
Drainage Engineer

Re: Willband Creek Integrated Stormwater Management Plan
***Existing Environmental Conditions***

Dear Mr. Seibert:

Dillon Consulting Limited is pleased to provide the City of Abbotsford with our updated report of the existing environmental conditions for the Willband Creek Integrated Stormwater Management Plan. This report expands the discussion from our July 4, 2017 report to include the assessment of the benthic invertebrate data collected within the Horn/Boa system in September 2017.

We trust this report meets your requirements. Please contact the undersigned should you have any questions about this report or any other component of this assignment.

Sincerely,

DILLON CONSULTING LIMITED

Nathan Gregory, R.P.Bio.
Project Manager, Senior Biologist

NRG:mlp

Our file: 16-3437

# Table of Contents

## Figures

## Tables



## Appendices

# Definitions of Terms

*– Channel, ephemeral – Flow for only part of the year, usually in the winter and spring in coastal drainages and in spring, early summer and the autumn in interior ones.*

*– Channel, intermittent – Do not dry up completely during season periods of low rainfall, but retain water in separated pools along the channel.*

*– Channel, permanent – Flow and surface water are present year-round.*

*– Channelized Watercourse – A natural watercourse that has been realigned for land development purposes, typically along roadways or property lines.*

*– Complexity (channel) – The characteristics of a channel that make it "complex" from a fish habitat perspective. This includes instream Large Woody Debris, overhanging and instream vegetation, a varied morphology, cover structures for fish, and a mixture of substrate types.*

*– Invasive Species –Plant or wildlife species that are not native to BC with the ability to aggressively establish populations and reduce the diversity of the natural ecosystem.*

*– Pool – Generally wider sections of a stream channel with greater depth and lower flow velocity.*

*– Riffle – Sections of stream channel where water flows over cobbles, gravels and boulders. The surface of the water is visibly broken.*

*– Riparian – Streamside vegetation that contributes to fish habitat quality through shade, nutrient input, bank stability, Large Woody Debris input, and water quality improvements.*

*– Run – Sections of a stream channel with greater flow velocity but with the surface unbroken by underlying substrates.*

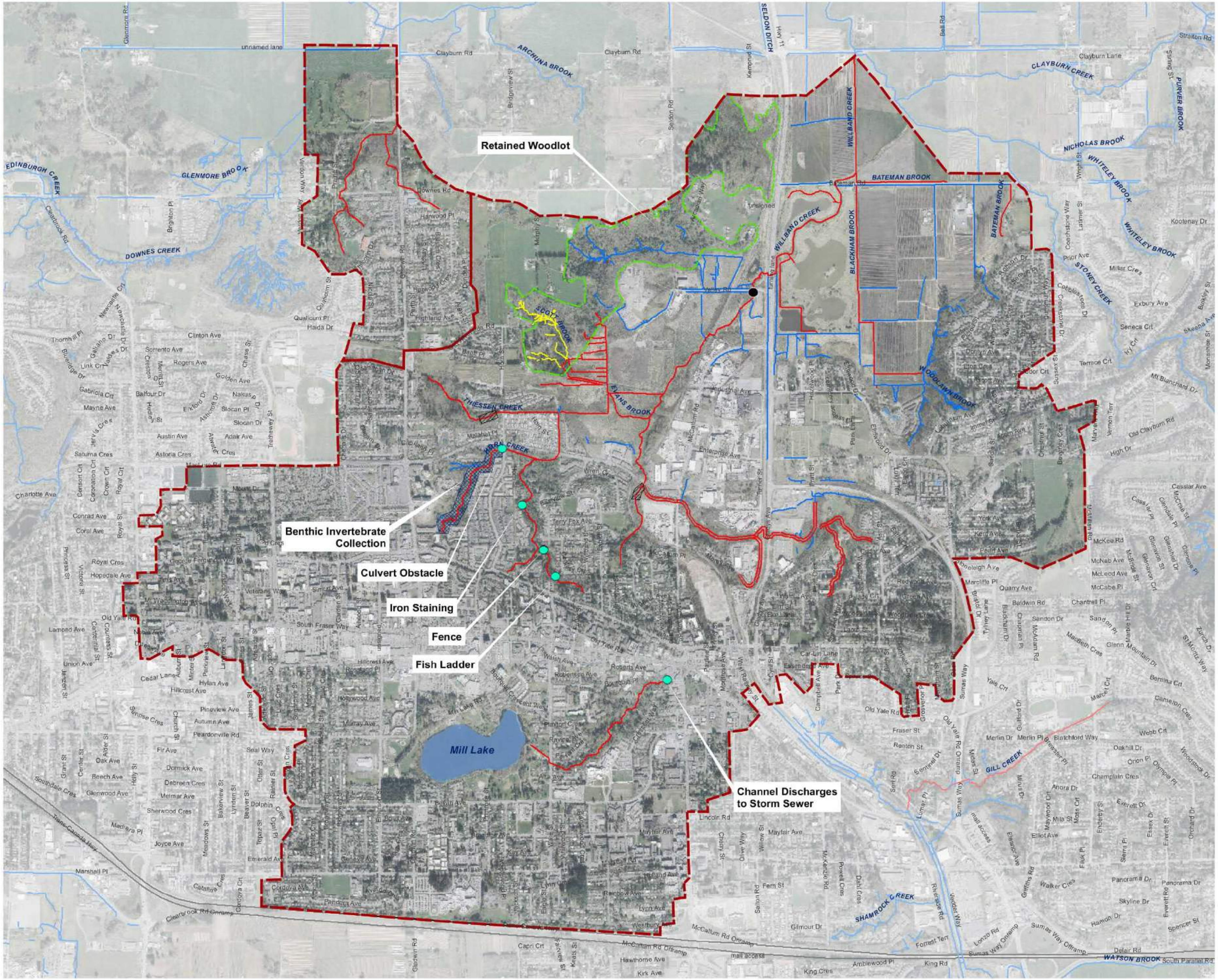
# 1.0 Introduction

The Willband Creek watershed and Prairie Creek sub-watershed (the Study Area), is located in central Abbotsford north of Highway 1. The southern portion of the watershed is a mix of residential properties, both single- and multi-family, and commercial development. Industrial properties are located in the central portion of the watershed immediately west of Highway 11. The northern portion of the watershed is primarily agricultural land with sections of intact forest. Flow is conveyed via a series of creeks in the higher gradient areas of the watershed to Willband Creek or Gifford Slough. Flow is subsequently conveyed north to the Fraser River (see **Figure 1**). Many of the watercourses have groundwater inputs along the escarpment above Matsqui Prairie. As the watercourses move further away from the escarpment, the water quality reduces due to agricultural inputs and reduced riparian cover.

Historic development has significantly altered the aquatic habitat values supported within the Study Area, primarily as a result of the removal of riparian vegetation, channelization of sections of creeks onto linear alignments (*e.g.*, Thiessen Creek, Blackham Brook) or channel infill with pipes (*e.g.*, the Mill Lake outlet channel). Development can also restrict fish access in sections (*e.g*., the Trafalgar Street culvert on Horn Creek). In addition, development has the potential to significantly impact water quality, either through inputs of deleterious substances typical of an urban setting or through increased stormwater flow which may cause erosion or damage spawning beds. Despite these impacts, much of drainage network appears to be intact with a number of the channels retained on their original alignments. In addition, with the exception of the channel draining Mill Lake, fish access has either been retained or can be re-established with comparatively limited effort.

Development has also affected terrestrial habitat. As would be expected in an urban setting, the large majority of the formerly forested areas have been removed. Some habitat value has been re-established as a result of landscaping, but this habitat is fragmented and largely consisting of non-native species. In addition, landscape alteration creates a significant potential for the establishment of invasive species which can reduce native species extent and diversity.

The City of Abbotsford (the City) has initiated an Integrated Stormwater Management Plan (ISMP) for the Willband Creek watershed. The purpose of the ISMP is to establish objectives for the watersheds that will allow for the continuation of viable development/redevelopment while at the same time mitigating impacts to aquatic and terrestrial habitat and, where possible, introducing measures to protect and enhance existing aquatic and riparian habitat. The ultimate intention of the ISMP will be to provide input into the formulation of land use and infrastructure policies and guidelines that will be incorporated into future development plans for the watershed and to develop an integrated approach to stormwater management.




ABBOTSFORD

**City of Abbotsford**
Willband Creek ISMP

**Site Location Map & Habitat Features**
FIGURE 1

- Water Quality Sampling Location
- Site Specific Features
- 100m Detailed Reach Assessment
- Woodlot Extent
- Benthic Invertebrate Collection

**FISH CLASSIFICATION**

- Class 'A' - Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply.
- Class 'A(OW)' - Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round.
- Class 'B' - Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown.
- Creeks, Streams, Channels with Unknown Classifications

SCALE 1:22,000
0 0.25 0.5 1 Kilometers

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF ABBOTSFORD

MAP CREATED BY: MZO
MAP CHECKED BY: NRG
MAP PROJECTION: NAD 1983 UTM Zone 10N

FILE LOCATION:
G:\GIS\2016\163437\163437 - Site Location Map - Figure 1.mxd

DILLON CONSULTING

PROJECT: 16-3437
STATUS: FINAL
DATE: February, 2018

Dillon Consulting Limited (Dillon) was retained as part of the Urban Systems Limited team to assist the City in the completion of an investigation of the existing habitat conditions of the Study Area to support the development of the ISMP. This report outlines existing aquatic and terrestrial conditions and provides a summary of the existing habitat supported within the watershed. To determine the existing conditions, a desktop review of existing background information was completed and supplemented by field investigations. Field investigation served to fill gaps identified during the literature review and to collect site-specific information as required. As part of the desktop and field investigations, specific information that was reviewed and compiled as part of this summary included:

- Confirmation of existing watercourse classifications and locations;
- Assessment of the composition of aquatic habitat;
- Fish species presence or potential presence;
- Obstacles or barriers to fish migration;
- Composition of riparian vegetation;
- Benthic community composition;
- Water quality;
- Habitat enhancement opportunities;
- Vegetation community composition;
- Invasive plant species presence;
- Wildlife habitat and species presence or potential; and
- Rare species presence or potential.

Some of the data obtained during the investigation has been utilized to determine current watershed health. It can also be utilized as a baseline for comparisons to environmental conditions and ecological health as the watershed develops in the future. Finally, it serves to identify areas of environmental sensitivity and importance in order to act as a tool to direct any future development in such a way as to sustain critical aquatic and terrestrial habitat, as required.

# 2.0 Methodology

## 2.1 Background Review

The investigation of existing habitat conditions of the Study Area consisted of a review of background information supplemented by a series of field assessments. Initially, a desktop review of compiled and summarized background information, specific to the Study Area, was completed. This information was provided by the City and included studies for park master plans, drainage, water quality as well assessments completed within and adjacent to creeks for infrastructure projects.

The background review also included a series of online databases and information sources in order to compile any additional information available for the watershed. This included fish and wildlife inventories, ecosystem information and rare species databases.

A summary of the background information reviewed includes, but is not necessarily limited to, the following:

*Information provided by the City*

- Report to Ker Priestmand & Associates on Site Investigation, Proposed Trunk Sewer Diversion, Abbotsford, British Columbia. Prepared by Golder Associates. May 1978.
- Willband Creek Drainage Study. Prepared by UMA Engineering. December 1989.
- Willband Creek Park Master Plan Study. Prepared by UMA Engineering. 1996.
- Proposed Mill Lake Centre, 2353 Ware Street, Mill Lake Road, Abbotsford, BC. Prepared by Took Engineering Ltd. July 1999.
- Fish Presence/Absence Study and Water Quality Assessment of the Matsqui Prairie Drainage and Irrigation Ditches, Fall 1999 Prepared by the City of Abbotsford's Environmental Office. March 2000.
- Geotechnical Engineering Report Maclure Road Reconstruction – Horn Road to McCallum Road, Abbotsford, BC. Prepared by Valley Geotechnical Engineering Services Ltd. March 2001.
- Flood and Erosion Assessment of Horn Creek/Boa Creek Downstream of Maclure Road, Abbotsford, BC. Prepare by Golder Associates. May 2001.
- Overview Geotechnical Assessment, Lands for Proposed Clayburn Industrial Area, Abbotsford, BC. Prepared by Golder Associates. January 2003.
- Mill Lake Water Quality Study. Prepared by CH2M Hill. March 2003.
- Phase 1 Investigation and Preliminary Assessment, Bank Stabilization at Marshall Creek and Horn Creek Erosion Sites, Abbotsford, BC. Prepared by Golder Associates. March 2007.
- Bank Stabilization, Marshall Creek and Horn Creek Erosion Sites, Abbotsford, BC. Prepared by Golder Associates. May 2009.
- First of three annual follow-up inspections for the compensation planting study along Willband Creek associated with the City of Abbotsford bike lanes project, Abbotsford. BC. Prepared by Scott Resources Services Inc. December 2009.

- Willband Creek Detention Expansion, Preliminary Design. Prepared by AECOM. September 2011.
- Development Bylaw Update: Clayburn Watershed Rainwater Management Measures. Prepared by KWL Consulting Engineers. October 2014.
- Compiled fish sampling data (shapefiles).

*Additional information sources*

- Conservation Data Centre online database of rare species (BC Ministry of Environment);
- Species at Risk Public Registry (Government of Canada);
- Habitat Wizard (BC Ministry of Environment); and
- BC Species and Ecosystems Explorer (BC Ministry of Environment).

A list of references is provided in **Section 6.0**.

## 2.2 Field Investigations

The information obtained during the background review and from aerial photography was utilized to identify information gaps, identify watercourses and key natural areas, and prepare a series of maps to assist the field team in orienting to the watershed. Field investigations were conducted as follows:

- April 18, 2016 – Study Area orientation with City staff;
- May 26 and 27, 2016 – Assessment of aquatic and terrestrial habitat;
- August 26, 2016 – Collection of water quality data; and
- May 17 and 18, 2017 – Detailed channel reach assessments.

### 2.2.1 Study Area Orientation

The initial Study Area orientation with City staff consisted of visits to areas of particular habitat value, primarily named watercourses, and discussion of issues of particular concern or relevance to the project.

### 2.2.2 Assessment of Aquatic and Terrestrial Habitat

The field team then conducted assessments at a number of sites that had been identified during the background review and Study Area orientation. Each site was assigned an identifier code. Assessed aquatic habitat parameters included the potential for rearing and spawning habitat, particularly as it relates to salmonids. The channels were also assessed for habitat components such as physical morphology, gradient, substrate, and instream complexity in order to determine the overall value of fish habitat from a qualitative perspective. Obstacles and barriers that may impede or prevent fish access were identified. Additionally, opportunities for enhancement, restoration and compensation were recorded.

The terrestrial assessment of the Study Area was conducted primarily through visual observation of retained habitat patches and corridors. Information collected as part of the terrestrial assessment included:

- Wildlife observations and potential wildlife habitat;
- Vegetation community composition and structure;

- Invasive species presence and concentration;
- Habitat connectivity; and
- Wildlife tree presence.

Photographs indicating habitat conditions were taken at each location.

Data was collected during the field assessment using Survey 123, a smart phone based application. Survey 123 uses Geographic Positioning System technology which can be converted to GIS files for the creation of maps and figures. Initially, a field form was created with standardized fields for the relevant habitat information.

### 2.2.3 Water Quality Data

In-situ water quality data was collected using a YSI 6920 multi-meter that had been professionally calibrated prior to use. Sampled parameters included:

- Temperature;
- Conductivity;
- Total Dissolved Solids (TDS);
- Salinity;
- Dissolved oxygen (DO);
- pH; and
- Redox potential (ORP).

Samples were also collected for analysis at an accredited laboratory. Sampled data included:

- Metals;
- Total Suspended Solids (TSS);
- Ammonia (N);
- Total and Dissolved Metals;
- Hardness;
- Faecal and Total Coliforms;
- Extractable Petroleum Hydrocarbons (EPH); and
- Biochemical Oxygen Demand (BOD).

### 2.2.4 Detailed Channel Reach Assessments

The channel reach assessments were completed using a modified Resources Inventory Standards Committee (RISC, 2008) standard for fish and fish habitat inventory within two sections of channel at Upper Willband Creek and Thiessen Creek. This consisted of placing minnow traps within a 100-m reach in each channel which were left to trap overnight. Subsequently, an electrofisher was employed in a methodical manner to cover the 100-m reach in each channel at a consistent pace and level of effort. All collected individuals were identified to species, measured for weight and fork length and assigned an age class in the field.

Other assessed values within the subject sections included:

- Falls, cascades and obstructions;
- Significant habitat features (pools, areas of braiding, off-channel habitat);
- Points of erosion;
- Anthropogenic alterations (culverts, modified banks, impacted riparian areas);
- Fish congregations; and
- Riparian extent, composition and structure.

### 2.2.5 Benthic Invertebrate Sample Collection

Benthic samples were collected in Horn Creek upstream of Maclure Road on September 6, 2017 as indicated in **Figure 1**. Benthic samples were collected with a 500 µm Surber sampler. The rocks upstream of the sampler were scrubbed by hand and with a soft brush to loosen benthic invertebrates which were collected in the sampler before being transferred to jars and preserved with 95% ethanol for safer handling and shipping. Please note that the standard protocol indicates formalin should be utilized for preservation; however, the use of ethanol was confirmed as acceptable by the project benthic taxonomist. Three samples were collected at each of four separate locations within the sampling reach. Each of the three samples at each location was composited into one (*i.e.*, a total of 4 sample jars for analysis for the channel). Sampled invertebrates were then couriered to Living Streams Environmental Services where they were identified to the lowest practical taxonomic level. Each sample was aggregated to generate the 10-metric Benthic Index of Biological Integrity (B-IBI) score for each channel.

As indicated, the B-IBI score is determined by assigning a numerical value to each of 10 metrics that assess the richness (a measure of the number of species) and presence of various taxonomic groups of invertebrates. The number generated for each channel would range between a minimum of 10 and maximum of 50. A score of 10 would be indicative of a severely degraded watershed. A value of 50 would be indicative of a pristine watershed that has likely never been logged or developed. The range of scores indicating watershed condition is provided in **Table 1**.

Table 1. B-IBI Scores as Indicators of Watershed Health

| B-IBI Range | Watershed Health |
|---|---|
| 46-50 | Excellent |
| 38-44 | Good |
| 28-36 | Fair |
| 18-26 | Poor |
| 10-16 | Very Poor |

# 3.0 Existing Site Conditions

This section provides an overview of key features of the existing environment within the Study Area, including aquatic and terrestrial resources, rare species, and riparian communities. Existing habitat conditions for the watershed are based on available background information and observations made at the time of field investigations.

## 3.1 Description of the Study Area

As previously referenced, the Study Area is located in central Abbotsford. It measures approximately 1841.3 ha. The Study Area is has an irregular configuration generally bound by Highway 1 to the south, Clearbrook Road to the west, and McMillan Road to the east. Flow is conveyed out of the Study Area's northern limit at Clayburn Road for both the Willband Creek watershed and the Prairie Creek sub-watershed. The watershed has a mixed land use including single- and multi-family residential, commercial/industrial, agricultural and park.

The most significant habitat feature of the Study Area is Willband Creek and its various named tributary channels and waterbodies: Thiessen Creek, Blackham Brook, Bateman Brook, Horn Creek, Boa Brook, Scott Brook, Evans Brook, Mill Lake and the Mill Creek outlet channel. Significant terrestrial habitat is provided around Mill Lake, within local parks and within a retained woodlot at the north extent of the Study Area. Prairie Creek is the main habitat feature in its sub-watershed.

## 3.2 Aquatic Species and Habitat Inventory

This section outlines the habitat supported by the Study Area's network of watercourses, and includes descriptions of channel morphology, fish presence or potential, and riparian characteristics. Each channel has been classified according to the City's watercourse classification system. The City's classification system has many categories based on fish presence, permanence of flow, whether or not the channel is constructed or in a lowland area, and food and nutrient contribution. Watercourse classifications specific to creeks in the Study Area are outlined below in **Table 2** and shown on **Figure 1**. The complete classification system for the City is attached as **Appendix A**.

Table 2. Watercourse Classification[1]

| Class | Sub-class | Definition |
|---|---|---|
| Red (A) | Red (A)-P | Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply. |
| | Red (A)-OW | Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round. |
| | Red (A)-NP | Watercourses with non-permanent (i.e., flow for <6 months) water supply that dry up in the summer months. Inhabited by fish during the over-wintering |

| Class | Sub-class | Definition |
|---|---|---|
| | | period. |
| Blue | N/A | Creeks, streams, and channels with unconfirmed classification |

[1] Provided by the City of Abbotsford

Qualitative descriptions of overall habitat quality have been provided for each channel and are defined in **Table 3**.

Table 3. Description of Stream Habitat Quality

| Description | Definition |
|---|---|
| Excellent | Channel displays a number of criteria that makes it highly suitable as fish habitat, particularly for salmonids. Typically the channel is highly complex, has a varied morphology, mixed cobble/gravel substrate, good water quality, and productive, well-established riparian vegetation. |
| Good | Channel still highly suitable as fish habitat but may lack one of the criteria characteristic of excellent habitat or may have the extent of these criteria reduced. |
| Fair | Channel can still support fish populations but generally lacking in several of the criteria for excellent habitat or may have all these criteria significantly reduced. |
| Poor | Channel generally exhibits low complexity, silt/organic substrate, uniform morphology, poor water quality and has significantly reduced riparian vegetation. Fish presence generally limited to tolerant species. |

Photographs are provided for each channel and are attached as **Appendix B**.

## 3.2.1 Willband Creek

Willband Creek originates as three tributary channels in its upper reaches. The western tributary originates near Babich Place and is conveyed north to its confluence with the eastern tributary immediately upstream of Maclure Road. The eastern tributary is formed by two secondary tributaries: one originating from a series of channels southeast of Sumas Way and Gladys Avenue; and a second conveying flow from Mill Lake (see **Section 3.2.8**). The secondary tributaries are confluent immediately west of Gladys Avenue. From the confluence of the western and eastern tributaries (*i.e.*, the lower reach), flow is conveyed in a generally northeast direction prior to discharging from the Study Area at Clayburn Road.

### 3.2.1.1 Western Tributary

The western tributary of Willband Creek, upstream of Maclure Road, is located within a ravine. It is characterized as a higher gradient system transitioning to a lower gradient section of channel to the north. The reach is a meandering, permanent channel exhibiting a high degree of complexity, particularly in its upper reach. Large Woody Debris is present in moderate amounts. The upper section has a varied morphology of run (60%), riffle (20%) and pool (20%) habitat. The channel transitions to 100% run habitat at Maclure Road. The upper section displays a substrate consisting of an equal amount of boulders, cobbles and gravels with a small amount of silt. The lower section is dominated by sand which would be anticipated as the gradient decreases. Channel width in the upper section was narrow (1.0 m) with depths up to 0.5 m.

Riparian vegetation was well-established with a mixture of mature and young growth stages. Invasive species presence was generally limited to a disturbed area in the vicinity of Maclure Road. The tree canopy was predominantly deciduous and included black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*). The understory included immature red alder and black cottonwood, vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformis*), salmonberry (*Rubus spectabilis*), horsetail (*Equisetum* spp.), reed canary grass (*Phalaris arundinacea*), herb-Robert (*Geranium robertianum*) and ferns. Some skunk cabbage (*Lysichiton americanum*) was observed in the lower reach.

No records of fish presence in the western tributary were identified in the background review. One Chinook (*Onchorhynchus tshawytscha*) fry and lamprey were collected during the May 2017 detailed site assessments (see **Section 3.3.1** for additional detail). Based on this occurrence, the channel has been assigned a classification of Red (A)-P.

The channel provides good habitat value given its complexity. Given its relatively small dimensions, fish presence could be reduced which prevented the channel from receiving an excellent rating.

#### 3.2.1.2 Eastern Tributary

The eastern tributary originates to the southeast of Sumas Way and Gladys Avenue. The area is predominantly a wetland located north and east of Gateway Christian Reformed Church. The wetland discharges to the west under Gladys Avenue and subsequently to the Willband Creek mainstem. The wetland was entirely pool habitat with a substrate dominated by silt with some organic detritus. Complexity was generally low although a moderate amount of Large Woody Debris was present. Other than possibly the culvert conveying flow under Gladys Avenue, barriers to fish access were not observed.

The riparian vegetation was largely deciduous for the tree canopy and consisted of paper birch (*Betula papyrifera*) and red alder. Tree presence was limited on the north and west sides of the wetland due to ongoing industrial activity. The understory included immature paper birch, willow (*Salix* spp.) and hardhack (*Spiraea douglasii*) but was largely dominated by reed canary grass. Duckweed (*Lemna minor*) was present in the water column.

Habitat quality within this section of channel was considered fair to good. The wetland would serve to improve water quality through uptake of pollutants. In addition, the deeper pool habitat could assist in buffering water quality deterioration often typical of summer conditions. Decomposition of duckweed could affect water quality, however.

It should be noted that existing mapping indicates two channels discharging into this section of the eastern tributary immediately south of Sumas Way on the Pratt Street alignment (see **Figure 1**). One channel is a swale located along the south side of a construction site at the intersection of Gladys Avenue and Sumas Way with minimal habitat value. The second is a wet area located to the east of the substation. A connection to the Eastern Tributary could not be confirmed.

A channel discharges to the eastern tributary; it originates at the base of a mature, forested slope near Pratt Crescent. Flow is conveyed north into the above-described wetland. The watercourse is a small (1.0 m wide with a depth of 0.05 m at the time of assessment) and has limited flow contribution to the mainstem. However, it is a permanent, meandering channel. Habitat is predominantly riffle habitat (80%) with the remainder being run. The substrate was largely dominated by silt with a small amount of sand and organic detritus. Large Woody Debris was not present and the complexity was moderate. Barriers to fish access were not observed. However, fish presence is unlikely due to the low flow, small size, and dense vegetation overgrowing the channel.

The riparian vegetation was predominantly deciduous forest but has been limited by residential landscaping. Tree species included bigleaf maple and red alder. Willow, Himalayan blackberry (*Rubus armeniacus*), horsetail, lamium (*Lamium* sp.) and ferns were present in the understory. Bamboo and manicured lawn was also present on adjacent residential properties.

Overall, habitat value was considered to be fair within this small channel due to the moderate complexity and the food/nutrient contribution from the riparian vegetation. However, the lack of fish access and significant habitat (pools, etc.) limited its potential for a higher rating.

The eastern tributary becomes more channelized to the west of Gladys Avenue, with 20% of the channel constituting run habitat. However, the remainder is pool and a significant wetland component remains. Some of the pool habitat was created by a beaver dam. The watercourse is confined to a permanent, low gradient channel with some meander. The substrate consisted entirely of silt. The channel displayed moderate complexity with some Large Woody Debris present. Barriers to fish access were not observed. The water was observed to be very turbid.

Riparian vegetation was predominantly deciduous forest and included red alder and black cottonwood within the tree canopy. The understory included large willows, Himalayan blackberry, reed canary grass, herb-Robert and horsetail. Instream vegetation was dominated by reed canary grass.

There is one report of a cutthroat trout (*Onchorhynchus clarkii clarkii*) being sampled in this channel. However, as it was sampled in the winter, the suitability of this channel to support salmonids during the summer is currently unknown. As such, the channel may be considered Class Red (A)-OW. However, additional studies may indicate year-round salmonid presence which would result in a Red (A)-P designation.

Overall habitat quality downstream of Gladys Avenue was fair. The poor water quality may exclude fish other than some of the more tolerant species.

#### 3.2.1.3 Lower Reach

The lower reaches of the Willband Creek mainstem (*i.e.*, downstream of the confluence of the eastern and western tributaries at Maclure Road) can be characterized as a permanent, low-gradient, gently meandering channel. The channel was up to 3 m wide through this section. It exhibited run habitat with no pools or riffles observed. Substrates consisted entirely of silt and organic detritus. Complexity was generally low with the channel exhibiting a comparatively unvaried morphology. Instream Large Woody

Debris was limited, which is to be expected given that trees were only present in low numbers and were generally immature. Barriers or obstacles to fish access were not observed. The water was somewhat turbid which is typical for larger, lower gradient streams.

The detention pond system within Willband Creek Park discharges to this reach of the mainstem. The ponds are exposed with limited riparian canopy coverage. As such, water quality could be compromised, particularly during the summer.

Riparian vegetation was established along the channel although in some places it had been cleared to the top-of-bank for agricultural use. Tree species included black cottonwood and red alder. The understory vegetation included willow, immature red alder, hawthorn (*Crataegus* spp.), Himalayan blackberry, hardhack, salmonberry, snowberry (*Symphoricarpos albus*), reed canary grass, horsetail, stinging nettle (*Urtica dioica*) and fireweed (*Epilobium angustifolium*). Reed canary grass dominated the riparian zone along sections of the channel. Other invasive species dominated in other sections of the riparian zone. Instream vegetation consisted primarily of reed canary grass.

Fish presence based on past sampling efforts have indicated that the lower reach of Willband Creek provides habitat for coho salmon (*Oncorhynchus kisutch*), coast cutthroat trout, rainbow trout (*O. mykiss*), pumpkinseed (*Lepomis gibbosus*), threespine stickleback (*Gasterosteus aculeatus*), bass (unidentified species), lamprey (*Lampetra* sp.), redside shiner (*Richardsonius balteatus*), northern pikeminnow (*Ptychocheilus oregonensis*), and coast range sculpin (*Cottus aleuticus*). Signal crayfish (*Pacifastacus leniusculus*) have also been reported. It should be noted that this species can be an indicator of good water quality given its lack of tolerance for poor water quality. There was a single report for a Kokanee (typically referring to a land-locked sockeye salmon [*O. nerka*]); however, given that this species would have access to the Fraser River, this report may not be accurate.

Coho salmon have been sampled in Lower Willband Creek in previous summers. As such, the channel has been assigned a classification of Red (A)-P.

A number of the criteria for habitat quality have been impacted along this reach of the channel as a result of past land use activities. A significant tree canopy is generally lacking, water quality was observed to be turbid, and instream complexity was generally low. However, given the size and depth of the channel, fish populations, particularly for minnows and other species tolerant of poorer water quality, are expected to be present. As such, this reach has been assessed as providing fair habitat value.

### 3.2.2 Blackham Brook/Bateman Brook

Blackham Brook is a channelized watercourse conveying flow directly north to the confluence with Willband Creek immediately north of Bateman Road (see **Figure 1**). It can be characterized as permanent, low gradient, linear channel with limited complexity. It was observed to consist entirely of run habitat with silt substrates. Large Woody Debris was not observed. The channel was up to 4.0 m wide with a depth averaging 1-2 m. Barriers to fish access were not observed.

Land use adjacent to the channel was agricultural. As such, riparian vegetation has been largely removed and was restricted to 5 m from the top-of-bank in sections. Tree presence was limited and consisted primarily of red alder. Reed canary grass and hardhack were the dominant species present. Other species included willow and Himalayan blackberry. Reed canary grass was present instream.

Blackham Brook has been designated as fair habitat despite the limited complexity and reduced riparian zone. This is largely due to the size and depth of the channel which is anticipated to support species more tolerant of reduced habitat quality (*e.g.*, threespine stickleback).

Bateman Brook has been channelized as a linear, roadside ditch along the south side of Bateman Road. Only its lower reach is within the Study Area. It is a permanent, low gradient channel with limited complexity. It consists entirely of run habitat with a silt substrate. There appear to be no barriers to fish access. Riparian vegetation is largely limited to reed canary grass.

Coho salmon, cutthroat trout, rainbow trout, threespine stickleback, brown catfish (*Amereiurus nebulosus*), pumpkinseed, redside shiner, and lamprey have all been observed in the Blackham/Bateman system during previous sampling efforts. Signal crayfish have also been collected. Given that salmonids have been sampled in previous summers, this channel has been classified as Red (A)-P (see **Figure 1**).

Despite the generally low complexity and lack of significant riparian vegetation for large sections, Bateman Brook provides moderate quality fish habitat. This is largely due to the diverse fish species utilization as well as the presence of good water quality as indicated by the crayfish.

### 3.2.3 Evans Brook

Evans Brook originates in a marshy area south of the terminus of Valley Road (see **Figure 1**). It conveys flow from both Thiessen Creek and Scott Brook to its confluence Willband Creek south of the Industrial Avenue alignment. The channel is permanent, low gradient and largely conveyed through a wetland area which also discharges to the stream via a series of small channels in the area. Channel morphology was observed to consist entirely of pool habitat. Substrate was an even mixture of silt and organic detritus. Habitat complexity was observed to be low. There was limited presence of Large Woody Debris. Barriers to fish access were not observed. There was a heavy presence of common duckweed which would tend to reduce dissolved oxygen within the water column as it decomposes.

The riparian area was dominated by wetland plants, primarily reed canary grass. Other species included willow, Himalayan blackberry, hardhack, Scotch broom (*Cytisus scoparius*) and stinging nettle. In addition to duckweed, instream vegetation also included reed canary grass.

Fish presence from past sampling activities confirms that cutthroat and rainbow trout, threespine stickleback and lamprey utilize this channel. These were sampled during the summer when it would be anticipated that water quality, specifically dissolved oxygen, would be impacted. As such, the channel is Class Red (A)-P (see **Figure 1**).

Overall habitat quality within Evans Brook was observed to be fair. The channel has been confirmed as being fish accessible and has sufficient depth for fish presence. However, the lack of significant complexity prevented it being given a higher rating than indicated.

A small, unnamed channel is confluent with Evans Brook immediately north of the Industrial Avenue right-of-way. Flow is conveyed east from its origin in an upslope area within the BC Hydro right-of-way. The channel is permanent, has a moderate gradient and exhibits some meander. Channel morphology consisted of run (60%) and riffle (40%) habitat. The substrate was a mixture of sand (30%), silt (60%) and organic detritus (10%). The channel exhibited moderate complexity with some Large Woody Debris present. Although no barriers were observed, the channel was quite shallow, had low flow, and does not appear to have significant pools or other cover for fish, which may preclude access.

The riparian vegetation was primarily deciduous forest. Given that it is located within a BC Hydro right-of-way, the vegetation is likely maintained on a regular basis and would not be allowed to reach maturity. Recent indications of tree cutting were observed. Tree species included red alder, paper birch and bigleaf maple. The understory included willow, vine maple, Himalayan blackberry, salmonberry, horsetail, creeping buttercup (*Ranunculus repens*), ferns and mosses. Some skunk cabbage was present adjacent to the channel.

The channel provides fair habitat based on its complexity and fairly well-established riparian zone, which would provide a significant food and nutrient contribution to downstream reaches. However, the small size and probable lack of fish access prevents it from being rated higher.

### 3.2.4 Scott Brook

Scott Brook originates within a small ravine in a forested patch north of the Old Riverside Road alignment (see **Figure 1**). Flow is conveyed east, then south on a natural alignment. It enters a channelized section where it is subsequently conveyed directly east to its confluence with Evans Brook. The channel transitions from intermittent flow in its upper reaches to permanent flow downstream as observed at the time of the site assessment. The gradient is initially moderate before discharging to the low gradient channelized reach. Some meander to the channel is present in the upper reaches. Channel morphology was predominantly run habitat. The substrate was a mixture of silt (80%) and organic detritus (20%). Habitat complexity was observed to be moderate due to the presence of overhanging vegetation and some Large Woody Debris. Significant fish presence is not expected due to the small size of the channel, low water levels, limited refugia, and intermittent nature.

The riparian vegetation was quite well-developed in the channel's upper reaches and was dominated by deciduous species. Tree species included bigleaf maple and red alder. The understory included Indian plum, red elderberry (*Sambucus racemosa*), Himalayan blackberry, salmonberry, horsetail, reed canary grass, skunk cabbage, policeman's helmet (*Impatiens glandulifera*), and mosses.

Records of fish presence in Scott Brook are generally quite limited. However, a steelhead was captured immediately north of the Old Riverside Road unconstructed right-of-way in 2015. Flow was observed to be intermittent in the upper reaches of the channel. As such, the classification is considered to be Red(A)-NP (see **Figure 1**).

Overall, habitat value has been rated as moderate despite the well-developed riparian area and moderately complex channel. As referenced, fish presence is likely limited which prevented the channel from being assigned a higher rating.

### 3.2.5 Thiessen Creek

Thiessen Creek originates within a forested patch in Old Riverside Park. Flow is conveyed on its original alignment southeast, then east, prior to flowing into a marshy area east of Horn Street. From there, flow is conveyed east, then north within a channelized reach to its confluence with Evans Brook.

Its upper reaches are encompassed within a ravine prior to flowing into the low gradient marshy area. The channel is permanent with moderate sinuosity and gradient in its upper reaches. The upper reach is predominantly riffle habitat (80%) with the remainder equal areas of run and pool. Substrate consists of a mix of boulder (10%), cobble (10%), gravel (40%), sand (30%) and silt (10%). The upper reach is highly complex with significant cover from overhanging vegetation and a large amount of Large Woody Debris although it is quite shallow (0.2 m depth at the time of assessment). No barriers to fish access were observed. Water quality was observed to be clear with no sedimentation.

The riparian zone was predominantly deciduous forest. Tree species include red alder and bigleaf maple. The understory included immature western hemlock, vine maple, salmonberry, thimbleberry (*Rubus parviflorus*), horsetail and ferns. Skunk cabbage was present at the margins of the channel.

Previous fish sampling efforts have identified threespine stickleback in the channel. The detailed assessment conducted for this project identified Chinook salmon, cutthroat trout and lamprey (see **Section 3.3.2** for additional detail). As such, the channel has been classified as Class Red (A)-P (see **Figure 1**).

The upper reach of the channel provides excellent habitat despite its shallow nature due to its complexity and well-established riparian vegetation.

As referenced, the lower reach of Thiessen Creek has been channelized within a marshy area.

### 3.2.6 Horn Creek

The mainstem of Horn Creek originates in Horn Creek Park near Nelson Place (see **Figure 1**). Flow is conveyed in a generally northern direction to Maclure Road. From there flow is conveyed east along the south side of Maclure Road before being conveyed north again to its confluence with Thiessen Creek. The channel displays a sinuous nature prior to flowing north under Maclure Road. The portion of the creek north of Maclure Road has been channelized.

Horn Creek is a permanent channel encompassed within a moderate gradient ravine in its upper reaches. Approximately 50% of the channel displayed riffle characteristics. Run and pool habitat made up 35% and 15% respectively. The channel is fairly wide (8-15 m bankful widths at the assessment locations) and displays high complexity due to its sinuous nature, instream cover, overhanging vegetation, varied substrate, and well-established riparian zone. The substrate is dominated by cobble and gravels with smaller amounts of boulder and sand present.

Fish access may be compromised by the culvert at Trafalgar Street. It is long and appears to be angled slightly downslope. Under baseflow conditions, it is expected that depth would be minimal and difficult for fish to access. High flow may create a velocity barrier. There was a 0.4 m drop at the culvert inlet and accumulated woody debris that might preclude access. Additionally, the culvert outlet was perched approximately 0.3 m. The upper reaches of the channel may be difficult for fish access as well due to an increasing channel gradient.

The tree canopy was a mixture of mature deciduous and coniferous trees and included western redcedar (*Thuja plicata*), bigleaf maple, and red alder. The understory was well-developed and included red elderberry, salmonberry, horsetail, lamium and ferns.

Coho salmon, cutthroat trout, rainbow trout, threespine stickleback, and lamprey have been collected during previous sampling efforts, the majority from the sediment basin immediately upstream of Maclure Road. Signal crayfish have also been sampled. The channel provides Class Red (A)-P habitat (see **Figure 1**).

Despite the possible restrictions on fish access and reports of medium risk erosion sites identified as a component of this project, Horn Creek provides excellent value fish habitat due to its varied and complex nature and well-established riparian zone.

### 3.2.7 Boa Brook

Boa Brook originates on private properties immediately north of George Ferguson Way (see **Figure 1**). It is conveyed north through Century Park and other private properties to its confluence with Horn Creek at Maclure Road. The channel is a permanent watercourse located within a ravine with a moderate gradient. It is retained on its original alignment and exhibits moderate sinuosity. Run and riffle make up the majority of the habitat (35% and 40% respectively). However, there is also a significant pool component (25%). Channel width averaged 2-3 m. Sand is the dominant substrate, particularly in the channel's lower reaches but there is also a significant amount of gravels. Boulders and cobbles are located in the upper reaches with silt and organic detritus more prevalent in the lower reaches. The channel is highly complex with instream cover, significant amounts of Large Woody Debris, overhanging vegetation, a varied morphology, and mixed substrate. Some iron staining of the water column was present at the time of assessment.

The lower reaches of the channel appear to be accessible to fish with no obvious barriers observed and a number of deep pools to provide cover for fish. However, the channel becomes very shallow in the upstream reaches (0.2 m depth at the time of assessment) with limited pool habitat. A log jam barrier observed may also affect fish access. A fish ladder was observed to the west of Century Crescent which is indicative of fish access potential, at least historically.

The tree canopy may be described as mixed forest with varying age classes. Coniferous species were more prevalent in the upper reaches. Tree species included western redcedar, red alder, bigleaf maple, and black cottonwood. The understory included immature western redcedar and black cottonwood, vine maple, red elderberry, thimbleberry, Indian plum, salmonberry, skunk cabbage, large-leaved avens

(*Geum macrophyllum*), horsetail, coltsfoot (*Petasites* sp.) and ferns. The understory was less developed in the upper reaches due to the greater proliferation of western redcedar reducing light penetration.

There has been limited fish sampling effort in Boa Brook. Current records indicate one cutthroat trout has been collected in the summer of 1998. As such, the channel provides Class Red (A)-P habitat (see **Figure 1**).

Boa Brook provides excellent habitat in its lower reaches due to its varied complexity and significant pool habitat to provide refugia for fish. The upper reach provides only fair habitat given the low depth and potentially restricted fish access. It should be noted that erosion is a concern within Boa Brook.

### 3.2.8 Mill Lake and Mill Lake Outlet Channel

Flow from Mill Lake is conveyed via the storm sewer system to an unnamed section of channel in Ravine Park where it is again enclosed in the storm sewer system before discharging to the upper reaches of Willband Creek.

Mill Lake is fed entirely by ground water and the storm sewer system. It is approximately 18.5 hectares (ha) in area, with approximately 73% of the surface area less than 2.0 m in depth (CH2M Hill, 2003). It has a maximum depth of 10.5 m. It is anticipated that substrates would consist almost entirely of silt and decaying organic matter. The lake includes a perimeter trail system with a mixture of native and riparian vegetation including black cottonwood, Douglas-fir (*Pseudotsuga menziesii*),western redcedar, bitter cherry (*Prunus emarginata*), Himalayan blackberry, salmonberry, policeman's helmet and reed canary grass. Instream vegetation includes emergent aquatic species around the periphery of the lake, primarily lily pads, cattail (*Typha latifolia*) and yellow-flag iris (*Iris pseudacorus*). Yellow-flag iris is an invasive species and is considered "noxious" per the provincial *Weed Control Act.*

There are a number of factors that impact water quality, the primary being a high faecal coliform count from the waterfowl that frequent the lake. There is also a lack of oil/water separators for the storm sewer system. As a result, hydrocarbons are known to discharge directly to the lake (*pers.comm.*). Finally, the lack of depth through the majority of the lake would likely result in high summer water temperatures, which would significantly affect dissolved oxygen levels. Additional detail on Mill Lake water quality is provided in **Section 3.6**.

Fish species include largemouth bass (*Micropterus salmoides*) and rainbow trout (*Oncorhynchus mykiss*), both of which have previously been stocked. The bass is an aggressive, introduced species that can have a significant impact to native species of fish as a result of predation.

The Mill Lake outlet channel is located within a large ravine. Flow is conveyed in a generally northeast direction prior to discharging to the storm sewer system. It can be characterized as permanent, moderate gradient channel with a slightly meandering morphology. The channel was predominantly run habitat with some small sections of pool at the time of assessment. The wetted width at the time of assessment was approximately 3.0 m. Bankful width was estimated at up to 15 m at some locations. The depth was as low as 0.1 m in sections. Substrate was predominantly silt (50-60%) with the remainder a mixture of cobbles, gravels, sand and organic detritus. Boulders were occasionally present throughout



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the channel. Habitat complexity was generally low given that the channel had a comparatively unvaried morphology. Complexity was provided primarily by of overhanging vegetation and a limited amount of Large Woody Debris. Fish access would be restricted by the storm sewer system.

Riparian vegetation consisted of a mixed deciduous/coniferous tree canopy. Tree species included bigleaf maple, red alder, western redcedar, and black cottonwood. Understory vegetation included immature trees (red alder, western redcedar and bitter cherry), salmonberry, Himalayan blackberry, red elderberry, Indian plum, English holly, horsetail and ferns. Skunk cabbage and reed canary grass were present in wetter sections. The riparian vegetation was well-established throughout the ravine. No instream vegetation was observed.

There is limited indication of fish presence within the outlet channel, with one record of a rainbow trout from June 2010. As such, the channel provides Class Red (A)-P habitat (see **Figure 1**).

Fish habitat quality is fair in the channel due to the comparatively low depth and complexity. However, it may be able to sustain a fish population in sections of the channel, particularly if larger pools are present. Given the lack of access and poor water quality discharging from Mill Lake, it is expected that any resident fish population would be vulnerable to extirpation.

### 3.2.9 Prairie Creek

The Prairie Creek system originates as two secondary channels in a residential area south of Downes Road (see **Figure 1**). Flow is conveyed north where the two channels are confluent upstream of Gladwin Road before flowing out of the Study Area and into Gifford Slough. The upstream sections are contained within ravines. The channel displays permanent flow with meandering sinuosity and a steep gradient upstream of Downes Road. The gradient becomes much gentler north of Downes Road before it flows out of the Study Area. The channel had a mixture of run (50%), riffle (30%) and pool (20%) habitat. Sand was the dominant substrate (50%) with a mixture of boulders, cobbles, gravel and silt making up the remainder. The channel displayed moderate complexity which included numerous pieces of Large Woody Debris and overhanging vegetation. The channel has been modified at the road where it is lined with lock blocks. No barriers to fish access were observed.

The riparian area was predominantly deciduous. The tree canopy was a mixed age stand that included red alder, bigleaf maple with some black cottonwood, Douglas-fir and western redcedar also present. Understory species included immature trees, Himalayan blackberry, red-osier dogwood, salmonberry, thimbleberry and horsetail. Skunk cabbage was present in wetter areas. There is a dense cover of vegetation over the creek with native species dominating the reaches upstream of Downes Road. Himalayan blackberry dominated the downstream reaches.

Limited effort has been made to sample for fish within Prairie Creek. The only reports are for observations of unidentified species north of Downes Road. However, given the quality of the habitat and assumed fish access to this reach, the channel likely provides Class Red (A)-P habitat.

Overall habitat quality has been rated as good. However, similar to Horn Creek and Boa Brook, erosion and sediment deposits in the lower reaches have been an issue.

## 3.3 Detailed Channel Reach Assessments

Detailed fish assessments were conducted within two 100-m reaches in the west branch of Upper Willband Creek and Thiessen Creek (see **Figure 1**). Assessments were conducted on May 17 and 18, 2017. This baseline assessment of existing conditions may be used as comparison to future conditions to determine if the implementation of recommendations from the ISMP is having an effect on habitat conditions.

### 3.3.1 Upper Willband Creek

The channel was measured at 20-m intervals within the subject reach. Channel dimensions were as follows:

- Bankfull width ranged from 0.9 to 2.55 m. The average was 1.76 m.
- Wetted width ranged from 0.9 to 1.91 m. The average was 1.37 m.
- Bankfull depth ranged from 0.55 to 0.72 m. The median was 0.64 m.
- Wetted depth ranged from 0 to 0.25 m. The average was 0.15 m.

At the time of survey, the channel was estimated to be at a medium flow stage where wetted depth ranged between 30-90% of bankfull depth. Channel gradient over the subject reach was 8%.

A visual assessment was utilized to determine instream cover, which is defined as "any structure within the wetted channel or within 1.0 m above the water surface that provides hiding, resting or feeding places for fish" (RISC, 2008). Instream cover observed within the channel consisted of:

- Small woody debris – Trace (a small amount ranging less than 3-5%);
- Undercut bank – Abundant (more than 20% of the site is considered covered);
- Deep pool – Trace;
- Overstream vegetation – Abundant; and
- Instream vegetation – Trace. Note that instream vegetation within this reach consisted of vascular plants.

There was no functional Large Woody Debris providing cover in the subject reach.

Channel banks on both sides of the reach displayed a variety of shape characteristics including "V-shaped", undercut, sloping and overhanging. The texture of the bank material was dominated by fines.

Crown closure (vegetation directly over the channel at a height of greater than 1.0 m) was determined to be at Stage 3 (41-70% cover). The canopy was predominantly deciduous and is considered to be at a "Young Forest" stage. Young Forests are differentiated into distinct layers and are typically 30-80 years of age.

The channel substrate was dominated by fines (<2 mm). Gravels (2-64 mm) and cobbles (64-256 mm) were sub-dominant. The $D_{95}$ (the largest substrate particle typically moved by flow) was measured at 150 mm. Disturbance indicators of changes in streamflow discharge and sediment/debris loads consisted of small woody debris and a homogenous bed texture.

Channel morphology was classified as $CP_c$-w (Cascade/Pool-Cobble). The channel exhibited an "irregular, wandering" pattern with stream bed bars against either bank. The channel was considered to be "uncoupled" from adjacent hillslopes (where mobilized hillslope sediment would not normally enter the stream channel).

Fish species sampled during electrofishing within the 100 m reach are outlined below in **Table 4**.

Table 4. Fish Species in Upper Willband Creek

| Species | Number | Age Class | Forklength (mm) | Weight (g) |
|---|---|---|---|---|
| Chinook salmon | 1 | Fry | 3.2 | 1.1 |
| Lamprey | 1 | Juvenile | 11.0 | 3.0 |

Please note that a second lamprey was observed but not captured for measurement.

Field measurements of water quality were taken during the assessment. Results are as follows:

- Temperature – 11.88 C
- pH – 7.16
- Conductivity – 0.129 µS/cm
- Turbidity – 6.1 NTU

Both pH and temperature were well within the limits required by salmonids to carry out their life functions. The low conductivity and turbidity are indicative of good, clean flow, which are favourable for species that are sensitive to poor water quality, such as salmonids. The presence of clean flow is also confirmed by the observation of a crayfish (*Pacifasticus leniusculus*) in the channel. Crayfish are known to prefer areas of cool, clean flow.

The assessment confirmed that this section of Upper Willband Creek is highly complex. It had a varied width and depth, cover provided by multiple sources, a mixed substrate, and varied bank types. The morphology is also quite varied.

The regenerating forest canopy improves overall habitat value. As indicated, riparian vegetation serves numerous functions that benefit habitat, including improvement of water quality. These improvements are demonstrated by the field measurements collected during the assessment, all of which are well within ranges that are preferred by salmonids.

Please note that a low-lying wetland was observed along the channel. There is also a large amount of garbage and debris in the channel, possibly originating from the homeless camp in the area.

### 3.3.2 Thiessen Creek

The channel was measured at 20m intervals within the subject reach. Channel dimensions were as follows:

- Bankfull width ranged from 0.6 to 7.9 m. The average was 3.02 m.
- Wetted width ranged from 0.45 to 7.1 m. The average was 2.56 m.
- Bankfull depth ranged from 0.3 to 0.25 m. The average was 0.35 m.
- Wetted depth ranged from 0.07 to 0.25 m. The average was 0.17 m.

At the time of survey, the channel was estimated to be at a medium flow stage where wetted depth ranged between 30-90% of bankfull depth. Channel gradient over the subject reach was 1%.

A visual assessment was utilized to determine instream cover, which may be defined as "any structure within the wetted channel or within 1 m above the water surface that provides hiding, resting or feeding places for fish". Instream cover observed within the channel consisted of:

- Small woody debris – Moderate (5-20% of the site);
- Large Woody Debris – Trace (a small amount ranging less than 3-5%). The LWD that was present was evenly distributed within the reach;
- Undercut bank – Trace; and
- Overstream vegetation – Abundant.

Channel banks on both sides of the reach displayed a variety of shape characteristics including "V-shaped", undercut, sloping and overhanging. The texture of the bank material was dominated by fines.

Crown closure (vegetation directly over the channel at a height of greater than 1 m) was determined to be at Stage 3 (41-70% cover). The canopy was predominantly deciduous forest and is considered to be at a "Young Forest" stage. Young Forests are differentiated into distinct layers and are typically 30-80 years of age.

The channel substrate was dominated by fines (<2mm). Gravels (2-64 mm) were sub-dominant. The $D_{95}$ (the largest substrate particle typically moved by flow) was measured at 1.0 cm. Disturbance indicators of changes in streamflow discharge and sediment/debris loads consisted of small woody debris, Large Woody Debris and minimal pool area within the channel.

Channel morphology was classified as $RP_g$-w (Riffle/Pool-Gravel). The channel exhibited an "irregular, meandering" pattern (a slightly more sinuous pattern that the "irregular, wandering" pattern determined for the Upper Willband assessment). Stream bed bars were located against either bank. Vegetated islands were found occasionally within the reach. The channel was considered to be "uncoupled" from adjacent hillslopes (where mobilized hillslope sediment would not normally enter the stream channel).

Fish species sampled during electrofishing within the 100 m reach are outlined below in **Table 5** on the next page.

Table 5. Fish Species in Thiessen Creek

| Species | Number | Age Class | Forklength (mm) | Weight (g) |
|---|---|---|---|---|
| Chinook salmon | 1 | Fry | 3.2 | <1.0 |
| Cutthroat trout | 2 | Juvenile | 4.9, 7.2 | 1.0, 3.9 |
| | 1 | Fry | 5.2 | 2.4 |
| Lamprey | 2 | Juvenile | 12.0, 15.0 | 3.6, 4.0 |

Additionally, 12 threespine stickleback were captured in a minnow trap placed downstream of Horn Street where a large pool was observed. This section of Thiessen Creek was not within the 100 m reach; therefore specific fish measurements were not recorded.

Field measurements of water quality were taken during the assessment. Results are as follows:

- Temperature – 11.89 C;
- Conductivity – 0.151 µS/cm; and
- Turbidity – 7.5 NTU.

Temperature was well within the limits required by salmonids to carry out their life functions. The low conductivity and turbidity are indicative of good, clean flow, which are favourable for species that are sensitive to poor water quality, such as salmonids.

The assessment confirmed that this section of Thiessen Creek is highly complex with variable widths, depths and sources of instream and overhanging cover.

The regenerating forest canopy improves overall habitat value. As indicated, riparian vegetation serves numerous functions that benefit habitat, including improvement of water quality. These improvements are demonstrated by the field measurements collected during the assessment, all of which are well within ranges that are preferred by salmonids.

## 3.4 Benthic Community Composition

Data specific to benthic invertebrate composition within the Study Area was not available in the background information reviewed. Benthic data was collected from four sampling reaches in the Horn/Boa system on September 6, 2017.

Various benthic metrics were calculated for each sampling reach to provide insight into community composition and overall stream health. Many of the metrics considered are included in the B-IBI and have predicted responses to human disturbance (*e.g.*, *Ephemeroptera* taxa are expected to decrease with increasing urbanization, agriculture, grazing and recreation). A detailed summary of the metrics as well as taxonomic data are presented in **Appendix C**.

Overall, the 2017 B-IBI scores for the four (4) Horn Creek benthic invertebrate survey sites were found to be in “poor” condition. The total B-IBI scores range from 18 to 24, with an average of 20. When aggregated, these scores indicate an overall “fair” stream condition (see **Table 6**). Note that per the standard protocol, individual samples were combined to produce an aggregate score for the entirety of the sampled reach within Horn Creek. As such, while any one sample may indicate a "poor" condition, the aggregate for the creek indicated a "fair" result due to the diversity of taxa found among all sites.

Table 6: Summary of B-IBI Scores for Horn Creek, September 2017

| Metric | Metric B-IBI score (1, 3 or 5) at each sample location | | | | Aggregate | Predicted response to Human Impact |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | | |
| Total Taxa Richness | 3 | 3 | 3 | 3 | 5 | decrease |
| Number of Ephemeroptera Taxa | 1 | 1 | 1 | 1 | 1 | decrease |
| Number of *Plecoptera* Taxa | 1 | 1 | 1 | 1 | 1 | decrease |
| Number of Trichoptera Taxa | 1 | 1 | 1 | 1 | 3 | decrease |
| Number of Long-lived Taxa | 1 | 1 | 1 | 1 | 3 | decrease |
| Number of Intolerant Taxa | 1 | 1 | 1 | 1 | 1 | decrease |
| Number of Tolerant Taxa | 5 | 5 | 5 | 5 | 5 | increase |
| Percent of Predator Individuals | 3 | 5 | 1 | 1 | 3 | increase |
| Number of Clinger Taxa | 1 | 1 | 1 | 1 | 3 | decrease |
| Percent Dominance | 3 | 5 | 3 | 3 | 5 | increase |
| Total B-IBI | 20 | 24 | 18 | 18 | 30 | - |
| Stream Condition | Poor | Poor | Poor | Poor | Fair | - |
| Stream Condition | Poor | Poor | Poor | Poor | Fair | - |

Taxa richness, overall abundance and %EPT (*Ephemeroptera, Plecoptera, Trichoptera*) were also calculated for each Horn Creek survey site (**Table 7**). In 2017, taxa richness within Horn Creek ranged from 20 to 25, with an average of 22.5. As referenced, taxa richness is simply a count of the number of species in any one sample.

Overall abundance (the number of individuals per sample) ranged from 404 to 427, with an average of 417. This is above the minimum requirement of 400 as outlined in the Monitoring and Adaptive Management Framework for Stormwater (Metro Vancouver, 2014) sampling protocol.

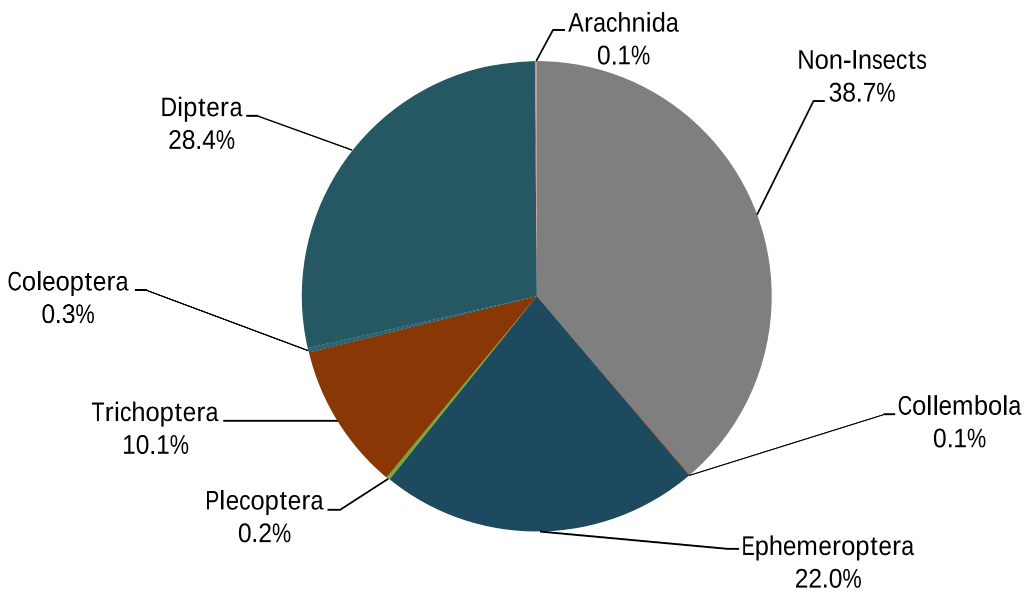
The %EPT (Richness) ranged from 14% to 28% throughout the creek. This is a measure of the percentage of pollution intolerant taxa that were present at each sample location.

Table 7: Summary of B-IBI Scores for Horn Creek, September 2017

| Station | Richness | Abundance | %EPT (Richness) |
|---|---|---|---|
| H1 | 20 | 404 | 20% |
| H2 | 25 | 420 | 28% |
| H3 | 24 | 417 | 21% |
| H4 | 21 | 427 | 14% |

The overall community composition within Horn Creek has also been considered. **Figure 2** displays the benthic community composition of Horn Creek, with non-insects comprising 38.7% of the overall composition. *Diptera* comprised 28.4% and *Ephemeroptera* comprised 22.0%, while the remaining communities consisted of *Trichoptera* (10.1%) and traces of *Coleoptera* (0.3%), *Plecoptera* (0.2%), *Arachnida* (0.1%), and *Collembola* (0.1%).

Figure 2: Horn Creek Community Composition[1]




[1] Note: non-insects include annelida, mollusca, crustacea, and platyhelminthes

As outlined above, based on the total B-IBI, the results of the 2017 benthic survey indicate that the overall stream conditions within Horn Creek are “fair” (although each individual sample site resulted in a “poor” stream condition). This score is indicative of a system that has been influenced by human activity. The most abundant species in the combined sample locations was *Baetis* sp. (a member of *Baetidae* family, and *Ephemeroptera* order). In general, presence of *Ephemoptera* in a stream system is a positive indicator of stream health. However *Baetis* sp. in particular are one of the more pollution tolerant *Ephemoptera* taxa and can be found in higher numbers where organic pollution exists (with an organic pollution tolerance value of 6 on a scale of 10) (Mandaville, 1999). Furthermore, nutrient enrichment is known at times to increase the number of *Ephemeroptera* order species in a stream system (*Page et al*., 2008). As Horn Creek is located in close proximity to residential development, it is possible that this may be influencing nutrient loading to the creek system. Furthermore, the %EPT (Richness) found in Horn Creek was low (with an average of 20.75%); decreased rates of these taxa (*Ephemeroptera, Plecoptera* and *Trichoptera*) are an indication of disturbance or stress to the stream.

The results of the benthic survey are only one (1) of many indicators of watershed health for the Horn Creek watershed. Overall watershed health is further discussed in **Section 3.8**.

As indicated, the theoretical B-IBI results for the Willband watershed would be "very poor" whereas Horn Creek is rated as "fair". This may be reflective of the lack of industrial discharges in the Horn Creek subwatershed as well as the intact riparian vegetation within the ravine.

It is important to note that basing the condition of a stream on one sampling period is not generally recommended and future examination of the watercourses should be considered. In addition, caution should be exercised in using one year of data to determine the aquatic integrity of a stream system. Long term monitoring across the watershed would help facilitate separation of naturally occurring broad scale impacts (*e.g*., a low water year, forest fire, etc.) from human-induced impacts (*e.g*., paving, urbanization, forest harvesting).

## 3.5 Water Quality

### 3.5.1 Mill Lake Study

There was limited water quality data available within the background information provided for the Study Area. One report was provided for a Mill Lake Water Quality study (CH2M Hill, 2003). Samples were collected on two occasions during the summer of 2001. Sampled parameters included the following:

- Total Dissolved Solids
- Hardness
- Extractable Hydrocarbons
- pH
- Total Suspended Solids
- Total Metals
- Biochemical Oxygen Demand

The results indicated that each parameter was either at or below what is considered "typical" for urban stormwater runoff. However, the report indicated that there is potential for metals to accumulate in the sediment where it could be taken up by bottom feeders and work its way into the tissues of aquatic life.

A number of field parameters were also assessed. Temperature in the top water mass (up to 2.5 m depth) was found to be 23.6 C. Despite this elevated temperature, dissolved oxygen (DO) was in the range of 6.5-8.0 mg/L. This meets the BC Water Quality Criteria (MoE, 1997) for all aquatic life stages other than buried embryos/alevins. As such, a self-sustaining population of aquatic life would need to hatch and enter the water column prior to the summer months to avoid peak temperatures and possible DO levels below their life requirements.

Temperature and DO in the lower water mass were 7.9 C and 0.0-1.5 mg/L, respectively. DO was significantly reduced at these lower depths, likely due to biochemical oxygen demand from decaying organic material in the lake bed material. Most aquatic organisms would not be expected to be able to survive under these conditions.

Two pH readings were taken with results of 7.01 and 7.70, both of which are well within the normal range.

Total Suspended Solids (TSS) results were shown to be 4 mg/L at the surface and 233 mg/L in the lower water mass. The higher TSS at depth is reflective of the accumulation of organic matter typical of lake bottoms which typically decomposes under anoxic (lacking in oxygen) conditions. TSS can also negatively affect fish through clogging of gills, smothering of eggs and reducing visibility such that prey is more difficult to locate.

Nitrates and orthophosphates can enrich a lake environment such that algal blooms can occur, which can results in significantly impacted water quality through reduction in DO levels. The assessment indicated nitrates and phosphates were not at excessive concentrations. However, there was nutrient enrichment as evidenced by the emergent vegetation at the site.

Sampling for coliform bacteria indicated a low level of contamination in the lake (a maximum of 240 cnts/100 ml). However, as communicated during the April 2016 site tour, faecal coliform levels are a concern due to the number of geese and other waterfowl utilizing the lake. It may be that these levels have become elevated subsequent to the 2003 study. It should be noted that there is no applicable standard for freshwater aquatic life for coliforms. It is primarily a concern if recreational contact is made with the water.

As referenced, Mill Lake outlets to the Willband Creek mainstem via its outlet channel in Ravine Park. Based on the results of the CH2M Hill study, it is anticipated that the primary impact to water quality within the mainstem would be the potential effects of elevated faecal coliforms being conveyed downstream.

### 3.5.2 Field Investigation

One round of water quality sampling was conducted on August 29, 2016. Samples were collected from the Willband Creek mainstem upstream of Highway 11 at Valley Road as indicated in **Figure 1**. Both field parameters and lab analysis were conducted. Results are provided in the **Table 8** below. Please note that only dissolved and total metals with applicable standards per the BC Approved or Working Water Quality Guidelines and the Canadian Council of Ministers of the Environment Water Quality Guidelines are included. A complete list of sampled parameters is included as **Appendix D**.

Table 8. Water Quality Results

| Parameter | Result | Comments |
|---|---|---|
| **Field Parameters** | | |
| Temperature | 15.76 C | Below maximum for salmonids |
| Conductivity | 0.213/0.259 ms/cm | No freshwater aquatic life standard; below the lowest Working Water Quality Guideline of 0.7 mS/cm for the protection of low tolerance crops |
| Total Dissolved Solids | 0.168 mg/L | No freshwater aquatic life standard; below the lowest Working Water Quality Guideline of 500 mg/L for the protection of low tolerance crops |
| Dissolved oxygen | 5.40 mg/L | Above standard for life stages other than buried embryos/alevins (standard is 9.0 mg/L instantaneous minimum for embryos/alevins and 5.0 for other life stages) |
| pH | 6.86 | Within limits of 6.5-9.0 (CCME Guidelines) for Freshwater Aquatic Life |
| **Lab Results** | | |
| Biochemical Oxygen Demand | <6.0 mg/L | No applicable standard but this results indicates demand for oxygen from bacteria and decomposition is low |
| Total Ammonia | 0.076 mg/L | Well below minimum possible standard of maximum 4.82 mg/L (CCME Guidelines) |
| Total Suspended Solids | <4.0 mg/L | CCME standard limits to an permissible increase above background; results were below detection limits |
| Extractable Petroleum Hydrocarbons | <2.0 mg/L | Below detection limits |
| Faecal coliforms | 300 CFU/100 ml | No applicable freshwater aquatic life standard but can be an indication of contamination |
| Total coliforms | 1500 CFU/100 ml | |
| **Dissolved Metals** | | |
| Dissolved Aluminum (Al) | 4.7 ug/L | Below 0.1 mg/L instantaneous maximum for freshwater aquatic life |
| Dissolved Antimony (Sb) | <0.50 ug/L | Below detection limits; standard is 9 ug/L |
| Dissolved Iron (Fe) | 183 ug/L | Below standard of 350 mg/L |
| **Total Metals** | | |
| Total Arsenic (As) | 0.99 ug/L | Below 5.0 ug/L standard |
| Total Barium (Ba) | 14.2 ug/L | Below working quality guideline of 1000 ug/L |
| Total Beryllium (Be) | <0.10 ug/L | Below detection limits; standard is 0.13 ug/L |
| Total Boron (B) | <50 ug/L | Below detection limits; standard is 1200 ug/L |
| Total Cobalt (Co) | <0.50 ug/L | Below detection limits; standard is 110 ug/L maximum |

| Parameter | Result | Comments |
|---|---|---|
| Total Copper (Cu) | 1.09 ug/L | Below Approved Water Quality Guideline of 11 ug/L (water hardness 93 mg/L) for the protection of freshwater aquatic life |
| Total Iron (Fe) | 410 ug/L | Below 1000 ug/L standard |
| Total Lead (Pb) | <0.20 ug/L | Below Approved Water Quality Guideline of 74 ug/L (water hardness 93 mg/L) for the protection of freshwater aquatic life |
| Total Manganese (Mn) | 88.0 ug/L | Below Approved Water Quality Guideline of 1,565 ug/L (water hardness 93 mg/L) for the protection of freshwater aquatic life |
| Total Mercury | <0.010 ug/L | Maximum standard for freshwater aquatic life is 0.02 ug/L; results below detection limits |
| Total Molybdenum (Mo) | <1.0 ug/L | Below detection limits; standard is 2000 ug/L maximum |
| Total Nickel (Ni) | <1.0 ug/L | Below Approved Water Quality Guideline of 35.25 ug/L (water hardness 93 mg/L) for the protection of freshwater aquatic life |
| Total Selenium (Se) | <0.10 ug/L | Below detection limits; standard is 1 ug/L |
| Total Silver (Ag) | <0.020 ug/L | Below detection limits; standard is 0.1 ug/L maximum |
| Total Thallium (Tl) | <0.050 ug/L | Below detection limits; standard is 0.8 ug/L maximum |
| Total Uranium (U) | <0.10 ug/L | Below detection limits; standard is 8.5 ug/L maximum |
| Total Zinc (Zn) | <5.0 ug/L | Below Approved Water Quality Guideline of 35.25 ug/L (for water hardness 93 mg/L) |

The results indicated that very few of the parameters exceeded limits for freshwater aquatic life. Many were below detection limits. Only two parameters exceeded standards.

Dissolved oxygen was lower than the standard for buried embryos/alevins. This is to be expected during the summer months when temperatures are elevated. Given that most embryos and alevins would be expected to have emerged by late summer when the sample was taken, this result is not indicative of water quality issues.

Coliforms were somewhat elevated, perhaps as a result of local agricultural activity and/or discharges from Mill Lake. Given that there is no standard for freshwater aquatic life, this is not a concern unless the channel is used for recreation.

The data collected for this project is indicative of conditions at a single moment. Additional data collection may be warranted to obtain a more thorough understanding of conditions over time. However, these results indicate that water quality does not appear to be a concern for freshwater aquatic life.

## 3.6 Terrestrial Species and Habitat Inventory

The Study Area is located in the Coastal Western Hemlock Very Dry Maritime Eastern variant (CWHxm1) biogeoclimatic zone (MFLRNO, 2016). The CWHxm1 is the driest of the CWH sub-regions. Regardless, the CWH zone receives the most rainfall of all the biogeoclimatic zones in British Columbia. The climate is considered moderate with cool summers and mild winters (UBC CFCG, 2017). In an undisturbed state, this zone is dominated by coniferous forests with western hemlock and western redcedar being the most common tree species. As is typical in a developed watershed, much of the coniferous forest within the Study Area has been removed and replaced with non-native species on landscape properties. However, there are still blocks of contiguous forested habitat, particularly along upland watercourses within ravines and at the northern extent of the Study Area west of Highway 11. The CWHdm zone also encompasses the greatest diversity and abundance of wildlife in BC (UVic, 2017). Given the extensive urban development characteristic of this watershed, wildlife species that are expected to occur are those that are better adapted to disturbed and altered landscapes as well as being more tolerant of human presence.

Terrestrial habitat within the Study Area has been significantly impacted as a result of urban development. As referenced previously, the southern portion of the watershed is a mix of residential properties, both single- and multi-family, and commercial development. Industrial properties are located in the central portion of the watershed immediately west of Highway 11. The northern portion of the watershed is primarily agricultural land. There is one large section of intact forest block in the northern portion of the Study Area west of Highway 11 (see **Figure 1**) that measures approximately 71.1 ha (as estimated from aerial photograph interpretation). There are smaller habitat patches (intact forest blocks measuring 0.1 to 10 ha in area) which provide wildlife habitat as well, generally within the southern portion of the Study Area. Intact riparian corridors often facilitate access between intact hubs and patches of forested area. However, this interconnectivity has been impacted in the Study Area due to isolation by street networks, local development and removal of forested areas. As such, wildlife presence is anticipated to consist of those species that are adapted to urban environments (*e.g.*, raccoons, rodents, coyotes), those with a greater ability to disperse over obstacles (*e.g.*, birds) and those that require a relatively small range and are not required to move between habitat patches (*e.g*., amphibians).

The remnant 71.1 ha forest patch provides the most significant, contiguous terrestrial habitat in the Study Area. It is primarily on private land so site access during the assessment was poor. However, the patch appears to be mixture of mature 2$^{nd}$ growth deciduous and coniferous species. Species include red alder, bigleaf maple, western redcedar and Douglas-fir. The understory includes Indian plum, salmonberry, red elderberry and horsetail. Invasive species include Himalayan blackberry, policeman's helmet and reed canary grass. There are some wetland areas that include skunk cabbage, policeman's helmet and reed canary grass. The habitat is quite diverse and would be expected to support a wide range of wildlife species (see **Section 3.7.2** below).

A large part of the terrestrial habitat within the watershed consists of landscaped residential properties. The extent and composition of this habitat varies considerably. Some properties retain larger sections of vegetation which includes native vegetation, non-native plant species, or a mixture of the two. Some properties are largely devoid of habitat value with lawn and ornamental shrubs being the primary vegetation. Regardless, given the size and lack of connectivity to larger sections of intact vegetation, these areas have limited value and can be expected to be primarily used by common wildlife habitat generalists that are well-adapted to urban/suburban environments.

A list of terrestrial species observed during the site assessment is provided in **Table 9** below.

Table 9. Common plant species of the Study Area

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| Tree Species | | | |
| Douglas-fir | Pseudotsuga menziesii | Western redcedar | Thuja plicata |
| Western hemlock | Tsuga heterophylla | Bigleaf maple | Acer macrophyllum |
| Red alder | Alnus rubra | Black cottonwood | Populus balsamifera ssp. trichocarpa |
| Paper birch | Betula papyrifera | Bitter cherry | Prunus emarginata |
| Shrub Species | | | |
| Vine maple | Acer circinatum | Salmonberry | Rubus spectabilis |
| Red elderberry | Sambucus racemosa | Thimbleberry | Rubus parviflorus |
| Himalayan blackberry | Rubus discolor | Scotch broom | Cytisus scoparius |
| Snowberry | Symphoricarpos albus | Willow | Salix sp. |
| Hawthorn | Crataegus sp. | Indian plum | Oemleria cerasiformis |
| Hardhack | Spiraea douglasii | | |
| Herbaceous and Other Species | | | |
| Reed canary grass | Phalaris arundinacea | Jewelweed | Impatiens capensis |
| Sword fern | Polysitchum munitum | Coltsfoot | Petasites sp. |
| Herb robert | Geranium robertianum | Horsetail | Equisetum sp. |
| Creeping buttercup | Ranunculus repens. | Lamium | Lamium sp. |
| Large-leaved avens | Geum macrophyllum | Fireweed | Epilobium angustifolium |
| Stinging nettle | Urtica dioica | Policeman's helmet | Impatiens glandulifera |

### 3.6.1 Invasive Plant Species

Invasive plant species are not native to BC with the ability to aggressively establish populations and reduce the diversity of the natural ecosystem. Invasive species can spread and establish in new areas and will often out-compete native species. Invasive plant species can come to dominate the understory of intact blocks of habitat such that they exclude native species and the native wildlife that has come to depend on them. As a result, biodiversity can be negatively impacted.

The following plant species were observed during the site assessment or are listed in the provincial Invasive Alien Plant Program database for the area (see **Table 9**) are considered to be invasive:

- Himalayan blackberry
- Scotch broom
- Reed canary grass
- Lamium
- Policeman's helmet
- Yellow flag iris

While invasive, only one of these species, yellow flag iris, is considered noxious per the *BC Weed Control Act*. Property owners are required to take steps to avoid the spread of these weed species per the legislation.

Although invasive species were common throughout the Study Area, they typically did not dominate the understory at any particular location. They could be locally dominant over a limited area; however, taken as a whole, riparian areas and intact forested blocks tended to be composed of a higher percentage of native species with a mix of invasive species throughout. The one exception to this general trend was the lowland areas of Willband Creek north of Maclure Road. Reed canary grass tended to dominate the area, as is often the case in wet, open fields in the Lower Mainland. This could change over time as native species colonize into these areas. However, given the dense root mass established by reed canary grass, it may be difficult for native vegetation to become established without intervention in the form of a native planting coupled with ongoing maintenance. This could be cost prohibitive over a large area.

### 3.6.2 Wildlife

As referenced, large-scale urban development in the Study area would be expected to limit wildlife utilization to more generalist species that are tolerant of human presence and can disperse across the road network.

#### 3.6.2.1 Mammals

Small mammals such as voles and shrews are expected, particularly within the intact habitat of the forested block in the northern portion of the Study Area or within intact riparian areas adjacent to Study Area creeks. Other rodent species such as squirrels, rats, and mice are expected to be common throughout the watershed given their adaptability to urban/suburban environments. Bat species can be expected to utilize wildlife trees (*i.e.*, dead, dying or deteriorating trees that provide roost habitat) such as those observed along Willband Creek near the confluence with Evans Brook, along Scott Brook as well as in the large intact forest block west of Highway 11. Species that are well-adapted to urban environments (*e.g.*, raccoon, skunk, coyote) are also expected to be present. With the possible exception of the intact forest patch, larger mammal presence is not expected to be significant given the lack of wildlife corridor connectivity to adjacent watersheds with intact blocks of terrestrial habitat. Habitat for aquatic mammals such as beaver and muskrat is anticipated along some of the larger, lower gradient sections of watercourse, particularly along the Willband Creek mainstem.

It is likely that the large intact forested areas are the only terrestrial habitat in the Study Area where it might be expected that larger mammals (*e.g.*, mule deer) might be present on a regular basis. The lack of forested wildlife corridors may make access challenging. However, there is ample habitat available if access can be achieved. It should be noted that a recent black bear sighting north of Mill Lake (Abbotsford News, 2017) indicates that they could be present in the forested area.

Mammal sign was not observed in the Study Area. Regardless, numerous mammal species are anticipated to be present.

#### 3.6.2.2 Birds

Birds are the most common wildlife group within the Study Area. This is to be expected given that they are best suited to disperse across developed areas that would normally constitute barriers or obstacles for many species restricted to movement on the ground.

Passerines (perching birds) are the most common species expected within the watershed given that they make up the majority of species in British Columbia. In addition, the intact blocks of terrestrial vegetation and the landscaped properties provide habitat suitable for utilization by passerines. Waterfowl and shorebirds are expected to occur in more open, wetted habitats such as the Willband Creek mainstem and eastern tributary, the Willband Creek Park detention pond system and Mill Lake. Raptor presence would be anticipated in the large intact forested area west of Highway 11 given the presence of suitable nesting trees and the proximity to open foraging habitat. The wildlife trees observed around Willband Creek, Scott Creek and the large, intact forested area would provide habitat for cavity nesters such as woodpeckers. Marshy areas would be preferred by species that preferentially nest on emergent aquatic vegetation such as red-winged blackbird.

In general, the best habitat for birds, particularly passerines, is located in riparian areas with an intact tree canopy and the retained forested block west of Highway 11. The intact trees and well-established understories in these locations provide ample nesting and foraging opportunities. Waterfowl would tend to prefer more open bodies of water such as Mill Lake, the detention pond system in Willband Creek Park, and the wetland area on the Eastern Tributary of Upper Willband Creek. Raptor species would tend to prefer large trees on the edge of open areas to allow for nesting opportunities adjacent to their preferred foraging areas.

Species observed, either through sight, call or sign are outlined in **Table 10**.

Table 10. Observed bird species of the Study Area

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| Passerines | | | |
| Common Yellowthroat | Geothlypis trichas | Pacific wren | Troglodytes pacificus |
| Spotted towhee | Pipilo maculatus | Marsh wren | Cistothorus palustris |
| American robin | Turdus migratorius | Rufous hummingbird | Selasphorus rufus |
| Black-headed grosbeak | Pheucticus melanocephalus | European starling | Sturnus vulgaris |
| Swainson’s thrush | Catharus ustulatus | Sparrows | - |
| Swallows | - | | |

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| Other Species | | | |
| Barred Owl | Strix varia | Mallard | Anas platyrhynchos |
| Gulls | - | | |

### 3.6.2.3 Herptiles

Significant amphibian presence is anticipated in the lower gradient sections of the Willband Study Area where flow would tend to be reduced and the exposure to the sun due to limited riparian vegetation would serve to increase water temperatures. Larger, ponded areas with emergent aquatic vegetation provide excellent habitat for amphibians. Open water habitats are preferred by many insect species that amphibians prey upon. These areas tend also to have silty or organic substrates which allow for burial during winter hibernation. Reptile presence is expected to largely be limited to garter snakes, primarily in proximity to areas occupied by amphibians which form a significant part of their diets (Gregory and Campbell, 1984).

**Table 11** outlines herptile species known to occur in the Study Area.

Table 11. Observed herptile species of the Study Area

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| Western painted turtle | Chrysemys picta | Northern red-legged frog | Rana aurora |
| Northwestern salamander | Ambystoma gracile | Bullfrog | Lithobates catesbeianus |
| Pacific tree frog | Pseudacris regilla | | |

Background information provided by the City indicated that bullfrog, northern red-legged frog and northwestern salamander have been collected in and around Willband Creek Park. The bullfrog is an aggressive invasive species that can have a significant impact on the ecosystem, particularly as adults prey upon native amphibians, birds and fish (Green and Campbell, 1984).

The northern red-legged frog is a provincially listed species. Additional detail for is provided in **Section 3.8**.

There are reports of presence of western painted turtle in Mill Lake. See **Section 3.8** for additional details.

Pacific tree frogs were heard calling in the vicinity of Scott Creek during the site assessment. No additional herptile sign was observed.

## 3.7 Rare Species Presence and Potential

Through a review of the records and resources outlined in **Section 2.1** and Conservation Data Centre (CDC) mapping layers on iMapBC (Government of BC, 2017), rare species that have been identified or have the potential to occur in the Willband Study are outlined below in **Table 12**.

Table 12. Rare Species with the Potential to Occur in the Willband Creek Study Area

| Common Name | Scientific Name | BC List[1] | SARA[2] |
|---|---|---|---|
| Western painted turtle | *Chrysemys picta* pop 1 | Red | Endangered |
| Northern red-legged frog | *Rana aurora* | Blue | Special Concern |
| Pacific water shrew | *Sorex bendrii* | Red | Endangered |
| Oregon forestsnail | *Allogona townsendiana* | Red | Endangered |
| Roell's brotherella | *Brotherella roellii* | Red | No Status |
| Pacific waterleaf | *Hydrophyllum tenuipes* | Red | No Status |
| Batwing vinyl | *Leptogium platynum* | Red | Endangered |

[1]BC List Status - Red: Candidates for Extirpated, Endangered or Threatened stats in BC; Blue: Considered Special Concern in BC,
[2]SARA – Listing under Schedule 1 of the Federal *Species at Risk Act*

These species are discussed in more detail below. An extirpated/historical record for mountain beaver (*Aplodontia rufa*) was identified in the central Willband Creek watershed. Additionally, a "masked occurrence" was shown adjacent to the eastern perimeter of the Study Area. An information request was sent to the CDC and was provided the species name and location. Due to the sensitivity of this occurrence, discussion of the species and its location may not be provided. However, it is unlikely that development in the watershed could affect this species.

### 3.7.1 Western Painted Turtle

Western painted turtle has occurrence records in Mill Lake (Government of BC, 2017) and was also identified by the City of Abbotsford in the project start up meeting in 2016. The western painted turtle is highly aquatic. It is often found in lakes, ponds and streams with muddy bottoms, low flow and emergent aquatic vegetation. It is known to move several hundred metres from land (Gregory and Campbell, 1984). Eggs are typically laid in June but can begin in May in milder climates. They often prefer well-drained, southern-exposed slopes with a soft substrate that is easy to dig in. The young hatch later in the summer but often do not emerge from the nest until the following spring.

### 3.7.2 Northern Red-Legged Frog

Based on compiled fish sampling records provided by the City of Abbotsford, northern red-legged frog has been observed in Willband Creek Park. The northern red-legged frog tends to prefer small pools, swamps or ponds with muddy substrates adjacent to damp forests. They have been known to forage far from standing water. Eggs are typically laid as masses within standing water. Tadpoles emerge in summer and mature in two to three years (Green and Campbell, 1984).

### 3.7.3 Pacific Water Shrew

Although Pacific water shrew was not observed in the watershed and no CDC records (current or historical) have been identified on iMapBC (Government of BC, 2017), there is potential for this species to occur within the Study Area. Within BC, their range is restricted to the lower Fraser Valley (MELP, 1995). Pacific water shrews prefer valley bottom forest lands along streams and wetlands which also coincide with the preferred urban development areas in the Lower Mainland. Should they be present, their anticipated presence would be in the forested areas adjacent to creeks in the Study Area such as the Horn, Boa or Thiessen systems.

### 3.7.4 Oregon Forestsnail

The habitat requirements of Oregon forestsnail are not well known. It occupies mixed wood and deciduous forests, typically dominated by bigleaf maple (*Acer macrophyllum*) with a dense cover of low herbaceous vegetation. They may require coarse woody debris and abundant leaf litter (BC CDC, 2017a).

Oregon forestsnail has been identified at multiple locations throughout the Willband Creek Watershed through CDC records on iMapBC (Government of BC, 2017). Four Oregon forestsnails were observed within mixed riparian forest along Willband Creek, east of Gladys Avenue and south of Sumas Way in 2010. An empty shell was found west of Willband Creek near the BC Hydro substation, north of Valley Road in 2006. Two individuals were found along the western portion of the Sahhacum Indian Reserve 1, west of Highway 11, in 2008. Shell fragments were also found near Prairie Creek around the intersection of Downes Road and Verdon Way. A historical/extirpated record also exists for this species southeast of the Mill Lake area.

Mature woodlands throughout the Willband Creek watershed may provide suitable habitat for this species.

### 3.7.5 Roell's Brotherella

Roell's brotherella is a moss species that forms mats on rotten logs, stumps and bases of trees in cool to moist deciduous and coniferous forests (BC CDC, 2017b). It is usually found at low elevations along valley margins.

Roell's brotherella was observed along Boa Brook in disturbed swampy woods at the base of a tree and on a rotten log in 2007 according to CDC records on iMapBC (Government of BC, 2017). Additionally, this species was observed along Willband Creek, west of Braun Avenue on a reclining cedar trunk near the edge of the water, in 2007.

### 3.7.6 Pacific Waterleaf

Pacific waterleaf is a herbaceous plant found in riparian areas, lowland and hillside seepages, floodplains within deciduous and mixed forests and borders of trails and forest edges where moist saturated soils are present (South Coast Conservation Program, 2010). This species has been identified at multiple locations within the Horn Creek ravine and within the western parcel of the Sahhacum Indian Reserve 1 near the intersection of Highway 11 and Bateman Road according to CDC records on iMapBC (Government of BC, 2017).

### 3.7.7 Batwing Vinyl

Batwing vinyl is a jellyskin lichen that occurs at low elevations on rock outcrops where it colonizes inclined rock faces where there is periodic seepage (COSEWIC, 2011). This species has been observed at the east end of the Study Area on a damp sandstone cliff along the west end of Sumas Mountain according to CDC records on iMapBC (Government of BC, 2017). However, it was noted that this population may be extirpated.

## 3.8 Watershed Health

According to the Template for Integrated Stormwater Management Planning 2005 (KWL, 2005), plotting Total Impervious Area (TIA) vs. Riparian Forest Integrity (RFI) can be used as a measure of watershed health. It should be noted that this is a Metro Vancouver – specific document which can be applied to Abbotsford given the similar habitat conditions. TIA is a measure of the impervious surface in the watershed where there is no infiltration of storm water into the ground. Rainfall in these areas often discharges directly to creeks via the storm sewer system and can have detrimental effects to water quality or habitat from pollutants or erosive flow. RFI is calculated through aerial photograph interpretation and consists of determining the percentage of intact forested areas within 30 m of a creek. This calculation is based on the current alignments of the creeks and other watercourses in the watershed as well as historical alignments, if known. It includes those sections of a watercourse that have been enclosed in the storm sewer system (*e.g.*, the Mill Lake outlet channel downstream of Ravine Park).

The RFI was estimated at 31% for the Willband Creek watershed, most of which is located in the ravines in the upper reaches of the watershed. The Prairie Creek watershed was estimated as having an RFI of 54%. TIA as provided by Urban Systems Limited was 37% and 26% for Willband Creek and Prairie Creek, respectively.

Intact forested areas are indicated in **Figure 3**. A figuring indicating TIA vs. RFI is attached as **Figure 4**.

Utilizing this process, channels that have low %TIA and high %RFI would tend to be in the upper left of the graph in **Figure 4**. The trend toward the upper left is specific to healthier, less developed watersheds. Conversely, those watersheds where the %TIA vs. %RFI are located in the lower right corner of the graph, tend to be significantly more impacted.

As can be seen, the results for Willband Creek tend to be toward the lower right of the graph. This is to be expected given that large sections of the watershed have been developed and the percentage of imperviousness. It would be expected that impacted water quality and erosive flow could impact habitat value under these circumstances. Conversely, some area of more intact habitat (*e.g.*, Horn and Thiessen Creeks) could buffer these impacts and provide localized areas where habitat value would be maintained.

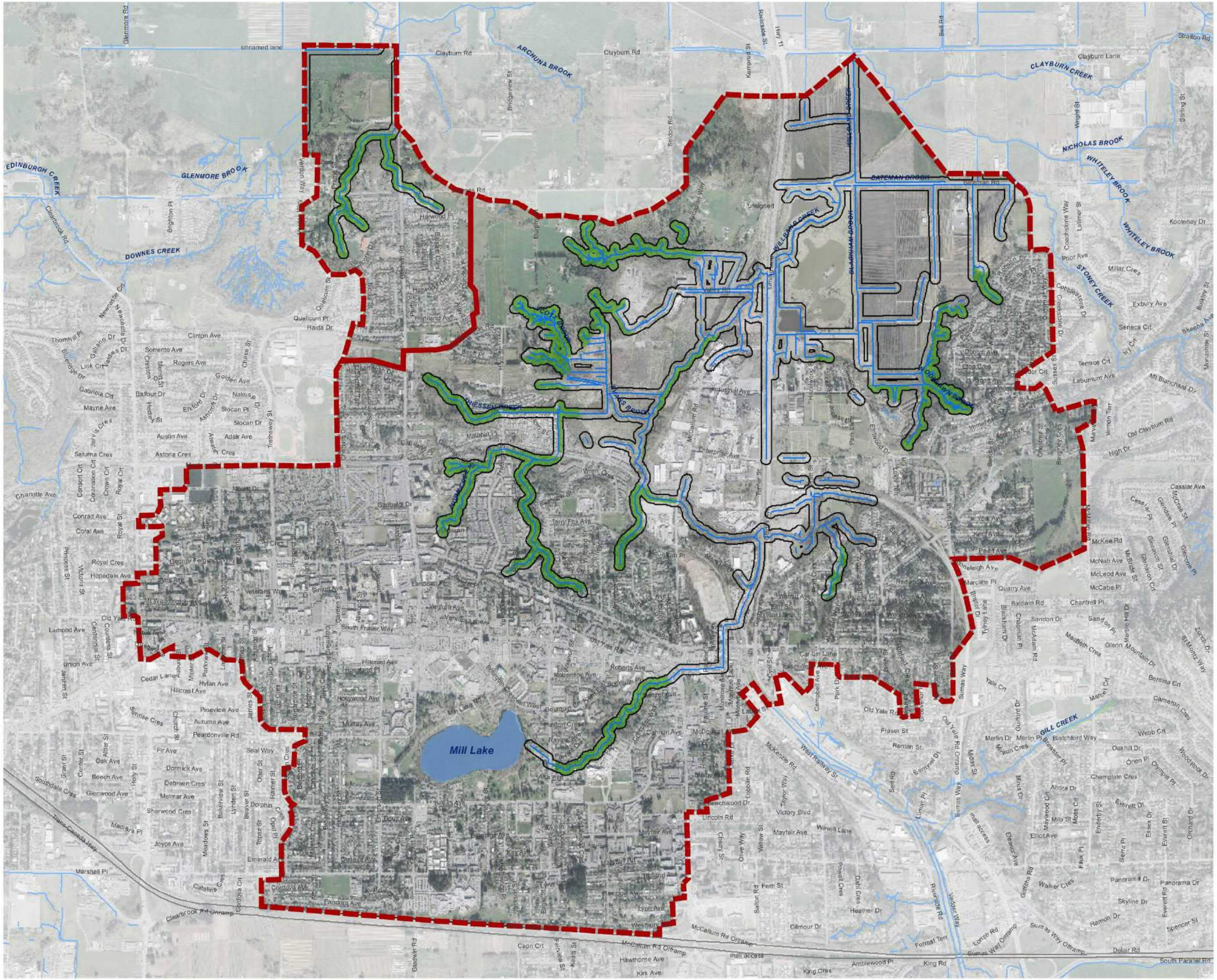
The Prairie Creek sub-watershed tends more toward the upper right of the graph. This is expected given the lower level of development and the large intact riparian areas around the creek. It is anticipated that erosive flow and water quality impacts would be considerably lower than for the Willband Creek watershed.

The graph may also be used to predict the B-IBI for the watershed. As referenced in **Section 2.5**, B-IBI is a 10-metric measure of the presence of benthic invertebrates in the watershed which ranges from a theoretical maximum of 50 (a pristine, undeveloped, old-growth watershed) to a minimum of 10 (severely impacted). In practice, a B-IBI score would be considered excellent with a score of 40.

As can be seen, following the diagonal access to the upper right from the intersection of the RFI and TIA for Willband Creek would result in a predicted B-IBI score of 13.9, which approaches the minimum. This is indicative of an extremely impacted watershed, which is not unexpected given the loss of over 70% of the original intact riparian forest and imperviousness over 35%. The predicted B-IBI score for the Prairie Creek sub-watershed would be higher than Willband Creek at 17.2%. According to the Greater Vancouver Regional District Benthic Macroinvertebrate B-IBI guide (GVRD, 2003), these results would be "poor" for Prairie Creek and "very poor" for Willband Creek.

The results from the individual sample locations in Horn Creek ranged from 18-24 ("poor") with an aggregate score of 30 ("fair"). These results are indicative of a system in better condition than the overall Willband Creek watershed ("very poor"). This is expected and is likely due to the greater extent of intact riparian vegetation in the upper reaches of Horn Creek and the lack of storm water input from industrial properties as is experienced further downstream in the Willband watershed.

Please note that the theoretical B-IBI score was calibrated based on data provided in the Template for Integrated Stormwater Management Planning 2005. It may be that more recent data would allow for recalibration of the graph and would results in a different predicted B-IBI score.




**City of Abbotsford**
Willband Creek ISMP

**Intact Forested Habitat**
FIGURE 3

- Study Area
- Creeks and Streams
- Creek and Stream 30m Buffer
- Intact Forested Area within Buffer

SCALE 1:22,000
0 0.25 0.5 1 Kilometers

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF ABBOTSFORD

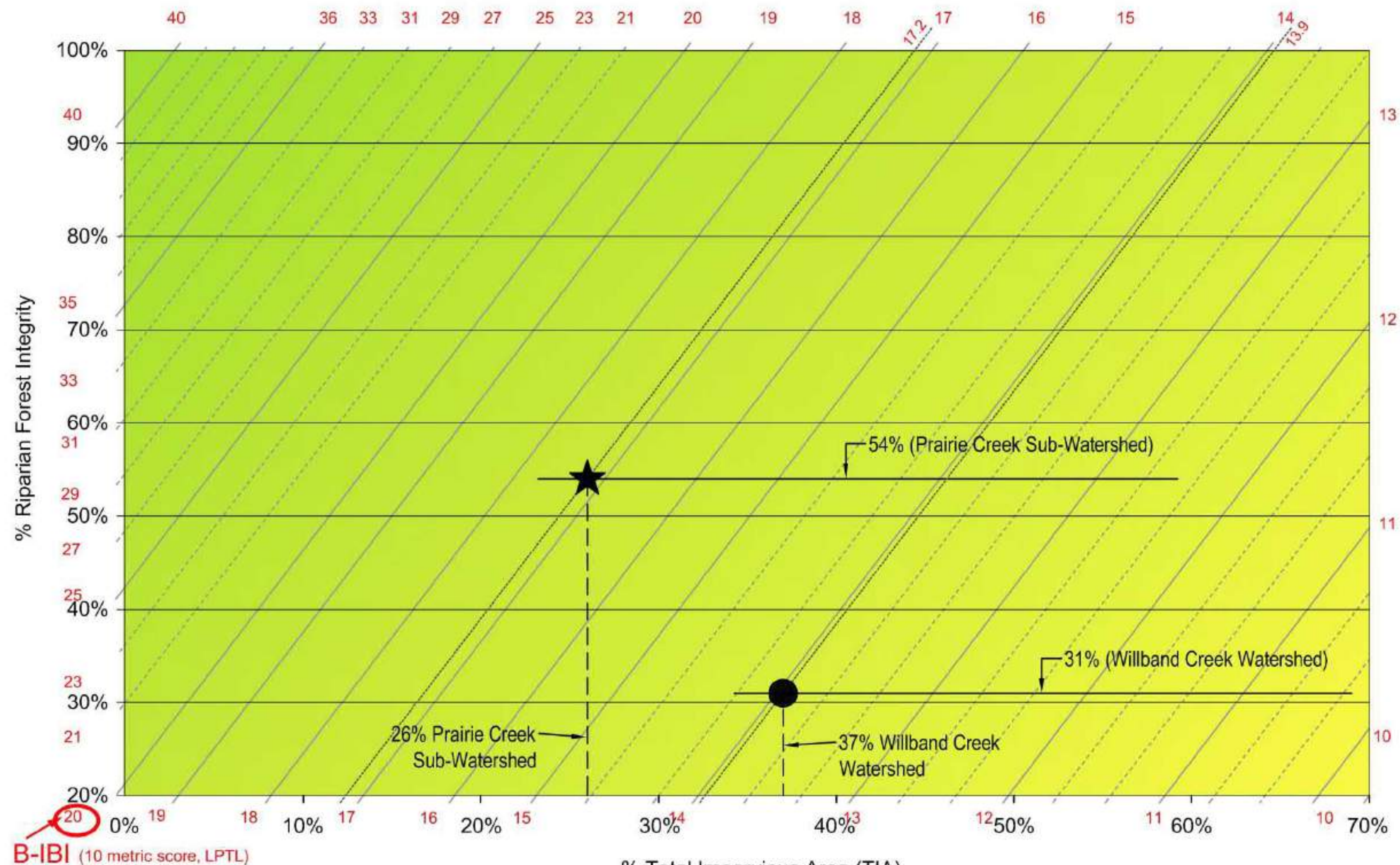
MAP CREATED BY: MZO
MAP CHECKED BY: NRG
MAP PROJECTION: NAD 1983 UTM Zone 10N

FILE LOCATION:
G:\GIS\163437\163437 - Intact Riparian Habitat - Figure 2.mxd

DILLON CONSULTING

PROJECT: 16-3437
STATUS: FINAL
DATE: June, 2017

WATERSHED HELATH TRACKING SYSTEM - Permanent Flow Creeks




Source: Kerr Wood Leidal Associates Ltd. 2005

**City of Abbotsford**
Willband Creek ISMP

**Riparian Forest Integrity vs Total Impervious Area**
FIGURE 4

● WILLBAND CREEK WATERSHED
★ PRAIRIE CREEK SUB-WATERSHED

SCALE N.T.S.

CREATED BY: MZO
CHECKED BY: NRG

File Location:
g:\gis\2016\163437\163437-watershed health tracking system.dwg February, 27, 2018 3:01 PM

PROJECT #: 16-3437
DATE: 02/27/2018

# 4.0 Discussion

## 4.1 Opportunities and Constraints

There are a number of opportunities available to the City to improve the habitat value in the Study Area. However, a number of constraints are associated with each of them. Discussion is provided below. Specific locations are indicated on **Figure 5**.

### 4.1.1 Riparian Infill

Riparian infill consists of the installation of native vegetation in areas currently lacking riparian vegetation. Native vegetation would significantly improve habitat for both aquatic and terrestrial species. However, a number of drawbacks are associated with this opportunity. These include:

- Expense – the cost associated with both the initial installation and the ongoing maintenance, particularly in areas dominated by reed canary grass, can be prohibitive;
- The presence of the BC Hydro right-of-way on Lower Willband Creek precludes the installation of tree species; and
- Some landowners may be reluctant to implement an infill program if it is seen as reducing future development or redevelopment potential. The City may wish to consider financial incentives to address this concern. The City could also require some land be dedicated to riparian enhancement through their Streamside Protection and Enhancement bylaw.

Specific locations for riparian infill include:

- Willband Creek starting approximately 380 m downstream of Maclure Road and extending to Highway 11;
- Willband Creek between Highway 11 and Bateman Road. This area may be challenging due to its wetland characteristics; and
- Willband Creek downstream of Bateman Road.

### 4.1.2 Fish Access Improvement

A number of culverts in the watershed may restrict access for fish to upstream reaches. This can be addressed through replacement with a properly sized and situated culvert that promotes access. Culverts can also be baffled to improve access. Fish ladders could also be installed to improve access to existing culverts. Weirs can also be installed to backwater culverts for improved accessibility. Constraints for these options include:

- Expense – this would be of particular relevance for long culverts with significant cover; and
- Baffling, ladders and weirs can restrict flow capacity. An engineering assessment would be required to determine if this would be possible.

The City would also need to consider the value of installing culverts, particularly in areas where natural barriers (*e.g.*, channel gradient) may preclude significant fish access.

Erosion and sediment deposition may also serve to restrict fish access. Sufficient accumulation can block culverts. The deposition of sediment into pool habitat can infill refugia and resting areas for fish which may compromise access. In addition, sufficient erosion can deposit large volumes of woody debris into the channel which can accumulate at culvert inlets and impede fish access.

Specific locations for which access improvement may be considered include:

- Horn Creek crossing at Trafalgar Street; and
- Willband Creek east tributary crossing at Gladys Avenue. This location may be particularly challenging given it is a major road.

### 4.1.3 Habitat Construction and Enhancement

Habitat could be constructed in areas where adequate land is available. This could include instream enhancement such as the placement of log cover structures or the creation of offline pools. Constraints include:

- Land acquisition may be required;
- Construction of new habitat can be expensive; and
- Offline pools can lead to localized increases in water temperature if not adequately buffered by riparian vegetation.

Identified locations for habitat construction and enhancement include:

- Willband Creek starting approximately 380 m downstream of Maclure Road and extending to Highway 11;
- Willband Creek between Highway 11 and Bateman Road; and
- Willband Creek downstream of Bateman Road.

### 4.1.4 Instream Maintenance

The removal of garbage and other anthropogenic debris would serve to improve water quality. The primary constraint for this option is that it is an ongoing requirement although it can be comparatively inexpensive.

Garbage removal would be particularly beneficial to the western tributary of Willband Creek upstream of Maclure Road.

### 4.1.5 Channel Daylighting

A significant habitat benefit could be realized through the daylighting of that portion of the Mill Lake outlet channel currently enclosed within the storm sewer system. A direct benefit would be realized through the creation of approximately 900 linear metres of new channel which could be constructed with a high degree of complexity and planted with a diverse assemblage of native riparian vegetation. An indirect benefit would be the creation of access for fish that cannot currently reach the channel due to the extensive length of the storm sewer system. In addition, any remnant population(s) of fish that may remain within the outlet channel would no longer be isolated and, as a result, would be much less vulnerable to extirpation as a result of an environmental incident (*e.g.*, a spill).

It should be noted that there are a number of significant drawbacks to this potential opportunity. Land acquisition would be required along the entire length of any sections of daylighted channel, likely at a significant expense. Municipal infrastructure would also be impacted. Finally, the cost of design and construction would be substantial. As such, daylighting may not be practical.

### 4.1.6 Water Quality Improvements – Mill Lake

There are a number of options that could be implemented to improve water quality within Mill Lake. For example, the installation of oil/water separators at select locations within the storm sewer system could reduce the volume of hydrocarbons reportedly discharging to the lake. Mechanized aerators and/or water circulation devices would serve to increase DO levels in the lake to the benefit of aquatic life. However, it should be noted that increased DO may also provide a benefit for the invasive largemouth bass reported to be present.

Another benefit would be the removal of accumulated sediment and organic detritus currently reducing water depth throughout much of the lake. Deeper water would serve to buffer the increased temperature typical during the summer months and would likely increase DO levels in the water column. However, as previously indicated, metals and hydrocarbons could have accumulated in the sediment, which many indicate the material is contaminated per the *Environmental Management Act*. Any material dredged from the lake would need to be sampled to determine the extent of contamination. If contamination is confirmed, disposal at a designated facility would be required at a potentially significant cost per cubic metre. In addition, the excavation of sediment could mobilize existing contamination that may be present.

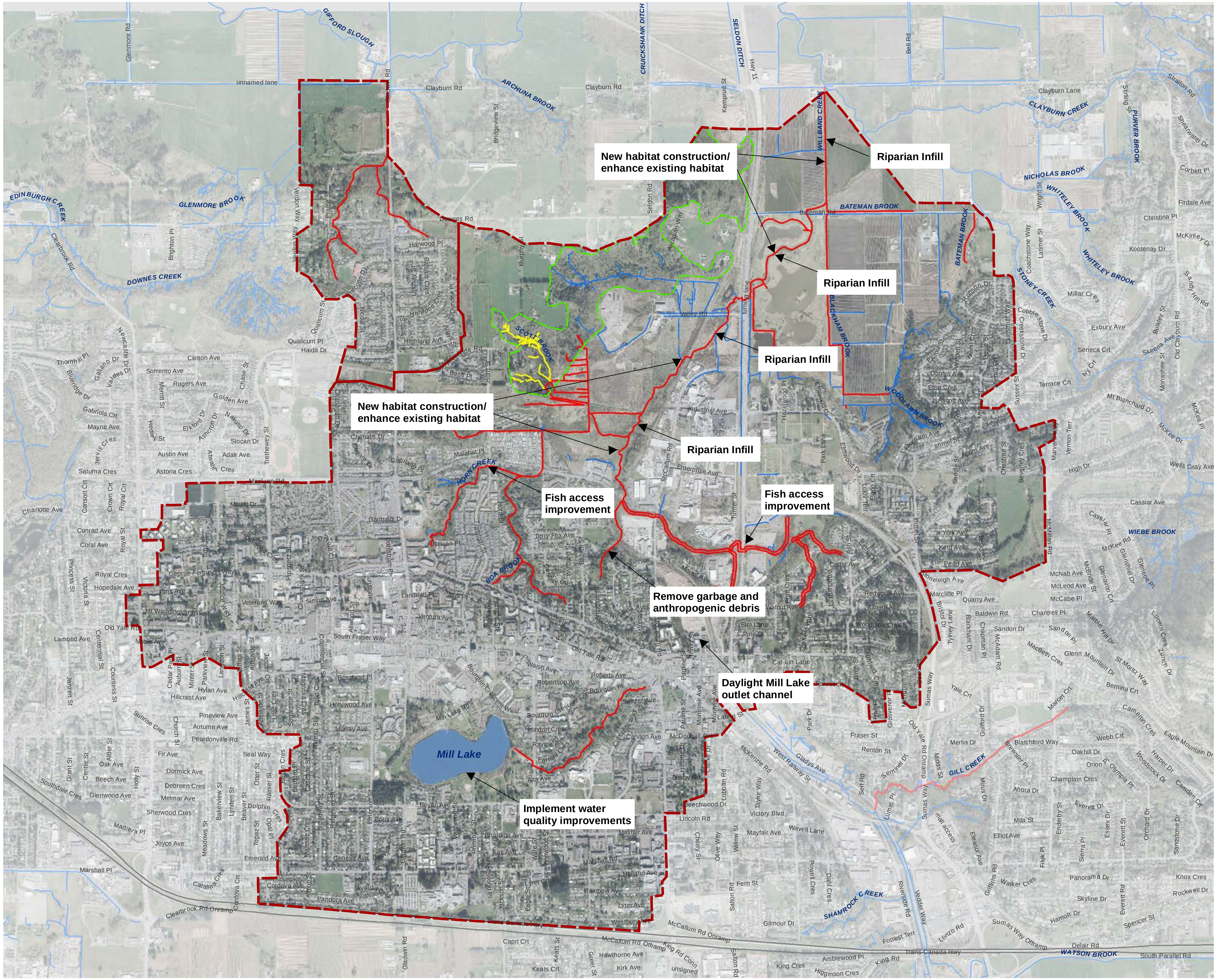
### 4.1.7 Integration of Habitat Features into Stormwater Controls

As referenced in Urban Systems Limited's Part 2, Projections for Future Conditions report, the integration of storm water controls in response to development and climate change is expected to have a significant contribution to protecting overall health of the aquatic habitat supported within the watershed. These controls may be implemented in a decentralized manner when sites redevelop. In areas where space is limited, such as the City Centre, a centralized control facility may be considered. In either case, these control facilities can be integrated with features to improve overall watershed health. Habitat features and enhancements could include the following:

- Biofiltration swales to improve water quality discharging from sites. The swales could be planted with instream vegetation and riparian vegetation for a food/nutrient contribution to downstream, fish-occupied reaches.
- Detention ponds could include a wetland component. Wetlands improve water quality and provide a food/nutrient contribution to downstream, fish-occupied reaches. Wetlands are also

selectively used by some wildlife species including birds (red-winged blackbird, waterfowl), mammals (muskrats, beavers) and amphibians.

- Detention ponds can be designed to allow for fish access. The ponds can be incorporated with complexing elements such as log crib structures, boulder clusters, and large woody debris.
- Increasing the tree canopy at decentralized locations is anticipated to help attenuate discharge of storm water into the drainage system. Tree also provide habitat for numerous wildlife species.

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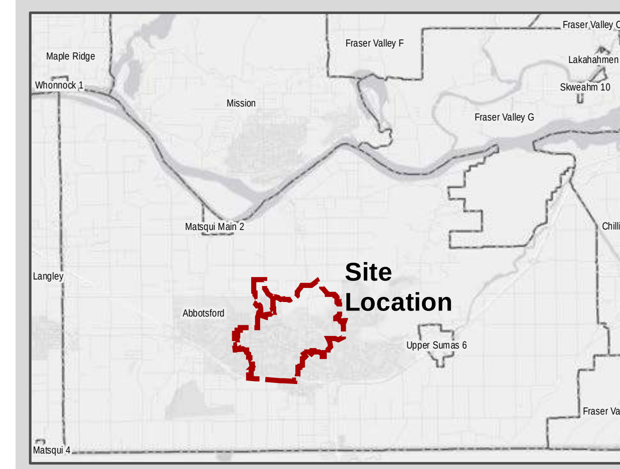
**City of Abbotsford**
Willband Creek ISMP

## Enhancement Opportunities
FIGURE 5

**FISH CLASSIFICATION**

- Class 'A' - Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply.
- Class 'A(OW)' - Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round.
- Class 'B' - Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown.
- Creeks, Streams, Channels with Unknown Classifications




SCALE 1:23,000
0 0.25 0.5 1 Kilometers

MAP DRAWING INFORMATION:
DATA PROVIDED BY CITY OF ABBOTSFORD

MAP CREATED BY: MZO
MAP CHECKED BY: NRG
MAP PROJECTION: NAD 1983 UTM Zone 10N

DILLON CONSULTING

PROJECT: 16-3437
STATUS: FINAL
DATE: July, 2018

# 5.0 Conclusion

Aquatic habitat in the Study Area has been significantly impacted by past land use activities. A large portion of the riparian forest has been removed, significant sections of channel have been enclosed within the storm sewer system, and fish access has been restricted in places. Despite these impacts, salmonid presence has been confirmed for every channel. Riparian forest is often intact within the upland ravine areas of Horn, Boa and Thiessen Creeks. These sections are retained on their original alignment and typically display high complexity and good to excellent fish habitat value. However, these sections represent relatively little of the overall watershed.

Terrestrial habitat has also been impacted by fragmentation, making access and migration challenging for some species. However, despite these drawbacks, there is a great diversity of habitat present in isolated patches. Invasive plants are widespread; however, there is a high percentage of native plants present with invasive species typically not dominating other than in parts of Lower Willband Creek. Rare species are known to occupy the watershed, and other species not previously noted may be present.

Notwithstanding the intact sections of creek and riparian areas, salmonid presence, terrestrial habitat diversity and rare species potential, overall watershed health is still considered poor by Metro Vancouver standards due to the significant loss of much of the formerly forested habitat, the loss of large sections of creek and riparian areas and the high degrees of imperviousness.

The City has several opportunities to improve habitat value, either through its ongoing maintenance requirements, capital projects dedicated to habitat improvement, or through the planning process. The ISMP process will assist the City in this process.

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# Appendix A

## City of Abbotsford Watercourse Classification System

| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Setback: Vegetation Category 1 | Setback: Vegetation Category 2 | Setback: Vegetation Category 3 | Description | Methodology |
|---|---|---|---|---|---|---|---|---|---|---|
| | | red | A | | Red (A) | 30m | Greater of: (1) existing width, (2) potential width[1], or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Watercourses with fish[2] presence at some point in the year. Permanence is unknown (i.e. water supply can be permanent [i.e. flow for >6 months] or non-permanent [i.e.flow for <6 months]). | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction[3] OR reach with gradient >25%[4] |
| | | red | A | P (Permanent) | Red (A) - P | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply. | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction OR reach with gradient >25%<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | red-dotted | A | NP (Non-permanent) | Red (A) - NP | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Watercourses with non-permanent (i.e. flow for <6 months) water supply that dry up in the summer months. Inhabited by fish during the over-wintering period. | • Where no obstruction data exists, the upstream extent is based on recorded observations.<br>• Where obstruction data exists, the classification is extended upstream until the first complete obstruction OR reach with gradient >25%<br>• Non-permanence classification is based on site visits over multiple years |
| | | red double line | A | OW (Overwintering. Wet year round) | Red (A) - OW | 30m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Greater of: (1) existing width, (2) potential width, or (3) 15m | Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round. | • Salmonid presence is based on recorded observations and an analysis of obstructions.<br>• Water quality monitoring is conducted during the summer over multiple years. Extended periods of high temperatures and low dissolved oxygen preclude fish presence. |
| | | red-dashed | A | CD (Constructed Ditch) | Red (A) - CD | 5-10m (as per RAR) | 5-10m (as per RAR) | 5-10m (as per RAR) | Constructed ditches that contain salmonids. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are fed by surface runoff rather than groundwater, and consequently can dry up quickly after a rain event. The RAR provides specific setbacks for these types of watercourses. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• If groundwater seepages/springs are found, then it's a channelized A |
| | | orange | UFH (Unclassified Fish Habitat) | | Orange (UFH) | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Watercourses with unknown classification that we know have fish habitat value (i.e. are either red or yellow), versus watercourses with unknown classification that may be class C. Example: a natural reach upstream of a natural obstruction that prevents anadromous fish access. Resident trout may exist upstream of the obstruction. In this case, property owners should default to red-coded or undertake an assessment for fish presence. | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.) |
| | | orange | UFH (Unclassified Fish Habitat) | P (Permanent) | Orange (UFH) - P | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Permanent watercourses (i.e. flow for >6 months) with unknown classification that we know have fish habitat value (i.e. are either red or yellow). | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.)<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | orange-dotted | UFH (Unclassified Fish Habitat) | NP (Non-permanent) | Orange (UFH) - NP | TBD (default is 30m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | TBD (default is greater of: (1) existing width, (2) potential width, or (3) 15m) | Non-permanent watercourses (i.e. flow for <6 months) with unknown classification that we know have fish habitat value (i.e. are either red or yellow). | • Watercourse is clearly part of the natural drainage system (e.g. it is non-channelized, has riparian vegetation, etc.)<br>• Non-permanence classification is based on site visits over multiple years |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | yellow | B | | Yellow (B) | 30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown (i.e. water supply can be permanent [i.e. year-round] or non-permanent [i.e. ephemeral]), so setbacks default to permanent values. | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or a reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e. too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.) |
| | | yellow | B | P (Permanent) | Yellow (B) - P | 30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Water supply is permanent (i.e. year-round). | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e .too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.), AND<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | yellow-dotted | B | NP (Non-permanent) | Yellow (B) -NP | 15-30m | 15m | 5-15m | Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Water supply is non-permanent (i.e. ephemeral). | • Upstream of a complete natural obstruction and fish sampling confirms no fish, OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND channel reaches further upstream cannot support resident trout populations (i.e .too steep, limited flow as evidenced by lack of scour/alluvial deposition, etc.) OR<br>• Upstream of a complete natural obstruction or reach with a gradient >25%, AND all upstream reaches completely and simultaneously dry up during the summer (i.e. with no remnant pools to provide refuge), AND<br>• Non-permanence classification is based on site visits over multiple years |
| | | green | C | | Green (C) | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m[6]<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc. |
| | | green | C | P (Permanent) | Green (C) - P | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Permanently flowing (i.e. >6 months) constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc.<br>• Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | green-dotted | C | NP (Non-permanent) | Green (C) - NP | 2m (per RAR) | 2m (per RAR) | 2m (per RAR) | Non-permanent (i.e. < 6 months) constructed ditches that have no fish presence documented or reasonable potential for fish presence. These ditches were created to drain property/roadways and were not part of the natural historic drainage system. They are only fed by surface runoff and don't intercept the water table; consequently, they usually dry up quickly after a rain event. Based on observations over multiple years, these ditches are known to dry up seasonally. They do not receive any water from any watercourses with fish habitat value. | • Watercourse is channelized<br>• Headwaters are assessed for contributions of groundwater through springs and seepages, and found to have none. Flow is entirely dependant on surface runoff.<br>• Channels with no visible channel (i.e. no scoured channel bed or alluvial deposition) for >100m5<br>• Lack of potential for fish presence is thoroughly investigated and documented by examining water quality, obstructions, channel characteristics, etc.<br>• Non-permanence classification is based on site visits over multiple years |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | green double line | C | WSA - Not Fish Habitat | WSA - NFH | none | none | none | Watercourses that are not connected via surface flow to fish habitat. | watercourse connectivity must be assessed during saturated conditions immediately following a significant rainfall event |
| | | blue | U | | Unknown (U) | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Watercourses for which the approximate location is known but insufficient information precludes classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | |
| | | blue | U | P (Permanent) | Unknown (U) - P | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Permanently flowing (i.e. >6 months) watercourses for which the approximate location is known but insufficient information precludes further classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | • Watercourse has been observed flowing in the summer or throughout the majority of the year |
| | | blue-dotted | U | NP (Non-permanent) | Unknown (U) - NP | TBD (default is 30m) | TBD (default is 30m) | TBD (default is 30m) | Non-permanent (i.e. flow <6 months) watercourses for which the approximate location is known but insufficient information precludes further classification. Property owners and applicants should adopt the classification of the downstream watercourse reach until otherwise established. | • Non-permanence classification is based on site visits over multiple years |

1 Potential width = width from the top of bank to the edge of an existing permanent structure, as defined by the RAR
2 Fish = includes salmonids, game fish, and regionally significant fish
3 Obstruction = impassible conditions or barriers where no reasonable potential for fish presence can be expected include:
- Natural impassable barriers such as falls or steep cascades that are too high even in high flow periods for fish of any life stage to jump.
- Human made permanent barriers that cannot be reasonably modified to allow fish passage; e.g., large weirs or dams, or extensive enclosed or channelized reaches.

4 The Fish Stream Identification Guidebook identifies 20% as the gradient that leads to a designation as a non-fish stream, however, 25% is utilized in order to provide room for measurement error
5 Fish sampling done in accordance with the methods identified in the Fish Stream Identification Guidebook
6 As per the Fish Stream Identification Guidebook

NOTES:

1 Unless noted, all watercourses are assumed to be fed by groundwater seepages/springs, rather than just surface runoff.

2. Vegetation Category based on the City of Abbotsford's Streamside Protection Bylaw (which is the same as the RAR Simple Assessment):

| Vegetation Category: | Existing or potential streamside vegetation conditions |
|---|---|
| 1 | continuous areas >30m or discontinuous but occasionally >30m to 50m |
| 2 | narrow but continuous areas =15m or discontinuous but occasionally >15m to 30m |
| 3 | very narrow but continuous areas up to 5m or discontinuous but occasionally >5m to 15m |

3. The City will adopt coding that was reviewed and accepted by DFO, as long as there is no new information that would change the accepted classification.

# Appendix B

## Site Photographs

| | | |
|---|---|---|
|  |  |  |
| **Photo 1:** Lower Willband Creek, typical conditions (May 26, 2016) | **Photo 2:** Lower Willband Creek, typical conditions (May 26, 2016) | **Photo 3:** Willband Western Tributary, typical conditions (May 26,2016) |
|  |  |  |
| **Photo 4:** Lower reach of Willband West Tributary, Substrate (May 26, 2016) | **Photo 5:** Willband East Tributary downstream of Turner Street (May 27, 2016) | **Photo 6:** Willband East Tributary Wetland area east of Abbotsford/Mission Highway (May 27, 2017) |

| | | |
|---|---|---|
|  |  |  |
| **Photo 7:** Small channel discharging to Willband Eastern Tributary (May 27, 2016) | **Photo 8:** Blackham Creek, typical conditions on (May 27, 2016) | **Photo 9:** Evans Brook, typical conditions (May 26, 2016) |
|  |  |  |
| **Photo 10:** Evans Brook, typical conditions (May 26, 2016) | **Photo 11:** Scott Brook, typical conditions (May 26, 2016) | **Photo 12:** Scott Brook, riparian conditions (May 26, 2016) |

**Photo 13:** Theissen Creek, channel conditions (May 26, 2017)

**Photo 14:** Theissen Creek, riparian conditions (May 26, 2016)

**Photo 15:** Horn Creek, typical conditions in lower reach (May 26, 2016)

**Photo 16:** Horn Creek, typical conditions in upper reach (May 26, 2016)

**Photo 17:** Boa Brook, typical conditions in lower reach (May 26, 2016)

**Photo 18:** Boa Brook, typical conditions in upper reach (May 26, 2016)

| | | |
|---|---|---|
|  |  |  |
| **Photo 19:** Mill Lake (May 26, 2016) | **Photo 20:** Mill Lake emergent vegetation (May 26, 2016) | **Photo 21:** Mill Lake outlet channel near inlet to storm sewer system (May 26, 2016) |
|  |  |  |
| **Photo 22:** Mill Lake outlet channel upper reach in wetted area (May 26, 2016) | **Photo 23:** Prairie Creek, altered channel upstream of Downes Road (May 27, 2016) | **Photo 24:** Prairie Creek, riparian area dominated by blackberry downstream of Downes Road (May 27, 2016) |

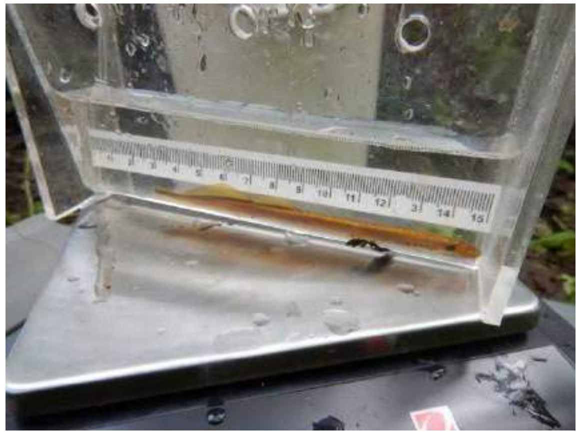
| | | |
|---|---|---|
|  |  |  |
| **Photo 25:** Upper Willband Detailed Assessment (May 19, 2017) | **Photo 26:** Upper Willband Detailed Assessment (May 19, 2017) | **Photo 27:** Upper Willband Detailed Assessment (May 19, 2017) |
|  |  |  |
| **Photo 28:** Upper Willband Detailed Assessment (May 19, 2017) | **Photo 29:** Upper Willband Detailed Assessment, Chinook fry (May 19, 2017) | **Photo 30:** Upper Willband Detailed Assessment, Lamprey (May 19, 2017) |

**Photo 31:** Theissen Creek Detailed Assessment (May 19, 2017)

**Photo 32:** Theissen Creek Detailed Assessment (May 19, 2017)

**Photo 33:** Theissen Creek Detailed Assessment, note Large Woody Debris (May 19, 2017)


**Photo 34:** Theissen Creek Detailed Assessment, Chinook fry (May 19, 2017)


**Photo 35:** Theissen Creek Detailed Assessment, cutthroat trout juvenile (May 19, 2017)


**Photo 36:** Theissen Creek Detailed Assessment, threespine stickleback (May 19, 2017)

# Appendix C

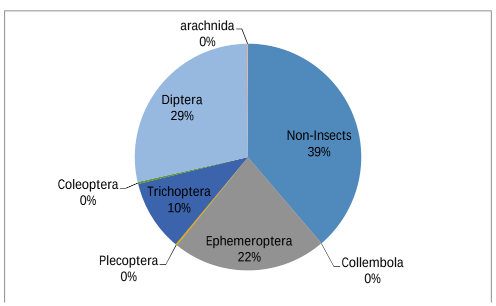
## Benthic Invertebrate Composition

Thibault Doix, Certified Taxonomi
Living Streams Environmental Serv
E-mail: livingstreams@live.ca

**Creek name: Horn Creek**

**Project References:** 16-3437
Project Name: Willband ISMP

| Phylum | Class | Order | Family | Genus/Species | H1 | H2 | H3 | H4 | Horn Creek Aggregate | Non-Insects | Predator | Clinger | Tolerant | Intolerant | Long lived |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Life History Traits | | | | |
| P. ANNELIDA | Cl. CLITELLATA | O. Opisthopora | F. Lumbricidae | (unidentified) | 8 | 3 | 39 | 6 | 56 | 56 | | | | | |
| | | O. Lumbriculida | F. Lumbriculidae | Kincaidiana sp. | 101 | 93 | 71 | 31 | 296 | 296 | | | | | |
| | | | | Lumbriculus sp. | | | 65 | | 65 | 65 | | | | | |
| | | | F. Enchytraeidae | (unidentified) | 26 | 37 | 115 | 16 | 194 | 194 | | | | | |
| | | O. Tubificida | F. Naididae | Nais sp. | 1 | | 1 | | 2 | 2 | | | | | |
| P. MOLLUSCA | Cl. GASTROPODA | O. Basommatophora | F. Planorbidae | Gyraulus sp. | 11 | | 2 | | 13 | 13 | | | X | | |
| | | | | Helisoma sp. | | | 1 | | 1 | 1 | | | X | | |
| | | | F. Hydrobiidae | (unidentified) | 3 | | 1 | | 4 | 4 | | | | | |
| | | | F. Physidae | Physa sp. | | 1 | | | 1 | 1 | | | X | | |
| P. ARTHROPODA | Cl. ARACHNIDA | | F. Sperchontidae | Sperchon sp. | | 1 | | | 1 | Insects | | | | | |
| | | | F. Lebertiidae | Lebertia sp. | | | | 1 | 1 | 0.11990 | | | | | |
| | Cl. COLLEMBOLA | O. Collembola | F. Entomobryidae | (unidentified) | | 1 | | | 1 | 0.05995 | | | | | |
| | Cl. INSECTA | O. Ephemeroptera | F. Baetidae | Baetis sp. | 18 | 61 | 40 | 243 | 362 | 367 | | X | | | |
| | | | F. Heptageniidae | Damaged/Immature | | 4 | | 1 | 5 | 22.00240 | | X | | | |
| | | O. Plecoptera | F. Nemouridae | Zapada sp. | | 3 | 1 | | 4 | 0.23981 | | | | | |
| | | O. Trichoptera | F. Hydropsychidae | (immature) | | 17 | 6 | | 23 | 169 | | X | | | |
| | | | | Arctopsyche sp. | 10 | 4 | 3 | | 17 | 10.13189 | | X | | | |
| | | | | Parapsyche sp. | 37 | 51 | 8 | | 96 | | X | X | | | X |
| | | | F. Hydroptilidae | Hydroptila sp. | | | | 27 | 27 | | | X | X | | |
| | | | F. Philopotamidae | Wormaldia sp. | 2 | 4 | | | 6 | | X | X | | | |
| | | O. Coleoptera | F. Dytiscidae | Laccophilus sp. | | | | 3 | 3 | 0.29976 | X | | X | | X |
| | | | | Tropisternus sp. | | | 1 | | 1 | | X | | | | X |
| | | | F. Hydrophilidae | Hydrophilus sp. | 1 | | | | 1 | | X | | | | X |
| | | O. Diptera | F. Ceratopogonidae | Mallochohelea sp. | | 1 | | | 1 | 474 | X | | | | |
| | | | F. Chironomidae | Orthocladiinae (Immature) | | 6 | | 11 | 17 | 28.41727 | | | | | |
| | | | | Brillia sp. | 5 | 1 | 1 | 2 | 9 | | | | | | |
| | | | | Corynoneura sp. | | 1 | 1 | 1 | 3 | | | | | | |
| | | | | Eukiefferiella sp. | 12 | 4 | 3 | 3 | 22 | | | | | | |
| | | | | Micropsectra sp. | 3 | 4 | 4 | 1 | 12 | | | | | | |
| | | | | Orthocladius sp. | | | | 2 | 2 | | | | | | |
| | | | | Polypedilum sp. | | 1 | | | 1 | | | X | | | |
| | | | | Prodiamesa sp. | | | | 2 | 2 | | | | | | |
| | | | | Rheocricotopus sp. | | | | 1 | 1 | | | | | | |
| | | | | Thienemaniella sp. | | 1 | | | 1 | | | | | | |
| | | | | Tvetenia sp. | 12 | 34 | 1 | | 47 | | X | | X | | |
| | | | | Zavrelimyia sp. | | | | 2 | 2 | | X | | X | | |
| | | | F. Dixidae | Dixa sp. | | | 1 | 1 | 2 | | | | | | |
| | | | F. Empididae | Neoplasta sp. | 1 | | | | 1 | | X | | | | |
| | | | | Oreogeton sp. | | | 2 | 7 | 9 | | X | | | X | |
| | | | F. Simuliidae | Simulium sp. | 144 | 82 | 35 | 61 | 322 | | | X | | | |
| | | | F. Tipulidae | Tipula sp. | 3 | 3 | 9 | 5 | 20 | | | | | | |
| P. CRUSTACEA | Cl. MALCOSTRACA | O. Amphipoda | F. Gammaridae | Gammarus sp. | 2 | 2 | | | 4 | 4 | | | | | |
| P. Platyhelminthe | Cl. TREPAXONEMAT/ | O. Neophora | F. Planariidae | Polycelis coronata | 4 | | 6 | | 10 | 10 | | | | | |
| | | | | Total Number of Organisms | 404 | 420 | 417 | 427 | 1668 | 646 | | | | | |
| | | | | Total Number of Taxa | 20 | 25 | 24 | 21 | 43 | 38.72902 | | | | | |




| | H1 | H2 | H3 | H4 | Aggregate |
|---|---|---|---|---|---|
| Nb Ephemeroptera taxa | 1 | 2 | 1 | 2 | 2 |
| Nb Plecoptera taxa | 0 | 1 | 1 | 0 | 1 |
| Nb Trichoptera taxa | 3 | 4 | 3 | 1 | 5 |
| % Dominant 3 Taxa | 70% | 56% | 60% | 78% | 59% |
| % Predators | 13% | 21% | 3% | 3% | 10% |
| %Tolerant | 6% | 8% | 1% | 7% | 6% |
| Long Lived Taxa Richness | 2 | 1 | 2 | 1 | 4 |
| Number of Intolerant Tax | 0 | 0 | 1 | 1 | 1 |
| Clinger Taxa Richness | 5 | 8 | 5 | 4 | 9 |

| | H1 | H2 | H3 | H4 |
|---|---|---|---|---|
| Ephemeroptera Richness | 1 | 2 | 1 | 2 |
| Plecoptera Richness | 0 | 1 | 1 | 0 |
| Trichoptera Richness | 3 | 4 | 3 | 1 |
| % EPT Richness | 20.00000 | 28.00000 | 20.83333 | 14.28571 |

| | | |
|---|---|---|
| Non-Insects | 646 | 38.72902 |
| Collembola | 1 | 0.05995 |
| Ephemeroptera | 367 | 22.00240 |
| Plecoptera | 4 | 0.23981 |
| Trichoptera | 169 | 10.13189 |
| Coleoptera | 5 | 0.29976 |
| Diptera | 474 | 28.41727 |
| arachnida | 2 | 0.11990 |
| | 1668 | |

| | | |
|---|---|---|
| Ephemeroptera | 367 | 67.962963 |
| Plecoptera | 4 | 0.7407407 |
| Trichoptera | 169 | 31.296296 |
| Sum | 540 | |

| Non-Insects | Collembola | phemeropte | Plecoptera | Trichoptera | Coleoptera | Diptera | arachnida |
|---|---|---|---|---|---|---|---|
| 38.72902 | 0.05995 | 22.00240 | 0.23981 | 10.13189 | 0.29976 | 28.41727 | 0.1199 |

# Appendix D

## Water Quality Results

Your Project #: 16-3437
Site Location: WILLBAND ISMP
Your C.O.C. #: 504164-01-01

**Attention:Lindsay Knezevich**
DILLON CONSULTING LTD.
510 - 3820 CESSNA DRIVE
Richmond, BC
CANADA V7B 0A2

**Report Date: 2016/09/08**
Report #: R2256209
Version: 1 - Final

# CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B673794**
**Received: 2016/08/29, 16:04**

Sample Matrix: Water
# Samples Received: 1

| Analyses | Quantity | Date Extracted | Date Analyzed | Laboratory Method | Analytical Method |
|---|---|---|---|---|---|
| Biochemical Oxygen Demand | 1 | 2016/09/03 | 2016/09/08 | BBY6SOP-00045 | SM 22 5210 B m |
| Coliform by membrane filtration | 1 | N/A | 2016/08/29 | BBY4SOP-00001 | SM 22 9222 m |
| Fecal Coliform by membrane filtration | 1 | N/A | 2016/08/29 | BBY4SOP-00001 | SM 22 9222 m |
| Hardness Total (calculated as CaCO3) | 1 | N/A | 2016/09/01 | BBY WI-00033 | Auto Calc |
| Hardness (calculated as CaCO3) | 1 | N/A | 2016/09/07 | BBY WI-00033 | Auto Calc |
| Mercury (Dissolved) by CVAF | 1 | N/A | 2016/09/06 | BBY7SOP-00015 | BCMOE BCLM Oct2013 m |
| Mercury (Total) by CVAF | 1 | 2016/09/05 | 2016/09/06 | BBY7SOP-00015 | BCMOE BCLM Oct2013 m |
| Na, K, Ca, Mg, S by CRC ICPMS (diss.) | 1 | N/A | 2016/09/07 | BBY7SOP-00002 | EPA 6020A R1 m |
| Elements by CRC ICPMS (dissolved) | 1 | N/A | 2016/09/06 | BBY7SOP-00002 | EPA 6020B R2 m |
| Na, K, Ca, Mg, S by CRC ICPMS (total) | 1 | 2016/08/29 | 2016/09/01 | BBY7SOP-00002 | EPA 6020A R1 m |
| Elements by CRC ICPMS (total) | 1 | 2016/09/01 | 2016/09/01 | BBY7SOP-00003, | BCLM2005,EPA6020bR2m |
| Ammonia-N (Preserved) | 1 | N/A | 2016/08/31 | BBY6SOP-00009 | SM 22 4500-NH3- G m |
| Filter and HNO3 Preserve for Metals | 1 | N/A | 2016/09/06 | BBY7 WI-00004 | BCMOE Reqs 08/14 |
| EPH in Water by GC/FID | 1 | 2016/08/30 | 2016/09/01 | BBY8SOP-00029 | BCMOE EPH w 07/99 m |
| Total Suspended Solids | 1 | 2016/09/01 | 2016/09/02 | BBY6SOP-00034 | SM 22 2540 D |

Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Samantha Fregien, Project Manager
Email: SFregien@maxxam.ca
Phone# (604)639-8418
==================================================================
This report has been generated and distributed using a secure automated process.
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## RESULTS OF CHEMICAL ANALYSES OF WATER

| | | | | |
|---|---|---|---|---|
| **Maxxam ID** | | PJ7719 | | |
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| **Demand Parameters** | | | | |
| Biochemical Oxygen Demand | mg/L | <6.0 (1) | 6.0 | 8387319 |
| **Nutrients** | | | | |
| Total Ammonia (N) | mg/L | 0.076 | 0.0050 | 8382583 |
| **Physical Properties** | | | | |
| Total Suspended Solids | mg/L | <4.0 | 4.0 | 8383082 |

RDL = Reportable Detection Limit

(1) Sample analysed past hold time: sample was received on the hold time expiry date which did not allow sufficient time for preparation and analysis.

Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
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## TOTAL PETROLEUM HYDROCARBONS (WATER)

| **Maxxam ID** | | PJ7719 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| **Ext. Pet. Hydrocarbon** | | | | |
| EPH (C10-C19) | mg/L | <0.20 | 0.20 | 8381528 |
| EPH (C19-C32) | mg/L | <0.20 | 0.20 | 8381528 |
| **Surrogate Recovery (%)** | | | | |
| O-TERPHENYL (sur.) | % | 89 | | 8381528 |
| RDL = Reportable Detection Limit | | | | |


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Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## MICROBIOLOGY (WATER)

| | | | | |
|---|---|---|---|---|
| **Maxxam ID** | | PJ7719 | | |
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| **Microbiological Param.** | | | | |
| Fecal Coliforms | CFU/100mL | 300 | 1 | 8381203 |
| Total Coliforms | CFU/100mL | 1500 | 1 | 8381202 |
| RDL = Reportable Detection Limit | | | | |

Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## CSR DISSOLVED METALS IN WATER WITH CV HG (WATER)

| **Maxxam ID** | | PJ7719 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| **Calculated Parameters** | | | | |
| Filter and HNO3 Preservation | N/A | FIELD | N/A | ONSITE |
| **Misc. Inorganics** | | | | |
| Dissolved Hardness (CaCO3) | mg/L | 99.4 | 0.50 | 8381187 |
| **Elements** | | | | |
| Dissolved Mercury (Hg) | ug/L | <0.010 | 0.010 | 8387996 |
| **Dissolved Metals by ICPMS** | | | | |
| Dissolved Aluminum (Al) | ug/L | 4.7 | 3.0 | 8386162 |
| Dissolved Antimony (Sb) | ug/L | <0.50 | 0.50 | 8386162 |
| Dissolved Arsenic (As) | ug/L | 0.72 | 0.10 | 8386162 |
| Dissolved Barium (Ba) | ug/L | 15.9 | 1.0 | 8386162 |
| Dissolved Beryllium (Be) | ug/L | <0.10 | 0.10 | 8386162 |
| Dissolved Bismuth (Bi) | ug/L | <1.0 | 1.0 | 8386162 |
| Dissolved Boron (B) | ug/L | <50 | 50 | 8386162 |
| Dissolved Cadmium (Cd) | ug/L | <0.010 | 0.010 | 8386162 |
| Dissolved Chromium (Cr) | ug/L | <1.0 | 1.0 | 8386162 |
| Dissolved Cobalt (Co) | ug/L | <0.50 | 0.50 | 8386162 |
| Dissolved Copper (Cu) | ug/L | 0.72 | 0.20 | 8386162 |
| Dissolved Iron (Fe) | ug/L | 183 | 5.0 | 8386162 |
| Dissolved Lead (Pb) | ug/L | <0.20 | 0.20 | 8386162 |
| Dissolved Manganese (Mn) | ug/L | 99.3 | 1.0 | 8386162 |
| Dissolved Molybdenum (Mo) | ug/L | 1.1 | 1.0 | 8386162 |
| Dissolved Nickel (Ni) | ug/L | <1.0 | 1.0 | 8386162 |
| Dissolved Selenium (Se) | ug/L | <0.10 | 0.10 | 8386162 |
| Dissolved Silicon (Si) | ug/L | 8940 | 100 | 8386162 |
| Dissolved Silver (Ag) | ug/L | <0.020 | 0.020 | 8386162 |
| Dissolved Strontium (Sr) | ug/L | 134 | 1.0 | 8386162 |
| Dissolved Thallium (Tl) | ug/L | <0.050 | 0.050 | 8386162 |
| Dissolved Tin (Sn) | ug/L | <5.0 | 5.0 | 8386162 |
| Dissolved Titanium (Ti) | ug/L | <5.0 | 5.0 | 8386162 |
| Dissolved Uranium (U) | ug/L | <0.10 | 0.10 | 8386162 |

RDL = Reportable Detection Limit
N/A = Not Applicable

Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## CSR DISSOLVED METALS IN WATER WITH CV HG (WATER)

| **Maxxam ID** | | PJ7719 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| Dissolved Vanadium (V) | ug/L | <5.0 | 5.0 | 8386162 |
| Dissolved Zinc (Zn) | ug/L | <5.0 | 5.0 | 8386162 |
| Dissolved Zirconium (Zr) | ug/L | <0.50 | 0.50 | 8386162 |
| Dissolved Calcium (Ca) | mg/L | 27.5 | 0.050 | 8379975 |
| Dissolved Magnesium (Mg) | mg/L | 7.47 | 0.050 | 8379975 |
| Dissolved Potassium (K) | mg/L | 1.69 | 0.050 | 8379975 |
| Dissolved Sodium (Na) | mg/L | 11.7 | 0.050 | 8379975 |
| Dissolved Sulphur (S) | mg/L | 4.2 | 3.0 | 8379975 |
| RDL = Reportable Detection Limit | | | | |



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Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## CSR TOTAL METALS IN WATER WITH CV HG (WATER)

| **Maxxam ID** | | PJ7719 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| **Calculated Parameters** | | | | |
| Total Hardness (CaCO3) | mg/L | 93.0 | 0.50 | 8381199 |
| **Elements** | | | | |
| Total Mercury (Hg) | ug/L | <0.010 | 0.010 | 8387997 |
| **Total Metals by ICPMS** | | | | |
| Total Aluminum (Al) | ug/L | 12.6 | 3.0 | 8384744 |
| Total Antimony (Sb) | ug/L | <0.50 | 0.50 | 8384744 |
| Total Arsenic (As) | ug/L | 0.99 | 0.10 | 8384744 |
| Total Barium (Ba) | ug/L | 14.2 | 1.0 | 8384744 |
| Total Beryllium (Be) | ug/L | <0.10 | 0.10 | 8384744 |
| Total Bismuth (Bi) | ug/L | <1.0 | 1.0 | 8384744 |
| Total Boron (B) | ug/L | <50 | 50 | 8384744 |
| Total Cadmium (Cd) | ug/L | <0.010 | 0.010 | 8384744 |
| Total Chromium (Cr) | ug/L | <1.0 | 1.0 | 8384744 |
| Total Cobalt (Co) | ug/L | <0.50 | 0.50 | 8384744 |
| Total Copper (Cu) | ug/L | 1.09 | 0.50 | 8384744 |
| Total Iron (Fe) | ug/L | 410 | 10 | 8384744 |
| Total Lead (Pb) | ug/L | <0.20 | 0.20 | 8384744 |
| Total Manganese (Mn) | ug/L | 88.0 | 1.0 | 8384744 |
| Total Molybdenum (Mo) | ug/L | <1.0 | 1.0 | 8384744 |
| Total Nickel (Ni) | ug/L | <1.0 | 1.0 | 8384744 |
| Total Selenium (Se) | ug/L | <0.10 | 0.10 | 8384744 |
| Total Silicon (Si) | ug/L | 9540 | 100 | 8384744 |
| Total Silver (Ag) | ug/L | <0.020 | 0.020 | 8384744 |
| Total Strontium (Sr) | ug/L | 119 | 1.0 | 8384744 |
| Total Thallium (Tl) | ug/L | <0.050 | 0.050 | 8384744 |
| Total Tin (Sn) | ug/L | <5.0 | 5.0 | 8384744 |
| Total Titanium (Ti) | ug/L | <5.0 | 5.0 | 8384744 |
| Total Uranium (U) | ug/L | <0.10 | 0.10 | 8384744 |
| Total Vanadium (V) | ug/L | <5.0 | 5.0 | 8384744 |
| Total Zinc (Zn) | ug/L | <5.0 | 5.0 | 8384744 |
| Total Zirconium (Zr) | ug/L | <0.50 | 0.50 | 8384744 |
| RDL = Reportable Detection Limit | | | | |



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Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## CSR TOTAL METALS IN WATER WITH CV HG (WATER)

| **Maxxam ID** | | PJ7719 | | |
|---|---|---|---|---|
| **Sampling Date** | | 2016/08/29 14:05 | | |
| **COC Number** | | 504164-01-01 | | |
| | **UNITS** | **WILLBAND ISMP** | **RDL** | **QC Batch** |
| Total Calcium (Ca) | mg/L | 25.2 | 0.050 | 8380320 |
| Total Magnesium (Mg) | mg/L | 7.30 | 0.050 | 8380320 |
| Total Potassium (K) | mg/L | 1.68 | 0.050 | 8380320 |
| Total Sodium (Na) | mg/L | 11.7 | 0.050 | 8380320 |
| Total Sulphur (S) | mg/L | 3.5 | 3.0 | 8380320 |
| RDL = Reportable Detection Limit | | | | |


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## GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

| | |
|---|---|
| Package 1 | 18.7°C |

**Results relate only to the items tested.**


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# QUALITY ASSURANCE REPORT



| | | | Matrix Spike | | Spiked Blank | | Method Blank | | RPD | |
|---|---|---|---|---|---|---|---|---|---|---|
| QC Batch | Parameter | Date | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits |
| 8381528 | O-TERPHENYL (sur.) | 2016/09/01 | 92 | 50 - 130 | 92 | 50 - 130 | 92 | % | | |
| 8381528 | EPH (C10-C19) | 2016/09/01 | 76 | 50 - 130 | 84 | 50 - 130 | <0.20 | mg/L | NC | 30 |
| 8381528 | EPH (C19-C32) | 2016/09/01 | 88 | 50 - 130 | 93 | 50 - 130 | <0.20 | mg/L | NC | 30 |
| 8382583 | Total Ammonia (N) | 2016/08/31 | NC | 80 - 120 | 100 | 80 - 120 | <0.0050 | mg/L | 1.3 | 20 |
| 8383082 | Total Suspended Solids | 2016/09/02 | 110 | 80 - 120 | 101 | 80 - 120 | <4.0 | mg/L | NC | 20 |
| 8384744 | Total Aluminum (Al) | 2016/09/01 | 112 | 80 - 120 | 116 | 80 - 120 | <3.0 | ug/L | NC | 20 |
| 8384744 | Total Antimony (Sb) | 2016/09/01 | 115 | 80 - 120 | 110 | 80 - 120 | <0.50 | ug/L | NC | 20 |
| 8384744 | Total Arsenic (As) | 2016/09/01 | 115 | 80 - 120 | 108 | 80 - 120 | <0.10 | ug/L | 6.7 | 20 |
| 8384744 | Total Barium (Ba) | 2016/09/01 | NC | 80 - 120 | 99 | 80 - 120 | <1.0 | ug/L | 1.1 | 20 |
| 8384744 | Total Beryllium (Be) | 2016/09/01 | 119 | 80 - 120 | 114 | 80 - 120 | <0.10 | ug/L | NC | 20 |
| 8384744 | Total Bismuth (Bi) | 2016/09/01 | 102 | 80 - 120 | 104 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8384744 | Total Boron (B) | 2016/09/01 | 120 | 80 - 120 | 113 | 80 - 120 | <50 | ug/L | NC | 20 |
| 8384744 | Total Cadmium (Cd) | 2016/09/01 | 117 | 80 - 120 | 113 | 80 - 120 | <0.010 | ug/L | NC | 20 |
| 8384744 | Total Chromium (Cr) | 2016/09/01 | 110 | 80 - 120 | 106 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8384744 | Total Cobalt (Co) | 2016/09/01 | 110 | 80 - 120 | 109 | 80 - 120 | <0.50 | ug/L | NC | 20 |
| 8384744 | Total Copper (Cu) | 2016/09/01 | 108 | 80 - 120 | 112 | 80 - 120 | <0.50 | ug/L | NC | 20 |
| 8384744 | Total Iron (Fe) | 2016/09/01 | NC | 80 - 120 | 111 | 80 - 120 | <10 | ug/L | 3.3 | 20 |
| 8384744 | Total Lead (Pb) | 2016/09/01 | 101 | 80 - 120 | 100 | 80 - 120 | <0.20 | ug/L | NC | 20 |
| 8384744 | Total Manganese (Mn) | 2016/09/01 | NC | 80 - 120 | 107 | 80 - 120 | <1.0 | ug/L | 1.4 | 20 |
| 8384744 | Total Molybdenum (Mo) | 2016/09/01 | NC | 80 - 120 | 107 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8384744 | Total Nickel (Ni) | 2016/09/01 | 111 | 80 - 120 | 111 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8384744 | Total Selenium (Se) | 2016/09/01 | 117 | 80 - 120 | 110 | 80 - 120 | <0.10 | ug/L | NC | 20 |
| 8384744 | Total Silicon (Si) | 2016/09/01 | | | | | <100 | ug/L | 1.6 | 20 |
| 8384744 | Total Silver (Ag) | 2016/09/01 | 113 | 80 - 120 | 109 | 80 - 120 | <0.020 | ug/L | NC | 20 |
| 8384744 | Total Strontium (Sr) | 2016/09/01 | NC | 80 - 120 | 100 | 80 - 120 | <1.0 | ug/L | 0.30 | 20 |
| 8384744 | Total Thallium (Tl) | 2016/09/01 | 109 | 80 - 120 | 107 | 80 - 120 | <0.050 | ug/L | NC | 20 |
| 8384744 | Total Tin (Sn) | 2016/09/01 | 95 | 80 - 120 | 98 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8384744 | Total Titanium (Ti) | 2016/09/01 | 107 | 80 - 120 | 100 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8384744 | Total Uranium (U) | 2016/09/01 | 102 | 80 - 120 | 99 | 80 - 120 | <0.10 | ug/L | NC | 20 |
| 8384744 | Total Vanadium (V) | 2016/09/01 | 114 | 80 - 120 | 107 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8384744 | Total Zinc (Zn) | 2016/09/01 | 100 | 80 - 120 | 122 (1) | 80 - 120 | <5.0 | ug/L | NC | 20 |

Maxxam Job #: B673794
Report Date: 2016/09/08

## QUALITY ASSURANCE REPORT(CONT'D)

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

| | | | Matrix Spike | | Spiked Blank | | Method Blank | | RPD | |
|---|---|---|---|---|---|---|---|---|---|---|
| QC Batch | Parameter | Date | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits |
| 8384744 | Total Zirconium (Zr) | 2016/09/01 | | | | | <0.50 | ug/L | NC | 20 |
| 8386162 | Dissolved Aluminum (Al) | 2016/09/06 | 103 | 80 - 120 | 109 | 80 - 120 | <3.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Antimony (Sb) | 2016/09/06 | 99 | 80 - 120 | 102 | 80 - 120 | <0.50 | ug/L | NC | 20 |
| 8386162 | Dissolved Arsenic (As) | 2016/09/06 | NC | 80 - 120 | 100 | 80 - 120 | <0.10 | ug/L | 0.50 | 20 |
| 8386162 | Dissolved Barium (Ba) | 2016/09/06 | NC | 80 - 120 | 103 | 80 - 120 | <1.0 | ug/L | 2.1 | 20 |
| 8386162 | Dissolved Beryllium (Be) | 2016/09/06 | 102 | 80 - 120 | 104 | 80 - 120 | <0.10 | ug/L | NC | 20 |
| 8386162 | Dissolved Bismuth (Bi) | 2016/09/06 | 93 | 80 - 120 | 101 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Boron (B) | 2016/09/06 | NC | 80 - 120 | 109 | 80 - 120 | <50 | ug/L | 0.23 | 20 |
| 8386162 | Dissolved Cadmium (Cd) | 2016/09/06 | 97 | 80 - 120 | 102 | 80 - 120 | <0.010 | ug/L | NC | 20 |
| 8386162 | Dissolved Chromium (Cr) | 2016/09/06 | 98 | 80 - 120 | 101 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Cobalt (Co) | 2016/09/06 | 96 | 80 - 120 | 102 | 80 - 120 | <0.50 | ug/L | NC | 20 |
| 8386162 | Dissolved Copper (Cu) | 2016/09/06 | 95 | 80 - 120 | 103 | 80 - 120 | <0.20 | ug/L | NC | 20 |
| 8386162 | Dissolved Iron (Fe) | 2016/09/06 | NC | 80 - 120 | 103 | 80 - 120 | <5.0 | ug/L | 5.5 | 20 |
| 8386162 | Dissolved Lead (Pb) | 2016/09/06 | 97 | 80 - 120 | 100 | 80 - 120 | <0.20 | ug/L | NC | 20 |
| 8386162 | Dissolved Manganese (Mn) | 2016/09/06 | NC | 80 - 120 | 95 | 80 - 120 | <1.0 | ug/L | 0.72 | 20 |
| 8386162 | Dissolved Molybdenum (Mo) | 2016/09/06 | NC | 80 - 120 | 103 | 80 - 120 | <1.0 | ug/L | 0.68 | 20 |
| 8386162 | Dissolved Nickel (Ni) | 2016/09/06 | 97 | 80 - 120 | 101 | 80 - 120 | <1.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Selenium (Se) | 2016/09/06 | 104 | 80 - 120 | 103 | 80 - 120 | <0.10 | ug/L | NC | 20 |
| 8386162 | Dissolved Silicon (Si) | 2016/09/06 | | | | | <100 | ug/L | 1.7 | 20 |
| 8386162 | Dissolved Silver (Ag) | 2016/09/06 | 91 | 80 - 120 | 105 | 80 - 120 | <0.020 | ug/L | NC | 20 |
| 8386162 | Dissolved Strontium (Sr) | 2016/09/06 | NC | 80 - 120 | 95 | 80 - 120 | <1.0 | ug/L | 0.75 | 20 |
| 8386162 | Dissolved Thallium (Tl) | 2016/09/06 | 95 | 80 - 120 | 102 | 80 - 120 | <0.050 | ug/L | NC | 20 |
| 8386162 | Dissolved Tin (Sn) | 2016/09/06 | 117 | 80 - 120 | 106 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Titanium (Ti) | 2016/09/06 | 111 | 80 - 120 | 103 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Uranium (U) | 2016/09/06 | 99 | 80 - 120 | 103 | 80 - 120 | <0.10 | ug/L | 1.3 | 20 |
| 8386162 | Dissolved Vanadium (V) | 2016/09/06 | 100 | 80 - 120 | 99 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Zinc (Zn) | 2016/09/06 | 91 | 80 - 120 | 99 | 80 - 120 | <5.0 | ug/L | NC | 20 |
| 8386162 | Dissolved Zirconium (Zr) | 2016/09/06 | | | | | <0.50 | ug/L | NC | 20 |
| 8387319 | Biochemical Oxygen Demand | 2016/09/08 | | | 96 | 85 - 115 | <6.0 | mg/L | 1.6 | 20 |
| 8387996 | Dissolved Mercury (Hg) | 2016/09/06 | 100 | 80 - 120 | 100 | 80 - 120 | <0.010 | ug/L | NC | 20 |

## QUALITY ASSURANCE REPORT(CONT'D)



| | | | Matrix Spike | | Spiked Blank | | Method Blank | | RPD | |
|---|---|---|---|---|---|---|---|---|---|---|
| QC Batch | Parameter | Date | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits |
| 8387997 | Total Mercury (Hg) | 2016/09/06 | 108 | 80 - 120 | 102 | 80 - 120 | <0.010 | ug/L | NC | 20 |

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

(1) Blank Spike outside acceptance criteria (10% of analytes failure allowed).

Maxxam Job #: B673794
Report Date: 2016/09/08

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Location: WILLBAND ISMP
Sampler Initials: LK

## VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Rob Reinert, B.Sc., Scientific Specialist

---

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam

Maxxam Analytics International Corporation o/a Maxxam Analytics
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B673794_COC

Chain Of Custody Record

Page of

Bottle Order #: 504164

Project Manager: Samantha Fregien

C#504164-01-01

| INVOICE TO: | | Report Information | | Project Information | |
|---|---|---|---|---|---|
| Company Name | #15986 DILLON CONSULTING LTD. | Company Name | | Quotation # | B40134 |
| Contact Name | Accounts Payable | Contact Name | Lindsay Knezevich | P.O. # | |
| Address | 510 - 3820 CESSNA DRIVE<br>Richmond BC V7B 0A2 | Address | | Project # | 16-3437 |
| | | | | Project Name | Willband ISMP |
| Phone | (604) 278-7847 Fax (604) 278-7894 | Phone | Fax | Site # | |
| Email | tcruickshank@dillon.ca; eglover@dillon.ca; ydavidov@ | Email | lknezevich@dillon.ca | Sampled By | LK |

Regulatory Criteria:
- [ ] CSR
- [ ] CCME
- [ ] BC Water Quality
- [ ] Other

Special Instructions

**SAMPLES MUST BE KEPT COOL ( < 10ºC ) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM**

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

Turnaround Time (TAT) Required:

Please provide advance notice for rush projects

**Regular (Standard) TAT:** ☑
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

**Job Specific Rush TAT (if applies to entire submission)**
1 DAY [ ] 2 Day [ ] 3 Day [ ] Date Required: ______ [ ]
Rush Confirmation Number: ______ (call lab for #)

| | Sample Barcode Label | Sample (Location) Identification | Date Sampled | Time Sampled | Matrix | Metals Field Filtered ? ( Y / N ) | Total Suspended Solids | Ammonia-N (Preserved) | Total and Dissolved Metals w/ CV Hg - Including Hardness | Faecal and Total Coliforms | EPH in Water by GC/FID | Biochemical Oxygen Demand | | | | | # of Bottles | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | Willband ISMP | Aug 29/16 | 14:05 | | Y | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | 10 | Total metal + total ~~[illegible]~~ mercury were field filtered |
| 2 | | " | " | " | | | | | | | | | | | | | | |
| 3 | | " | " | " | | | | | | | | | | | | | | |
| 4 | | " | " | " | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | |

| * RELINQUISHED BY: (Signature/Print) | Date: (YY/MM/DD) | Time | RECEIVED BY: (Signature/Print) | Date: (YY/MM/DD) | Time | # jars used and not submitted | Time Sensitive | Temperature (°C) on Receipt | Custody Seal Intact on Cooler? |
|---|---|---|---|---|---|---|---|---|---|
| Lindsay Knezevich | 16/08/29 | 16:00 | ALDEAN ALICANDO | 16/08/29 | 16:04 | N/A | [ ] | 18, 19, 19 | N/A Yes [ ] No [ ] |

Lab Use Only

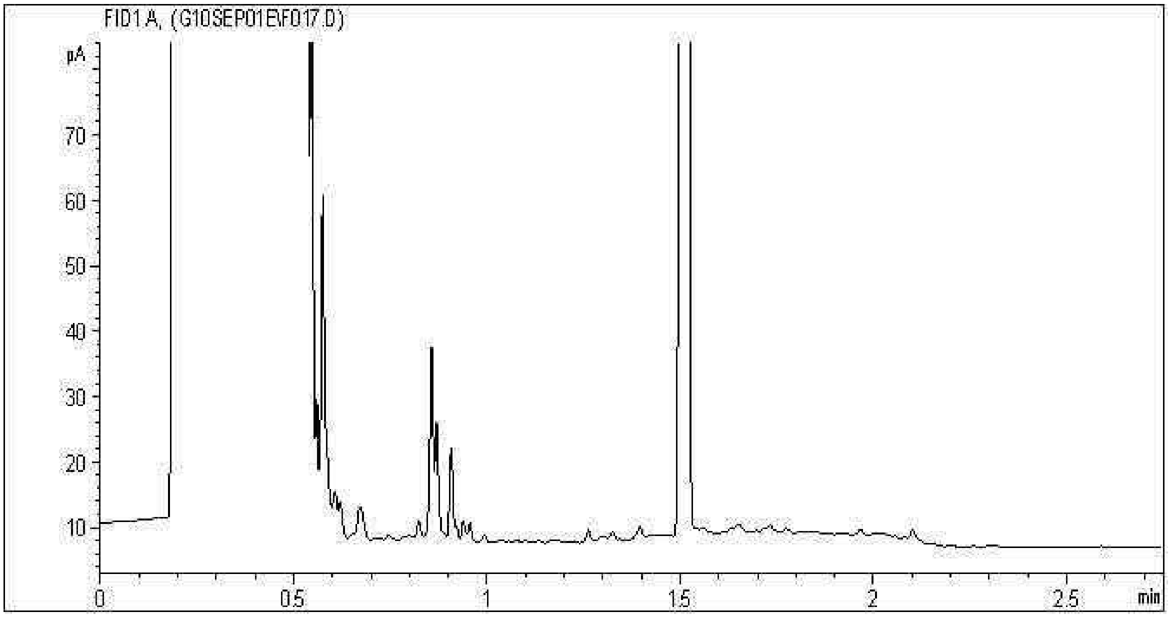
JUST SAMPLED
ICE - PRESENT

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

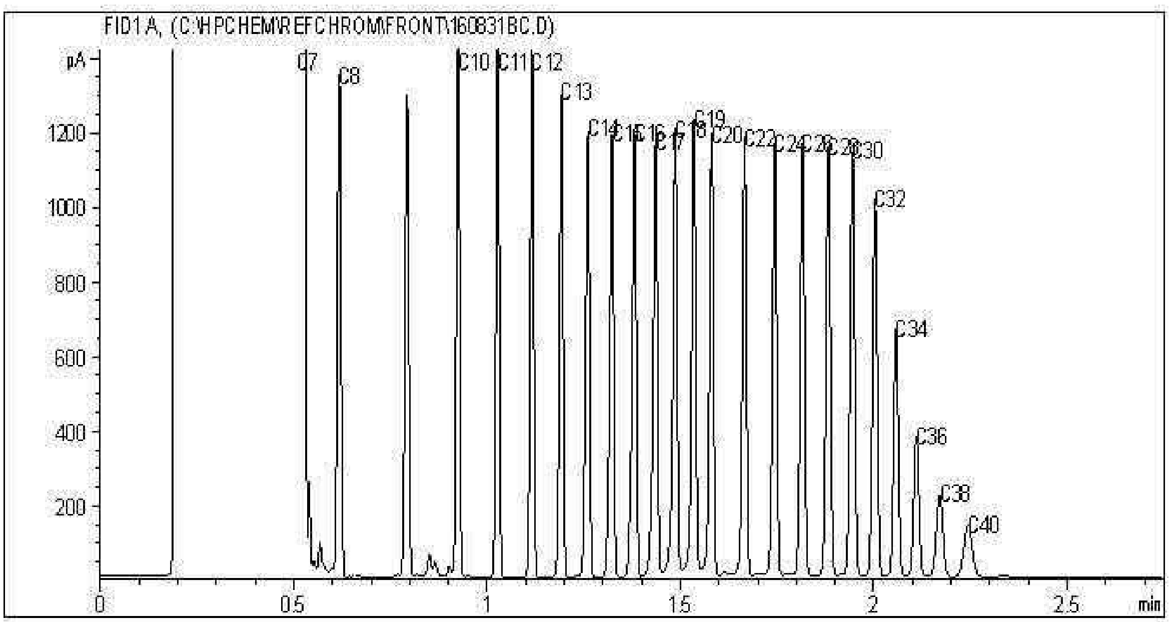
White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

**EPH in Water by GC/FID Chromatogram**




Carbon Range Distribution - Reference Chromatogram




TYPICAL PRODUCT CARBON NUMBER RANGES

| | | | |
|---|---|---|---|
| Gasoline: | C4 - C12 | Diesel: | C8 - C22 |
| Varsol: | C8 - C12 | Lubricating Oils: | C20 - C40 |

**Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.**

# APPENDIX D

Watercourse Stability Assessment Data Sheets

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THURBER

60 YEARS

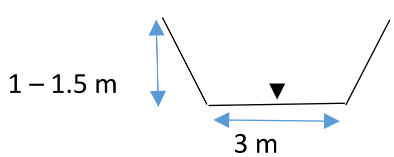
| | | | | | | |
|---|---|---|---|---|---|---|
| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Boa-01 |
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Boa Brook | | | | Date: | April 13, 2017 |
| Site Location | 2901 Century Crescent | | | | Easting | 0550815 |
| Time | Start: | 9:50 a.m. | Bank: | Within Channel | Northing | 5433756 |
| | End: | 10:25 a.m. | | | Datum | WGS84 |
| Weather | Overcast | | | | Inspector | BSP |

**Type:** Obstruction

**Description:**
- Concrete dam/weir within the main channel. Appears to have historically flowed into concrete culvert near right bank.

**Slope:**
- Banks 1 to 1.5 m high gently sloping to near vertical.
- Left bank about 10 m down stream of dam undercut near tree.
- Houses approximately 20 to 30 m back from creek.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- Channel base comprises grey, silty, fine to medium SAND.

**Stability Issues:**
- Erosion of creek bank due to concrete dam redirecting flow around onto left bank.

**Access:**
- Access via trail.

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** | **Low to Medium** |

**Consequence:**

- Continued erosion could cause the tree to topple.
- Possibility for tree to topple onto the nearby houses, but unlikely as the houses are well back.

**Likelihood:**

- Appears slow.

**Remedial Options:**

- Remove dam and concrete pipe, direct flows away from left bank.
- Protect right bank near dam and tree.
- Add step pools to slow down water flow.

| Photo No. | Bearing | Description |
|---|---|---|
| 319-320 | South West | Upstream view at dam |
| 321 | North West | Dam |
| 322 | South | Upstream view |
| 323 | North East | Undercut area |
| 324 | South West | Dam |
| 325-326 | North | Dam showing left bank |
| 327 | South | Upstream view about 20 m above dam showing log across the creek |

**Photographs:**

Photo 319

Photo 320

Photo 321

Photo 322

THURBER

60 YEARS


Photo 323


Photo 324


Photo 325


Photo 326


Photo 327

THURBER

60 YEARS

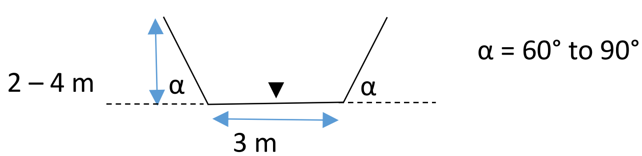
| Watercourse Stability Assessment Data Sheet | | | | | Report | Chilcotin-01 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Chilcotin Park Creek | | | | Date: | April 25, 2017 |
| Site Location | Back of houses on Prairie Road | | | | Easting | 0549556 |
| Time | Start: | 8:35 a.m. | Bank: | Left / Right | Northing | 5435775 |
| | End: | 9:30 a.m. | | | Datum | WGS84 |
| Weather | Mix of sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

**Description:**
- Eroded left bank and right bank.

**Slope:**
- Eroded banks 2 to 4 m high sloping 60° to near vertical.
- In some areas eroded banks are overhung by root balls 100 to 150 mm long.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- Bank comprises brown (weathered) over hard, grey, moist, sandy SILT and CLAY, with a trace of rounded gravel (till-like).

**Stability Issues:**
- Gradual softening of the till results in sloughing of the sides and undermining of trees.
- Flow is restricted in some plunge pools by roots and logs.

**Access:**
- Access via school or road.

**Comparison to Previous Years:**
- First year assessed.

THURBER

60 YEARS

| | |
|---|---|
| **Risk:** | **Low** |

**Consequence:**

- Continued erosion could cause the tree to topple.
- Possibility for tree to topple onto the nearby houses.

**Likelihood:**

- Erosion of the till appears to advance slowly, as is evident by the observed moss growing on some areas.

**Remedial Options:**

- Monitor progression of erosion.
- Cut back banks and vegetate.
- Reduce channel gradient with steps and pools.
- Remind residents to avoid dumping yard clippings near the creek.

| Photo No. | Bearing | Description |
|---|---|---|
| 429 | North West | Upstream view |
| 430 | South South East | Downstream view |
| 431 | South East | Upstream view, toppled tree |
| 432 | South | Upstream view, photo taken approx. 50 m upstream |
| 433 | North West | Downstream view, top of erosion area |

**Photographs:**

Photo 429

Photo 430

Photo 431

Photo 432

Photo 433

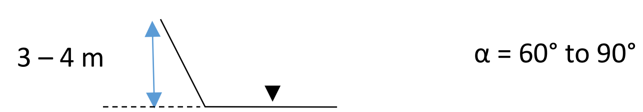
| Watercourse Stability Assessment Data Sheet | | | | | Report | Horn-01 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | 2962 Nelson Place | | | | Easting | 0550243 |
| Time | Start: | 11:05 a.m. | Bank: | Left | Northing | 5434037 |
| | End: | 11:30 a.m. | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

**Type:** Existing Slough / Slide

**Description:**
- Left bank toe erosion causing top to slough in.

**Slope:**
- Right bank rip rapped. Debris blockage near upstream side of feature.
- Left bank about 3 to 4 m high and 20 m long. Near vertical slope.
- Recent (within a few years) slump with trees on left bank about 5 m downstream of start of feature and 1 m downstream of debris blockage.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- Very stiff to hard SILT with some clay and fine to medium sand.
- Weathered till above on west side.
- Compact, brown, moist SAND and GRAVEL with some cobbles to 100 mm in diameter on the east side.

**Stability Issues:**
- Over steep slope will continue to weather and erode.

**Access:**
- Via trail.

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** | **Medium** |

**Consequence:**

- Trees falling on trail potentially causing injury to public.

**Likelihood:**

- Dense soils will result in slow progression.

**Remedial Options:**

- Move trail and cut back crest of slope.
- Vegetate
- Protect toe from future erosion

| Photo No. | Bearing | Description |
|---|---|---|
| 329 | South West | Upstream view at debris blockage |
| 330 | South West | Bank |
| 331 | North West | Bank |
| 332 | North East | Downstream view |
| 333 | Down | Slump |
| 328 | North East | Downstream view above blockage |
| 334 | South West | Upstream view from bank crest |

**Photographs:**

Photo 329

Photo 330

Photo 331

Photo 332


Photo 333


Photo 328


Photo 334

THURBER

60 YEARS

| | | | | | | |
|---|---|---|---|---|---|---|
| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Horn-02 |
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | 3055 Trafalgar Street | | | | Easting | 0550274 |
| Time | Start: | 11:30 a.m. | Bank: | Right | Northing | 5434062 |
| | End: | 11:40 | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

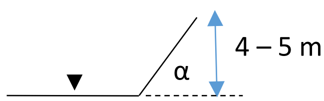
**Type:** Existing Slough-Slide

**Description:**
Slough on right bank with exposed soil on upstream end and two toppled trees on the downstream side

**Slope:**
- Right bank about 4 to 5 m high.
- Overstep with eroding toe.
- Two trees that previously toppled into creek, still alive, fallen from right bank. Branches are now growing upwards indicating trees toppled many years earlier.

**Sketch:** (Not to scale. Facing downstream)

α = 60° to 90°




**Soil and Water Conditions:**
- Stiff, brown, sandy SILT.

**Stability Issues:**
- Over steep bank with toe erosion. Upper oversteep soil weathers and sloughs off. Toe erodes causing bank to be oversteep.

**Access:**
- Via trail.

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** **Medium** | |
| **Consequence:**<br>- Houses back from crest. | |
| **Likelihood:**<br>- On-going. Slow. | |
| **Remedial Options:**<br>- Protect toe<br>- Cut back crest<br>- Vegetate slope and toe. | |

| Photo No. | Bearing | Description |
|---|---|---|
| 335-338 | North East-North | Right bank erosion panorama |
| 340 | Right Bank | Panorama upstream to downstream |

**Photographs:**

Photos 335-338

Photo 340

| Watercourse Stability Assessment Data Sheet | | | | | Report | Horn-03 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | 3055 Trafalgar Street | | | | Easting | 0550276 |
| Time | Start: | 11:45 a.m. | Bank: | Left | Northing | 5434102 |
| | End: | 11:55 a.m. | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

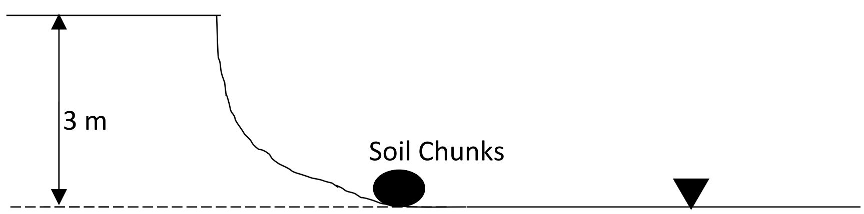
**Description:**

- Left bank toe erosion and top of bank sloughing.

**Slope:**

- Toe eroding under high flows on outside bend of creek. Left bank becomes undermined and sloughs/caves in.
- Path set back 3 to 4 m from crest. Chunks of soil at base indicating that slope crest is retrogressing at a constant rate.
- Black berries hanging over edge of slope.
- Some seepage observed out of bank on upstream side.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**

- Very stiff, clayey SILT with some sand.

**Stability Issues:**

- Toe erosion and over steep slope weathering.

**Access:**

- Via trail.

**Comparison to Previous Years:**

- First year assessed.

| |
|---|
| **Risk:** **Medium** |
| **Consequence:**<br>- Path will become undermined. |
| **Likelihood:**<br>- Moderate. Appears to happen continuously in small amounts.<br>- High water flows increase the rate of erosion. |
| **Remedial Options:**<br>- Cut back slope, protect toe, vegetate.<br>- Remove blackberries and vegetate with deep rooting species. |

| Photo No. | Bearing | Description |
|---|---|---|
| 341-348 | | Left bank panorama |

**Photographs:**

Photo 341-348

THURBER

60 YEARS

| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Horn-04 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd. / Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | 3055 Trafalgar Street | | | | Easting | 0550301 |
| Time | Start: | 11:55 a.m. | Bank: | Right | Northing | 5434132 |
| | End: | 12:05 p.m. | | | Datum | WGS84 |
| Weather | Light rain | | | | Inspector | BSP |

**Type:** Erosion

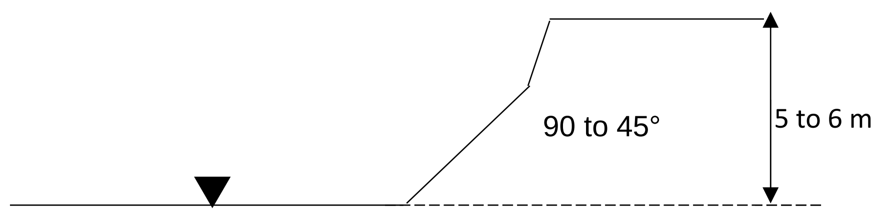
**Description:**

- Right bank erosion and sloughing.

**Slope:**

- 5 to 6 m high near vertical to 45°.
- About 20 m long.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**

- Stiff, clayey SILT with some sand.

**Stability Issues:**

- Toe eroding in stream causing upper slope to slump and become oversteep

**Access:**

- Via trail

**Comparison to Previous Years:**

- First year assessed.

| | |
|---|---|
| **Risk:** **Medium** | |
| **Consequence:**<br>- Houses appear to be a significant distance back from crest of slope. | |
| **Likelihood:**<br>- Erosion is ongoing, impact to houses will be sometime in future. | |
| **Remedial Options:**<br>- Cut back crest.<br>- Soil bio-engineering to stabilize exposed soil.<br>- Protect toe | |

THURBER

60 YEARS

| Photo No. | Bearing | Description |
|---|---|---|
| 349-353<br>353 | East<br>North East | Right bank panorama<br>Right bank erosion |

**Photographs:**

Photos 349-353

Photo 353

THURBER

60 YEARS

| Watercourse Stability Assessment Data Sheet | | | | | Report | Horn-05 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | 3115 Trafalgar Street | | | | Easting | 550317 |
| Time | Start: | 12:05 p.m. | Bank: | Left | Northing | 5434222 |
| | End: | 12:15 p.m. | | | Datum | WGS84 |
| Weather | Light Rain | | | | Inspector | BSP |

**Type:** Existing Slough / Slide

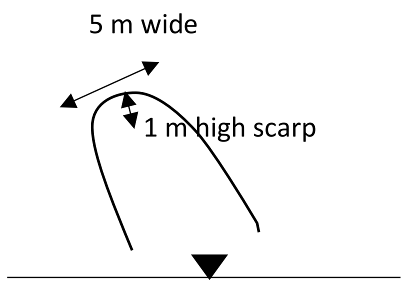
**Description:**

- Slide about 1 m deep.

**Slope:**

- Slump/slide on left bank in peat. Soil is saturated, water flowing out of toe.
- Scarp about 1 m high and 5 m wide.
- Toe will be eroded at high water level. Not currently eroding.

**Sketch:** (Not to scale)




**Soil and Water Conditions:**

- Peat over stiff silt.

**Stability Issues:**

- Slide will continue to move if toe is eroded.

**Access:**

- Via creek.

**Comparison to Previous Years:**

- First year assessed.

| | |
|---|---|
| **Risk:** | **Low** |
| **Consequence:**<br>- Trail back from edge of slump and on stiff soil. | |
| **Likelihood:**<br>- Low. Slow unless significant water flow. | |
| **Remedial Options:**<br>- Soil bio-engineering to remove water.<br>- Planting to remove water and stabilize soil. | |

| Photo No. | Bearing | Description |
|---|---|---|
| 355 | South West | Slide |
| 354 | North West | About 10 m upstream of slide, left bank |
| 356 | North | Downstream view |
| 357 | South | Upstream view |

**Photographs:**

Photo 355

Photo 354

Photo 356

Photo 357

| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Horn-06 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 13, 2017 |
| Site Location | Pedestrian Bridge and Ariel Pipe | | | | Easting | 550373 |
| Time | Start: | 12:15 p.m. | Bank: | Left/Right | Northing | 5434297 |
| | End: | 12:30 p.m. | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

**Type:** Existing Slough-Slide

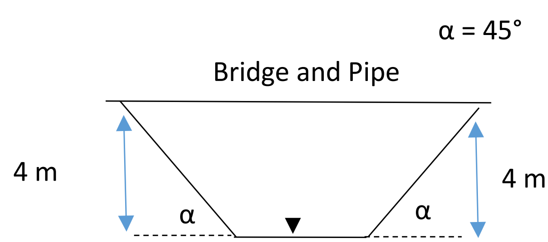
**Description:**

- Erosion of left bank under bridge and upstream/downstream sporadically.

**Slope:**

- Slope banks are about 4 m high and slope near vertical.
- The left bank beneath the bridge abutment is at about a 45° slope.  The slope is covered in coco matting.  Erosion is occurring underneath.
- Minimal erosion under pipe, but bank is over-steepened.
- Bridge on lock blocks.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**

- Stiff SILT with some clay and sand.  Angular gravel and cobble fill above.

**Stability Issues:**

- Continued erosion will undermine the bridge abutments and pipe supports.

**Access:**

- Via trail.

**Comparison to Previous Years:**

- First year assessed.

| |
|---|
| **Risk:** **High** |
| **Consequence:**<br>- Continued erosion will undermine the bridge and pipe.<br>- Erosion will cause sedimentation in creek |
| **Likelihood:**<br>- Continue seasonally. |
| **Remedial Options:**<br>- Riprap to protect banks.<br>- Step pools to reduce energy.<br>- Vegetate slopes outside bridge and pipe footprint |

| Photo No. | Bearing | Description |
|---|---|---|
| 363 | South West | Upstream view |
| 364 | South East | Right bank pipe support |
| 365 | South East | Right bank under bridge |
| 366 | South | Upstream view |
| 367 | South West | Downstream view |
| 362 | South West | Left bank at bridge |
| 358-359 | Left Bank | Upstream of bridge erosion |

**Photographs:**

Photo 363

Photo 364

Photo 365

Photo 366


Photo 367


Photo 362


Photo 358


Photo 359

| | | | | | | |
|---|---|---|---|---|---|---|
| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Horn-07 |
| Client: | Urban Systems Ltd. / Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 25, 2017 |
| Site Location | About 50 m downstream of pipe and bridge | | | | Easting | 0550377 |
| Time | Start: | 10:00 a.m. | Bank: | Right | Northing | 5434314 |
| | End: | 10:15 a.m. | | | Datum | WGS84 |
| Weather | Mix of sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

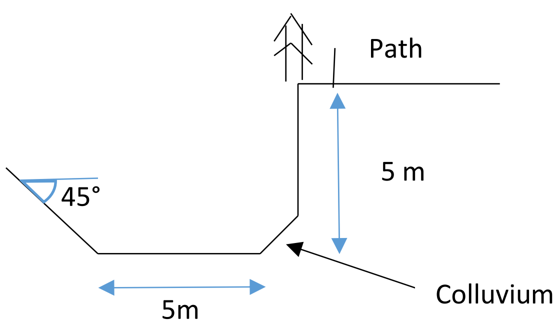
**Description:**

- Undermining of right bank may impact the path.

**Slope:**

- About 5 m high near vertical slope on right bank, which undercut tree roots at the crest of the slope.
- Colluvial deposits had accumulated at the toe of the slope.
- Some sloughing observed on left bank.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**

- Slope was generally dry, some wet spots in the slough at the base.
- The lower 4 m of the slope generally comprised hard, grey, sandy SILT and CLAY.
- The upper 1 m of the slope comprised sandy, cobbly GRAVEL.

**Stability Issues:**

- The oversteep slope will very likely continue to slough and retrogress.

**Access:**

- Via creek or path, likely difficult.

**Comparison to Previous Years:**

- First year assessed.

THURBER

60 YEARS

| | |
|---|---|
| **Risk:** **High** | |

**Risk:** **High**

**Consequence:**
- Retrogressing slope will undermine the path and houses above.
- Erosion will cause sedimentation in creek

**Likelihood:**
- The slope could retrogress quickly if the trees fall.

**Remedial Options:**
- Review the tree health by an arborist.
- Build up the base of the slope and cut back the slope crest to reduce overall slope angle.
- Geotextile reinforced slope, mechanically stabilized earth wall, and/or soil bio-engineering to buttress toe.

| Photo No. | Bearing | Description |
|---|---|---|
| 436 | East | Right bank, erosion feature |
| 437 | North East | Left bank |
| 438 | North East | Downstream view |
| 439 | South West | Upstream view |
| 440 | East | Bank soil |

**Photographs:**

Photo 436

Photo 437

Photo 438

Photo 439

Photo 440

| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Horn-08 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 25, 2017 |
| Site Location | Between Theissen and Bridge / pipe | | | | Easting | 0550466 |
| Time | Start: | 10:15 a.m. | Bank: | Right | Northing | 5434369 |
| | End: | 10:30 a.m. | | | Datum | WGS84 |
| Weather | Mix of sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

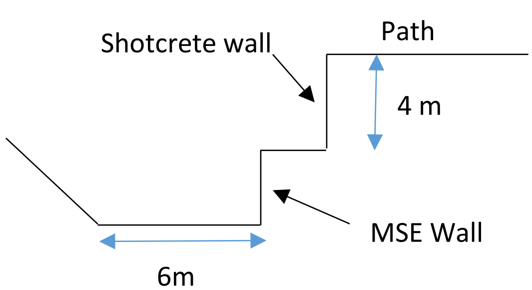
**Description:**

- Erosion on upstream side of shotcrete and downstream mechanically stabilized earth (MSE) wall toe.

**Slope:**

- The slope on upstream of feature above the portion of the shotcrete wall upstream of the lock block MSE wall exhibits erosion over a height of about 2 to 3 m. The eroded slope is supported by tree roots.
- Minor undermining of the MSE wall on downstream end of feature.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**

- The eroded area comprised brown, silty SAND and GRAVEL.

**Stability Issues:**

- Minor sloughing is likely to continue within the eroded area.

**Access:**

- Via Creek

**Comparison to Previous Years:**

- First year assessed.

| | |
|---|---|
| **Risk:** | **Medium** |

**Consequence:**

- Erosion of the slope may undermine the path.
- Erosion will cause sedimentation in creek

**Likelihood:**

- Erosion appears to advance at a slow rate.

**Remedial Options:**

- Monitor the eroded area.
- Apply additional shotcrete if erosion continues
- Place large rip-rap at the toe of the MSE wall for protection.

| Photo No. | Bearing | Description |
|---|---|---|
| 443 | South East | Feature on right bank |
| 444 | East | Feature on right bank |
| 445 | South East | Panorama view, upstream on right of center of picture, downstream on left of center |
| 446 | East | Shotcrete retaining path |
| 447 | North | Downstream view |
| 448 | South East | Erosion feature on right bank |
| 449 | North East | Downstream view of corner undermining of MSE wall |

**Photographs:**

Photo 443

Photo 444

Photo 445


Photo 446


Photo 447


Photo 448


Photo 449

THURBER

60 YEARS

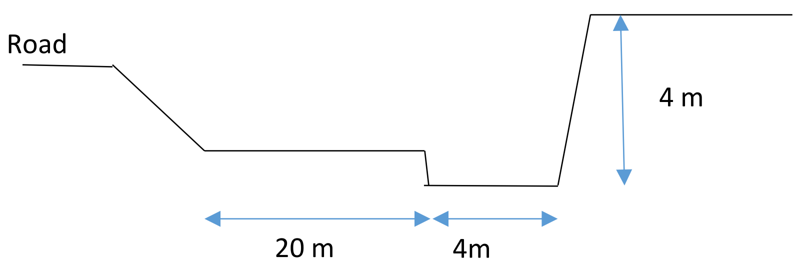
| Watercourse Stability Assessment Data Sheet | | | | | Report | Horn-09 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd. / Abbotsford | | | | File No. | 12189 |
| Watercourse | Horn Creek | | | | Date: | April 25, 2017 |
| Site Location | 3192 Horn Street | | | | Easting | 0550648 |
| Time | Start: | 10:35 a.m. | Bank: | Right | Northing | 5434411 |
| | End: | 10:50 a.m. | | | Datum | WGS84 |
| Weather | Mix of sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

**Description:**
- Erosion of the right bank due to undermining of the toe.

**Slope:**
- The erosion feature is about 4 m high and 25 m long.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- The slope comprises a stratified layering of silty SAND and GRAVEL, with some layers of sand.

**Stability Issues:**
- Erosion at the toe causes undermining of the slope.

**Access:**
- Access via Maclure Road

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** | **Low** |

**Consequence:**

- No nearby houses or infrastructure.
- Erosion will cause sedimentation in creek

**Likelihood:**

- Erosion appears to be ongoing.

**Remedial Options:**

- Place erosion protection at the toe of the slope to reduce toe erosion.
- Cut back crest of slope and vegetate

| Photo No. | Bearing | Description |
|---|---|---|
| 450 | South West | Right bank |
| 451 | South West | Right bank |
| 452 | South | Right bank |
| 453 | South East | Downstream view, right bank |
| 454 | South | Panorama view from upstream (right) to downstream (left) |

**Photographs:**

Photo 450

Photo 451

Photo 452

Photo 453

Photo 454

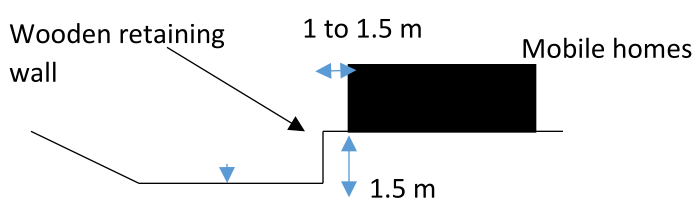
| Watercourse Stability Assessment Data Sheet | | | | | Report | Thiessen-01 |
|---|---|---|---|---|---|---|
| Client: | Urban Systems Ltd. / Abbotsford | | | | File No. | 12189 |
| Watercourse | Thiessen Creek | | | | Date: | April 13, 2017 |
| Site Location | Behind mobile homes | | | | Easting | 550702 |
| Time | Start: | 1:15 p.m. | Bank: | Right | Northing | 5434676 |
| | End: | 1:30 p.m. | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

**Type:** Erosion

**Description:**
- Property manager reported erosion behind mobile homes

**Slope:**
- Ground generally relatively flat.
- Creek about 0.5 to 1 m below surrounding banks.
- Mobile homes approximately 1 m to 1.5 m setback from the retaining wall.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- Ground generally saturated
- Soil not observed

**Stability Issues:**
- Retaining wall appears to be rotting.

**Access:**
- Via mobile home park.

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** | **Medium** |

**Consequence:**

- Degrading retaining walls could potentially impact the mobile homes and creek.

**Likelihood:**

- Slow rotting of wood, could increase during higher flows.

**Remedial Options:**

- Remove or rebuild retaining walls.
- Recommend property and home owners retain geotechnical engineer to assess foundations for mobile homes and condition of retaining wall.
- Move mobile homes away from the creek to reduce potential for undermining.

| Photo No. | Bearing | Description |
|---|---|---|
| 382 | South West | Across Creek view |
| 383 | South | Downstream view |
| 385 | South West West | Upstream view, retaining walls and mobile homes |
| 386 | South West | Mobile homes and retaining walls |

**Photographs:**


Photo 382


Photo 383


Photo 385


Photo 386

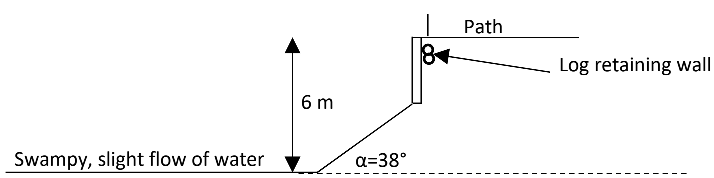
| | | | | | | |
|---|---|---|---|---|---|---|
| **Watercourse Stability Assessment Data Sheet** | | | | | **Report** | Willband-01 |
| Client: | Urban Systems Ltd./Abbotsford | | | | File No. | 12189 |
| Watercourse | Willband Creek | | | | Date: | April 13, 2017 |
| Site Location | 33338 Bourquin Crescent | | | | Easting | 0551100 |
| Time | Start: | 9:10 a.m. | Bank: | Right | Northing | 5434943 |
| | End: | 9:30 a.m. | | | Datum | WGS84 |
| Weather | Sun and clouds | | | | Inspector | BSP |

**Type:** Existing Slough-Slide

**Description:**
- Right bank of creek, north east side of path.

**Slope:**
- 38° slope about 6 m high and 20 m long.  Over-steepened slope on side of path.
- Path retained by wooden posts with logs and timber behind.

**Sketch:** (Not to scale. Facing downstream)




**Soil and Water Conditions:**
- Compact/firm, brown, moist SILT and SAND.
- Path comprises 19 mm minus SAND and GRAVEL.

**Stability Issues:**
- Bank over-steepened, erosion and raveling occurring.
- Rubbish on slope (old Christmas trees).
- Some leaves appear piled on the north end.

**Access:**
- Easy.  Access via path from Bourquin Street.

**Comparison to Previous Years:**
- First year assessed.

| | |
|---|---|
| **Risk:** | **Medium** |

**Consequence:**

- Environmental damage to creek and habitat if retaining wall fails.

**Likelihood:**

- Erosion appears contained to small sloughs on surface.

**Remedial Options:**

- Cut back slope crest and vegetate if possible to move path.
- If retaining wall is designed to remain, monitor and remediate as required. Complete revegetation and / or soil bio-engineering to stabilize surficial sloughing below retaining wall.

| Photo No. | Bearing | Description |
|---|---|---|
| 309, 310, 317 | North | Retaining wall |
| 311, 315, 316 | North East | Downslope |
| 312, 318 | South | Retaining wall |
| 313 | Down | Soil on slope |
| 314 | North | Along path at top of slope |

**Photographs:**


Photo 309


Photo 310


Photo 317


Photo 311

THURBER

60 YEARS


Photo 315


Photo 316


Photo 312


Photo 318


Photo 313


Photo 314

# APPENDIX E

Hydrological Model

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# Technical Memorandum

## Future Condition Drainage Modeling of Willband Creek Watershed

**FINAL**

| | |
|---|---|
| **project:** | Willband Creek Integrated Stormwater Management Plan |
| **project ID:** | 2016-006-ABB |
| **date:** | July 6, 2018 |
| **issued to:** | Urban Systems Ltd. (USL) |
| **issued by:** | GeoAdvice Engineering Inc. (GeoAdvice) |

## 1. Introduction

The purpose of this technical memorandum is to document the modeling assumptions and results for the Willband Creek future condition stormwater model.

Please refer to the technical memorandum *Drainage Modeling of Willband Creek Watershed (Interim Results for Review)* dated June 19, 2017 for detailed descriptions of the existing condition model development, calibration, and results.

## 2. Future Condition Model Development

### 2.1. Future Condition Land Use

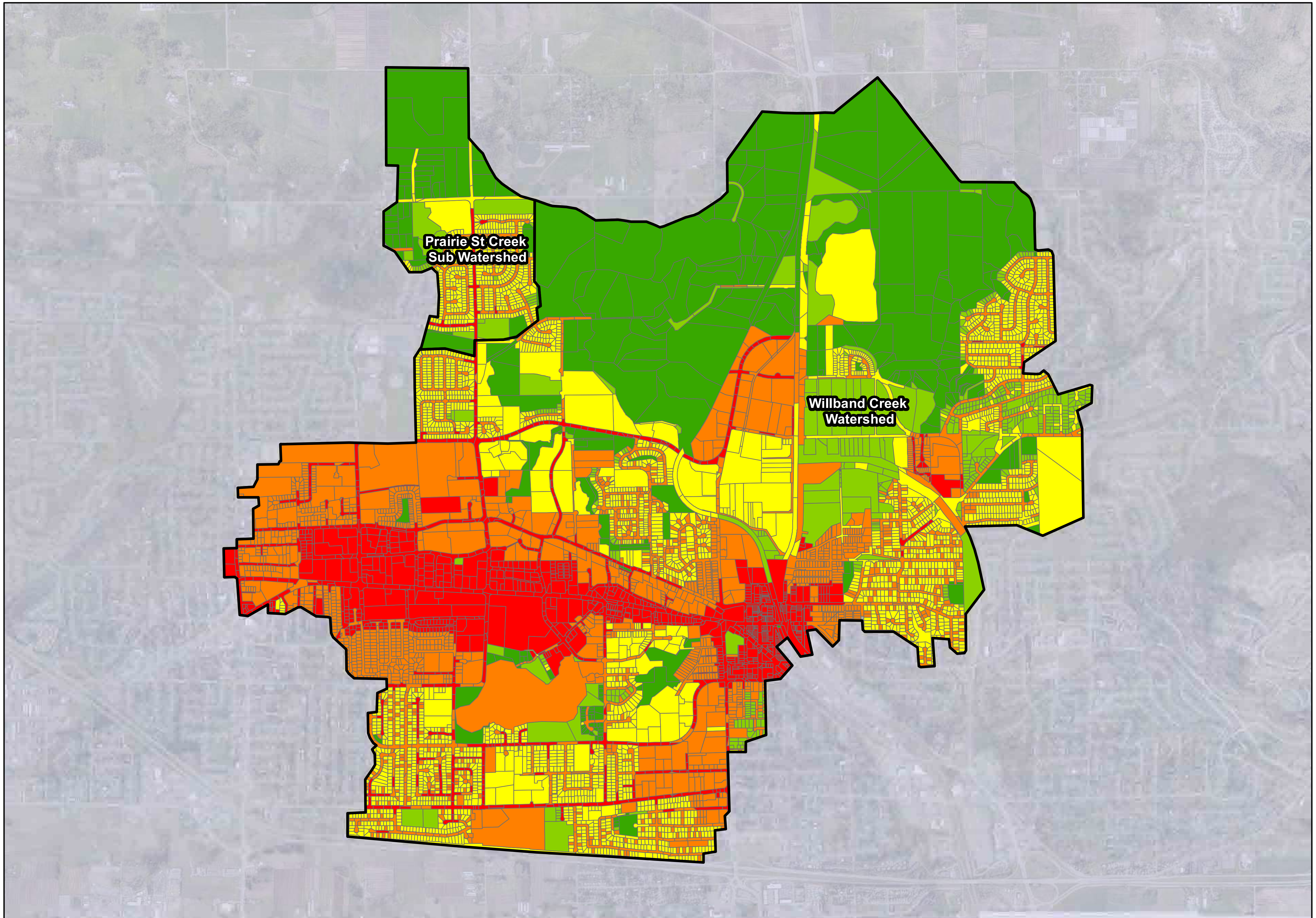
In consultation with Urban Systems, the Willband Creek total impervious areas and the portion of total impervious area redirected to ground for infiltration were estimated based on land use designations from the City Official Community Plan (OCP). Further, it was assumed that only the properties defined in the City's "Build_35" dataset experience a land use change. The assumptions used in defining the hydrology parameters are summarized in **Table 2.1.**

**Table 2.1: Willband Creek Future Condition Total Impervious Parameters**

| Willband OCP Land Use Designations | Total Impervious Area % | Portion of Total Impervious Area Redirected to Ground for Infiltration (%) |
|---|---|---|
| FN Reserve | Existing* | Existing* |
| City Centre | 90 | 50 |
| Urban Centre | 90 | 50 |
| Neighbourhood Centre | 90 | 50 |
| Urban 1 – Midrise | 80 | 50 |
| Urban 2 – Ground | 80 | 50 |
| Urban 3 – Infill | 65 | 90 |
| Urban 4 – Detached | 60 | 90 |
| Urban Large Lot | 40 | 90 |
| Suburban | 40 | 90 |
| Secondary Commercial | 90 | 50 |
| Regional Commercial | 90 | 50 |
| General Industrial | 90 | 0 |
| High Impact Industrial | 90 | 0 |
| Hospital | 90 | 50 |
| Institutional Complex | 90 | 50 |
| Institutional | 90 | 50 |
| Agricultural | Existing* | Existing* |
| Open Space | Existing* | Existing* |

* Parameters do not change from the existing condition.

**Figure 2.1** shows the subcatchment total impervious percentage under the future land use condition.




GeoAdvice Engineering Inc.

## Legend

Watershed Area

**Total Impervious Percentage**

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

**Future Land Use Subcatchment Impervious Percentage**

ABBOTSFORD

Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure 3.2**

## 2.2. Site Controls

Site controls were applied to the model as summarized in **Table 2.2**. As with the future land use change, only the “Build_35” dataset was considered for the application of site controls.

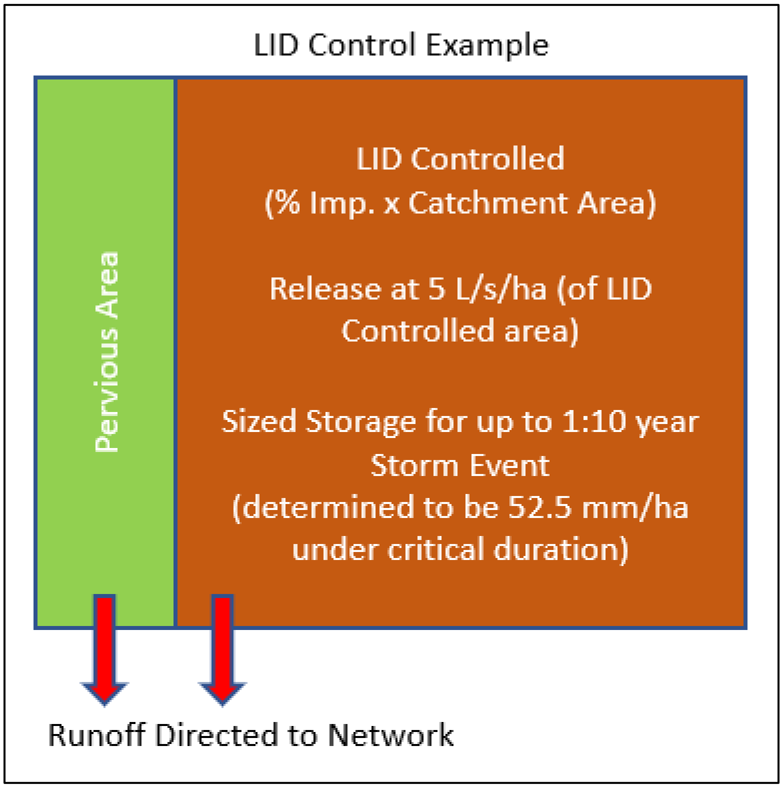
**Table 2.2: Willband Creek Future Condition Hydrology Parameters**

| Willband OCP Land Use Designations | Are Engineered Detention Control Applied? | Modeling Site Control Assumptions |
|---|---|---|
| **FN Reserve** | No | No controls |
| **City Centre** | Yes | 100% of runoff from impervious surfaces is controlled by a detention facility to 5 L/s/ha (up to the 10-year event)* |
| **Urban Centre** | Yes | |
| **Neighbourhood Centre** | Yes | |
| **Urban 1 – Midrise** | Yes | |
| **Urban 2 – Ground** | Yes | |
| **Urban 3 – Infill** | No | Applied 95.5 mm (1:10 year 24-hour rainfall total) of depression storage to represent rock pits/drain wells designed to store and infiltrate a 1:10 year 24-hour rainfall event |
| **Urban 4 – Detached** | No | |
| **Urban Large Lot** | No | |
| **Suburban** | No | |
| **Secondary Commercial** | Yes | 100% of runoff from impervious surfaces is controlled by a detention facility to 5 L/s/ha (up to the 10-year event)* |
| **Regional Commercial** | Yes | |
| **General Industrial** | Yes | |
| **High Impact Industrial** | Yes | |
| **Hospital** | Yes | |
| **Institutional Complex** | Yes | |
| **Institutional** | Yes | |
| **Agricultural** | No | No controls |
| **Open Space** | No | No controls |

* For the 10-year event at minimum. If an unsuitable major flow path exists, detention is required to the 100-year level at a release rate of 5 L/s/ha.

The Low Impact Development (LID) module in the SWMM program was used to model the site controls that required both detention and controlled release components. **Figure 2.2** below provides an illustration of how LID controls were applied. While the prescribed release rate is set to 5 L/s/ha, the required detention was determined to be 52.5 mm/ha.

**Figure 2.2: LID Control Example**




## 2.3. Climate Change

Climate change was considered in the modeling and capacity analysis by directly scaling the design storm hyetographs by an additional 10%.

## 2.4. Flood Cells

Flood cell storage information from the Matsqui drainage study[1] was provided by Kerr Wood Leidal (KWL). This information was incorporated into the Willband Creek drainage model to simulate the available storage in the lowland areas. The modeled flood cells also serve to support flood mapping.

**Figure 2.3** shows the flood cell boundaries.

**Figure 2.4** and **Figure 2.5** show the flood cell storage rating curves.

[1] Kerr Wood Leidal, Matsqui Prairie Drainage Study – Phase I Final Report, June 2013

**Figure 2.3: Willband Creek Flood Cell Areas**

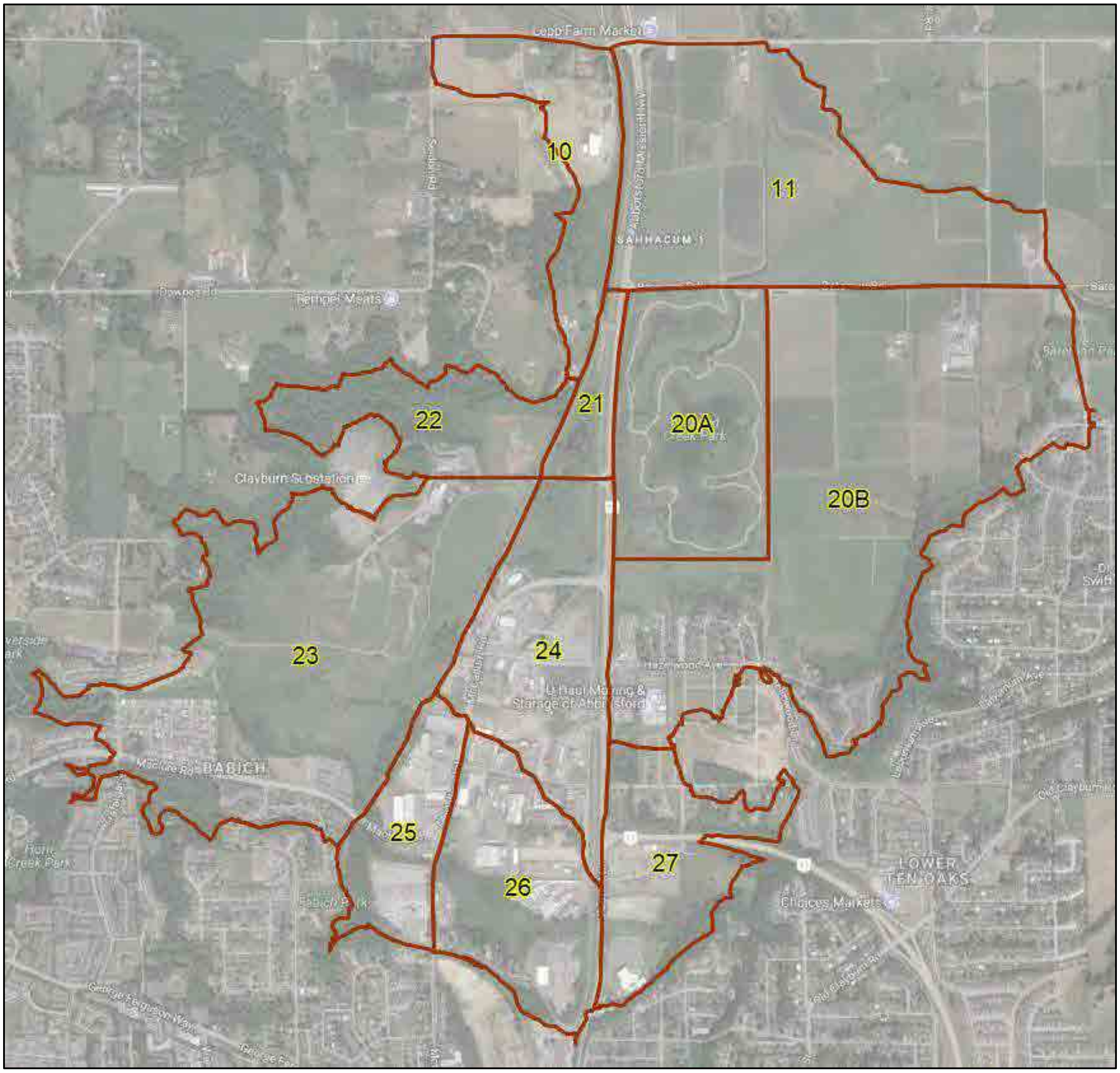


**Figure 2.4: Willband Creek Flood Cell Storage Rating Curves**

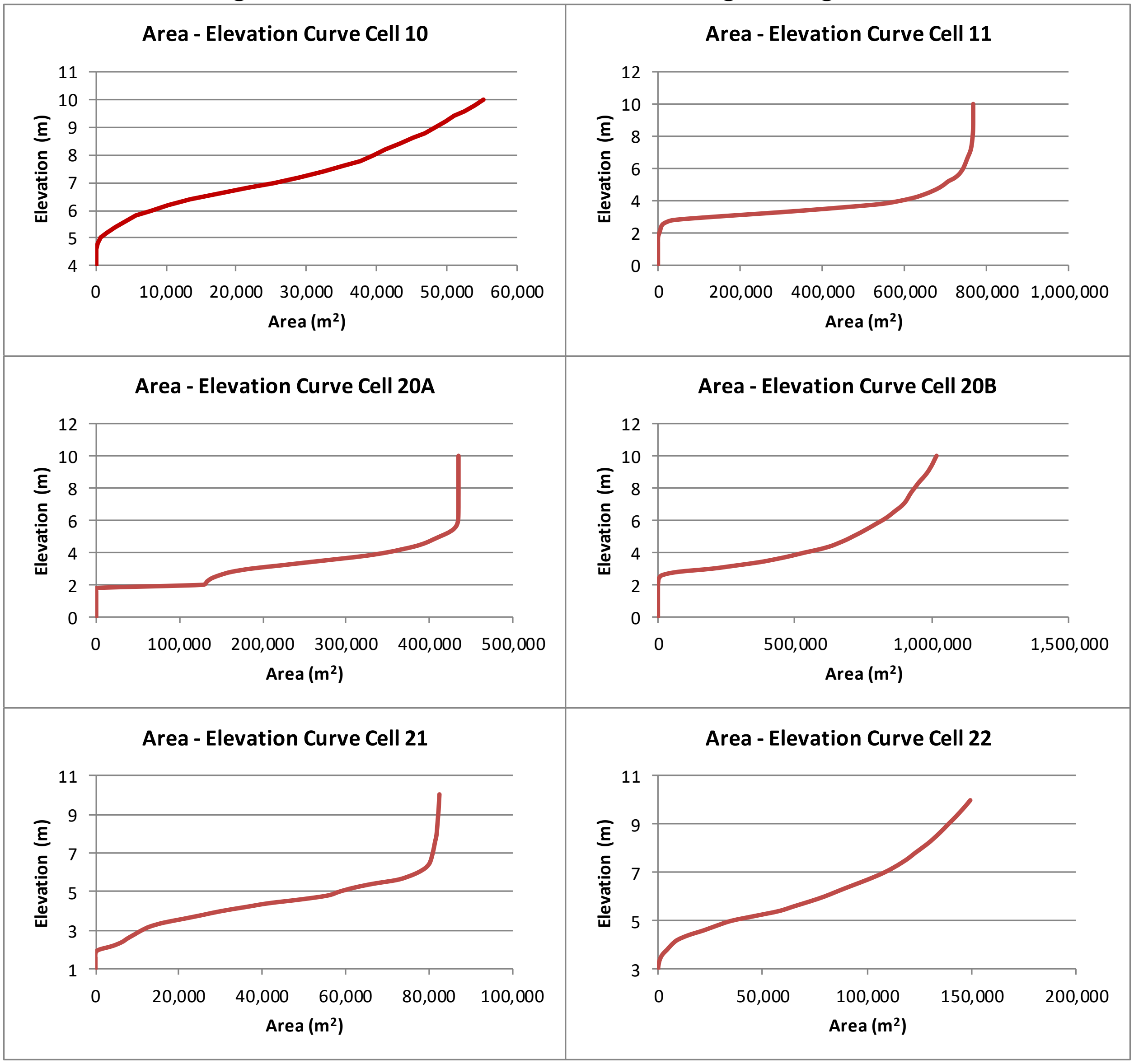
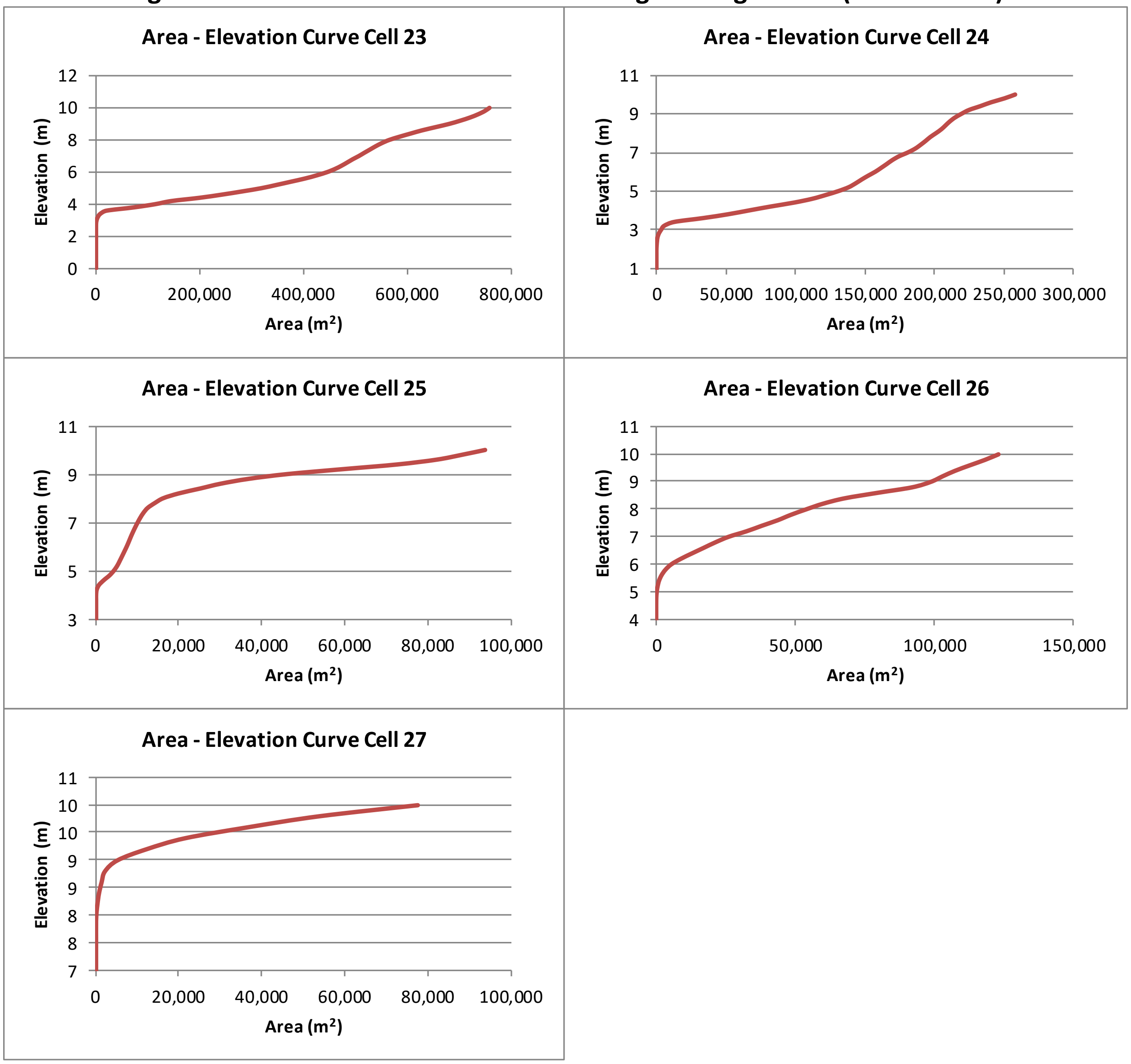


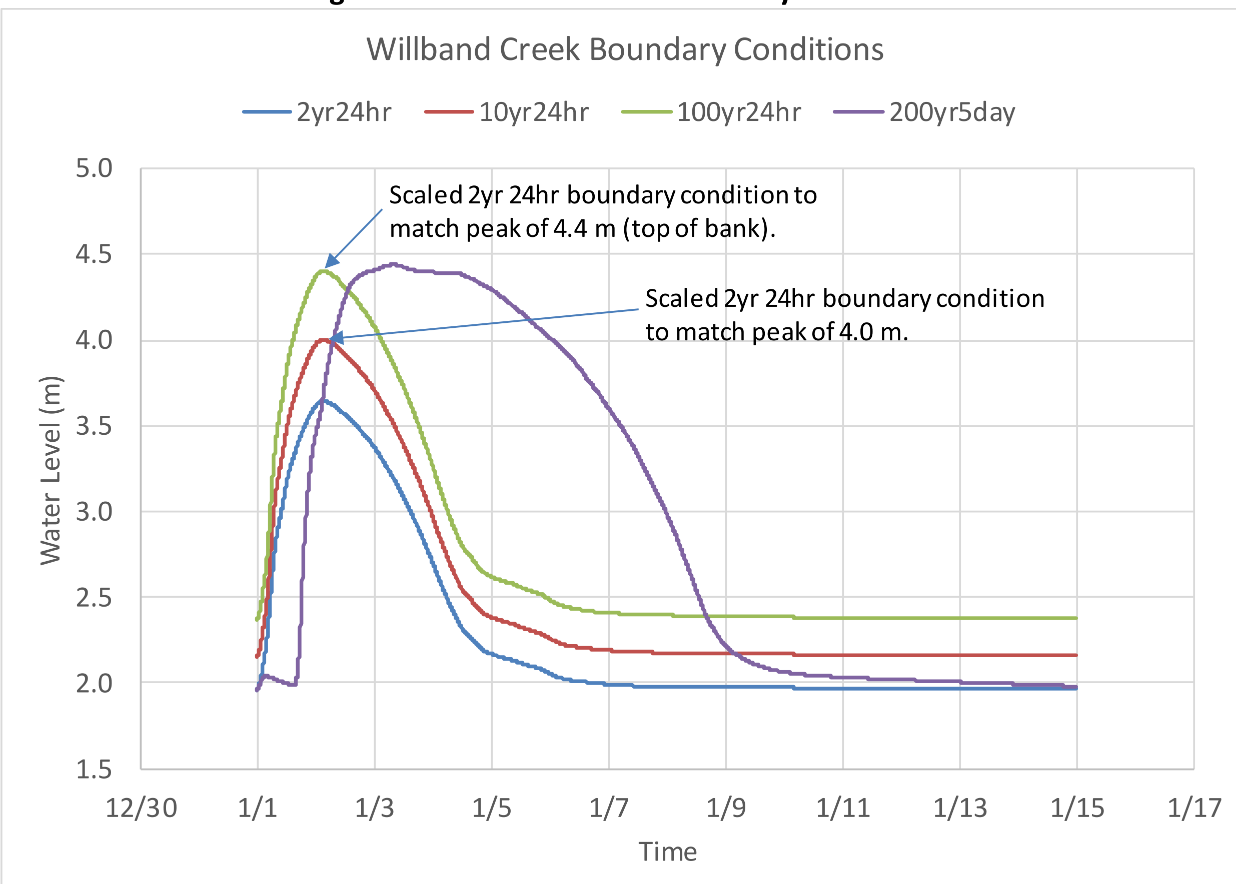
**Figure 2.5: Willband Creek Flood Cell Storage Rating Curves (Continued…)**



## 2.5. Boundary Conditions

Model boundary conditions at the Matsqui Slough were provided by KWL. It was concluded that these boundary conditions were applicable only to design storm events that were 24 hours or longer in duration. Hence, the future land use boundary conditions as shown in **Figure 2.6** were applied to the outfall of the Willband Creek drainage model. The 10-year and 100-year 24-hour boundary conditions were not provided; therefore, the 2-year 24-hour boundary condition was scaled up until the peak level reached 4.0 m and 4.4 m, respectively.

**Figure 2.6: Willband Creek Boundary Conditions**




The boundary condition for all other design storm scenarios assumes a fixed water level of 2.0 m.

### 2.6. City Centre and Historic Downtown Neighbourhood Plans

City Centre and Historic Downtown Neighbourhoods were modeled assuming full build-out land use conditions. Please refer to the City Centre and Historic Downtown neighbourhood plans for more details regarding the modeling assumptions, system assessments and proposed upgrades.

## 3. Storm Main and Culvert Upgrades

The storm main upgrades were categorized as follows:

- **Upgrade Priority 1** – Upgrade is recommended to alleviate mains that do not meet design criteria. This is applicable to minor and major systems. The highest priorities are for existing mains that remain surcharged even with the application of on-site controls.
- **Upgrade Priority 2** – Upgrade is recommended to alleviate mains that do not meet design criteria. This is applicable to minor and major systems. Surcharging of these mains could be rectified with implementation of on-site controls.
- **Upgrade Priority 3** – Existing storm mains with a diameter of less than 300 mm are upgraded to the City's desired minimum diameter of 300 mm.
- **New Main** – New storm mains are proposed along road right-of-ways where existing storm mains are not present.

The following is a summary of the storm main upgrades.

**Table 3.1: Willband Storm Main and Culvert Upgrade Summary***

| Upgrade Category | 10-Year Design Upgrade Length (m) | 100-Year Design Upgrade Length (m) |
|---|---|---|
| **Upgrade Priority 1 - Culvert** | 12 | 0 |
| **Upgrade Priority 2 - Culvert** | 35 | 10 |
| **Upgrade Priority 1** | 2,804 | 0 |
| **Upgrade Priority 2** | 1,466 | 0 |
| **Upgrade Priority 3** | 7,038 | 0 |
| **New Main** | 7,672 | 0 |
| **Total** | **19,026** | **10** |

* Excludes upgrades within the City Centre and Historic Downtown Neighbourhood Plans.

**Table 3.2: City Centre Neighbourhood Storm Main and Culvert Upgrade Summary**

| Upgrade Category | 10-Year Design Upgrade Length (m) | 100-Year Design Upgrade Length (m) |
|---|---|---|
| Upgrade Priority 1 | 695 | 0 |
| Upgrade Priority 2 | 2,433 | 0 |
| Upgrade Priority 3 | 966 | 0 |
| New Main | 4,481 | 0 |
| **Total** | **8,575** | **0** |

**Table 3.3: Historic Downtown Neighbourhood Storm Main and Culvert Upgrade Summary**

| Upgrade Category | 10-Year Design Upgrade Length (m) | 100-Year Design Upgrade Length (m) |
|---|---|---|
| Upgrade Priority 1 - Culvert | 0 | 14 |
| Upgrade Priority 1 | 61 | 166 |
| Upgrade Priority 2 | 1,127 | 108 |
| Upgrade Priority 3 | 2,817 | 0 |
| New Main | 2,979 | 0 |
| **Total** | **6,985** | **288** |

All new mains and main upgrades were assigned a Manning's 'n' roughness coefficient of 0.013.

The storm main and culvert upgrades are shown in **Figure 3.1** and listed in **Appendix G**.

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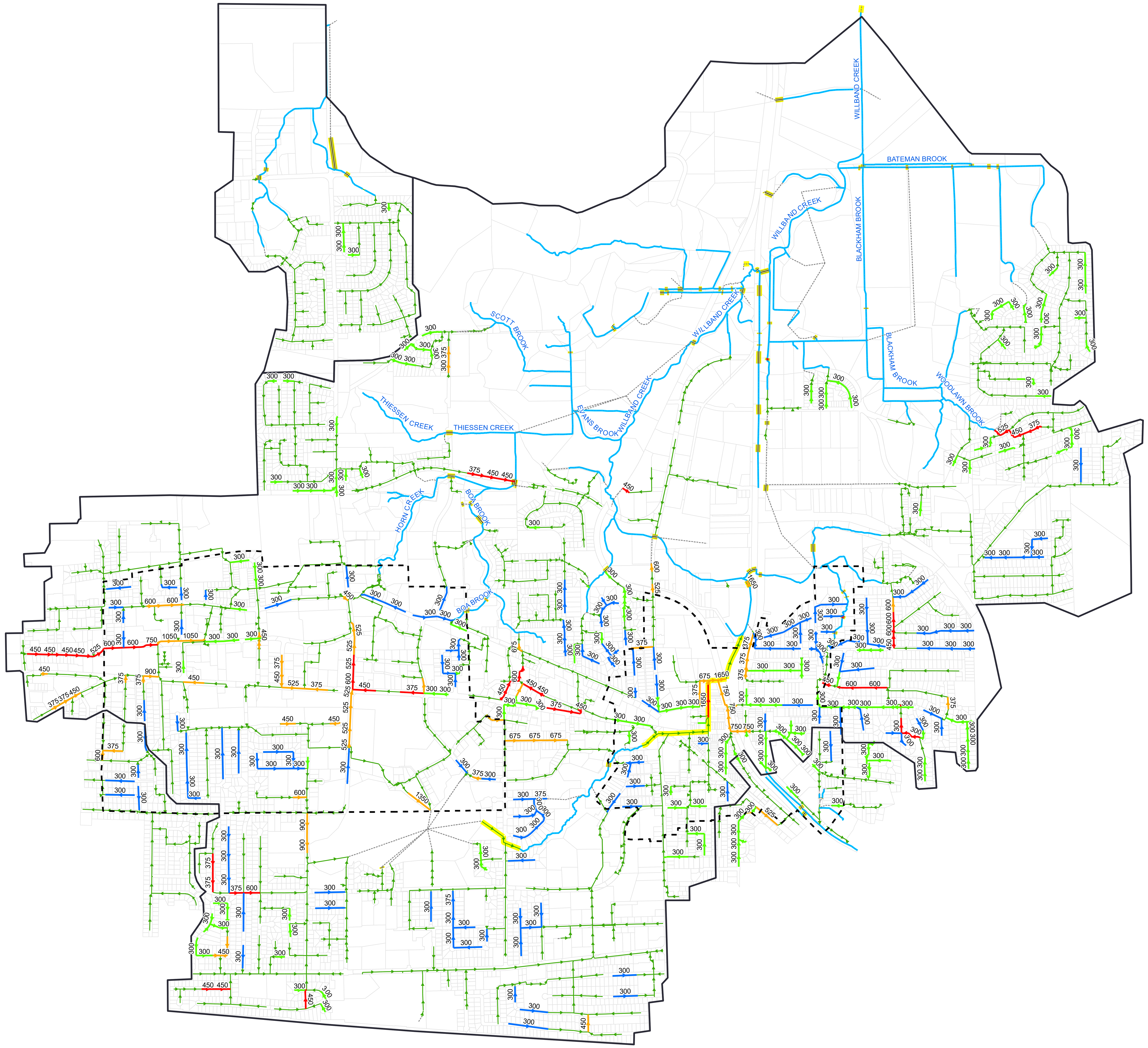


## Legend

- Willband Creek Watershed Area
- City Centre Neighbourhood Boundary
- Historic Downtown Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments

## Upgrade Category

- Upgrade Priority 1
- Upgrade Priority 2
- Upgrade Priority 3
- New Main

Upgrade Priority 1 – Upgrade is recommended to alleviate mains that do not meet design criteria. This is applicable to minor and major systems. The highest priorities are for existing mains that remain surcharged even with the application of on-site controls under Scenario 2.

Upgrade Priority 2 – Upgrade is recommended to alleviate mains that do not meet design criteria. This is applicable to minor and major systems. Surcharging of these mains cold be rectified with implementation of on-site controls.

Upgrade Priority 3 – Existing storm mains with a diameter of less than 300 mm are upgraded to the City's desired minimum diameter of 300 mm.

New Main – New storm mains are proposed along road right-of-ways where existing storm mains are not present.

**Required Storm Main and Culvert Upgrades to Meet Established Criteria**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure 3.1**

# 4. Drainage Assessment

## 4.1. Scenarios and Map Figures

The future condition model was assessed under various design storms and site controls for comparison. The list of scenarios and the associated figures showing the modeled system performance and assessment results are summarized in **Table 4.1**. The figures listed in **Table 4.1** are provided in the appendices.

**Table 4.1: List of Scenarios and Figures**

| Scenario | Figure | Figure Title |
|---|---|---|
| Future Land Use "**Appendix A**" | A.1 | 10-Year, Critical Duration System Performance (Future Land Use) |
| | A.2 | 100-Year, Critical Duration System Performance (Future Land Use) |
| | A.3 | 200-Year, 5-Day System Performance (Future Land Use) |
| | A.4 | Storm Sewers Assessed Against Established Criteria (Future Land Use) |
| | A.5 | Culverts Assessed Against Established Criteria (Future Land Use) |
| | A.6 | Detention Facilities Assessed Against Established Criteria (Future Land Use) |
| | A.7 | Creeks Assessed Against Established Criteria (Future Land Use) |
| Future Land Use with Controls "**Appendix B**" | B.1 | 10-Year, Critical Duration System Performance (Future Land Use with Controls) |
| | B.2 | 100-Year, Critical Duration System Performance (Future Land Use with Controls) |
| | B.3 | 200-Year, 5-Day System Performance (Future Land Use with Controls) |
| | B.4 | Storm Sewers Assessed Against Established Criteria (Future Land Use with Controls) |
| | B.5 | Culverts Assessed Against Established Criteria (Future Land Use with Controls) |
| | B.6 | Detention Facilities Assessed Against Established Criteria (Future Land Use with Controls) |
| | B.7 | Creeks Assessed Against Established Criteria (Future Land Use with Controls) |

| Scenario | Figure | Figure Title |
|---|---|---|
| Future Land Use (Climate Change) "**Appendix C**" | C.1 | 10-Year, Critical Duration System Performance (Future Land Use - Climate Change) |
| | C.2 | 100-Year, Critical Duration System Performance (Future Land Use - Climate Change) |
| | C.3 | 200-Year, 5-Day System Performance (Future Land Use - Climate Change) |
| | C.4 | Storm Sewers Assessed Against Established Criteria (Future Land Use - Climate Change) |
| | C.5 | Culverts Assessed Against Established Criteria (Future Land Use - Climate Change) |
| | C.6 | Detention Facilities Assessed Against Established Criteria (Future Land Use - Climate Change) |
| | C.7 | Creeks Assessed Against Established Criteria (Future Land Use - Climate Change) |
| Future Land Use with Controls (Climate Change) "**Appendix D**" | D.1 | 10-Year, Critical Duration System Performance (Future Land Use with Controls - Climate Change) |
| | D.2 | 100-Year, Critical Duration System Performance (Future Land Use with Controls - Climate Change) |
| | D.3 | 200-Year, 5-Day System Performance (Future Land Use with Controls - Climate Change) |
| | D.4 | Storm Sewers Assessed Against Established Criteria (Future Land Use with Controls - Climate Change) |
| | D.5 | Culverts Assessed Against Established Criteria (Future Land Use with Controls - Climate Change) |
| | D.6 | Detention Facilities Assessed Against Established Criteria (Future Land Use with Controls - Climate Change) |
| | D.7 | Creeks Assessed Against Established Criteria (Future Land Use with Controls - Climate Change) |

| Scenario | Figure | Figure Title |
|---|---|---|
| Future Land Use with Upgrades and No Controls (Climate Change) "**Appendix E**" | E.1 | 10-Year, Critical Duration System Performance (Future Land Use with Upgrade - Climate Change) |
| | E.2 | 100-Year, Critical Duration System Performance (Future Land Use with Upgrades - Climate Change) |
| | E.3 | 200-Year, 5-Day System Performance (Future Land Use with Upgrades - Climate Change) |
| | E.4 | Storm Sewers Assessed Against Established Criteria (Future Land Use with Upgrades - Climate Change) |
| | E.5 | Culverts Assessed Against Established Criteria (Future Land Use with Upgrades - Climate Change) |
| | E.6 | Detention Facilities Assessed Against Established Criteria (Future Land Use with Upgrades - Climate Change) |
| | E.7 | Creeks Assessed Against Established Criteria (Future Land Use with Upgrades - Climate Change) |

Design storm durations impact the time of concentration of flows within a drainage system. Peak flows within the upper regions may be governed by shorter durations while lower regions by longer durations. Hence it was necessary to simulate the full suite of duration storms for each return period to determine the condition in which the highest flows occur in the system. The duration of the storm event causing the highest flow is referred to as the critical duration.

## 4.2. Design Criteria

**Table 4.2** summarizes the City's stormwater criteria consolidated from City Bylaws and past reports. A clear distinction is made between the criteria for upland and lowland regions.

**Table 4.2: City's Stormwater Criteria**

| Stormwater System | Stormwater Criteria |
|---|---|
| Detention Requirement | 10-year peak flows detained to 5 L/s/ha. |
| Storm sewer | Safe conveyance of 10-year peak flows in minor systems.<br>Safe conveyance of 100-year peak flows in major systems. |
| ***Upland Region Criteria*** | |
| Culvert | Safe conveyance of 100-year peak flows. |
| Creek | 200-year peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands. |
| ***Lowland Region Criteria*** | |
| Culvert | Safe conveyance of 10-year peak flows. |
| Creek | 2-year peak flow to be contained within the lowland creek banks. |
| Sources:<br>City of Abbotsford Storm Water Source Control Bylaw, 2011 (Bylaw No. 2045-2011)<br>City of Abbotsford Development Bylaw, 2011 (Bylaw No. 2070-2011)<br>Clayburn Creek Integrated Stormwater Management Plan, May 2012<br>Matsqui Prairie Drainage Study - Phase I, June 2013 | |

## 4.3. Storm Main Assessment

### *Minor System Assessment*

The storm mains of the minor system were assessed by simulating their ability to safely convey the minor flow, generated from the 10-year return period rainfall event. Storm sewers were determined to be undersized if the following criteria were met:

- Modeled peak flow is greater than full pipe capacity;
- Pipe surcharged for longer than 5 minutes; and
- Water surcharged above the crown of the pipe.

### *Major System Assessment*

The storm mains that convey stormwater flows from Mill Lake and stormwater flows in between creeks were considered as part of the major system. The major storm sewers were assessed by simulating their ability to safely convey the major flow, generated during the 100-year return period rainfall event. Storm mains were defined as undersized if the following criteria were met:

- Simulated peak flow is greater than full pipe capacity;
- Pipe is surcharged for longer than 15 minutes; and
- Peak water level is surcharged above the crown of the pipe.

**Table 4.3** shows the storm main assessment results statistics comparing the various scenarios.

**Table 4.3: Storm Main Assessment Results Statistics**

| Scenario | Total Length (m) | Length Undersized (m) | % Undersized |
|---|---|---|---|
| **Minor System (10-Year)** | | | |
| Future Land Use | 89,790 | 6,805 | 8% |
| Future Land Use with Controls | 89,790 | 2,520 | 3% |
| Future Land Use (Climate Change) | 89,790 | 9,618 | 11% |
| Future Land Use with Controls (Climate Change) | 89,790 | 3,749 | 4% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 116,375 | 1,211* | 1% |
| **Major System (100-Year)** | | | |
| Future Land Use | 1,194 | 189 | 16% |
| Future Land Use with Controls | 1,194 | 0 | 0% |
| Future Land Use (Climate Change) | 1,194 | 372 | 31% |
| Future Land Use with Controls (Climate Change) | 1,194 | 166 | 14% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 1,194 | 0 | 0% |

* The remaining undersized storm mains of the “Future Land Use with Upgrades” scenario do not warrant an upgrade as they were surcharged due to downstream flow control structured or backwater from a change in pipe size.

## 4.4. Culvert Assessment

The culverts were assessed by evaluating their ability to safely convey minor and major flows generated from the 10-year and 100-year return period rainfall events.

Culverts were determined to be undersized if the following criteria were met:

- Upland Culvert – Modeled 100-year peak flow is greater than full flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.
- Lowland Culvert – Modeled 10-year peak flow is greater than full flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.

**Table 4.4** shows the culvert assessment results statistics comparing the various scenarios.

**Table 4.4: Culvert Assessment Results Statistics**

| Scenario | Total Length (m) | Length Undersized (m) | % Undersized |
|---|---|---|---|
| **Lowland (10-Year)** | | | |
| Future Land Use | 1,182 | 63 | 5% |
| Future Land Use with Controls | 1,182 | 0 | 0% |
| Future Land Use (Climate Change) | 1,182 | 75 | 6% |
| Future Land Use with Controls (Climate Change) | 1,182 | 12 | 1% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 1,182 | 29* | 2% |
| **Upland (100-Year)** | | | |
| Future Land Use | 471 | 10 | 2% |
| Future Land Use with Controls | 471 | 0 | 0% |
| Future Land Use (Climate Change) | 471 | 10 | 2% |
| Future Land Use with Controls (Climate Change) | 471 | 0 | 0% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 471 | 0 | 0% |

* Culvert ID 115005 (length of 29 m) crossing Maclure Rd is undersized in the "Future Land Use with Upgrades" scenario due to an increase in flows as the upstream capacity constraints are alleviated. However, an upgrade was not recommended as this culvert is part of a triple culvert system that has sufficient capacity.

## 4.5. Creek Assessment

The creeks of the major system were assessed by simulating their ability to safely convey and contain the 2-year and 200-year flows. Creek capacity was assessed based on the following criteria:

- 2-year 24-hour peak flow to be contained within the lowland creek banks.
- 200-year 5-day peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands.

**Table 4.5** shows the creek assessment results statistics comparing the various scenarios.

**Table 4.5: Creek Assessment results Statistics**

| Scenario | Total Length (m) | Length Undersized (m) | % Undersized |
|---|---|---|---|
| **Lowland (2-Year)** | | | |
| Future Land Use | 24,668 | 7,141 | 29% |
| Future Land Use with Controls | 24,668 | 7,208 | 29% |
| Future Land Use (Climate Change) | 24,668 | 7,208 | 29% |
| Future Land Use with Controls (Climate Change) | 24,668 | 7,208 | 29% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 24,668 | 7,219 | 29% |
| **Upland (200-Year)** | | | |
| Future Land Use | 6,654 | 76 | 1% |
| Future Land Use with Controls | 6,654 | 40 | 1% |
| Future Land Use (Climate Change) | 6,654 | 76 | 1% |
| Future Land Use with Controls (Climate Change) | 6,654 | 40 | 1% |
| Future Land Use with Upgrades and No Controls (Climate Change) | 6,654 | 250 | 4% |

The lowland creek system performance is dependant on the boundary condition at the Matsqui Slough and therefore does not change significantly between scenarios.

The model predicts a greater number of undersized upland creek segments as the pipe upgrades alleviated upstream capacity constraints.

## 4.6. Detention Assessment

The detention facilities were assessed by evaluating their ability to detain the 10-year flow and release at a rate of 5 L/s/ha.

**Table 4.6** shows the undersized detention facilities under each scenario.

**Table 4.6: Willband Detention Assessment**

| Scenario | Undersized Detention Facilities |
|---|---|
| Future Land Use | SU01, SU04, SU07, SU11, SU12 |
| Future Land Use with Controls | SU01, SU04, SU07, SU11, SU12 |
| Future Land Use (Climate Change) | SU01, SU04, SU07, SU11, SU12, SU13 |
| Future Land Use with Controls (Climate Change) | SU01, SU04, SU07, SU11, SU12, SU13 |
| Future Land Use with Upgrades and No Controls (Climate Change) | SU01, SU04, SU07, SU11, SU12, SU13 |

Detailed detention assessment results are provided in **Appendix F**.

## 4.7. Mill Lake Assessment

The Mill Lake detention pond discharge flow rate and water surface elevation are controlled by the weir control structure at the outlet. **Table 4.7** summarizes the peak discharge flow rate and maximum water surface elevation under the various modeling scenarios and return periods. The performance is based on the assumption that the outlet stop logs are at their highest setting of 51.65 m.

**Table 4.7: Mill Lake Performance Results**

| Model Results | Return Period | | | |
|---|---|---|---|---|
| | 2-year 24-hour | 10-year Critical Duration | 100-year Critical Duration | 200-year 5-day |
| **Future Land Use** | | | | |
| Peak Discharge Flow ($m^3/s$) | 0.55 | 1.08 | 1.27 | 1.25 |
| Max. HGL (m) | 51.80 | 51.87 | 51.98 | 51.97 |
| **Future Land Use with Controls** | | | | |
| Peak Discharge Flow ($m^3/s$) | 0.56 | 0.81 | 1.11 | 1.17 |
| Max. HGL (m) | 51.80 | 51.83 | 51.91 | 51.93 |
| **Future Land Use (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | 0.61 | 1.11 | 1.40 | 1.38 |
| Max. HGL (m) | 51.81 | 51.90 | 52.03 | 52.02 |
| **Future Land Use with Controls (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | 0.60 | 0.93 | 1.22 | 1.29 |
| Max. HGL (m) | 51.81 | 51.84 | 51.95 | 51.99 |
| **Future Land Use with Upgrades and No Controls (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | 0.61 | 1.11 | 1.40 | 1.38 |
| Max. HGL (m) | 51.81 | 51.90 | 52.03 | 52.02 |

Notes:
Results presented under the 10 and 100-year return periods represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour). The 5-day duration was run for the 200-year return period.

## 4.8. Willband Stormwater Detention Facility Assessment

The Willband stormwater detention facility is situated in the lowland area and is impacted by backwater from the Matsqui Slough. **Table 4.8** summarizes the peak discharge flow rate of Willband Creek on Bateman Rd and the maximum water surface elevation under the various modeling scenarios and return periods.

**Table 4.8: Willband Stormwater Detention Facility Performance Results**

| Model Results | Return Period | | | |
|---|---|---|---|---|
| | 2-year 24-hour | 10-year Critical Duration | 100-year Critical Duration | 200-year 5-day |
| **Future Land Use** | | | | |
| Peak Discharge Flow ($m^3/s$) | -4.50 | -6.29 | -8.71 | -5.42 |
| Max. HGL (m) | 3.63 | 3.97 | 4.18 | 4.28 |
| **Future Land Use with Controls** | | | | |
| Peak Discharge Flow ($m^3/s$) | -4.37 | -6.33 | -8.89 | -6.19 |
| Max. HGL (m) | 3.63 | 3.97 | 4.18 | 4.40 |
| **Future Land Use (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | -4.24 | -6.02 | -8.35 | -4.84 |
| Max. HGL (m) | 3.63 | 3.97 | 4.18 | 4.40 |
| **Future Land Use with Controls (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | -4.18 | -6.13 | -8.61 | -5.74 |
| Max. HGL (m) | 3.63 | 3.97 | 4.18 | 4.40 |
| **Future Land Use with Upgrades and No Controls (Climate Change)** | | | | |
| Peak Discharge Flow ($m^3/s$) | -4.20 | -5.99 | -8.29 | -4.79 |
| Max. HGL (m) | 3.63 | 3.97 | 4.18 | 4.40 |

Notes:
Results presented under the 10 and 100-year return periods represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour). The 5-day duration was run for the 200-year return period.
Negative discharge flows represent backwater flows from the Matsqui Slough boundary condition.

## Submission

**Prepared by:**

July 6, 2018

Jonathan Hung, P.Eng.
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**Reviewed and Approved by:**

July 6, 2018

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Senior Modeling Review

Chuck Linders
Stormwater Expert

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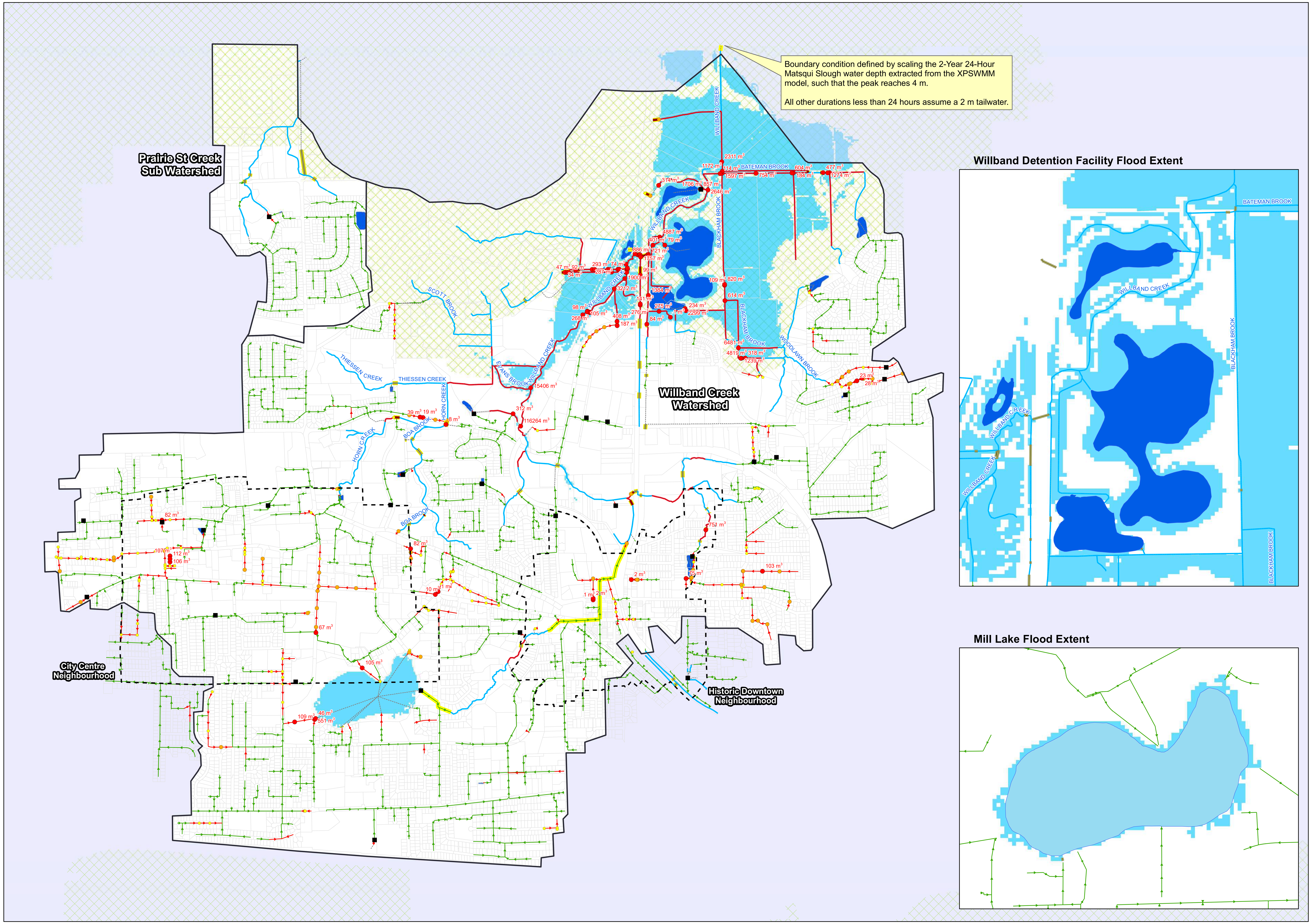
# Appendix A Future Land Use Figures




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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Kilometers

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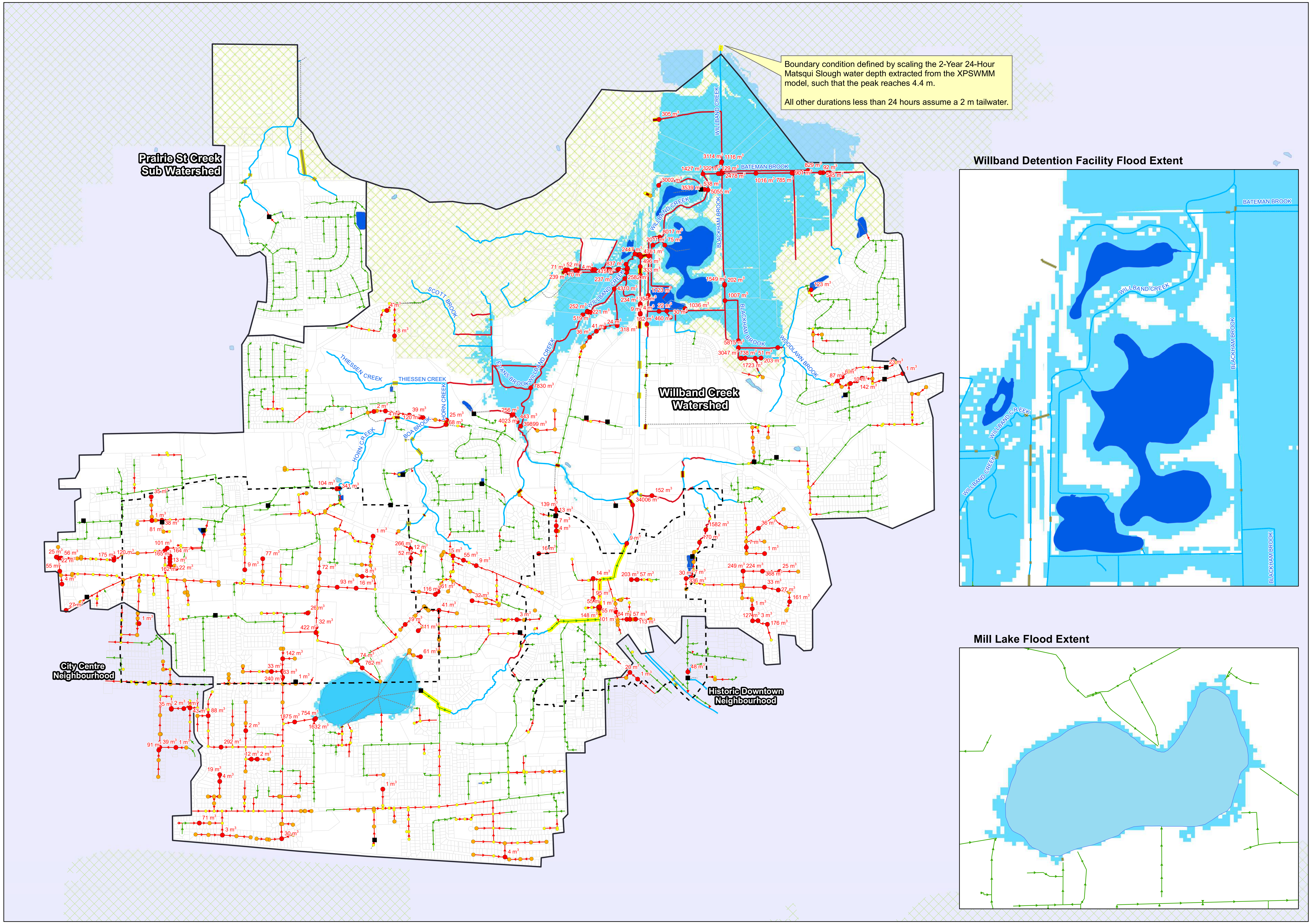
# Figure A.1




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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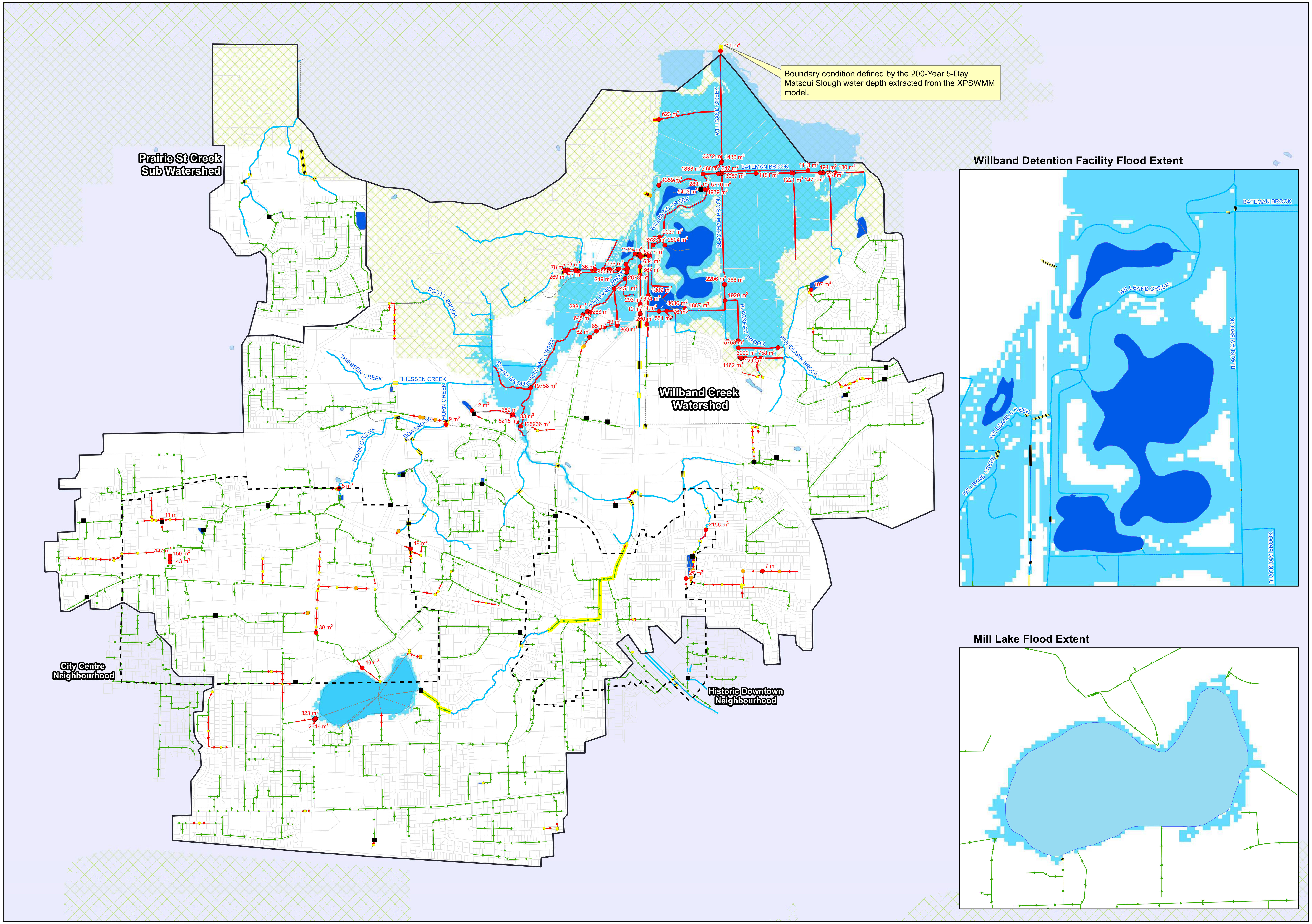
**Figure A.2**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

**200-Year, 5-Day System Performance (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



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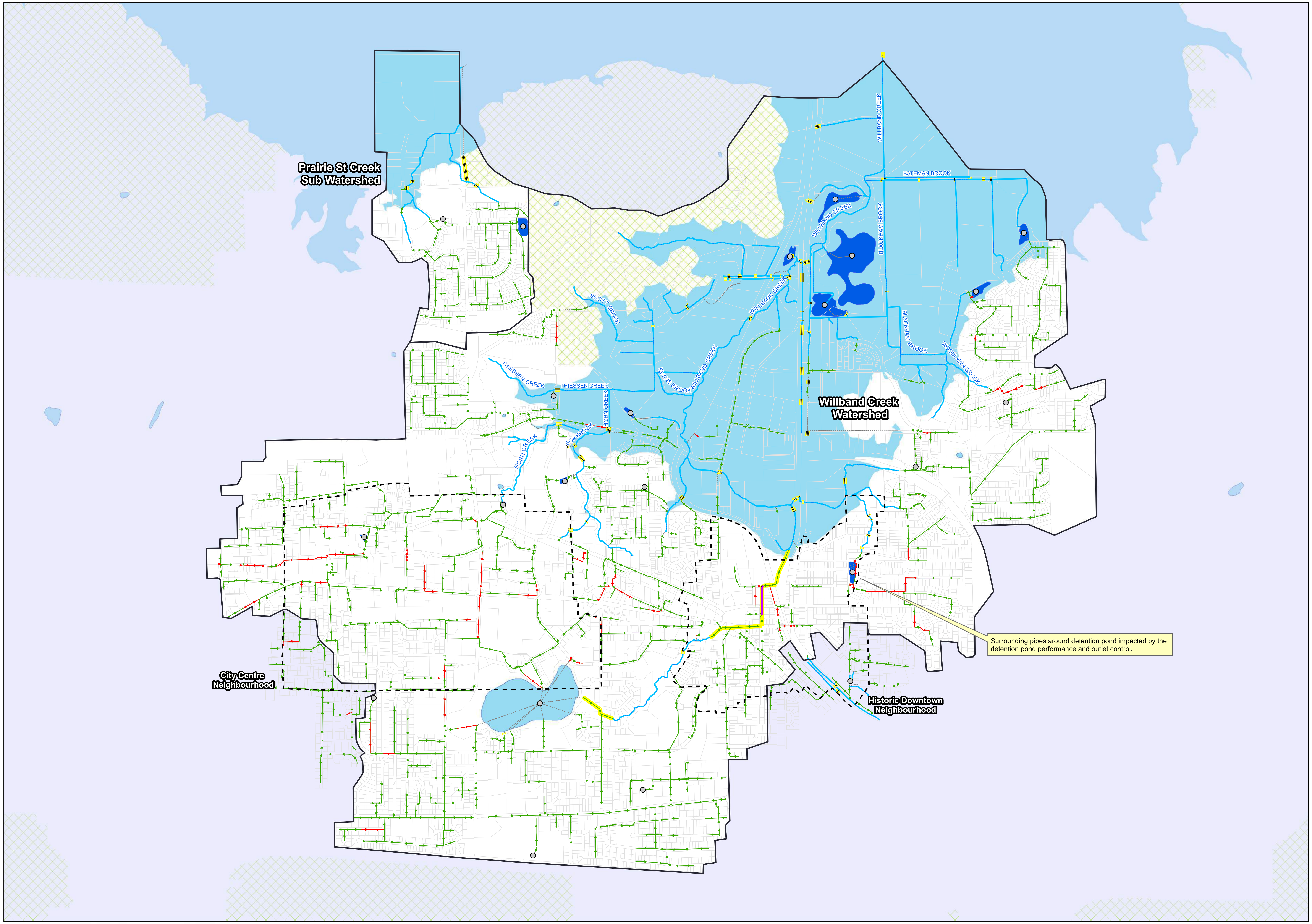
# Figure A.3




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Storage
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Watershed_Screen
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Storm Sewer Assessment

- Major Main (100-Year) Surcharge > 15 min
- Minor Main (10-Year) Surcharge > 5-min

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Storm Sewer Assessment Against Established Criteria (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



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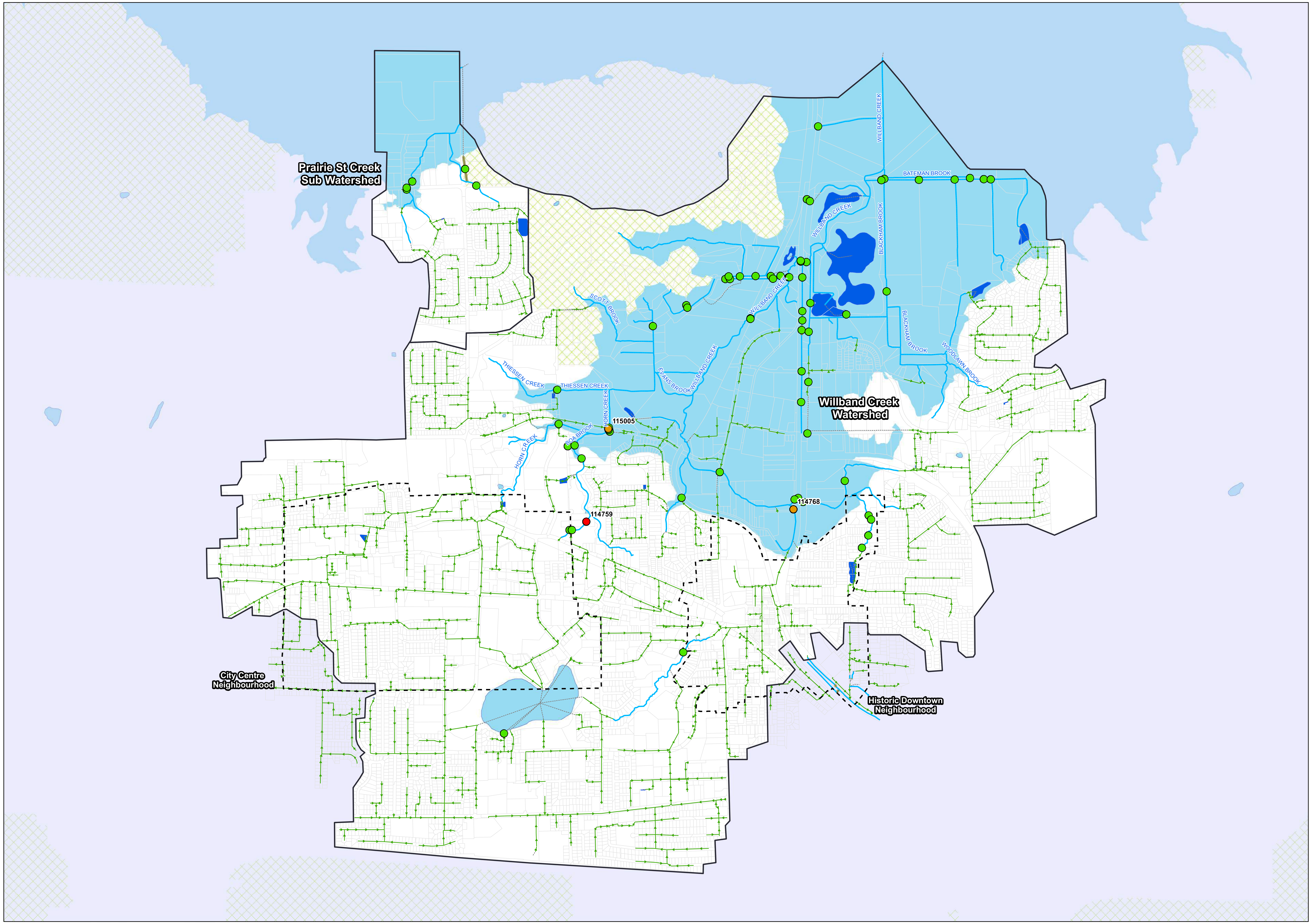
**Figure A.4**

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## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Subcatchments
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

## Culvert

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culvert Assessment Against Established Criteria (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



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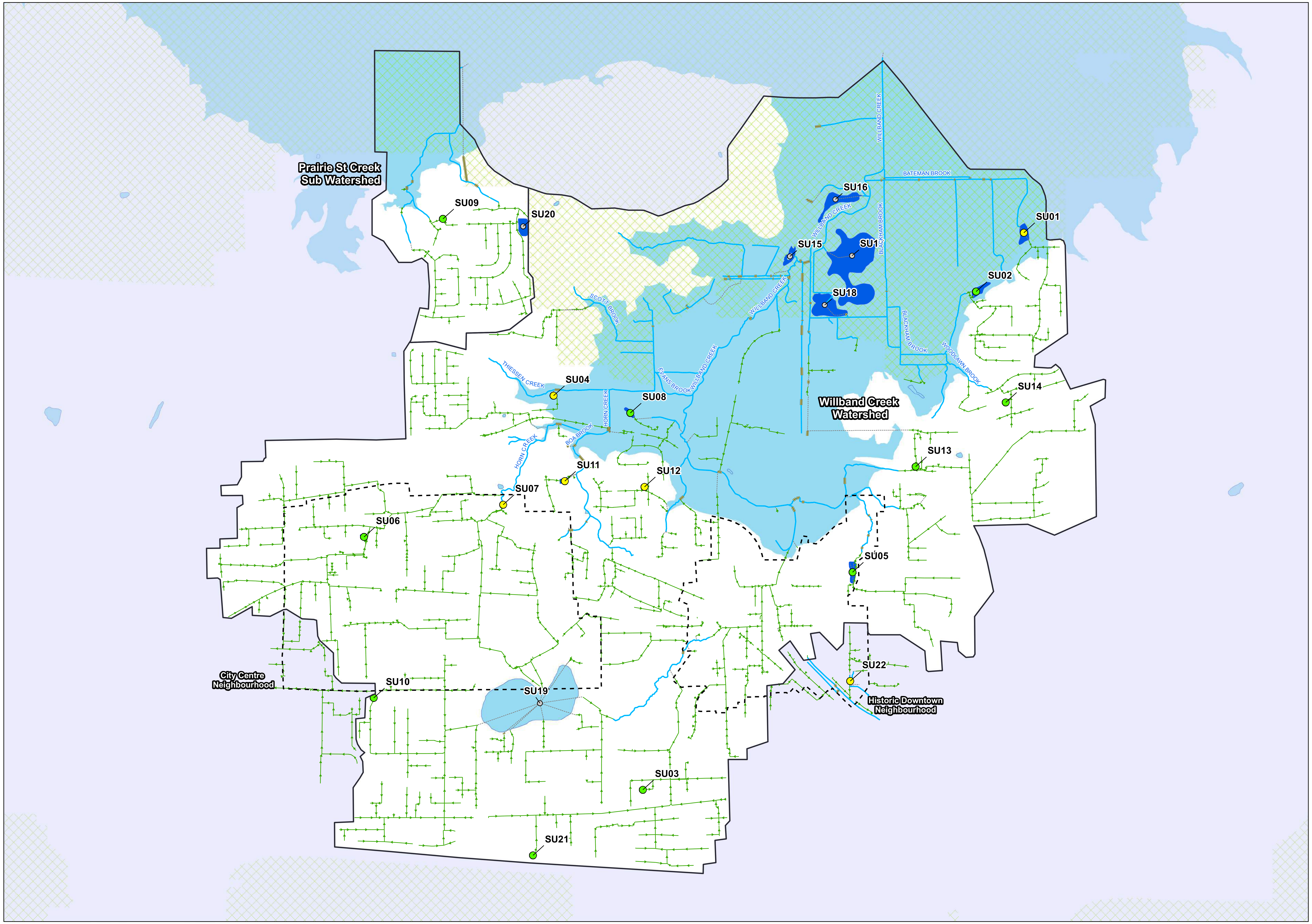
**Figure A.5**

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## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Storage

## Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume Required to Meet Criteria

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Assessment Against Established Criteria (Future Land Use - No Controls)**

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Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
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Kilometers

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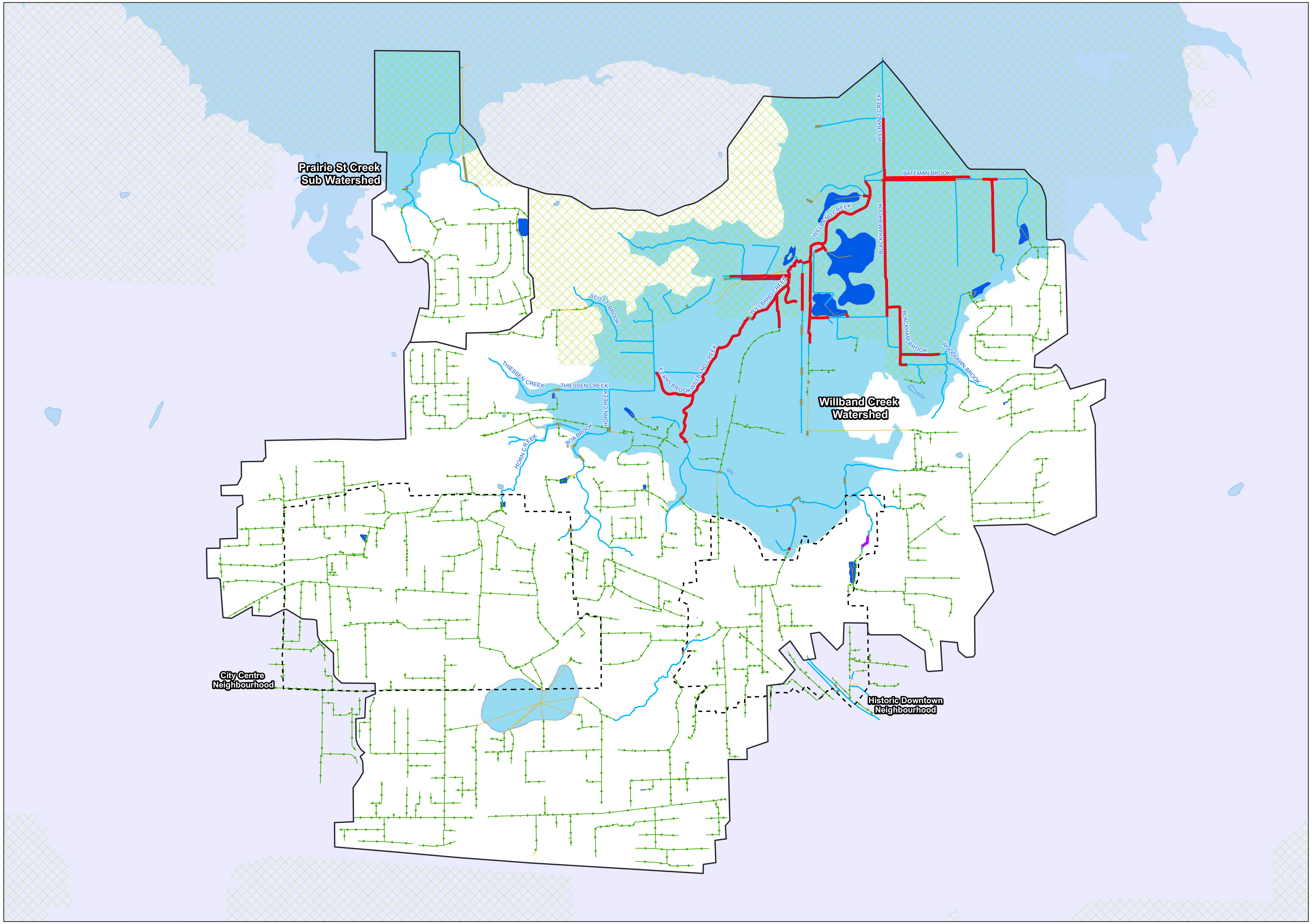
**Figure A.6**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Creek Assessment Against Established Criteria (Future Land Use - No Controls)**

ABBOTSFORD

Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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Kilometers

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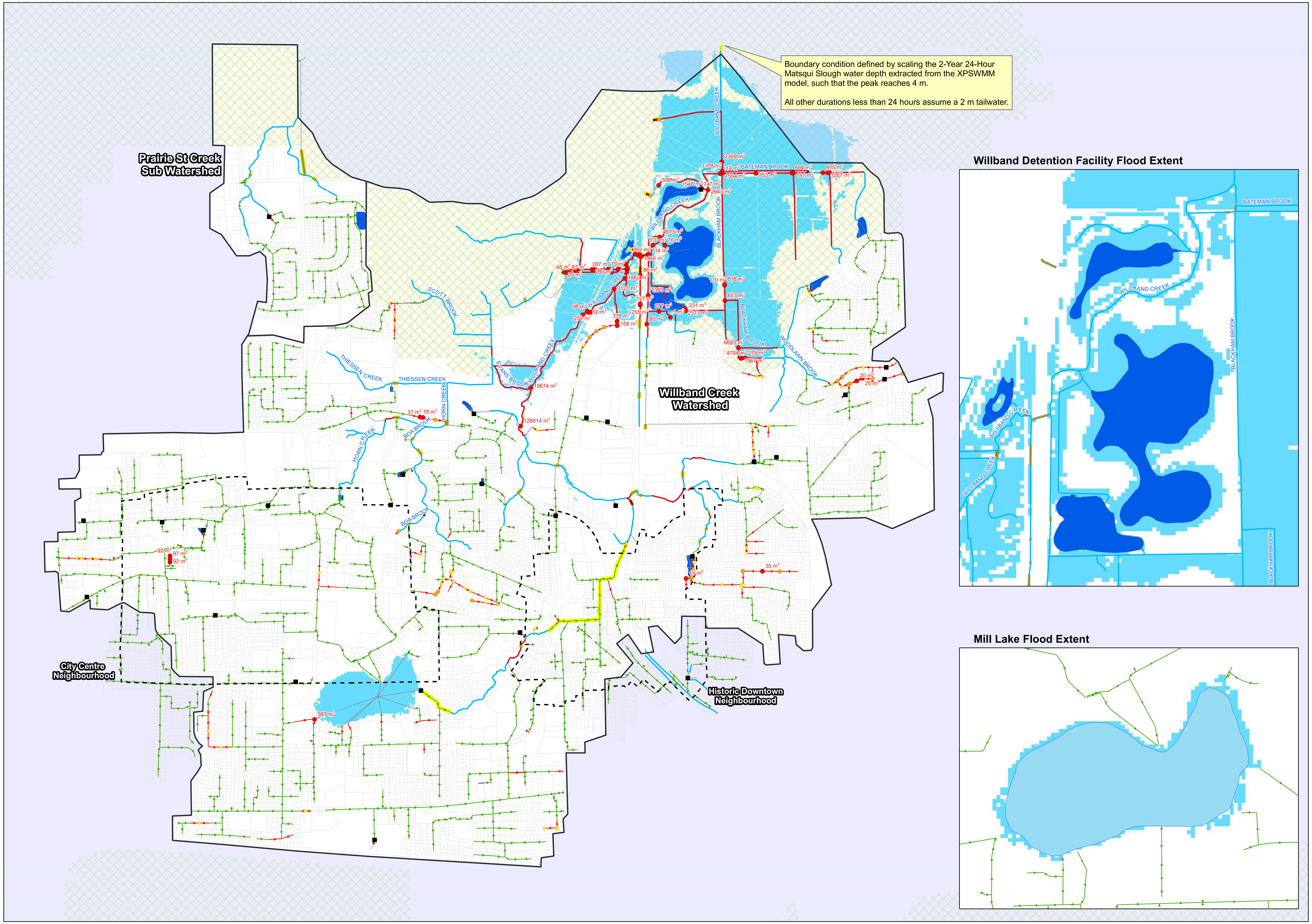
**Figure A.7**

# Appendix B Future Land Use with Controls Figures




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Future Land Use - With Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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Kilometers

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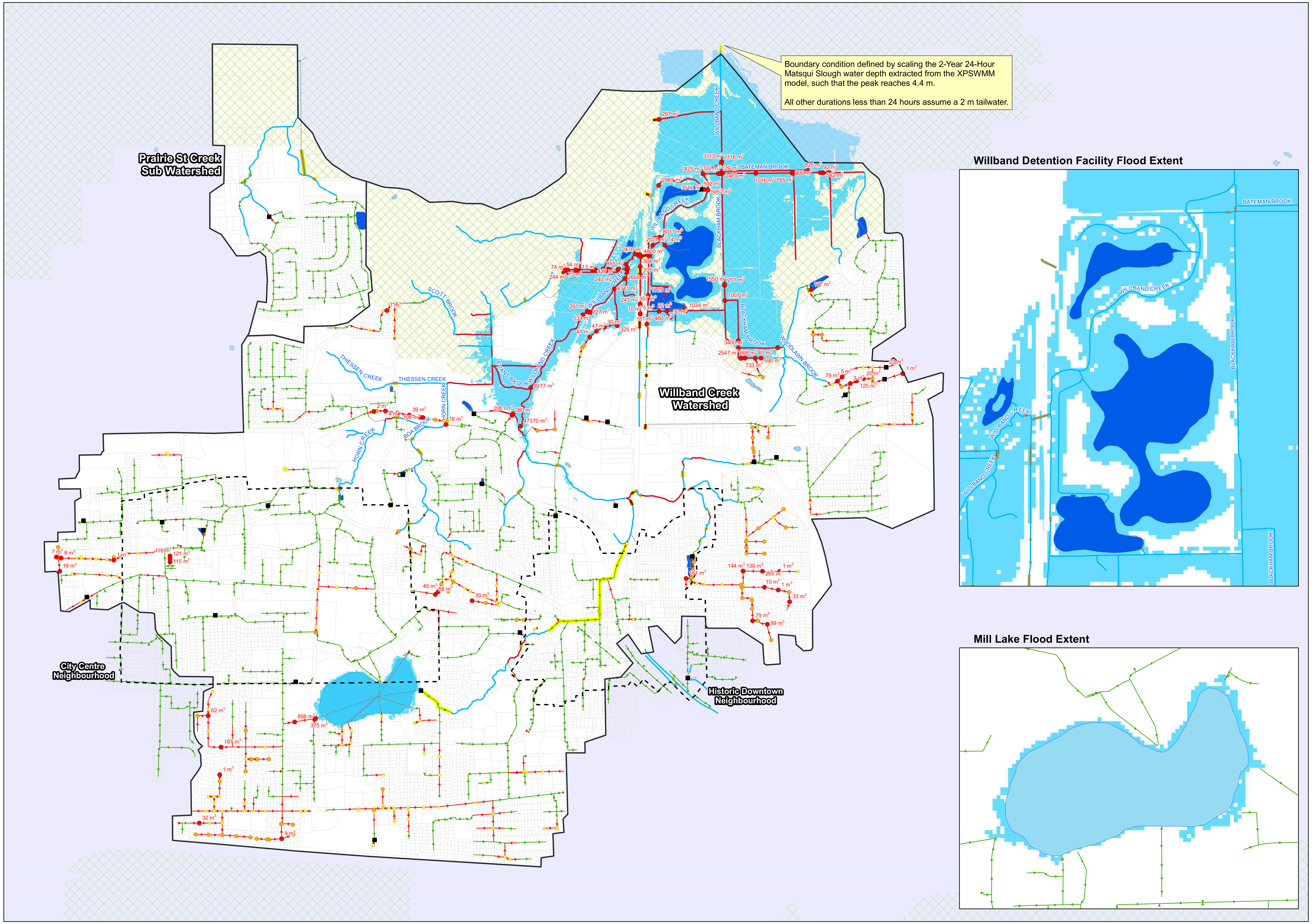
# Figure B.1

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## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Future Land Use - With Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



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Kilometers

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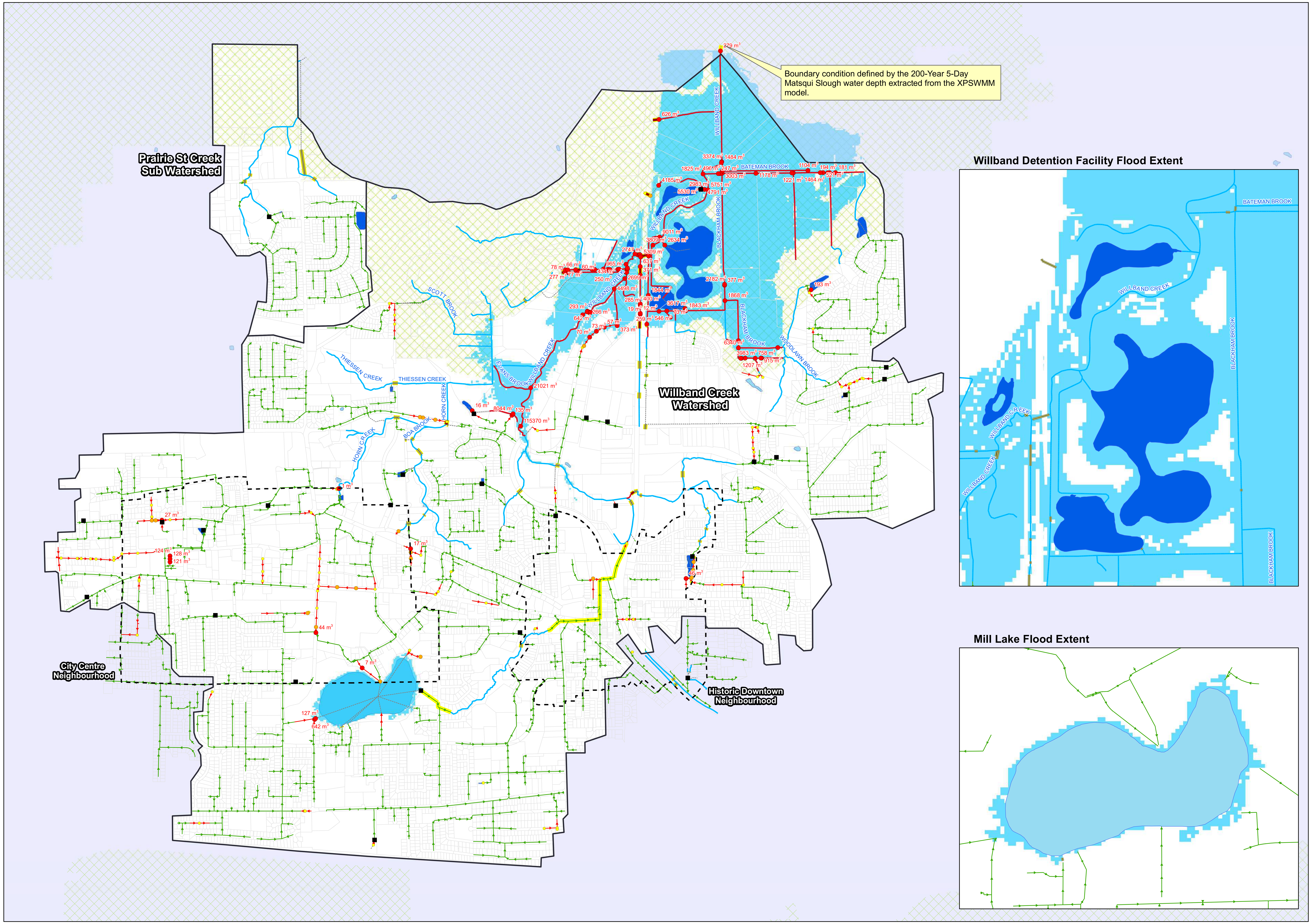
**Figure B.2**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

**200-Year, 5-Day System Performance (Future Land Use - With Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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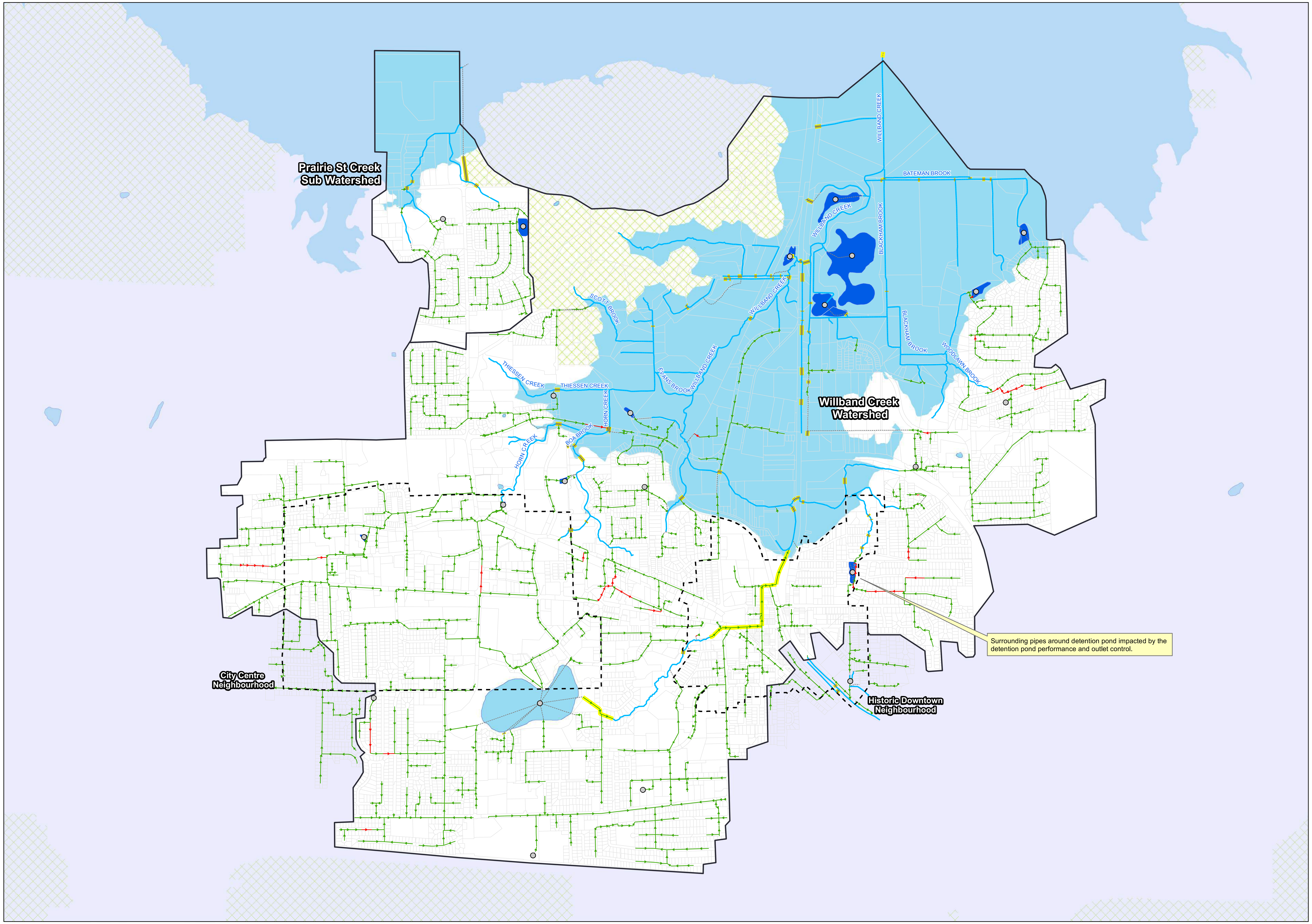
# Figure B.3




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Storage
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Watershed_Screen
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

**Storm Sewer Assessment**

- Major Main (100-Year) Surcharge > 15 min
- Minor Main (10-Year) Surcharge > 5-min

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Storm Sewer Assessment Against Established Criteria (Future Land Use - With Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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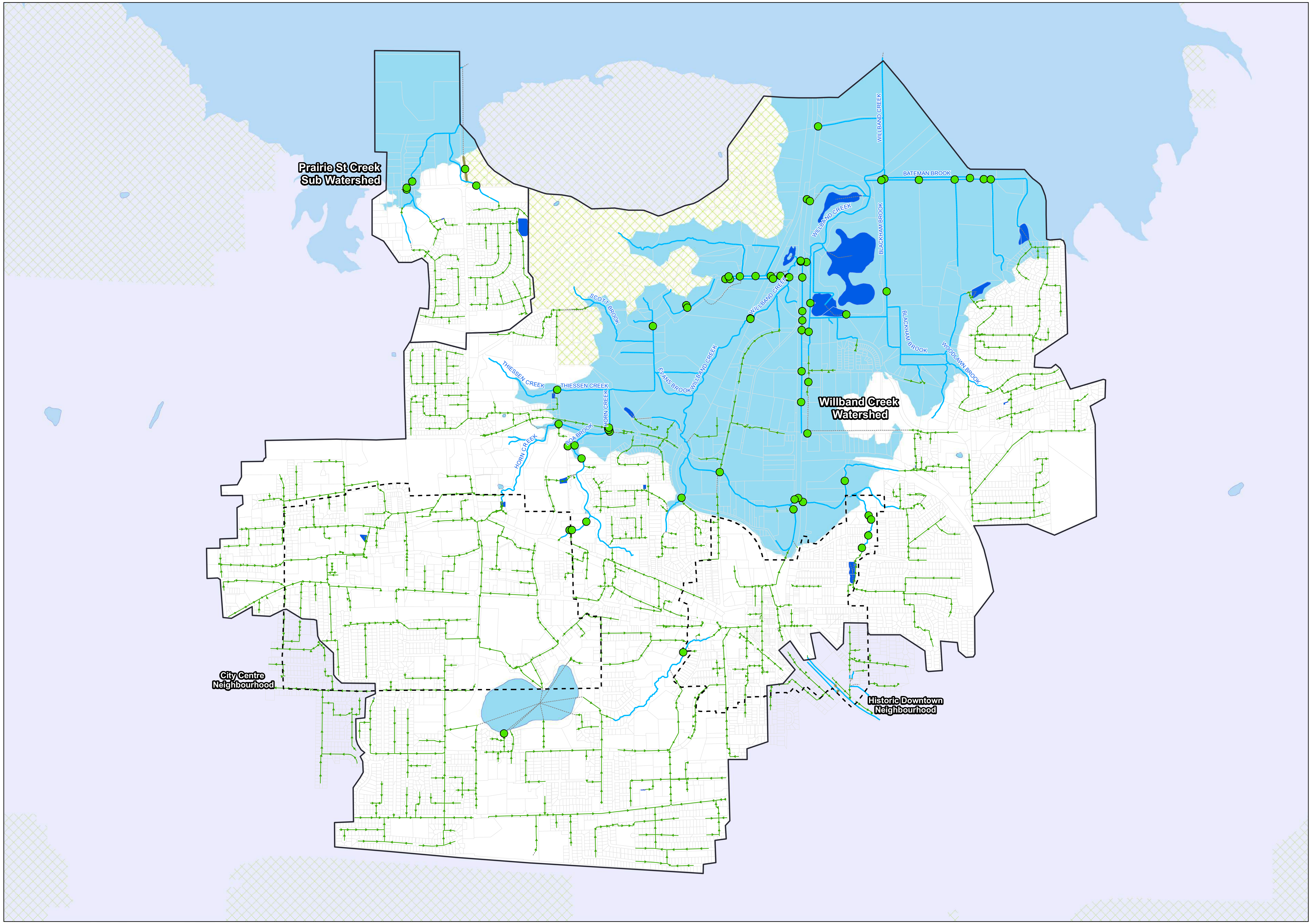
0 0.25 0.5 1
Kilometers

N W E S

# Figure B.4




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Subcatchments
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Culvert Assessment

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culvert Assessment Against Established Criteria (Future Land Use - With Controls)**

ABBOTSFORD

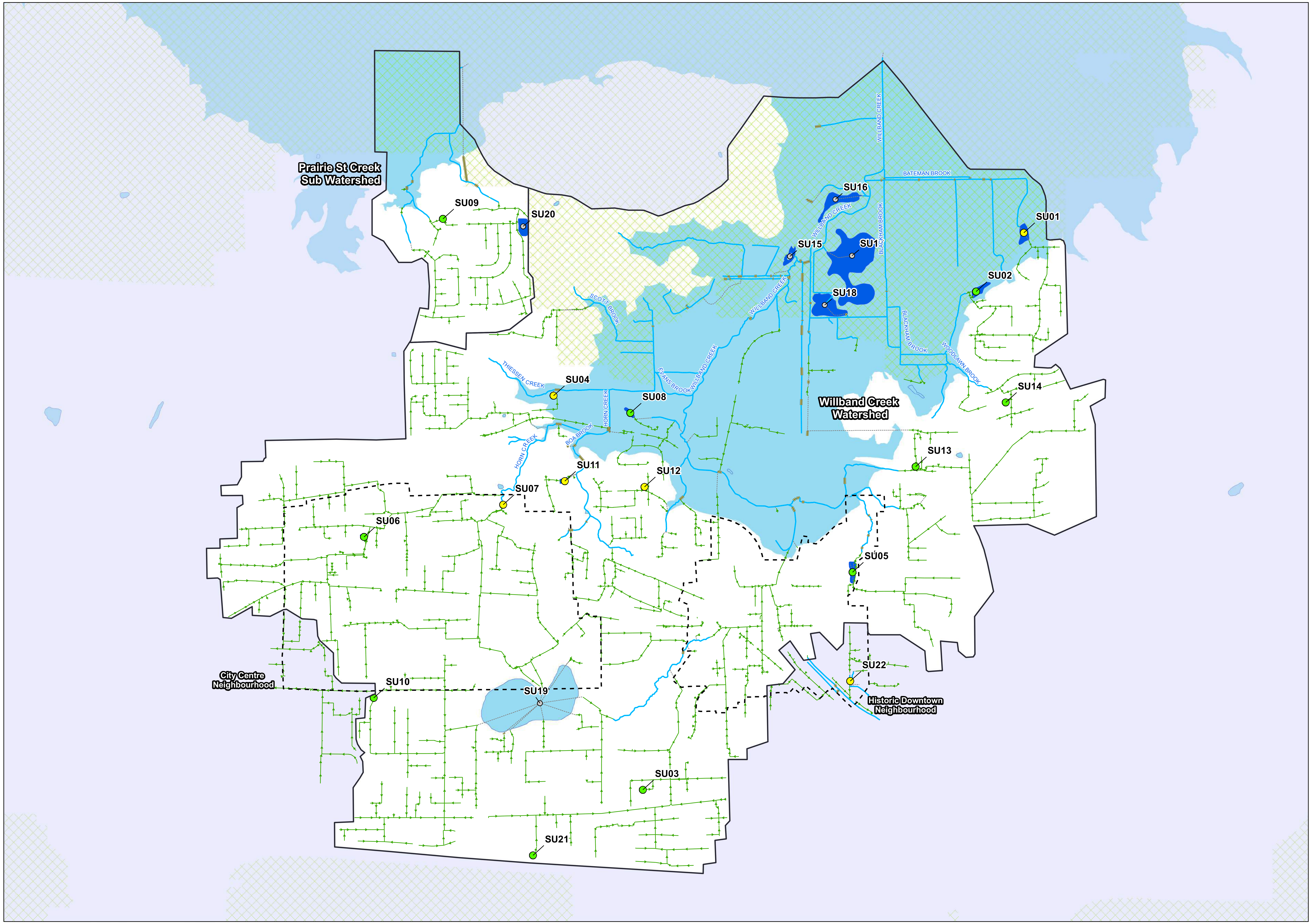
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure B.5**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Storage

### Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume Required to Meet Criteria

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Assessment Against Established Criteria (Future Land Use - With Controls)**

ABBOTSFORD

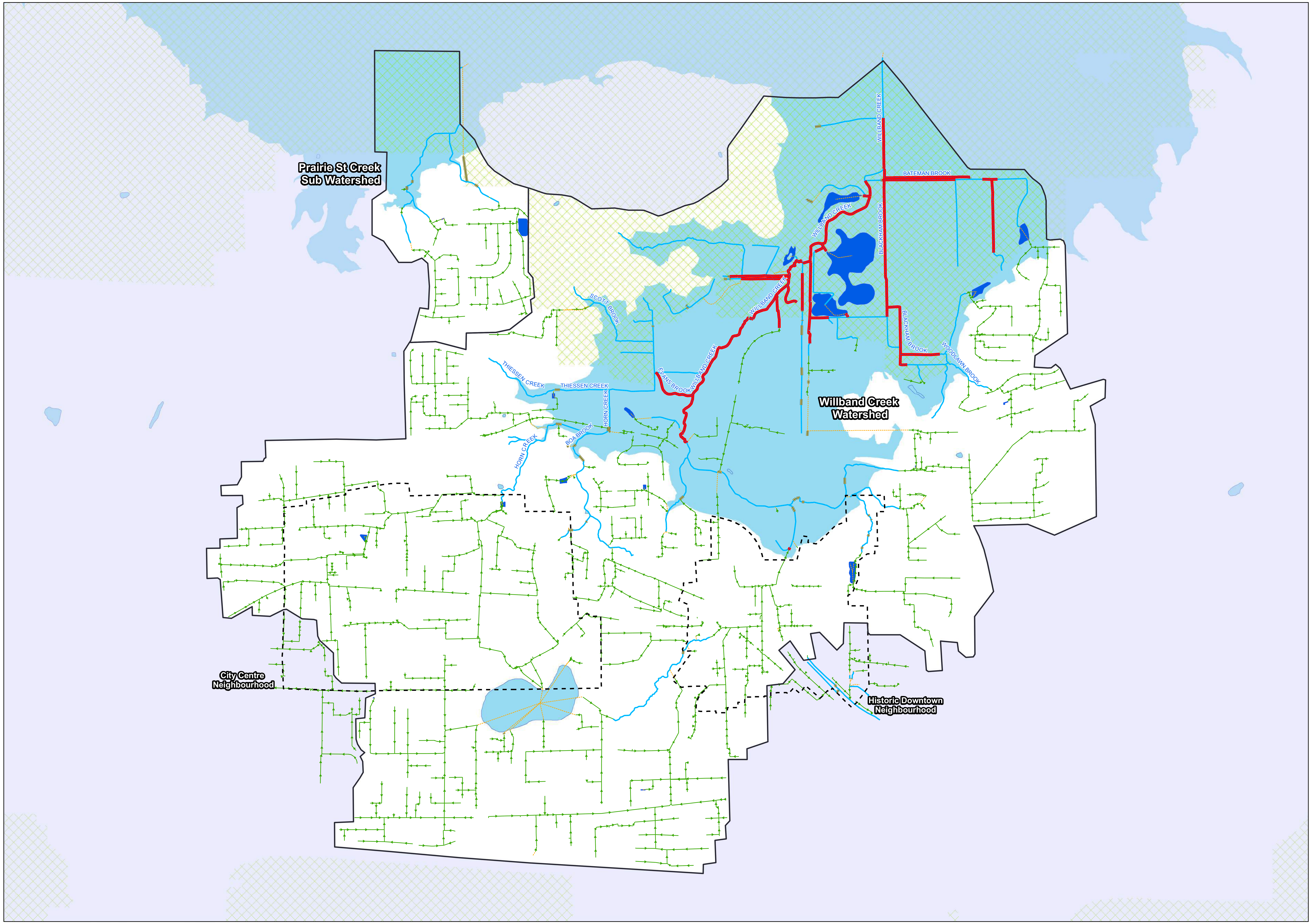
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure B.6**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Creek Assessment Against Established Criteria (Future Land Use - With Controls)**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

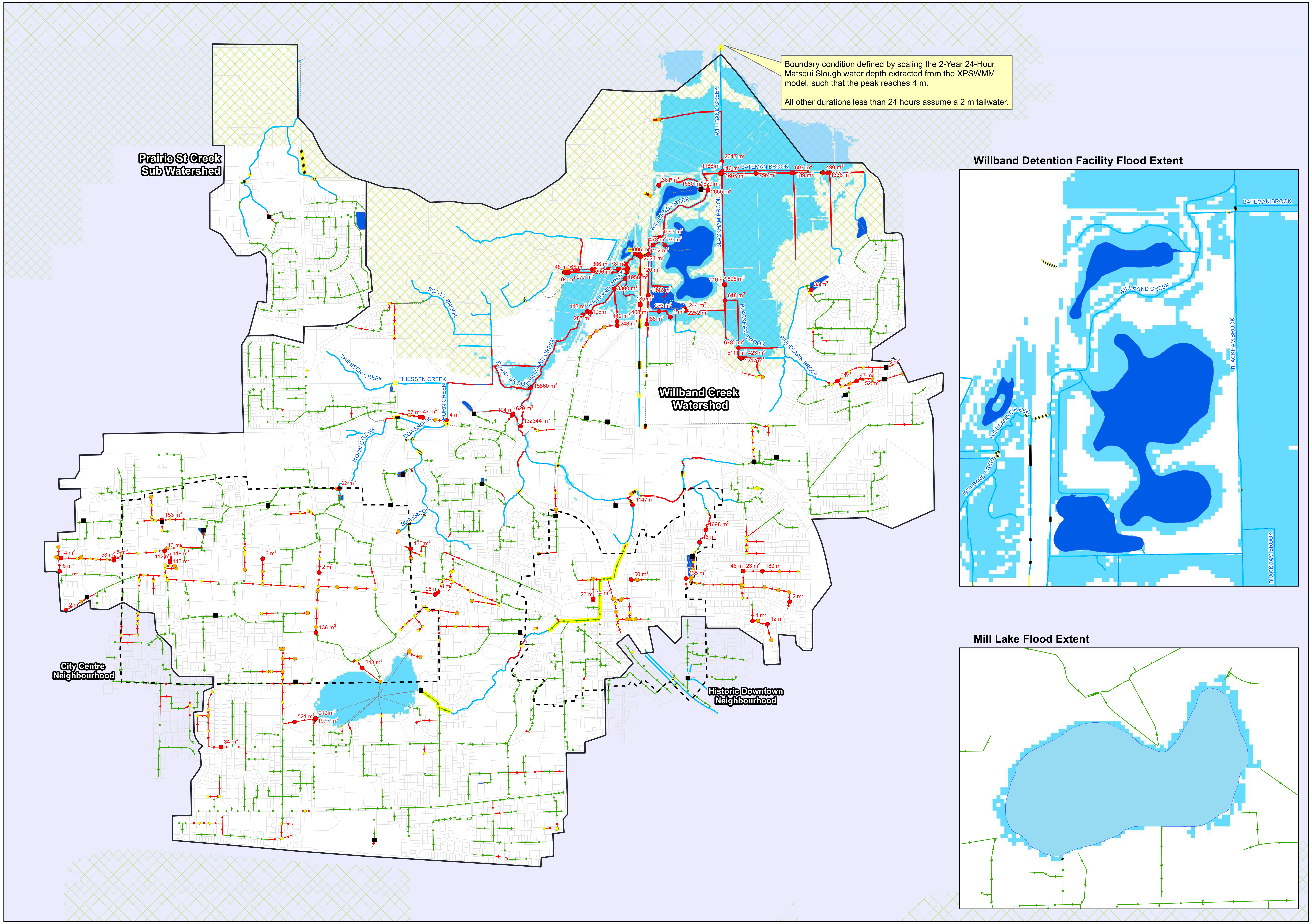


0 0.25 0.5 1
Kilometers

N W E S

**Figure B.7**

# Appendix C Future Land Use with Climate Change Figures




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Future Land Use - No Controls) With Climate Change**

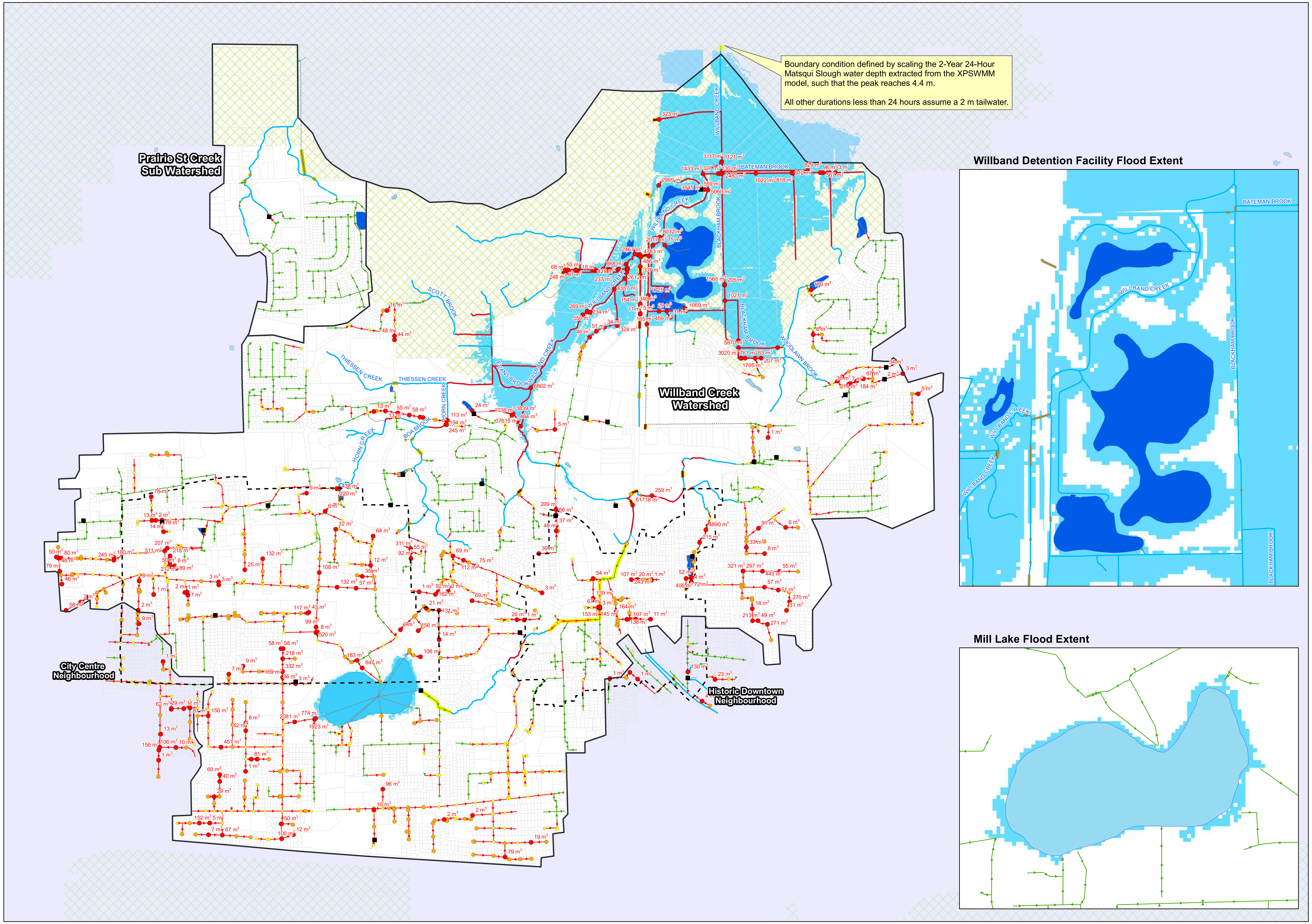
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure C.1**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

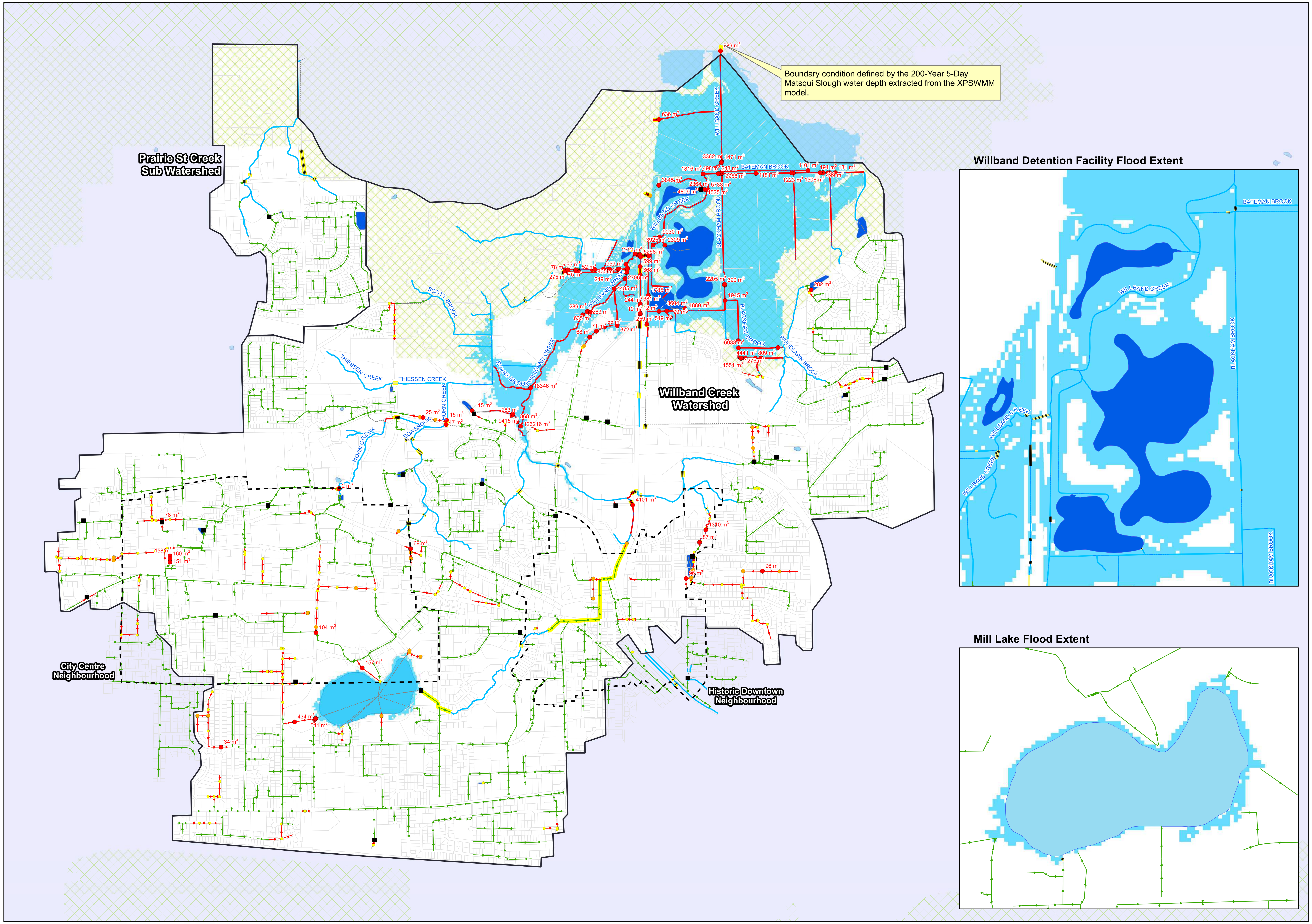
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure C.2**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

**200-Year, 5-Day System Performance (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

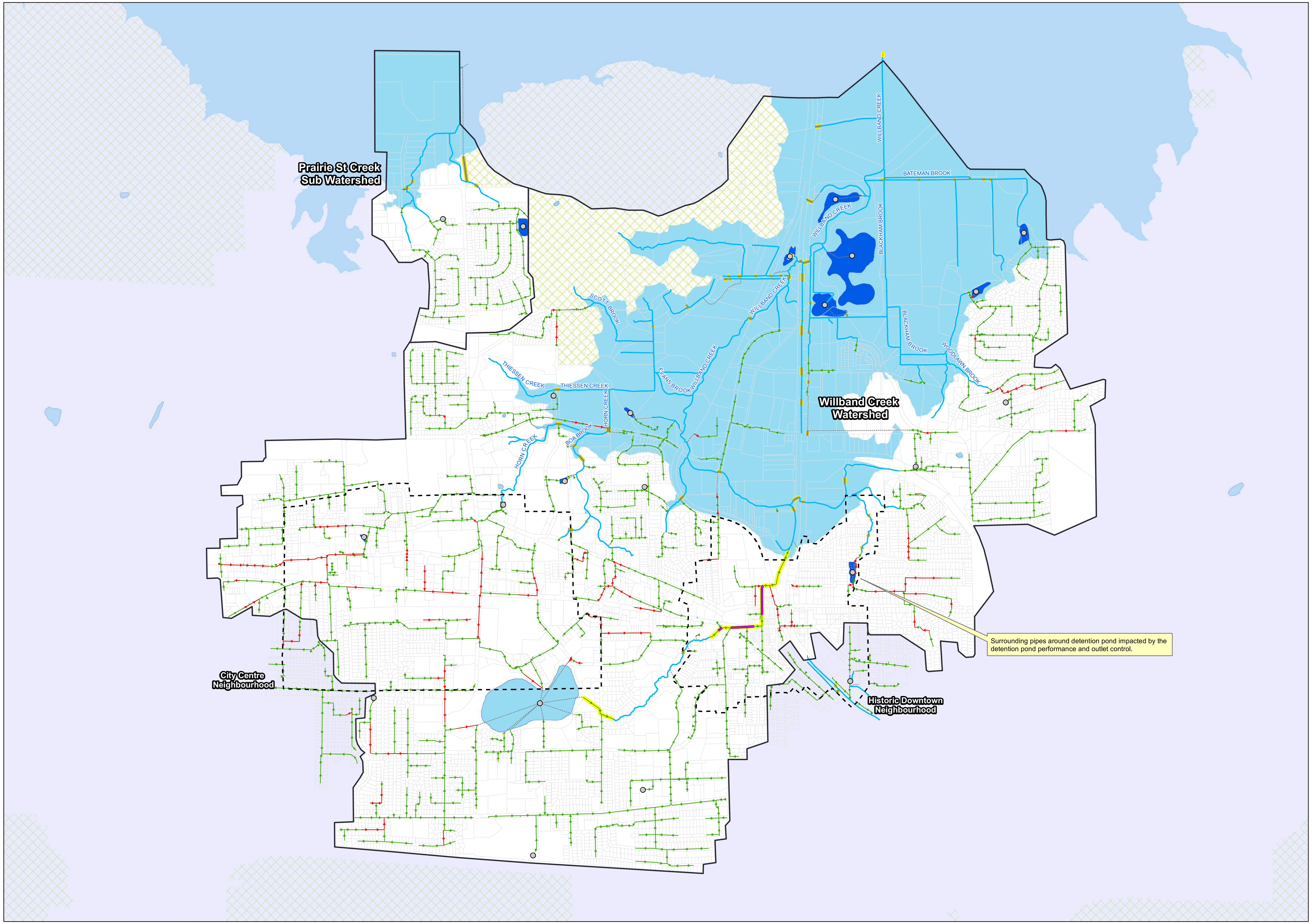
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1 Kilometers

N W E S

## Figure C.3




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Storage
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Watershed_Screen
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Storm Sewer Assessment

- Major Main (100-Year) Surcharge > 15 min
- Minor Main (10-Year) Surcharge > 5-min

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

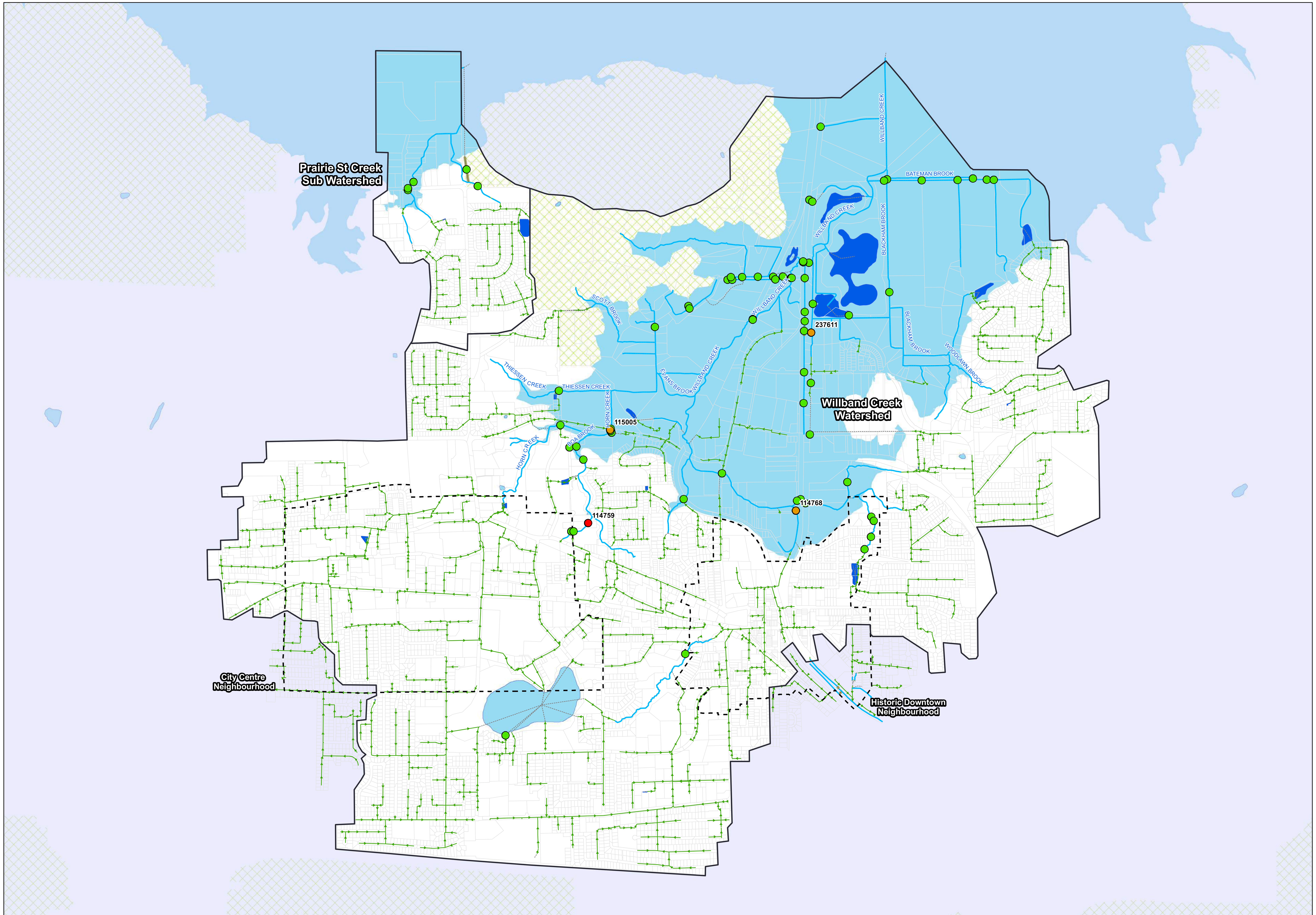
**Storm Sewer Assessment Against Established Criteria (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



**Figure C.4**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Subcatchments
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

## Culvert Assessment

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culvert Assessment Against Established Criteria (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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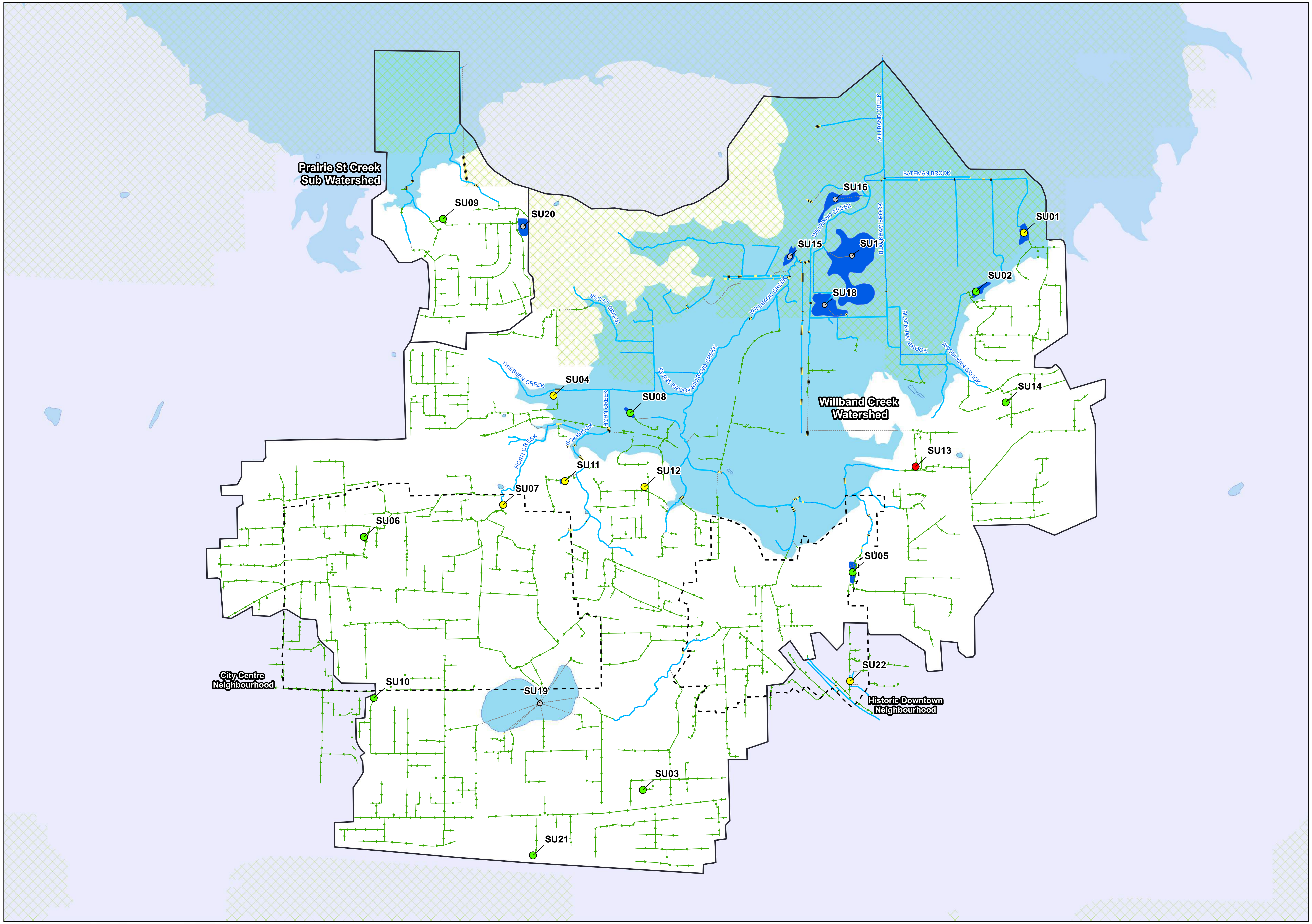
0 0.25 0.5 1
Kilometers

N W E S

**Figure C.5**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Storage

## Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume Required to Meet Criteria

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Assessment Against Established Criteria (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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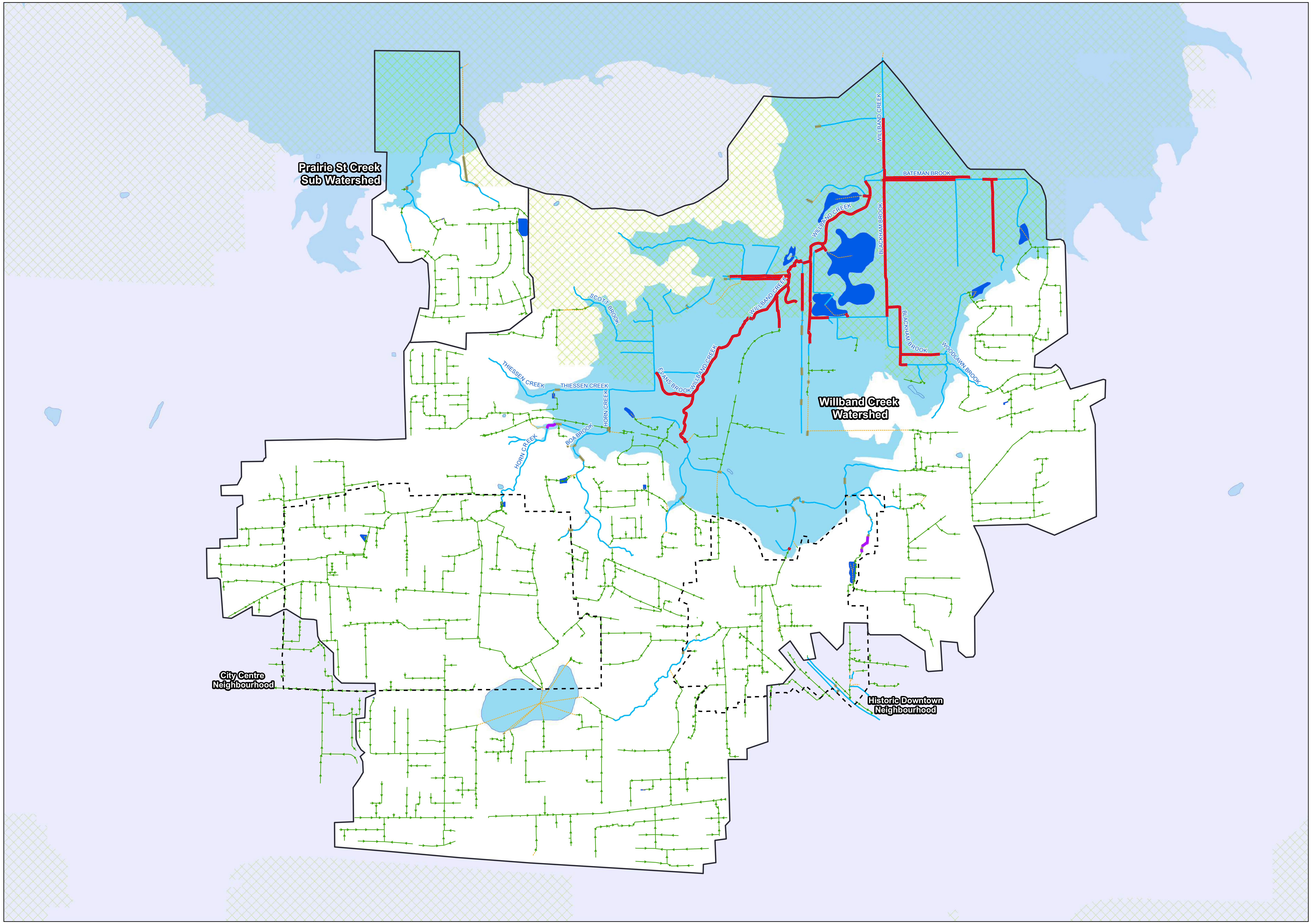
0 0.25 0.5 1
Kilometers

N E S W

**Figure C.6**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Creek Assessment Against Established Criteria (Future Land Use - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

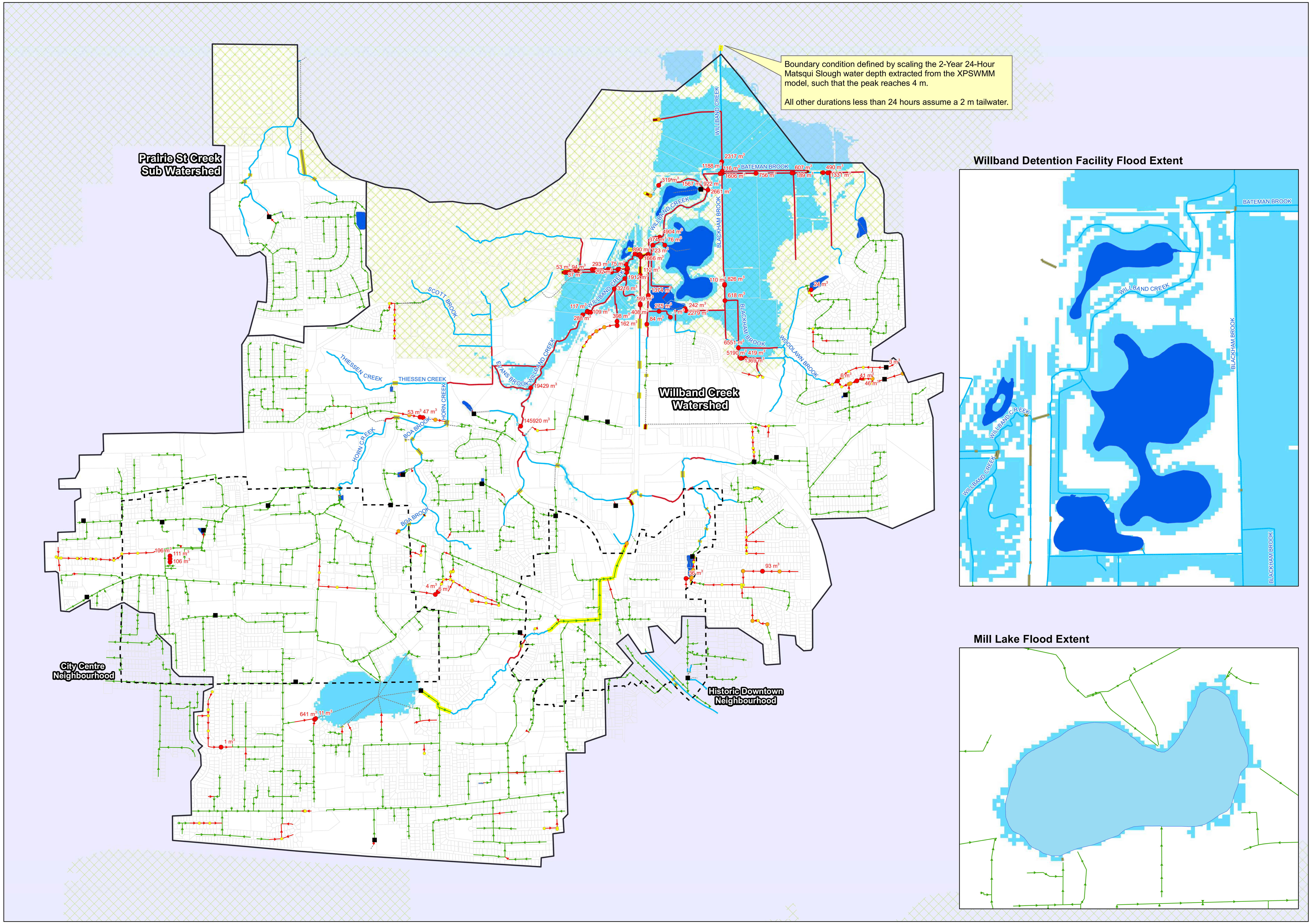


0 0.25 0.5 1
Kilometers

N W E S

# Figure C.7

# Appendix D Future Land Use with Controls and Climate Change Figures




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

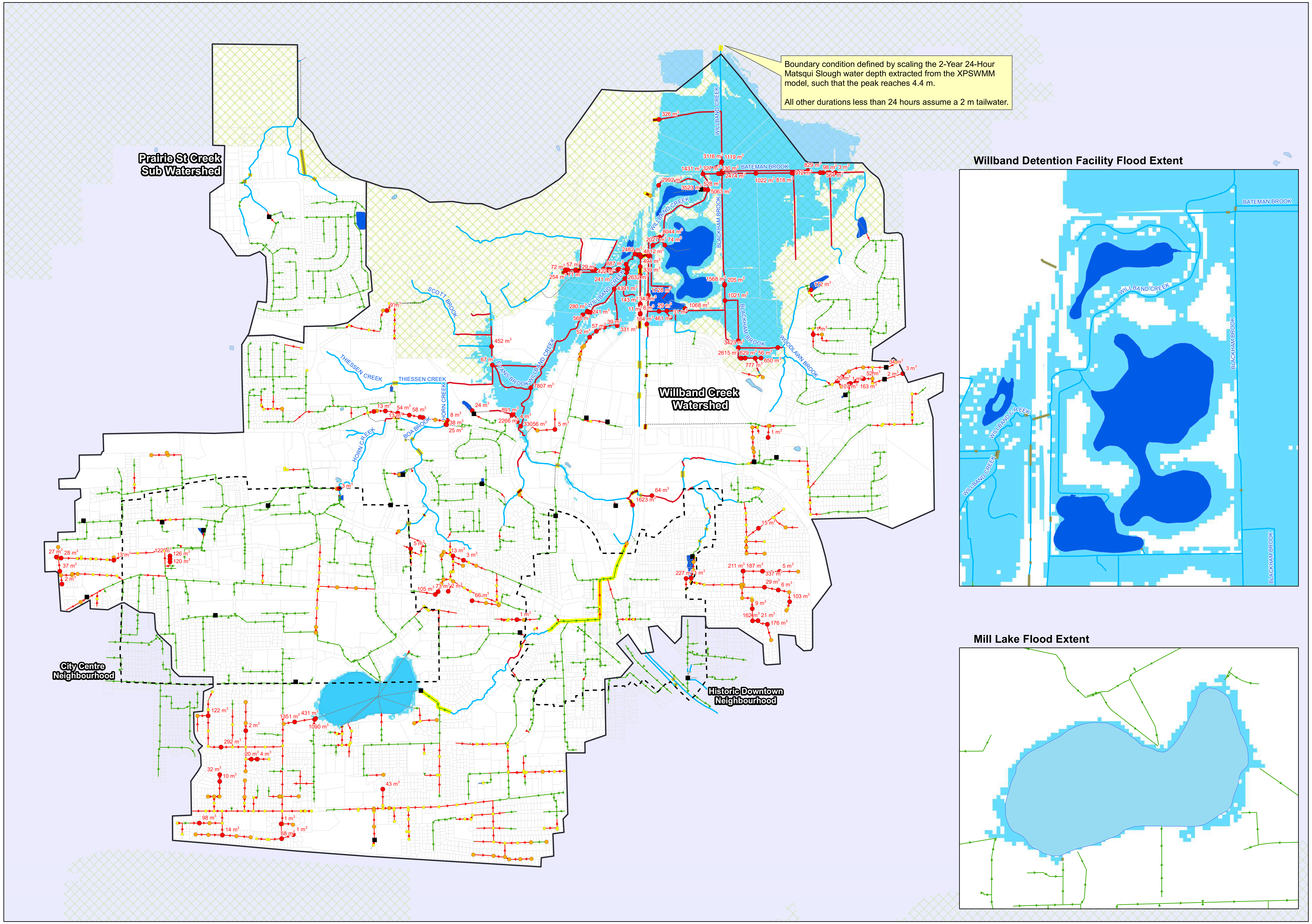
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure D.1**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

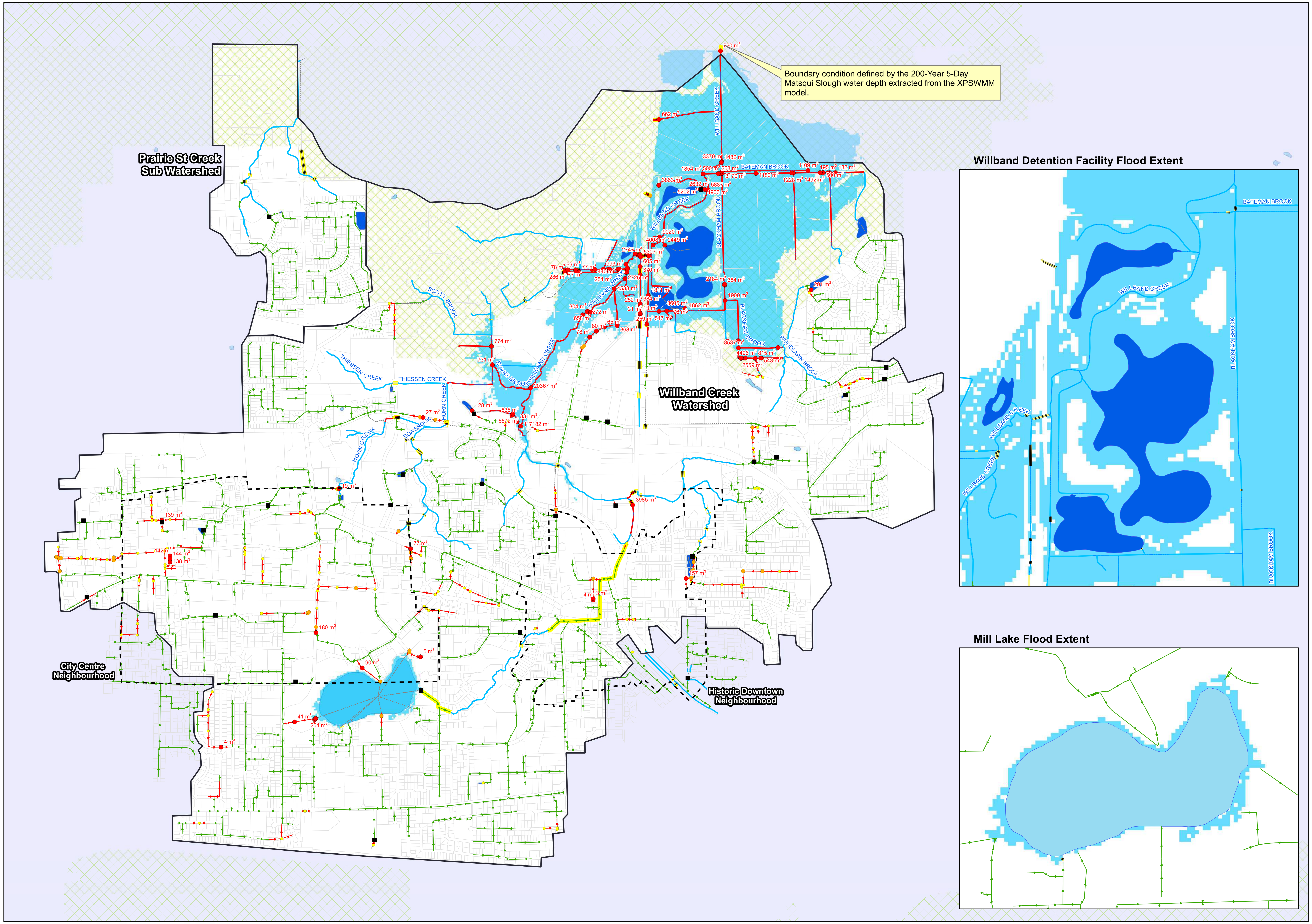
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure D.2**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

**200-Year, 5-Day System Performance (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

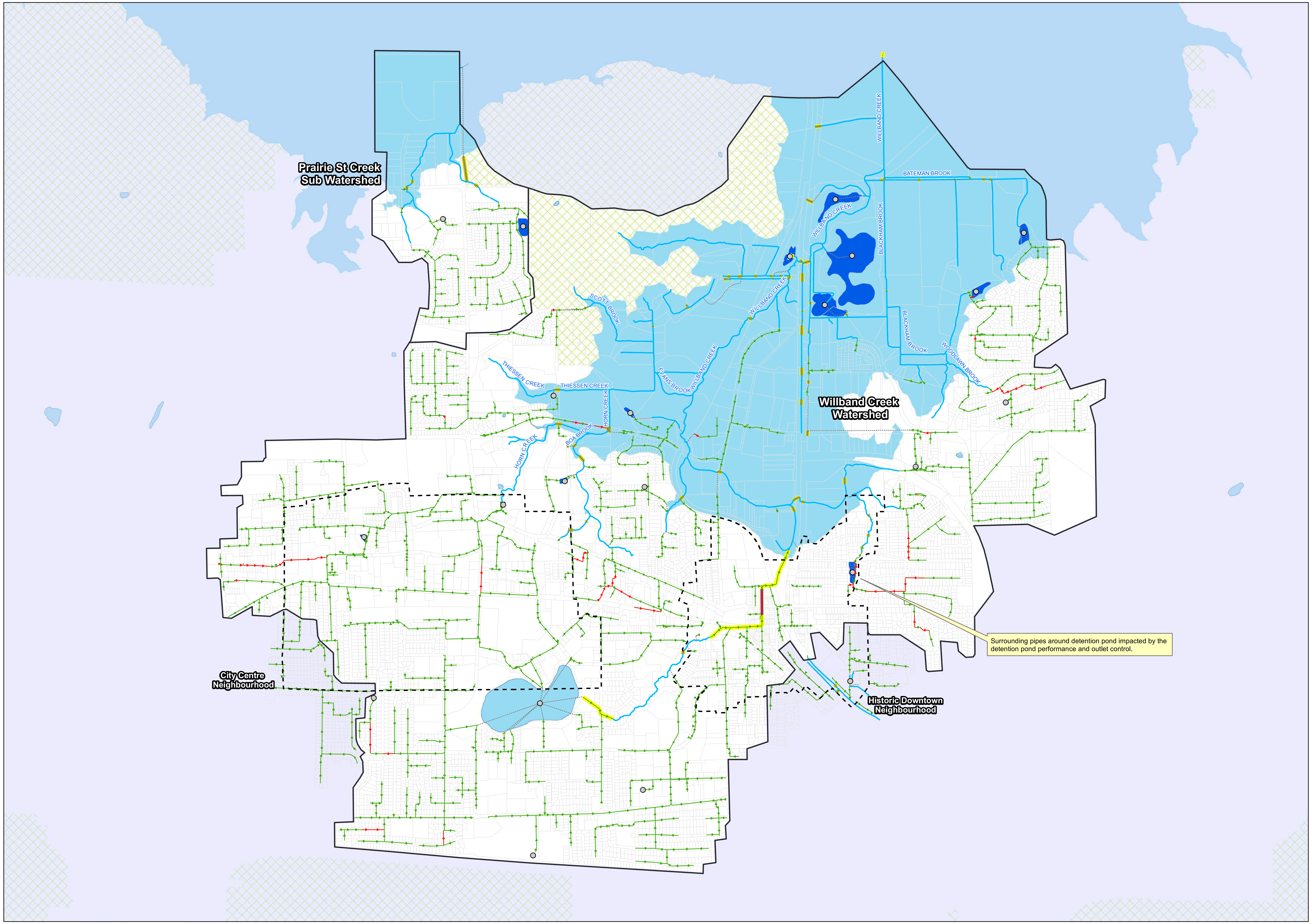
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure D.3**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Storage
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Watershed_Screen
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Storm Sewer Assessment

- Major Main (100-Year) Surcharge > 15 min
- Minor Main (10-Year) Surcharge > 5-min

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Storm Sewer Assessment Against Established Criteria (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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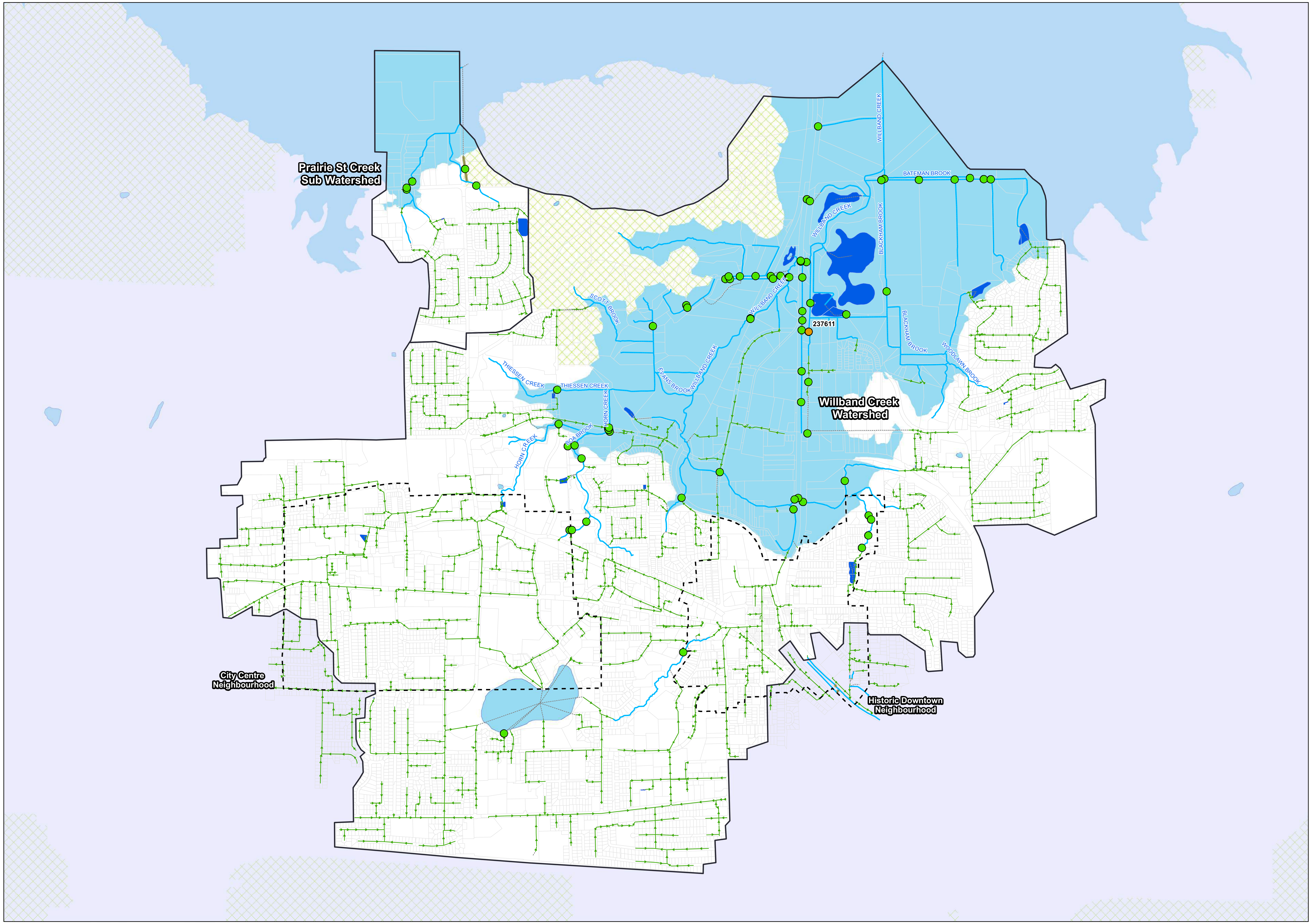
0 0.25 0.5 1
Kilometers

N W E S

## Figure D.4




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Subcatchments
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

## Culvert Assessment

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culvert Assessment Against Established Criteria (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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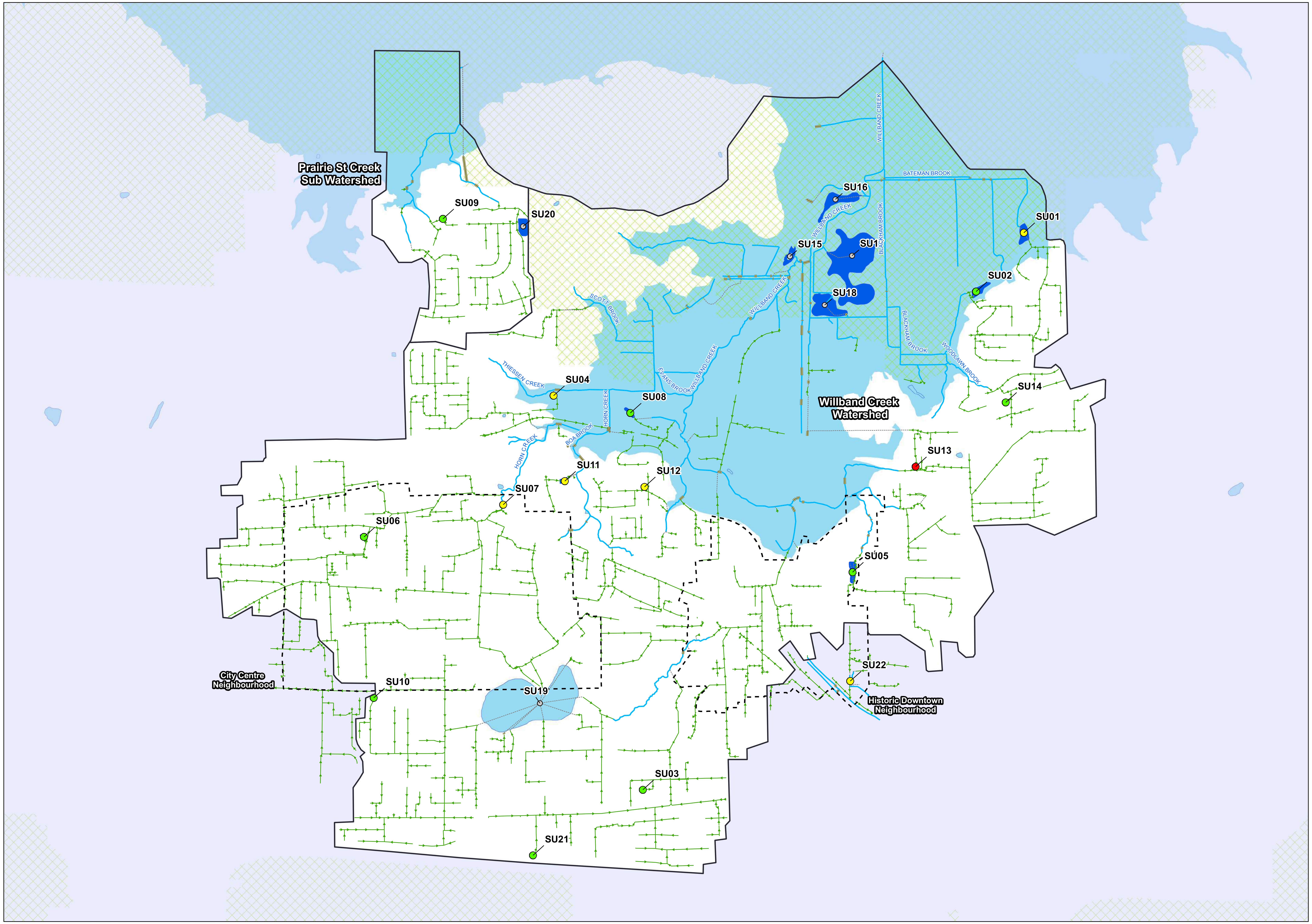
0 0.25 0.5 1
Kilometers

N W E S

**Figure D.5**

GeoAdvice Engineering Inc.




## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Storage

## Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume Required to Meet Criteria

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Assessment Against Established Criteria (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

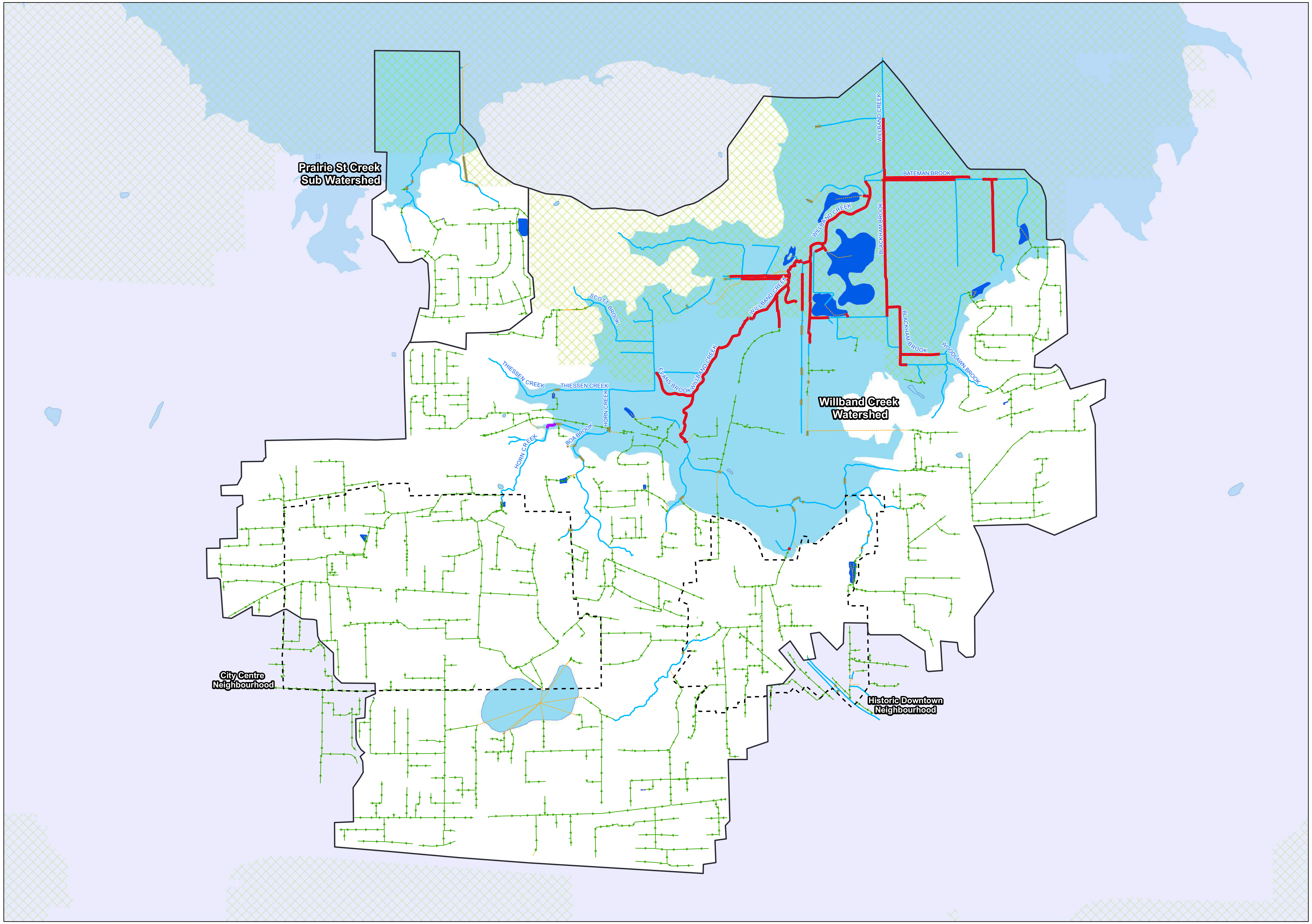
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure D.6**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Creek Assessment Against Established Criteria (Future Land Use - With Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

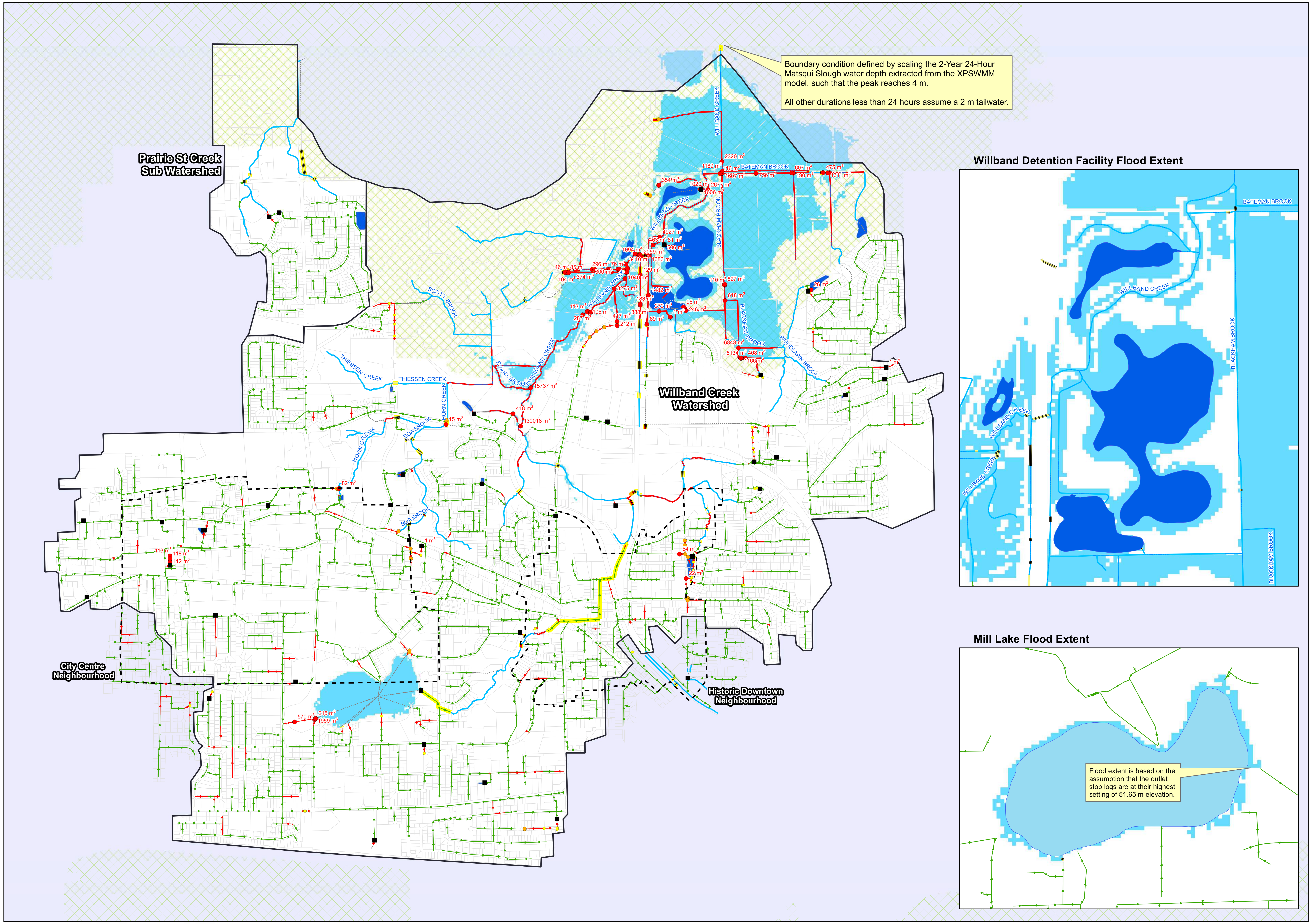


0 0.25 0.5 1
Kilometers

N W E S

**Figure D.7**

# Appendix E Future Land Use with Upgrades and Climate Change Figures




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Future Land Use With Upgrades - No Controls) With Climate Change**

ABBOTSFORD

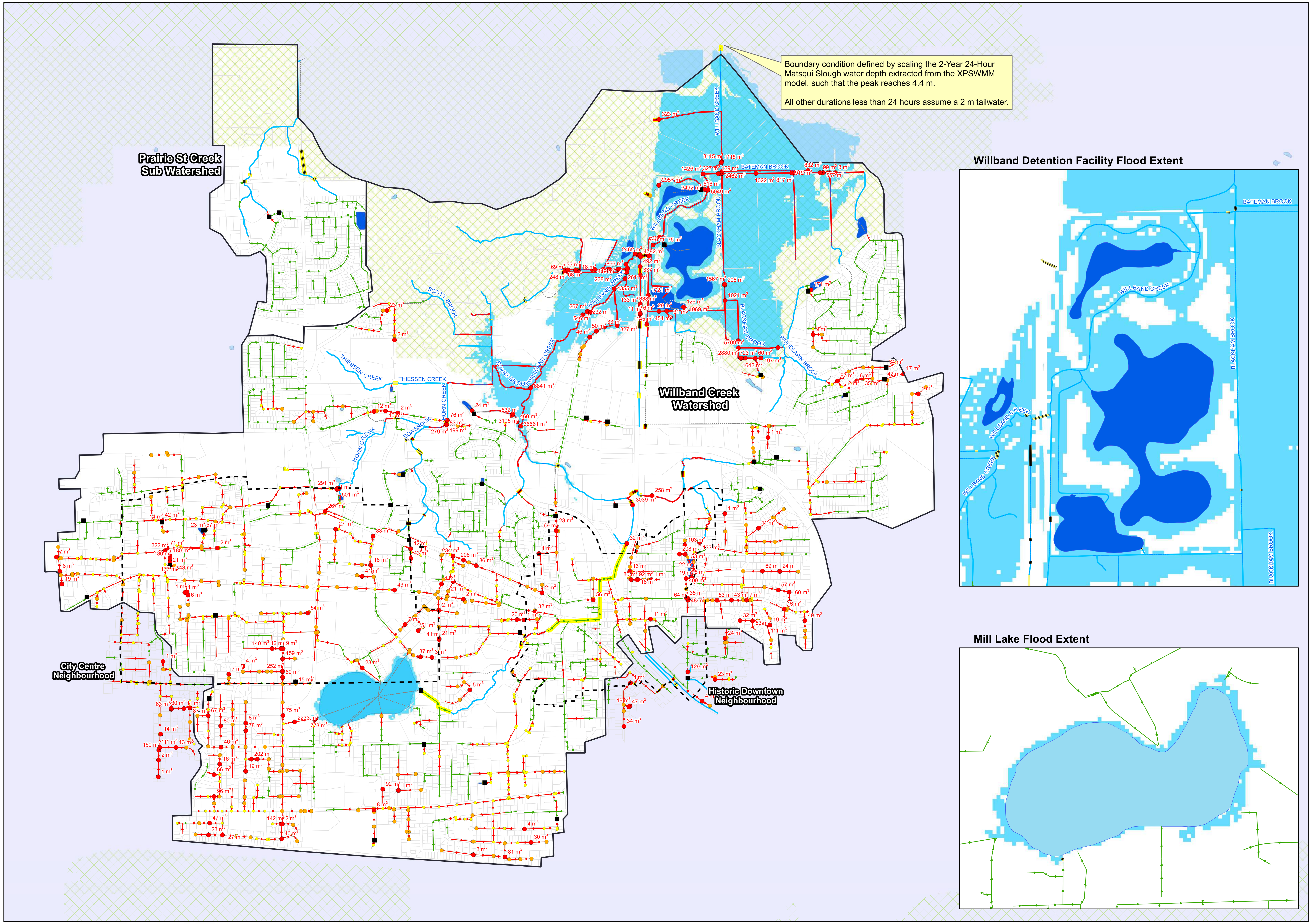
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure F.1**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Future Land Use With Upgrades - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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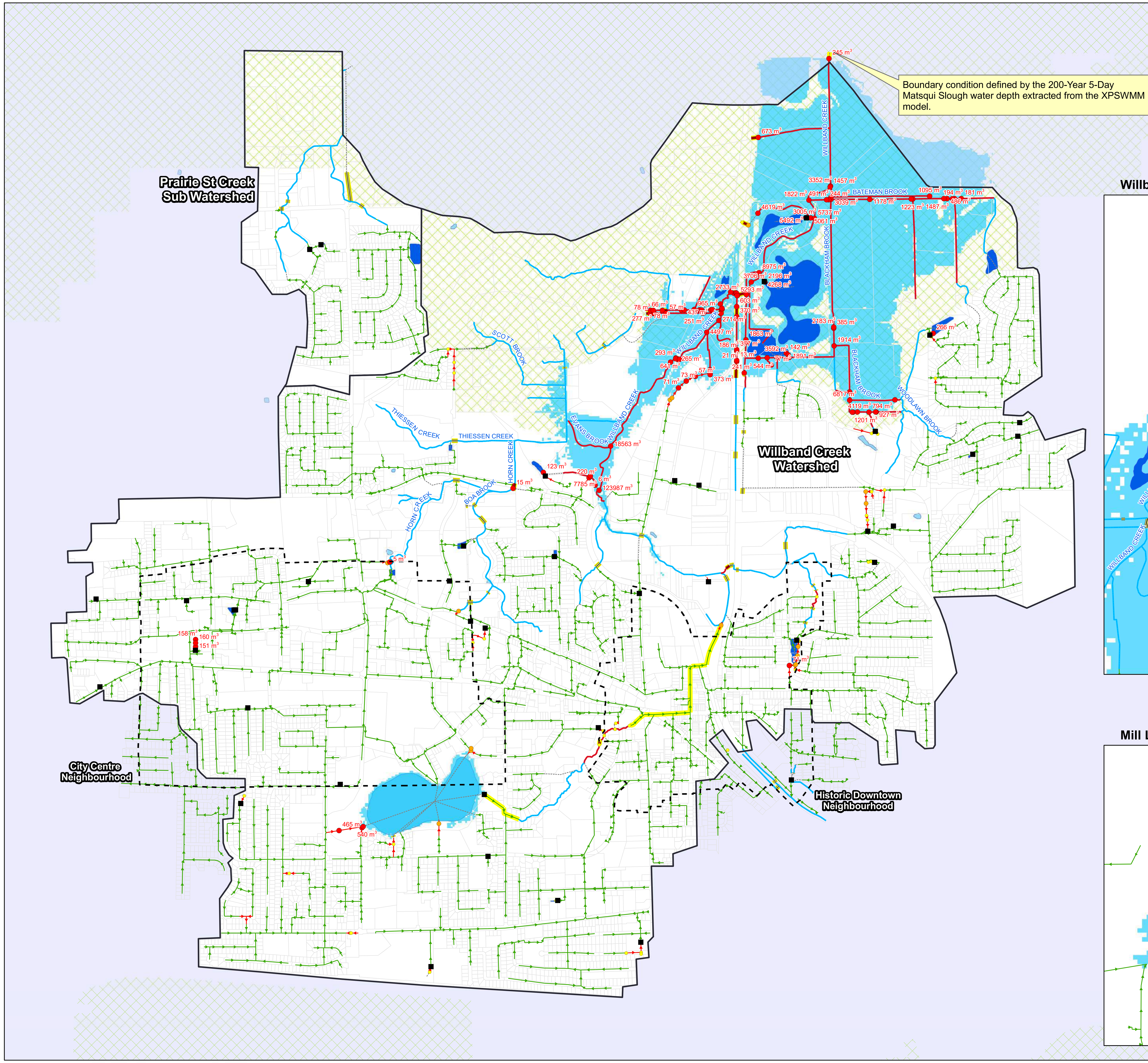
0 0.25 0.5 1
Kilometers

N W E S

**Figure F.2**



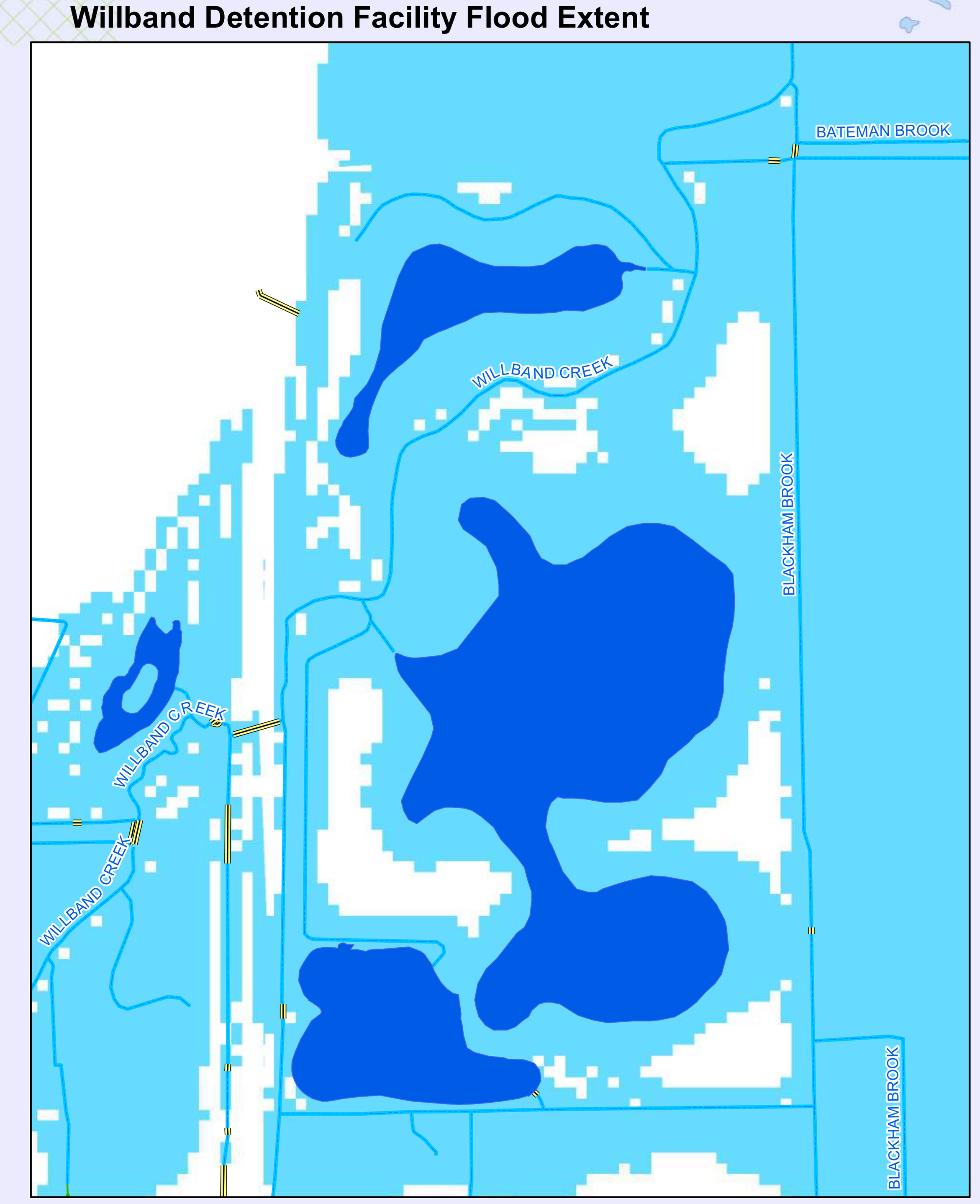

GeoAdvice Engineering Inc.

## Legend

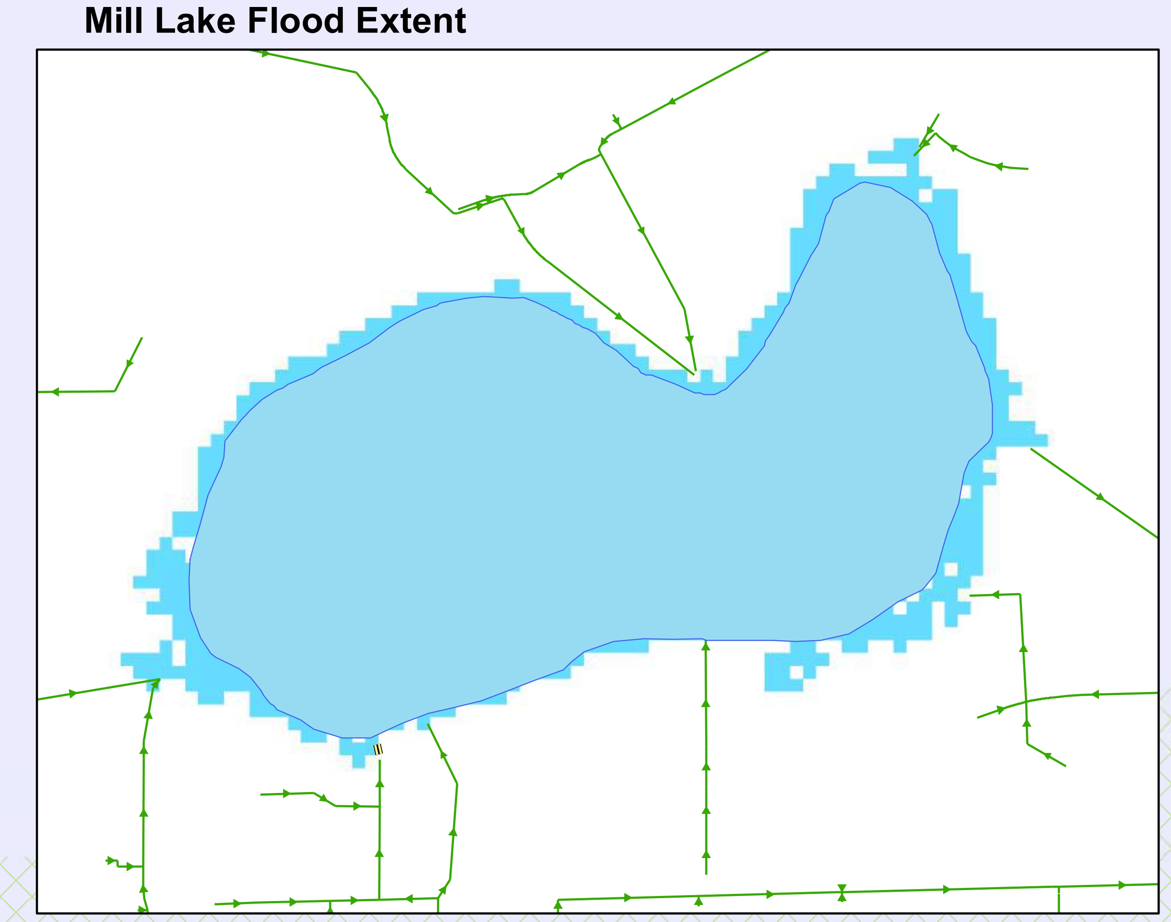
- Willband Creek Watershed Area
- Neighbourhood Boundary
- Control Manhole
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > 0.5m below ground)
- Potential Surcharge (0.5 below ground >= HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Watershed_Screen
- Detention Facility
- Lowland and Mill Lake Flood Extent
- Lake
- Agricultural Land Reserve

Flood extent shown is approximate and have not been updated to reflect scenario.

### Willband Detention Facility Flood Extent




### Mill Lake Flood Extent



**200-Year, 5-Day System Performance (Future Land Use With Upgrades - No Controls) With Climate Change**

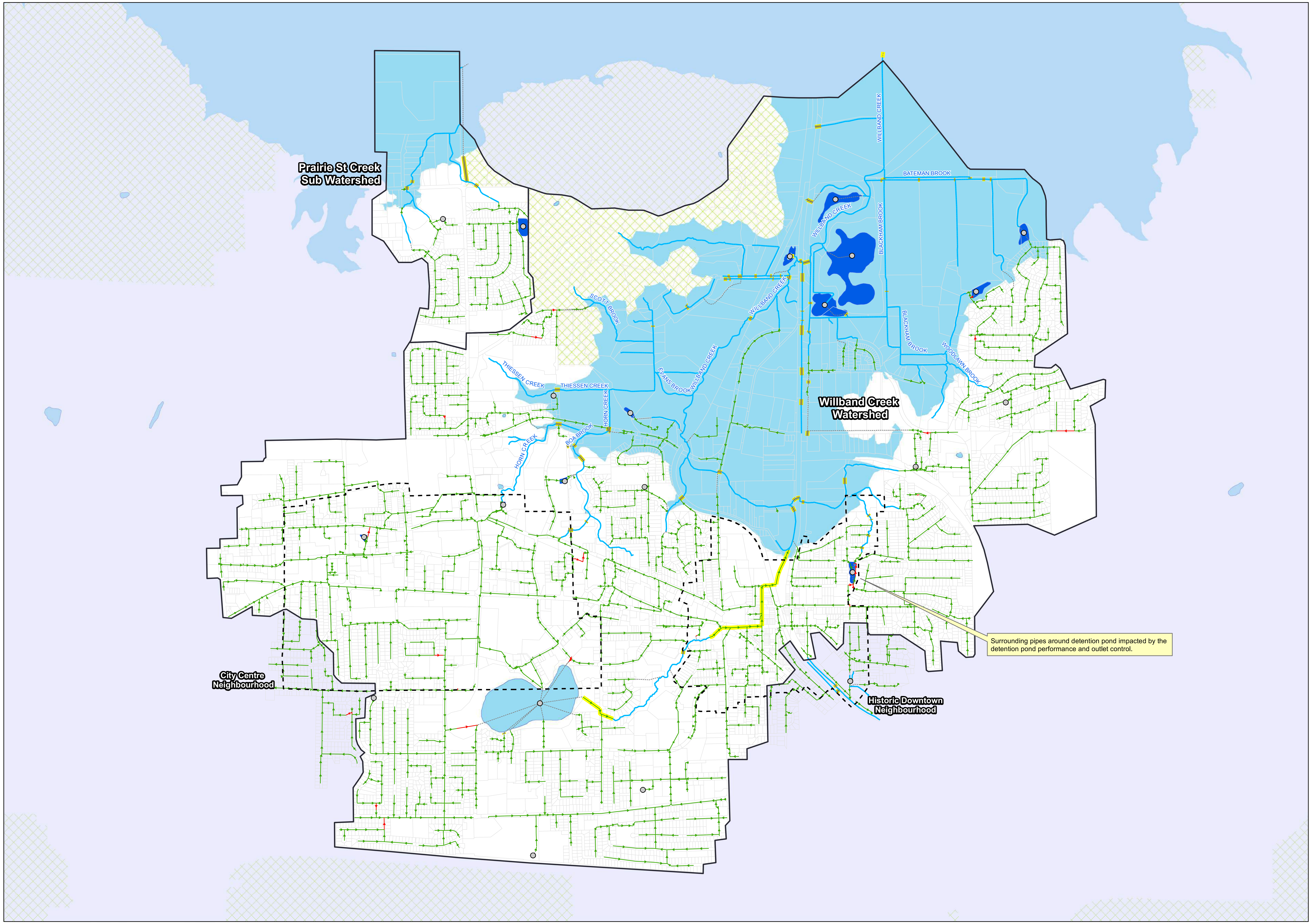
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure F.3**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Storage
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Major System
- Subcatchments
- Detention Facility
- Watershed_Screen
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Storm Sewer Assessment

- Major Main (100-Year) Surcharge > 15 min
- Minor Main (10-Year) Surcharge > 5-min

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Storm Sewer Assessment Against Established Criteria (Future Land Use With Upgrades - No Controls) With Climate Change**

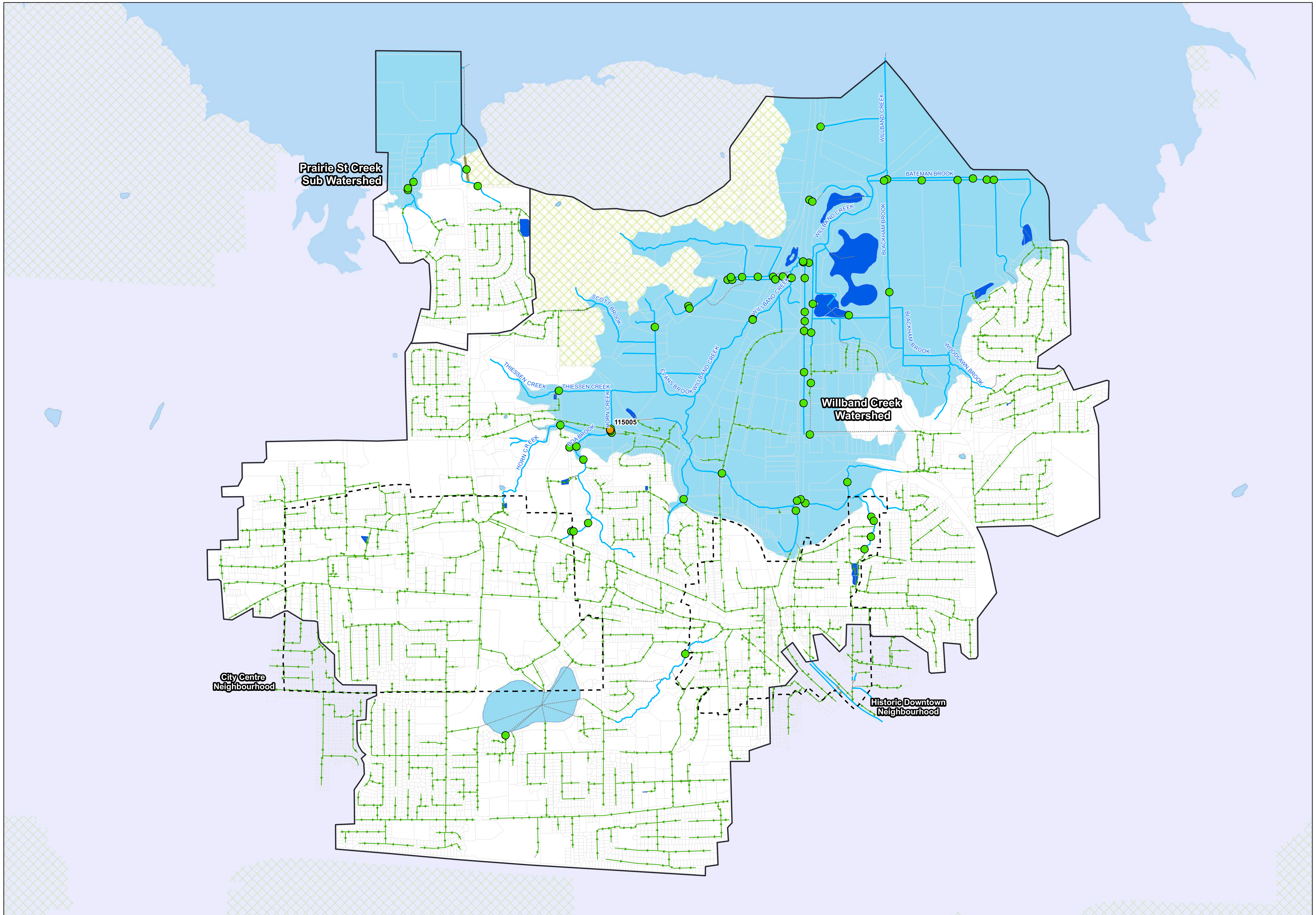
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure F.4**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Subcatchments
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Lake
- Agricultural Land Reserve

### Culvert Assessment

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culvert Assessment Against Established Criteria (Future Land Use With Upgrades - No Controls) With Climate Change**

ABBOTSFORD

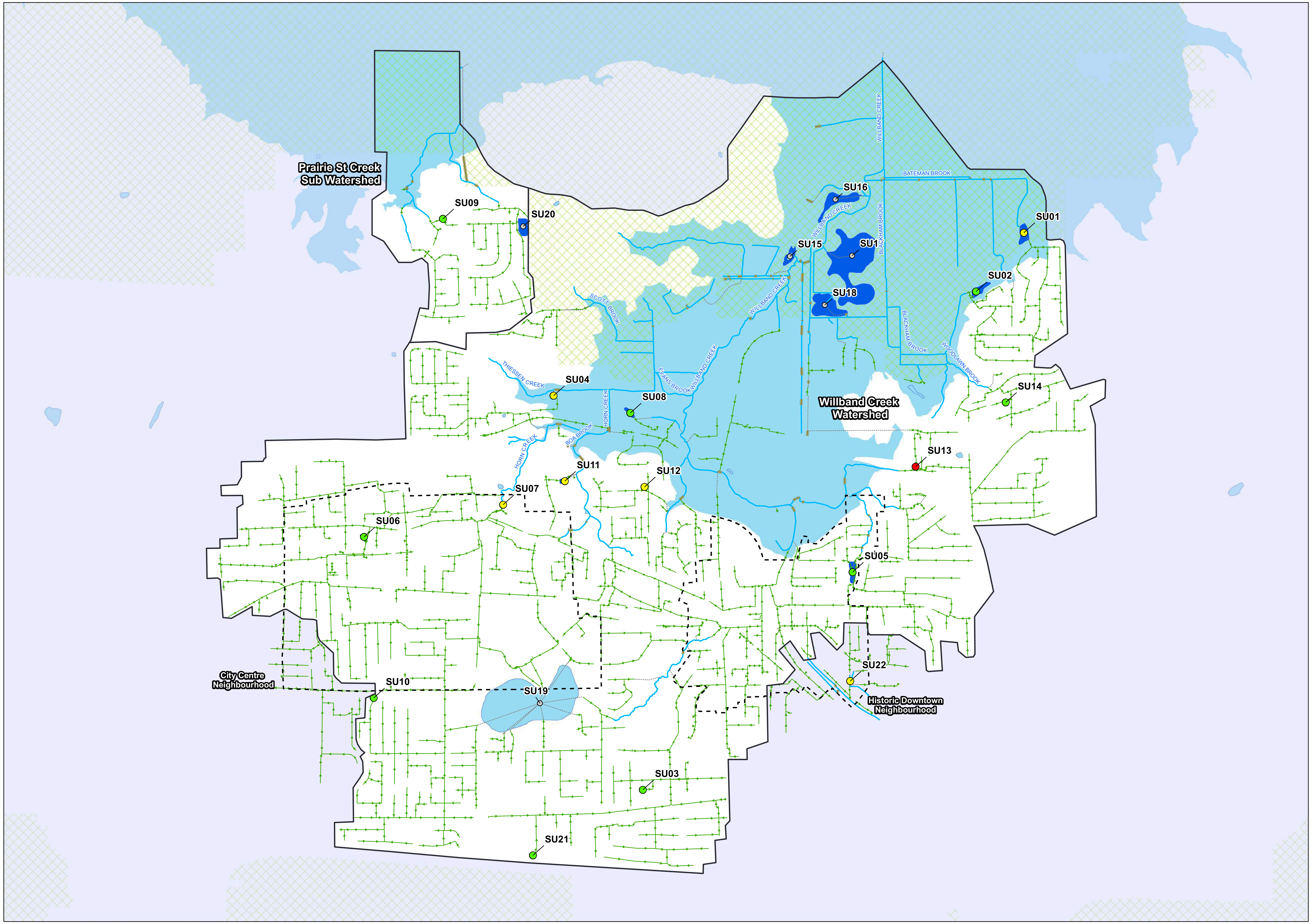
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure F.5**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Storage

## Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume Required to Meet Criteria

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Assessment Against Established Criteria (Future Land Use With Upgrades - No Controls) With Climate Change**

ABBOTSFORD

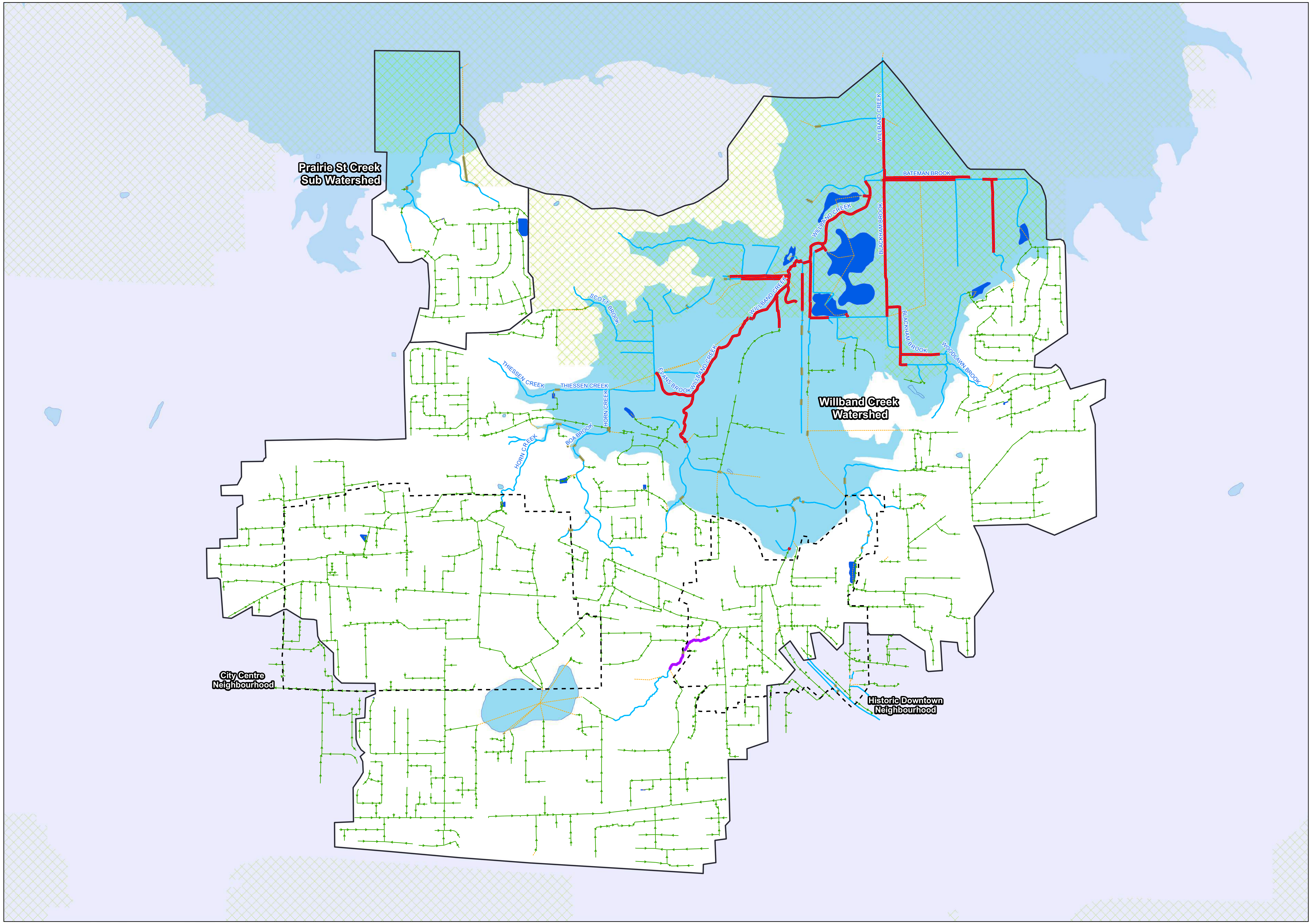
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure F.6**




GeoAdvice Engineering Inc.

## Legend

- Willband Creek Watershed Area
- Neighbourhood Boundary
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Detention Facility
- Lake
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Creek Assessment Against Established Criteria (Future Land Use With Upgrades - No Controls) With Climate Change**

ABBOTSFORD

Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS



**Figure F.7**

# Appendix F Detention Assessment

**Table F.1: Detention Facility Performance Assessment – Future Land Use**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 16.2 | 7.8 | 3,580 | 29% | No - Control+ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.1 | 1.9 | 3,943 | 42% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 7.4 | 3.2 | 439 | 34% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 36.9 | 21.3 | 1,047 | 9% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 5.1 | 2.3 | 3,389 | 79% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 48.7 | 2.5 | 1.6 | 670 | 20% | Yes | |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 32.6 | 32.5 | 757 | 6% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 3.1 | 1.3 | 2,808 | 29% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 5.5 | 2.7 | 212 | 26% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 24.9 | 3.3 | 132 | 26% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 22.8 | 15.3 | 1,511 | 8% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 18.9 | 18.7 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 9.7 | 4.4 | 270 | 98% | Yes | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 4.8 | 3.1 | 637 | 6% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

+ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

**Table F.2: Detention Facility Performance Assessment – Future Land Use with Controls**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 16.0 | 7.7 | 3,580 | 29% | No - Control+ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.1 | 1.9 | 3,943 | 40% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 7.4 | 3.2 | 439 | 34% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 36.9 | 21.3 | 1,047 | 9% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 4.5 | 2.5 | 3,389 | 55% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 48.7 | 1.4 | 1.4 | 670 | 5% | Yes | |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 5.9 | 5.9 | 757 | 3% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 3.1 | 1.3 | 2,808 | 29% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 5.4 | 2.7 | 212 | 26% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 10.0 | 2.6 | 132 | 11% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 22.4 | 14.9 | 1,511 | 8% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 18.1 | 17.9 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 9.7 | 4.3 | 270 | 97% | Yes | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 6.2 | 3.1 | 637 | 6% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

+ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

**Table F.3: Detention Facility Performance Assessment – Future Land Use (Climate Change)**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 19.1 | 9.5 | 3,580 | 32% | No - Control⁺ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.5 | 2.0 | 3,943 | 49% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 8.2 | 3.4 | 439 | 38% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 44.1 | 25.6 | 1,047 | 10% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 5.8 | 2.5 | 3,389 | 92% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 48.7 | 2.7 | 1.6 | 670 | 24% | Yes | |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 39.7 | 39.6 | 757 | 7% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 3.4 | 1.6 | 2,808 | 31% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 6.0 | 2.9 | 212 | 29% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 36.0 | 3.6 | 132 | 34% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 26.1 | 16.6 | 1,511 | 10% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 22.0 | 22.0 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 11.0 | 8.0 | 270 | 99% | No - Storage | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 5.3 | 3.3 | 637 | 7% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

⁺ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

**Table F.4: Detention Facility Performance Assessment – Future Land Use with Controls (Climate Change)**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 18.7 | 9.1 | 3,580 | 32% | No - Control+ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.5 | 2.0 | 3,943 | 48% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 8.2 | 3.4 | 439 | 38% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 44.1 | 25.6 | 1,047 | 10% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 5.0 | 2.7 | 3,389 | 67% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 48.7 | 1.4 | 1.4 | 670 | 5% | Yes | |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 6.4 | 6.3 | 757 | 3% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 3.4 | 1.6 | 2,808 | 31% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 5.9 | 2.9 | 212 | 29% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 14.8 | 2.8 | 132 | 16% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 25.0 | 16.1 | 1,511 | 9% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 20.4 | 20.2 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 10.9 | 8.2 | 270 | 99% | No - Storage | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 6.8 | 3.3 | 637 | 7% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

+ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

**Table F.5: Detention Facility Performance Assessment – Future Land Use with Upgrades (Climate Change)**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 19.3 | 9.3 | 3,580 | 32% | No - Control⁺ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.5 | 2.0 | 3,943 | 48% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 8.2 | 3.4 | 439 | 38% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 44.1 | 25.6 | 1,047 | 10% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 5.9 | 2.8 | 3,389 | 81% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 48.7 | 3.3 | 1.7 | 670 | 27% | Yes | |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 39.7 | 39.6 | 757 | 7% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 3.4 | 1.6 | 2,808 | 31% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 6.0 | 2.9 | 212 | 29% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 41.6 | 3.9 | 132 | 40% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 26.1 | 16.6 | 1,511 | 10% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 0.4 | 22.0 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 10.9 | 8.1 | 270 | 99% | No - Storage | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 8.8 | 3.9 | 637 | 10% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

⁺ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

# Appendix G Required Storm Main and Culvert Upgrades

## Table G.1: Required Storm Main and Culvert Upgrades

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 114759 | 9.7 | 1.0 | 450 | 525 | 100-Year | 0.381 | Upgrade Priority 2 - Culvert | Willband |
| 237611 | 11.6 | 0.1 | 600 | 675 | 10-Year | 0.515 | Upgrade Priority 1 - Culvert | Willband |
| 114768 | 34.7 | 0.2 | 1500 | 1650 | 10-Year | 5.909 | Upgrade Priority 2 - Culvert | Willband |
| 121362 | 67.1 | 0.4 | 300 | 450 | 10-Year | 0.145 | Upgrade Priority 1 | Willband |
| 121380 | 96.1 | 0.2 | 375 | 450 | 10-Year | 0.098 | Upgrade Priority 1 | Willband |
| 121381 | 7.8 | 0.4 | 375 | 450 | 10-Year | 0.130 | Upgrade Priority 1 | Willband |
| 121505 | 80.4 | 0.4 | 375 | 450 | 10-Year | 0.170 | Upgrade Priority 1 | Willband |
| 121516 | 97.4 | 0.4 | 300 | 375 | 10-Year | 0.093 | Upgrade Priority 1 | Willband |
| 121524 | 84.2 | 1.2 | 450 | 600 | 10-Year | 0.424 | Upgrade Priority 1 | Willband |
| 121525 | 74.0 | 2.0 | 300 | 375 | 10-Year | 0.255 | Upgrade Priority 1 | Willband |
| 121527 | 99.5 | 0.4 | 300 | 375 | 10-Year | 0.118 | Upgrade Priority 1 | Willband |
| 126460 | 68.3 | 0.4 | 450 | 525 | 10-Year | 0.273 | Upgrade Priority 1 | Willband |
| 126461 | 71.2 | 0.4 | 375 | 450 | 10-Year | 0.208 | Upgrade Priority 1 | Willband |
| 126462 | 43.7 | 2.8 | 375 | 450 | 10-Year | 0.245 | Upgrade Priority 1 | Willband |
| 126463 | 35.9 | 0.4 | 375 | 450 | 10-Year | 0.191 | Upgrade Priority 1 | Willband |
| 126471 | 103.8 | 0.5 | 375 | 450 | 10-Year | 0.147 | Upgrade Priority 1 | Willband |
| 126969 | 59.1 | 0.4 | 375 | 450 | 10-Year | 0.184 | Upgrade Priority 1 | Willband |
| 126970 | 25.0 | 0.4 | 375 | 450 | 10-Year | 0.170 | Upgrade Priority 1 | Willband |
| 127282 | 25.3 | 0.5 | 300 | 450 | 10-Year | 0.179 | Upgrade Priority 1 | Willband |
| 127288 | 91.5 | 0.5 | 300 | 375 | 10-Year | 0.053 | Upgrade Priority 1 | Willband |
| 127289 | 82.6 | 0.5 | 300 | 450 | 10-Year | 0.098 | Upgrade Priority 1 | Willband |
| 127290 | 13.4 | 0.4 | 300 | 450 | 10-Year | 0.119 | Upgrade Priority 1 | Willband |
| 127296 | 19.9 | 0.4 | 375 | 450 | 10-Year | 0.122 | Upgrade Priority 1 | Willband |
| 127315 | 44.1 | 0.3 | 375 | 450 | 10-Year | 0.133 | Upgrade Priority 1 | Willband |
| 127316 | 81.7 | 0.4 | 375 | 450 | 10-Year | 0.177 | Upgrade Priority 1 | Willband |
| 127544 | 30.5 | 3.0 | 300 | 375 | 10-Year | 0.204 | Upgrade Priority 1 | Willband |
| 127545 | 54.0 | 1.2 | 300 | 450 | 10-Year | 0.189 | Upgrade Priority 1 | Willband |
| 127614 | 44.8 | 2.5 | 300 | 375 | 10-Year | 0.209 | Upgrade Priority 1 | Willband |
| 127637 | 46.4 | 1.0 | 450 | 600 | 10-Year | 0.554 | Upgrade Priority 1 | Willband |
| 127642 | 23.2 | 1.5 | 450 | 525 | 10-Year | 0.579 | Upgrade Priority 1 | Willband |
| 127643 | 3.8 | 1.6 | 450 | 600 | 10-Year | 0.56 | Upgrade Priority 1 | Willband |
| 127644 | 12.7 | 0.9 | 450 | 600 | 10-Year | 0.561 | Upgrade Priority 1 | Willband |
| 127645 | 2.6 | 0.8 | 450 | 600 | 10-Year | 0.572 | Upgrade Priority 1 | Willband |
| 127936 | 69.5 | 1.4 | 250 | 300 | 10-Year | 0.100 | Upgrade Priority 1 | Willband |
| 127937 | 35.3 | 2.7 | 250 | 300 | 10-Year | 0.118 | Upgrade Priority 1 | Willband |
| 127939 | 78.1 | 3.6 | 250 | 300 | 10-Year | 0.184 | Upgrade Priority 1 | Willband |
| 127941 | 14.1 | 1.2 | 375 | 450 | 10-Year | 0.211 | Upgrade Priority 1 | Willband |
| 127955 | 39.0 | 0.3 | 375 | 450 | 10-Year | 0.087 | Upgrade Priority 1 | Willband |
| 127956 | 38.5 | 0.2 | 375 | 450 | 10-Year | 0.097 | Upgrade Priority 1 | Willband |
| 127964 | 26.9 | 0.2 | 525 | 600 | 10-Year | 0.172 | Upgrade Priority 1 | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 127965 | 79.3 | 0.3 | 525 | 600 | 10-Year | 0.300 | Upgrade Priority 1 | Willband |
| 128048 | 125.6 | 1.1 | 450 | 600 | 10-Year | 0.571 | Upgrade Priority 1 | Willband |
| 128049 | 114.1 | 0.8 | 450 | 600 | 10-Year | 0.589 | Upgrade Priority 1 | Willband |
| 131869 | 70.0 | 4.3 | 300 | 375 | 10-Year | 0.210 | Upgrade Priority 1 | Willband |
| 131870 | 20.0 | 4.3 | 300 | 375 | 10-Year | 0.218 | Upgrade Priority 1 | Willband |
| 131871 | 80.0 | 1.3 | 300 | 450 | 10-Year | 0.228 | Upgrade Priority 1 | Willband |
| 131872 | 65.0 | 0.9 | 300 | 450 | 10-Year | 0.241 | Upgrade Priority 1 | Willband |
| 131873 | 10.0 | 2.8 | 300 | 450 | 10-Year | 0.246 | Upgrade Priority 1 | Willband |
| 131969 | 41.5 | 0.3 | 300 | 450 | 10-Year | 0.118 | Upgrade Priority 1 | Willband |
| 132422 | 40.6 | 0.5 | 375 | 525 | 10-Year | 0.277 | Upgrade Priority 1 | Willband |
| 132423 | 13.7 | 1.0 | 375 | 525 | 10-Year | 0.280 | Upgrade Priority 1 | Willband |
| 132424 | 10.0 | 0.6 | 300 | 375 | 10-Year | 0.066 | Upgrade Priority 1 | Willband |
| 132425 | 36.5 | 0.5 | 300 | 375 | 10-Year | 0.069 | Upgrade Priority 1 | Willband |
| 132426 | 44.9 | 0.5 | 300 | 375 | 10-Year | 0.074 | Upgrade Priority 1 | Willband |
| 132427 | 10.5 | 0.5 | 300 | 375 | 10-Year | 0.079 | Upgrade Priority 1 | Willband |
| 132428 | 49.3 | 0.5 | 300 | 450 | 10-Year | 0.199 | Upgrade Priority 1 | Willband |
| 132429 | 46.4 | 0.5 | 300 | 450 | 10-Year | 0.204 | Upgrade Priority 1 | Willband |
| 132534 | 38.5 | 29.8 | 250 | 300 | 10-Year | 0.303 | Upgrade Priority 1 | Willband |
| 254977 | 17.2 | 1.0 | 450 | 600 | 10-Year | 0.595 | Upgrade Priority 1 | Willband |
| 121387 | 96.9 | 0.5 | 375 | 450 | 10-Year | 0.145 | Upgrade Priority 2 | Willband |
| 121474 | 84.5 | 0.3 | 750 | 900 | 10-Year | 1.111 | Upgrade Priority 2 | Willband |
| 121513 | 39.6 | 0.4 | 300 | 450 | 10-Year | 0.078 | Upgrade Priority 2 | Willband |
| 121517 | 34.9 | 0.6 | 375 | 450 | 10-Year | 0.159 | Upgrade Priority 2 | Willband |
| 121548 | 118.9 | 0.3 | 750 | 900 | 10-Year | 1.032 | Upgrade Priority 2 | Willband |
| 121687 | 88.8 | 0.4 | 375 | 450 | 10-Year | 0.141 | Upgrade Priority 2 | Willband |
| 126423 | 47.2 | 0.6 | 375 | 450 | 10-Year | 0.164 | Upgrade Priority 2 | Willband |
| 126717 | 34.5 | 0.5 | 300 | 450 | 10-Year | 0.101 | Upgrade Priority 2 | Willband |
| 126816 | 72.9 | 0.5 | 300 | 375 | 10-Year | 0.079 | Upgrade Priority 2 | Willband |
| 126817 | 49.9 | 0.4 | 300 | 375 | 10-Year | 0.046 | Upgrade Priority 2 | Willband |
| 127187 | 105.2 | 0.4 | 600 | 675 | 10-Year | 0.504 | Upgrade Priority 2 | Willband |
| 127188 | 95.7 | 0.5 | 600 | 675 | 10-Year | 0.546 | Upgrade Priority 2 | Willband |
| 127192 | 118.0 | 0.5 | 600 | 675 | 10-Year | 0.563 | Upgrade Priority 2 | Willband |
| 127287 | 70.8 | 1.7 | 300 | 375 | 10-Year | 0.145 | Upgrade Priority 2 | Willband |
| 127301 | 31.1 | 2.5 | 600 | 675 | 10-Year | 1.125 | Upgrade Priority 2 | Willband |
| 127302 | 19.1 | 1.3 | 600 | 675 | 10-Year | 1.000 | Upgrade Priority 2 | Willband |
| 127449 | 44.2 | 4.1 | 375 | 525 | 10-Year | 0.392 | Upgrade Priority 2 | Willband |
| 127451 | 41.2 | 1.2 | 450 | 600 | 10-Year | 0.402 | Upgrade Priority 2 | Willband |
| 127966 | 76.7 | 0.5 | 525 | 600 | 10-Year | 0.317 | Upgrade Priority 2 | Willband |
| 128022 | 61.3 | 1.5 | 300 | 375 | 10-Year | 0.173 | Upgrade Priority 2 | Willband |
| 131958 | 75.6 | 0.2 | 250 | 300 | 10-Year | 0.033 | Upgrade Priority 2 | Willband |
| 132001 | 58.8 | 0.2 | 300 | 375 | 10-Year | 0.052 | Upgrade Priority 2 | Willband |
| 121377 | 48.3 | 0.5 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 121383 | 54.9 | 1.0 | 250 | 300 | 10-Year | 0.018 | Upgrade Priority 3 | Willband |
| 121384 | 50.6 | 0.4 | 250 | 300 | 10-Year | 0.004 | Upgrade Priority 3 | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 121389 | 57.8 | 2.5 | 250 | 300 | 10-Year | 0.040 | Upgrade Priority 3 | Willband |
| 121390 | 67.7 | 1.1 | 250 | 300 | 10-Year | 0.059 | Upgrade Priority 3 | Willband |
| 121394 | 82.9 | 8.1 | 250 | 300 | 10-Year | 0.045 | Upgrade Priority 3 | Willband |
| 121397 | 37.1 | 1.9 | 250 | 300 | 10-Year | 0.057 | Upgrade Priority 3 | Willband |
| 121398 | 74.4 | 7.6 | 200 | 300 | 10-Year | 0.020 | Upgrade Priority 3 | Willband |
| 121399 | 55.8 | 2.1 | 200 | 300 | 10-Year | 0.017 | Upgrade Priority 3 | Willband |
| 121400 | 52.4 | 4.6 | 200 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Willband |
| 121401 | 92.1 | 4.6 | 200 | 300 | 10-Year | 0.019 | Upgrade Priority 3 | Willband |
| 121405 | 49.1 | 2.7 | 250 | 300 | 10-Year | 0.003 | Upgrade Priority 3 | Willband |
| 121413 | 62.8 | 0.5 | 250 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Willband |
| 121416 | 67.7 | 0.5 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 121569 | 54.7 | 9.0 | 250 | 300 | 10-Year | 0.042 | Upgrade Priority 3 | Willband |
| 121879 | 13.5 | 0.3 | 200 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Willband |
| 121933 | 83.8 | 0.2 | 250 | 300 | 10-Year | 0.026 | Upgrade Priority 3 | Willband |
| 121936 | 32.6 | 0.4 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Willband |
| 121937 | 34.9 | 0.4 | 250 | 300 | 10-Year | 0.003 | Upgrade Priority 3 | Willband |
| 122333 | 87.4 | 2.1 | 150 | 300 | 10-Year | 0.025 | Upgrade Priority 3 | Willband |
| 122403 | 111.8 | 0.8 | 150 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Willband |
| 122405 | 104.0 | 0.3 | 250 | 300 | 10-Year | 0.032 | Upgrade Priority 3 | Willband |
| 122407 | 5.5 | 0.4 | 250 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Willband |
| 122410 | 2.6 | 0.4 | 250 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Willband |
| 127283 | 76.2 | 0.4 | 250 | 300 | 10-Year | 0.007 | Upgrade Priority 3 | Willband |
| 127284 | 52.4 | 0.4 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 127285 | 106.1 | 0.5 | 250 | 300 | 10-Year | 0.048 | Upgrade Priority 3 | Willband |
| 127286 | 20.4 | 0.5 | 250 | 300 | 10-Year | 0.024 | Upgrade Priority 3 | Willband |
| 127419 | 97.6 | 2.3 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | Willband |
| 127427 | 55.4 | 6.0 | 250 | 300 | 10-Year | 0.043 | Upgrade Priority 3 | Willband |
| 127431 | 62.5 | 3.3 | 250 | 300 | 10-Year | 0.043 | Upgrade Priority 3 | Willband |
| 127432 | 21.1 | 15.1 | 250 | 300 | 10-Year | 0.053 | Upgrade Priority 3 | Willband |
| 127435 | 36.0 | 30.9 | 250 | 300 | 10-Year | 0.074 | Upgrade Priority 3 | Willband |
| 127436 | 31.3 | 11.3 | 250 | 300 | 10-Year | 0.086 | Upgrade Priority 3 | Willband |
| 127437 | 33.0 | 23.6 | 250 | 300 | 10-Year | 0.086 | Upgrade Priority 3 | Willband |
| 127456 | 55.8 | 6.9 | 250 | 300 | 10-Year | 0.077 | Upgrade Priority 3 | Willband |
| 127487 | 17.5 | 37.9 | 250 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Willband |
| 127520 | 33.7 | 1.7 | 250 | 300 | 10-Year | 0.103 | Upgrade Priority 3 | Willband |
| 127521 | 19.8 | 2.5 | 250 | 300 | 10-Year | 0.037 | Upgrade Priority 3 | Willband |
| 127543 | 14.2 | 4.0 | 250 | 300 | 10-Year | 0.086 | Upgrade Priority 3 | Willband |
| 127574 | 23.0 | 13.1 | 250 | 300 | 10-Year | 0.075 | Upgrade Priority 3 | Willband |
| 127925 | 73.5 | 5.0 | 200 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 127926 | 43.2 | 0.5 | 200 | 300 | 10-Year | 0.020 | Upgrade Priority 3 | Willband |
| 127927 | 65.0 | 0.4 | 250 | 300 | 10-Year | 0.045 | Upgrade Priority 3 | Willband |
| 127929 | 29.0 | 5.1 | 200 | 300 | 10-Year | 0.012 | Upgrade Priority 3 | Willband |
| 127931 | 73.2 | 1.8 | 250 | 300 | 10-Year | 0.031 | Upgrade Priority 3 | Willband |
| 127932 | 46.5 | 1.6 | 250 | 300 | 10-Year | 0.049 | Upgrade Priority 3 | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 127934 | 16.8 | 4.1 | 250 | 300 | 10-Year | 0.028 | Upgrade Priority 3 | Willband |
| 127935 | 42.7 | 1.2 | 250 | 300 | 10-Year | 0.025 | Upgrade Priority 3 | Willband |
| 127946 | 44.0 | 0.5 | 250 | 300 | 10-Year | 0.045 | Upgrade Priority 3 | Willband |
| 127947 | 39.4 | 0.0 | 250 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Willband |
| 127948 | 51.6 | 0.7 | 250 | 300 | 10-Year | 0.076 | Upgrade Priority 3 | Willband |
| 127949 | 11.6 | 0.3 | 250 | 300 | 10-Year | 0.099 | Upgrade Priority 3 | Willband |
| 128002 | 75.3 | 3.7 | 250 | 300 | 10-Year | 0.058 | Upgrade Priority 3 | Willband |
| 128021 | 57.3 | 0.4 | 250 | 300 | 10-Year | 0.051 | Upgrade Priority 3 | Willband |
| 128029 | 58.5 | 0.8 | 250 | 300 | 10-Year | 0.080 | Upgrade Priority 3 | Willband |
| 128030 | 53.2 | 0.8 | 250 | 300 | 10-Year | 0.068 | Upgrade Priority 3 | Willband |
| 128037 | 65.0 | 8.4 | 250 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Willband |
| 128038 | 13.4 | 0.0 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Willband |
| 128040 | 94.1 | 0.9 | 250 | 300 | 10-Year | 0.039 | Upgrade Priority 3 | Willband |
| 128054 | 75.9 | 0.6 | 250 | 300 | 10-Year | 0.016 | Upgrade Priority 3 | Willband |
| 128055 | 21.4 | 1.4 | 200 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Willband |
| 128058 | 77.7 | 0.8 | 150 | 300 | 10-Year | 0.057 | Upgrade Priority 3 | Willband |
| 128255 | 8.1 | 2.7 | 250 | 300 | 10-Year | 0.199 | Upgrade Priority 3 | Willband |
| 128256 | 16.1 | 3.7 | 250 | 300 | 10-Year | 0.199 | Upgrade Priority 3 | Willband |
| 128257 | 43.0 | 30.2 | 250 | 300 | 10-Year | 0.198 | Upgrade Priority 3 | Willband |
| 131589 | 64.3 | 4.6 | 250 | 300 | 10-Year | 0.019 | Upgrade Priority 3 | Willband |
| 131590 | 68.7 | 0.7 | 250 | 300 | 10-Year | 0.034 | Upgrade Priority 3 | Willband |
| 131591 | 64.7 | 4.6 | 250 | 300 | 10-Year | 0.045 | Upgrade Priority 3 | Willband |
| 131592 | 37.3 | 3.6 | 250 | 300 | 10-Year | 0.048 | Upgrade Priority 3 | Willband |
| 131593 | 57.4 | 2.2 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Willband |
| 131594 | 83.5 | 4.3 | 250 | 300 | 10-Year | 0.063 | Upgrade Priority 3 | Willband |
| 131599 | 62.0 | 2.8 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Willband |
| 131623 | 79.9 | 2.2 | 250 | 300 | 10-Year | 0.054 | Upgrade Priority 3 | Willband |
| 131639 | 45.0 | 3.8 | 250 | 300 | 10-Year | 0.002 | Upgrade Priority 3 | Willband |
| 131640 | 56.5 | 2.1 | 250 | 300 | 10-Year | 0.002 | Upgrade Priority 3 | Willband |
| 131875 | 60.1 | 0.3 | 250 | 300 | 10-Year | 0.008 | Upgrade Priority 3 | Willband |
| 131878 | 50.7 | 1.4 | 250 | 300 | 10-Year | 0.007 | Upgrade Priority 3 | Willband |
| 131899 | 81.0 | 4.8 | 250 | 300 | 10-Year | 0.024 | Upgrade Priority 3 | Willband |
| 131901 | 68.0 | 3.4 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 131912 | 59.0 | 5.7 | 250 | 300 | 10-Year | 0.008 | Upgrade Priority 3 | Willband |
| 131949 | 40.4 | 2.3 | 200 | 300 | 10-Year | 0.048 | Upgrade Priority 3 | Willband |
| 131950 | 61.7 | 7.7 | 250 | 300 | 10-Year | 0.018 | Upgrade Priority 3 | Willband |
| 131955 | 105.5 | 4.7 | 250 | 300 | 10-Year | 0.008 | Upgrade Priority 3 | Willband |
| 131992 | 38.5 | 1.3 | 250 | 300 | 10-Year | 0.004 | Upgrade Priority 3 | Willband |
| 132000 | 42.6 | 8.7 | 250 | 300 | 10-Year | 0.108 | Upgrade Priority 3 | Willband |
| 132002 | 90.8 | 4.0 | 250 | 300 | 10-Year | 0.070 | Upgrade Priority 3 | Willband |
| 132056 | 7.5 | 0.7 | 200 | 300 | 10-Year | 0.042 | Upgrade Priority 3 | Willband |
| 132075 | 32.7 | 3.8 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Willband |
| 132076 | 50.9 | 4.8 | 250 | 300 | 10-Year | 0.002 | Upgrade Priority 3 | Willband |
| 132077 | 15.0 | 1.3 | 250 | 300 | 10-Year | 0.007 | Upgrade Priority 3 | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 132136 | 66.9 | 7.3 | 250 | 300 | 10-Year | 0.025 | Upgrade Priority 3 | Willband |
| 132138 | 57.6 | 0.8 | 200 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Willband |
| 132143 | 38.7 | 7.0 | 250 | 300 | 10-Year | 0.001 | Upgrade Priority 3 | Willband |
| 132144 | 84.2 | 4.5 | 250 | 300 | 10-Year | 0.022 | Upgrade Priority 3 | Willband |
| 132148 | 101.6 | 4.9 | 250 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Willband |
| 132171 | 111.6 | 2.6 | 250 | 300 | 10-Year | 0.012 | Upgrade Priority 3 | Willband |
| 132225 | 80.7 | 1.0 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | Willband |
| 132226 | 8.2 | 14.9 | 250 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Willband |
| 132250 | 61.2 | 9.2 | 250 | 300 | 10-Year | 0.023 | Upgrade Priority 3 | Willband |
| 132270 | 99.1 | 0.5 | 250 | 300 | 10-Year | 0.017 | Upgrade Priority 3 | Willband |
| 132271 | 38.9 | 0.7 | 250 | 300 | 10-Year | 0.019 | Upgrade Priority 3 | Willband |
| 132277 | 48.0 | 12.9 | 250 | 300 | 10-Year | 0.012 | Upgrade Priority 3 | Willband |
| 132288 | 29.3 | 0.8 | 250 | 300 | 10-Year | 0.003 | Upgrade Priority 3 | Willband |
| 132289 | 31.1 | 1.1 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | Willband |
| 132290 | 66.5 | 6.1 | 250 | 300 | 10-Year | 0.019 | Upgrade Priority 3 | Willband |
| 132295 | 82.9 | 3.5 | 250 | 300 | 10-Year | 0.017 | Upgrade Priority 3 | Willband |
| 132296 | 30.5 | 1.7 | 250 | 300 | 10-Year | 0.009 | Upgrade Priority 3 | Willband |
| 132305 | 81.4 | 1.0 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Willband |
| 132308 | 90.0 | 3.1 | 250 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Willband |
| 132309 | 119.9 | 3.6 | 250 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Willband |
| 132313 | 59.0 | 7.1 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 132327 | 59.0 | 3.3 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | Willband |
| 132331 | 45.0 | 7.2 | 250 | 300 | 10-Year | 0.003 | Upgrade Priority 3 | Willband |
| 132332 | 103.5 | 11.4 | 250 | 300 | 10-Year | 0.020 | Upgrade Priority 3 | Willband |
| 132336 | 65.2 | 3.6 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | Willband |
| 132337 | 18.3 | 12.1 | 150 | 300 | 10-Year | 0.002 | Upgrade Priority 3 | Willband |
| 132338 | 15.0 | 64.9 | 250 | 300 | 10-Year | 0.017 | Upgrade Priority 3 | Willband |
| 132339 | 3.0 | 0.0 | 250 | 300 | 10-Year | 0.028 | Upgrade Priority 3 | Willband |
| 132342 | 64.1 | 9.3 | 250 | 300 | 10-Year | 0.015 | Upgrade Priority 3 | Willband |
| 132438 | 86.0 | 0.6 | 250 | 300 | 10-Year | 0.008 | Upgrade Priority 3 | Willband |
| 132439 | 43.1 | 6.5 | 250 | 300 | 10-Year | 0.016 | Upgrade Priority 3 | Willband |
| 132448 | 39.6 | 8.4 | 250 | 300 | 10-Year | 0.004 | Upgrade Priority 3 | Willband |
| 132449 | 47.5 | 1.7 | 250 | 300 | 10-Year | 0.012 | Upgrade Priority 3 | Willband |
| 132450 | 42.4 | 1.2 | 250 | 300 | 10-Year | 0.015 | Upgrade Priority 3 | Willband |
| 132451 | 46.6 | 41.6 | 250 | 300 | 10-Year | 0.018 | Upgrade Priority 3 | Willband |
| 132452 | 18.2 | 2.6 | 250 | 300 | 10-Year | 0.018 | Upgrade Priority 3 | Willband |
| 251090 | 43.7 | 6.7 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Willband |
| 251091 | 48.0 | 2.4 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Willband |
| 254997 | 20.8 | 0.5 | 200 | 300 | 10-Year | 0.002 | Upgrade Priority 3 | Willband |
| 254998 | 31.7 | 1.3 | 250 | 300 | 10-Year | 0.090 | Upgrade Priority 3 | Willband |
| 254999 | 28.4 | 1.7 | 250 | 300 | 10-Year | 0.083 | Upgrade Priority 3 | Willband |
| 255000 | 21.9 | 1.5 | 250 | 300 | 10-Year | 0.094 | Upgrade Priority 3 | Willband |
| PR-C048 | 196.4 | 2.0 | 0 | 300 | 10-Year | 0.042 | New Main | Willband |
| PR-C050 | 119.2 | 3.5 | 0 | 300 | 10-Year | 0.024 | New Main | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| PR-C068 | 154.4 | 1.5 | 0 | 300 | 10-Year | 0.021 | New Main | Willband |
| PR-C079 | 119.3 | 1.0 | 0 | 375 | 10-Year | 0.129 | New Main | Willband |
| PR-C080 | 64.5 | 2.2 | 0 | 300 | 10-Year | 0.014 | New Main | Willband |
| PR-C081 | 146.3 | 0.3 | 0 | 300 | 10-Year | 0.024 | New Main | Willband |
| PR-C082 | 102.3 | 0.7 | 0 | 300 | 10-Year | 0.062 | New Main | Willband |
| PR-C083 | 101.3 | 1.2 | 0 | 300 | 10-Year | 0.099 | New Main | Willband |
| PR-C084 | 113.6 | 1.1 | 0 | 300 | 10-Year | 0.010 | New Main | Willband |
| PR-C085 | 143.6 | 0.4 | 0 | 300 | 10-Year | 0.017 | New Main | Willband |
| PR-C086 | 107.1 | 3.1 | 0 | 300 | 10-Year | 0.067 | New Main | Willband |
| PR-C087 | 205.5 | 1.2 | 0 | 300 | 10-Year | 0.024 | New Main | Willband |
| PR-C088 | 81.4 | 1.3 | 0 | 300 | 10-Year | 0.010 | New Main | Willband |
| PR-C089 | 144.8 | 1.5 | 0 | 300 | 10-Year | 0.014 | New Main | Willband |
| PR-C090 | 64.6 | 1.5 | 0 | 300 | 10-Year | 0.003 | New Main | Willband |
| PR-C091 | 117.8 | 1.1 | 0 | 300 | 10-Year | 0.025 | New Main | Willband |
| PR-C092 | 113.8 | 1.8 | 0 | 300 | 10-Year | 0.044 | New Main | Willband |
| PR-C093 | 80.5 | 1.6 | 0 | 300 | 10-Year | 0.005 | New Main | Willband |
| PR-C094 | 89.8 | 1.2 | 0 | 300 | 10-Year | 0.023 | New Main | Willband |
| PR-C095 | 56.2 | 1.4 | 0 | 300 | 10-Year | 0.040 | New Main | Willband |
| PR-C096 | 67.9 | 1.8 | 0 | 300 | 10-Year | 0.053 | New Main | Willband |
| PR-C097 | 176.7 | 1.2 | 0 | 300 | 10-Year | 0.021 | New Main | Willband |
| PR-C098 | 97.7 | 2.6 | 0 | 300 | 10-Year | 0.016 | New Main | Willband |
| PR-C099 | 114.2 | 0.3 | 0 | 300 | 10-Year | 0.024 | New Main | Willband |
| PR-C100 | 120.7 | 0.7 | 0 | 300 | 10-Year | 0.046 | New Main | Willband |
| PR-C101 | 100.3 | 1.9 | 0 | 300 | 10-Year | 0.005 | New Main | Willband |
| PR-C102 | 104.6 | 2.3 | 0 | 300 | 10-Year | 0.093 | New Main | Willband |
| PR-C103 | 86.3 | 10.5 | 0 | 300 | 10-Year | 0.099 | New Main | Willband |
| PR-C104 | 26.4 | 25.1 | 0 | 300 | 10-Year | 0.102 | New Main | Willband |
| PR-C105 | 68.5 | 0.4 | 0 | 300 | 10-Year | 0.015 | New Main | Willband |
| PR-C106 | 76.5 | 2.7 | 0 | 300 | 10-Year | 0.026 | New Main | Willband |
| PR-C107 | 62.4 | 3.5 | 0 | 300 | 10-Year | 0.034 | New Main | Willband |
| PR-C108 | 80.9 | 0.5 | 0 | 300 | 10-Year | 0.014 | New Main | Willband |
| PR-C109 | 91.3 | 0.5 | 0 | 300 | 10-Year | 0.030 | New Main | Willband |
| PR-C110 | 63.0 | 0.9 | 0 | 300 | 10-Year | 0.011 | New Main | Willband |
| PR-C111 | 90.1 | 0.5 | 0 | 300 | 10-Year | 0.057 | New Main | Willband |
| PR-C112 | 93.1 | 4.3 | 0 | 300 | 10-Year | 0.076 | New Main | Willband |
| PR-C113 | 56.1 | 1.6 | 0 | 300 | 10-Year | 0.089 | New Main | Willband |
| PR-C114 | 175.6 | 0.2 | 0 | 300 | 10-Year | 0.026 | New Main | Willband |
| PR-C115 | 123.1 | 1.8 | 0 | 300 | 10-Year | 0.029 | New Main | Willband |
| PR-C116 | 126.3 | 0.7 | 0 | 300 | 10-Year | 0.024 | New Main | Willband |
| PR-C117 | 70.1 | 0.5 | 0 | 300 | 10-Year | 0.016 | New Main | Willband |
| PR-C118 | 102.5 | 1.0 | 0 | 300 | 10-Year | 0.022 | New Main | Willband |
| PR-C119 | 87.1 | 3.7 | 0 | 300 | 10-Year | 0.032 | New Main | Willband |
| PR-C120 | 155.8 | 1.1 | 0 | 300 | 10-Year | 0.017 | New Main | Willband |
| PR-C121 | 152.7 | 0.9 | 0 | 300 | 10-Year | 0.019 | New Main | Willband |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| PR-C122 | 97.4 | 0.9 | 0 | 300 | 10-Year | 0.022 | New Main | Willband |
| PR-C123 | 105.8 | 2.7 | 0 | 300 | 10-Year | 0.056 | New Main | Willband |
| PR-C124 | 135.8 | 1.6 | 0 | 300 | 10-Year | 0.091 | New Main | Willband |
| PR-C125 | 101.4 | 0.3 | 0 | 300 | 10-Year | 0.023 | New Main | Willband |
| PR-C126 | 124.0 | 1.7 | 0 | 300 | 10-Year | 0.035 | New Main | Willband |
| PR-C127 | 139.9 | 1.3 | 0 | 300 | 10-Year | 0.012 | New Main | Willband |
| PR-C128 | 80.5 | 0.2 | 0 | 300 | 10-Year | 0.029 | New Main | Willband |
| PR-C129 | 131.7 | 7.4 | 0 | 300 | 10-Year | 0.026 | New Main | Willband |
| PR-C130 | 73.0 | 8.0 | 0 | 300 | 10-Year | 0.022 | New Main | Willband |
| PR-C131 | 66.4 | 0.8 | 0 | 375 | 10-Year | 0.131 | New Main | Willband |
| PR-C132 | 106.1 | 2.9 | 0 | 300 | 10-Year | 0.025 | New Main | Willband |
| PR-C133 | 63.1 | 0.8 | 0 | 300 | 10-Year | 0.089 | New Main | Willband |
| PR-C134 | 56.3 | 1.3 | 0 | 300 | 10-Year | 0.029 | New Main | Willband |
| PR-C135 | 77.4 | 4.5 | 0 | 300 | 10-Year | 0.017 | New Main | Willband |
| PR-C136 | 68.7 | 0.2 | 0 | 300 | 10-Year | 0.053 | New Main | Willband |
| PR-C137 | 90.5 | 0.8 | 0 | 300 | 10-Year | 0.034 | New Main | Willband |
| PR-C138 | 98.9 | 1.9 | 0 | 300 | 10-Year | 0.010 | New Main | Willband |
| PR-C139 | 138.2 | 0.3 | 0 | 300 | 10-Year | 0.029 | New Main | Willband |
| PR-C140 | 87.5 | 0.1 | 0 | 300 | 10-Year | 0.013 | New Main | Willband |
| PR-C141 | 84.0 | 14.4 | 0 | 300 | 10-Year | 0.036 | New Main | Willband |
| PR-C142 | 58.6 | 2.6 | 0 | 300 | 10-Year | 0.004 | New Main | Willband |
| PR-C143 | 65.0 | 3.1 | 0 | 300 | 10-Year | 0.021 | New Main | Willband |
| PR-C144 | 62.0 | 6.1 | 0 | 300 | 10-Year | 0.027 | New Main | Willband |
| PR-C145 | 94.6 | 1.3 | 0 | 300 | 10-Year | 0.016 | New Main | Willband |
| PR-C146 | 60.6 | 5.2 | 0 | 300 | 10-Year | 0.028 | New Main | Willband |
| PR-C147 | 51.6 | 0.7 | 0 | 300 | 10-Year | 0.016 | New Main | Willband |
| PR-C148 | 22.8 | 3.4 | 0 | 300 | 10-Year | 0.020 | New Main | Willband |
| PR-C149 | 78.6 | 4.5 | 0 | 300 | 10-Year | 0.036 | New Main | Willband |
| PR-C150 | 48.4 | 0.7 | 0 | 300 | 10-Year | 0.005 | New Main | Willband |
| PR-C151 | 77.0 | 2.8 | 0 | 300 | 10-Year | 0.002 | New Main | Willband |
| PR-C152 | 65.8 | 3.2 | 0 | 300 | 10-Year | 0.009 | New Main | Willband |
| PR-C153 | 61.9 | 1.5 | 0 | 300 | 10-Year | 0.030 | New Main | Willband |
| PR-C154 | 58.7 | 3.1 | 0 | 300 | 10-Year | 0.009 | New Main | Willband |
| PR-C155 | 47.8 | 1.2 | 0 | 300 | 10-Year | 0.016 | New Main | Willband |
| 114766 | 14.4 | 1.5 | 450 | 600 | 100-Year | 0.420 | Upgrade Priority 1 - Culvert | Historic DT |
| 128406 | 156.3 | 0.9 | 1350 | 1650 | 100-Year | 8.376 | Upgrade Priority 1 | Historic DT |
| 128407 | 9.6 | 0.8 | 1350 | 1650 | 100-Year | 8.335 | Upgrade Priority 1 | Historic DT |
| 127776 | 44.0 | 1.4 | 1500 | 1650 | 100-Year | 10.343 | Upgrade Priority 2 | Historic DT |
| 127777 | 40.2 | 1.1 | 1500 | 1650 | 100-Year | 9.117 | Upgrade Priority 2 | Historic DT |
| 127779 | 23.5 | 1.6 | 1350 | 1650 | 100-Year | 8.412 | Upgrade Priority 2 | Historic DT |
| 128168 | 35.6 | 25.9 | 300 | 450 | 10-Year | 0.660 | Upgrade Priority 1 | Historic DT |
| 227684 | 25.6 | 0.5 | 375 | 600 | 10-Year | 0.660 | Upgrade Priority 1 | Historic DT |
| 122327 | 143.4 | 0.8 | 450 | 525 | 10-Year | 0.298 | Upgrade Priority 2 | Historic DT |
| 127441 | 115.0 | 0.5 | 300 | 375 | 10-Year | 0.082 | Upgrade Priority 2 | Historic DT |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 127793 | 121.1 | 2.9 | 300 | 375 | 10-Year | 0.236 | Upgrade Priority 2 | Historic DT |
| 127815 | 52.8 | 0.6 | 525 | 675 | 10-Year | 0.541 | Upgrade Priority 2 | Historic DT |
| 127885 | 10.9 | 0.9 | 600 | 750 | 10-Year | 0.939 | Upgrade Priority 2 | Historic DT |
| 127886 | 7.8 | 6.6 | 600 | 750 | 10-Year | 0.943 | Upgrade Priority 2 | Historic DT |
| 127887 | 133.8 | 1.5 | 600 | 750 | 10-Year | 0.970 | Upgrade Priority 2 | Historic DT |
| 128074 | 48.0 | 0.9 | 600 | 750 | 10-Year | 0.627 | Upgrade Priority 2 | Historic DT |
| 128076 | 59.5 | 0.0 | 600 | 750 | 10-Year | 0.482 | Upgrade Priority 2 | Historic DT |
| 128077 | 21.1 | 0.1 | 525 | 750 | 10-Year | 0.461 | Upgrade Priority 2 | Historic DT |
| 128078 | 20.9 | 0.1 | 525 | 750 | 10-Year | 0.329 | Upgrade Priority 2 | Historic DT |
| 128155 | 12.9 | 0.5 | 375 | 450 | 10-Year | 0.208 | Upgrade Priority 2 | Historic DT |
| 128191 | 42.3 | 0.2 | 300 | 375 | 10-Year | 0.067 | Upgrade Priority 2 | Historic DT |
| 128192 | 106.6 | 5.4 | 250 | 375 | 10-Year | 0.307 | Upgrade Priority 2 | Historic DT |
| 128193 | 60.3 | 4.1 | 250 | 375 | 10-Year | 0.262 | Upgrade Priority 2 | Historic DT |
| 128194 | 40.5 | 2.1 | 250 | 375 | 10-Year | 0.179 | Upgrade Priority 2 | Historic DT |
| 128195 | 29.7 | 2.1 | 250 | 375 | 10-Year | 0.257 | Upgrade Priority 2 | Historic DT |
| 128196 | 12.1 | 0.6 | 200 | 375 | 10-Year | 0.081 | Upgrade Priority 2 | Historic DT |
| 128301 | 53.1 | 0.5 | 600 | 750 | 10-Year | 0.660 | Upgrade Priority 2 | Historic DT |
| 128302 | 24.5 | 0.5 | 600 | 750 | 10-Year | 0.690 | Upgrade Priority 2 | Historic DT |
| 227686 | 10.9 | 0.4 | 300 | 450 | 10-Year | 0.604 | Upgrade Priority 2 | Historic DT |
| 122304 | 36.8 | 4.7 | 200 | 300 | 10-Year | 0.166 | Upgrade Priority 3 | Historic DT |
| 127176 | 15.3 | 25.9 | 200 | 300 | 10-Year | 0.109 | Upgrade Priority 3 | Historic DT |
| 127255 | 57.2 | 8.5 | 250 | 300 | 10-Year | 0.245 | Upgrade Priority 3 | Historic DT |
| 127600 | 125.9 | 4.1 | 250 | 300 | 10-Year | 0.155 | Upgrade Priority 3 | Historic DT |
| 127601 | 76.0 | 5.1 | 250 | 300 | 10-Year | 0.104 | Upgrade Priority 3 | Historic DT |
| 127752 | 84.1 | 2.2 | 250 | 300 | 10-Year | 0.028 | Upgrade Priority 3 | Historic DT |
| 127755 | 89.4 | 1.5 | 250 | 300 | 10-Year | 0.025 | Upgrade Priority 3 | Historic DT |
| 127791 | 58.5 | 8.5 | 250 | 300 | 10-Year | 0.125 | Upgrade Priority 3 | Historic DT |
| 127796 | 13.7 | 1.1 | 250 | 300 | 10-Year | 0.015 | Upgrade Priority 3 | Historic DT |
| 127797 | 3.0 | 16.6 | 250 | 300 | 10-Year | 0.016 | Upgrade Priority 3 | Historic DT |
| 127798 | 6.1 | 1.0 | 250 | 300 | 10-Year | 0.024 | Upgrade Priority 3 | Historic DT |
| 127799 | 11.9 | 1.8 | 250 | 300 | 10-Year | 0.024 | Upgrade Priority 3 | Historic DT |
| 127816 | 61.7 | 6.4 | 250 | 300 | 10-Year | 0.125 | Upgrade Priority 3 | Historic DT |
| 127834 | 80.0 | 10.7 | 150 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | Historic DT |
| 127836 | 63.6 | 1.5 | 150 | 300 | 10-Year | 0.033 | Upgrade Priority 3 | Historic DT |
| 127837 | 8.5 | 3.8 | 150 | 300 | 10-Year | 0.038 | Upgrade Priority 3 | Historic DT |
| 127838 | 8.0 | 0.5 | 150 | 300 | 10-Year | 0.042 | Upgrade Priority 3 | Historic DT |
| 127839 | 23.0 | 2.6 | 150 | 300 | 10-Year | 0.063 | Upgrade Priority 3 | Historic DT |
| 127840 | 5.0 | 2.0 | 150 | 300 | 10-Year | 0.063 | Upgrade Priority 3 | Historic DT |
| 127853 | 45.0 | 0.7 | 250 | 300 | 10-Year | 0.008 | Upgrade Priority 3 | Historic DT |
| 127888 | 79.5 | 10.6 | 200 | 300 | 10-Year | 0.112 | Upgrade Priority 3 | Historic DT |
| 127892 | 86.9 | 7.0 | 250 | 300 | 10-Year | 0.032 | Upgrade Priority 3 | Historic DT |
| 127893 | 21.5 | 2.0 | 200 | 300 | 10-Year | 0.014 | Upgrade Priority 3 | Historic DT |
| 127894 | 35.2 | 0.3 | 200 | 300 | 10-Year | 0.025 | Upgrade Priority 3 | Historic DT |
| 127895 | 29.4 | 1.9 | 200 | 300 | 10-Year | 0.030 | Upgrade Priority 3 | Historic DT |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 127896 | 13.0 | 12.7 | 250 | 300 | 10-Year | 0.032 | Upgrade Priority 3 | Historic DT |
| 127897 | 11.1 | 150.4 | 200 | 300 | 10-Year | 0.083 | Upgrade Priority 3 | Historic DT |
| 127898 | 19.4 | 29.0 | 200 | 300 | 10-Year | 0.071 | Upgrade Priority 3 | Historic DT |
| 127899 | 11.4 | 4.0 | 200 | 300 | 10-Year | 0.083 | Upgrade Priority 3 | Historic DT |
| 127900 | 62.0 | 0.6 | 200 | 300 | 10-Year | 0.042 | Upgrade Priority 3 | Historic DT |
| 127901 | 20.0 | 2.0 | 250 | 300 | 10-Year | 0.007 | Upgrade Priority 3 | Historic DT |
| 128019 | 40.0 | 1.4 | 150 | 300 | 10-Year | 0.045 | Upgrade Priority 3 | Historic DT |
| 128020 | 125.0 | 3.0 | 150 | 300 | 10-Year | 0.062 | Upgrade Priority 3 | Historic DT |
| 128039 | 105.0 | 4.1 | 250 | 300 | 10-Year | 0.137 | Upgrade Priority 3 | Historic DT |
| 128065 | 13.0 | 0.3 | 250 | 300 | 10-Year | 0.190 | Upgrade Priority 3 | Historic DT |
| 128102 | 49.5 | 0.3 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Historic DT |
| 128104 | 28.5 | 0.2 | 250 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Historic DT |
| 128129 | 23.2 | 6.6 | 250 | 300 | 10-Year | 0.125 | Upgrade Priority 3 | Historic DT |
| 128130 | 9.4 | 22.2 | 200 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Historic DT |
| 128136 | 13.5 | 8.9 | 250 | 300 | 10-Year | 0.038 | Upgrade Priority 3 | Historic DT |
| 128148 | 73.8 | 3.0 | 200 | 300 | 10-Year | 0.114 | Upgrade Priority 3 | Historic DT |
| 128152 | 29.0 | 4.9 | 200 | 300 | 10-Year | 0.113 | Upgrade Priority 3 | Historic DT |
| 128165 | 60.2 | 31.1 | 250 | 300 | 10-Year | 0.094 | Upgrade Priority 3 | Historic DT |
| 128183 | 146.1 | 5.1 | 150 | 300 | 10-Year | 0.075 | Upgrade Priority 3 | Historic DT |
| 128185 | 84.1 | 1.2 | 250 | 300 | 10-Year | 0.027 | Upgrade Priority 3 | Historic DT |
| 128187 | 64.7 | 0.7 | 250 | 300 | 10-Year | 0.006 | Upgrade Priority 3 | Historic DT |
| 128189 | 29.3 | 0.7 | 250 | 300 | 10-Year | 0.004 | Upgrade Priority 3 | Historic DT |
| 128248 | 41.2 | 10.8 | 250 | 300 | 10-Year | 0.115 | Upgrade Priority 3 | Historic DT |
| 128249 | 20.6 | 12.7 | 250 | 300 | 10-Year | 0.115 | Upgrade Priority 3 | Historic DT |
| 128267 | 88.8 | 8.7 | 250 | 300 | 10-Year | 0.093 | Upgrade Priority 3 | Historic DT |
| 128268 | 48.7 | 2.1 | 250 | 300 | 10-Year | 0.055 | Upgrade Priority 3 | Historic DT |
| 128269 | 30.0 | 4.3 | 250 | 300 | 10-Year | 0.035 | Upgrade Priority 3 | Historic DT |
| 128311 | 114.0 | 0.3 | 200 | 300 | 10-Year | 0.026 | Upgrade Priority 3 | Historic DT |
| 128313 | 65.9 | 1.8 | 200 | 300 | 10-Year | 0.009 | Upgrade Priority 3 | Historic DT |
| 128349 | 38.0 | 1.0 | 250 | 300 | 10-Year | 0.024 | Upgrade Priority 3 | Historic DT |
| 128376 | 13.2 | 1.0 | 250 | 300 | 10-Year | 0.023 | Upgrade Priority 3 | Historic DT |
| 128392 | 15.3 | 0.4 | 150 | 300 | 10-Year | 0.001 | Upgrade Priority 3 | Historic DT |
| 128393 | 49.4 | 0.7 | 150 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | Historic DT |
| 128394 | 1.3 | 3.8 | 150 | 300 | 10-Year | 0.003 | Upgrade Priority 3 | Historic DT |
| 128405 | 7.3 | 7.4 | 200 | 300 | 10-Year | 0.013 | Upgrade Priority 3 | Historic DT |
| 239996 | 10.3 | 2.9 | 250 | 300 | 10-Year | 0.047 | Upgrade Priority 3 | Historic DT |
| 250926 | 28.7 | 0.3 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Historic DT |
| 250927 | 10.5 | 0.7 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Historic DT |
| 250936 | 77.6 | 0.7 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | Historic DT |
| PR-C019 | 142.5 | 1.1 | 0 | 300 | 10-Year | 0.040 | New Main | Historic DT |
| PR-C020 | 52.9 | 1.2 | 0 | 300 | 10-Year | 0.023 | New Main | Historic DT |
| PR-C021 | 111.0 | 2.3 | 0 | 300 | 10-Year | 0.012 | New Main | Historic DT |
| PR-C022 | 100.5 | 3.3 | 0 | 300 | 10-Year | 0.019 | New Main | Historic DT |
| PR-C023 | 96.4 | 0.3 | 0 | 300 | 10-Year | 0.016 | New Main | Historic DT |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| PR-C024 | 25.1 | 3.8 | 0 | 300 | 10-Year | 0.076 | New Main | Historic DT |
| PR-C025 | 66.8 | 0.9 | 0 | 300 | 10-Year | 0.025 | New Main | Historic DT |
| PR-C026 | 75.4 | 1.6 | 0 | 300 | 10-Year | 0.031 | New Main | Historic DT |
| PR-C027 | 118.4 | 0.9 | 0 | 300 | 10-Year | 0.042 | New Main | Historic DT |
| PR-C028 | 155.7 | 6.7 | 0 | 300 | 10-Year | 0.053 | New Main | Historic DT |
| PR-C029 | 90.2 | 4.0 | 0 | 300 | 10-Year | 0.060 | New Main | Historic DT |
| PR-C030 | 83.6 | 2.1 | 0 | 300 | 10-Year | 0.039 | New Main | Historic DT |
| PR-C031 | 153.3 | 4.5 | 0 | 300 | 10-Year | 0.038 | New Main | Historic DT |
| PR-C032 | 58.0 | 0.2 | 0 | 300 | 10-Year | 0.009 | New Main | Historic DT |
| PR-C033 | 37.2 | 0.1 | 0 | 300 | 10-Year | 0.024 | New Main | Historic DT |
| PR-C034 | 26.6 | 0.2 | 0 | 300 | 10-Year | 0.022 | New Main | Historic DT |
| PR-C035 | 61.3 | 1.5 | 0 | 300 | 10-Year | 0.010 | New Main | Historic DT |
| PR-C036 | 106.4 | 1.3 | 0 | 300 | 10-Year | 0.012 | New Main | Historic DT |
| PR-C037 | 99.7 | 3.3 | 0 | 300 | 10-Year | 0.041 | New Main | Historic DT |
| PR-C038 | 144.2 | 8.6 | 0 | 300 | 10-Year | 0.056 | New Main | Historic DT |
| PR-C039 | 36.7 | 7.8 | 0 | 300 | 10-Year | 0.116 | New Main | Historic DT |
| PR-C040 | 88.8 | 3.7 | 0 | 300 | 10-Year | 0.003 | New Main | Historic DT |
| PR-C041 | 145.9 | 3.1 | 0 | 300 | 10-Year | 0.026 | New Main | Historic DT |
| PR-C042 | 45.5 | 21.6 | 0 | 300 | 10-Year | 0.035 | New Main | Historic DT |
| PR-C043 | 75.0 | 1.2 | 0 | 300 | 10-Year | 0.005 | New Main | Historic DT |
| PR-C044 | 115.2 | 1.8 | 0 | 300 | 10-Year | 0.015 | New Main | Historic DT |
| PR-C045 | 136.1 | 0.5 | 0 | 300 | 10-Year | 0.031 | New Main | Historic DT |
| PR-C046 | 101.3 | 1.3 | 0 | 300 | 10-Year | 0.024 | New Main | Historic DT |
| PR-C047 | 52.9 | 1.6 | 0 | 300 | 10-Year | 0.019 | New Main | Historic DT |
| PR-C049 | 118.1 | 1.8 | 0 | 300 | 10-Year | 0.020 | New Main | Historic DT |
| PR-C075 | 10.0 | 0.4 | 0 | 300 | 10-Year | 0.021 | New Main | Historic DT |
| PR-C076 | 30.4 | 0.3 | 0 | 300 | 10-Year | 0.005 | New Main | Historic DT |
| PR-C077 | 113.1 | 0.9 | 0 | 300 | 10-Year | 0.007 | New Main | Historic DT |
| PR-C078 | 104.9 | 3.0 | 0 | 300 | 10-Year | 0.026 | New Main | Historic DT |
| 126454 | 60.0 | 0.6 | 450 | 750 | 10-Year | 0.566 | Upgrade Priority 1 | City Centre |
| 126458 | 101.6 | 0.5 | 450 | 600 | 10-Year | 0.314 | Upgrade Priority 1 | City Centre |
| 126459 | 115.6 | 0.5 | 450 | 600 | 10-Year | 0.405 | Upgrade Priority 1 | City Centre |
| 126498 | 87.6 | 0.5 | 375 | 600 | 10-Year | 0.372 | Upgrade Priority 1 | City Centre |
| 126499 | 88.7 | 1.0 | 375 | 525 | 10-Year | 0.426 | Upgrade Priority 1 | City Centre |
| 127276 | 119.5 | 0.4 | 375 | 450 | 10-Year | 0.130 | Upgrade Priority 1 | City Centre |
| 127365 | 121.9 | 0.4 | 300 | 375 | 10-Year | 0.046 | Upgrade Priority 1 | City Centre |
| 126344 | 70.8 | 0.2 | 450 | 600 | 10-Year | 0.217 | Upgrade Priority 2 | City Centre |
| 126428 | 8.4 | 0.5 | 300 | 375 | 10-Year | 0.125 | Upgrade Priority 2 | City Centre |
| 126429 | 31.3 | 0.5 | 300 | 375 | 10-Year | 0.136 | Upgrade Priority 2 | City Centre |
| 126434 | 82.1 | 0.0 | 750 | 900 | 10-Year | 0.718 | Upgrade Priority 2 | City Centre |
| 126439 | 108.2 | 0.4 | 375 | 450 | 10-Year | 0.139 | Upgrade Priority 2 | City Centre |
| 126442 | 36.6 | 0.4 | 300 | 375 | 10-Year | 0.098 | Upgrade Priority 2 | City Centre |
| 126453 | 24.5 | 0.4 | 900 | 1050 | 10-Year | 1.855 | Upgrade Priority 2 | City Centre |
| 126481 | 90.0 | 0.5 | 900 | 1050 | 10-Year | 1.868 | Upgrade Priority 2 | City Centre |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 126482 | 135.5 | 0.6 | 900 | 1050 | 10-Year | 1.912 | Upgrade Priority 2 | City Centre |
| 126490 | 22.6 | 0.5 | 300 | 450 | 10-Year | 0.193 | Upgrade Priority 2 | City Centre |
| 126494 | 119.5 | 0.5 | 300 | 375 | 10-Year | 0.084 | Upgrade Priority 2 | City Centre |
| 126495 | 116.3 | 0.7 | 450 | 525 | 10-Year | 0.344 | Upgrade Priority 2 | City Centre |
| 126497 | 82.2 | 6.5 | 375 | 525 | 10-Year | 0.522 | Upgrade Priority 2 | City Centre |
| 126500 | 88.7 | 2.0 | 375 | 525 | 10-Year | 0.506 | Upgrade Priority 2 | City Centre |
| 126501 | 36.6 | 0.3 | 300 | 525 | 10-Year | 0.167 | Upgrade Priority 2 | City Centre |
| 126502 | 122.0 | 0.3 | 375 | 525 | 10-Year | 0.178 | Upgrade Priority 2 | City Centre |
| 126503 | 111.3 | 0.3 | 375 | 525 | 10-Year | 0.195 | Upgrade Priority 2 | City Centre |
| 126504 | 30.5 | 0.3 | 375 | 525 | 10-Year | 0.207 | Upgrade Priority 2 | City Centre |
| 126511 | 82.0 | 0.5 | 300 | 375 | 10-Year | 0.092 | Upgrade Priority 2 | City Centre |
| 126512 | 61.0 | 0.5 | 300 | 450 | 10-Year | 0.153 | Upgrade Priority 2 | City Centre |
| 126513 | 15.1 | 1.3 | 250 | 375 | 10-Year | 0.115 | Upgrade Priority 2 | City Centre |
| 126523 | 17.1 | 0.4 | 300 | 375 | 10-Year | 0.103 | Upgrade Priority 2 | City Centre |
| 126524 | 24.1 | 0.4 | 300 | 375 | 10-Year | 0.107 | Upgrade Priority 2 | City Centre |
| 126529 | 30.4 | 0.3 | 375 | 450 | 10-Year | 0.163 | Upgrade Priority 2 | City Centre |
| 126560 | 14.9 | 0.1 | 450 | 600 | 10-Year | 0.391 | Upgrade Priority 2 | City Centre |
| 126564 | 84.1 | 0.4 | 375 | 600 | 10-Year | 0.356 | Upgrade Priority 2 | City Centre |
| 126588 | 34.3 | 0.7 | 375 | 450 | 10-Year | 0.228 | Upgrade Priority 2 | City Centre |
| 126870 | 78.0 | 0.1 | 375 | 450 | 10-Year | 0.078 | Upgrade Priority 2 | City Centre |
| 126872 | 45.6 | 0.2 | 300 | 450 | 10-Year | 0.109 | Upgrade Priority 2 | City Centre |
| 126915 | 9.4 | 0.6 | 300 | 450 | 10-Year | 0.106 | Upgrade Priority 2 | City Centre |
| 126940 | 50.5 | 0.1 | 450 | 600 | 10-Year | 0.186 | Upgrade Priority 2 | City Centre |
| 126941 | 102.5 | 0.3 | 300 | 375 | 10-Year | 0.085 | Upgrade Priority 2 | City Centre |
| 127199 | 66.5 | 0.4 | 450 | 525 | 10-Year | 0.264 | Upgrade Priority 2 | City Centre |
| 127210 | 18.0 | 0.4 | 450 | 525 | 10-Year | 0.214 | Upgrade Priority 2 | City Centre |
| 127230 | 46.3 | 0.4 | 300 | 375 | 10-Year | 0.104 | Upgrade Priority 2 | City Centre |
| 127244 | 144.8 | 0.2 | 1050 | 1350 | 10-Year | 1.558 | Upgrade Priority 2 | City Centre |
| 127376 | 79.4 | 2.8 | 300 | 375 | 10-Year | 0.132 | Upgrade Priority 2 | City Centre |
| 127608 | 17.0 | 0.5 | 450 | 525 | 10-Year | 0.236 | Upgrade Priority 2 | City Centre |
| 127610 | 3.4 | 4.7 | 450 | 525 | 10-Year | 0.245 | Upgrade Priority 2 | City Centre |
| 127076_1 | 40.0 | 0.6 | 375 | 600 | 10-Year | 0.199 | Upgrade Priority 2 | City Centre |
| 127076_2 | 52.0 | 0.5 | 375 | 600 | 10-Year | 0.292 | Upgrade Priority 2 | City Centre |
| 126337 | 58.8 | 0.4 | 250 | 300 | 10-Year | 0.010 | Upgrade Priority 3 | City Centre |
| 126474 | 64.0 | 1.1 | 250 | 300 | 10-Year | 0.005 | Upgrade Priority 3 | City Centre |
| 126526 | 40.5 | 0.6 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | City Centre |
| 126527 | 74.4 | 1.1 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | City Centre |
| 126528 | 100.0 | 2.2 | 250 | 300 | 10-Year | 0.109 | Upgrade Priority 3 | City Centre |
| 126531 | 84.1 | 2.4 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | City Centre |
| 126566 | 56.5 | 5.5 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | City Centre |
| 126567 | 75.6 | 4.5 | 250 | 300 | 10-Year | 0.019 | Upgrade Priority 3 | City Centre |
| 126568 | 97.6 | 0.2 | 250 | 300 | 10-Year | 0.011 | Upgrade Priority 3 | City Centre |
| 126931 | 65.9 | 4.8 | 250 | 300 | 10-Year | 0.000 | Upgrade Priority 3 | City Centre |
| 126932 | 10.3 | 5.9 | 250 | 300 | 10-Year | 0.109 | Upgrade Priority 3 | City Centre |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| 127341 | 22.4 | 3.3 | 250 | 300 | 10-Year | 0.062 | Upgrade Priority 3 | City Centre |
| 127596 | 34.4 | 2.2 | 250 | 300 | 10-Year | 0.065 | Upgrade Priority 3 | City Centre |
| 127599 | 90.0 | 1.7 | 250 | 300 | 10-Year | 0.122 | Upgrade Priority 3 | City Centre |
| 127621 | 90.0 | 1.9 | 200 | 300 | 10-Year | 0.035 | Upgrade Priority 3 | City Centre |
| 127622 | 1.6 | 3.2 | 200 | 300 | 10-Year | 0.035 | Upgrade Priority 3 | City Centre |
| PR-C001 | 128.1 | 2.6 | 0 | 300 | 10-Year | 0.018 | New Main | City Centre |
| PR-C002 | 61.2 | 1.8 | 0 | 300 | 10-Year | 0.022 | New Main | City Centre |
| PR-C003 | 85.2 | 2.8 | 0 | 300 | 10-Year | 0.016 | New Main | City Centre |
| PR-C004 | 153.8 | 5.0 | 0 | 300 | 10-Year | 0.037 | New Main | City Centre |
| PR-C005 | 85.0 | 5.5 | 0 | 300 | 10-Year | 0.100 | New Main | City Centre |
| PR-C006 | 56.8 | 2.4 | 0 | 300 | 10-Year | 0.159 | New Main | City Centre |
| PR-C007 | 81.4 | 3.4 | 0 | 300 | 10-Year | 0.027 | New Main | City Centre |
| PR-C008 | 185.1 | 5.9 | 0 | 300 | 10-Year | 0.045 | New Main | City Centre |
| PR-C009 | 220.0 | 9.7 | 0 | 300 | 10-Year | 0.072 | New Main | City Centre |
| PR-C010 | 263.1 | 6.6 | 0 | 300 | 10-Year | 0.051 | New Main | City Centre |
| PR-C011 | 64.6 | 7.0 | 0 | 300 | 10-Year | 0.005 | New Main | City Centre |
| PR-C012 | 167.1 | 1.9 | 0 | 300 | 10-Year | 0.026 | New Main | City Centre |
| PR-C013 | 164.8 | 3.0 | 0 | 300 | 10-Year | 0.058 | New Main | City Centre |
| PR-C014 | 82.0 | 0.8 | 0 | 300 | 10-Year | 0.030 | New Main | City Centre |
| PR-C015 | 107.5 | 1.7 | 0 | 300 | 10-Year | 0.023 | New Main | City Centre |
| PR-C016 | 128.8 | 0.5 | 0 | 300 | 10-Year | 0.027 | New Main | City Centre |
| PR-C017 | 149.2 | 1.7 | 0 | 300 | 10-Year | 0.029 | New Main | City Centre |
| PR-C018 | 149.7 | 1.4 | 0 | 300 | 10-Year | 0.023 | New Main | City Centre |
| PR-C051 | 93.7 | 1.7 | 0 | 300 | 10-Year | 0.007 | New Main | City Centre |
| PR-C052 | 66.6 | 2.2 | 0 | 300 | 10-Year | 0.003 | New Main | City Centre |
| PR-C053 | 50.0 | 3.4 | 0 | 300 | 10-Year | 0.002 | New Main | City Centre |
| PR-C054 | 74.9 | 1.8 | 0 | 300 | 10-Year | 0.015 | New Main | City Centre |
| PR-C055 | 79.1 | 1.7 | 0 | 300 | 10-Year | 0.017 | New Main | City Centre |
| PR-C056 | 142.9 | 2.5 | 0 | 300 | 10-Year | 0.025 | New Main | City Centre |
| PR-C057 | 110.1 | 4.7 | 0 | 300 | 10-Year | 0.015 | New Main | City Centre |
| PR-C058 | 129.6 | 0.5 | 0 | 300 | 10-Year | 0.023 | New Main | City Centre |
| PR-C059 | 125.4 | 3.5 | 0 | 300 | 10-Year | 0.039 | New Main | City Centre |
| PR-C060 | 88.0 | 4.7 | 0 | 300 | 10-Year | 0.039 | New Main | City Centre |
| PR-C061 | 125.6 | 1.1 | 0 | 300 | 10-Year | 0.029 | New Main | City Centre |
| PR-C062 | 121.2 | 5.1 | 0 | 300 | 10-Year | 0.029 | New Main | City Centre |
| PR-C063 | 67.3 | 1.8 | 0 | 300 | 10-Year | 0.015 | New Main | City Centre |
| PR-C064 | 122.8 | 0.9 | 0 | 300 | 10-Year | 0.013 | New Main | City Centre |
| PR-C065 | 180.8 | 3.1 | 0 | 300 | 10-Year | 0.020 | New Main | City Centre |
| PR-C066 | 89.7 | 0.5 | 0 | 300 | 10-Year | 0.032 | New Main | City Centre |
| PR-C067 | 73.2 | 0.3 | 0 | 300 | 10-Year | 0.036 | New Main | City Centre |
| PR-C069 | 68.5 | 1.5 | 0 | 300 | 10-Year | 0.000 | New Main | City Centre |
| PR-C070 | 94.6 | 1.1 | 0 | 300 | 10-Year | 0.029 | New Main | City Centre |
| PR-C071 | 63.6 | 2.9 | 0 | 300 | 10-Year | 0.057 | New Main | City Centre |
| PR-C072 | 51.5 | 3.4 | 0 | 300 | 10-Year | 0.011 | New Main | City Centre |

| Name | Length (m) | Slope (%) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Study Area |
|---|---|---|---|---|---|---|---|---|
| PR-C073 | 61.9 | 6.6 | 0 | 300 | 10-Year | 0.050 | New Main | City Centre |
| PR-C074 | 66.3 | 10.9 | 0 | 300 | 10-Year | 0.005 | New Main | City Centre |

# Technical Memorandum

## Drainage Modeling of Willband Creek Watershed

## (Interim Results for Review)

**project:** Willband Creek Integrated Stormwater Management Plan
**project ID:** 2016-006-ABB
**date:** July 5, 2017
**issued to:** City of Abbotsford, BC (City) and Urban Systems Ltd. (USL)
**issued by:** GeoAdvice Engineering Inc. (GeoAdvice)

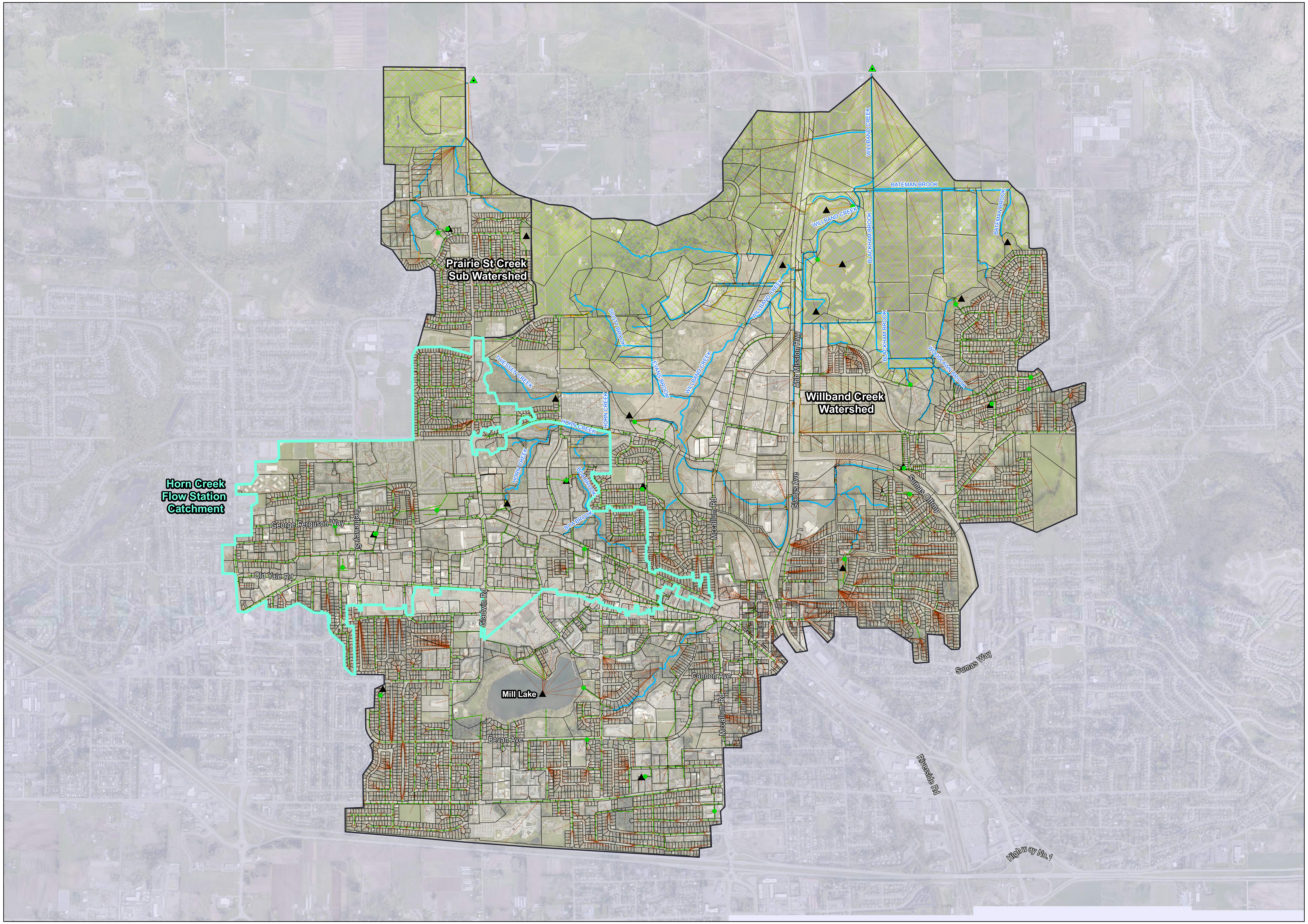
## 1. Introduction

The City of Abbotsford, BC retained Urban Systems Ltd. (USL) to develop the Willband Creek Integrated Stormwater Management Plan (ISMP). GeoAdvice Engineering Inc. (GeoAdvice) partnered with USL as the modeling sub-consultant for this project. The study area consists the Willband Creek watershed and includes the Prairie St Creek sub watershed. The GeoAdvice scope of work was to develop a hydrologic and hydraulic model of the Willband Creek drainage system to determine stormwater runoff volumes and flow rates under varying storm events. The model will then be used to define capacity-driven improvement requirements and drainage management practices necessary to service future urban growth and respond to potential changes in climate.

The model was developed using PCSWMM software; a fully-dynamic stormwater management modeling software package from CHI Software Inc.

## 2. Hydraulic Model Development

**Figure 2.1** shows the modeled drainage system elements including storm sewers, culverts creeks, detention ponds and subcatchments. As agreed with the City, the drainage model was truncated to pipes with diameter of 300 mm or greater, plus the larger open channel streams which comprise the primary system. Pipes with smaller diameter were included only as required for connectivity. Road side ditches and catch basins were not included in the model. In addition, privately owned infrastructure (pipes and stormwater controls) were excluded from the model unless required for connectivity.




GeoAdvice Engineering Inc.

## Legend

- Horn Creek Flow Station Catchment
- Watershed Area
- Agricultural Land Reserve
- Control Manhole
- Outfall
- Storage
- Subcatchment
- Subcatchment Allocation Line
- Conduit Added for Connectivity
- Creek
- Culvert
- Main

**Interim Results**

**Model Study Area**

ABBOTSFORD

Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure 2.1**

The model's existing condition scenario includes the following features:

- Study area size: 1,841 ha
- 7,734 subcatchments
- 2,041 conduit links
    - 30 km of creek channels
    - 85 km of drainage mains
    - 1.6 km of culverts
- 2,015 junction nodes
    - 25 control manholes
- 20 storage nodes
    - 1 lake (Mill Lake)
    - 14 detention ponds
    - 5 detention tanks

The City provided the GIS geodatabases used to build the model on May 11, 2016. The following layers were used to develop the model network:

**Table 2.1: GIS Layers Used to Develop the Model Network**

| Point Feature | Line Feature | Other Dataset |
|---|---|---|
| Manholes | Drainage Mains | Detention Ponds |
| Control Manholes | Culverts | 2013 Contours and LiDAR |
| Inlets | Creeks and Streams | 2015 Airphoto |
| Outlets | | Parcels |
| Fittings | | |
| Chambers | | |

A detailed review of the GIS was completed to identify data gaps and to recommend resolutions. Please refer to the GeoAdvice Technical Memorandum titled *GIS Data Review and Modeling Assumptions*, dated June 7, 2016. The City addressed the data gap issues and provided an updated GIS database on October 31, 2016.

Certain features, such as culverts and creeks, required that a distinction between the upland and lowland regions be defined. This distinction is critical so that features within each region may be governed by unique design criteria. To be consistent with the Matsqui Drainage Study, the flood cell shapefile as provided by Kerr Wood Leidal on behalf of the City was used to define the boundary between the upland and lowland regions.

## 2.1. Drainage Mains and Culverts

The “Drainage Mains” and “Culverts” GIS layers provided the spatial representation of the storm pipes and included size, material, length, and invert elevation. Manning’s “n” roughness coefficients were assigned to the pipes based on material according to **Table 2.2** which is a general reflection of the City’s design criteria defined in the City’s Subdivision and Development Bylaw.

**Table 2.2: Pipe Roughness Coefficient**

| Material | Manning's Roughness Coefficient* |
|---|---|
| PVC | 0.013 |
| Asbestos Cement | 0.013 |
| CIPP (Cured-in-place-pipe) | 0.013 |
| Concrete | 0.013 |
| Corrugated Steel | 0.020 |
| Ductile Iron | 0.013 |
| Glass Reinforced Plastic | 0.013 |
| HDPE | 0.013 |
| PVCO | 0.013 |
| SLIP | 0.013 |
| Steel | 0.013 |
| Vitrified Clay | 0.013 |
| Wood Stave | 0.013 |
| Unknown | 0.013 |

***Roughness coefficients based on information from the City of Abbotsford Development Bylaw, 2011.**

Modeled culverts were assigned an entrance loss coefficient of 0.5 and an exit loss coefficient of 1.0. This assumes that all culverts have an entrance headwall with square edge.

## 2.2. Creeks and Streams

The “Creeks and Streams” GIS layer provided by the City was analyzed for spatial representation of the major open channel features.

The open channel geometry information was not included in the GIS. As such, the creek transects and invert elevations were extracted from LiDAR data. Standardized ditch geometries were used for the smaller channels where the LiDAR was not accurate enough to create a reasonably accurate transect.

Manning's "n" roughness coefficients were assigned to the open channels based on the type of creek specified in the GIS according to **Table 2.3**.

**Table 2.3: Creek Roughness Coefficient**

| Feature Type | Manning's Roughness Coefficient* |
|---|---|
| Natural Watercourse | 0.05 |
| Channelized Watercourse | 0.03 |
| Ditch | 0.03 |

***Roughness coefficients based on information from the City of Abbotsford Development Bylaw, 2011.**

## 2.3. Junctions

Junctions were added in the model to provide pipe-to-pipe and open channel connectivity. Some of the junctions were used in the model to represent where runoff is loaded into the system and to allow stormwater to exit the system. Junctions also provide connectivity where transitions between different physical attributes such as size and slope occur.

The following GIS point layers were used to define the junction features in the model:

- Manholes
- Control Manholes
- Inlets
- Outlets
- Fittings
- Chambers

Rim elevation for junctions with missing ground elevation data were extracted from LiDAR data provided by the City.

Control manholes are utilized to provide hydraulic control in the storm main system. **Table 2.4** summarizes the modeled control manholes and data sources provided by the City.

**Table 2.4: Modeled Control Manholes**

| Control Manhole ID | Location | Asbuilt Dwg # |
|---|---|---|
| 113754 | 30564 Horn St., West of Eastview Park | SUB310 |
| 113758 | Mc Callum Pl. and Mc Callum Rd. | SUB485 |
| 113759 | North-East of Terry Fox Ave. and Babich St. | SUB268 |
| 113797 | 100 m North of Earls Ct. | SUB1685 |
| 113810 | 3097 Lukiv Terrace | SUB1985 |
| 113811 | Walnut Ave. at Pratt St. | D708/D1012 |
| 113894 | 32717 Chilcotin Dr. | SUB611 |
| 113895 | East of Harwood Crescent and Gatefield Ave. | SUB617 |
| 113902 | North of 32737 Chilcotin Dr. | SUB1702 |
| 113907 | 34175 Hazelwood Ave. | SUB607 |
| 113912 | South of Abbotsford-Mission Hwy 11 and Batman Rd. | D707 |
| 113913 | Abbotsford-Mission Hwy 11 and Batman Rd. | D707 |
| 113915 | 3281 Saddle St. and Immel St. | SUB1316 |
| 113917 | Picton Park, North of 34435 Thoreau Ave. | SUB395 |
| 113929 | 34645-34650 Laburnum Ave. | SUB69 |
| 113930 | 34646-34649 Immel St. | SUB69 |
| 113515 | North of 2368 Bedford Pl. | SUB1742 |
| 113525 | Bevan Ave. and Godson Ct. | SUB308 |
| 113533 | South-East of Mayfair Ave. and Sandalwood Crescent | SUB1488 |
| 113544 | 33545 Rainbow Ave. | SUB1745 |
| 113696 | 113696 George Ferguson Way | SUB365* |
| 113728 | 150 m North-West of S Fraser Way and Trethewey St. | SUB1857 |
| 113729 | 32320 George Ferguson Way | A289 |
| 113749 | 33136 George Ferguson Way | SUB227 |
| 113692 | North-East of Trethewey St. and Simon Ave. | SUB492 |

* Drawing did not include control manhole details.

## 2.4. Detention Facilities

Drainage within the Willband Creek watershed is managed in part by detention facilities. These facilities serve a key role in creek flow and flood management. Depending on whether the facility is situated in the upland or lowland region, they will be governed by differing design criteria.

The largest natural detention facility in the upland region is Mill Lake which captures an urbanized area of about 197 ha. Mill Lake provides detention and discharges through a weir structure to Willband Creek. The weir structure includes a sluice gate and adjustable stop logs to control the base flow during different seasons. The model was developed assuming a winter condition when the sluice gate is closed and the weir set to its maximum elevation of 51.65 m.

Runoff from the upland regions of the catchment area is collected and ultimately directed into Willband Creek. Flood management in the lowland region is assisted by the Willband Stormwater Detention Facility. This facility provides detention as the water level in Willband Creek rises and overflows to three storage ponds. The City has indicated that the performance of this facility is coming into question since flooding from recent events show that the facility is taking much longer to drain.

The storage geometry for each of the modeled detention facilities was either extracted from asbuilt drawings when available or estimated using the LiDAR data. Inlet and outlet controls of each detention facility were defined using weirs and/or orifices based on information from asbuilt drawings.

In addition to the detention facilities mentioned above, local runoff from urban developments is sometimes managed by private detention facilities. Private facilities typically include storage tanks, rain gardens, infiltration trenches, and storage pipes.

Detention ponds and tanks were modeled if they are owned by the City. It was agreed with the City that all private detention facilities be excluded from the model.

**Table 2.5** summarizes the detention features included in the model.

**Table 2.5: Modeled Detention Features**

| Storage ID | Type | Location | Asbuilt Dwg # |
|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | SUB250* |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | SUB395 |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | SUB1488 |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | SUB351 |
| SU05 | Pond | Walnut Ave. at Pratt St. | D1012 |
| SU06 | Pond | North-East of Trethewey St. and Simon Ave. | SUB492 |
| SU07 | Pond | North of Nelson Pl. | SUB239 |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | SUB1702 |
| SU09 | Tank | North of 32737 Chilcotin Dr. | SUB617 |
| SU10 | Tank | North of 2368 Bedford Pl. | SUB1742 |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | SUB310 |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | SUB268 |
| SU13 | Tank | 3097 Lukiv Terrace | SUB1985 |
| SU14 | Tank | 3281 Saddle St. and Immel St. | SUB1316 |
| SU15 | Pond | 33825 Valley Rd. | N/A |
| SU16 | Pond | Willband Stormwater Detention Facility – North Pond | D-707 |
| SU17 | Pond | Willband Stormwater Detention Facility – South Pond | D-707 |
| SU18 | Pond | Willband Stormwater Detention Facility – South Pond Expansion | D-1033 |
| SU19 | Lake | Mill Lake | N/A |
| SU20** | Pond | East of Harwood Crescent and Gatefield Ave. | SUB228 |

* Drawing missing detention pond details.
** GIS inconsistent with asbuilt drawing. To confirm if this detention pond is presently used.

Modeled storage curves for each detention facility are presented in **Appendix A.**

# 3. Hydrology Model Development

## 3.1. Subcatchment Delineation

Subcatchments are hydrologic units of land whose topography and drainage system elements are defined to direct surface runoff to the network system. In developed areas, model subcatchments are set to the parcel level, meaning that each parcel is defined as a unique subcatchment. These subcatchments were defined using the GIS parcel layer. Further, in developed areas, land not covered by parcels were assumed to be road right-of-way areas and were delineated based on the location of model nodes. Over 7,700 subcatchments were created from the parcels and road right-of-way areas. The subcatchments for the undeveloped areas were manually delineated as the parcel boundaries for these areas do not generally match the topography.

### *Subcatchment Width and Length*

Width and length subcatchment properties characterize the overland flow path and the time of concentration for sheet flow runoff to the loading point.

Subcatchment widths for small subcatchments (less than or equal to 0.2 ha) were estimated based on the assumption that the flow length is 50 m, representing the typical distance between the furthest point of the parcel to the fronting storm sewer. The subcatchment width formula is thus:

$$width = \frac{Area}{length} = \frac{Area}{50\ m}$$

Subcatchment widths for larger subcatchments (greater than 0.2 ha) were estimated based on the presumption that both catchment shape and local flow barriers increase the overland flow length. The subcatchment width formula is thus:

$$width = \frac{Area}{length};\ \ length = 1.7\ \times\ \sqrt{Area}$$

A factor of 1.7 was used to define the initial subcatchment width based on the above formula. This factor was later adjusted during the model calibration process.

### *Subcatchment Slope*

Subcatchment slopes were estimated based on calculating the average slope over the catchment using LiDAR data and then dividing by 2. The division by 2 provides for a longer simulated time of concentration due to meandering channels and piped networks that are not parallel with the direction of the average slope.

### *Subcatchment Hydrologic Parameters*

**Table 3.1** summarizes the initial hydrologic parameters that were uniformly applied to all the subcatchments. These values were selected based on industry publications.

**Table 3.1: Subcatchment Hydrologic Modeling Parameters**

| Hydrologic Parameter | Value |
|---|---|
| Depression Storage | |
| *Pervious Area (mm)* | 5.0 |
| *Impervious Area (mm)* | 0.5 |
| Manning's "n" Roughness Coefficient | |
| Pervious Area "n" | 0.40 |
| Impervious Area "n" | 0.05 |

Source: Parameter values based on consideration of ASCE (1992)[1] and McCuen, R. et al. (1996)[2].

## 3.2. Subcatchment Impervious Percentage

The impervious percentage for each subcatchment was determined based on the airphoto imagery analysis completed by USL. It was initially assumed that 50% of runoff from impervious areas is routed to pervious surfaces. **Figure 3.1** illustrates the airphoto and the corresponding impervious areas generated from the imagery analysis of a representative area.

**Figure 3.1: Impervious Areas from Orthophoto Imagery**


[1] ASCE (1992). *Design & Construction of Urban Stormwater Management Systems*, New York, NY
[2] McCuen, R. et al. (1996). *Hydrology*, FHWA-SA-96-067, Federal Highway Administration, Washington, DC

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Port Moody, British Columbia
V3H 2B4 Canada
Tel (604) 931-0550

**Figure 3.2** shows the subcatchment total impervious percentage within the Willband Creek watershed.

## 3.3. Base Flow

A winter baseflow of 0.15 L/s/ha was applied to all areas. This is based on the analysis of flow monitoring data on Clayburn Creek measured at Clayburn Road. No directly comparable data was available for Willband Creek.

## 3.4. Soils and Catchment Infiltration

Soil information was provided by Thurber Engineering (Thurber). A soil type classification GIS layer was provided with the corresponding infiltration rates. The infiltration rates were estimated by Thurber from hydrogeological field testing compiled from other reports provided by the City. Areas with no existing reports were assigned infiltration rates based on literature values from Freeze and Cherry (1979) for the materials depicted in test hole logs.

**Table 3.2** summarizes the soil groups and the corresponding minimum and maximum infiltration rates provided by Thurber. The soil group names are consistent with the classification found in the "Soil Type Classification" layer provided by the City. Soil groups 3 and 4 were further divided into (A) and (B) groups.

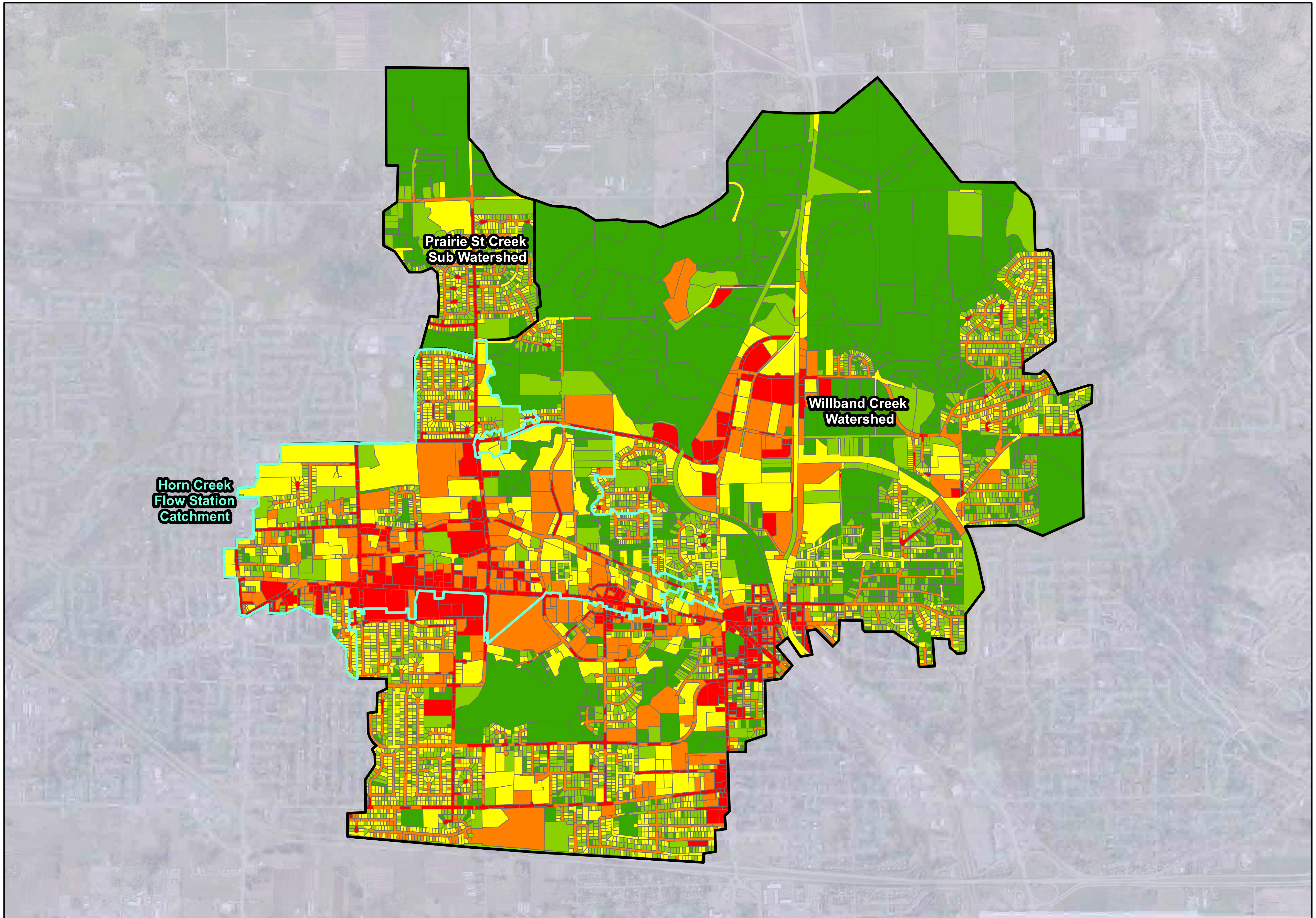
**Table 3.2: Soil Group Runoff and Infiltration Characteristics**

| Soil Group | Minimum Infiltration Rate (m/s) | Maximum Infiltration Rate (m/s) |
|---|---|---|
| 2 - Peat | 1E-08 | 1E-05 |
| 3 - Silt & Clay (A) | 1E-09 | 1E-07 |
| 3 - Silt & Clay (B) | 1E-09 | 1E-06 |
| 4 - Sand & Silt (A) | 1E-08 | 1E-05 |
| 4 - Sand & Silt (B) | 1E-07 | 1E-03 |
| 6 - Silt & Clay | 1E-10 | 1E-06 |
| 8 - Gravel & Sand | 1E-06 | 1E-03 |
| 9 - Till | 1E-06 | 1E-04 |

Please refer to the Thurber report[3] for further information regarding the soils within the study area.

**Figure 3.3** shows the distribution of soil groups within the Willband Creek watershed.

[3] Thurber Engineering Ltd., *Geotechnical and Hydrogeological Assessment (Draft)*, May 26, 2017.




GeoAdvice Engineering Inc.

## Legend

- Horn Creek Flow Station Catchment
- Watershed Area

**Total Impervious Percentage**

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

**Interim Results**

**Subcatchment Impervious Percentage**

ABBOTSFORD

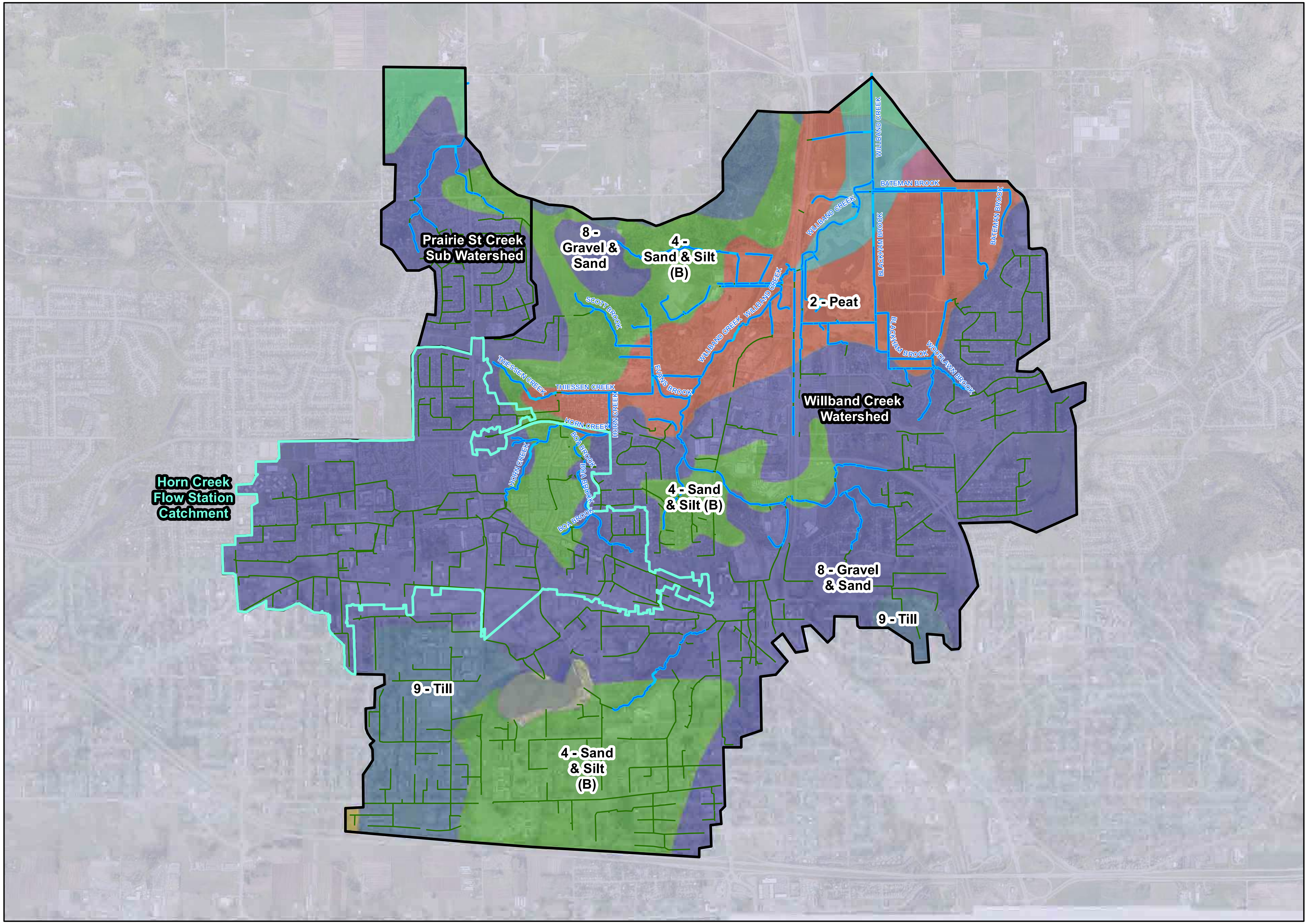
Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N
W E
S

**Figure 3.2**




GeoAdvice Engineering Inc.

## Legend

- Horn Creek Flow Station Catchment
- Watershed Area
- Creek
- Main

**Soil Group***

- 2 - Peat
- 3 - Silt & Clay (A)
- 3 - Silt & Clay (B)
- 4 - Sand & Silt (A)
- 4 - Sand & Silt (B)
- 6 - Silt & Clay
- 8 - Gravel & Sand
- 9 - Till

* Soil group names are consistent with the classification found in the "Soil Type Classification" layer provided by the City.

**Interim Results**

**Soil Type Classification**

ABBOTSFORD

Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure 3.3**

The modified Horton infiltration process was used to characterize soil infiltration characteristics in the model. The soil infiltration rates provided by Thurber were translated to Horton infiltration parameters as shown in **Table 3.3**.

**Table 3.3: Horton Infiltration Parameters**

| Soil Group | Minimum Infiltration Rate (mm/hr) | Maximum Infiltration Rate (mm/hr) | Decay Constant | Drying Time (days) | Percentage of Willband Creek Watershed |
|---|---|---|---|---|---|
| 2 - Peat | 0.036 | 36 | 4 | 2 | 13% |
| 3 - Silt & Clay (A) | 0.0036 | 0.36 | 4 | 2 | 2% |
| 3 - Silt & Clay (B) | 0.0036 | 3.6 | 4 | 2 | <1% |
| 4 - Sand & Silt (A) | 0.036 | 36 | 4 | 2 | 2% |
| 4 - Sand & Silt (B) | 0.36 | 3600 | 4 | 2 | 20% |
| 6 - Silt & Clay | 0.00036 | 3.6 | 4 | 2 | <1% |
| 8 - Gravel & Sand | 3.6 | 3600 | 4 | 2 | 53% |
| 9 - Till | 3.6 | 360 | 4 | 2 | 7% |

Decay Constant: Decay constant for the Horton infiltration curve (mm/hr)
Drying Time: Time for a fully saturated soil to completely dry (days)

The “Decay Constant” and “Drying Time” Horton parameters were assumed to be 4 mm/hr and 2 days, respectively.

## 3.1. Groundwater

As there were insufficient flow monitoring data to calibrate groundwater flow parameters, the groundwater processes have not been included in the model. Further discussion on this topic with the City during Phase 2 is recommended.

# 4. Field Data Analysis

## 4.1. Precipitation Data

Rain gauge data was used to load precipitation for the stormwater model's simulations. Principal input properties used by the model include time interval, rainfall intensity and volume. Precipitation data from the City Hall rain gauge was obtained from FlowWorks. This rain gauge was selected as it was within the Willband Creek drainage basin. The location of the City Hall rain gauge is shown in **Figure 4.1**.

## 4.2. Flow Data

Data from the Horn Creek flow station was obtained from FlowWorks. This station is the only flow station within the Willband Creek drainage basin. The location of the Horn Creek flow station is shown in **Figure 4.1**.

The Horn Creek flow station has been performing abnormally since its inception in 2012. However, since March 1, 2017 data appears to be normal. Therefore, data from March 1, 2017 to April 1, 2017 was considered for model calibration. As the City artificially pumps water into Horn Creek, typical base flow values cannot be applied within the Horn Creek catchment. The data has only been used to calibrate to precipitation response.

## 4.3. Storm Event Analysis

By analyzing the rainfall data in conjunction with the flow monitoring data, individual storm events were identified as potential model calibration events. Rainfall data between March 1-15, 2017 showed signs of questionable data and was therefore excluded. The selected calibration storm events are summarized in **Table 4.1**.

**Figure 4.1: City Hall Rain Gauge and Horn Creek Flow Station Location**

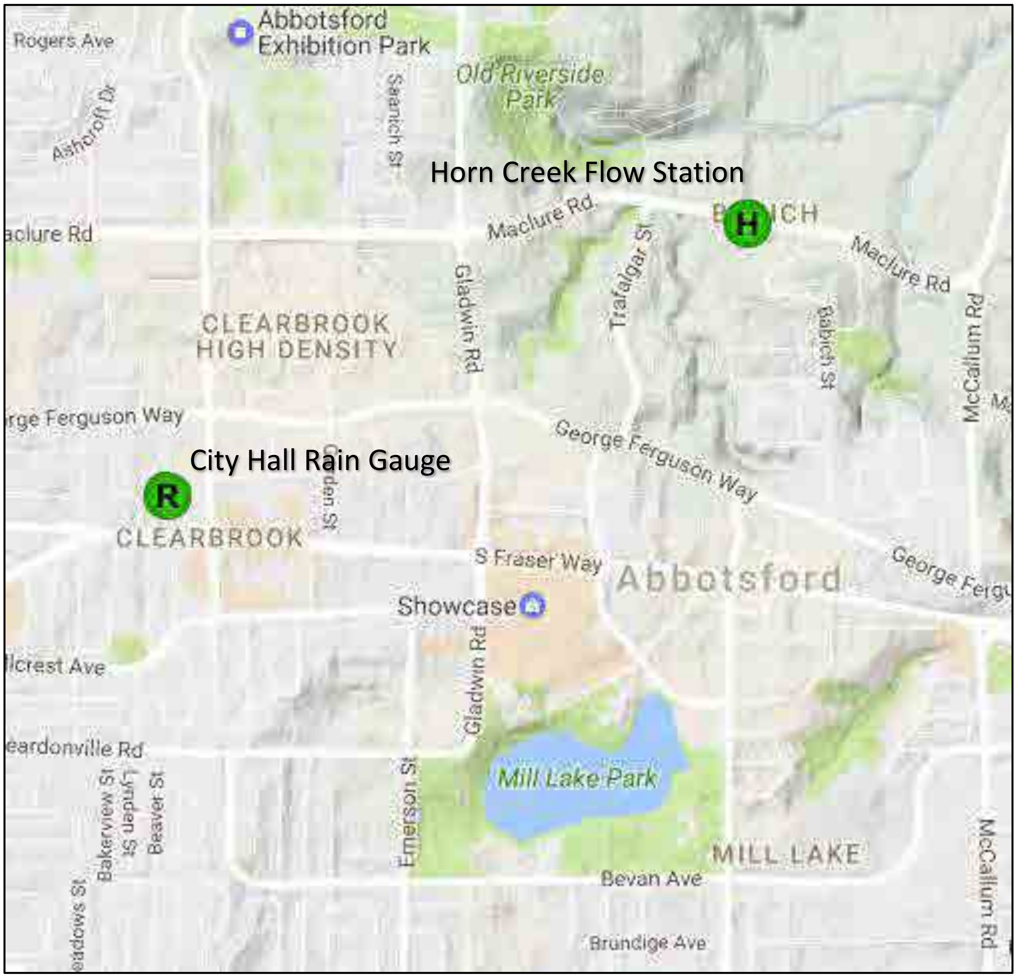



**Table 4.1: Calibration Storm Events (City Hall Rain Gauge)**

| Event | Start Date / Time | Duration (hr) | Maximum Rainfall Intensity (mm/hr) | Total Rainfall (mm) | Return Period* |
|---|---|---|---|---|---|
| 1 | 3/17/2017 9:25 | 33 | 6.9 | 49.5 | < 2-year |
| 2 | 3/21/2017 5:15 | 8 | 2 | 4.0 | < 2-year |
| 3 | 3/22/2017 16:00 | 7 | 1.5 | 1.5 | < 2-year |
| 4 | 3/23/2017 19:25 | 17 | 2.6 | 11.5 | < 2-year |
| 5 | 3/24/2017 18:55 | 8 | 9.4 | 10.4 | < 2-year |
| 6 | 3/26/2017 8:30 | 8 | 2 | 4.0 | < 2-year |
| 7 | 3/26/2017 17:25 | 12 | 2.1 | 10.2 | < 2-year |
| 8 | 3/27/2017 17:40 | 50 | 5.8 | 90.0 | < 2-year |
| 9 | 4/1/2017 1:05 | 12 | 3.9 | 14.8 | < 2-year |

* Estimated return period based on the Abbotsford A AES Station IDF curves.

# 5. Model Calibration

The available flow monitoring data for model calibration was limited to the Horn Creek flow station, which captures approximately 18% of the Willband watershed. Although the Horn Creek flow station does not capture the entire watershed, it is representative of an urban developed area in the upland region. As such, adjustments were made to model parameters that were applicable to the Horn Creek catchment as well as to the entire watershed, where possible.

Rather than simulating individual storm events for calibration and validation, a continuous simulation from March 15 to April 1, 2017 was run. Continuous simulation allows the model to simulate the impacts of antecedent moisture conditions on the basin between back-to-back storm events. The model parameters were adjusted in an iterative manner until model results achieved an acceptable correlation with the Horn Creek flow data for the 9 storm events identified. The model adjustments are discussed in detail below.

### *Base Flows*

The field data from the Horn Creek hydrometric station suggests that a winter time base flow of approximately 280 L/s was occurring. As such, a base flow rate of approximately 0.84 L/s/ha was modeled to simulate the 280 L/s at the station. However, due to the base flows being pumped into Horn Creek, the base flow rate of 0.84 L/s/ha was applied only to the Horn Creek catchment. As noted earlier, a baseflow of 0.15 L/s/ha was applied elsewhere.

### *Runoff Routing Percentage*

The runoff routing percentage parameter was decreased from 50% to 30% to improve the correlation with flow volumes recorded at the Horn Creek flow station. This adjustment was applied to the entire Willband watershed and assumes that approximately 30% of the runoff from impervious surfaces are routed to pervious areas. This parameter accounts for conditions where roof leaders that drain impervious surface runoff are directed to pervious surfaces rather than directly into creek channels or storm mains.

### *Subcatchment Flow Length*

The default subcatchment flow length equation for areas greater than 0.2 ha defined in **Section 3.1** was adjusted to $length = 3 * \sqrt{Area}$ to improve the correlation with peak flows recorded at the Horn Creek flow station. This adjustment was applied to the entire Willband watershed and assumes that the actual flow length within the larger subcatchments are longer than initially estimated.

The adjusted parameters, namely the *runoff routing percentage* and *subcatchment flow length*, were applied globally and made no distinctions between different areas or land uses within the watershed. This approach was selected, as there were insufficient flow data to justify further adjustments.

The following model parameters were not adjusted and are believed to be accurate based on the information that was available:

- Subcatchment slopes;
- Subcatchment depression storage and roughness parameters;
- Subcatchment impervious percentages; and
- Soil group infiltration rates.

## 5.1. Model Calibration Results

**Table 5.1** summarizes the model calibration results by comparing field recorded peak flows and total volumes against simulation results.

**Table 5.1: Willband Creek Calibration Results**

| Event | Peak Flow ($m^3/s$) | | Difference (%) | Total Volume ($m^3$) | | Difference (%) |
|---|---|---|---|---|---|---|
| | Model | Field | | Model | Field | |
| 1 | 2.7 | 2.4 | +13% | 92,600 | 94,020 | -2% |
| 2 | 0.9 | 0.9 | +3% | 23,740 | 22,490 | +6% |
| 3 | 0.6 | 0.7 | -8% | 12,770 | 12,090 | +6% |
| 4 | 1.1 | 1.1 | -1% | 33,700 | 33,890 | -1% |
| 5 | 3.6 | 2.5 | +46% | 34,440 | 31,770 | +8% |
| 6 | 0.8 | 0.9 | -4% | 14,180 | 13,500 | +5% |
| 7 | 0.9 | 1.2 | -20% | 34,240 | 38,050 | -10% |
| 8 | 2.3 | 2.3 | -1% | 184,200 | 202,300 | -9% |
| 9 | 1.6 | 1.7 | -3% | 44,280 | 46,790 | -5% |

**Figure 5.1** to **Figure 5.5** show the calibration flow hydrographs comparing the Horn Creek modeled flows and the measured flows.

**Figure 5.1**

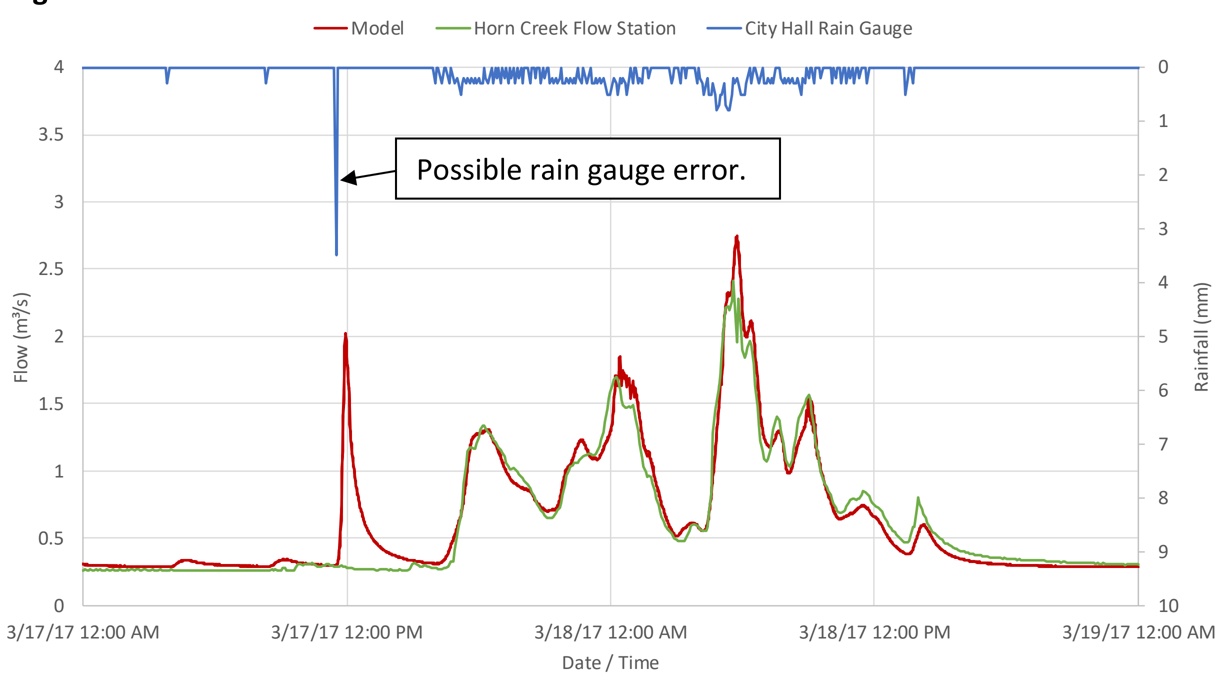



**Figure 5.2**

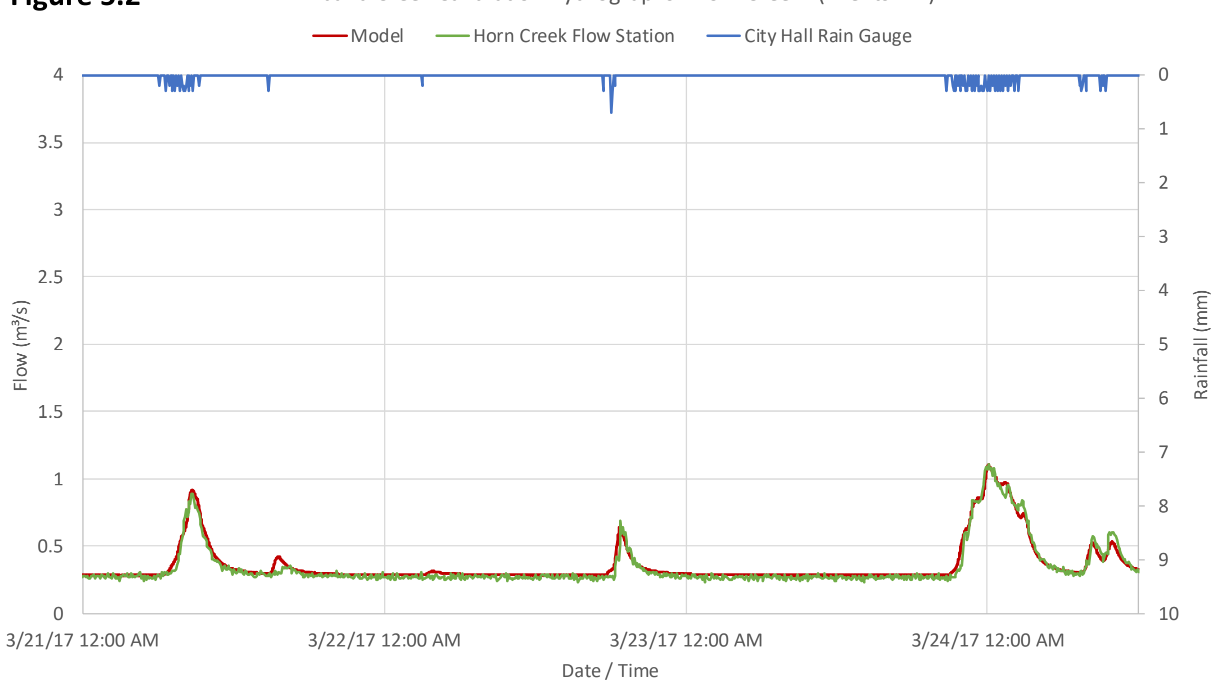


**Figure 5.3** Willband Creek Calibration Hydrographs - Horn Creek (Events 5-7)

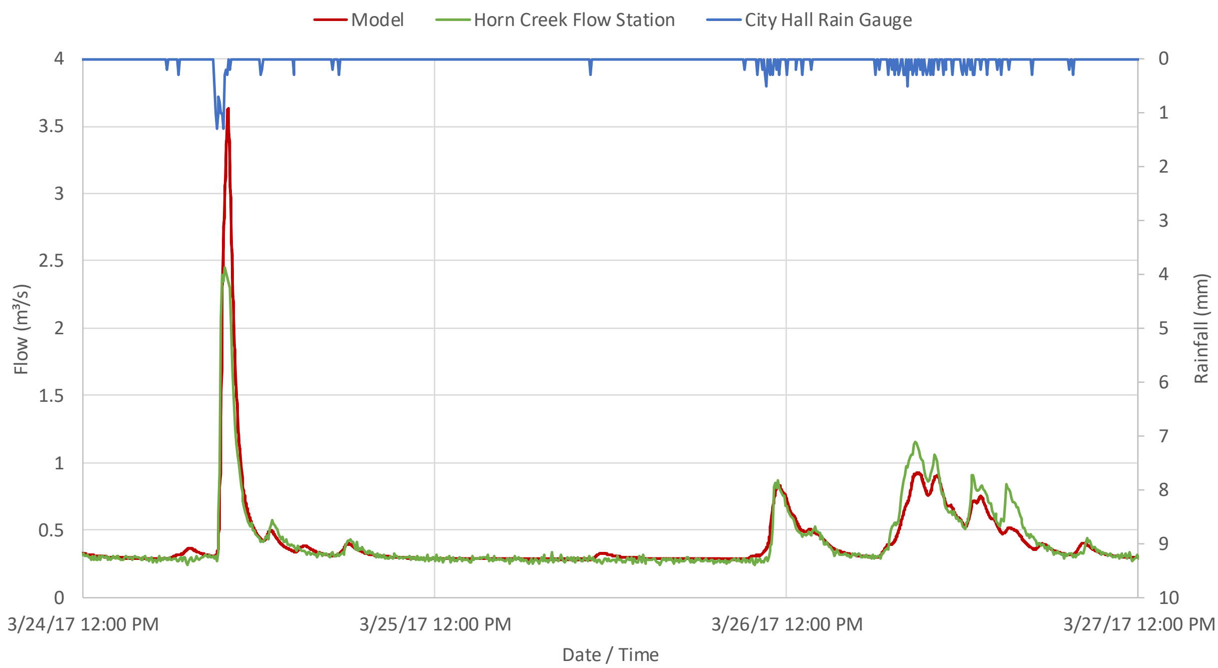



**Figure 5.4** Willband Creek Calibration Hydrographs - Horn Creek (Event 8)

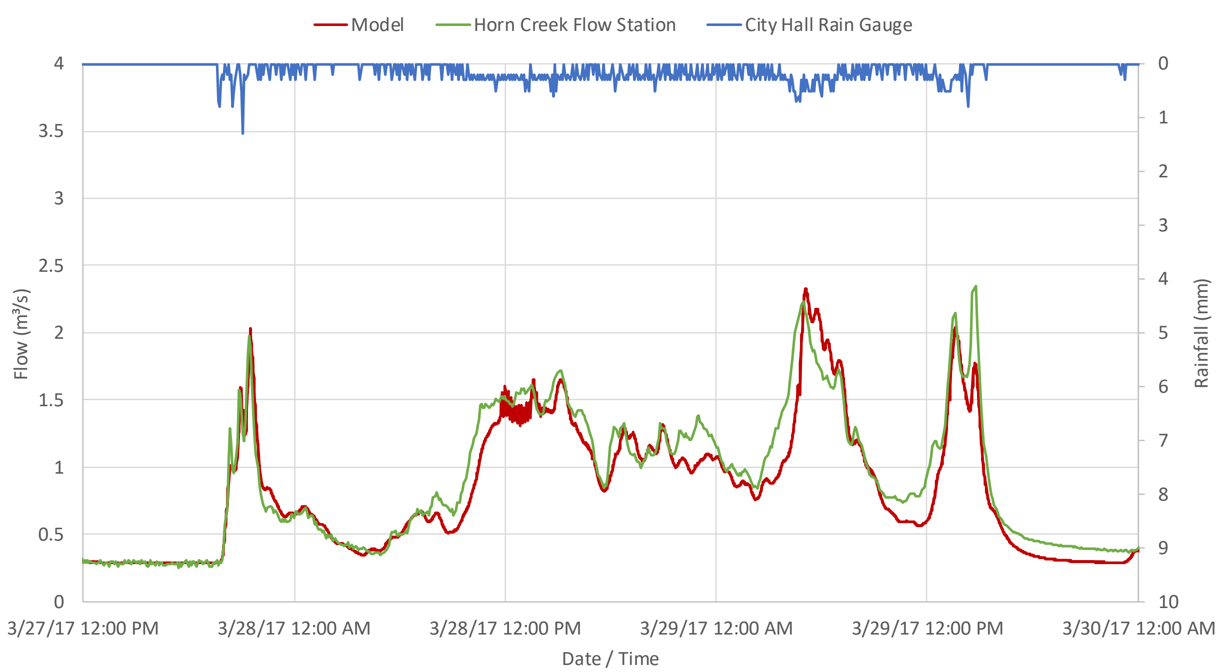
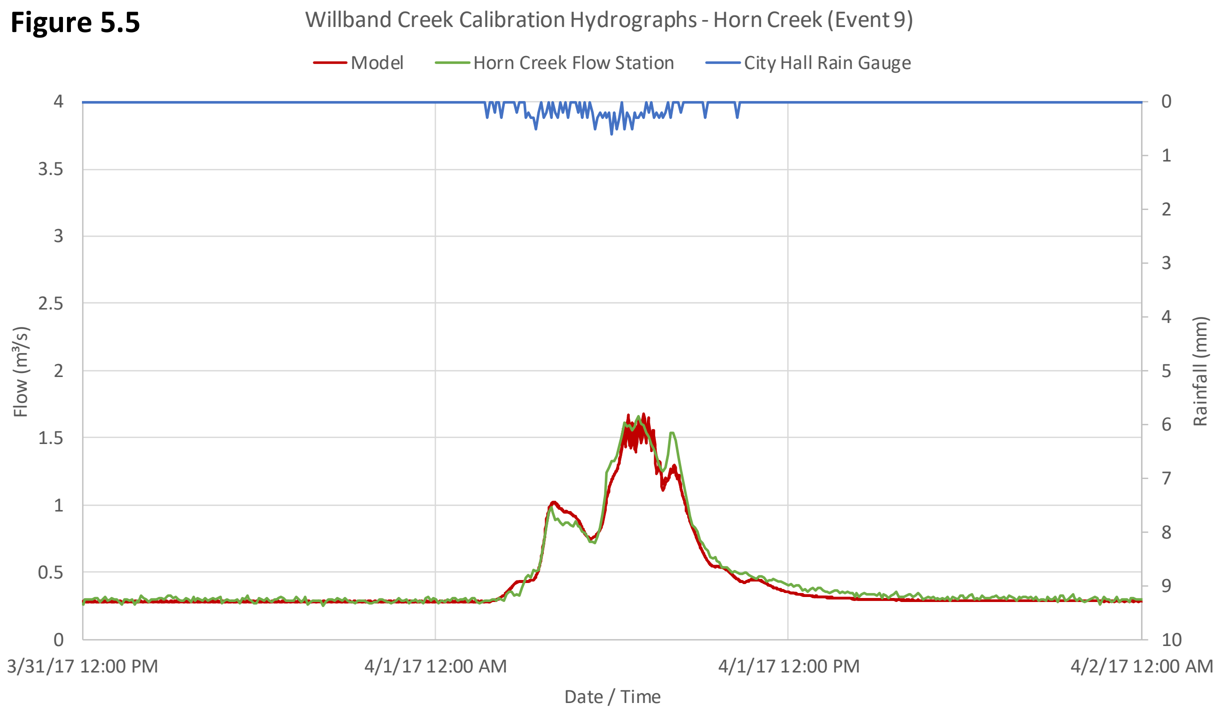


**Figure 5.5**




Overall, the model shows good agreement with the measured flows at the Horn Creek flow station. Events 5 and 7 show larger flow and volume discrepancies, which may be caused by precipitation inaccuracies as described below:

- There is a certain degree of uncertainty when rainfall data recorded at a fixed location are applied to large or distant areas. Microclimates often exist within large areas and often cause variations in localized precipitation volume and intensity that cannot be reflected in the model.
- Additionally, the storm events used for model calibration consisted of less than 2-year return periods. For best calibration results, it is recommended that the model be validated against larger recorded storm events when data becomes available.

As discussed above, the parameters derived during calibration of the Horn Creek basin were applied to the rest of the Willband watershed. Final summary of the catchment characteristics and calibrated parameters are summarized in **Table 5.2** below.

**Table 5.2: Willband Creek Catchment Characteristics and Calibrated Model Parameters**

| Subcatchment Parameter | Horn Creek Catchment | Remainder of Study Area |
|---|---|---|
| Area (ha) | 332 | 1,509 |
| Average Width (m) | 35 | 52 |
| Width Formula (Area <= 0.2 ha) | $width = \frac{Area}{length} = \frac{Area}{50\ m}$ | |
| Width Formula (Area > 0.2 ha) | $width = \frac{Area}{length};\ length = 3 \times \sqrt{Area}$ | |
| Average Slope (%) | 6.2% | 6.9% |
| Slope Formula | $subcatchment\ slope = \frac{Average\ LiDAR\ Slope}{2}$ | |
| Impervious (%) – Airphoto Imagery Analysis | 56% | 32% |
| Directly Connected Impervious (%) – 30% of runoff from impervious areas are directed to pervious areas | 39% | 22% |
| Depression Storage<br>Pervious Area (mm)<br>Impervious Area (mm) | <br>5.0<br>0.5 | |
| Manning's "n" Roughness Coefficient<br>Pervious Area "n"<br>Impervious Area "n" | <br>0.40<br>0.05 | |
| Base Flow (L/s/ha) | 0.84 | 0.15 |
| Soil Distribution | 90% - Gravel & Sand<br>9% - Sand & Silt (B)<br>1% - Peat/Till | 45% - Gravel & Sand<br>23% - Sand & Silt (B)<br>16% - Peat<br>9% - Till<br>7% - Other |
| Land Use Distribution | 25% - Single Family Res.<br>36% - Multi Family Res.<br>27% - Commercial<br>3% - Institutional<br>2% - Comprehensive<br>7% - Park/Open Space | 35% - Single Family Res.<br>8% - Multi Family Res.<br>5% - Commercial<br>9% - Institutional<br>7% - Industrial<br>23% - Agricultural<br>13% - Park/Open Space |

| Subcatchment Parameter | Horn Creek Catchment | Remainder of Study Area |
|---|---|---|
| Area with Controlled Runoff (ha)* | 70 (21%) | 308 (20%) |
| Number of Detention Facilities** (365 present in watershed) | 128 | 237 |
| Number of Private Detention Facilities** (312 present in watershed) | 113 | 199 |
| Number of Modeled Detention Ponds/Tanks | 3 | 17 |

* Runoff controlled by modeled detention features and/or control manholes.
** May include facilities such as detention tanks, dry/wet ponds, storm pipes, infiltration trenches, rain gardens, biofiltration ditches, etc.

# 6. Drainage Assessment

The Willband Creek drainage system is separated into minor and major systems, in addition to upland and lowland regions, as shown in **Figure 6.1**.

## 6.1. Design Storms

Design storm hyetographs used in the Clayburn Creek ISMP and the Matsqui Prairie Drainage Study – Phase 1 were supplied by the City and applied to the calibrated model. **Table 6.1** summarizes the total rainfall volume for each design storm event used to assess the minor and major drainage systems.

**Table 6.1: Design Storm Events**

| Duration | 6-month Total Rainfall (mm) | 2-year Total Rainfall (mm) | 5-year Total Rainfall (mm) | 10-year Total Rainfall (mm) | 100-year Total Rainfall (mm) |
|---|---|---|---|---|---|
| 1-hour | 9.72 | 13.50 | 17.65 | 20.50 | 29.25 |
| 2-hour | 13.72 | 19.05 | 24.55 | 28.20 | 39.60 |
| 6-hour | 25.06 | 34.80 | 41.30 | 45.70 | 59.25 |
| 12-hour | 36.79 | 51.10 | 61.00 | 67.55 | 88.05 |
| 24-hour | 51.05 | 70.90 | 85.70 | 95.50 | 126.20 |

The design storms were developed by averaging the rainfall intensity values from the Abbotsford A AES station (1100030) and the Mission West Abby AES station (1105192).

**Table 6.2** summarizes the total rainfall volume for each design storm event used to assess the system against the Agriculture and Rural Development Subsidiary Agreement (ARDSA) criteria.

**Table 6.2: ARDSA Design Storm Events**

| Duration | 10-year Total Rainfall (mm) | 200-year Total Rainfall (mm) |
|---|---|---|
| 2-day | 120.1 | N/A |
| 5-day | 182.8 | 262.2 |

The design storms were developed from rainfall intensity values from the Abbotsford A AES station (1100030).

Design storm durations impact the time of concentration of flows within a drainage system. Peak flows within the upper regions may be governed by shorter durations while lower regions by longer durations. Hence it was necessary to simulate the full suite of duration storms for each return period to determine the critical flows in the system.

**Figure 6.2** through **Figure 6.4** show the system performance under the 10-year, 100-year, and 200-year design storms.

## 6.2. Runoff Performance Indicators

The Willband Creek stormwater model was further validated by comparing runoff performance indicators at key points in the system. The following runoff performance indicators were analyzed and compared:

- **Peak runoff flow rate** per hectare – Areas with low infiltration and steeper terrain tend to produce higher runoff flow rates. Whereas, high infiltration and flatter terrain produce lower runoff flow rates.
- **Runoff coefficient** – This dimensionless coefficient is the ratio between runoff volume and storm event precipitation. This value is larger for areas of low infiltration and high runoff, and lower for high infiltration and less runoff.

**Table 6.3** summarizes the runoff performance indicators at 6 key points within the watershed.

The following observations were made based on the runoff performance indicators:

- Horn Creek has relatively high runoff flow rates and runoff coefficients due to higher impervious areas.
- Willband Creek outfall and Mill Lake outlet have lower flow rates and runoff coefficients as flows at these locations are influenced by upstream detention facilities.
- Prairie St Creek outfall has moderate flow rates with a low runoff coefficient as a result of topography that is steep with short flow lengths and low impervious areas.
- Willband Creek at Maclure Rd. has moderate flow rates with a low runoff coefficient. This site captures flow from Mill Lake in addition to other urban areas in the upland region.

**Table 6.3: Runoff Performance Indicator Summary**

| Point of Interest | Catchment Area (ha) | Average Impervious (%) | Average Slope (%) | Average Flow Length (m) |
|---|---|---|---|---|
| Willband Creek Outfall | 1,699 | 38% | 6.8 | 38 |
| Prairie St Creek Outfall | 142 | 24% | 7.1 | 24 |
| Willband Creek @ Maclure Rd. | 735 | 44% | 6.3 | 44 |
| Horn Creek @ Hydrometric Station | 332 | 56% | 6.2 | 56 |
| Mill Lake Outlet | 197 | 44% | 5.3 | 44 |
| Boa Creek | 67 | 48% | 7.9 | 48 |
| **Point of Interest** | **Peak Runoff Flow Rate (L/s/ha)** | | | |
| | **2-year Critical Duration** | **10-year Critical Duration** | **100-year Critical Duration** | **200-year 5-day** |
| Willband Creek Outfall | 2.6 | 3.5 | 4.3 | 4.5 |
| Prairie St Creek Outfall | 6.4 | 10.3 | 15.1 | 8.1 |
| Willband Creek @ Maclure Rd. | 6.4 | 9.5 | 12.2 | 9.9 |
| Horn Creek @ Hydrometric Station | 15.2 | 23.4 | 29.9 | 18.0 |
| Mill Lake Outlet | 2.3 | 3.5 | 5.1 | 5.2 |
| Boa Creek | 10.4 | 15.8 | 22.5 | 13.1 |
| **Point of Interest** | **Runoff Coefficient (/)** | | | |
| | **2-year Critical Duration** | **10-year Critical Duration** | **100-year Critical Duration** | **200-year 5-day** |
| Willband Creek Outfall | 0.32 | 0.34 | 0.35 | 0.37 |
| Prairie St Creek Outfall | 0.18 | 0.18 | 0.17 | 0.17 |
| Willband Creek at Maclure Rd. | 0.26 | 0.26 | 0.26 | 0.31 |
| Horn Creek @ Hydrometric Station | 0.39 | 0.42 | 0.41 | 0.39 |
| Mill Lake Outlet | 0.27 | 0.32 | 0.29 | 0.32 |
| Boa Creek | 0.32 | 0.34 | 0.34 | 0.32 |

Notes:
Results presented under the 2, 10, and 100-year return period represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour). The 5-day duration was run for the 200-year return period. The longer duration of the 200-year return period produced peak flows which were generally less than the peak flows of the 100-year duration.

The above peak flow rates were compared against the peak flow estimates reported in the Clayburn Creek ISMP and appear to be within reasonable ranges.

## 6.3. Design Criteria

**Table 6.4** summarizes the City's stormwater criteria consolidated from City Bylaws and past reports. A clear distinction is made between the criteria for upland and lowland regions.

**Table 6.4: District's Stormwater Criteria**

| Stormwater System | Stormwater Criteria |
|---|---|
| Detention Requirement | 10-year peak flows detained to 5 L/s/ha. |
| ***Upland Region Criteria*** | |
| Storm sewer | Safe conveyance of 10-year peak flows in minor systems.<br>Safe conveyance of 100-year peak flows in major systems. |
| Culvert | Safe conveyance of 100-year peak flows. |
| Creek | 200-year peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands. |
| ***Lowland Region Criteria*** | |
| Culvert | Safe conveyance of 10-year peak flows. |
| Creek | 2-year peak flow to be contained within the lowland creek banks. |
| Source:<br>City of Abbotsford Storm Water Source Control Bylaw, 2011 (Bylaw No. 2045-2011)<br>City of Abbotsford Development Bylaw, 2011 (Bylaw No. 2070-2011)<br>Clayburn Creek Integrated Stormwater Management Plan, May 2012<br>Matsqui Prairie Drainage Study - Phase I, June 2013 | |

## 6.4. Storm Sewer Assessment

### *Minor System Assessment*

The storm sewers of the minor system were assessed by simulating their ability to safely convey the minor flow, generated from the 10-year return period rainfall event. Storm sewers were determined to be undersized if the following criteria were met:

- Modeled peak flow is greater than full pipe capacity;
- Pipe surcharged for longer than 5 minutes; and
- Water surcharged higher than 0.3 m above the crown of the pipe.

**Table 6.5** summarizes the undersized storm sewers under the 10-year event.

**Table 6.5: Minor System Storm Sewers Undersized for 10-Year Event – Existing Land Use**

| GIS ID | Location | Existing Diameter (mm) | Existing Full Flow Capacity ($m^3/s$) | Model Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| 121362 | 32460 CORDOVA AVE | 300 | 0.06 | 0.12 |
| 121525 | 2210 CASCADE ST | 300 | 0.14 | 0.19 |
| 121556 | 2368 BEDFORD PL | 250 | 0.04 | 0.05 |
| 121687 | 33394 LYNN AVE | 375 | 0.11 | 0.13 |
| 121697 | 33306 MARSHALL RD | 525 | 0.62 | 0.62 |
| 121698 | 33342 MARSHALL RD | 600 | 0.50 | 0.64 |
| 121699 | 33112 MARSHALL RD | 600 | 0.46 | 0.56 |
| 121700 | 33270 MARSHALL RD | 600 | 0.49 | 0.60 |
| 121722 | 1989 MARCHALL RD | 525 | 0.26 | 0.42 |
| 121723 | 33112 MARSHALL RD | 525 | 0.26 | 0.45 |
| 121736 | 33172 MARSHALL RD | 600 | 0.44 | 0.59 |
| 121917 | 1948 HORIZON ST | 525 | 0.27 | 0.37 |
| 122053 | 33012 MARSHALL RD | 525 | 0.27 | 0.36 |
| 122054 | 33033 MARSHALL RD | 525 | 0.26 | 0.42 |
| 122055 | 2028 PRIMROSE ST | 300 | 0.07 | 0.10 |
| 122056 | 33033 MARSHALL RD | 300 | 0.07 | 0.10 |
| 122259 | 32900 MARSHALL RD | 300 | 0.06 | 0.28 |
| 126439 | 32500 SOUTH FRASER WAY | 375 | 0.11 | 0.16 |
| 126441 | 32500 SOUTH FRASER WAY | 300 | 0.07 | 0.07 |
| 126498 | 32835 SOUTH FRASER WAY | 375 | 0.13 | 0.21 |
| 126499 | 2790 GLADWIN RD | 375 | 0.18 | 0.23 |
| 126500 | 2790 GLADWIN RD | 375 | 0.25 | 0.28 |
| 126564 | 2885 TRETHEWEY ST | 375 | 0.11 | 0.18 |
| 126872 | 2575 GLADWIN RD | 300 | 0.05 | 0.11 |
| 126915 | 2575 GLADWIN RD | 300 | 0.08 | 0.10 |
| 126922 | 32500 SOUTH FRASER WAY | 300 | 0.06 | 0.10 |
| 126956 | 32718 GARIBALDI DR | 375 | 0.20 | 0.23 |
| 126957 | 32718 GARIBALDI DR | 375 | 0.17 | 0.23 |
| 127043 | 32390 SOUTH FRASER WAY | 300 | 0.10 | 0.12 |
| 127079 | 32320 GEORGE FERGUSON WAY | 250 | 0.05 | 0.06 |
| 127177 | 33550 SOUTH FRASER WAY | 300 | 0.07 | 0.14 |
| 127282 | 33177 SOUTH FRASER WAY | 300 | 0.07 | 0.10 |

| GIS ID | Location | Existing Diameter (mm) | Existing Full Flow Capacity ($m^3/s$) | Model Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| 127359 | 33110 GEORGE FERGUSON WAY | 300 | 0.06 | 0.09 |
| 127360 | 33136 GEORGE FERGUSON WAY | 300 | 0.06 | 0.12 |
| 127545 | 2731 WARE ST | 300 | 0.10 | 0.14 |
| 127936 | 2565 HIGHFIELD CR | 250 | 0.07 | 0.08 |
| 127939 | 2588 BIRCH ST | 250 | 0.11 | 0.13 |
| 128022 | 34320 LARCH ST | 300 | 0.12 | 0.17 |
| 128048 | 34174 LARCH ST | 450 | 0.31 | 0.37 |
| 128049 | 34076 LARCH ST | 450 | 0.25 | 0.38 |
| 128192 | 33879 GLADYS AVE | 250 | 0.14 | 0.16 |
| 128195 | 2722 GLADYS AVE | 250 | 0.09 | 0.11 |
| 128228 | 3008 ASH ST | 300 | 0.00 | 0.01 |
| 128320 | 34038 WALNUT AVE | 450 | 0.12 | 0.22 |
| 128452 | 3091 LUKIV TERRACE | 375 | 0.02 | 0.05 |
| 131871 | 33295 MACLURE RD | 300 | 0.11 | 0.14 |
| 131872 | 33295 MACLURE RD | 300 | 0.09 | 0.15 |
| 131873 | 33295 MACLURE RD | 300 | 0.16 | 0.16 |
| 131949 | 32942 BANFF PL | 200 | 0.05 | 0.06 |
| 131956 | 33071 OLD RIVERSIDE RD | 375 | 0.14 | 0.18 |
| 131958 | 3487 HORN ST | 250 | 0.03 | 0.06 |
| 131969 | 33541 MACLURE RD | 300 | 0.05 | 0.17 |
| 132001 | 3525 HORN ST | 300 | 0.04 | 0.08 |
| 132006 | 3201 MCCALLUM RD | 300 | 0.06 | 0.07 |
| 132231 | 34711 OLD CLAYBURN RD | 375 | 0.13 | 0.16 |
| 132282 | 34435 THOREAU AVE | 300 | 0.07 | 0.14 |
| 132294 | 3493 PICTON ST | 300 | 0.12 | 0.15 |
| 132422 | 34489 LABURNUM AVE | 375 | 0.12 | 0.20 |
| 132423 | 34481 LABURNUM AVE | 375 | 0.18 | 0.20 |
| 132424 | 3336 EPSON CT | 300 | 0.07 | 0.08 |
| 132425 | 3336 EPSON CT | 300 | 0.07 | 0.12 |
| 132426 | 3337 EPSON CT | 300 | 0.07 | 0.13 |
| 132427 | 3337 EPSON CT | 300 | 0.07 | 0.13 |
| 132428 | 34516 EPSON LANE | 300 | 0.07 | 0.14 |

| GIS ID | Location | Existing Diameter (mm) | Existing Full Flow Capacity ($m^3/s$) | Model Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| 132429 | 34516 EPSON LANE | 300 | 0.07 | 0.15 |
| 132458 | 34639 IMMEL ST | 250 | 0.04 | 0.04 |
| 227682 | 33952 PINE ST | 375 | 0.12 | 0.18 |
| 227684 | 2703 SHEFFIELD WAY | 375 | 0.37 | 0.44 |
| 227686 | 2723 SHEFFIELD WAY | 300 | 0.06 | 0.26 |
| 227690 | 34038 WALNUT AVE | 450 | 0.13 | 0.25 |
| 227691 | 34038 WALNUT AVE | 450 | 0.17 | 0.25 |
| 227692 | 34038 WALNUT AVE | 450 | 0.20 | 0.25 |
| 252357 | 34174 LARCH ST | 450 | 0.14 | 0.17 |
| 252359 | 2700 ASH ST | 450 | 0.14 | 0.17 |
| 252361 | 34236 WOODBINE CR | 375 | 0.09 | 0.15 |
| 254691 | 34406 DONLYN AVE | 300 | 0.01 | 0.15 |
| 127076_2 | 32320 GEORGE FERGUSON WAY | 375 | 0.13 | 0.14 |

### *Major System Assessment*

The storm sewers that convey stormwater flows from Mill Lake and stormwater flows in between creeks were considered as part of the major system. The major storm sewers were assessed by simulating their ability to safely convey the major flow, generated during the 100-year return period rainfall event. Storm sewers were defined as undersized if the following criteria were met:

- Simulated peak flow is greater than full pipe capacity;
- Pipe is surcharged for longer than 15 minutes; and
- Peak water level is surcharged higher than 0.3 m above the crown of the pipe.

**Table 6.6** summarizes the undersized storm sewers under the 100-year event.

**Table 6.6: Major System Storm Sewers Undersized for 100-Year Event – Existing Land Use**

| GIS ID | Location | Existing Diameter (mm) | Existing Full Flow Capacity ($m^3/s$) | Model Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| 128407 | 2636 MONTROSE AVE | 1350 | 4.87 | 6.47 |
| 128406 | 33737 MONTROSE AVE | 1350 | 4.98 | 6.46 |

**Figure 6.5** shows the storm sewers assessed against the established criteria under existing land use conditions.

## 6.5. Culvert and Bridge Assessment

The culverts and bridges were assessed by evaluating their ability to safely convey minor and major flows generated from the 10-year and 100-year return period rainfall events.

Culverts were determined to be undersized if the following criteria were met:

- Upland Culvert – Modeled 100-year peak flow is greater than full flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.
- Lowland Culvert – Modeled 10-year peak flow is greater than full flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.

**Table 6.7** summarizes the undersized culverts.

**Figure 6.6** shows the culverts assessed against the established criteria under existing land use conditions.

**Table 6.7: Culvert Undersized – Existing Land Use**

| GIS ID | Location | Existing Culvert Height (mm) | Existing Full Flow Capacity ($m^3/s$) | Peak Flow ($m^3/s$) |
|---|---|---|---|---|
| **Upland Culvert Undersized for Existing 100-Year Flow** | | | | |
| 114771 | 34055 OXFORD AVE | 600 | 0.32 | 0.41 |
| **Lowland Culvert Undersized for Existing 10-Year Flow** | | | | |
| 237611 | 33911 ABBOTSFORD MISSION HWY | 600 | 0.18 | 0.54 |

Two road bridges and one rail bridge were identified within the Willband watershed. However, asbuilt drawings for these bridges were not available to formulate a complete assessment. The table below provides the peak flows and maximum water depths and hydraulic grade lines reached under the various design storms along the creeks where each bridge is located.

**Table 6.8: Model Results Along Creeks at Bridge Locations – Existing Land Use**

| Model Results | Return Period | | | |
|---|---|---|---|---|
| | 2-year Critical Duration | 10-year Critical Duration | 100-year Critical Duration | 200-year 5-day |
| **Willband Creek at Maclure Rd (Road Bridge)** | | | | |
| Peak Flow ($m^3/s$) | 4.76 | 6.97 | 9.05 | 7.40 |
| Max. Flow Depth (m) | 0.57 | 0.68 | 0.72 | 0.67 |
| Hydraulic Grade (m) | 4.66 | 4.77 | 4.81 | 4.76 |
| **Willband Creek at Maclure Rd (Rail Bridge)** | | | | |
| Peak Flow ($m^3/s$) | 4.80 | 7.09 | 9.20 | 7.52 |
| Max. Flow Depth (m) | 0.65 | 0.70 | 0.73 | 0.70 |
| Hydraulic Grade (m) | 4.61 | 4.66 | 4.69 | 4.66 |
| **Willband Creek at Bateman Rd (Road Bridge)** | | | | |
| Peak Flow ($m^3/s$) | 4.26 | 5.54 | 6.70 | 7.35 |
| Max. Flow Depth (m) | 1.05 | 1.18 | 1.27 | 1.24 |
| Hydraulic Grade (m) | 2.78 | 2.91 | 3.00 | 2.97 |

Notes:
Results presented under the 2, 10, and 100-year return period represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour). The 5-day duration was run for the 200-year return period. The longer duration of the 200-year return period produced peak flows which were generally less than the peak flows of the 100-year duration.

## 6.6. Detention Assessment

The detention facilities were assessed by evaluating their ability to detain the 10-year flow and release at a rate of 5 L/s/ha.

**Table 6.10** summarizes the detention facility performance assessment.

**Figure 6.7** shows the detention facilities assessed against the established criteria under existing land use conditions.

### *Mill Lake*

The Mill Lake detention pond discharge flow rate and water surface elevation is controlled by the weir control structure at the outlet. **Table 6.8** summarizes the peak discharge flow rate and maximum water surface elevation under the various return periods and critical durations. **Figure 6.2** through **Figure 6.4** show the Mill Lake flood extent based on the assumption that the outlet stop logs are at their highest setting of 51.65 m. The asbuilt drawings for the outlet control structure did not state the criteria or a design discharge rate, therefore the criteria is unknown.

**Table 6.9: Mill Lake Performance – Existing Land Use**

| Model Results | Return Period | | | |
|---|---|---|---|---|
| | 2-year Critical Duration | 10-year Critical Duration | 100-year Critical Duration | 200-year 5-day |
| Peak Discharge Flow ($m^3$/s) | 0.48 | 0.72 | 1.04 | 1.07 |
| Peak Release Rate (L/s/ha) | 2.44 | 3.65 | 5.28 | 5.43 |
| Max. HGL (m) | 51.79 | 51.82 | 51.86 | 51.87 |

Notes:
Results presented under the 2, 10, and 100-year return period represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour). The 5-day duration was run for the 200-year return period.

### *Willband Stormwater Detention Facility*

The Willband stormwater detention facility is situated in the lowland area where unique criteria should be applied to assess its performance. The asbuilt drawings for the detention facility did not state the criteria or a design discharge rate, therefore the criteria is unknown.

Further discussion with the City is required to establish an applicable criteria to assess the performance of the Mill Lake and Willband Stormwater detention facilities in Phase 2 of this study.

**Table 6.10: Detention Facility Performance Assessment – Existing Land Use**

| Storage ID | Type | Location | Catchment Area (ha) Modeled & [Designed]* | Inflow (L/s/ha) | Outflow (L/s/ha) | Available Storage ($m^3$) | Storage Used (%) | Achieve Criteria? | Notes |
|---|---|---|---|---|---|---|---|---|---|
| SU01 | Pond | North of 3781 Robson Dr. | 20.7 | 18.7 | 9.3 | 3,580 | 32% | No - Control⁺ | Drawing missing pond details. No outflow control structure modeled. |
| SU02 | Pond | Picton Park, North of 34435 Thoreau Ave. | 17.2 [6.0] | 4.9 | 2.1 | 3,940 | 55% | Yes | Detention storage calculations in asbuilt dwg indicated a catchment area of 6 hectares with a design frequency of 100 years. |
| SU03 | Tank | South-East of Mayfair Ave. and Sandalwood Crescent | 1.7 [1.26] | 15.1 | 6.1 | 440 | 44% | Yes | |
| SU04 | Pond | Old Riverside Park, West of Horn St. and Grouse Dr. | 1.4 | 52.9 | 28.2 | 1,050 | 10% | No - Control | Flow control based on outlet pipe. This is a temporary tank according to asbuilt drawings. |
| SU05 | Pond | Walnut Ave. at Pratt St. | 40.2 | 5.1 | 2.7 | 3,390 | 70% | Yes | |
| SU06** | Pond | North-East of Trethewey St. and Simon Ave. | 1.4 | 67.1 | 52.4 | 670 | 10% | No - Control | Design catchment area unknown. |
| SU07 | Pond | North of Nelson Pl. | 4.1 | 27.2 | 26.6 | 760 | 5% | No - Control | Outflow controlled by sluice gate. Asbuilt did not indicate sluice gate setting, therefore model assumes fully open. |
| SU08 | Pond | 100 m North of Maclure Rd. and Babich St. | 2.9 [2.8] | 14.9 | 4.0 | 2,810 | 48% | Yes | |
| SU09 | Tank | North of 32737 Chilcotin Dr. | 1.1 [1.1] | 24.0 | 3.2 | 212 | 33% | Yes | |
| SU10 | Tank | North of 2368 Bedford Pl. | 0.4 [0.4] | 25.9 | 4.5 | 132 | 31% | Yes | |
| SU11 | Pond | 30564 Horn St., West of Eastview Park | 8.3 | 30.3 | 18.7 | 1,510 | 13% | No - Control | Control orifice size to review. |
| SU12 | Pond | North-East of Terry Fox Ave. and Babich St. | 6.5 | 26.8 | 25.0 | 219 | 1% | No - Control | Control orifice size to review. |
| SU13 | Tank | 3097 Lukiv Terrace | 1.7 [0.9] | 29.5 | 3.6 | 270 | 100% | No - Storage | Discrepancy in designed service area vs modeled service area. Detention storage calculations in asbuilt dwg indicated a catchment area of 0.9 ha, but did not indicate a design frequency. |
| SU14 | Tank | 3281 Saddle St. and Immel St. | 0.8 | 7.9 | 5.0 | 637 | 11% | Yes | Tank indicated in asbuilt as a secondary siltation control. |
| SU20*** | Pond | East of Harwood Crescent and Gatefield Ave. | N/A | N/A | N/A | N/A | N/A | N/A | |

⁺ No outflow control structure found.
* Designed catchment area provided if indicated in asbuilt drawings.
** To verify intended service area of detention facility.
*** GIS is inconsistent with asbuilt drawing. To confirm if the pond is still used for detention purposes.

Yes: Meets the 5 L/s/ha criterion.
No - Control: Outflow exceeds the 5 L/s/ha criterion due to inadequate downstream control.
No - Storage: Inadequate storage based on existing downstream flow control.
N/A: Not applicable as the storage is not a detention facility or the facility is no longer in use.

Notes:
Results presented represent the worst case from all storm durations assessed (1, 2, 6, 12, and 24 hour).
Control structures were modeled based on asbuilt drawing information and assuming an orifice coefficient of 0.65.

## 6.7. Creek Assessment

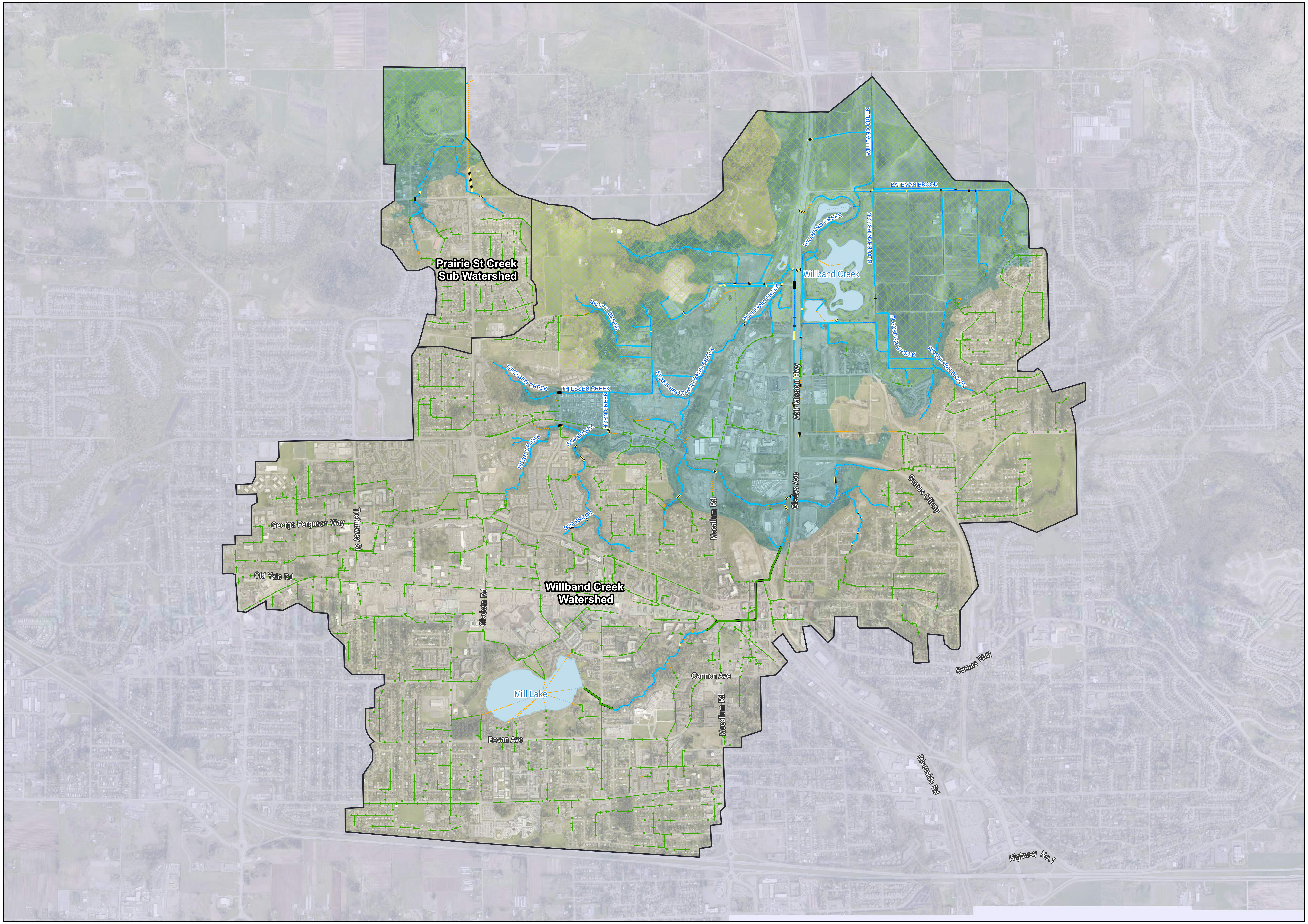
The creeks of the major system were assessed by simulating their ability to safely convey and contain the 2-year and 200-year flows. Creek capacity was assessed based on the following criteria:

- 2-year 24-hour peak flow to be contained within the lowland creek banks
- 200-year 5-day peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands

As creeks within the lowland region are influenced by the downstream water levels at Clayburn Creek, it was necessary to assess the system with downstream boundary conditions. For the purposes of this interim assessment, a boundary condition that set a water elevation of 2.3 m was applied at the Willband Creek outfall. This assumption was based on an estimation of the average Clayburn Creek water level measured at Clayburn Rd. during the winter season.

**Figure 6.8** shows the creeks assessed against the established criteria under existing land use conditions.

The drainage assessment under the 200-year 5-day peak flow will be assessed in the next phase when flood maps will be generated based on flood cell storage and boundary condition information recently provided by Kerr Wood Leidal on behalf of the City. Flood mapping will be used to assess roadways and railways that may be overtopping. In addition, flood mapping will be used to assess the performance of the Willband Detention Facility.




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Lake
- Marsh
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Conduit Added for Connectivity

### Minor System

- Minor Storm Sewer

### Major System

- Creek
- Culvert
- Major Storm Sewer

**Interim Results**

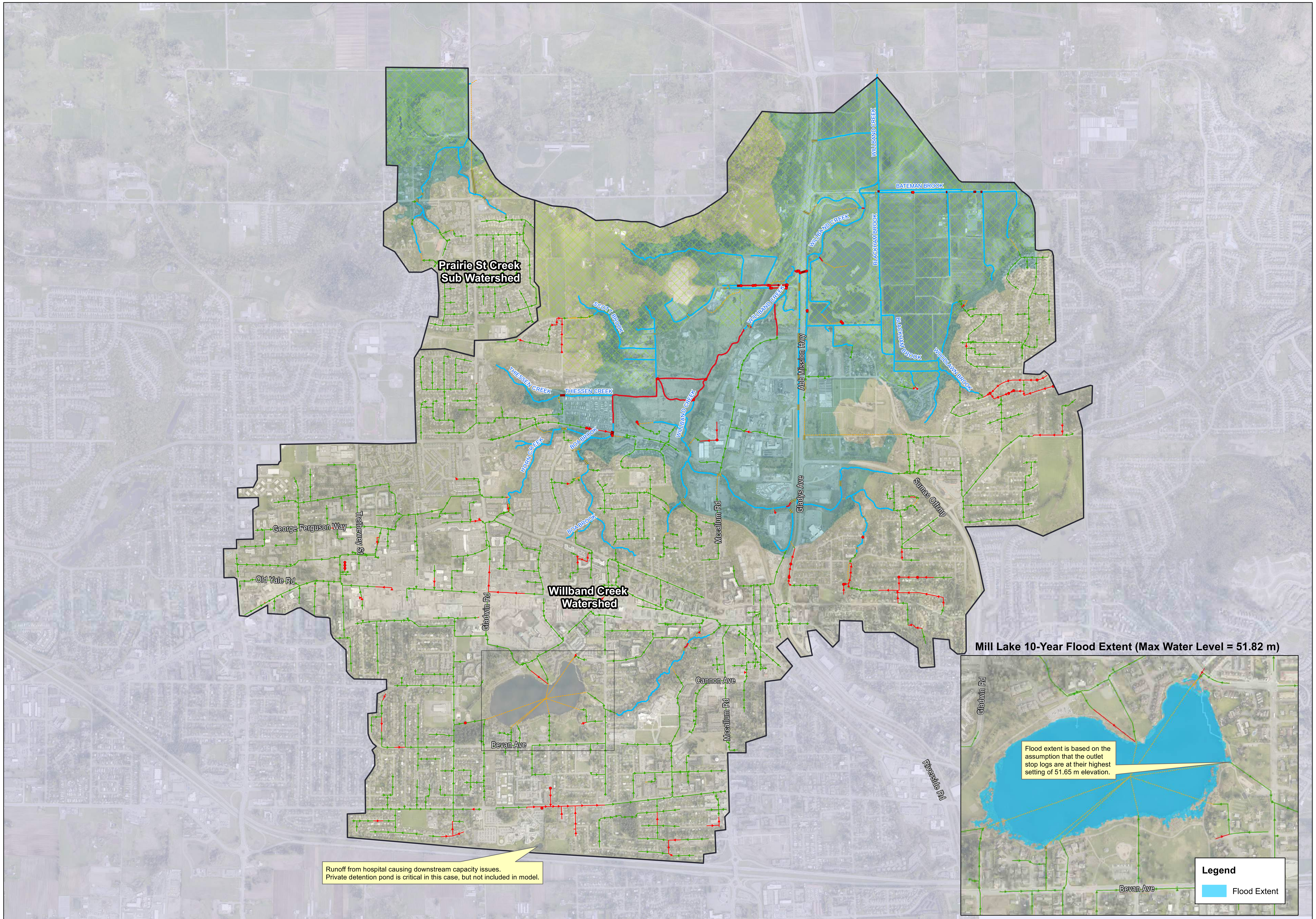
**Minor and Major Systems**

Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1 Kilometers

**Figure 6.1**




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Potential Flood (HGL > Ground Surface)
- Storm Sewer Surcharged (d/D > 1)
- Culvert Surcharged (d/D > 1)
- Potential Breach of Creek (d/D > 1)
- Conduit Added for Connectivity
- Creek
- Culvert
- Main

**Interim Results**

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**10-Year, Critical Duration System Performance (Existing Land Use)**

ABBOTSFORD

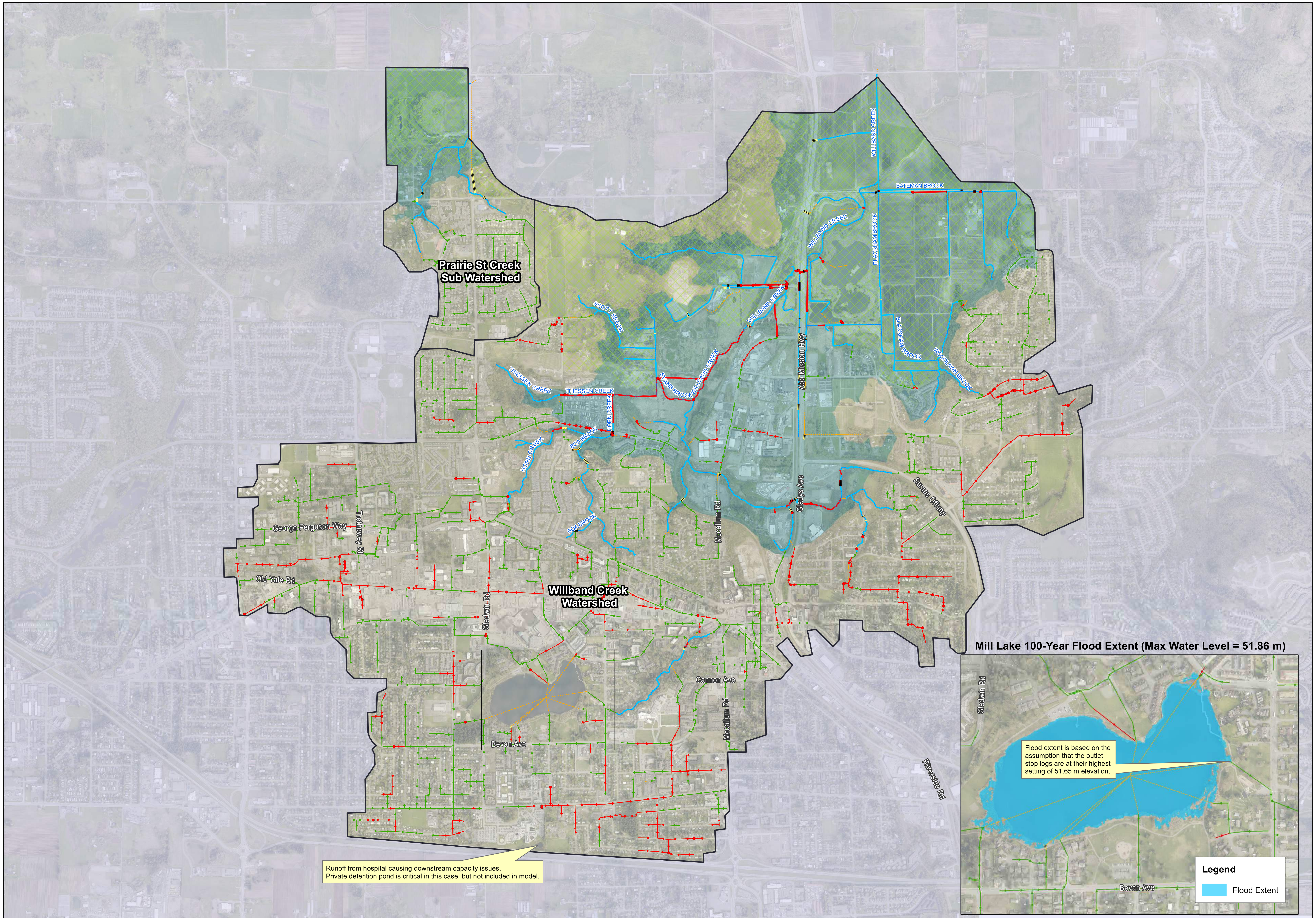
Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1 Kilometers

N S W E

**Figure 6.2**




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Potential Flood (HGL > Ground Surface)
- Storm Sewer Surcharged (d/D > 1)
- Culvert Surcharged (d/D > 1)
- Potential Breach of Creek (d/D > 1)
- Conduit Added for Connectivity
- Creek
- Culvert
- Main

**Interim Results**

Results presented represent the worst case for each reach and control from all storm durations assessed (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**100-Year, Critical Duration System Performance (Existing Land Use)**

ABBOTSFORD

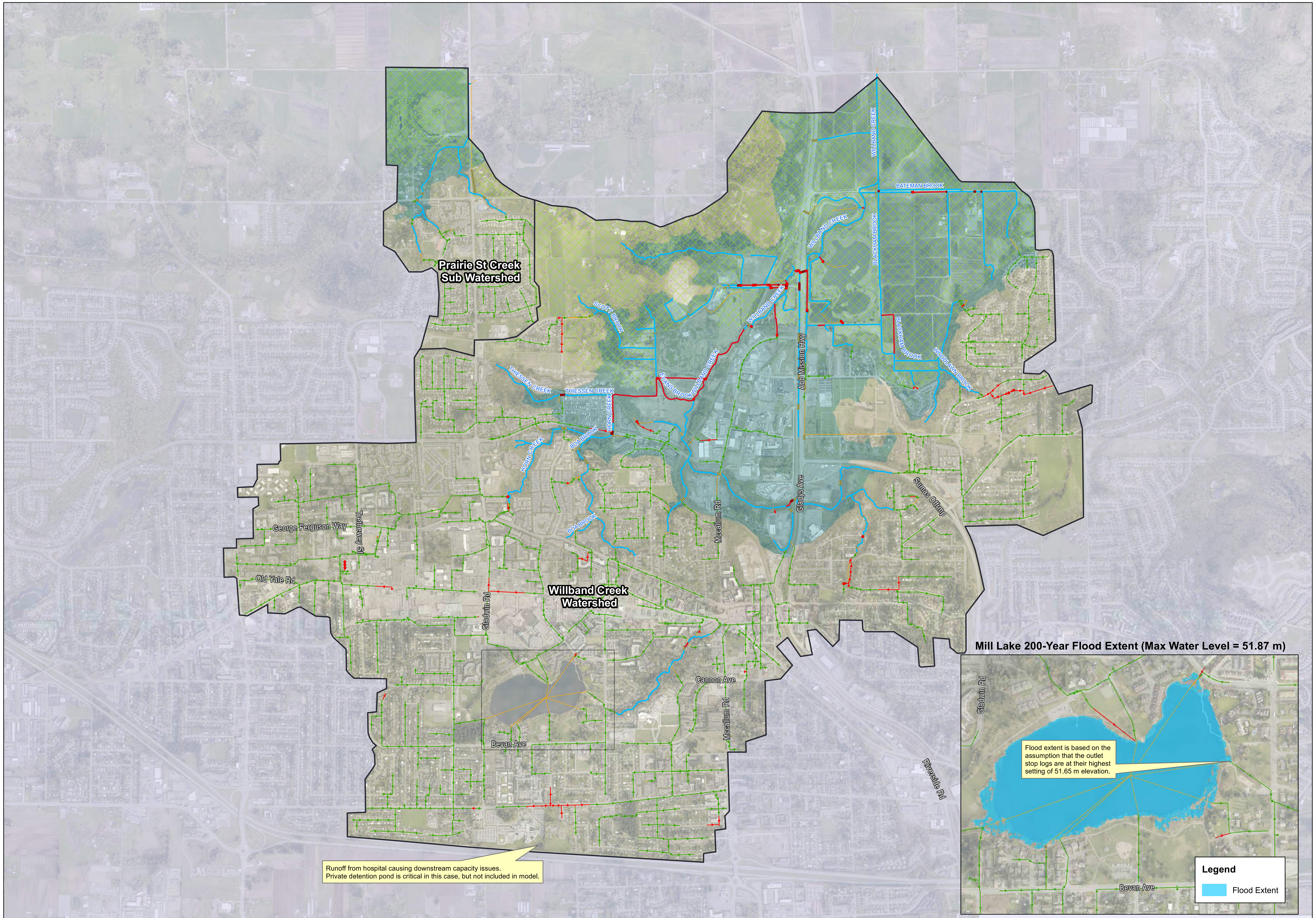
Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure 6.3**




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Potential Flood (HGL > Ground Surface)
- Storm Sewer Surcharged (d/D > 1)
- Culvert Surcharged (d/D > 1)
- Potential Breach of Creek (d/D > 1)
- Conduit Added for Connectivity
- Creek
- Culvert
- Main

**Interim Results**

**200-Year, 5-Day System Performance (Existing Land Use)**

ABBOTSFORD

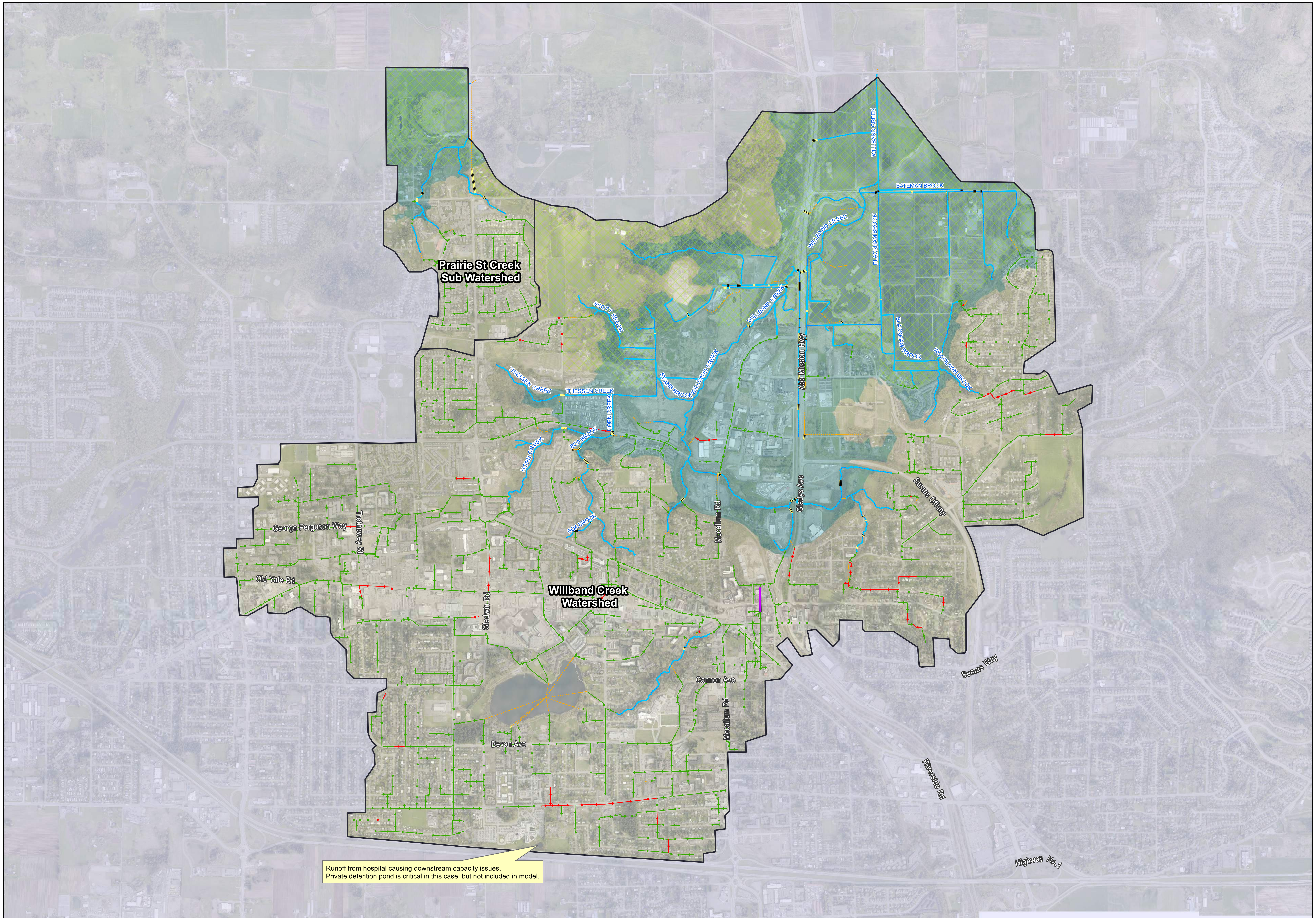
Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure 6.4**




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Conduit Added for Connectivity
- Creek
- Main
- Culvert

### Storm Sewer Assessment

- Minor Main (10-Year) Surcharge 0.3 m over Crown for > 5 min
- Major Main (100-Year) Surcharge 0.3 m over Crown for > 15 min

## Interim Results

Assessment based on critical results from simulating design storms of all durations (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Storm Sewer Assessed Against Established Criteria (Existing Land Use)**

ABBOTSFORD

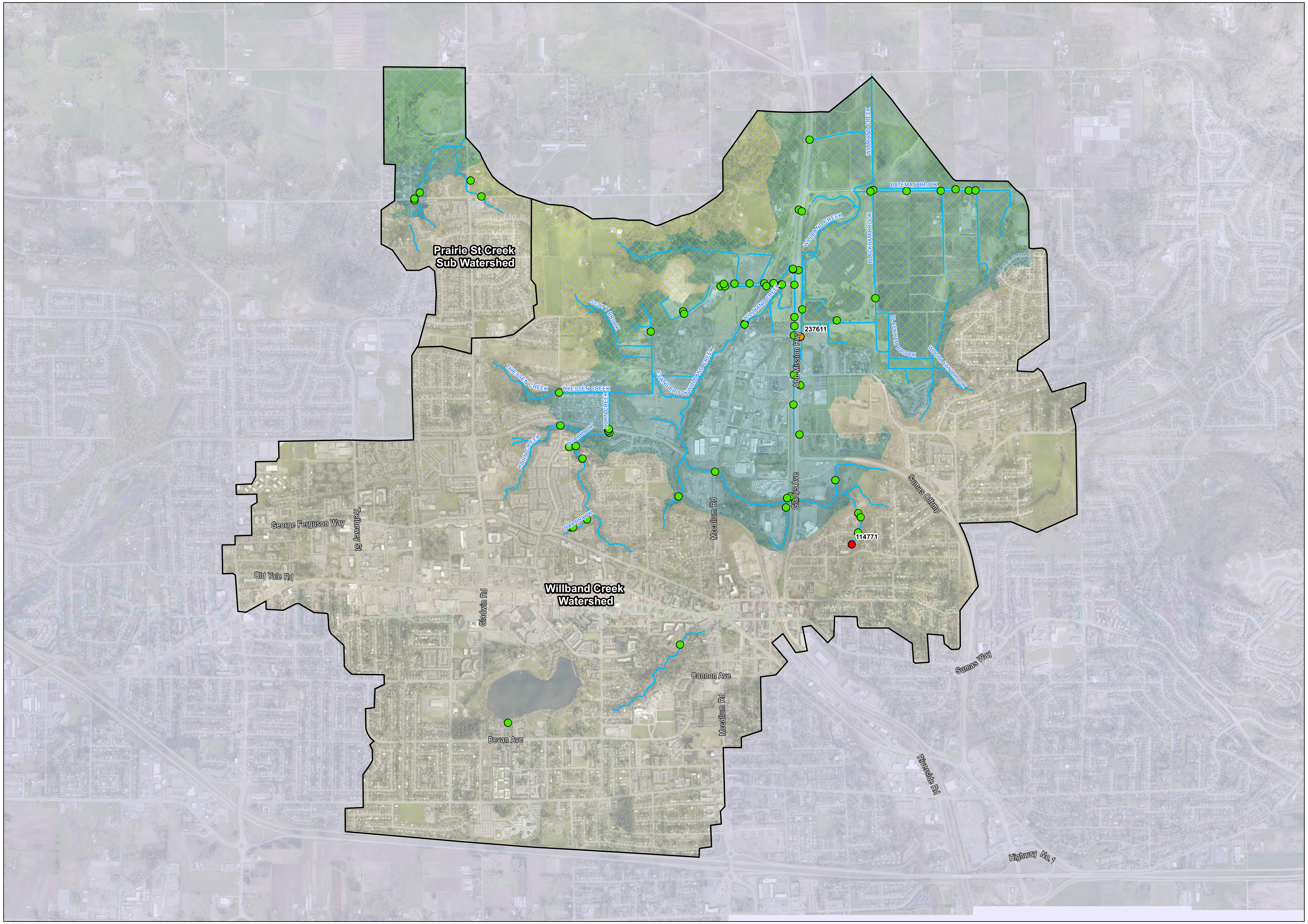
Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

## Figure 6.5




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Creek

**Culvert Assessment**

- Meets Criteria
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown [1]
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown [1]

**Interim Results**

Assessment based on critical results from simulating design storms of all durations (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Culverts Assessed Against Established Criteria (Existing Land Use)**

ABBOTSFORD

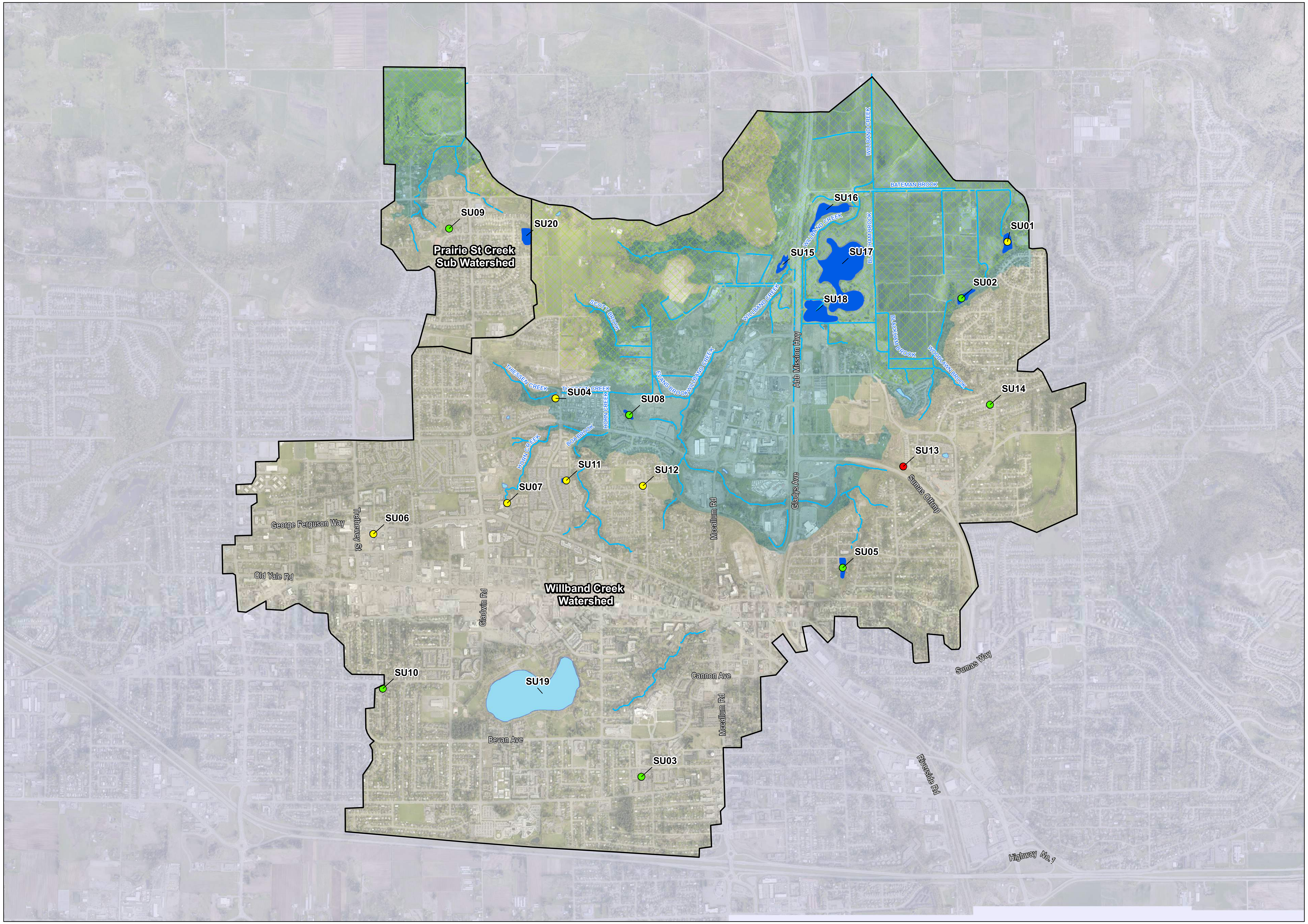
Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure 6.6**




GeoAdvice Engineering Inc.

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Detention Facility
- Lake
- Creek

**Detention Assessment**

- Meets Criteria [7]
- Outlet Modification Required to Meet Criteria [6]
- Insufficient Storage Volume Required to Meet Criteria [1]

**Interim Results**

Assessment based on critical results from simulating design storms of all durations (1-hr, 2-hr, 6-hr, 12-hr, and 24-hr)

**Detention Facilities Assessed Against Established Criteria (Existing Land Use)**

ABBOTSFORD

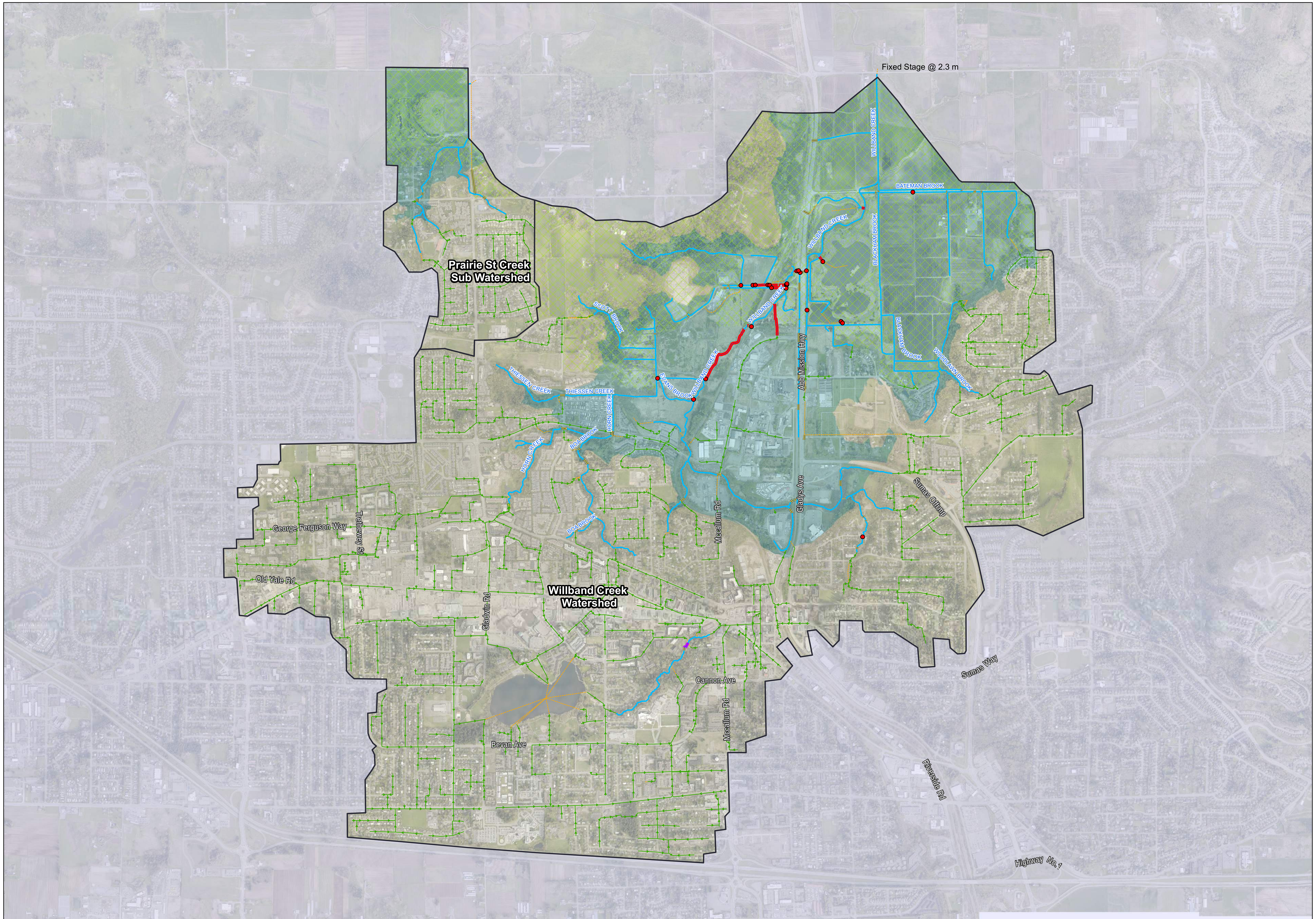
Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N W E S

**Figure 6.7**

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2006 - 2016

## Legend

- Watershed Area
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Conduit Added for Connectivity
- Creek
- Culvert
- Main

## Creek Assessment

- Potential 200-Year Flood (HGL > Ground Surface)
- Upland Creek (200-Year, 5-Day) Potential Breach of Creek (d/D > 1)
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek (d/D > 1)

**Interim Results**

**Creeks Assessed Against Established Criteria (Existing Land Use)**

ABBOTSFORD

Project: Willband Creek Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS



0 0.25 0.5 1
Kilometers

N E S W

**Figure 6.8**

# 7. Conclusion

Conclusions and recommendations have yet to be developed and will be incorporated into the Phase 2 technical memorandum.

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## Submission

**Prepared by:**

| | |
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**Reviewed and Approved by:**

Werner de Schaetzen, Ph.D., P.Eng.
Senior Modeling Review

*Enclosed:*

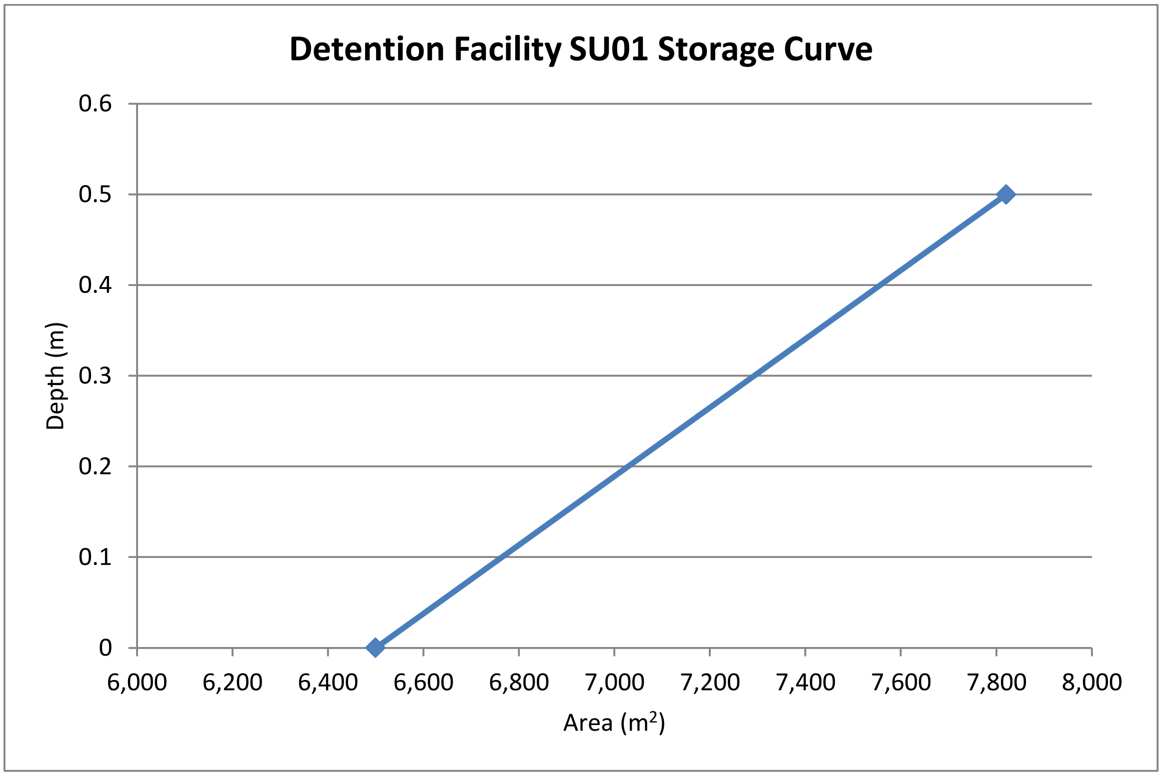
*Appendix A – Detention Facility Storage Curves*

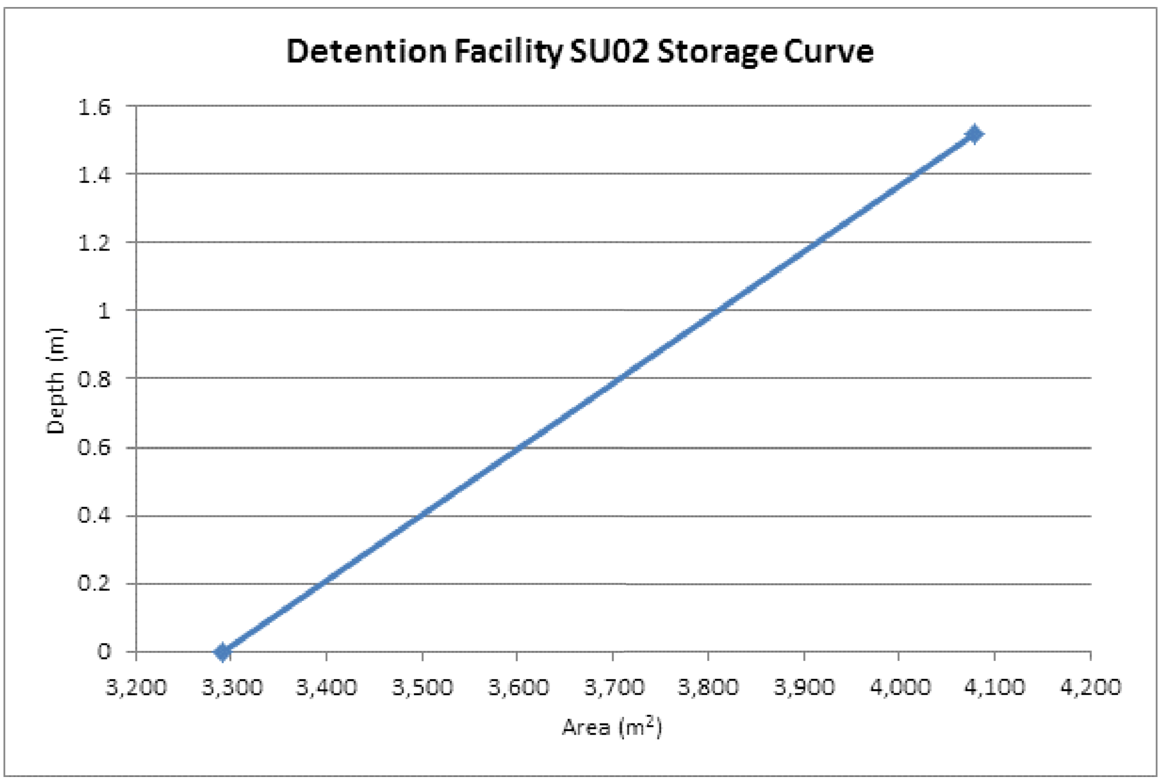


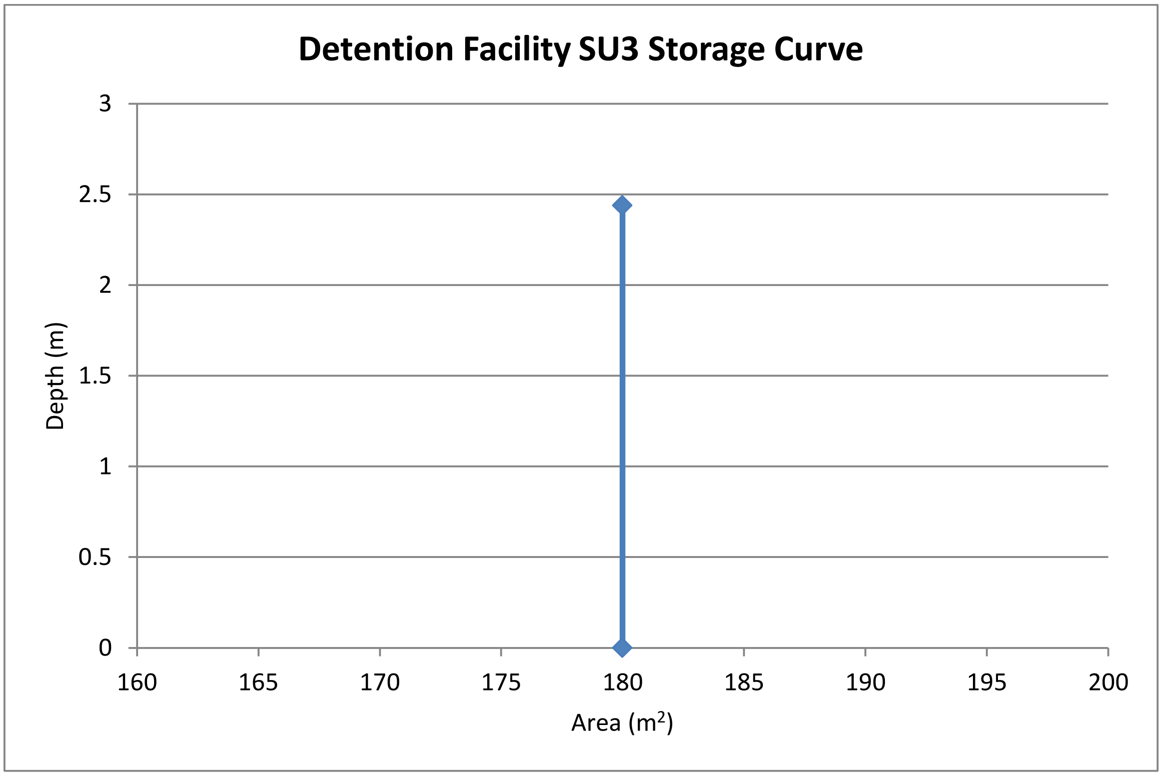
### Statement of Qualifications and Limitations

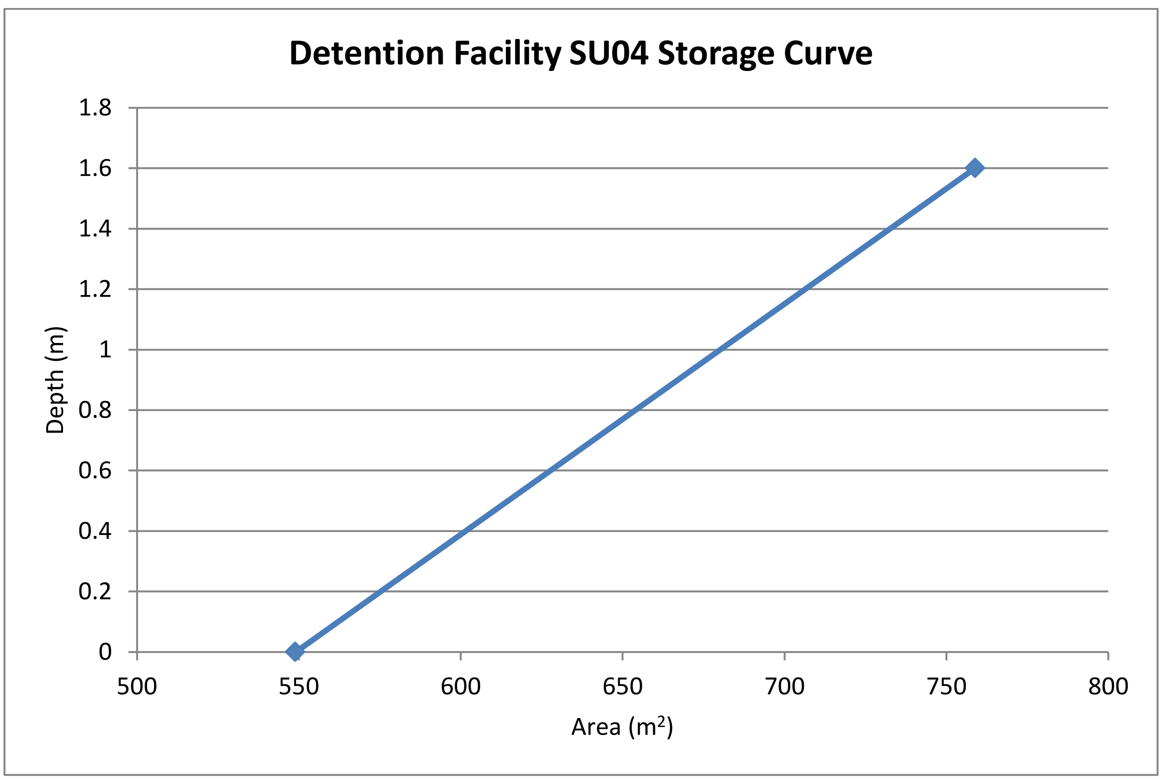
This document represents GeoAdvice Engineering Inc. best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinary exercised by member of the engineering profession currently practicing under similar conditions. No warranty, express or implied is made.

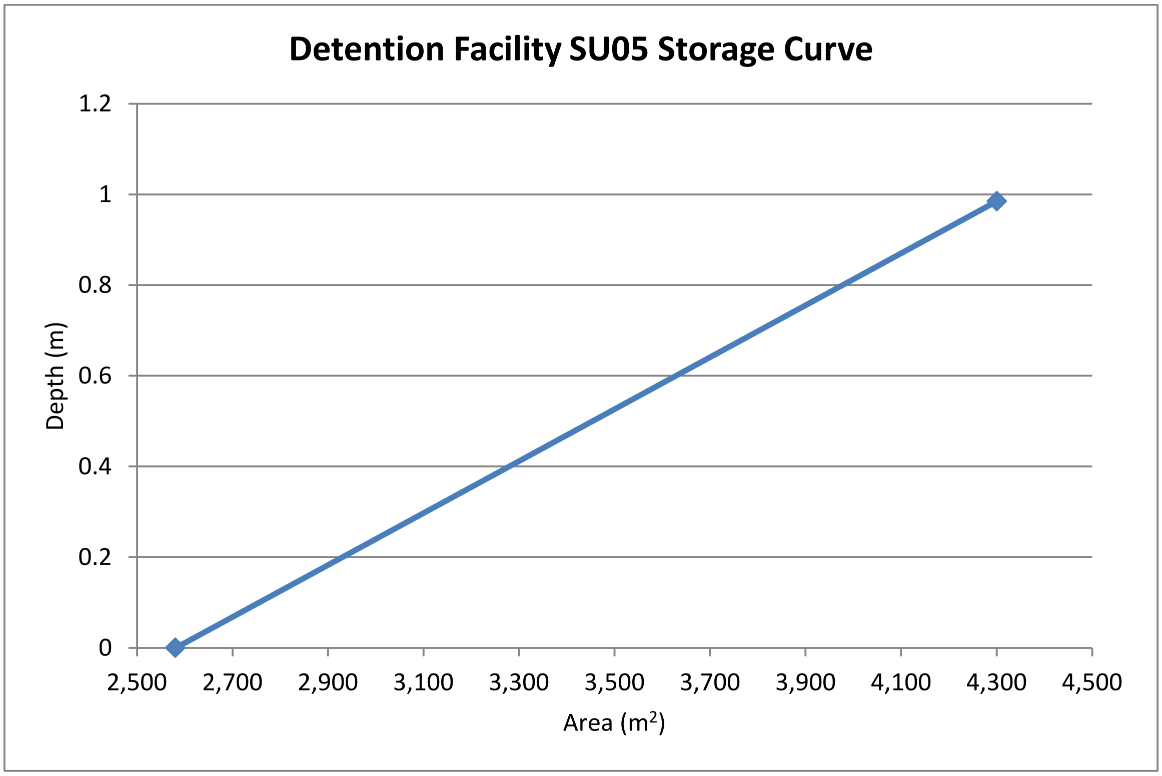
# Appendix A Detention Facility Storage Curves

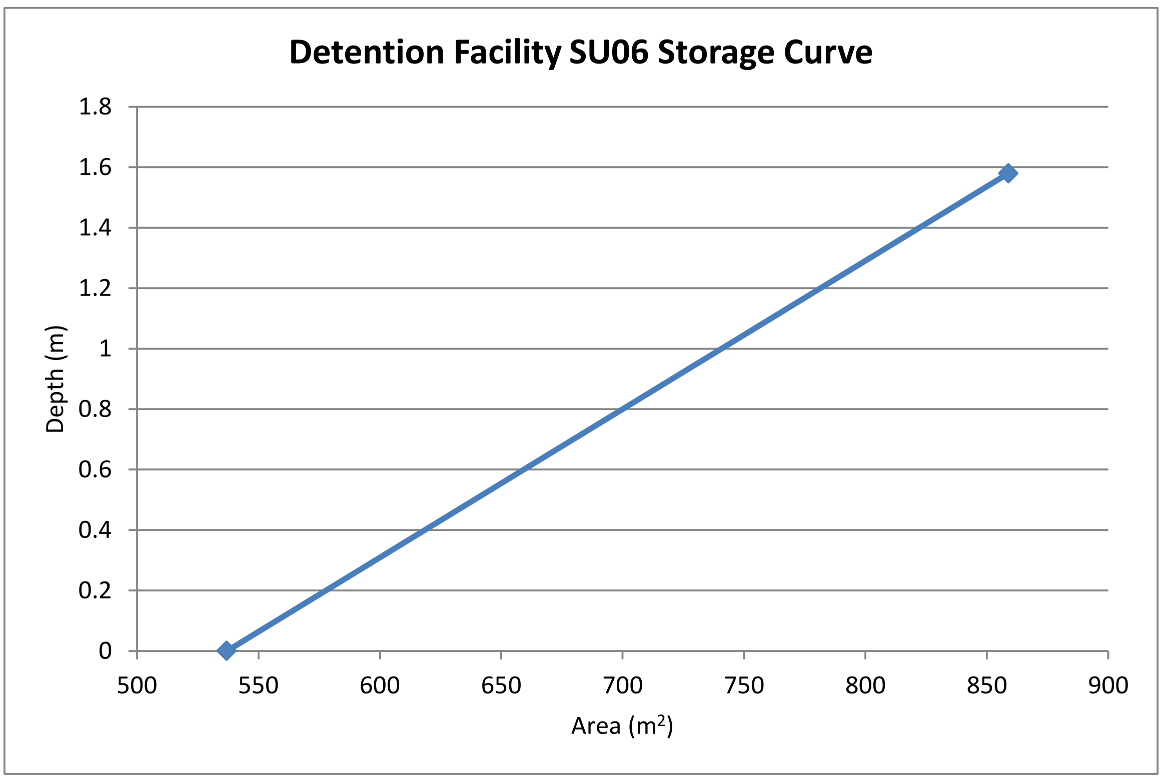

Detention Facility SU01 Storage Curve
Depth (m)
0.6
0.5
0.4
0.3
0.2
0.1
0
6,000
6,200
6,400
6,600
6,800
7,000
7,200
7,400
7,600
7,800
8,000
Area (m2)

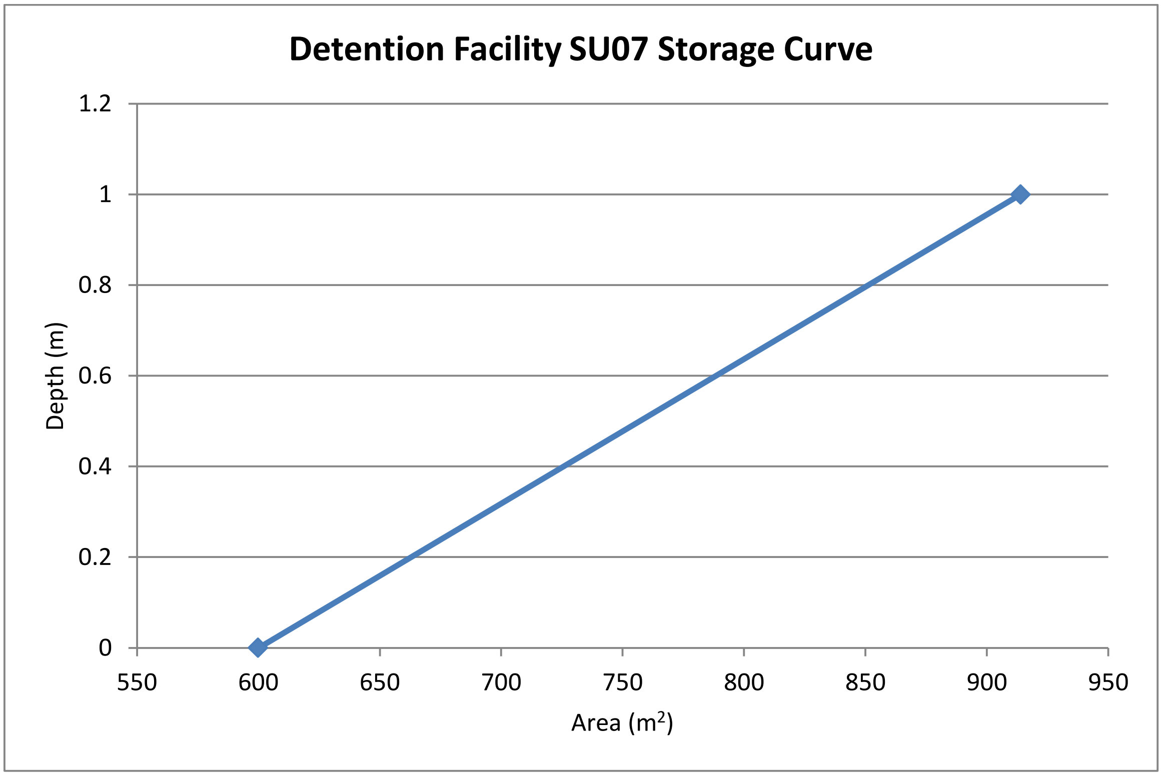

Detention Facility SU02 Storage Curve
Depth (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3,200
3,300
3,400
3,500
3,600
3,700
3,800
3,900
4,000
4,100
4,200
Area (m2)

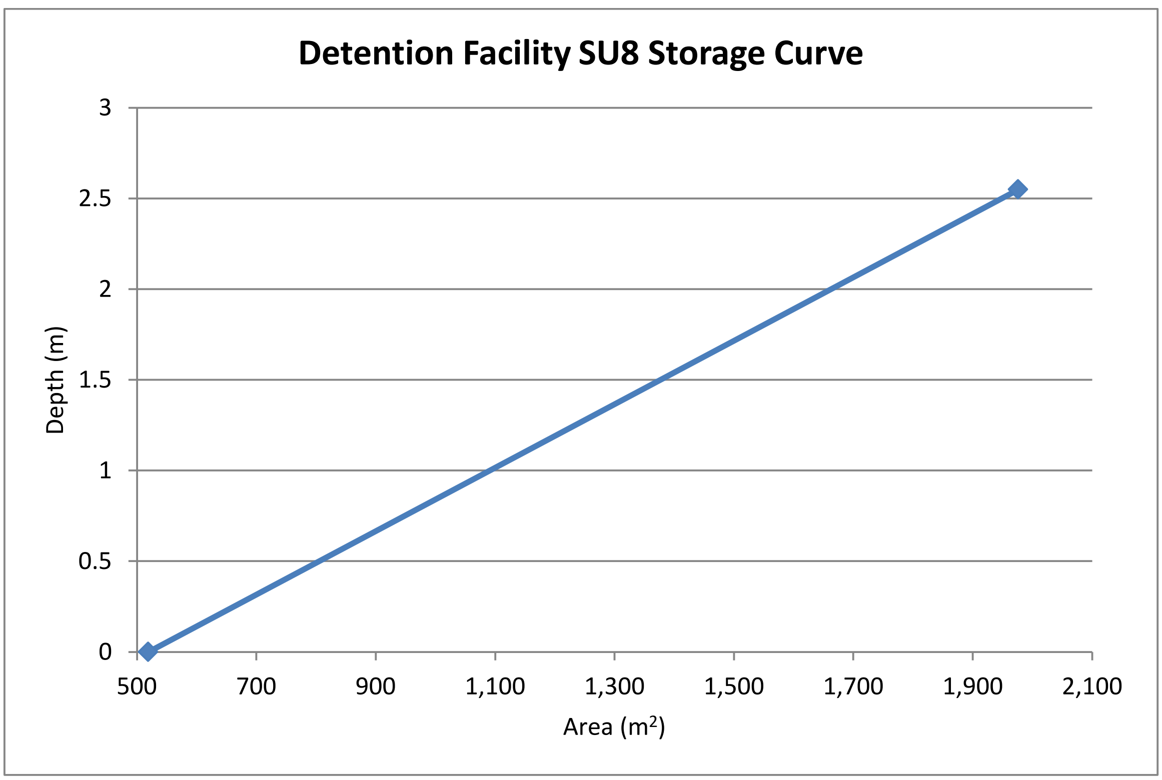

Detention Facility SU3 Storage Curve
Depth (m)
3
2.5
2
1.5
1
0.5
0
160
165
170
175
180
185
190
195
200
Area (m2)

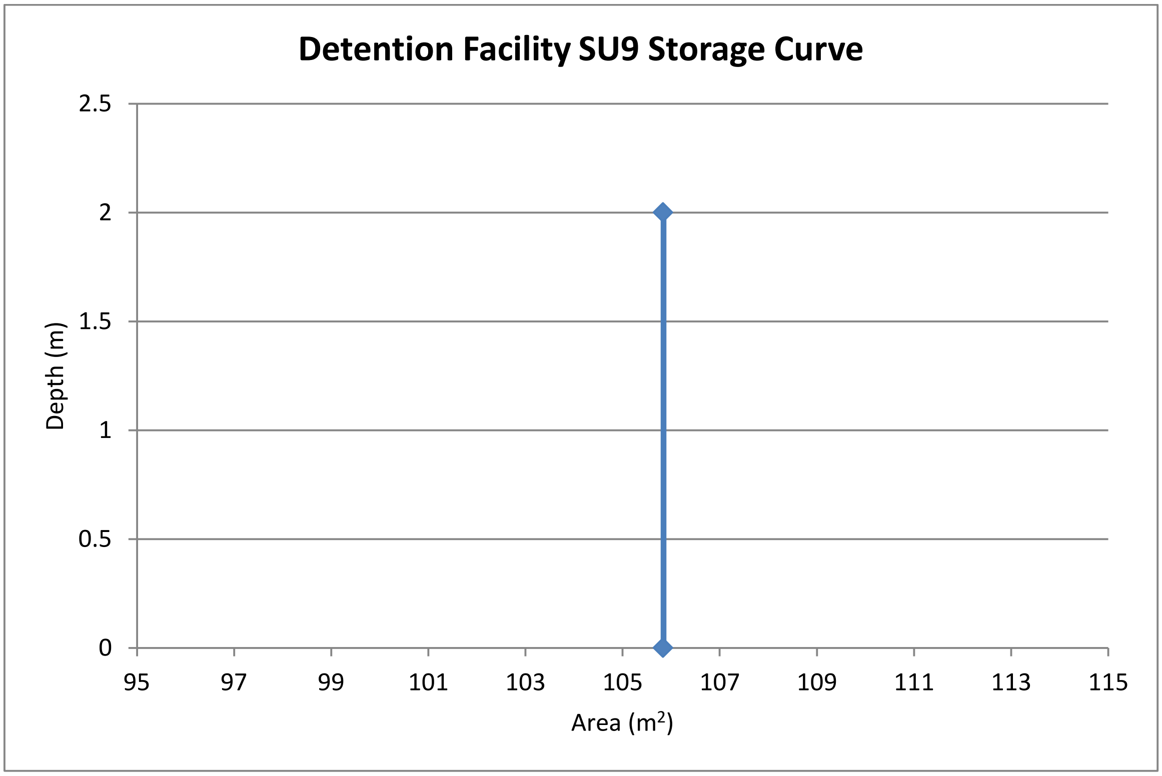

Detention Facility SU04 Storage Curve
Depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500
550
600
650
700
750
800
Area (m2)

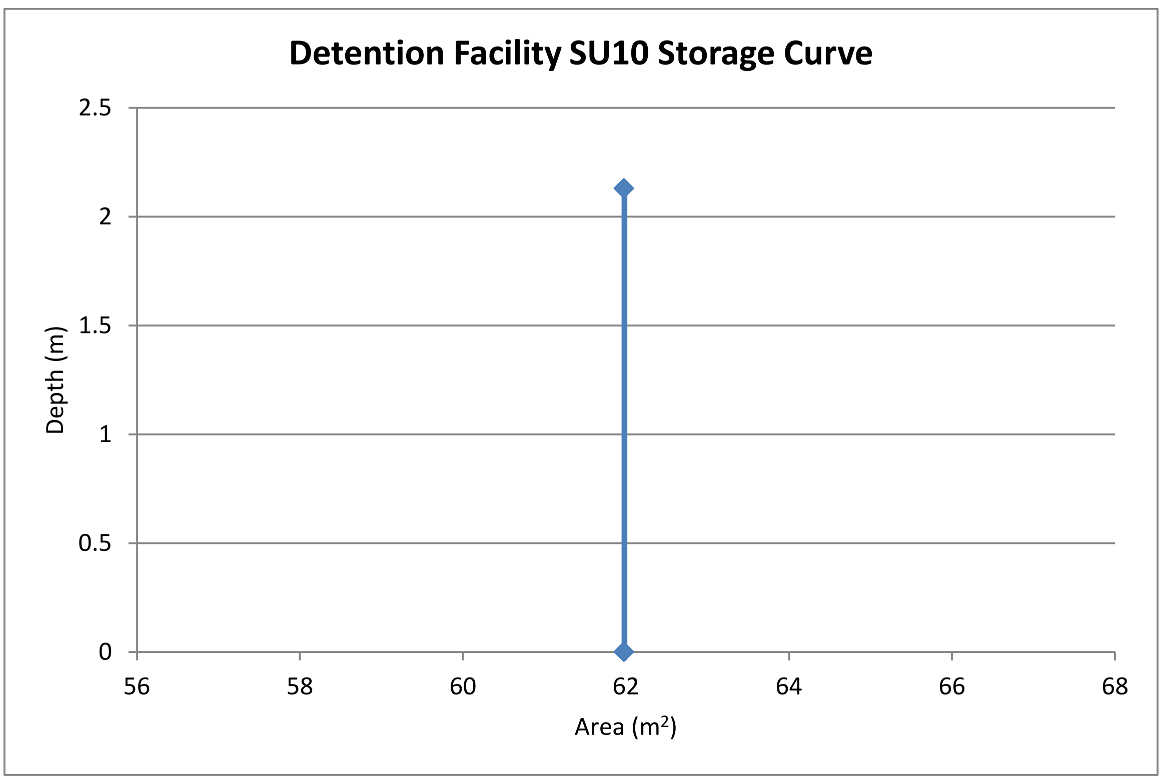

Detention Facility SU05 Storage Curve
1.2
1
0.8
0.6
0.4
0.2
0
Depth (m)
2,500
2,700
2,900
3,100
3,300
3,500
3,700
3,900
4,100
4,300
4,500
Area (m2)

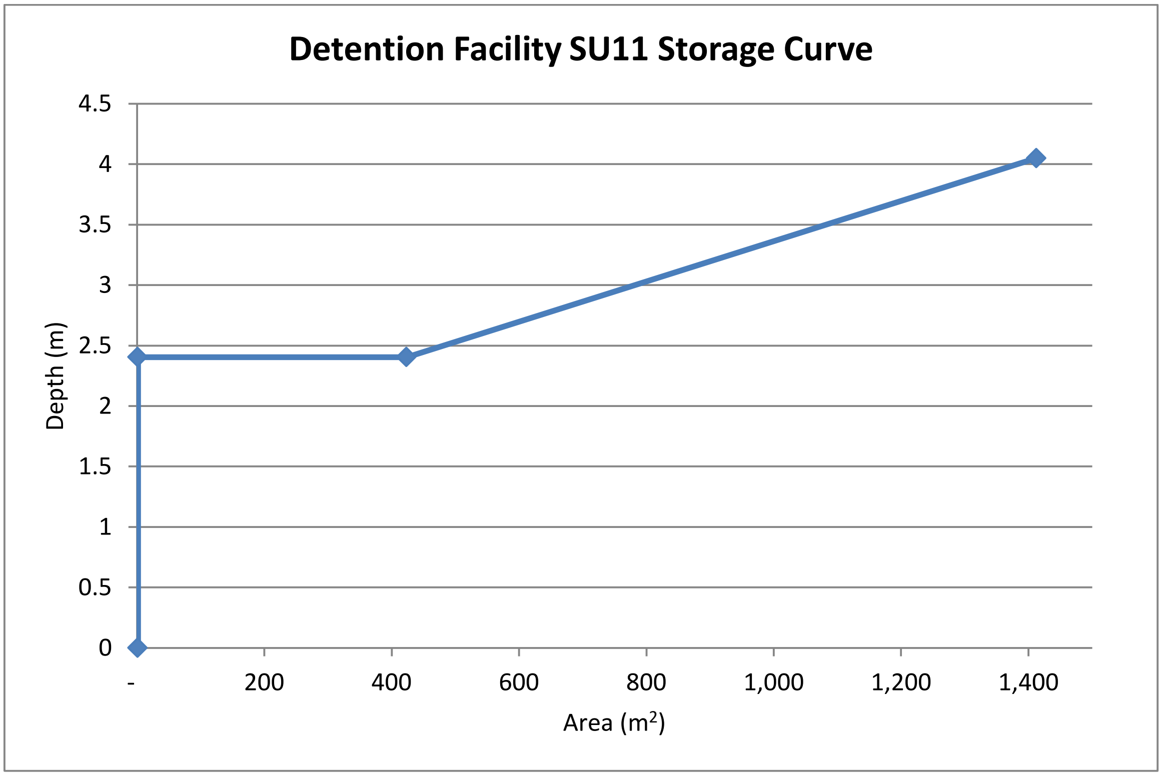

Detention Facility SU06 Storage Curve
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Depth (m)
500
550
600
650
700
750
800
850
900
Area (m2)

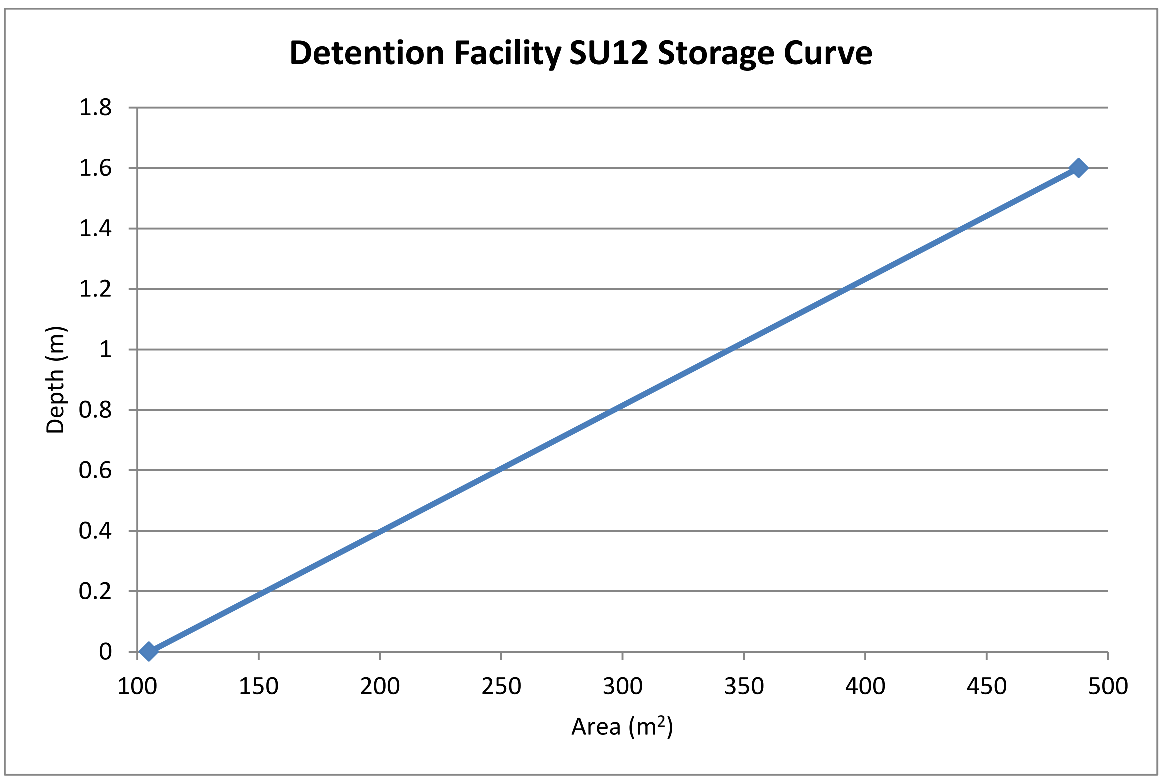

Detention Facility SU07 Storage Curve
Depth (m)
1.2
1
0.8
0.6
0.4
0.2
0
550
600
650
700
750
800
850
900
950
Area (m2)


Detention Facility SU8 Storage Curve
Depth (m)
3
2.5
2
1.5
1
0.5
0
500
700
900
1,100
1,300
1,500
1,700
1,900
2,100
Area (m2)


Detention Facility SU9 Storage Curve
2.5
2
1.5
1
0.5
0
Depth (m)
95
97
99
101
103
105
107
109
111
113
115
Area (m²)

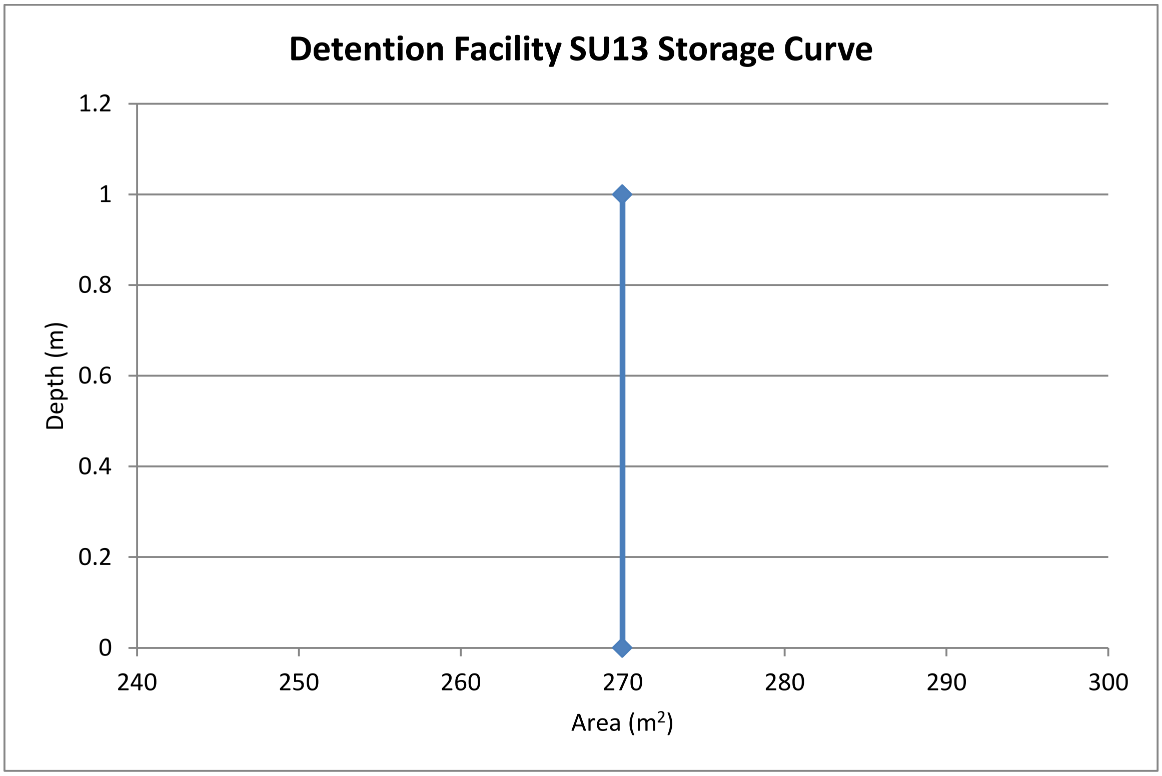

Detention Facility SU10 Storage Curve
2.5
2
1.5
1
0.5
0
Depth (m)
56
58
60
62
64
66
68
Area (m²)

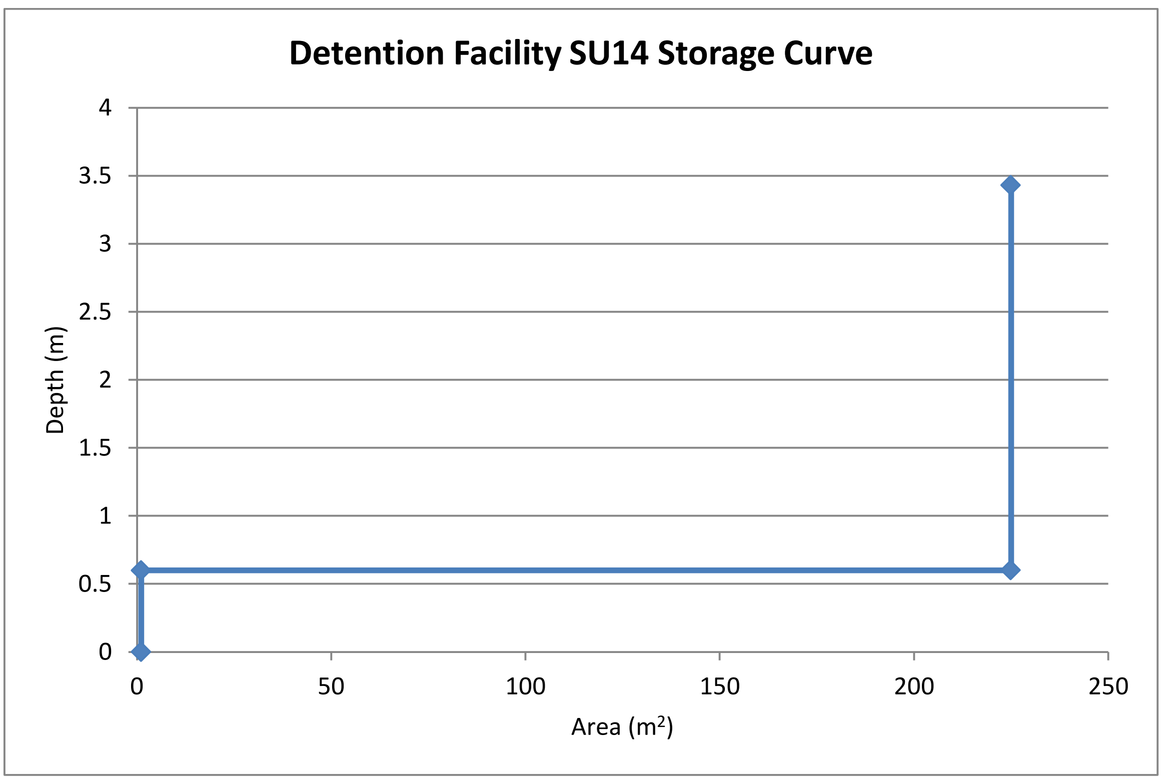


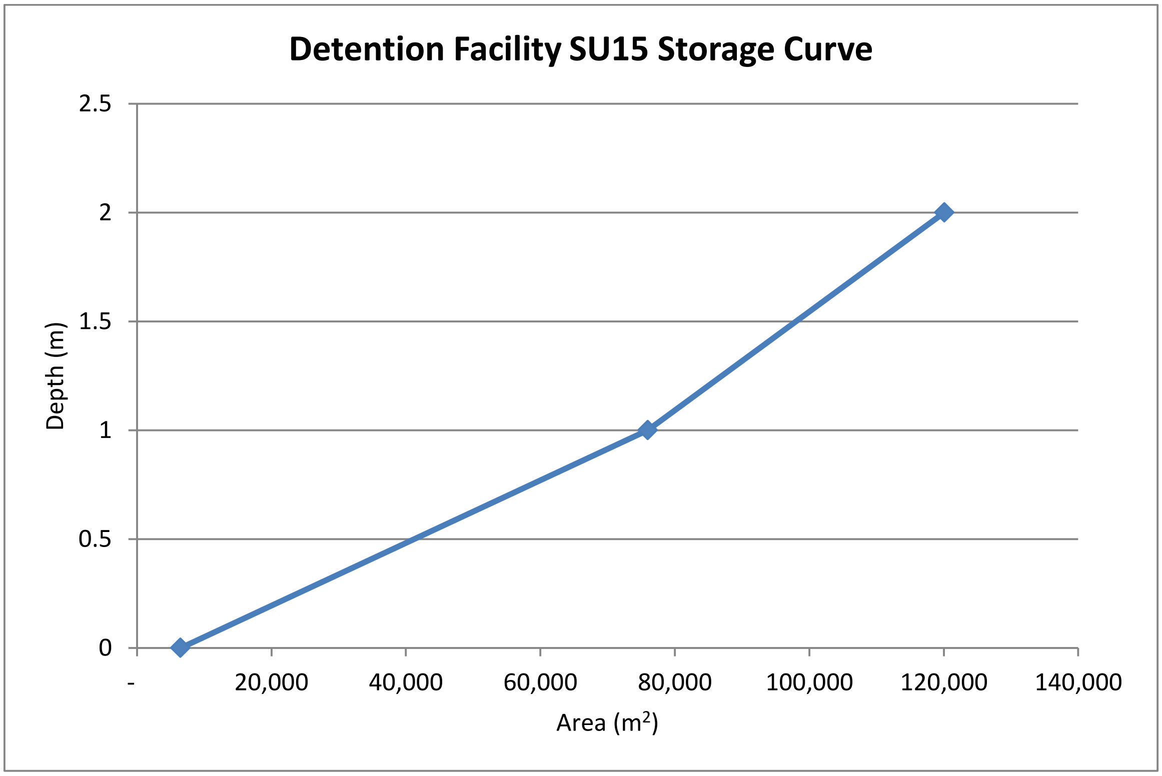



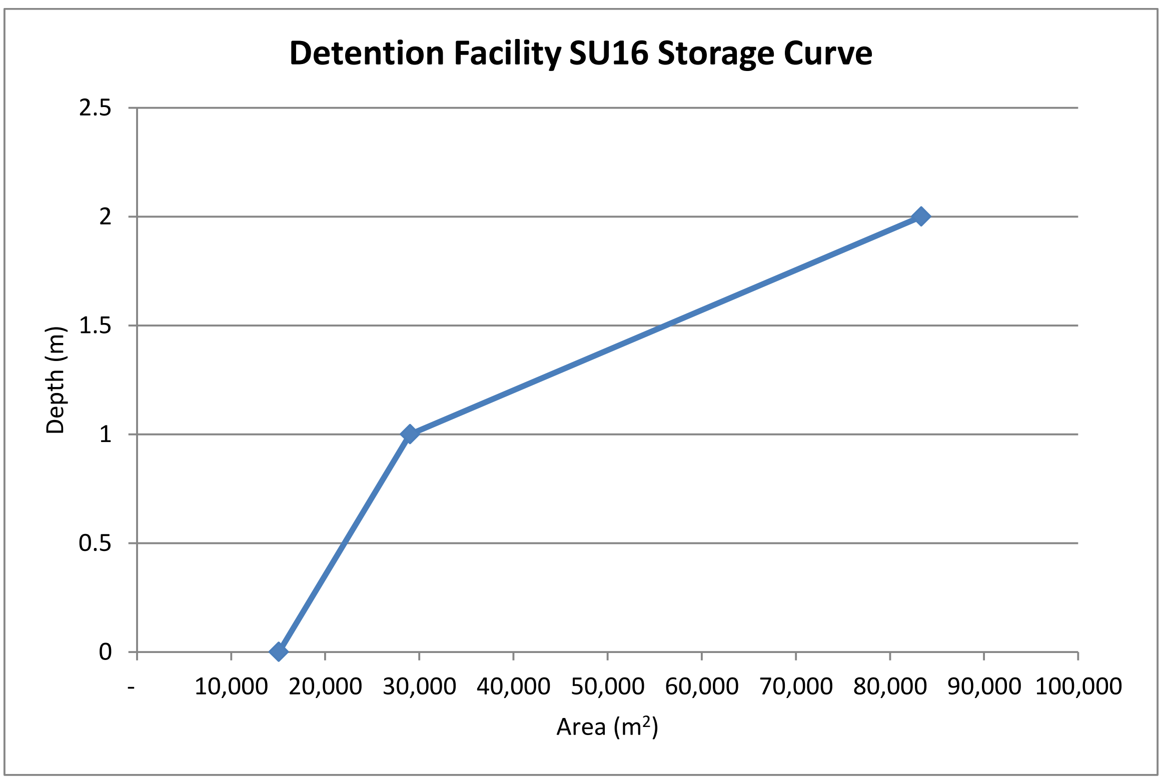


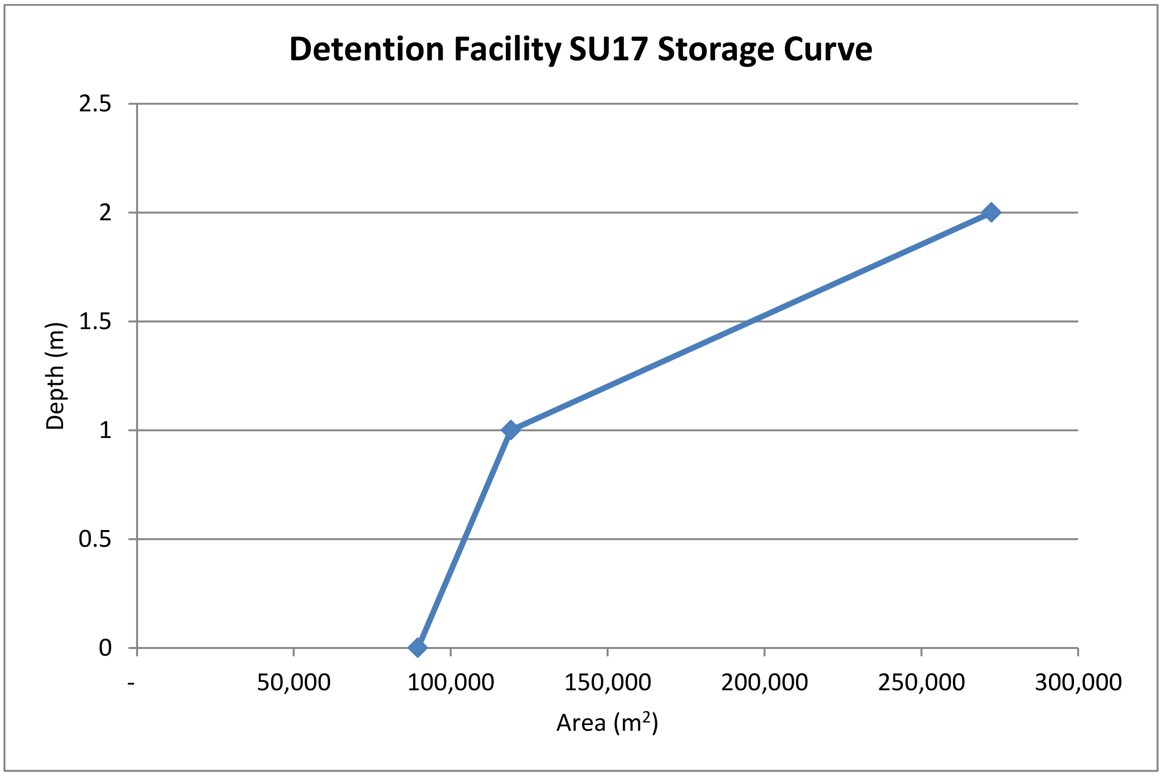
Unit 203, 2502 St Johns Street
Port Moody, British Columbia
V3H 2B4 Canada
Tel (604) 931-0550

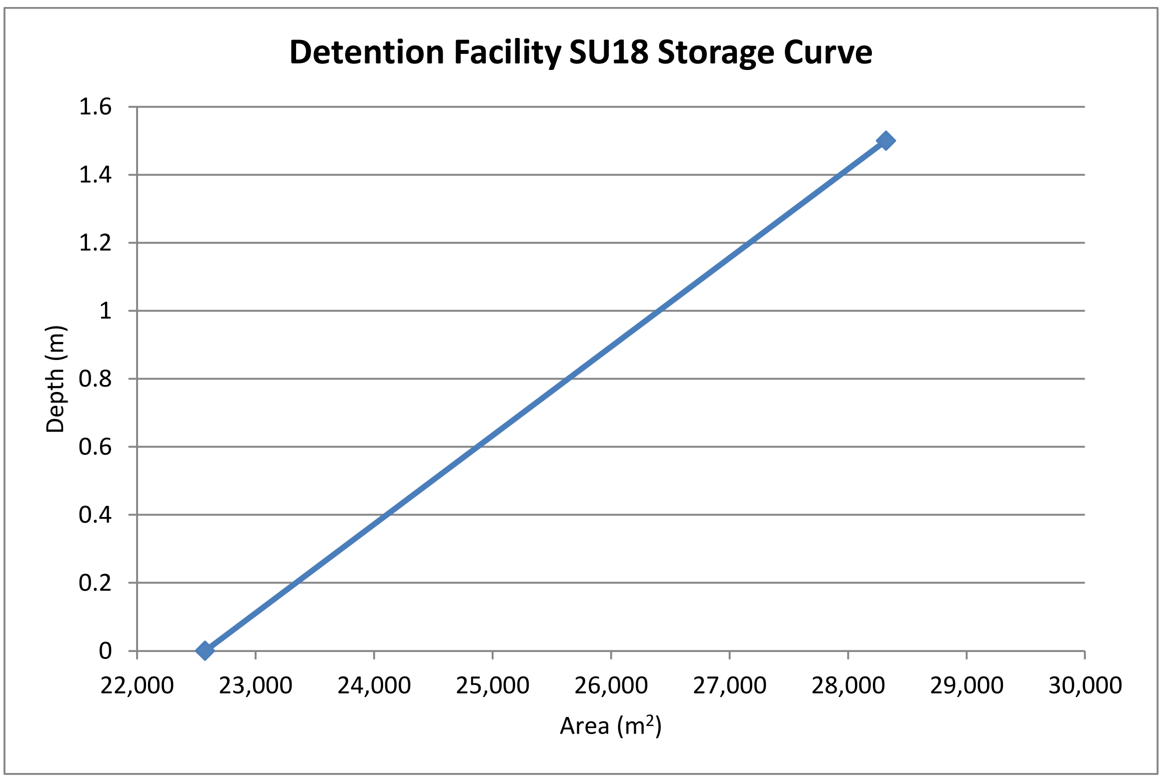

Detention Facility SU13 Storage Curve
1.2
1
0.8
0.6
0.4
0.2
0
Depth (m)
240
250
260
270
280
290
300
Area (m2)

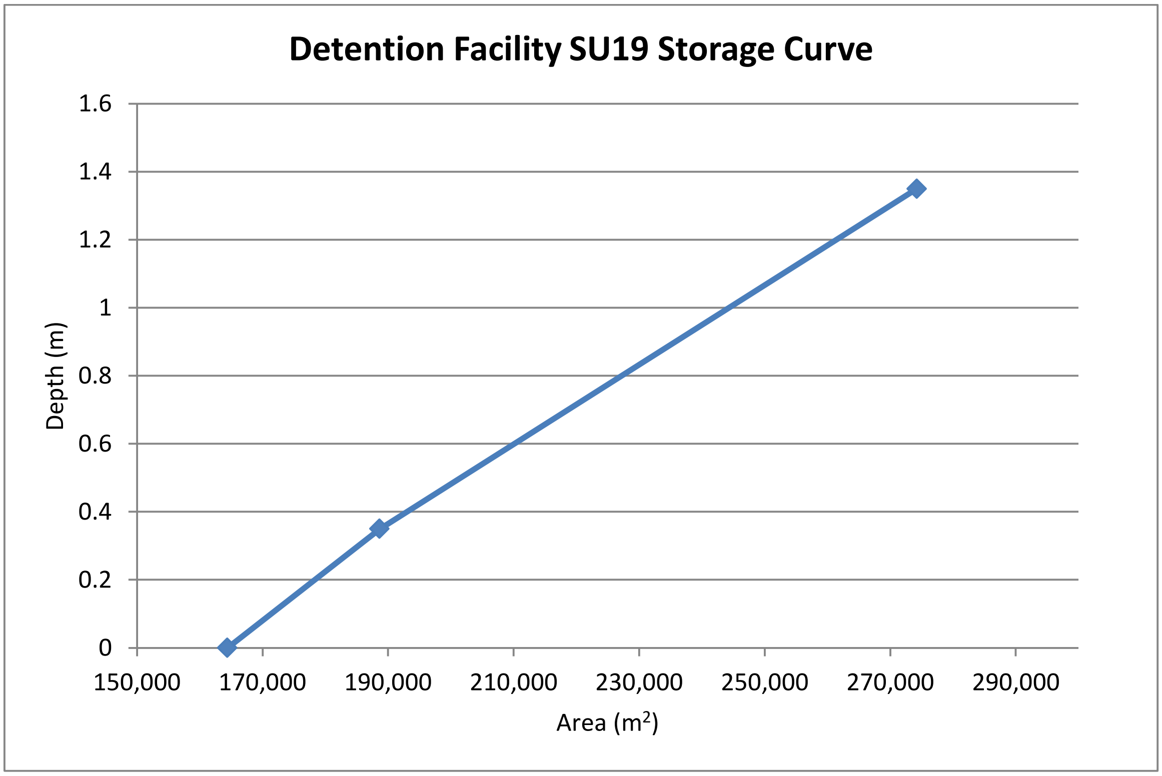

Detention Facility SU14 Storage Curve
4
3.5
3
2.5
2
1.5
1
0.5
0
Depth (m)
0
50
100
150
200
250
Area (m2)


Detention Facility SU15 Storage Curve
Depth (m)
2.5
2
1.5
1
0.5
0
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
Area (m2)


Detention Facility SU16 Storage Curve
Depth (m)
2.5
2
1.5
1
0.5
0
-
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
Area (m2)


Detention Facility SU17 Storage Curve
Depth (m)
2.5
2
1.5
1
0.5
0
-
50,000
100,000
150,000
200,000
250,000
300,000
Area (m2)


Detention Facility SU18 Storage Curve
Depth (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
22,000
23,000
24,000
25,000
26,000
27,000
28,000
29,000
30,000
Area (m2)


Detention Facility SU19 Storage Curve
Depth (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
150,000
170,000
190,000
210,000
230,000
250,000
270,000
290,000
Area (m2)

# Appendix B [Appendix]

# Appendix C [Appendix]

# Appendix D [Appendix]

# Technical Memorandum

## Drainage Modeling of Willband Creek Watershed
## (Calibration Results for Review)

**project:** Willband Creek Integrated Stormwater Management Plan
**project ID:** 2016-006-ABB
**date:** July 5, 2017
**issued to:** City of Abbotsford, BC (City) and Urban Systems Ltd. (USL)
**issued by:** GeoAdvice Engineering Inc. (GeoAdvice)

## 1. Introduction

The City of Abbotsford, BC retained Urban Systems Ltd. (USL) to develop the Willband Creek Integrated Stormwater Management Plan (ISMP). GeoAdvice Engineering Inc. (GeoAdvice) partnered with USL as the modeling sub-consultant for this project. The study area consists the Willband Creek watershed and includes the Prairie St Creek sub watershed. The GeoAdvice scope of work was to develop a hydrologic and hydraulic model of the Willband Creek drainage system to determine stormwater runoff volumes and flow rates under varying storm events. The model will then be used to define capacity-driven improvement requirements and drainage management practices necessary to service future urban growth and respond to potential changes in climate.

The model was developed using PCSWMM software; a fully-dynamic stormwater management modeling software package from CHI Software Inc.

The purpose of this technical memorandum is to summarize the field data review and model calibration results.

# 2. Field Data Analysis

## 2.1. Precipitation Data

Rain gauge data was used to load precipitation for the stormwater model's simulations. Principal input properties used by the model include time interval, rainfall intensity and volume. Precipitation data from the City Hall rain gauge was obtained from FlowWorks. This rain gauge was selected as it was within the Willband Creek drainage basin. The location of the City Hall rain gauge is shown in **Figure 2.1**.

## 2.2. Flow Data

Data from the Horn Creek flow station was obtained from FlowWorks. This station is the only flow station within the Willband Creek drainage basin. The location of the Horn Creek flow station is shown in **Figure 2.1**.

The Horn Creek flow station has been performing abnormally since its inception in 2012. However, since March 1, 2017 data appears to be normal. Therefore, data from March 1, 2017 to April 1, 2017 was considered for model calibration. As the City artificially pumps water into Horn Creek, typical base flow values cannot be applied within the Horn Creek catchment. The data has only been used to calibrate to precipitation response.

## 2.3. Storm Event Analysis

By analyzing the rainfall data in conjunction with the flow monitoring data, individual storm events were identified as potential model calibration events. Rainfall data between March 1-15, 2017 showed signs of questionable data and was therefore excluded. The selected calibration storm events are summarized in **Table 2.1**.

**Figure 2.1: City Hall Rain Gauge and Horn Creek Flow Station Location**

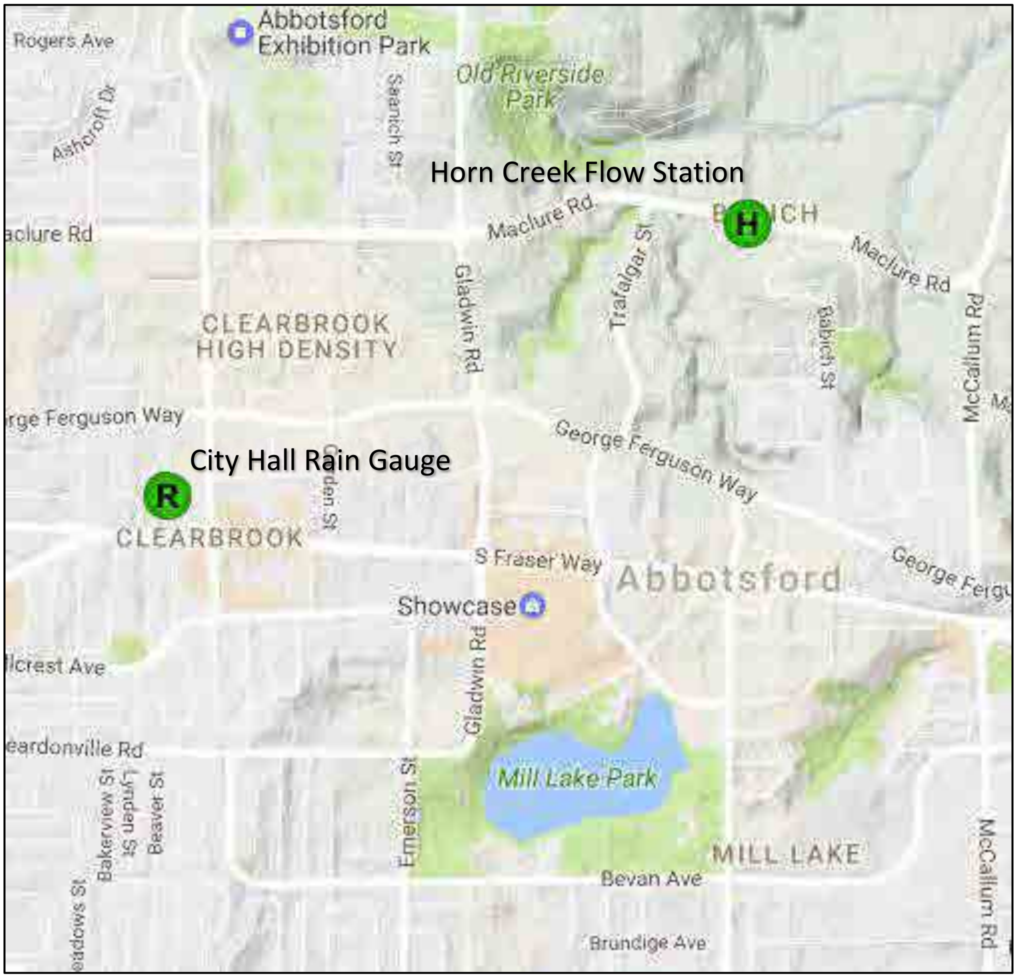



**Table 2.1: Calibration Storm Events (City Hall Rain Gauge)**

| Event | Start Date / Time | Duration (hr) | Maximum Rainfall Intensity (mm/hr) | Total Rainfall (mm) | Return Period* |
|---|---|---|---|---|---|
| 1 | 3/17/2017 9:25 | 33 | 6.9 | 49.5 | < 2-year |
| 2 | 3/21/2017 5:15 | 8 | 2 | 4.0 | < 2-year |
| 3 | 3/22/2017 16:00 | 7 | 1.5 | 1.5 | < 2-year |
| 4 | 3/23/2017 19:25 | 17 | 2.6 | 11.5 | < 2-year |
| 5 | 3/24/2017 18:55 | 8 | 9.4 | 10.4 | < 2-year |
| 6 | 3/26/2017 8:30 | 8 | 2 | 4.0 | < 2-year |
| 7 | 3/26/2017 17:25 | 12 | 2.1 | 10.2 | < 2-year |
| 8 | 3/27/2017 17:40 | 50 | 5.8 | 90.0 | < 2-year |
| 9 | 4/1/2017 1:05 | 12 | 3.9 | 14.8 | < 2-year |

* Estimated return period based on the Abbotsford A AES Station IDF curves.

# 3. Model Calibration

The available flow monitoring data for model calibration was limited to the Horn Creek flow station, which captures approximately 18% of the Willband watershed. Although the Horn Creek flow station does not capture the entire watershed, it is representative of an urban developed area in the upland region. As such, adjustments were made to model parameters that were applicable to the Horn Creek catchment as well as to the entire watershed, where possible.

Rather than simulating individual storm events for calibration and validation, a continuous simulation from March 15 to April 1, 2017 was run. Continuous simulation allows the model to simulate the impacts of antecedent moisture conditions on the basin between back-to-back storm events. The model parameters were adjusted in an iterative manner until model results achieved an acceptable correlation with the Horn Creek flow data for the 9 storm events identified. The model adjustments are discussed in detail below.

### *Base Flows*

The field data from the Horn Creek hydrometric station suggests that a winter time base flow of approximately 280 L/s was occurring. As such, a base flow rate of approximately 0.84 L/s/ha was modeled to simulate the 280 L/s at the station. However, due to the base flows being pumped into Horn Creek, the base flow rate of 0.84 L/s/ha was applied only to the Horn Creek catchment. As noted earlier, a baseflow of 0.15 L/s/ha was applied elsewhere.

### *Runoff Routing Percentage*

The runoff routing percentage parameter was decreased from 50% to 30% to improve the correlation with flow volumes recorded at the Horn Creek flow station. This adjustment was applied to the entire Willband watershed and assumes that approximately 30% of the runoff from impervious surfaces are routed to pervious areas. This parameter accounts for conditions where roof leaders that drain impervious surface runoff are directed to pervious surfaces rather than directly into creek channels or storm mains.

### *Subcatchment Flow Length*

The default subcatchment flow length equation for areas greater than 0.2 ha defined in **Section 3.1** was adjusted to $length = 3 * \sqrt{Area}$ to improve the correlation with peak flows recorded at the Horn Creek flow station. This adjustment was applied to the entire Willband watershed and assumes that the actual flow length within the larger subcatchments are longer than initially estimated.

The adjusted parameters, namely the *runoff routing percentage* and *subcatchment flow length*, were applied globally and made no distinctions between different areas or land uses within the watershed. This approach was selected, as there were insufficient flow data to justify further adjustments.

The following model parameters were not adjusted and are believed to be accurate based on the information that was available:

- Subcatchment slopes;
- Subcatchment depression storage and roughness parameters;
- Subcatchment impervious percentages; and
- Soil group infiltration rates.

## 3.1. Model Calibration Results

**Table 3.1** summarizes the model calibration results by comparing field recorded peak flows and total volumes against simulation results.

**Table 3.1: Willband Creek Calibration Results**

| Event | Peak Flow ($m^3/s$) | | Difference (%) | Total Volume ($m^3$) | | Difference (%) |
|---|---|---|---|---|---|---|
| | Model | Field | | Model | Field | |
| 1 | 2.7 | 2.4 | +13% | 92,600 | 94,020 | -2% |
| 2 | 0.9 | 0.9 | +3% | 23,740 | 22,490 | +6% |
| 3 | 0.6 | 0.7 | -8% | 12,770 | 12,090 | +6% |
| 4 | 1.1 | 1.1 | -1% | 33,700 | 33,890 | -1% |
| 5 | 3.6 | 2.5 | +46% | 34,440 | 31,770 | +8% |
| 6 | 0.8 | 0.9 | -4% | 14,180 | 13,500 | +5% |
| 7 | 0.9 | 1.2 | -20% | 34,240 | 38,050 | -10% |
| 8 | 2.3 | 2.3 | -1% | 184,200 | 202,300 | -9% |
| 9 | 1.6 | 1.7 | -3% | 44,280 | 46,790 | -5% |

**Figure 3.1** to **Figure 3.5** show the calibration flow hydrographs comparing the Horn Creek modeled flows and the measured flows.

**Figure 3.1**

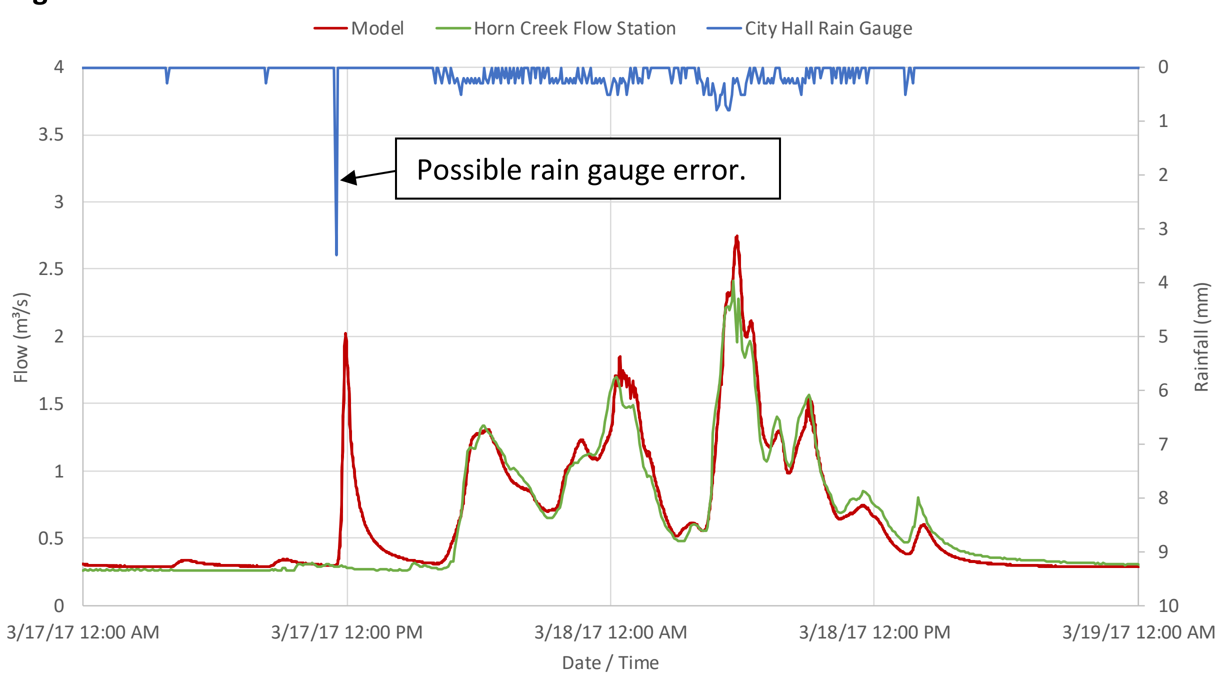



**Figure 3.2**

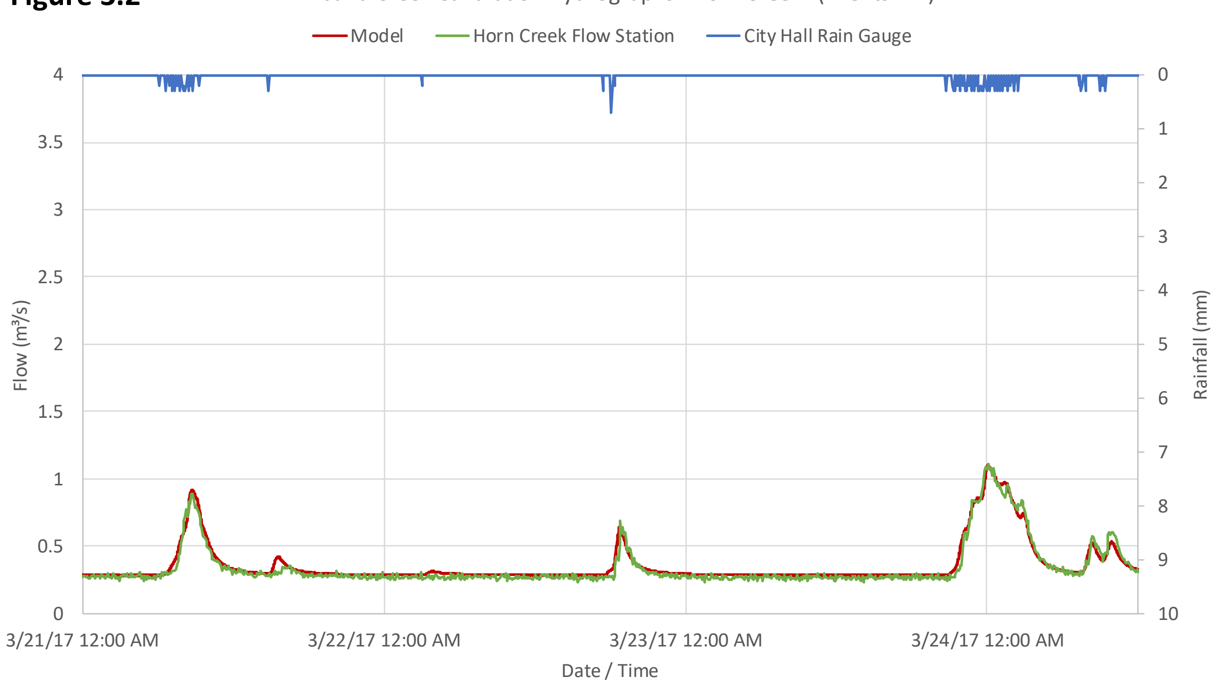


**Figure 3.3**

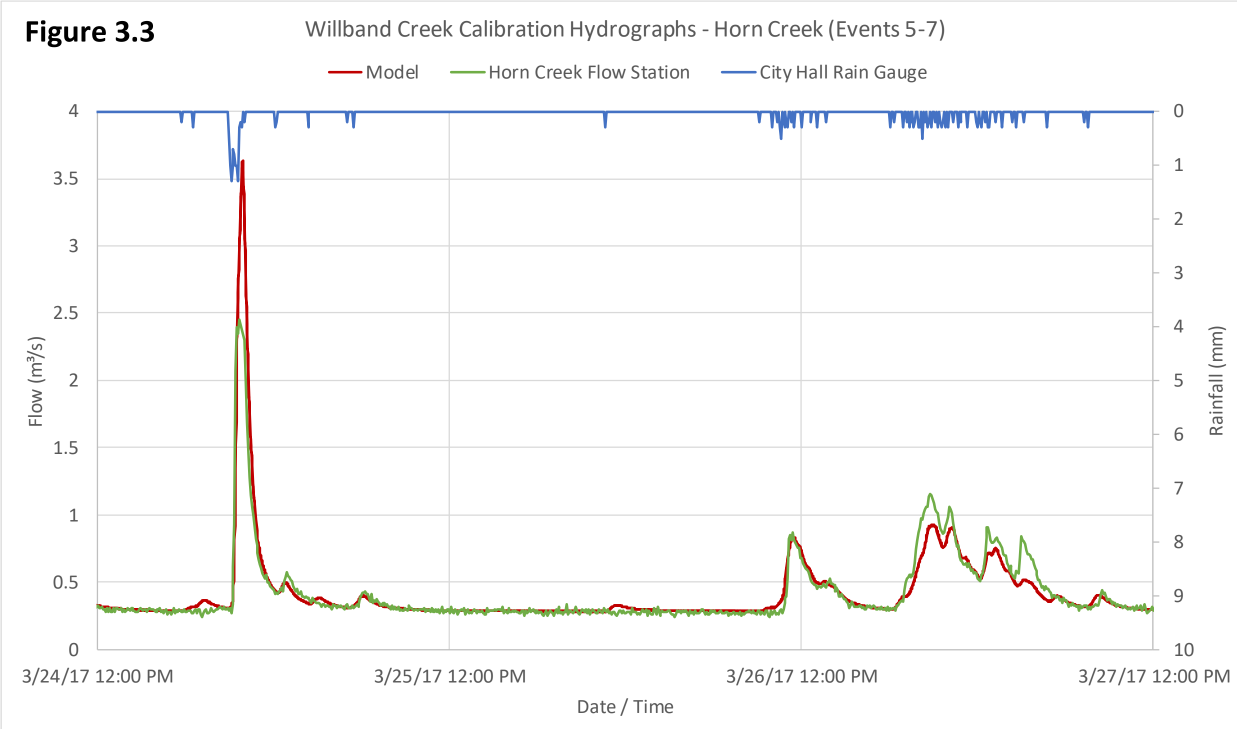



**Figure 3.4**

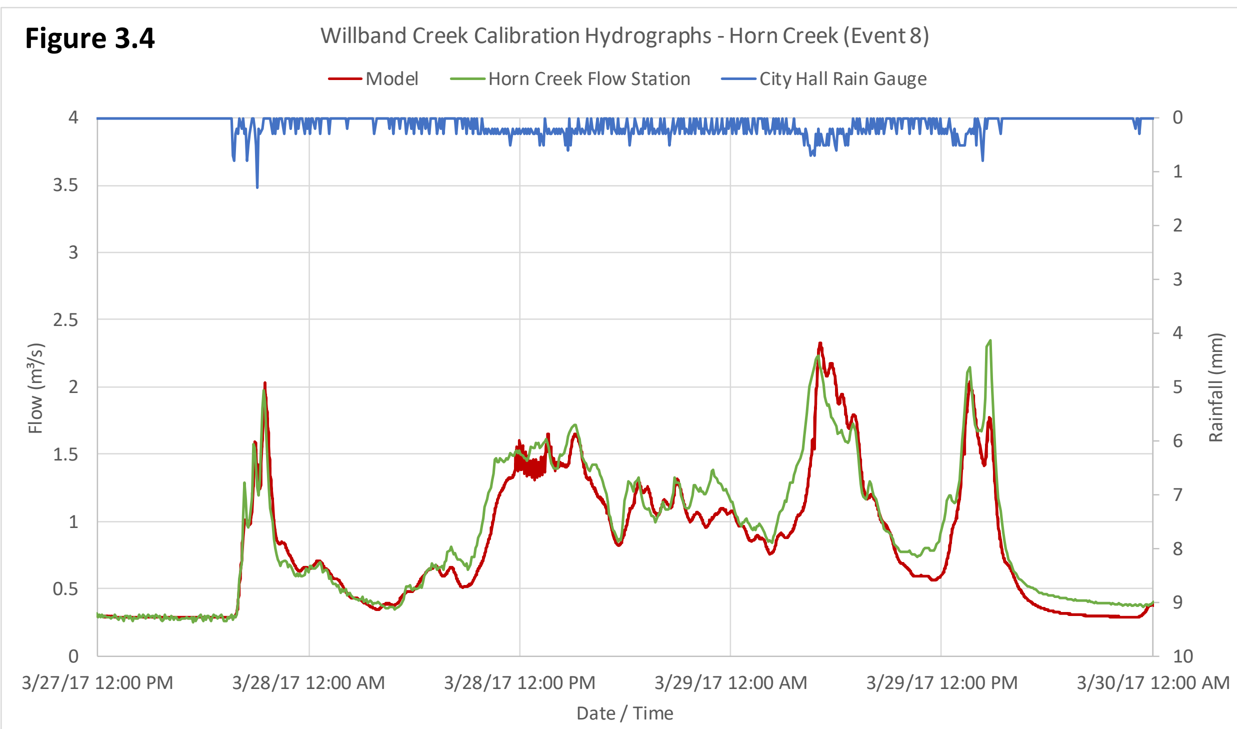
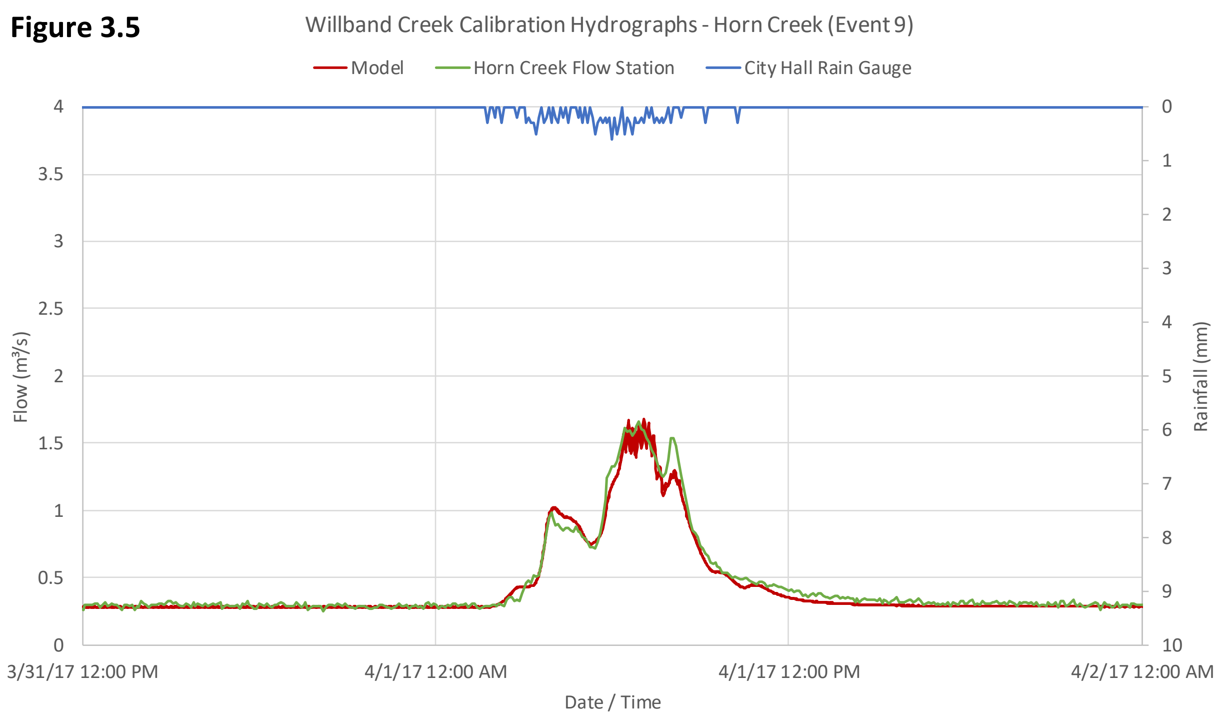


**Figure 3.5**




Overall, the model shows good agreement with the measured flows at the Horn Creek flow station. Events 5 and 7 show larger flow and volume discrepancies, which may be caused by precipitation inaccuracies as described below:

- There is a certain degree of uncertainty when rainfall data recorded at a fixed location are applied to large or distant areas. Microclimates often exist within large areas and often cause variations in localized precipitation volume and intensity that cannot be reflected in the model.
- Additionally, the storm events used for model calibration consisted of less than 2-year return periods. For best calibration results, it is recommended that the model be validated against larger recorded storm events when data becomes available.

As discussed above, the parameters derived during calibration of the Horn Creek basin were applied to the rest of the Willband watershed. Final summary of the catchment characteristics and calibrated parameters are summarized in **Table 5.2** below.

**Table 3.2: Willband Creek Catchment Characteristics and Calibrated Model Parameters**

| Subcatchment Parameter | Horn Creek Catchment | Remainder of Study Area |
|---|---|---|
| Area (ha) | 332 | 1,509 |
| Average Width (m) | 35 | 52 |
| Width Formula (Area <= 0.2 ha)<br>Width Formula (Area > 0.2 ha) | $width = \frac{Area}{length} = \frac{Area}{50\ m}$<br>$width = \frac{Area}{length};\ length = 3 \times \sqrt{Area}$ | |
| Average Slope (%) | 6.2% | 6.9% |
| Slope Formula | $subcatchment\ slope = \frac{Average\ LiDAR\ Slope}{2}$ | |
| Impervious (%) – Airphoto Imagery Analysis | 56% | 32% |
| Directly Connected Impervious (%) – 30% of runoff from impervious areas are directed to pervious areas | 39% | 22% |
| Depression Storage<br>Pervious Area (mm)<br>Impervious Area (mm) | <br>5.0<br>0.5 | |
| Manning's "n" Roughness Coefficient<br>Pervious Area "n"<br>Impervious Area "n" | <br>0.40<br>0.05 | |
| Base Flow (L/s/ha) | 0.84 | 0.15 |
| Soil Distribution | 90% - Gravel & Sand<br>9% - Sand & Silt (B)<br>1% - Peat/Till | 45% - Gravel & Sand<br>23% - Sand & Silt (B)<br>16% - Peat<br>9% - Till<br>7% - Other |
| Land Use Distribution | 25% - Single Family Res.<br>36% - Multi Family Res.<br>27% - Commercial<br>3% - Institutional<br>2% - Comprehensive<br>7% - Park/Open Space | 35% - Single Family Res.<br>8% - Multi Family Res.<br>5% - Commercial<br>9% - Institutional<br>7% - Industrial<br>23% - Agricultural<br>13% - Park/Open Space |

| Subcatchment Parameter | Horn Creek Catchment | Remainder of Study Area |
|---|---|---|
| Area with Controlled Runoff (ha)* | 70 (21%) | 308 (20%) |
| Number of Detention Facilities** (365 present in watershed) | 128 | 237 |
| Number of Private Detention Facilities** (312 present in watershed) | 113 | 199 |
| Number of Modeled Detention Ponds/Tanks | 3 | 17 |

* Runoff controlled by modeled detention features and/or control manholes.
** May include facilities such as detention tanks, dry/wet ponds, storm pipes, infiltration trenches, rain gardens, biofiltration ditches, etc.

# 4. Conclusion

Conclusions and recommendations have yet to be developed and will be incorporated into the Phase 2 technical memorandum.

## Submission

**Prepared by:**

| | |
|---|---|
| Jonathan Hung, P.Eng.<br>Water Resources Engineer | Chuck Linders<br>Project Manager |

**Reviewed and Approved by:**

Werner de Schaetzen, Ph.D., P.Eng.
Senior Modeling Review



### Statement of Qualifications and Limitations

This document represents GeoAdvice Engineering Inc. best professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinary exercised by member of the engineering profession currently practicing under similar conditions. No warranty, express or implied is made.

# APPENDIX F

Storm Sewer and Culvert Cost Estimates

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# Unit Storm Sewer Capital Costs

Class D, Existing Development, all open cut, <3 m deep

| Diameter (mm) | Constuction Rate per meter | E&C (50%) per meter | Total $ per meter |
|---|---|---|---|
| 200 | $500 | $250 | $750 |
| 250 | $550 | $275 | $825 |
| 300 | $625 | $313 | $938 |
| 375 | $700 | $350 | $1,050 |
| 450 | $825 | $413 | $1,238 |
| 525 | $950 | $475 | $1,425 |
| 600 | $1,050 | $525 | $1,575 |
| 675 | $1,200 | $600 | $1,800 |
| 750 | $1,350 | $675 | $2,025 |
| 900 | $1,600 | $800 | $2,400 |
| 1050 | $1,800 | $900 | $2,700 |
| 1200 | $2,000 | $1,000 | $3,000 |
| 1350 | $2,250 | $1,125 | $3,375 |
| 1500 | $2,500 | $1,250 | $3,750 |
| 1650 | $2,750 | $1,375 | $4,125 |
| 1800 | $3,000 | $1,500 | $4,500 |

For culverts, the unit rate is doubled.

APPENDIX A

ITEMIZED LIST OF STORM SEWER AND CULVERT UPGRADES

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 114766 | 14.4 | 450 | 600 | 100-Year | 0.42 | Priority 1 - Culvert | $ 30,219 | $ 15,110 | $ 45,329 |
| 128406 | 156.3 | 1350 | 1650 | 100-Year | 8.38 | Priority 1 | $ 429,770 | $ 214,885 | $ 644,655 |
| 128407 | 9.6 | 1350 | 1650 | 100-Year | 8.34 | Priority 1 | $ 26,483 | $ 13,241 | $ 39,724 |
| | | | | | | Sub-Total | $ 486,472 | $ 243,236 | $ 729,707 |
| 237611 | 11.6 | 600 | 675 | 10-Year | 0.52 | Priority 1 - Culvert | $ 27,912 | $ 13,956 | $ 41,868 |
| 126454 | 60.0 | 450 | 750 | 10-Year | 0.57 | Priority 1 | $ 81,000 | $ 40,500 | $ 121,500 |
| 126458 | 101.6 | 450 | 600 | 10-Year | 0.31 | Priority 1 | $ 106,712 | $ 53,356 | $ 160,067 |
| 126459 | 115.6 | 450 | 600 | 10-Year | 0.41 | Priority 1 | $ 121,328 | $ 60,664 | $ 181,991 |
| 126498 | 87.6 | 375 | 600 | 10-Year | 0.37 | Priority 1 | $ 91,970 | $ 45,985 | $ 137,954 |
| 126499 | 88.7 | 375 | 525 | 10-Year | 0.43 | Priority 1 | $ 84,284 | $ 42,142 | $ 126,426 |
| 127276 | 119.5 | 375 | 450 | 10-Year | 0.13 | Priority 1 | $ 98,571 | $ 49,286 | $ 147,857 |
| 127365 | 121.9 | 300 | 375 | 10-Year | 0.05 | Priority 1 | $ 85,344 | $ 42,672 | $ 128,016 |
| 128168 | 35.6 | 300 | 450 | 10-Year | 0.66 | Priority 1 | $ 29,345 | $ 14,673 | $ 44,018 |
| 227684 | 25.6 | 375 | 600 | 10-Year | 0.66 | Priority 1 | $ 26,859 | $ 13,430 | $ 40,289 |
| 121362 | 67.1 | 300 | 450 | 10-Year | 0.15 | Priority 1 | $ 55,341 | $ 27,671 | $ 83,012 |
| 121380 | 96.1 | 375 | 450 | 10-Year | 0.10 | Priority 1 | $ 79,250 | $ 39,625 | $ 118,874 |
| 121381 | 7.8 | 375 | 450 | 10-Year | 0.13 | Priority 1 | $ 6,402 | $ 3,201 | $ 9,603 |
| 121505 | 80.4 | 375 | 450 | 10-Year | 0.17 | Priority 1 | $ 66,355 | $ 33,177 | $ 99,532 |
| 121516 | 97.4 | 300 | 375 | 10-Year | 0.09 | Priority 1 | $ 68,166 | $ 34,083 | $ 102,249 |
| 121524 | 84.2 | 450 | 600 | 10-Year | 0.42 | Priority 1 | $ 88,410 | $ 44,205 | $ 132,615 |
| 121525 | 74.0 | 300 | 375 | 10-Year | 0.26 | Priority 1 | $ 51,793 | $ 25,897 | $ 77,690 |
| 121527 | 99.5 | 300 | 375 | 10-Year | 0.12 | Priority 1 | $ 69,664 | $ 34,832 | $ 104,496 |
| 126460 | 68.3 | 450 | 525 | 10-Year | 0.27 | Priority 1 | $ 64,876 | $ 32,438 | $ 97,313 |
| 126461 | 71.2 | 375 | 450 | 10-Year | 0.21 | Priority 1 | $ 58,740 | $ 29,370 | $ 88,110 |
| 126462 | 43.7 | 375 | 450 | 10-Year | 0.25 | Priority 1 | $ 36,053 | $ 18,026 | $ 54,079 |
| 126463 | 35.9 | 375 | 450 | 10-Year | 0.19 | Priority 1 | $ 29,618 | $ 14,809 | $ 44,426 |
| 126471 | 103.8 | 375 | 450 | 10-Year | 0.15 | Priority 1 | $ 85,627 | $ 42,813 | $ 128,440 |
| 126969 | 59.1 | 375 | 450 | 10-Year | 0.18 | Priority 1 | $ 48,741 | $ 24,371 | $ 73,112 |
| 126970 | 25.0 | 375 | 450 | 10-Year | 0.17 | Priority 1 | $ 20,650 | $ 10,325 | $ 30,975 |
| 127282 | 25.3 | 300 | 450 | 10-Year | 0.18 | Priority 1 | $ 20,873 | $ 10,436 | $ 31,309 |
| 127288 | 91.5 | 300 | 375 | 10-Year | 0.05 | Priority 1 | $ 64,029 | $ 32,015 | $ 96,044 |
| 127289 | 82.6 | 300 | 450 | 10-Year | 0.10 | Priority 1 | $ 68,170 | $ 34,085 | $ 102,255 |
| 127290 | 13.4 | 300 | 450 | 10-Year | 0.12 | Priority 1 | $ 11,072 | $ 5,536 | $ 16,607 |
| 127296 | 19.9 | 375 | 450 | 10-Year | 0.12 | Priority 1 | $ 16,393 | $ 8,196 | $ 24,589 |
| 127315 | 44.1 | 375 | 450 | 10-Year | 0.13 | Priority 1 | $ 36,358 | $ 18,179 | $ 54,537 |
| 127316 | 81.7 | 375 | 450 | 10-Year | 0.18 | Priority 1 | $ 67,411 | $ 33,705 | $ 101,116 |
| 127544 | 30.5 | 300 | 375 | 10-Year | 0.20 | Priority 1 | $ 21,350 | $ 10,675 | $ 32,025 |
| 127545 | 54.0 | 300 | 450 | 10-Year | 0.19 | Priority 1 | $ 44,517 | $ 22,259 | $ 66,776 |
| 127614 | 44.8 | 300 | 375 | 10-Year | 0.21 | Priority 1 | $ 31,339 | $ 15,670 | $ 47,009 |
| 127637 | 46.4 | 450 | 600 | 10-Year | 0.55 | Priority 1 | $ 48,720 | $ 24,360 | $ 73,080 |
| 127642 | 23.2 | 450 | 525 | 10-Year | 0.58 | Priority 1 | $ 22,069 | $ 11,034 | $ 33,103 |
| 127643 | 3.8 | 450 | 600 | 10-Year | 0.56 | Priority 1 | $ 4,011 | $ 2,006 | $ 6,017 |
| 127644 | 12.7 | 450 | 600 | 10-Year | 0.56 | Priority 1 | $ 13,367 | $ 6,683 | $ 20,050 |
| 127645 | 2.6 | 450 | 600 | 10-Year | 0.57 | Priority 1 | $ 2,751 | $ 1,376 | $ 4,127 |
| 127936 | 69.5 | 250 | 300 | 10-Year | 0.10 | Priority 1 | $ 43,406 | $ 21,703 | $ 65,109 |
| 127937 | 35.3 | 250 | 300 | 10-Year | 0.12 | Priority 1 | $ 22,069 | $ 11,034 | $ 33,103 |
| 127939 | 78.1 | 250 | 300 | 10-Year | 0.18 | Priority 1 | $ 48,819 | $ 24,409 | $ 73,228 |
| 127941 | 14.1 | 375 | 450 | 10-Year | 0.21 | Priority 1 | $ 11,624 | $ 5,812 | $ 17,436 |
| 127955 | 39.0 | 375 | 450 | 10-Year | 0.09 | Priority 1 | $ 32,134 | $ 16,067 | $ 48,201 |
| 127956 | 38.5 | 375 | 450 | 10-Year | 0.10 | Priority 1 | $ 31,721 | $ 15,861 | $ 47,582 |
| 127964 | 26.9 | 525 | 600 | 10-Year | 0.17 | Priority 1 | $ 28,214 | $ 14,107 | $ 42,320 |
| 127965 | 79.3 | 525 | 600 | 10-Year | 0.30 | Priority 1 | $ 83,265 | $ 41,633 | $ 124,898 |
| 128048 | 125.6 | 450 | 600 | 10-Year | 0.57 | Priority 1 | $ 131,912 | $ 65,956 | $ 197,867 |
| 128049 | 114.1 | 450 | 600 | 10-Year | 0.59 | Priority 1 | $ 119,847 | $ 59,924 | $ 179,771 |
| 131869 | 70.0 | 300 | 375 | 10-Year | 0.21 | Priority 1 | $ 49,000 | $ 24,500 | $ 73,500 |
| 131870 | 20.0 | 300 | 375 | 10-Year | 0.22 | Priority 1 | $ 14,000 | $ 7,000 | $ 21,000 |
| 131871 | 80.0 | 300 | 450 | 10-Year | 0.23 | Priority 1 | $ 66,000 | $ 33,000 | $ 99,000 |
| 131872 | 65.0 | 300 | 450 | 10-Year | 0.24 | Priority 1 | $ 53,625 | $ 26,813 | $ 80,438 |
| 131873 | 10.0 | 300 | 450 | 10-Year | 0.25 | Priority 1 | $ 8,250 | $ 4,125 | $ 12,375 |
| 131969 | 41.5 | 300 | 450 | 10-Year | 0.12 | Priority 1 | $ 34,254 | $ 17,127 | $ 51,381 |
| 132422 | 40.6 | 375 | 525 | 10-Year | 0.28 | Priority 1 | $ 38,523 | $ 19,261 | $ 57,784 |
| 132423 | 13.7 | 375 | 525 | 10-Year | 0.28 | Priority 1 | $ 13,034 | $ 6,517 | $ 19,551 |
| 132424 | 10.0 | 300 | 375 | 10-Year | 0.07 | Priority 1 | $ 6,993 | $ 3,497 | $ 10,490 |
| 132425 | 36.5 | 300 | 375 | 10-Year | 0.07 | Priority 1 | $ 25,529 | $ 12,765 | $ 38,294 |
| 132426 | 44.9 | 300 | 375 | 10-Year | 0.07 | Priority 1 | $ 31,416 | $ 15,708 | $ 47,124 |
| 132427 | 10.5 | 300 | 375 | 10-Year | 0.08 | Priority 1 | $ 7,336 | $ 3,668 | $ 11,004 |
| 132428 | 49.3 | 300 | 450 | 10-Year | 0.20 | Priority 1 | $ 40,656 | $ 20,328 | $ 60,984 |
| 132429 | 46.4 | 300 | 450 | 10-Year | 0.20 | Priority 1 | $ 38,239 | $ 19,119 | $ 57,358 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 132534 | 38.5 | 250 | 300 | 10-Year | 0.30 | Priority 1 | $ 24,038 | $ 12,019 | $ 36,056 |
| 254977 | 17.2 | 450 | 600 | 10-Year | 0.60 | Priority 1 | $ 18,050 | $ 9,025 | $ 27,074 |
| | | | | | | Sub-Total | $ 3,077,385 | $ 1,538,693 | $ 4,616,078 |
| 114768 | 34.7 | 1500 | 1800 | 100-Year | 5.91 | Priority 2 - Culvert | $ 208,080 | $ 104,040 | $ 312,120 |
| 114759 | 9.7 | 450 | 525 | 100-Year | 0.38 | Priority 2 - Culvert | $ 18,430 | $ 9,215 | $ 27,645 |
| 127776 | 44.0 | 1500 | 1650 | 100-Year | 10.34 | Priority 2 | $ 121,110 | $ 60,555 | $ 181,665 |
| 127777 | 40.2 | 1500 | 1650 | 100-Year | 9.12 | Priority 2 | $ 110,495 | $ 55,248 | $ 165,743 |
| 127779 | 23.5 | 1350 | 1650 | 100-Year | 8.41 | Priority 2 | $ 64,570 | $ 32,285 | $ 96,855 |
| | | | | | | Sub-Total | $ 522,685 | $ 261,343 | $ 784,028 |
| 126344 | 70.8 | 450 | 600 | 10-Year | 0.22 | Priority 2 | $ 74,372 | $ 37,186 | $ 111,557 |
| 126428 | 8.4 | 300 | 375 | 10-Year | 0.13 | Priority 2 | $ 5,852 | $ 2,926 | $ 8,778 |
| 126429 | 31.3 | 300 | 375 | 10-Year | 0.14 | Priority 2 | $ 21,882 | $ 10,941 | $ 32,823 |
| 126434 | 82.1 | 750 | 900 | 10-Year | 0.72 | Priority 2 | $ 131,344 | $ 65,672 | $ 197,016 |
| 126439 | 108.2 | 375 | 450 | 10-Year | 0.14 | Priority 2 | $ 89,265 | $ 44,633 | $ 133,898 |
| 126442 | 36.6 | 300 | 375 | 10-Year | 0.10 | Priority 2 | $ 25,599 | $ 12,800 | $ 38,399 |
| 126453 | 24.5 | 900 | 1050 | 10-Year | 1.86 | Priority 2 | $ 44,118 | $ 22,059 | $ 66,177 |
| 126481 | 90.0 | 900 | 1050 | 10-Year | 1.87 | Priority 2 | $ 162,018 | $ 81,009 | $ 243,027 |
| 126482 | 135.5 | 900 | 1050 | 10-Year | 1.91 | Priority 2 | $ 243,936 | $ 121,968 | $ 365,904 |
| 126490 | 22.6 | 300 | 450 | 10-Year | 0.19 | Priority 2 | $ 18,612 | $ 9,306 | $ 27,918 |
| 126494 | 119.5 | 300 | 375 | 10-Year | 0.08 | Priority 2 | $ 83,636 | $ 41,818 | $ 125,454 |
| 126495 | 116.3 | 450 | 525 | 10-Year | 0.34 | Priority 2 | $ 110,514 | $ 55,257 | $ 165,770 |
| 126497 | 82.2 | 375 | 525 | 10-Year | 0.52 | Priority 2 | $ 78,071 | $ 39,036 | $ 117,107 |
| 126500 | 88.7 | 375 | 525 | 10-Year | 0.51 | Priority 2 | $ 84,284 | $ 42,142 | $ 126,426 |
| 126501 | 36.6 | 300 | 525 | 10-Year | 0.17 | Priority 2 | $ 34,761 | $ 17,380 | $ 52,141 |
| 126502 | 122.0 | 375 | 525 | 10-Year | 0.18 | Priority 2 | $ 115,872 | $ 57,936 | $ 173,807 |
| 126503 | 111.3 | 375 | 525 | 10-Year | 0.20 | Priority 2 | $ 105,726 | $ 52,863 | $ 158,588 |
| 126504 | 30.5 | 375 | 525 | 10-Year | 0.21 | Priority 2 | $ 28,966 | $ 14,483 | $ 43,448 |
| 126511 | 82.0 | 300 | 375 | 10-Year | 0.09 | Priority 2 | $ 57,400 | $ 28,700 | $ 86,100 |
| 126512 | 61.0 | 300 | 450 | 10-Year | 0.15 | Priority 2 | $ 50,358 | $ 25,179 | $ 75,537 |
| 126513 | 15.1 | 250 | 375 | 10-Year | 0.12 | Priority 2 | $ 10,584 | $ 5,292 | $ 15,876 |
| 126523 | 17.1 | 300 | 375 | 10-Year | 0.10 | Priority 2 | $ 11,942 | $ 5,971 | $ 17,913 |
| 126524 | 24.1 | 300 | 375 | 10-Year | 0.11 | Priority 2 | $ 16,877 | $ 8,439 | $ 25,316 |
| 126529 | 30.4 | 375 | 450 | 10-Year | 0.16 | Priority 2 | $ 25,080 | $ 12,540 | $ 37,620 |
| 126560 | 14.9 | 450 | 600 | 10-Year | 0.39 | Priority 2 | $ 15,624 | $ 7,812 | $ 23,436 |
| 126564 | 84.1 | 375 | 600 | 10-Year | 0.36 | Priority 2 | $ 88,263 | $ 44,132 | $ 132,395 |
| 126588 | 34.3 | 375 | 450 | 10-Year | 0.23 | Priority 2 | $ 28,289 | $ 14,145 | $ 42,434 |
| 126870 | 78.0 | 375 | 450 | 10-Year | 0.08 | Priority 2 | $ 64,358 | $ 32,179 | $ 96,537 |
| 126872 | 45.6 | 300 | 450 | 10-Year | 0.11 | Priority 2 | $ 37,595 | $ 18,798 | $ 56,393 |
| 126915 | 9.4 | 300 | 450 | 10-Year | 0.11 | Priority 2 | $ 7,755 | $ 3,878 | $ 11,633 |
| 126940 | 50.5 | 450 | 600 | 10-Year | 0.19 | Priority 2 | $ 52,974 | $ 26,487 | $ 79,460 |
| 126941 | 102.5 | 300 | 375 | 10-Year | 0.09 | Priority 2 | $ 71,728 | $ 35,864 | $ 107,592 |
| 127199 | 66.5 | 450 | 525 | 10-Year | 0.26 | Priority 2 | $ 63,147 | $ 31,573 | $ 94,720 |
| 127210 | 18.0 | 450 | 525 | 10-Year | 0.21 | Priority 2 | $ 17,110 | $ 8,555 | $ 25,664 |
| 127230 | 46.3 | 300 | 375 | 10-Year | 0.10 | Priority 2 | $ 32,424 | $ 16,212 | $ 48,636 |
| 127244 | 144.8 | 1050 | 1350 | 10-Year | 1.56 | Priority 2 | $ 325,868 | $ 162,934 | $ 488,801 |
| 127376 | 79.4 | 300 | 375 | 10-Year | 0.13 | Priority 2 | $ 55,559 | $ 27,780 | $ 83,339 |
| 127608 | 17.0 | 450 | 525 | 10-Year | 0.24 | Priority 2 | $ 16,169 | $ 8,085 | $ 24,254 |
| 127610 | 3.4 | 450 | 525 | 10-Year | 0.25 | Priority 2 | $ 3,221 | $ 1,610 | $ 4,831 |
| 127076_1 | 40.0 | 375 | 600 | 10-Year | 0.20 | Priority 2 | $ 42,042 | $ 21,021 | $ 63,063 |
| 127076_2 | 52.0 | 375 | 600 | 10-Year | 0.29 | Priority 2 | $ 54,632 | $ 27,316 | $ 81,947 |
| 122327 | 143.4 | 450 | 525 | 10-Year | 0.30 | Priority 2 | $ 136,199 | $ 68,099 | $ 204,298 |
| 127441 | 115.0 | 300 | 375 | 10-Year | 0.08 | Priority 2 | $ 80,528 | $ 40,264 | $ 120,792 |
| 127793 | 121.1 | 300 | 375 | 10-Year | 0.24 | Priority 2 | $ 84,791 | $ 42,396 | $ 127,187 |
| 127815 | 52.8 | 525 | 675 | 10-Year | 0.54 | Priority 2 | $ 63,408 | $ 31,704 | $ 95,112 |
| 127885 | 10.9 | 600 | 750 | 10-Year | 0.94 | Priority 2 | $ 14,715 | $ 7,358 | $ 22,073 |
| 127886 | 7.8 | 600 | 750 | 10-Year | 0.94 | Priority 2 | $ 10,503 | $ 5,252 | $ 15,755 |
| 127887 | 133.8 | 600 | 750 | 10-Year | 0.97 | Priority 2 | $ 180,563 | $ 90,281 | $ 270,844 |
| 128074 | 48.0 | 600 | 750 | 10-Year | 0.63 | Priority 2 | $ 64,827 | $ 32,414 | $ 97,241 |
| 128076 | 59.5 | 600 | 750 | 10-Year | 0.48 | Priority 2 | $ 80,325 | $ 40,163 | $ 120,488 |
| 128077 | 21.1 | 525 | 750 | 10-Year | 0.46 | Priority 2 | $ 28,485 | $ 14,243 | $ 42,728 |
| 128078 | 20.9 | 525 | 750 | 10-Year | 0.33 | Priority 2 | $ 28,148 | $ 14,074 | $ 42,221 |
| 128155 | 12.9 | 375 | 450 | 10-Year | 0.21 | Priority 2 | $ 10,601 | $ 5,301 | $ 15,902 |
| 128191 | 42.3 | 300 | 375 | 10-Year | 0.07 | Priority 2 | $ 29,631 | $ 14,816 | $ 44,447 |
| 128192 | 106.6 | 250 | 375 | 10-Year | 0.31 | Priority 2 | $ 74,585 | $ 37,293 | $ 111,878 |
| 128193 | 60.3 | 250 | 375 | 10-Year | 0.26 | Priority 2 | $ 42,182 | $ 21,091 | $ 63,273 |
| 128194 | 40.5 | 250 | 375 | 10-Year | 0.18 | Priority 2 | $ 28,371 | $ 14,186 | $ 42,557 |
| 128195 | 29.7 | 250 | 375 | 10-Year | 0.26 | Priority 2 | $ 20,818 | $ 10,409 | $ 31,227 |
| 128196 | 12.1 | 200 | 375 | 10-Year | 0.08 | Priority 2 | $ 8,461 | $ 4,230 | $ 12,691 |
| 128301 | 53.1 | 600 | 750 | 10-Year | 0.66 | Priority 2 | $ 71,685 | $ 35,843 | $ 107,528 |
| 128302 | 24.5 | 600 | 750 | 10-Year | 0.69 | Priority 2 | $ 33,062 | $ 16,531 | $ 49,592 |
| 227686 | 10.9 | 300 | 450 | 10-Year | 0.60 | Priority 2 | $ 8,976 | $ 4,488 | $ 13,464 |
| 121387 | 96.9 | 375 | 450 | 10-Year | 0.15 | Priority 2 | $ 79,967 | $ 39,984 | $ 119,951 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 121474 | 84.5 | 750 | 900 | 10-Year | 1.11 | Priority 2 | $ 135,136 | $ 67,568 | $ 202,704 |
| 121513 | 39.6 | 300 | 450 | 10-Year | 0.08 | Priority 2 | $ 32,695 | $ 16,347 | $ 49,042 |
| 121517 | 34.9 | 375 | 450 | 10-Year | 0.16 | Priority 2 | $ 28,793 | $ 14,396 | $ 43,189 |
| 121548 | 118.9 | 750 | 900 | 10-Year | 1.03 | Priority 2 | $ 190,192 | $ 95,096 | $ 285,288 |
| 121687 | 88.8 | 375 | 450 | 10-Year | 0.14 | Priority 2 | $ 73,268 | $ 36,634 | $ 109,902 |
| 126423 | 47.2 | 375 | 450 | 10-Year | 0.16 | Priority 2 | $ 38,957 | $ 19,478 | $ 58,435 |
| 126717 | 34.5 | 300 | 450 | 10-Year | 0.10 | Priority 2 | $ 28,430 | $ 14,215 | $ 42,644 |
| 126816 | 72.9 | 300 | 375 | 10-Year | 0.08 | Priority 2 | $ 51,037 | $ 25,519 | $ 76,556 |
| 126817 | 49.9 | 300 | 375 | 10-Year | 0.05 | Priority 2 | $ 34,958 | $ 17,479 | $ 52,437 |
| 127187 | 105.2 | 600 | 675 | 10-Year | 0.50 | Priority 2 | $ 126,240 | $ 63,120 | $ 189,360 |
| 127188 | 95.7 | 600 | 675 | 10-Year | 0.55 | Priority 2 | $ 114,888 | $ 57,444 | $ 172,332 |
| 127192 | 118.0 | 600 | 675 | 10-Year | 0.56 | Priority 2 | $ 141,600 | $ 70,800 | $ 212,400 |
| 127287 | 70.8 | 300 | 375 | 10-Year | 0.15 | Priority 2 | $ 49,546 | $ 24,773 | $ 74,319 |
| 127301 | 31.1 | 600 | 675 | 10-Year | 1.13 | Priority 2 | $ 37,320 | $ 18,660 | $ 55,980 |
| 127302 | 19.1 | 600 | 675 | 10-Year | 1.00 | Priority 2 | $ 22,872 | $ 11,436 | $ 34,308 |
| 127449 | 44.2 | 375 | 525 | 10-Year | 0.39 | Priority 2 | $ 42,000 | $ 21,000 | $ 62,999 |
| 127451 | 41.2 | 450 | 600 | 10-Year | 0.40 | Priority 2 | $ 43,218 | $ 21,609 | $ 64,827 |
| 127966 | 76.7 | 525 | 600 | 10-Year | 0.32 | Priority 2 | $ 80,567 | $ 40,283 | $ 120,850 |
| 128022 | 61.3 | 300 | 375 | 10-Year | 0.17 | Priority 2 | $ 42,882 | $ 21,441 | $ 64,323 |
| 131958 | 75.6 | 250 | 300 | 10-Year | 0.03 | Priority 2 | $ 47,263 | $ 23,631 | $ 70,894 |
| 132001 | 58.8 | 300 | 375 | 10-Year | 0.05 | Priority 2 | $ 41,160 | $ 20,580 | $ 61,740 |
| | | | | | | Sub-Total | $ 5,191,671 | $ 2,595,835 | $ 7,787,506 |
| 126337 | 58.8 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 36,737 | $ 18,368 | $ 55,105 |
| 126474 | 64.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 40,020 | $ 20,010 | $ 60,030 |
| 126526 | 40.5 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 25,337 | $ 12,668 | $ 38,005 |
| 126527 | 74.4 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 46,482 | $ 23,241 | $ 69,723 |
| 126528 | 100.0 | 250 | 300 | 10-Year | 0.11 | Priority 3 | $ 62,499 | $ 31,250 | $ 93,749 |
| 126531 | 84.1 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 52,559 | $ 26,280 | $ 78,839 |
| 126566 | 56.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 35,338 | $ 17,669 | $ 53,006 |
| 126567 | 75.6 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 47,244 | $ 23,622 | $ 70,866 |
| 126568 | 97.6 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 60,981 | $ 30,490 | $ 91,471 |
| 126931 | 65.9 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 41,188 | $ 20,594 | $ 61,782 |
| 126932 | 10.3 | 250 | 300 | 10-Year | 0.11 | Priority 3 | $ 6,437 | $ 3,218 | $ 9,655 |
| 127341 | 22.4 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 13,993 | $ 6,996 | $ 20,989 |
| 127596 | 34.4 | 250 | 300 | 10-Year | 0.07 | Priority 3 | $ 21,500 | $ 10,750 | $ 32,250 |
| 127599 | 90.0 | 250 | 300 | 10-Year | 0.12 | Priority 3 | $ 56,224 | $ 28,112 | $ 84,336 |
| 127621 | 90.0 | 200 | 300 | 10-Year | 0.04 | Priority 3 | $ 56,266 | $ 28,133 | $ 84,399 |
| 127622 | 1.6 | 200 | 300 | 10-Year | 0.04 | Priority 3 | $ 992 | $ 496 | $ 1,488 |
| 122304 | 36.8 | 200 | 300 | 10-Year | 0.17 | Priority 3 | $ 23,019 | $ 11,509 | $ 34,528 |
| 127176 | 15.3 | 200 | 300 | 10-Year | 0.11 | Priority 3 | $ 9,531 | $ 4,766 | $ 14,297 |
| 127255 | 57.2 | 250 | 300 | 10-Year | 0.25 | Priority 3 | $ 35,769 | $ 17,884 | $ 53,653 |
| 127600 | 125.9 | 250 | 300 | 10-Year | 0.16 | Priority 3 | $ 78,681 | $ 39,341 | $ 118,022 |
| 127601 | 76.0 | 250 | 300 | 10-Year | 0.10 | Priority 3 | $ 47,519 | $ 23,759 | $ 71,278 |
| 127752 | 84.1 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 52,544 | $ 26,272 | $ 78,817 |
| 127755 | 89.4 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 55,886 | $ 27,943 | $ 83,829 |
| 127791 | 58.5 | 250 | 300 | 10-Year | 0.13 | Priority 3 | $ 36,575 | $ 18,288 | $ 54,863 |
| 127796 | 13.7 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 8,573 | $ 4,286 | $ 12,859 |
| 127797 | 3.0 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 1,904 | $ 952 | $ 2,857 |
| 127798 | 6.1 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 3,810 | $ 1,905 | $ 5,715 |
| 127799 | 11.9 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 7,438 | $ 3,719 | $ 11,156 |
| 127816 | 61.7 | 250 | 300 | 10-Year | 0.13 | Priority 3 | $ 38,564 | $ 19,282 | $ 57,846 |
| 127834 | 80.0 | 150 | 300 | 10-Year | 0.01 | Priority 3 | $ 50,018 | $ 25,009 | $ 75,027 |
| 127836 | 63.6 | 150 | 300 | 10-Year | 0.03 | Priority 3 | $ 39,775 | $ 19,888 | $ 59,663 |
| 127837 | 8.5 | 150 | 300 | 10-Year | 0.04 | Priority 3 | $ 5,312 | $ 2,656 | $ 7,968 |
| 127838 | 8.0 | 150 | 300 | 10-Year | 0.04 | Priority 3 | $ 5,000 | $ 2,500 | $ 7,500 |
| 127839 | 23.0 | 150 | 300 | 10-Year | 0.06 | Priority 3 | $ 14,351 | $ 7,175 | $ 21,526 |
| 127840 | 5.0 | 150 | 300 | 10-Year | 0.06 | Priority 3 | $ 3,135 | $ 1,568 | $ 4,703 |
| 127853 | 45.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 28,124 | $ 14,062 | $ 42,187 |
| 127888 | 79.5 | 200 | 300 | 10-Year | 0.11 | Priority 3 | $ 49,688 | $ 24,844 | $ 74,531 |
| 127892 | 86.9 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 54,296 | $ 27,148 | $ 81,443 |
| 127893 | 21.5 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 13,438 | $ 6,719 | $ 20,156 |
| 127894 | 35.2 | 200 | 300 | 10-Year | 0.03 | Priority 3 | $ 22,016 | $ 11,008 | $ 33,024 |
| 127895 | 29.4 | 200 | 300 | 10-Year | 0.03 | Priority 3 | $ 18,354 | $ 9,177 | $ 27,531 |
| 127896 | 13.0 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 8,125 | $ 4,063 | $ 12,188 |
| 127897 | 11.1 | 200 | 300 | 10-Year | 0.08 | Priority 3 | $ 6,943 | $ 3,471 | $ 10,414 |
| 127898 | 19.4 | 200 | 300 | 10-Year | 0.07 | Priority 3 | $ 12,113 | $ 6,056 | $ 18,169 |
| 127899 | 11.4 | 200 | 300 | 10-Year | 0.08 | Priority 3 | $ 7,125 | $ 3,563 | $ 10,688 |
| 127900 | 62.0 | 200 | 300 | 10-Year | 0.04 | Priority 3 | $ 38,749 | $ 19,375 | $ 58,124 |
| 127901 | 20.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 12,500 | $ 6,250 | $ 18,750 |
| 128019 | 40.0 | 150 | 300 | 10-Year | 0.05 | Priority 3 | $ 25,008 | $ 12,504 | $ 37,512 |
| 128020 | 125.0 | 150 | 300 | 10-Year | 0.06 | Priority 3 | $ 78,124 | $ 39,062 | $ 117,187 |
| 128039 | 105.0 | 250 | 300 | 10-Year | 0.14 | Priority 3 | $ 65,624 | $ 32,812 | $ 98,437 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 128065 | 13.0 | 250 | 300 | 10-Year | 0.19 | Priority 3 | $ 8,125 | $ 4,063 | $ 12,188 |
| 128102 | 49.5 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 30,940 | $ 15,470 | $ 46,410 |
| 128104 | 28.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 17,834 | $ 8,917 | $ 26,752 |
| 128129 | 23.2 | 250 | 300 | 10-Year | 0.13 | Priority 3 | $ 14,509 | $ 7,255 | $ 21,764 |
| 128130 | 9.4 | 200 | 300 | 10-Year | 0.00 | Priority 3 | $ 5,858 | $ 2,929 | $ 8,787 |
| 128136 | 13.5 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 8,438 | $ 4,219 | $ 12,656 |
| 128148 | 73.8 | 200 | 300 | 10-Year | 0.11 | Priority 3 | $ 46,141 | $ 23,071 | $ 69,212 |
| 128152 | 29.0 | 200 | 300 | 10-Year | 0.11 | Priority 3 | $ 18,132 | $ 9,066 | $ 27,198 |
| 128165 | 60.2 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 37,616 | $ 18,808 | $ 56,424 |
| 128183 | 146.1 | 150 | 300 | 10-Year | 0.08 | Priority 3 | $ 91,281 | $ 45,641 | $ 136,922 |
| 128185 | 84.1 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 52,573 | $ 26,286 | $ 78,859 |
| 128187 | 64.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 40,451 | $ 20,226 | $ 60,677 |
| 128189 | 29.3 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 18,313 | $ 9,156 | $ 27,469 |
| 128248 | 41.2 | 250 | 300 | 10-Year | 0.12 | Priority 3 | $ 25,776 | $ 12,888 | $ 38,663 |
| 128249 | 20.6 | 250 | 300 | 10-Year | 0.12 | Priority 3 | $ 12,877 | $ 6,438 | $ 19,315 |
| 128267 | 88.8 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 55,480 | $ 27,740 | $ 83,220 |
| 128268 | 48.7 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 30,420 | $ 15,210 | $ 45,630 |
| 128269 | 30.0 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 18,743 | $ 9,372 | $ 28,115 |
| 128311 | 114.0 | 200 | 300 | 10-Year | 0.03 | Priority 3 | $ 71,265 | $ 35,633 | $ 106,898 |
| 128313 | 65.9 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 41,181 | $ 20,591 | $ 61,772 |
| 128349 | 38.0 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 23,759 | $ 11,879 | $ 35,638 |
| 128376 | 13.2 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 8,269 | $ 4,135 | $ 12,404 |
| 128392 | 15.3 | 150 | 300 | 10-Year | 0.00 | Priority 3 | $ 9,549 | $ 4,774 | $ 14,323 |
| 128393 | 49.4 | 150 | 300 | 10-Year | 0.01 | Priority 3 | $ 30,888 | $ 15,444 | $ 46,331 |
| 128394 | 1.3 | 150 | 300 | 10-Year | 0.00 | Priority 3 | $ 813 | $ 407 | $ 1,220 |
| 128405 | 7.3 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 4,577 | $ 2,288 | $ 6,865 |
| 239996 | 10.3 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 6,429 | $ 3,215 | $ 9,644 |
| 250926 | 28.7 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 17,938 | $ 8,969 | $ 26,907 |
| 250927 | 10.5 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 6,583 | $ 3,291 | $ 9,874 |
| 250936 | 77.6 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 48,518 | $ 24,259 | $ 72,776 |
| 121377 | 48.3 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 30,205 | $ 15,103 | $ 45,308 |
| 121383 | 54.9 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 34,303 | $ 17,151 | $ 51,454 |
| 121384 | 50.6 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 31,647 | $ 15,823 | $ 47,470 |
| 121389 | 57.8 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 36,114 | $ 18,057 | $ 54,171 |
| 121390 | 67.7 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 42,293 | $ 21,146 | $ 63,439 |
| 121394 | 82.9 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 51,785 | $ 25,893 | $ 77,678 |
| 121397 | 37.1 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 23,167 | $ 11,583 | $ 34,750 |
| 121398 | 74.4 | 200 | 300 | 10-Year | 0.02 | Priority 3 | $ 46,499 | $ 23,249 | $ 69,748 |
| 121399 | 55.8 | 200 | 300 | 10-Year | 0.02 | Priority 3 | $ 34,896 | $ 17,448 | $ 52,344 |
| 121400 | 52.4 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 32,750 | $ 16,375 | $ 49,125 |
| 121401 | 92.1 | 200 | 300 | 10-Year | 0.02 | Priority 3 | $ 57,547 | $ 28,773 | $ 86,320 |
| 121405 | 49.1 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 30,671 | $ 15,335 | $ 46,006 |
| 121413 | 62.8 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 39,256 | $ 19,628 | $ 58,884 |
| 121416 | 67.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 42,306 | $ 21,153 | $ 63,458 |
| 121569 | 54.7 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 34,177 | $ 17,088 | $ 51,265 |
| 121879 | 13.5 | 200 | 300 | 10-Year | 0.03 | Priority 3 | $ 8,438 | $ 4,219 | $ 12,656 |
| 121933 | 83.8 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 52,388 | $ 26,194 | $ 78,581 |
| 121936 | 32.6 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 20,383 | $ 10,192 | $ 30,575 |
| 121937 | 34.9 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 21,812 | $ 10,906 | $ 32,718 |
| 122333 | 87.4 | 150 | 300 | 10-Year | 0.03 | Priority 3 | $ 54,638 | $ 27,319 | $ 81,957 |
| 122403 | 111.8 | 150 | 300 | 10-Year | 0.01 | Priority 3 | $ 69,846 | $ 34,923 | $ 104,768 |
| 122405 | 104.0 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 65,024 | $ 32,512 | $ 97,536 |
| 122407 | 5.5 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 3,438 | $ 1,719 | $ 5,156 |
| 122410 | 2.6 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 1,651 | $ 825 | $ 2,476 |
| 127283 | 76.2 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 47,643 | $ 23,821 | $ 71,464 |
| 127284 | 52.4 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 32,754 | $ 16,377 | $ 49,132 |
| 127285 | 106.1 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 66,316 | $ 33,158 | $ 99,474 |
| 127286 | 20.4 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 12,768 | $ 6,384 | $ 19,151 |
| 127419 | 97.6 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 60,983 | $ 30,492 | $ 91,475 |
| 127427 | 55.4 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 34,606 | $ 17,303 | $ 51,909 |
| 127431 | 62.5 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 39,063 | $ 19,531 | $ 58,594 |
| 127432 | 21.1 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 13,194 | $ 6,597 | $ 19,791 |
| 127435 | 36.0 | 250 | 300 | 10-Year | 0.07 | Priority 3 | $ 22,481 | $ 11,241 | $ 33,722 |
| 127436 | 31.3 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 19,538 | $ 9,769 | $ 29,306 |
| 127437 | 33.0 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 20,650 | $ 10,325 | $ 30,975 |
| 127456 | 55.8 | 250 | 300 | 10-Year | 0.08 | Priority 3 | $ 34,875 | $ 17,438 | $ 52,313 |
| 127487 | 17.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 10,944 | $ 5,472 | $ 16,416 |
| 127520 | 33.7 | 250 | 300 | 10-Year | 0.10 | Priority 3 | $ 21,061 | $ 10,531 | $ 31,592 |
| 127521 | 19.8 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 12,379 | $ 6,190 | $ 18,569 |
| 127543 | 14.2 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 8,844 | $ 4,422 | $ 13,266 |
| 127574 | 23.0 | 250 | 300 | 10-Year | 0.08 | Priority 3 | $ 14,375 | $ 7,188 | $ 21,563 |
| 127925 | 73.5 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 45,910 | $ 22,955 | $ 68,865 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 127926 | 43.2 | 200 | 300 | 10-Year | 0.02 | Priority 3 | $ 27,022 | $ 13,511 | $ 40,533 |
| 127927 | 65.0 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 40,599 | $ 20,300 | $ 60,899 |
| 127929 | 29.0 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 18,104 | $ 9,052 | $ 27,157 |
| 127931 | 73.2 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 45,735 | $ 22,868 | $ 68,603 |
| 127932 | 46.5 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 29,085 | $ 14,543 | $ 43,628 |
| 127934 | 16.8 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 10,478 | $ 5,239 | $ 15,716 |
| 127935 | 42.7 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 26,679 | $ 13,339 | $ 40,018 |
| 127946 | 44.0 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 27,469 | $ 13,734 | $ 41,203 |
| 127947 | 39.4 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 24,603 | $ 12,301 | $ 36,904 |
| 127948 | 51.6 | 250 | 300 | 10-Year | 0.08 | Priority 3 | $ 32,219 | $ 16,109 | $ 48,328 |
| 127949 | 11.6 | 250 | 300 | 10-Year | 0.10 | Priority 3 | $ 7,239 | $ 3,620 | $ 10,859 |
| 128002 | 75.3 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 47,076 | $ 23,538 | $ 70,613 |
| 128021 | 57.3 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 35,825 | $ 17,913 | $ 53,738 |
| 128029 | 58.5 | 250 | 300 | 10-Year | 0.08 | Priority 3 | $ 36,561 | $ 18,281 | $ 54,842 |
| 128030 | 53.2 | 250 | 300 | 10-Year | 0.07 | Priority 3 | $ 33,257 | $ 16,628 | $ 49,885 |
| 128037 | 65.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 40,625 | $ 20,313 | $ 60,938 |
| 128038 | 13.4 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 8,379 | $ 4,189 | $ 12,568 |
| 128040 | 94.1 | 250 | 300 | 10-Year | 0.04 | Priority 3 | $ 58,792 | $ 29,396 | $ 88,188 |
| 128054 | 75.9 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 47,428 | $ 23,714 | $ 71,142 |
| 128055 | 21.4 | 200 | 300 | 10-Year | 0.00 | Priority 3 | $ 13,357 | $ 6,678 | $ 20,035 |
| 128058 | 77.7 | 150 | 300 | 10-Year | 0.06 | Priority 3 | $ 48,574 | $ 24,287 | $ 72,862 |
| 128255 | 8.1 | 250 | 300 | 10-Year | 0.20 | Priority 3 | $ 5,066 | $ 2,533 | $ 7,598 |
| 128256 | 16.1 | 250 | 300 | 10-Year | 0.20 | Priority 3 | $ 10,054 | $ 5,027 | $ 15,082 |
| 128257 | 43.0 | 250 | 300 | 10-Year | 0.20 | Priority 3 | $ 26,881 | $ 13,441 | $ 40,322 |
| 131589 | 64.3 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 40,171 | $ 20,086 | $ 60,257 |
| 131590 | 68.7 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 42,923 | $ 21,461 | $ 64,384 |
| 131591 | 64.7 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 40,421 | $ 20,211 | $ 60,632 |
| 131592 | 37.3 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 23,319 | $ 11,660 | $ 34,979 |
| 131593 | 57.4 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 35,866 | $ 17,933 | $ 53,799 |
| 131594 | 83.5 | 250 | 300 | 10-Year | 0.06 | Priority 3 | $ 52,216 | $ 26,108 | $ 78,324 |
| 131599 | 62.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 38,749 | $ 19,375 | $ 58,124 |
| 131623 | 79.9 | 250 | 300 | 10-Year | 0.05 | Priority 3 | $ 49,931 | $ 24,966 | $ 74,897 |
| 131639 | 45.0 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 28,136 | $ 14,068 | $ 42,203 |
| 131640 | 56.5 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 35,311 | $ 17,655 | $ 52,966 |
| 131875 | 60.1 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 37,560 | $ 18,780 | $ 56,340 |
| 131878 | 50.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 31,694 | $ 15,847 | $ 47,542 |
| 131899 | 81.0 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 50,624 | $ 25,312 | $ 75,936 |
| 131901 | 68.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 42,499 | $ 21,249 | $ 63,748 |
| 131912 | 59.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 36,888 | $ 18,444 | $ 55,331 |
| 131949 | 40.4 | 200 | 300 | 10-Year | 0.05 | Priority 3 | $ 25,263 | $ 12,631 | $ 37,894 |
| 131950 | 61.7 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 38,539 | $ 19,269 | $ 57,808 |
| 131955 | 105.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 65,941 | $ 32,971 | $ 98,912 |
| 131992 | 38.5 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 24,062 | $ 12,031 | $ 36,093 |
| 132000 | 42.6 | 250 | 300 | 10-Year | 0.11 | Priority 3 | $ 26,631 | $ 13,316 | $ 39,947 |
| 132002 | 90.8 | 250 | 300 | 10-Year | 0.07 | Priority 3 | $ 56,750 | $ 28,375 | $ 85,125 |
| 132056 | 7.5 | 200 | 300 | 10-Year | 0.04 | Priority 3 | $ 4,700 | $ 2,350 | $ 7,050 |
| 132075 | 32.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 20,448 | $ 10,224 | $ 30,671 |
| 132076 | 50.9 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 31,804 | $ 15,902 | $ 47,707 |
| 132077 | 15.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 9,358 | $ 4,679 | $ 14,036 |
| 132136 | 66.9 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 41,823 | $ 20,911 | $ 62,734 |
| 132138 | 57.6 | 200 | 300 | 10-Year | 0.01 | Priority 3 | $ 36,020 | $ 18,010 | $ 54,030 |
| 132143 | 38.7 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 24,192 | $ 12,096 | $ 36,288 |
| 132144 | 84.2 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 52,617 | $ 26,308 | $ 78,925 |
| 132148 | 101.6 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 63,521 | $ 31,761 | $ 95,282 |
| 132171 | 111.6 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 69,746 | $ 34,873 | $ 104,619 |
| 132225 | 80.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 50,455 | $ 25,228 | $ 75,683 |
| 132226 | 8.2 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 5,118 | $ 2,559 | $ 7,676 |
| 132250 | 61.2 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 38,262 | $ 19,131 | $ 57,393 |
| 132270 | 99.1 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 61,931 | $ 30,966 | $ 92,897 |
| 132271 | 38.9 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 24,330 | $ 12,165 | $ 36,495 |
| 132277 | 48.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 29,998 | $ 14,999 | $ 44,996 |
| 132288 | 29.3 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 18,321 | $ 9,160 | $ 27,481 |
| 132289 | 31.1 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 19,429 | $ 9,715 | $ 29,144 |
| 132290 | 66.5 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 41,593 | $ 20,797 | $ 62,390 |
| 132295 | 82.9 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 51,831 | $ 25,916 | $ 77,747 |
| 132296 | 30.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 19,056 | $ 9,528 | $ 28,583 |
| 132305 | 81.4 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 50,850 | $ 25,425 | $ 76,275 |
| 132308 | 90.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 56,249 | $ 28,125 | $ 84,374 |
| 132309 | 119.9 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 74,936 | $ 37,468 | $ 112,404 |
| 132313 | 59.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 36,875 | $ 18,438 | $ 55,313 |
| 132327 | 59.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 36,874 | $ 18,437 | $ 55,311 |
| 132331 | 45.0 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 28,124 | $ 14,062 | $ 42,187 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 132332 | 103.5 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 64,686 | $ 32,343 | $ 97,028 |
| 132336 | 65.2 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 40,749 | $ 20,375 | $ 61,124 |
| 132337 | 18.3 | 150 | 300 | 10-Year | 0.00 | Priority 3 | $ 11,438 | $ 5,719 | $ 17,156 |
| 132338 | 15.0 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 9,378 | $ 4,689 | $ 14,067 |
| 132339 | 3.0 | 250 | 300 | 10-Year | 0.03 | Priority 3 | $ 1,875 | $ 938 | $ 2,813 |
| 132342 | 64.1 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 40,066 | $ 20,033 | $ 60,099 |
| 132438 | 86.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 53,721 | $ 26,860 | $ 80,581 |
| 132439 | 43.1 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 26,925 | $ 13,463 | $ 40,388 |
| 132448 | 39.6 | 250 | 300 | 10-Year | 0.00 | Priority 3 | $ 24,764 | $ 12,382 | $ 37,146 |
| 132449 | 47.5 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 29,718 | $ 14,859 | $ 44,576 |
| 132450 | 42.4 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 26,479 | $ 13,240 | $ 39,719 |
| 132451 | 46.6 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 29,146 | $ 14,573 | $ 43,719 |
| 132452 | 18.2 | 250 | 300 | 10-Year | 0.02 | Priority 3 | $ 11,385 | $ 5,693 | $ 17,078 |
| 251090 | 43.7 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 27,299 | $ 13,649 | $ 40,948 |
| 251091 | 48.0 | 250 | 300 | 10-Year | 0.01 | Priority 3 | $ 29,969 | $ 14,985 | $ 44,954 |
| 254997 | 20.8 | 200 | 300 | 10-Year | 0.00 | Priority 3 | $ 12,970 | $ 6,485 | $ 19,455 |
| 254998 | 31.7 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 19,784 | $ 9,892 | $ 29,676 |
| 254999 | 28.4 | 250 | 300 | 10-Year | 0.08 | Priority 3 | $ 17,759 | $ 8,880 | $ 26,639 |
| 255000 | 21.9 | 250 | 300 | 10-Year | 0.09 | Priority 3 | $ 13,697 | $ 6,848 | $ 20,545 |
| | | | | | | Sub-Total | $ 6,763,180 | $ 3,381,590 | $ 10,144,770 |
| PR-C048 | 196.4 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 122,721 | $ 61,360 | $ 184,081 |
| PR-C050 | 119.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 74,529 | $ 37,264 | $ 111,793 |
| PR-C068 | 154.4 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 96,494 | $ 48,247 | $ 144,741 |
| PR-C079 | 119.3 | 0 | 375 | 10-Year | 0.13 | Priority 3 - New Main | $ 83,500 | $ 41,750 | $ 125,250 |
| PR-C080 | 64.5 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 40,301 | $ 20,150 | $ 60,451 |
| PR-C081 | 146.3 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 91,433 | $ 45,717 | $ 137,150 |
| PR-C082 | 102.3 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 63,960 | $ 31,980 | $ 95,940 |
| PR-C083 | 101.3 | 0 | 300 | 10-Year | 0.10 | Priority 3 - New Main | $ 63,300 | $ 31,650 | $ 94,950 |
| PR-C084 | 113.6 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 71,024 | $ 35,512 | $ 106,537 |
| PR-C085 | 143.6 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 89,733 | $ 44,867 | $ 134,600 |
| PR-C086 | 107.1 | 0 | 300 | 10-Year | 0.07 | Priority 3 - New Main | $ 66,966 | $ 33,483 | $ 100,448 |
| PR-C087 | 205.5 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 128,408 | $ 64,204 | $ 192,612 |
| PR-C088 | 81.4 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 50,899 | $ 25,449 | $ 76,348 |
| PR-C089 | 144.8 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 90,510 | $ 45,255 | $ 135,765 |
| PR-C090 | 64.6 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 40,389 | $ 20,194 | $ 60,583 |
| PR-C091 | 117.8 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 73,618 | $ 36,809 | $ 110,426 |
| PR-C092 | 113.8 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 71,143 | $ 35,571 | $ 106,714 |
| PR-C093 | 80.5 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 50,315 | $ 25,158 | $ 75,473 |
| PR-C094 | 89.8 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 56,136 | $ 28,068 | $ 84,204 |
| PR-C095 | 56.2 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 35,117 | $ 17,558 | $ 52,675 |
| PR-C096 | 67.9 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 42,452 | $ 21,226 | $ 63,678 |
| PR-C097 | 176.7 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 110,422 | $ 55,211 | $ 165,633 |
| PR-C098 | 97.7 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 61,079 | $ 30,540 | $ 91,619 |
| PR-C099 | 114.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 71,391 | $ 35,696 | $ 107,087 |
| PR-C100 | 120.7 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 75,414 | $ 37,707 | $ 113,121 |
| PR-C101 | 100.3 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 62,696 | $ 31,348 | $ 94,044 |
| PR-C102 | 104.6 | 0 | 300 | 10-Year | 0.09 | Priority 3 - New Main | $ 65,376 | $ 32,688 | $ 98,063 |
| PR-C103 | 86.3 | 0 | 300 | 10-Year | 0.10 | Priority 3 - New Main | $ 53,933 | $ 26,967 | $ 80,900 |
| PR-C104 | 26.4 | 0 | 300 | 10-Year | 0.10 | Priority 3 - New Main | $ 16,514 | $ 8,257 | $ 24,771 |
| PR-C105 | 68.5 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 42,822 | $ 21,411 | $ 64,233 |
| PR-C106 | 76.5 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 47,841 | $ 23,920 | $ 71,761 |
| PR-C107 | 62.4 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 39,006 | $ 19,503 | $ 58,509 |
| PR-C108 | 80.9 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 50,580 | $ 25,290 | $ 75,870 |
| PR-C109 | 91.3 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 57,034 | $ 28,517 | $ 85,552 |
| PR-C110 | 63.0 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 39,374 | $ 19,687 | $ 59,062 |
| PR-C111 | 90.1 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 56,298 | $ 28,149 | $ 84,446 |
| PR-C112 | 93.1 | 0 | 300 | 10-Year | 0.08 | Priority 3 - New Main | $ 58,179 | $ 29,089 | $ 87,268 |
| PR-C113 | 56.1 | 0 | 300 | 10-Year | 0.09 | Priority 3 - New Main | $ 35,093 | $ 17,546 | $ 52,639 |
| PR-C114 | 175.6 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 109,763 | $ 54,882 | $ 164,645 |
| PR-C115 | 123.1 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 76,953 | $ 38,477 | $ 115,430 |
| PR-C116 | 126.3 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 78,959 | $ 39,480 | $ 118,439 |
| PR-C117 | 70.1 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 43,833 | $ 21,916 | $ 65,749 |
| PR-C118 | 102.5 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 64,033 | $ 32,017 | $ 96,050 |
| PR-C119 | 87.1 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 54,461 | $ 27,230 | $ 81,691 |
| PR-C120 | 155.8 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 97,372 | $ 48,686 | $ 146,058 |
| PR-C121 | 152.7 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 95,454 | $ 47,727 | $ 143,181 |
| PR-C122 | 97.4 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 60,898 | $ 30,449 | $ 91,346 |
| PR-C123 | 105.8 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 66,117 | $ 33,058 | $ 99,175 |
| PR-C124 | 135.8 | 0 | 300 | 10-Year | 0.09 | Priority 3 - New Main | $ 84,878 | $ 42,439 | $ 127,317 |
| PR-C125 | 101.4 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 63,369 | $ 31,685 | $ 95,054 |
| PR-C126 | 124.0 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 77,473 | $ 38,737 | $ 116,210 |
| PR-C127 | 139.9 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 87,452 | $ 43,726 | $ 131,178 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| PR-C128 | 80.5 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 50,339 | $ 25,170 | $ 75,509 |
| PR-C129 | 131.7 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 82,294 | $ 41,147 | $ 123,441 |
| PR-C130 | 73.0 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 45,641 | $ 22,821 | $ 68,462 |
| PR-C131 | 66.4 | 0 | 375 | 10-Year | 0.13 | Priority 3 - New Main | $ 46,457 | $ 23,228 | $ 69,685 |
| PR-C132 | 106.1 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 66,333 | $ 33,166 | $ 99,499 |
| PR-C133 | 63.1 | 0 | 300 | 10-Year | 0.09 | Priority 3 - New Main | $ 39,413 | $ 19,706 | $ 59,119 |
| PR-C134 | 56.3 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 35,166 | $ 17,583 | $ 52,748 |
| PR-C135 | 77.4 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 48,396 | $ 24,198 | $ 72,593 |
| PR-C136 | 68.7 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 42,939 | $ 21,469 | $ 64,408 |
| PR-C137 | 90.5 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 56,588 | $ 28,294 | $ 84,882 |
| PR-C138 | 98.9 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 61,804 | $ 30,902 | $ 92,706 |
| PR-C139 | 138.2 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 86,344 | $ 43,172 | $ 129,517 |
| PR-C140 | 87.5 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 54,706 | $ 27,353 | $ 82,059 |
| PR-C141 | 84.0 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 52,478 | $ 26,239 | $ 78,716 |
| PR-C142 | 58.6 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 36,633 | $ 18,317 | $ 54,950 |
| PR-C143 | 65.0 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 40,616 | $ 20,308 | $ 60,924 |
| PR-C144 | 62.0 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 38,776 | $ 19,388 | $ 58,164 |
| PR-C145 | 94.6 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 59,132 | $ 29,566 | $ 88,698 |
| PR-C146 | 60.6 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 37,887 | $ 18,943 | $ 56,830 |
| PR-C147 | 51.6 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 32,226 | $ 16,113 | $ 48,339 |
| PR-C148 | 22.8 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 14,226 | $ 7,113 | $ 21,339 |
| PR-C149 | 78.6 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 49,139 | $ 24,570 | $ 73,709 |
| PR-C150 | 48.4 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 30,256 | $ 15,128 | $ 45,383 |
| PR-C151 | 77.0 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 48,121 | $ 24,060 | $ 72,181 |
| PR-C152 | 65.8 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 41,107 | $ 20,553 | $ 61,660 |
| PR-C153 | 61.9 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 38,691 | $ 19,346 | $ 58,037 |
| PR-C154 | 58.7 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 36,664 | $ 18,332 | $ 54,997 |
| PR-C155 | 47.8 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 29,844 | $ 14,922 | $ 44,766 |
| PR-C019 | 142.5 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 89,087 | $ 44,543 | $ 133,630 |
| PR-C020 | 52.9 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 33,058 | $ 16,529 | $ 49,587 |
| PR-C021 | 111.0 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 69,349 | $ 34,675 | $ 104,024 |
| PR-C022 | 100.5 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 62,827 | $ 31,413 | $ 94,240 |
| PR-C023 | 96.4 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 60,263 | $ 30,132 | $ 90,395 |
| PR-C024 | 25.1 | 0 | 300 | 10-Year | 0.08 | Priority 3 - New Main | $ 15,676 | $ 7,838 | $ 23,514 |
| PR-C025 | 66.8 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 41,761 | $ 20,881 | $ 62,642 |
| PR-C026 | 75.4 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 47,121 | $ 23,561 | $ 70,682 |
| PR-C027 | 118.4 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 73,999 | $ 36,999 | $ 110,998 |
| PR-C028 | 155.7 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 97,286 | $ 48,643 | $ 145,928 |
| PR-C029 | 90.2 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 56,389 | $ 28,194 | $ 84,583 |
| PR-C030 | 83.6 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 52,277 | $ 26,138 | $ 78,415 |
| PR-C031 | 153.3 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 95,815 | $ 47,908 | $ 143,723 |
| PR-C032 | 58.0 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 36,262 | $ 18,131 | $ 54,393 |
| PR-C033 | 37.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 23,248 | $ 11,624 | $ 34,872 |
| PR-C034 | 26.6 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 16,625 | $ 8,313 | $ 24,938 |
| PR-C035 | 61.3 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 38,313 | $ 19,156 | $ 57,469 |
| PR-C036 | 106.4 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 66,491 | $ 33,245 | $ 99,736 |
| PR-C037 | 99.7 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 62,318 | $ 31,159 | $ 93,477 |
| PR-C038 | 144.2 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 90,138 | $ 45,069 | $ 135,207 |
| PR-C039 | 36.7 | 0 | 300 | 10-Year | 0.12 | Priority 3 - New Main | $ 22,965 | $ 11,483 | $ 34,448 |
| PR-C040 | 88.8 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 55,521 | $ 27,761 | $ 83,282 |
| PR-C041 | 145.9 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 91,164 | $ 45,582 | $ 136,746 |
| PR-C042 | 45.5 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 28,428 | $ 14,214 | $ 42,641 |
| PR-C043 | 75.0 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 46,899 | $ 23,449 | $ 70,348 |
| PR-C044 | 115.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 72,025 | $ 36,013 | $ 108,038 |
| PR-C045 | 136.1 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 85,063 | $ 42,531 | $ 127,594 |
| PR-C046 | 101.3 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 63,297 | $ 31,648 | $ 94,945 |
| PR-C047 | 52.9 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 33,059 | $ 16,529 | $ 49,588 |
| PR-C049 | 118.1 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 73,825 | $ 36,913 | $ 110,738 |
| PR-C075 | 10.0 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 6,250 | $ 3,125 | $ 9,375 |
| PR-C076 | 30.4 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 19,028 | $ 9,514 | $ 28,541 |
| PR-C077 | 113.1 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 70,695 | $ 35,348 | $ 106,043 |
| PR-C078 | 104.9 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 65,568 | $ 32,784 | $ 98,351 |
| PR-C001 | 128.1 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 80,075 | $ 40,038 | $ 120,113 |
| PR-C002 | 61.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 38,253 | $ 19,126 | $ 57,379 |
| PR-C003 | 85.2 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 53,273 | $ 26,636 | $ 79,909 |
| PR-C004 | 153.8 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 96,133 | $ 48,067 | $ 144,200 |
| PR-C005 | 85.0 | 0 | 300 | 10-Year | 0.10 | Priority 3 - New Main | $ 53,122 | $ 26,561 | $ 79,683 |
| PR-C006 | 56.8 | 0 | 300 | 10-Year | 0.16 | Priority 3 - New Main | $ 35,520 | $ 17,760 | $ 53,280 |
| PR-C007 | 81.4 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 50,879 | $ 25,440 | $ 76,319 |
| PR-C008 | 185.1 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 115,696 | $ 57,848 | $ 173,544 |
| PR-C009 | 220.0 | 0 | 300 | 10-Year | 0.07 | Priority 3 - New Main | $ 137,474 | $ 68,737 | $ 206,211 |
| PR-C010 | 263.1 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 164,446 | $ 82,223 | $ 246,669 |

| Conduit ID | Length (m) | Existing Diameter (mm) | Required Diameter (mm) | Criteria | Design Flow (m3/s) | Upgrade Category | Constuction Cost | E&C (50%) | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| PR-C011 | 64.6 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 40,346 | $ 20,173 | $ 60,519 |
| PR-C012 | 167.1 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 104,443 | $ 52,221 | $ 156,664 |
| PR-C013 | 164.8 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 103,016 | $ 51,508 | $ 154,523 |
| PR-C014 | 82.0 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 51,219 | $ 25,610 | $ 76,829 |
| PR-C015 | 107.5 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 67,200 | $ 33,600 | $ 100,800 |
| PR-C016 | 128.8 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 80,494 | $ 40,247 | $ 120,741 |
| PR-C017 | 149.2 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 93,261 | $ 46,631 | $ 139,892 |
| PR-C018 | 149.7 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 93,553 | $ 46,777 | $ 140,330 |
| PR-C051 | 93.7 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 58,556 | $ 29,278 | $ 87,834 |
| PR-C052 | 66.6 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 41,623 | $ 20,811 | $ 62,434 |
| PR-C053 | 50.0 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 31,281 | $ 15,640 | $ 46,921 |
| PR-C054 | 74.9 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 46,842 | $ 23,421 | $ 70,263 |
| PR-C055 | 79.1 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 49,435 | $ 24,718 | $ 74,153 |
| PR-C056 | 142.9 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 89,300 | $ 44,650 | $ 133,950 |
| PR-C057 | 110.1 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 68,829 | $ 34,415 | $ 103,244 |
| PR-C058 | 129.6 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 81,021 | $ 40,510 | $ 121,531 |
| PR-C059 | 125.4 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 78,371 | $ 39,186 | $ 117,557 |
| PR-C060 | 88.0 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 54,989 | $ 27,494 | $ 82,483 |
| PR-C061 | 125.6 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 78,478 | $ 39,239 | $ 117,717 |
| PR-C062 | 121.2 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 75,721 | $ 37,860 | $ 113,581 |
| PR-C063 | 67.3 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 42,071 | $ 21,036 | $ 63,107 |
| PR-C064 | 122.8 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 76,733 | $ 38,366 | $ 115,099 |
| PR-C065 | 180.8 | 0 | 300 | 10-Year | 0.02 | Priority 3 - New Main | $ 112,973 | $ 56,486 | $ 169,459 |
| PR-C066 | 89.7 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 56,059 | $ 28,030 | $ 84,089 |
| PR-C067 | 73.2 | 0 | 300 | 10-Year | 0.04 | Priority 3 - New Main | $ 45,743 | $ 22,871 | $ 68,614 |
| PR-C069 | 68.5 | 0 | 300 | 10-Year | 0.00 | Priority 3 - New Main | $ 42,829 | $ 21,415 | $ 64,244 |
| PR-C070 | 94.6 | 0 | 300 | 10-Year | 0.03 | Priority 3 - New Main | $ 59,112 | $ 29,556 | $ 88,668 |
| PR-C071 | 63.6 | 0 | 300 | 10-Year | 0.06 | Priority 3 - New Main | $ 39,777 | $ 19,888 | $ 59,665 |
| PR-C072 | 51.5 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 32,188 | $ 16,094 | $ 48,281 |
| PR-C073 | 61.9 | 0 | 300 | 10-Year | 0.05 | Priority 3 - New Main | $ 38,713 | $ 19,356 | $ 58,069 |
| PR-C074 | 66.3 | 0 | 300 | 10-Year | 0.01 | Priority 3 - New Main | $ 41,444 | $ 20,722 | $ 62,167 |
| | | | | | | Sub-Total | $ 9,471,801 | $ 4,735,901 | $ 14,207,702 |