# WILLBAND CREEK ISMP

FULL REPORT

October 18, 2019

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ABBOTSFORD

**Willband Creek Integrated Stormwater Management Plan**


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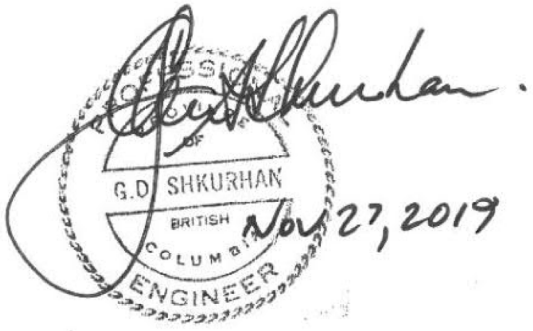



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# EXECUTIVE SUMMARY

The City of Abbotsford (the City) has developed an Integrated Stormwater Management Plan (ISMP) for the Willband Creek watershed to allow for the continuation of viable development and redevelopment, while at the same time mitigating impacts to the environment and the existing drainage system and to plan for the effects of climate change.

The ISMP is developed and described in four parts:

- **Part 1** describes existing conditions, issues, and opportunities that need to be considered by the City in terms of integrated stormwater management;
- **Part 2** describes the future conditions, and an assessment of the potential impacts of development (if unmitigated) that need to be considered by the City;
- **Part 3** describes stormwater management strategy to address the issues, opportunities, and potential future impacts of development;
- **Part 4** describes the implementation strategy and adaptive management strategy.

## Part 1: Existing Conditions

### Land Use

The Willband Creek watershed is located within the heart of Abbotsford with a tremendous diversity of land uses. Major land uses include residential, commercial, industrial, agricultural, institutional, and park and school uses. The study area is already highly urbanized, and incorporates several neighbourhoods (or portions) including:

- City Centre;
- Fairfield;
- Marshall – McCallum;
- Historic Downtown;
- Hazelwood;
- South Clearbrook;
- Immel – McMillan, and
- Clayburn

With redevelopment in and around the South Fraser Way being a priority in the coming years, there is great opportunity for stormwater management, as it provides the opportunity to implement source controls where they do not currently exist. However, challenges also occur due to increased building footprints and less area for surface-based rainwater management. Based on the 2016 aerial photograph of the study area, approximately 45% of the total study area is currently impervious (ie. asphalt and roof tops) surface. However, in the highly urbanized centres the impervious surface is around 90% with very little tree canopy. While redevelopment poses on opportunity to change, a challenge is the relative slow speed at which that change will occur if left to redevelopment alone.

### Environmental Conditions

Historic development has significantly altered the aquatic habitat, water quality, and terrestrial habitat. As part of the ISMP, an investigation of existing habitat conditions within the study are was completed and consisted of a review of background information supplemented by a series of field assessments.

Willband Creek and its various named tributary channels and waterbodies are the most significant habitat features of the study area. The most significant water bodies include:

Mill Lake and its creek through Ravine Park, Willband Creek, Boa Brook, Horn Creek, Prairie Street Creek, and although man-made the

Willband Creek Stormwater Detention Facility near Willband Creek's junction with Clayburn Creek.

Naturally, the terrestrial portion of the study area is dominated by coniferous forests with western hemlock and western red cedar being the most common tree species. Much of the coniferous forest within the study area has been removed and replaced with non-native species on landscape properties, and a large part of the terrestrial habitat within the watershed consisted of landscaped residential properties.

The Watershed Health Tracking Score in metro Vancouver's Template for Integrated Stormwater Management Planning 2005 was applied to measure watershed health. Using this template, Willband Creek would be indicated as an extremely impacted watershed, which can be expected given the loss of intact riparian forest and high imperviousness.

The conditions across the watershed are highly varied and the high-quality components are outweighed by the poor-quality components. Overall, the watershed health is considered poor based on Metro Vancouver standards.

While it is evident that the City is placing an increased emphasis on environmental planning and protection, this has not been a seamless effort. Developers and individual property owners often do not fully understand the purpose of the City's environmental protection measures, and instead see it as an increased expense and burden. Education to identify, understand, and address these gaps between policy direction and on-the-ground implementation will be essential to a successful ISMP.

## Geotechnical & Hydrogeology Conditions

The surficial geology of the Study area was mapped at a regional scale by the Geological Survey of Canada and published in 1980. The geologic conditions within the Study area are complex and varied.

Most of the surficial sediments within the Study area are associated with the repeated advance and retreat of glaciers, but the modern-day river and hill-slope processes continue to shape the landscape by eroding and depositing sediments.

While some of the lower lying areas of the watershed have moderate to poor infiltration capabilities, 70% of the study area is considered good for infiltration which provides a significantly opportunity to return rainwater to the ground. However, doing so increases the need to consider water quality prior to return to ground in an urban setting.

## Hydrologic and Hydraulic Conditions

In addition to natural features, the Willband Creek watershed's management system is comprised extensively of manmade features; storm sewers, detention ponds, culverts, and ditches. An important aspect of an ISMP is to understand the hydrology of the watershed, the working hydraulics of the management systems, and how it performs against established criteria. A hydrologic (relationship between rainfall and land) and hydraulic model (the performance of conveyance and management structures) was compiled to assess system performance, highlights of which are noted in the summary below.

## Existing Condition Summary

- Both aquatic and terrestrial habitats have been significantly impacted by past development and watercourse encroachment. Overall, the watershed health is deemed to be poor.

- Despite the overall assessment noted above, there are some local cases where aquatic and riparian health is considered fair; including in Horn Creek, Boa Brook, and Thiessen Creek. Ironically, Horn Creek has also been identified as having the largest number of bank erosion sites.
- Erosion in Horn Creek, Boa Brook and Prairie Street Creek persist despite some instream repairs having been completed in Horn Creek. While source control through redevelopment provide an opportunity to improve the situation, the timeline with that approach is expected to be long, therefore the City will likely need to intervene with communal solutions more near term.
- Water quality is considered somewhat poor in the lowlands and in Mill Lake. In the case of lowland watercourses, mainly a result of urban runoff and likely insufficient water circulation and lack of riparian cover. In the case of Mill Lake, this is mainly attributed to stratification and insufficient water circulation.
- There is good infiltration potential for the majority of the upland study area; this opens a strong opportunity to apply low impact development techniques as redevelopment occurs.
- Modelling indicates that portions of the lowland system do not meet current conveyance criteria. System performance is hampered even further due to downstream effects of the broader Matsqui Prairie system.
- Generally, the performance of the storm sewer network appears to be reasonably good against established criteria; however, under the 100-year (major) event, the potential of flooding is widespread.
- Seven of 14 public upland detention facilities modelled (excluding Mill Lake and Willband Creek Park ponds) do not appear to be meeting criteria.

## Part 2: Potential Future Conditions

Based on the City's 2016 Official Community Plan, the City has developed a "Build_35" GIS dataset, which represents a prediction of that extent of lands that may be redeveloped by year 2035. To represent the potential effects of future land use changes, three primary parameters were adjusted in the analysis; the total impervious fraction, the portion of the impervious fraction that is redirected to ground, and whether engineered controls are applied. In addition, the potential impacts of climate change area also considered.

Many different land use sub-scenarios were created to test the outcomes of different level of controls and influence of potential climate change, results of which are compared against existing conditions. For this ISMP, the following land use sub-scenarios have been created:

- Future Land Use (Build_35) with no controls and historic precipitation.
- Future Land Use (Build_35) with controls and historic precipitation.
- Future Land Use (Build_35) with no controls, but climate change precipitation.
- Future Land Use (Build_35) with controls and climate change precipitation.

Based on the analysis, is appears as though climate change will potentially be a more significant driver of erosion potential than future land use, but that implementing effective source controls through redevelopment can largely compensate for the impacts of climate change and redevelopment. As such, in this case redevelopment poses a significant opportunity for betterment rather than a detriment.

Within the historic downtown there is some aged piping infrastructure within private property to which the City does not have a right of way. Options exist to redirect City systems away from private property.

A critical component to the drainage system is a large diameter storm sewer pipe through the Historic Downtown that was installed to infill the original Mill Lake Ravine and settle the area. The current condition of this pipe is unknown and its considered high priority to assess. Hydraulic modeling suggests is marginally undersized to meet current criteria. The strategy for managing this critical piece of infrastructure will be determined through an assessment of its condition. The costs associated with its failure and its replacement are both very high.

The City's current design criteria for storm sewer infrastructure is different than what likely existed at the time when much of the historic infrastructure was installed. Despite the majority of trunk infrastructure currently meeting criteria, there are many segments which long term that will be replaced and upgraded; either to ensure capacity meets criteria under future conditions, that the infrastructure meets the minimum size requirement of current criteria, and that drainage infrastructure is installed in areas that currently don't have it.

Analysis does not indicate that flooding within the lowland floodplain to the north will worsen if successful source controls in the uplands are implemented. Again, redevelopment poses an opportunity for betterment. However, performance of the lowland floodplain is highly governed by downstream systems within the Matsqui Prairie and its outfall to the Fraser River. Performance of the floodplain will be governed more significantly by that system. The City has budgeted to conduct a more comprehensive study of ways to improve performance of the Matsqui Prairie system.

## Part 3: Management Strategy

Based on the findings of Part 2, a number of recommended management strategies are identified, as follows:

### Storm Sewer Capital Program and Priorities

Storm sewer and culvert improvements are grouped into one of three priority levels using the following logic:

**Priority 1** – components that will fail against current criteria in the future even with the application of source controls.

**Priority 2** – components that will fail against current criteria in the future only if successful source controls are not applied.

**Priority 3** – components that will meet capacity criteria but do not meet minimum size requirements or where infrastructure does not currently exist.

The recommendations for storm sewer capital program and priorities are:

**1** Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.

**2** Develop a strategy to redirect City infrastructure in Historic Downtown to Montrose Avenue and communicate service connection redirection and private sewer abandonment requirements to property owners (also flag these properties in the City data bases to ensure this requirement is not missed during any future building or development permit application).

**3** Conduct a condition assessment of the trunk sewer downstream of Ravine Park (high priority), then as the results dictate, conduct a study to confirm the viability and cost effectiveness of creating on-line temporary storage within Ravine Park.

**4** Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted flood loss of 100 $m^3$ or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 $m^3$ and 100 $m^3$.

**5** Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.

## Environmental Opportunities

There are several opportunities available to the City to improve the habitat value in the study area. However, several constraints are associated with each of them. Opportunity areas included:

- riparian infill;
- fish access improvement;
- habitat construction;
- instream maintenance;
- channel daylighting;
- water quality improvements; and
- integration of habitat features into stormwater controls.

Based on the analysis, the following recommendations relating to environmental opportunities are provided:

**1** Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.

**2** Replace or modify stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.

**3** Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation (collaboration with Fraser Valley Conservancy).

**4** Removal of garbage and other anthropogenic debris from watercourses.

**5** Recognized to have significant challenges, however, review the practicality of daylighting a portion of ravine previously infilled with piping downstream of Mill Lake.

**6** Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.

**7** Subject to item 6 above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.

**8** Install “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators, yet more sophisticated treatment options exist at higher expense.

**9** Develop necessary programs and regulations to increase the tree canopy in the City Centre and Historic Downtown area.

## Geotechnical and Source Controls

It is expected that to protect a high vulnerability aquifer, runoff treatment should involve media filtration, either in the form of amended landscape growing media or with proprietary media filtration devices.

Recommendations and action items for Geotechnical and Source Controls include:

**1** Further develop a mitigation strategy for high risk erosion sites in ravines.

**2** Explore candidate sites for communal ponds that may arrest erosion in Horn Creek and Boa Brook. Further evaluate these pond

sites against the alternative option of a high flow diversion that was previously identified in a 2009 study.

**3** Implement source controls at Civic sites such as the parking lot at Five Corners and the Municipal Hall site to demonstrate leadership in source controls, however these facilities will not change the performance of local storm sewer conveyance in a design event.

**4** The City has an established Stormwater Source Control Bylaw that currently applies to CICP Lands and the Abbotsford Airport Lands and is a supplement to the Development bylaw. Consistent with the recent Master Drainage Plan, its recommended that this Storm Water Source Control Bylaw be adopted as a City-wide document.

**5** Develop criteria and standards for the application of roadside swales or other form of control in urban streets.

**6** Conduct annual observation and evaluation of geotechnical stability in creek ravines.

**7** Create a Development Permit Area for the application of infiltration system in proximity to steep slopes, under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.

### Mill Lake and Willband Creek Floodplain

The City has particular interest to understand the potential change in floodplain performance as a result of changes to the upland systems and climate change. The following recommendations or provided:

**1** Conduct Phase 2 Matsqui Prairie Drainage Study.

**2** Upon completion of the Phase 2 Matsqui Prairie Drainage Study, establish a new Flood Construction Level (FCL) as necessary.

**3** Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.

## Actions and Capital Costs

Based on the recommendations above, the following table of actions, relative priority and planning level budgetary costs are provided for inclusion into the capital program. Costs are Class D and include 50% engineering and contingencies but exclude taxes.

**Table ES-1**
**Summary of Actions, Priority and Budgetary Costs**

| Action | Priority | Budget Cost |
|---|---|---|
| **LAND USE MANAGEMENT** | | |
| Explore the design of rainwater management facilities for both retention and water quality treatment in the Municipal Hall lands site and the City owned parking lot at West Railway Street and Essendene Avenue. Both facilities would serve local catchments and demonstrate the City as leaders. | Medium | $50,000 (pre-design study only) |
| Designate the 4 blocks of Historic Downtown between South Fraser Way to George Ferguson Way, Pauline Street to Montvue Avenue, as a special area exempting it from current stormwater site control criteria but pay cash-in-lieu for detention. However, onsite source controls are still encouraged where feasible. | High | N/A |
| Develop policy around service connections for subsurface floor space, both in terms of the mechanical requirements for the physical connection and statements to limit the City's liability. | High | $20,000 (excluding creation of regulatory documents) |
| Establish tree canopy targets and landscape standards to suit (both private and public spaces). Determine what regulatory processes would trigger implementation (eg. Building permit, re-development, capital reconstruction). | High | $30,000 (excluding creation of regulatory documents) |
| **ENVIRONMENTAL OPPORTUNITIES** | | |
| Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road. | Low | $50,000 to develop a program<br>$100,000 to $500,000 for planting |
| Modify or replace stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street. | Low | TBD through design review |

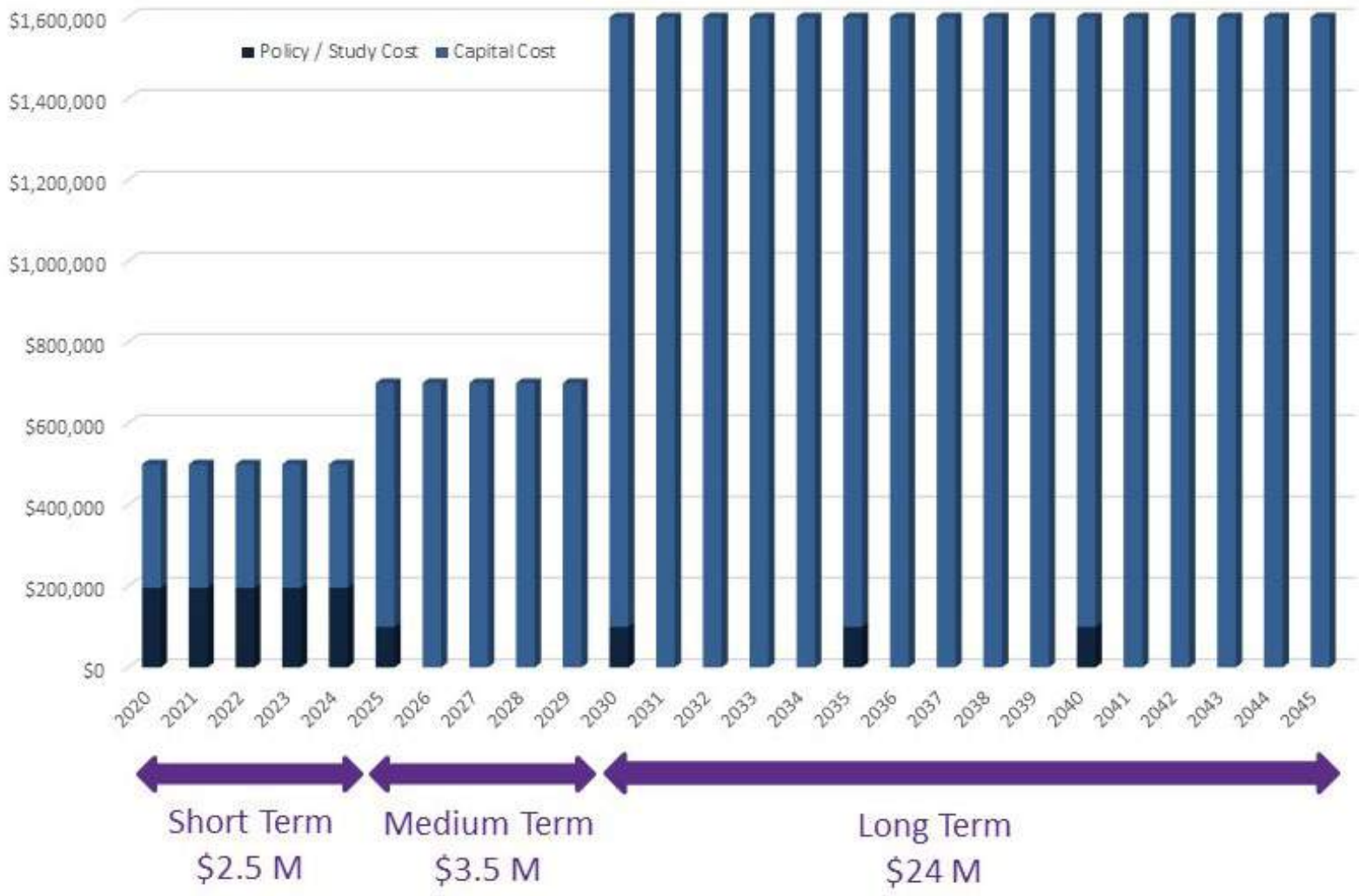
| Action | Priority | Budget Cost |
|---|---|---|
| **ENVIRONMENTAL OPPORTUNITIES Cont.** | | |
| Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation. | Low | $50,000 to develop a program<br>Premature to offer an implementation budget, particularly if off-line pools are considered. |
| Removal of garbage and other anthropogenic debris from watercourses. | High | N/A |
| Recognized to have significant challenges, however review the practicality of daylighting a portion of ravine downstream of Mill Lake. | Low | $50,000 for investigation only |
| Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged. | Medium | $20,000 |
| Subject to item above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake. | Medium | TBD |
| Consider “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators. (7 outfalls) | Medium | $1.5M to $3.0M assuming O/G, not media filltration |
| Apply landscaped based biofiltration site controls wherever possible. | High | N/A |
| **GEOTECHNICAL AND SOURCE CONTROLS** | | |
| Expand Stormwater Source Control Bylaw to City-wide, and to ensure it is enforceable through the Development and Building Permit processes. | High | $50,000 |
| Identify high risk sites (eg. auto-wreckers, service stations) which would be restricted from infiltration systems. | High | N/A |

| Action | Priority | Budget Cost |
|---|---|---|
| **GEOTECHNICAL AND SOURCE CONTROLS Cont.** | | |
| Further develop an erosion mitigation strategy for Horn Creek and Boa Brook. Done in concert with the exploration of communal detention ponds discussed under "Infrastructure" below. | High | $50,000 |
| Conduct an annual review and assessment of geotechnical stability in Horn Creek, Boa Brook and Prairie Street Creek. | High | $20,000 per year |
| Develop criteria and standards for the application of urban roadway Green Infrastructure. This would also include the potential application of perforated storm sewers provided water quality pre-treatment is provided. | High | $50,000 |
| Develop a comprehensive tracking GIS database of public and private site controls. | High | TBD |
| Explore operating permit requirements for long term inspection and maintenance of private site controls. | Medium | $20,000 |
| Create a Development Permit Area for the application of infiltration system in proximity to steep slopes under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose. | High | $20,000 |
| **INFRASTRUCTURE** | | |
| Video inspect trunk sewer downstream of Mill Lake Ravine Park and conduct condition assessment. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis. | **High** | $20,000 |
| Subject to result of the above action, conduct a pre-design study to explore the potential for restricting flow at the storm sewer inlet at the downstream end of Mill Lake Ravine Park. | High | $50,000 |

| Action | Priority | Budget Cost |
|---|---|---|
| **INFRASTRUCTURE Cont.** | | |
| Subject to the findings of items above, decide to upgrade the trunk sewers downstream of Mill Lake Ravine Park, either through full replacement or supplemental capacity, or restrict flow at the inlet. | High | TBD |
| Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment. | Low | $50,000 |
| Notify private property owners in Historic Downtown that need to reconnect to realigned City infrastructure on Montrose Avenue and flag these properties in the City database to ensure reconnection is achieved through Building or Development permitting. | Low | N/A |
| Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary. | Priority 1 – Medium-High<br>Priority 2 – Medium<br>Priority 3 – Low | Priority 1 - $5,345,800<br>Priority 2 – $8,571,500<br>Priority 3 - $24,352,500 |
| Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted floodloss of 100 $m^3$ or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 $m^3$ and 100 $m^3$. | Medium | $200,000 to $500,000 depending on the level of detail |
| Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study. | High | $100,000 |

| Action | Priority | Budget Cost |
|---|---|---|
| **INFRASTRUCTURE Cont.** | | |
| Monitor flows in storm sewer system to validate performance at most problematic (in theory) areas (see Figure 15.1) – based on seven sites monitored November to April. Then conduct an updated hydraulic assessment. | High | $100,000 |
| Conduct a predesign study to further explore the potential of communal detention ponds to reduce erosion in Horn Creek and Boa Brook and compare to the diversion conceived by previous 2009 study. | High | $100,000 |
| **MILL LAKE AND WILLBAND CREEK FLOODPLAIN** | | |
| Conduct Phase 2 Matsqui Prairie floodplain assessment | High | N/A (budgeted by the City for 2020) |
| Initiate discussions with the Fraser Valley Conservancy regarding a floodplain storage and habitat facility west of Highway 11. | High | N/A |
| Review need to establish new Flood Construction Levels (FCL's) in the floodplain. | High | N/A |
| Adjust operational protocols for Mill Lake to offer greater freeboard in the winter. | High | N/A |

**Figure ES-1**
**Preliminary Capital Expenditures and Timelines**



## Part 4: Adaptive Management

Adaptive management is a process of monitoring, reviewing, learning, and adjusting.

### *Monitoring*

Environmental health and flow monitoring are two important components of an Adaptive Management process, but the program needs to be expanded. Monitoring is broken into several categories, including physical (e.g. are the desired flows and quality of water being achieved?), regulatory (e.g. are the City's regulatory tools successfully guiding development?), and process (e.g. are City staff properly informed and are inter-departmental processes in place to successfully direct the plan's implementation).

#### *Physical Monitoring*

- It is recommended that the City implement some short term (at least one winter season) monitoring within the storm sewer system and existing detention ponds in order to validate performance.
- It is recommended that the City implement a semi-permanent water level (not flow) gauge on Willband Creek on the upstream side of Highway 11.
- It is recommended that the City require short term monitoring (one winter season) of all future stormwater source controls, private and public, to validate that their performance in accordance with design criteria.
- It is recommended that the City retain a qualified geotechnical professional to inspect Horn Creek, Boa Brook and Prairie Street Creek each year for soil instabilities and risk assessment.
- Finally, is recommended that water quality and benthic sampling be repeated on a 5-year cycle at the same locations as previously sampled.

#### *Regulatory Monitoring*

The most significant regulatory aspect to track is that source controls are being implemented in accordance with bylaws and criteria.

- It is recommended that the City set up appropriate record systems to track that source controls are in fact being implemented through both the Development and Building Permit processes, and in accordance with the bylaws. As an extension, also track that inspection and maintenance reporting is being done.
- It is anticipated that an Urban Forestry Management Strategy would include some form of regulation to guide development and private property owners. It is therefore recommended that if and when such regulation is created that tracking be implemented.
- And finally, it is recommended that inspection and monitoring occur at occupancy permit that a development / building has not exceeded the permissible site coverage as permitted by the zoning bylaw, and that directly connected impervious surface does not exceed those permitted by design criteria.

#### *Process Monitoring*

The most significant aspects of process monitoring are to ensure that City inspectors are knowledgeable of design criteria and standards of the Development Bylaw and Stormwater Source Control Bylaw. An equally important process to monitor is that implementation of controls is not "slipping through the cracks" during the Development or Building Permit process.

- It is recommended that a "checklist" field be created in the application registry to track whether or not controls are successfully implemented.

### *Assessment*

It is recommended that an audit of all above monitoring be undertaken on a 5-year cycle. Physical monitoring data would be processed for evaluation by hydrologists and environmental professionals and evaluated against all preceding data. Its recommended that the City implement a central database to record and track data for each monitoring period. The fundamental goal is to see if the hydrologic response to rainfall of the built lands is reducing, and that the water quality and watershed health is improving.

### *Key Performance Indicators*

Cost effective, measurable, and reliable key performance indicators allow the City to determine whether or not the watershed vision is being achieved. Performance indicators need to be selected for things that can be observed and measured frequently. In the context of Willband Creek, recommended key performance indicators are:

- Reduced sediment deposits at the base of Horn Creek, Boa Brook, and Prairie Street Creek
- Stability of creek bed and banks in Horn Creek, Boa Brood, and Prairie Street Creek
- Fewer annual service complaints due to flooding
- Increase in tree canopy as measured from aerial photos
- A positive differential between the number of trees planted to the number of trees removed
- No reduction in the riparian vegetation as measured from aerial photos
- Successful implementation of source controls with all development and building permits that require them
- Improved water quality as measured in Horn Creek
- Improved benthic health as measured in Horn Creek
- Successful implementation of the Capital Program.

### *Responses*

The monitoring program is important to assess the specific failure mechanism, should failure occur. Was there a poor design(s)? Has there been a significant change in weather patterns? Was there a breakdown in approval process that prevented bylaws from being enforced? Was there an infrastructure failure due to insufficient maintenance? There can be many reasons why objectives may not be met. The response(s) need to align with the cause. It is therefore premature to articulate a specific response plan at this time, but some fundamental responses may be as follows:

**1** If watercourse erosion and environmental health do not stabilize, or preferably improve, the City may need to accelerate the implementation of communal management infrastructure through its capital program; either with high flow diversions or stormwater detention ponds. As determined herein this ISMP, there are relatively few opportunities for effective ponds on lands where no buildings currently exist, therefore land acquisition and building demolition may be required.

**2** If development or building permits are being completed without successful source controls, the City needs to evaluate whether this was a procedural failure, or if it needs to strengthen the enforcement and penalties of the bylaws, making amendments to them accordingly.

**3** If service calls occur due to structural or maintenance failure, the City needs to strengthen its Asset Management Program.

**4** If maintenance of private source controls is not validated, the City should consider implementing a formal Stormwater Source Control Operating Permit program.

**5** If there is increased flooding in the upland urban area not caused by structural or maintenance failure, the City may consider

accelerating its pipe replacement program on a priority basis or explore alternative mitigative measures.

**6** If the funding for infrastructure change cannot keep up with demand (i.e. worsening conditions) the City needs to revisit its funding stream and look to a program that provides more reliable funding.

**7** If the City is not leading by example in implementing and maintaining source controls in public spaces, the City needs to evaluate its interdepartmental collaboration and priorities.

# PART 1 – EXISTING CONDITION

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# 1 INTRODUCTION

## 1.1 Purpose

The purpose of developing an Integrated Stormwater Management Plan (ISMP) for the Willband Creek watershed is to allow for the continuation of viable development and redevelopment, while at the same time mitigating impacts to the environment and the existing drainage system and to plan for the effects of climate change. This ISMP will inform the formulation of land use and infrastructure policies and guidelines that will be incorporated into future development and capital plans for the watershed.

The ISMP is developed and described in parts:

- Part 1 describes existing conditions, issues, and opportunities that need to be considered by the City in terms of integrated stormwater management;
- Part 2 describes the future conditions, and an assessment of the potential impacts of development (if unmitigated) that need to be considered by the City;
- Part 3 describes stormwater management strategy to address the issues, opportunities, and potential future impacts of development;
- Part 4 describes the implementation strategy and adaptive management strategy.

## 1.2 Study Area

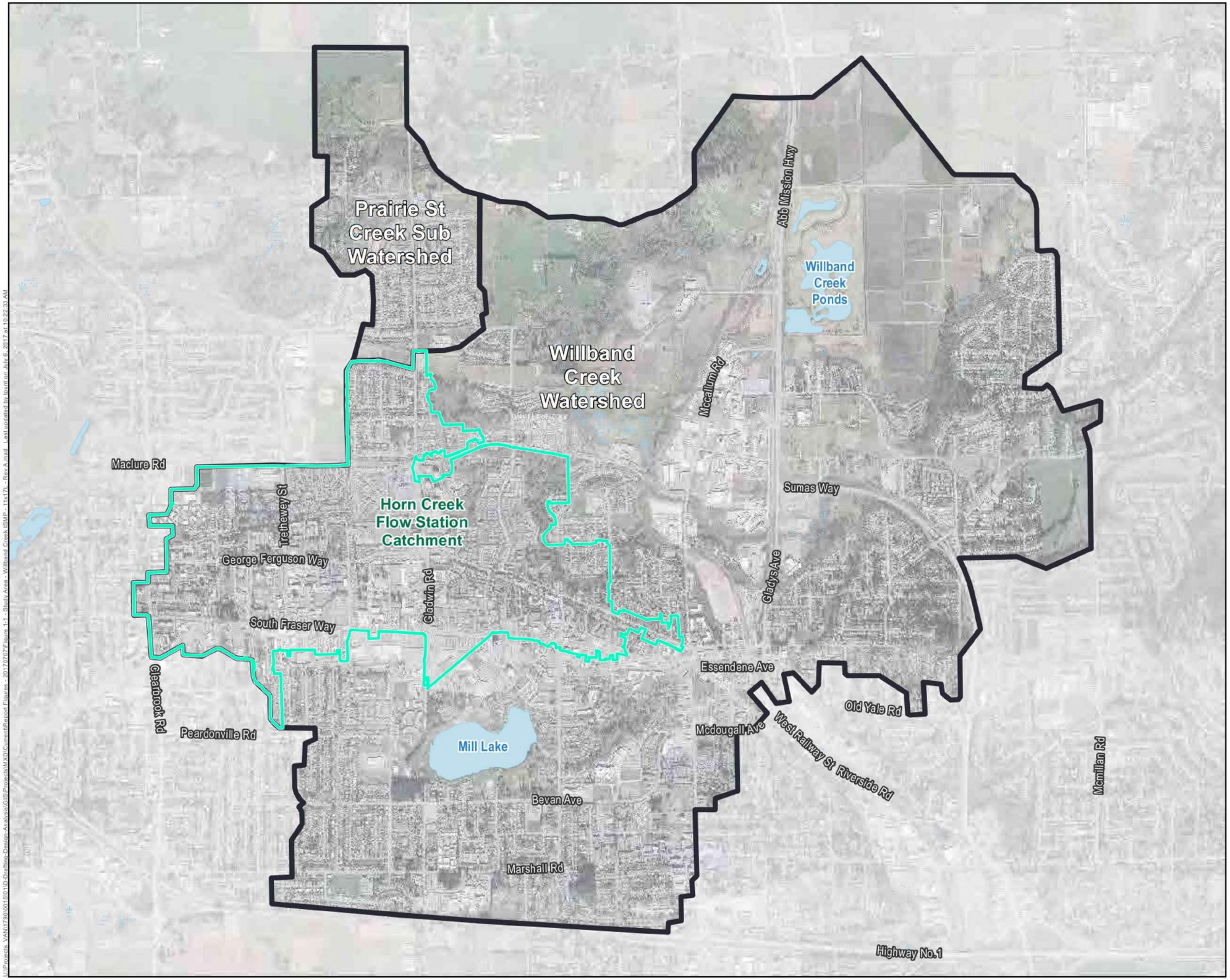
As shown on Figure 1.1, the Willband Creek watershed is located in the centre of the City and spans south to Highway 1, west as far as Clearbrook Road, north to Matsqui Prairie and east beyond McMillan Road. It includes Mill Lake. A sub-catchment of approximately 130 hectares (ha), defined as the Prairie Street Creek Sub-Catchment, is not tributary to Willband Creek but is included in the Study Area as it is of special interest to the City, as described further in this report. The total Study Area is an estimated 1,840 ha.

## 1.3 Known Issues

On January 23, 2017, the consultant team facilitated a workshop with a broad selection of City staff to discuss the scope of the ISMP and to identify issues pertinent to the watershed. The City identified specific areas of concerns and issues on the figures provide in Appendix A.

A generalized summary of known issues identified by the City includes:

- Increased flooding and wet conditions in the Matsqui Prairie floodplain, affecting the performance of the Willband Creek detention facility and influencing land usage;
- numerous sites of channel erosion and poor water quality;
- risk to flooding to properties around Mill Lake if water levels not actively managed;
- wide spread invasive species in creek corridors; and
- some critical trunk infrastructure in poor condition or not functioning properly.

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Willband Creek
Integrated Storm Water
Management Plan

**Study Area**

Legend

- Willband Creek Watershed
- Horn Creek Flow Station Catchment

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.

0 145 290 580 870
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,010

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2017 / 7 / 6 |

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**FIGURE 1.1**

A few comments from the City relate to potential strategies and management alternatives to address issues, including:

- improved development bylaw and a plan to guide infill development; and
- consideration for improving the function of Willband Creek detention facility east of Highway 11 and the potential to add new detention storage west of Highway 11.

## 1.4 Relationship to Matsqui Prairie and Clayburn Creek Studies

The City previously completed an ISMP for the Clayburn Creek watershed (KWL, 2012), with the terminus point being the confluence of Clayburn Creek with Willband Creek at Clayburn Road; this is therefore the same terminus of the Willband Creek ISMP. Design rainfall events and applicable criteria have been applied to the Willband Creek ISMP, consistent with the Clayburn ISMP. However, the terms of reference for this Willband ISMP notes ARDSA criteria are applied to the agricultural lands. While the Clayburn Creek ISMP acknowledges this standard, the process to develop it did not include specific analysis using the ARDSA criteria; rather, a recommendation of the Clayburn ISMP was that a separate Matsqui Prairie Study be undertaken.

Since completing the Clayburn Creek ISMP, the City completed a Phase 1 Matsqui Prairie Drainage Study (June 2013, KWL), and has intent to complete a more comprehensive Phase 2 Matsqui Prairie Drainage Study in 2019 following the completion of the Willband ISMP. The Phase 1 Matsqui Prairie Drainage Study computed flood cell acquired light detection and ranging (LiDAR) data. For this report, LiDAR data was used to measure storage within the Willband Creek detention facility and a storage zone on the west side of Highway 11 opposite the Willband Creek detention facility that was designed for MOTI as compensation associated with highway widening. Additionally, LiDAR data were used to create channel sections where other sources of information were limited.

For this report, modeling focused on assessing system performance against established municipal criteria. The adequacy of the Willband Creek Detention Ponds was not particularly assessed against that criteria. "[Its] design philosophy was that it would provide detention for storms less than a 10-year recurrence, to provide some protection of the Matsqui Prairie farmland. Since the site is low lying, storms greater than 10-year recurrence will tend to inundate the entire site, rendering the pond of marginal usefulness."[1]

[1] City of Abbotsford Willband Stormwater Detention Facility, Operation and Maintenance Manual, UMA, 2000

# 2 RELEVANT REGULATIONS AND GUIDELINES

## 2.1 Local Regulations and Guidelines

A number of City regulations and guidelines relate to stormwater management in the Study area. These are summarized in **Table 2.1** below.

**Table 2.1 - Relevant City Regulations and Guidelines**

| Document | Date | Relevance to Stormwater Management |
|---|---|---|
| Waterways Protection Bylaw | 1996 | Prohibits fouling or obstructing water or sewer flow regardless of private or public property. |
| Consolidated Farm (Mushroom Growing Operation Stormwater and Waste Management and On-farm Composting) Bylaw | 1998 | Provides requirements when establishing or expanding a mushroom growing operation to include a storm water and waste water management plan and comply with setback requirements. Also addresses mushroom composting. |
| Watercourse Management Policy Manual | 2001 | Outlines policies the City abides by when maintaining watercourses within specified areas. |
| Petroleum Products Storage Tank Bylaw | 2003 | Regulations to protect water systems from contamination including location related to utilities and dispensing pumps located over a body of water. |
| Soil Removal and Deposit Bylaw | 2003 | Regulates soil removal as it affects natural watercourses and drainage. |
| Streamside Protection Bylaw | 2005 | Protects streams within the City that support fish habitat from harmful conditions associated with development, and to preserve, protect, restore and enhance the natural environment near streams that support fish habitat. |
| Sewer Rates and Regulations Bylaw | 2009 | Main regulatory instrument in achieving objectives of the Abbotsford/Mission Water & Sewer Commission Source Control Program (SCP) for the purpose of source control. |
| Tree Protection Bylaw | 2009 | Outlines tree cutting permits, exemptions and regulations. |
| Development Cost Charges Imposition Bylaw | 2010 | Outlines potential costs for drainage for different types of development. |

| Document | Date | Relevance to Stormwater Management |
|---|---|---|
| Erosion and Sediment Control Bylaw | 2010 | Outlines among other things: prohibition against discharge, ESC submission requirements; sign and plan requirements; monitoring and reporting |
| Development Bylaw 2070-2011 | 2011 | Outlines rules for drainage collection and control and water distribution; requires rainwater management plan |
| Storm Water Source Control Bylaw | 2011 | Outlines provisions to control, manage, treat and dispose of runoff in specified areas. |
| Abbotsford Floodplain Ditch Maintenance | 2013 | Outlines details of Ditch Maintenance Program. |
| Zoning Bylaw | 2014 | Regulations: Floodproofing provisions; setbacks, and requires CICP and Abbotsford Airport lands conform to Stormwater Source Control Bylaw 2045-2011; |
| Erosion and Sediment Control (ESC) Bylaw: Best Management Practices | 2014 | Provides an overview of ESC requirements and best practices for compliance |
| Information Package for Developing Near Streams and Ravines | 2016 | Provides information to landowners and buildings about developing near streams and ravines. |
| Official Community Plan - Part 3 | 2016 | Outlines the City's vision and policies for sustainable infrastructure such as stormwater and flood protection |
| Official Community Plan - Part 4 | 2016 | Outlines the City's vision for neighbourhoods including considering the environment in areas such as streams, riparian area etc. Includes goal to update ISMPs. |
| Official Community Plan - Part 5, Chapter 5 | 2016 | Provides development guidelines for rainwater management and landscape buffers |
| Official Community Plan - Part 5, Chapter 6 | 2016 | Development guidelines for riparian habitat, flows, drainage and channel geometry, water quality, tree standards, crossings through natural environment areas etc. |
| Official Community Plan - Part 5, Chapter 7 | 2016 | Development guidelines in relation to steep slopes including site drainage, vegetation maintenance and installment, tree removal, erosion and sediment control |
| Official Community Plan - Maps | 2016 | Maps for various uses including drainage + flood control, natural environment DP areas, steep slope DP areas etc. |
| Five-year Financial Plan Bylaw, 2017-2021 | 2017 | Identifies water/drainage costs. |

## 2.2 Regional

In addition to the City's regulations and guidelines, the regional documents outlined in **Table 2.2** are also relevant to the ISMP.

**Table 2.2 - Relevant Regional Regulations and Guidelines**

| Document | Date | Relevance to Stormwater Management |
|---|---|---|
| FVRD Regional Growth Management Strategy | 2003 | Outlines sustainable planning initiatives when planning for growth including: protecting the natural environment and promoting environmental stewardship; and protecting and managing rural and recreational lands. |
| Fraser Valley - BC Agriculture & Climate Change Regional Adaptation Strategies Series (Climate Action Initiative) | - | Strategic document addressing agriculture and climate change in the Fraser Valley region. Issues of stormwater and runoff are addressed, and overall strategies and action items are addressed. |

## 2.3 Senior Government Regulations and Guidelines

The following Provincial regulations and guidelines relate to stormwater management in the Study area:

- Agricultural Land Commission Act
- Dike Maintenance Act
- Drainage, Ditch and Dike Act
- Drinking Water Protection Act
- Environment and Land Use Act
- Environmental Assessment Act
- Environmental Management Act (including Waste Discharge Regulation)
- Fish Protection Act (and Riparian Areas Protection Act)
- Integrated Pest Management Act
- Water Protection Act
- Water Sustainability Act
- Stormwater Planning: A Guidebook for British Columbia (2002)
- Guidelines for Preparing Liquid Waste Management Plans (2011)
- Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia (2010)
- Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia
- Standards and Best Practices for Instream Works (2004)

The following Federal regulations and guidelines relate to stormwater management in the Study ***area***:

- Canadian Environmental Assessment Act
- Fisheries Act
- Canada Water Act
- Pest Products Control Act
- Canadian Environmental Protection Act
- Species at Risk Act
- Canada Wildlife Act
- Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat

# 3 LAND USE

## 3.1 General

The Willband Creek watershed is located within the heart of Abbotsford. It includes much of the City's core urbanized area, and also extends into the Agricultural Land Reserve (ALR). Existing developed areas are shown on **Figure 1.1** (Study area).

There is a tremendous diversity of land uses within the watershed. Major land uses include residential, commercial, industrial, agricultural, institutional, and park and school uses. Based on infrastructure records in the City's online mapping system, much of the urban development within the Study area was built in the 1970's and early 1980's, placing it around 30 to 45 years old; however, there are some older portions in the Historic Downtown north east of Mill Lake.

The study area is already heavily urbanized with a high impervious fraction; largely absent of stormwater controls. The City's future Land Use Plan, from the 2016 Official Community Plan (OCP), is shown on **Figure 3.1**. And within the OCP the City Centre and Historic Downtown area is envisioned as "the area with the most redevelopment and intensification of uses" as depicted in **Figure 3.2**.

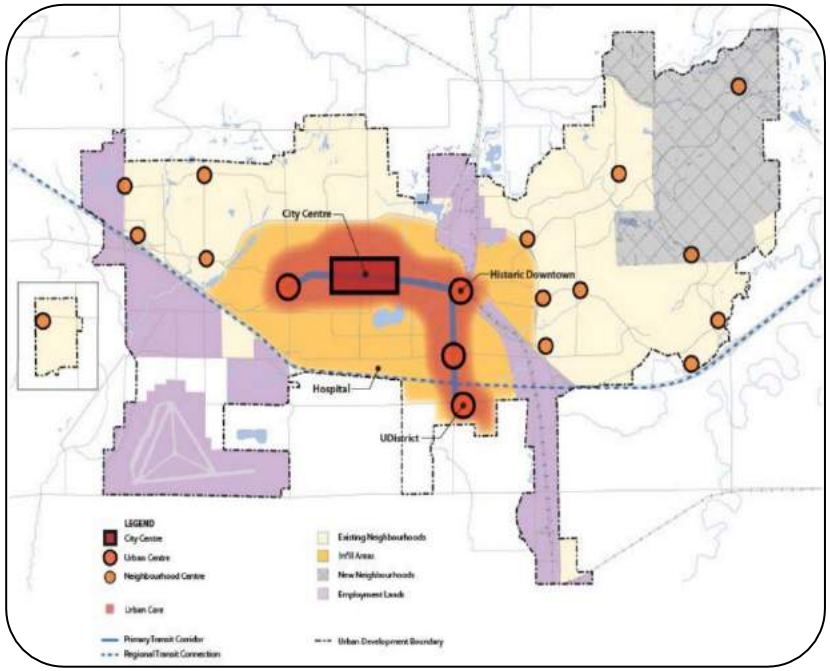
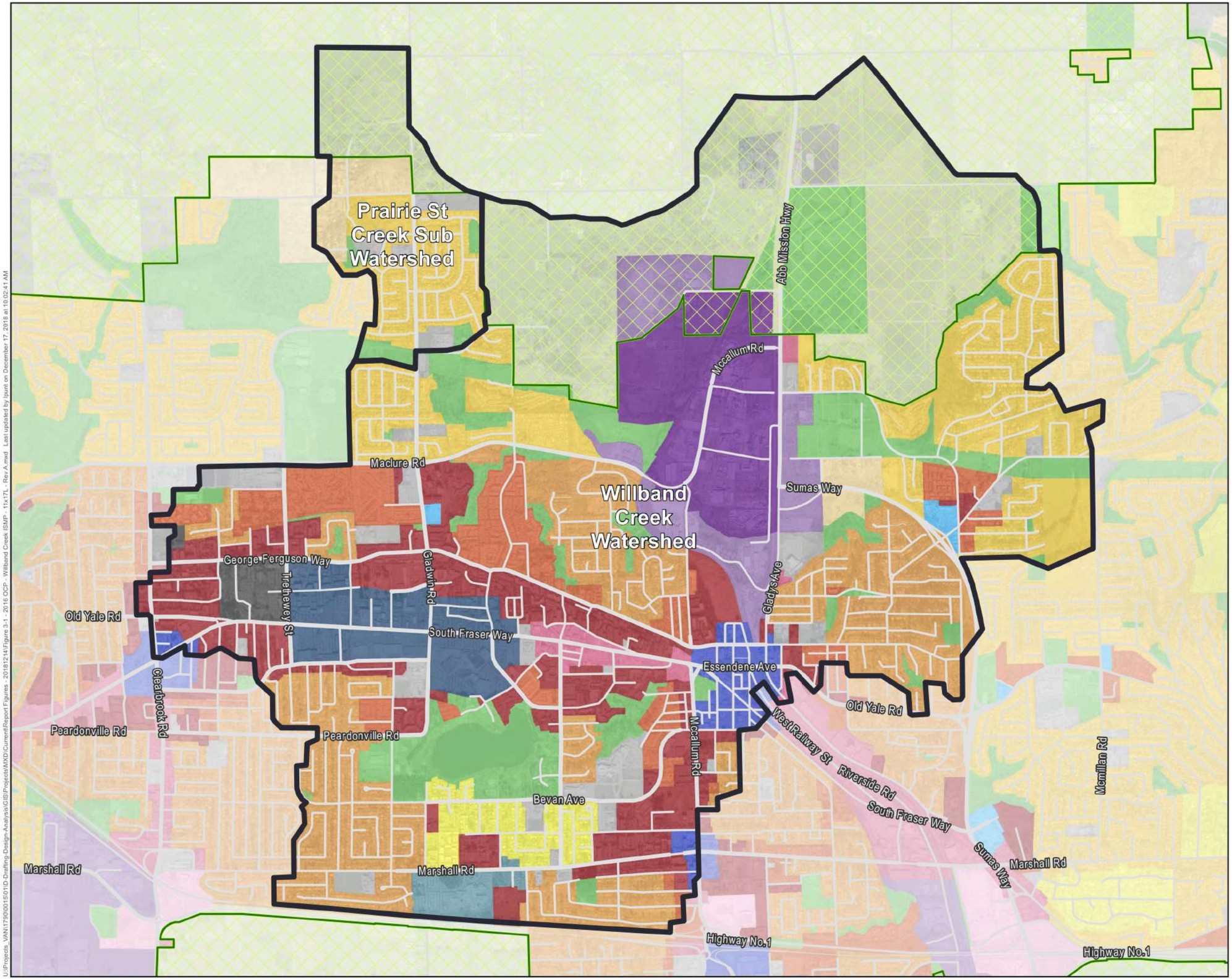



**Figure 3.1 - Future Urban Structure Map (City of Abbotsford 2016 OCP)**

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Willband Creek
Integrated Storm Water
Management Plan

**OCP (2016) Land Use Plan**

- Willband Creek Watershed
- City Centre
- Urban Centre
- Neighbourhood Centre
- Urban 1 - Midrise
- Urban 2 - Ground
- Urban 3 - Infill
- Urban 4 - Detached
- Urban Large Lot
- Suburban
- Secondary Commercial
- Regional Commercial
- General Industrial
- High Impact Industrial
- Hospital
- Institutional Complex
- Institutional
- Agriculture
- Open Space
- Agricultural Land Reserve

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Metres

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| Project #: | 1790.0015.01 |
| Author: | LP |
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| Status: | FINAL |
| Revision: | A |
| Date: | 2018 / 12 / 17 |

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**FIGURE 3.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\12\14\Figure 3-1 - 2016 OCP - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on December 17, 2018 at 10:02:41 AM

The Willband Creek watershed wholly or partially covers the following neighbourhoods:

- City Centre;
- Fairfield;
- Marshall – McCallum;
- Historic Downtown;
- Hazelwood;
- South Clearbrook;
- Immel – McMillian; and
- Clayburn

### *City Centre*

City Centre is located at the western end of the watershed, northwest of Mill Lake. It is defined by its primary arterial, South Fraser Way, which runs east/west through the core of the neighbourhood. The predominant land use along South Fraser Way is low density, car-oriented, commercial development. On the ground, this takes the form of shopping centres, large parking lots, and large format retail stores. Due to the nature of the development, the area is heavily urbanized, with a significant amount of impermeable surface area with very few trees or natural areas. This core commercial area is surrounded by a mix of single-family infill development to the south and multi-family development to the north. It also includes some institutional uses, including City Hall.

Moving forward, this area is anticipated to experience significant change in its form, character, and land uses: the 2016 OCP has designated this area as the new 'city centre', envisioning a higher density, walkable, mixed-use form of development. This will occur through substantial redevelopment of the existing commercial sites, which will present a significant opportunity to influence stormwater management practices in this key area.

Additionally, the southern end of Clearbrook Centre has been identified for small-scale residential infill, which will moderately increase density in these existing single-family areas.

### *Marshall- McCallum, South Clearbrook*

Along the south edge of the watershed is the Marshall – McCallum and South Clearbrook neighbourhoods which includes a hospital and mixed density residential between Highway 1 and Mill Lake.

This area is to see increased densification and residential infill. One of the few areas remaining the same will be the existing single-family area immediate south of Mill Lake, which has been designated for 'urban large lot' residential use.

### *Historic Downtown*

This Historic Downtown is predominantly a walkable mix of urban shops, restaurants, and services. Beyond the downtown, the neighbourhood contains a substantial amount of moderate-to-low density residential development.

It is envisioned in the 2016 OCP that this area retains its general form and character, with moderate change coming in the form of residential infill in the existing single-family neighbourhoods to the south and east of the historic downtown. The historic downtown has been designated as an 'urban centre' under the OCP, which may include an introduction of higher density mixed use development (currently, development is predominantly one to two storeys). The existing commercial area along Highway 11 has been designated for 'secondary commercial' use and will therefore retain its general character.

The Historic Downtown has posed a particular challenge from a stormwater management perspective because zoning permits building coverage with zero setbacks from the property lines, not providing land space beyond the building footprint for on-lot management techniques.

***Hazelwood***

Hazelwood is the north central portion of the study area. From a land use perspective, Hazelwood is defined by its industrial area – a mix of general and high impact industrial and one of the largest in the City. The 2016 OCP has designated a substantial portion of land west of Willband Creek – currently undeveloped and designated as 'high impact' industrial uses.

From a natural perspective, this area is at a key intersection of the Willband Creek watershed, where many of the watershed's various creeks, brooks, and outflows converge on their way to Willband Creek Park, including an engineering detention and park facility.

***Clayburn and Immel – McMillian***

The north-eastern portion of the Willband Creek watershed includes portions of the Clayburn and Immel – McMillian neighbourhoods. These lands include ALR, industrial, and low density residential. Moving forward, it is envisioned in the OCP that the area within the ALR remains; however, 'general' industrial uses will be introduced across Highway 11, adjacent to the newly designated 'high impact industrial'.

## 3.2 Impervious Surfaces

Hydrologic functions are directly related to the relationship between impervious and pervious surfaces; therefore, it is important to consider the "total impervious area" (TIA) in the Study area. To compute this value, the 2016 aerial photograph for the study area was processed with GIS tools, the results of which are presented on **Figure 3.3** and summarized in **Table 3.1**.

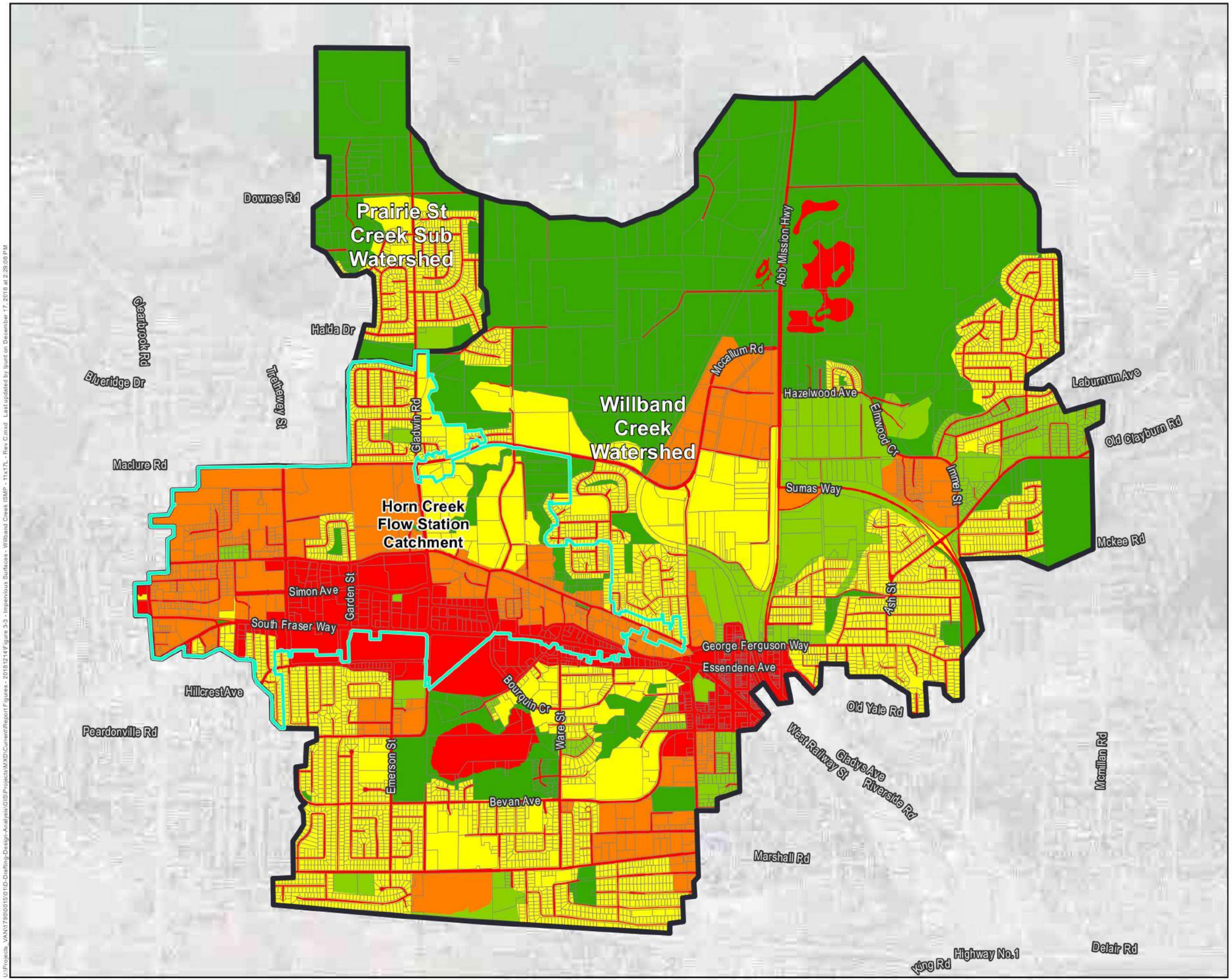
**Table 3.1 - Total Impervious Area - Existing Land Use Conditions**

| Area | Total Area (ha) | Impervious Area (ha) | TIA (%) |
|---|---|---|---|
| Prairie Creek | 130 | 37 | 28% |
| Horn Creek Flow Station Catchment | 330 | 227 | 69% |
| Willband Creek Remained | 1,380 | 558 | 40% |
| **Total Study area** | **1,840** | **822** | **45%** |

## 3.3 Issues and Opportunities

Preliminary OCP directions indicate that in the coming years the City will be placing a strong emphasis on redevelopment, particularly in and around South Fraser Way. This involves shifting future development patterns away from the existing low-density, car-oriented development toward a more compact (i.e., dense), walkable, and sustainable form of development.

Such a shift presents a tremendous opportunity for stormwater management, as it provides the opportunity to implement source controls where they do not currently exist. However, challenges also occur due to increased building footprints and less area for surface-based rainwater management systems. Another challenge is the relative slow speed at which change will occur if left to redevelopment alone to address problems. For example, erosion persists in Horn Creek and Boa Brook, and while redevelopment within the catchment provides a great opportunity to improve conditions through the implementation of source controls, it will likely take many years to see enough redevelopment occur to significantly diminish the erosion. The City may need to intervene with communal solutions to address significant problems.

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Willband Creek
Integrated Storm Water
Management Plan

**Impervious Surfaces**

Willband Creek Watershed
Horn Creek Flow Station Catchment
Parcel

Total Impervious Percentage

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

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Metres

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| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2018 / 12 / 17 |

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**FIGURE 3.3**

U:\Projects_VAN\1790\0015\01\0-Drafting\Design\Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\1214\Figure 3.3 - Impervious Surfaces - Willband Creek ISMP - 11x17L - Rev C.mxd Last updated by lpunt on December 17, 2018 at 2:29:08 PM

# 4 ENVIRONMENTAL CONDITIONS

## 4.1 Potential Impacts of Development on the Environment

Historic development has significantly altered the aquatic habitat, primarily due to the removal of riparian vegetation, a change in creek flow inducing channel erosion (eg. Horn Creek and Boa Brook), and in some cases channel infill with pipes, such as through the Historic Downtown.

In some cases, barriers restrict fish access (e.g., the Trafalgar Street culvert on Horn Creek). Additionally, development has impacted water quality. With exception to the Mill Lake Ravine system, barrier to fish can be removed with comparable ease. A summary of the aquatic habitat features is presented on Figure 4.1.

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.

Development has also affected terrestrial habitat. As would be expected in an urban setting, the majority of the formerly forested areas have been removed. Some habitat value has been re-established with landscaping, but this habitat is fragmented and largely consists of non-native species. In turn, non-native vegetation can affect the conditions and diversity for native birds and wildlife.

## 4.2 Background Review and Field Investigations

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, and well assessments completed within and adjacent to creeks for infrastructure projects.

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

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.
- September 2017 – Benthic sampling

## 4.3 Conditions

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 (see **Figure 4.1**). 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 Street Creek is the main habitat feature in its sub-watershed.

A description of stream habitat quality is defined in **Table 4.1**.

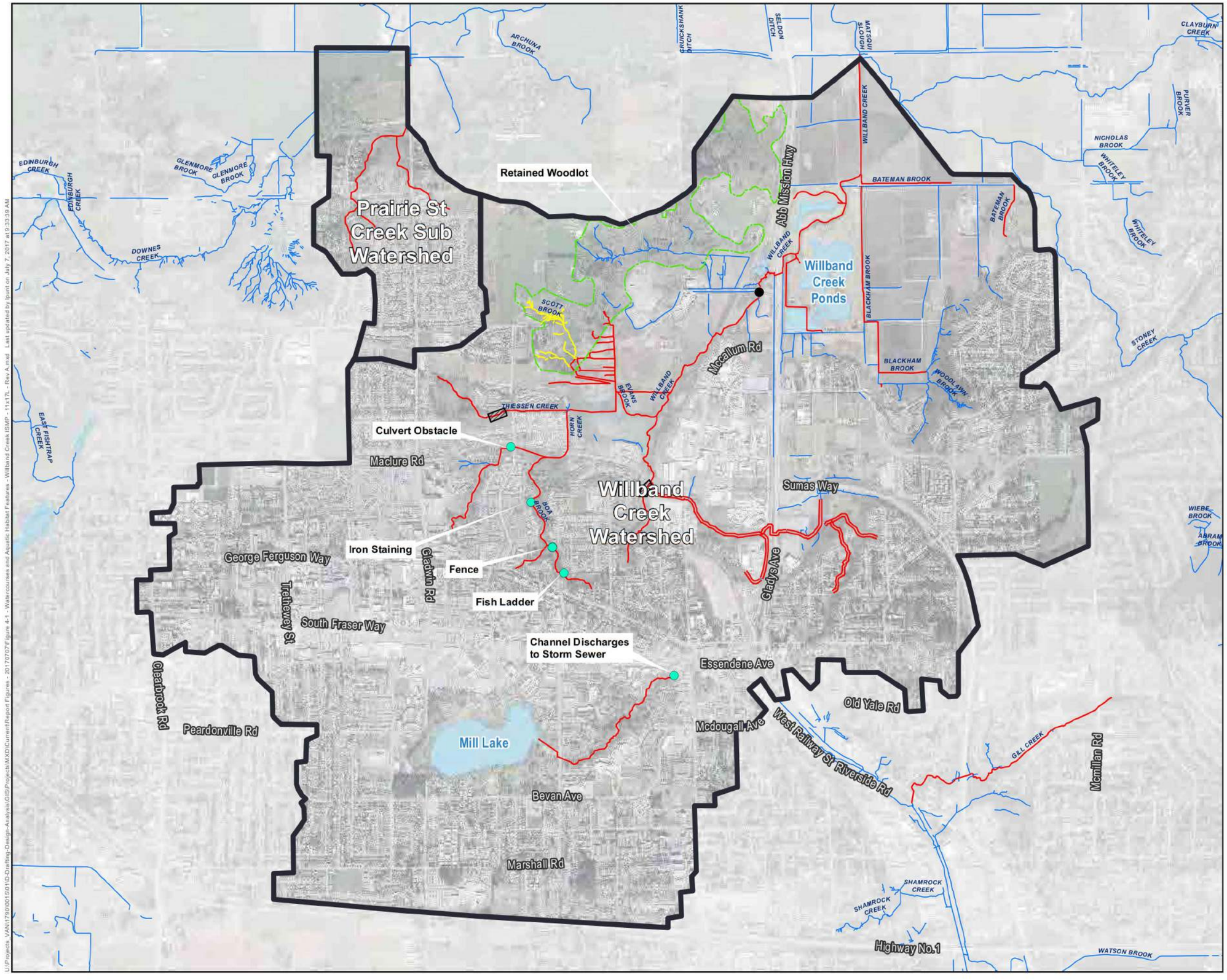
**Table 4.1 - Description of Stream Habitat Quality**

| 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. |

Watercourse classifications, as defined by the City, are presented on **Figure 4.1**. The definitions of watercourses that are represented in the Study area are provided in **Table 4.2**. The complete classification system is attached as Appendix B.

**Table 4.2 - Watercourse Classification Relevant to the Willband Creek Watershed**

| Class | Sub-Class | Definition |
|---|---|---|
| Red (A) | Red (A)-P | Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply. |
| Red (A) | 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) | 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 period. |
| Blue | N/A | Creeks, streams, and channels with unconfirmed classification |

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## Watercourses and Aquatic Habitat Features

- Willband Creek Watershed
- Woodlot Extent
- Detailed Reach Assessment
- Water Quality Sampling Location
- Site Specific Features

Fish Classification

- Class 'A' - Fish-bearing watercourses with permanent (i.e. flow for >6 months)
- 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
- 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

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.

0 145 290 580 870
Metres

N

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,010

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2017 / 7 / 7 |

URBAN systems

FIGURE 4.1

L:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20170707\Figure 4-1 - Watercourses and Aquatic Habitat Features - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurton July 7, 2017 at 9:33:39 AM

### 4.3.1 Willband Creek

Willband Creek is comprised of a number of tributaries. The western tributary of Willband Creek originates near Babich Place upstream of Maclure Road and 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. Riparian vegetation was well-established with a mixture of mature and young growth stages. Invasive species presence was generally limited to the vicinity of Maclure Road. The tree canopy was predominantly deciduous. No records of fish presence in the western tributary were identified in the background review. One Chinook fry and lamprey were collected during the May 2017 detailed site assessments, which are attached in Appendix C. 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.

The eastern tributary has several sub-tributaries but 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. Tree presence and riparian quality are impacted by adjacent development.

Habitat quality of the eastern tributary network was considered fair to good overall.

The lower reaches of the Willband Creek mainstem (i.e., downstream of Maclure Road) can be characterized as a permanent, low-gradient, gently meandering channel. Complexity was generally low. 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 are located within this reach. The ponds are exposed with limited riparian canopy coverage. As such, water quality could be compromised, particularly during the summer.

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. Riparian vegetation was established along the channel although in some places it had been cleared to the top-of-bank for agricultural use. 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.

Based on past sampling efforts, the lower reach of Willband Creek provides habitat for many species of fish. As such, the channel has been assigned a classification of Red (A)-P. Despite the impacted riparian area, given the varied fish presence this reach has been assessed as providing fair habitat value.

### 4.3.2 Blackham Brook / Bateman Brook

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.

Bateman Brook has been channelized as a linear, roadside ditch along the south side of Bateman Road. 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.

Given that salmonids have been sampled in previous summers, these channels have been classified as Red (A)-P.

### 4.3.3 Evans Brook

Evans Brook originates in a marshy area south of the terminus of Valley Road. It is conveys flow from both Thiessen Creek and Scott Brook into Willband Creek. Overall habitat quality within Evans Brook was observed to be fair. The channel was 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.

A small, unnamed channel is confluent with Evans Brook immediately north of the Industrial Avenue right-of-way. 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 than fair.

### 4.3.4 Scott Brook

Scott Brook originates within a small ravine in a forested patch north of the Old Riverside Road alignment. 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. Overall, habitat value has been rated as moderate despite the well-developed riparian area and moderately complex channel.

### 4.3.5 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 detailed reach assessment in Appendix C). As such, the channel has been classified as Class Red (A)-P (see Figure 4.1).

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.

### 4.3.6 Horn Creek

The mainstem of Horn Creek originates in Horn Creek Park near Nelson Place. Flow is conveyed in a generally northern direction to Maclure Road. 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. Despite the possible restrictions on fish access, Horn Creek provides excellent value fish habitat. It should be noted that erosion is a concern within Horn Creek.

### 4.3.7 Boa Brook

Boa Brook originates on private properties immediately north of George Ferguson Way. 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. The tree canopy may be described as mixed forest with varying age classes. Coniferous species were more prevalent in the upper reaches. 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. 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.

### 4.3.8 Mill Lake and Mill Lake Outlet Channel

Mill Lake is fed 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.

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.

Fish species include largemouth bass and rainbow trout, 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.

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. Fish habitat quality is fair in the channel due to the comparatively low depth and complexity. It may

be able to sustain a fish population in sections of the channel, particularly if larger pools were present., but given the lack of access from the bottom and poor water quality discharging from Mill Lake, it is expected that any resident fish population would be vulnerable to extirpation.

### 4.3.9 Prairie Street Creek

The Prairie Street Creek system originates as two secondary channels in a residential area south of Downes Road. Limited effort has been made to sample for fish within Prairie Street 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.

## 4.4 Mill Lake Water Quality

Limited water quality data were 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 and included:

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

The results indicated that each parameter was either at or below what is considered “typical” for urban stormwater runoff. However, the report indicated potential for metals to accumulate in the sediment where it could be taken up by bottom feeders and work 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 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, 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. There is no applicable standard for freshwater aquatic life for coliforms; it is primarily a concern if recreational contact is made with the water.

One round of water quality sampling was conducted on August 29, 2016, as part of this ISMP and compared against BC Approved or Working Water Quality Guidelines and the Canadian Council of Ministers of the Environment Water Quality Guidelines. The results indicate (refer to Appendix C) that very few of the parameters exceeded limits for freshwater aquatic life. Many were below detection limits. Two parameters exceeded standards. DO was lower than the standard for buried embryos/alevins. This is 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. Given that there is no standard for freshwater aquatic life, this is not a concern unless the channel is used for recreational use. The data collected for this project are 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.

## 4.5 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.

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.

Terrestrial habitat within the Study area has been significantly impacted from urban development.

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.

### 4.5.1 Invasive Plant Species

The following plant species were observed during the site assessment or are listed in the provincial Invasive Alien Plant Program database and are considered invasive:

- Himalayan blackberry
- Lamium
- Scotch broom
- Policeman's helmet
- Reed canary grass
- 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. 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.

## 4.6 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. Species that are well-adapted to urban environments (e.g., raccoon, skunk, coyote) are also expected to be present.

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.

## 4.7 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.

In general, the best habitat for birds, particularly passerines (perching birds), is in the 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.

## 4.8 Herptiles (Amphibians and Reptiles)

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).

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. There are reports of presence of western painted turtle in Mill Lake. Pacific tree frogs were heard calling in the vicinity of Scott Creek during the site assessment. No additional herptile sign was observed.

## 4.9 Rare Species Presence and Potential

Through a review of the records and resources 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 4.3** below.

**Table 4.3 - Rare Species Presence or Potential**

| 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

## 4.10 Watershed Health

The Watershed Health Tracking Score in Metro Vancouver's Template for Integrated Stormwater Management Planning 2005 (KWL, 2005) was applied to measure watershed health. The score is assessed by plotting Total Impervious Area (TIA) against Riparian Forest Integrity (RFI). As previously described, TIA is a measure of the impervious surface in the watershed where there is no infiltration of storm water into the ground. 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. The resulting mapped riparian areas are presented on **Figure 4.2** as "intact forested area within buffer".

The RFI was estimated at 31% for the Willband Creek watershed, most of which is in the ravines in the upper reaches of the watershed. The Prairie Street Creek watershed was estimated as having an RFI of 54%. TIA was measured as 37% and 26% for Willband Creek and Prairie Creek, respectively. These values are plotted on **Figure 4.3**.

**Figure 4.3** may also be used to predict the Benthic Index of Biotic Integrity (B -IBI) for the watershed. 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 of 40 would be considered excellent.

As can be seen with **Figure 4.3**, 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 can be expected given the loss of over 70% of the original intact riparian forest and imperviousness over 35%. The predicted B-IBI score for the Prairie Street Creek sub-watershed is 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.

In September 2017, benthic invertebrate samples were collected from four (4) distinct sampling locations in Horn Creek.

Various benthic metrics were calculated for each station to provide insight on 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).

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. These scores indicate an overall “fair” stream condition (**Table 4.4**). 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 because of the diversity of taxa found at all sites.

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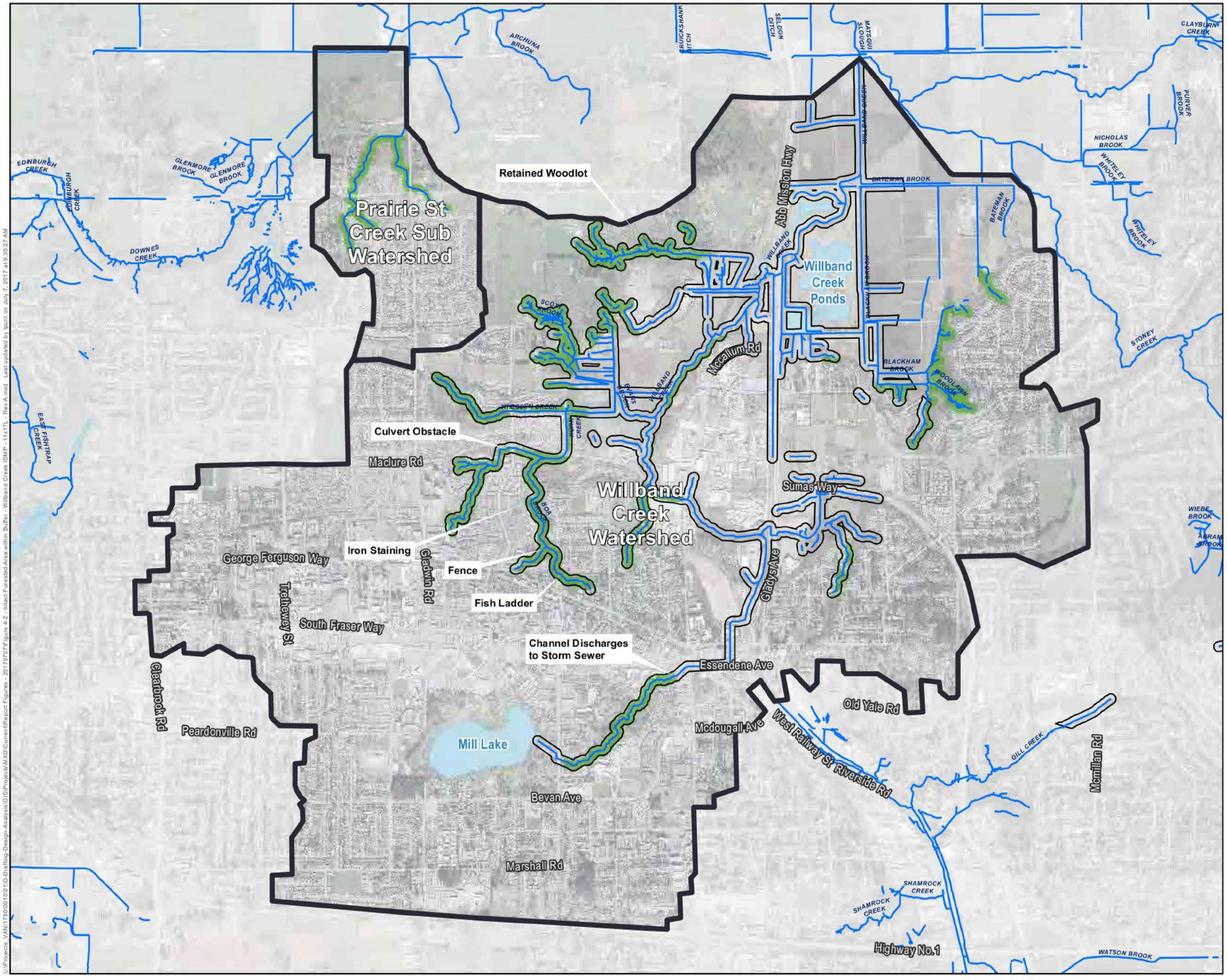
**Intact Forested Area Within Buffer**

Legend

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




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.

0 145 290 580 870
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,010

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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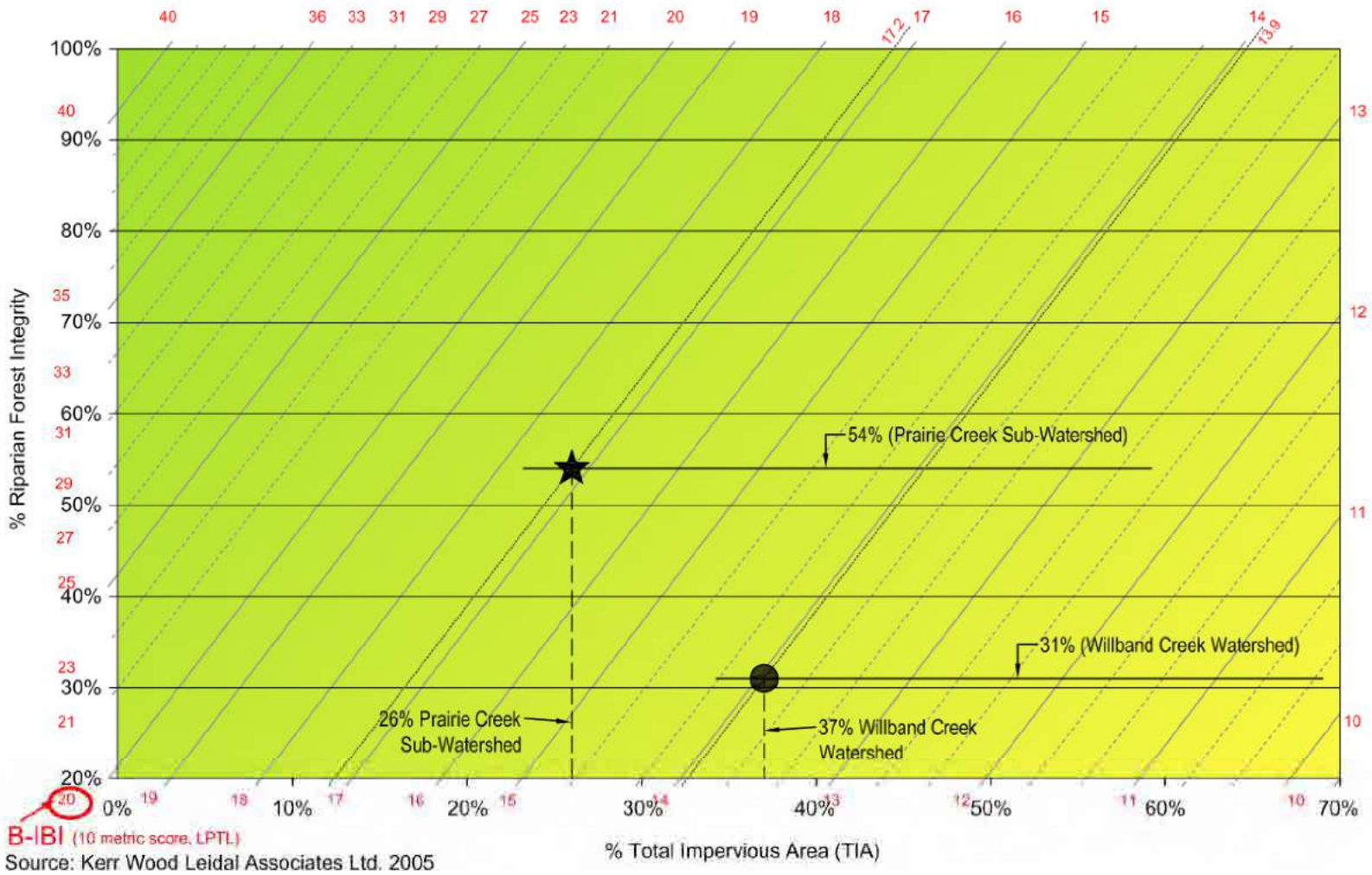
| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2017 / 7 / 7 |

URBAN systems

**FIGURE 4.2**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2017\07\Figure 4.2 - Intact Forested Area within Buffer - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurin on July 7, 2017 at 9:35:27 AM

WATERSHED HEALTH TRACKING SYSTEM - Permanent Flow Creeks




Source: Kerr Wood Leidal Associates Ltd. 2005

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Willband Creek Integrated Storm Water Management Plan

**Watershed Health Tracking Score**

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.

**Data Sources:**
Data provided by Dillon (2017) and Kerr Wood Leidal Associates (2005).

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URBAN systems

**FIGURE 4.3**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20170707\Figure 4.3 - Watershed Health Tracking Score - Willband Creek ISMP - 8x85x11L - Rev A.mxd Last updated by lpunt on July 7, 2017 at 10:21:33 AM

**Table 4.4 - Summary of B-IBI Scores for Horn Creek, 2017**

| Metric | Metric B-IBI Score (1,3 or 5) | | | | | Predicted response due to human impact |
|---|---|---|---|---|---|---|
| | H1 | H2 | H3 | H4 | Aggregate | |
| 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 | |

Taxa richness, overall abundance and %EPT (Ephemeroptera, Plecoptera, Trichoptera) were also calculated for each Horn Creek survey sites (**Table 4.5**). In 2017, taxa richness within Horn Creek ranged from 20 to 25, with an average of 22.5. Overall abundance ranged from 404 to 427, with an average of 417, while %EPT (Richness) ranged from 14% to 28% throughout the creek.

**Table 4.5 - Additional Analysis for Horn Creek, 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 4.4** 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%).

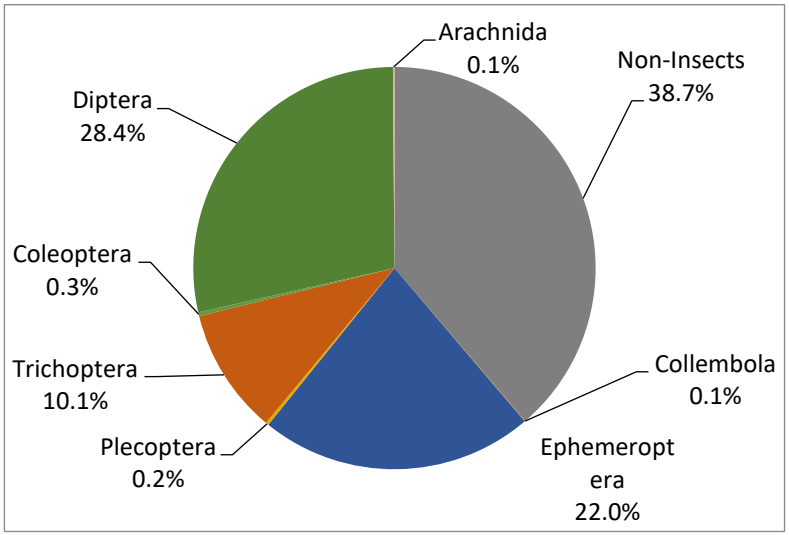



**Figure 4.4 - Horn Creek Community Composition, 2017**

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

**Discussion of 2017 Horn Creek Data**

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 sites 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 system.

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 (i.e., drought, etc.) from human-induced impacts (i.e., urbanization, tree removal, etc).

The benthic summary is attached as **Appendix C**.

## 4.11 Opportunities and Constraints

There are opportunities (and related constraints) available to the City to improve the habitat value in the Study area.

### 4.11.1 Riparian Infill

Riparian infill consists of the installation of native vegetation in areas currently lacking riparian vegetation. In particular, this consists of the Willband Creek lowlands north of Maclure Road. Native vegetation would significantly improve habitat for both aquatic and terrestrial species. Constraints and disadvantages include:

- Expense
- Limitations to plant trees within the BC Hydro corridor in Lower Willband Creek, and
- Land Owner and buy-in by property owners. Fish Access Improvements

### 4.11.2 Fish Access Improvements

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 or retrofitted with fish ladders to improve access. Such improvements would only be done where the channel itself is not a barrier and offers good 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.

### 4.11.3 Habitat Construction

Habitat could be constructed in areas where adequate land is available, such as on Lower Willband Creek. 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
- Off-line pools can lead to localized increases in water temperature if not adequately buffered by riparian vegetation.

### 4.11.4 Instream Maintenance

The removal of garbage and other anthropogenic 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.

### 4.11.5 Mill Lake and Creek Daylighting

There are options for improving 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 and if confirmed through sampling, disposal at a designated facility would be required at a potentially significant cost.

Daylighting the Mill Lake outlet channel represents a significant opportunity, and also a significant challenge that is likely impractical to consider. The cost and impact to built land would be extreme. However, the culvert currently in place is critical piece of infrastructure that may be vulnerable and costly in itself to repair if in poor condition. This culvert is discussed further in subsequent sections.

## 4.12 Environmental Condition Summary

Aquatic habitat in the study area has been significantly impacted by past land use activities. Riparian forest has been removed, sections of channel have been enclosed, fish access has been restricted in places, and erosion persists in some streams. Despite these impacts, salmonid presence has been confirmed for every channel. Riparian forest is often intact with the upland ravines of Horn Creek, Boa Brook, and Thiessen Creek. 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 is 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.

Overall, the conditions across the watershed are highly varied and the high-quality components are outweighed by the poor-quality components. Overall, the watershed health is considered poor based on Metro Vancouver standards.

## 4.13 Implementation Challenges to Consider

It is evident that the City is placing an increased emphasis on environmental planning and protection. This is demonstrated by the work of its dedicated Environmental Coordinators, its robust Natural Environment Development Permit process, a range of regulatory Bylaws (i.e. ESC, Streamside, Tree Protection), and an increased focus on enforcement by Building Department inspectors.

At the same time, this effort has not been seamless. Developers and individual property owners often do not fully understand the purpose of the City's environmental protection measures – rather, they see it as an increased expense and burden. The emphasis on enforcement has placed additional strain on the Building Department inspectors, who must enforce measures they might not fully understand or feel comfortable with them. Further identifying, understanding, and

addressing these ‘gaps’ between policy direction and on-the-ground implementation will be essential to a successful ISMP. The City recognizes the need for improved regulatory tools, such as broader application of stormwater source controls to guide infill development.

# 5 GEOTECHNICAL AND HYDROGEOLOGY CONDITIONS

## 5.1 General

The surficial geology of the Study area was mapped at a regional scale by the Geological Survey of Canada and published in 1980 (GSC Map 1485A). The geologic conditions within the Study area are complex and heterogenous. Surficial sediments are underlain by the Eocene-aged Kitsilano Formation. The Kitsilano Formation is a sedimentary bedrock sequence consisting of sandstone, siltstone, shale, conglomerate, and minor volcanic rocks.

Most of the surficial sediments within the Study area are associated with the repeated advance and retreat of glaciers. During glacial periods, sea levels were significantly higher relative to the land surface, which was depressed under the weight of the ice-sheet. During and following deglaciation, the land surface rebounded upward. Increased rates of sediment erosion and deposition were likely associated with this period of relatively rapid uplift and resulted in the initial formation of many of the ravines and alluvial fans observed today. The rates of erosion and deposition likely have subsided since the most recent deglaciation, as the rate of uplift decreased and mature forests developed.

Modern day river (Fluvial) and hill-slope (Colluvial) processes continue to shape the landscape by eroding and depositing sediments. Anthropogenic deposits (i.e. fill) is present near surface for some of the Study area.

### 5.1.1 Surficial Geology

Bedrock is generally overlain by thick glaciomarine and marine sediments composed predominantly of clay and silt from the Fort Langley Formation. This unit is present at depth throughout the Study area and is only mapped at surface in the southwest corner of the Study area.

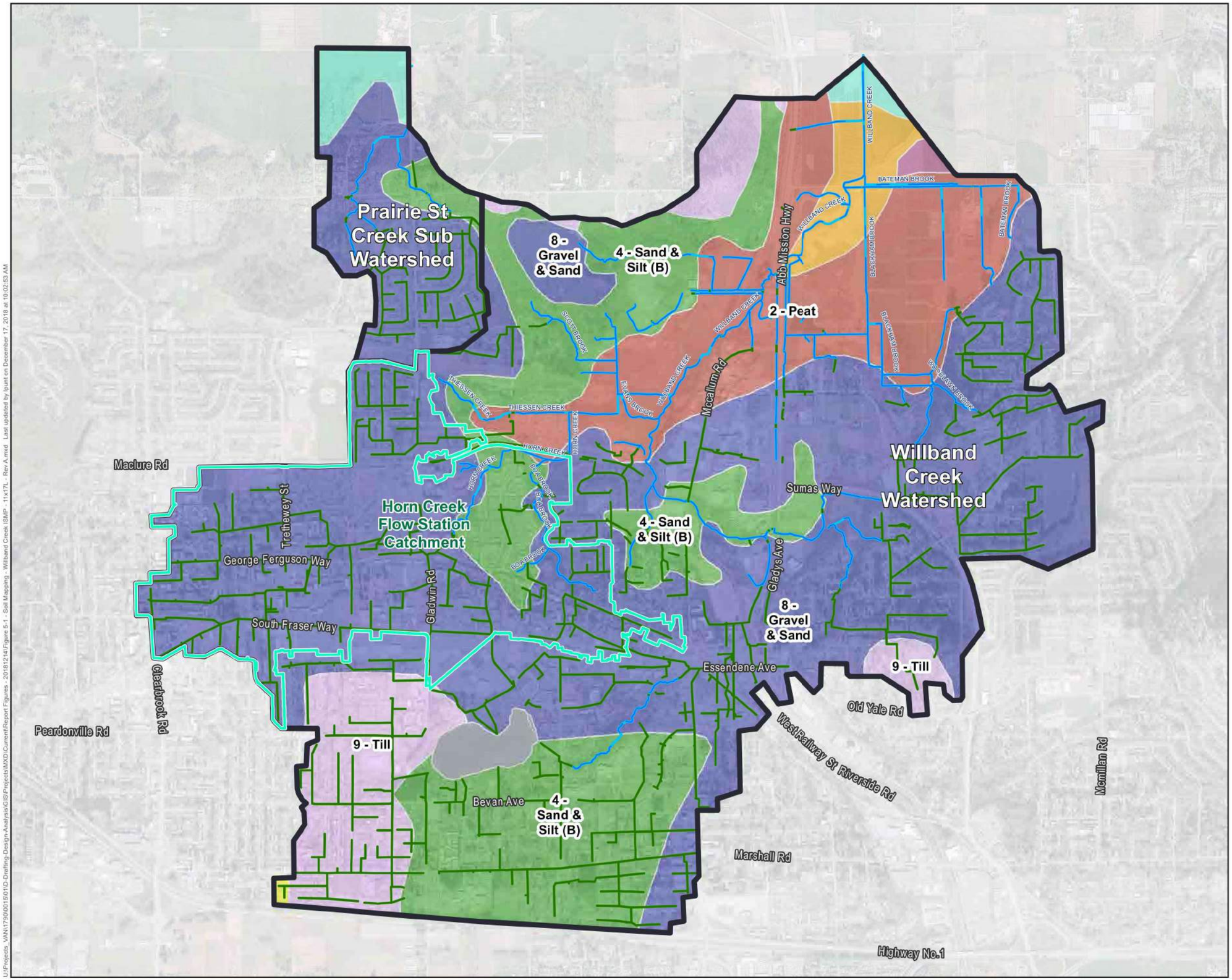
In the uplands, Fort Langley Formation is overlain by Sumas Drift, which consists of sequences of proglacial outwash sands and gravels up to 40 m thick. The area is mantled with eolian deposits consisting of windblown sand, silt, and silt loam. Lodgment and minor flow till composed of sandy till and sub-stratified drift between 2 and 10 m thick is mapped in the east portion of the Study area.

The lowlands consist of complex interfingering of postglacial Salish Sediments and Fraser River Sediments, which include of sequences of peat, organic silt loam and silty clay loam, and stratified clays, silts and sands, respectively.

### 5.1.2 General Hydrogeologic Conditions

A conceptual hydrogeological model is a qualitative representation of a Study area which is used to describe the flow of groundwater through the subsurface. In the context of the ISMP, a conceptual model provides an improved understanding of the interactions of surface and groundwater and can be used to identify opportunities for enhanced stormwater infiltration (groundwater recharge).

The process of developing a conceptual model includes subdividing the subsurface into hydrostratigraphic units (e.g., aquifers and aquitards) based on their relative estimated hydraulic properties. Conditions which bound the system are identified, including: established groundwater levels, surface water bodies, and watercourses, and areas of groundwater recharge and discharge.

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Willband Creek
Integrated Storm Water
Management Plan

**Soil Mapping**

Legend

- Willband Creek Watershed
- Horn Creek Flow Station Catchment
- 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

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**Coordinate System:**
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**Scale:**
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**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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**FIGURE 5.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\12\4\Figure 5-1 - Soil Mapping - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:02:53 AM

can be correlated with Fort Langley Formation, and low permeable Salish and Fraser River Sediments located in the Lowlands. This hydrostratigraphic unit is present at surface in the lowlands and is locally overlain by the Lowland Aquifer.

***Unit 2 – Upland Aquifer***

The Upland Aquifer is a partially confined aquifer that can be correlated with Sumas Drift, eolian- deposited Salish Sediments and well drained Shallow Soils. This unit is mapped at surface and is unconfined through most of the Study area but is confined in some areas where it is capped by low permeable fill, till or colluvium.

***Unit 3 – Intermediate Sand & Gravel Aquifer***

This unit is defined as a partially confined aquifer. It consists of complex sequences of sand and gravel material interpreted as Sumas Drift glacial outwash and till. It is hydraulically connected to the Upland Aquifer. In some areas, the unit is partially confined between the Clay Aquitard and local till, and bedrock.

***Unit 4 – Fractured Bedrock (Kitsilano)***

This unit consists of fractured bedrock that underlies the other units within the Study area, and it consists of the Kitsilano Formation.

***Unit 5 – Lowland Aquifer (Salish, Fraser River)***

This unconfined- to-confined aquifer consists of surficial geological units interpreted to be composed of silts and sands from the Salish Sediments and Fraser River Sediments. The unit is complex, and its materials consist of poorly drained shallow soils, peat, and interbedded mixtures of sand and silt, and clay. There are no water wells reported to have been drilled into this unit. Locally perched water tables are present where permeable materials overlie less permeable soils.

### 5.1.5 Provincial Aquifer Mapping

The extents of the aquifers could not be mapped in detail within the scope of this study and due to limited available data. To support the management of groundwater, the British Columbia Ministry of Environment (MOE) has published an online tool (BC Aquifer Classification System), which provides limited two-dimensional (2D) mapping and aquifer classification. The boundaries of the aquifers mapped by the Province are likely based on limited data. Further, there are likely additional aquifers within the Study area that are unmapped.

## 5.2 Groundwater Hydrology

Water table elevations were compiled from water well records, provincial monitoring well data, and other consultant reports.

### 5.2.1 Uplands

Water well and geotechnical test hole data indicate that static groundwater elevations in the uplands vary between about El. 42 m to El. 70 m. Water well records from the BC Wells Database, and soils reports from the City indicate that groundwater is relatively shallow, usually less than 10 m below ground surface. Seasonal groundwater fluctuations range between 1.0 m and 3.0 m from static at Provincial Monitoring Wells located outside the Study area, and groundwater recharge response to precipitation events occurs within 1 to 2 days of rainfall events.

### 5.2.2 Lowlands

Geotechnical test hole data indicates that static ground water elevations in the lowlands vary between about El. 3 m to about El. 28 m. Groundwater depths in the lowlands are typically within 3 m of

ground surface, and are often at or within 1 m of ground surface. There are few water well reports in the BC Wells database for wells located in the lowland areas. Static water level is shallow, and ponding occurs in areas during periods of high intensity rainfall.

Water levels may drop over the summer, but are quick to rise after continued rain. Ponding water is slow to dissipate, and has been observed by others to last longer than it has in the past. Regions mapped as having annual or seasonally high water tables, perched water tables, or those prone to flooding are unlikely to provide adequate drainage.

Groundwater levels in the lowlands may be artificially influenced through controls in the drainage system that force storage for the purposes of agricultural irrigation, which is typically done May 15 through September 15.

### 5.2.3 Groundwater Flow

An understanding of the interactions between groundwater and surface water is important to the effective management of the Study area. Precipitation and surface water are regarded to be the widespread sources of groundwater recharge in the area. In turn, surface water is likely recharged by precipitation and groundwater baseflow. Groundwater baseflow likely becomes the dominant source of recharge during longer periods with no precipitation.

The Upland area is drained by various creeks which have incised into the terrain draining into the Lowlands. These creeks are supplied with water from precipitation, and small wetlands and lakes distributed across the surface of the Uplands. The primary natural drainage in the lowlands is Willband Creek, which drains northward into Matsqui Slough. Willband Creek is supplied with water from tributary creeks. Mill Lake is likely supplied with contributions from groundwater and precipitation, which fluctuate seasonally.

Gradients suggest groundwater flows towards creeks in some areas. Precipitation is likely the dominant source of flow in the creeks for much of the year, and creek flow may contribute to the recharge of groundwater in upland areas where groundwater levels are deeper.

In the summer months when there is little precipitation, groundwater discharge is likely an important source of recharge to many creeks in the region (baseflow or gaining stream), especially in lower elevation areas where groundwater is relatively shallow. Watercourses may dry up when static water table deepens over the summer and when there are long periods with no precipitation.

Where shallow aquitards or local impermeable surficial soils are present, infiltrating precipitation may remain in local perched aquifer subunits and flow laterally as interflow or throughflow rather than recharging deep aquifers. Groundwater discharge in sloping areas in the form of surface seepage is possible due to throughflow in stratified aquifers (e.g. Upland Aquifer, Intermediate Sand & Gravel Aquifer). Deep aquifers may receive significant recharge from precipitation where they are unconfined. Upward and lateral flow of groundwater from bedrock may also contribute to the recharge of deep aquifers.

Inferred horizontal hydraulic gradients in the uplands suggest groundwater flow generally drains towards the lowlands. The horizontal hydraulic gradient in the lowlands indicate that groundwater flow is generally northward towards the Matsqui Prairie.

The available groundwater data indicate shallow regional groundwater flow is generally consistent with topography and watershed catchments. Data are insufficient to adequately assess vertical hydraulic gradients; however, they are generally inferred to promote the downward movement of water.

## 5.3 Infiltration Rates

Best attempts were made to assign infiltration rates. Areas where there is poor test hole coverage have been assigned a broader range of infiltration rates to account for uncertainty.

Non-native fill may be present in variable thickness overlying the mapped native surficial geology units but is not possible to quantify.

Infiltration rates were estimated for the geologic map units shown on Figure 5.1, and are summarized below in Table 5.1.

**Table 5.1 - Estimated Infiltration Rates**

| Soil Group | Material Type | Estimated Minimum Infiltration Rate (mm/hr) | Estimated Maximum Infiltration Rate (mm/hr) |
|---|---|---|---|
| 2 | Peat | 0.036 | 36 |
| 3 | Silt & Clay (A) | 0.0036 | 0.36 |
| 4 | Silt & Clay (B) | 0.0036 | 3.6 |
| 5 | Sand & Silt (A) | 0.036 | 36 |
| 6 | Sand & Silt (B) | 0.36 | 3600 |
| 7 | Silt & Clay | 0.00036 | 3.6 |
| 8 | Gravel & Sand | 3.6 | 3600 |
| 9 | Till | 3.6 | 360 |

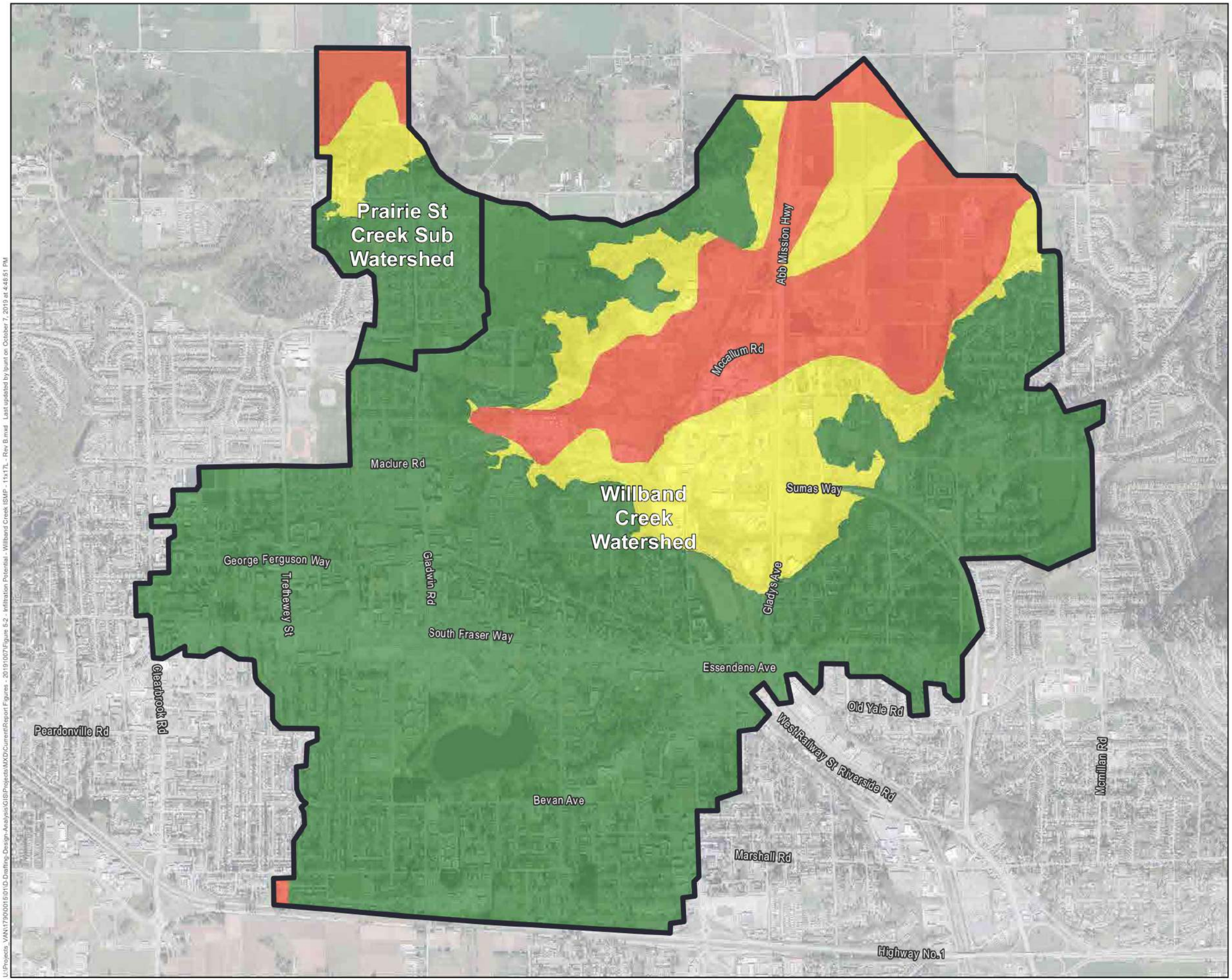
### 5.3.1 Infiltration Potential

One objective of stormwater management is to reduce stormwater runoff and demands on the storm water infrastructure system by implementing source controls. The conceptual hydrogeological model described above provides a framework for high-level screening of areas which have the potential for the enhancement of stormwater infiltration. Factors which influence the potential for infiltration enhancement include: the hydraulic properties of the near-surface sediments and soils, and the existing groundwater levels and soil saturation. In general, 70% of the Study area has good potential, as shown on **Figure 5.2**.

More detailed assessments should be carried out by a qualified professional in areas where stormwater infiltration enhancement measures are considered, however within the scope of this ISMP, the following is a brief discussion of areas where there is potential stormwater infiltration enhancement.

**1** The soils and sediments underlying most of the Lowlands are relatively impermeable with shallow static water table. The area has poor potential for stormwater infiltration. In these locations, organic soils overlay poorly drained silts and clays. Wetlands, ponding surface water, and peat deposits are indicative of high water table and saturated conditions.

**2** An exception is the area south of the Willband Storm Detention Facility near Hazelwood Avenue and Sumas Way which is mapped as Marble Hill soils overlying eolian deposits and/or Sumas Drift (Soil group 8 in Figure 5.1). Available data indicates that static water levels may be greater than 5 m depth within this area. This area may have potential for stormwater infiltration enhancement.

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Willband Creek
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**Infiltration Potential**

Legend

- Willband Creek Watershed
- Good Infiltration Potential (70%)
- Marginal Infiltration Potential (15%)
- Poor Infiltration Potential (15%)

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**FIGURE 5.2**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2019\1007\Figure 5.2 - Infiltration Potential - Willband Creek ISMP - 11x17L - Rev B.mxd Last updated by lpunt on October 7, 2019 at 4:48:51 PM

**3** Abbotsford, and Laxton soils overly well drained Sumas Drift. There is a substantial aquifer at depth to accept infiltrating stormwater, but static water depth is poorly constrained in this area. This means that despite the soils being conducive to infiltration, the high-water table will limit water movement through it.

**4** Upland areas mapped as Lonzo Creek, Ryder and Calkins shallow soils may be subject to perched and shallow water table (less than 5 m depth), as they may overlay less permeable till-like material.

The investigation of stormwater infiltration enhancement must also consider the potential unintended consequences of causing changes to groundwater conditions. Specifically, concentrated stormwater infiltration measures can lead to geotechnical hazards. The best practice management of stormwater should include consideration of these issues. Infiltration enhancement may not be appropriate in some areas of the City, particularly close to steep slopes or where groundwater mounding may cause seepage failures or flooding elsewhere. Areas prone to perched water tables are more susceptible to risk.

## 5.4 Geotechnical Erosion Site Assessment

The City expressed concern for channel erosion at a number of creek segments throughout the Study area. Priority sites were selected for inspection and assessed by Thurber on April 13 and 25, 2017 within the following creeks:

- Boa Creek;
- Horn Creek;
- Thiessen Creek; and
- Willband Creek.

Singular sites were identified on Boa Brook, Thiessen Creek, and Willband Creek. Within Horn Creek there were number of reaches identified where multiple erosion sites existed.

Watercourse Stability Assessment Data Sheets (WSADS) record key information and photographs for each site and are provided in Appendix D.

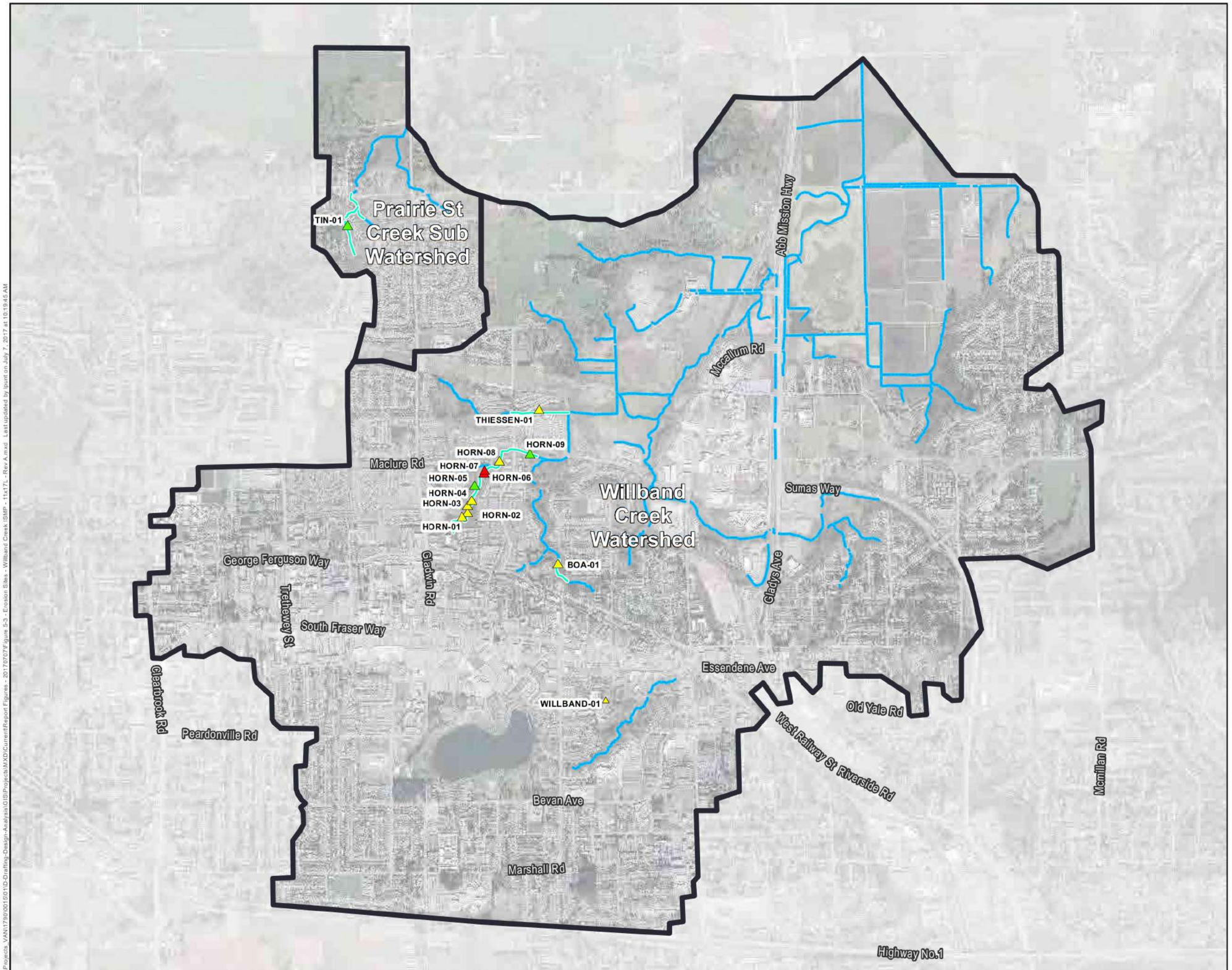
Creek bank erosion and channel migration are natural mechanisms in stream geomorphology and an eroded bank is not necessarily of concern. Conversely, excessive creek bank erosion in an urban environment is often a sign of increased creek flow, typically resulting from accelerated stormwater runoff discharging into the creek from the storm sewer system. Therefore, it was necessary to establish a criterion that would differentiate natural creek bank erosion and that likely caused by increased creek flow as these sites would be vulnerable to further rapid erosion which could lead to ravine slope instability and deposition of sediment into the creek. A 1 m vertical eroded face height on the channel bank was applied as the lower limit for identifying and recording potentially problematic erosion sites.

The overall risk rating is a qualitative assessment based only on visual observations made during the reconnaissance. The rating uses a combination of consequence and severity/likelihood based on engineering judgement and experience. It should be noted that the rating is subjective and may not be directly comparable to the ratings used by others. The rationale for the hazard rating used for this ISMP is described in Table 5.2. The erosion sites are shown on **Figure 5.3**.

The sites within Horn creek were often about 5 m high and in some cases extended 10 m to 20 m in length along the creek. Further, pedestrian walking paths and houses were often near the sites. Retrogression of the erosion features within Horn Creek may pose a risk to residents and infrastructure. No “very high risk” sites were observed during the assessment.

**Table 5.2 - Geotechnical Hazard Risk Ratings**

| Risk | Description |
|---|---|
| Very Low | Site identified primarily for record keeping purposes. Generally, the site conditions are not severe, are not anticipated to change significantly with time, and/or the consequences of continued erosion are very low. |
| Low | Generally, the site conditions are not anticipated to change significantly with time and/or the consequences of continued erosion are low. Site should be checked periodically to reassess risk. |
| Medium | Erosion is moderate and erosion is ongoing. Site conditions anticipated to deteriorate with time but are currently not in urgent need of repair. Site should be inspected and a plan for remediation formulated. The exact details and timeline of the remediation will depend on risk tolerance and particulars of site. |
| High | Eroded creek channel faces are significant and continued erosion and deteriorating conditions should be anticipated. Site should be inspected regularly and a plan for remediation developed to address site issues in the near future. Potential for danger to public and/or infrastructure and/or severe environmental degradation if not remediated. |
| Very High | Eroded creek channel faces/ravine slopes are significant, and erosion is severe. Slope instability has already occurred or is anticipated imminently. Requires immediate response and remediation. Currently there is a danger to public and/or infrastructure and/or severe environmental degradation if not remediated. (no “Very High” risk sites have been identified within the Willband study area) |

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Willband Creek
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**Erosion Sites**

Legend

- Willband Creek Watershed
- Traversed Creek Section
- Low to Very Low Risk Level
- Medium Risk Level
- High Risk Level

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**FIGURE 5.3**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20170707\Figure 5-3 - Erosion Sites - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on July 7, 2017 at 10:19:45 AM

# 6 HYDROLOGIC AND HYDRAULIC CONDITIONS

In addition to the natural systems described in prior sections of this report, the Willband Creek watershed's management system is comprised extensively of manmade features; storm sewers, detention ponds, culverts, and ditches. An important aspect of an ISMP is to understand the hydrology of the watershed, the working hydraulics of the management systems, and how it performs against established criteria.

## 6.1 Modeled System

The modeled system was determined through discussion with City staff. The hydrodynamic 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 are included only as required for system connectivity. Roadside ditches and catch basins were not included. Also, only a single private stormwater management facility at the hospital has been included in the model at this time. It was agreed with the City that an assessment would first be conducted for public infrastructure only, and that consideration for private infrastructure would be made based on the initial findings.

An inventory of the modeled system is presented on **Figure 6.1**. It is comprised of 30 km of open channels, 85 km of storm sewers, 1.6 km of culverts, 25 controls structures, 14 public storage facilities, excluding Mill Lake and multiple cells of the Willband Creek detention facilities, and 1 private pond at the Hospital.

All geometric information for the system was obtained from desktop sources, including City GIS databases, City record drawings, and LiDAR (for Creek transects and pond volumes). Early in the ISMP study process, initial records provided from the City were assessed for completeness and large anomalies identified. The City undertook the necessary field work to address the data gaps and anomalies and provided a verified GIS data base, which was applied to the model.

## 6.2 Mill Lake

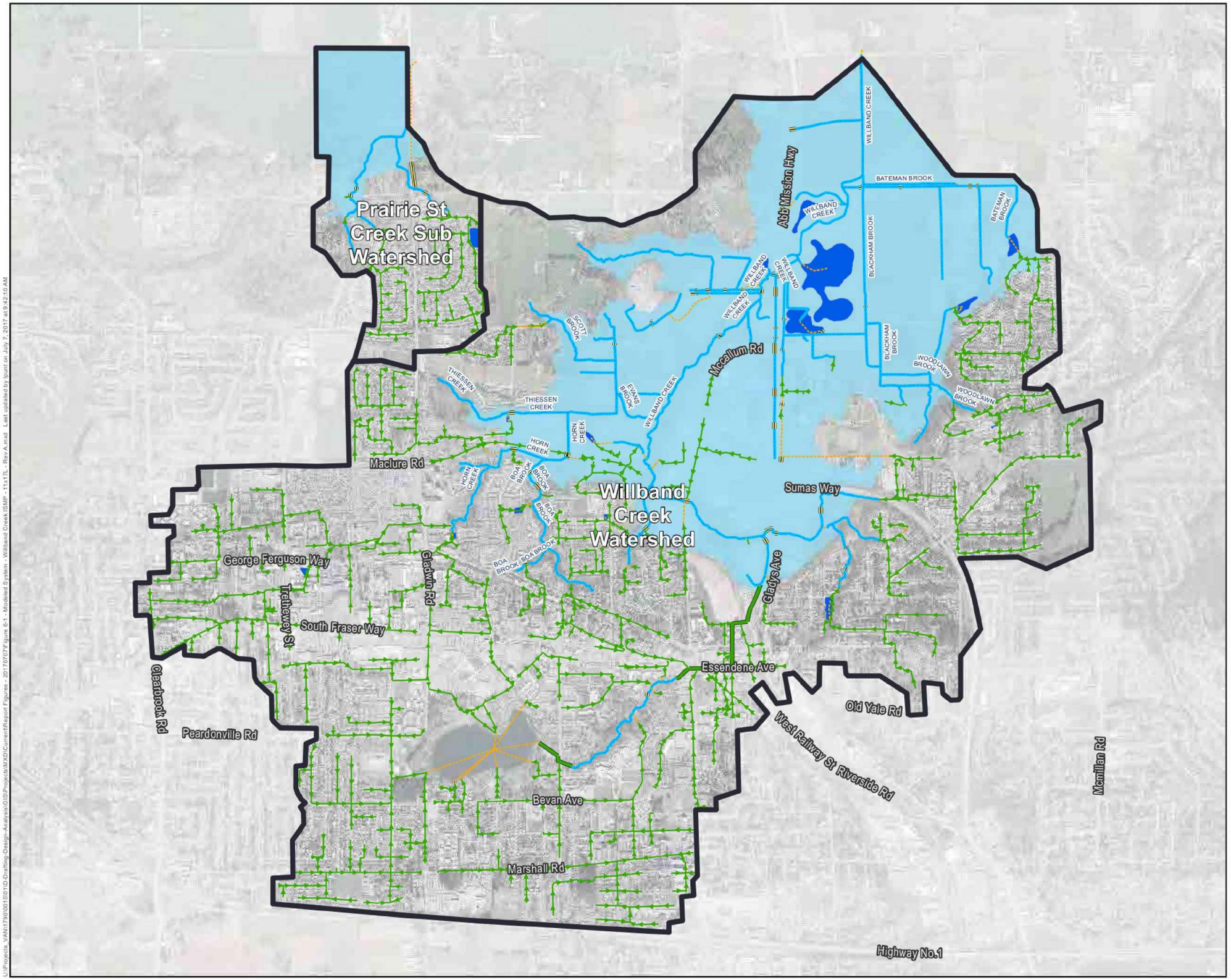
Mill Lake represents a very significant feature within the southern portion of the watershed. Its outflow is controlled by a sluice gate and stop log structure that is manually operated by City staff, but with no set protocol. Mill Lake is monitored with SCADA systems. Some basements have been known to flood adjacent to Mill Lake. 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.

## 6.3 Land Use and Soils Parameters

To represent existing conditions, TIA percentages shown on **Figure 3.3** were applied. Soils infiltration rates were applied from **Table 5.1.**

## 6.4 Model Calibration

Only a single monitoring station, on Horn Creek, lies directly within the Willband Creek watershed that can provide data for model calibration. While this station has been collecting data since 2012, only data March 1, 2017 and April 1, 2017 were applied to model calibration because of anomalies in other data that did not allow for confident application. The 2017 dataset is limited, but offers reasonable

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Willband Creek
Integrated Storm Water
Management Plan

**Modeled System**

Legend

- Willband Creek Watershed
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Conduit Added for Connectivity

Minor System

- Minor Storm Sewer

Major System

- Creek
- Culvert
- Major Storm Sewer

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.

0 145 290 580 870
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,010

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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**FIGURE 6.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20170707\Figure 6-1 - Modeled System - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on July 7, 2017 at 9:42:10 AM

confidence, as it was a wet month, yielding several precipitation events despite not being overly significant in intensity.

Corresponding precipitation data was obtained from the City's Flowworks account for the "City Hall" raingauge station. A total of nine precipitation events occurred; some single day events and some multi-day events. The magnitude of all events was below a 1:2 year return period level. A detailed table of these events, and the model calibration process, is provided in Appendix E. These events were modeled continuously, rather than in isolation for each event. This provides for both model calibration and validation. Results of the model calibration are also provided in Appendix E, but yielded very good with observed data, recognizing, however, the limited magnitude of the events.

The catchment for the Horn Creek flow monitoring station is shown on Figure 1.1. It represents 18% of the overall Willband Creek watershed and represents some of the most densely developed portions. One of the key calibration parameters was to adjust the directly connected impervious fraction, also known as the Effective Imperious Area (EIA). For Horn Creek, calibration yielded a total impervious area (TIA) of 69% and an EIA of 39%. As such, 30% of the impervious area appears disconnected to some degree from the conveyance system.

Even in a highly urbanized area, this value is not uncommon, particularly in older areas where rainwater capture is not always effective and with leakage out of aging storm sewers where infiltration is possible. In the absence of data for other parts of the watershed, this 30% reduction from TIA to EIA has been applied to all other areas.

The overall TIA for the entire Willband Creek watershed has been measured at 45%, with a resulting EIA of 32%.

## 6.5 Performance Criteria

**Table 6.1** below summarizes the current City performance criteria consolidation from the City's bylaws and past studies.[2]

**Table 6.1 - Performance Criteria**

| System Component | Performance Criteria |
|---|---|
| Peak Flow Attenuation (Detention) | 10-year peak flow detained to 5 L/s/ha<br><br>100-year peak flow detained to 5 L/s/ha if major flow paths cannot be identified. |
| **Upland Criteria** | |
| Storm sewer | Safe conveyance of 10-year peak flows in minor systems.<br><br>Safe conveyance of 100-year peak flows in major systems. |
| Culvert | Safe conveyance of 100-year peak flows. |
| Channel | 200-year peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands. |

[2] City of Abbotsford Storm Water Source Control Bylaw, 2011 (Bylaw No. 2045-2011)
City of Abbotsford Development Bylaw, 2011 (Bylaw No. 2070-2011)

| Lowland Criteria | |
|---|---|
| Culvert | Safe conveyance of 10-year peak flows. |
| Channel | 2-year peak flow to be contained within the lowland creek banks. |
| Agricultural Flooding | 10-year ARDSA Summer and Winter Criteria |

## 6.6 Design Storms

Design storm hyetographs as used in the Clayburn Creek ISMP and the Matsqui Prairie Drainage Study–Phase 1 were applied herein to ensure consistency and compatibility between models. **Table 6.2** summarizes the total rainfall volume for each single day design storm event.

**Table 6.2 - Single Event Design Storm Precipitation**

| Duration (hr) | 6-month (mm) | 2-year (mm) | 5-year (mm) | 10-year (mm) | 100-year (mm) |
|---|---|---|---|---|---|
| 1 | 9.72 | 13.50 | 17.65 | 20.50 | 29.25 |
| 2 | 13.72 | 19.05 | 24.55 | 28.20 | 39.60 |
| 6 | 25.06 | 34.08 | 41.30 | 45.70 | 59.25 |
| 12 | 36.79 | 51.10 | 61.00 | 67.55 | 88.05 |
| 24 | 51.05 | 70.90 | 85.70 | 95.50 | 126.20 |

Developed by averaging the rainfall intensity values from the Abbotsford A AES station (1100030) and the Mission West Abby AES station (1105192).

Precipitation events for the evaluation of multi-day events are shown in **Table 6.3**.

**Table 6.3 - Multi-Day Design Storm Precipitation**

| Duration (days) | 10 year (mm) (ARDSA) | 200 year (mm) |
|---|---|---|
| 2 day (summer) | 120.1 | n/a |
| 5 day (winter) | 182.8 | 262.2 |

## 6.7 System Performance

Assessment of the conveyance systems was broken into its individual components of:

- Minor Storm Sewers;
- Major Storm Sewers;
- Creeks; and
- Culverts.

The inventory of these systems is presented on **Figure 6.1**.

Results presented under the 2-, 10-, and 100-year return period represent the worst case from all storm durations assessed (i.e., 1-, 2-, 6-, 12-, and 24-hour durations). 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 because of lower peak intensity.

### 6.7.1 Winter Base Flow

The City's Flowworks account was used to obtain data from representative creeks, from which an estimated winter base flow value of 0.15 L/s/ha was judged, therefore applied to analysis herein.

Before describing the performance assessment of the individual components, **Table 6.4** on the following page presents some general findings of the hydrologic response at key points of interest.

**Table 6.4 - Hydrologic Response Indicators**

| Point of Interest | Catchment Area (ha) | Average TIA (%) | Peak Flow Rate (L/s/ha) | | | |
|---|---|---|---|---|---|---|
| | | | 2-year critical storm duration | 10-year critical storm duration | 100-year critical storm duration | 200-year, 5-day |
| Willband Creek Outfall | 1699 | 46 | 2.8 | 3.7 | 4.6 | 4.8 |
| Prairie St Creek Outfall | 130 | 28 | 6.6 | 10.4 | 15.2 | 8.2 |
| Willband Creek at Maclure Road | 735 | 44 | 6.5 | 9.7 | 12.3 | 10.0 |
| Horn Creek at hydrometric station | 330 | 69 | 16.0 | 24.1 | 30.8 | 18.8 |
| Mill Lake Outlet | 197 | 44 | 2.5 | 3.8 | 5.3 | 5.4 |
| Boa Brook | 67 | 48 | 11.2 | 16.6 | 23.3 | 13.9 |
| | | | Runoff Coefficient | | | |
| Willband Creek Outfall | 1699 | 46 | 0.32 | 0.34 | 0.35 | 0.37 |
| Prairie St Creek Outfall | 130 | 28 | 0.18 | 0.18 | 0.18 | 0.17 |
| Willband Creek at Maclure Road | 735 | 44 | 0.26 | 0.26 | 0.26 | 0.31 |
| Horn Creek at hydrometric station | 330 | 69 | 0.39 | 0.42 | 0.41 | 0.39 |
| Mill Lake Outlet | 197 | 44 | 0.27 | 0.32 | 0.29 | 0.32 |
| Boa Brook | 67 | 48 | 0.32 | 0.34 | 0.34 | 0.32 |

### 6.7.2 Unit Peak Flow

Unit peak flow is a function of many factors, therefore they cannot be compared with precision, but in general it is shown that as the impervious fraction goes up, so does flow rate, however as the size of the watershed goes up, the peak flow goes down.

As expected, being only of moderate size and having the highest impervious fraction, Horn Creek is generating the greatest peak flow response.

Mill Lake appears to be providing a very important role in protecting downstream systems with a significant attenuation of peak flows. This Lake is considered a very valuable natural asset. Should that lake be reduced in capacity or function, the impacts to downstream systems and lands would be significant.

Given the vast size of the overall Willband Creek watershed, lowland gradients, and available lowland storage, there is also a dramatic peak flow reduction in Willband Creek at Clayburn Road.

### 6.7.3 Storm Sewer Assessment

Within the uplands, 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 that convey stormwater flows from Mill Lake and infilled creek segments 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.

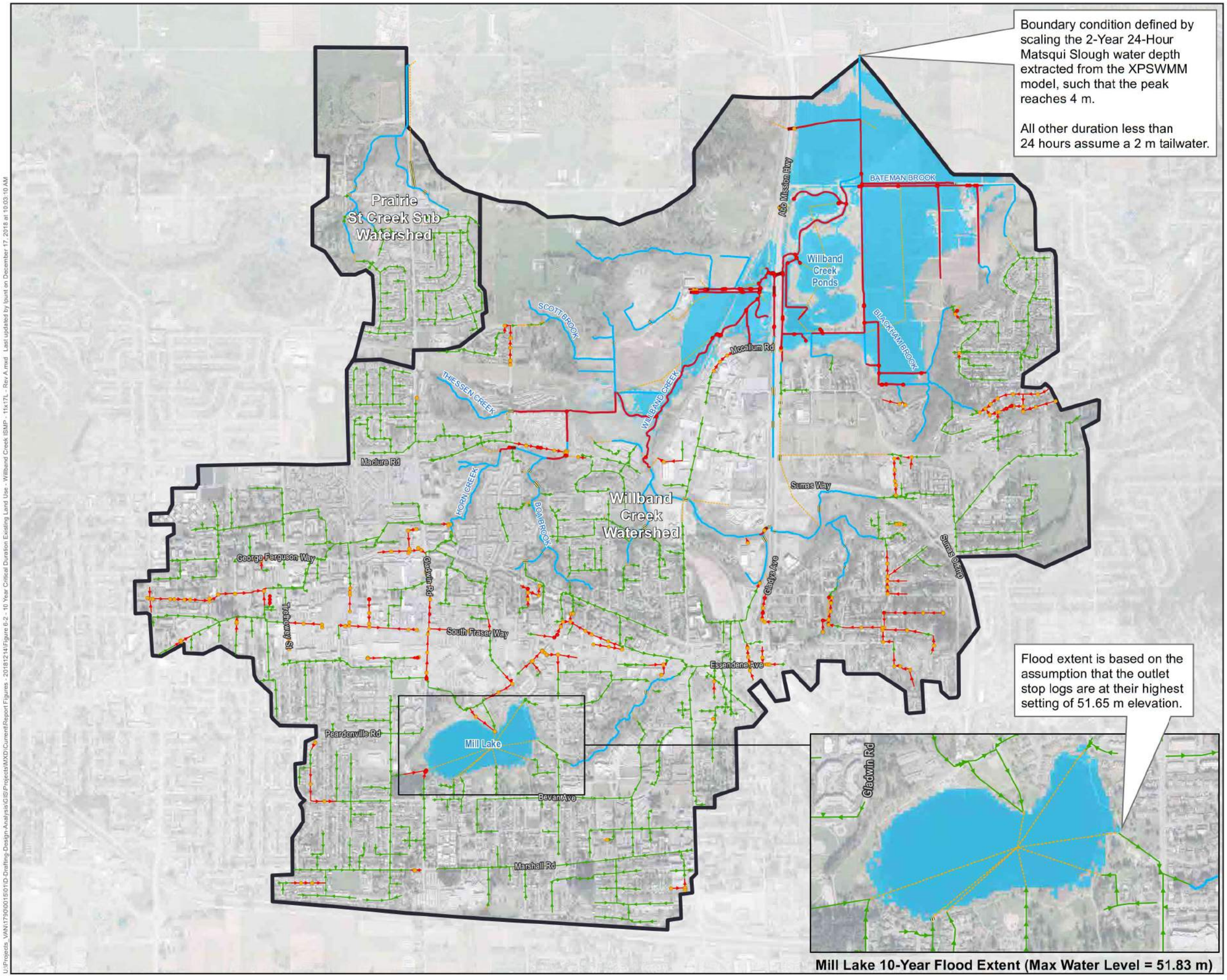
Storm sewers were flagged if any of the following criteria were met:

- 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.

**Figure 6.2** shows the results of the storm sewer performance assessment for the existing land use condition against the 10-year design events, while **Figure 6.3** shows the results for the 100-year design events, both without considering the effects of private stormwater management systems; a conservative assessment.

Given the extent of conveyances assessed, system performance against the 10-year criteria look generally favourable. Given the criticality of Mill Lake, the predicted HGL and flood extent of it is shown. This depiction is based on the assumption of the control structure being set at its highest level. Results do indicate that the top of bank would breach, flooding landscaped area around the park, however no impact to adjacent building appears likely by surface waters. The predicted maximum level (51.82 m) may result in backwater into the storm sewer system and service connections, therefore if there is subsurface habitable space in surrounding buildings; it is possible they may be impacted. The City has indicated that flooding has occurred in the past.

As expected, conveyance performance worsens under the 100-year level, as shown on **Figure 6.3**. However, the minor system is not required to perform to that level. Generally, the portions of the system designated as “major” and required to perform to the 100-year level, do perform reasonably well. Only two major storm sewer reaches on Montrose Avenue have been found deficient against the 100-year criteria. Once again, flood level and extent in Mill Lake are shown, and given the relative size of the lake results are not significantly dissimilar to the 10-year event. The predicated maximum water level increases from 51.82 m in the 10-year event to 51.86 m in the 100-year event. The position of the discharge weir leaving the Lake is critical to the resulting lake level. Management of the weir is discussed in subsequent sections of the report.

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Willband Creek
Integrated Storm Water
Management Plan

**10-Year, Critical Duration System Performance (Existing Land Use)**

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

**Coordinate System:** NAD 1983 UTM Zone 10N

**Scale:** 1:22,000

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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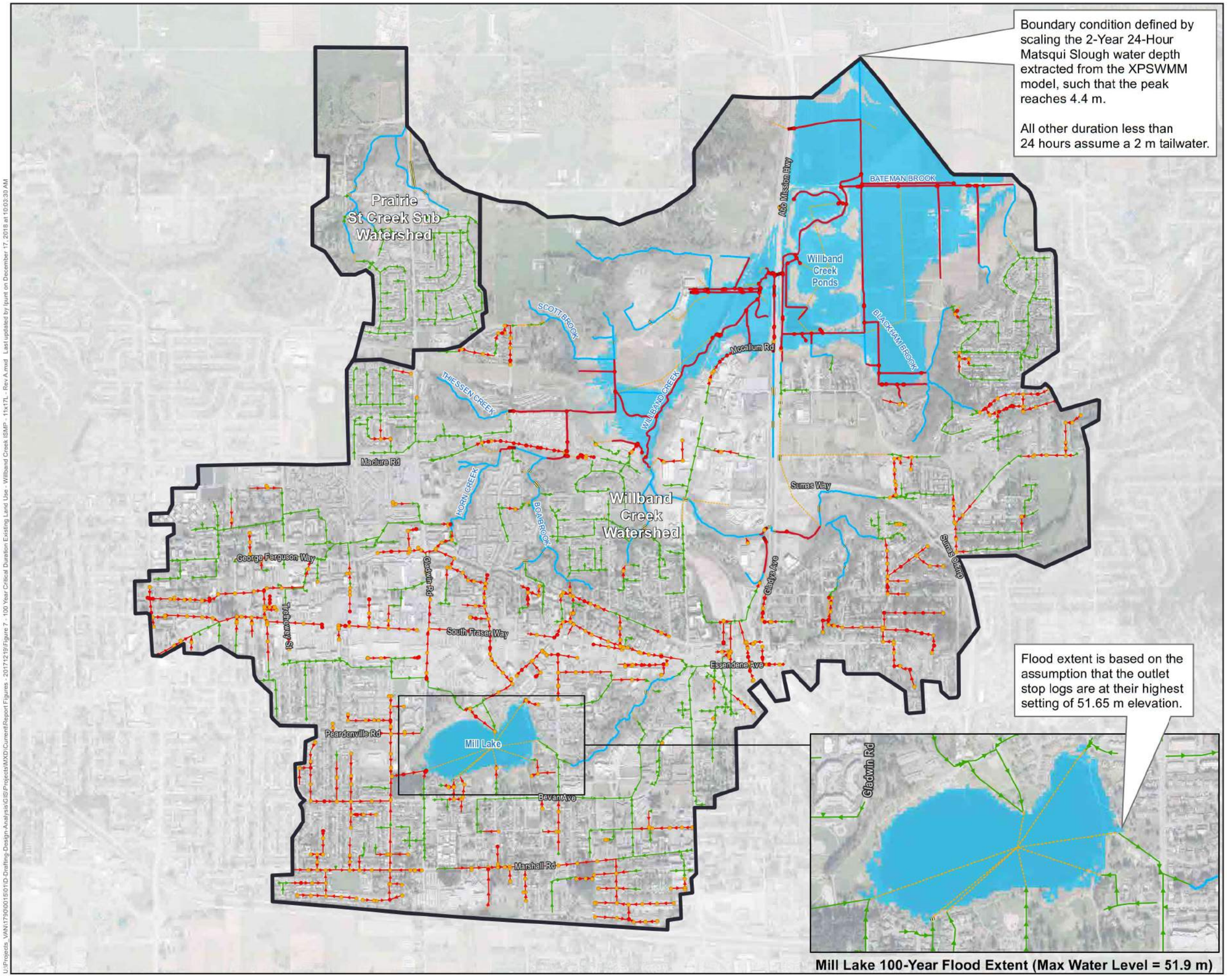
**FIGURE 6-2**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 6-2 - 10 Year Critical Duration Existing Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on December 17, 2018 at 10:03:10 AM




Mill Lake 100-Year Flood Extent (Max Water Level = 51.9 m)

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Willband Creek
Integrated Storm Water
Management Plan

**100-Year, Critical Duration System Performance (Existing Land Use)**

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

N

**Coordinate System:** NAD 1983 UTM Zone 10N

**Scale:** 1:22,000

**Data Sources:**

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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| Status: | FINAL |
| Revision: | A |
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**FIGURE 6.3**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20171219\Figure 7 - 100 Year Critical Duration Existing Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on December 17, 2018 at 10:03:30 AM

Assessment results for each storm sewer component, when measured against the established criteria, are presented on **Figure 6.4**.

### 6.7.4 Culverts and Bridges

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

Using the criteria previously noted in Table 6.1 only two culverts have been identified deficient under current conditions. One upland culvert crossing Oxford Avenue (assessed against the 100-year event), and one lowland culvert crossing Highway 11 (assessed against the 10-year event).

Two road bridges and one rail bridge were identified within the Willband watershed; however, as-built drawings for these bridges were not available to formulate a complete assessment. Peak flows, maximum water depths, and hydraulic grade line elevations have been reported in the adjacent creek to each bridge in the detailed report contained in Appendix E.

A summary of culvert performance against criteria is presented on **Figure 6.5.**

### 6.7.5 Detention Facilities

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, with exception to Mill Lake and the Willband Creek Park ponds, which were not designed to the same criteria.

A total of 14 upland public stormwater detention ponds or tanks have been assessed (excluding Mill Lake and Willband Creek detention facility). Based on the information available and the 5 L/s/ha criteria, 7 of them appear to meet criteria, while 7 do not. In 6 of the 7 cases, it appears that the control device needs to be revisited. The results also indicate relatively poor utilization of available storage. Of those ponds not meeting criteria, modeling suggests that on average only 12% of available storage is being utilized.

A summary of detention facility performance is presented on **Figure 6.6.**

### 6.7.6 Creeks

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 criteria outlined in Table 6.1.

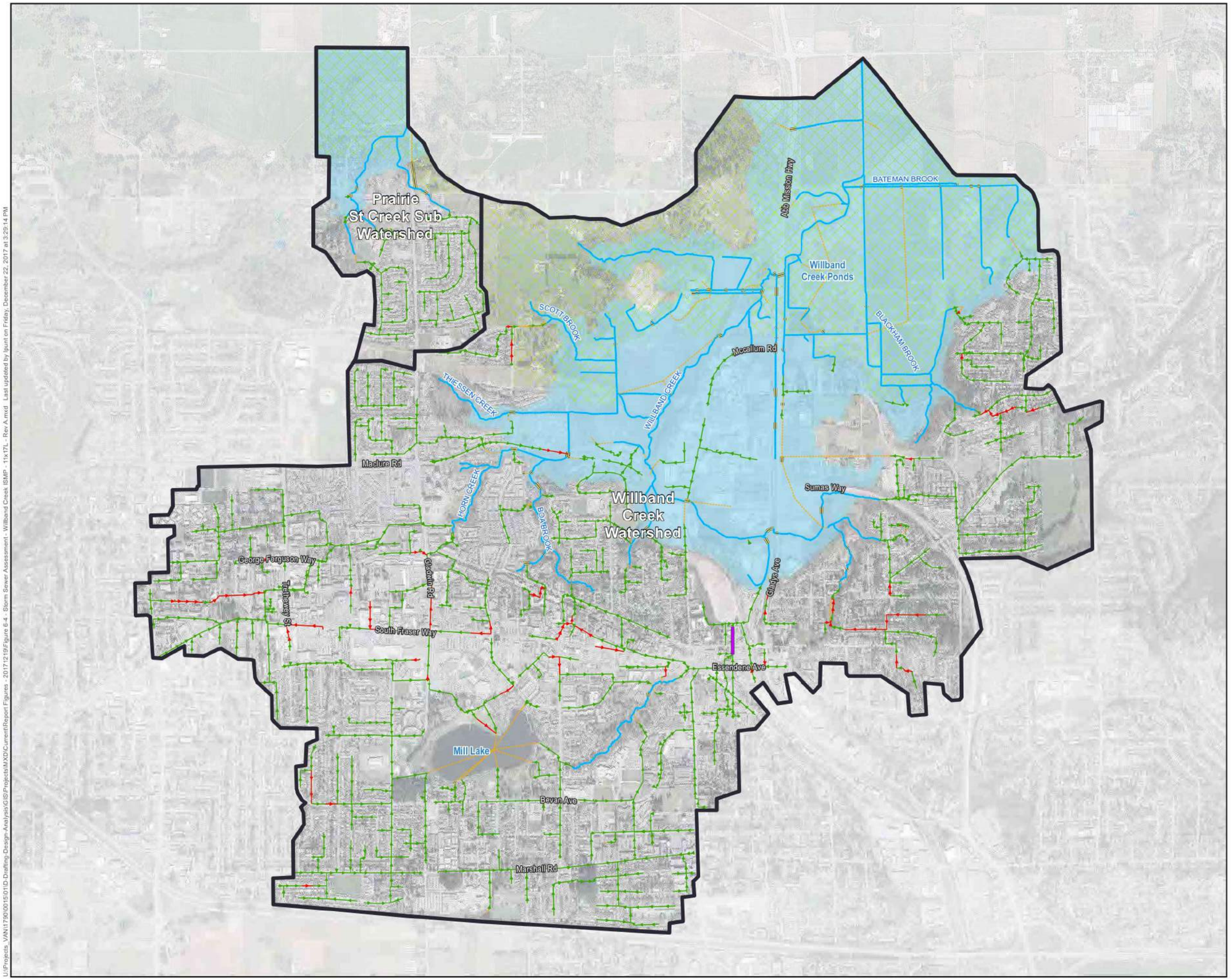
As creeks within the lowland region are influenced by the downstream water levels at Clayburn Creek, it was necessary to assess the system with downstream boundary conditions. For the purposes of this assessment, hydraulic grade line boundary conditions at Clayburn Road were provided from Kerr Wood Leidal who had previously completed the Clayburn Creek ISMP and the Phase 1 Matsqui Prairie Drainage Study.

The results of the creek assessment are presented on **Figure 6.7**. Overall the system appears to meet criteria, however there is a

concentrated area in the lowlands, downstream of Maclure Road not meeting criteria that corresponds with the areas reported as problematic by the City.

### 6.7.7 Floodplains

Performance and the extent of flooding predicted in the City's 200 year 5-Day winter event is shown in **Figure 6.8.**

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Willband Creek
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Management Plan

**Storm Sewer Assessed Against Established Criteria (Existing Land Use)**

- Willband Creek Watershed
- Major Main (100-Year) Surcharge 0.3 m over Crown for > 15 min
- Minor Main (10-Year) Surcharge 0.3 m over Crown for > 5-min
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

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.

0 145 290 580 870
Metres

N

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,000

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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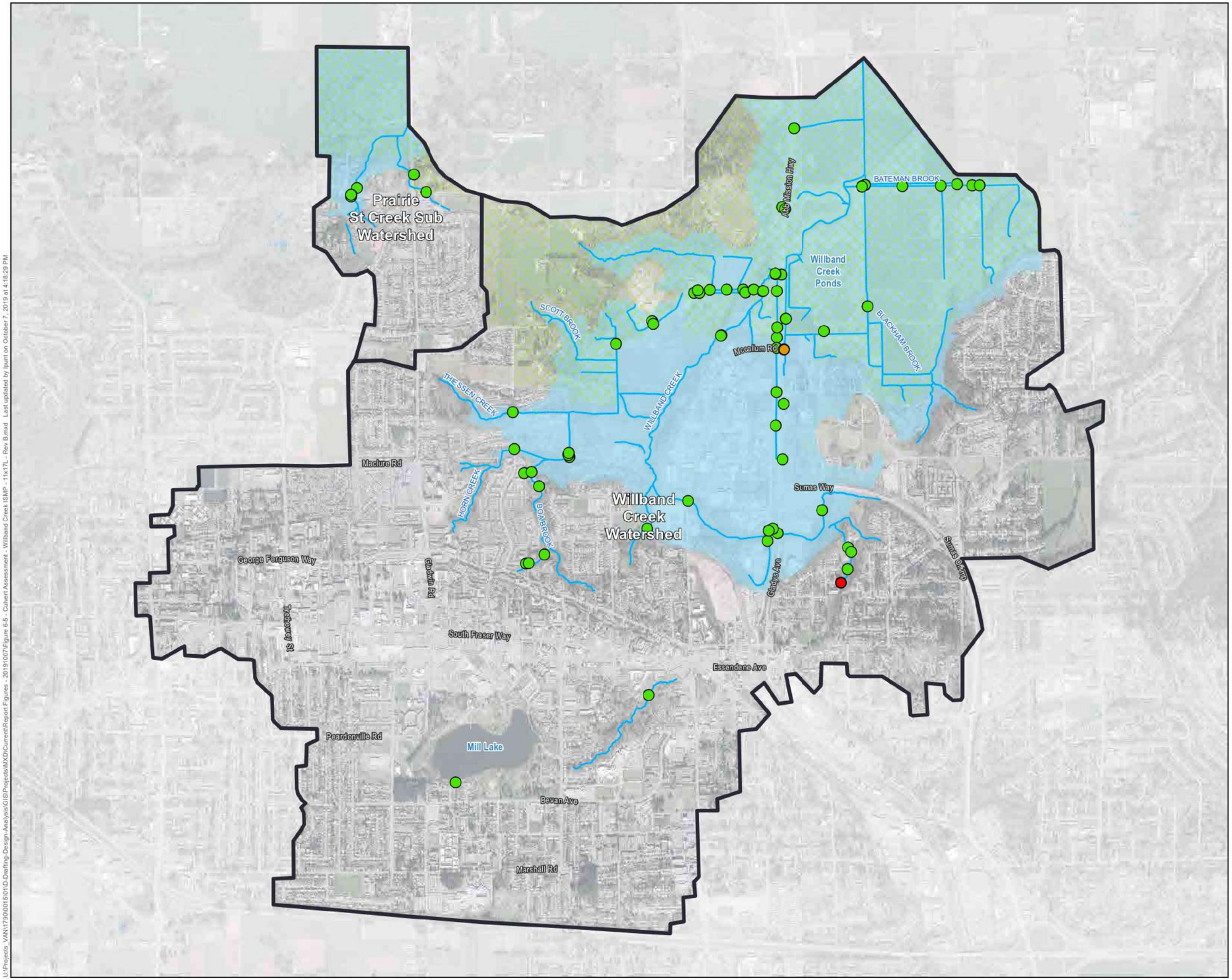
**FIGURE 6.4**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2017\2019\Figure 6.4 - Storm Sewer Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on Friday, December 22, 2017 at 3:29:14 PM

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Willband Creek
Integrated Storm Water
Management Plan

## Culverts Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

### Culvert Assessment

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

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0 145 290 580 870
Metres

N

**Coordinate System:**
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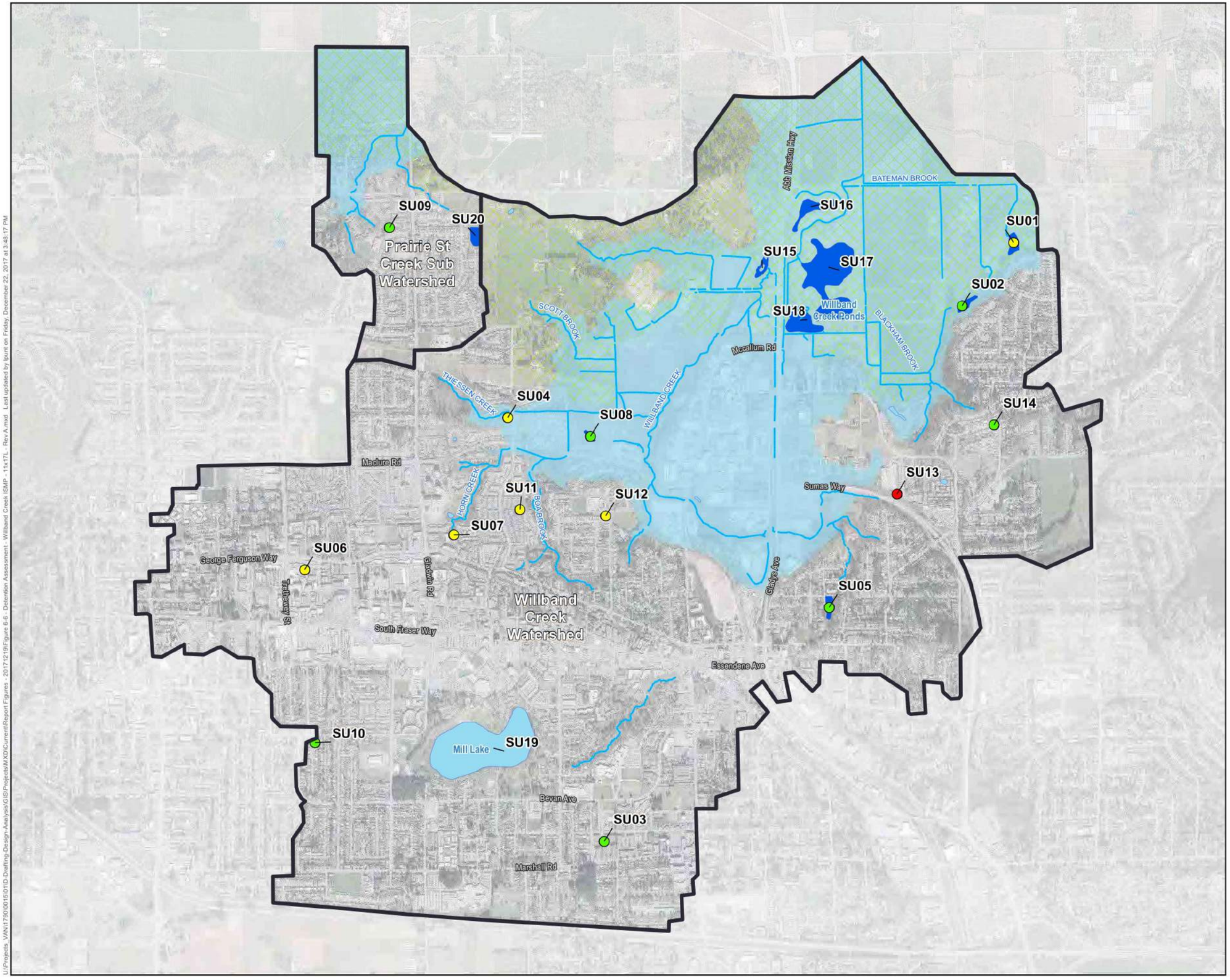
FIGURE 6.5

L:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2019\1007\Figure 6.5 - Culvert Assessment - Willband Creek ISMP - 11x17L - Rev B.mxd Last updated by lpunt on October 7, 2019 at 4:18:29 PM

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Willband Creek
Integrated Storm Water
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## Detention Facilities Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Detention Facility
- Lake
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

## Detention Assessment

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

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.

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Metres

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**Coordinate System:**
NAD 1983 UTM Zone 10N

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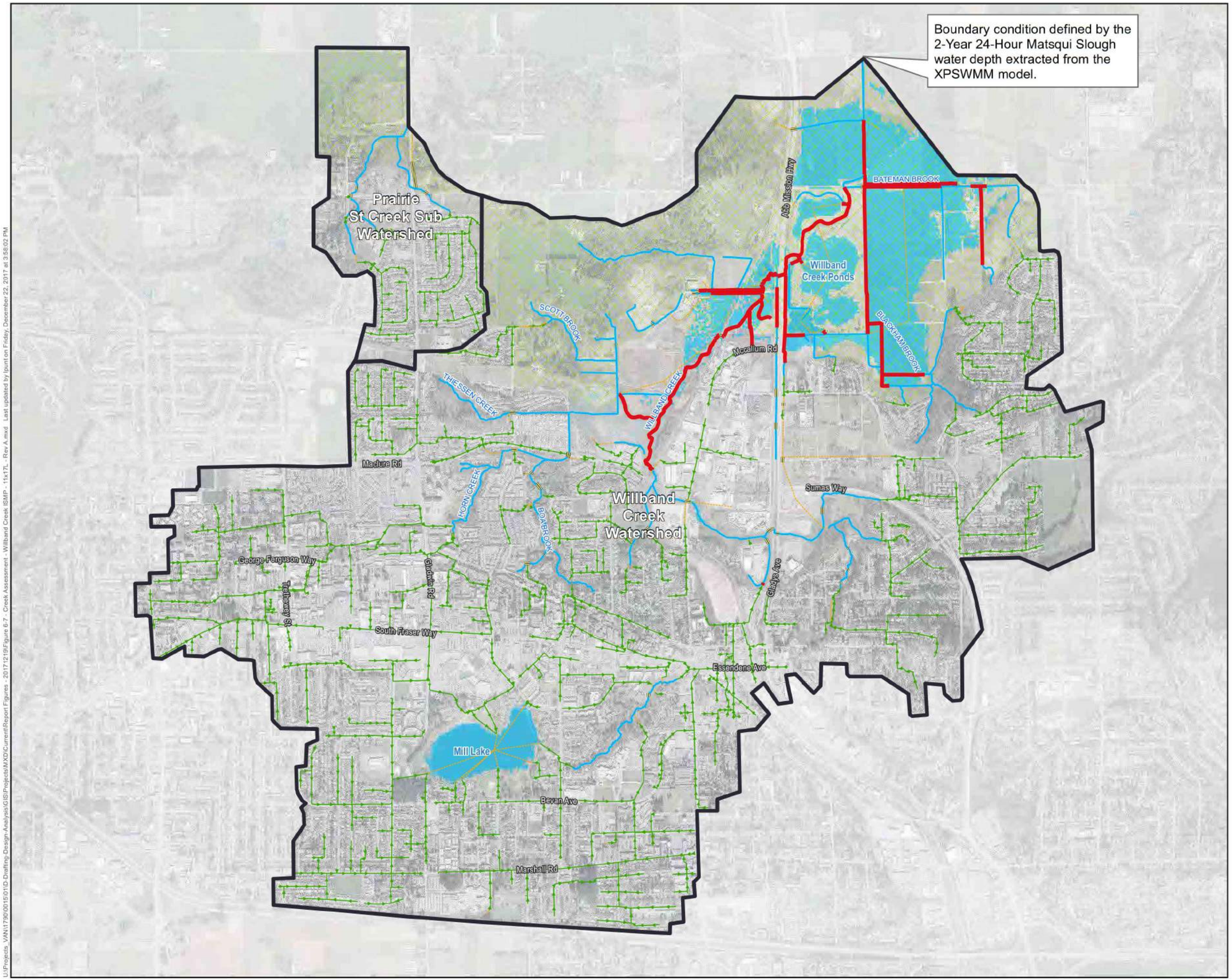
FIGURE 6.6

U:\Projects_VAN\1790\0015\01\D_Drafting\Design Analysis\GIS\Projects\MXD\Current\Report Figures 2017\2019\Figure 6.6 Detention Assessment Willband Creek ISMP 11x17L Rev A.mxd Last updated by lpunt on Friday, December 22, 2017 at 3:48:17 PM

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Willband Creek
Integrated Storm Water
Management Plan

**Creeks Assessed Against Established Criteria (Existing Land Use)**

- Willband Creek Watershed
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland and Mill Lake Flood Extent (2-Year, 24-Hour)

**Creek Assessment**

- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek

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Metres

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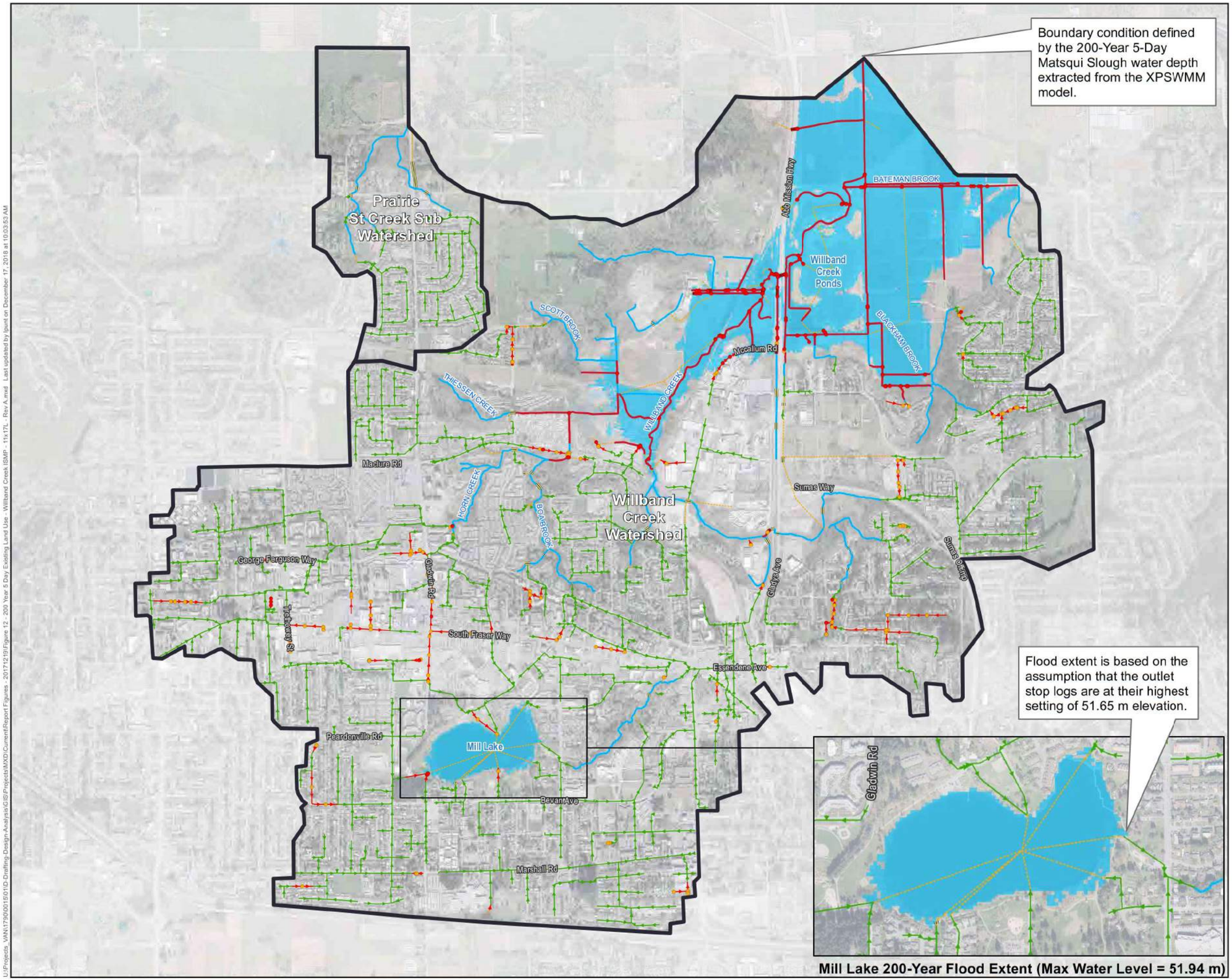
**FIGURE 6.7**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20171219\Figure 6.7 - Creek Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurtt on Friday, December 22, 2017 at 3:58:02 PM




Mill Lake 200-Year Flood Extent (Max Water Level = 51.94 m)

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

**200-Year, 5-Day System Performance (Existing Land Use)**

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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.

0 145 290 580 870
Metres

N

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,000

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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FIGURE 6.8

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2017\2019\Figure 12 - 200 Year 5 Day Existing Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:03:53 AM

# 7 EXISTING CONDITION SUMMARY

Based on the preceding sections, the following summary statements are made to describe the existing systems.

**1** Both aquatic and terrestrial habitats have been significantly impacted by past development and watercourse encroachment. Overall, the watershed health is deemed to be poor.

**2** Despite the overall assessment noted in item 1 above, there are some local cases where aquatic and riparian health is considered fair; including in Horn Creek, Boa Brook, and Thiessen Creek. Ironically, Horn Creek has also been identified as having the largest number of bank erosion sites.

**3** Erosion in Horn Creek, Boa Brook and Prairie Street Creek persist despite some instream repairs having been completed in Horn Creek. While source control through redevelopment provide an opportunity to improve the situation, the timeline with that approach is expected to be long, therefore the City will likely need to intervene with communal solutions more near term.

**4** Water quality is considered somewhat poor in the lowlands and in Mill Lake. In the case of lowland watercourses, mainly a result of urban runoff and likely insufficient water circulation and lack of riparian cover. In the case of Mill Lake, this is mainly attributed to stratification and insufficient water circulation.

**5** There is good infiltration potential for the majority of the upland study area; this opens a strong opportunity to apply low impact development techniques as redevelopment occurs.

**6** Modeling indicates that portions of the lowland system do not meet current conveyance criteria. System performance is hampered even further due to downstream effects of the broader Matsqui Prairie system.

**7** Generally, the performance of the storm sewer network appears to be reasonably good against established criteria; however, under the 100-year (major) event, the potential of flooding is widespread.

Seven of 14 public upland detention facilities modeled (excluding Mill Lake and Willband Creek Park ponds) do not appear to be meeting criteria.

Recommendations and actions to address these issues are discussion in following sections.

# PART 2 – POTENTIAL FUTURE CONDITIONS

# 8 FUTURE CONDITIONS

## 8.1 Future Land Use Parameters

Based on the City's 2016 Official Community Plan (OCP), the City has developed a "Build_35" GIS dataset, which represents a portion lands that may redevelopment by year 2035. Through consultation with the City, this "Build_35" data set has been applied to the analysis rather than the OCP at full build out. The reason being that the timeline for complete redevelopment is considered too far out, and it's predicted that climate change will have a more significant impact on system performance than redevelopment.

To represent the potential effects of future land use changes, three primary parameters were adjusted; the total impervious fraction, the portion of the impervious fraction that is redirected to ground, and whether engineered controls are applied. Such parameters have been assigned for each land use type as described in Table 8.1 below.

## 8.2 Controls

For low density land uses where only rock-pits or drywells are applied, control is represented in the SWMM model by routing impervious area to pervious, however, 95.5 mm of depression storage is added to the pervious area to reflect the City's requirement to retain the 1:10 year, 24 hour rainfall volume.

For those land uses where on-site engineered controls are applied, controls were represented in the SWMM model using a "Rain Barrel" LID (low impact development) tool directly within the software. While full retention is desired, criteria permits storage and release to a maximum of 5 L/s/ha for the 1:10 year event at a minimum. The "Rain Barrel" LID tool in SWMM offers the best representation of this. It also permits analysis of this control on a lot-by-lot basis. Within the scope of this ISMP, the SWMM model does not permit the ability to first route impervious surface runoff to the pervious area prior to "Rain Barrel" controls. As such, the model is generally representative, but conservative from what the City seeks from developers.

**Table 8.1 - Future Condition Land Use Parameters**

| Willband OCP Land Use Designations | Future Condition Total Impervious Area (%) | Portion of Total Impervious Area Redirected to Ground for Infiltration | Remaining Impervious Area Directly Connected to Control System or Storm Sewer | Are On-site Engineered Detention Control Applied? |
|---|---|---|---|---|
| **FN Reserve** | Maintain Existing | Maintain Existing | Maintain Existing | N |
| **City Centre** | 90 | 50 | 50 | Y |
| **Urban Centre** | 90 | 50 | 50 | Y |
| **Neighbourhood Centre** | 90 | 50 | 50 | Y |
| **Urban 1 - Midrise** | 80 | 50 | 50 | Y |
| **Urban 2 - Ground** | 80 | 50 | 50 | Y |
| **Urban 3 - Infill** | 65 | 90 | 10 | N |
| **Urban 4 - Detached** | 60 | 90 | 10 | N |
| **Urban Large Lot** | 40 | 90 | 10 | N |
| **Suburban** | 40 | 90 | 10 | N |
| **Secondary Commercial** | 90 | 50 | 50 | Y |
| **Regional Commercial** | 90 | 50 | 50 | Y |
| **General Industrial** | 90 | 0 | 100 | Y |
| **High Impact Industrial** | 90 | 0 | 100 | Y |
| **Hospital** | 90 | 50 | 50 | Y |
| **Institutional Complex** | 90 | 50 | 50 | Y |
| **Institutional** | 90 | 50 | 50 | Y |
| **Agricultural** | 20 | 100 | 0 | N |
| **Open Space** | Maintain Existing | Maintain Existing | Maintain Existing | N |

## 8.3 Precipitation Event Sub-Scenarios

System performance is assessed for the same historic storms as described in previous sections for the Existing Condition, however, the design precipitation events are scaled up 10% to represent potential climate change impacts. This scaling factor was recommended by Kerr Wood Leidal (KWL) to be consistent with other analysis conducted in the City.

The future conditions have been analysed for three single event return periods, namely:

- 1:10 year (range of storm durations up to 24 hours)
- 1:100 year (range of storm durations up to 24 hours)
- 1:200 year 5 day event which is for agricultural areas only
- Continuous simulation

## 8.4 Land Use Sub-Scenarios

At this stage, many different land use sub-scenarios have been created to test the outcomes of different level of controls and influence of potential climate change, results of which are compared against existing conditions.

The following land use sub-scenarios have been created:

- Future Land Use (Build_35) with no controls and historic precipitation.
- Future Land Use (Build_35) with controls and historic precipitation.
- Future Land Use (Build_35) with no controls, but climate change precipitation.
- Future Land Use (Build_35) with controls and climate change precipitation.

## 8.5 Summary of System Performance

Inserted below are **Figures 8.1** through **Figure 8.12**; a collection of figures representing the outcomes of the above noted sub-scenarios in various combinations, with a summary statement provided in the sub-sections below:

### 8.5.1 Future Land Use (No Controls)

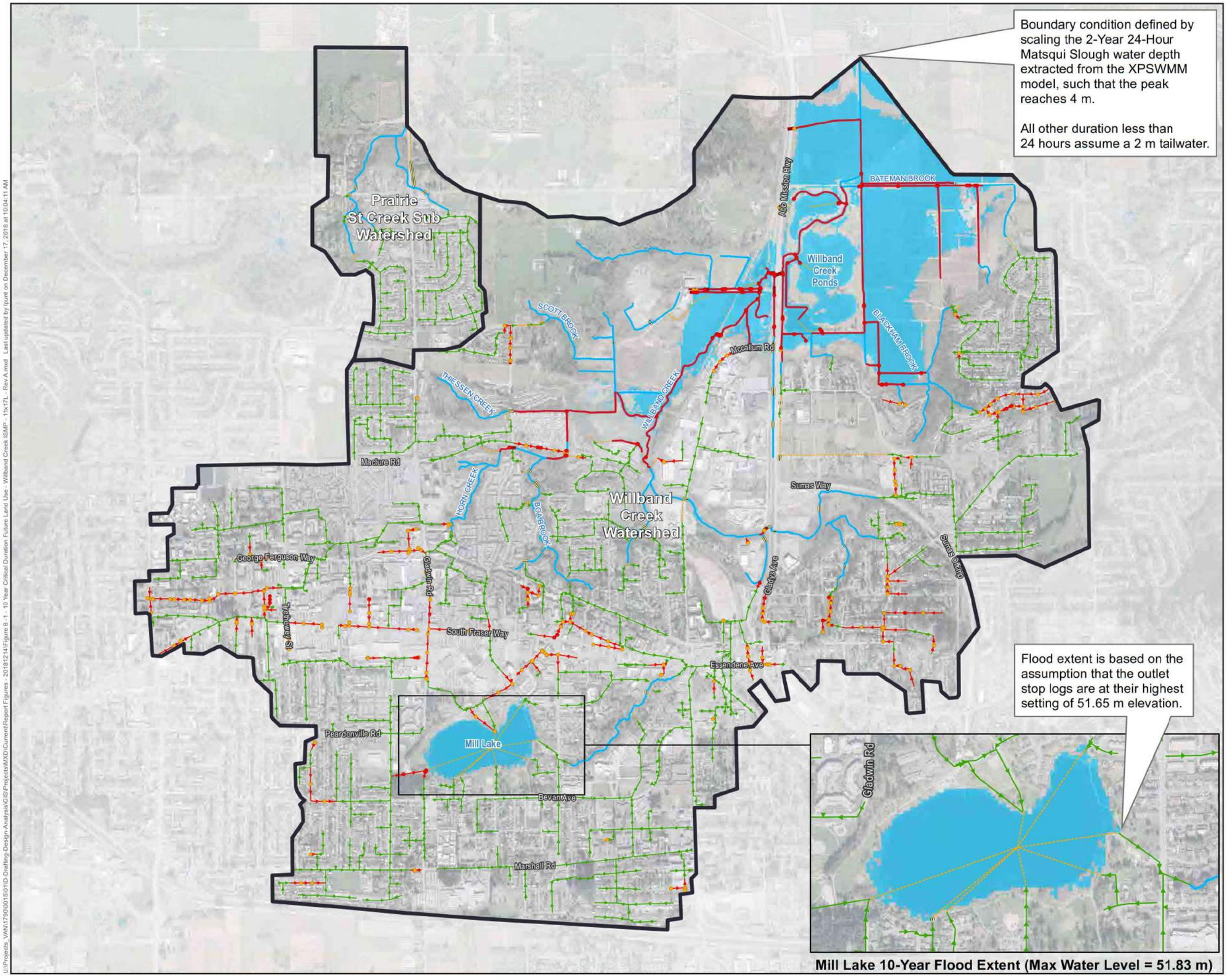
Regardless of what precipitation event is considered, at a watershed scale the extent of development in the Build_35 layer does not result is a dramatic change in system performance, but some local systems in vicinity of the land use change do worsen if development occurs in absence of any controls.

### 8.5.2 Future Land Use (With Controls)

For all design events, analysis shows the application of controls to Build_35 properties can provide a significant reduction in system surcharging; not only in mitigating the impacts of redevelopment but improving over existing conditions. This is particularly the case in the higher density areas in the central and southern portions of the watershed. This affirms that the application of controls through redevelopment provides an opportunity to improve over current conditions. Not only will this reduce flood risk, but it will improve overall watershed health.

### 8.5.3 Future Land Use (No Controls with Climate Change)

As one would expect, scaling design flows up by 10% to represent climate change, along with developing without controls, results in a noticeable increase in system surcharging. This represents the potential worst case and conservative scenario. For comparison, systems were once again assessed against established criteria,




**Mill Lake 10-Year Flood Extent (Max Water Level = 51.83 m)**

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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.

0 145 290 580 870
Metres

N

**Coordinate System:** NAD 1983 UTM Zone 10N

**Scale:** 1:22,000

**Data Sources:**

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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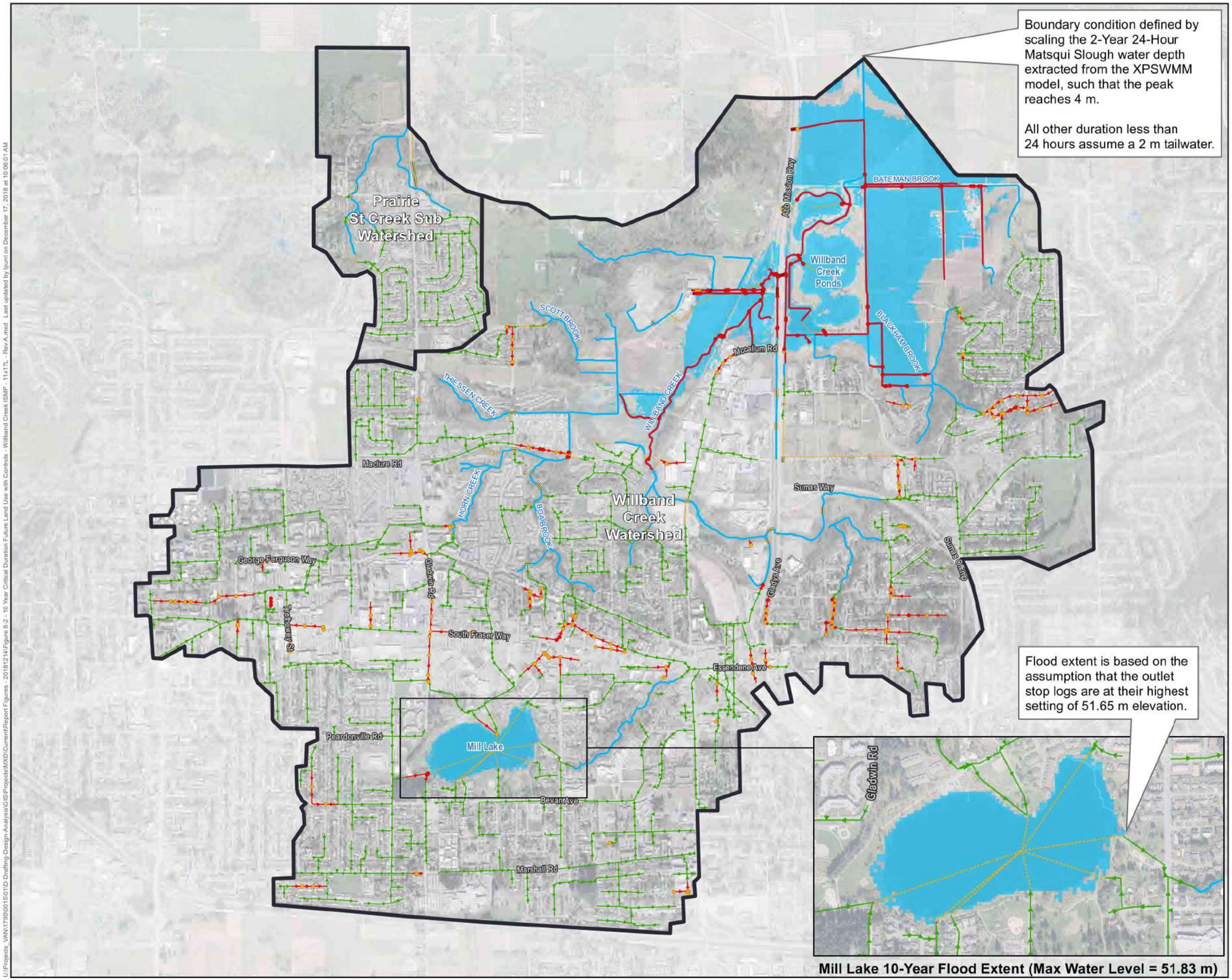
**FIGURE 8.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.1 - 10 Year Critical Duration Future Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd - Last updated by lpurt on December 17, 2018 at 10:04:11 AM




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

N

**Coordinate System:**
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**Scale:**
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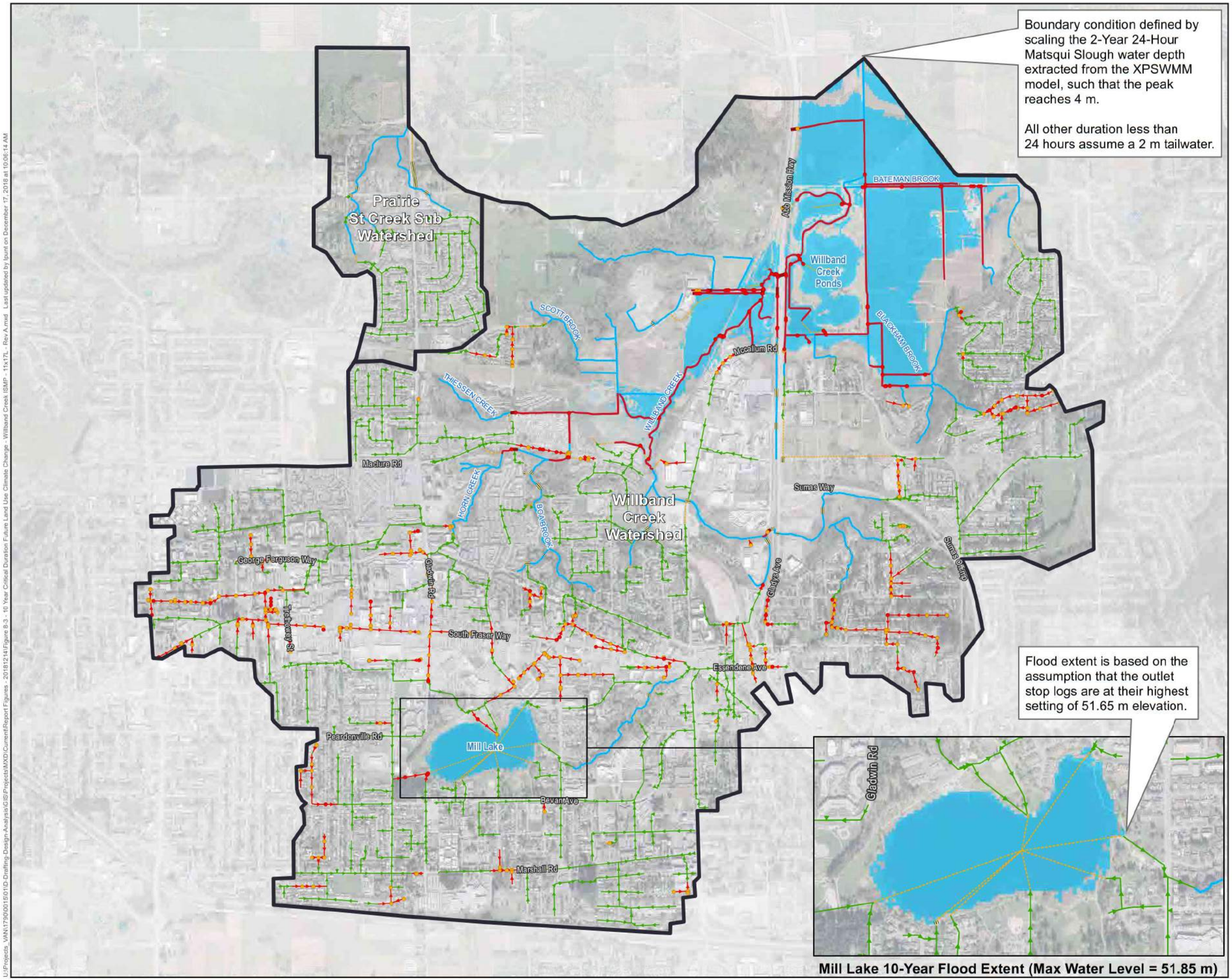
**FIGURE 8.2**

U:\Projects_VAN\1790\0015\01\D-Drafting\Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.2 - 10 Year Critical Duration Future Land Use with Controls - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by ljurri on December 17, 2018 at 10:06:01 AM




Mill Lake 10-Year Flood Extent (Max Water Level = 51.85 m)

ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

N

**Coordinate System:** NAD 1983 UTM Zone 10N

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**Data Sources:**

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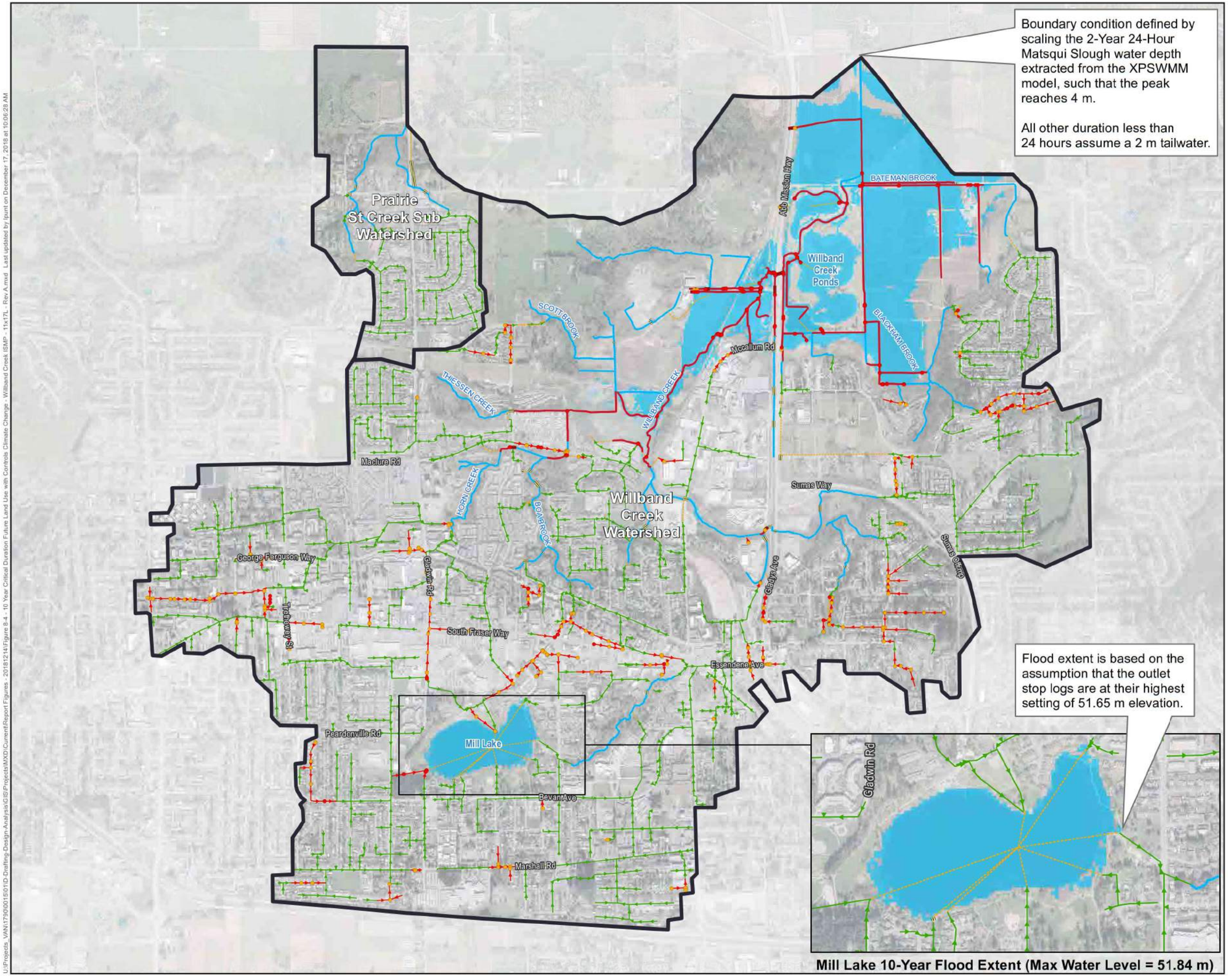
**FIGURE 8.3**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.3 - 10 Year Critical Duration Future Land Use Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:06:14 AM




Mill Lake 10-Year Flood Extent (Max Water Level = 51.84 m)

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

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**Scale:** 1:22,000

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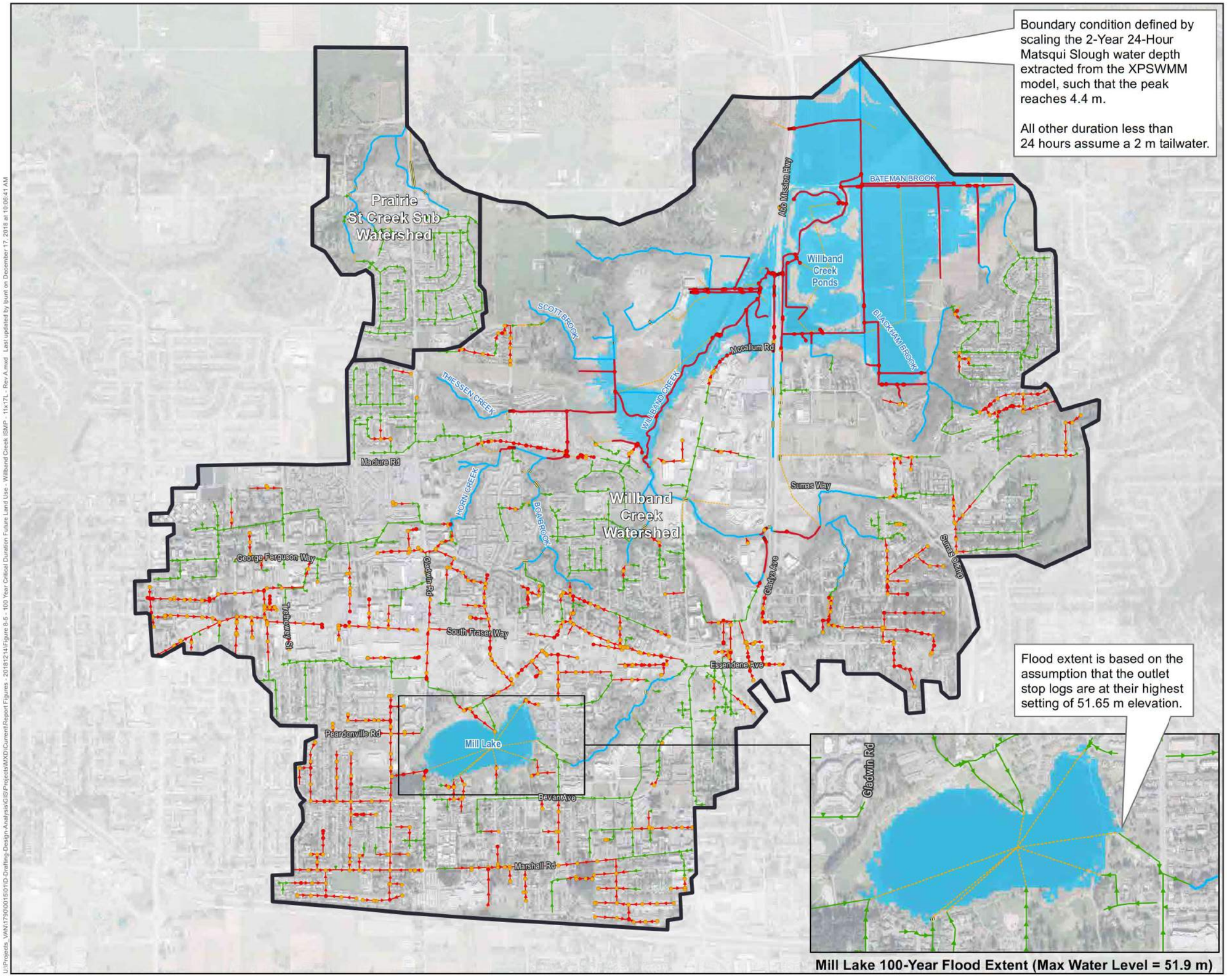
FIGURE 8.4

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-4 - 10 Year Critical Duration Future Land Use with Controls Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on December 17, 2018 at 10:06:23 AM




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

N

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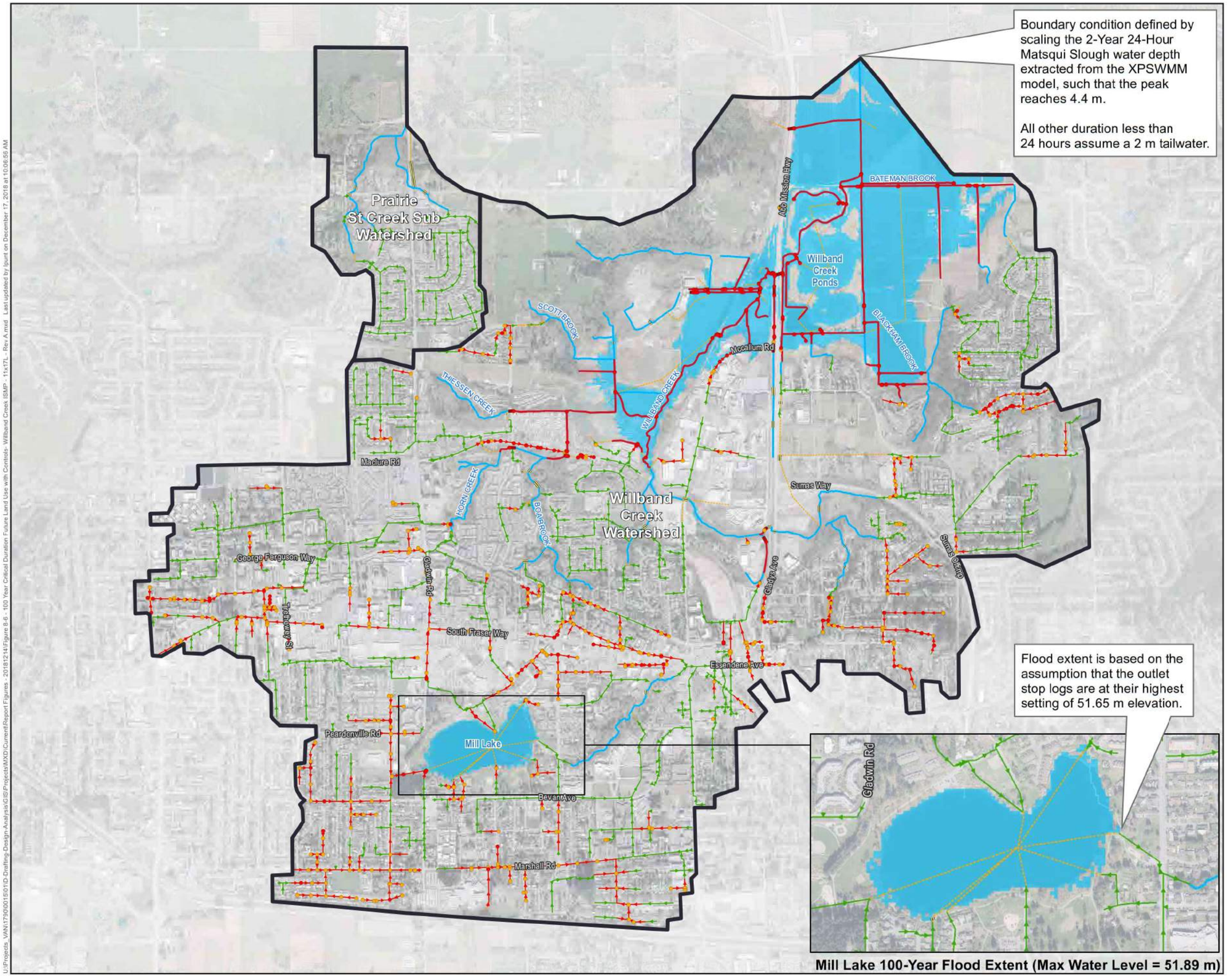
**FIGURE 8.5**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\1214\Figure 8-5 - 100 Year Critical Duration Future Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:09:41 AM




**Mill Lake 100-Year Flood Extent (Max Water Level = 51.89 m)**

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

N

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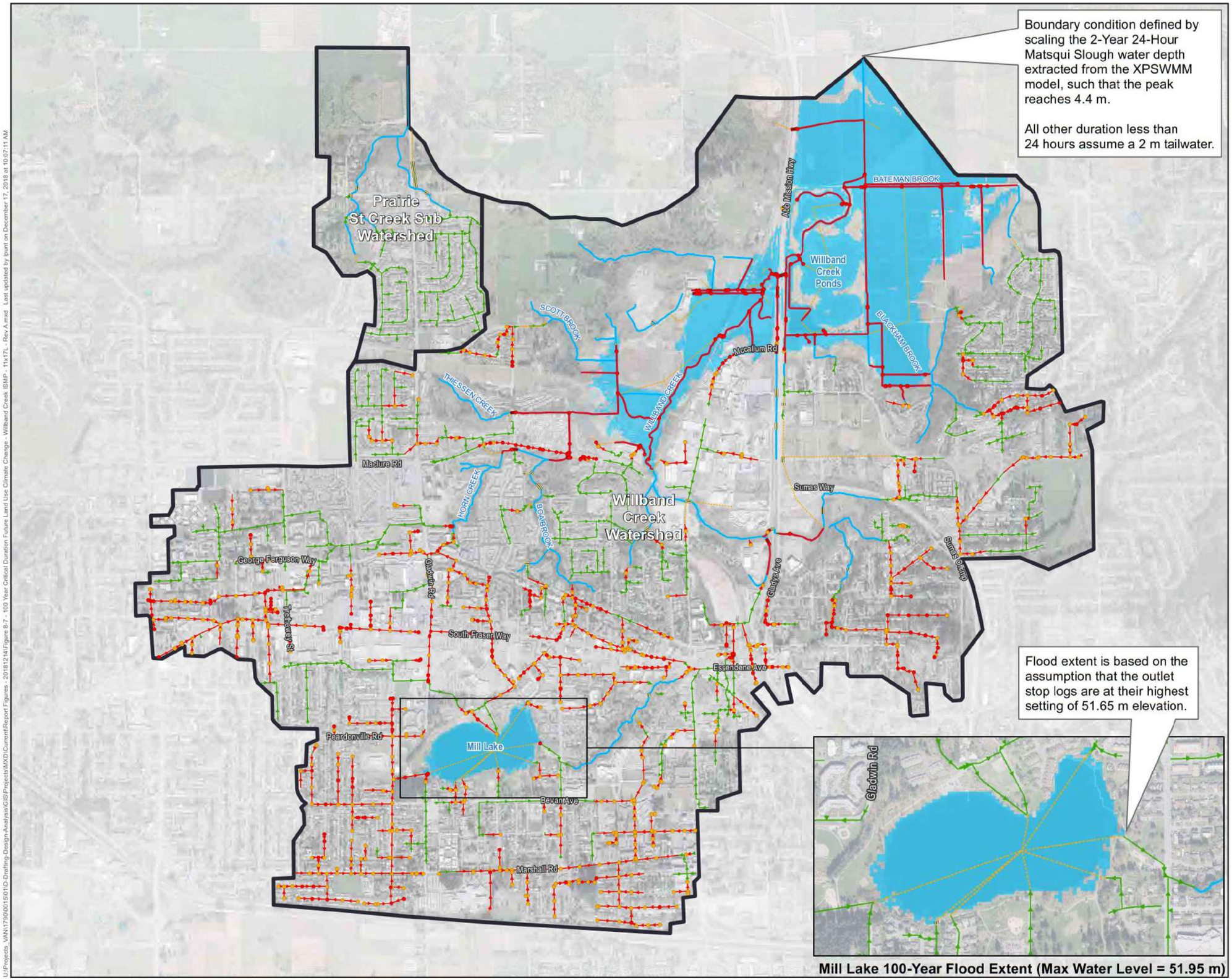
**FIGURE 8.6**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.6 - 100 Year Critical Duration Future Land Use with Controls- Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpurt on December 17, 2018 at 10:06:55 AM




**Mill Lake 100-Year Flood Extent (Max Water Level = 51.95 m)**

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

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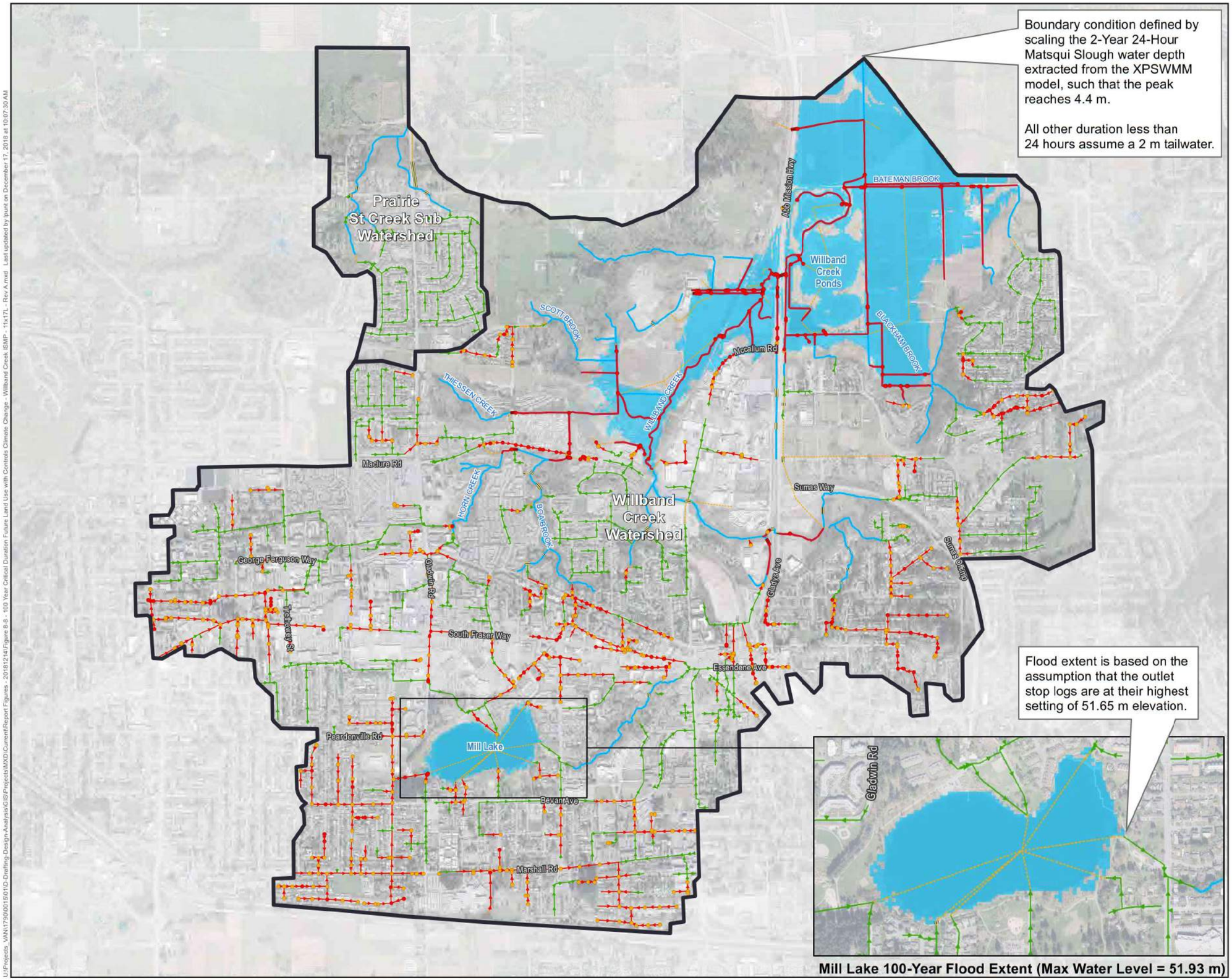
**FIGURE 8.7**

U:\Projects_VAN\1790\0015\01\D-Drafting Design Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.7 - 100 Year Critical Duration Future Land Use Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:07:11 AM

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Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
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- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

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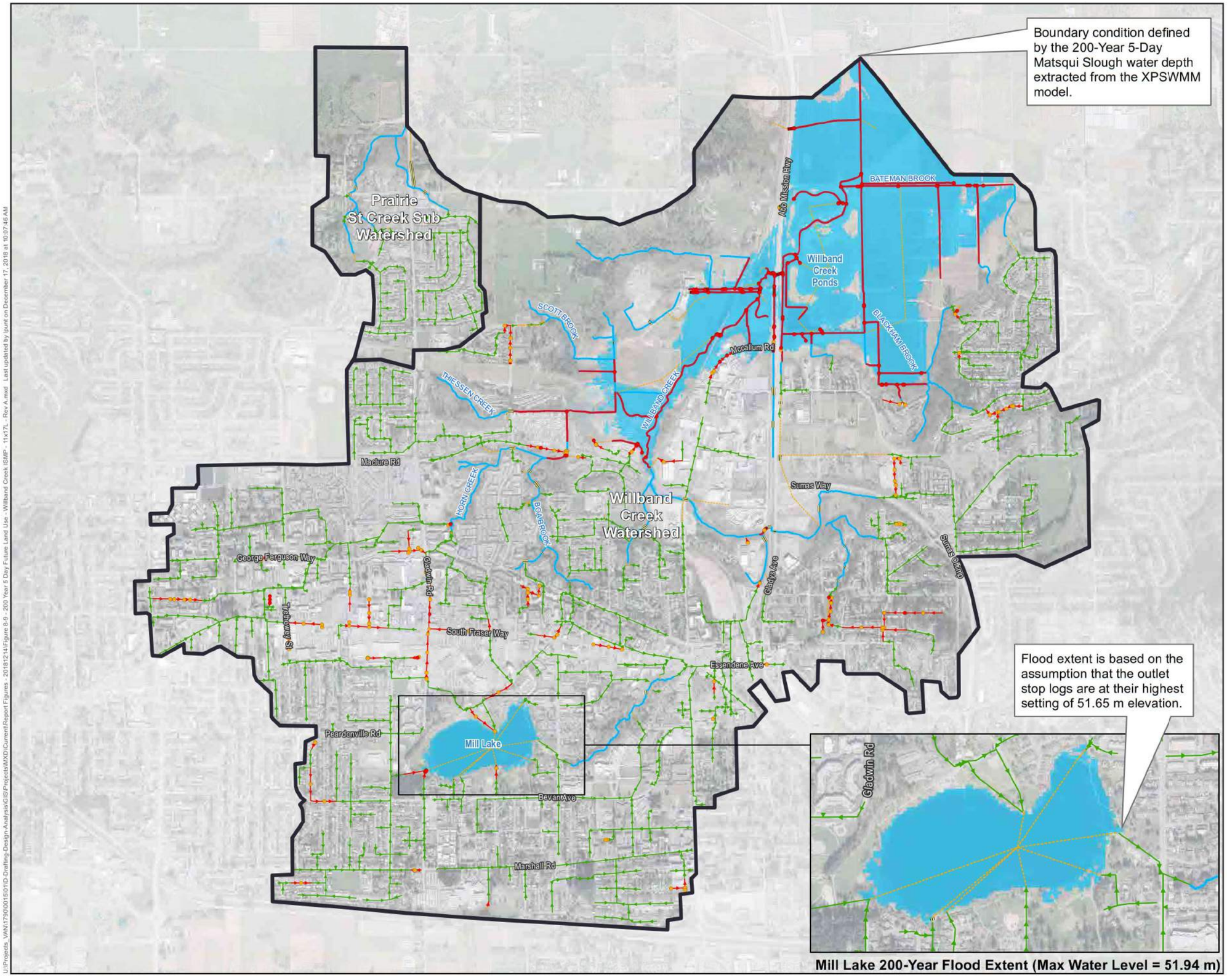
**FIGURE 8.8**

U:\Projects_VAN\1790\0015\01\D-Drafting Design Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.8 - 100 Year Critical Duration Future Land Use with Controls Climate Change - Willband Creek IBMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:07:30 AM




**Mill Lake 200-Year Flood Extent (Max Water Level = 51.94 m)**

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
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- Potential Breach of Creek
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- Lowland and Mill Lake Flood Extent

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Metres

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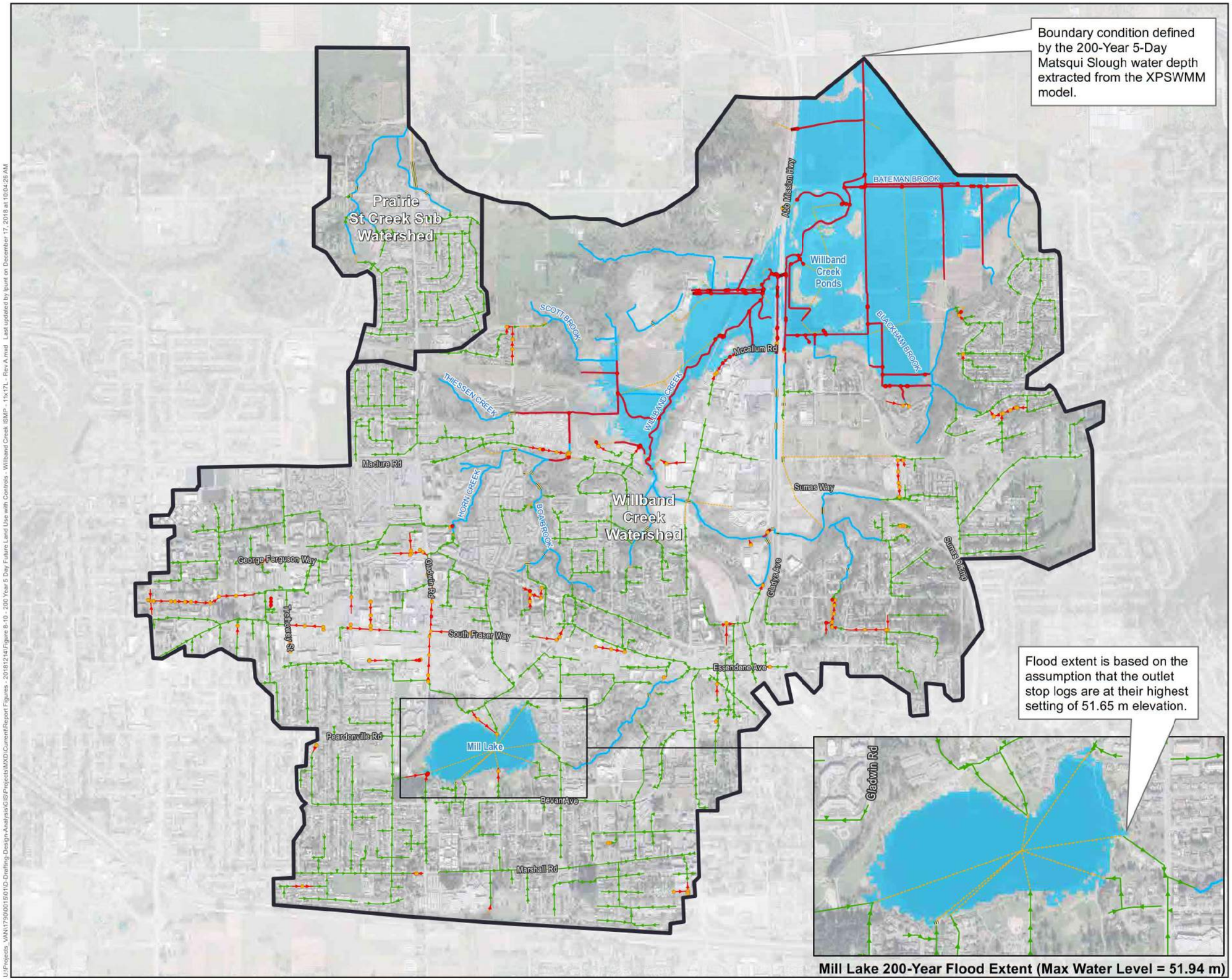
**FIGURE 8.9**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\1214\Figure 8-9 - 200 Year 5 Day Future Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:07:46 AM

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Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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.

0 145 290 580 870
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,000

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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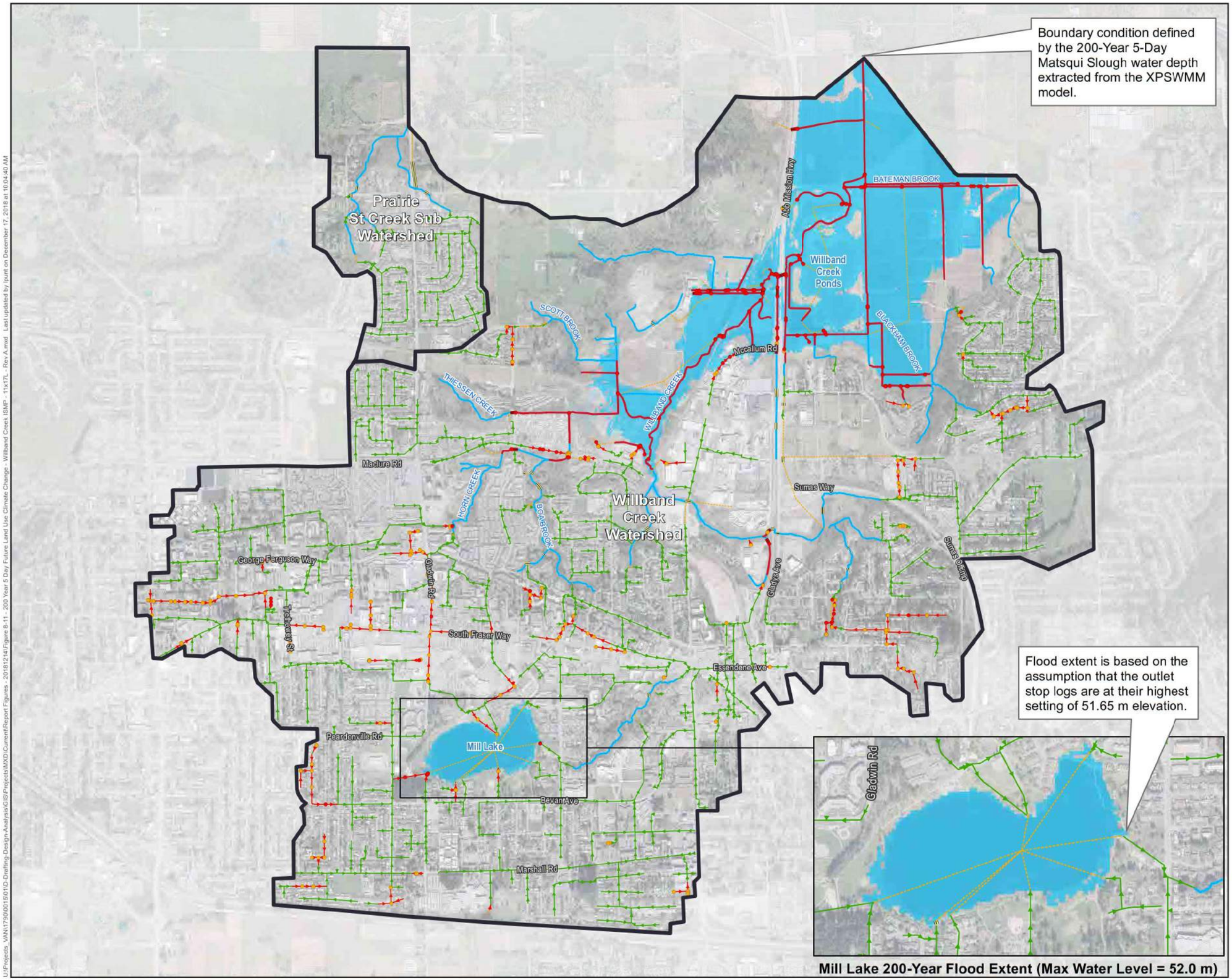
URBAN systems

**FIGURE 8.10**

U:\Projects_VAN\1790\0015\01\D-Drafting Design Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.10 - 200 Year 5 Day Future Land Use with Controls - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:04:26 AM




Mill Lake 200-Year Flood Extent (Max Water Level = 52.0 m)

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Willband Creek Integrated Storm Water Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

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**Coordinate System:** NAD 1983 UTM Zone 10N

**Scale:** 1:22,000

**Data Sources:**

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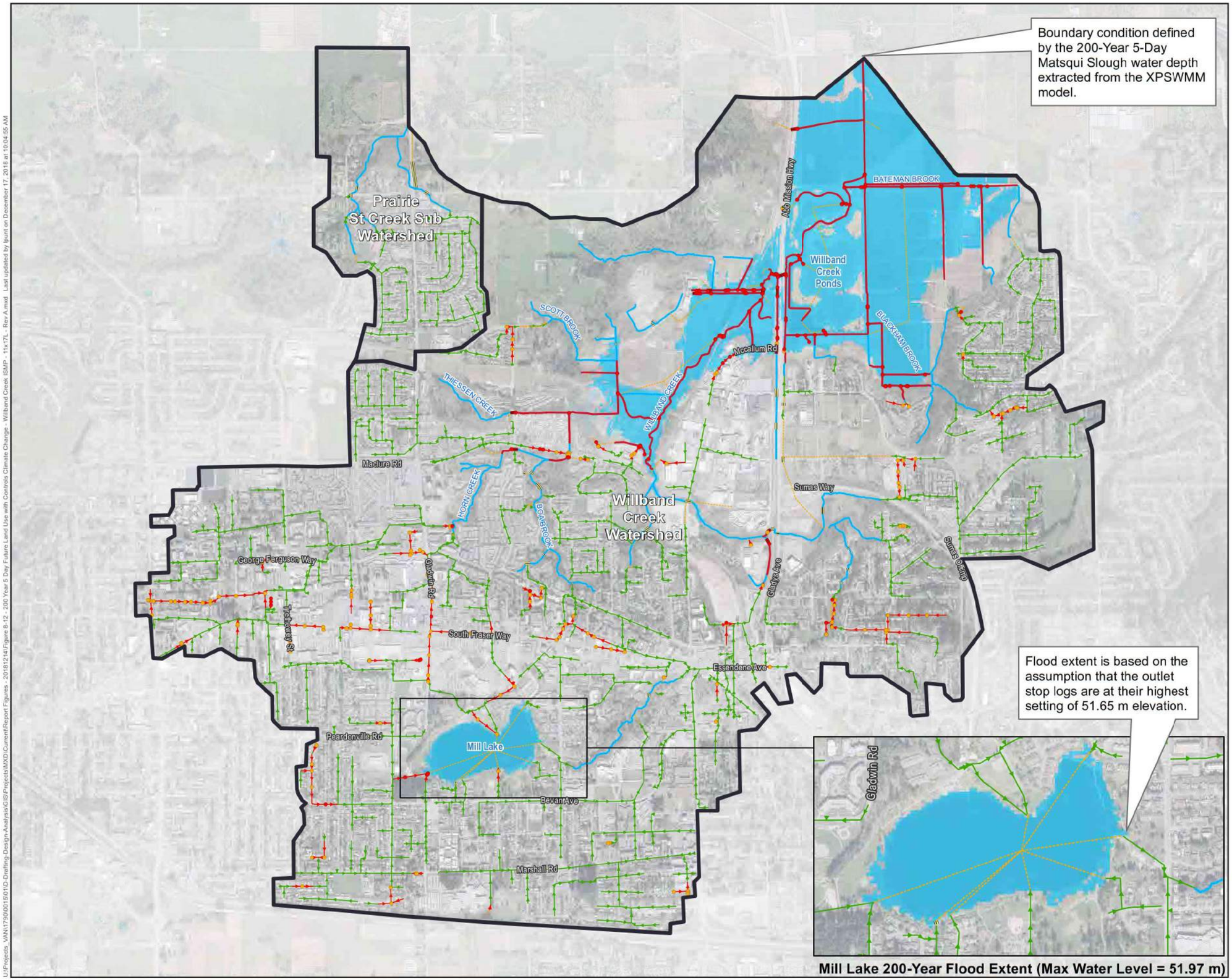
URBAN systems

**FIGURE 8.11**

U:\Projects_VAN\1790\0015\01\D-Drafting Design Analysis\GIS\Projects\MXD\Current\Report Figures - 2018\1214\Figure 8.11 - 200 Year 5 Day Future Land Use Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:04:40 AM




**Mill Lake 200-Year Flood Extent (Max Water Level = 51.97 m)**

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Willband Creek
Integrated Storm Water
Management Plan

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

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

**Coordinate System:** NAD 1983 UTM Zone 10N
**Scale:** 1:22,000

**Data Sources:**
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**FIGURE 8.12**

U:\Projects_VAN\1790\0015\01\D-Drafting Design Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.12 - 200 Year 5 Day Future Land Use with Controls Climate Change - Willband Creek IBMP - 11x17L - Rev A.mxd - Last updated by lpunt on December 17, 2018 at 10:04:55 AM

results of which are presented in **Figures 8.13** to **Figure 8.16**. When compared against Figures 6.4 to Figure 6.7 (existing condition), the following observations are made.

Storm Sewers Assessed Against Established Criteria – A very modest increase in sewer failures in the downtown area.

Culverts Assessed Against Established Criteria – Two lowland culverts are not meeting 10 Year criteria in the future condition that appeared to meet criteria in the existing condition. This may be a result of assigning the downstream boundary condition and not the culvert size directly.

Detention Ponds Assessed Against Established Criteria – No observed changes from existing conditions.

Creeks Assessed Against Established Criteria – No observed changes to the lowland systems, but one small reach in lower Horn Creek is flagged for the future conditions that did not appear for the existing condition.

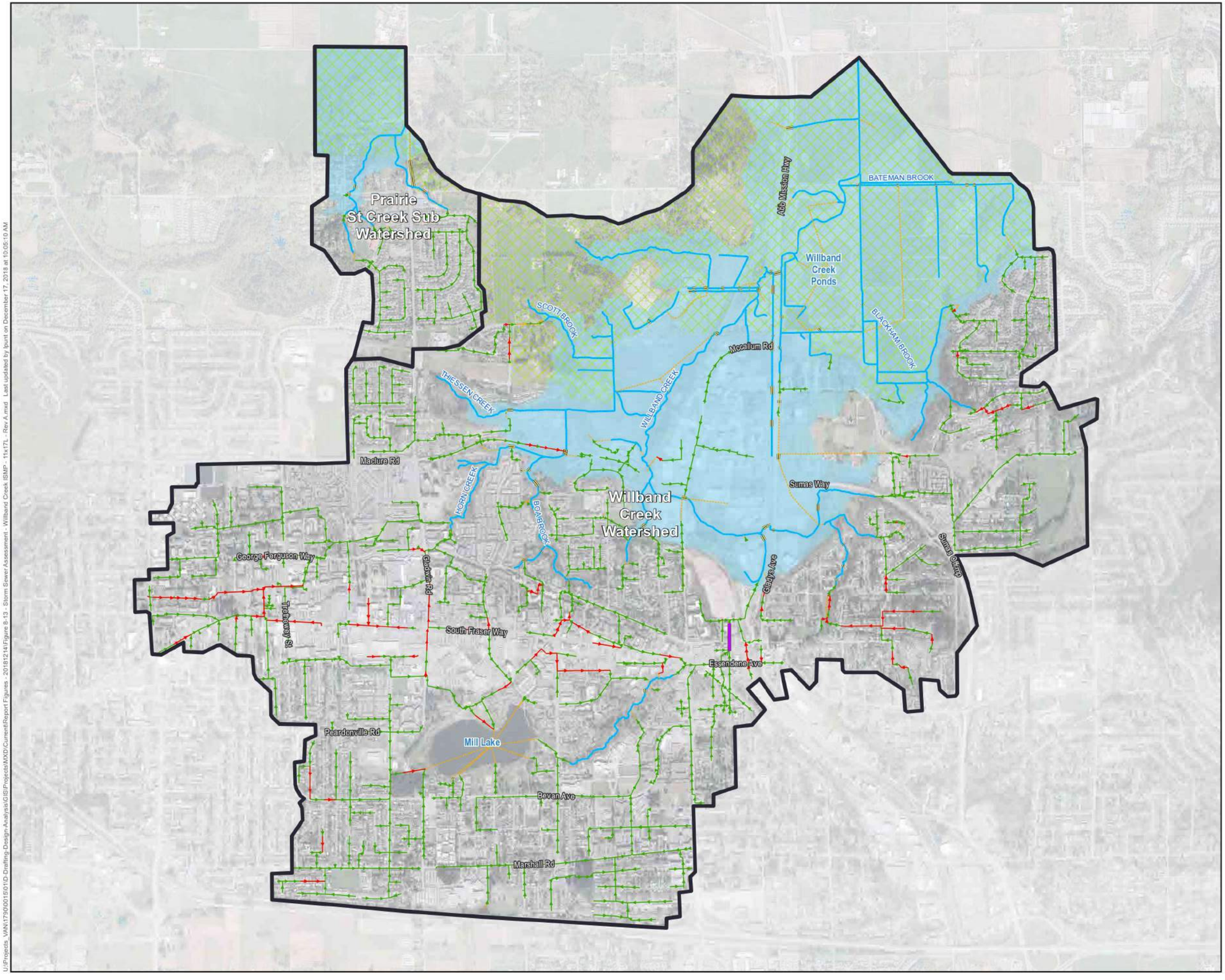
In general, the most conservative future condition scenario does not appear to have dramatic impact on the ability of infrastructure to meet established criteria.

### 8.5.4 Future Land Use (Controls and Climate Change)

With consideration for climate change, system performance tends to worsen where no redevelopment is occurring. But in areas that are to redevelop, the application of controls demonstrates the ability to more than compensate for the negative effects of climate change; showing in some area's performance better than the existing condition.

### 8.5.5 Continuous Simulation and Erosion Potential Assessment

The Stream Erosion Index (SEI) method compares results from various land use, stormwater management and climate scenarios against a baseline, often a "pre-development condition" but, in this case, the existing condition since predevelopment has not been assessed. This method has been applied to three natural channel reaches to assess the potential change in erosion risk with various future condition scenarios. The sites are numbered by their conduit ID as applied in the hydraulic model, located and highlighted blue in **Figures 8.17** to **Figure 8.19** below.

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Willband Creek
Integrated Storm Water
Management Plan

**Storm Sewer Assessed Against Established Criteria (Future Land Use - Climate Change)**

**No Controls**

- Willband Creek Watershed
- Major Main (100-Year) Surcharge 0.3 m over Crown for > 15 min
- Minor Main (10-Year) Surcharge 0.3 m over Crown for > 5-min
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

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0 145 290 580 870
Metres

N

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:**
1:22,000

**Data Sources:**
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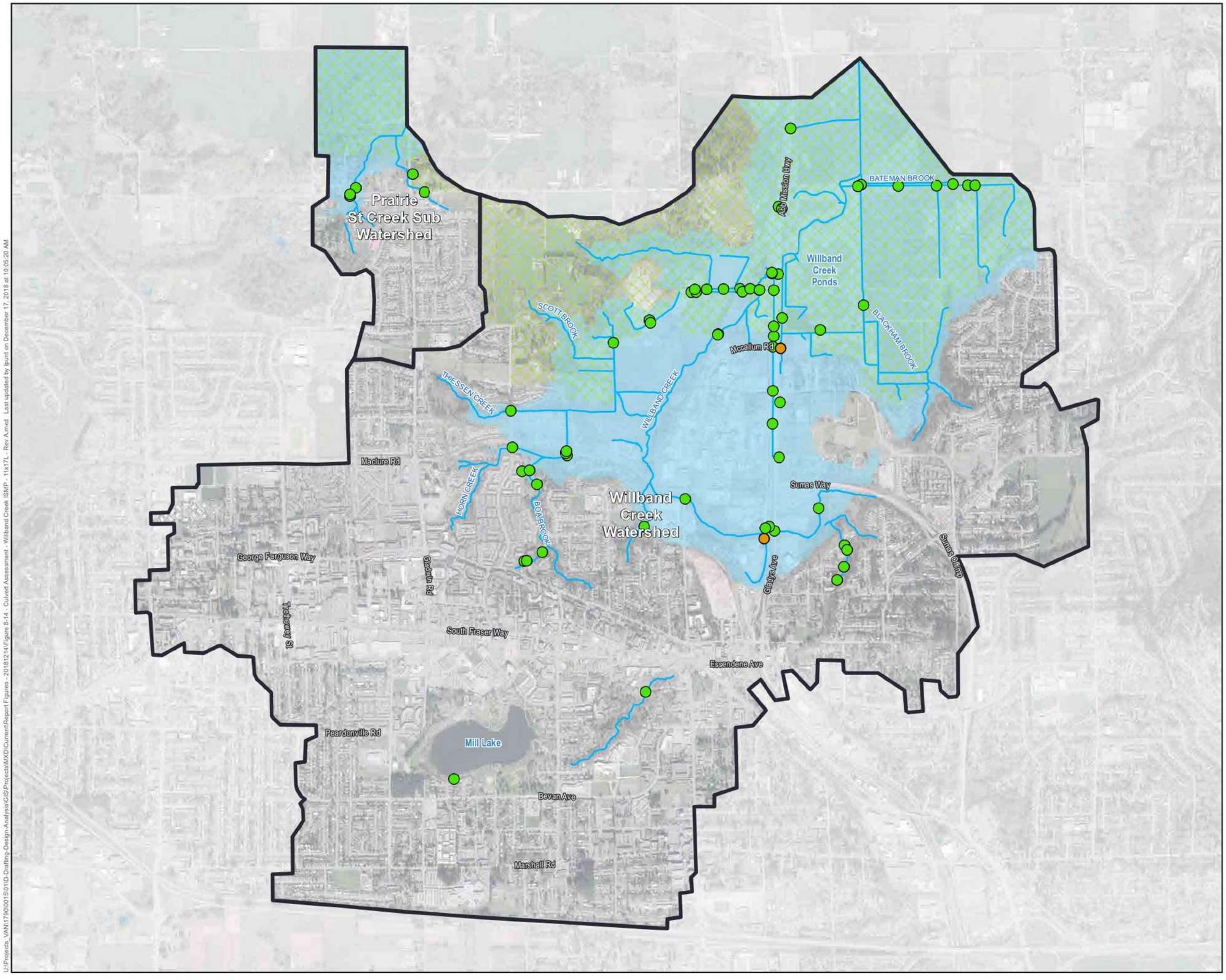
**FIGURE 8.13**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures_20181214\Figure 8.13_Storm Sewer Assessment_Willband Creek ISMP_11x17L_Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:05:10 AM

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Willband Creek
Integrated Storm Water
Management Plan

**Culverts Assessed Against Established Criteria (Future Land Use - Climate Change) No Controls**

- Willband Creek Watershed
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

**Culvert Assessment**

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

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Metres

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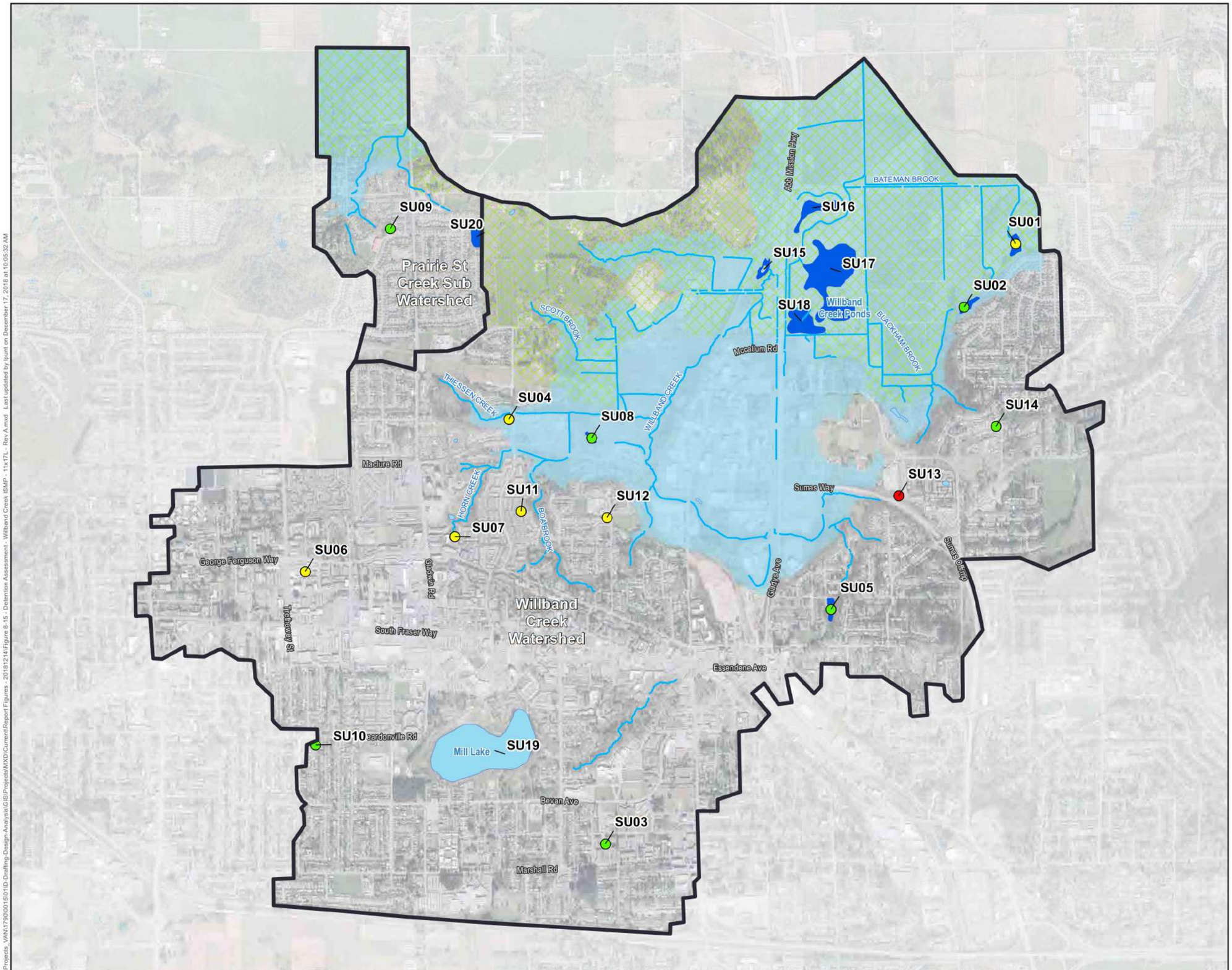
**FIGURE 8.14**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-14 - Culvert Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:05:20 AM

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Willband Creek
Integrated Storm Water
Management Plan

## Detention Facilities Assessed Against Established Criteria (Future Land Use - Climate Change)

### No Controls

- Willband Creek Watershed
- Detention Facility
- Lake
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

### Detention Assessment

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

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0 145 290 580 870
Metres

N

**Coordinate System:**
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**Scale:**
1:22,000

**Data Sources:**
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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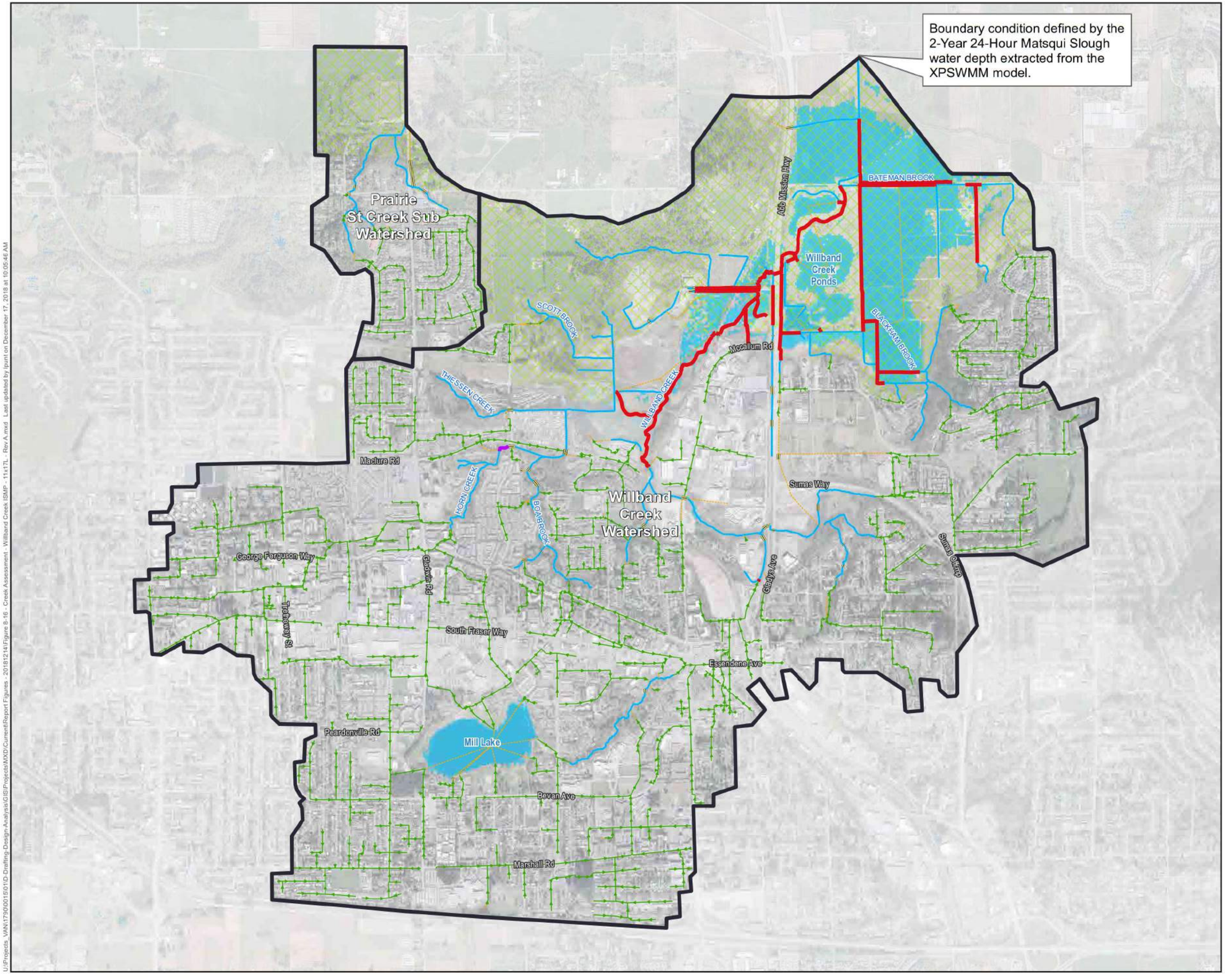
**FIGURE 8.15**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-15 - Detention Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:05:32 AM

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Willband Creek
Integrated Storm Water
Management Plan

## Creeks Assessed Against Established Criteria (Future Land Use - Climate Change)

### No Controls

- Willband Creek Watershed
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland and Mill Lake Flood Extent (2-Year, 24-Hour)

### Creek Assessment

- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek

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0 145 290 580 870
Metres

N

**Coordinate System:**
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**Scale:**
1:22,000

**Data Sources:**
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**FIGURE 8.16**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures_20181214\Figure 8.16 - Creek Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:05:46 AM

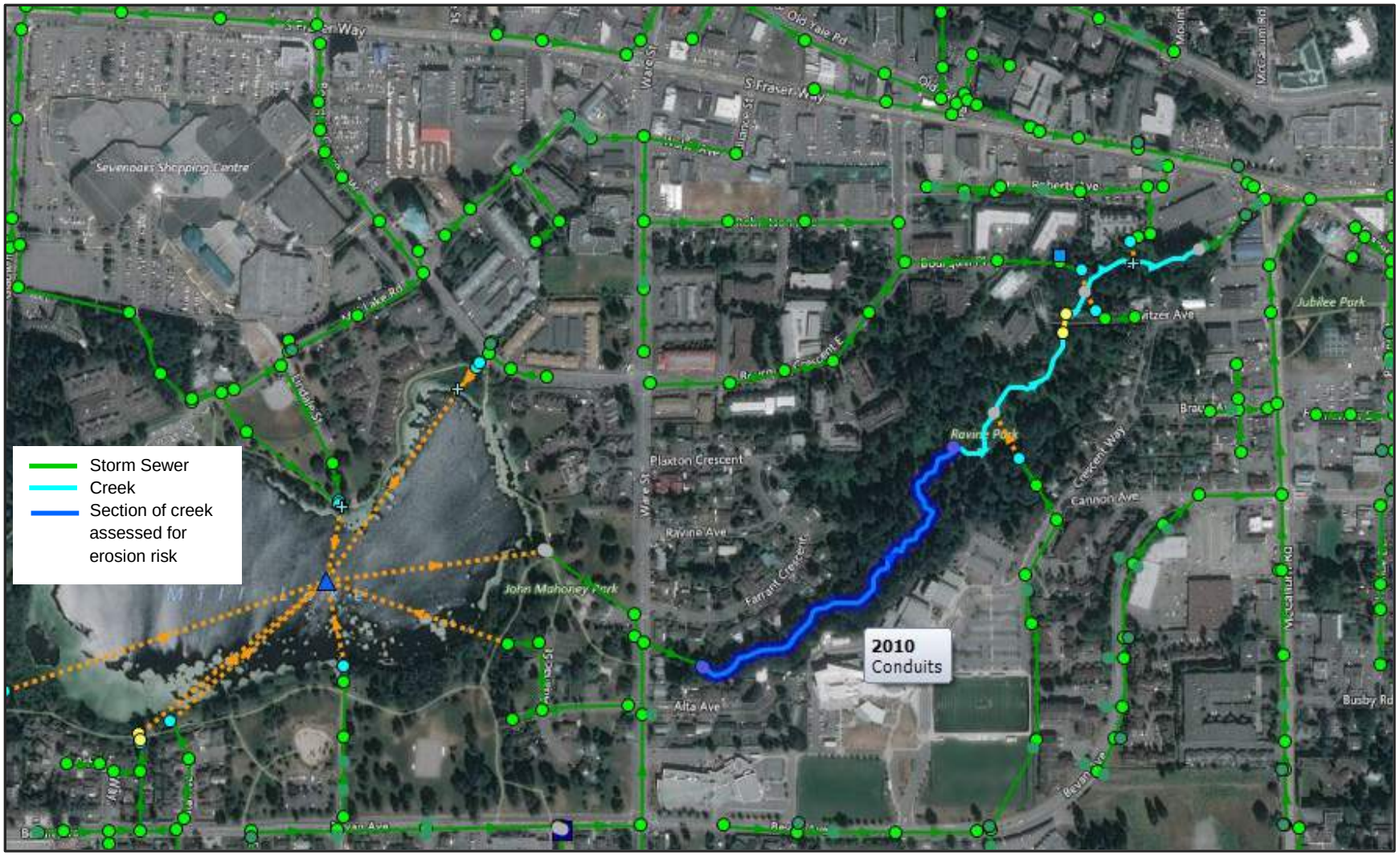


**Figure 8.17 - Conduit 2010 - A section of creek (highlighted blue) immediately downstream of the storm sewer outfall from Mill Lake, and within Ravine Park.**

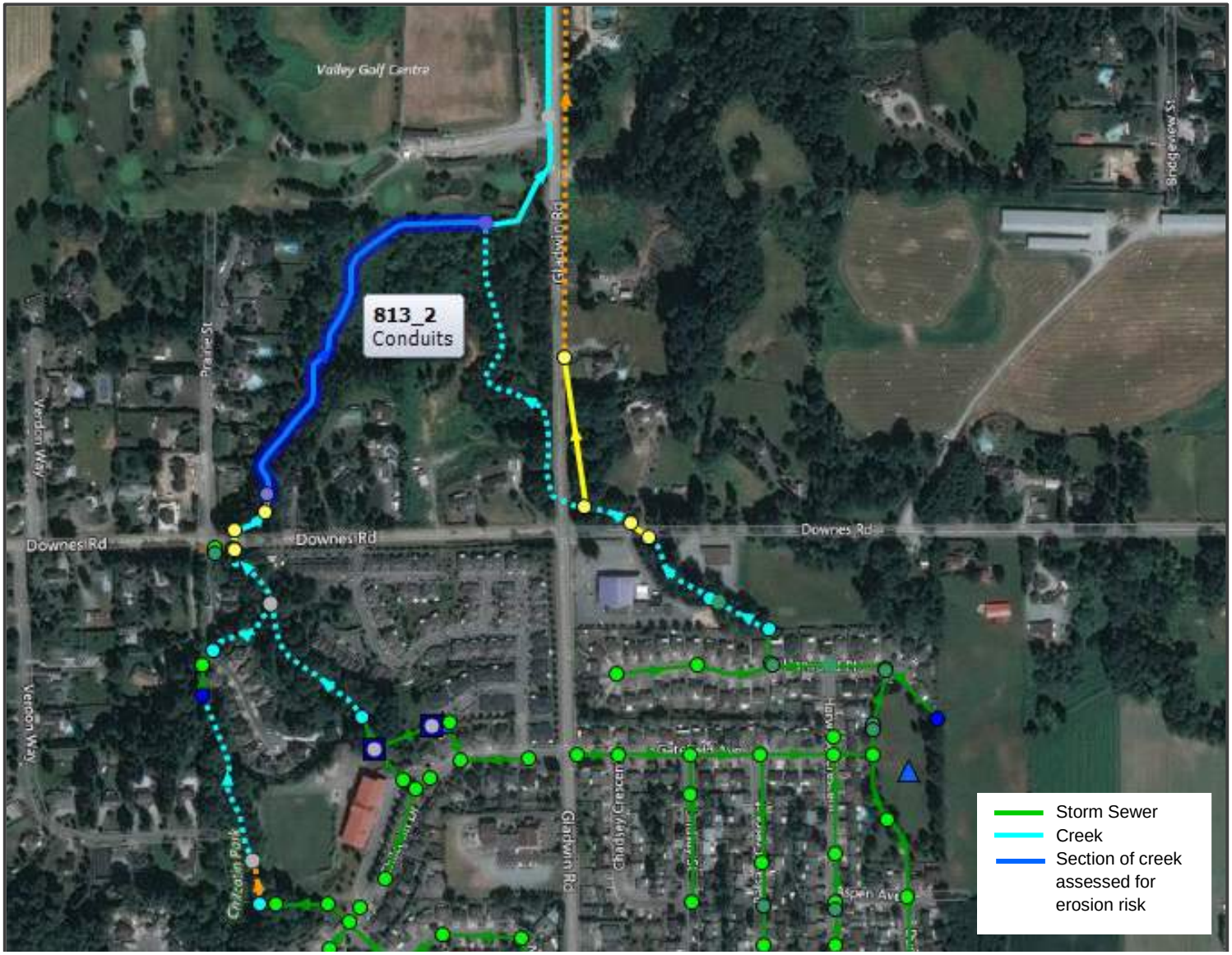


**Figure 8.18 - A section of Prairie Street Creek (highlighted blue) between Downes Road and Gladwin Road**

**Figure 8.19 - Conduit 2635_3 - A section of Horn Creek (highlighted blue) through Horn Creek Park**

Creek erosion is a function of flow over time and, more specifically, the duration flows exceed a discharge that can, or is likely to, erode a creek due to the type and size of bed materials, creek morphology, and other factors. Using continuous simulation results, this process can be calculated by comparing the flow at each time step of a hydraulic simulation to a flow estimated to be indicative of that which is channel forming. Often this "channel forming" discharge ($Q_{ChlFrm}$) is conceptualized as something near the 2-year return period flow but could be as low as 0.3-year to upwards of 10-year. Research has shown that a stream may experience exceedances of $Q_{ChlFrm}$ on average 4-8 days per year, up to 24 days, therefore for this assessment a flow rate in that range has been selected through engineering judgement.

Continuous precipitation data was obtained from the City's Flowwork's database and applied for the period of 2013-2017. The selected channel-forming flows, and number of exceedances during the simulation period, are tabulated below in **Table 8.2.** A sensitivity test of these values is discussed further on in this sub-section. An assessment of potential erosion impact was then conducted for four different future condition scenarios:

- "Future" Land Use with no stormwater controls nor climate change.
- "Future with Controls" as described above, but with no climate change.
- "Future with Climate Change" but with no stormwater controls.
- "Future with Controls and Climate Change".

The flow-duration plots for each of the three sites, shown on the following pages, illustrate that the flow regimes are very similar for all tested scenarios and against the existing condition. Each site is graphed twice; first for the full range of simulation period (2013-2017), and second for the flows that are exceeded 2% of the time to show more detail.

**Table 8.2 - Channel Forming Flow Estimates**

| Conduit | Location | $Q_{ChlFrm}$ ($m^3/s$) | Number of Exceedances | Average Annual Exceedances |
|---|---|---|---|---|
| 2010 | Ravine Park | 0.56 | 28 | 5.6 |
| 2635_3 | Horn Creek Park | 2.40 | 28 | 5.6 |
| 813_2 | Prairie Street Creek | 0.14 | 28 | 5.6 |

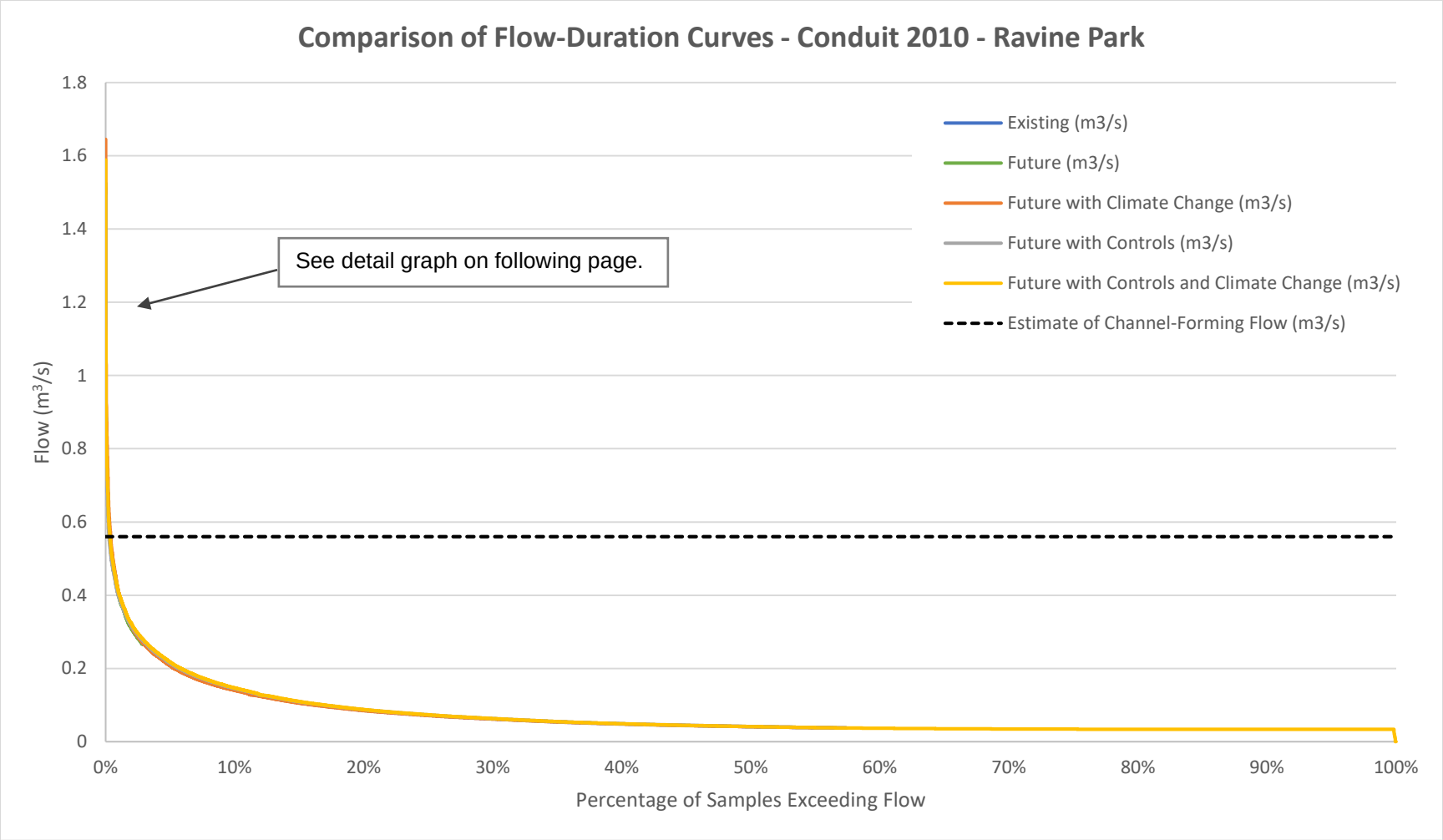


**Figure 8.20 -Comparison of Flow Duration Curves for Conduit 2010 (Ravine Park)**

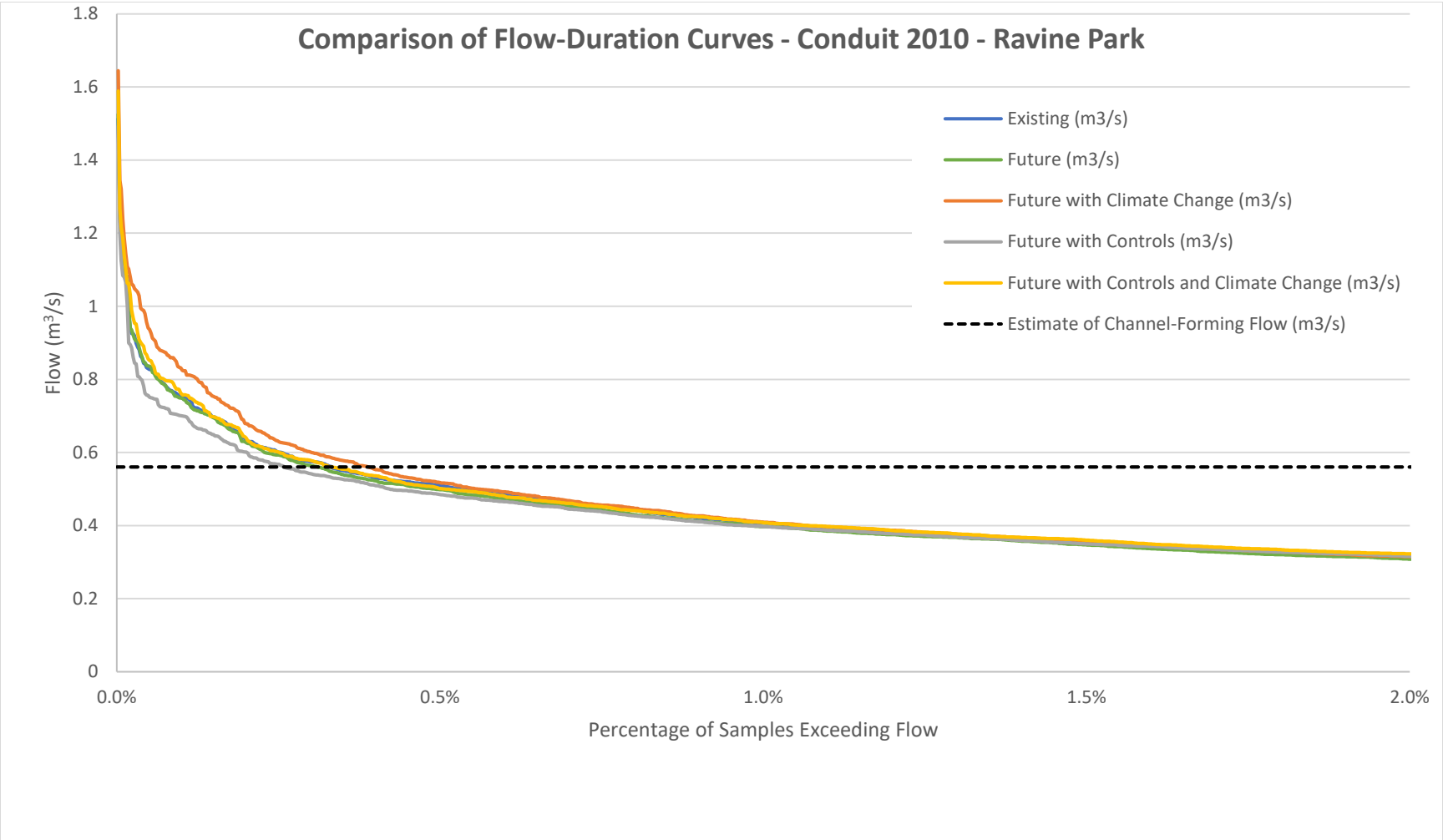


**Figure 8.21 - Comparison of Flow Duration Curves for Conduit 2010 (Ravine Park) (<2%)**

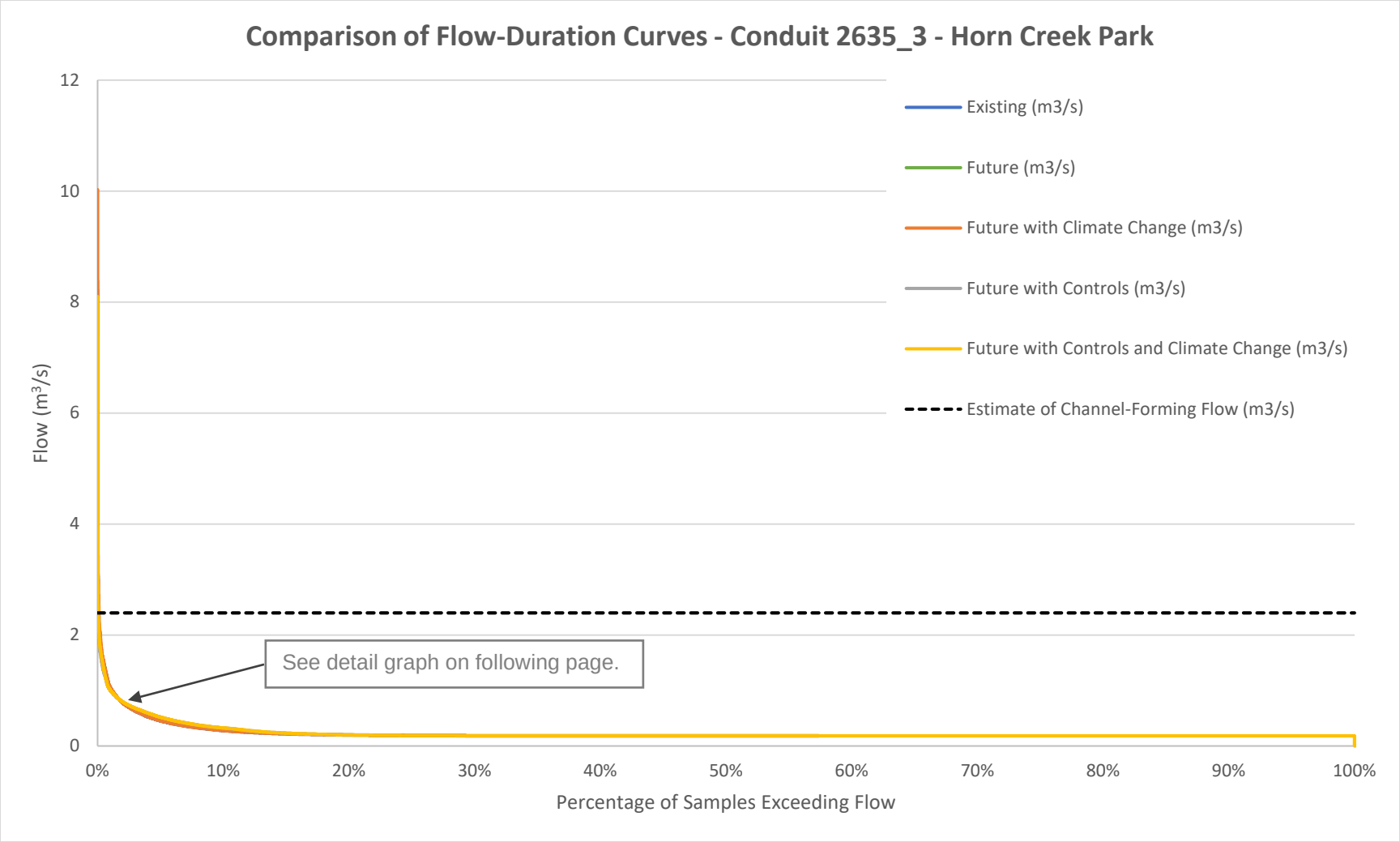


**Figure 8.22 - Comparison of Flow Duration Curves for Conduit 2635_3 (Horn Creek)**

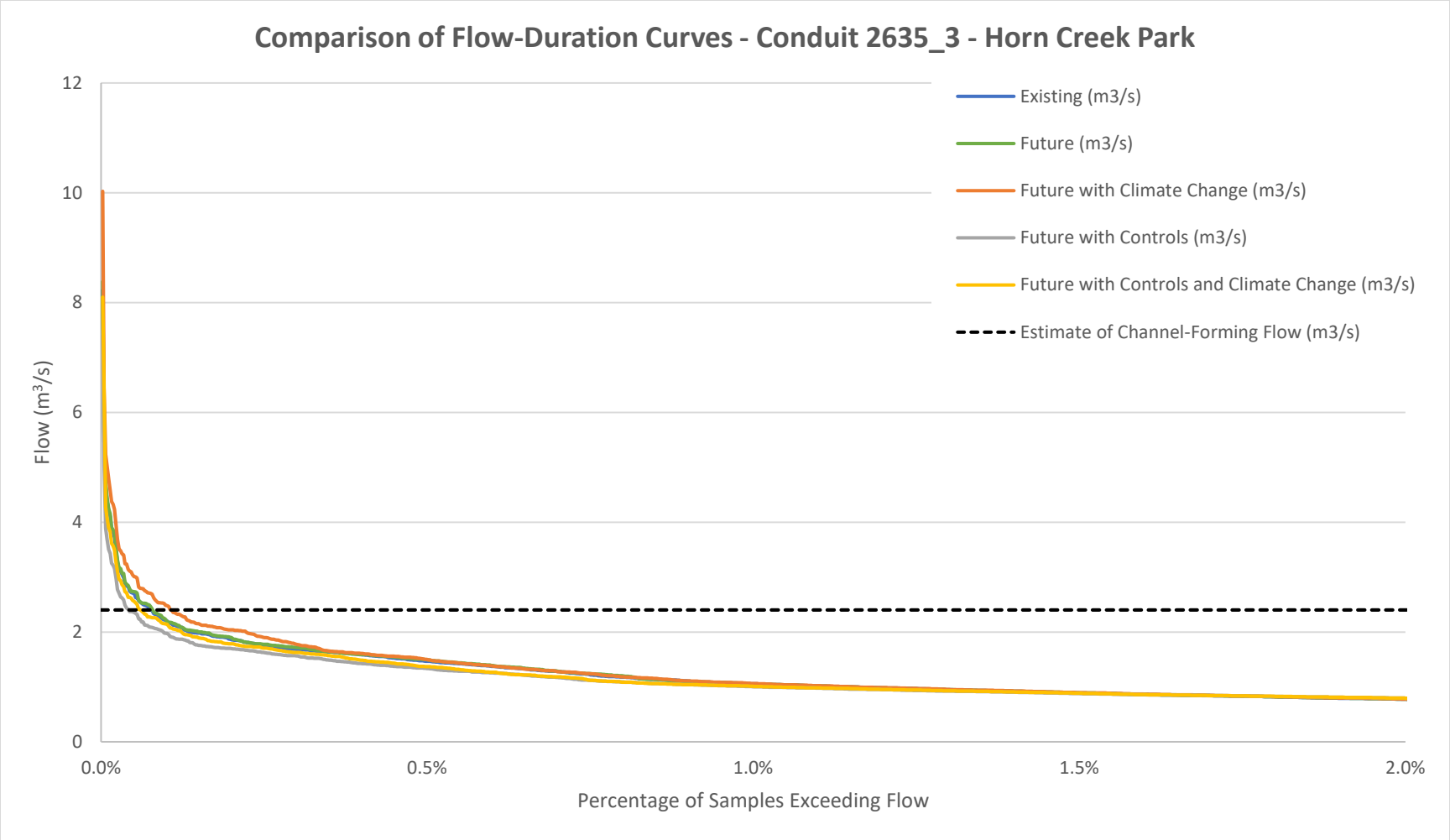


**Figure 8.23 - Comparison of Flow Duration Curves for Conduit 2635_3 (Horn Creek) (<2%)**

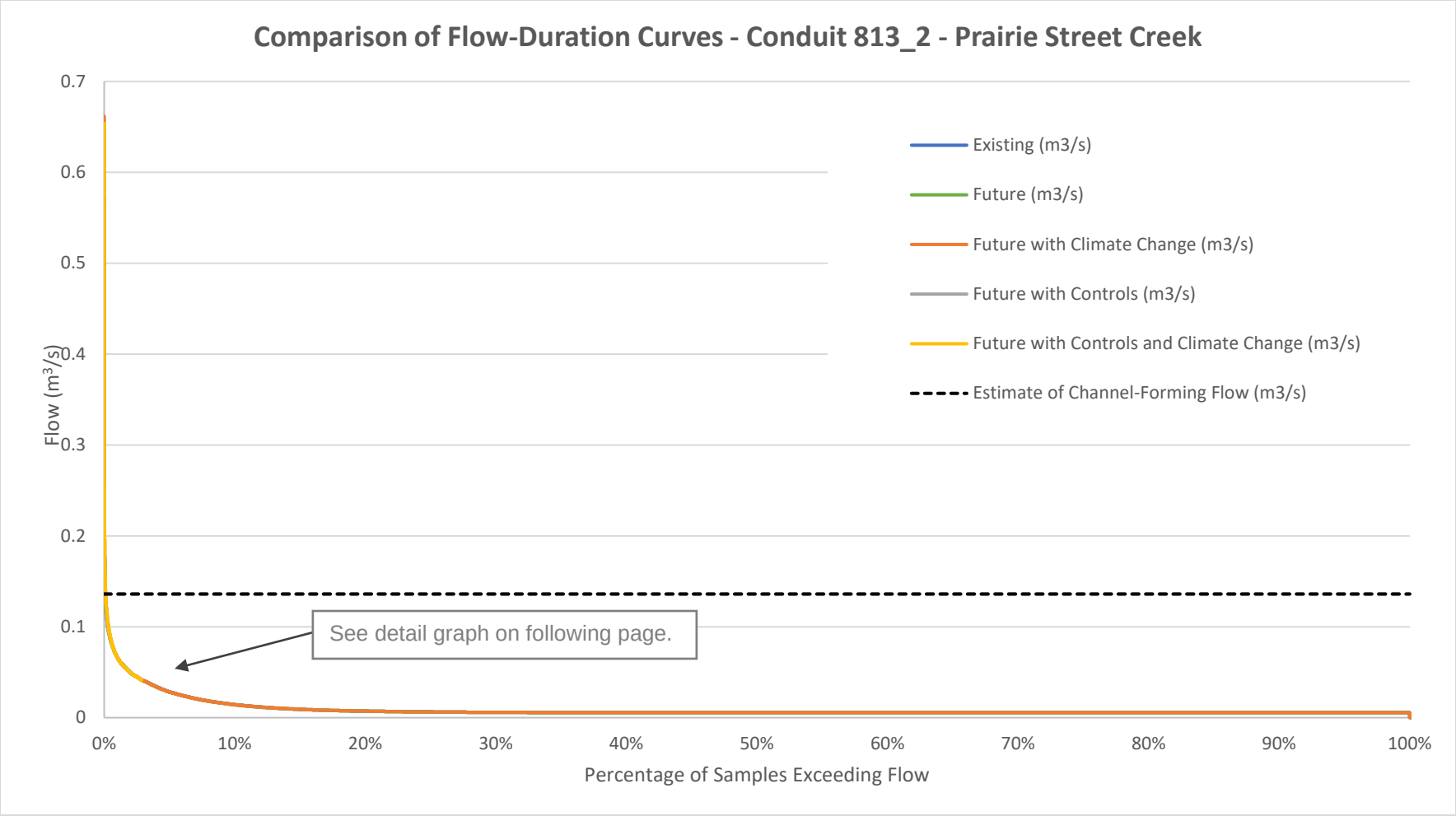


**Figure 8.24 - Comparison of Flow Duration Curves for Conduit 813_2 (Prairie Street Creek)**

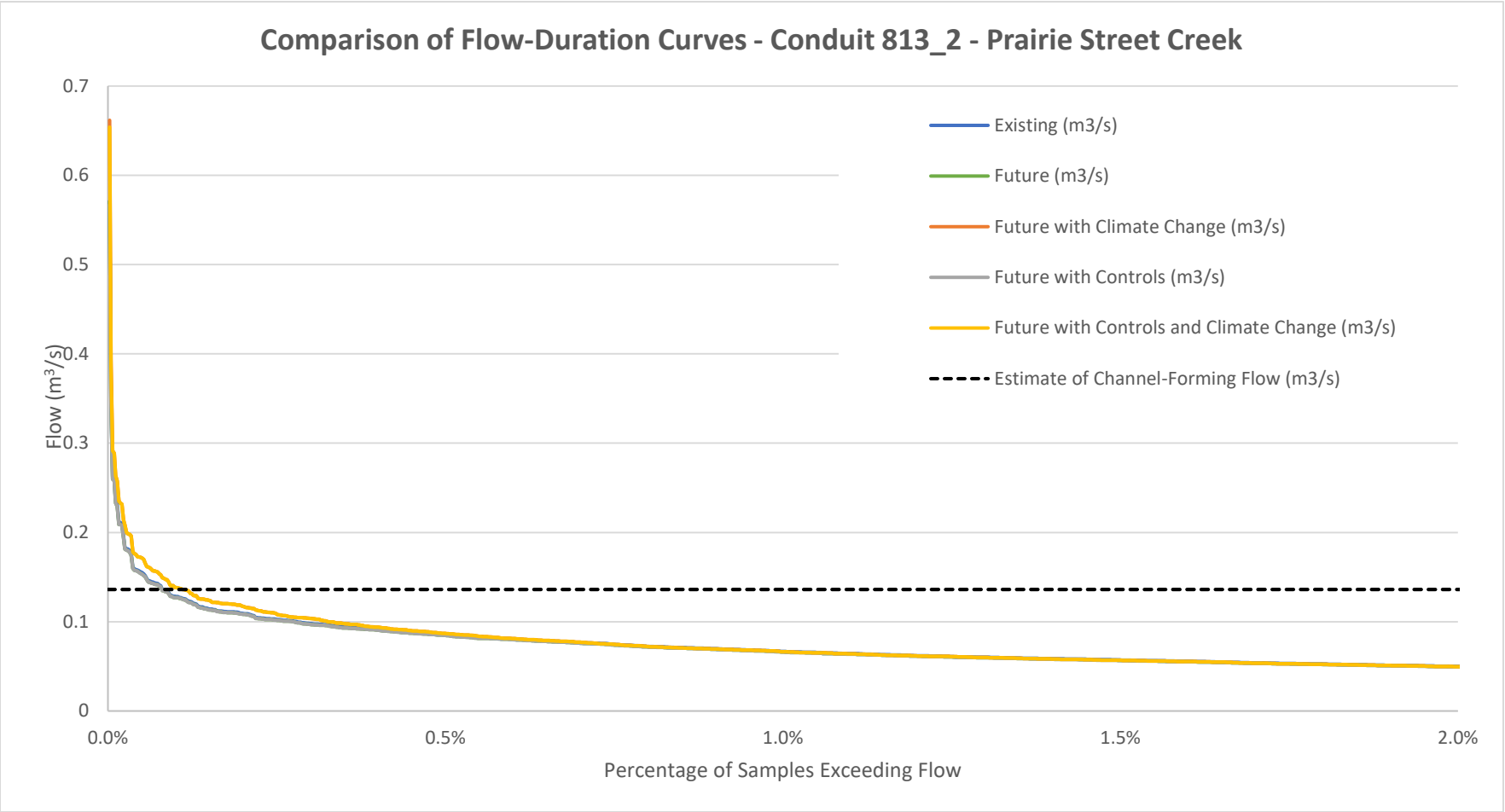


**Figure 8.25 - Comparison of Flow Duration Curves for Conduit 813_2 (Prairie Street Creek) (<2%)**

For the baseline condition (existing) the SEI is one (1). The SEI is the ratio of the plotted area above the channel forming Q line to that of the existing conditions. For the four scenarios assessed, SEI's at the three conduits are presented in the tables below. Because the choice of channel-forming flow is not prescriptive, the sensitivity of SEI was tested against variable $Q_{ChlFrm}$ values; one selected 20% higher, and one selected 20% lower.

**Table 8.3 - SEI Estimation**

| Scenario | Conduit 2010 | Conduit 2635_3 | Conduit 813_2 |
|---|---|---|---|
| Future | 0.96 | 1.06 | 0.97 |
| Future with Climate Change | 1.42 | 1.56 | 1.43 |
| Future with Controls | 0.71 | 0.58 | 0.97 |
| Future with Controls and Climate Change | 1.06 | 0.85 | 1.42 |

**Table 8.4 - SEI Estimation with $Q_{ChlFrm}$ 20% Higher**

| Scenario | Conduit 2010 | Conduit 2635_3 | Conduit 813_2 |
|---|---|---|---|
| Future | 0.98 | 1.06 | 0.98 |
| Future with Climate Change | 1.65 | 1.60 | 1.44 |
| Future with Controls | 0.64 | 0.59 | 0.97 |
| Future with Controls and Climate Change | 1.13 | 0.88 | 1.42 |

**Table 8.5 - SEI Estimation with QChlFrm 20% Lower**

| Scenario | Conduit 2010 | Conduit 2635_3 | Conduit 813_2 |
|---|---|---|---|
| Future | 0.94 | 1.05 | 0.97 |
| Future with Climate Change | 1.23 | 1.51 | 1.39 |
| Future with Controls | 0.78 | 0.60 | 0.96 |
| Future with Controls and Climate Change | 1.02 | 0.86 | 1.39 |

As demonstrated by the tables above, the SEI is not sensitive to a change in $Q_{ChlFrm}$ flow. The three sites are predicted to be relatively stable when measured against existing conditions. This is to say that predicted future changes are not expected to significantly change erosion risk. However, it is known that these streams are currently exhibiting erosion that should be addressed, which is discussed in subsequent sections of this study.

It appears as though climate change will potentially be a more significant driver of erosion potential than future land use, and that the 'controls' scenario is able to compensate for any increased impervious surface and bring the SEI back down below 1. However, none of the SEI's are very high, with the highest value being 1.65. It is not out of the question to find SEI's of 3 in streams that could still be classified as stable, depending on bed material(s). Although more detailed analysis could be performed to confirm or strengthen the analysis, the SEI's listed in the table do not trigger significant concern for future erosion over what may be experienced today. If the observation of erosion is considered unacceptable today, then more rigorous analysis using detailed channel geometry and bed and bank material sampling is required. As presented in Figure 5.3, a number of medium risk erosion sites, and one high risk erosion sites, were identified in the Horn Creek system.

# PART 3 – MANAGEMENT STRATEGY

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# 9 INFRASTRUCTURE

## 9.1 Future Land Use - Revisited

During the conduct of this ISMP and following the analysis described in Section 8 above, the City completed Neighbourhood Plans for both the City Centre and the Historic Downtown. For those studies the City assumed full build out in accordance with the OCP. Therefore, this assumption was carried forward into the completion of this ISMP analysis. The results presented in subsequent sections represent full build out of the Neighbourhood Plan areas, whereas the "Build_35" database for redevelopment was applied everywhere else. The "Build_35" database is not a precise depiction of which properties will redevelop in the foreseeable future, but rather a depiction of anticipated redevelopment patterns and extent in the near term.

## 9.2 Storm Sewer Infrastructure - Revisited

The original scope of this ISMP was that only storm sewer infrastructure 300 mm in diameter or larger would be assessed for performance. But through the conduct of the Neighbourhood Plans, the City wished to assess performance of all pipes and identify future pipes on roadways that do not currently have them. For consistency, the same approach was adopted to the completion of this ISMP, therefore the results presented herein account for a greater number of storm sewers and infrastructure upgrades.

## 9.3 Criteria, Scenarios, and Priorities - Revisited

The criteria applied in subsequent sections remains unchanged from what was previously applied in Section 8, however system performance, upgrade requirements, and priorities have been further reviewed, and applied as follows:

### 9.3.1 Minimum Basement Elevations (MBE's)

Current criteria require minimum basement elevations (MBE's), or habitable floor space, to be located a minimum of 0.15 m above the major (1:100 year) hydraulic grade line. It is not current practice in the City to permit backflow preventers and pump stations, but to require gravity connections. Despite the current criteria and the fact that the existing storm sewer system was not sized for the 1:100 year event, there are some legacy buildings that have subsurface basements connected to the existing system. An inventory of these basement buildings has not been mapped by the City, and the City has also not reported any claims of flooding associated with these basement connections. Regardless, there is legitimate concern for any actions that may worsen system performance, in turn increasing the likelihood and risk of surcharging and backups into private property.

It is recommended that the City not permit additional basements (habitable floor space) below ground surface, unless one of the following three approaches are taken:

i. Upsizing, and typically deepening, the storm sewer system to accommodate gravity connections protected to the 1:100 year (major flow) level;
ii. Permit a service connection with a backflow preventer and sump-pump, along with a restrictive covenant with wording protecting the City against liability due to surcharging.
iii. Not permit a service connection, assuming foundation design can satisfy building code requirements with on-site drainage disposal (to be determined by applicant).

The above recommendations are not unique to this area but should apply to any area in the City where it is known (predicted) that the

1:100 year hydraulic grade line will be above the crown of the storm sewer system.

The cost of upsizing the storm sewer system to a 1:100 year level to accommodate gravity connections is expectedly very high. It is expected that the City would recoup upsizing costs through development cost charges (DCC's), however developers paying a DCC charge and seeking approval for basement connections would anticipatedly expect immediate service without need for added protection or limited liability to the City. Therefore, an added challenge in attempting to resize the storm sewer system for the 1:100 year event is that implementation process and risk reduction is expected to take many years. Any basement that is implemented before system improvement is complete is likely still vulnerable and will require added protection. It therefore may be unrealistic to significantly increase the level of service near term. There may be small pocket areas with sufficient grade that can be more reasonably improved in a shorter time frame, but flat topographic areas will be difficult to improve without large capital investment and expansive replacement.

### 9.3.2 Future Development Servicing Scenarios

Redevelopment presents an opportunity to improve storm sewer performance through successful application of on-site controls, however, it is understood that variable conditions exist and don't provide certainty to the benefits derived from them. As such, the analysis has assumed different scenarios with varying degrees of conservatism, as follows:

**Scenario 1** - Future Land Use with no site controls, but with climate change[3] and existing municipal drainage systems. This scenario is used to understand the anticipated existing system performance should climate change and redevelopment proceed without controls. This is considered a "worst case" scenario.

**Scenario 2** - Future Land Use with site controls applied to all lands, with climate change and existing municipal drainage systems. This scenario is used to understand the potential benefit of achieving currently defined controls on all parcels of land. This is considered a "best case" scenario.

**Scenario 3** - Future Land Use with no site controls, but with storm sewer improvements to resolve performance issues to fully satisfy the City's current criteria of storm sewers sized to prevent surcharging under a 1:10 year event, or in the case of the Mill Lake Ravine trunk system, the 1:100 year event. This is a conservative, but preferred scenario for the City.

### 9.3.3 Key Catchment Parameters

Regardless of whether engineered infiltration systems (stormwater source controls) are successfully implemented or not, the assumption for Directly Connected Impervious Areas (DCIA) are important to the performance of the storm sewer system. Although modeling scenarios have been tested and storm sewer sizing developed on the assumption that engineered infiltration systems are not broadly applied, it remains important that impervious surfaces to the extent presented in **Table 9.1** be disconnected and routed to a pervious surface.

Through discussion with City staff, **Table 9.1** presents what is felt realistically achievable in terms of total impervious area (TIA) and the

[3] Climate change design storms are scaled up 10% from current levels.

DCIA. Please note that the DCIA represents the percent of TIA, not the percent of the total site.

**Table 9.1 - Assigned Impervious Areas**

| Land Use | Total Impervious Area (TIA) % | Directly Connected Imp. Area (DCIA) % of TIA |
|---|---|---|
| Historic Downtown | 100 | 100 |
| Urban Centre Mixed | 90 | 50 |
| Urban Centre Residential | 90 | 50 |
| Employment | 90 | 50 |
| General Industrial | 90 | 100 |
| Industrial | 90 | 100 |
| City Centre Core | 90 | 50 |
| City Centre Residential | 90 | 50 |
| Secondary Commercial | 90 | 50 |
| Institutional | 90 | 50 |
| Urban 1 – Midrise | 80 | 50 |
| Urban 2 – Ground | 80 | 50 |
| Urban 3 - Infill | 65 | 10 |

## 9.4 Potential Communal Detention Facilities to Reduce Storm Sewer Improvements

This section explores the potential of communal detention facilities on City owned land for the purpose of reducing peak flows in the storm sewer system, with the goal of reducing the need for storm sewer improvements.

### 9.4.1 City Centre Neighbourhood Plan Area (CCNP)

An opportunity to create a communal detention facility in the Municipal Hall civic site was evaluated for its potential to reduce surcharging in neighbouring storm sewer systems. In this case, the greatest storm sewer deficiencies exist upstream of the Municipal Hall site. Therefore, a communal pond at this location provides little benefit in reducing storm sewer surcharging. However, this site provides an opportunity for the City to implement site controls and set a positive precedence for the community. It may also serve as a local amenity and water quality facility.

### 9.4.2 Historic Downtown Neighbourhood Plan Area (HDNP)

An opportunity to create a communal detention facility in the vicinity the Five Corner intersection of McCallum Road, South Fraser Way, and Essendene Avenue was identified by the City. This location is upstream of deficient trunk sewers on Montrose Avenue and theoretically may have the ability to reduce surcharging, but the challenge is that the flow needing to be arrested is entering from the upstream Mill Lake Ravine Park ravine. The elevation of land at the Five Corners intersection is excessively high relative to the ravine invert, therefore, there is no realistic means to create an open storage deep enough to sufficiently arrest the flow.

### *Mill Lake Ravine*

As an alternate, storage directly within the Mill Lake Ravine may be created by restricting flow at the transition from the ravine into the 1800 mm diameter trunk storm sewer. Using available topographic surface data (LiDAR), the storage potential of the ravine was measured as presented in **Table 9.2** below.

**Table 9.2 - Mill Lake Ravine Storage**

| Elevation (m) | Surface area (m2) | Cumulative Volume (m3) |
|---|---|---|
| 30 | 100 | 0 |
| 31 | 1,847 | 973 |
| 32 | 7,448 | 5,621 |
| 33 | 13,997 | 16,344 |
| 34 | 23,085 | 34,885 |

To prevent surcharging in the existing 1350 mm diameter pipe further downstream on Montrose Avenue during a 1:100 year event, a flow control structure would need to limit flow from the ravine to no more than 2 $m^3/s$. Activation would occur rarely, therefore would not interrupt the typical flow regime nor the navigability of any fish that may be present. Analysis shows that for the variety of 1:100 year events, up to 24 hours, the maximum detained volume in the ravine would be 15,000 $m^3$ if flows were restricted to 2 $m^3/s$.

Based on **Table 9.2**, the resulting maximum water surface elevation in the ravine is approximately 33 m, or a maximum depth of 3 m at the control structure. The trunk storm sewer at the inlet structure is 1.8 m in diameter, therefore depth of water above the pipe crown would be approximately 1.2 m.

Using the LiDAR topographic surface information, the extent of storage within the ravine with maximum water surface at 33 m elevation is shown in **Figure 9.1**. From a flood extent perspective this option appears viable, however before a conclusion can be reached it's recommended that regulatory agencies be consulted regarding on-line storage within the ravine, a geotechnical engineer be consulted to assess potential slope stability issues and an arborist be consulted on the potential impact to trees within the flood zone. A biologist also will need to evaluate the effects on fish and wildlife. And finally, landscape architects will need to review if there is any effect on parks tails and associated structures.

The control structure would need thoughtful consideration for debris, turbulence / erosion, and provide an emergency overflow.

### *Mill Lake*

Consideration was also given to whether the Mill Lake outfall structure may be modified to reduce 1:100 year discharge in the trunk system downstream of Mill Lake Ravine, however, with significant flows entering the ravine from trunk storm sewers downstream of the Mill Lake, controlling at the lake cannot sufficiently arrest the total flow to prevent surcharge within the Historic Downtown. In addition, Mill Lake already reaches maximum capacity and the existing control structure is actively managed to prevent water backup into adjacent property. If any further restriction on lake flows were to occur, it would be necessary to significantly lower the normal water level in the lake during a winter season to create additional freeboard. And new operating protocols for the lake outfall would need to be established.

### *City Owned Parking Lot – West Railway Street and Essendene Avenue*

The City had discussed the potential to build an infiltration or detention facility within the City owned parking lot at West Railway Street and Essendene Avenue. There are several deficient storm sewers in the area, but only those downstream of a detention facility would benefit;

presumably the existing 600 mm diameter storm sewer north of Essendene Avenue running through the parking lot to George Ferguson Way. To reduce the hydraulic grade line in the existing storm sewer, detention storage would be required at or below the elevation of the storm sewer. Assuming the City will still wish to maintain the site as a parking lot, a subsurface reservoir would be required to support traffic above. Without detention, this 130 m long storm sewer through the parking lot from Essendene Avenue to George Ferguson Way would need to be replaced to a 750 mm diameter if there are insufficient controls implemented upstream. Replacement of this pipe has a planning level capital value of $263,000. In order to prevent the existing 600 mm diameter storm sewer from surcharging, a detention storage of 180 $m^3$ and 1,700 $m^3$ would be required for the 1:10 year and 1:100 year events respectively. At roughly $1,500 per $m^3$, the planning level capital value of underground storage is $270,000 and $2.6M for the 1:10 year and 1:100 year events respectively. In addition, a detention vessel will have added maintenance and create a costly structure to remove if the property was to be repurposed for a building in the future. It is recommended that in this case upgrading the storm sewer through the property would be more cost effective.

However, the opportunity to create a surface-based infiltration facility to manage the runoff from the parking lot itself, and perhaps some surrounding roads or lands, is a worthwhile and recommended action. It would demonstrate the City as a leader in implementing site controls, as required by others.

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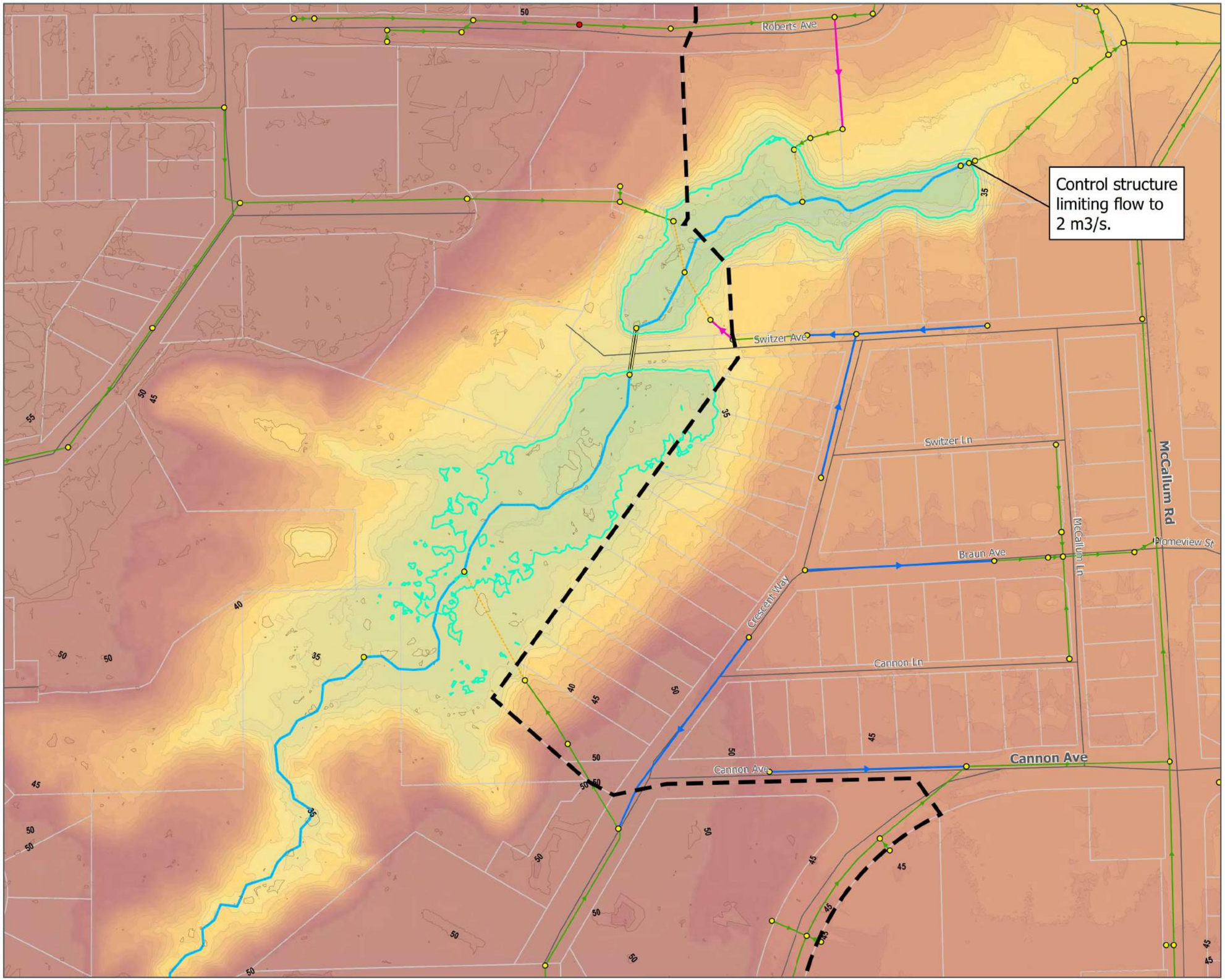
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Prp_Projects\1790.0015.01_Part_4.aprx\Figure 9-1 - Ravine Park Flooding (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

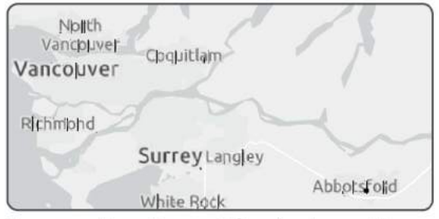
**Ravine Park Flooding**

**Legend**

- Historic Downtown Neighbourhood Boundary
- Upgrade Main
- Proposed Main
- Existing Main
- Creek
- Culvert
- Conduit Added for Connectivity
- Contours (1 Metre)
- 33 m Contour

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:1,877
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

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|---|---|
| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2018 / 12 / 17 |

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**FIGURE 9.1**

### 9.4.3 Historic Centre

As noted earlier, due to zoning allowances, it is very problematic to provide retention controls in the Historic Downtown (refer to the Historic Downtown Neighbourhood Plan), which covers an area of approximately 44 hectares in total when including the road right-of-ways, or 31 hectares in total of land parcels, excluding the road rights-of-ways. Criteria requires that retention and infiltration be provided for the 1:10 year 24-hour precipitation volume. For current precipitation, this is a rainfall depth of 95.5 mm. Applying an additional 10% for climate change this depth increases to 105 mm. Therefore, for the area noted the total volume of capture to satisfy the criteria ranges from 29,605 $m^3$ to 46,200 $m^3$ depending on whether or not road right-of-ways are included and what precipitation is applied. These are extensive volumes to manage and dispose of in a centralized facility. This information is provided for reference only as requested by the City. Sensitivity analysis was conducted to determine that not achieving the required controls within the Historic Downtown alone will not change the storm sewer capital program.

## 9.5 System Reconfiguration In Historic Downtown

There is a segment of historic storm sewer paralleling to the west of Montrose Avenue through the Historic Centre that runs beneath historic buildings. These are believed to have been privately installed pipes by landowners to facilitate infilling of the water course and gaining more usable land for their benefit. These properties have likely connected foundation, roof, and parking area drainage to this historical pipe. Aside from the roadway crossings, the City does not have a right of way or access to these private sewers, therefore the City has intent to reroute the City infrastructure. During redevelopment owners should be required to connect to the City system. It is possible that significant groundwater exists along the alignment of the historic private pipe if in fact is was the infill of a natural creek. Decommissioning of this private pipe by landowners will require thoughtful consideration of groundwater.

The City engaged ISL Engineering separately to conduct a preliminary design investigation for this redirection of City infrastructure. A letter report titled “Montrose and South Fraser Way Storm Review Draft Report – Rev02” (ISL Engineering, March 20, 2018) was produced.

Through dialogue with the City, additional lots fronting South Fraser Way have been allocated to Montrose Avenue within this ISMP study than previously assumed by ISL, but otherwise the routing is fundamentally the same as assumed by ISL. The allocation of lot drainage to support the realignment is shown in **Figure 9.2**.

ISL Engineering, using the Rational Method, identified two pipe reaches on Montrose Avenue between Laurel Street and South Fraser Way that would surcharge under a 10-year event, and therefore ISL Engineering recommended that the storm sewer from Laurel Street to Essendene Avenue be upsized to 750 mm to prevent pipe downsizing.

The analysis as described herein (using the hydrograph method) indicates that the existing storm sewer on Montrose Avenue has sufficient capacity under the 10-year event to allow for service connection redirections and abandonment of the existing main underneath building. It is recommended that the City complete a condition assessment and monitor the observed performance of the existing Montrose Avenue storm sewer prior to reaching full conclusion on the adequacy of the existing storm sewer to accept the redirections.

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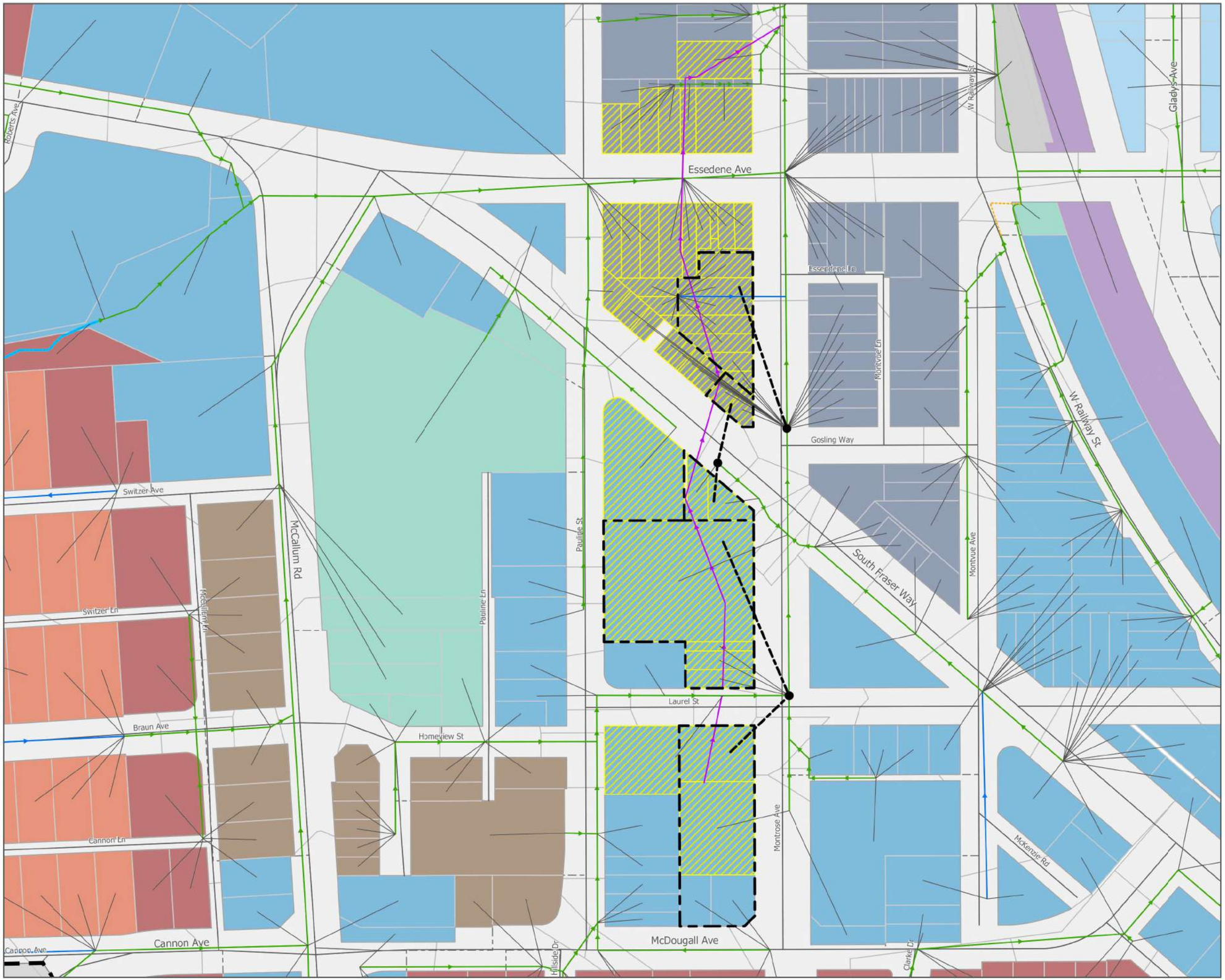


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# Willband Creek Integrated Storm Water Management Plan

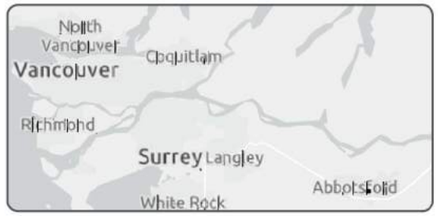
## Re-routing of Parcels to Abandon Mains Under Buildings

**Legend**

- Study Area
- Main Under Building (To Abandon)
- Main
- Proposed Main
- Creek
- Conduit Added for Connectivity
- Re-routed Parcel
- Sub-catchment boundary and loading point to Montrose Ave. as assumed by ISL Engineering (March 20, 2018)

Build-out Land Use

- Historic Centre
- Urban Centre Mixed
- Urban Centre Residential
- Employment
- Urban 1 - Midrise
- Urban 2 - Ground
- Secondary Commercial
- General Industrial
- Institutional
- Open Space
- Roadway Subcatchments (Allocated to Closest Node)

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Metres

**Coordinate System:**
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**Scale:** 1:1,800
(When plotted at 11"x17")

**Data Sources:**

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| Revision: | A |
| Date: | 2018 / 12 / 17 |

URBAN systems

**FIGURE 9.2**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 9.2 - Re-routing of Parcels to Abandon Mains Under Buildings (11x17)

## 9.6 Upland Storage for Horn Creek and Boa Brook

Erosion potential analysis demonstrates that future development is not expected to create ***additional*** erosion risk over today's condition, however significant erosion within Horn Creek and Boa Brook has been triggered from passed development and continues to persist.

Erosion within these watercourses, and solutions, have been studied in the past, including a 2001 study prepared by Golder Associates titled "Flood and Erosion Assessment of Horn Creek / Boa Brook Downstream of Maclure Road", and a report from 2009 also by Golder Associates titled "Bank Stabilization Marshall Creek and Horn Creek Erosion Sites, Phase II and Phase III Report". The 2001 study discussed a variety of in-stream, or near stream actions such as berms, bank stabilization, armoring, bioengineering, etc. A number of bank stabilization repairs were completed between 2004 and 2011, but erosion persists at locations that have not been stabilized.

In addition to in-stream repairs, the 2009 study presented a concept for a storm water diversion pipe to potentially reduce future erosion in Horn Creek. However, the Golder study stated that *"it would not mitigate the existing bank instability issues on Horn Creek and will not reduce bank instability caused by windthrow of trees."* The study contemplated three different diversion routes, all serving a 140-hectare catchment upstream (west) of Gladwin Road, and all terminating downstream of the confluence of Horn Creek and Boa Brook adjacent to Maclure Road.

Sizing of the diversion was based on diverting 50% of the peak 1:100 year peak flow estimate of 10 $m^3/s$, or a diverted flow of 5 $m^3/s$. The Class D cost estimated for the diversion in 2009 was $4.4M for a 1.35 m diameter pipe, excluding conflicts with existing utilities, but including design and construction services. The cost is expected to be much higher today. This City has not acted on this option and has sought commentary on alternate solutions, if they exist.

The analysis conducted for this ISMP demonstrates that a reduction in flows and erosion risk can occur over time through redevelopment and the broad application of source controls. However, this process will take many years through redevelopment, yet existing erosion problems require a more immediate response.

Shy of distributed source controls or further stabilizing the creek channels, an alternative is to implement communal detention facilities to attenuate discharges to the stream. However, in this scenario the volume of water being released does not change; only the release rate. As such, there is still risk for erosion if flow rates are not reduced sufficiently.

From the erosion potential assessment presented is Section 8.5.5 - Continuous Simulation and Erosion Potential Assessment, the current "channel forming flow" for Horn Creek was estimated to be in the order of 2.4 $m^3/s$, which is approximately equal to the current 1:2 year peak flow. However, this current estimate is significantly higher than the historic pre-development channel forming flow that would have existing prior to development. Shy of doing comprehensive erosion threshold analysis, it is recommended that the City's discharge criteria of 5 L/s/ha be used as a reasonable planning level value as the permissible release rate to combat erosion.

While numerous small outfalls exist, this assessment has identified the three largest outfalls, as identified in **Figure 9.3** below; two on Horn Creek and one on Boa Brook.

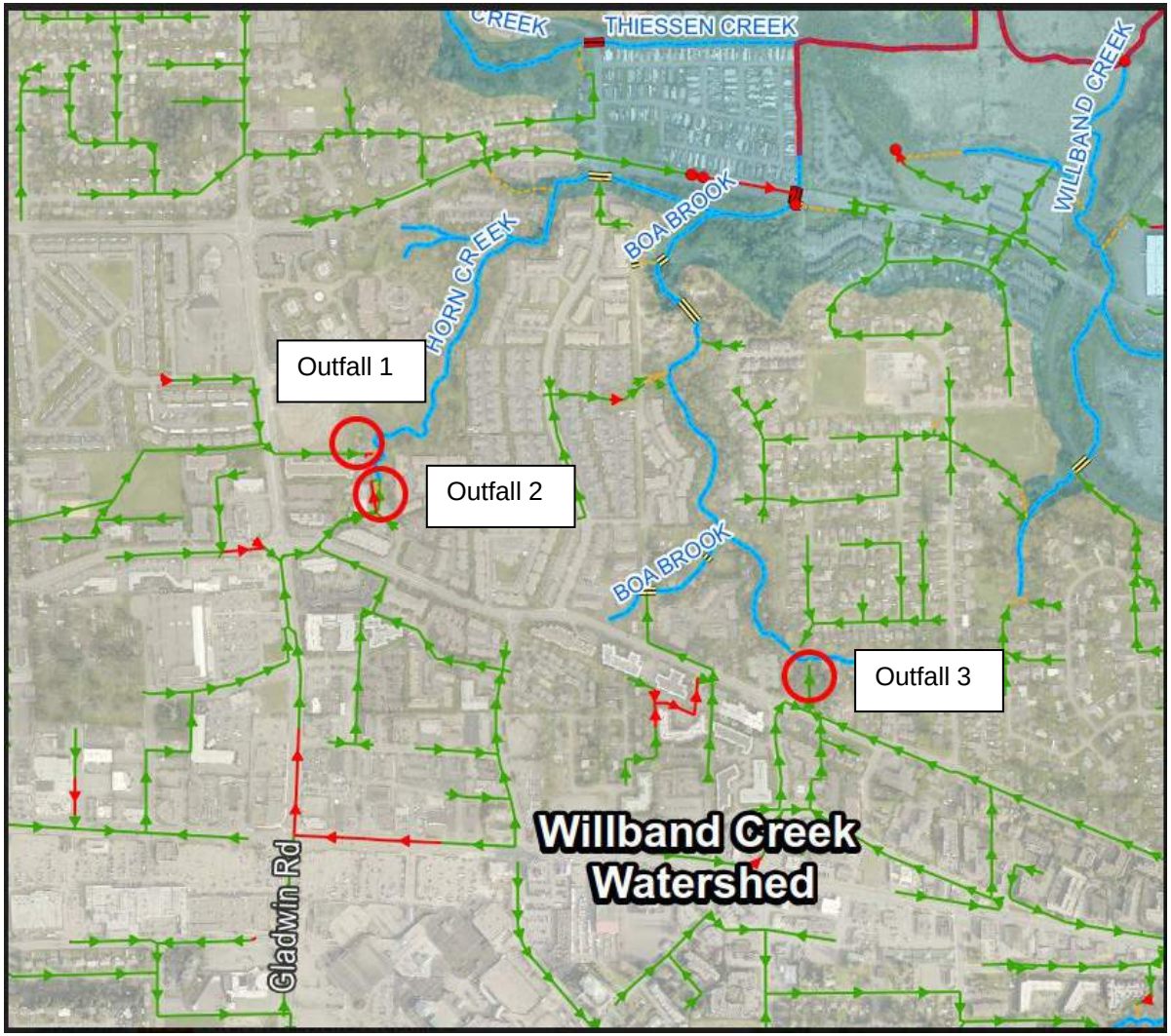


**Figure 9.3 - Horn Creek and Boa Brook Primary Outfalls**

Flow statistics for each of the three outfalls are provided in **Table 9.3** below:

**Table 9.3 - Outfall Statistics**

| Outfall | Catchment Area (ha) | Permitted flow ($m^3/s$) at 5 L/s/ha | Existing Peak Flows ($m^3/s$) | | |
|---|---|---|---|---|---|
| | | | 1:2 | 1:10 | 1:100 |
| 1 | 148 | 0.74 | 2.7 | 4.2 | 5.8 |
| 2 | 50 | 0.25 | 1.5 | 2.6 | 3.5 |
| 3 | 20 | 0.10 | 0.6 | 0.9 | 1.2 |

The estimated required storage volumes at each outfall have been computed for the full range of storm events, as presented in **Tables 9.4 to 9.6** below. In all cases the volumes consider future conditions with climate change. Land base requirements are based on an assumed live storage depth of 2 meters and a land use efficient factor of 0.8 to account for such things as side slopes, access, etc. The maximum storage value for each return period is highlighted in red.

**Table 9.4 - Outfall 1**

| Event | Live Detention Volume ($m^3$) | Estimated Land Requirement ($m^2$) |
|---|---|---|
| Future+CC 2yr 1hr | 5,400 | 3,400 |
| Future+CC 2yr 2hr | 7,900 | 4,900 |
| Future+CC 2yr 6hr | **10,300** | 6,500 |
| Future+CC 2yr 12hr | 7,900 | 4,900 |
| Future+CC 2yr 24hr | 800 | 500 |
| Future+CC 10yr 1hr | 12,100 | 7,600 |
| Future+CC 10yr 2hr | 17,600 | 11,000 |
| Future+CC 10yr 6hr | **23,100** | 14,400 |
| Future+CC 10yr 12hr | 17,600 | 11,000 |
| Future+CC 10yr 24hr | 1,700 | 1,100 |
| Future+CC 100yr 1hr | 21,800 | 13,600 |
| Future+CC 100yr 2hr | 31,800 | 19,900 |
| Future+CC 100yr 6hr | **41,500** | 26,000 |
| Future+CC 100yr 12hr | 31,700 | 19,800 |
| Future+CC 100yr 24hr | 3,000 | 1,900 |

**Table 9.5 - Outfall 2**

| Event | Detention Volume ($m^3$) | Estimated Land Requirement ($m^2$) |
|---|---|---|
| Future+CC 2yr 1hr | 3,200 | 2,000 |
| Future+CC 2yr 2hr | 4,700 | 3,000 |
| Future+CC 2yr 6hr | 7,100 | 4,500 |
| Future+CC 2yr 12hr | **7,500** | 4,700 |
| Future+CC 2yr 24hr | 3,800 | 2,400 |
| Future+CC 10yr 1hr | 6,600 | 4,100 |
| Future+CC 10yr 2hr | 9,600 | 6,000 |
| Future+CC 10yr 6hr | 14,500 | 9,100 |
| Future+CC 10yr 12hr | **15,300** | 9,600 |
| Future+CC 10yr 24hr | 12,800 | 8,000 |
| Future+CC 100yr 1hr | 10,800 | 6,800 |
| Future+CC 100yr 2hr | 15,900 | 10,000 |
| Future+CC 100yr 6hr | 23,900 | 15,000 |
| Future+CC 100yr 12hr | 25,300 | 15,800 |
| Future+CC 100yr 24hr | **25,700** | 16,100 |

**Table 9.6 - Outfall 3**

| Event | Detention Volume ($m^3$) | Estimated Land Requirement ($m^2$) |
|---|---|---|
| Future+CC 2yr 1hr | 1,300 | 800 |
| Future+CC 2yr 2hr | 1,800 | 1,100 |
| Future+CC 2yr 6hr | 2,600 | 1,700 |
| Future+CC 2yr 12hr | **2,900** | 1,800 |
| Future+CC 2yr 24hr | 1,600 | 1,000 |
| Future+CC 10yr 1hr | 2,400 | 1,500 |
| Future+CC 10yr 2hr | 3,400 | 2,200 |
| Future+CC 10yr 6hr | 5,100 | 3,200 |
| Future+CC 10yr 12hr | **5,500** | 3,400 |
| Future+CC 10yr 24hr | 4,900 | 3,100 |
| Future+CC 100yr 1hr | 4,000 | 2,500 |
| Future+CC 100yr 2hr | 5,600 | 3,500 |
| Future+CC 100yr 6hr | 8,300 | 5,200 |
| Future+CC 100yr 12hr | 9,000 | 5,600 |
| Future+CC 100yr 24hr | **9,300** | 5,800 |

The largest challenge to creating communal detention will be having the necessary land in an effective location. At this time only ponds are considered, however buried tanks could also be considered, but would come at a higher construction cost.

In **Figure 9.4**, City owned properties in the general vicinity of Horn Creek and Boa Brook are highlighted and numbered. Additional privately-owned sites that are in favorable locations are also identified and numbered. However, no site has been identified that currently has a building present. Also, due to environmental impacts and expected approval difficulties, detention directly on-line of Horn Creek and Boa Brook are not yet considered.

Parameters for each site are summarized in **Table 9.7** below.

**Table 9.7 - Evaluation of Candidate Communal Pond Sites**

| Site | Ownership | Site Area ($m^2$) | Outfall Served | Storage Potential ($m^3$) | Rough Cost (excluding land) | Approximate Service Level Offered by the Site | Relative Benefit Offered by the Site |
|---|---|---|---|---|---|---|---|
| 1 | Private | 12,100 | 1 | 19,000 | $3,135,000 | 1:10 | High |
| 2 | Private | 6,400 | 1 | 10,000 | $1,650,000 | 1:2 | Moderate |
| 3 | City | 1,300 | 3 | 2,100 | $346,500 | <1:2 | Low |
| 4 | City | 2,500 | 2 | 4,000 | $660,000 | <1:2 | Low |
| 5 | City | 8,200 | 1 | 13,000 | $2,145,000 | >1:2 | Moderate |
| 6 | City | 1,800 | 1 | 2,900 | $478,500 | <1:2 | Low |
| 7 | School Board | 7,600 | 1 | 12,000 | $1,980,000 | >1:2 | Moderate |
| 8 | School Board | 7,900 | 1 | 12,600 | $2,079,000 | >1:2 | Moderate |

Storage potential is based on average depth of 2 meters and land efficiency factor of 0.8 (assuming entire site is used). Storage volumes noted are preliminary and would need further review through a preliminary design process.

Cost is based on $165 per $m^3$ of live storage, including 30% E&C, but excluding land. This represents a well landscaped pond facility and may be reduced if only basic landscape finishing. It also does not include resolution of conflicts with existing infrastructure.

There are multiple sites that offer significant opportunity to regulate flows to Outfall 1 (Horn Creek), which is the largest of the three outfalls and is the same catchment that would be controlled by the alternative diversion pipe previously proposed by Golder Associates. The detention ponds would provide greater benefit during more frequent,

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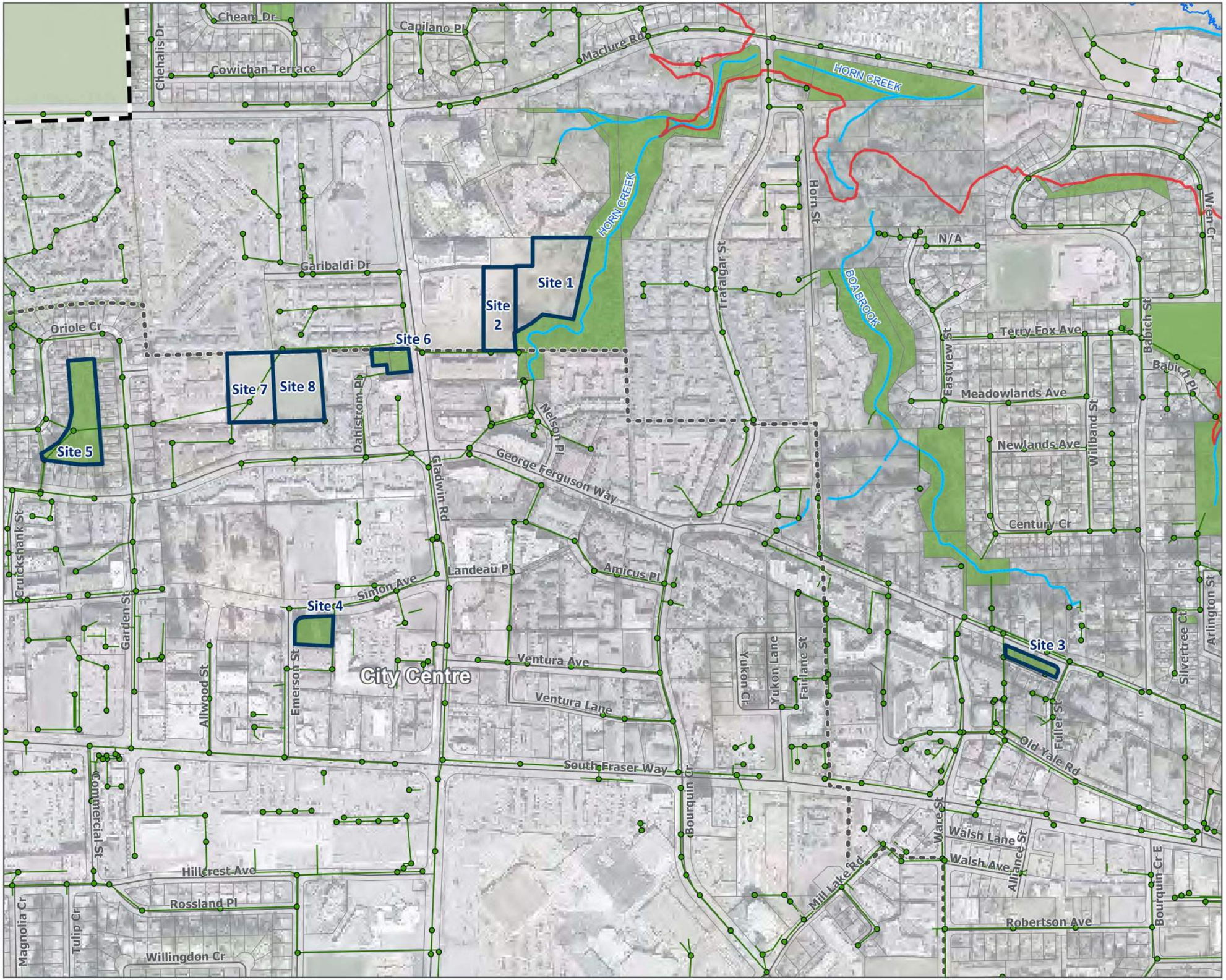
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 9-4 - Potential Pond Sites for Horn Creek and Boa Brook (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

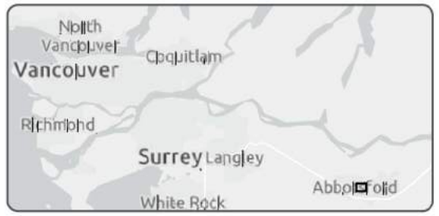
## Potential Pond Sites for Horn Creek and Boa Brook

**Legend**

- Potential Pond Sites
- Existing Manhole
- Existing Main
- Maximum Future Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary Study Area
- Creek
- Parcel

City Land Types

- Parks (Dedicated and Undedicated)
- Road

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Metres

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FIGURE 9.4

channel forming flows, whereas the diversion was proposed to only function during rare, high flows. The diversion could be sized to also service a wider range of storm events, however, would need to be sized larger than that previously proposed by Golder Associates. If the diversion were to service Outfall 1 alone (148 ha area), a conservative design would be to size the pipe for the current 1:100 year peak flow (5.8 $m^3/s$) less the 0.74 $m^3/s$ that is based on a 5 L/s/ha criteria. In round number, the diversion would be sized for 5 $m^3/s$, which is the same design flow proposed by Golder thereby requiring the same pipe size of 1.35 m diameter. However, the matching design flow is a coincidence only, while the operating range is significantly different based on the difference in projected peak flow between the Rational Method calculation done by Golder and the SWMM modeling conducted for this ISMP.

Given the close proximity of Outfall 1 with Outfall 2, it may be possible to service both outfalls with a single diversion, with a combined service area of 198 hectares, and a combined 1:100 year peak flow of 9.3 $m^3/s$ (refer to Table 9.3). Staying consistent with applying the 5 L/s/ha flow as the permissible flow in the creek, the total flow remaining in the creek would be 0.99 $m^3/s$, leaving a remainder of 8.3 $m^3/s$ to the diversion thereby requiring a pipe 1.5 meters in diameter if a smooth walled HDPE pipe (manning N=0.011) was selected (assuming a critical pipe grade of 1% that needs to be confirmed through design).

For Site 1 and 2, environmental approvals, land acquisition, and geotechnical stability of the steep slope on Site 1 will be significant factors that need to be explored early to evaluate the viability of these sites. For Site 7 and 8, it would be envisioned that the sports fields would need to be depressed and re-established at the bottom of surface ponds. But to be effective for the creeks these ponds need to activate frequently, which may interrupt usage of the sports fields. There may be a design concept where subsurface storage and/or an infiltration gallery is built below the fields to manage frequent rain events causing surface storage on top of the fields. This configuration, however, will increase construction cost. In combination, Sites 7 and 8 provide very significant opportunity, similarly does Site 1 and 2 in combination.

This assessment indicates that significant opportunities exist to implement communal detention ponds to address the erosion problem in at least Horn Creek. But most of the highest valued candidate sites are not owned by the City and some have environmental sensitivity. Before the viability of any site can be confirmed, preliminary engineering, property negotiations, and environmental and geotechnical stability assessment reviews are required.

Few opportunities currently exist to protect Boa Brook, unless the City acquires currently built property or seeks to implement costlier underground storage within road corridors or roadside swales, rain gardens, etc.

## 9.7 Lowland Storage for Willband Creek and Matsqui Prairie

The City has noted perceived changes to the frequency and extent of flooding in some portions of the Willband Creek floodplain and downstream of the Prairie Street Creek sub-catchment. However, modeling demonstrates that increased frequency of flooding should not relate to land use changes. The hypotheses for perceived increased flooding are;

**1** The climate change trend of increased winter precipitation is increasing runoff volume and frequency.

**2** Sedimentation and vegetation build up in watercourses is reducing the ease of water conveyance and causing the floodplain to activate more frequently.

And the predicted increase in floodplain water levels into the future are more a direct influence of climate change than re-development. The maximum water levels, whether the Willband Creek floodplain or Mill Lake, are heavily governed by downstream boundary conditions, which are dependant on the operation of the Mill Lake outfall and the performance of the Matsqui Prairie system downstream of Clayburn Road.

Dredging and removal of vegetation in existing watercourses within the floodplain will be a challenge from an environmental regulation perspective, however may be possible. Increased capacity through creation of new features, done in a manner that expands habitat, is also an option.

The City has expressed interest to install a sediment trap and increased flood storage within the lowland portion west of Highway 11. Potential candidate sites for management ponds or sediment basins are presented in **Figure 9.5**. The greatest benefit for improved flood storage will be realized by building new storage on the fringe (in the shallows) of the floodplain. But any new facility would need to avoid interactions with the landfill. While some opportunity may exist for City lands fronting Valley Road, greater hydraulic benefit will be realized if placed on property south of the landfill owned by the Fraser Valley Conservancy (Conservancy). The effective size of a facility at this location, and its cost benefit, is premature to state at this time because its performance will be governed by the long-term performance of the downstream Matsqui Prairie drainage system. During the public consultation stage of this ISMP, conversation occurred with the Conservancy who expressed concern for an urban settlement management facility being considered on their land, since their mandate is for habitat. The intent of any new facilities would be to also meet habitat objectives. It is recommended that the City reach out to the Conservancy seeking a collaborative partnership to explore designs that could meet multiple objectives.

The City has intent in 2020 to undertake a Phase II Matsqui Prairie Floodplain Study which is to look at improving lowland performance. It is therefore recommended that planning of a new management facility occur in concert with that study. The City may elect to initiate dialogue with the Conservancy early to discuss possibilities and limitations ahead of technical analysis.

## 9.8 Tree Canopy and Landscaping

Trees and landscaping in an urban setting have been proven to offer many hydrologic, environmental, and social benefits. The current tree canopy in the CCNP and HDNP areas is extremely low. Aside from infiltration, increasing the tree canopy and other forms of landscape will expectedly offer significant rainwater retention through evapotranspiration. In addition, trees and other forms of plants will also assist with water quality treatment. Tree canopy and minimum landscape standards for both private and public lands is strongly encouraged for beneficial rainwater management.

**Infrastructure Summary of Recommendations:**

**1** Build a priority-based capital program for infrastructure not meeting criteria.

**2** Explore candidate sites for communal ponds that may arrest erosion in Horn Creek and Boa Brook. Further evaluate these against the diversion option identified in 2009 and discussed herein.

**3** Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment.

**4** Conduct a condition assessment of the trunk sewer downstream of Ravine Park (high priority), then as the results dictate, conduct a study to confirm the viability and cost effectiveness of creating on-line temporary storage within Ravine Park.

**5** Implement source controls at Civic sites such as the parking lot at Five Corners and the Municipal Hall site to demonstrate leadership in source controls, however these facilities will not change the performance of local storm sewer conveyance in a design event.

**6** Explore a lowland detention pond in the lowlands west of Highway 11 as part of the Phase 2 Matsqui Prairie Drainage Study. Seek collaboration with the Fraser Valley Conservancy.

**7** Implement stormwater source controls to the degree possible for all future developments.

**8** Develop necessary programs and regulations to increase the tree canopy in the City Centre and Historic Downtown area.

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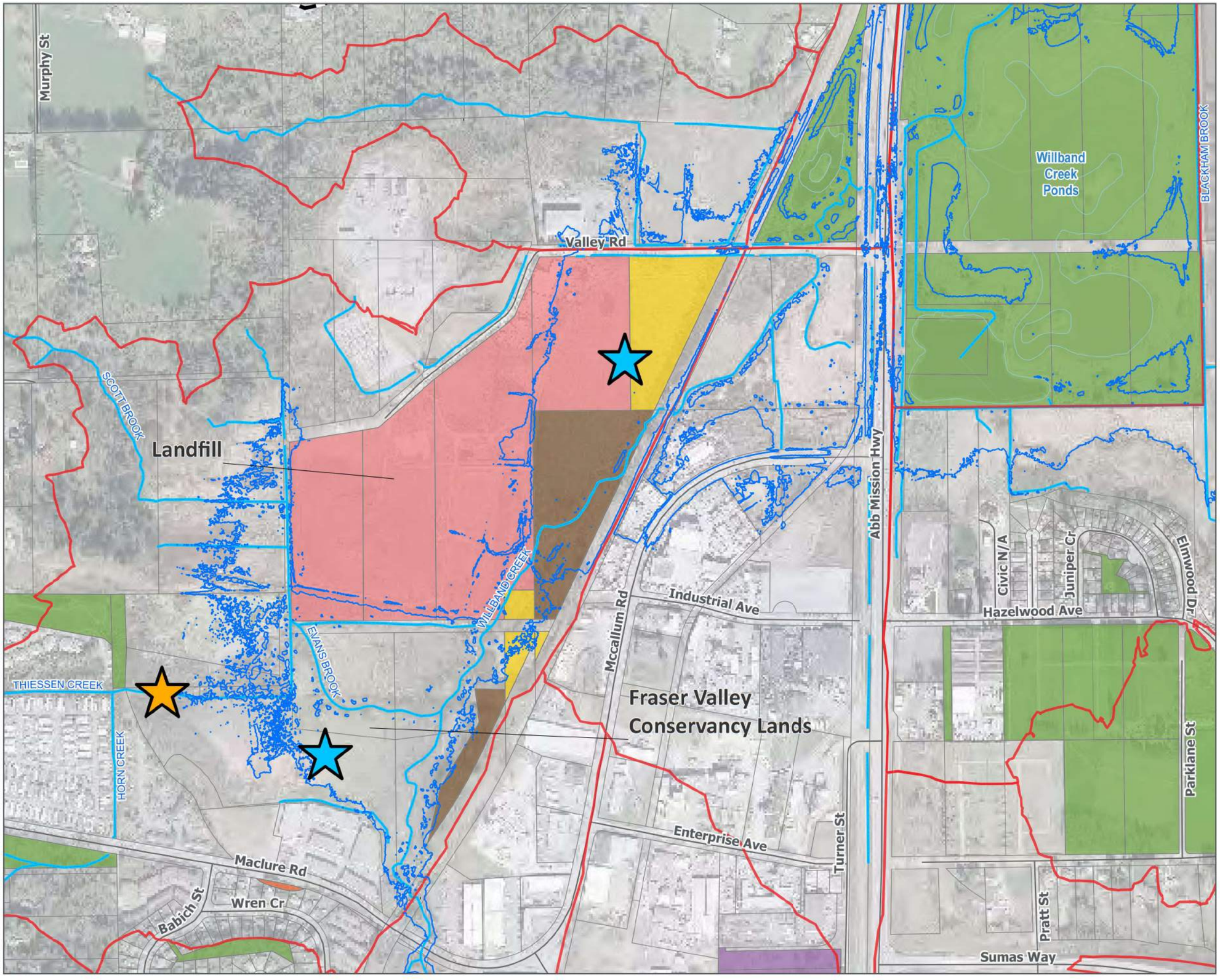
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 9-5 - Potential Lowland Basins (11x17)

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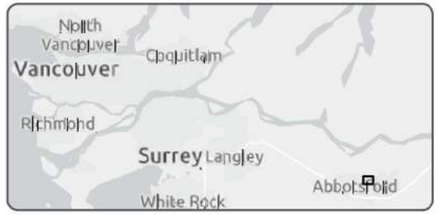
## Potential Lowland Basins

**Legend**

- Potential Storm Basin
- Potential Sediment Trap (with Property Aquisition)
- Maximum Future Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Creek

**City Land Types**

- General Municipal
- Parks (Dedicated and Undedicated)
- Road unconstructed
- Utility
- Vacant
- Road
- Parcel

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0 200
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:6,000
(When plotted at 11"x17")

**Data Sources:**
- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

| | |
|---|---|
| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2018 / 12 / 17 |

URBAN systems

**FIGURE 9.5**

# 10 ENVIRONMENTAL OPPORTUNITIES

There are several opportunities available to the City to improve the habitat value in the Study area. However, several constraints are associated with each of them. Discussion is provided below, with opportunity locations shown in **Figure 10.1**.

## 10.1 Riparian Infill

Riparian infill consists of the installation of native vegetation in areas currently lacking riparian vegetation. In particular, this consists of the Willband Creek lowlands north of Maclure Road. Native vegetation would significantly improve habitat for both aquatic and terrestrial species. However, several 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.

## 10.2 Fish Access Improvement

Several culverts in the watershed (e.g., the crossing of Horn Creek at Trafalgar Street) 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 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 replacing or modifying culverts where barriers preclude significant fish access.

## 10.3 Habitat Construction

Habitat could be constructed in areas where adequate land is available, such as on Lower Willband Creek. 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.

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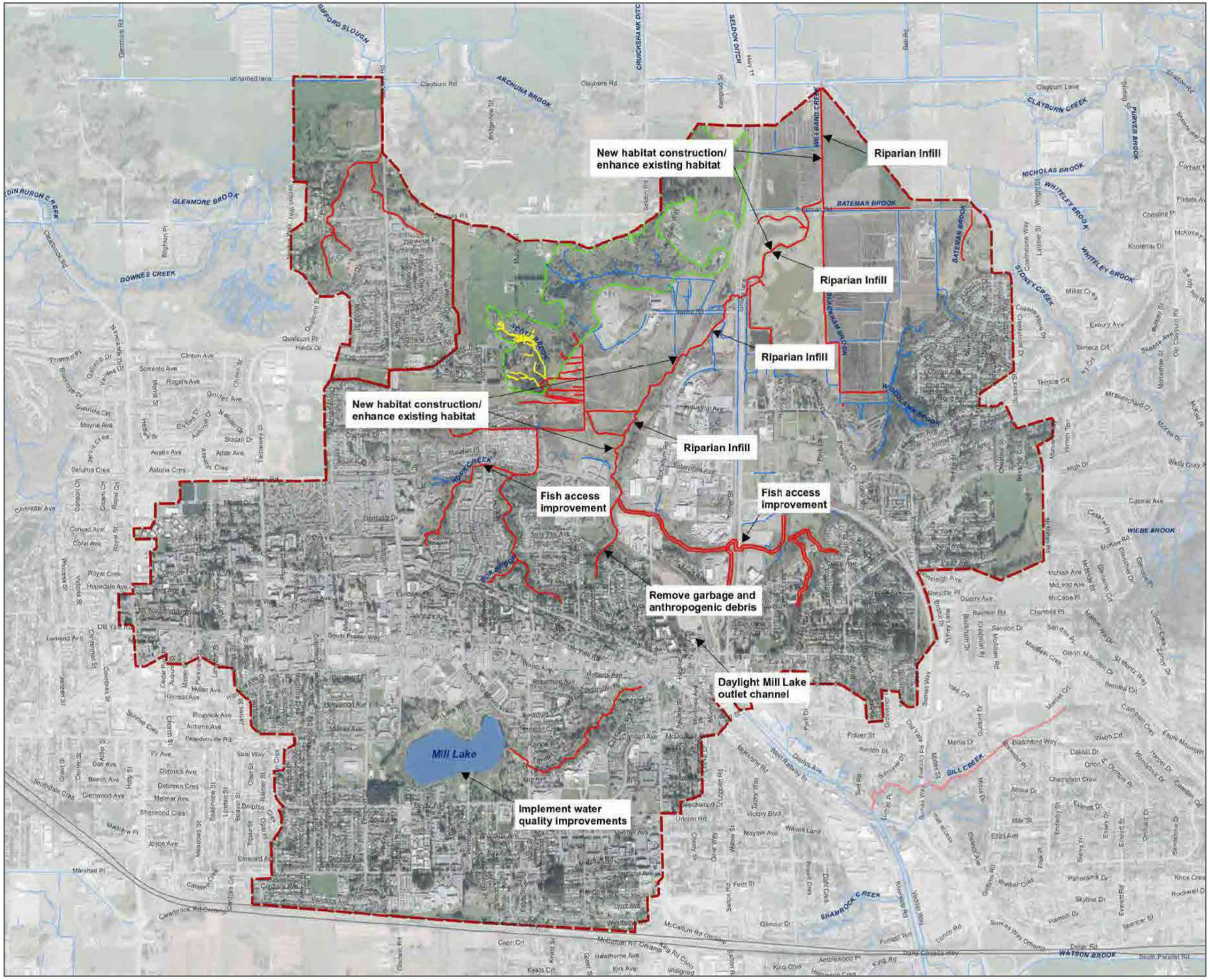


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## Environmental Opportunities

**Legend**

**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

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Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:22,000
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- Dillon (2016-18)

DILLON CONSULTING

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| Date: | 2018 / 12 / 17 |

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**FIGURE 10.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 10-1 - Environmental Options (11x17)

## 10.4 Instream Maintenance

The removal of garbage and other anthropogenic debris (e.g., the Western Tributary on Willband Creek) 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.

## 10.5 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 (noted on Figure 10.1). 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 remaining 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 because of an environmental incident (e.g., a spill).

It should be noted that there are several 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.

## 10.6 Water Quality Improvements – Mill Lake

There are several 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.

## 10.7 Integration of Habitat Features into Stormwater Controls

As referenced in 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.

However, detention ponds described above area more suitable for lower areas of the watershed where infiltration potential is low to medium. Where infiltration capacity it high, it may not be realist to sustain sufficient water during the summer season to accommodate aquatic species. Detention facilities in the uplands likely need to be designed as ephemeral.

**Environmental Opportunities Summary of Recommendations:**

**1** Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.

**2** Replace or modify stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.

**3** Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation (collaboration with Fraser Valley Conservancy).

**4** Removal of garbage and other anthropogenic debris from watercourses.

**5** Recognized to have significant challenges, however, review the practicality of daylighting a portion of ravine downstream of Mill Lake.

**6** Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.

**7** Subject to item 6 above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.

**8** Recommend “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators.

**9** Apply landscaped based biofiltration site controls wherever possible.

# 11 GEOTECHNICAL AND SOURCE CONTROLS

## 11.1 Geotechnical Ravine Erosion Assessment

The scope of this ISMP did not permit for an exhaustive inspection of all watercourse segments but was limited to select reaches where issues had been reported as concern by the City. Without a series of observations or extensive research it is not possible to provide a statement on how active these erosion sites are or what the long-term fate may be. It is recommended that the City implement an annual inspection program for all watercourses. It is recommended that the inspections occur in the fall or winter when leaves have fallen, and sites are most visible.

As presented previously, 13 sites of observed channel erosion were reported by Thurber Engineering as part of this ISMP. Of the sites observed, two sites on Horn Creek were identified as "high" risk because of their proximity to infrastructure and should therefore undergo a comprehensive assessment and establishment of mitigative solutions. These sites are:

**1** A pedestrian bridge and aerial pipe crossing Horn Creek (Site Horn-06) – Continued erosion will undermine the bridge abutments and pipe supports.

**2** Approximately 50 m downstream of site 1 above (Site Horn 07). – Retrogressing slope will undermine the path and possibly houses. It is recommended at this site that an arborist be engaged to assess the safety of trees.

There were an additional seven (7) sites identified by Thurber as medium risk. At these sites the erosion is generally significant but does not pose a risk to adjacent infrastructure and is likely to progress somewhat more slowly. It is recommended that these sites be inspected more comprehensively, and a mitigation strategy developed. However, these sites have less urgency than the two high risk sites noted above.

The Prairie Street Creek sub-watershed was specifically added to the Willband Creek ISMP because of the City's interest in erosion concerns. Of the portions reviewed by Thurber, only a single site was identified, and as low risk. In addition, hydrologic assessment indicates that with the application of source controls, increased risk of erosion should be successfully managed. However, if no controls are implemented through future redevelopment, climate change may pose gradual increased risk over time. As noted above, it is recommended at this time that the City simply monitor the creeks on an annual basis to track changing conditions.

## 11.2 Infiltration Systems and Source Controls

Soil infiltration potential mapping was presented earlier. To reiterate the conditions, soils in most of the upland areas where most redevelopment is expected are characterized as rapidly to well drained. But the underlying aquifer is classified by the Province as being highly vulnerable to surface contamination. As such, while infiltration should be promoted from a hydrologic perspective, the siting and design of infiltration facilities should consider water quality.

The City's current Development Bylaw engineering and standards (Schedule F, Section 8 – Infiltration Systems) note that "Infiltration Systems in Commercial, Institutional and Multi-Family Developments are intended for runoff from roof areas only. Rooftops draining to an infiltration facility may not be used for storage of materials which may

contaminate or pollute the run-off. Runoff from all other areas may be permitted to infiltrate provided groundwater protection measures and strategies are provided to the satisfaction of the engineer".

For the above noted land uses, pavement represents a significant portion of the sites and not applying infiltration measures to those areas will make them unlikely to achieve the criterial targets.

The City's current Development Bylaw engineering and standards (Schedule F, Section 8 – Infiltration Systems) further states "Rock pits/drain wells shall be used for single family infill lot Development or replacement or reconstruction of existing homes unless otherwise recommended by a geotechnical Engineer. The rock pit/drain well shall be designed by a geotechnical engineer and sized to store and infiltrate a 1:10 year rainfall event." Though not explicitly stated for rock pits/drain wells, the need for water quality treatment should also apply.

To meet the City criteria, infiltration systems may need to be coupled with temporary storage depending on the site-specific soil infiltration rate and the footprint area of the proposed infiltration system relative to the impervious area draining to it. The specific combination of infiltration surface and storage will need to be determined by the designer.

The Bylaw also provides for roadside swales, but Schedule F - Section 8 of the Bylaw notes that "*swales may be used on a **rural** highway for road drainage at the discretion of the Engineer*". The Bylaw then requires a minimum of 150 mm of topsoil lining the roadside swales. Special criteria will be needed to recognize and permit roadside swales within the urban areas.

Paved surfaces (roadways and parking lots) represent a significant source of runoff within the high density urban areas. There are positive merits to infiltration systems for these areas, however there must be an elevated attention to water quality treatment prior to infiltration. With this said, such systems should be prohibited in high pollutant risk sites such as gas stations, auto wreckers, automobile service stations or other sites involving known pollutants harmful to groundwater. This is not unique to the Willband watershed and is a common restriction in many municipalities.

It is expected that to protect a high vulnerability aquifer, runoff treatment should involve media filtration, either in the form of amended landscape growing media or with proprietary media filtration devices. Basic oil / grit separation is not considered adequate.

Within road corridors, perforated storm sewers offer some opportunity for infiltration, but these would also need to ensure sufficient treatment prior to runoff entering the sewer system. As such, roadside swales, raingardens and the like should be applied ahead of perforated storm sewers. Also, perforated sewers are intended only for low gradient systems and where the groundwater table is confirmed to be a minimum of 0.6 meters below the sewer elevation and infiltration rate appropriate.

The current Development Bylaw is relatively generic on design requirements of infiltration systems and leaves significant onus on the designer to make recommendations. It is not clear on what designs will satisfy the City.

The City has an established Storm Water Source Control Bylaw (Bylaw 2045-2011) that currently applies to CICP Lands and the Abbotsford Airport Lands and is a supplement to the Development Bylaw. Consistent with the recommendation made in the City's 2018 Master Drainage Plan update, it is recommended that this Storm Water Source Control Bylaw be adopted as a City-wide document. However, a review and potential amendments should be undertaken prior to a blanket adoption across the City. Further discussion regarding this is provided in Part 4 – Implementation.

To mitigate potential negative effects on slope stability, groundwater infiltration and recharge systems to be located within 200 m of a steep slope (i.e. greater than 25% grade) or ravine should have design input provided by a geotechnical engineer.

On a site specific basis, the recommended setback of the infiltration system from the crest of a slope should be determined by a geotechnical engineer and confirmed by a qualified professional. Local conditions, including history of instability and presence of groundwater seepage on nearby slopes should be considered. These professionals should review this report to provide regional context to their assessments.

### Geotechnical and Source Controls Summary of Recommendations and Action Items:

**1** Further develop a mitigation strategy for high risk erosion sites in ravines.

**2** Conduct annual observation and evaluation of geotechnical stability in creek ravines.

**3** Adopt the Stormwater Source Control Bylaw City-wide and not limit it to CICP and Airport Lands. A review and potential amendments are recommended prior to blanket adoption.

**4** Develop criteria and standards for the application of roadside swales or other form of control in urban streets.

**5** Create a Development Permit Area for the application of infiltration system in proximity to steep slopes, under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.

# 12 STORM SEWER CAPITAL PROGRAM AND PRIORITIES

There are several roadways within the Plan area that do not currently have storm sewers, and many other roadways that have storm sewers smaller than the City's desired 300 mm minimum size. As desired by the City, when identifying infrastructure needs for the future storm sewers have been added to the inventory to ensure all roads have sewers, and that all sewers meet the City's desired minimum size of 300 mm. However, there are many instances where existing storm sewers smaller than 300 mm have capacity to sufficiently meet long term needs. Therefore, the priority for replacement of these is low, and itemized separately.

Storm sewer improvements have been identified to satisfy the 1:10 year criteria, with exception to the trunk storm sewer part of the Mill Lake Ravine Park system which is to satisfy the 1:100 year criteria. Similarly, culverts crossing roadways, particularly major roadways, are recommended to convey the 1:100 year flows.

Infrastructure improvements are prioritized as follows:

- **Priority 1** sewers represent those expected to surcharge even with the broad application of on-site controls, therefore should form part of the capital plan in any case.

In the case of the trunk sewer on Montrose Avenue as part of the Mill Lake Ravine Park trunk system, there are two options to consider. Each need to be explored through predesign processes. One option is to fully reconstruct the deficient section of pipe for the major (100-year) flow, which is included in **Table 12.1** below. A predesign process would assess whether full replacement is in fact required, or whether performance could be improved with only a parallel supplemental pipe.

As discussed previously, the other option is to restrict flow at the inlet to the trunk sewer to 2 $m^3/s$ and allow temporary flooding in the Mill Lake Ravine. A predesign study should assess the potential slope stability risks and potential impact to vegetation and habitat (both aquatic and terrestrial). Construction of this option would require both Provincial and Federal environmental approvals for instream works.

An important aspect of the decision for flow control is the physical condition and life expectancy of the existing trunk storm sewer. The City has not completed a comprehensive condition assessment; therefore, its condition is unknown at this time. This is considered critical infrastructure, and structural failure of this pipe, particularly the deep portion under Essendene Avenue, could be catastrophic. **It is strongly recommended that a complete condition assessment be undertaken as soon as possible along the length from the inlet at Ravine Park to the outlet near Morey Avenue; a total length of approximately 1,000 meters.**

It is also recommended that the City process with the rerouting of City infrastructure along Montrose Avenue south of Essendene Avenue, then to notify private property owners of the reconnection strategy when redeveloping. Thoughtful consideration to how the existing pipes through private property are to be abandoned is warranted and it will require collaboration among private property owners. Abandonment will need to happen sequentially from upstream to downstream, or as a combined single initiative. How they are abandoned, if not removed, will require professional guidance from a geotechnical engineer with consideration for both risk of structural failure of the existing pipes weighed against risk of groundwater piping of soils surrounding the pipe if the pipes are infilled. And whether removed fully or abandoned in place, guidance is required to assess and accommodate groundwater movement.

- **Priority 2** sewers represent those that will not meet criteria if no site controls are applied, however could be potentially eliminated

by the successful broad application of site controls. These upgrades would be included in the capital plan for a conservative approach but may be deferred and their need confirmed through further monitoring and more detailed assessment.

- **Priority 3** sewers represent those that meet criteria, but that are smaller than the City's preferred 300 mm diameter. Also considered priority 3 sewers are new mains for roads that do not currently have sewers. These are highly discretionary changes, perhaps only done when opportunity arises through road reconstruction or development, or if condition assessment indicates existing infrastructure has reached the end of its life.

Based on the above, a summary of infrastructure improvements is listed in **Table 12.1**. A detailed inventory is provided in **Appendix F**. These improvements are graphically represented in a series of plates making up **Figure 12.1**. This program is based on capacity performance only and does not involve condition or operational issues. Note that the inventory of pipes specific to the City Centre Neighbourhood Plan and Historic Downtown Neighbourhood Plan are slightly different than those presented herein because both Neighbourhood Plan boundaries are beyond the Willband Creek watershed boundary. Only upgrades contained within the Willband Creek watershed boundary are presented herein.

In all cases, pipe upgrades have been inventoried to prevent surcharge in accordance with City criteria. If some amount of surcharging can be tolerated, the extent of pipe replacement would expectedly decrease. And to re-iterate, pipe upgrades **do** include a 10% factor for climate change.

**Table 12.1 - Summary of Storm Sewer and Culvert Improvements**

| Priority – Reason for upgrade | Minor (10-year) Criteria | Major (100-year) Criteria |
|---|---|---|
| **Priority 1** – Performance does not meet criteria with or without the application of site controls. These upgrades include upsizing a portion of trunk sewer downstream of Mill Lake Ravine Park, on the assumption that storage in Ravine Park is not provided. | 3,572 m | 180 m |
| **Priority 2** – Performance does not meet criteria if site controls are not applied extensively. These upgrades include upsizing a portion of trunk sewer downstream of Mill Lake Ravine Park, on the assumption that storage in Ravine Park is not provided. | 5,026 m | 152 m |
| **Priority 3** – Meet desired minimum main size, despite adequate performance of existing main. | 10,821 m | 0 m |
| **Priority 3** – Provide a main where one does not exist. | 15,133 m | 0 m |
| **Total** | 34,552 m | 332 m |

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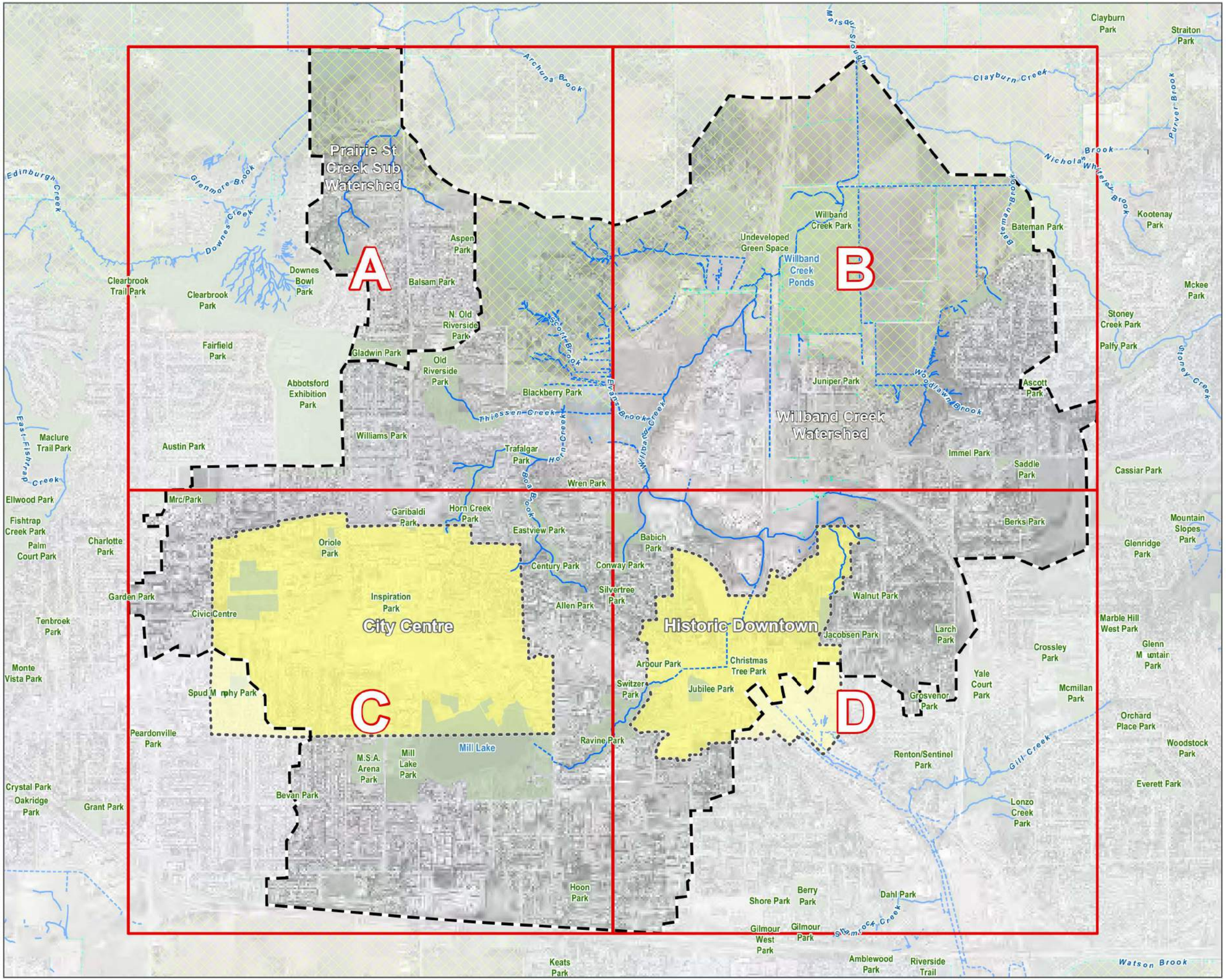


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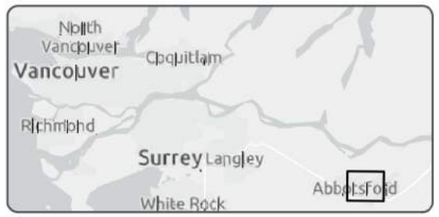
**Study Area Overview**

Legend

- Map Index
- Willband Creek Watershed
- Neighbourhood Plan Area
- Agricultural Land Reserve
- Natural Watercourse
- Channelized Watercourse
- Ditch
- Park

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0 200 400 600 800
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:22,000
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoAdvice

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| Revision: | A |
| Date: | 2018 / 12 / 17 |

URBAN systems

**FIGURE 12.1**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Study Area Overview (11x17)

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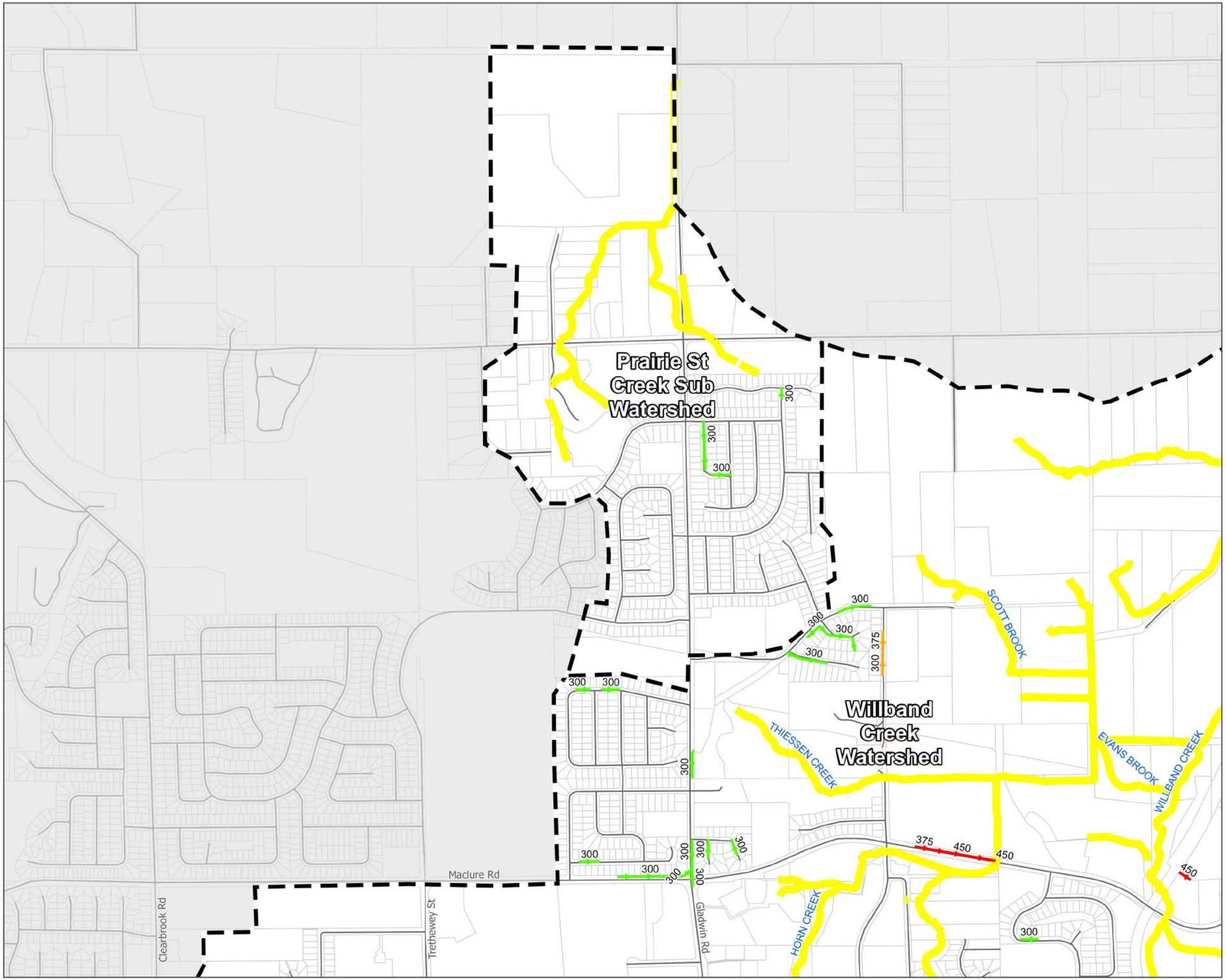



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

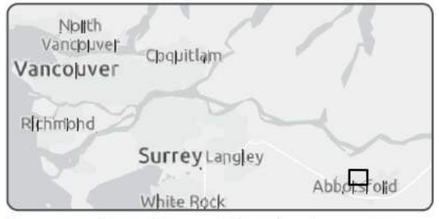
**Storm Sewer Improvements**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

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




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.

0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

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**FIGURE 12.1A**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Storm Sewer Improvements (11x17)

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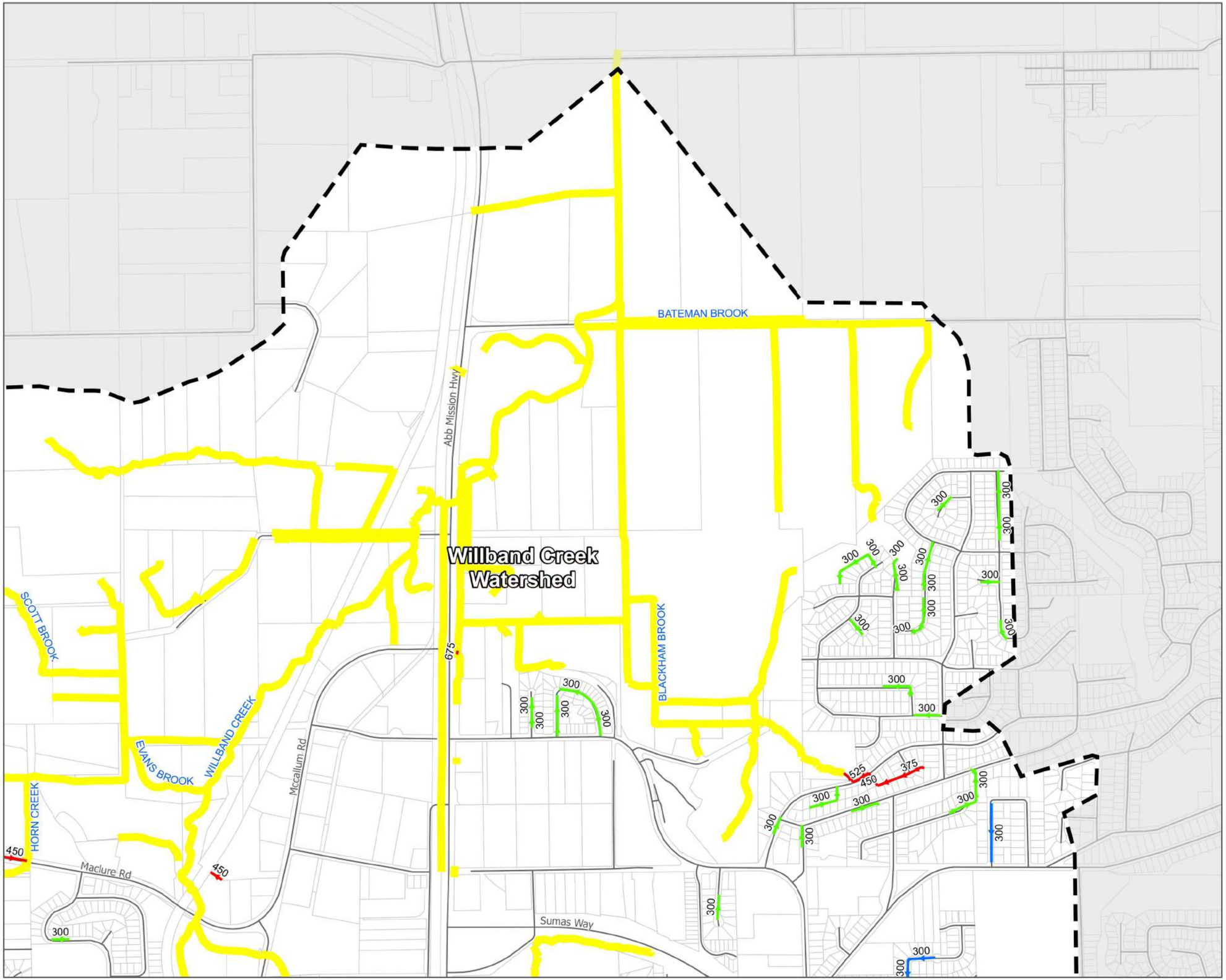


ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

**Storm Sewer Improvements**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

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

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0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

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- GeoAdvice (2016-18)

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URBAN systems

**FIGURE 12.1B**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 12-1 - Storm Sewer Improvements (11x17)

Last updated by lpunt on December 17, 2018 at 10:23 AM
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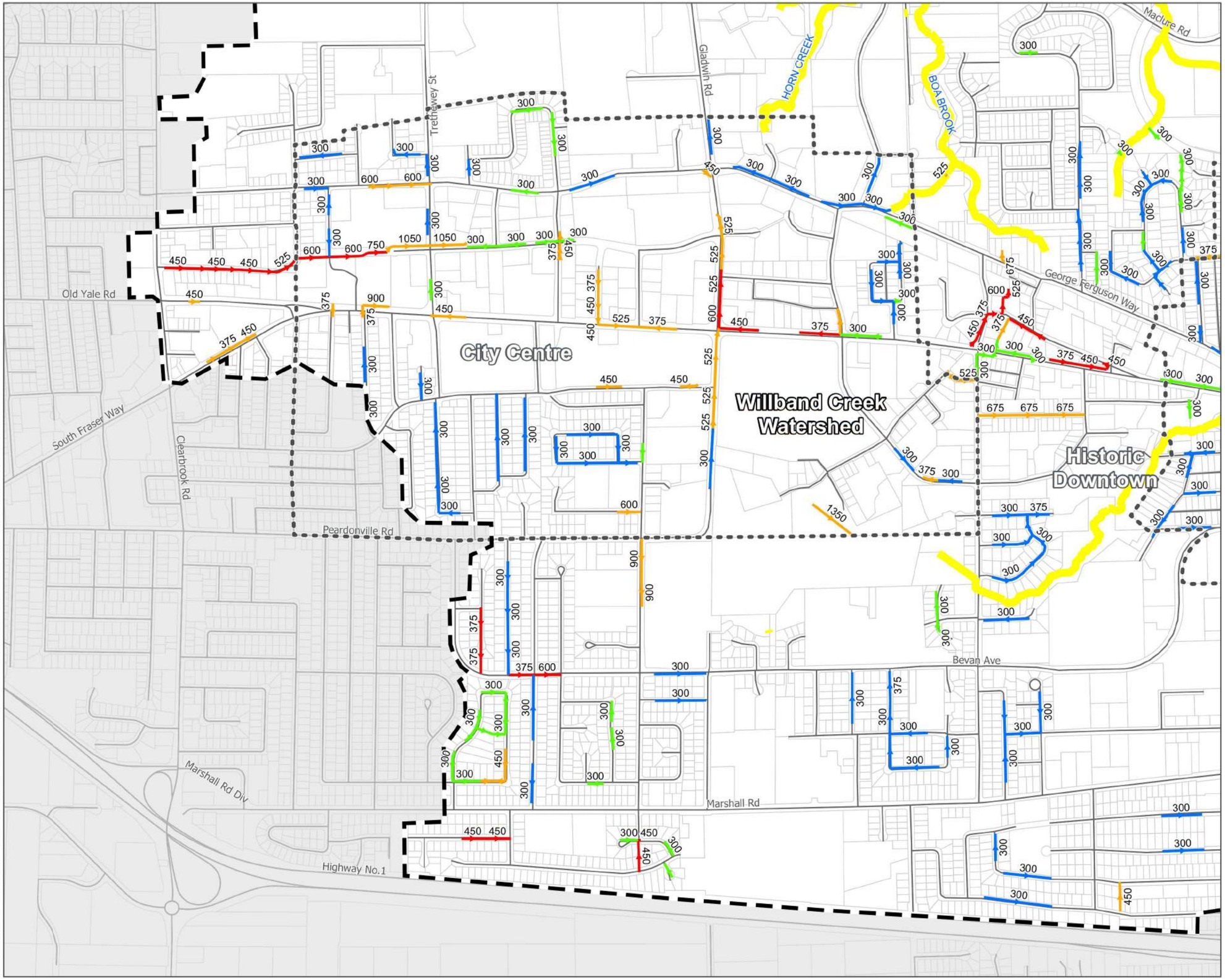
Last printed by lpunt on September 25, 2017 11:46 AM




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

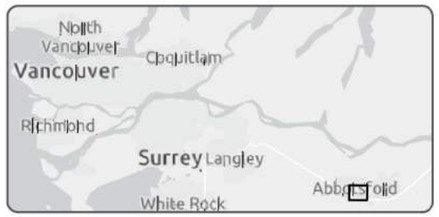
**Storm Sewer Improvements**

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

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

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0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

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GeoADVICE

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**FIGURE 12.1C**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Storm Sewer Improvements (11x17)

Last updated by lpunt on December 17, 2018 at 10:23 AM
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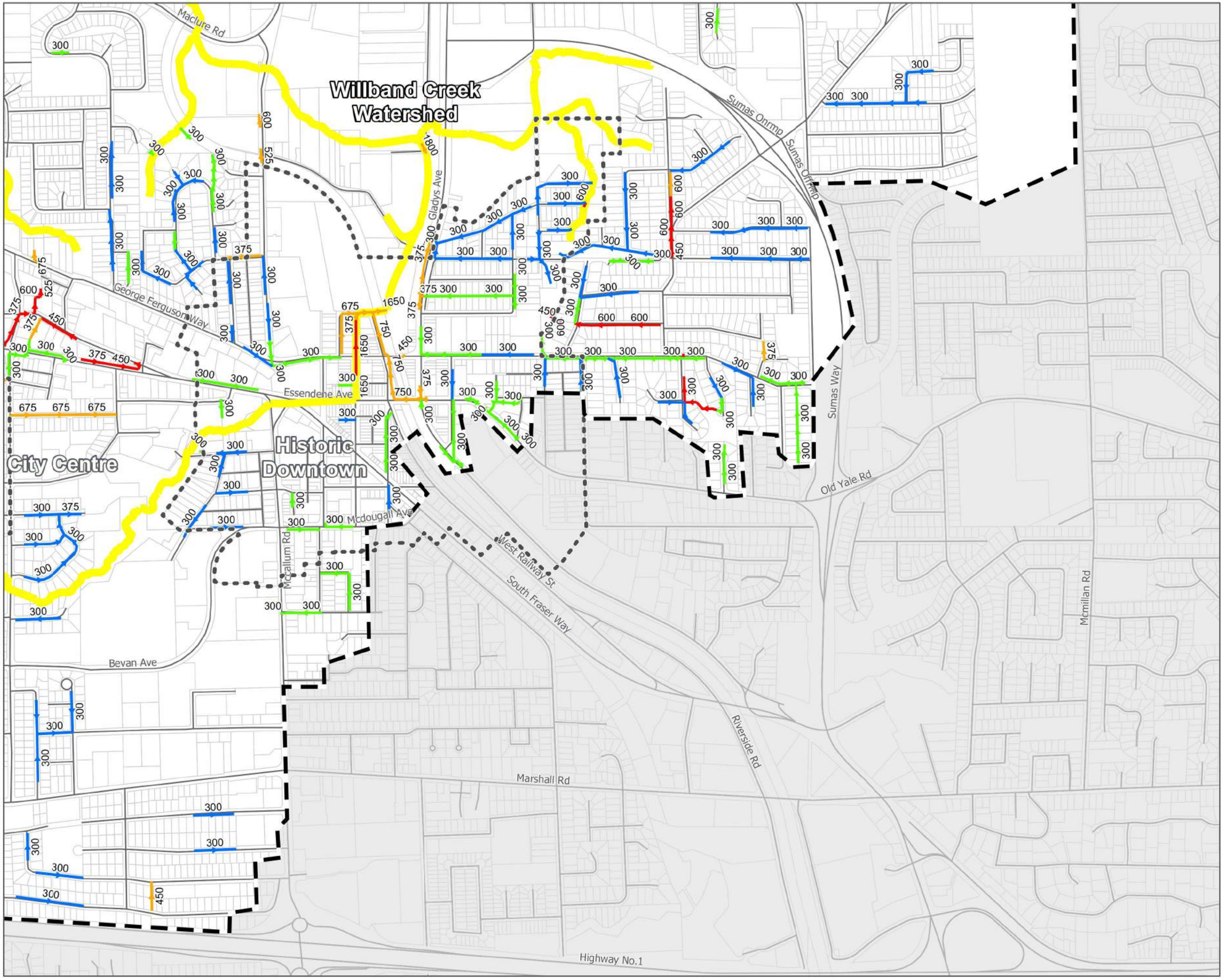
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Storm Sewer Improvements (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

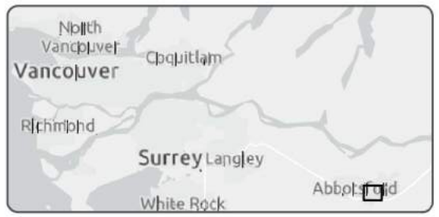
**Storm Sewer Improvements**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

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

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0 200 400 600
Metres

**Coordinate System:**
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**Data Sources:**

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URBAN systems

**FIGURE 12.1D**

With exception to 23 meters of road crossing culverts, the remaining 100-year criteria pipe length (274 m in total) is associated with upgrade of the trunk sewer part of the Mill Lake Ravine Park system. These upgrades would be required without the application of detention within Ravine Park, but can be eliminated with storage in Ravine Park limiting its flow at 2 $m^3/s$.

As noted above, 8,930 m of storm sewer improvements (Priority 1 and 2) (26% of total) are deemed necessary to satisfy performance requirements assuming a conservative approach of there being no significant on-site controls being achieved. Of those, 3,752 m (10%) are deemed high priority in that performance deficiencies can not be resolved even with the application of site controls. This includes upgrade to the major 100-year trunk sewer from Mill Lake Ravine.

The remaining 25,954 m of priority 3 pipes are considered low priority and discretionary to be completed as opportunity presents itself during other capital improvement projects, redevelopment frontage improvements, or end of the life replacement of existing infrastructure.

## 12.1 Potential Upland Flooding and Major Flow Paths

Hydraulic performance under a 1:10 year event with identified conveyance upgrades are presented in **Figure 12.2**, while performance under a 1:100 year (major) event is presented in **Figure 12.3**. For both these sets of figures it is assumed conservatively that site controls are ***not*** successfully applied. Nodes (ie. manholes) are colour coded based on surcharging and the predicted volume of water that may flood to ground surface. As noted in the legend for **Figure 12.2 and 12.3**, flood loss volumes are presented in mega-litres (1 ML = 1,000 $m^3$). For both 1:10 year and 1:100 year, the clear majority of nodes (highlighted yellow) are not expected to flood or may flood less than 0.001 ML (1 $m^3$); all deemed very low risk. Nodes identified as potentially flooding under the 1:10 year event are associated with back-flooding from Mill Lake and detention ponds, not conveyance deficiencies, as all identified pipe upgrades are to satisfy the 1:10 year criteria, at minimum.

Conveyance improvements in the expansive lowland system have not been identified at this time because performance is significantly governed by the downstream Matsqui Prairie system which should have higher priority. Further consideration for lowland improvements is recommended through the City's Phase 2 Matsqui Prairie Drainage Study planned for 2019.

Flood loss volumes between 0.01 and 0.1 ML (10 to 100 $m^3$) are possibly significant, and flood volumes of 0.1 ML (100 $m^3$) or more are significant and warrant further investigation to assess potential impacts. Assessing the likely consequence of flooding at these locations extend beyond the scope of the ISMP and would need to be investigated as a separate initiative. For comparison and priority planning by the City, a set of **Figure 12.4** is also provided which demonstrates predicted surface flooding under the 1:100 year (major) event ***with*** successful application of site controls. By comparing the results of **Figure 12.3** and **Figure 12.4**, it can be seen that the successful application of site controls is substantial to reducing flood risk.

## 12.2 Detention Pond Modifications

- In **Figure 8.15** seven existing detention ponds were identified as not meeting current criteria based on the information available for this study. One of these ponds is predicted to have insufficient storage volume, and perhaps at this stage it will be unrealistic to expand it. The remaining six ponds are predicted to be under-optimized with the opportunity to improve performance through modifications to the control structure. It is recommended that these detention ponds undergo an optimization study. It would be

advantageous to monitor water levels in each pond for a full winter season in advance of that study.

### Storm Sewer Capital Program and Priorities Summary of Recommendations and Action Items

**1** Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.

**2** Develop a strategy to redirect City infrastructure in Historic Downtown to Montrose Avenue and communicate service connection redirection and private sewer abandonment requirements to property owners (also flag these properties in the City data bases to ensure this requirement is not missed during any future building or development permit application).

**3** Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted flood loss of 100 $m^3$ or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 $m^3$ and 100 $m^3$.

**4** Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.

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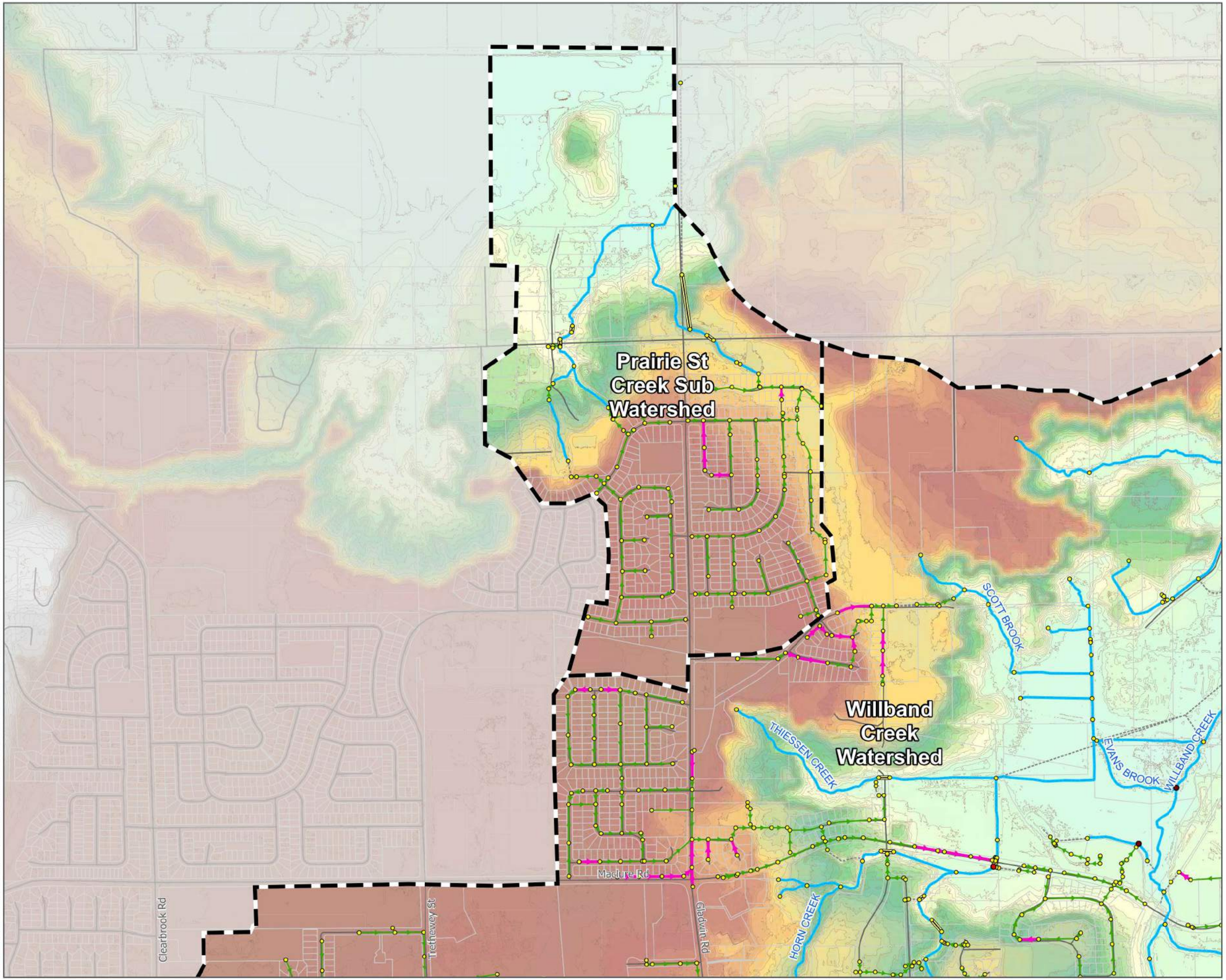
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-2 - Future System Performance (10 Year, Climate Change, No Controls, Upgrades) (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

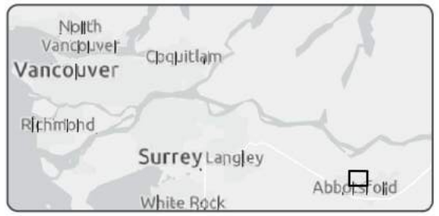
**Future System Performance**
**(10 Year, Climate Change,**
**No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

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**FIGURE 12.2A**

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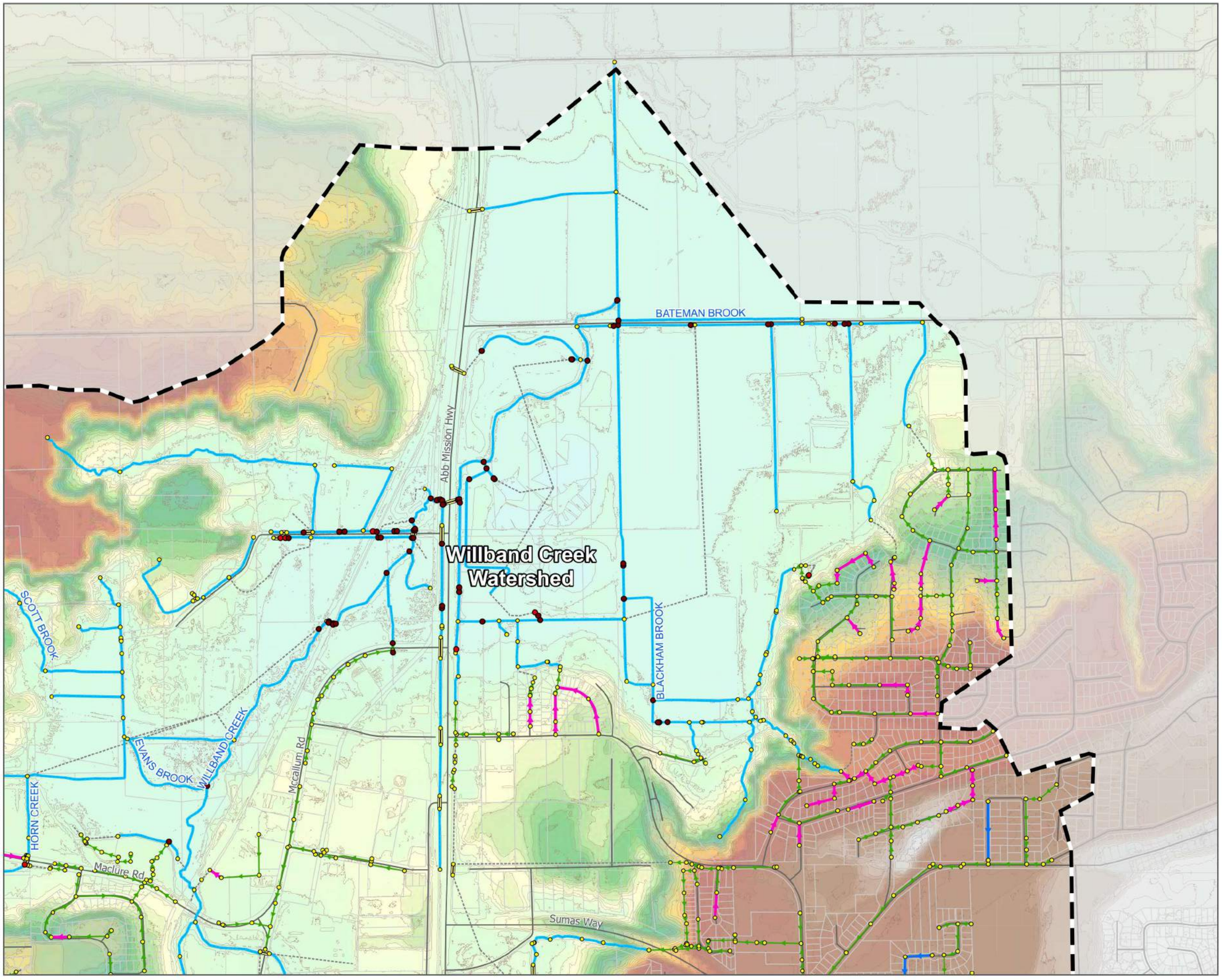
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015-01_Part_4.aprx\Figure 12-2 - Future System Performance (10 Year, Climate Change, No Controls, Upgrades) (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

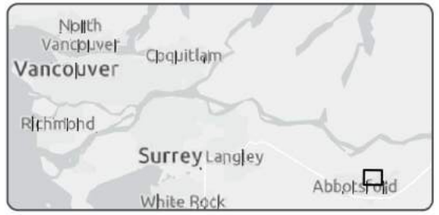
**Future System Performance (10 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

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**FIGURE 12.2B**

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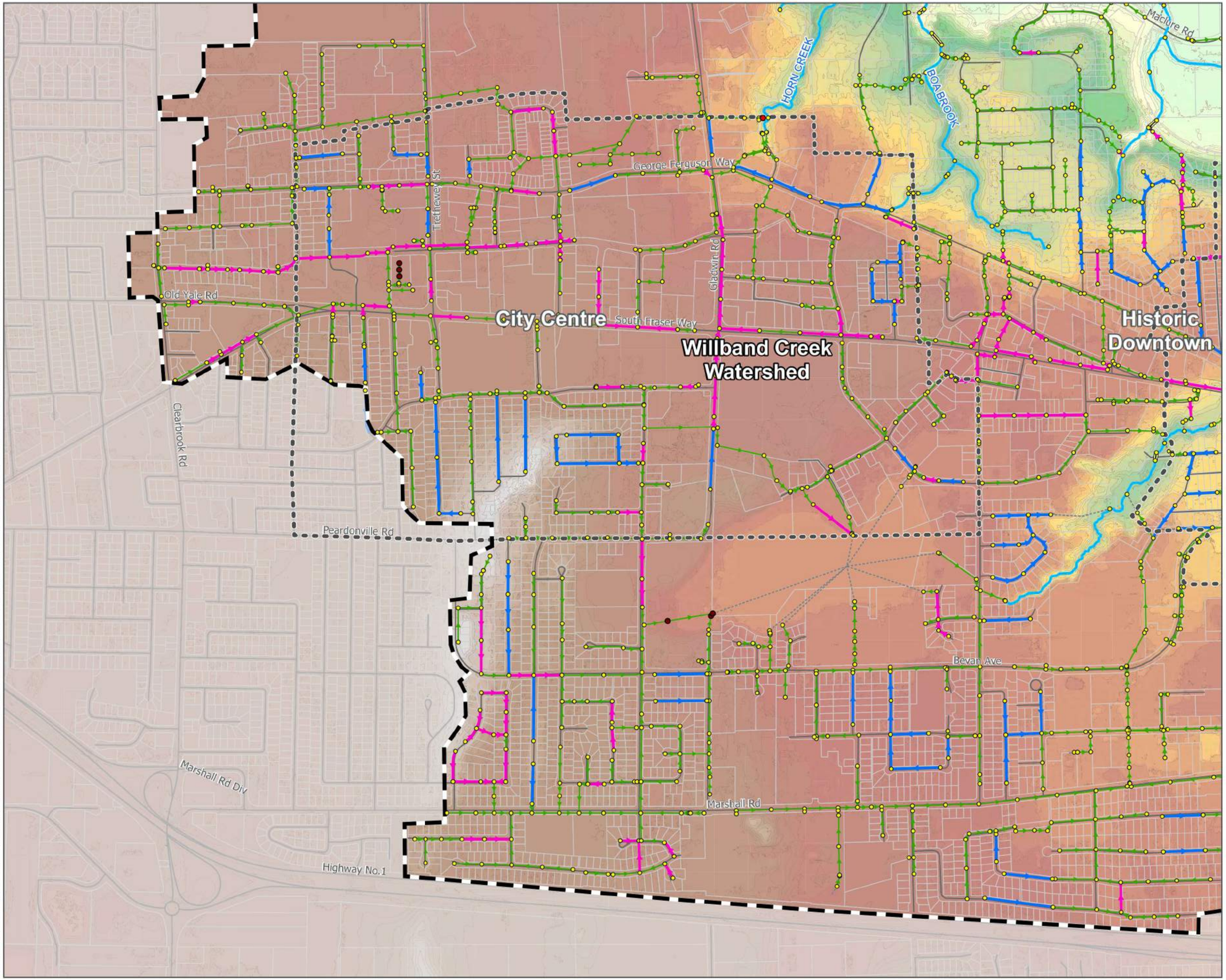



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

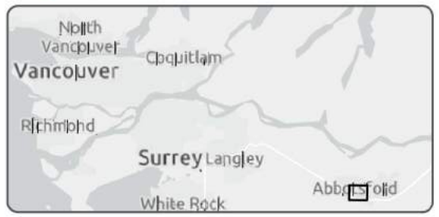
**Future System Performance (10 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

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**FIGURE 12.2C**

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 12-2 - Future System Performance (10 Year, Climate Change, No Controls, Upgrades) (11x17)

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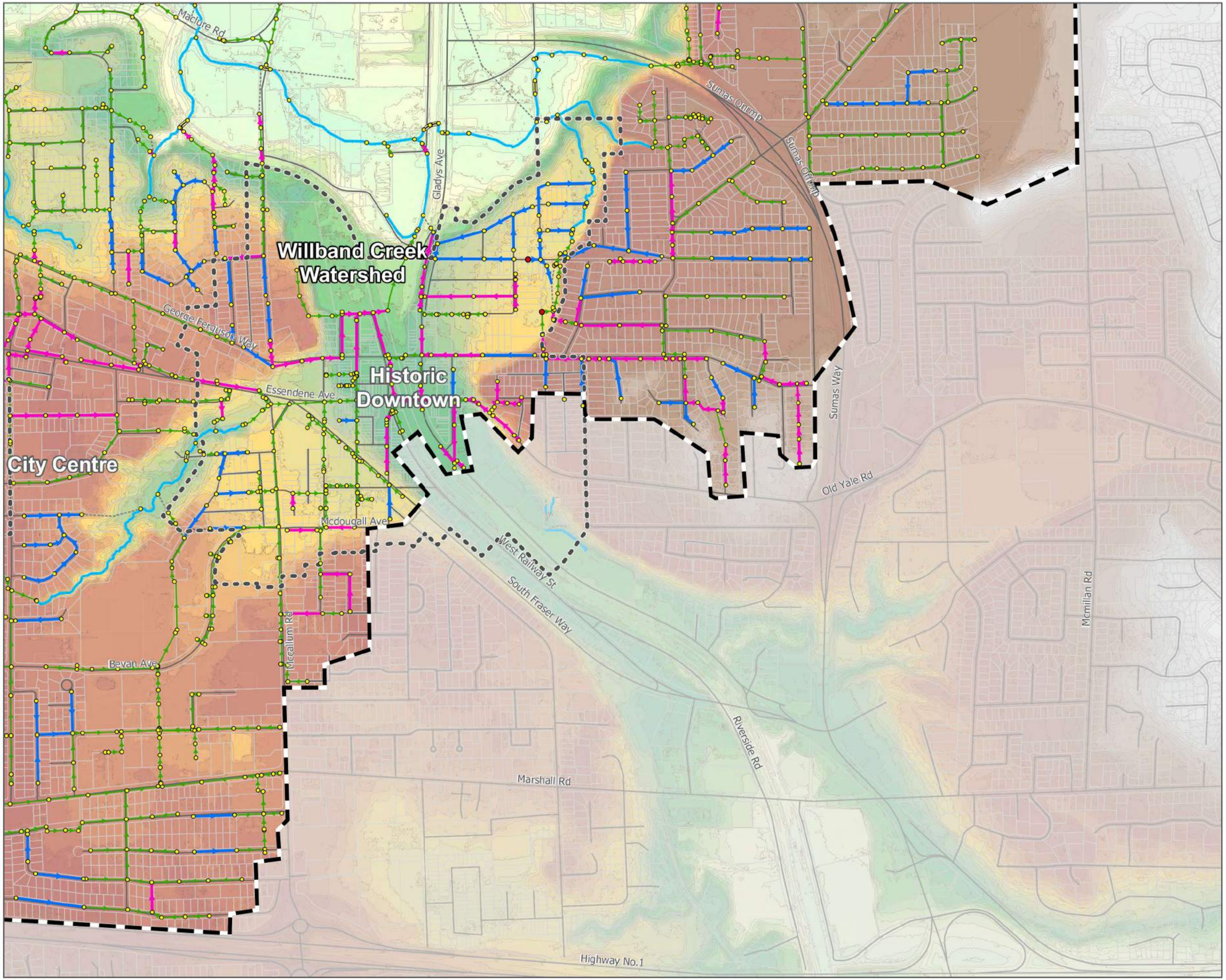
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 12-2 - Future System Performance (10 Year, Climate Change, No Controls, Upgrades) (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

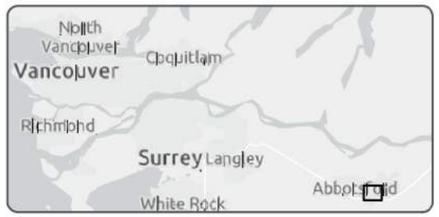
**Future System Performance (10 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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Metres

**Coordinate System:**
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**FIGURE 12.2D**

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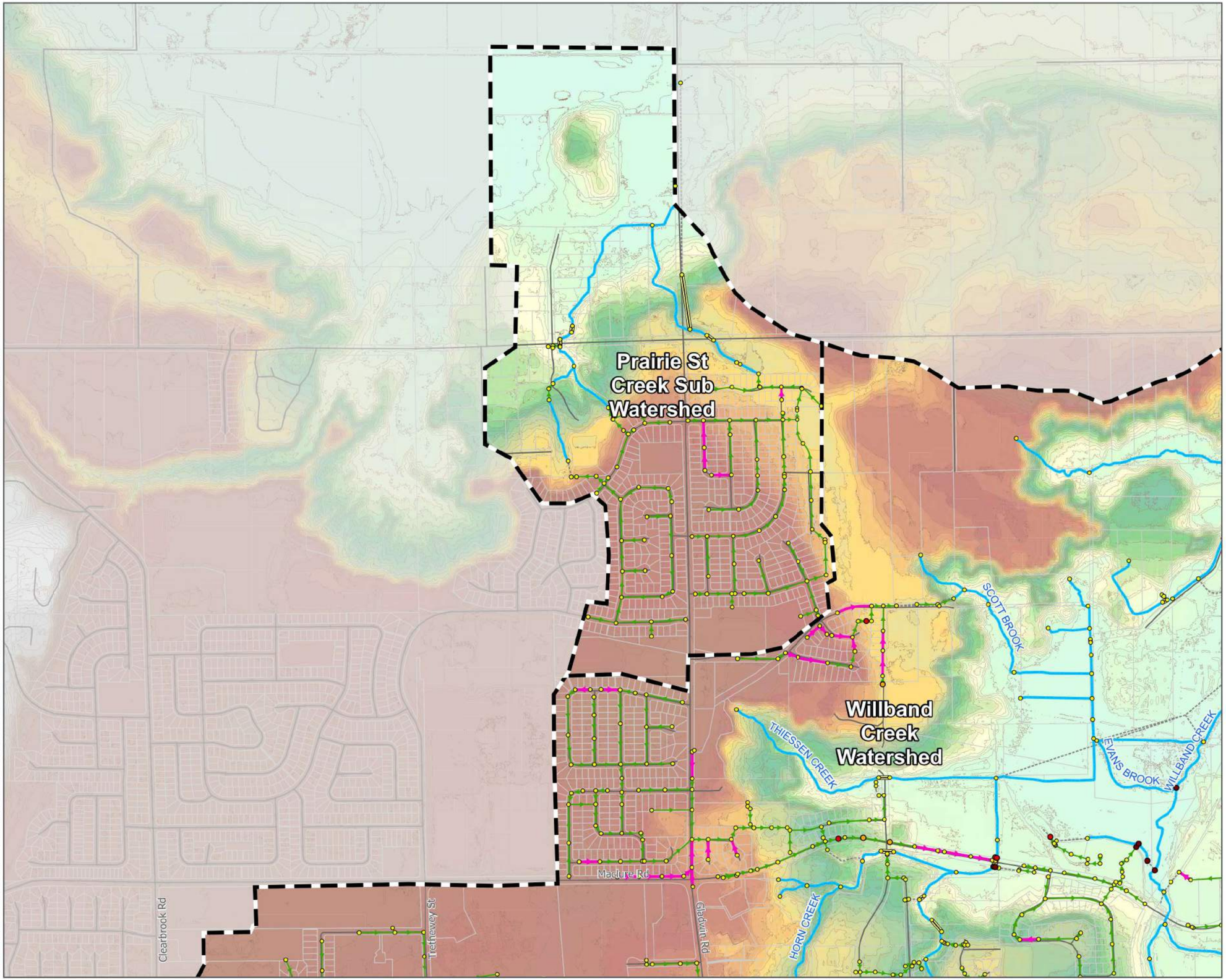
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-3 - Future System Performance (100 Year, Climate Change, No Controls, Upgrades) (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

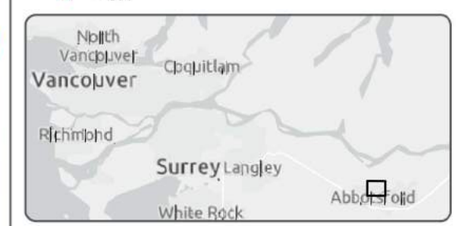
**Future System Performance (100 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

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**FIGURE 12.3A**

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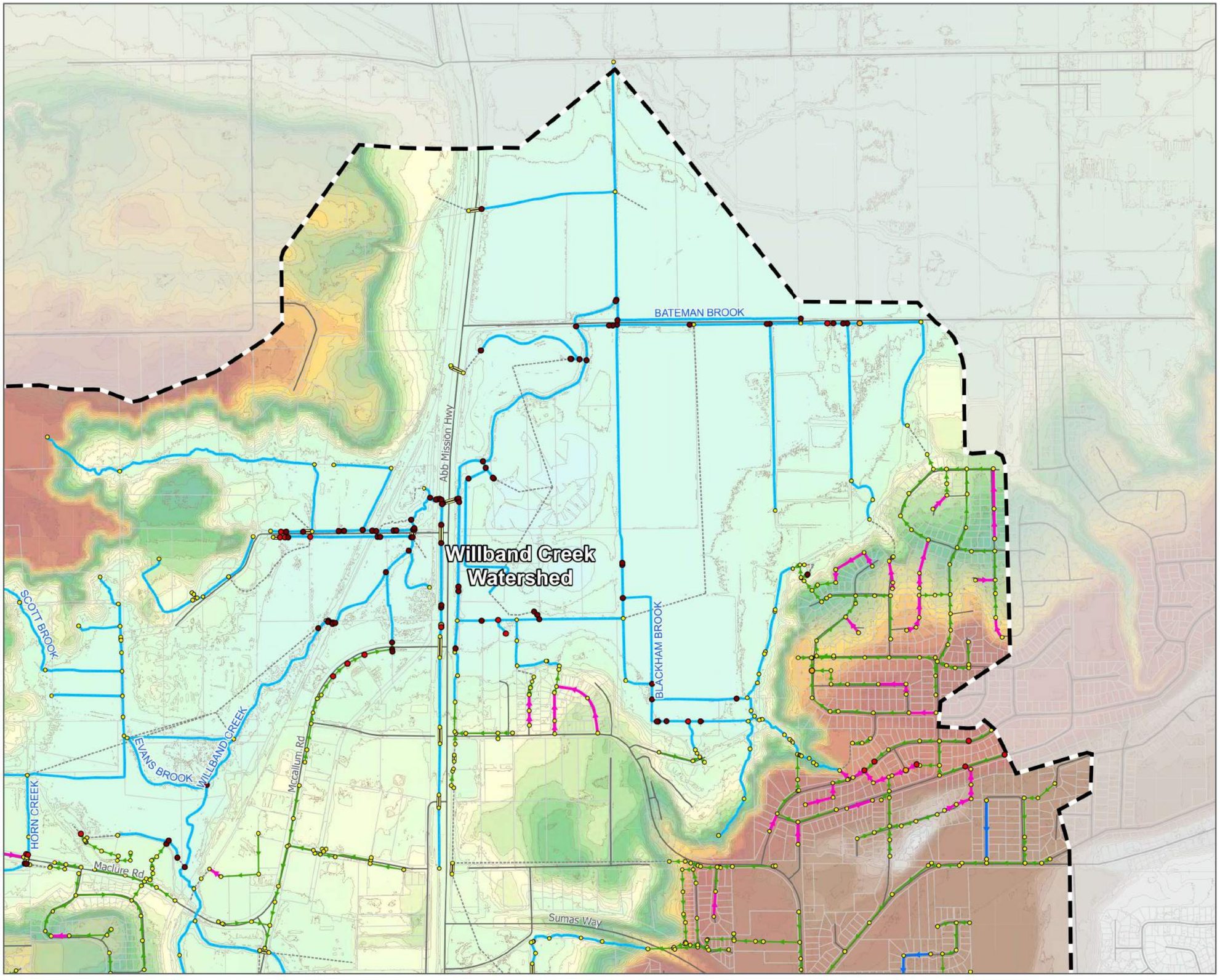
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015-01_Part_4.aprx\Figure 12-3 - Future System Performance (100 Year, Climate Change, No Controls, Upgrades) (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

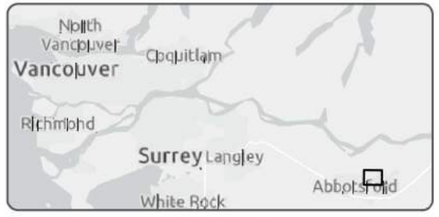
**Future System Performance (100 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:11,000
(When plotted at 11"x17")

**Data Sources:**

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- GeoAdvice (2016-18)

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**FIGURE 12.3B**

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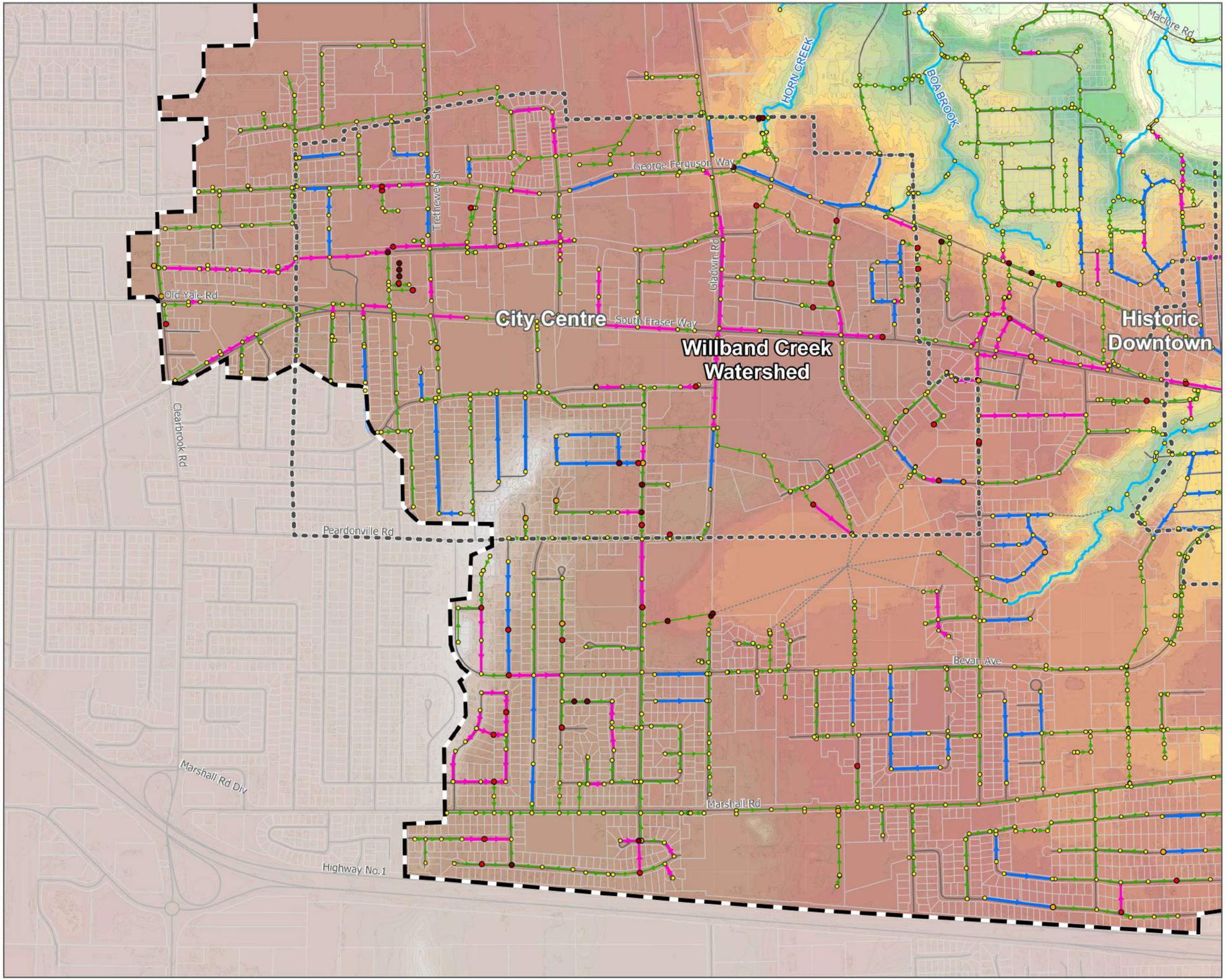
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-3 - Future System Performance (100 Year, Climate Change, No Controls, Upgrades) (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Neighbourhood Plan Boundary Study Area
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

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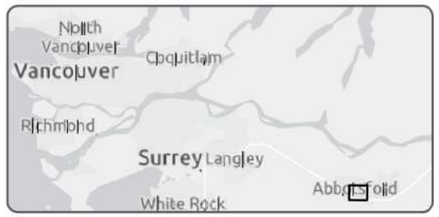


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**FIGURE 12.3C**

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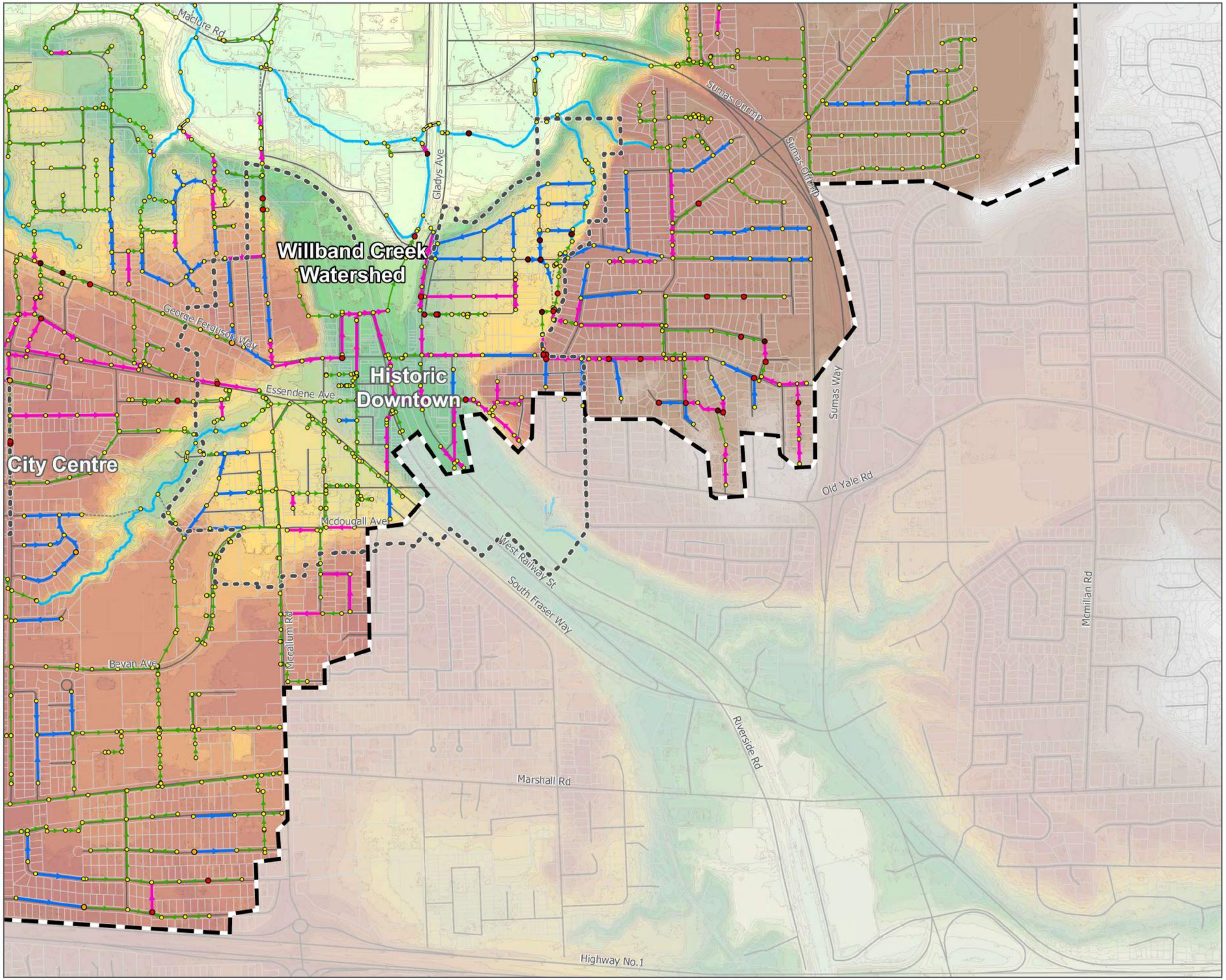


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Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, No Controls, Upgrades)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Neighbourhood Plan Boundary Study Area
- Upgraded Main
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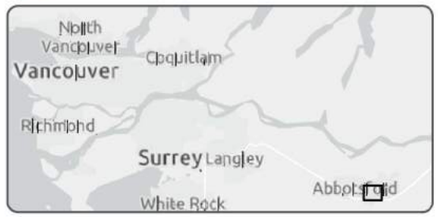


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**FIGURE 12.3D**

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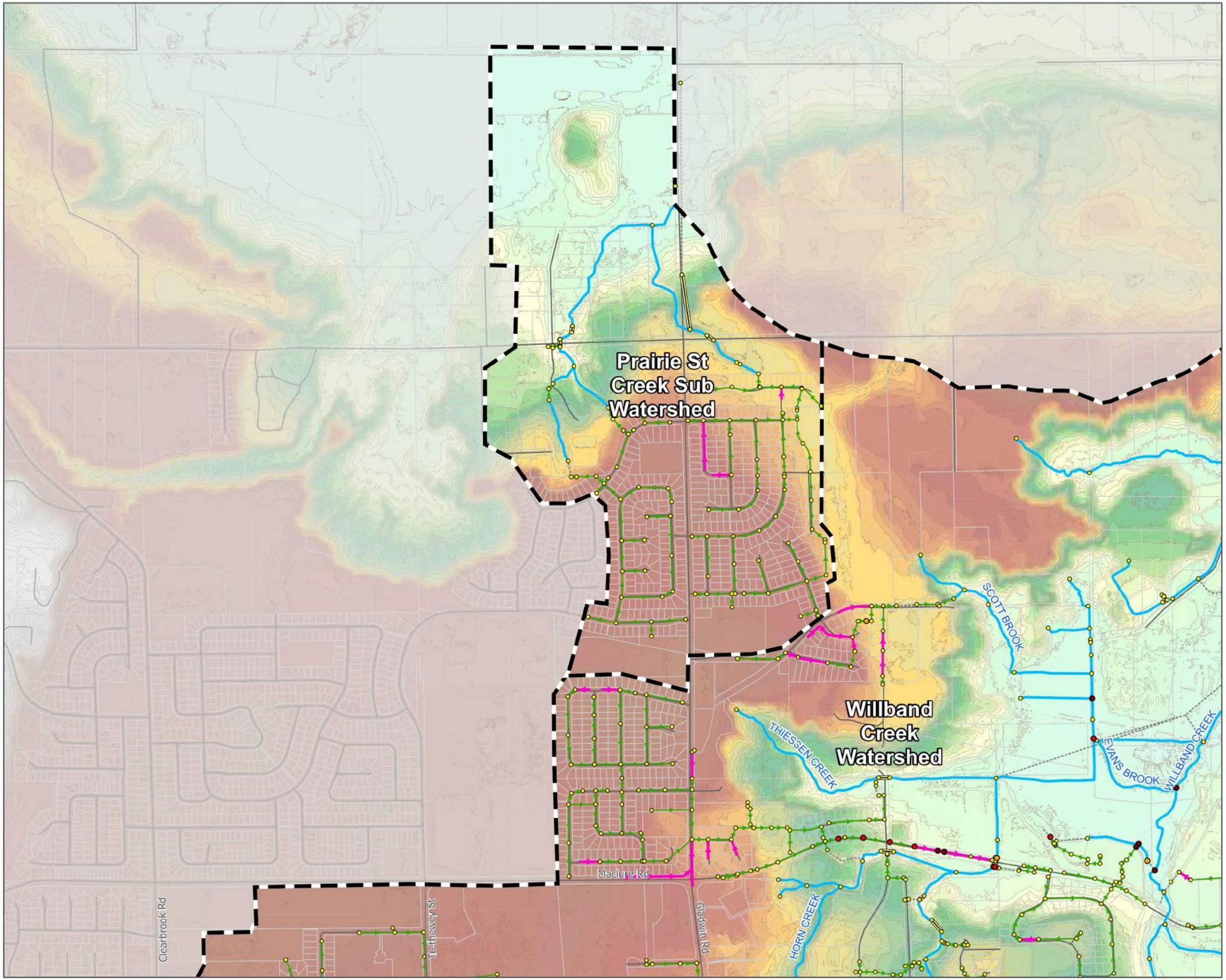
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-4 - Future System Performance (100 Year, Climate Change, With Controls) (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, With Controls)**

**Legend**

- Willband Creek Watershed
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- ≤0.001
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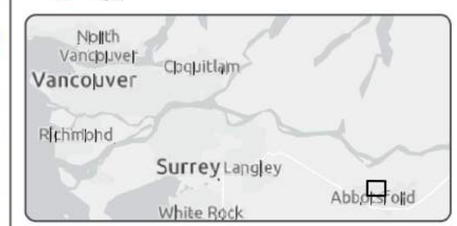


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0 200 400 600
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**FIGURE 12.4A**

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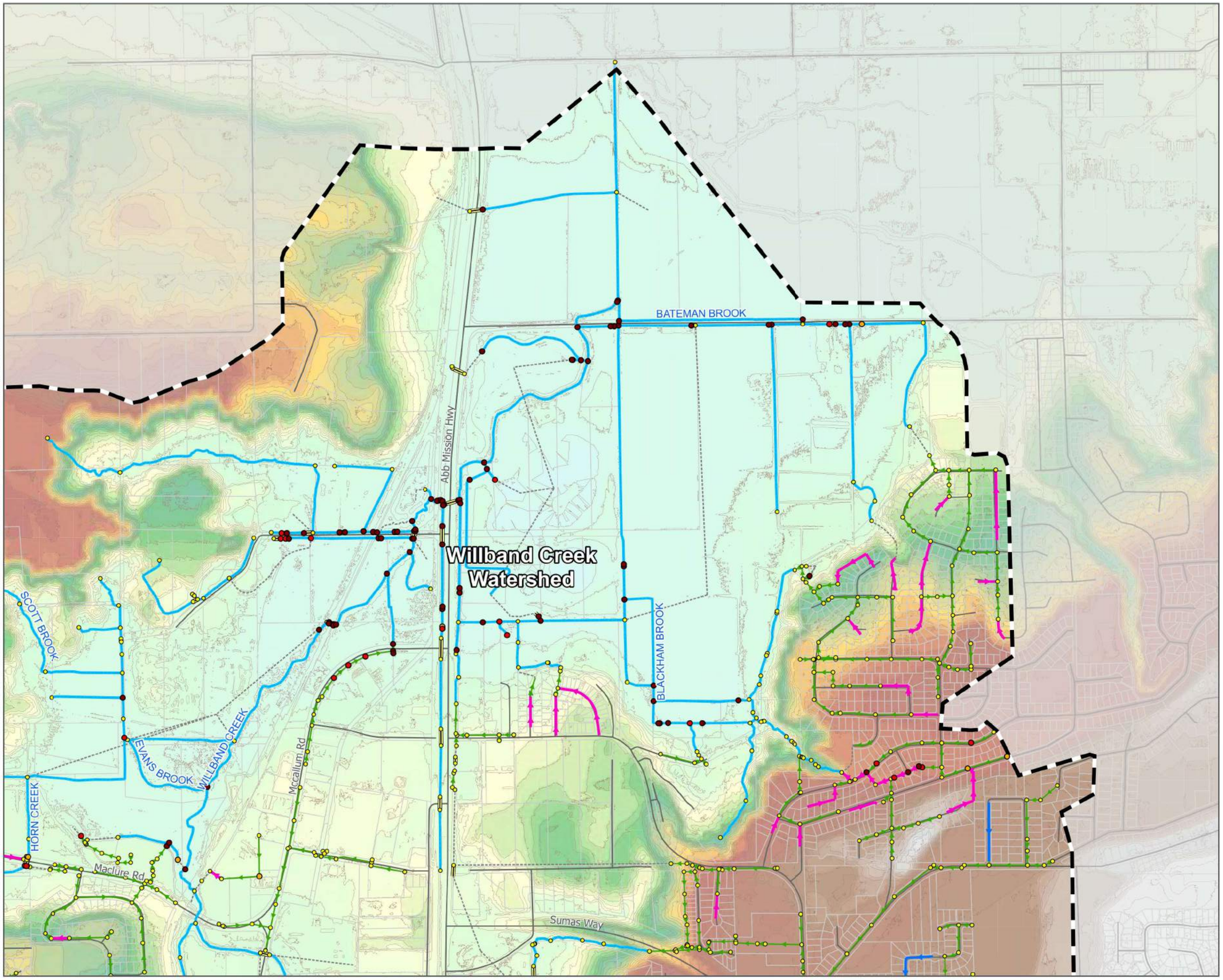
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015-01_Part_4.aprx\Figure 12-4 - Future System Performance (100 Year, Climate Change, With Controls) (11x17)

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Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, With Controls)**

**Legend**

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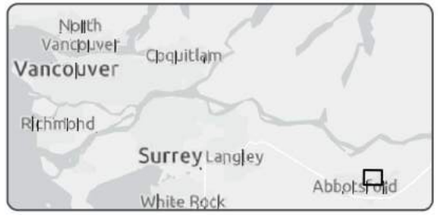


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**FIGURE 12.4B**

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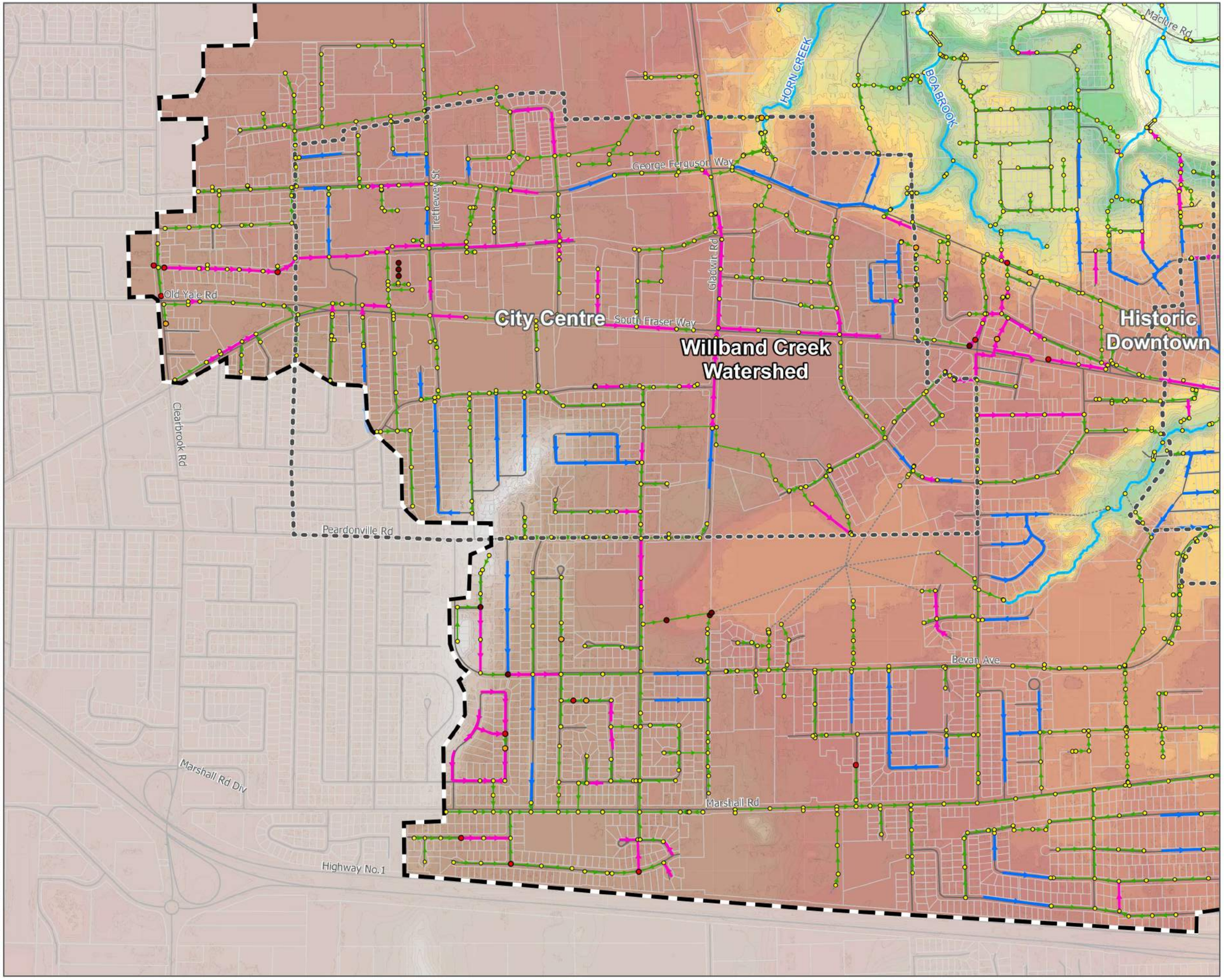
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 12-4 - Future System Performance (100 Year, Climate Change, With Controls) (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, With Controls)**

**Legend**

- Willband Creek Watershed
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- Upgraded Main
- Proposed Main
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Flood Loss Volumes (ML)

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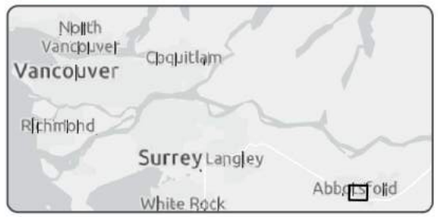
- >0.1

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0 200 400 600
Metres

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**FIGURE 12.4C**

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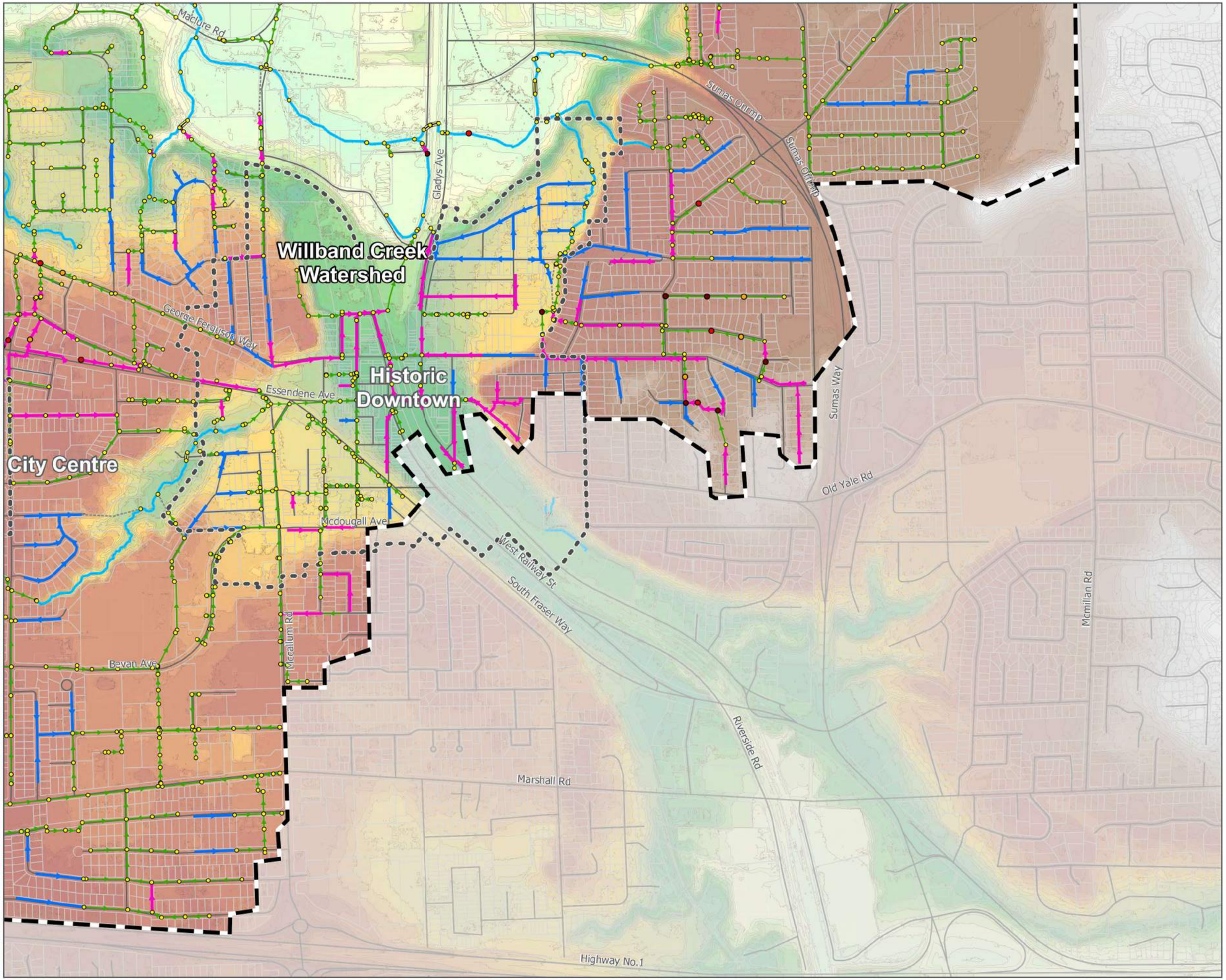
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790_0015.01_Part_4.aprx\Figure 12-4 - Future System Performance (100 Year, Climate Change, With Controls) (11x17)




ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance (100 Year, Climate Change, With Controls)**

**Legend**

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
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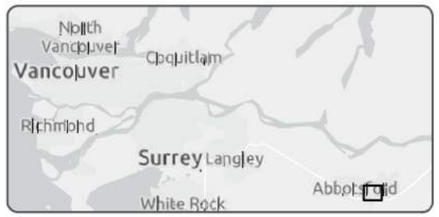


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Metres

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**FIGURE 12.4D**

# 13 MILL LAKE AND WILLBAND CREEK FLOODPLAIN

The City has particular interest to understand the potential change in floodplain performance as a result of changes to the upland systems and climate change. **Table 13.1** below presents a summary of the predicted maximum hydraulic grades lines within each of the modeled flood cells under various conditions. The boundary of each flood cell is depicted in **Figure 13.1.** The values for Mill Lake assume a constant position on the discharge weir and does not account for changing protocol to increase freeboard. Flooding is consistent in each flood cell across scenarios, with exception to cell 25; an apparent anomaly relative to the other cells. As shown in **Figure 13.1**, flood cell 25 is located at the transition of the uplands to the lowlands and has the main stem of Willband Creek through it. Also shown in **Figure 13.1** is the horizontal extent of projected flooding for both the existing 1:200 year condition and the maximum future condition 1:200 year condition, showing no perceptible difference between the two.

One would anticipate greater impact to the floodplain if change where a result of greenfield development (development planned for a site that is largely a green, undeveloped state), but in this case the development footprint has been previously established and proposed changes within it are not predicted to impact the floodplain performance at a macro scale. It is noted in Table 13.1, however, that when accounting for the application of site controls, the maximum water level in some cells is predicted to be minutely higher than when not considering site controls. Once again, these differences are considered within the margin of error of the analysis and the hypothesis is that the application of controls influences the timing of the runoff hydrograph peak from controlled lands to more closely coincide with the peak from the uncontrolled lands. These unvalidated differences are not considered a significant change in risk and should not dissuade the application of site controls.

**Table 13.1 - Summary of Flood Cell Maximum Hydraulic Grade Lines (water surface elevation in meters geodetic)**

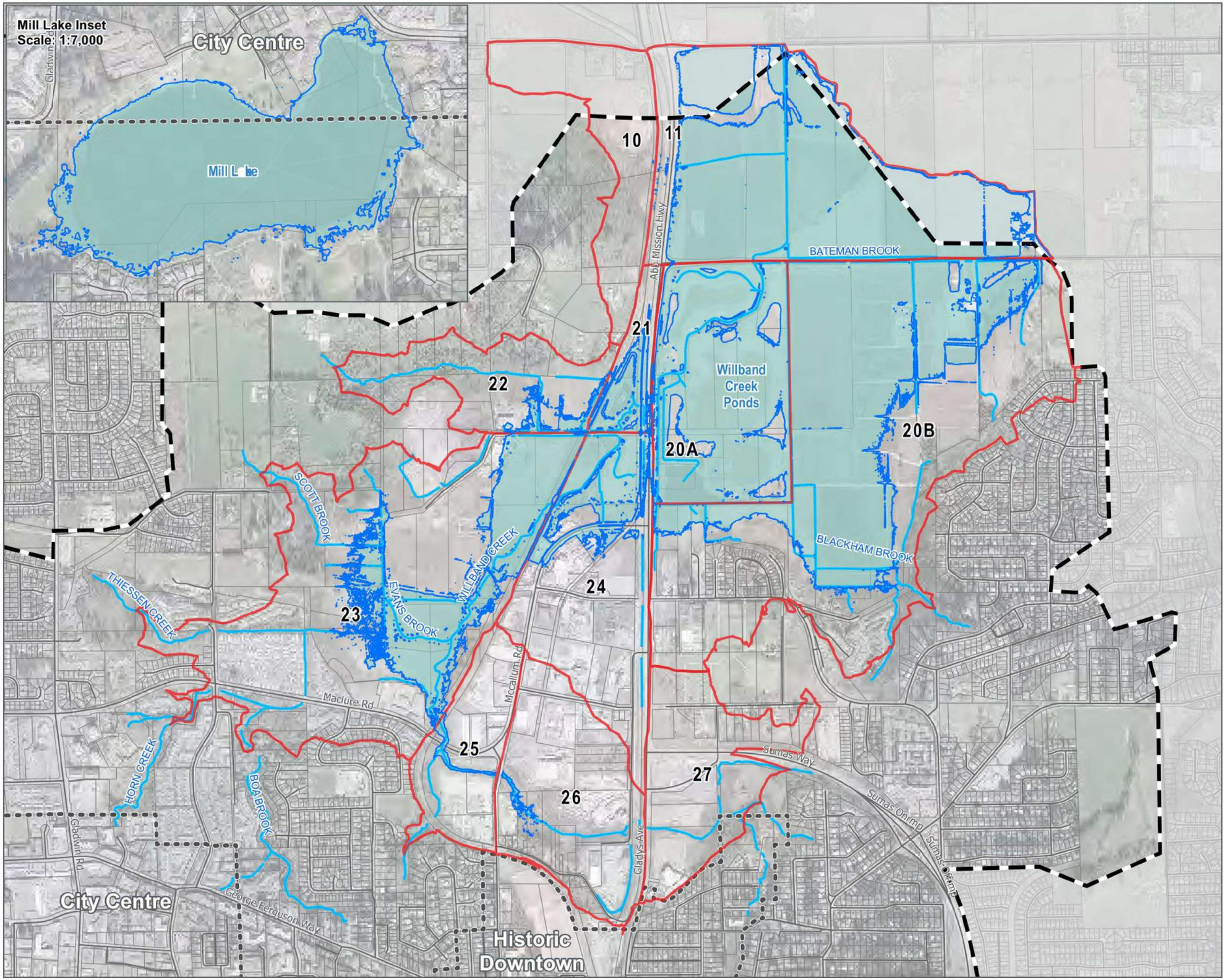
| Flood Cell | 1:10 year | | | | 1:100 year | | | | 1:200 year | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
| 10 | 4.00 | 4.00 | 4.00 | 4.00 | 4.40 | 4.40 | 4.40 | 4.40 | 4.44 | 4.44 | 4.44 | 4.44 |
| 11 | 3.87 | 3.87 | 3.87 | 3.87 | 4.25 | 4.25 | 4.25 | 4.25 | 4.42 | 4.42 | 4.43 | 4.43 |
| 20A | 4.00 | 4.00 | 4.00 | 4.00 | 4.18 | 4.18 | 4.18 | 4.18 | 4.40 | 4.40 | 4.40 | 4.40 |
| 20B | 3.74 | 3.74 | 3.74 | 3.74 | 4.05 | 4.05 | 4.05 | 4.05 | 4.38 | 4.38 | 4.38 | 4.38 |
| 21 | 4.00 | 4.00 | 4.00 | 4.00 | 4.43 | 4.45 | 4.46 | 4.45 | 4.47 | 4.47 | 4.50 | 4.49 |
| 22 | 4.02 | 4.03 | 4.04 | 4.03 | 4.43 | 4.45 | 4.46 | 4.45 | 4.47 | 4.47 | 4.50 | 4.49 |
| 23 | 4.12 | 4.15 | 4.17 | 4.15 | 4.57 | 4.63 | 4.66 | 4.62 | 4.58 | 4.58 | 4.68 | 4.63 |
| 24 | 4.03 | 4.03 | 4.04 | 4.04 | 4.44 | 4.46 | 4.47 | 4.46 | 4.48 | 4.48 | 4.51 | 4.50 |
| 25 | 4.49 | 4.56 | 4.60 | 4.59 | 4.88 | 5.04 | 5.12 | 5.03 | 5.19 | 5.33 | 5.51 | 5.24 |
| 26 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 | 5.75 |
| 27 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 | 7.61 |
| SU19 (Mill Lake) | 51.83 | 51.85 | 51.84 | 51.85 | 51.90 | 51.98 | 51.95 | 51.98 | 51.94 | 51.97 | 51.99 | 52.02 |

Scenario 1 – Existing Condition

Scenario 2 - Future land use, no site controls, with climate change

Scenario 3 - Future land use, with site controls and climate change

Scenario 4 - Future land use, no site controls, with system upgrades and climate change

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Willband Creek
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Management Plan

## Flood Extents (200 Year)

**Legend**

- Maximum Future Flood Extent (200 Year)
- Existing Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Creek

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0 200
Metres

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**FIGURE 13.1**

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U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 13-1 - Flood Extents (200 Year) (11x17)

It is recommended that the City proceed with its planned Phase 2 Matsqui Prairie Drainage Study. This study is recommended before considering modifications to the existing system or creation of new pond storages in the floodplain. But for the time being, the maximum water levels provided in **Table 13.1** can be reviewed against established Flood Construction Levels (FCL's) for any new construction. The City could inventory the elevations of existing buildings and critical infrastructure within the flood plain and use them as target thresholds to test solutions during the conduct of the Phase 2 Matsqui Prairie Drainage Study.

**Mill Lake and Willband Creek Floodplain Summary of Recommendations and Action Items**

**1** Conduct Phase 2 Matsqui Prairie Drainage Study.

**2** Review water levels in **Table 13.1** against currently established Flood Construction Levels (FCL's) for new construction in the floodplain.

**3** Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.

# 14 CAPITAL COSTS

To a large extent, system performance is not sensitive to the order in which implementation occurs, therefore pipe replacement, or provision of new pipes where they do not currently exist, can be governed by other programs and redevelopment opportunities. However, investigating the structural condition of the existing Mill Lake Ravine Park trunk sewer and selecting a preferred solution to address risks associated with this system are considered high priority.

## 14.1 Storm Sewer Capital Costs

A complete inventory of new pipes and unit prices are provided in **Appendix F**, with a summary of costs presented in **Table 14.1** on the following page. Costs are Class D and include 50% engineering and contingencies but exclude taxes.

**Table 14.1 - Summary of Storm Sewer and Culvert Costs**

| Priority – Reason for upgrade | Minor (10-year) Criteria | Estimated Capital Cost* | Major (100-year) Criteria | Estimated Capital Cost | Total Priority Capital Cost |
|---|---|---|---|---|---|
| **Priority 1** – Performance does not meet criteria with or without the application of site controls. These upgrades include upsizing a portion of trunk sewer downstream of Ravine Park, on the assumption that storage in Ravine Park is not provided. | 3,572 m | $4,616,100 | 180 m | $729,700 | $5,345,800 |
| **Priority 2** – Performance does not meet criteria if site controls are not applied extensively. These upgrades include upsizing a portion of trunk sewer downstream of Ravine Park, on the assumption that storage in Ravine Park is not provided. | 5,026 m | $7,787,500 | 152 m | $784,000 | $8,571,500 |
| **Priority 3** – To meet desired minimum main size of 300 mm, despite the current having adequate performance. | 10,821 m | $10,144,800 | 0 m | $ 0 | $10,144,800 |
| **Priority 3** – Provide a main where one does not exist. | 15,133 m | $14,207,700 | 0 m | $ 0 | $14,207,700 |
| **Total** | 34,552 m | $36,756,100 | 332 m | $1,513,700 | $38,269,800 |

It is worthy to re-emphasize that only the Priority 1 upgrades ($5,345,800 in total) are required regardless of site controls. Priority 2 upgrades ($8,571,500 in total) are subject to un-successful implementation of extensive site controls. The remaining Priority 3 upgrades ($24,352,500 in total) are fully discretionary.

In absence of a technical assessment for the creation of a control structure and storage within the Mill Lake Ravine Park, a recommended planning level cost for a control and storage in the ravine is $750,000, including 50% for engineering and contingencies, but excluding taxes. This also excludes modifications to the ravine itself, but it limited to the inlet structure alone. The creation of this storage would eliminate 288 m of Priority 1 and 2 storm sewer upgrades, currently valued at $1,128,641 (subject to a condition and pre-design assessment of existing pipes). The decision around which approach to take should be governed by the following steps:

**1** Conduct a condition assessment of the existing trunk storm sewers,

**2** Conduct a predesign assessment of the Ravine Park storage option, including geotechnical, environmental, and arborist reviews,

**3** Consult with Provincial and Federal regulatory agencies before conducting predesign assessment,

**4** Conduct a predesign assessment of the trunk sewer replacement option, including consideration for disruption to community and business, condition of the existing system, and need to fully replace or supplement the existing system, and

**5** Update construction cost estimates of each option and conduct cost / benefit assessment.

## 14.2 Summary of Recommendations, Priorities and Budgets

**Table 14.2** on the following pages present a summary of all recommendations. For each recommendation, a relative level of priority is assigned, along with a preliminary budget for consideration where possible. The actual budget of each item is highly subject to scope. For that reason, several recommendations have been provided a range of budget, or to be determined (TBD). It is recommended that for each item the City identify its capacity to fund each item and to conduct a scoping exercise to further define scope and budget before attempting to secure funding.

High priority items are recommended to be completed from 2019 to 2024, medium priority items from 2025 to 2030, and low priority items as funding allows.

**Table 14.2 - Summary of Recommendations / Action Items and Budgetary Costs**

| Action | Priority | Budget Cost |
|---|---|---|
| **LAND USE MANAGEMENT** | | |
| Explore the design of rainwater management facilities for both retention and water quality treatment in the Municipal Hall lands site and the City owned parking lot at West Railway Street and Essendene Avenue. Both facilities would serve local catchments and demonstrate the City as leaders. | Medium | $50,000 (pre-design study only) |
| Designate the 4 blocks of Historic Downtown between South Fraser Way to George Ferguson Way, Pauline Street to Montvue Avenue, as a special area exempting it from current stormwater site control criteria but pay cash-in-lieu for detention. However, onsite source controls are still encouraged where feasible. | High | N/A |
| Develop policy around service connections for subsurface floor space, both in terms of the mechanical requirements for the physical connection and statements to limit the City's liability. | High | $20,000 (excluding creation of regulatory documents) |
| Establish tree canopy targets and landscape standards to suit (both private and public spaces). Determine what regulatory processes would trigger implementation (eg. Building permit, re-development, capital reconstruction). | High | $30,000 (excluding creation of regulatory documents) |
| **ENVIRONMENTAL OPPORTUNITIES** | | |
| Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road. | Low | $50,000 to develop a program<br>$100,000 to $500,000 for planting |
| Modify or replace stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street. | Low | TBD through design review |

| Action | Priority | Budget Cost |
|---|---|---|
| **ENVIRONMENTAL OPPORTUNITIES Cont.** | | |
| Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation. | Low | $50,000 to develop a program<br><br>Premature to offer an implementation budget, particularly if off-line pools are considered. |
| Removal of garbage and other anthropogenic debris from watercourses. | High | N/A |
| Recognized to have significant challenges, however review the practicality of daylighting a portion of ravine downstream of Mill Lake. | Low | $50,000 for investigation only |
| Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged. | Medium | $20,000 |
| Subject to item above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake. | Medium | TBD |
| Consider “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators. (7 outfalls) | Medium | $1.5M to $3.0M assuming O/G, not media filltration |
| Apply landscaped based biofiltration site controls wherever possible. | High | N/A |
| **GEOTECHNICAL AND SOURCE CONTROLS** | | |
| Expand Stormwater Source Control Bylaw to City-wide, and to ensure it is enforceable through the Development and Building Permit processes. | High | $50,000 |
| Identify high risk sites (eg. auto-wreckers, service stations) which would be restricted from infiltration systems. | High | N/A |

| Action | Priority | Budget Cost |
|---|---|---|
| **GEOTECHNICAL AND SOURCE CONTROLS Cont.** | | |
| Further develop an erosion mitigation strategy for Horn Creek and Boa Brook. Done in concert with the exploration of communal detention ponds discussed under "Infrastructure" below. | High | $50,000 |
| Conduct an annual review and assessment of geotechnical stability in Horn Creek, Boa Brook and Prairie Street Creek. | High | $20,000 per year |
| Develop criteria and standards for the application of urban roadway Green Infrastructure. This would also include the potential application of perforated storm sewers provided water quality pre-treatment is provided. | High | $50,000 |
| Develop a comprehensive tracking GIS database of public and private site controls. | High | TBD |
| Explore operating permit requirements for long term inspection and maintenance of private site controls. | Medium | $20,000 |
| Create a Development Permit Area for the application of infiltration system in proximity to steep slopes under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose. | High | $20,000 |
| **INFRASTRUCTURE** | | |
| Video inspect trunk sewer downstream of Mill Lake Ravine Park and conduct condition assessment. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis. | **High** | $20,000 |
| Subject to result of the above action, conduct a pre-design study to explore the potential for restricting flow at the storm sewer inlet at the downstream end of Mill Lake Ravine Park. | High | $50,000 |

| Action | Priority | Budget Cost |
|---|---|---|
| **INFRASTRUCTURE Cont.** | | |
| Subject to the findings of items above, decide to upgrade the trunk sewers downstream of Mill Lake Ravine Park, either through full replacement or supplemental capacity, or restrict flow at the inlet. | High | TBD |
| Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment. | Low | $50,000 |
| Notify private property owners in Historic Downtown that need to reconnect to realigned City infrastructure on Montrose Avenue and flag these properties in the City database to ensure reconnection is achieved through Building or Development permitting. | Low | N/A |
| Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary. | Priority 1 – Medium-High<br>Priority 2 – Medium<br>Priority 3 – Low | Priority 1 - $5,345,800<br>Priority 2 – $8,571,500<br>Priority 3 - $24,352,500 |
| Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted floodloss of 100 $m^3$ or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 $m^3$ and 100 $m^3$. | Medium | $200,000 to $500,000 depending on the level of detail |
| Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study. | High | $100,000 |

| Action | Priority | Budget Cost |
|---|---|---|
| **INFRASTRUCTURE Cont.** | | |
| Monitor flows in storm sewer system to validate performance at most problematic (in theory) areas (see Figure 15.1) – based on seven sites monitored November to April. Then conduct an updated hydraulic assessment. | High | $100,000 |
| Conduct a predesign study to further explore the potential of communal detention ponds to reduce erosion in Horn Creek and Boa Brook and compare to the diversion conceived by previous 2009 study. | High | $100,000 |
| **MILL LAKE AND WILLBAND CREEK FLOODPLAIN** | | |
| Conduct Phase 2 Matsqui Prairie floodplain assessment | High | N/A (budgeted by the City for 2020) |
| Initiate discussions with the Fraser Valley Conservancy regarding a floodplain storage and habitat facility west of Highway 11. | High | N/A |
| Review need to establish new Flood Construction Levels (FCL's) in the floodplain. | High | N/A |
| Adjust operational protocols for Mill Lake to offer greater freeboard in the winter. | High | N/A |

## 14.3 Community Survey Summary

Public open house was advertised on the City web portal, newspaper and social media, and held in the afternoon of June 18, 2019 at the entrance to the Clearbrook Library. Staff were available to talk with the public and storyboards with key information were on display. Approximately 35 people took a few minutes to review the information presented and to ask questions. Generally, they were happy to see the consultation and no concerns were noted.

A second Invitational open house was advertised to local environmental groups, environmental consultants, civil consultants, first nations and government, downtown business association, and city staff. The information session was held at City Hall on June 20, 2019 with City and Urban Systems staff available to speak to storyboard displays and to answer questions. There were approximately 15 people that attended the invitational open house. Discussion centered around environmental concerns, and comments received were reviewed and incorporated into the report.

As part of identifying the publics perceptions and priorities regarding the Willband Creek watershed project, a survey was used to collect public feedback. The survey was open from April 23 to June 20, 2019 and a total of 56 surveys were completed. This is a summary of those responses.

This survey was available online and was completed on a voluntary basis.

### 14.3.1 Survey Participants

Survey respondents were asked to identify if they lived or worked in the study area. Of the 56 responses, 40 respondents live or work in the study area and 16 do not live or work in the study area.

### 14.3.2 Perceptions and Importance of the Willband Creek Watershed project

Survey participants were asked about their perception of the Willband Creek watershed project, and how important the project is for them. **Figures 14.1 through 14.4** summarize all responses. 46 of the 56 participants feel the health of the Willband Watershed is important to them and would support a moderate to significant level of community investment be used to support improvements to the watershed. As far as understanding the current overall health of the watershed, 36 participants felt optimistic about the watershed's overall health, but 16 respondents admitted they didn't know/weren't; sure.

Based on the survey responses, the top three areas of concern within the Willband Creek watershed are (1) poor water quality, (2) lack of tree canopy, and (3) invasive species in creek corridors. Each of the top three concerns received between 25 to 30 responses. The full list of concerns is shown in **Figure 14.4**.

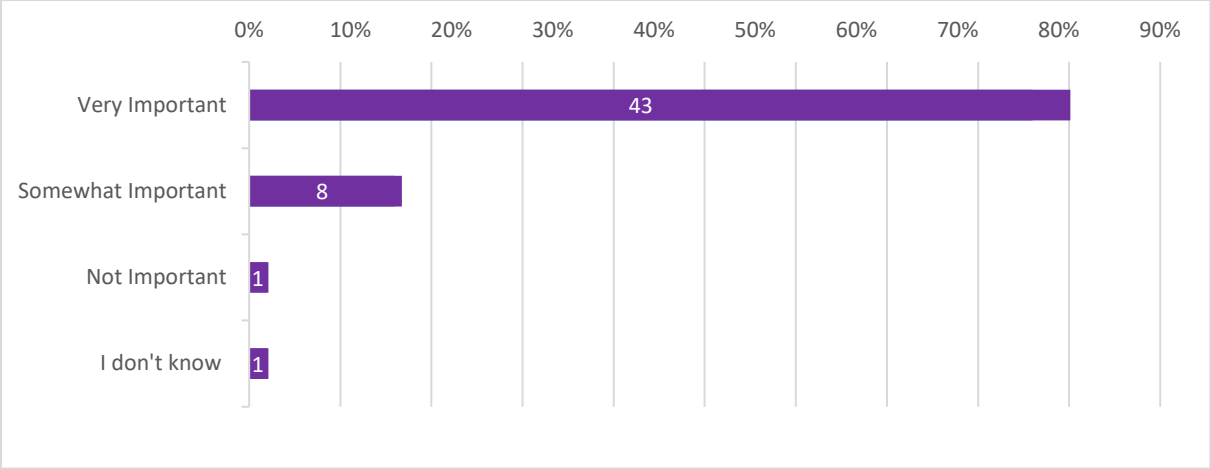


**Figure 14.1 - How Important is the health of the Willband Creek watershed to you?**

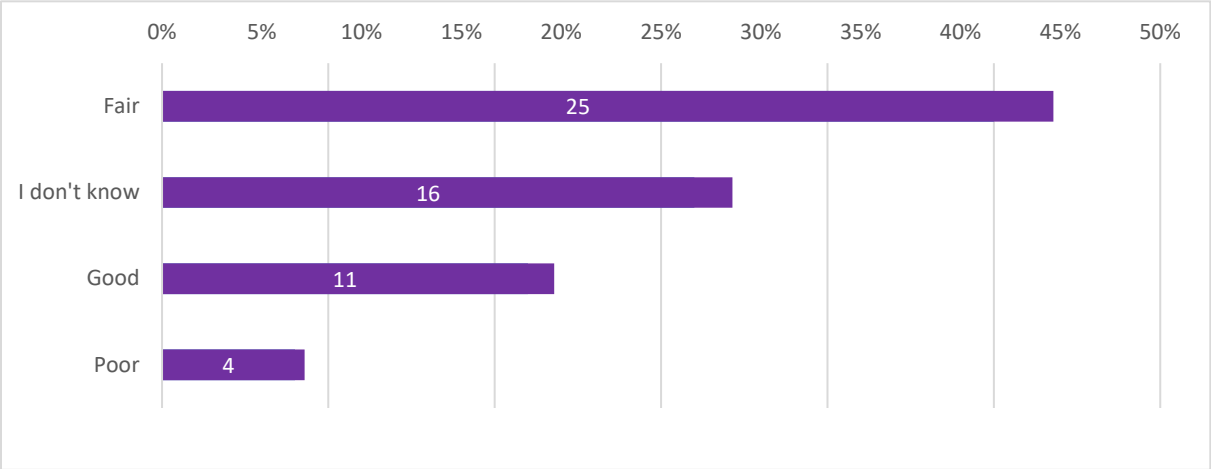


**Figure 14.2 - What is your perception of the current watershed health overall in the Willband Creek watershed?**

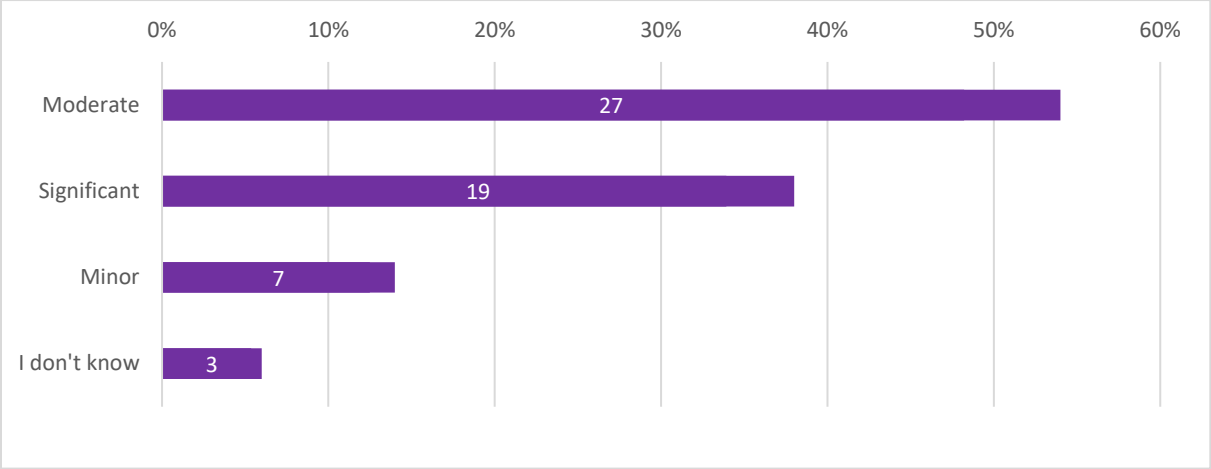


**Figure 14.3 - What relative level of community investment could you support to see watershed health improve in the Willband Creek watershed?**

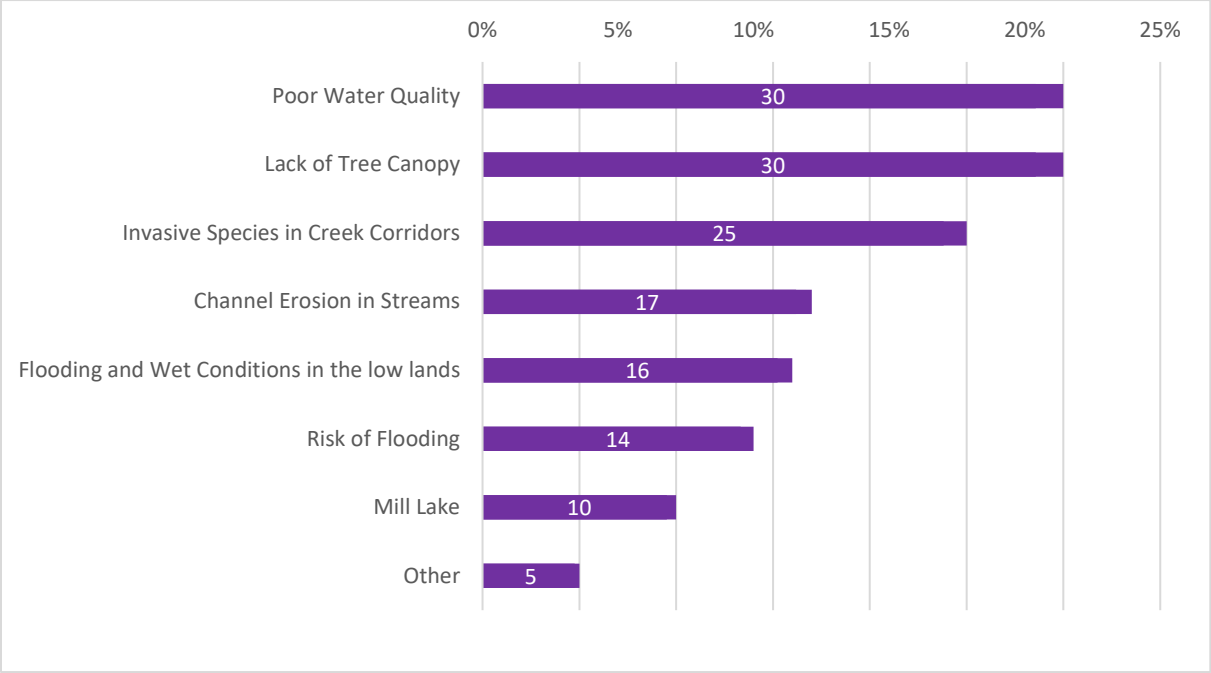


**Figure 14.4 - What are the top three issues you are most concerned with in the Willband Creek watershed?**

Respondents were also provided space to add any comments regarding their perceptions and importance of the Willband Creek watershed, or additional issues not listed in **Figure 14.4**. *(9 responses)*

Several respondents brought up that access via transit, trails, and automobiles was an issue.

Additional issues that were identified by respondents include:

- Animal life and habitats in the watershed (specifically fish and birds)
- Human degradation of the area including residential debris

### 14.3.3 Support for the Willband Creek Watershed project

In the next five questions, respondents were asked to identify their level of support for a variety of action items. The scale ranged from No Support to High Support with an additional I don't know option. **Figures 14.5 through 14.9** summarize the response data to each of the provided potential actions.

***Mill Lake and Willband Creek Floodplain***

As shown in **Figure 14.5**, the option to proceed with conducting a comprehensive drainage study of the downstream Matsqui Prairie drainage system and opportunities to improve water conveyance to the Fraser River received the highest support.

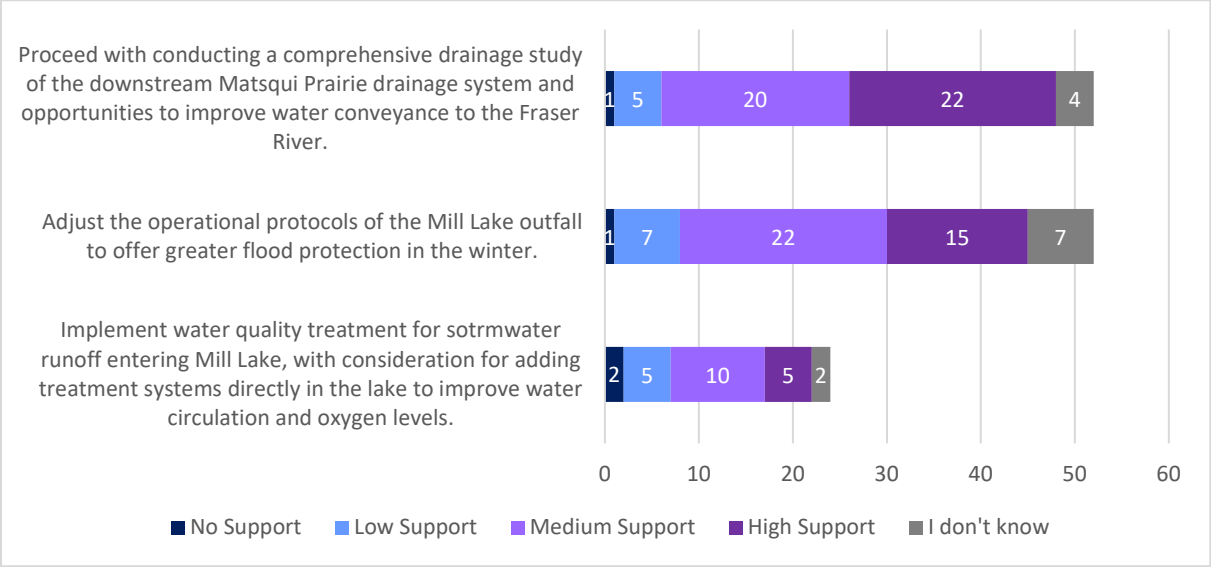


**Figure 14.5 - Mill Lake and Willband Creek Floodplain**

### *Infrastructure*

In response to the proposed infrastructure actions, there was a very even spread between the two most supported options. The first option is to conduct flood risk and overland flow path assessment for areas with a history of problems or for locations identified as having the greatest chance of flooding, and the second top selected action is to monitor the performance of seven existing public stormwater detention ponds and adjust their controls as required to optimize their performance.

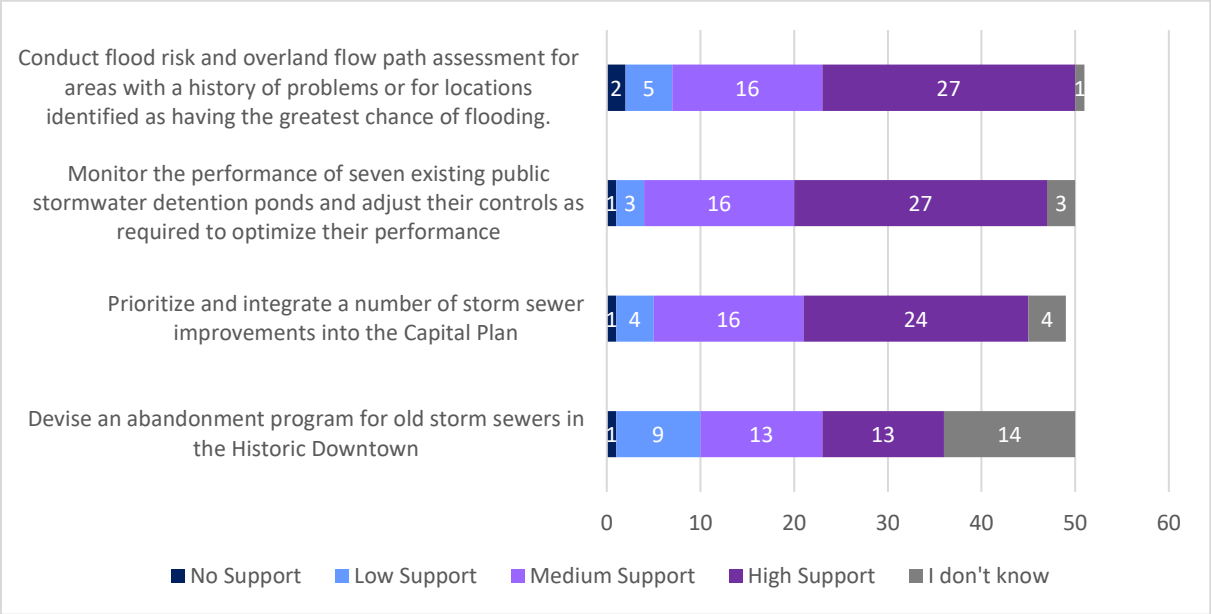


**Figure 14.6 - Infrastructure**

### *Geotechnical and Source Control*

A majority of respondents highly support the City reviewing design standards for its public road corridors for consideration of increased landscape and rainwater source controls.

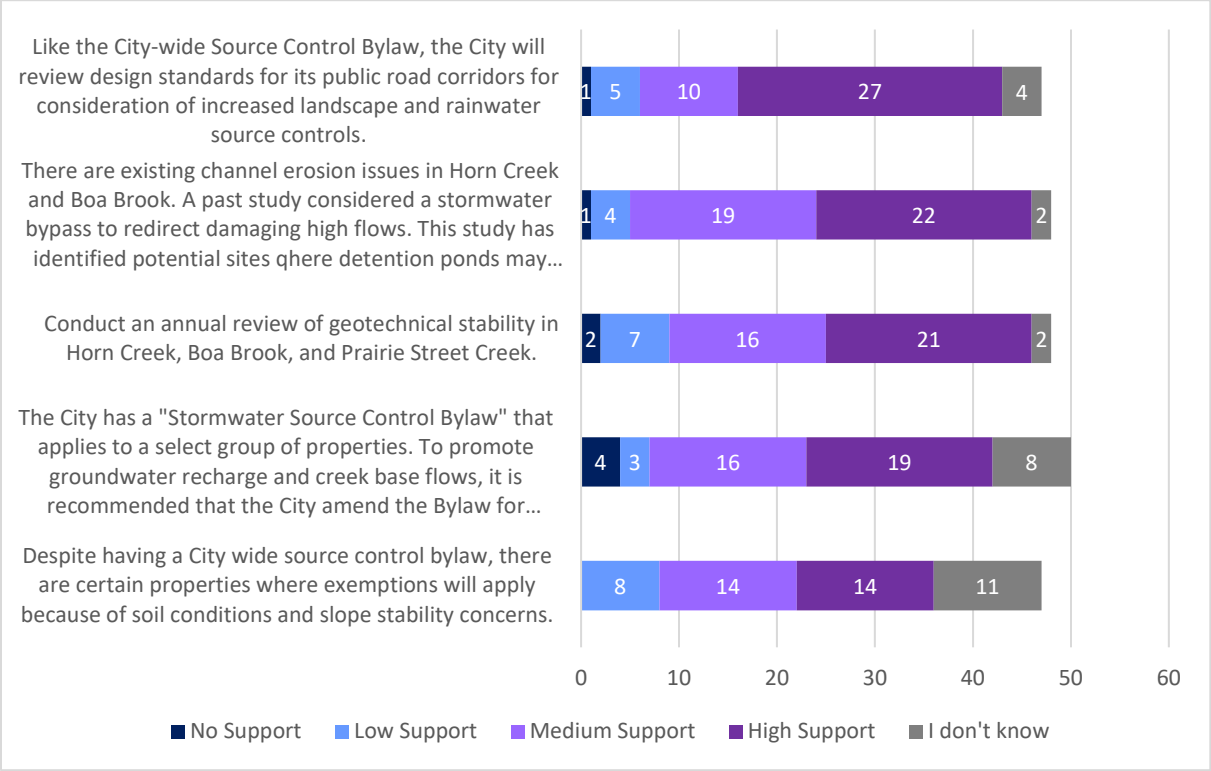


**Figure 14.7 - Geotechnical and Source Controls**

### *Environmental Opportunities*

As shown in **Figure 14.8**, the majority of respondents (more than 74% for both) highly support both of the presented actions.

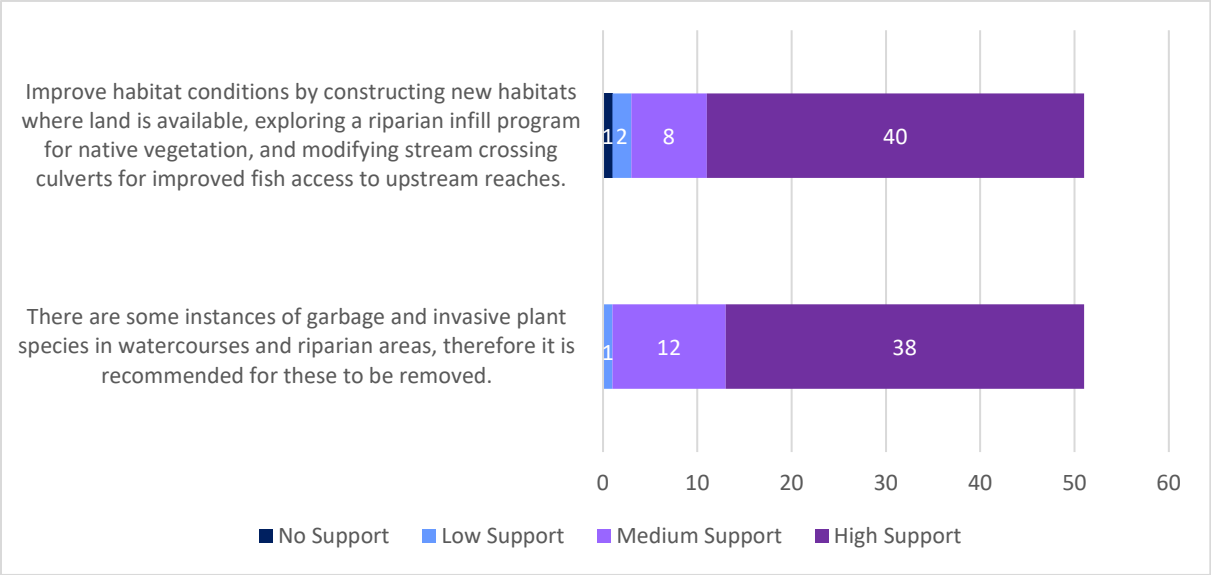


**Figure 14.8 - Environmental Opportunities**

***Land Use Management***

Of the Land Use Management actions, the more highly supported option recommends that the City establish tree canopy targets and landscape standards that suit both private and public spaces to offer hydrologic, environmental, and societal benefits. This aligns with the earlier survey question regarding the respondents' top issues most concerned within the Willband Creek watershed, where the lack of tree canopy was tied for the top concern.

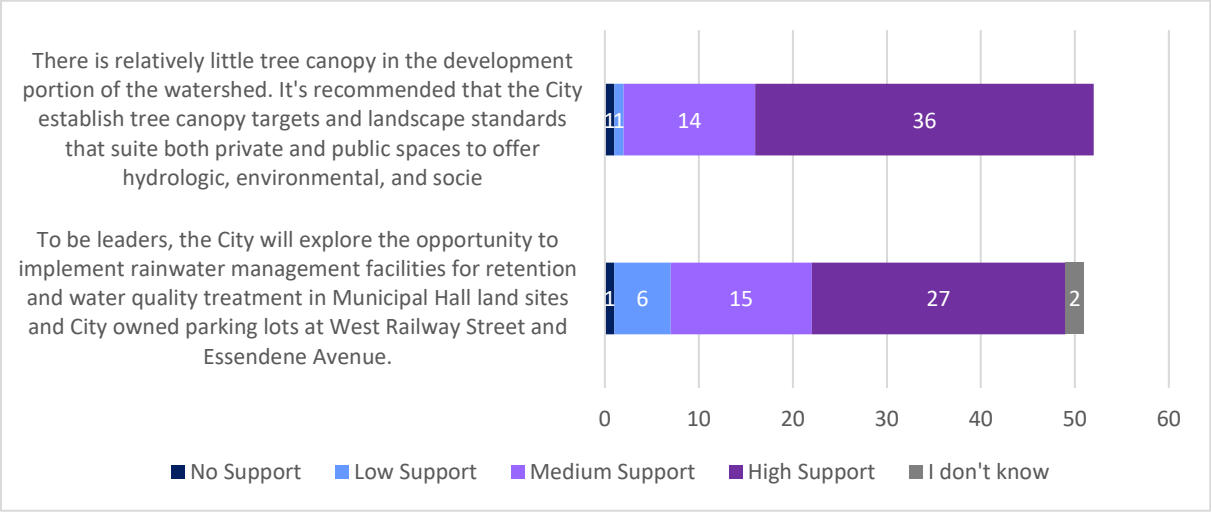


**Figure 14.9 - Land Use Management**

### 14.3.4 Final Thoughts / Suggestions

Respondents were presented with two additional open-ended questions. Themes from these responses are listed below.

**Are there any other actions that the City should consider in the Integrated Stormwater Management Plan (ISMP)? *(10 responses)***

- Maintain and update existing assets and infrastructure
- Utilizing natural and environmentally conscious solutions for the watershed, and for any new developments in the area
- Maintain more natural settings for the animal life in the area
- Provide more public education regarding the watershed and what the public can do to help

**Do you have any additional concerns or feedback about the Integrated Stormwater Management Plan (ISMP)? *(7 responses)***

- Concern about how agricultural runoff and increased industrial activity will affect the pollution levels in the watershed
- Need to protect and restore existing sloughs, creeks, and animal habitats
- With expansion in the Abbotsford area, the City needs to address the additional capacity required for absorbing rainfall and plan for future demand
- Need to upgrade and expand existing retention areas to accommodate higher volume

Based on the results described above, it is clear that the health of the Willband Creek watershed is important to the community and that preserving it is a priority. There is an understanding that development in the area has a negative impact on the watershed and needs to be properly addressed, especially with so much new development planning in the coming years. With the options presented in the survey, it seems that respondents are supportive of the City investing in monitoring and upgrading the infrastructure within the watershed to help with improving the health and quality of the Willband Creek watershed.

# PART 4 – IMPLEMENTATION AND ADAPTIVE MANAGEMENT

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# 15 IMPLEMENTATION AND ADAPTIVE MANAGEMENT

## 15.1 Practices, Bylaws, Standards.

The City currently has clear criteria in the Development Bylaw for flow control, but the Bylaw lacks specificity in the design and application of acceptable controls and how water quality objectives will be met. This can be achieved through broader application of the separate Stormwater Source Control Bylaw, and it has been recommended both herein and the City's recently completed Plan 200K Drainage Master Drainage Plan that this Source Control Bylaw be adopted City-wide.

According to the City's recent Plan 200K Drainage Master Plan (DMP), Development Services has had some developers submit drawings for infrastructure in accordance to the Stormwater Source Control Bylaw to meet zoning requirements but did not ultimately construct the measures once zoning was approved. As stated in the DMP "the Stormwater Source Control Bylaw is a compliance bylaw but is not enforceable after the zoning without the City going to court. An enforceable bylaw must be included in the City's "Consolidated Bylaw Notice Enforcement Bylaw, 2007 Bylaw No. 1703 – 2007. This makes the Stormwater Source Control Bylaw a regulatory bylaw allowing the Bylaw Department to enforce it."

The Development Bylaw, Schedule J - Specifications and Standards for the Installation of Landscaping provides for tree planting, growing medium and structural soils that could be suitable for green infrastructure. Section 7 – Highways of Schedule F, does not specify any allowance for vegetated swales or other forms of Green Infrastructure, but Table 7.3 does note a drainage corridor of 2.25 meters in width on either side of all road classes. However, Section 4 – Drainage Systems of Schedule F, subsection 8 (k) - Swales says: "Swales may be used on a rural highway for road drainage at the discretion of the Engineer." Then subsection 8 (n) provides geometric criteria for roadside swales but says that "Roadside drainage swales……shall be used where the road drainage is minimal and can be contained safety and practically in a swale rather than a ditch." Also, it requires the swale be "designed with the roadside edge of the swale at least 2 meters from the edge of pavement."

In general, the Stormwater Source Control Bylaw provides a solid base that the City can apply more broadly across the City, but is insufficiently adopted and enforceable through the Development Bylaw. In addition, the Development Bylaw does not provide for the application of green infrastructure within road corridors, which is a shortcoming in the City leading by example, as roadways represent a significant contributor to runoff detriments.

**Practices, Bylaws, and Standards Summary of Recommendations:**

**1** Review the Source Control Bylaw, modify as appropriate, and adopt as a City-wide document.

**2** Make the Source Control Bylaw enforceable through the Development Bylaw.

**3** Amend the Development Bylaw to provide clear criteria on the application of swales or other forms of Green Infrastructure within road right of ways. It is expected that developing this criterion will require collaboration between many City departments.

## 15.2 Integration with Other Plans

The City has recently completed a comprehensive update of its Master Plans through the Plan 200K initiative. That process resulted in several Master Plans that integrate to some degree with this Willband Creek ISMP. A synopsis of that integration is as follows:

### 15.2.1 Plan 200K Drainage Master Plan

The Drainage Master Plan (DMP) recognized that the Willband Creek ISMP was underway and therefore did not report significant information directly relevant to the Willband Creek watershed, however it did note the erosion issues within Horn Creek and Boa Brook, and flooding concerns around Mill Lake and in the lowlands to the north. The report also raised recommendations from past studies to address erosion in Horn Creek and Boa Brook, including site specific channel stabilization projects (several of which have since been complete by the City), and a potential stormwater bypass trunk sewer as mentioned herein Section 8 of this ISMP (not yet constructed).

As noted in Section 15.1 above, the DMP also made recommendation for the City-wide adaptation of the Stormwater Source Control Bylaw, and that the Building Permit process also adhere to it.

The capital program within the DMP did not account for any recommendations within the Willband Creek ISMP, therefore the information from this ISMP will need to be added.

Finally, the DMP also explored options for Stormwater Fees and Charges and recommended that a “feasibility study be conducted to explore and to investigate, analyze, and formulate an appropriate fee structure and ultimately develop a recommended implementation strategy for Council to decide how to proceed with the implementation phase.” This aligns well with needs for the Willbank Creek watershed.

In Figures 15.1 and 15.2, cash flow requirements are presented. Figure 15.1 is the cash flow for only the recommendations associated with the Willband Creek ISMP, but excluding the priority 3 storm sewer improvements, whereas Figure 15.2 is the cash flow combining the Willband Creek recommendations with the recently completed City-wide Master Drainage Plan.

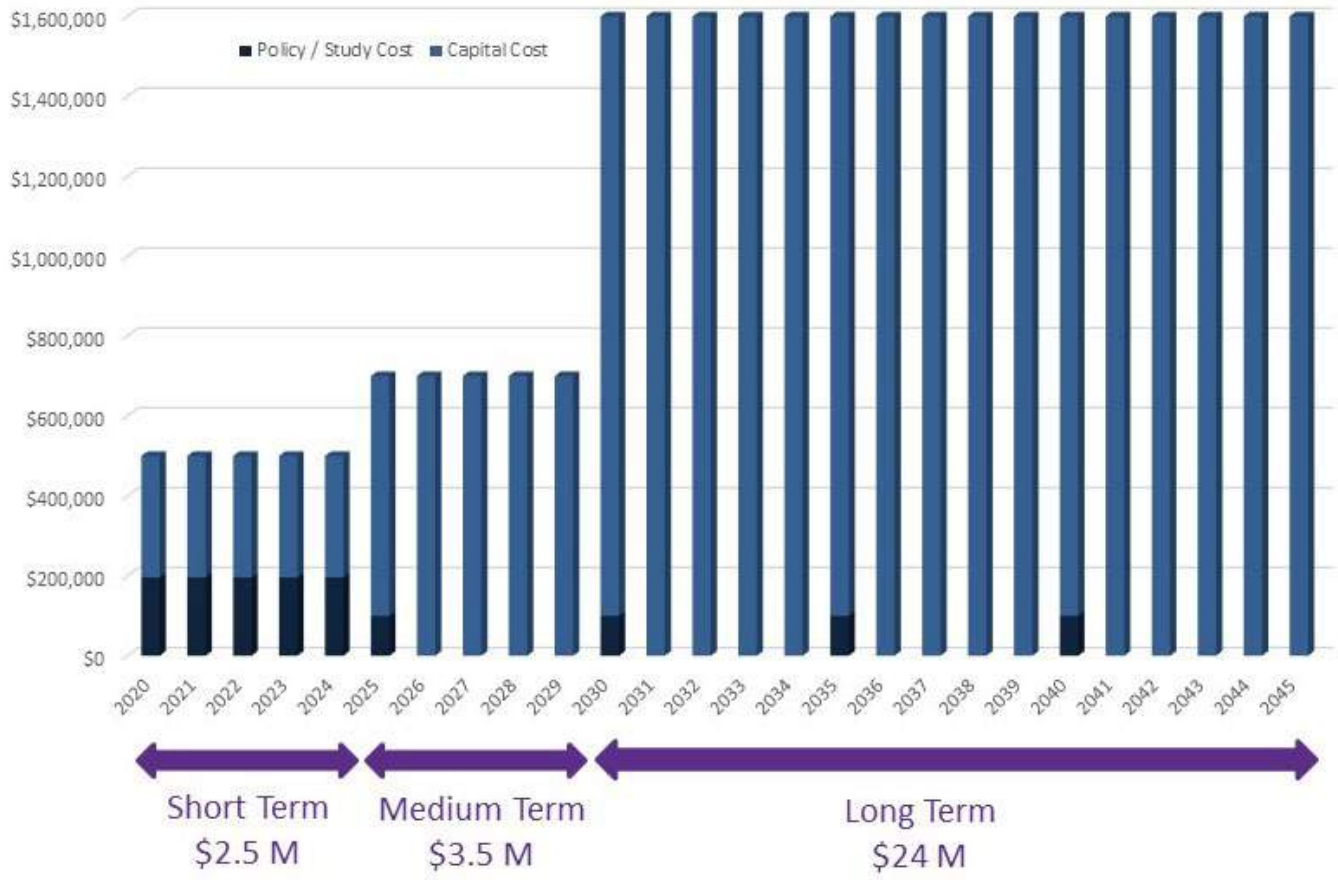



**Figure 15.1 - Finance and Timeline**

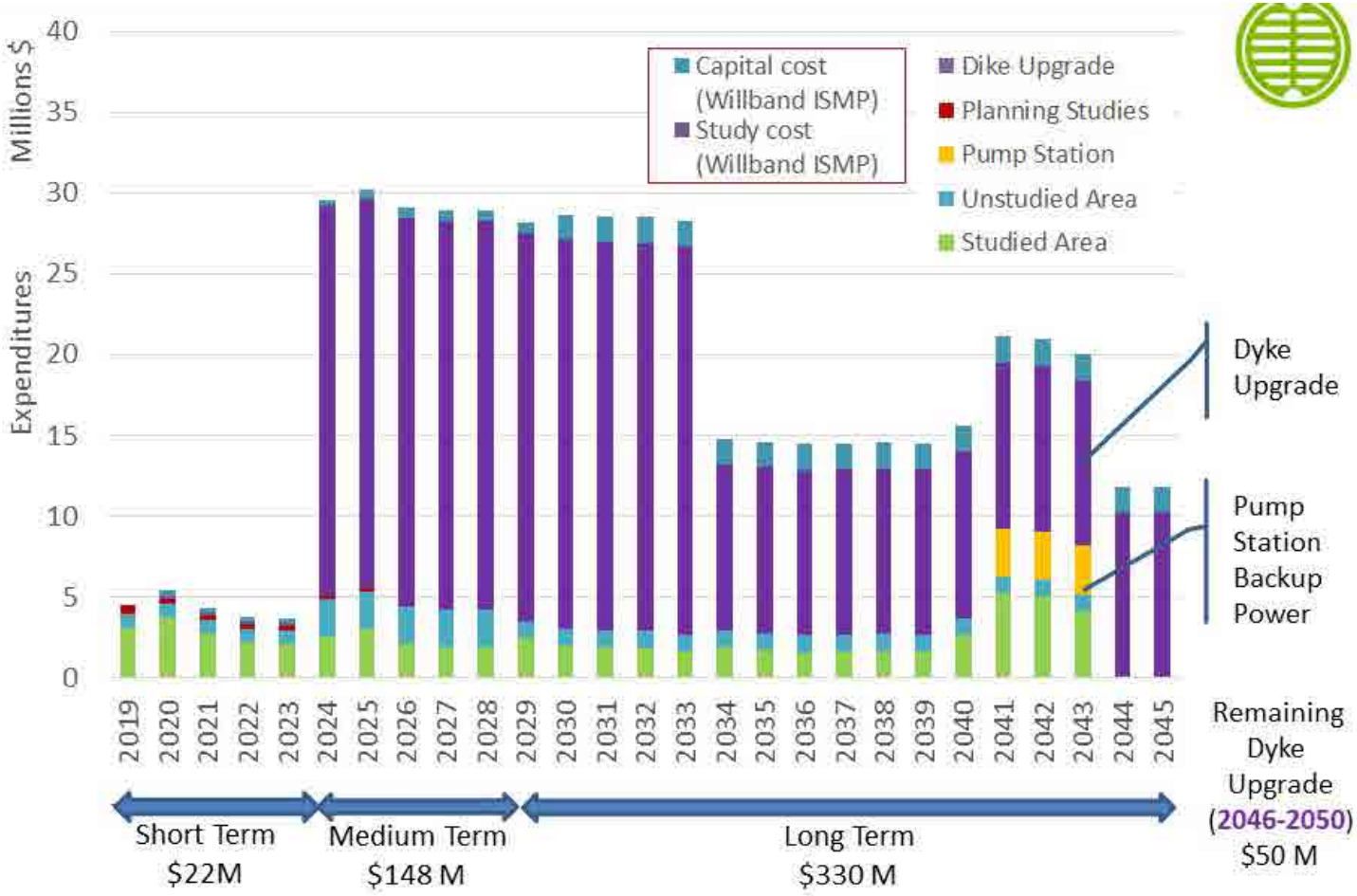



**Figure 15.2 - 2018 Drainage Master Plan and Willband Creek ISMP (2019 to 2045)**

### 15.2.2 Plan 200K Parks, Recreation and Culture Master Plan (PRCMP)

The PRCMP does not explicitly discuss stormwater management and drainage, however has significant references to tree canopy and natural assets that align well with the ISMP objectives.

Section 8.8.3 Issues and Opportunities of the PRCMP speak to "protecting natural areas", "managing natural areas", and "protecting the tree canopy". It also notes that the City does not have an Urban Forest Management strategy that could establish targets, strategies and policies for protecting existing trees and enhancing the urban forest.

Section 8.8.4 Long-Term Direction of the PRCMP makes recommendations around service delivery, policies, plans and studies, and land acquisitions. Specific recommendations that align well with the ISMP include:

- "Protect and maintain ecosystems, habitat corridors, and environmental values by embracing integrated stormwater management practices, and creating new greenways throughout the City."
- "Take efforts to increase the extent, health and diversity of the tree canopy to improve air quality, capture carbon dioxide, reduce heat island effects, support public health and quality of life, and support beauty."
- "Prepare an Urban Forest Management Strategy."

And finally, the PRCMP recognized the linkages to ISMP's stating that "It will be important to coordinate the ISMP's with the PRCMP so that any changes to the parks respects their values and opportunities to the community for recreation, leisure and nature appreciation". As discussed in Section 9 above, there are several opportunities to meet water management objectives with existing park land. Interdepartmental collaboration will be required to explore the practicality of meeting multiple objectives at these sites.

### 15.2.3 Plan200K Transportation Master Plan

There is relatively little alignment between the Transportation Master Plan (TMP) and this ISMP, but also no direct conflict. In general, the TMP is void of information relating to drainage or environmental protection. The only item of relevance in the TMP is support for street trees.

## 15.3 Operation and Maintenance

The City's mandate is to operate public infrastructure, but with current criteria there is increasing reliance on private controls. The long-term operation and maintenance (O&M) of both systems is important. Through a workshop discussion among City staff as part of the ISMP development, Operations staff expressed confidence that the current O&M of public infrastructure is sufficient and does not require adjustments. A key element of the program is active monitoring; particularly of ponds, outfalls and creeks. The City also has a routine CCTV inspection program with a 20-year cycle. This monitoring program allows the City to respond to issues in a timely manner. However, it is unclear if the City has priority ranking to its program. For instance, it is understood that the City does not currently know the condition of the trunk sewer through the Historic Downtown that takes the discharge from Mill Lake. This trunk sewer is perhaps the most critical piece of drainage infrastructure in the City upland system and should be very high priority. It is highly recommended that a condition assessment of this sewer be conducted near term. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis.

The City notes they inspect private controls on a 3 year cycle, however the City does not currently have any instrument to enforce maintenance of private stormwater management systems. The Stormwater Source Control Bylaw does have a section noting maintenance requirements, however as raised in the Plan 200K Drainage Master Plan, this bylaw currently applies to a select group of properties and is not enforceable through the Development or Building Bylaws. Adopting of this as a City-wide bylaw enforceable through the Development Permit and Building Permit would be a valuable first step. This City may wish to consider developing a more robust program for Green Infrastructure.

### 15.3.1 Green Infrastructure Operation and Maintenance

Green infrastructure (GI) refers to a set of stormwater management practices that collect, infiltrate, and reuse stormwater runoff as it is created when rain falls on the streets, roofs and other impervious areas found in built communities. Common examples of GI include:

- Bioretention, including bioswales, rain gardens, enhanced tree pits and green roofs and walls;
- Engineered wetlands and stormwater ponds;
- Permeable pavement; and,
- Downspout disconnection.

Learning from other jurisdictions, in particular the USA, there are various administrative tools for establishing legal responsibilities for the operation and maintenance of GI on private property. Such programs are rare in Canada. **The information below is introductory for consideration and will need to undergo a legal review to ensure any program adopted is appropriately tailored to municipal law locally.**

***Administrative Tools***

There are a range of administrative tools that can assist local governments in implementing GI operation and maintenance requirements. A local government can select and tailor these tools to meet requirements in a manner that fits within their existing program. Examples of administrative tools include the following:[4]

**Stormwater code/manual/plan**

A stormwater code/manual/plan can be used as the basis for setting inspection, operation and maintenance requirements. It can be used to define permitting and plan review processes, list required development project submittal elements, identify the party responsible for GI maintenance, define legal agreements, define the inspection process and establish enforcement measures.

With respect to incorporating private facilities into a local government stormwater maintenance program there are various option which include the following:

- Local government could inspect facilities and require that the property owner hire a qualified contractor to conduct necessary maintenance
- Local government could require facility owners to contract with a third-party inspector and provide an inspection certification letter to the local government, as well as proof that any required maintenance has been completed
- Local government could perform maintenance and charge the property owner
- Local government could assume maintenance responsibilities through a deed or easement.

[4] Herra Environmental Consultants, Inc. and Washington Stormwater Center, 2013. Guidance Document: Western Washington Low Impact Development (LID) Operation and Maintenance (O&M). Prepared for Washington State Department of Ecology Water Quality Program.

**Legal agreements (such as declarations of covenant and access easements between a property owner and the local government)**

Legal agreements between a private party, responsible for GI maintenance, and the local government can be recorded against a property title to help require and ensure long-term facility maintenance.

- Identify and characterize the stormwater features on site (i.e., attach as-built drawing of the lot with the location of the GI and the area served by them, design details, figures, and maintenance instructions)
- Require inspection and O&M activities and direct responsible party to local municipal code, manual, and/or project-specific O&M manual
- Identify the party responsible for retention, protection, and maintenance of GI facilities
- Describe how the responsibility for maintenance of GI facilities is transferred when property ownership changes
- Help give the local government legal access for inspection

**Project-specific GI maintenance requirements**

Local governments can require project specific maintenance with a requirement that O&M manuals be developed for each GI facility.

For GI on private property, a copy of each O&M manual must be retained onsite, or within reasonable access to the site, and must be transferred with the property to the new owner. If the GI facilities are distributed on individual lots, then each property owner should have an O&M manual. A log of maintenance activity, indicating actions taken, must be kept and made available for review upon request by the local government.

The project-specific maintenance requirements must be at least as stringent as those in the local maintenance standards. Because maintenance requirements and recommended procedures may evolve over time, consider allowing project proponents to include a reference to a document that can be updated periodically. The agreement can refer to the current version of the document. Some jurisdictions have online maintenance manuals that can be referenced in legal agreements, so that the most up-to-date maintenance information is available for property owners.

**Financial surety measures**

To ensure that GI facilities are protected and maintained after construction a local government can require a financial surety, such as a bond or an assignment of savings. If authorized by the jurisdiction's code, local governments can require that sureties are obtained by developers. This is particularly important if a jurisdiction assumes responsibility for private facility maintenance once construction has been completed. It is critical to ensure that adequate funds are available in the event of a non-compliant facility.

**Record keeping and tracking process**

An effective maintenance program requires the collection and tracking of GI facility maintenance information, beginning with the plan review process and continuing for the life of the facility. The following information should be included in a local government record keeping system for GI maintenance:

- Land parcel information
- As-builts or record drawings for individual lots and for public rights-of-way
- Legal agreements (e.g., covenants or easements)
- Location information (e.g., GPS data, digital maps)
- Project O&M manual
- Maintenance logs (typically included in a project O&M manual)
- Inspection forms (e.g., during construction, post-construction, ongoing annual)
- Enforcement documents

It is critical for local governments to develop effective interdepartmental recording and record management procedures to support ongoing inspections.

**Inspection programs**

Inspections are recommended for all GI facilities immediately post-construction. These inspections are critical to check that the facilities are installed per plan and functioning properly. Ongoing annual inspections are also recommended to ensure long-term functionality of GI facilities

Local governments could consider allowing third party inspection for GI in settings that are difficult for a local government inspector to access or if property owners do not want local government inspectors on their properties. The property owner would be required to provide the local government with inspection documentation from an approved third-party inspector, or inspections and maintenance could be arranged through a homeowner's association. This would reduce the potential liability concerns and reduce staffing needs while still allowing the jurisdiction to meet their annual inspection requirements. Local governments could consider mitigating the cost to the private property owner by crediting the inspection fee on their utility bill.

Inspectors should be trained on the function of GI facilities and proper procedures for inspection during and after construction. Inspection checklists for GI facilities are a good tool to support consistent inspection practices and can be used for record keeping. The project specific O&M document and record drawings should be reviewed before and during the inspection.

## 15.4 Green Infrastructure Maintenance Agreements For Private Property

In the case that local governments rely on property owners or homeowners' associations to maintain GI facilities that are on private property, maintenance agreements should be established. Before installing GI, a local government or developer should establish clear ownership of the facility and designate operation and maintenance responsibilities clearly through a written agreement[5].

The agreements tend to have language that specifies details on the following[6]:

- Party that is responsible for maintenance (private property owner or GI implementation program entity);
- Expected maintenance frequency;
- Whether or not the GI implementation agency will perform inspections of the GI project to ensure that maintenance is being performed and at what frequency the agency will inspect;
- Details on how the GI implementation agency will access the project for maintenance and/or inspections;
- Consequences if maintenance is not performed;
- Process for recording the maintenance agreement (deed record filing or easement); and,
- Permission(s) (i.e., photographing the project, etc.).

For development projects, these aspects can be incorporated into the permitting process.

[5] Environmental Protection Agency, 2012. Maintenance of Low Impact Development: Communities Are Easily Managing LID Practices. December 2012.

[6] Feehan, C., 2013. A Survey of Green Infrastructure Maintenance Programs in the United States. 2013 Hixon Fellowship Final Report. Yale School of Forestry and Environmental Studies.

## 15.5 Green Infrastructure Maintenance

In general, GI practices have lower long-term life cycle costs, perform better and provide additional benefits such as improved aesthetics and enhanced property values. However, no matter how well they are designed and constructed, GI will not function correctly or look attractive unless properly maintained. Maintenance activities and schedules depend on the type of facility and environmental context in which they are located. Maintenance activities could include the following[7]:

- Debris and litter removal
- Sediment removal and disposal
- Stability and erosion control
- Maintenance of mechanical components
- Vegetation maintenance
- Maintenance of the aquatic environment
- Insect control (i.e. mosquitos)
- Maintenance of other project features (i.e. fences, access roads, trails, lighting, signage, platforms)

## 15.6 Adaptive Management

Adaptive management is a process of monitoring, reviewing, learning, and adjusting.

### 15.6.1 Monitoring

Environmental health and flow monitoring are two important components of an Adaptive Management process, but the program needs to be expanded. Monitoring is broken into several categories, including physical (eg. are the desired flows and quality of water being achieved?), regulatory (eg. are the City's regulatory tools successfully guiding development?), and process (eg. are City staff properly informed and are inter-departmental processes in place to successfully direct the plan's implementation).

***Physical Monitoring***

Through this ISMP process, baseline water quality and health scores were stablished for Horn Creek, Boa Brook and Prairie Street Creek (refer to section 4). The Monitoring and Adaptive Management Framework developed by Metro Vancouver[8] provides a resource in developing an expanded program. As noted in that document, it is recommended that physical monitoring occur on a 5 year cycle. In the case of Horn Creek, the City has installed a semi permanent flow monitoring station and provided it provides reliable data, it is recommended the City keep this station functional long term, as it serves as a representative baseline to which future catchment changes can be measured against over time.

It is recommended that the City implement some short term (at least one winter season) monitoring within the storm sewer system and existing detention ponds as highlighted in **Figure 15.1** in order to

[7] North Carolina Environmental Quality, 2017. Stormwater Design Manual – Part A-7. Operation and Maintenance.https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Stormwater/BMP%20Manual/A-7%20%20Operation%20and%20Maintenance.pdf – Accessed December 7th, 2018.

[8]http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/Monitoring_Adaptive_Management_Framework_for_Stormwater.pdf

validate performance. The monitoring of existing ponds will be used to confirm whether or not these ponds are performing at their optimum level, and if not, what changes should be made. The monitoring locations for the storm sewers are identified where the theoretical SWMM model indicates storm sewer capacity is inadequate for a 1:10 year flow. The chance of capturing a significant storm event (>1:2 year) within a single winter season is relatively low, but this data will allow model calibration to more confidently predict performance under a design event, in turn providing greater confidence to capital plan priorities.

It is recommended that the City implement a semi-permanent water level (not flow) gauge on Willband Creek on the upstream side of Highway 11.

It is recommended that the City require short term monitoring (one winter season) of all future stormwater source controls, private and public, to validate that their performance in accordance with design criteria.

It is recommended that the City retain a qualified geotechnical professional to inspect Horn Creek, Boa Brook and Prairie Street Creek each year for soil instabilities and risk assessment.

Finally, is recommended that water quality and benthic sampling be repeated on a 5 year cycle at the same locations as presented in Section 4.

### *Regulatory Monitoring*

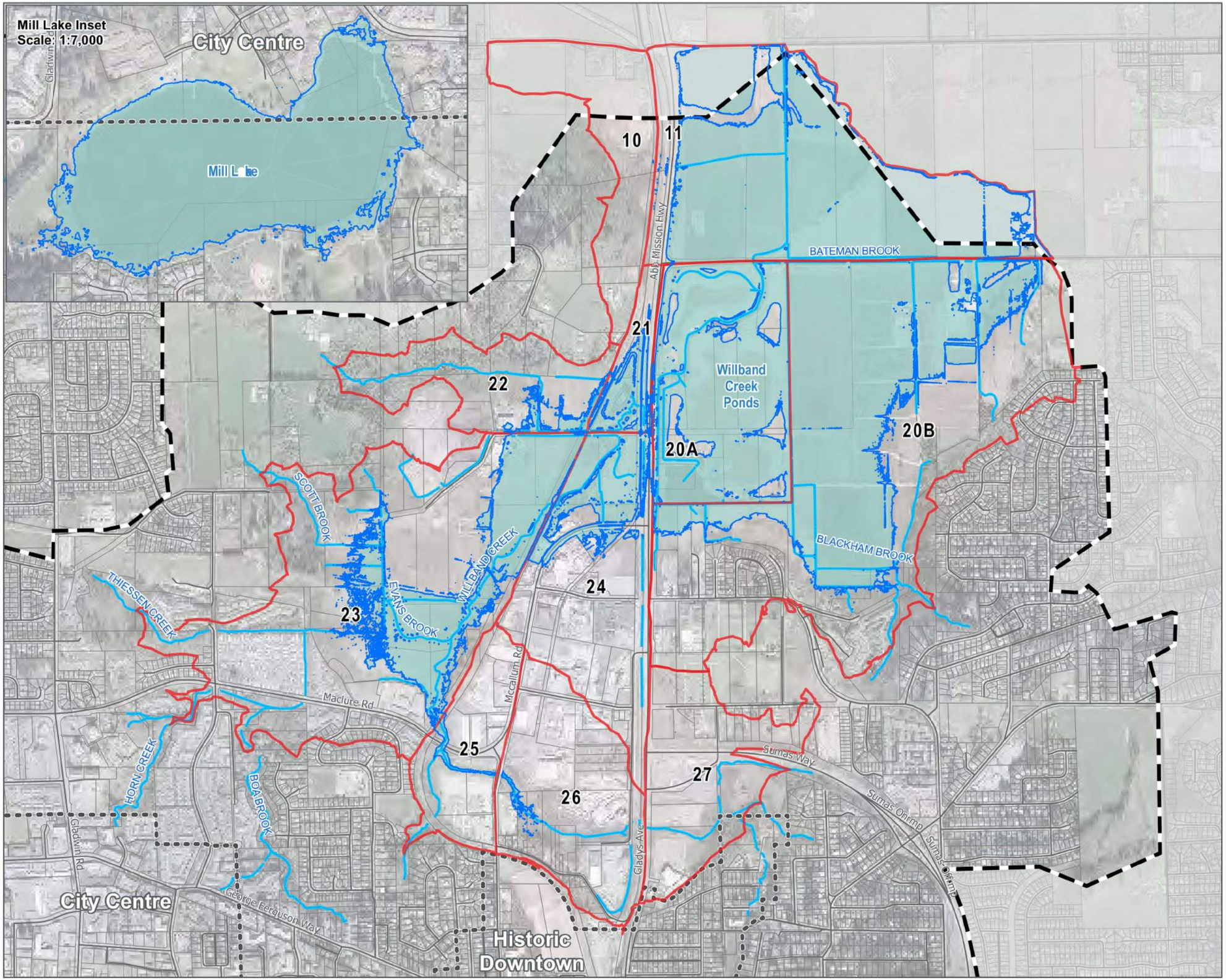
The most significant regulatory aspect to track is that source controls are being implemented in accordance with bylaws and criteria. The City's Drainage Master Plan states that because the Stormwater Source Control is not enforceable beyond Zoning, there have been instances where controls are not ultimately implemented through Development or Building. It is recommended that the City set up appropriate record systems to track that source controls are in fact being implemented through both the Development and Building Permit processes, and in accordance with the bylaws. As an extension, also track that inspection and maintenance reporting is being done.

It is anticipated that an Urban Forestry Management Strategy would include some form of regulation to guide development and private property owners. It is therefore recommended that if and when such regulation is created that tracking be implemented.

And finally, it is recommended that inspection and monitoring occur at occupancy permit that a development / building has not exceeded the permissible site coverage as permitted by the zoning bylaw, and that directly connected impervious surface does not exceed those permitted by design criteria.

### *Process Monitoring*

The most significant aspects of process monitoring are to ensure that City inspectors are knowledgeable of design criteria and standards of the Development Bylaw and Stormwater Source Control Bylaw. An equally important process to monitor is that implementation of controls is not "slipping through the cracks" during the Development or Building Permit process. It's recommended that a "checklist" field be created in the application registry to track whether or not controls are successfully implemented.

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Willband Creek
Integrated Storm Water
Management Plan

## Flood Extents (200 Year)

**Legend**

- Maximum Future Flood Extent (200 Year)
- Existing Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Creek

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.

0 200
Metres

**Coordinate System:**
NAD 1983 UTM Zone 10N

**Scale:** 1:13,500
(When plotted at 11"x17")

**Data Sources:**

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

| | |
|---|---|
| Project #: | 1790.0015.01 |
| Author: | LP |
| Checked: | GS |
| Status: | FINAL |
| Revision: | A |
| Date: | 2018 / 12 / 17 |

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**FIGURE 13.1**

Last updated by lpunt on December 17, 2018 at 10:20 AM
Last exported by lpunt on December 17, 2018 10:20 AM
Last printed by lpunt on September 25, 2017 11:46 AM
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 13-1 - Flood Extents (200 Year) (11x17)

### 15.6.2 Assessment

It is recommended that an audit of all above monitoring be undertaken on a 5-year cycle. Physical monitoring data would be processed for evaluation by hydrologists and environmental professionals and evaluated against all preceding data. Its recommended that the City implement a central database to record and track data for each monitoring period. The fundamental goal is to see if the hydrologic response to rainfall of the built lands is reducing, and that the water quality and watershed health is improving. This should be tracked in relationship to the changes that have occurred in the contributing catchment. As such, the number and location of development permits, building permits, and capital projects would be inventoried, and the details of their implemented source controls evaluated. The audit would first assess whether or not implementation has been successful, and then secondly assess whether or not the changes have resulted in a positive, neutral, or negative outcome to system performance, water quality, stream stability and health. It is expected that significant catchment changes will be required to result in an obvious positive outcome on the receiving watercourses. Given the anticipated influence of climate change, the assessment will need to consider the severity of precipitation that falls between audits. As such, its valuable that the City maintain permanent rain gauges and that rainfall frequency analysis be undertaken with each audit. The evaluation will be more meaningful if environmental factors can be separated from anthropogenic factors.

### 15.6.3 Key Performance Indicators

Cost effective, measurable, and reliable key performance indicators allow the City to determine whether or not the watershed vision is being achieved. Performance indicators need to be selected for things that can be observed and measured frequently. In the context of Willband Creek, recommended key performance indicators are:

- Reduced sediment deposits at the base of Horn Creek, Boa Brook, and Prairie Street Creek
- Stability of creek bed and banks in Horn Creek, Boa Brood, and Prairie Street Creek
- Fewer annual service complaints due to flooding
- Increase in tree canopy as measured from aerial photos
- A positive differential between the number of trees planted to the number of trees removed
- No reduction in the riparian vegetation as measured from aerial photos
- Successful implementation of source controls with all development and building permits that require them
- Improved water quality as measured in Horn Creek
- Improved benthic health as measured in Horn Creek
- Successful implementation of the Capital Program.

### 15.6.4 Responses

The monitoring program is important to assess the specific failure mechanism, should failure occur. Was there a poor design(s)? Has there been a significant change in weather patterns? Was there a breakdown in approval process that prevented bylaws from being enforced? Was there an infrastructure failure due to insufficient maintenance? There can be many reasons why objectives may not be met. The response(s) need to align with the cause. It is therefore premature to articulate a specific response plan at this time, but some fundamental responses may be as follows:

**1** If watercourse erosion and environmental health do not stabilize, or preferably improve, the City may need to accelerate the implementation of communal management infrastructure through its

capital program; either with high flow diversions or stormwater detention ponds. As determined herein this ISMP, there are relatively few opportunities for effective ponds on lands where no buildings currently exist, therefore land acquisition and building demolition may be required.

**2** If development or building permits are being completed without successful source controls, the City needs to evaluate whether this was a procedural failure, or if it needs to strengthen the enforcement and penalties of the bylaws, making amendments to them accordingly.

**3** If service calls occur due to structural or maintenance failure, the City needs to strengthen its Asset Management Program.

**4** If maintenance of private source controls is not validated, the City should consider implementing a formal Stormwater Source Control Operating Permit program.

**5** If there is increased flooding in the upland urban area not caused by structural or maintenance failure, the City may consider accelerating its pipe replacement program on a priority basis, or explore alternative mitigative measures.

**6** If the funding for infrastructure change cannot keep up with demand (ie. worsening conditions) the City needs to revisit its funding stream and look to a program that provides more reliable funding.

**7** If the City is not leading by example in implementing and maintaining source controls in public spaces, the City needs to evaluate its interdepartmental collaboration and priorities.

**Adaptive Management Summary of Recommendations:**

**1** Continue to monitor flows in Horn Creek.

**2** Implement a water level monitoring system in Willband Creek immediately upstream of Highway 11.

**3** Educate City Staff in Building and Development departments of new requirements and create a “checklist” field in the application registry to track whether or not controls are successfully implemented.

**4** Audit all monitoring data on a 5-year cycle.

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# APPENDIX A

Issues Identification - City of Abbotsford

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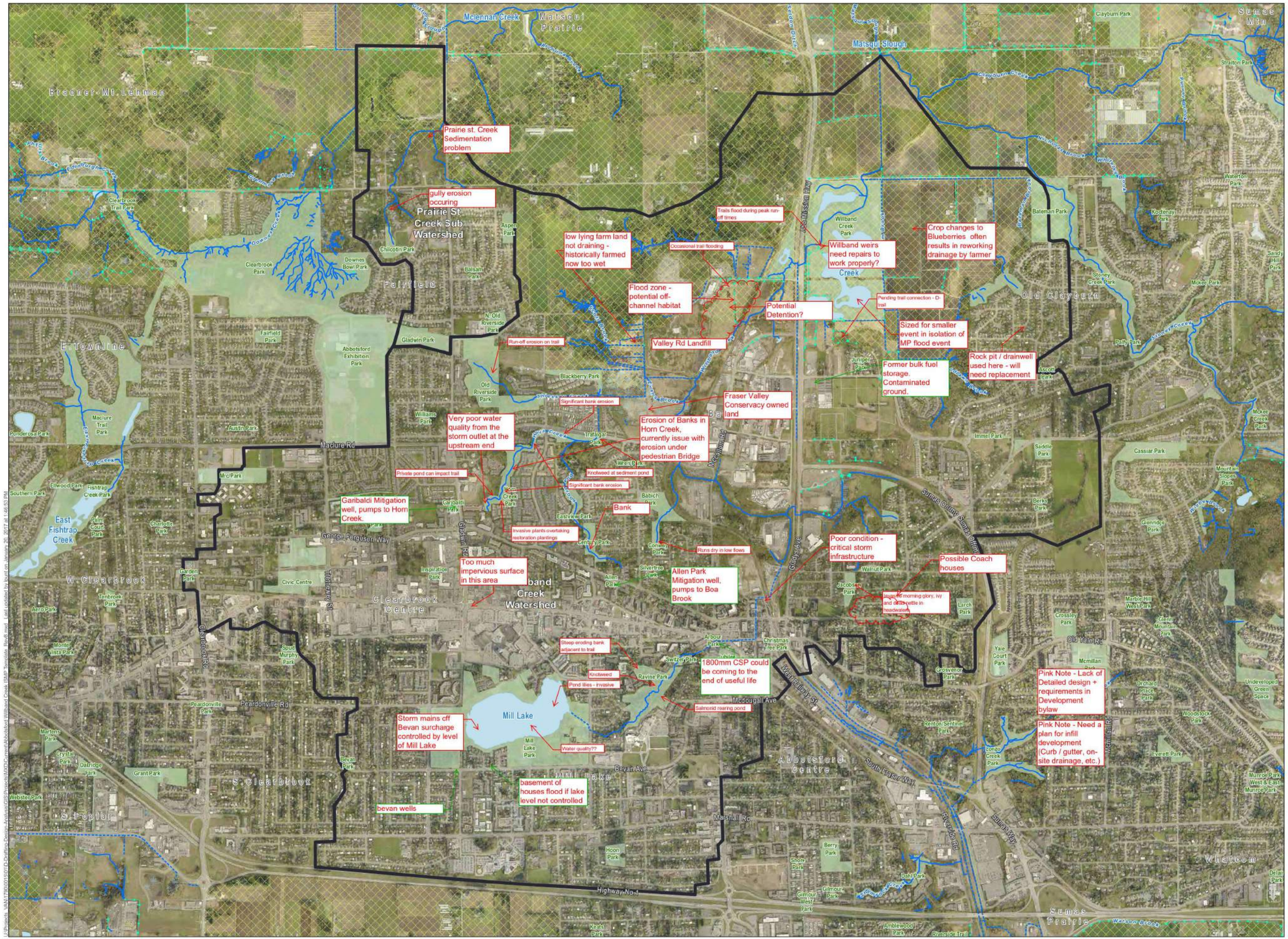


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Willband Creek
Integrated Storm Water
Management Plan

**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
Metres

**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 |

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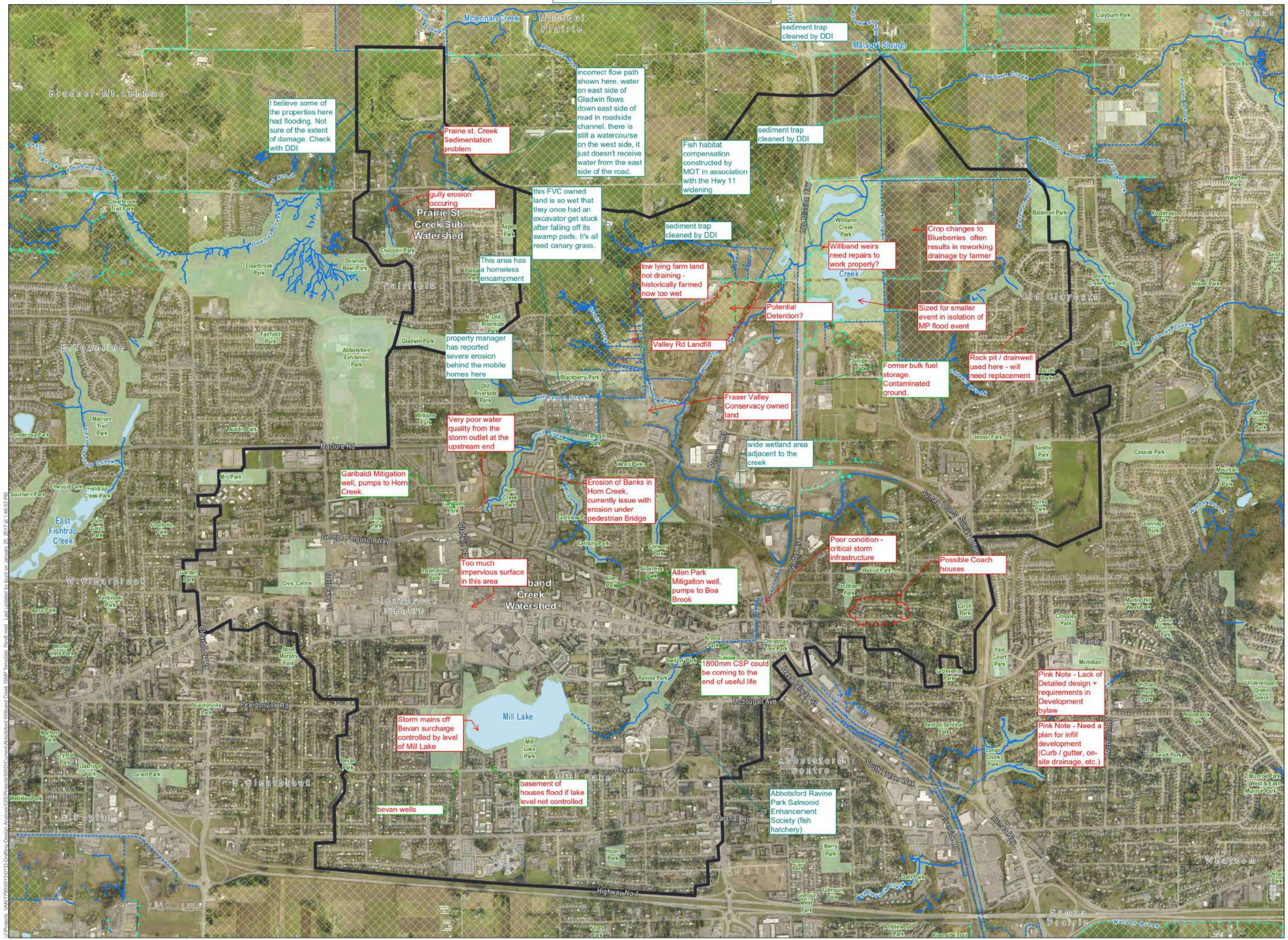
the map was created using the stream data available on our x drive, but this is missing some of the SHIM data that's been collected in the last few years. I believe this was sent to the consultant though.(?)

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Willband Creek
Integrated Storm Water
Management Plan

**Study Area**

Legend
- Willband Creek Watershed
- Lake
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0 50 100 200 300 400 500
Metres

**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 |

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# 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: Vegetation Category 1 | Setback: Vegetation Category 2 | Setback: Vegetation Category 3 | Description | Methodology |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 |

| Public Symbology | Internal Symbology | Color Code | Class | Sub-class | Coding | Setback: Vegetation Category 1 | Setback: Vegetation Category 2 | Setback: 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

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A City of Abbotsford Watercourse Classification System
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# 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.*

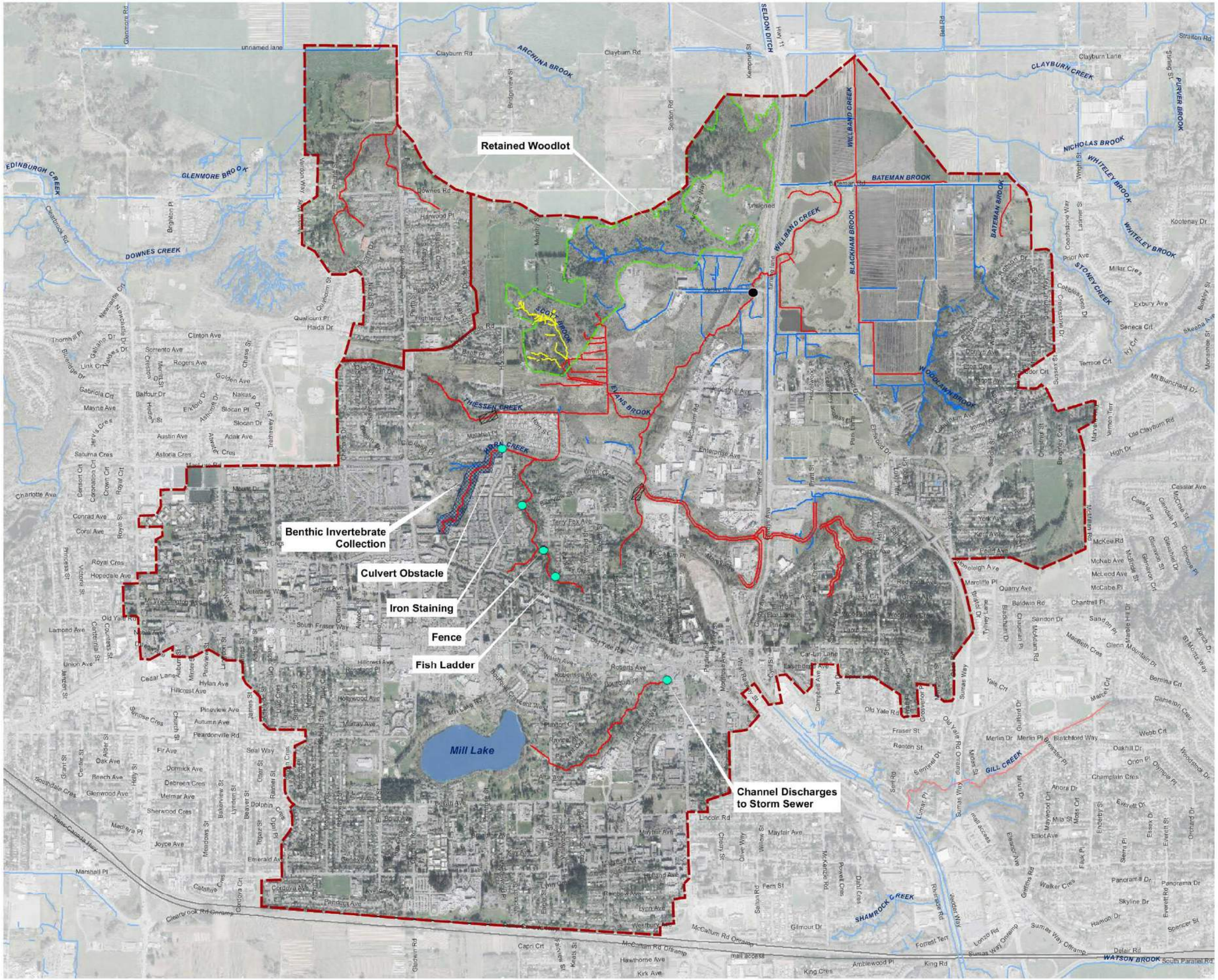
# 1.0 Introduction

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

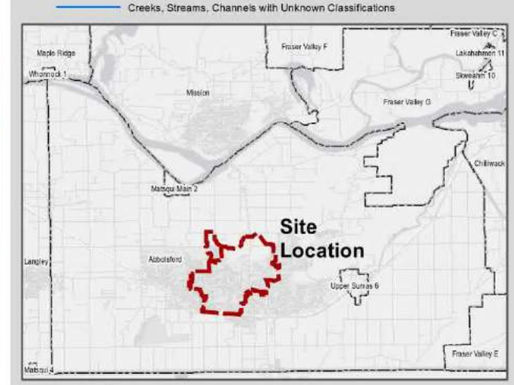
**City of Abbotsford**
Willband Creek ISMP

## 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

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.

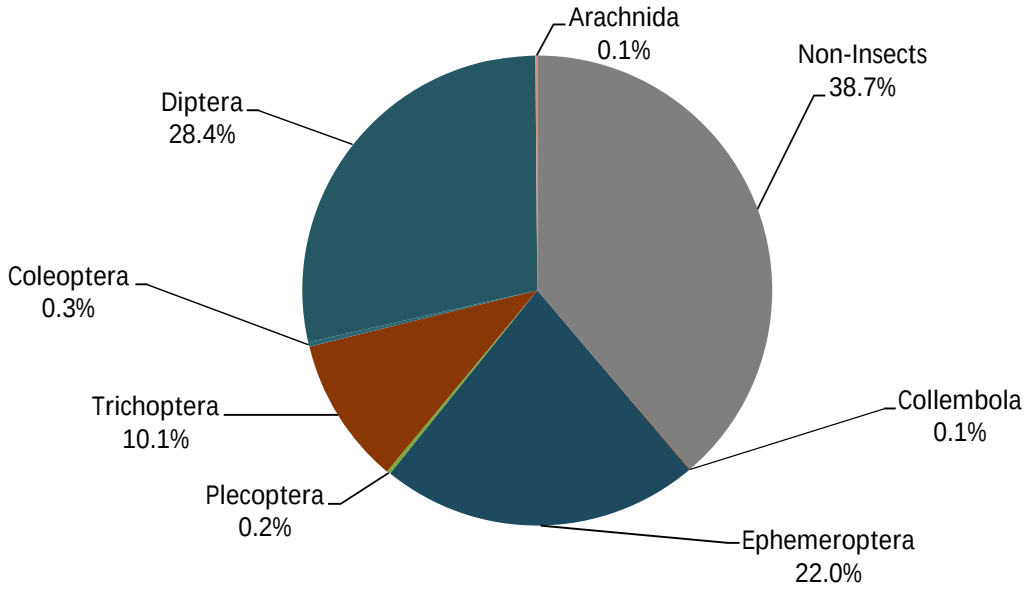
The %EPT (Richness) ranged from 14% to 28% throughout the creek. This is a measure of the percentage of pollution intolerant taxa that were present at each sample location.

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.

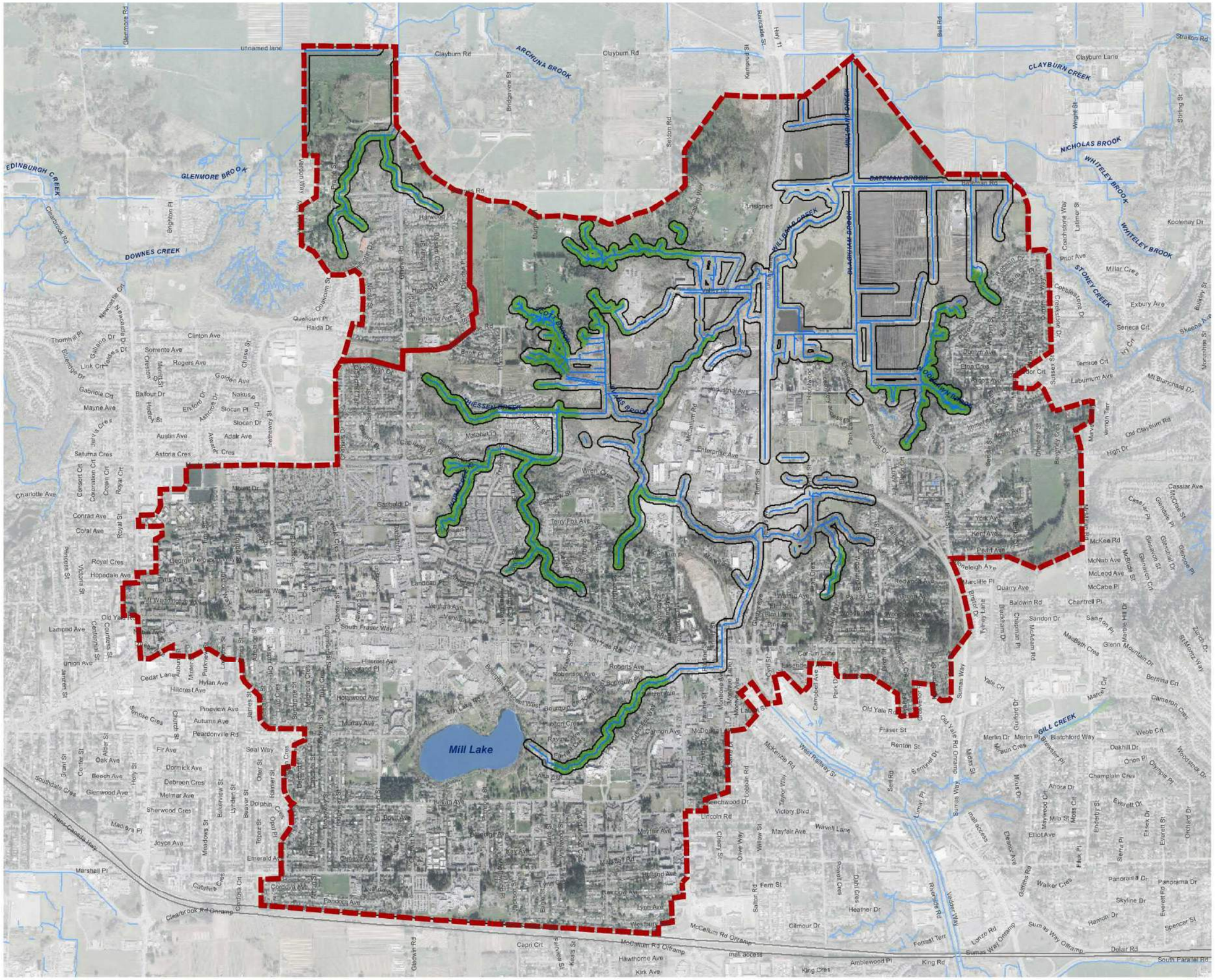
The Prairie Creek sub-watershed tends more toward the upper right of the graph. This is expected given the lower level of development and the large intact riparian areas around the creek. It is anticipated that erosive flow and water quality impacts would be considerably lower than for the Willband Creek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




ABBOTSFORD

**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

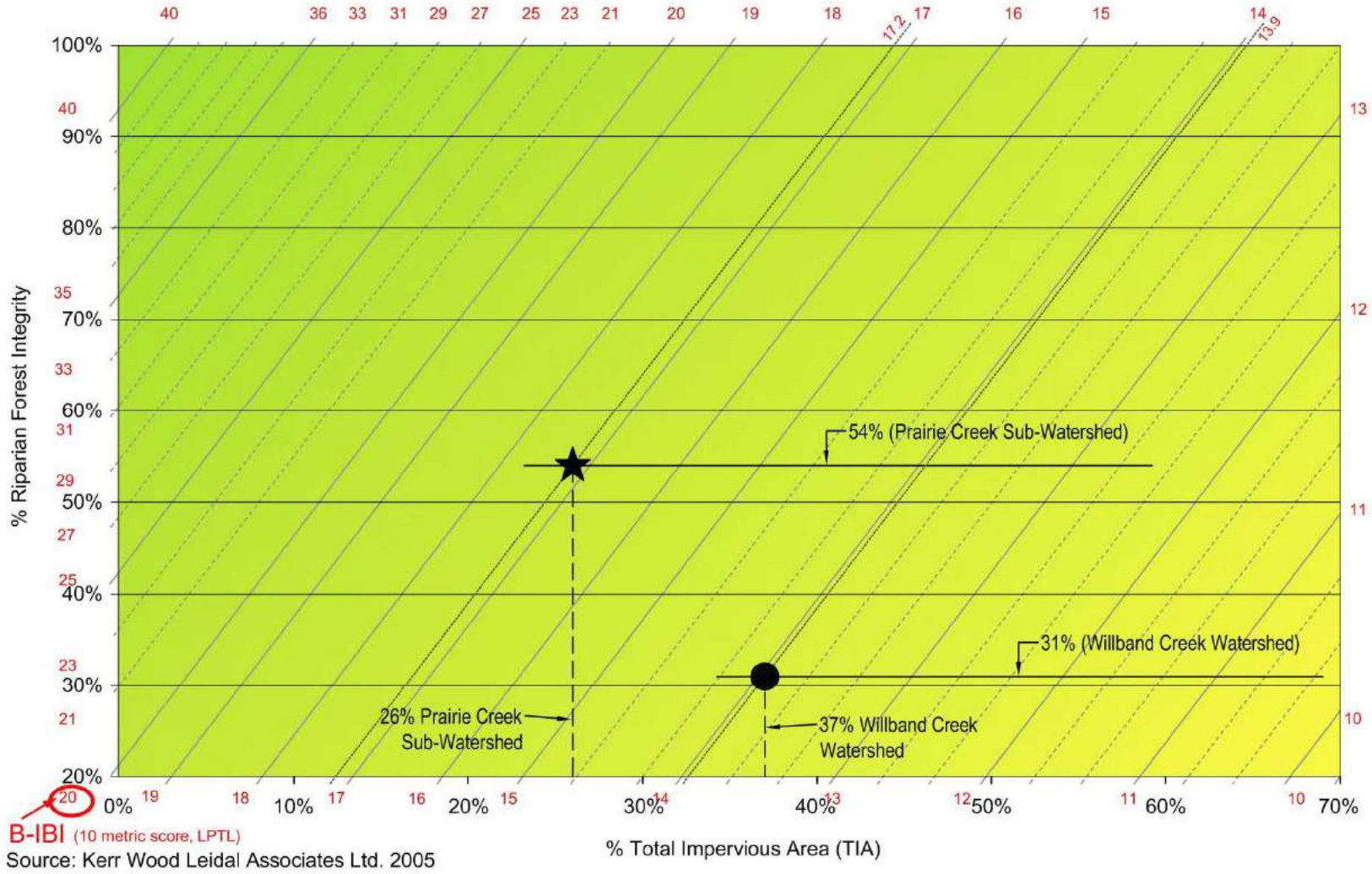
MAP CREATED BY: MZO
MAP CHECKED BY: NRG
MAP PROJECTION: NAD 1983 UTM Zone 10N

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

ABBOTSFORD

● WILLBAND CREEK WATERSHED
★ PRAIRIE CREEK SUB-WATERSHED

DILLON CONSULTING

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.

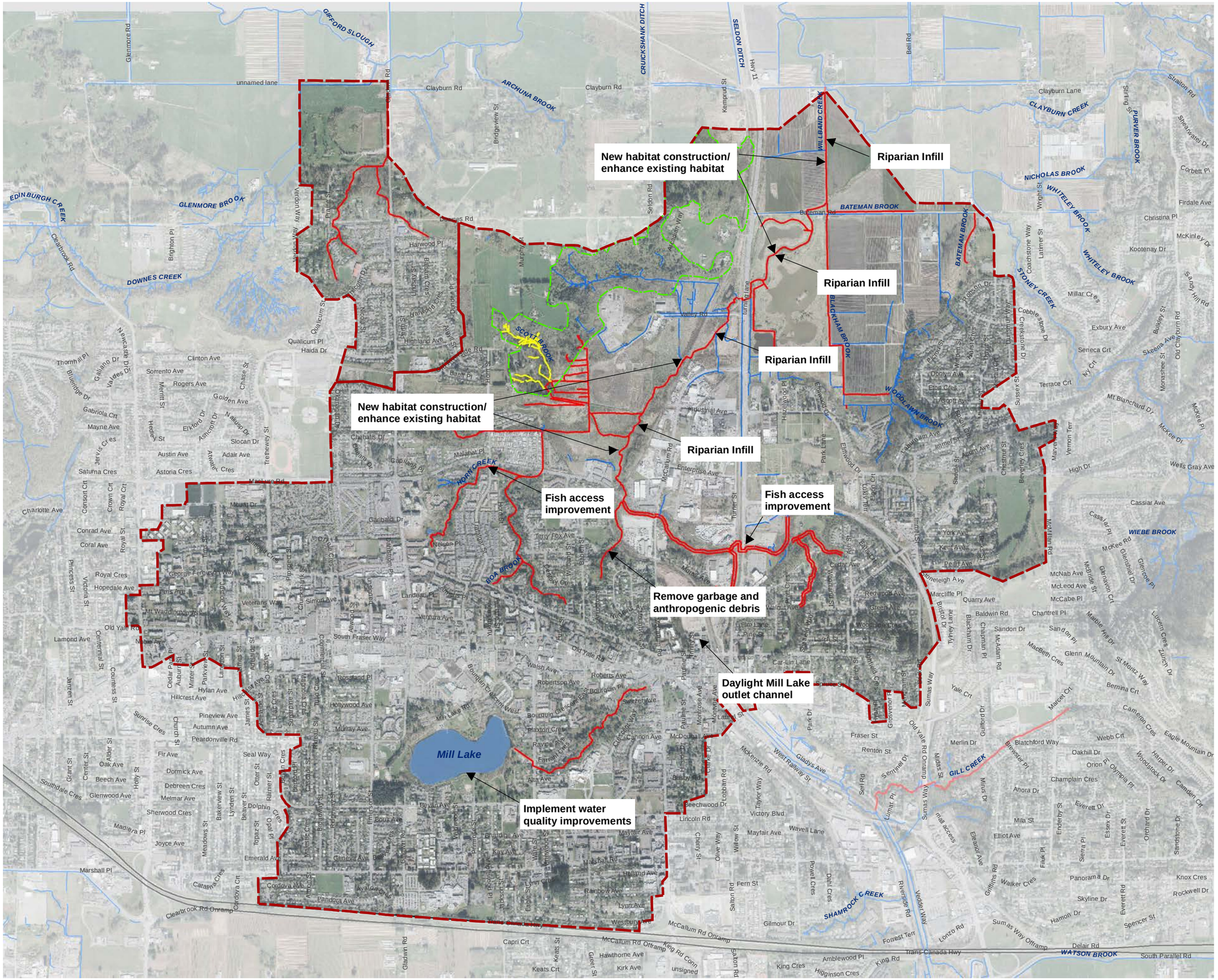
### 4.1.7 Integration of Habitat Features into Stormwater Controls

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.




# City of Abbotsford

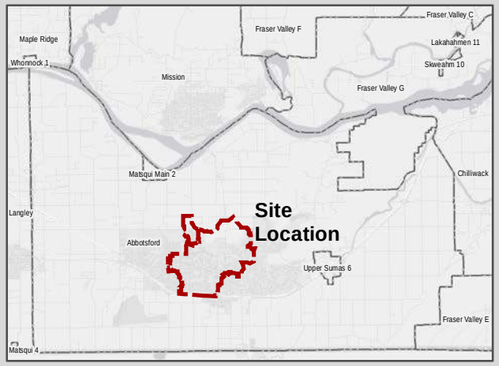
Willband Creek ISMP

## 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

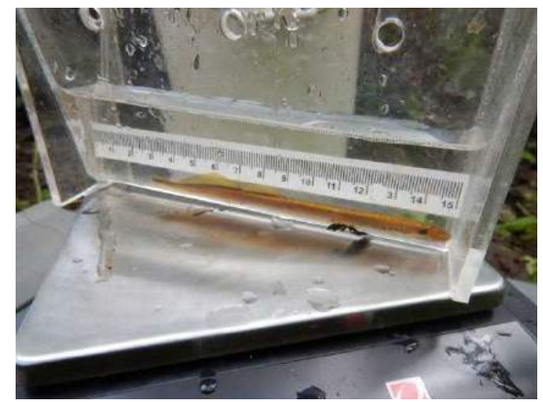
## Site Photographs

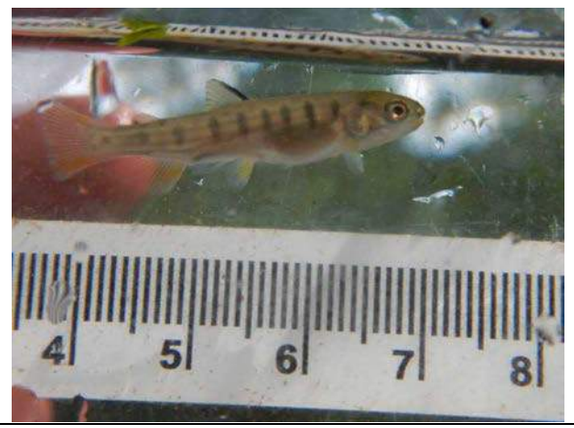
| | | |
|---|---|---|
| | | |
| **Photo 1:** Lower Willband Creek, typical conditions (May 26, 2016) | **Photo 2:** Lower Willband Creek, typical conditions (May 26, 2016) | **Photo 3:** Willband Western Tributary, typical conditions (May 26,2016) |
| | | |
| **Photo 4:** Lower reach of Willband West 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

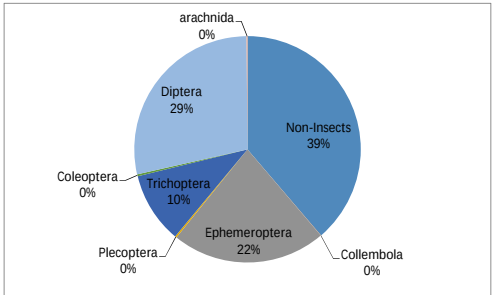
## Benthic Invertebrate Composition

Thibault Doix, Certified Taxonomi
Living Streams Environmental Ser
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 | Life History Traits: Predator | Clinger | Tolerant | Intolerant | Long lived |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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. TREPAXONEMATA | 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 | | | | | |




| | | | | | |
|---|---|---|---|---|---|
| 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 |

| | | | | |
|---|---|---|---|---|
| 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 | Ephemeroptera | 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

Maxxam
A Bureau Veritas Group Company

Success Through Science®

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 Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

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Success Through Science®

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.



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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

## 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 | | | | |


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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 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



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

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

## 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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Report Date: 2016/09/08

# QUALITY ASSURANCE REPORT

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 |
| 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 |



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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 |



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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 |
| 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).



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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

## 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.



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B673794_COC

Page of

Bottle Order #: 504164

Chain of Custody Record: C#504164-01-01

Project Manager: Samantha Fregien

| 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 | Address | | Project # | 16-3437 |
| | Richmond BC V7B 0A2 | | | 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 ( < 10°C ) 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 | Lab Use Only: 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 JUST SAMPLED ICE - PRESENT | N/A [ ] Yes [ ] No |

* 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.

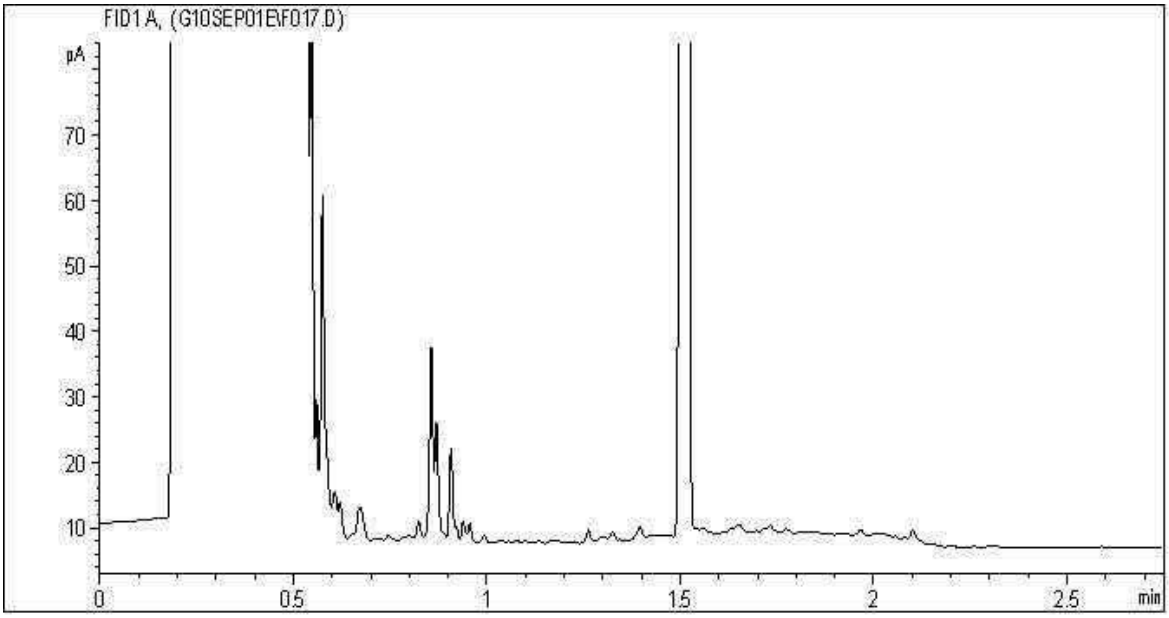
White: Maxxam Yellow: Client

Maxxam Analytics International Corporation o/a Maxxam Analytics

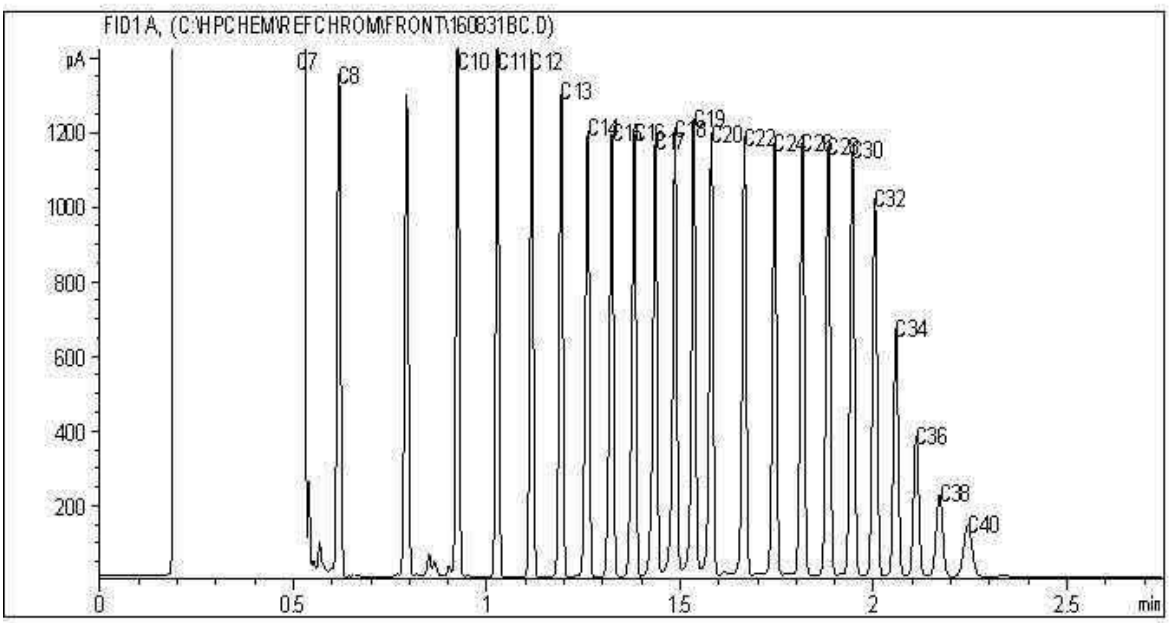
Maxxam Job #: B673794
Report Date: 2016/09/08
Maxxam Sample: PJ7719

DILLON CONSULTING LTD.
Client Project #: 16-3437
Site Reference: WILLBAND ISMP
Client ID: WILLBAND ISMP

**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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| 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

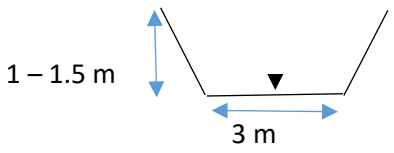
**Description:**

- 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

Photo 323

Photo 324

Photo 325

Photo 326

Photo 327

| 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

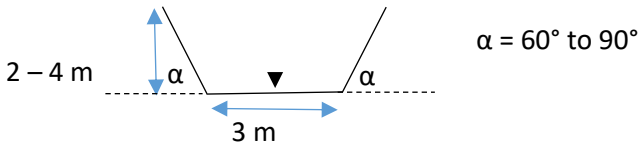
**Description:**

- 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.

| | |
|---|---|
| **Risk:** | **Low** |
| **Consequence:**<br>- Continued erosion could cause the tree to topple.<br>- Possibility for tree to topple onto the nearby houses. | |
| **Likelihood:**<br>- Erosion of the till appears to advance slowly, as is evident by the observed moss growing on some areas. | |
| **Remedial Options:**<br>- Monitor progression of erosion.<br>- Cut back banks and vegetate.<br>- Reduce channel gradient with steps and pools.<br>- 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:**<br>- Trees falling on trail potentially causing injury to public. | |
| **Likelihood:**<br>- Dense soils will result in slow progression. | |
| **Remedial Options:**<br>- Move trail and cut back crest of slope.<br>- Vegetate<br>- 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

| 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 |

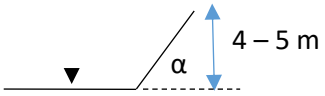
**Type:** Existing Slough-Slide

**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<br>340 | North East-North<br>Right Bank | Right bank erosion panorama<br>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

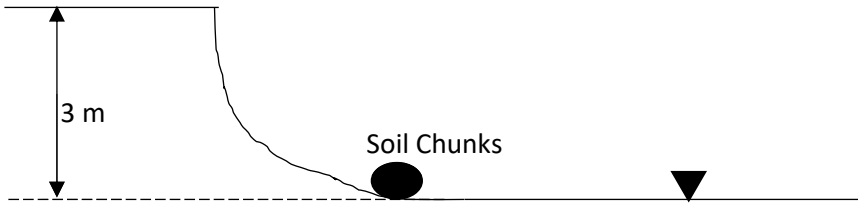
**Description:**

- 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

| 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

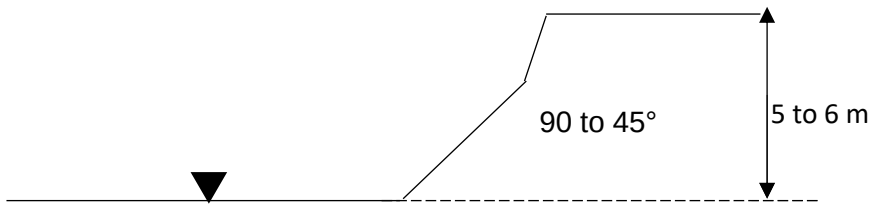
**Description:**

- 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 | |

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

**Photographs:**

Photos 349-353

Photo 353

| 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

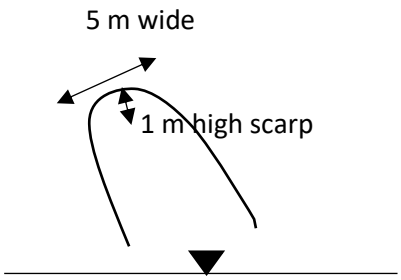
**Description:**

- 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

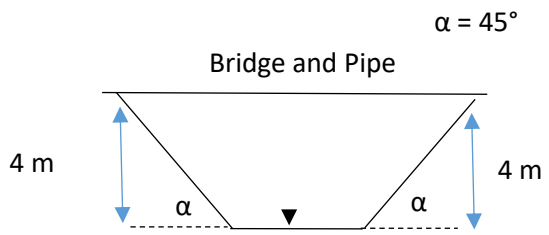
**Description:**

- 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

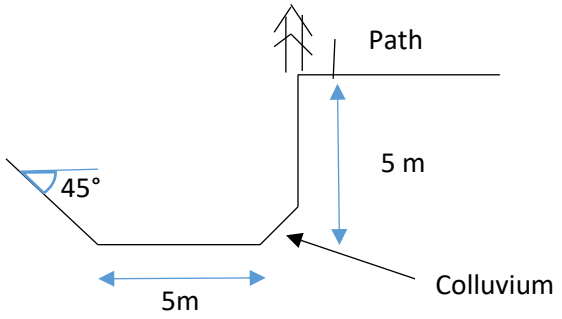
**Description:**

- 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.

| | |
|---|---|
| **Risk:** | **High** |
| **Consequence:**<br>- Retrogressing slope will undermine the path and houses above.<br>- Erosion will cause sedimentation in creek | |
| **Likelihood:**<br>- The slope could retrogress quickly if the trees fall. | |
| **Remedial Options:**<br>- Review the tree health by an arborist.<br>- Build up the base of the slope and cut back the slope crest to reduce overall slope angle.<br>- 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

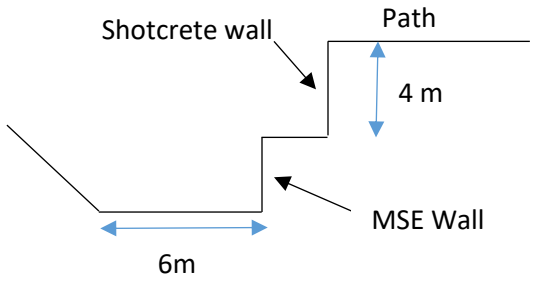
**Description:**

- 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:**<br>- Erosion of the slope may undermine the path.<br>- Erosion will cause sedimentation in creek | |
| **Likelihood:**<br>- Erosion appears to advance at a slow rate. | |
| **Remedial Options:**<br>- Monitor the eroded area.<br>- Apply additional shotcrete if erosion continues<br>- 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

| 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

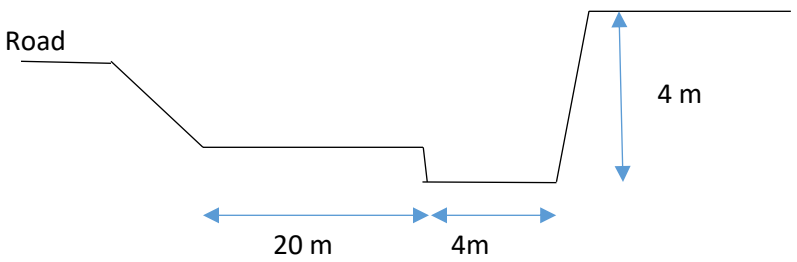
**Description:**

- 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:**<br>- No nearby houses or infrastructure.<br>- Erosion will cause sedimentation in creek | |
| **Likelihood:**<br>- Erosion appears to be ongoing. | |
| **Remedial Options:**<br>- Place erosion protection at the toe of the slope to reduce toe erosion.<br>- 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

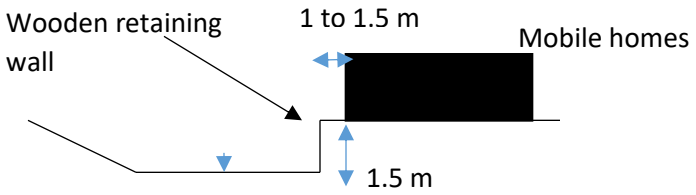
**Description:**

- 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:**<br>- Degrading retaining walls could potentially impact the mobile homes and creek. | |
| **Likelihood:**<br>- Slow rotting of wood, could increase during higher flows. | |
| **Remedial Options:**<br>- Remove or rebuild retaining walls.<br>- Recommend property and home owners retain geotechnical engineer to assess foundations for mobile homes and condition of retaining wall.<br>- 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

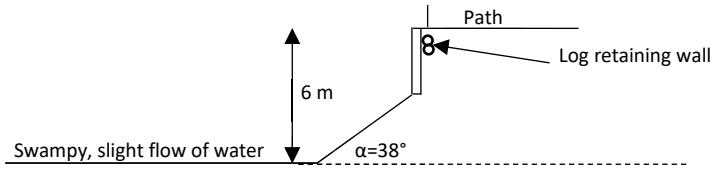
**Description:**

- 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:**<br>- Environmental damage to creek and habitat if retaining wall fails. | |
| **Likelihood:**<br>- Erosion appears contained to small sloughs on surface. | |
| **Remedial Options:**<br>- Cut back slope crest and vegetate if possible to move path.<br>- 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

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.**

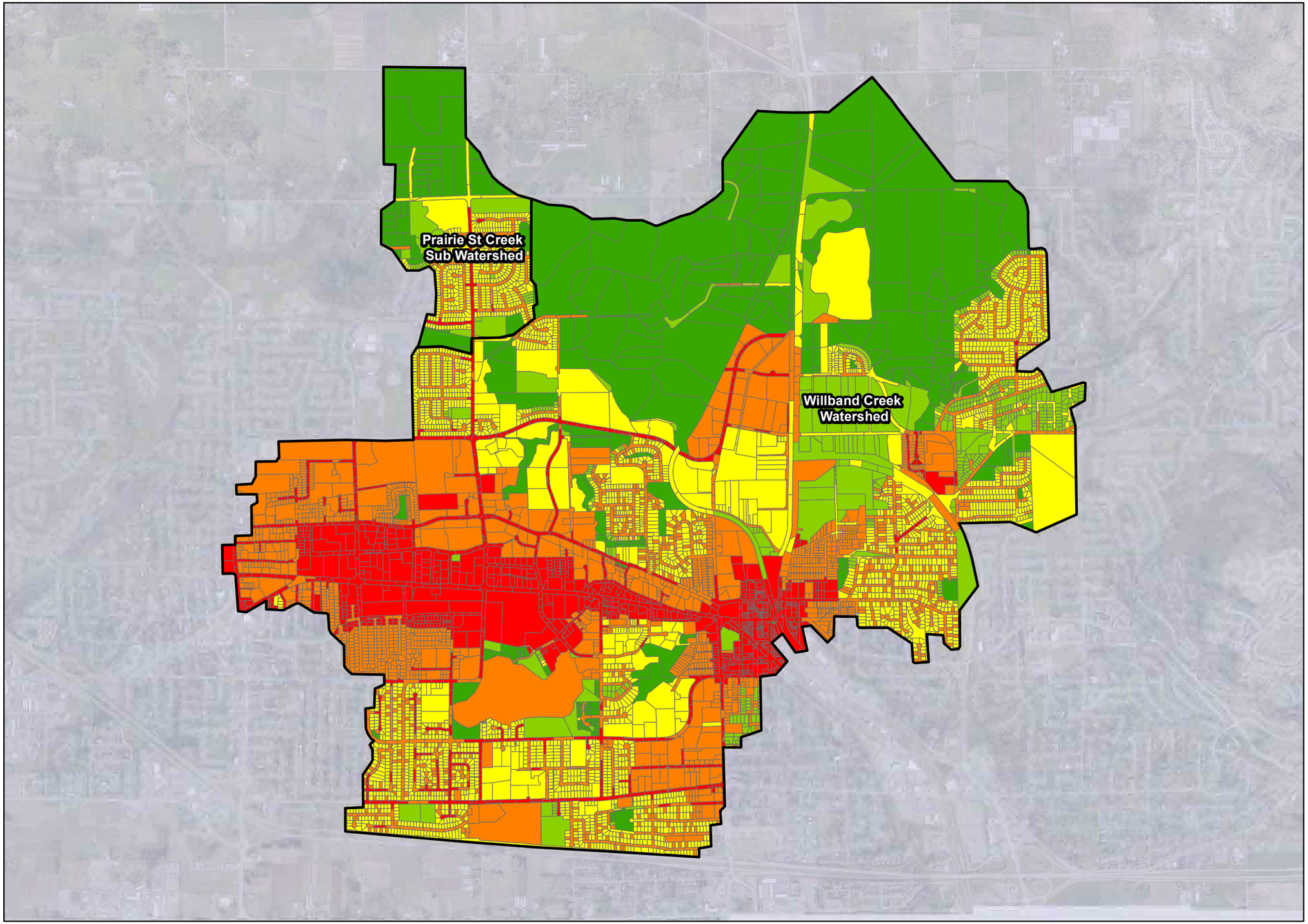
Unit 203, 2502 St Johns Street
Port Moody, British Columbia
V3H 2B4 Canada
Tel (604) 931-0550

**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.

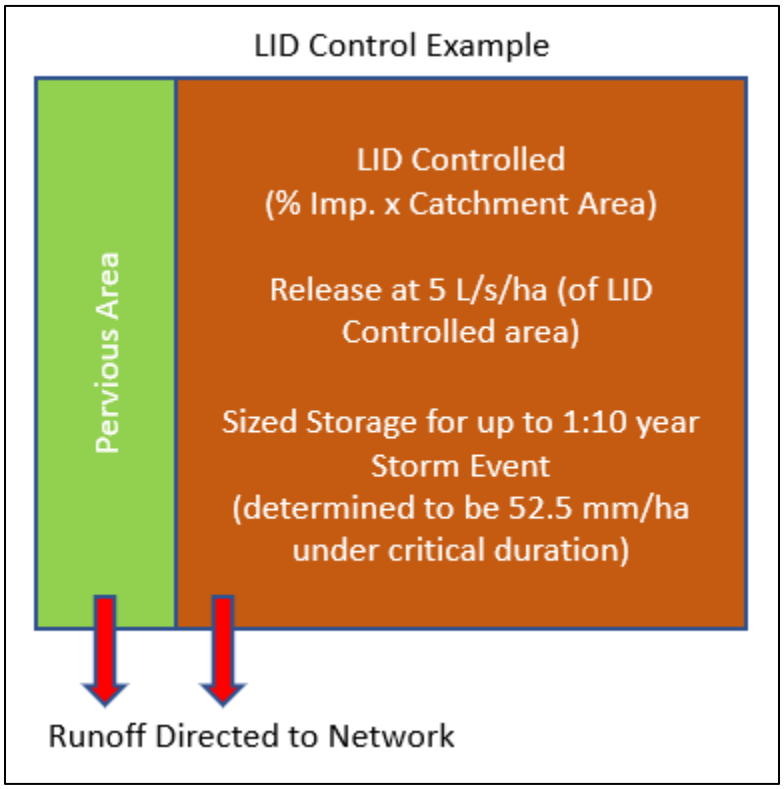
**Table 2.2: Willband Creek Future Condition Hydrology Parameters**

| 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**

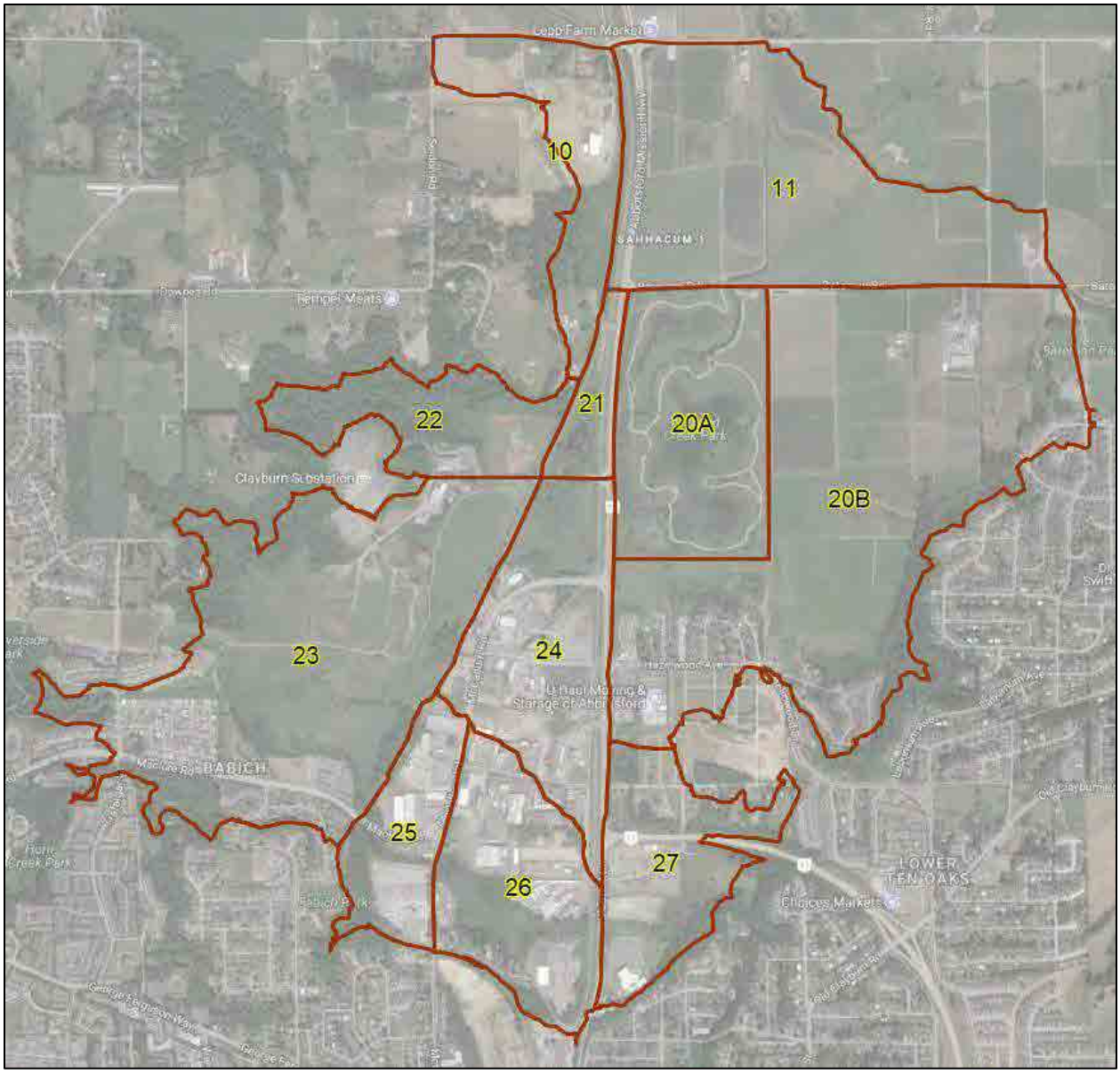


**Figure 2.4: Willband Creek Flood Cell Storage Rating Curves**

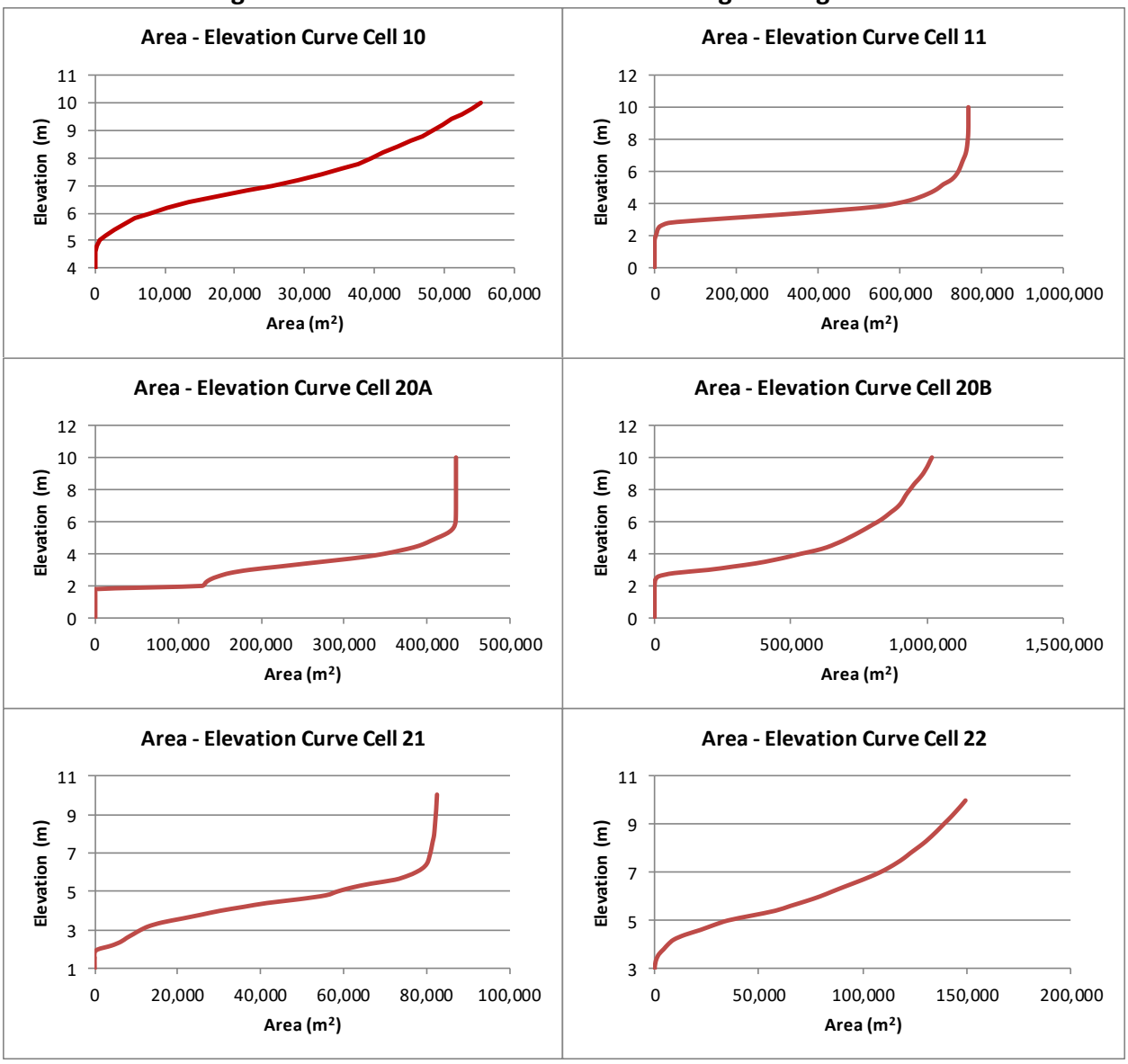
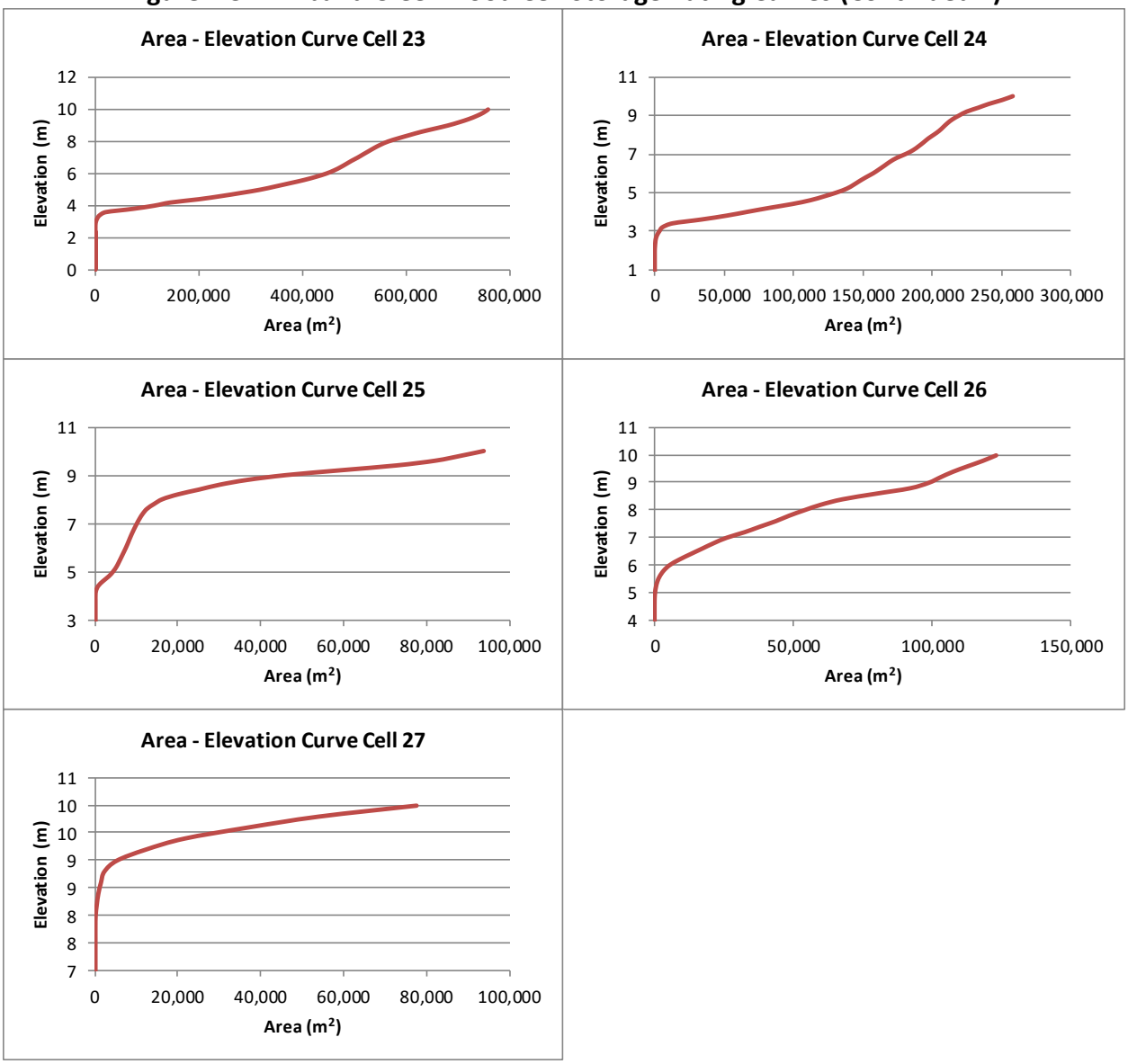


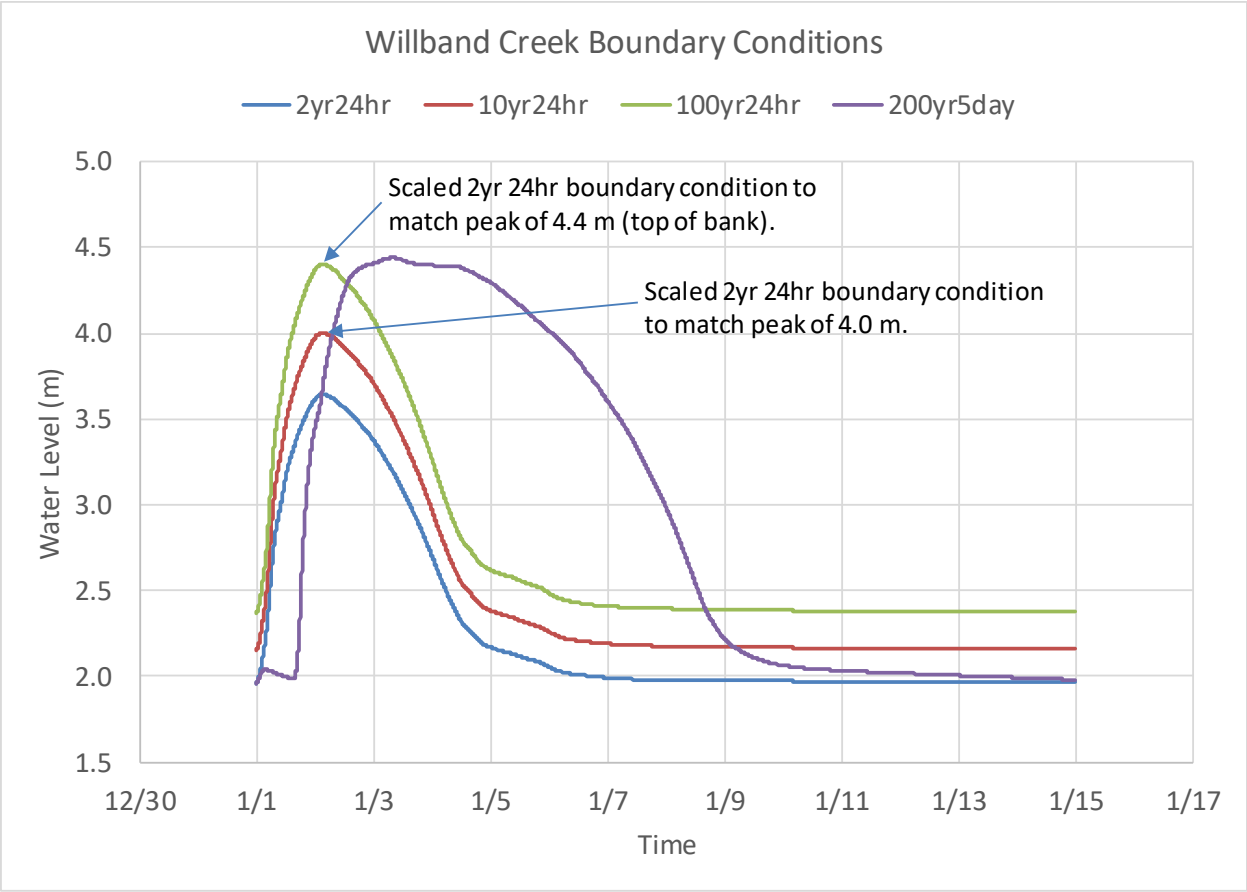
**Figure 2.5: Willband Creek Flood Cell Storage Rating Curves (Continued…)**



## 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**

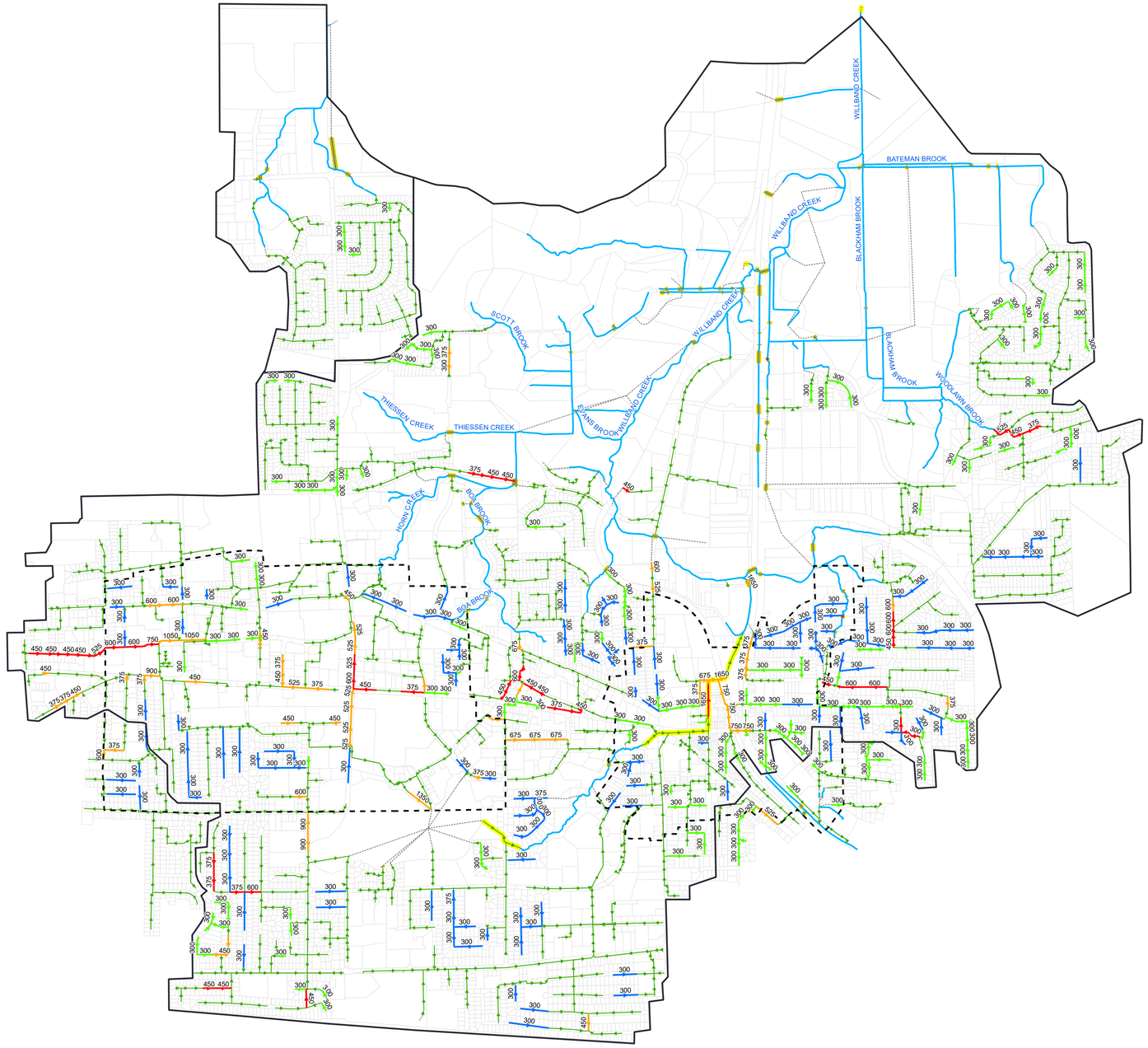
| Upgrade Category | 10-Year Design Upgrade Length (m) | 100-Year Design Upgrade Length (m) |
|---|---|---|
| **Upgrade Priority 1** | 695 | 0 |
| **Upgrade Priority 2** | 2,433 | 0 |
| **Upgrade Priority 3** | 966 | 0 |
| **New Main** | 4,481 | 0 |
| **Total** | **8,575** | **0** |

**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**.




GeoAdvice Engineering Inc.

## 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

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.

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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.
Water Resources Engineer

**Reviewed and Approved by:**

July 6, 2018

Werner de Schaetzen, Ph.D., P.Eng.
Senior Modeling Review

Chuck Linders
Stormwater Expert

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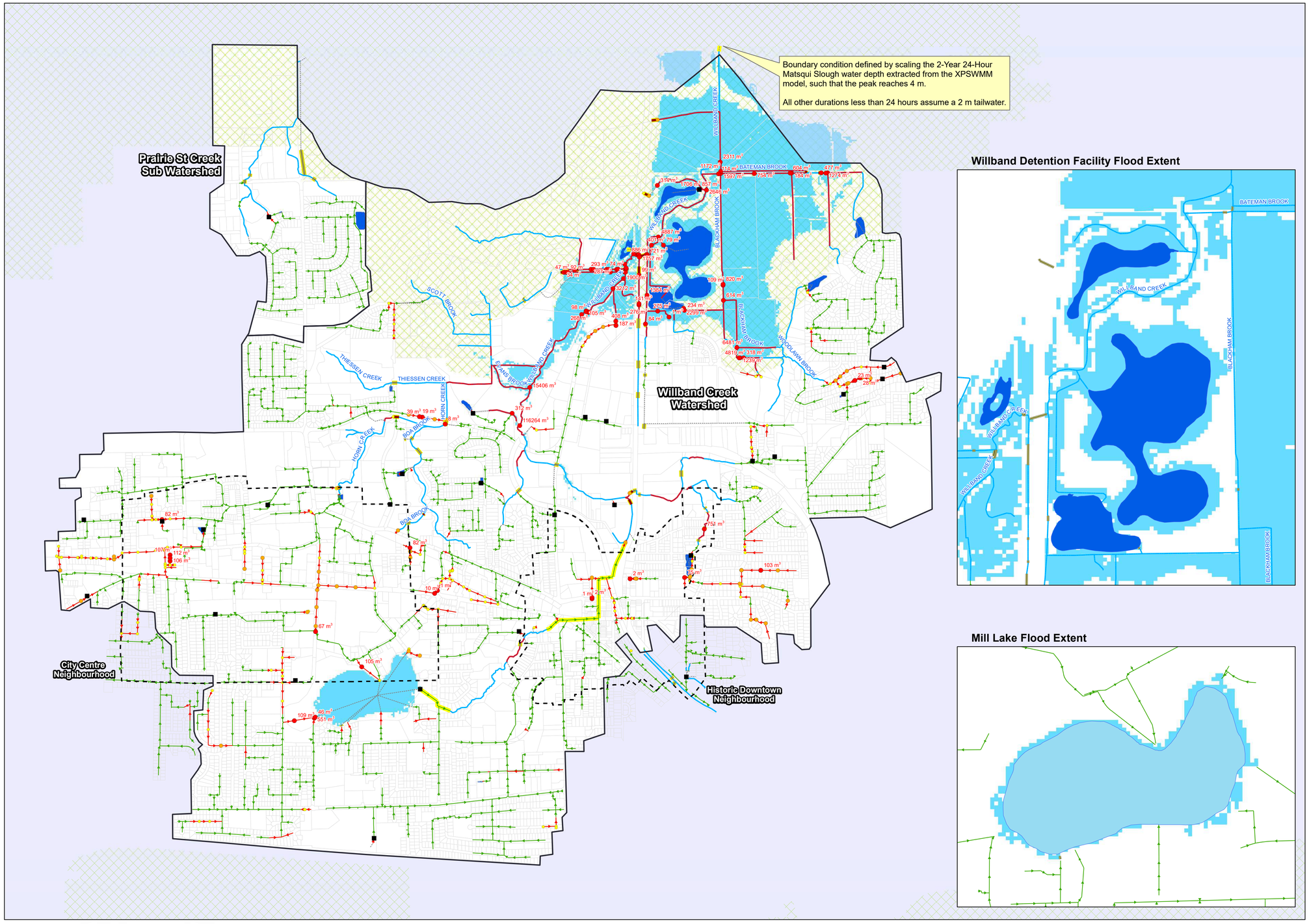
This document represents the best professional judgment of GeoAdvice Engineering Inc. based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by a member of the engineering profession currently practicing under similar conditions. No warranty, expressed or implied is made.

# 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

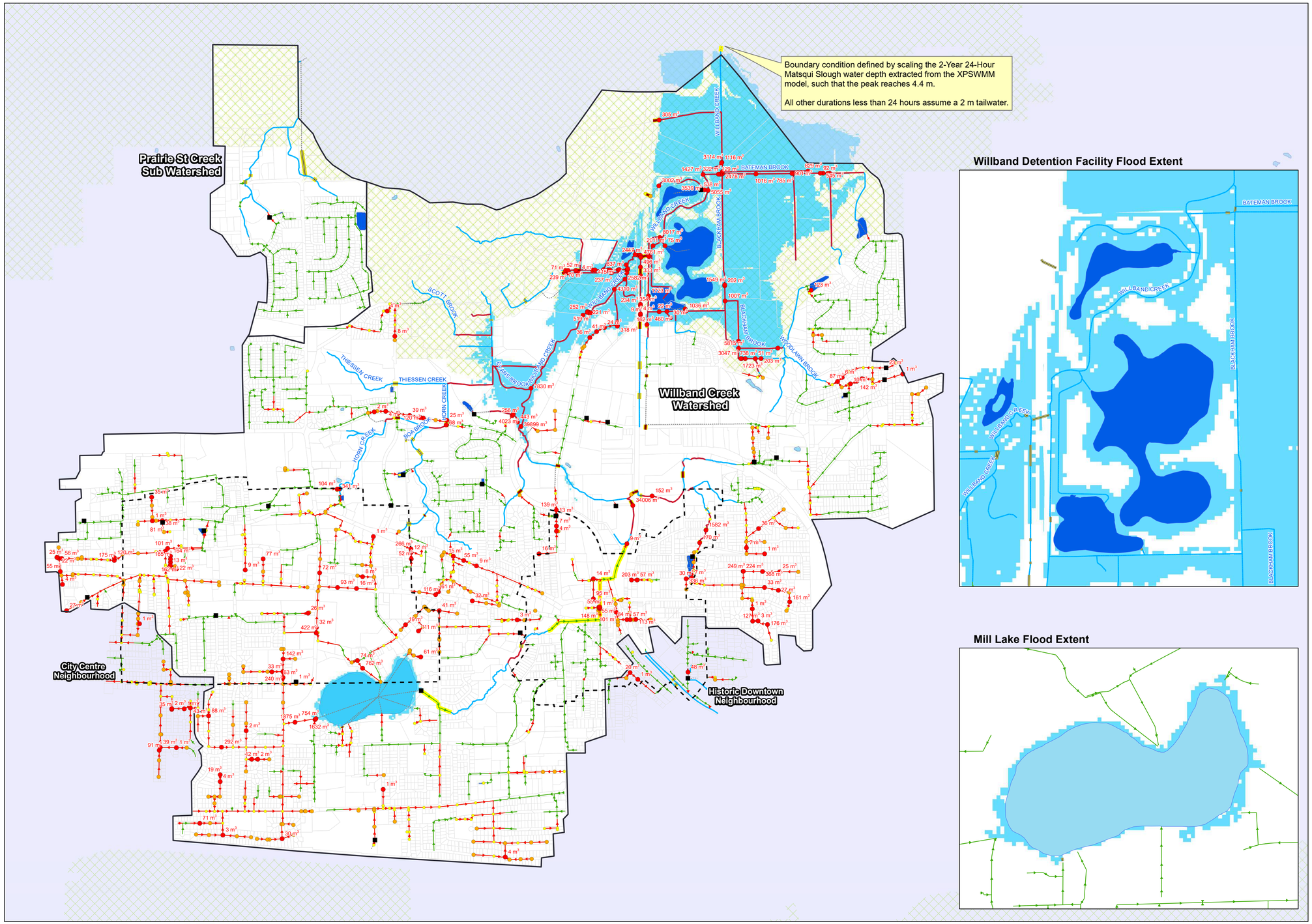
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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 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

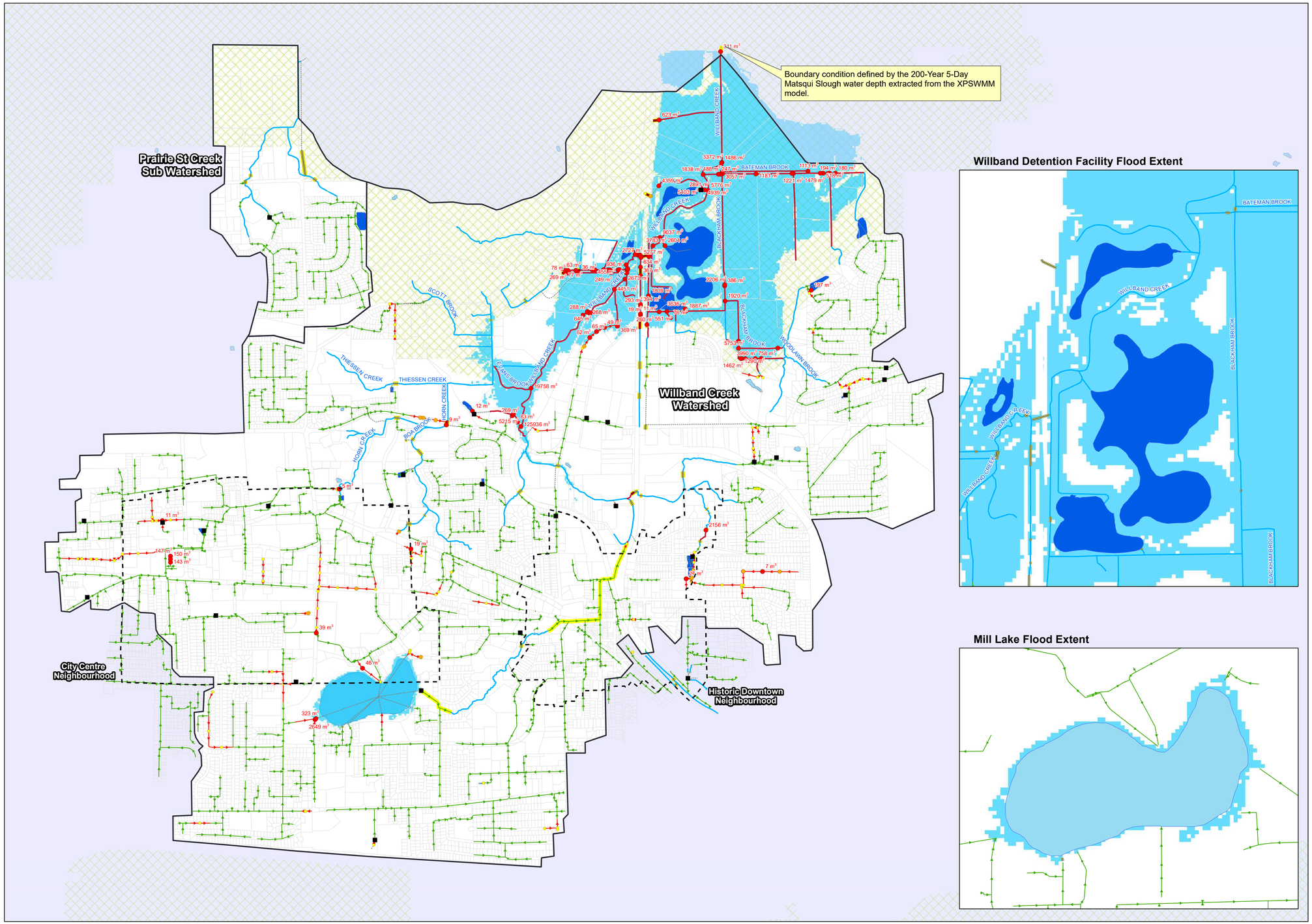
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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 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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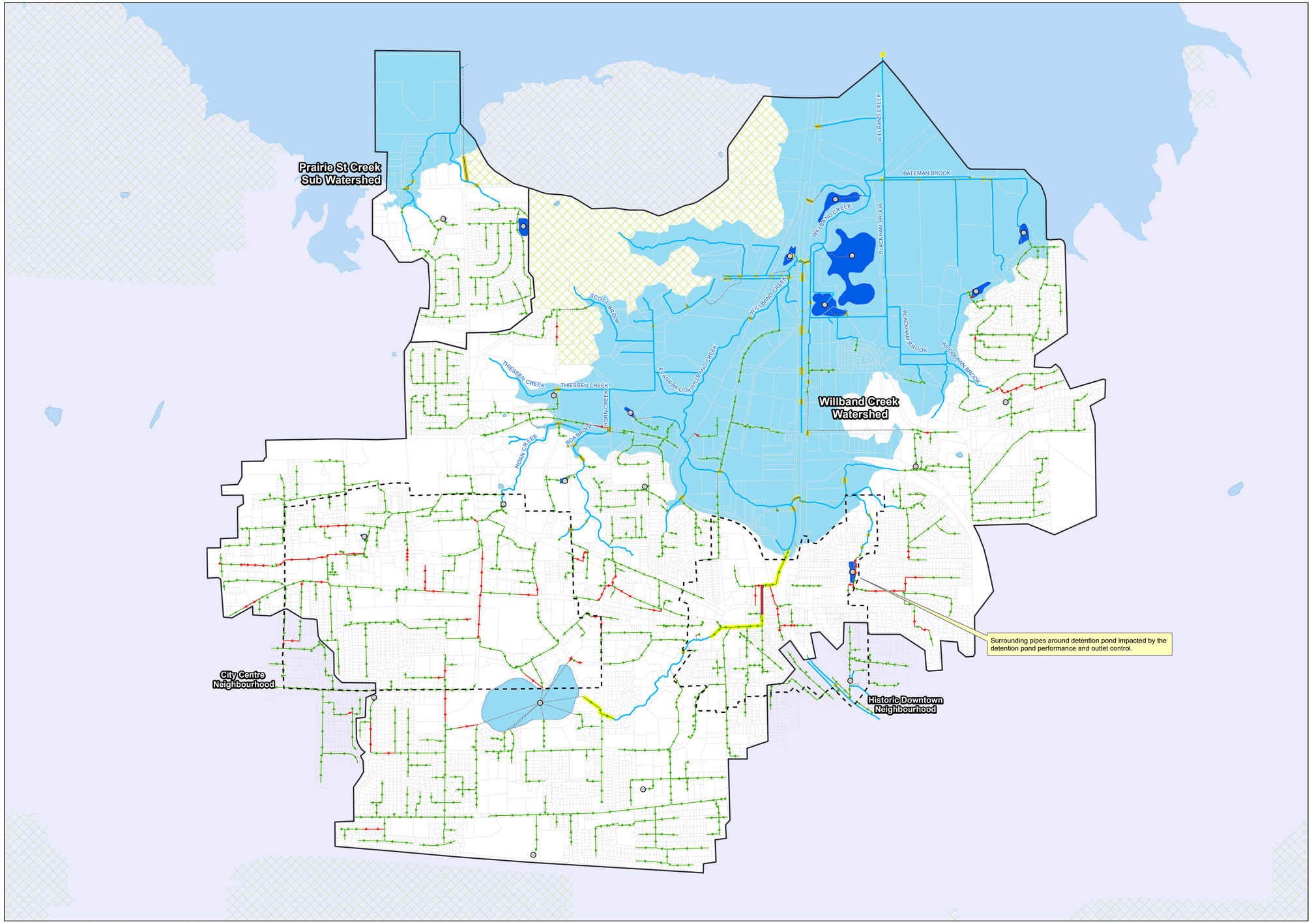
0 0.25 0.5 1
Kilometers

N W E S

**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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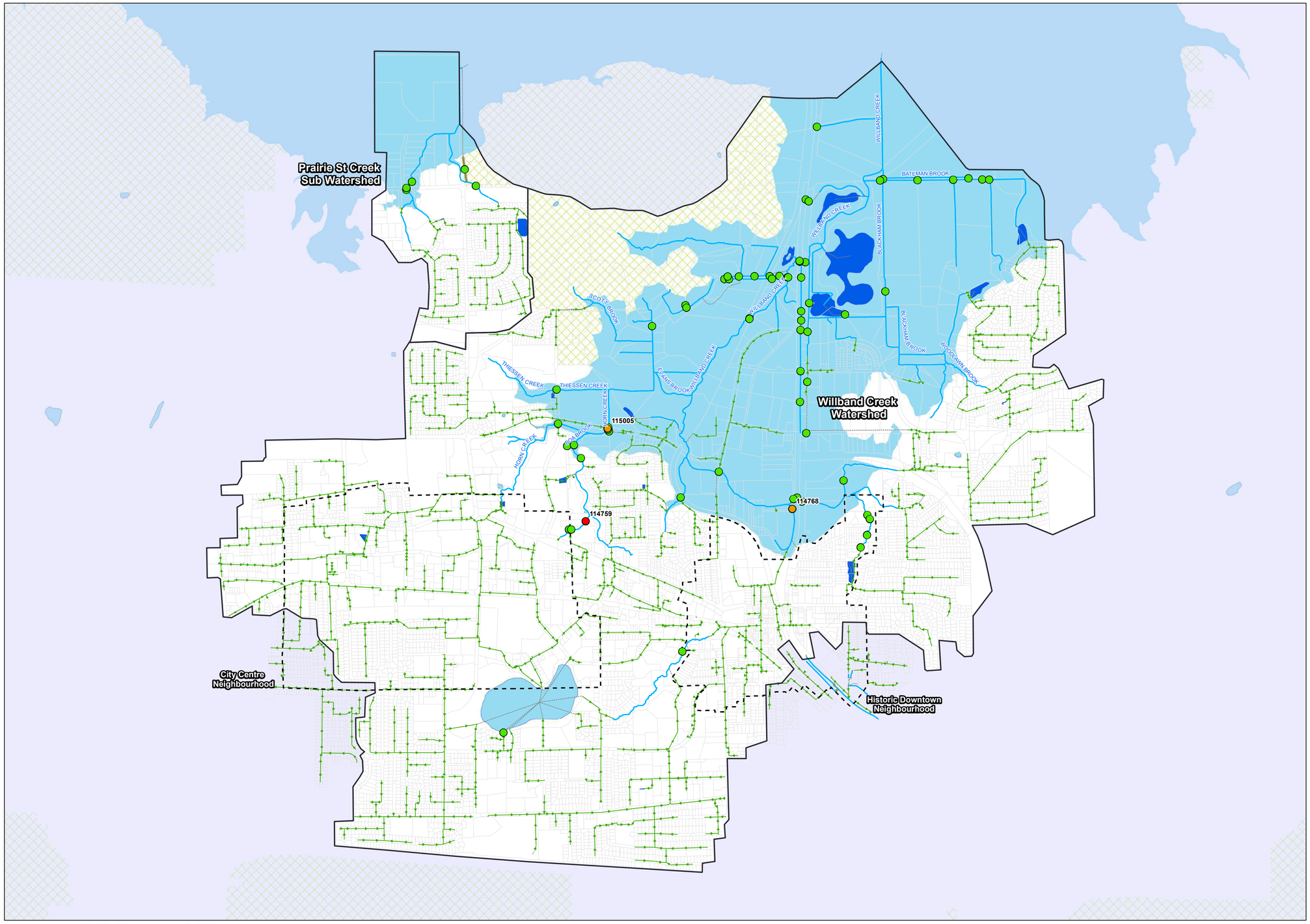
Kilometers

N W E S

**Figure A.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

- 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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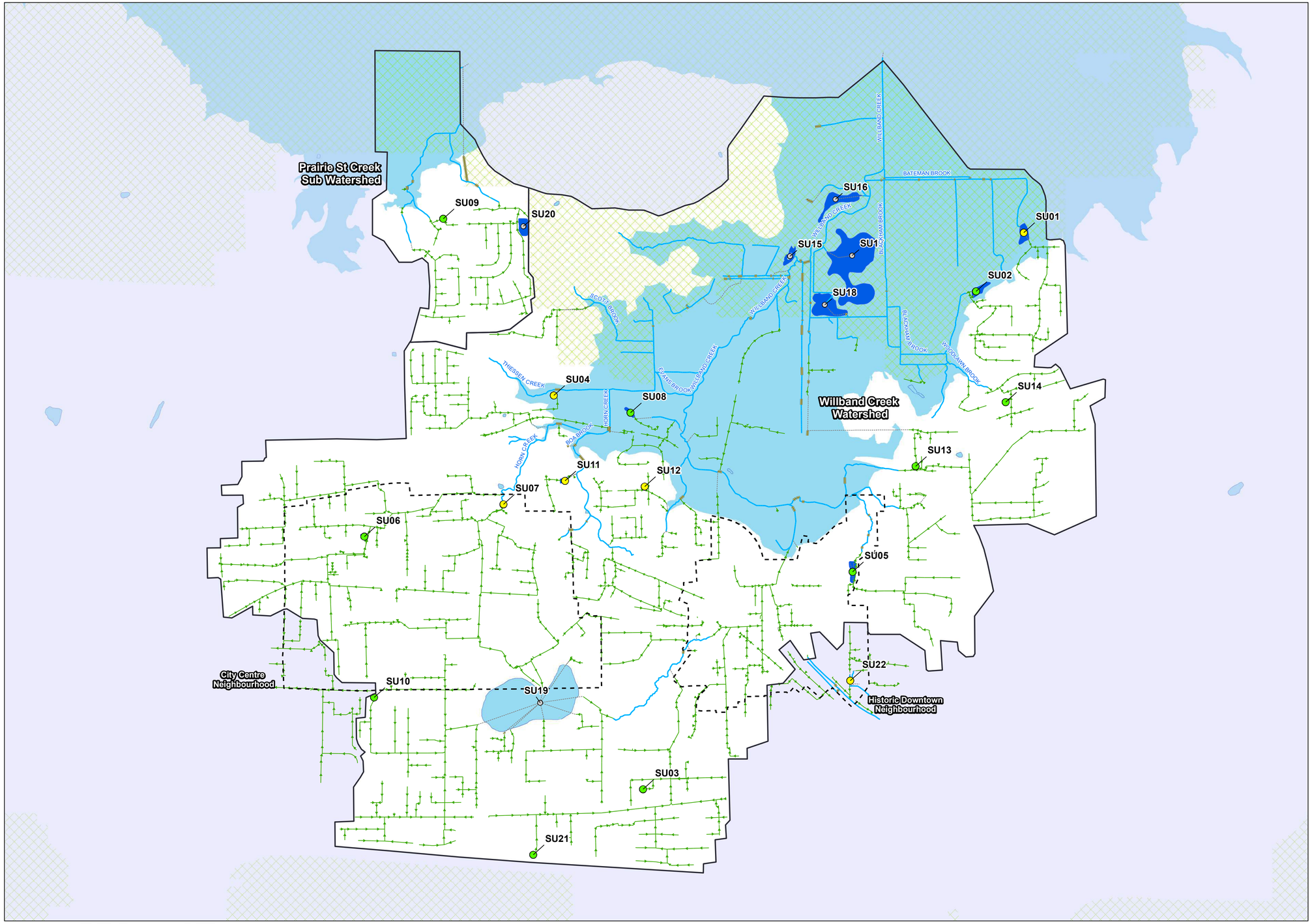
Kilometers

N W E S

**Figure A.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)**

ABBOTSFORD

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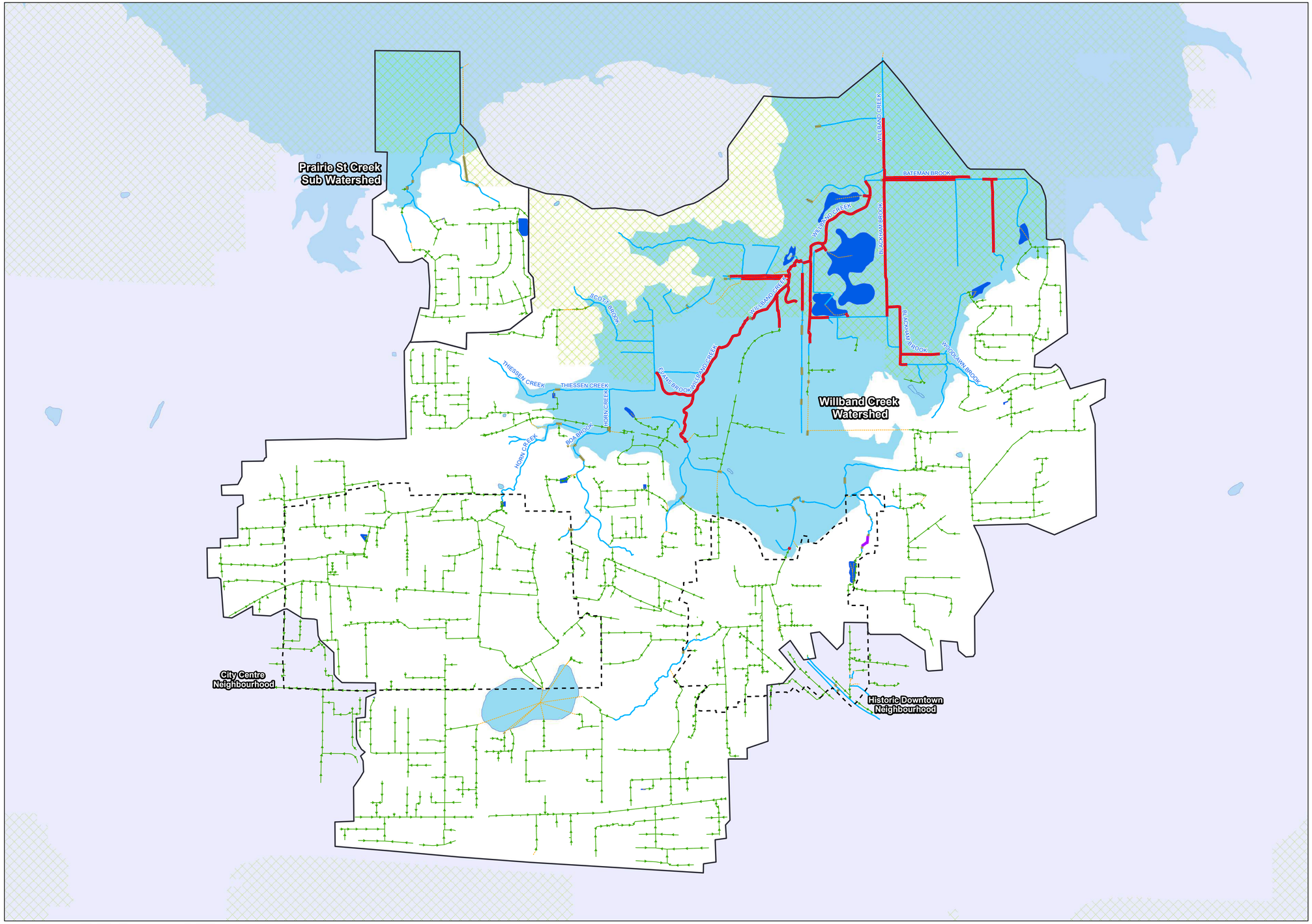
Kilometers

N W E S

**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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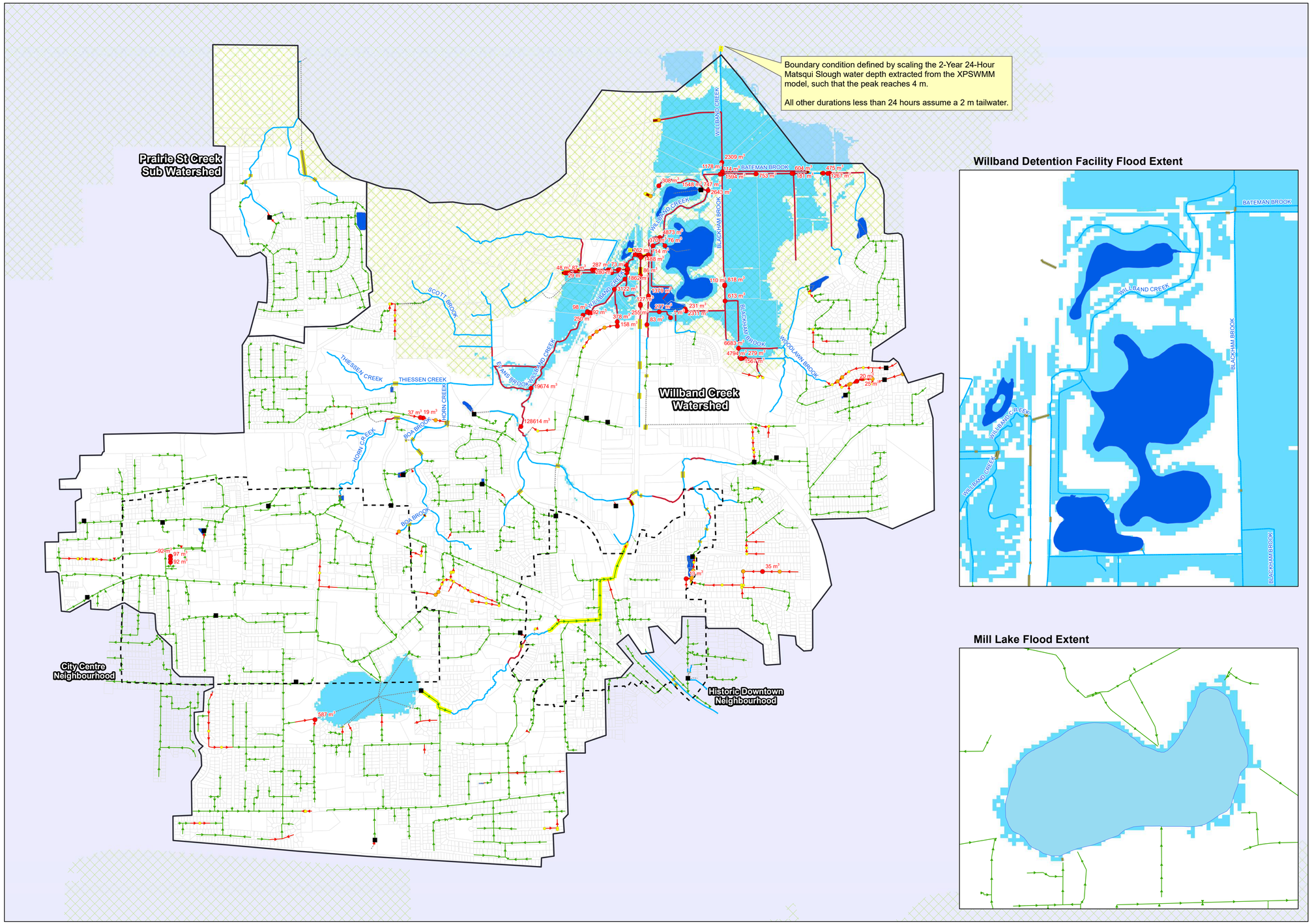
0 0.25 0.5 1
Kilometers

N W E S

**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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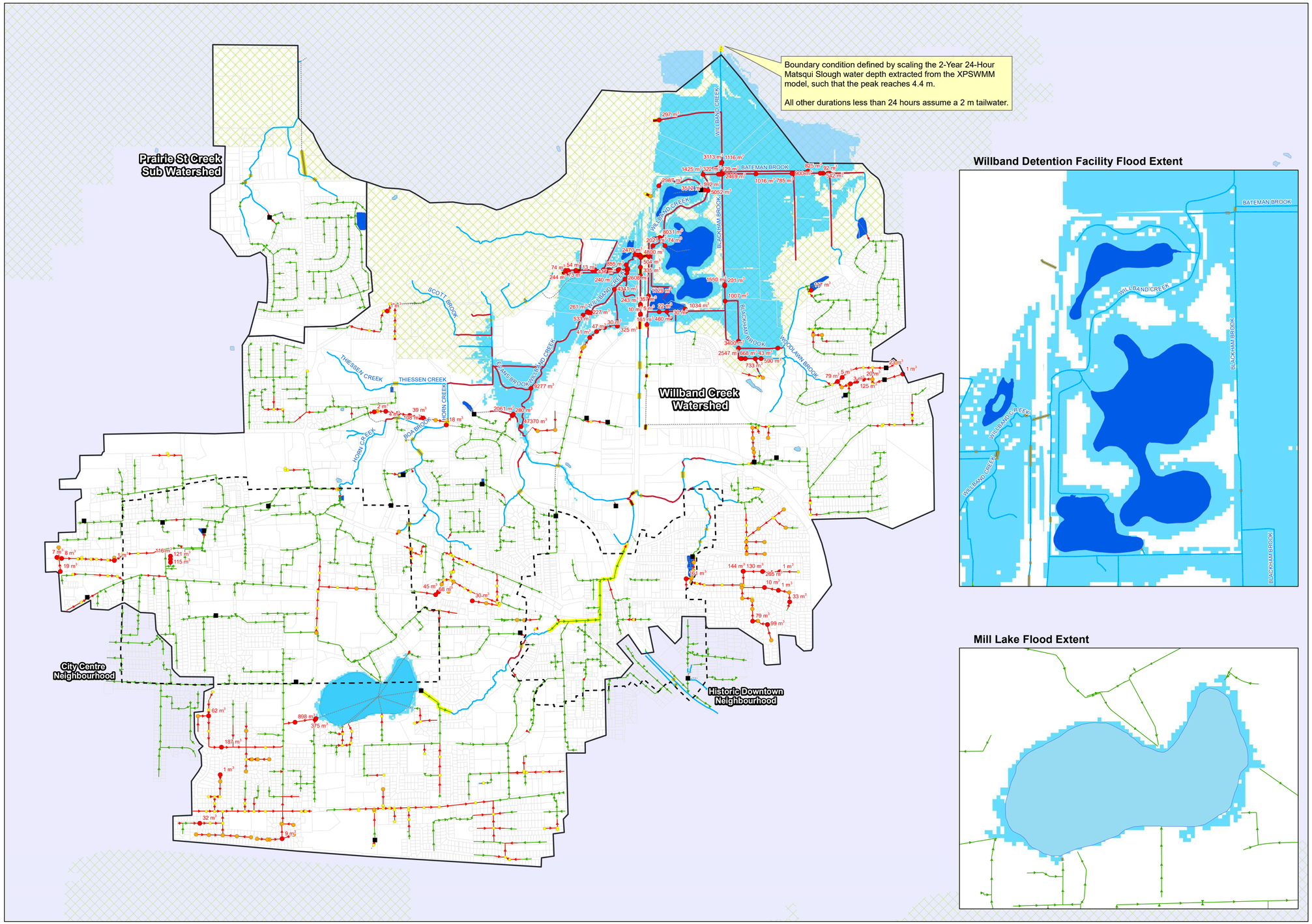
0 0.25 0.5 1
Kilometers

N W E S

**Figure B.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)**

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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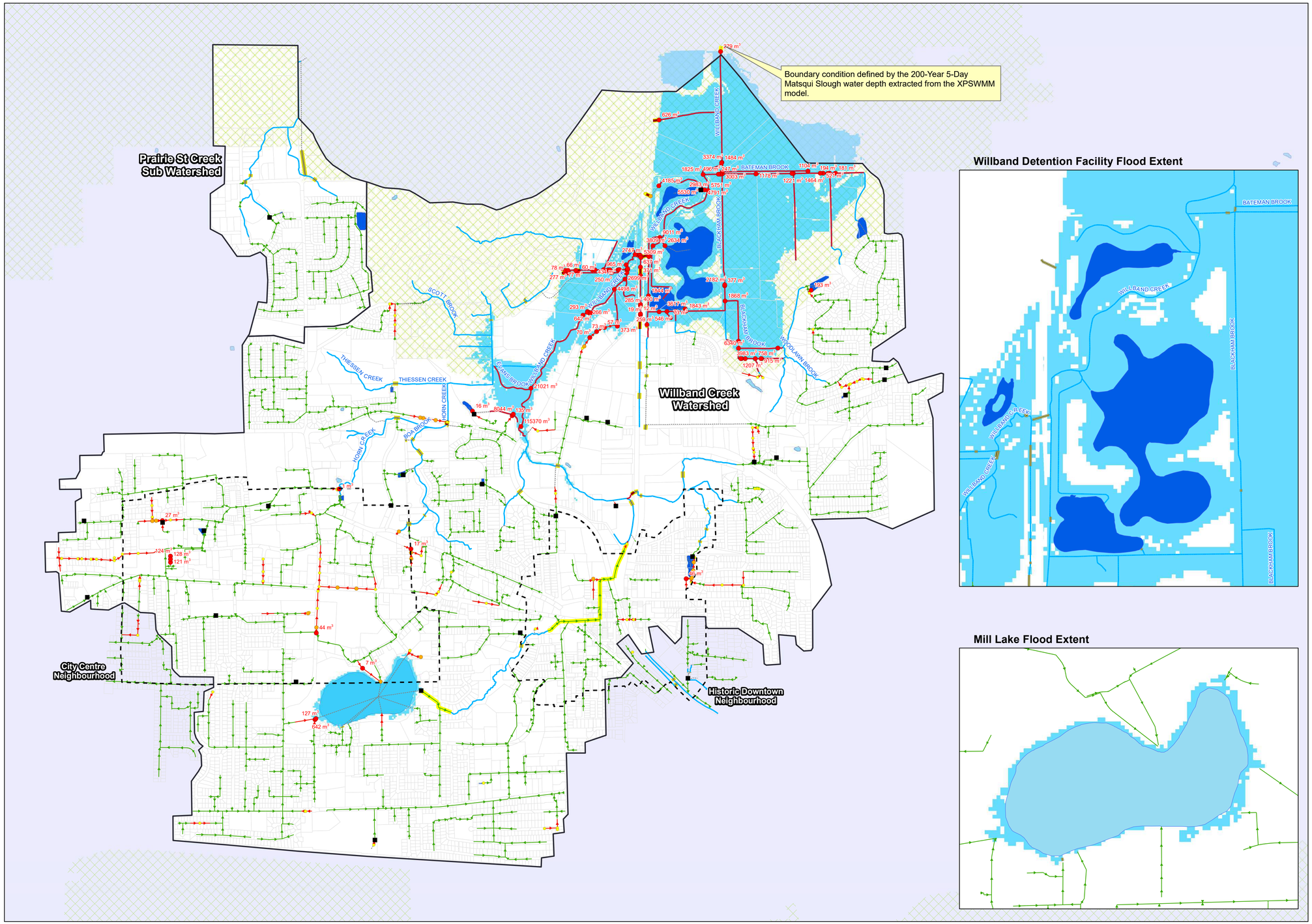
0 0.25 0.5 1
Kilometers

N W E S

**Figure B.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

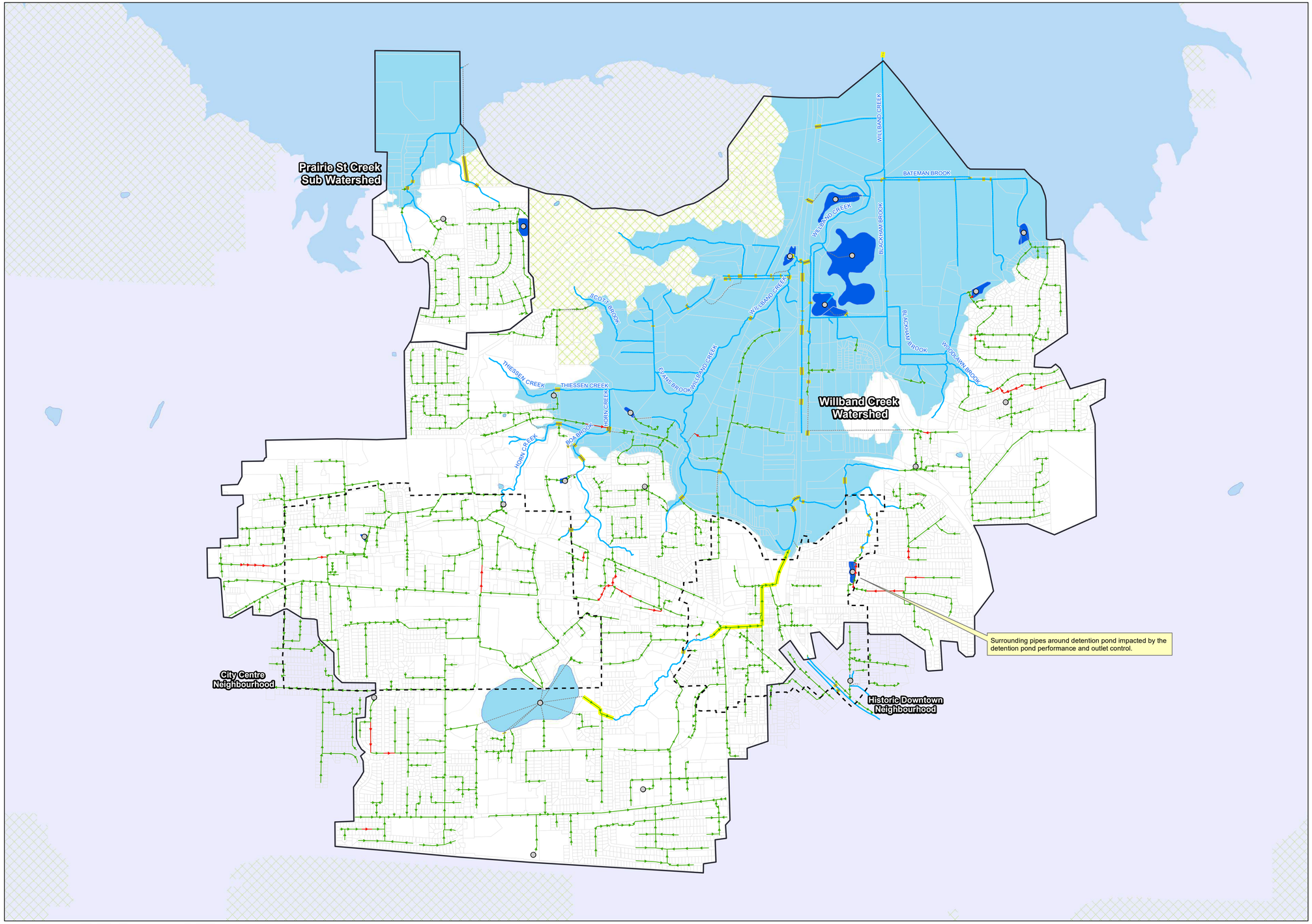
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

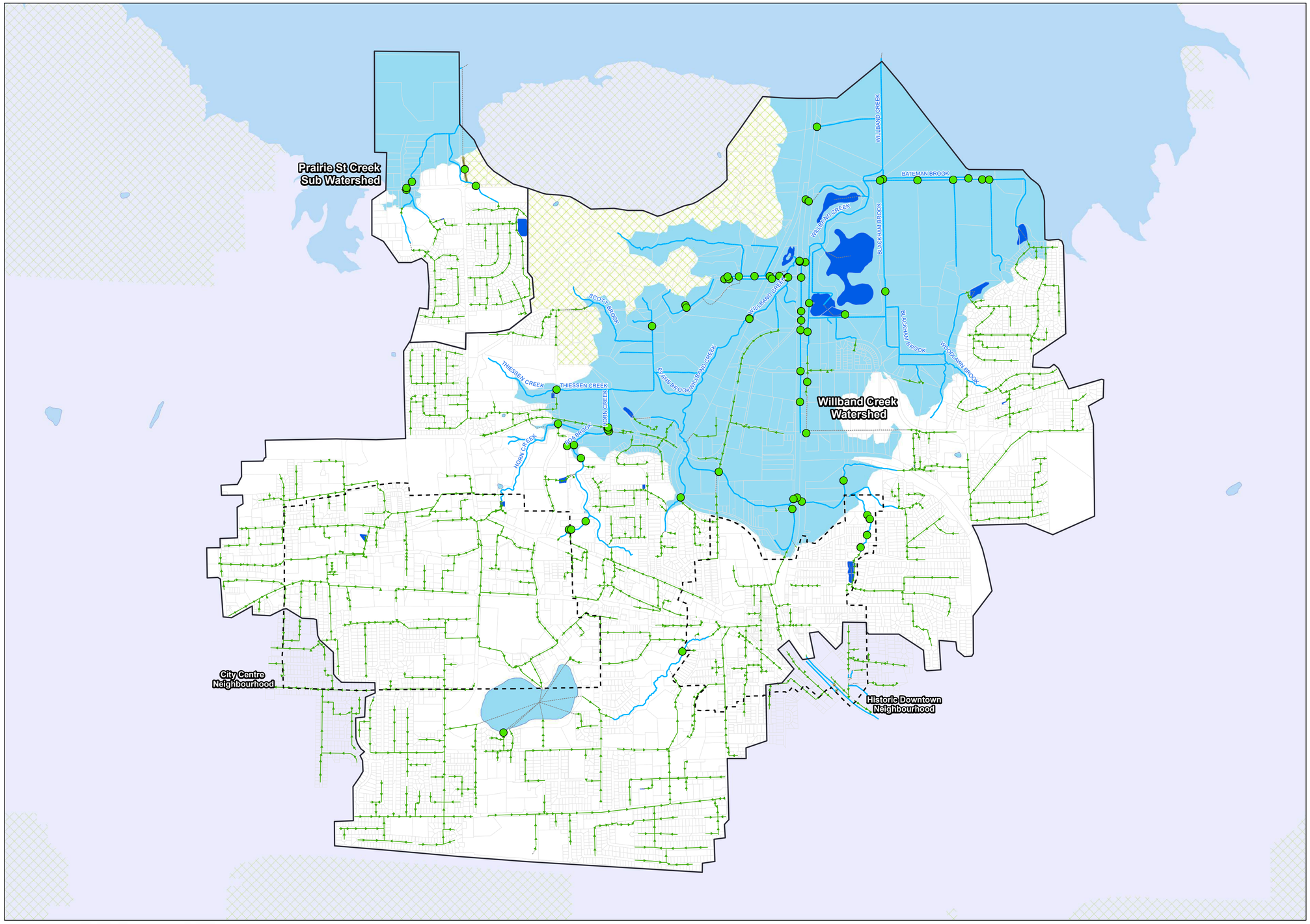
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

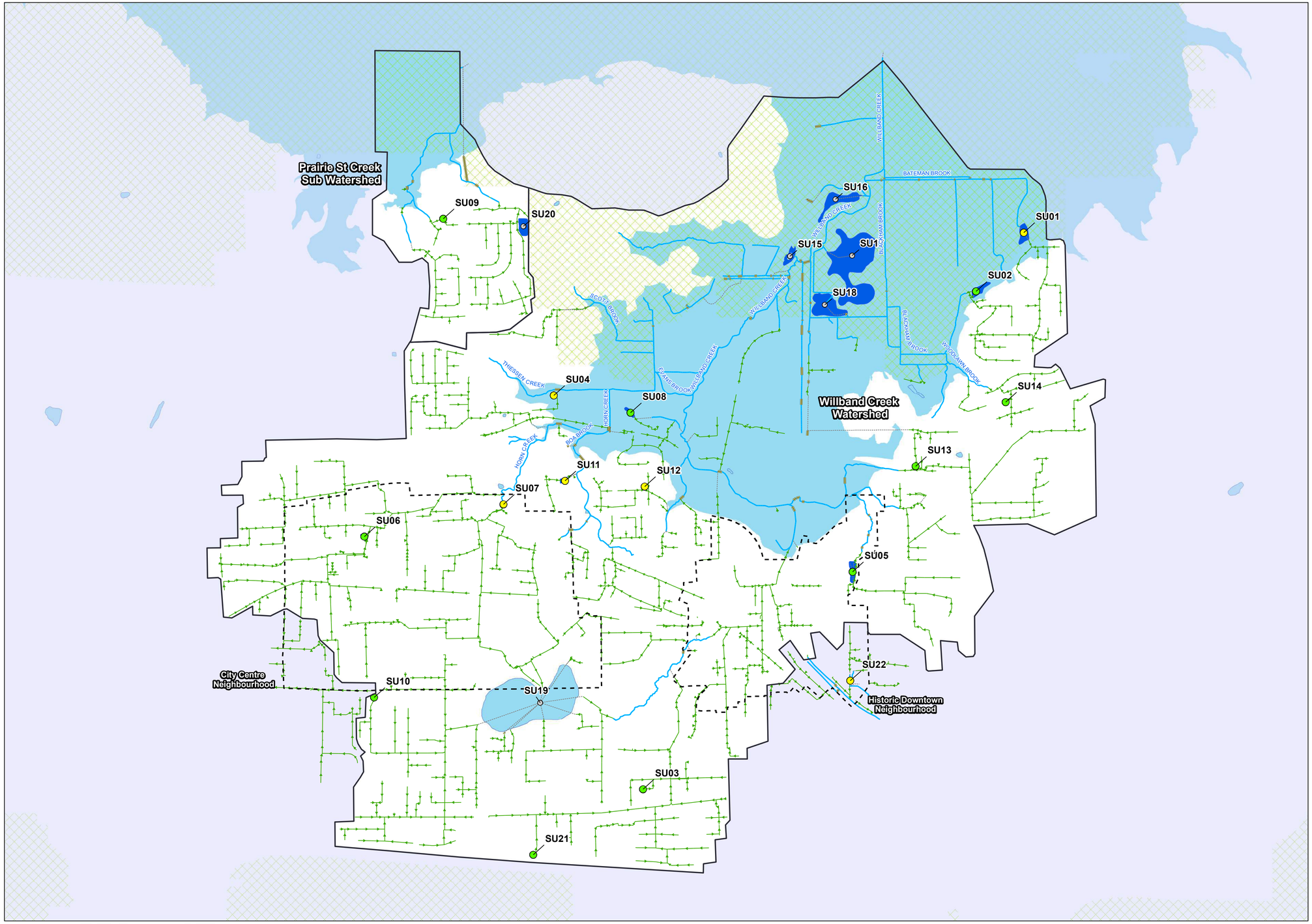
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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

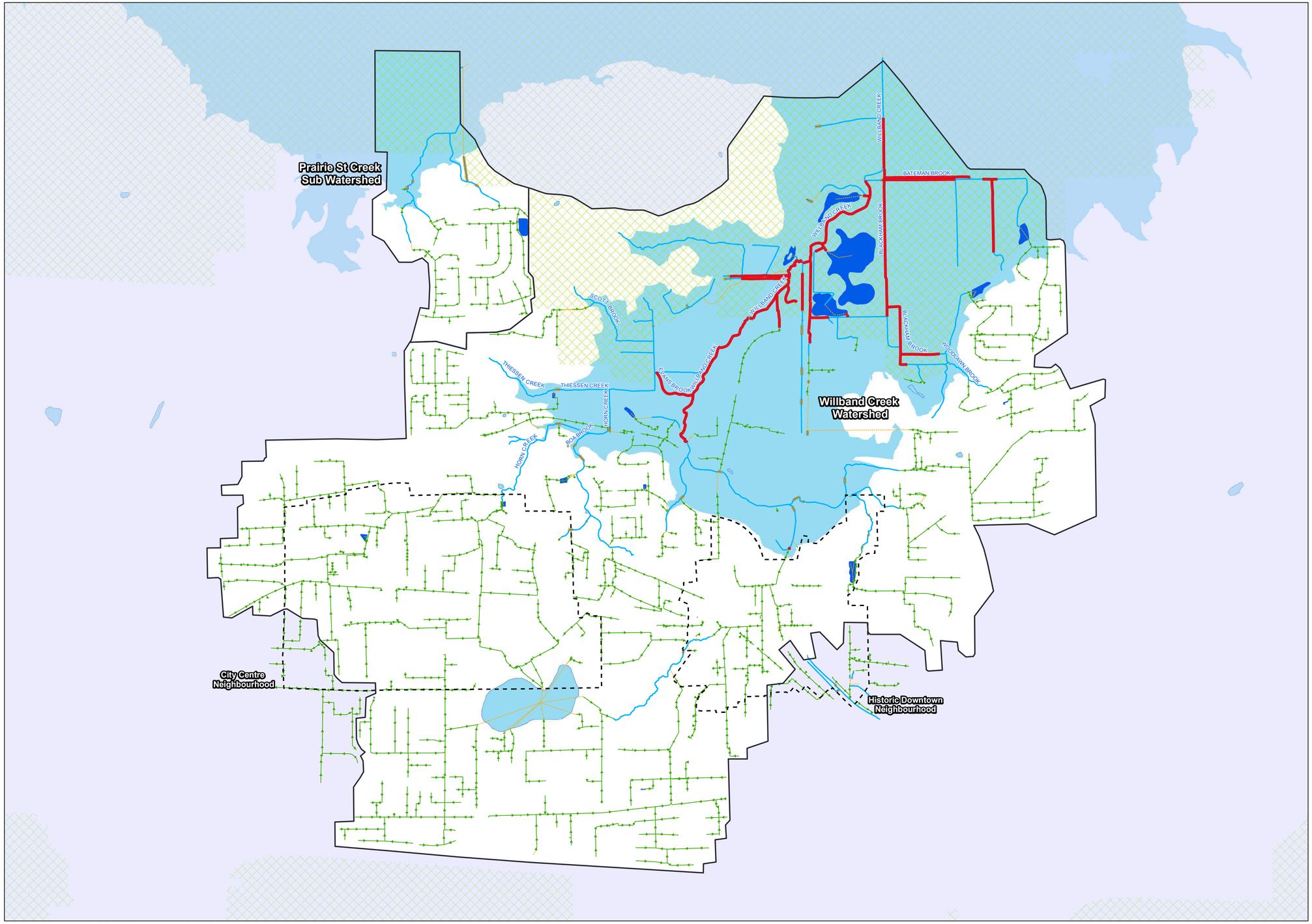
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

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.

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Kilometers

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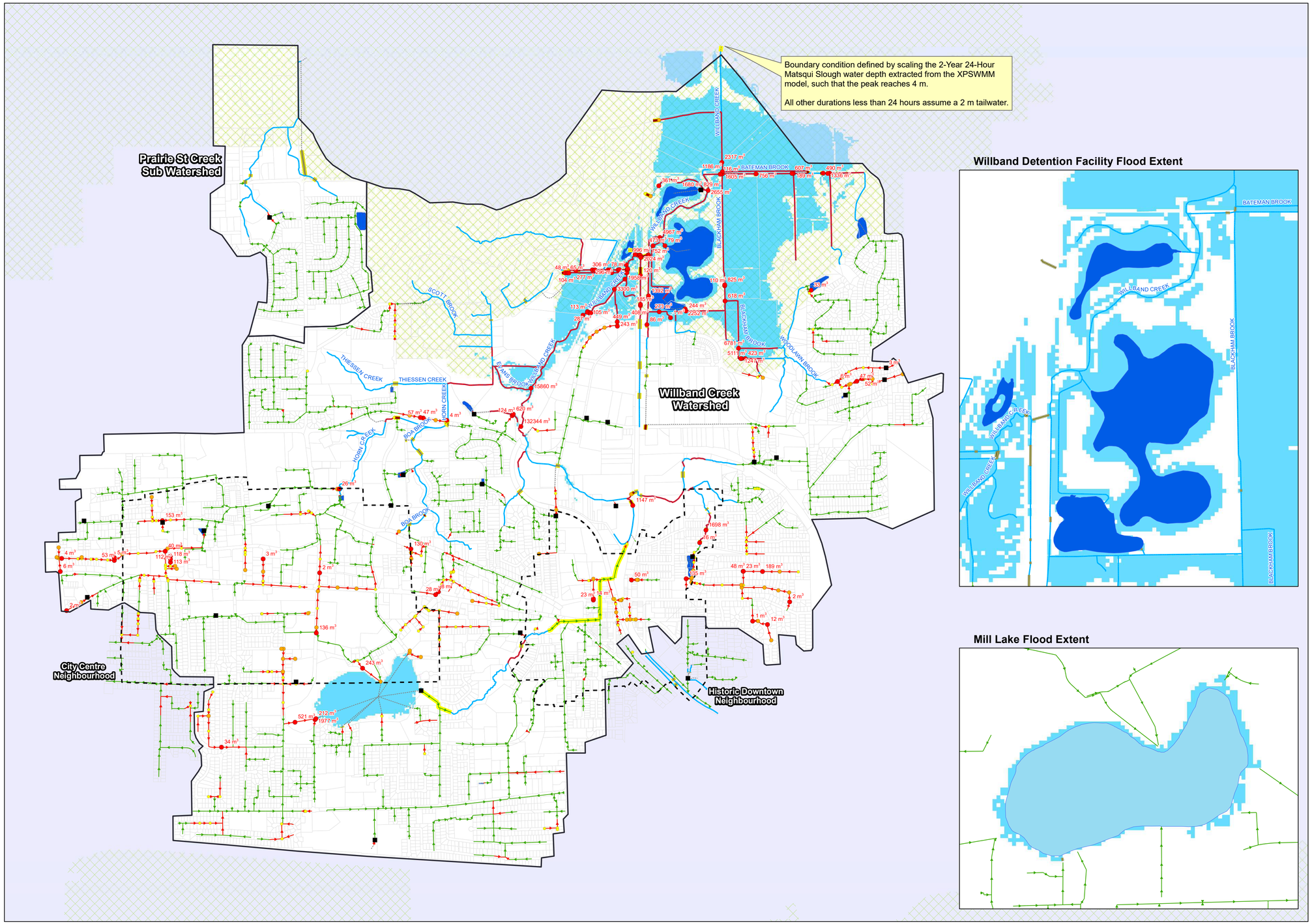
**Figure B.7**

# 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**

ABBOTSFORD

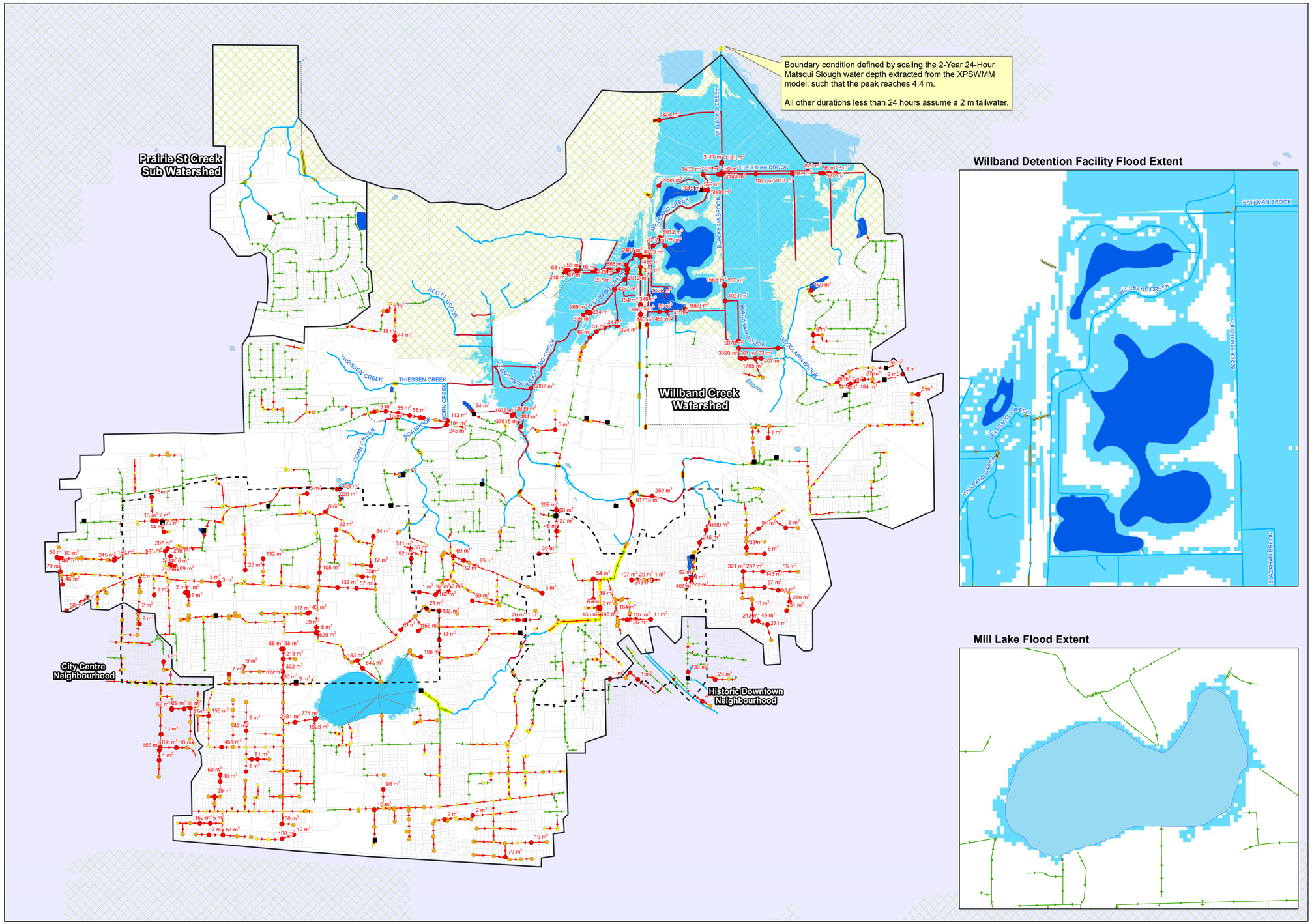
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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 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

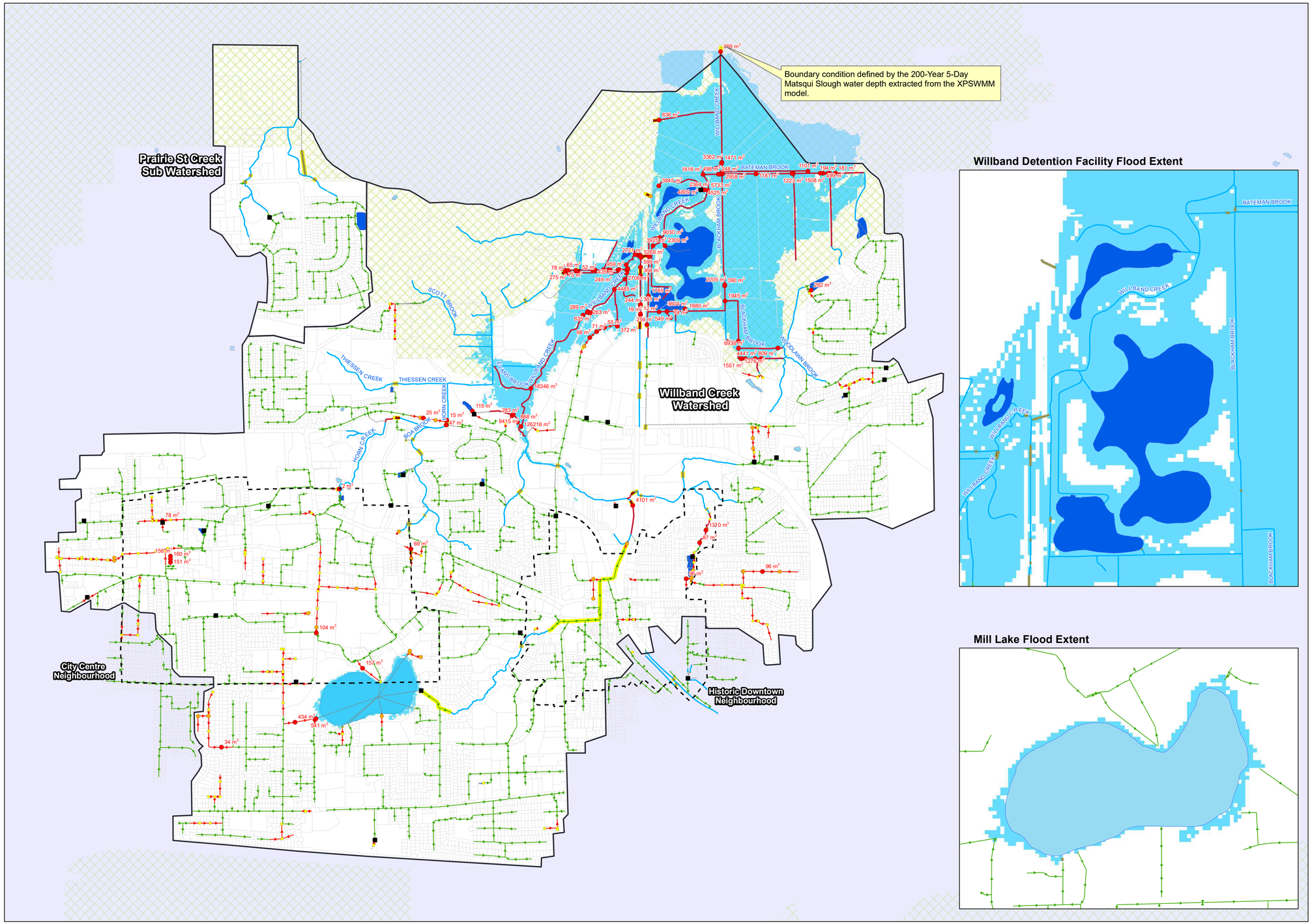
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

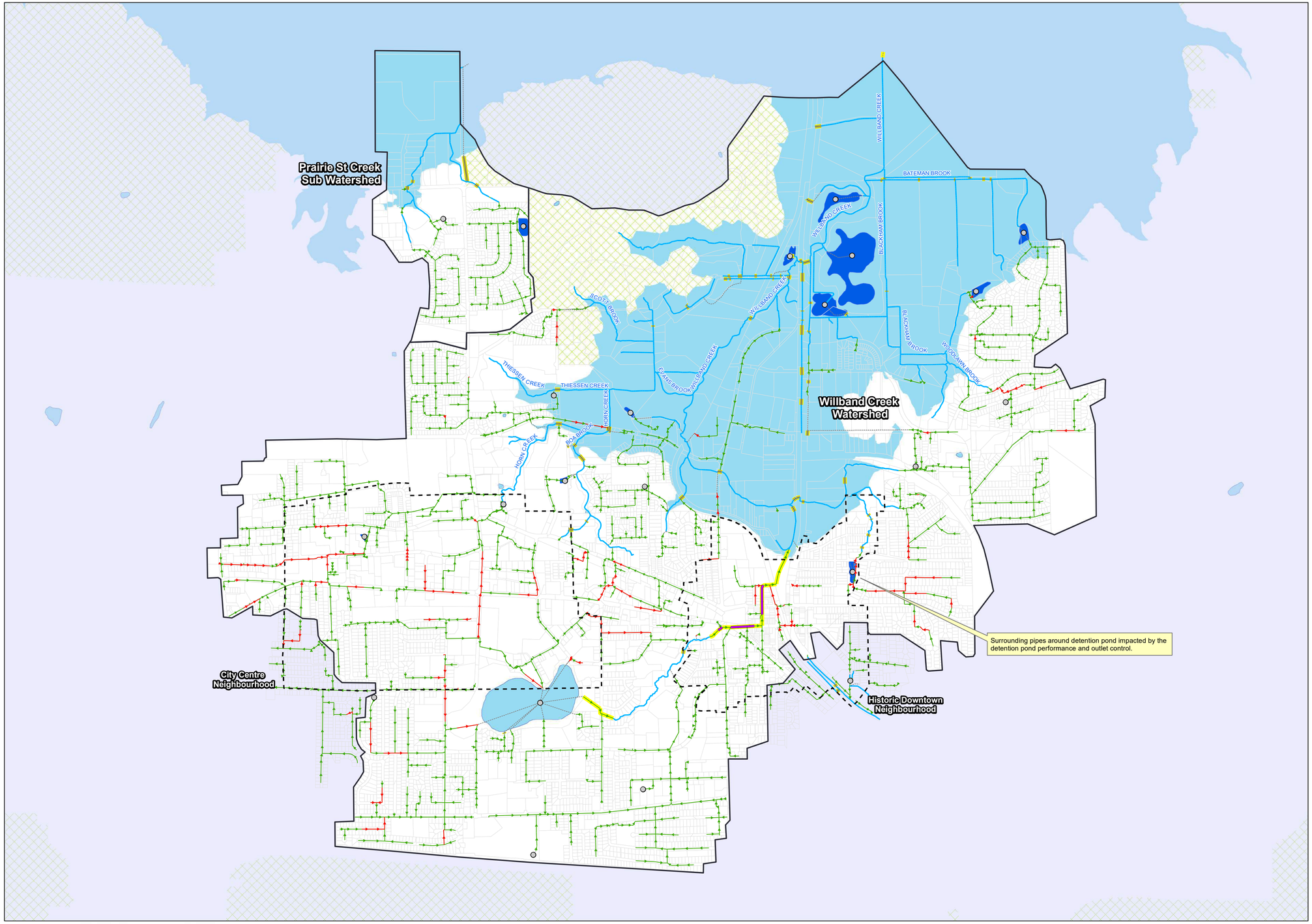
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

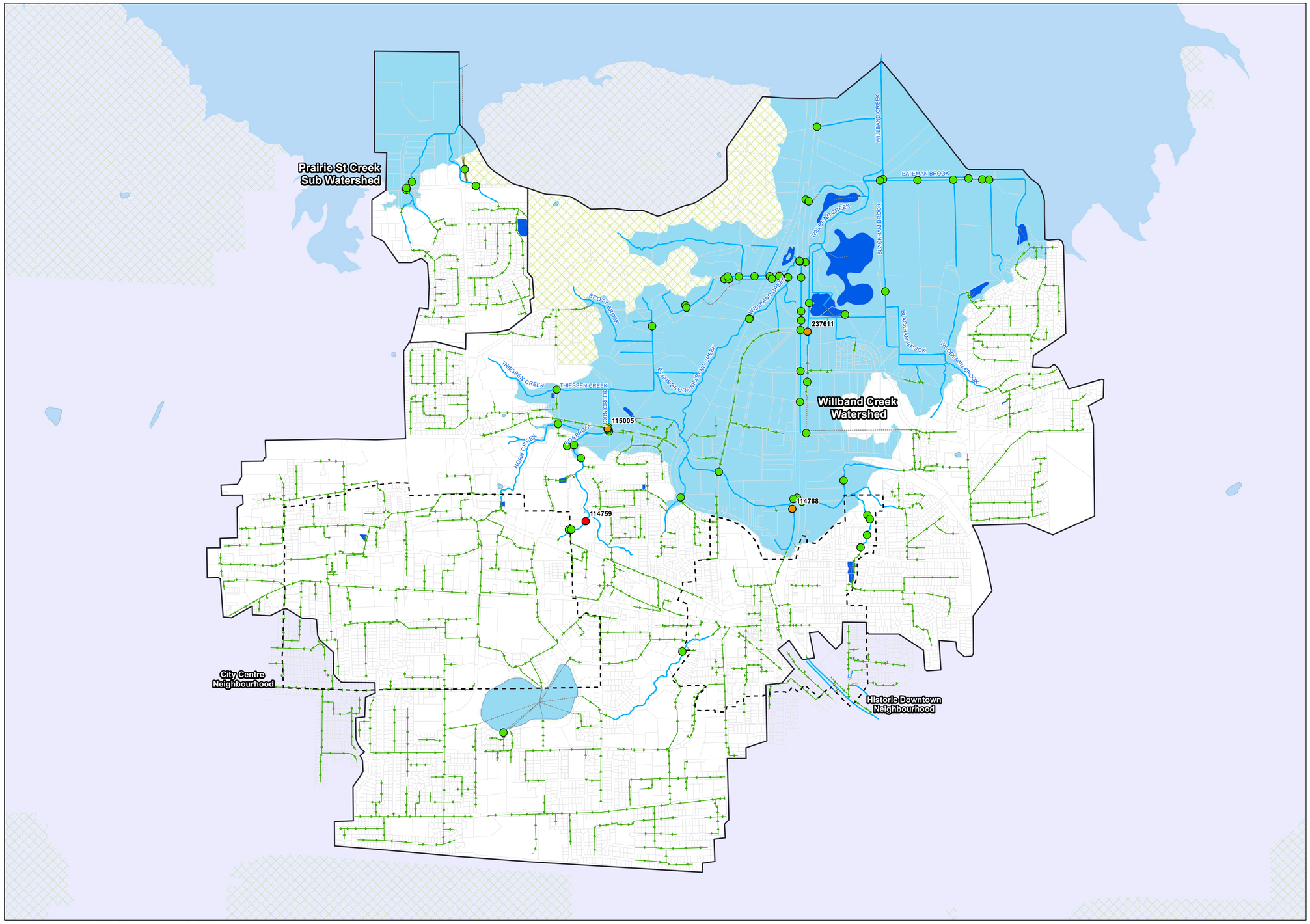
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

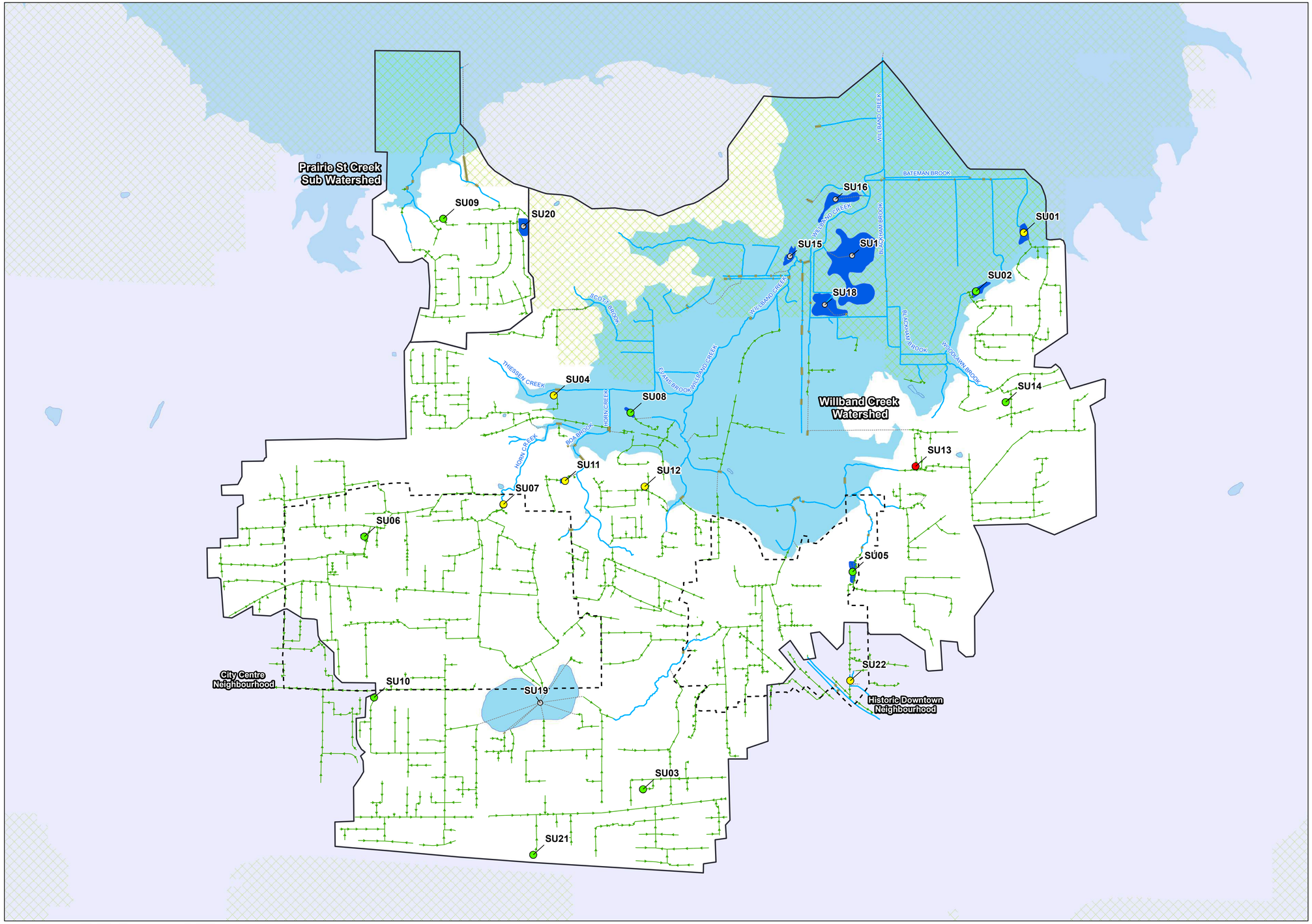
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

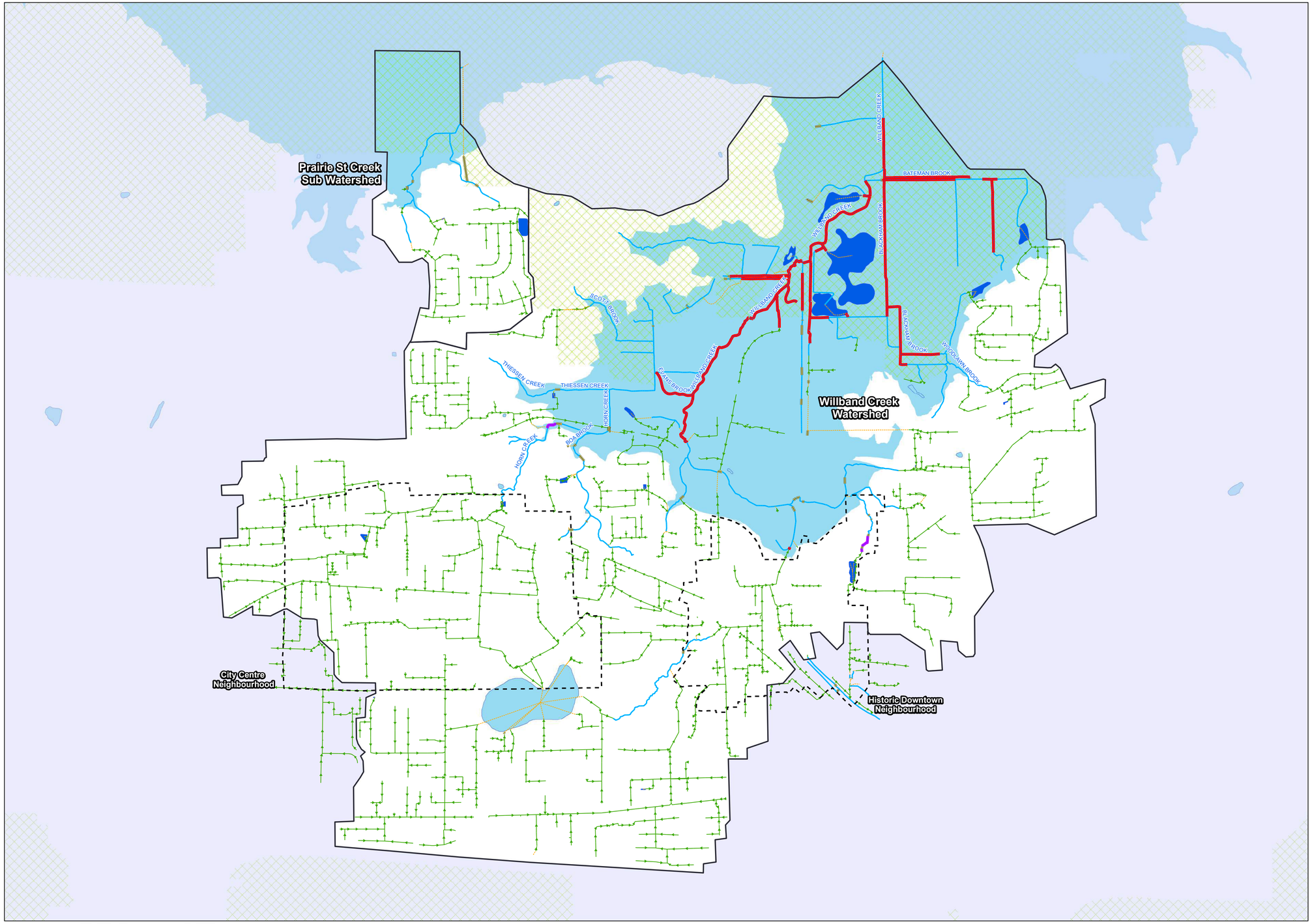
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

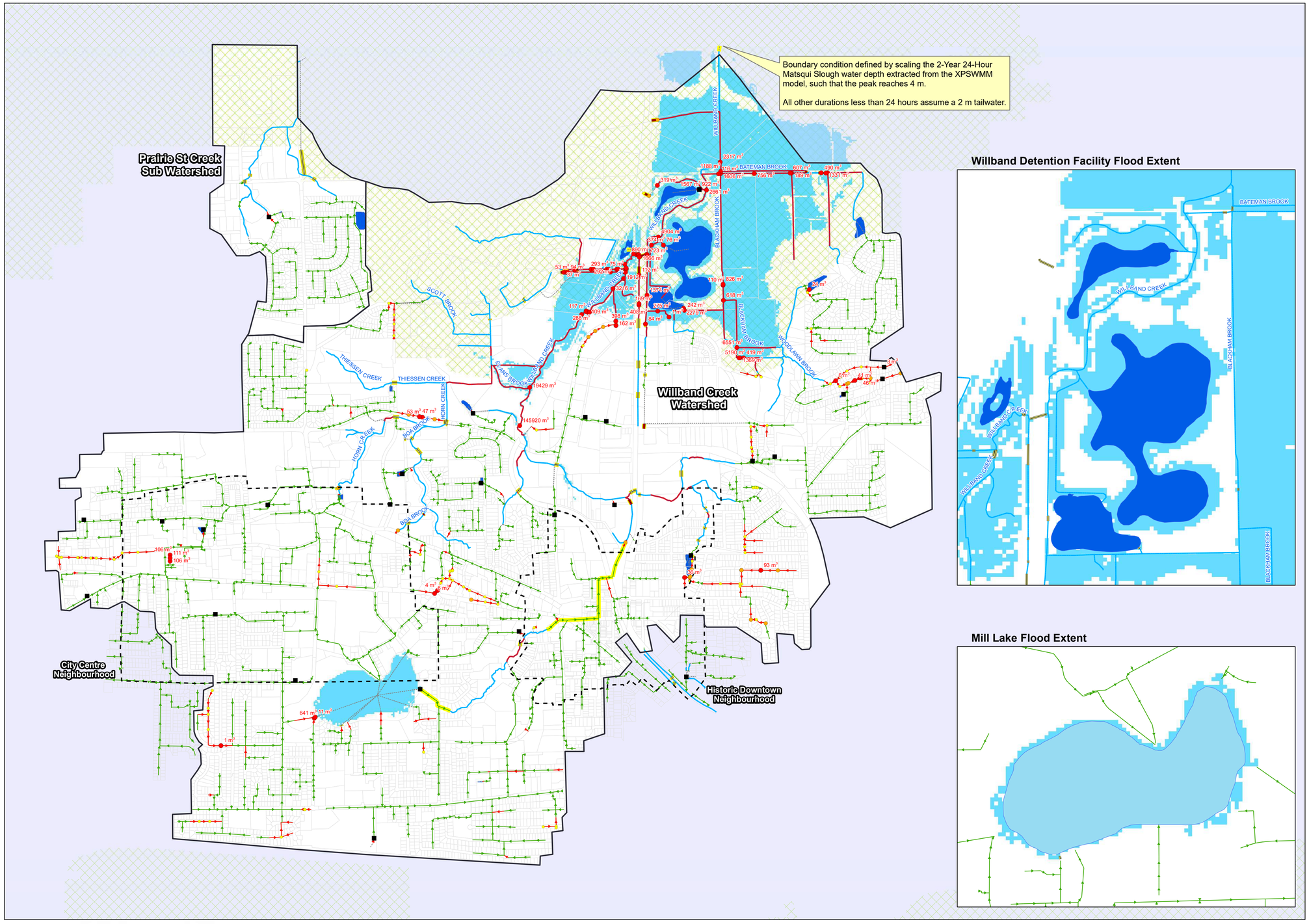
DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure C.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

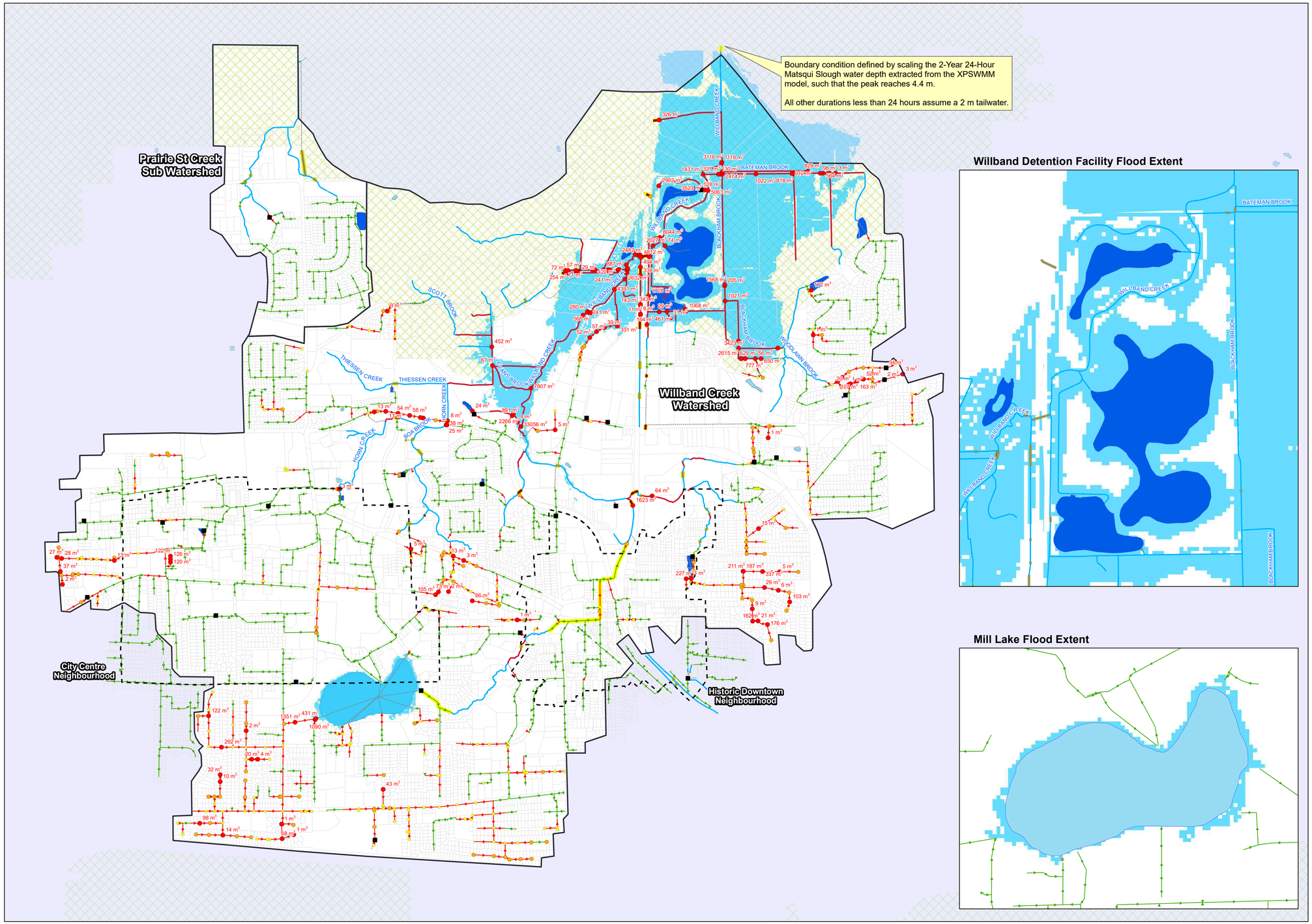
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

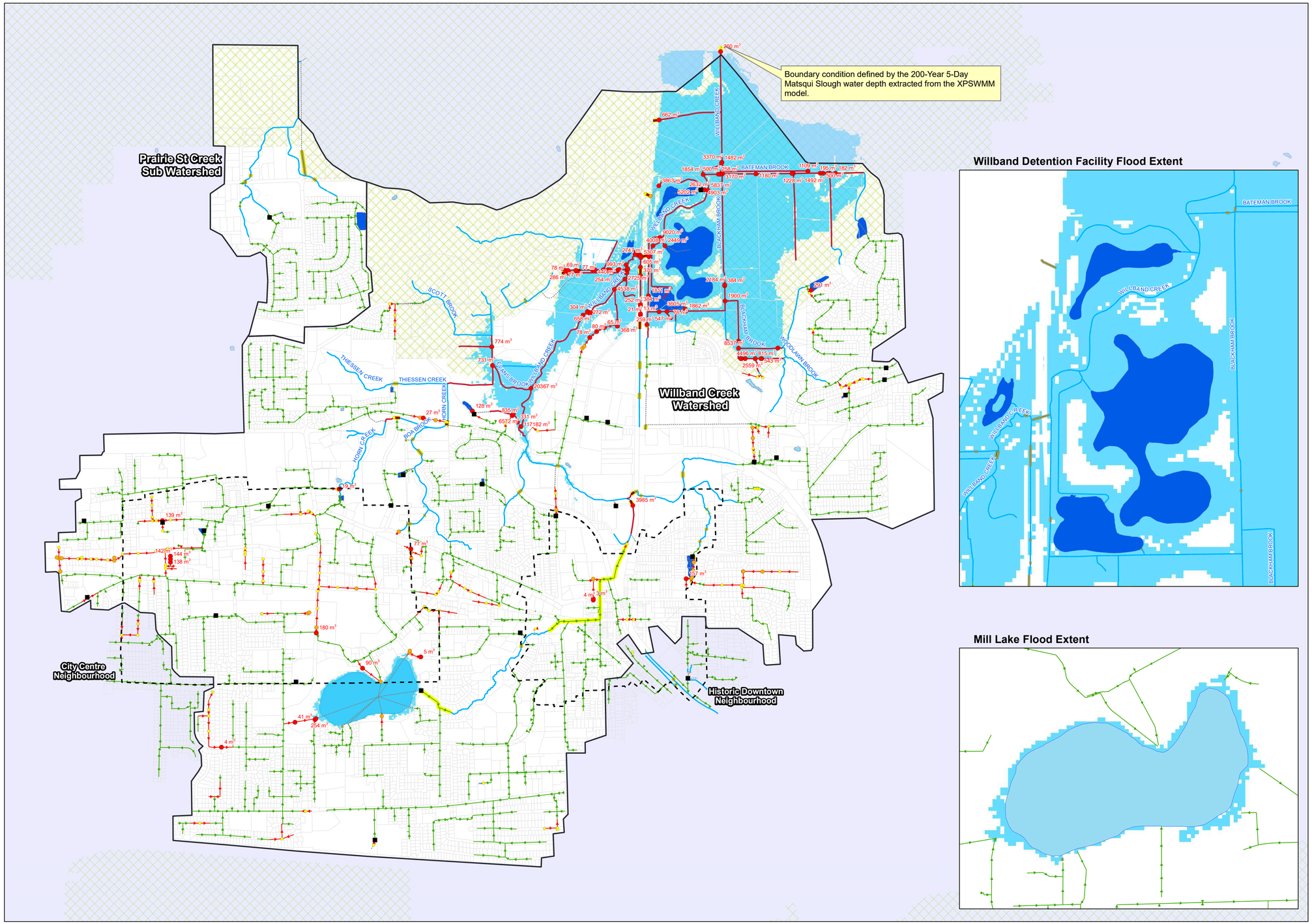
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

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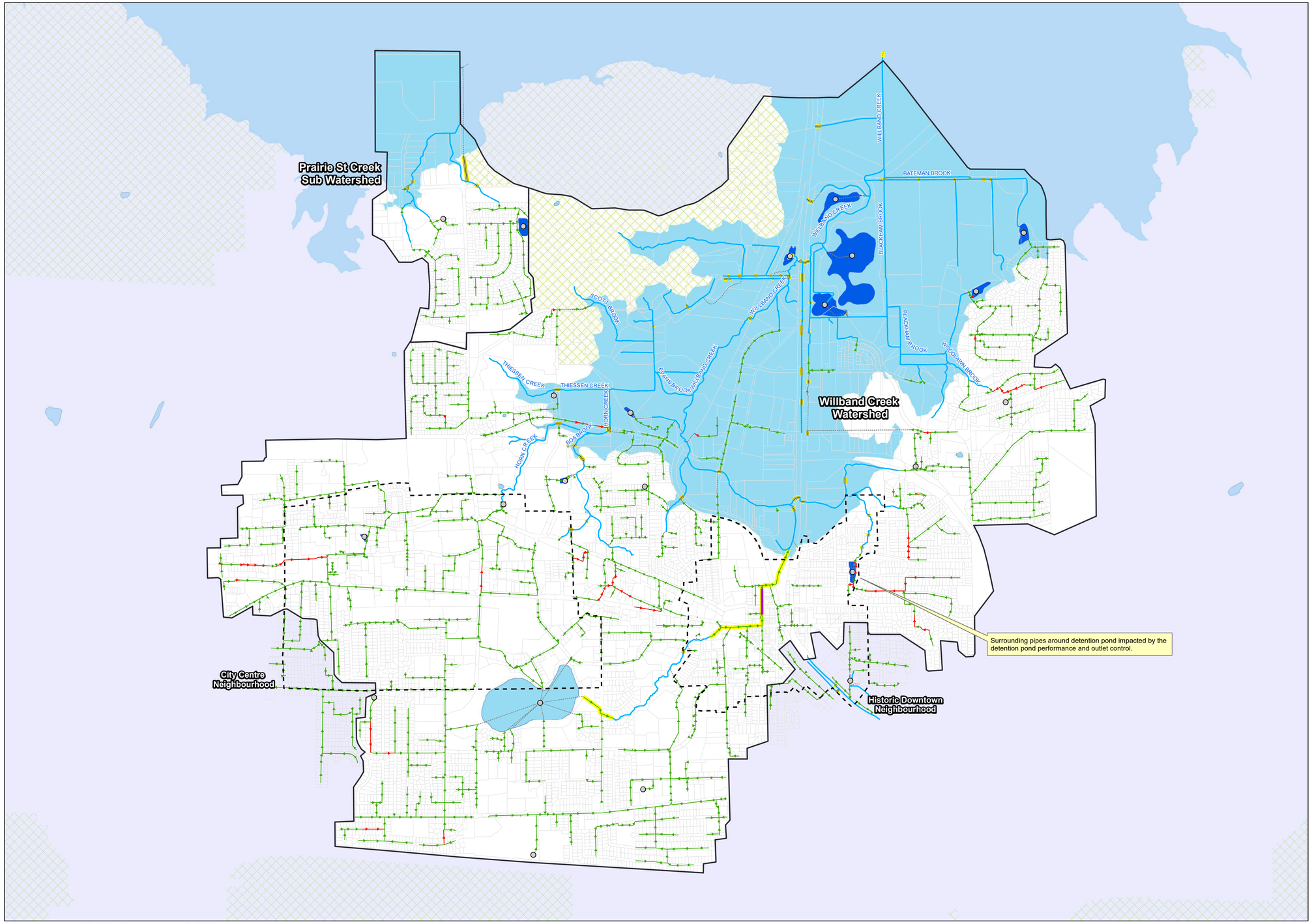
0 0.25 0.5 1
Kilometers

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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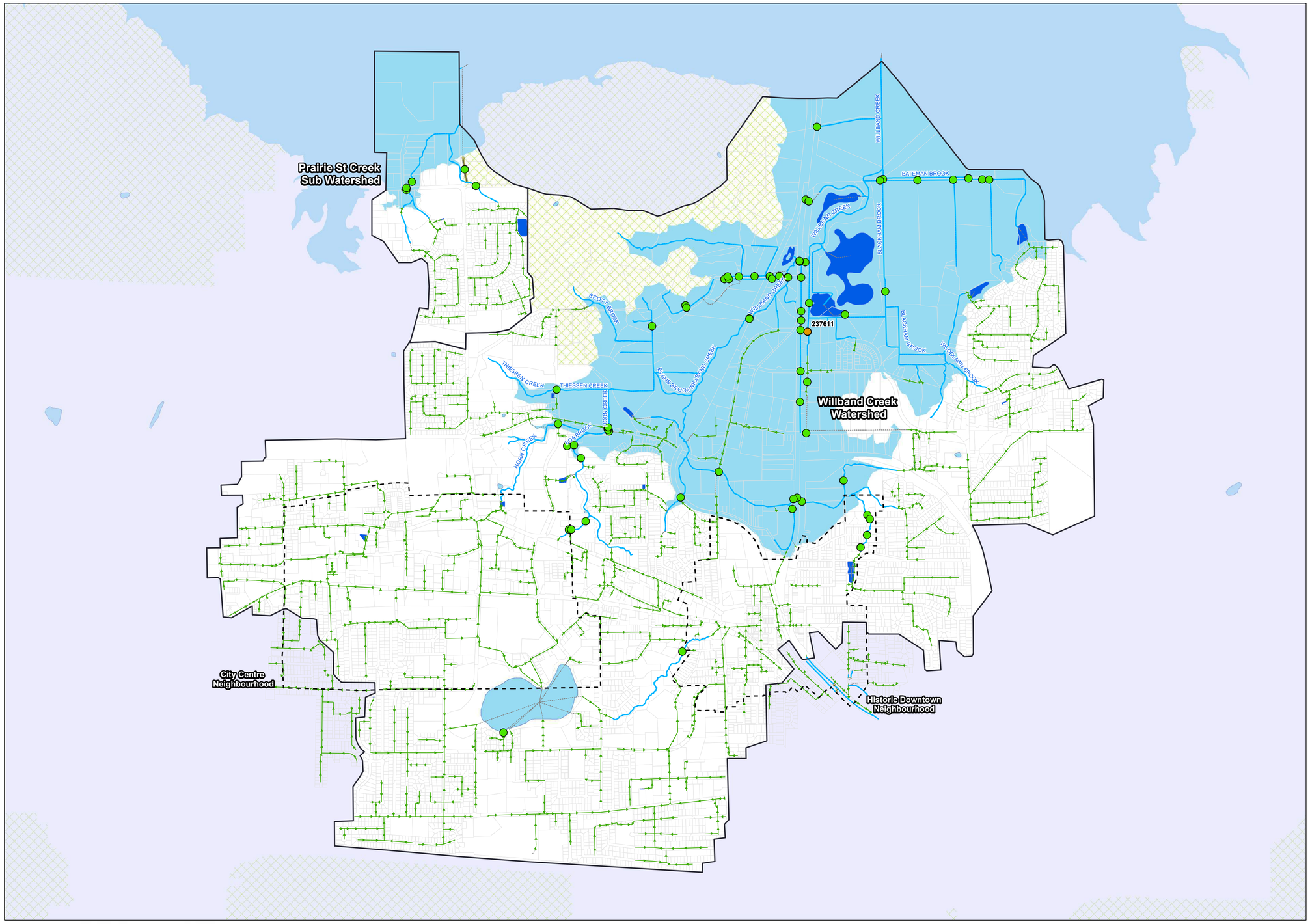
0 0.25 0.5 1
Kilometers

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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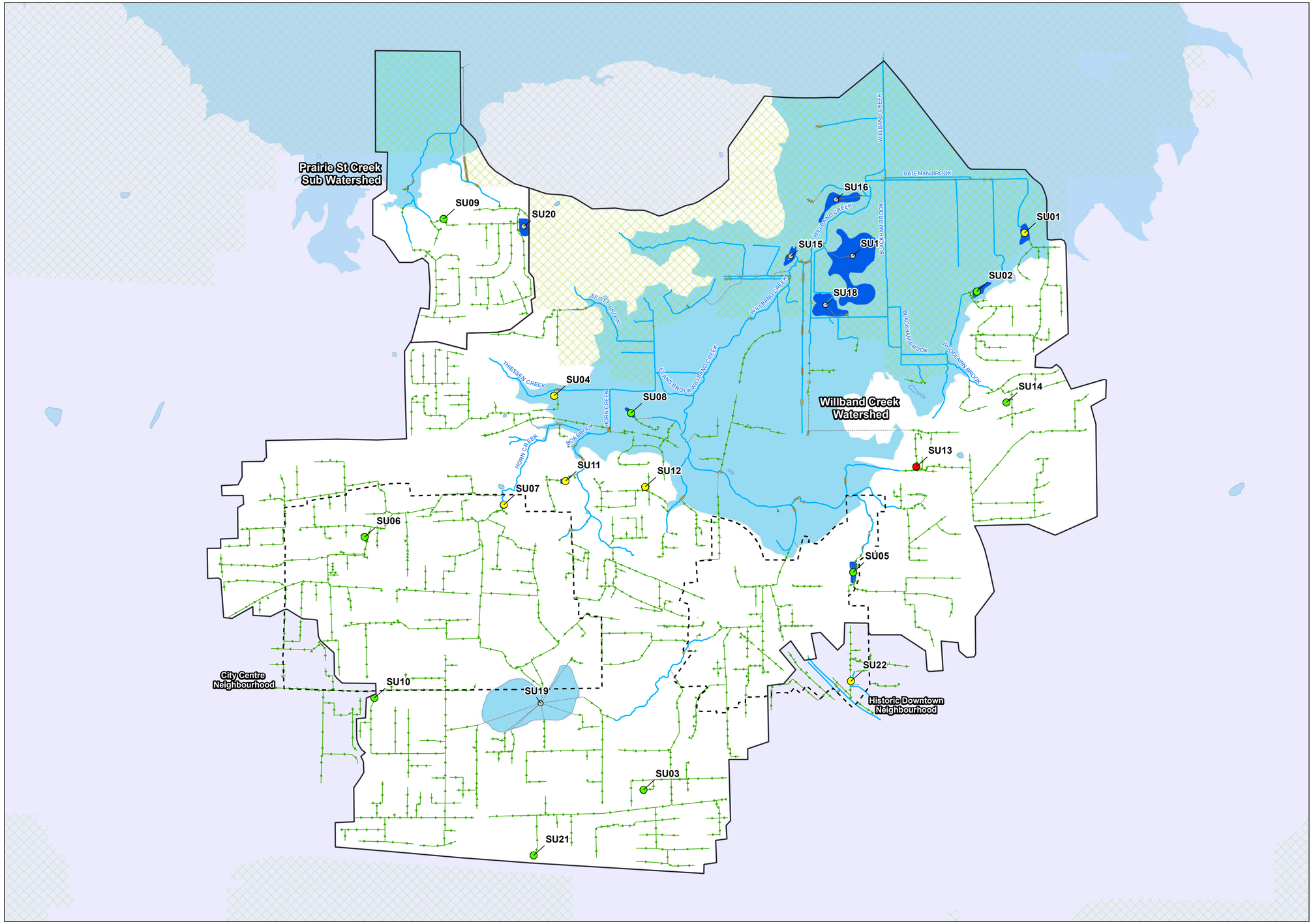
0 0.25 0.5 1
Kilometers

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

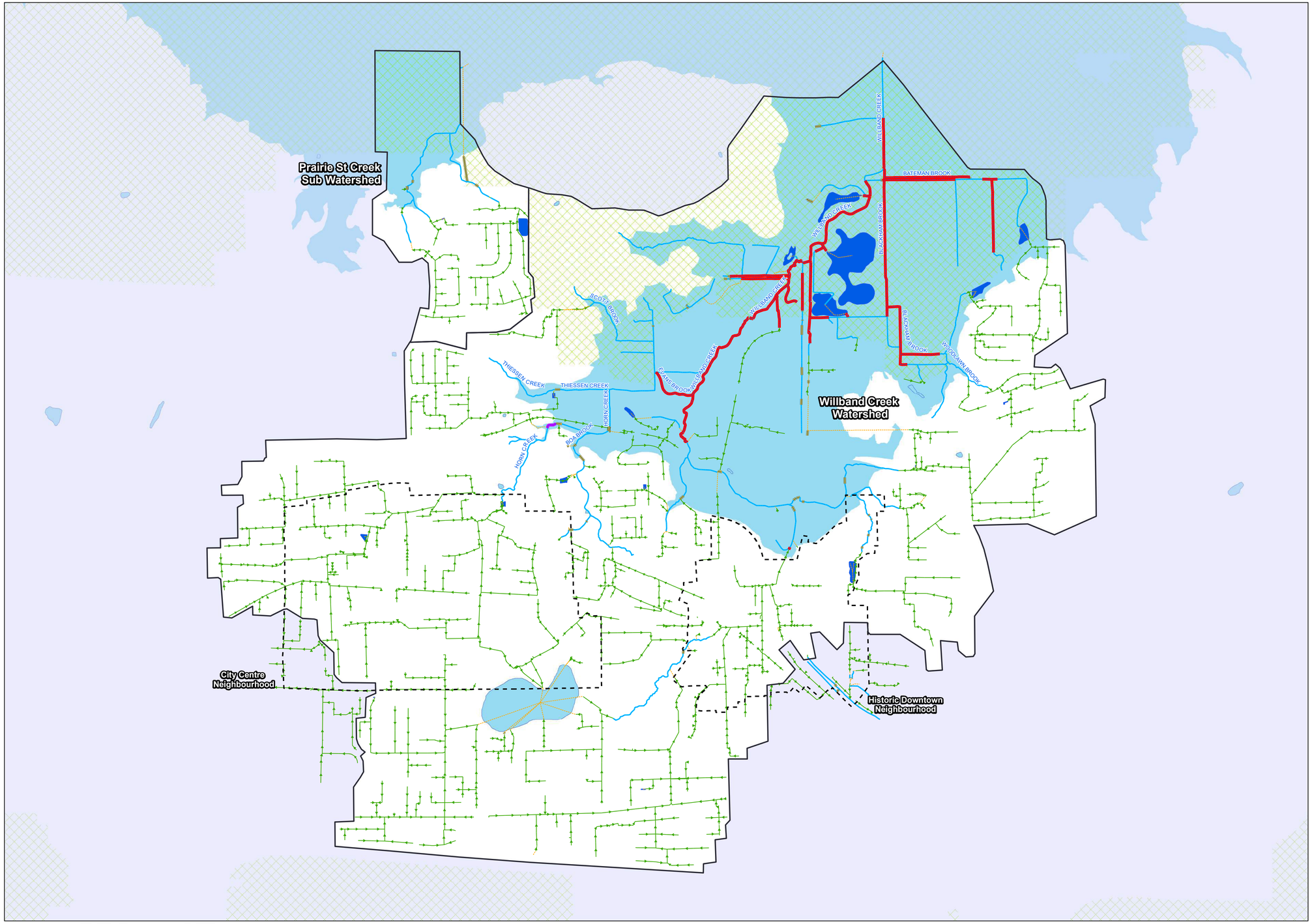
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

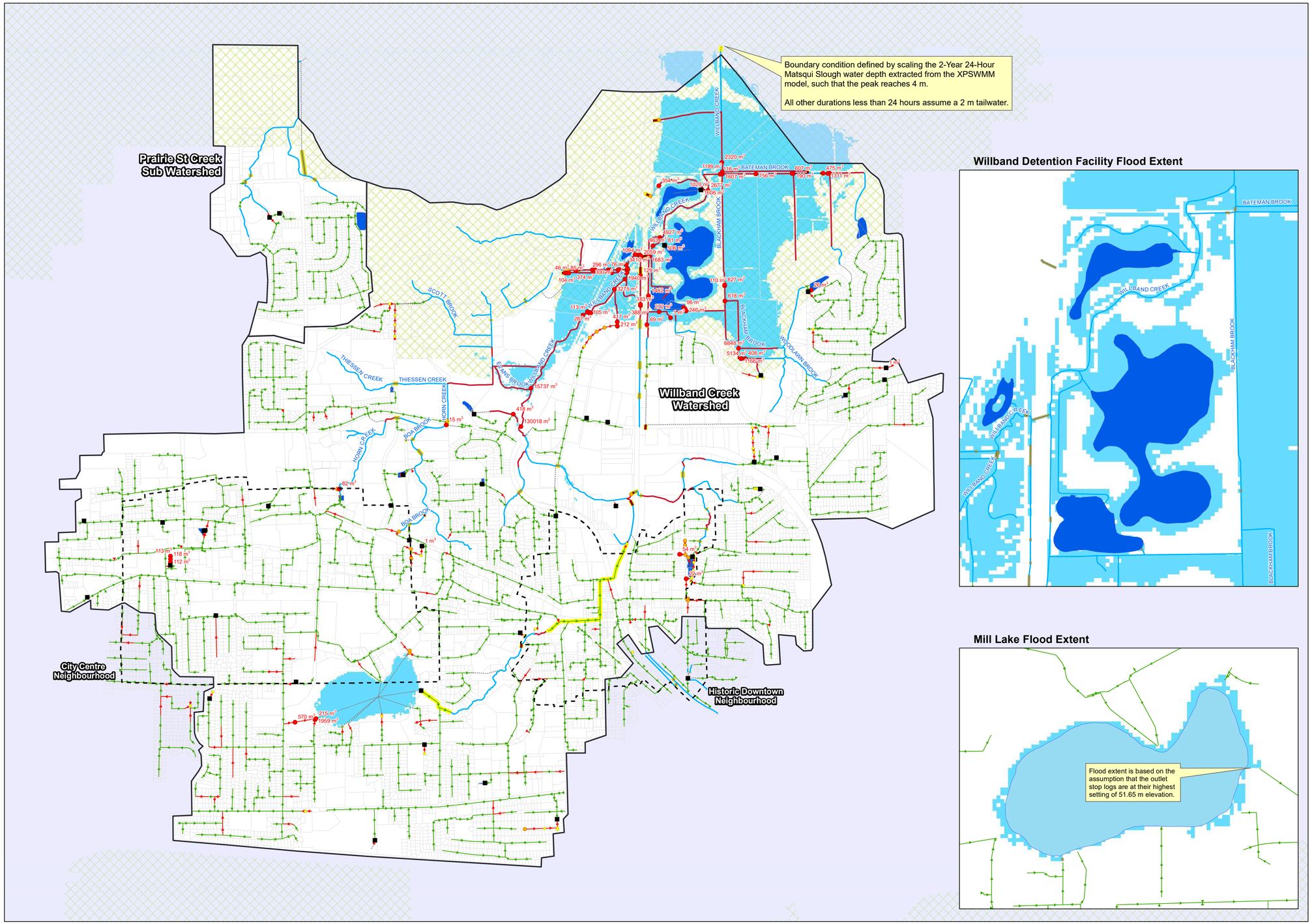
DISCLAIMER: GeoAdvice does not warrant in any way the accuracy and completeness of the information shown on this map. Field verification of the accuracy and completeness of the information shown on this map is the sole responsibility of the user.

0 0.25 0.5 1
Kilometers

N W E S

**Figure D.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

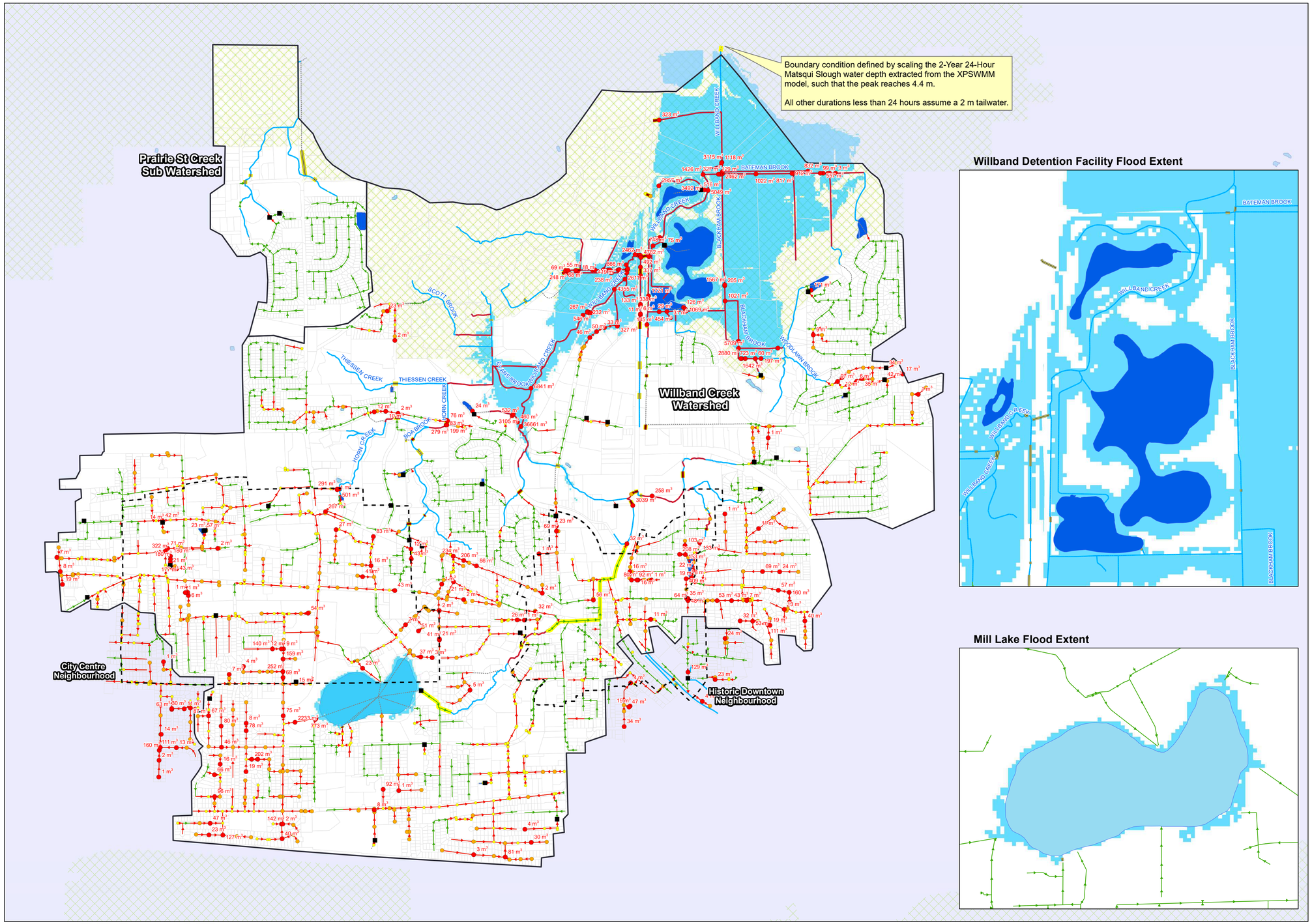
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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**




## Willband Detention Facility Flood Extent




## Mill Lake Flood Extent



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

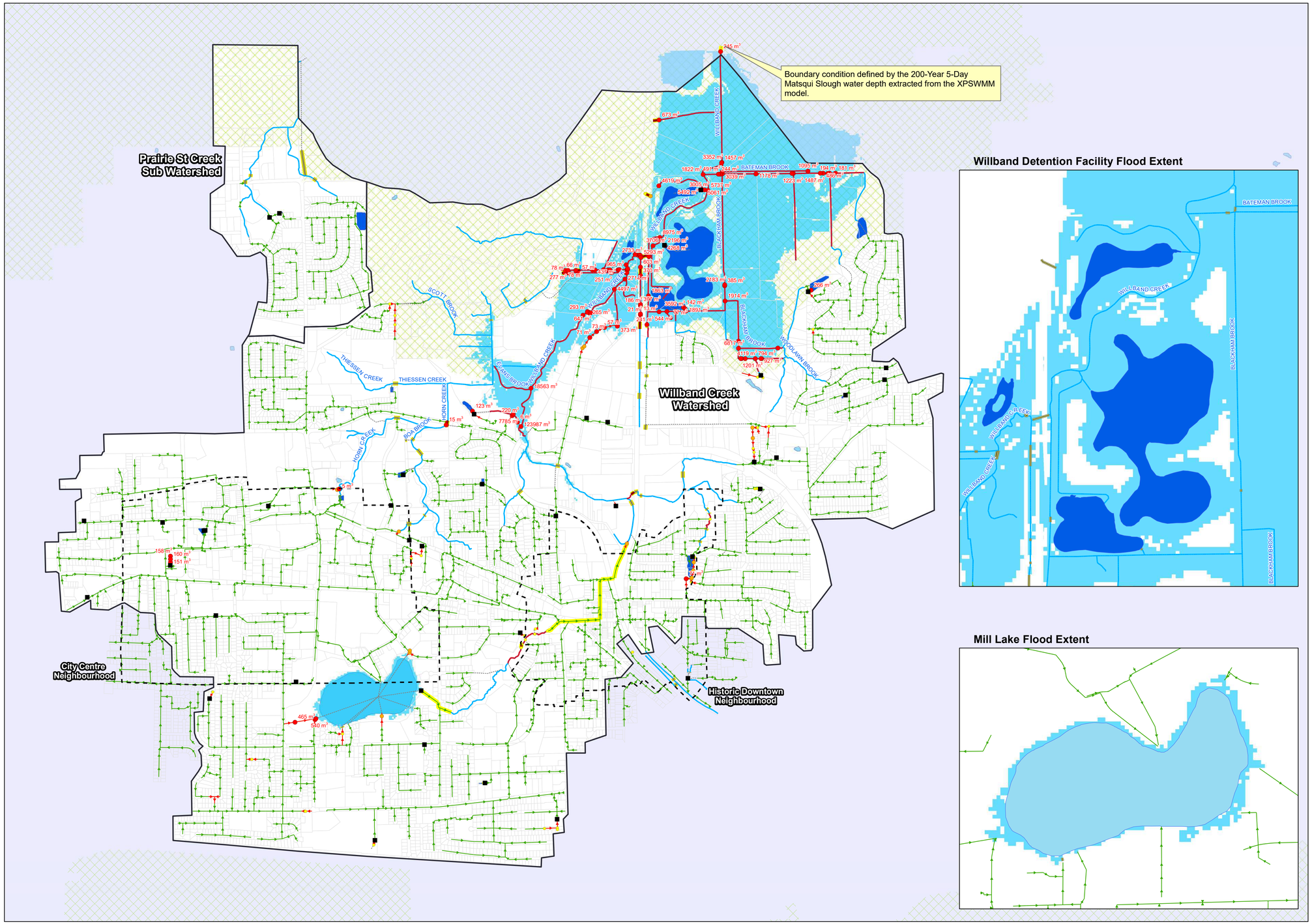
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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 Upgrades - No Controls) With Climate Change**

ABBOTSFORD

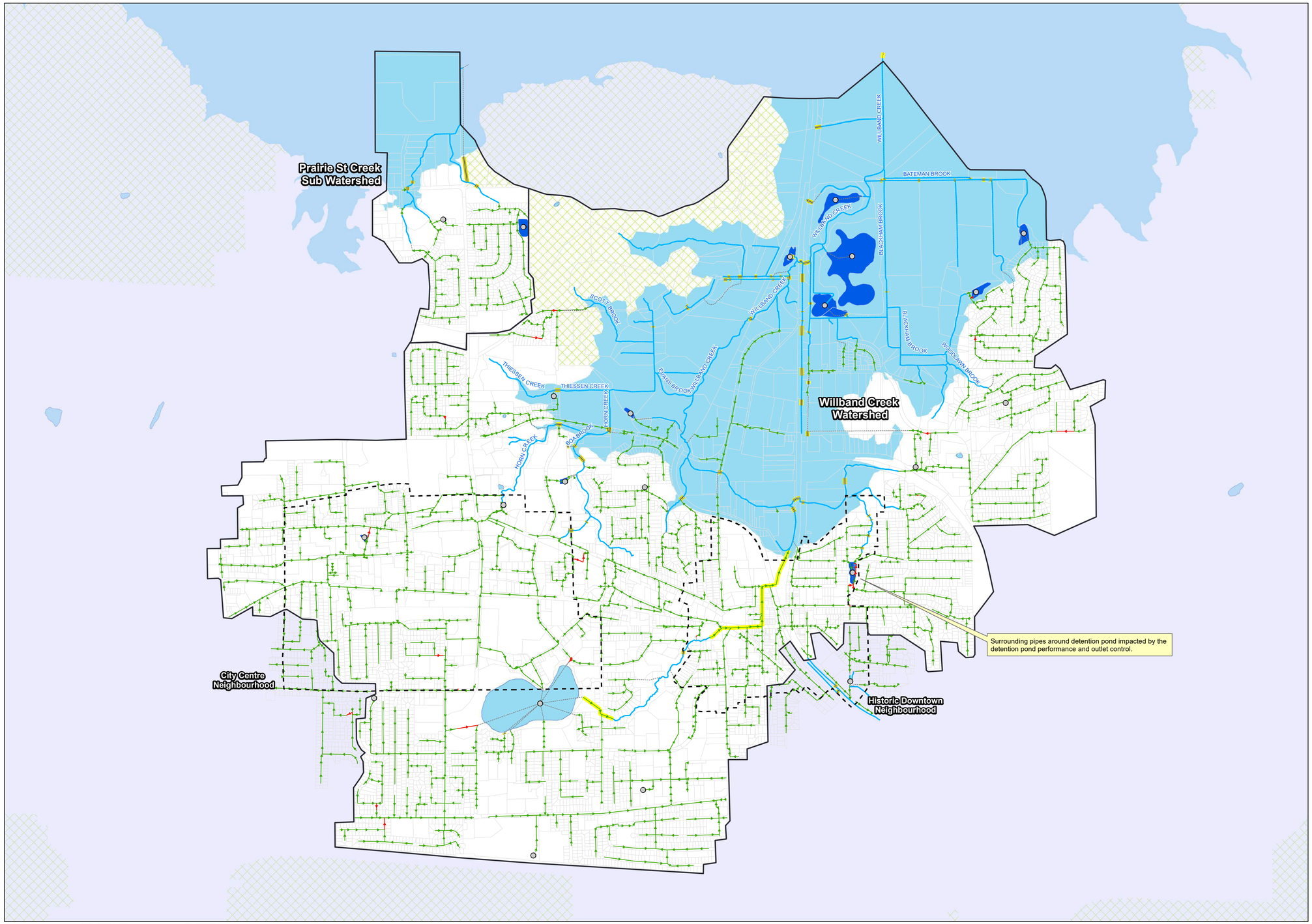
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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**

ABBOTSFORD

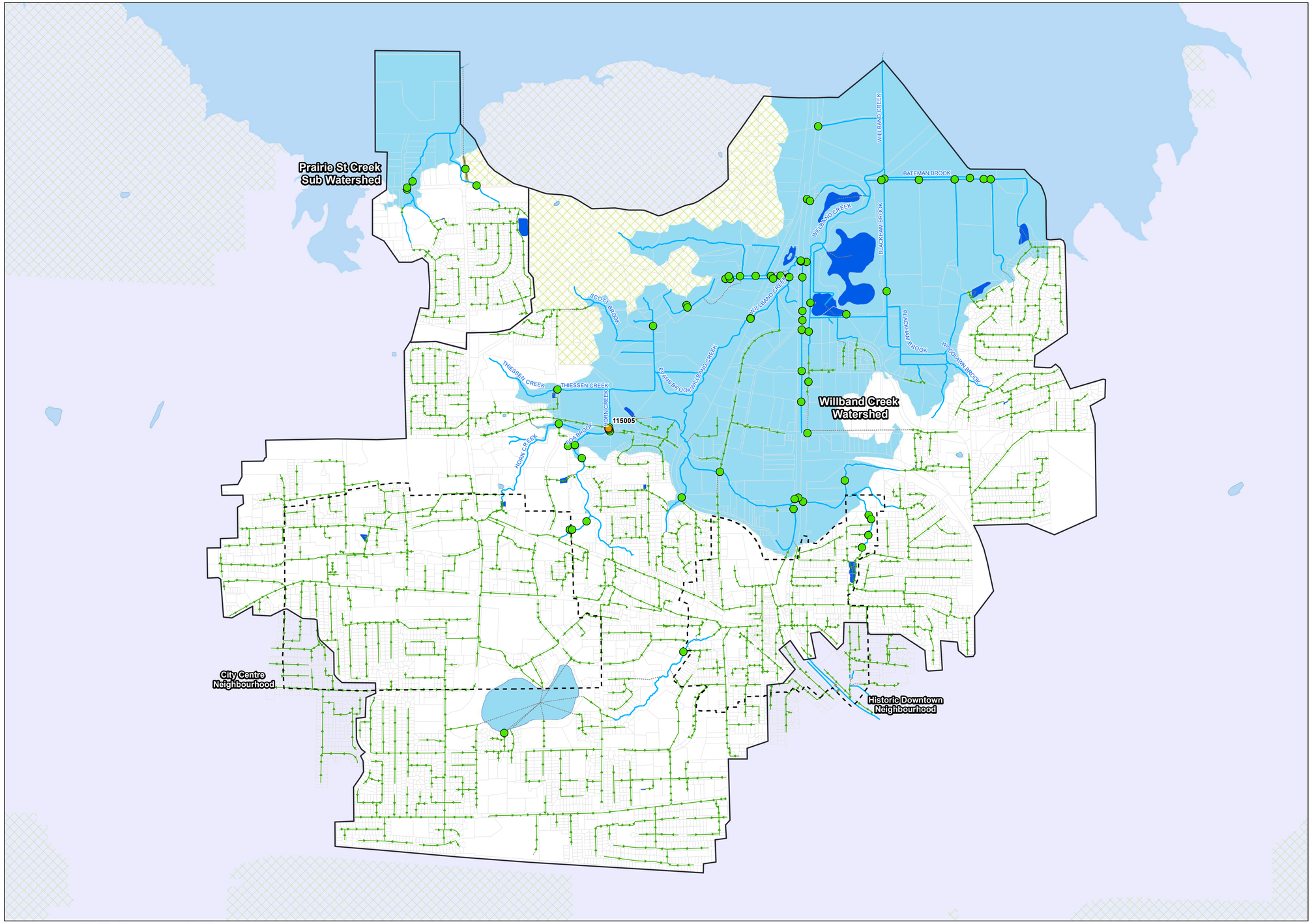
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

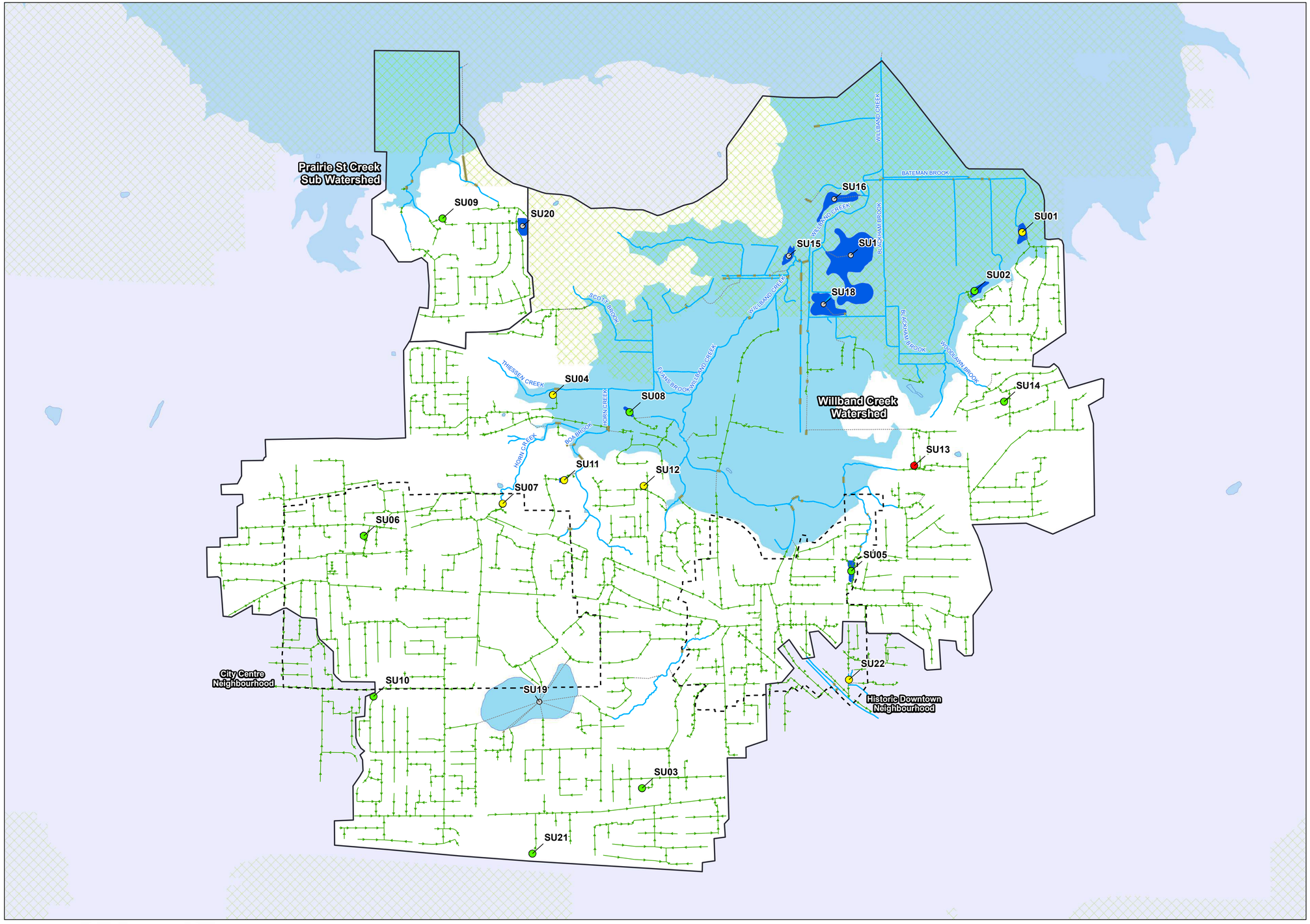
Project: Willband Creek Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

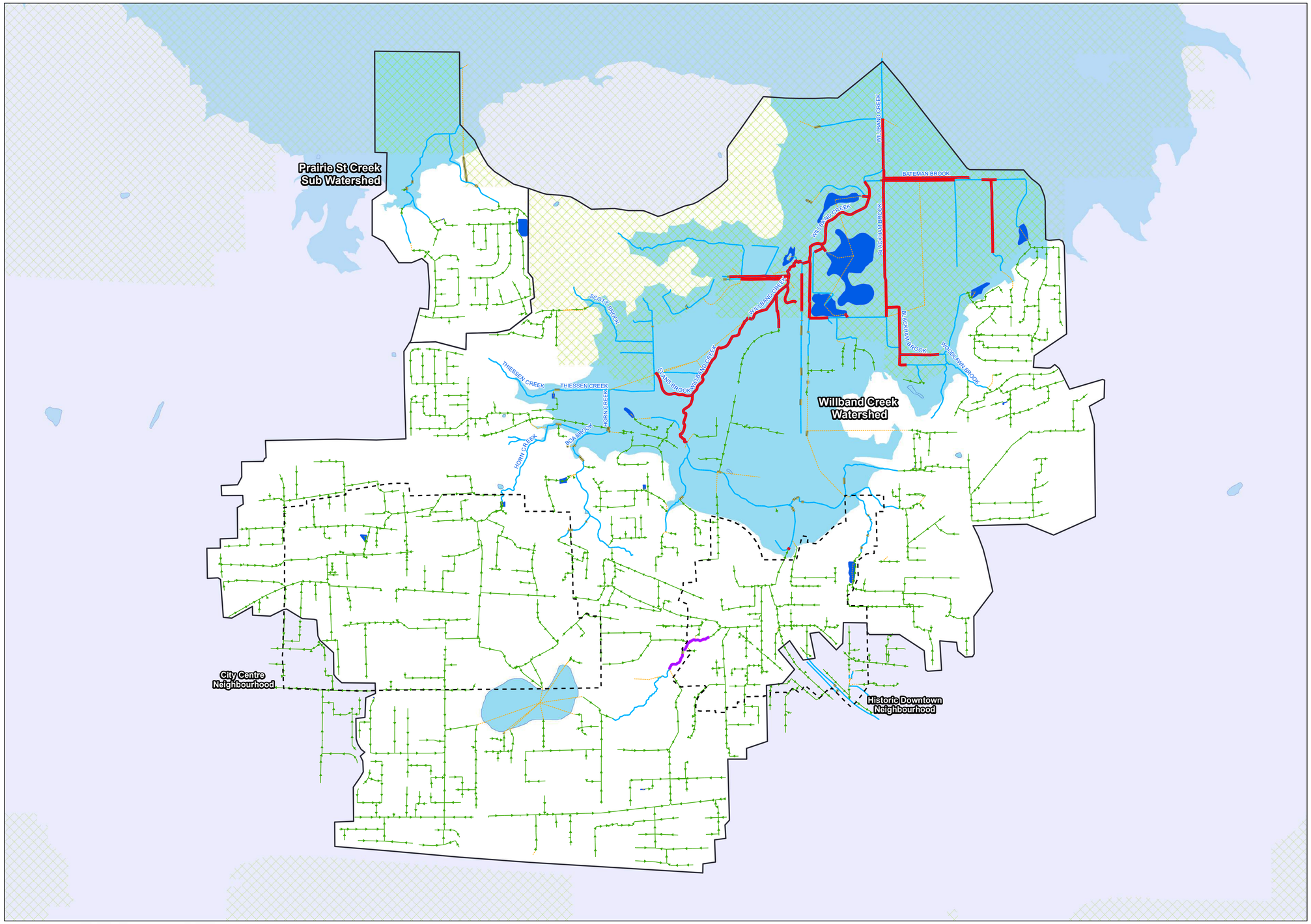
Project: Willband Creek
Integrated Stormwater Management Plan
Client: City of Abbotsford, BC
Date: July 2018
Created by: JH
Reviewed by: WdS

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.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

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.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) |

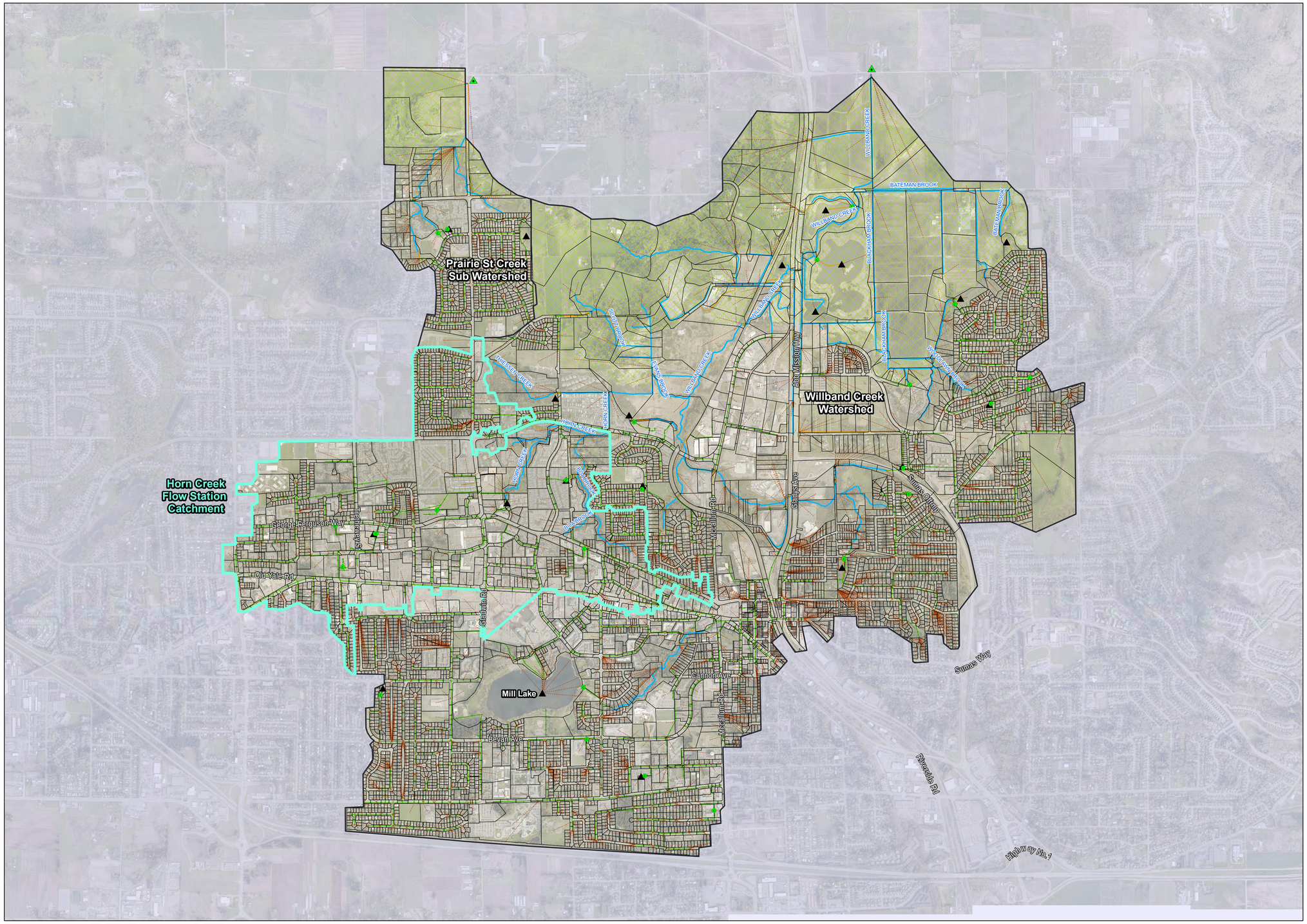
## 1. Introduction

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

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 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

**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.

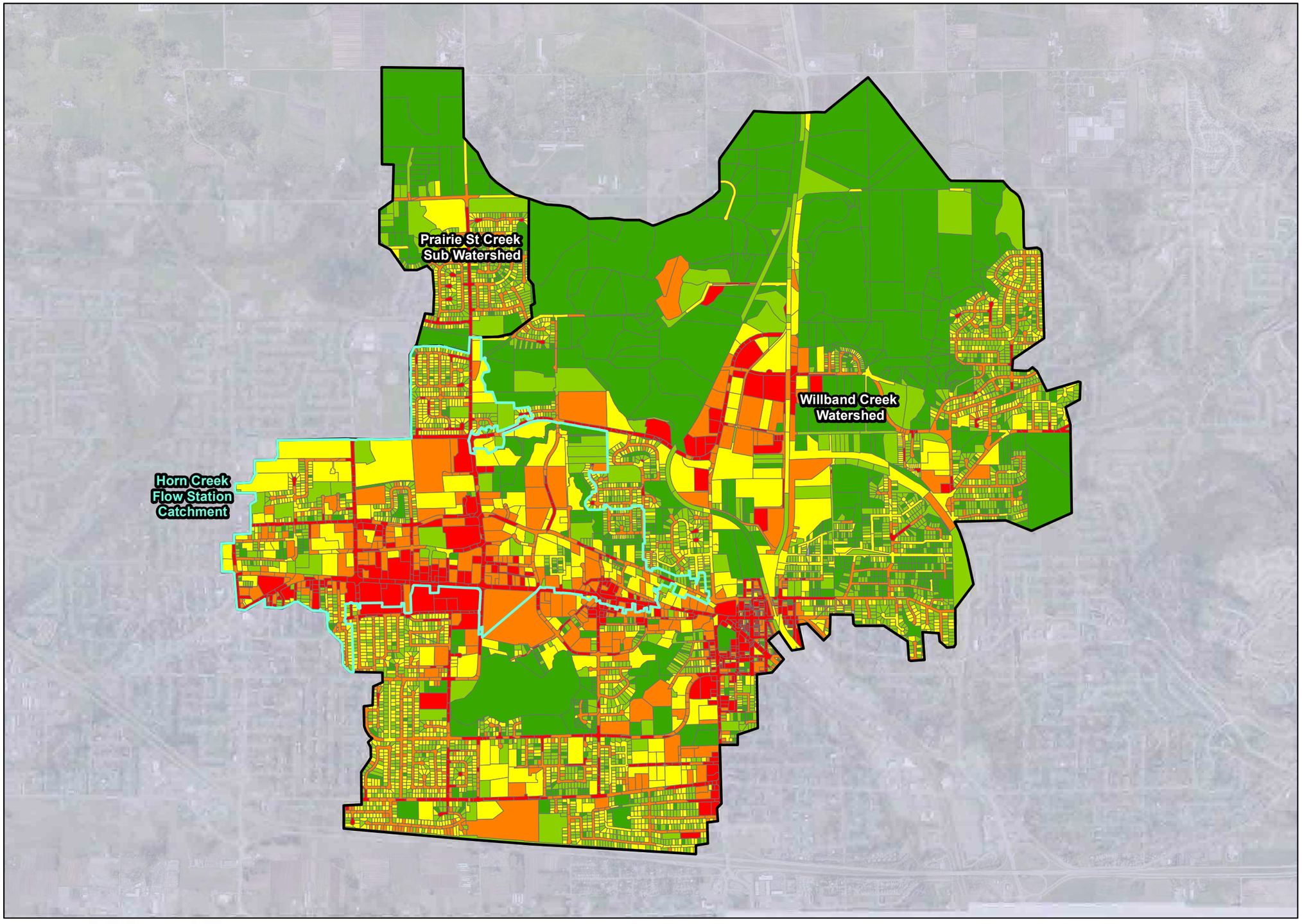
**Table 3.2: Soil Group Runoff and Infiltration Characteristics**

| 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

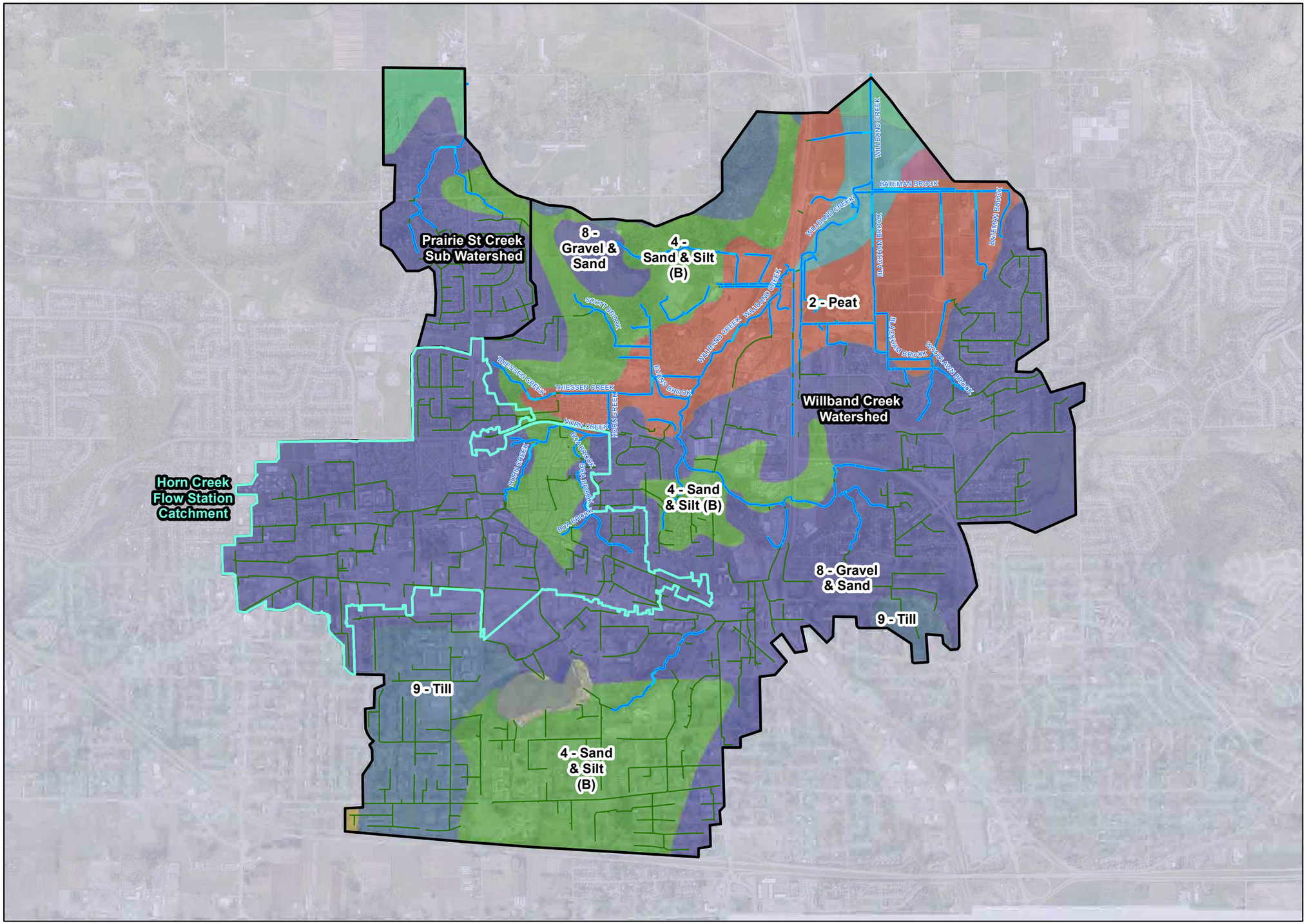
Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

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**




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**

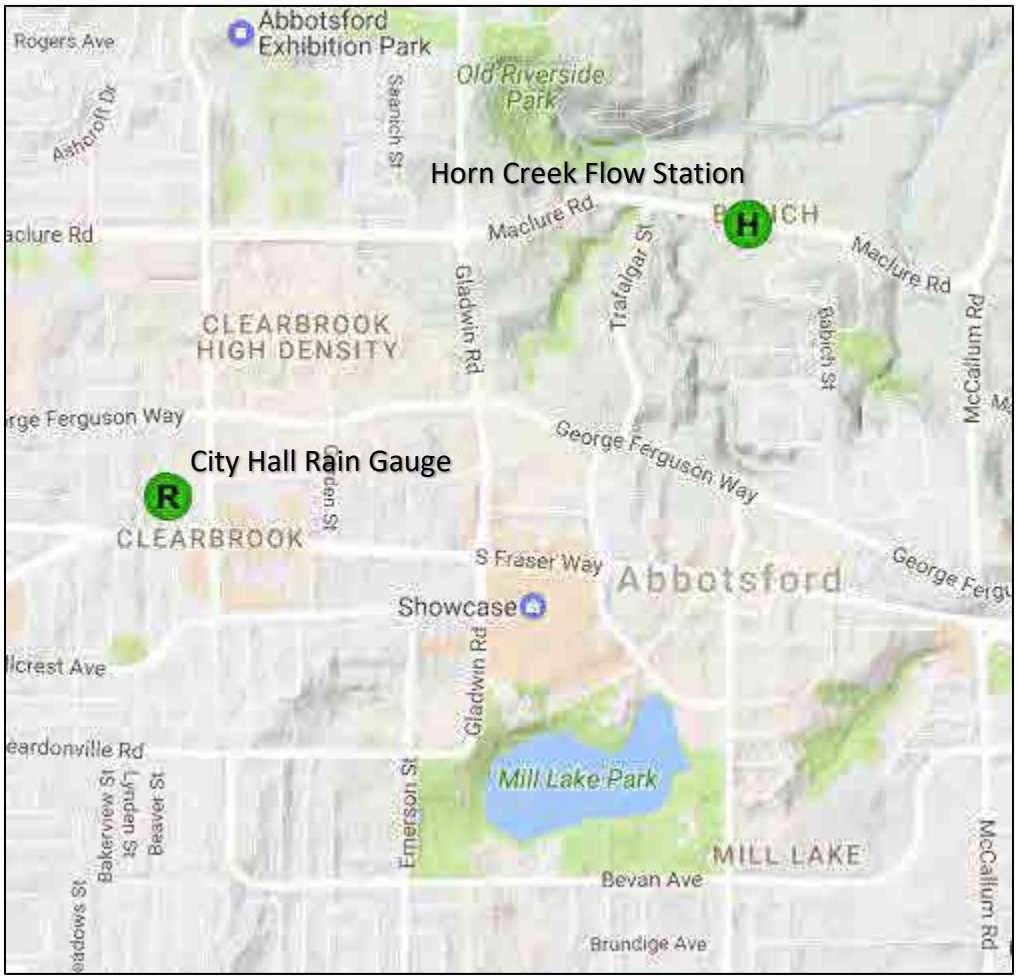



**Table 4.1: Calibration Storm Events (City Hall Rain Gauge)**

| 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**

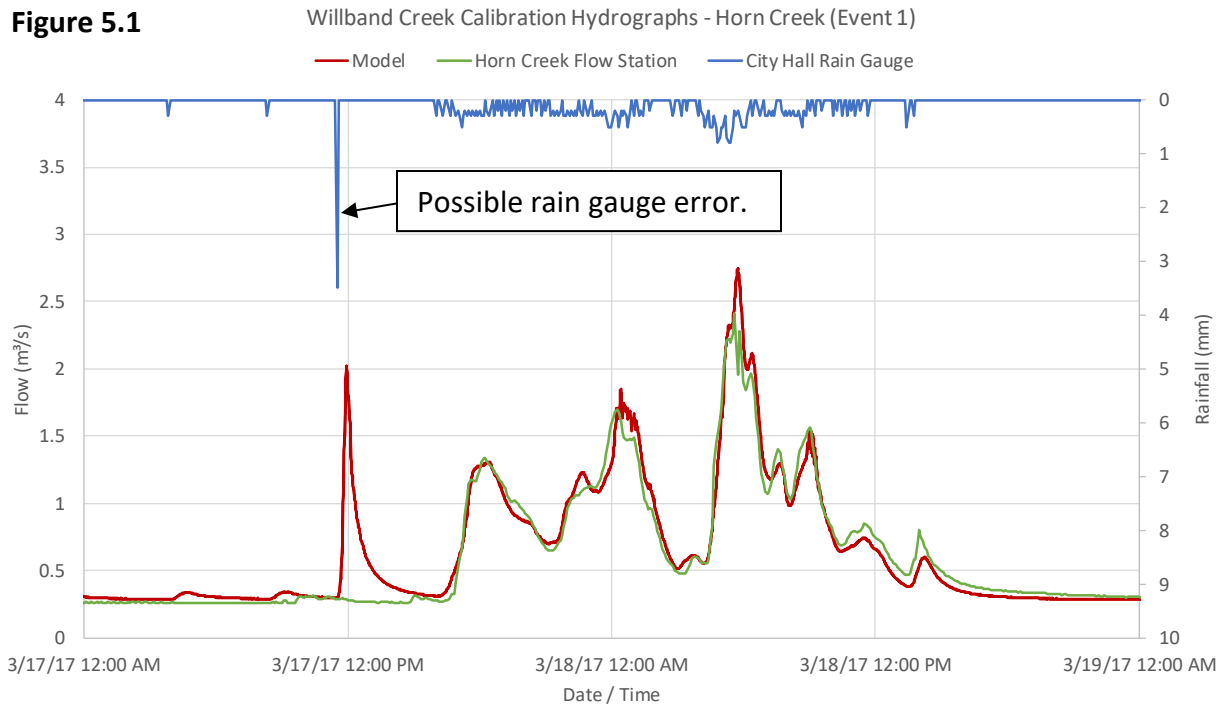



**Figure 5.2**

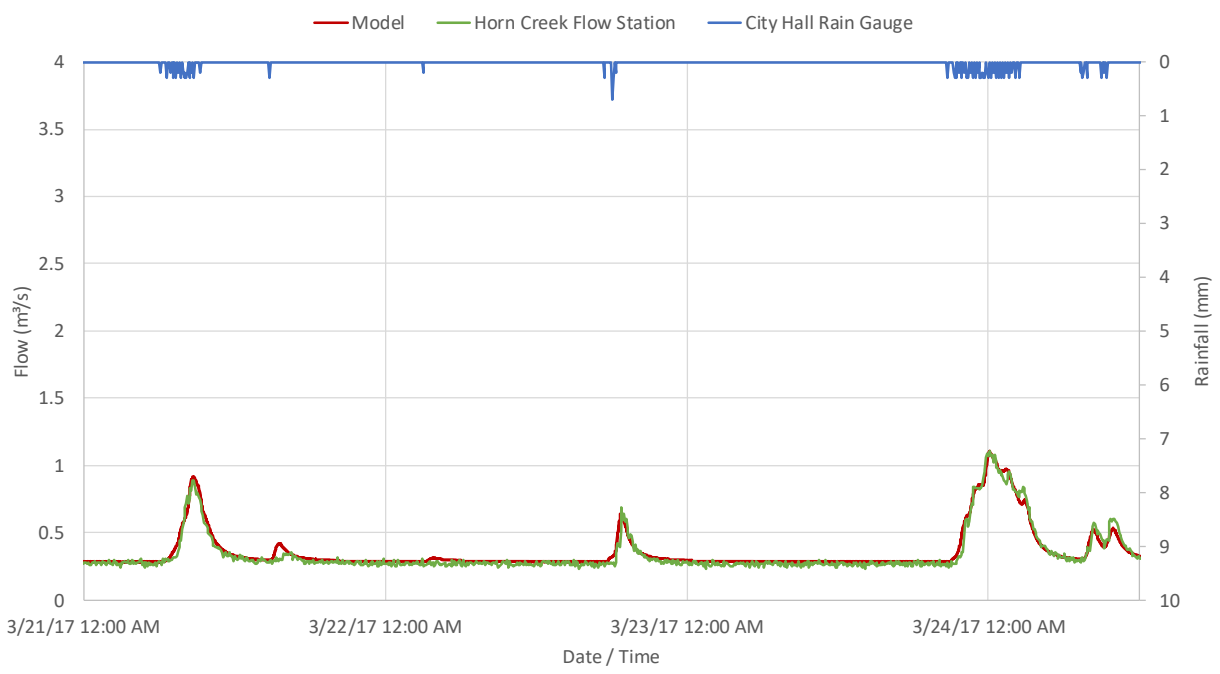


**Figure 5.3**

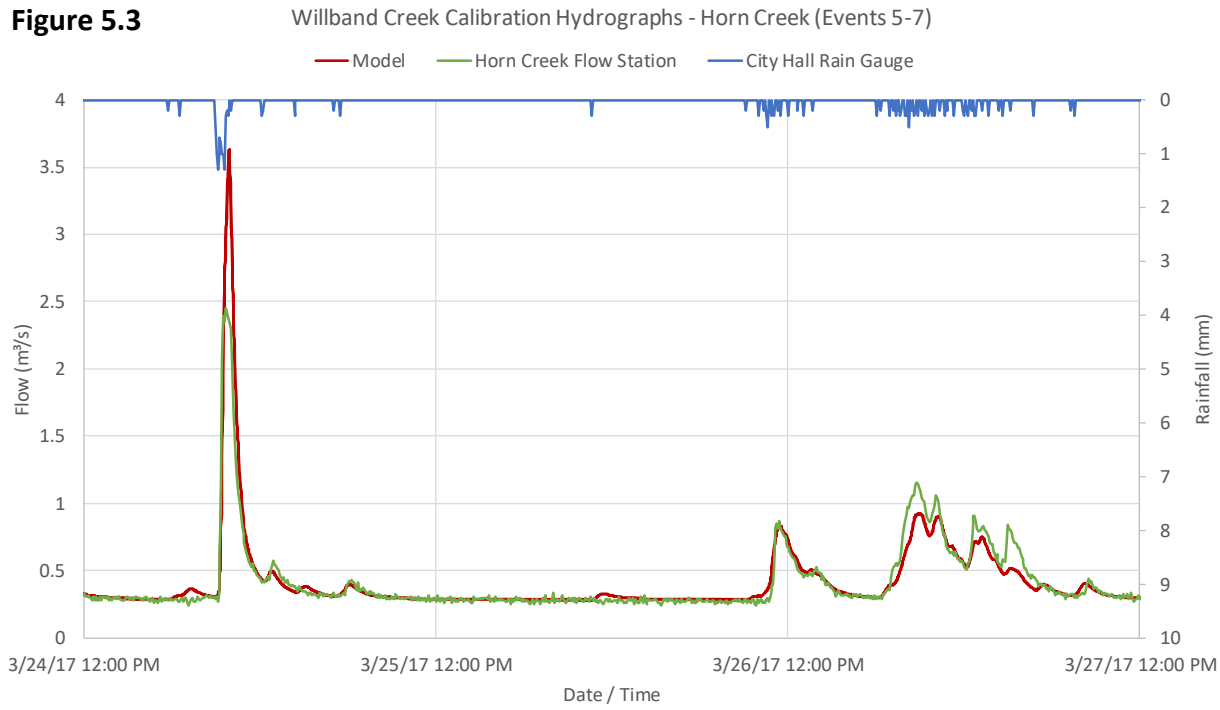



**Figure 5.4**

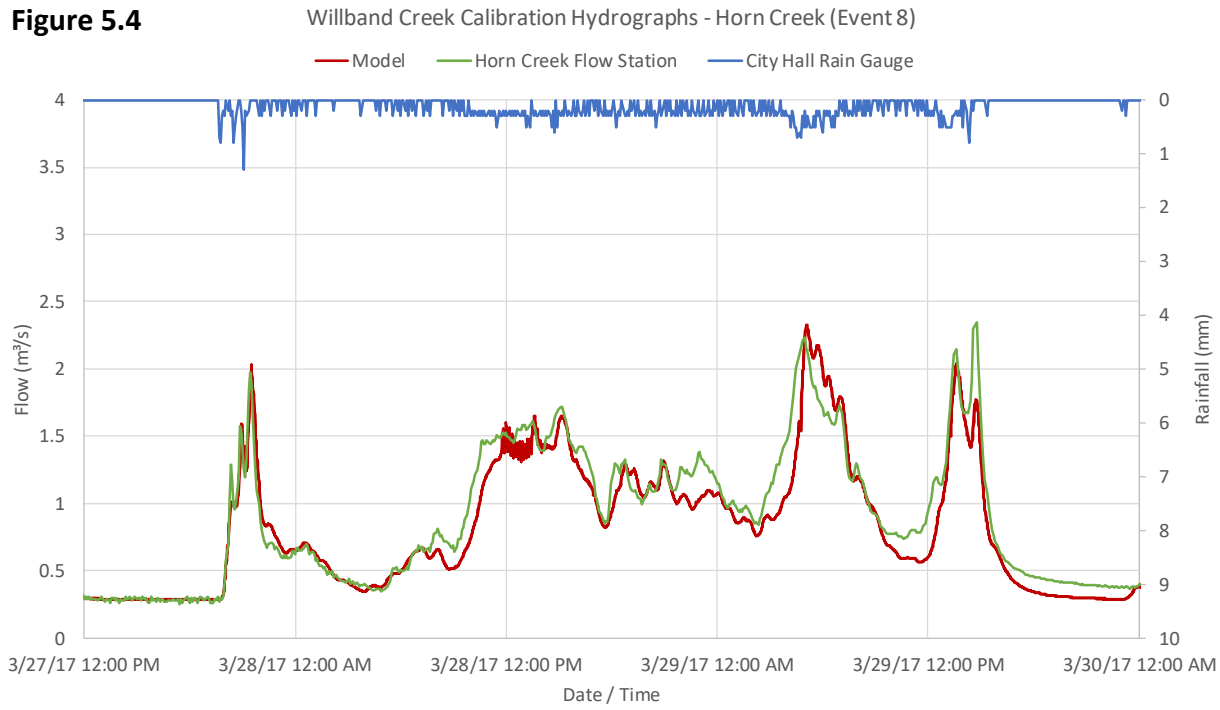
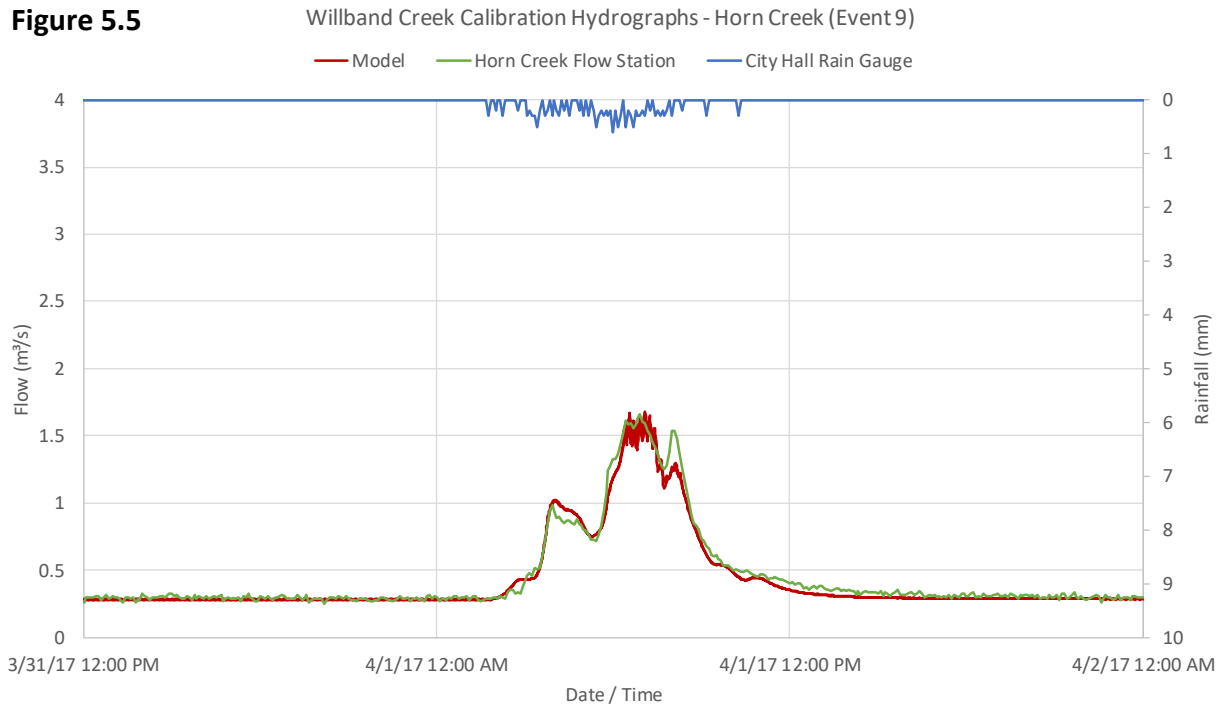


**Figure 5.5**




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

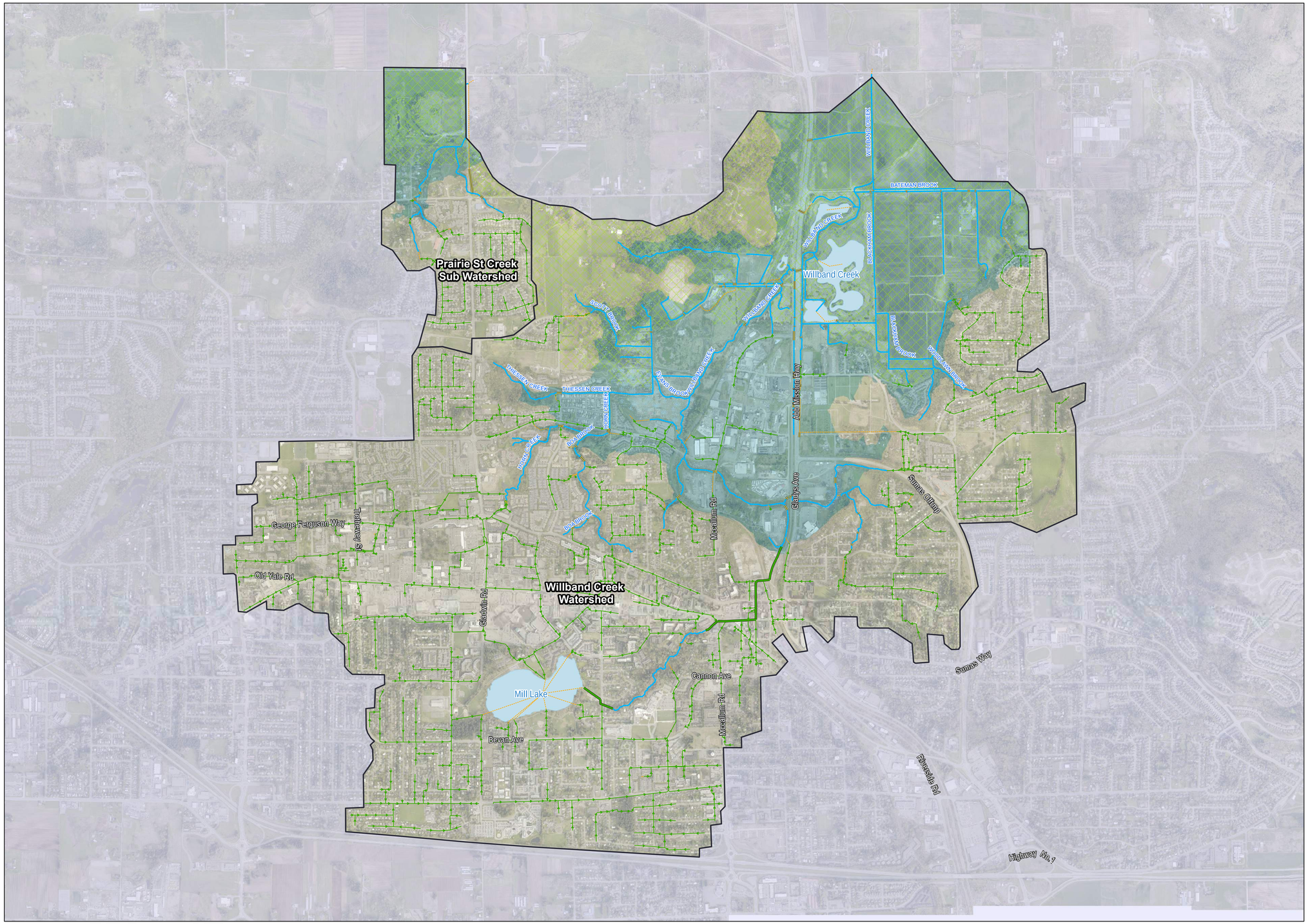
The creeks of the major system were assessed by simulating their ability to safely convey and contain the 2-year and 200-year flows. Creek capacity was assessed based on the following criteria:

- 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**

ABBOTSFORD

Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

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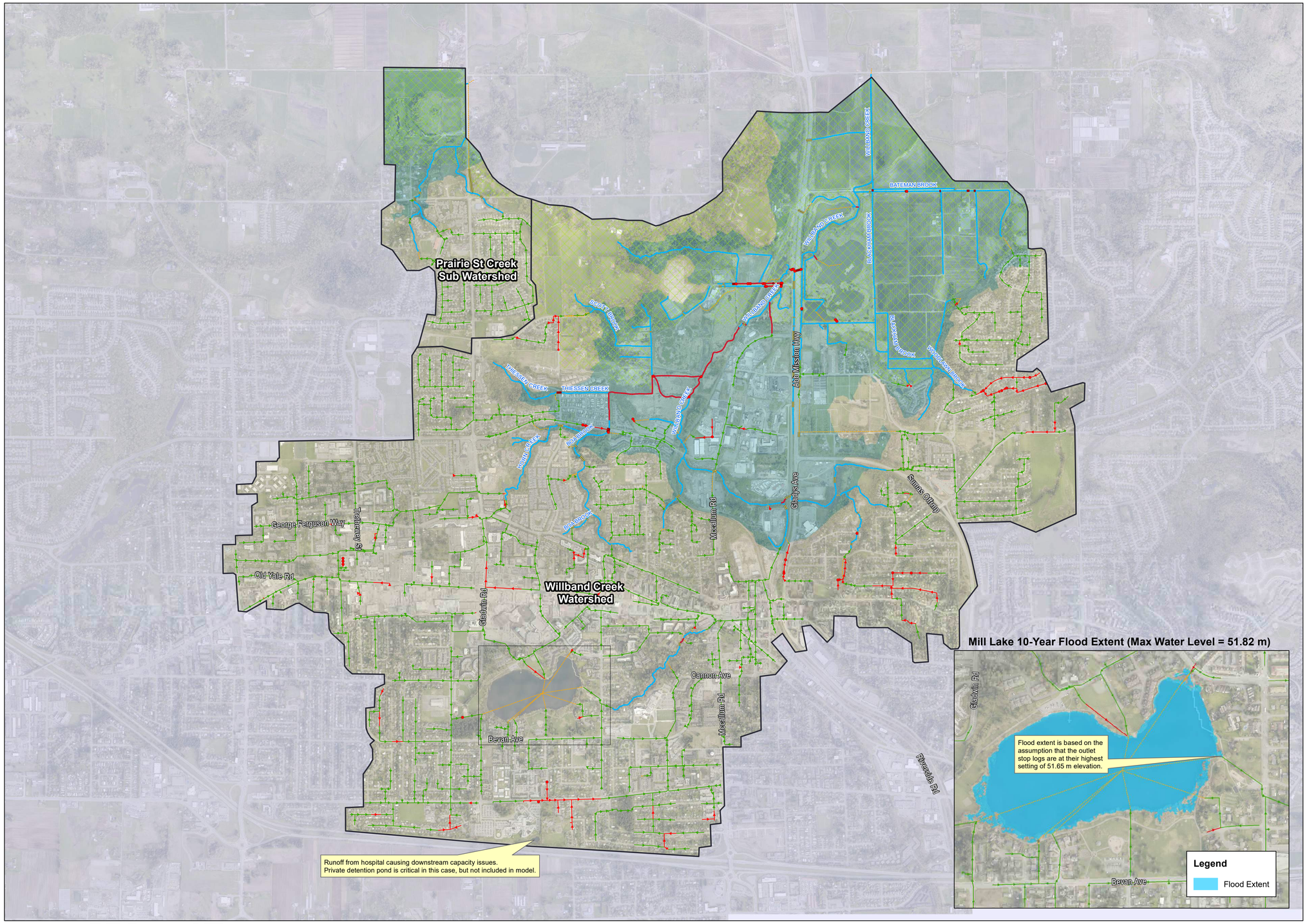
0 0.25 0.5 1
Kilometers

N W E S

**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

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Kilometers

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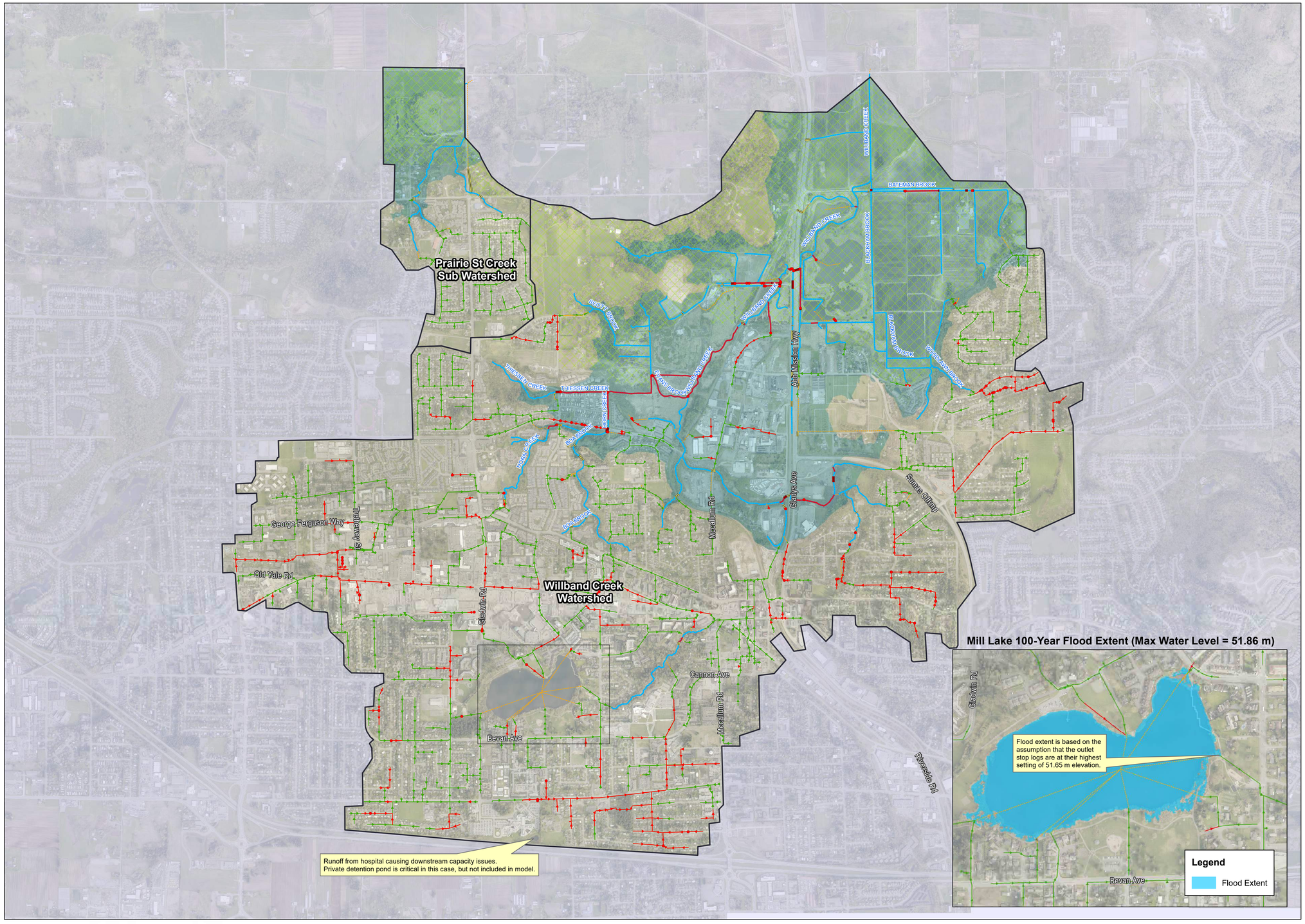
**Figure 6.2**




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

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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)**

Prairie St Creek Sub Watershed

Willband Creek Watershed

Runoff from hospital causing downstream capacity issues. Private detention pond is critical in this case, but not included in model.

Mill Lake 200-Year Flood Extent (Max Water Level = 51.87 m)

Flood extent is based on the assumption that the outlet stop logs are at their highest setting of 51.65 m elevation.

Legend: Flood Extent

Project: Willband Creek
Integrated Storm Water Management Plan
Client: City of Abbotsford, BC
Date: June 2017
Created by: JH
Reviewed by: WdS

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Kilometers

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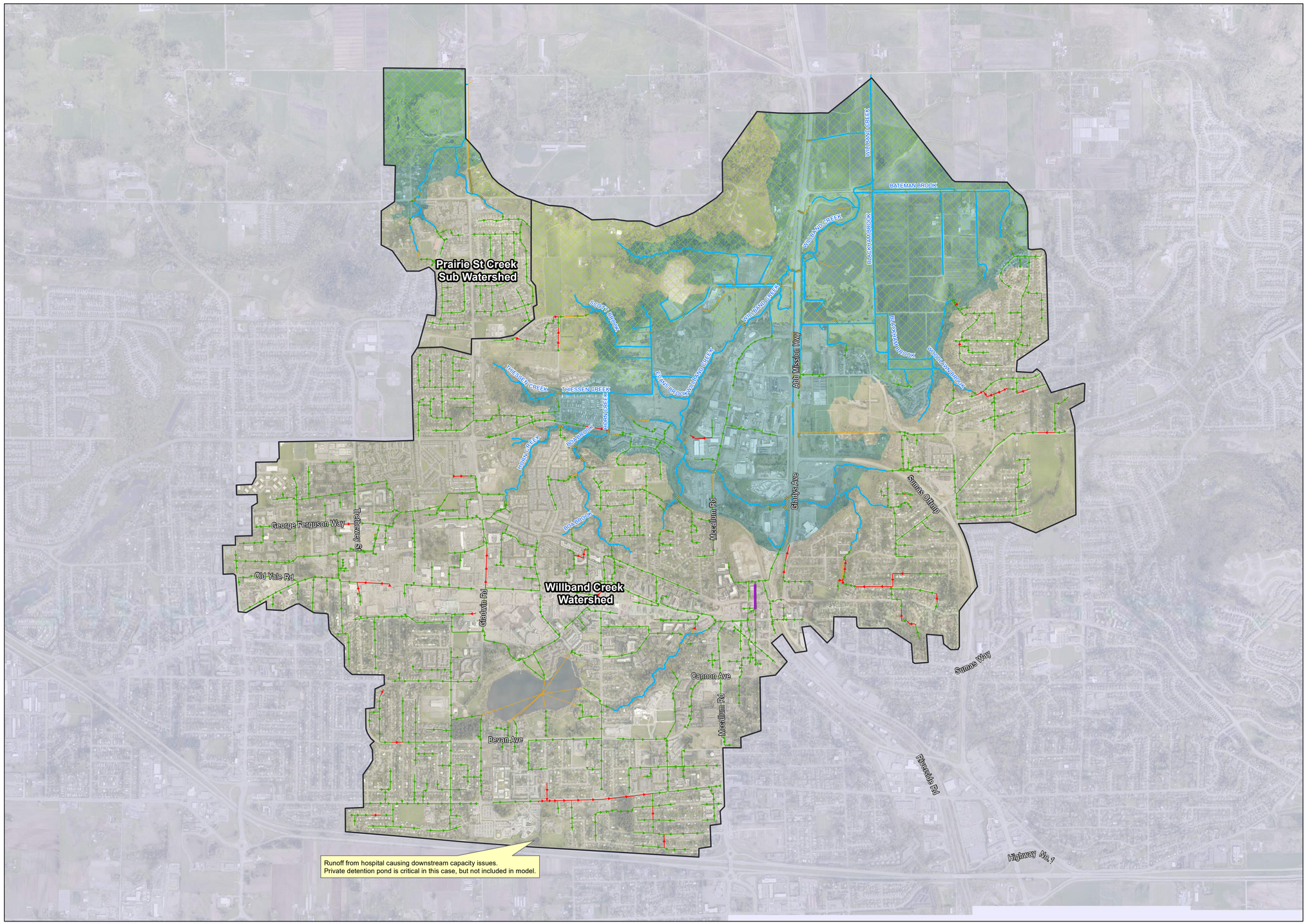
**Figure 6.4**




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

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Kilometers

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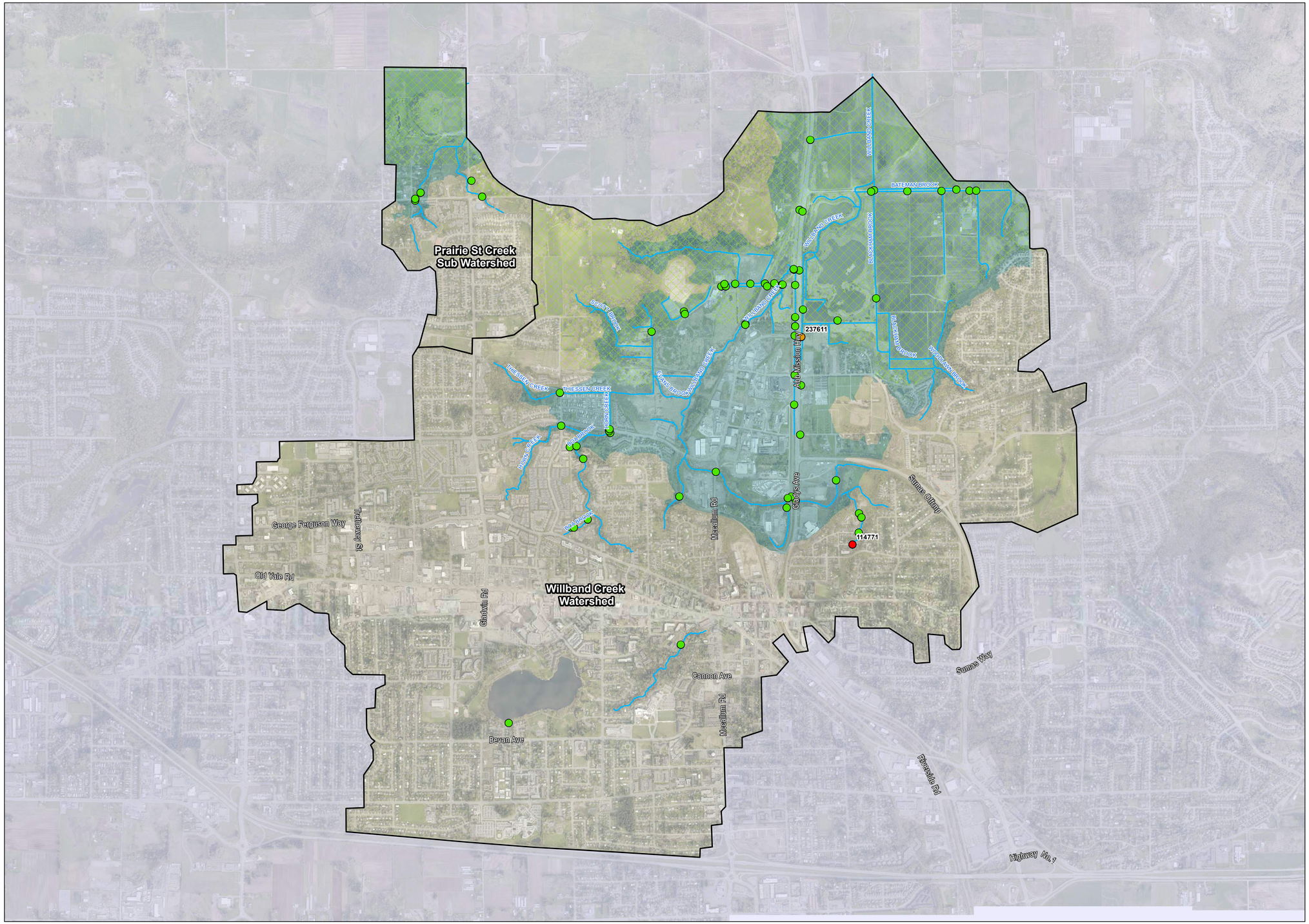
**Figure 6.5**




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
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Kilometers

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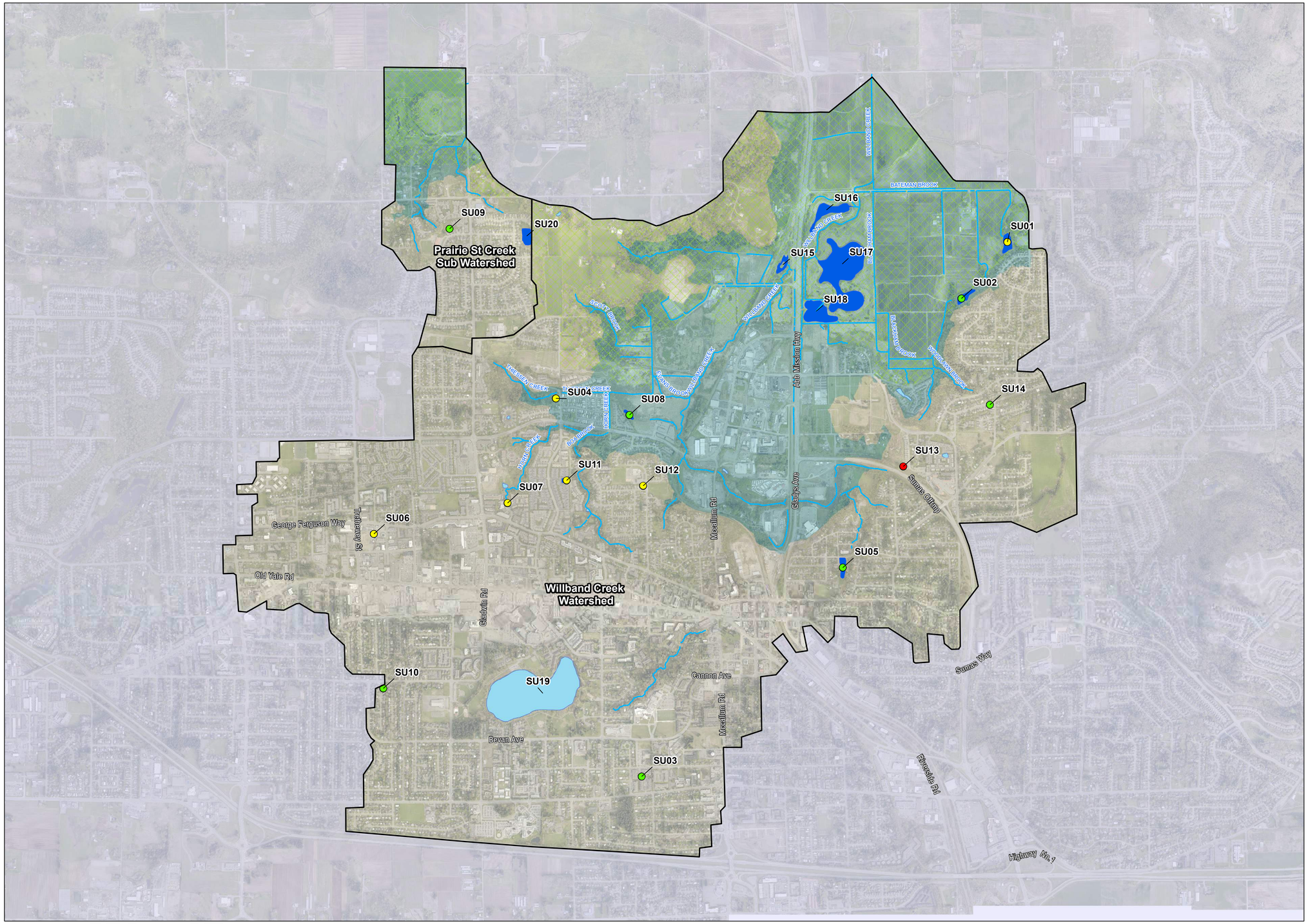
**Figure 6.6**




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

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Kilometers

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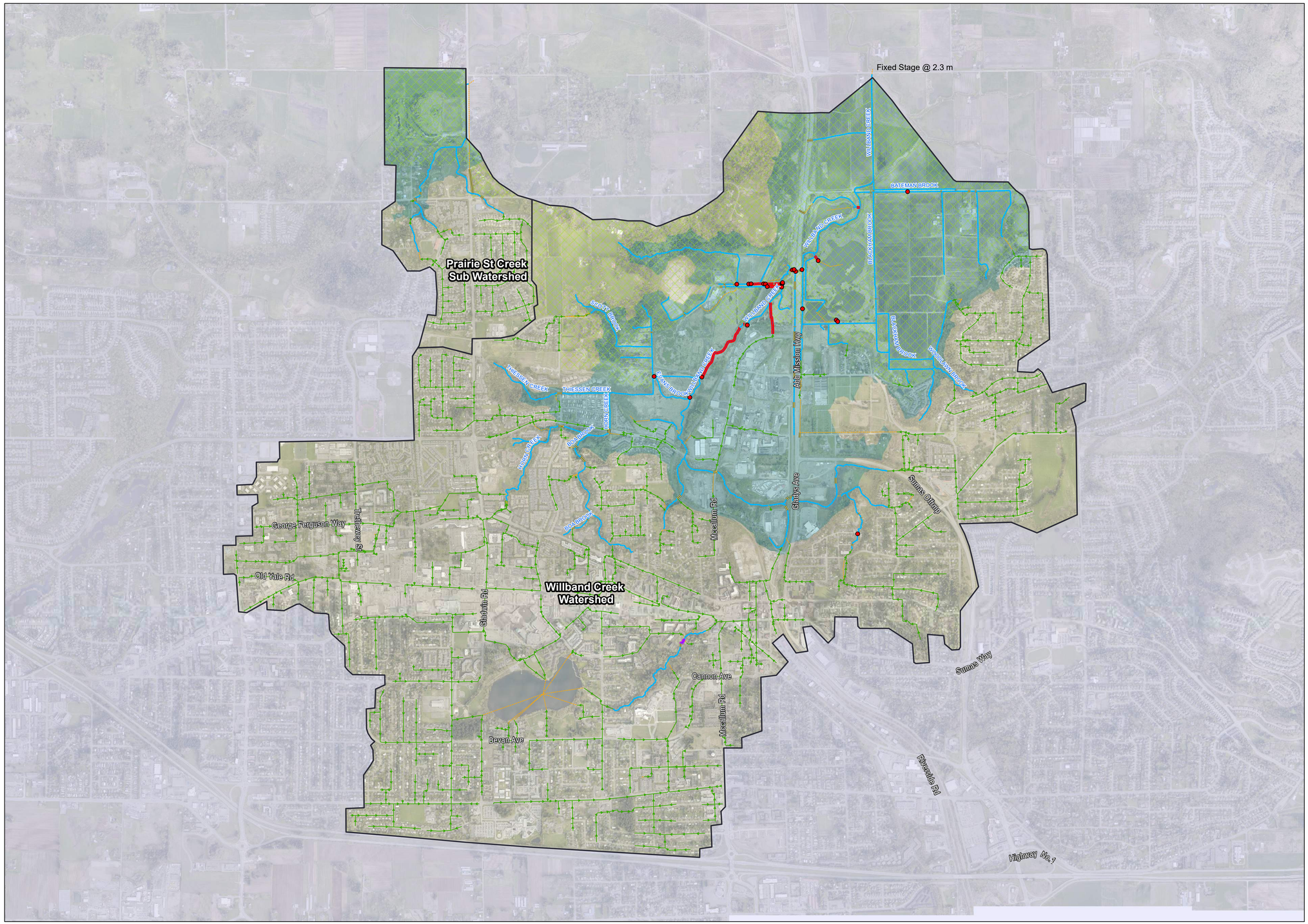
**Figure 6.7**

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## 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

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0 0.25 0.5 1
Kilometers

N W E S

**Figure 6.8**

# 7. Conclusion

Conclusions and recommendations have yet to be developed and will be incorporated into the Phase 2 technical memorandum.

## Submission

**Prepared by:**

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Water Resources Engineer

Chuck Linders
Project Manager

**Reviewed and Approved by:**

Werner de Schaetzen, Ph.D., P.Eng.
Senior Modeling Review

*Enclosed:*

*Appendix A – Detention Facility Storage Curves*

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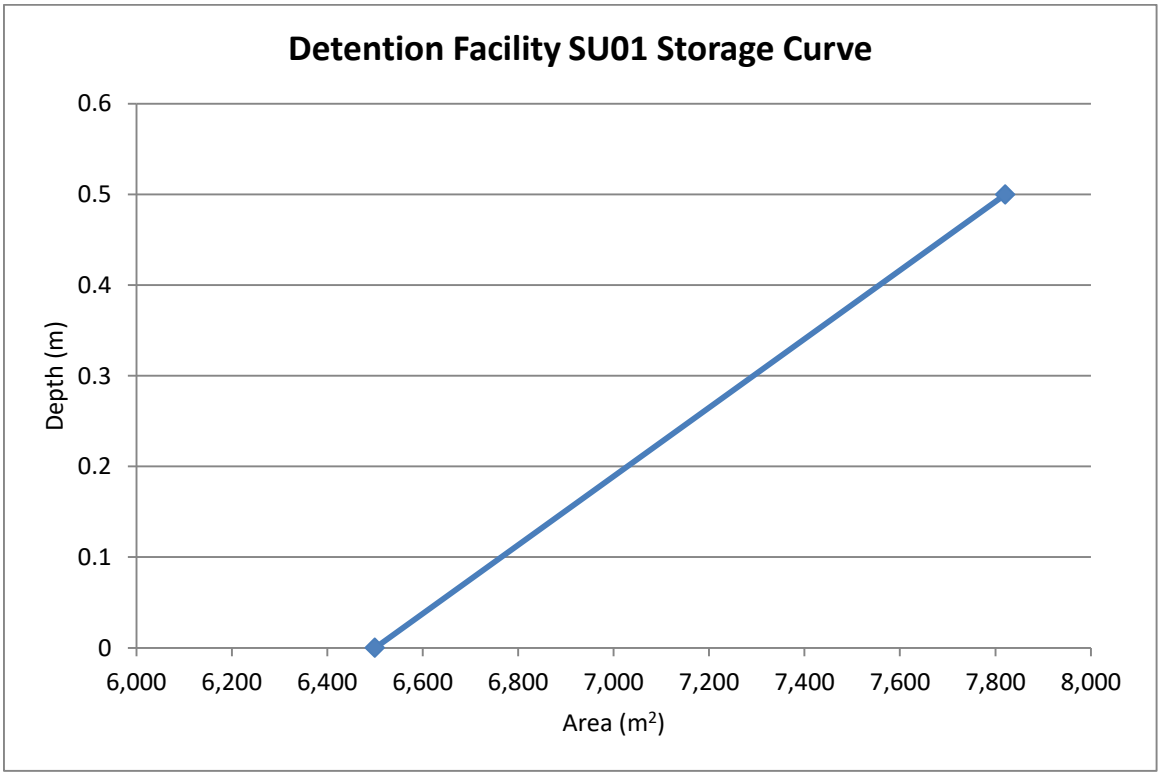
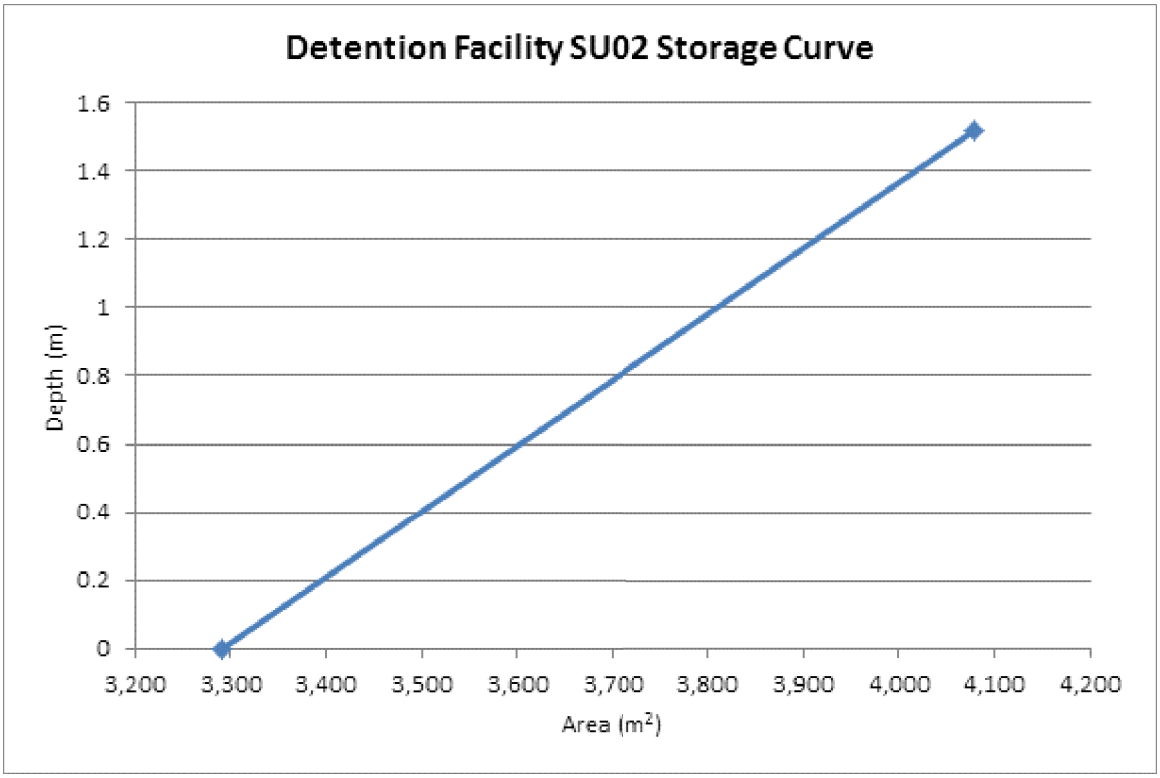
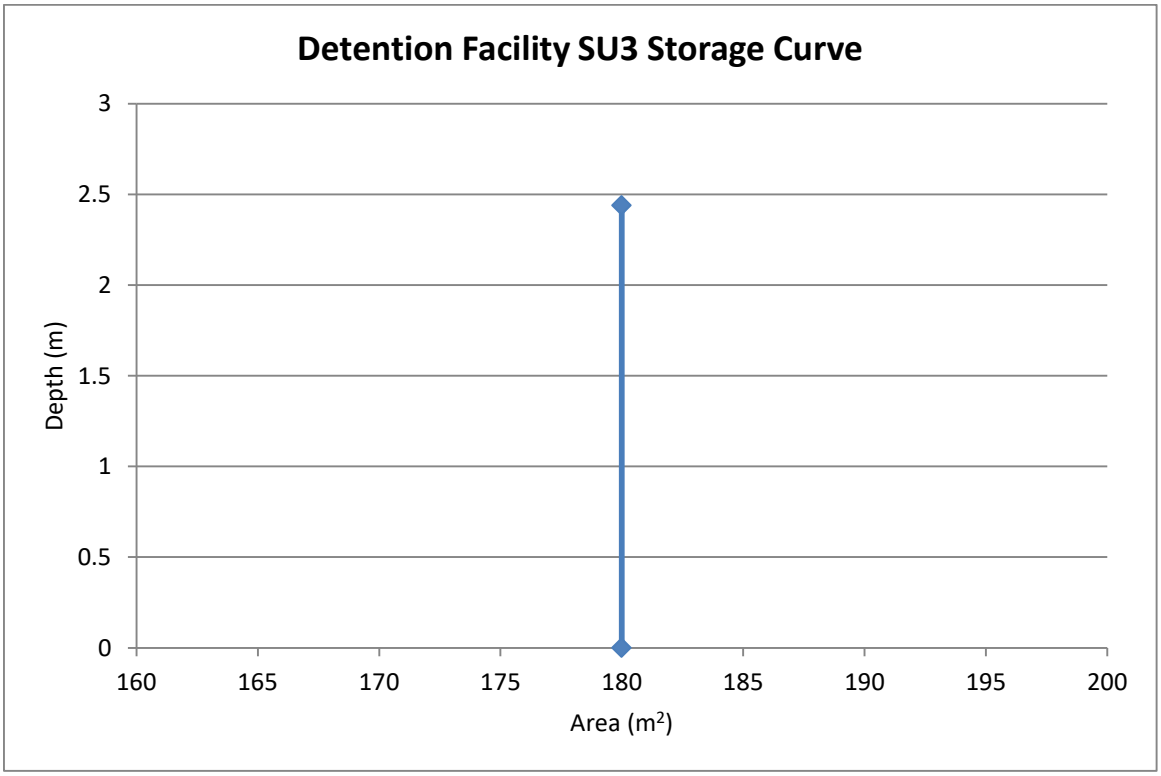
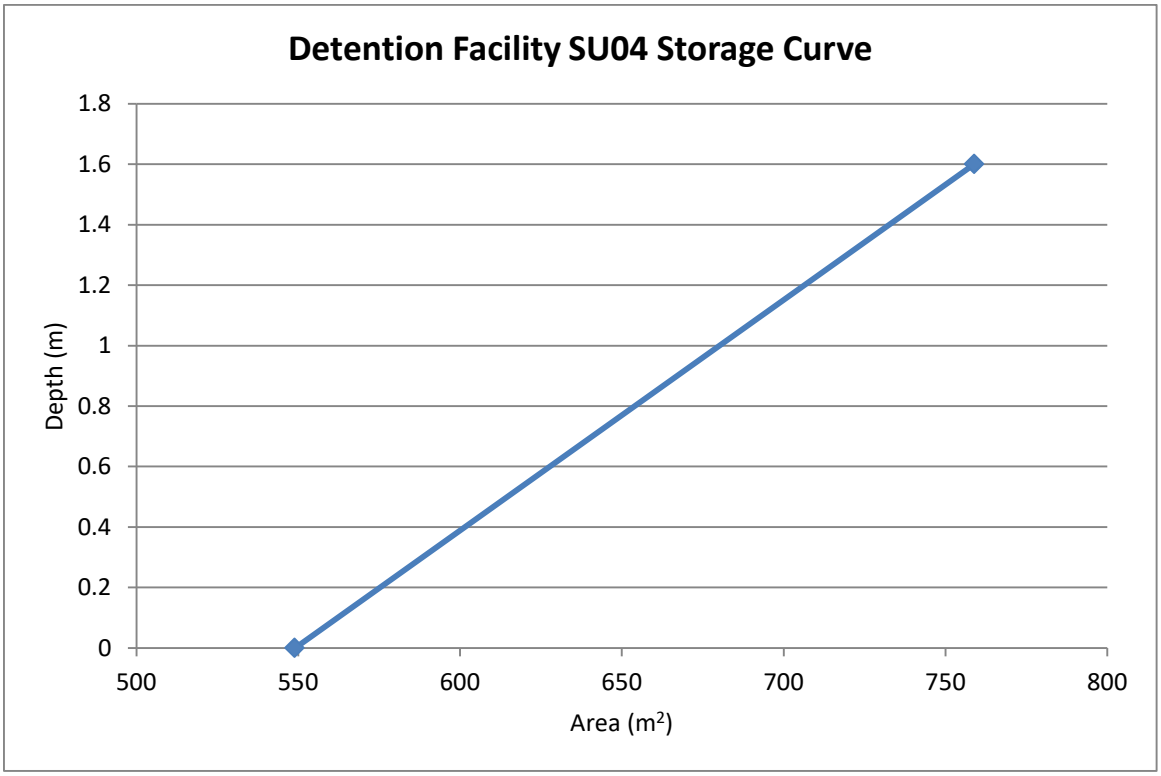
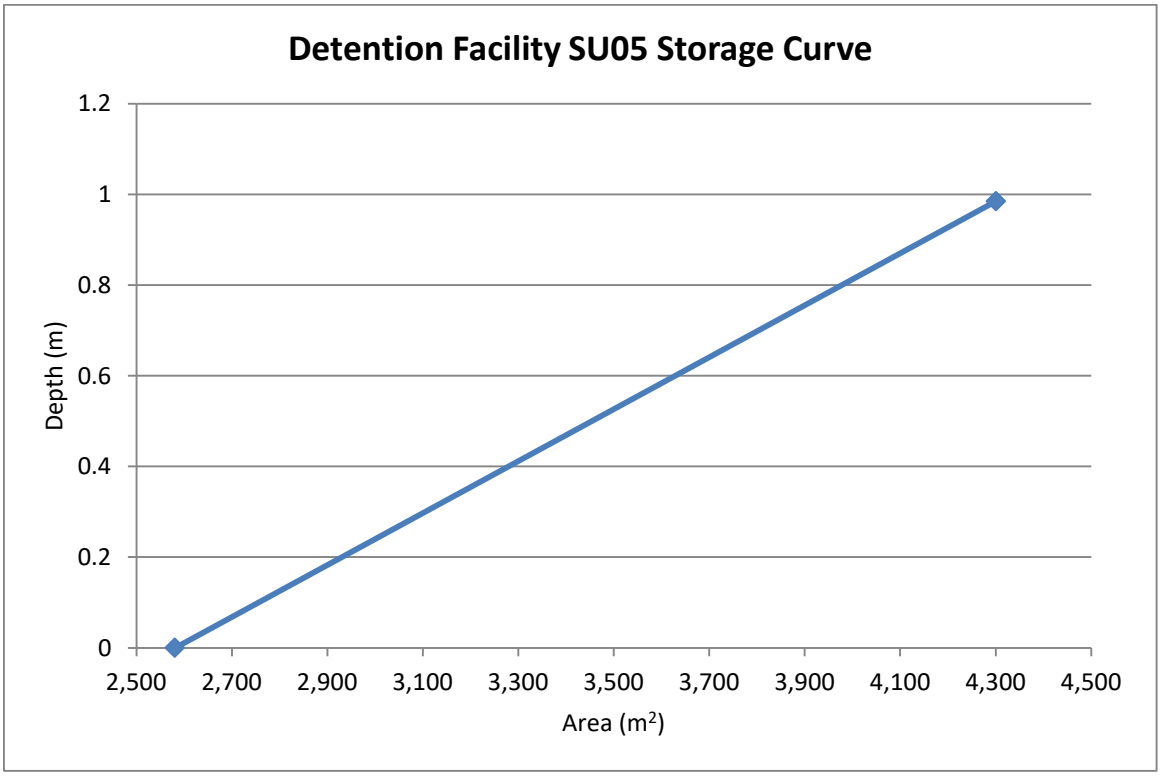
# Appendix A Detention Facility Storage Curves

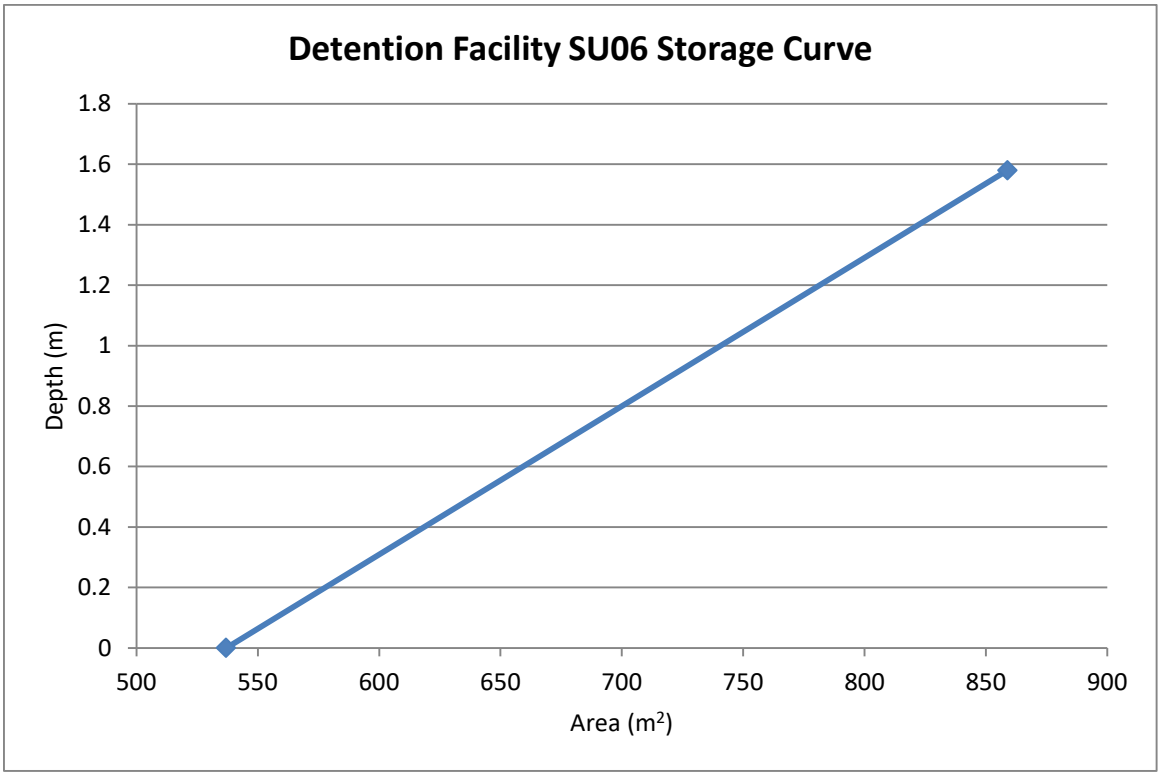

Detention Facility SU01 Storage Curve
Depth (m)
0.6
0.5
0.4
0.3
0.2
0.1
0
6,000
6,200
6,400
6,600
6,800
7,000
7,200
7,400
7,600
7,800
8,000
Area (m²)

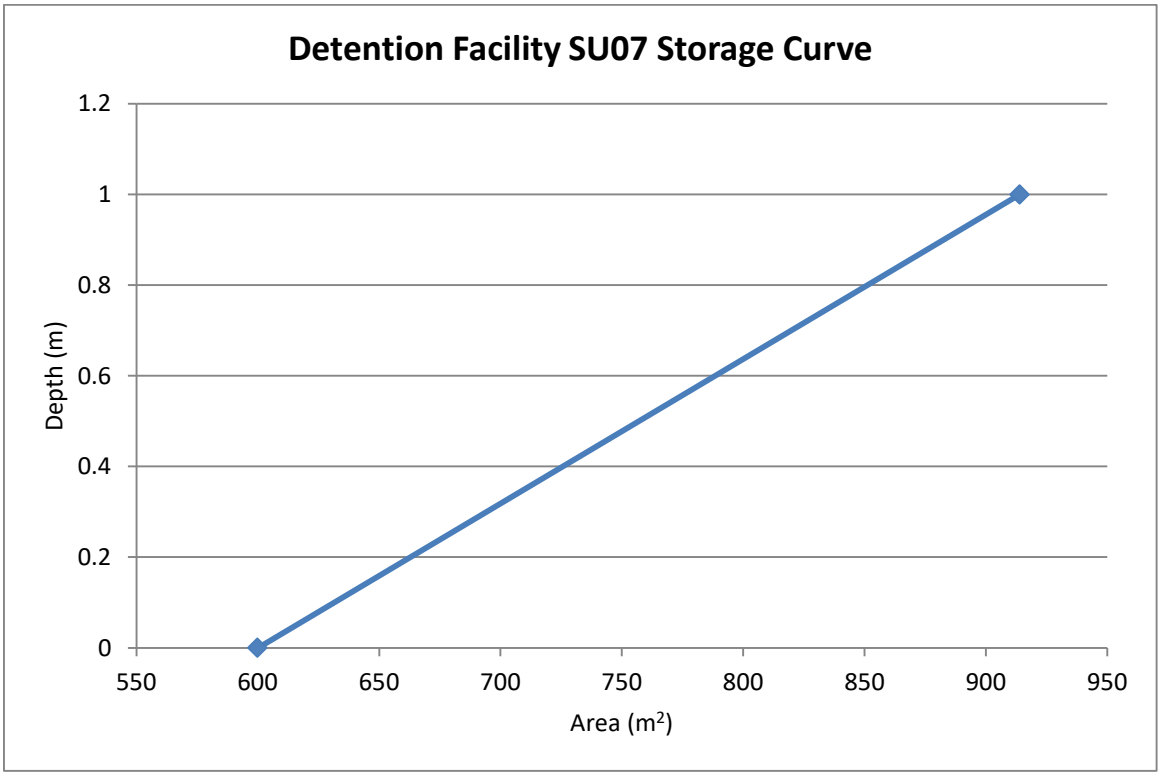

Detention Facility SU02 Storage Curve
Depth (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
3,200
3,300
3,400
3,500
3,600
3,700
3,800
3,900
4,000
4,100
4,200
Area (m²)

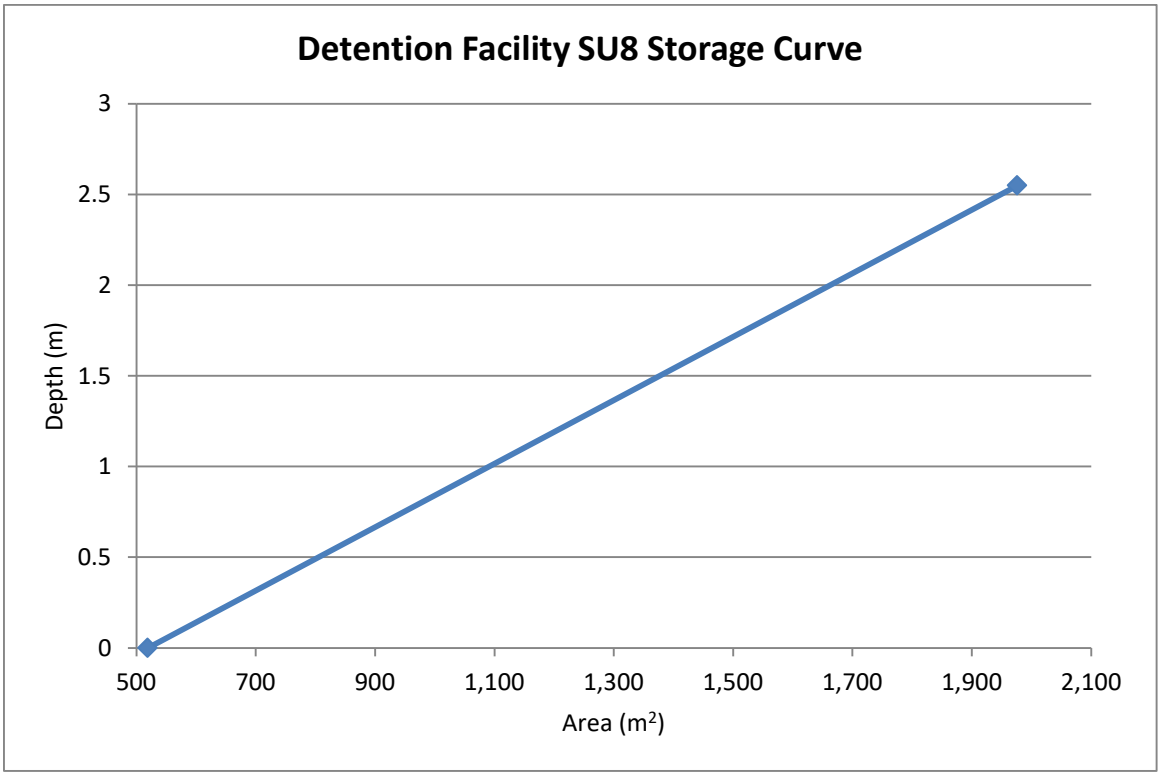

Detention Facility SU3 Storage Curve
Depth (m)
3
2.5
2
1.5
1
0.5
0
160
165
170
175
180
185
190
195
200
Area (m²)

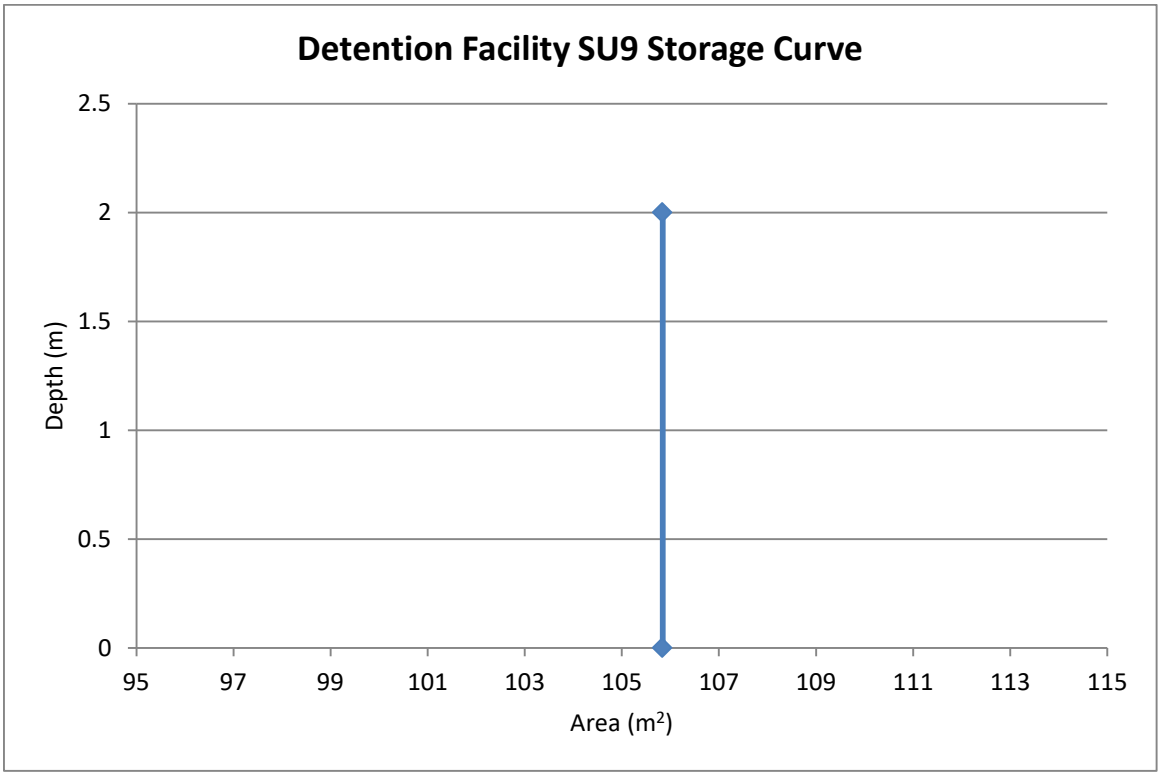

Detention Facility SU04 Storage Curve
Depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500
550
600
650
700
750
800
Area (m²)

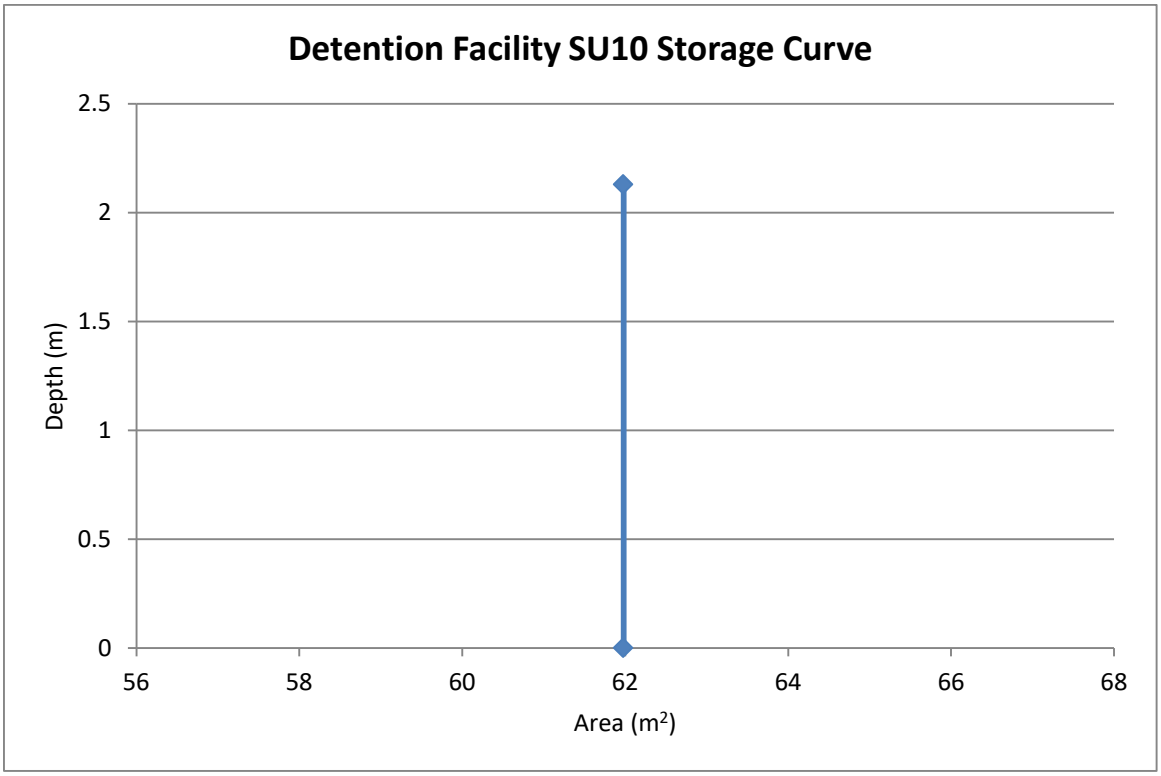

Detention Facility SU05 Storage Curve
Depth (m)
1.2
1
0.8
0.6
0.4
0.2
0
2,500
2,700
2,900
3,100
3,300
3,500
3,700
3,900
4,100
4,300
4,500
Area (m²)

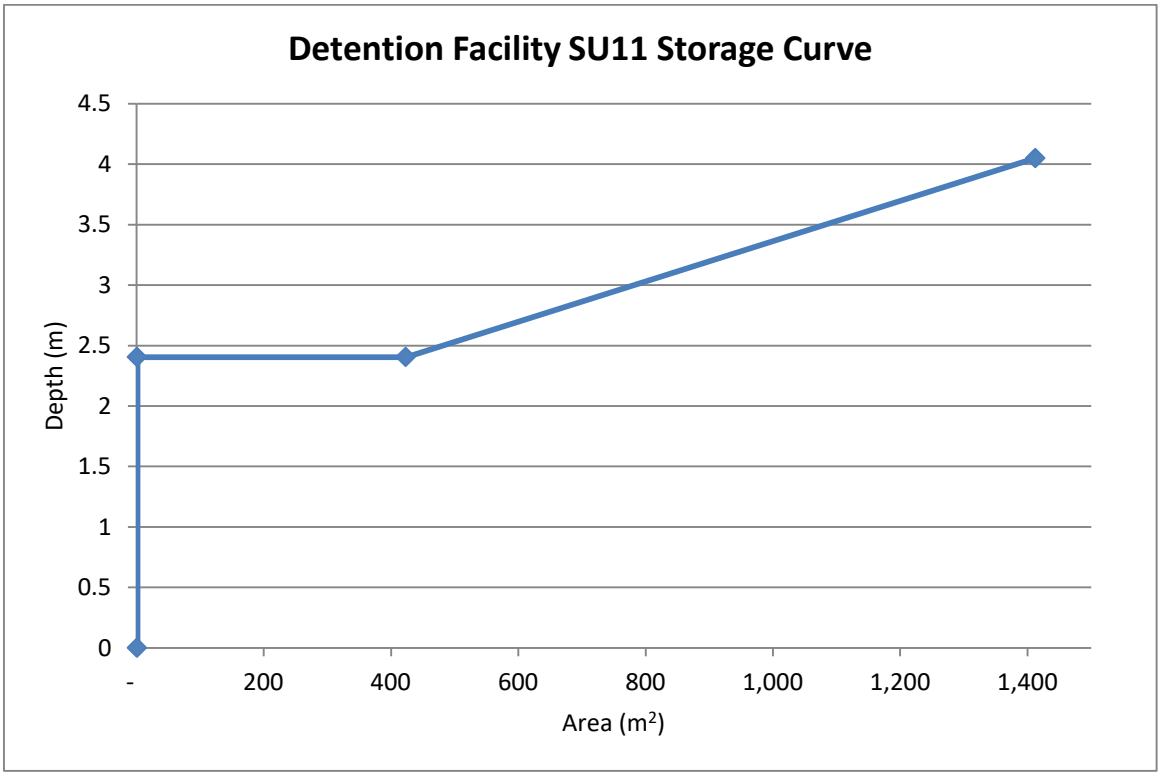

Detention Facility SU06 Storage Curve
Depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
500
550
600
650
700
750
800
850
900
Area (m²)

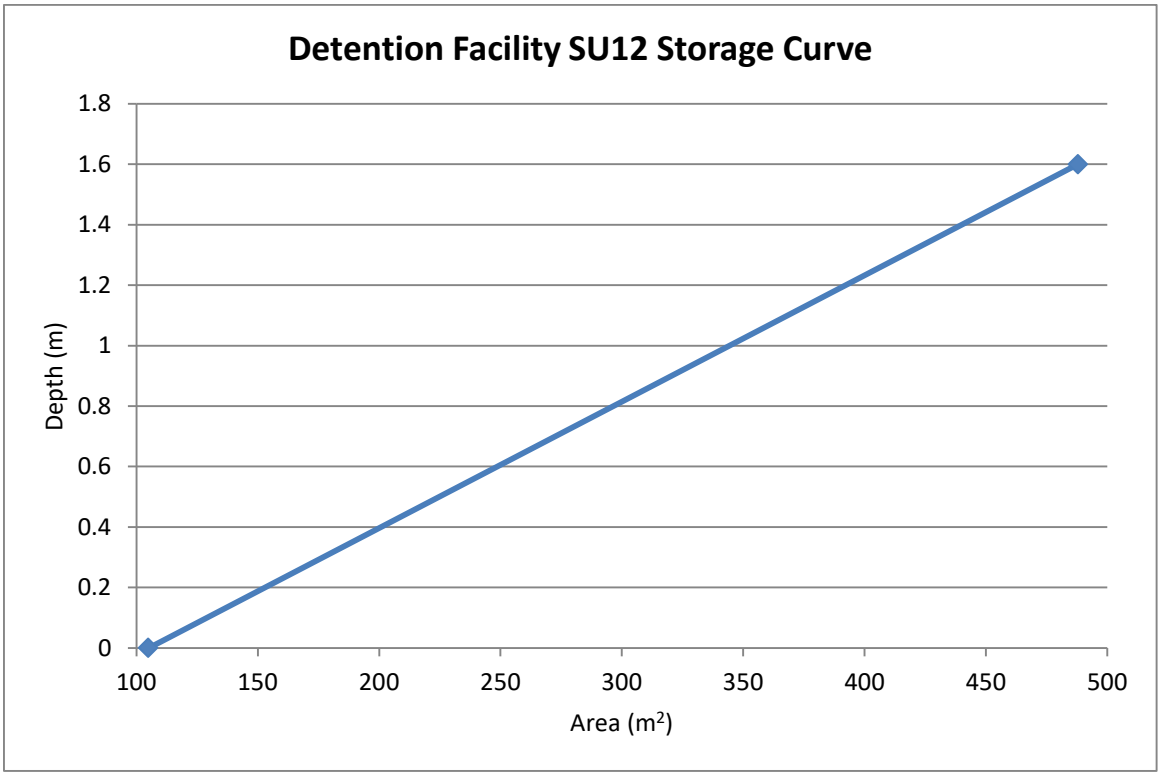

Detention Facility SU07 Storage Curve
Depth (m)
1.2
1
0.8
0.6
0.4
0.2
0
550
600
650
700
750
800
850
900
950
Area (m²)

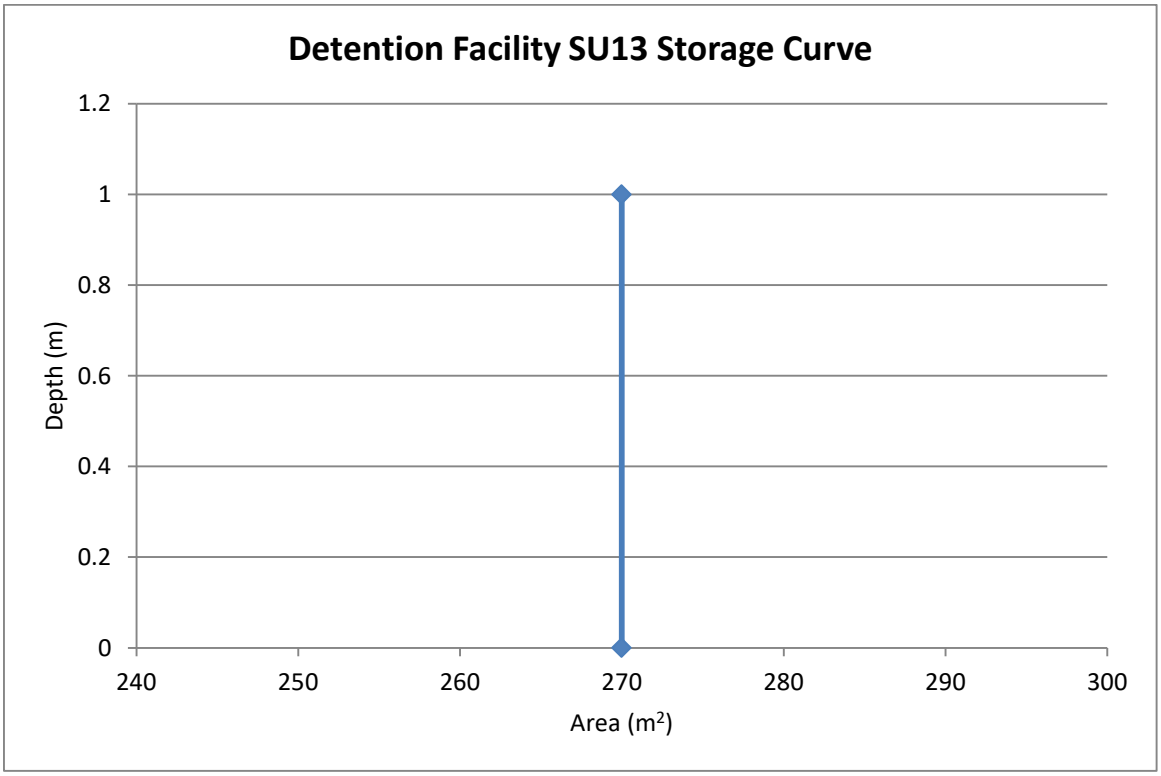

Detention Facility SU8 Storage Curve
Depth (m)
3
2.5
2
1.5
1
0.5
0
500
700
900
1,100
1,300
1,500
1,700
1,900
2,100
Area (m²)

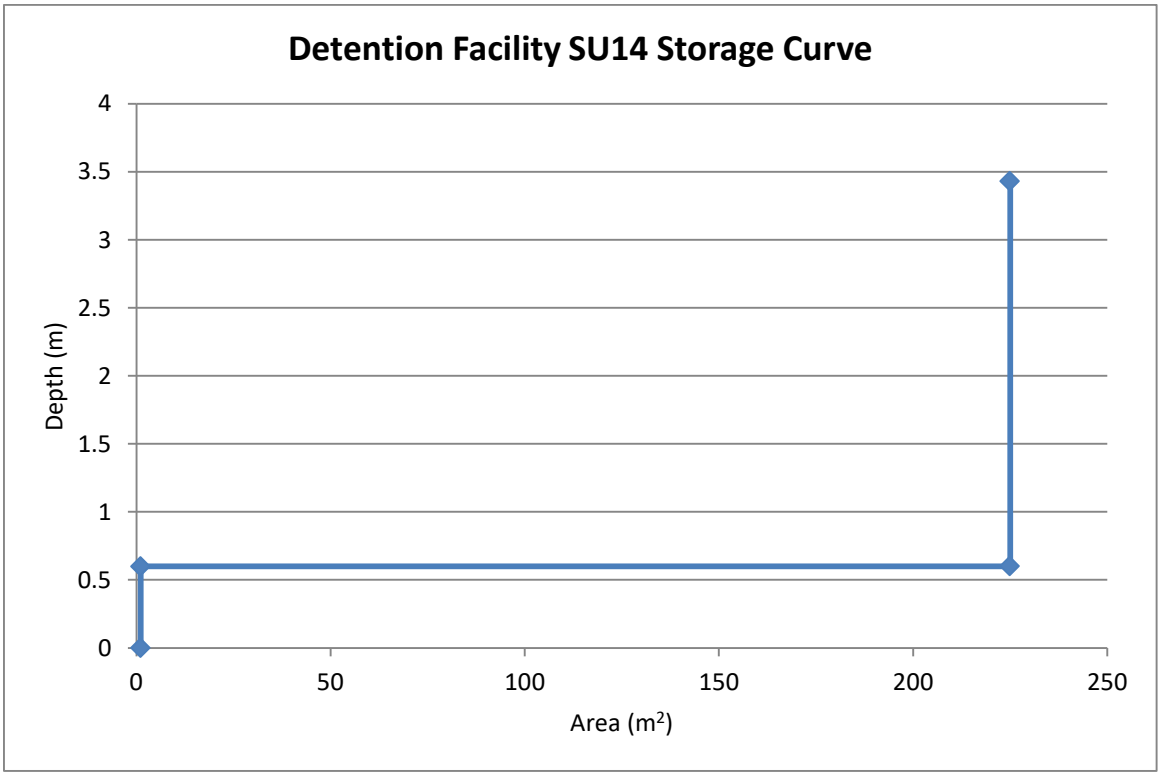

Detention Facility SU9 Storage Curve
Depth (m)
2.5
2
1.5
1
0.5
0
95
97
99
101
103
105
107
109
111
113
115
Area (m²)

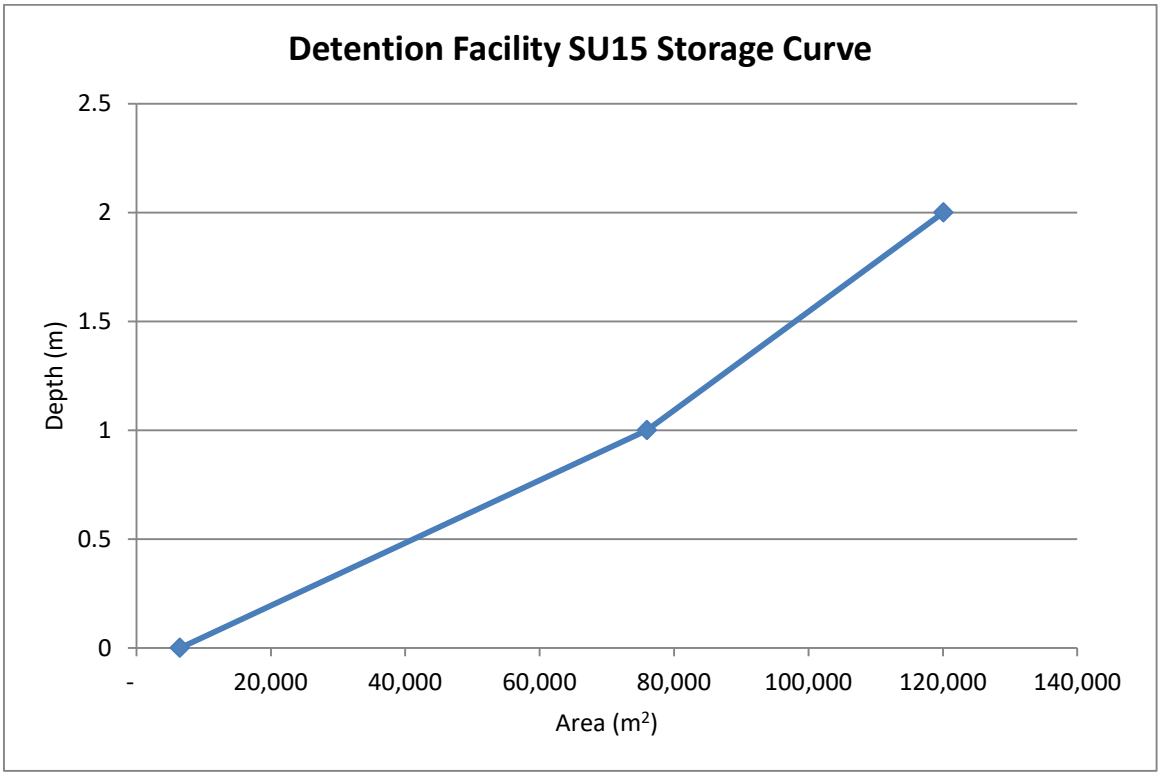

Detention Facility SU10 Storage Curve
Depth (m)
2.5
2
1.5
1
0.5
0
56
58
60
62
64
66
68
Area (m²)

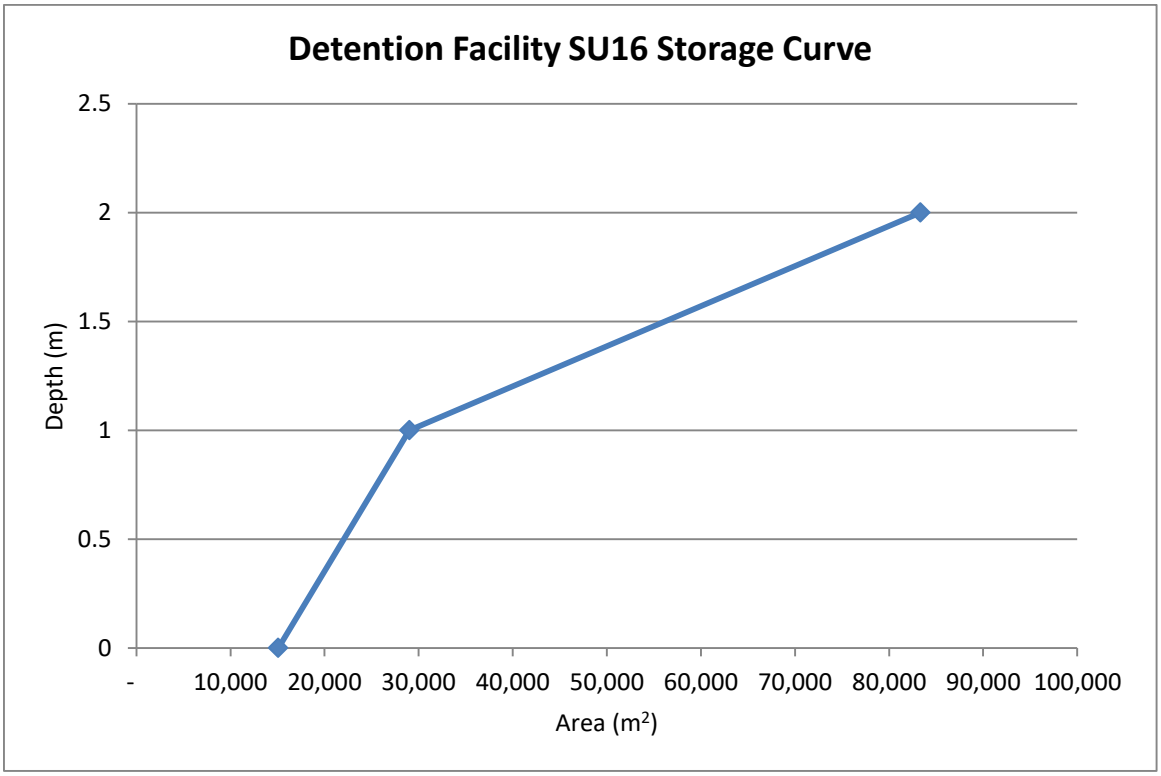

Detention Facility SU11 Storage Curve
Depth (m)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-
200
400
600
800
1,000
1,200
1,400
Area (m²)

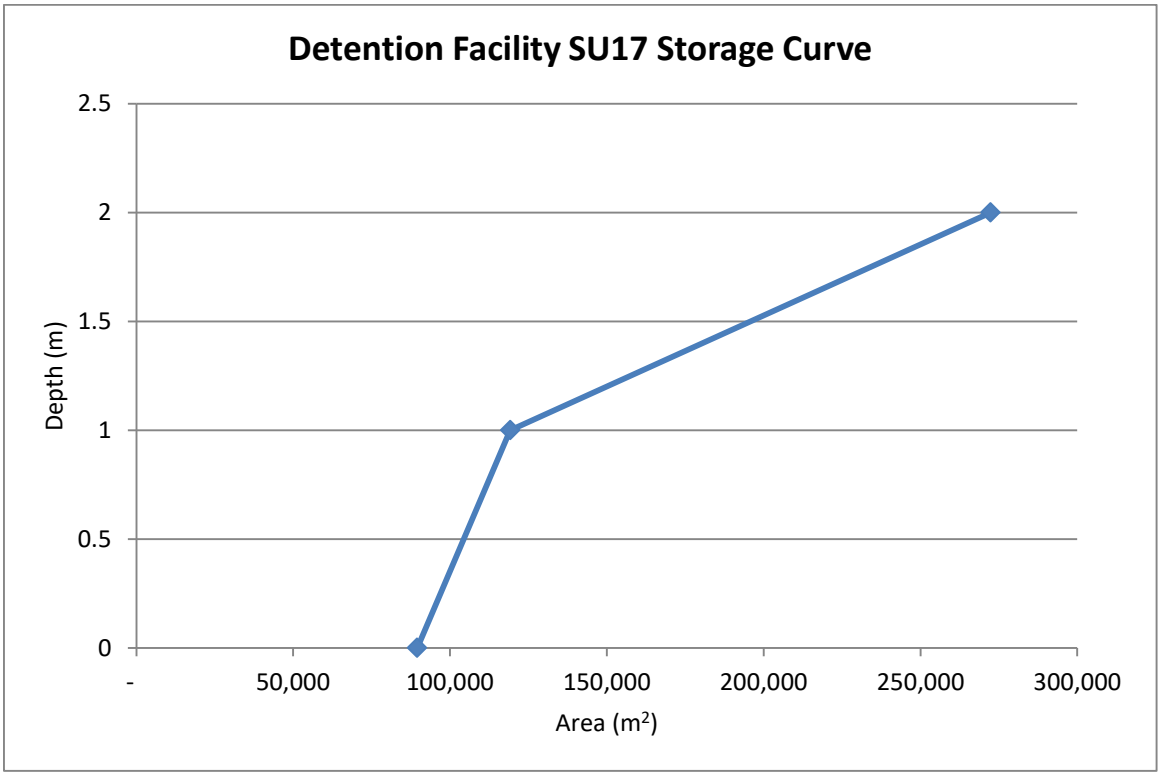

Detention Facility SU12 Storage Curve
Depth (m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
100
150
200
250
300
350
400
450
500
Area (m²)

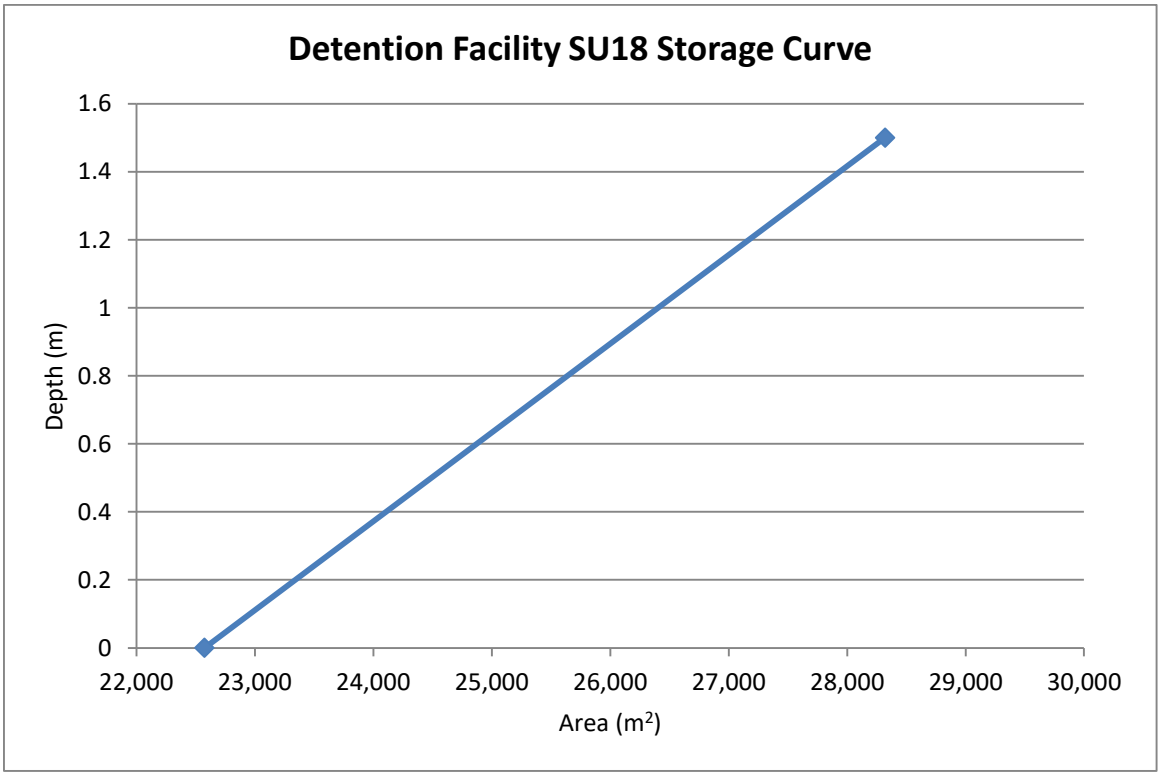

Detention Facility SU13 Storage Curve
Depth (m)
1.2
1
0.8
0.6
0.4
0.2
0
240
250
260
270
280
290
300
Area (m²)

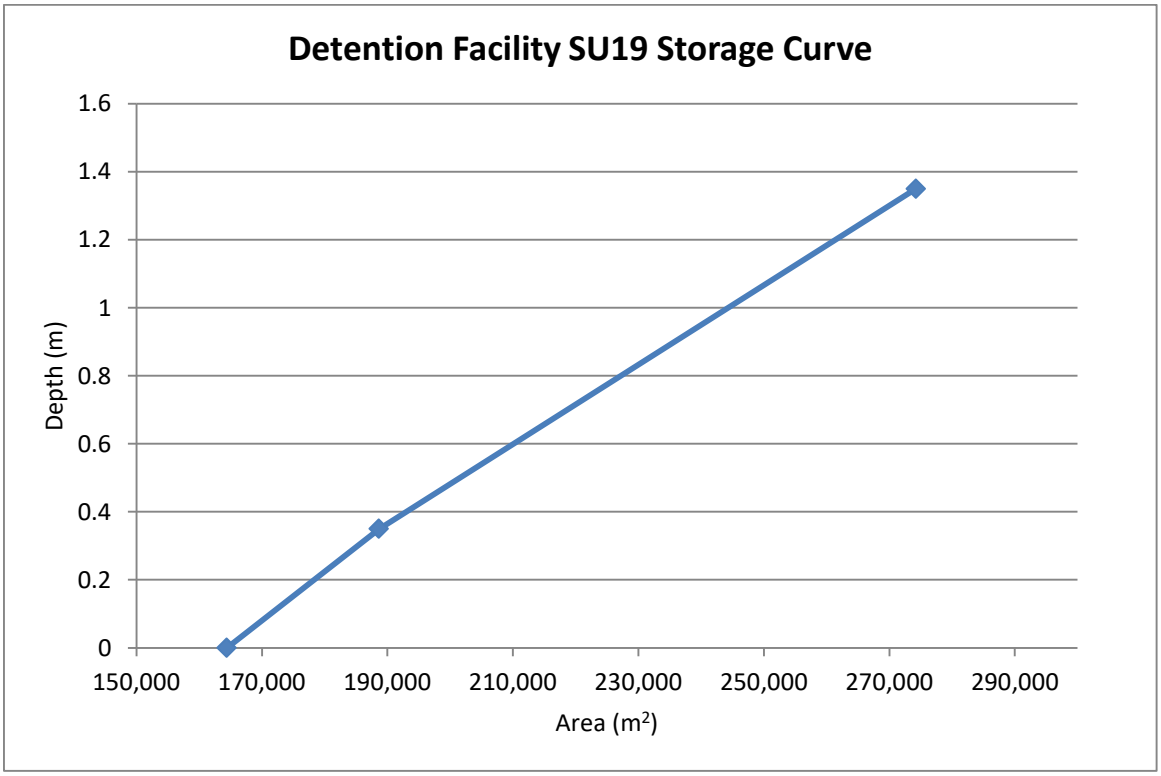

Detention Facility SU14 Storage Curve
Depth (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
Area (m²)


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**

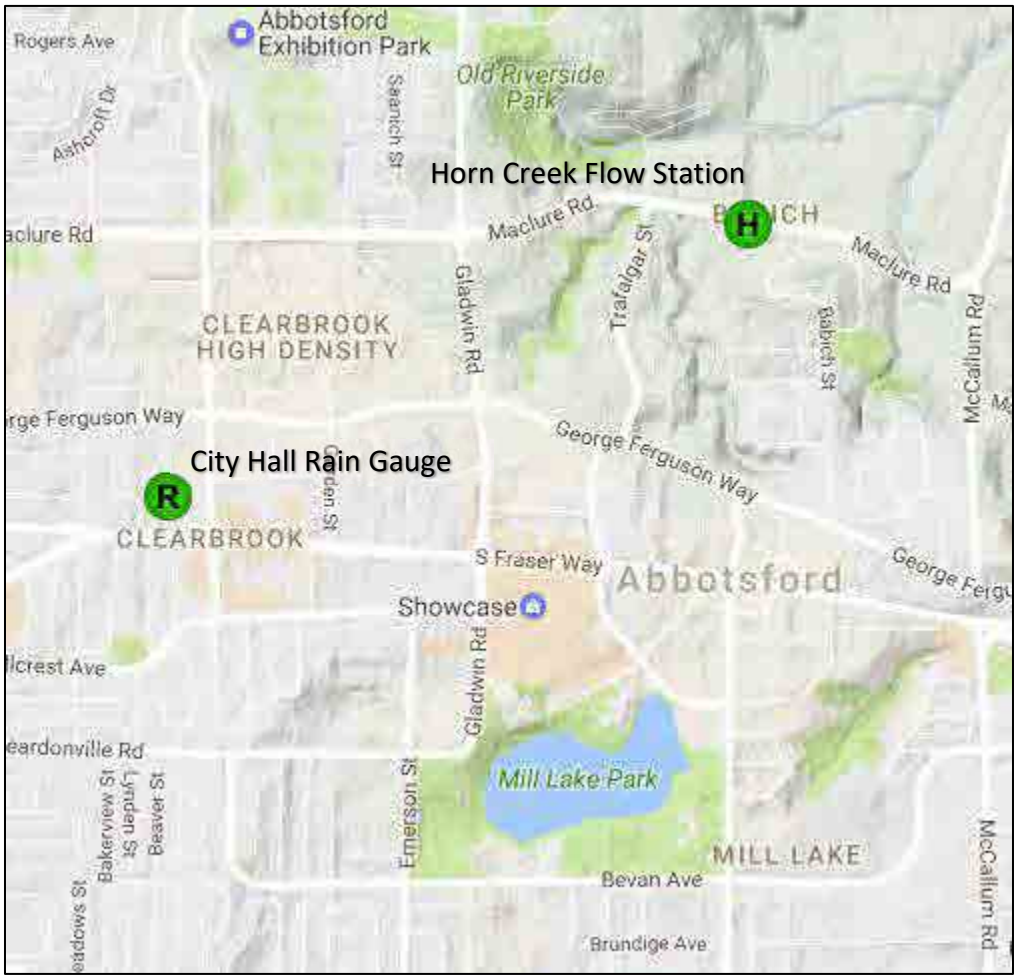



**Table 2.1: Calibration Storm Events (City Hall Rain Gauge)**

| 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**

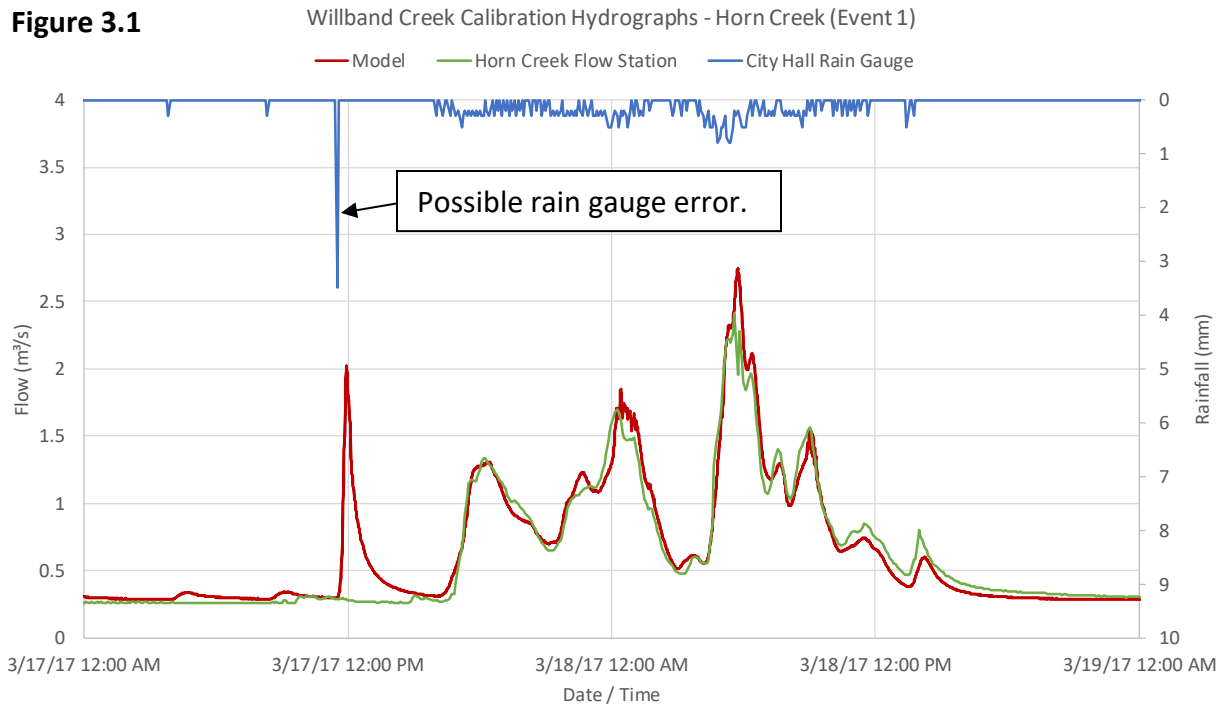



**Figure 3.2**

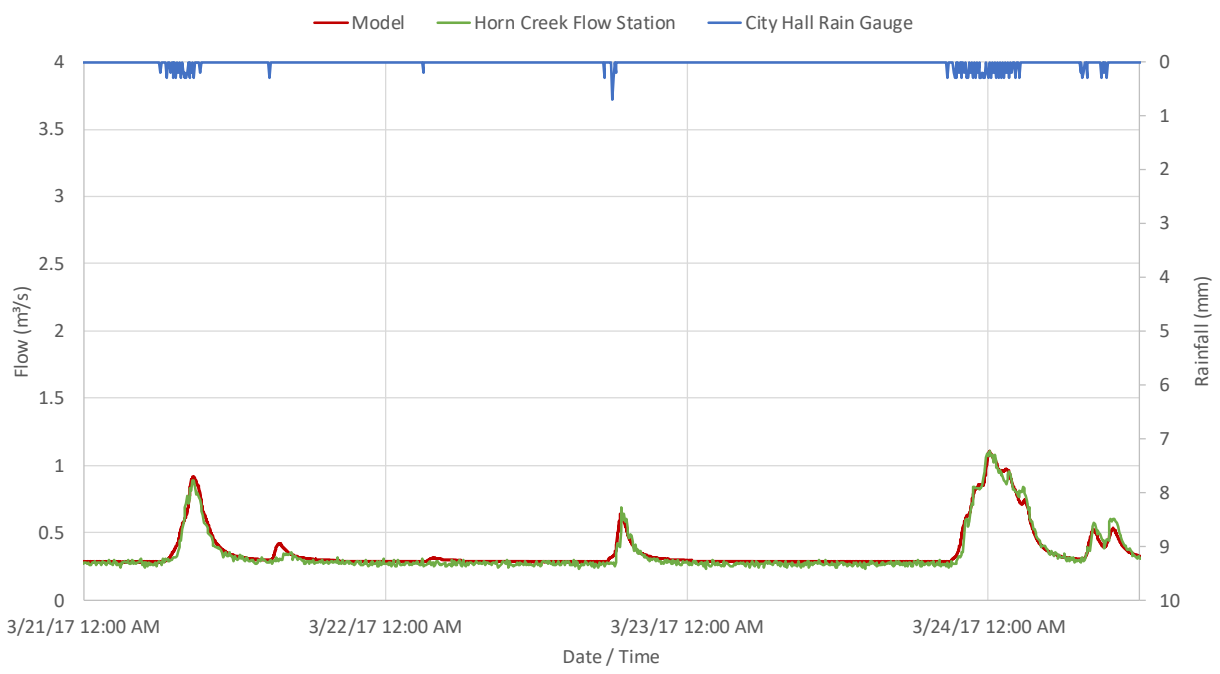


**Figure 3.3**

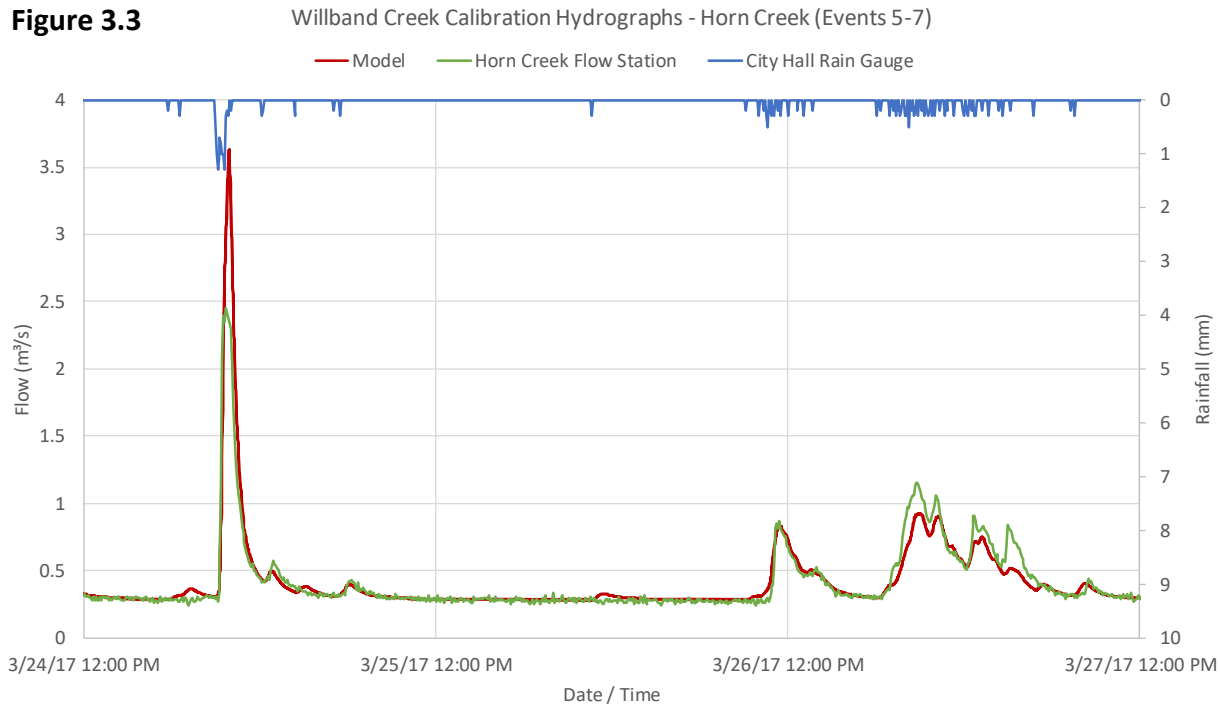
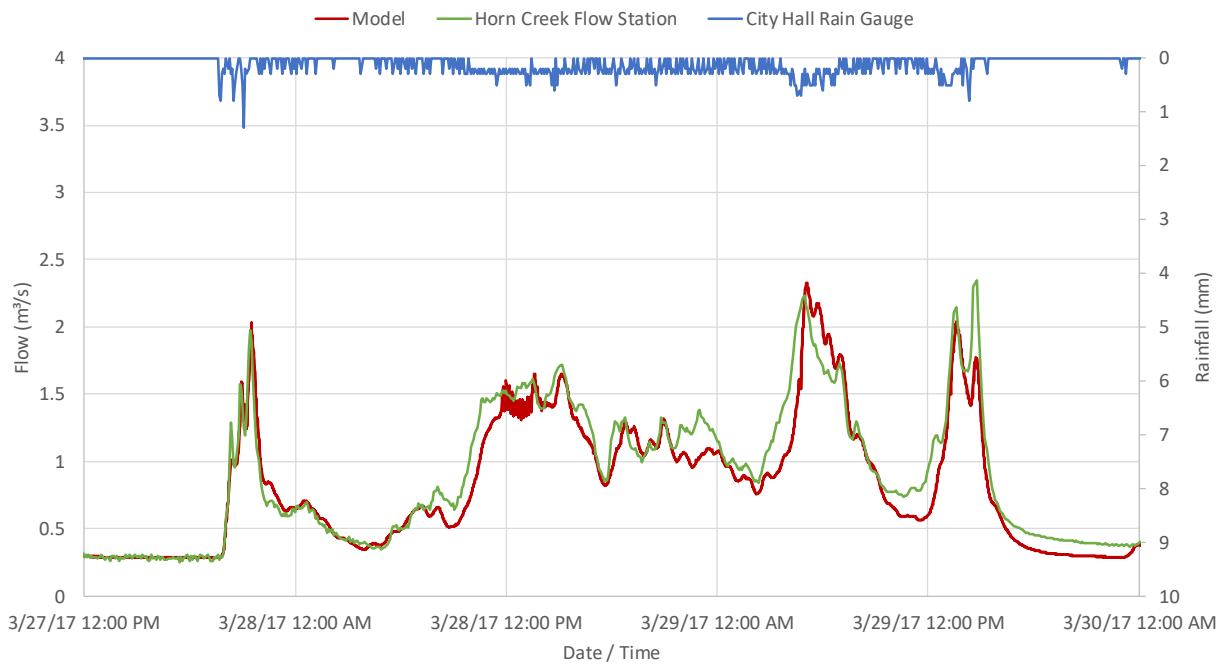
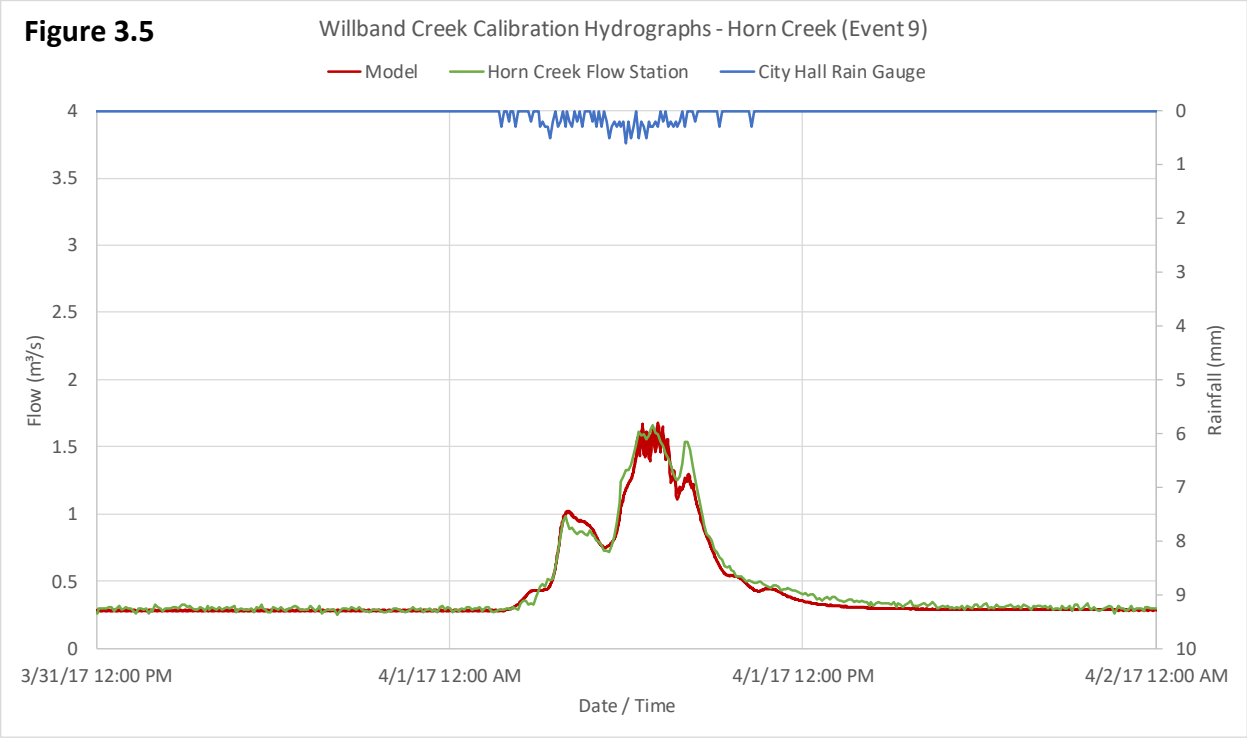



**Figure 3.4**






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) | $width = \frac{Area}{length} = \frac{Area}{50\ m}$ | |
| 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.

# 4. Conclusion

Conclusions and recommendations have yet to be developed and will be incorporated into the Phase 2 technical memorandum.

## Submission

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Chuck Linders
Project Manager

**Reviewed and Approved by:**

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Senior Modeling Review

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### Statement of Qualifications and Limitations

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# 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 |