Delta

2026

TSAWWASSEN INTEGRATED STORMWATER MANAGEMENT PLAN

Delta

Tsawwassen Area
Integrated Stormwater Management Plan

Associated Engineering

February 2019

ASSOCIATED ENGINEERING

QUALITY MANAGEMENT SIGN-OFF

Signature

Date 2019/02/06 (26-19-017)

Date Issued	**February 2019**

Watershed Overview:

The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations.

Existing land uses are predominantly single family residential in the uplands and agricultural in the lowlands. Tsawwassen Town Centre and Tsawwassen Mills make up the majority of the commercial development. The study area is almost fully built out. The main future development will be re-development in Point Roberts to single family residential, and general densification in residential areas.

In general, there is no more natural habitat or water courses in the study area other than Boundary Bay Regional Park and the steep treed bluff areas. Water quality throughout the study area is generally poor. The drainage system consists mainly of stormwater mains draining residential areas and a series of agricultural ditches leading to the pump stations.

Recommendations for City	**Description**
Infrastructure Upgrades	The drainage system has only a few existing deficiencies, and future development will not have a great impact on the system. However, we expect climate change to have a significant impact on the drainage system and Delta must consider upgrades to the major and minor system over the long-term to contain the additional runoff resulting from the projected increases to precipitation.
Environmental Enhancement Projects/Stormwater BMPs	To conform with updated Metro Vancouver source control guidelines, stormwater best management practices (BMPs) will be required on residential lots, and other BMPs should be implemented during redevelopment of roadways and commercial properties. Treatment wetlands should be installed at both Brandrith Pump Station and 12 Avenue Pump Station in addition to revegetating lowland ditches where possible to improve

Note: This summary sheet summarizes the contents of the ISMP only. Other documents may supersede or complement the guidance found here. The designer should ensure all relevant guidance is followed when designing within the ISMP study area.

	water quality. Altering operation schedules of pump stations to discharge at high tides would improve water quality in receiving water bodies.
Specific BMP Recommendations	Residential Lots: · Ensure all paved areas drain to a permeable surface (pervious pavement can be used as an alternative) and not directly to a roadway. · Limit impervious area to a maximum of 70% on each lot. · Disconnect downspouts from the storm system to drain to a permeable surface. · Increase the minimum absorbent topsoil depth to 450 mm. · Limit runoff to 40% of the 1 in 2-year storm of 24-hour duration as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with climate change. Commercial/Multifamily Lots: · Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff. · Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. · Provide a minimum required storage volume of 120 m^3 / hectare with a maximum allowable release rate (peak flow) of 21 L/s/ hectare.

Executive Summary

1 INTEGRATED STORMWATER MANAGEMENT PLANNING

The fundamental purpose of an Integrated Stormwater Management Plan (ISMP) is to maintain and enhance the overall health of a watershed, and provide effective stormwater management while allowing for future development. An ISMP is a comprehensive planning document that addresses a wide variety of components related to watershed health while considering economic growth.

2 STUDY AREA DESCRIPTION

The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations. However, an area of approximately 135 ha on the western bluff above the Strait of Georgia (Roberts Bank) drains directly via gravity outfalls and a significant area drains by gravity to an outfall at 12th Avenue.

3 WATERSHED GOALS AND OBJECTIVES

As outlined in the City of Delta's Terms of Reference, the overall goals for the Tsawwassen Area ISMP are to:

- Compose a future vision for the watershed that marries the interests of Engineering, Planning, Environment and Recreation.
- Prepare a comprehensive inventory of the watershed including confirmation of its boundaries.
- Identify any deficient drainage infrastructure to minimize risk to life and property by flooding.
- Quantify the overall health and natural features of the watershed.
- Protect watercourses and aquatic life.
- Prevent pollution and maintain / improve water quality.
- Protect and enhance the environment, wildlife and habitat corridors.
- Provide a sampling program outline in order to identify and monitor baseline water quality.
- Identify areas of existing and future residential, commercial, recreational and agricultural land uses (as per Delta's OCP).
- Inform stakeholders of the issues and objectives of the ISMP.
- Develop a comprehensive and cost-effective strategy for municipal capital improvements, potential projects for streamkeeper groups and improve community awareness of watershed issues.
- Develop a cost-effective implementation plan.

In consideration of the overall goals identified above, the vision statement developed for the Tsawwassen Area ISMP is presented below.

The Tsawwassen Area watershed is home to both farmers and residents of South Delta, and the marine, estuarine, freshwater, forested and agricultural ecosystems of the region. The ISMP goal for the Tsawwassen Area watershed is to strive for improvement of watershed health, encourage low impact stormwater practices, and maintain resilient drainage infrastructure as it undergoes development over the long-term.

4 IMPLEMENTATION STRATEGY

The Tsawwassen Area ISMP's recommendations include actionable items for the City of Delta to improve stormwater management. In table ES-1 we list the primary actions including recommended drainage upgrades and environmental enhancement opportunities. Following this table is a list of some of the specific changes to Delta's bylaws to enforce these recommendations. Other general recommendations for environmental enhancement opportunities and stormwater Best Management Practices (BMPs) can be found in Section 5 of this report.

The majority of the recommended upgrades are intended to be implemented in an opportunistic manner over the long term in association with broader scope infrastructure projects (such as road or other infrastructure upgrades) or in the context of drainage system renewal as a result of normal life cycle considerations. The identified capacities (e.g. pipe sizes or pumping capacities) of these upgrades address future impacts of climate change in terms of estimated increases in rainfall, and consequently runoff, that are likely to arise during the lifespan of the new components (i.e. 75 years or more). Storm infrastructure upgrades implemented in the future will have expected service lives that extend well into the time horizon of the estimated climate change impacts. While not necessarily required in the immediate time frame, drainage infrastructure projects from this point forward need to recognize these conditions.

Generally, land use changes are minor and are not a driver for most recommended infrastructure upgrades, and the priority ranking reflects whether the identified component is subject to capacity constraints under existing climatic conditions, or under a future time horizon related to climate change. Those indicated with 'High' priority should be prioritized and included in Capital Works projects over the next 5 years. 'Medium' priority should be included in Capital Works projects over the next 20 years. Upgrades and improvements indicated as 'Low' priority items should be upgraded in an opportunistic manner over the next 20-40 years.

Table ES-1
Improvements and Upgrades

ID	Priority	Location	Time Horizon	Description
Minor System Upgrades				
MN-1	Low	Beach Grove Road/17a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-2	High	North portion of 56 Street, 18 Avenue, Spyglass Crescent	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change. Smooth pipe profile to improve hydraulic efficiency.
MN-3	High	Trunk and Storm Siphon along 12 Avenue	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.
MN-4	Low	North side of 50b Street, 51 Street and Western extent of 50a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-5	High	Trunk along 10a Avenue, through Winskill park, and Ferguson Road,	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.

ID	Priority	Location	Time Horizon	Description
MN-6	Low	Pipes through Beach Grove Golf Club and along Boundary Bay Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change (by twinning the pipe).
MN-7	Low	Pipe Outfall from Pacific Drive to Tsawwassen Beach Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-8	Low	Trunk south of 8a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-9	Low	6 Avenue and 54 Street	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
MN-10	Low	3rd Avenue Trunk	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.
Major System Upgrades				
MA-1	Low	3rd Avenue Pump Station	Long Term (20-40 years)	Increase 3rd Avenue Pump Station capacity. Outfall pipe capacity should be increased in tandem.

ID	Priority	Location	Time Horizon	Description
MA-2	Low	12th Avenue Pump Station and Ditch along Boundary Bay Road	Long Term (20-40 years)	Increase 12th Avenue Pump Station capacity. Provisions to allow for climate change impacts have already been included in the design. Increase the capacity of the ditch along the west side of Boundary Bay Road and culverts.
MA-3	Low	Brandrith Pump Station and Ditches Upstream of Brandrith Pump Station	Long Term (20-40 years)	Increase ditch capacities upstream of the Brandrith pump station and associated culverts and increase pump station capacity. Alternatively consider building an additional pump station to reroute drainage to a separate location.
Environmental Enhancement Opportunities				
EV-1	Medium	12th Avenue Pump Station	Medium (5 – 20 years)	Expand the proposed wetland at the 12th Avenue Pump Station.
EV-2	Medium	Brandrith Pump Station	Medium (5 – 20 years)	Build a treatment wetland upstream of the Brandrith Pump Station to filter contaminants before discharging to the marine environment.
EV-3	High	3rd Avenue Pump Station/ 12th Avenue Pump Station	Short Term (0-5 years)	Change operation schedule to discharge at High Tides. Consider mechanical/chemical treatment options at 3rd Avenue to improve water quality. Limit flow velocities during discharge events to protect downstream ecosystem.

The City should look for opportunities to implement community scale detention storage to attenuate peak flows from the Tsawwassen uplands. The primary challenge with retrofitting detention storage in the Tsawwassen uplands will be obtaining sufficient open space, at appropriate locations in the drainage system. However, if successfully implemented, detention storage may allow for a reduction in the size and extents of future drainage infrastructure upgrades required to address climate change impacts.

In Table ES-2, we list relevant BMPs and associated performance criteria for residential and commercial/ multi-family lots:

Table ES-2
BMP Recommendations

Residential Lots	Commercial/Multi-Family Lots
• Ensure all paved areas drain to a permeable surface and not directly to a roadway. • Limit impervious area to a maximum of 70% on each lot. • Disconnect downspouts from the storm system to drain to a permeable surface. • Increase the minimum absorbent topsoil depth to 450 mm. • Limit runoff to 40% of the 24 hour, 2-year return period rainfall (equivalent to 28 mm).	• Require pre-treatment of stormwater runoff for hydrocarbon and sediment removal. • Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. • Provide a minimum required storage volume of 120 m^3 / ha with a maximum allowable release rate of 21 L/s/ha for a 24-hour duration, 10-year return period event. This release rate reflects the estimated peak flow rate under hypothetical natural conditions.

Infiltration based BMPs and source control strategies should only be employed in areas with suitable soils and with a minimum setback from steep slopes. Geotechnical engineers should be consulted on issues of slope stability and soil infiltration capacity.

5 ENFORCEMENT STRATEGY

To implement projects called out in the Implementation Strategy, the following changes should be made to the **Delta Subdivision and Development Standards Bylaw No. 7162**:

- Soil depth for lawns is recommended to be a minimum of 150 mm. This should be updated to 450 mm to fulfill Metro Vancouver's new guidelines.
- Text should be added to require implementation of BMPs or set a limit to maximum outflow rates from lots to achieve runoff targets ("limiting runoff to 40% of the 1 in 2-year storm of 24 hour duration") as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with climate change.
- Add in a requirement to disconnect downspouts on existing residential lots.
- Add in a requirement for impervious surfaces to drain to permeable surfaces for residential lots.
- Design minor system components to the 10-year event, including a climate change analysis.
- Update IDF curves for climate change or make a note to design storm systems with consideration for increased rainfall due to climate change.
- Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff from industrial, multi-family, and commercial lots. Minimum required storage volume on these lots should be 120 m^3/hectare and maximum allowable release rate should be 21 L/s/hectare
- Add more specific requirements and criteria on implementing stormwater BMPs (Section 5.2.16 of Drainage Schedule A), outline new requirements for residential properties.
- Reference Metro Vancouver Stormwater Source Control Design Guidelines (2012) for BMP design criteria.

- Provide clear guidance to designers as to how to incorporate climate change impacts into sizing of drainage infrastructure. Incorporation of climate change impacts in the design capacity (sizing) for future infrastructure renewal is critical, and should be carried into asset management and capital plans immediately, even if specific projects are not yet formulated.
- Maximum acceptable runoff rates by land use should be included.
- Source control design criteria, including:
  - Maximum outflow rates per hectare of tributary area.
  - Rainfall capture targets (72% of 2-year return period, 24-hour duration rainfall, as per the draft Land Development Guidelines [DFO/MoE]).
  - Water quality objectives and a list of acceptable mechanisms to achieve these targets (bioswales, manufactured treatment units, constructed ponds/wetlands).
- Update design criteria to lowland ditches to the 1:100 year design standard (including the impacts of climate change.
- Make reference to this ISMP and others in Delta to ensure designers take into account considerations specific to each ISMP study area.

6 FUNDING STRATEGY

A variety of funding sources exist within the City of Delta. These sources include the following:

- Development Cost Charges – Bylaw 7560
- Property Taxes – Bylaw 5751
- Contributions to stormwater management on private lots from land owners and developers
- Incentives (existing and proposed for the City of Delta)
- Federal funding opportunities include the New Building Canada Fund, Eco Action Community Funding Program, and Green Municipal Fund
- Provincial Funding such as the Infrastructure Planning Grant Program

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1 Introduction

1.1 STUDY AREA

The City of Delta engaged Associated Engineering to develop an Integrated Stormwater Management Plan (ISMP) for the Tsawwassen Area. The study area for the Tsawwassen Area Integrated Stormwater Management Plan (ISMP) is located in South Delta and is generally bounded by 28th Avenue to the north; the Strait of Georgia to the west; Boundary Bay to the east; and Point Roberts to the south. The study area is approximately 2,050 ha and has four drainage pump stations; 12th Avenue Pump Station, Brandrith Pump Station, Beach Grove Pump Station, and 3rd Avenue Pump Station. The majority of the study area is serviced by these pump stations. However, an area of approximately 135 ha on the western bluff above the Strait of Georgia (Roberts Bank) drains directly via gravity outfalls and a significant area drains by gravity to an outfall at 12th Avenue.

Map 1-1 provides a general overview of the study area for the Tsawwassen Area ISMP.

1.2 PROJECT PARTICIPANTS

The study team is comprised of personnel from Associated Engineering and our Environmental Sciences division, Associated Environmental. Key team members involved in the development of this ISMP are:

- Jamie Fitzgerald — Project Manager
- Michael MacLatchy — QA/QC Reviewer
- Jenna Lee — Technical Lead
- Jason Kindrachuk — Water Resources Engineer
- Julia Stafford — Water Resources Engineer
- Rob Hoogendoorn — Environmental Lead
- Stacy Boczulak — Environmental Scientist
- Corinna Hoodicoff — Terrestrial Biologist
- Aaron Deane — GIS Specialist

The City of Delta also played a crucial role in the development of this ISMP. The key contributors include:

- Suman Shergill — City of Delta Project Manager
- Hugh Fraser — Deputy Director of Engineering
- Harald Fograscher — Manager or Utilities
- Mike Brotherston — Manager of Climate Action & Environment.

1.3 GOALS AND OBJECTIVES

The fundamental purpose of any ISMP is to maintain and enhance the overall health of a watershed while addressing drainage and local flood protection requirements to allow for future development; this is true for the current Tsawwassen Area ISMP.

As outlined in the City of Delta's Terms of References, the overall goals for the Tsawwassen Area ISMP are to:

- Compose a future vision for the watershed that marries the interests of Engineering, Planning, Environment and Recreation.
- Prepare a comprehensive inventory of the watershed including confirmation of its boundaries.
- Identify any deficient drainage infrastructure to minimize risk to life and property by flooding.
- Quantify the overall health and natural features of the watershed.
- Protect watercourses and aquatic life.
- Prevent pollution and maintain / improve water quality.
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- Inform stakeholders of the issues and objectives of the ISMP.
- Develop a comprehensive and cost-effective strategy for municipal capital improvements, potential projects for streamkeeper groups and improve community awareness of watershed issues.
- Develop a cost-effective implementation plan.

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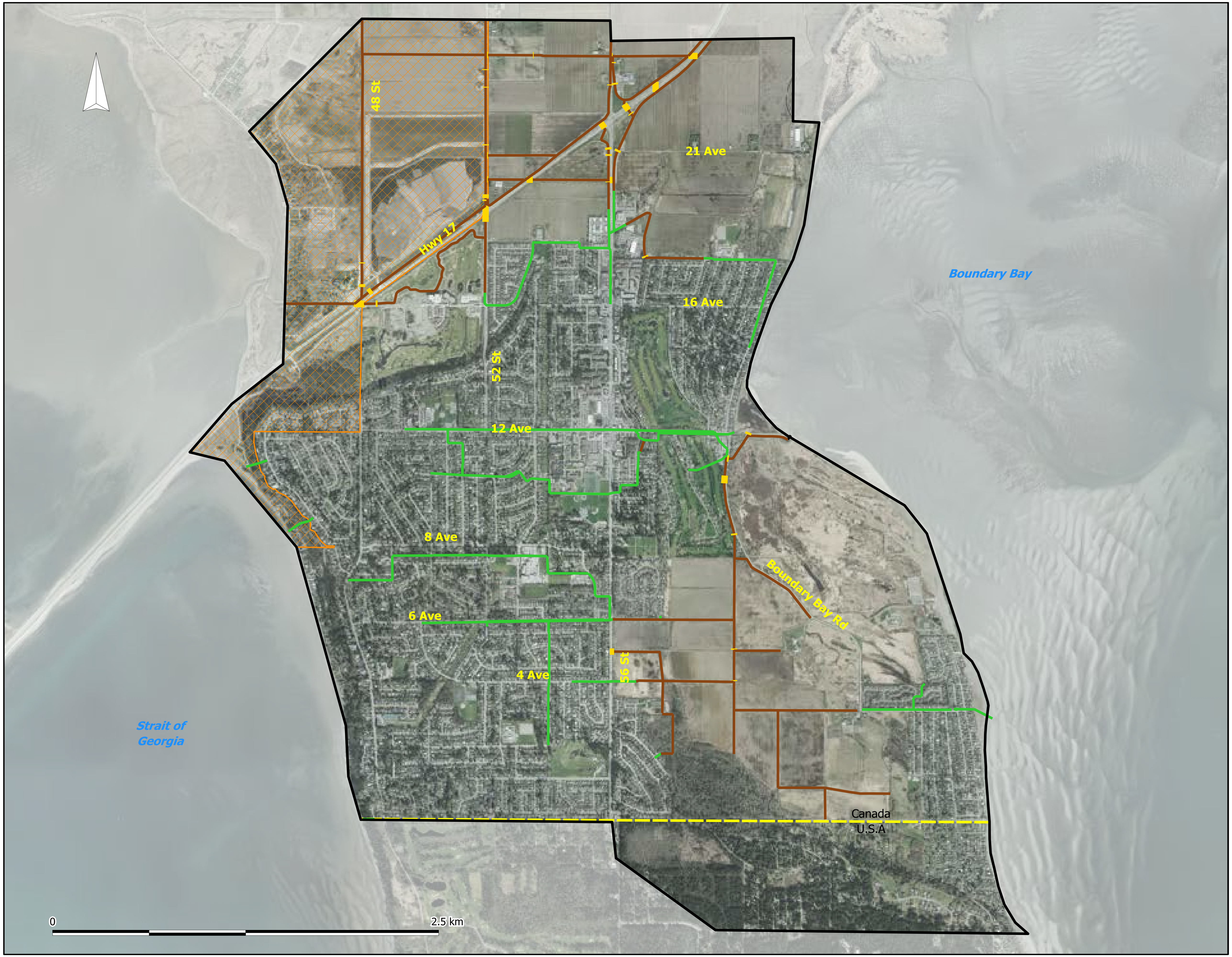
The Tsawwassen Area watershed is home to both farmers and residents of South Delta, and the marine, estuarine, freshwater, forested and agricultural ecosystems of the region. The ISMP goal for the Tsawwassen Area is to strive for improvement of watershed health, encourage low impact stormwater practices, and maintain resilient drainage infrastructure as it undergoes development over the long-term.



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LEGEND

- CULVERT
- DITCH
- STORM MAIN
- STUDY AREA
- TSAWWASSEN FIRST NATION

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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Delta

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TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

STUDY AREA OVERVIEW

DRAWING NUMBER	REV. NO.	SHEET
MAP 1-1		

2 Study Area Overview

2.1 LAND USE

2.1.1 Existing Conditions

In the uplands of the study area, the land is predominately developed as Single-Family Residential with some pockets of Medium Density Residential, Institutional, Mixed Use, Commercial and Parks. The lowlands areas are mainly Agricultural.

Major commercial areas include the shopping center at 12th Avenue and 56th Street and the newly built Tsawwassen Mills shopping centre on Tsawwassen First Nation lands near Highway 17 and 52nd Street.

Major park areas in the study area include Boundary Bay Regional Park and two golf courses; Tsawwassen Springs Golf Course and Beach Grove Golf Club. Boundary Bay Regional Park encompasses a significant area in the lowlands and is environmentally sensitive and provincially protected. Other parks include Brandrith Park near 12th Avenue and 52nd Street, Winskill Park near 56th Street and 9th Avenue, Pebble Hill Park west of 52nd Street between Milsom Wynd and 2a Avenue, and Diefenbaker Park near 56th Street and 1st Avenue.

Map 2-1 illustrates the existing land use of the study area.

One of the key parameters required for hydrologic modelling is estimation of the percent of impervious coverage of each subcatchment. In order to do this, percent impervious values are required for each land use type. Table 2-1 summarizes the impervious percent coverage assumed for the different land use types in the study area.

Table 2-1
Impervious Percent by Land Use

Land Use	Impervious Percent
Single-Family Residential	40%
Medium Density Residential	70%
Commercial	80%
Institutional	80%
Parks	20%
Agricultural	20%
Mixed Use	100%

2.1.2 Future Development

Minimal future changes to land use in the study area are anticipated. Development in the TFN lands and the Southlands is already underway, so we considered these to be existing conditions for this study. Minor build out in Point Roberts may occur in the future based on zoning in this area. We also expect residential areas to densify in the future as houses are redeveloped with larger footprints and residents add impervious coverage to their lot. This future densification is reflected in the modelling but not in the land use map.

Map 2-2 illustrates the future land use of the study area.

2.2 DRAINAGE NETWORK

The drainage network for the study area was assembled based on the City of Delta's GIS data and our knowledge of the study area as shown in Map 2-3.

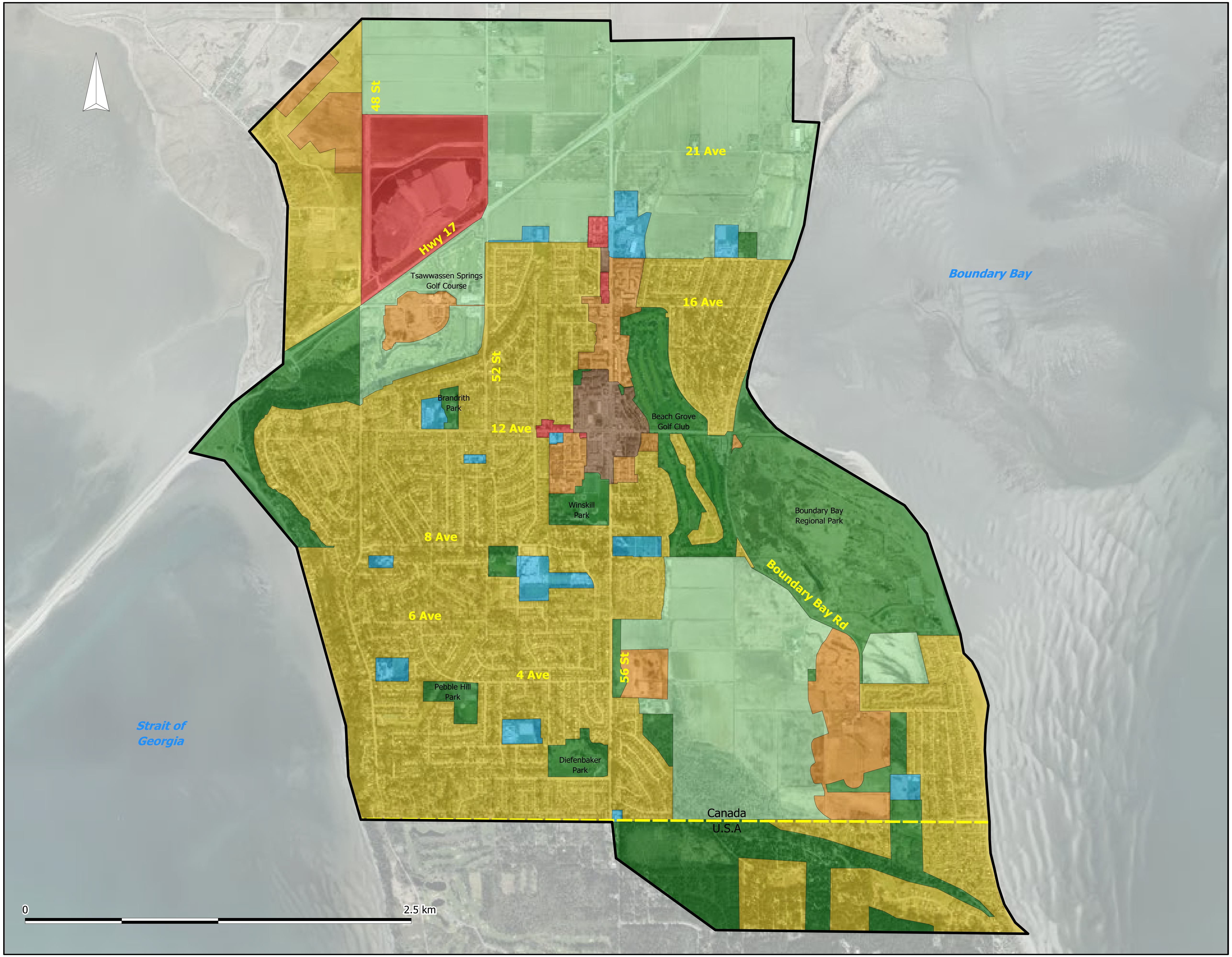
For the purpose of the ISMP, we divided the study area into 60 subcatchments. The subcatchments in the urban areas were delineated based on areas contributing to major storm trunks (450 mm and larger) and a minimum area of approximately 20 ha was used for the majority of the subcatchments, which is an appropriate scale for a planning-level assessment.

Major storm drainage pipes, generally 450 mm diameter and larger, were identified and included as part of the model for this planning level study. These storm pipes are predominantly located in the 12th Avenue catchment, and the remaining are in the 3rd Avenue catchment and Strait of Georgia catchment.

Using available data and mapping, we identified 39 culverts in the study area. Of these culverts, 29 culverts are Delta's responsibility and 10 culverts are the Ministry of Transportation and Infrastructure's (MoTI) responsibility (i.e. Highway 17). The culvert inventory is presented in Appendix A. We note that the GIS data provided by Delta for Highway 17 did not reflect the recent changes associated with the TFN developments. We updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

The study area has four pump stations; Brandrith Pump Station, Beach Grove Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station. Pump stations are critical for draining the lowland system, only the 12th Avenue system (portion not connected to the pump station) and the English Bluff sub-catchments are drained by gravity.

See Appendix A for more details of the stormwater network.



LEGEND

LANDUSE TYPE

- AGRICULTURAL
- COMMERCIAL
- INSTITUTIONAL
- MEDIUM DENSITY RESIDENTIAL
- MIXED-USE
- PARKS
- SINGLE FAMILY RESIDENTIAL

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

EXISTING LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-1		

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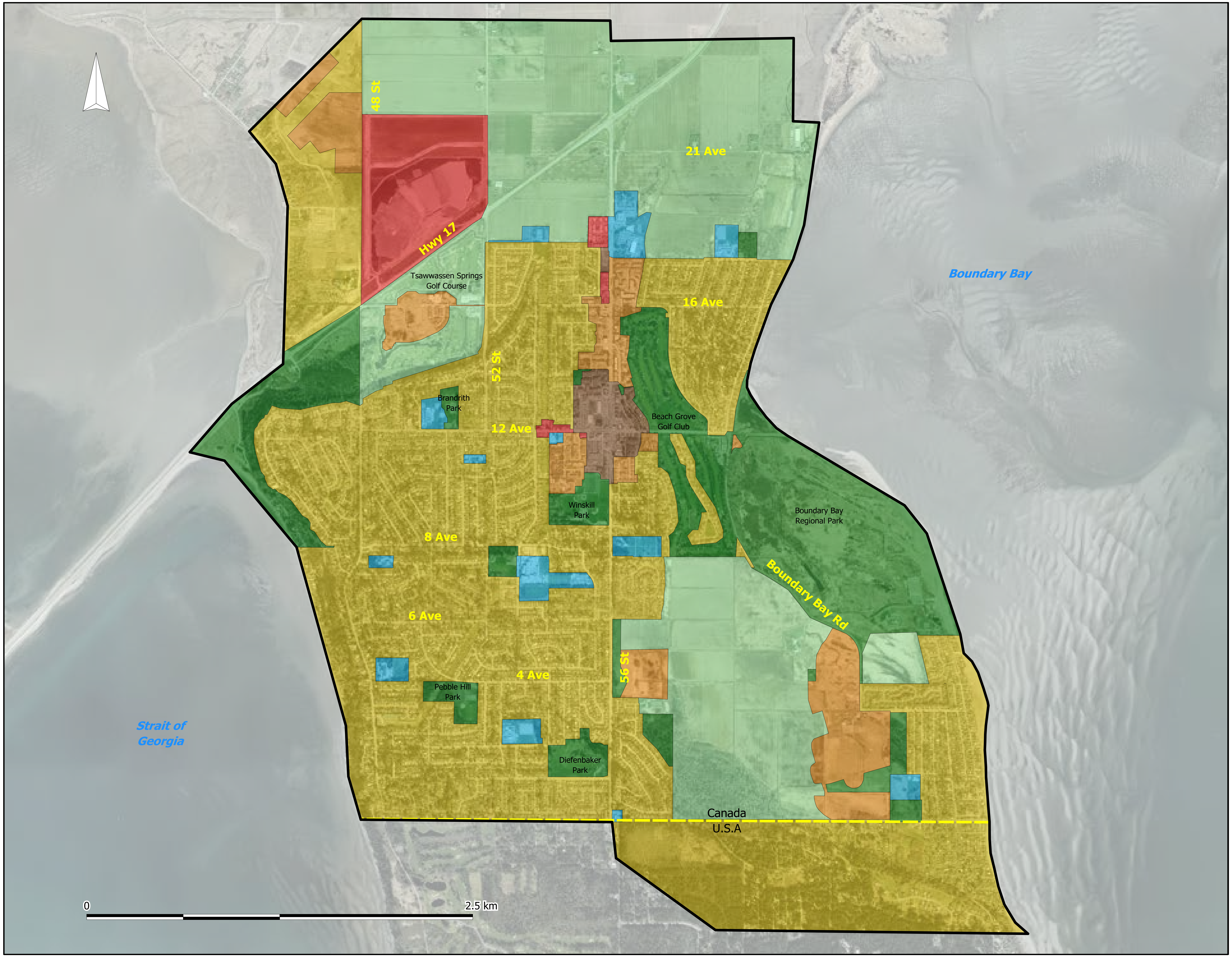

LEGEND

LANDUSE TYPE

- AGRICULTURAL
- COMMERCIAL
- INSTITUTIONAL
- MEDIUM DENSITY RESIDENTIAL
- MIXED-USE
- PARKS
- SINGLE FAMILY RESIDENTIAL

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MANAGEMENT PLAN

FUTURE LAND USE

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-2		

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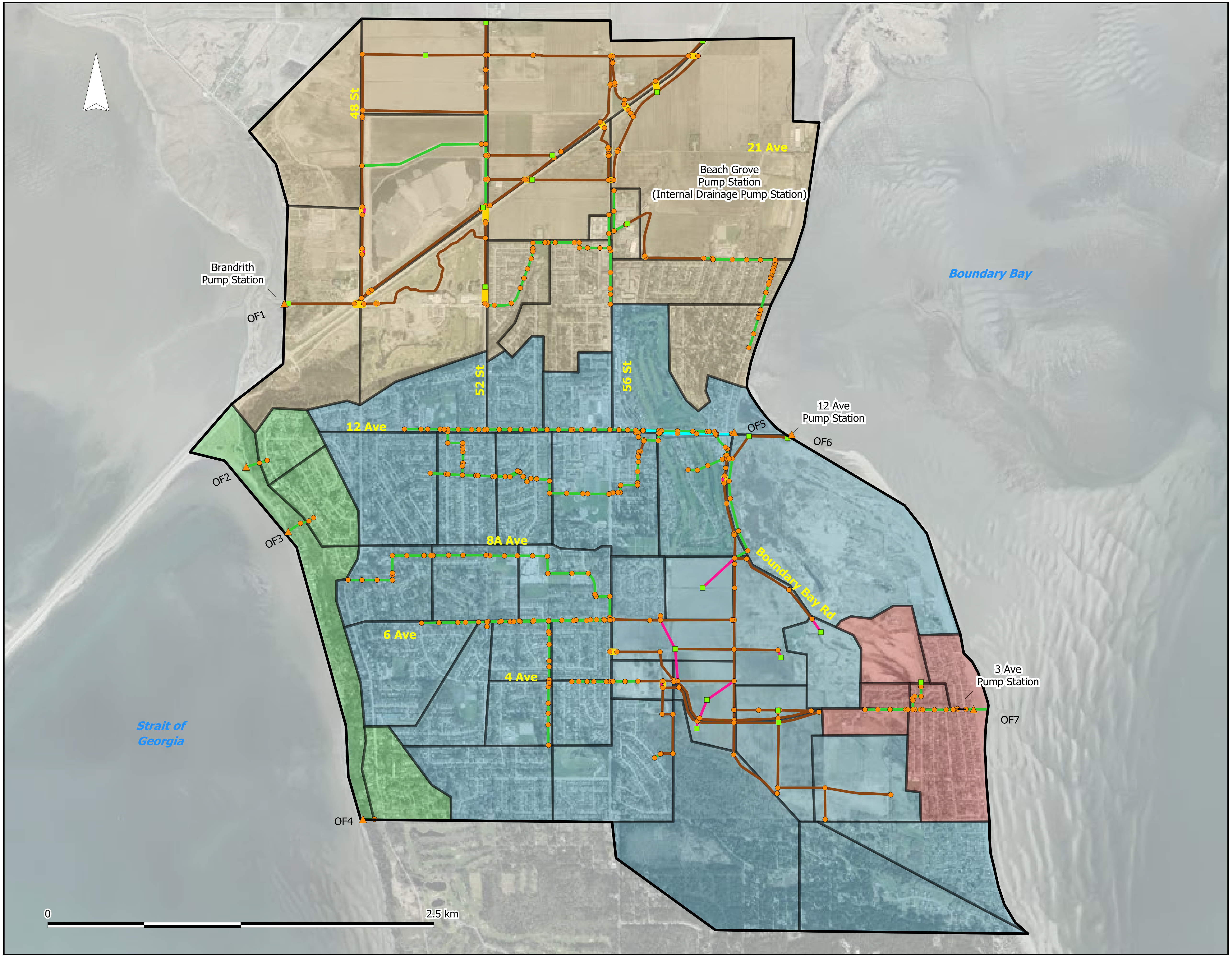

LEGEND

■	STORAGE NODES
●	NODES
▲	OUTFALLS
OF1	OUTFALL ID
	MODEL CONNECTION
	CULVERT
	DITCH
	STORM MAIN GRAVITY
	PRESSURIZED STORM MAIN
	SUBCATCHMENTS
	12 AVE
	3 AVE
	BRANDRITH
	STRAIT OF GEORGIA

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		JS	21-04-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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MODEL NETWORK

DRAWING NUMBER	REV. NO.	SHEET
MAP 2-3		

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3 Aquatic and Terrestrial Habitat

3.1 AQUATIC ENVIRONMENT

The Tsawwassen Integrated Stormwater Management Plan study area includes numerous ditches and drainage channels, and unnamed watercourses in the various sub-watersheds (i.e. Brandrith, 12th Avenue, 3rd Avenue, and Strait of Georgia catchments) that function as a drainage network for the surrounding residential and commercials lands and road systems, and as irrigation and drainage for the lowland agricultural areas. The study area is bound by the marine ecosystems of Boundary Bay to the east, and the Strait of Georgia (Pacific Ocean) to the west.

The aquatic habitat of watercourses in the study area includes man-made, highly modified, and disturbed drainage ditches, channels and riparian areas, and very little remaining undeveloped, natural watercourses. Many of the ditches in the study area are semi-permanent or temporal and not connected to fish bearing streams. Historic land development (residential, agricultural, and commercial) in the study area has resulted in aquatic habitat loss and degradation through channel re-alignment, flow alteration and water quality degradation.

Due to low base flows, the ditches in the study area typically have poor water quality characteristics for fish (i.e. low levels of dissolved oxygen, elevated total suspended solids), and exceeded several water quality parameters for the protection of aquatic life, notably for fecal coliform bacteria within the 12th and 3rd Avenue catchment [1,2] and within the Brandrith catchment[3]. These conditions are common in lowland agricultural areas.

For more detailed information on freshwater and marine habitat, please refer to Appendix A. Map 3-1 following this section illustrates the distribution of aquatic and terrestrial habitat.

The City of Delta has developed a classification system for watercourses, tributaries and ditches[4] that indicates fish and amphibian presence and provides timing windows for when work can be completed in the watercourse, as described in Table 3-1. Watercourses classified according to this system are indicated on Map 3-1.

[1] City of Delta. 2013. BBAMP Field Data.
[2] City of Delta. 2009-2010. Pump Station Results.
[3] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
[4] City of Delta. 2003. Watercourse Classification System. Available at: http://www.delta.ca/environment-sustainability/plants-wildlife/fish-frogs. Accessed Aug 2016.

Table 3-1
City of Delta Watercourse Classification System

Classification	Map Symbol	Description
Schedule A	Red	Salmonid presence (no works from October 1 to July 1)
Schedule B	Orange	Special fish/amphibian sensitive zone (no works from March 1 to August 15)
Schedule C	Yellow	Standard fish/amphibian work window (no works from May 1 to August 15)

None of the watercourses in the study area are considered Schedule A under Delta's Classification System. The majority of the study area watercourses and lowland ditches are Schedule C; however, a number of watercourses are listed as Schedule B as shown on Map 3-1, and include:

- The ditch along agricultural fields north of 17a Avenue and east of the South Delta Recreation Centre.
- The ditch along 16 Avenue from 56 Street to Gillespie Road, and south on Gillespie Road to Beach Grove Golf Club access.
- The ditch running from north end of Boundary Bay Road to where the ditch separates from the road.
- Watercourses B and C in the uplands of the study area.

3.2 TERRESTRIAL ENVIRONMENT

The study area includes a variety of forested, naturalized, disturbed, and herb dominated ecosystems. The terrestrial assessment of the study area uses the same catchment boundary delineation as the aquatic assessment for discussion (i.e. the Brandrith, 12th Avenue, 3rd Avenue, and Strait of Georgia catchments). The Brandrith catchment is characterized by moderate urbanization, while the 12th Avenue catchment is almost entirely urbanized with residential and commercial development in the uplands and is largely old field agriculture in the lowlands. Patches of green space and hedgerows are common in the uplands of the 12th Avenue catchment. This catchment contains the Boundary Bay Regional Park and intertidal area, a globally significant stopover for migratory birds along the Pacific Flyway. The 3rd Avenue catchment in the southeast is mainly residential development. The Strait of Georgia catchment is largely undeveloped except at the top of bank, as it is a steep coastal bluff, and is highly influenced by the climatic conditions of the Pacific Ocean.

For more detailed information on terrestrial habitat, visit Appendix A.

3.3 WATERSHED HEALTH ASSESSMENT

Metro Vancouver's 2005 ISMP Template proposed a methodology for a qualitative assessment of watershed health. The methodology requires three inputs:

- Total impervious area (TIA), representing the level of development and disturbance in the watershed relative to natural conditions. When such information is available, the effective impervious area (EIA) is often used instead. The EIA provides a better indicator of the degree of disturbance the watershed's development has by accounting for hydraulic disconnection of development from the receiving system. However, without significant data collection and interpretation, EIA is highly subjective and prone to uncertainty.
- Riparian forest integrity (RFI), representing the intactness of forest along the banks of natural watercourses.
- Benthic index of Biological Integrity (B-IBI), used as an indicator for ecological health of a stream.

The characteristics of the Tsawwassen area watersheds largely preclude the use of this methodology. The RFI of the study area is essentially zero, which would severely skew the watershed health assessment. Further, B-IBI scores, which are used to calibrate the tool are not available for the study area because the index is intended as a metric for high-gradient, coarse substrate, natural streams. There are no such streams within the study area.

We adapted the principles of the tool to conduct a qualitative assessment of the ecological health of the watersheds in the study area. It provides an overview of the current state of the watershed, and identifies how the ecological health could change in the future, in relation to development.

Watercourse Disturbance
No significant natural watercourses are present in the uplands. Lowland watercourses have generally been modified to serve agricultural purposes. The lowland ditches generally have a very narrow, or non-existent, vegetative buffer to the adjacent agricultural lands.

The upper watersheds in the study area therefore collect and convey runoff rapidly down the slopes via pipes and into the lowland agricultural watercourses. In the lowlands, generally slow moving drainage causes the water to stagnate within the ditches during low flow periods, and limited vegetative cover allows the temperature to increase during the summer. This results in poor water quality, particularly in the summer months when stagnation and temperature influences are the highest. Runoff from agricultural lands introduces organics, sediment and nutrients.

Degree of Development
Our assessment has taken the baseline 'existing' development condition to include the full build-out of the Southlands and Tsawwassen First Nation lands, in accordance with their respective land use plans. Against this baseline, the degree of anticipated additional future development is relatively low, and restricted primarily to sporadic densification of the residential neighbourhoods in the uplands and renewal of housing

stock. To estimate land use conditions for future development, we assumed a 10 percent increase in impervious surfaces for single family residences.

Table 3-2
Total Impervious Coverage under Existing and Future Development Conditions

Catchment	Existing Development Condition	Future Development Condition
Brandrith	41%	44%
12th Avenue	46%	54%
3rd Avenue	56%	58%
Strait of Georgia	53%	61%
Total Study Area	**45%**	**51%**

Overall Ecological Health of the Watersheds
Qualitatively, we interpret that the overall ecological health of the watersheds within the study area to be relatively poor. This interpretation is applied because of the following factors:

- Extensive development and near-full build-out in the uplands, and disturbance to the lowlands.
- A lack of natural watercourses through the study area.
- Poor water quality and very low riparian integrity in the lowland ditches.

Under future development conditions, there is some potential for watershed health to further degrade if development and densification occurs without mitigative measures for both ecological health, and hydrologic function. Mitigative measures are discussed in Section 5.

3.4 ENVIRONMENTALLY SENSITIVE AREAS AT RISK

As previously discussed, most of the significant new development was included as part of our existing condition as it is already underway. The remainder of anticipated impacts due to development will come from long-term general densification and redevelopment, the majority of which is not yet planned. We expect the forested area in Point Roberts that drains to our study area will also be developed into single family residential homes in the future which will significantly increase the impervious area in those sub catchments. However, activities in this area are not under Delta's control.

In our aquatic and terrestrial assessment, we identified environmentally sensitive areas across the study area. In general, the majority of inland Tsawwassen has previously been developed and does not have many sensitive areas. The environmental corridors along the few natural or ditched open channel watercourses, forested areas in the uplands area of Southlands, forested areas along the western perimeter of Tsawwassen, and Boundary Bay Park have the most current terrestrial ecological value. Additionally, the majority of marine habitat along the foreshore areas may also be sensitive to the water quality of storm runoff at outfalls. In particular, poor water quality has been recorded at the outfall of the 3rd Avenue Pump Station during low tide in the summer months.

Map 3-2 presents anticipated increases to impervious coverage to inform risk of development on environmentally sensitive areas.

Table 3-2 summarizes the risk that development poses to sensitive areas and to downstream features for each subcatchment. We briefly discuss each watershed in the context of development risk below.

Table 3-3
Estimated Risk of Development on Environmentally Sensitive Areas and Downstream Features

Subcatchments	Development Risk[1] to Terrestrial Habitats	Development Risk[1] to Downstream Watercourses
Point Roberts (48 & 49)	High	High
English Bluffs (17)	Moderate	Moderate
Tsawwassen Central and Surrounding Residential Neighborhoods (11-13,18-24, 26-37)	Low	Moderate
North Tsawwassen and Beach Grove (9, 10, 14 & 16)	Low	Moderate
Tsawwassen First Nation Lands (1-3)	Low	Moderate

[1] Risk refers to the potential impact of development absent of mitigative measures (improved development setbacks from watercourses and key environmental areas / stormwater source controls).

Point Roberts

If development of the natural forested lands to single family large lot residential housing occurs, it could significantly affect the terrestrial habitat in this area. Additionally, an increase from 20% impervious to 40-50% impervious area possible under the zoning for rural residential could cause a large increase in peak runoff and total flows draining from the area into the Southlands/Boundary Bay area. Water quality of the receiving watercourses could also be negatively impacted by the increase in contaminants from urban runoff. The City does not have direct control over development activities in this area so they may want to discuss these impacts with Whatcom County in Washington State.

English Bluffs

Densification of the single-family residential areas in the English bluffs neighborhood may cause a nominal increase to the runoff into the Strait of Georgia. Opportunities for improving water quality through BMPs should be considered in this area, as storm runoff is directly discharged into the foreshore environment without treatment.

Tsawwassen Central and Surrounding Residential Neighborhoods/ North Tsawwassen and Beach Grove

These areas are already greatly impacted by residential development and therefore the effect of further densification will be minimal. It is important for redevelopment in this area to take advantage of the resulting opportunities to enhance watershed health by employing restorative stormwater management measures or environmental reclamation approaches. Increased impervious area may contribute to poorer water quality downstream with less pervious surfaces to filter potential contaminants and greater peak flows in the system.

Tsawwassen First Nation Lands

Similar to the English Bluffs area, opportunities to improve water quality should be considered in this area as storm runoff will be directly discharged into the foreshore environment without prior treatment. Development/densification in this area could lead to increase stormwater runoff and discharge into the foreshore environment impacting the sensitive habitats such as marsh lands, eel grass, and mudflats that currently exist.

3.5 WATER QUALITY ASSESSMENT

Water quality sampling conducted in the first stages of the ISMP identified that the lowland ditches are prone to poor water quality. Water quality sampling results can be found in Appendix B. Many of the parameters exceeded water quality guidelines and were at levels of concern relative to Metro Vancouver's Adaptive Management Framework classifications.

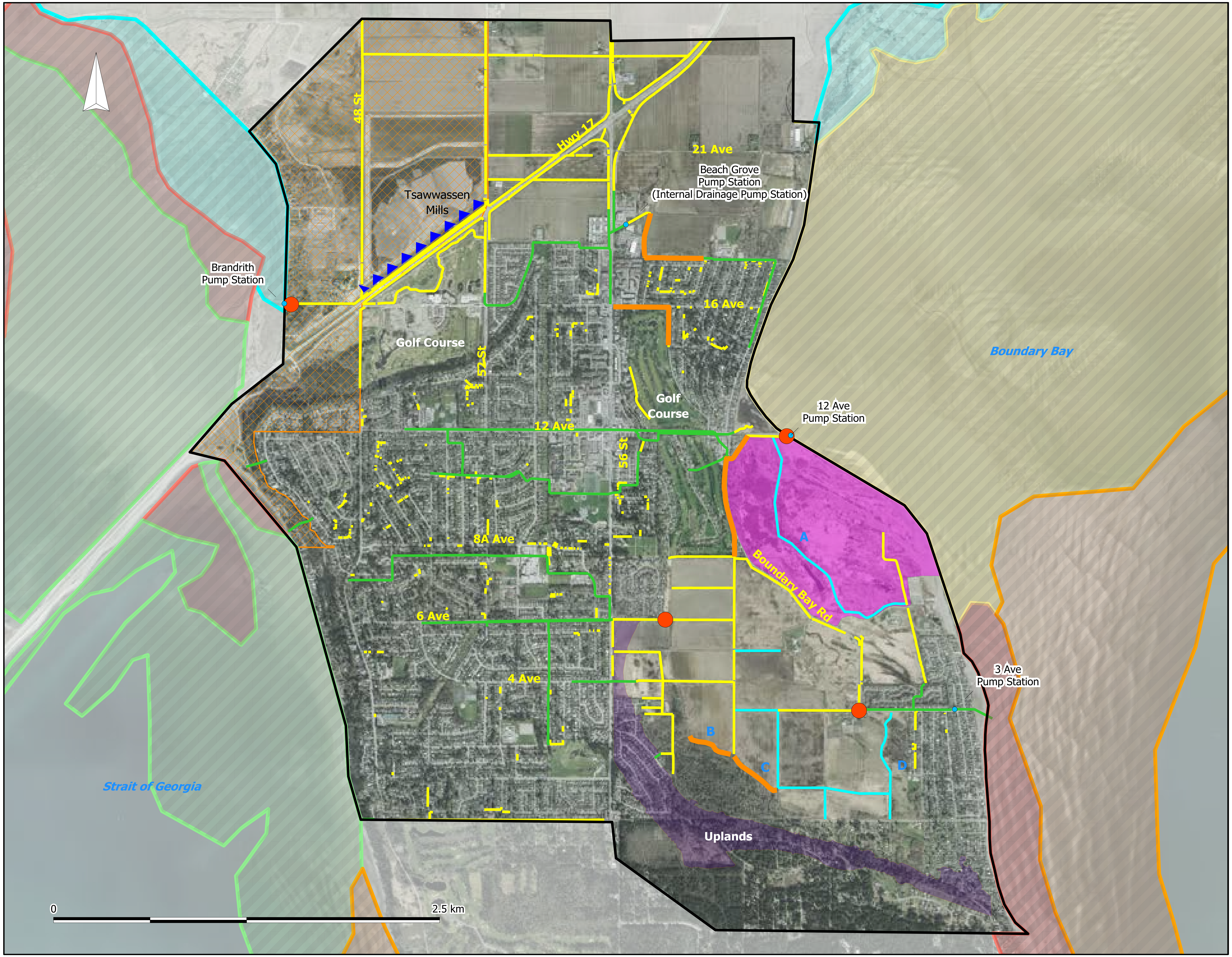
The poor water quality is likely attributed to a combination of:

- Contaminants originating from the upland developed areas, as well as those entering the ditches from the agricultural areas.
- Stagnant water within the ditches, particularly during the summer months so that temperatures also increase drastically and oxygen concentrations are depressed.
- Wildlife and waterfowl use.

Of the sites sampled, there was a distinct difference in water quality nearer the uplands than towards the discharge points of the lowlands near the pump stations where water quality was much poorer. This suggests that much of the degradation of the water quality is occurring within the lowland ditches and is related to stagnation and inputs from agricultural activities.

The City of Delta expressed particular concern with pumps discharging water with poor quality in Boundary Bay during low tide in the summer months while there are recreational users of the beaches. Alterations in pump station operation for the 3rd Avenue Pump Station, such that drainage discharges take place at night during the summer, could address this issue and will be discussed in Section 5.

In the context of the ISMP, it is important to address these water quality issues through a combination of enhancement measures. These measures will be discussed in detail in Section 5.



LEGEND

DRAINAGE FEATURES

- WATER QUALITY SAMPLING SITES
- PUMP STATION
- HABITAT COMPENSATION AREA
- AREA BOUNDARIES
- STORM MAIN

WATERCOURSE

- SCHEDULE B
- SCHEDULE C
- UNCLASSIFIED

TERRESTRIAL FEATURES

- TSAWWASSEN FIRST NATION
- BOUNDARY BAY REGIONAL PARK

FORESHORE HABITATS

- EEL-GRASS
- MARSH
- MUDFLAT
- SAND
- SAND/EEL-GRASS

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	02-04-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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Delta

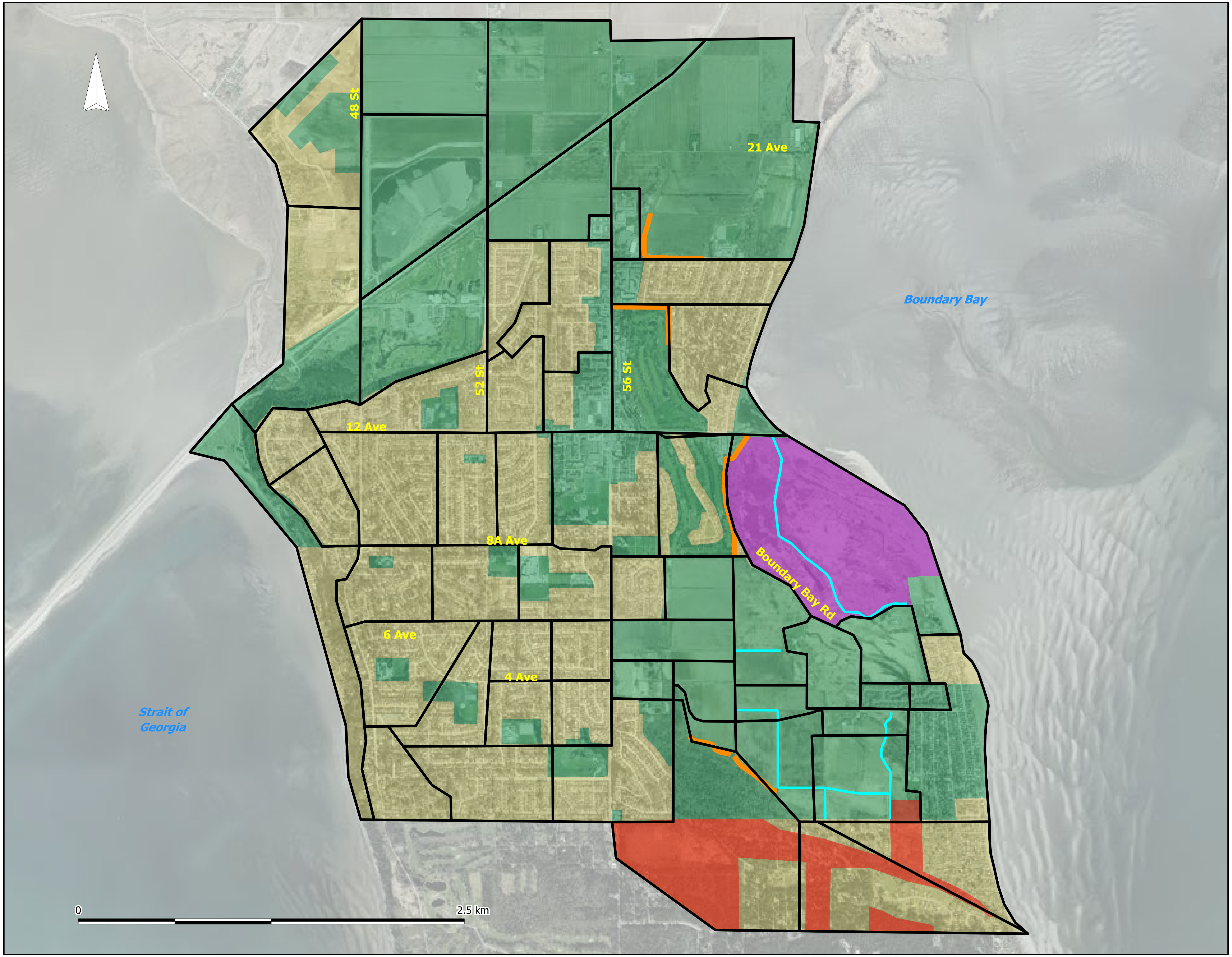
THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

ENVIRONMENTAL &
HABITAT CONTEXT

DRAWING NUMBER	REV. NO.	SHEET
MAP 3-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

UNDER FUTURE DEVELOPMENT
- MINIMAL INCREASE, 0-10%
- MODERATE INCREASE, 10%
- SIGNIFICANT INCREASE, >30%

WATERCOURSE
- SCHEDULE B
- UNCLASSIFIED

TERRESTRIAL FEATURES
- BOUNDARY BAY REGIONAL PARK

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		JS	21-04-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

ANTICIPATED INCREASES TO
IMPERVIOUS COVERAGE

DRAWING NUMBER	REV. NO.	SHEET
MAP 3-2		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

4 Hydrologic and Hydraulic Event-Based Modelling

4.1 EXISTING CONDITION MODEL AND CALIBRATION

We built a hydrologic and hydraulic model based on data from Delta's GIS mapping of drainage network components and information from the OCP on land use. Only major storm drainage trunks, 450 mm and above, and significant ditches were included in the model at this planning level study.

We developed design rainfall events using the SCS Type 1A curve and IDF data for the Pebble Hill Reservoir rain gauge (DT61) operated by Metro Vancouver.

We calibrated the model based on flow monitoring data collected by SFE in storm mains collected near the intersection of 56 Street and 6 Avenue. Flow monitoring data can be found in Appendix C. Calibration of the model allows us to more closely mimic the actual watershed response to precipitation in our model based on recorded flows in the storm system.

More details on model development can be found in Appendix D.

4.2 FUTURE CONDITION MODEL AND CLIMATE CHANGE

Our future condition modelling included updates to the system based on the expected densification of residential areas as well as build out of the area in Point Roberts which drains to Tsawwassen.

We applied a 50% percent increase to the total rainfall volume for the 24-hour storm which was based on similar lower bound increases found in a recent climate change study from the City of Surrey[5] through year 2080. In the study, computational routines were used to downscale global climate / circulation models to a local resolution for the Kwantlen rain gauge in Surrey for various climate change scenarios. Given the similar climatic conditions between Tsawwassen and Surrey, using Surrey's updated IDF curves allows us to take advantage of data based on detailed regional downscaling. Climate change projections should be reconfirmed when infrastructure upgrades are being advanced through planning and design.

Sea level rise and storm surge will both influence the shoreline of the Tsawwassen area and should be looked at in more detail. However, these aspects are beyond the scope of this ISMP. Gravity outfalls at the current Brandrith Pump Station, and the upland 12th Avenue system will become less effective as they will not be able to open as often or for as long with higher sea levels, combined with storm effects. Increased pump station capacify may be required, both in terms of total flow as well as static lift, to address the greater emphasis on drainage pumping. We referenced the *Southlands Area – Coastal Flood Modelling*

[5] Dillon Consulting on Behalf of City of Surrey. 2015. Development of Future IDF Statistics for the City of Surrey.

and Flood Construction Level Assessment [6] when estimating high tide events given climate change to apply values to boundary conditions in our model.

4.3 MODELLING STRATEGY

We created scenarios utilizing the 10- and 100-year return period 24-hour storm to assess the performance of the storm drainage network by reviewing peak hydraulic grade lines (HGL) and peak flow at significant locations within the study area.

The following criteria were used to evaluate locations with deficient infrastructure:

- Minor system storm pipes surcharging or showing significant head loss under the 10-year return period 24-hour storm.
- Major system culverts and ditches overflowing or showing significant head loss under the 100-year return period 24-hour storm.

All of the piped flows (with the exception of culverts within the study area and the under construction the 12th Avenue Stormwater Improvements project peak flow diversion pipe) are minor drainage system components and are therefore assessed based on the 10-year return period criteria.

The major drainage system is defined as overland flow paths, major open channels, and culverts that convey flows up to and including the 100-year return period design event. The major drainage system components we modelled for this ISMP were the major watercourses and their associated culverts, as well as the 12th Avenue Stormwater Improvements project peak flow diversion pipe. Overland flow paths were not modelled.

4.4 SYSTEM DEFICIENCIES

The results from our hydraulic modelling were used to identify deficiencies in the storm gravity mains, culverts, and ditches based on surcharging under either the 10-year (minor system) or 100-year (major system) return period design event as applicable. We assessed the deficiencies within the system under existing and future development conditions, and future development conditions with climate change.

4.4.1 Deficiencies under Existing and Future Conditions

Table 4-1 describes the location and nature of each identified deficiency under existing development and climatic conditions. Map 4-1 highlights the locations of deficient infrastructure in the existing condition. Long profiles indicating the system deficiencies for both existing and climate change conditions can be found at the end of Appendix D.

[6] Associated Engineering on Behalf of City of Delta. 2012. Southlands Area – Coastal Flood Modelling and Flood Construction Level Assessment.

We found no significant deficiencies in the major system based on the criteria listed above for the existing and future conditions.

Table 4-1
List of Deficiencies in the Minor System

MINOR SYSTEM		
Deficiency ID (Map 4-1)	**Location**	**Description**
D-2 (See Figure D-2 for 10-year peak HGL profile)	Storm main trunk extending along 18th Avenue to Spyglass Crescent	Some of the 1200 mm and 1500 mm diameter storm pipes along this roadway are undersized and surcharge in the 10-year return period event. These pipes are causing backwater effects and surcharged manholes upstream.
D-3 (See Figure D-3 for 10-year peak HGL profile)	Storm siphon along 12 Avenue	The storm siphon (varied pipe size) is undersized causing backwater effects and surcharged manholes upstream.
D-4 (See Figure D-4 for 10-year peak HGL profile)	Storm pipes along 10A Avenue and Ferguson Road	The storm mains (varied pipe size) are undersized along this profile. These pipes are causing backwater effects and surcharged manholes upstream.

Figures D-6 through D-8 show the same deficiencies under climate change.

In areas where pipes are surcharging to surface, there is a risk of overland flooding. Areas at risk of flooding under existing conditions include the North Tsawwassen residential areas, much of the central Tsawwassen single family residential neighborhoods, and the 3rd Avenue Pump Station service area.

These areas drained by the minor system storm mains could experience significantly more flooding overtime with climate change effects. We cannot quantify this risk with a 1D PCSWMM model. We recommend that more detailed 1D-2D modelling with coupled major and minor systems (including overland flow) be completed to assess the surficial flooding extents and severity. The lowland major drainage system appears to have adequate capacity during the existing and future scenarios. More detailed field reconnaissance and modelling could be completed to confirm these assumptions.

In the future development scenario, the same deficiencies remain apparent, and are exacerbated. No additional deficiencies were noted at this stage.

4.4.2 Deficiencies under Future Conditions with Climate Change

When modelling a rainfall scenario that includes the impacts of climate change, the problems listed in Table 4-1 are further exacerbated, and new problems are created in the system. Map 4-1 highlights the locations of deficient infrastructure during the future development condition with climate change scenario. Areas within the system that are deficient under both the existing and climate change scenario are indicated on the map in red. Long profiles comparing the deficiencies under the climate change event which are also deficient in the existing scenarios can be found in Appendix D, Figures D6-D8.

As discussed in Section 4.2 above, we estimate that Tsawwassen could experience a 50% increase in precipitation under the RCP 8.5 emissions scenario, by the year 2080. Storm mains typically have a design life of 50 years or more depending on their level of service, and over their service life, newly upgraded pipes will be subject to a significant increase in peak flows due to climate change. We expect that installing larger pipes sized for climate change will only have an incremental impact on the total replacement cost. This is likely more cost effective than undertaking a new replacement cycle before the end of the service life of a pipe. As such, our recommended pipe upgrades in Section 5 below are sized accounting for the estimated impacts of climate change on precipitation and the resulting peak flows.

In determining required pipe upgrades in the urban system, we assumed that new pipes would be graded in relatively smooth profiles, in contrast to portions of the existing network that vary widely in slope over short distances. Maintaining consistent pipe slopes is more hydraulically efficient, which allows for the use of smaller pipes for identified upgrades. See Figure 4-1 for an example of a pipe profile along Spyglass Crescent in its existing state, and after we made changes to both pipe diameters and inverts. The City should ensure that new pipe upgrades maintain a consistent downward slope when completing any pipe designs and installations.

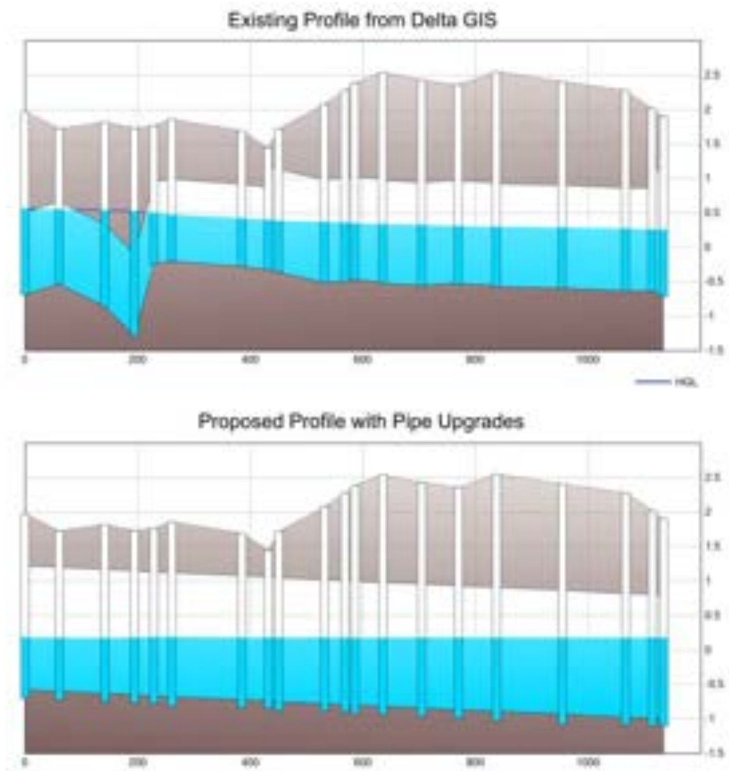
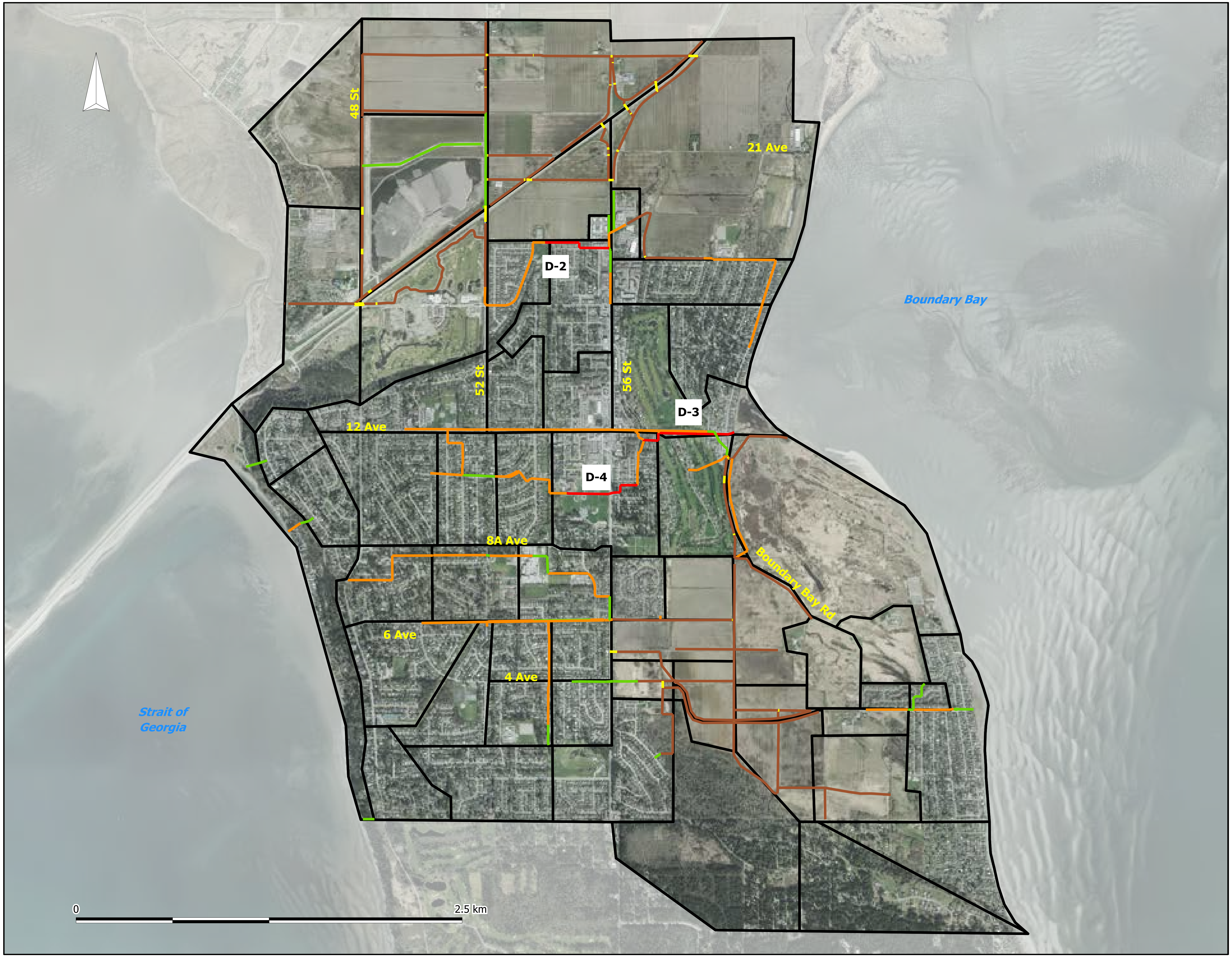


Figure 4-1
Example of Existing and Proposed Pipe Profiles

In addition to the deficiencies in the minor system, some of the downstream extents of the piped system are backwatered during the climate change scenario for the 100-year design storm due to a lack of ditch capacity downstream, or a lack of pump capacity. We identified these issues and other problems with capacity in the major system for the 100-year event with the impacts of climate change:

- Backwatering of the 3rd Avenue system upstream of the pump station.
- Backwatering of the minor system upstream of 12th Avenue Pump Station.
- Ditches upstream of Brandrith Pump Station are exceeding capacity and causing backwater effects upstream in the North Tsawwassen and Beach Grove catchments.
- Ditches downstream of the Southlands Development exceeding the 1.4 m HGL boundary condition stated for the development.

We will identify options to fix the issues in the minor and major system to mitigate the impacts of climate change in Section 5.



LEGEND

(red line)	DEFICIENT UNDER EXISTING CONDITIONS AND CLIMATE CHANGE
(orange line)	DEFICIENT UNDER CLIMATE CHANGE
(yellow line)	CULVERT
(brown line)	DITCH
(green line)	STORM GRAVITY MAIN
(cyan line)	PRESSURIZED STORM MAIN
(outline)	SUBCATCHMENTS
x-X	DEFICIENCIES ID

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	04-27-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

LOCATION OF DEFICIENCIES

DRAWING NUMBER	REV. NO.	SHEET
MAP 4-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

5 Implementation Strategy

In this section of the report, we present comprehensive recommendations to maintain or improve watershed health while allowing managed development to occur in the watershed. These recommendations include rainwater management measures, necessary and potential infrastructure upgrades, and environmental enhancement opportunities.

5.1 SPECIFIC IMPROVEMENTS TO STORMWATER MANAGEMENT

Table 5-1 outlines the proposed drainage upgrades and enhancement opportunities within the study area, and Map 5-1 shows the location of each specific recommendation. Of the minor system upgrades, Delta should prioritize areas noted in Section 4 as deficiencies in the existing condition. The LID and BMP measures as well as additional environmental enhancement options, which will be applied in general areas rather than specific locations, are discussed in subsequent sections. Upgrades to the major system (upgrades to ditches and culverts) have been developed for conveyance of the 100-year design flow with climate change effects.

The majority of the recommended upgrades are intended to be implemented in an opportunistic manner over the long term in association with broader scope infrastructure projects (such as road or other infrastructure upgrades) or in the context of drainage system renewal as a result of normal life cycle considerations. The identified capacities (e.g. pipe sizes or pumping capacities) of these upgrades address future impacts of climate change in terms of estimated increases in rainfall, and consequently runoff, that are likely to arise during the lifespan of the new components (i.e. 75 years or more). Storm infrastructure upgrades implemented in the future will have expected service lives that extend well into the time horizon of the estimated climate change impacts. While not necessarily required in an immediate sense, drainage infrastructure projects from this point forward need to recognize these conditions.

Generally, land use changes are minor and are not a driver for most recommended infrastructure upgrades, and the priority ranking reflects whether the identified component is subject to capacity constraints under existing climatic conditions, or under a future time horizon related to climate change. Those indicated with ‘High’ priority should be prioritized and included in Capital Works projects over the next 5 years. ‘Medium’ priority should be included in Capital Works projects over the next 20 years. Upgrades and improvements indicated as ‘Low’ priority items should be upgraded in an opportunistic manner over the next 20-40 years.

The upgrades within the system are high-level estimates primarily for planning purposes. It is expected that the City would complete further analysis of the system prior to any detailed design should they consider upgrading any components of the drainage system. Climate change projections should be reconfirmed when infrastructure upgrades are being advanced through planning and design.

In Appendix E we provide a detailed list of pipe upgrades for each group upgrade listed in the table below along with maps for each group. Cost estimates follow the pipe upgrades in Appendix E. Without detailed survey of ditch geometries throughout Tsawwassen, the existing dimensions provided in the tables in Appendix E are estimated from general observations of average ditch dimensions within the system.

Table 5-1
Improvements and Upgrades

ID	Priority	Location	Time Horizon	Description	Cost Estimate
Minor System Upgrades					
MN-1	Low	Beach Grove Road/17a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$4,900,000
MN-2	High	North portion of 56 Street, 18 Avenue, Spyglass Crescent	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change. Smooth pipe profile to improve hydraulic efficiency.	$15,500,000
MN-3	High	Trunk and Storm Siphon along 12 Avenue	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.	$12,200,000
MN-4	Low	North side of 50b Street, 51 Street and Western extent of 50a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$1,500,000
MN-5	High	Trunk along 10a Avenue, through Winskill park, and Ferguson Road,	Short Term (0-5 years)	Capacity constraints are present under existing condition, problems are further exacerbated by climate change. Minor system components should be sized for a 10-year return period event with climate change.	$7,500,000

ID	Priority	Location	Time Horizon	Description	Cost Estimate
MN-6	Low	Pipes through Beach Grove Golf Club and along Boundary Bay Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change (by twinning the pipe).	$3,700,000
MN-7	Low	Pipe Outfall from Pacific Drive to Tsawwassen Beach Road	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$400,000
MN-8	Low	Trunk south of 8a Avenue	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$5,600,000
MN-9	Low	6 Avenue and 54 Street	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$6,300,000
MN-10	Low	3rd Avenue Trunk	Long Term (20-40 years)	Pipes have capacity issues in the long term due to climate change impacts. Minor system components should be sized for a 10-year return period event with climate change.	$1,900,000
Major System Upgrades					
MA-1	Low	3rd Avenue Pump Station	Long Term (20-40 years)	Increase 3rd Avenue Pump Station capacity. Outfall pipe capacity should be increased in tandem.	$5,800,000
MA-2	Low	12th Avenue Pump Station and Ditch along Boundary Bay Road	Long Term (20-40 years)	Increase 12th Avenue Pump Station capacity. Provisions to allow for climate change impacts have already been included in the design. Increase the capacity of the ditch along the west side of Boundary Bay Road and culverts.	$31,700,000

ID	Priority	Location	Time Horizon	Description	Cost Estimate
MA-3	Low	Brandrith Pump Station and Ditches Upstream of Brandrith Pump Station	Long Term (20-40 years)	Increase ditch capacities upstream of the Brandrith pump station and associated culverts and increase pump station capacity. Alternatively consider building an additional pump station to reroute drainage to a separate location.	$35,600,000
Environmental Enhancement Opportunities					
EV-1	Medium	12th Avenue Pump Station	Medium (5 – 20 years)	Expand the proposed wetland at the 12th Avenue Pump Station.	$400,000
EV-2	Medium	Brandrith Pump Station	Medium (5 – 20 years)	Build a treatment wetland upstream of the Brandrith Pump Station to filter contaminants before discharging to the marine environment.	$400,000
EV-3	High	3rd Avenue Pump Station/ 12th Avenue Pump Station	Short Term (0-5 years)	Change operation schedule to discharge at High Tides. Consider mechanical/chemical treatment options at 3rd Avenue to improve water quality. Limit flow velocities during discharge events to protect downstream ecosystem.	N/A – Change operation schedule.

**Note: Cost Estimates were rounded up to the nearest $100,000 as these are high level estimates.*

Culvert upgrades for the major system projects can be found in Appendix E as part of MA-2 and MA-3. However, we included a summary table of all culvert upgrades for quick reference for the City in Table 5-2 below:

Table 5-2
Culvert Upgrades

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MA-2				
C-1364	435180	1050 x 1050	2400	13
C-1365	434761	1200	Two 2400 Culverts	49
C-1366	426617 / 426618	1200	Two 2400 Culverts	11

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
		MA-3		
C-1251	Culvert below Highway 17 from 16th Avenue to Eagle Way	1200	1800	63
C-1250	Culvert below Highway 17 from 16th Avenue to Eagle Way	1800	2750	64
C-1361	Culvert below Highway 17 from 16th Avenue to Eagle Way	1050	1500	70
C-1201	Culvert Along 16th Avenue	1500	2400	13
C-1344	Culvert parallel to Highway 17	1800	2750	28
C-1248	Culvert parallel to Salish Sea Drive	1500	2400	38
C-1249	Culvert below Blue Heron Drive	1500	2400	53

5.2 STORMWATER BMPS

5.2.1 Recommended Residential BMPs

In addition to the specific drainage upgrades outlined above, Stormwater Best Management Practices (BMPs) should be implemented to mitigate the potential hydrologic impacts of development within the study area and improve water quality. As discussed, the majority of the study area is already fully developed with no new "green-field" developments planned in the foreseeable future. However, we assume that as the housing stock is renewed overtime, houses will be built with bigger footprints and will have correspondingly greater impervious areas. Additionally, an area in Point Roberts which drains into the study area is currently sparsely developed but is zoned for future rural single family residential housing.

Currently, Delta has wording in their design criteria manual stating, "Stormwater BMPs shall be incorporated where applicable to improve quality of stormwater runoff from the developed properties and reduce stormwater volumes in accordance with provincial and federal guidelines" (Bylaw 7162). Metro Vancouver has recently released the "Region-wide Baseline for On-site Stormwater Management" providing minimum requirements for BMPs on single family lots (Metro Vancouver, 2017). As we expect most of the redevelopment in the future will be on single family lots, we assume that the baseline measures as stated in the Metro Vancouver report will be implemented to mitigate impacts of development:

- Ensure all paved areas drain to a permeable surface (pervious pavement can be used as an alternative) and not directly to a roadway.
- Limit total impervious area to a maximum of 70% on each lot.
- Disconnect downspouts from the storm system to drain to a permeable surface.
- Increase the minimum absorbent topsoil depth to 450 mm.

- Limit maximum outflow rates from lots to 40% of the 1 in 2 year storm of 24 hour duration as stated in Metro Vancouver's Baseline document (2017). For Tsawwassen this translates to approximately 28 mm of rainfall in 24 hours with climate change.

We assume that these BMPs will be applied in areas of future densification (single family lots) and redevelopment. This reflects the fact that future development activities will provide the City with an opportunity to enforce BMP measures as densification occurs. Conversely, it is more challenging to retrofit BMPs on existing development, but the City should consider incentives to encourage implementation of BMPS on existing lots where possible. The majority of the upland areas in Tsawwassen are single family residential, so implementing BMPs on these lots to reduce a major source of runoff and capture contaminants will contribute to improving downstream water quality and reducing peak flows. The BMPs recommended above are easier to implement by homeowners in comparison to rain gardens or infiltration trenches which require proper installation and maintenance. Pervious pavement does require long term maintenance, however, so options such as grading driveways to drain to pervious surfaces or using paved strips for driveways to minimize impervious coverage may be simpler alternatives. Encouraging use of rain barrels or planter boxes will also improve on lot stormwater retention. Of note, these two measures can be applied on existing properties without requiring residents to significantly alter their lots.

As with pipe upgrades, BMPs should be implemented on an opportunistic basis, whenever new or re-development plans are created or when roadways and housing developments are renewed. Taking advantage of new construction will help build the cost of BMPs into the redevelopment costs at a fraction of the amount than if they were installed retroactively. In general, detention systems should be considered as alternatives to pipe upgrades in areas with sufficient space to fit above or below ground detention systems. Controlling peak flows may reduce the required pipe sizes downstream. Surface detention can be considered in parks or green spaces, and underground detention on larger commercial and multi-family developments.

The City of Delta should consider hosting an education program for residents to inform them of the positive impacts of implementing BMPs on their lots and provide support to make these changes. Public buy in is essential to meet the above stated targets.

It is important to note that infiltration based source controls (BMPs) and runoff retention features such as raingardens and growing medium prescriptions are generally only effective over the spectrum of small, frequently occurring, rainfall events. Their ability to address large rainfall events of a design magnitude, such as a 10- or 100- year rainfall event is generally very limited, i.e. minor proportions of the overall rainfall volume. Additionally, consideration must be given to the likelihood that large events are often proceeded by wet antecedent conditions, reducing or nullifying the efficacy of these measures. Accordingly, at least in the context of the Lower Mainland, it is not realistic to expect that these systems will reliably reduce the total runoff volumes and peak flow rates that must be conveyed in conventional drainage systems. Also, as the estimates of climate change driven increases in precipitation continue to move upward, the benefit in using rainwater management approaches to reduce runoff volumes from design storm events becomes relatively minor. While there a great many environmental and ecological reasons why rainwater management of small storm events is beneficial and desirable, addressing capacity constraints and overland flooding risk from major storms, both with and without climate change, is not one of them.

The City should look for opportunities to implement community scale detention storage to attenuate peak flows from the Tsawwassen uplands. The primary challenge with retrofitting detention storage in the Tsawwassen uplands will be obtaining sufficient open space, at appropriate locations in the drainage system. However, if successfully implemented, detention storage may allow for a reduction in the size and extents of future drainage infrastructure upgrades required to address climate change impacts.

Infiltration based BMPs and source control strategies should only be employed in areas with suitable soils and with a minimum setback from steep slopes. Geotechnical engineers should be consulted on issues of slope stability and soil infiltration capacity.

5.2.2 Additional Recommended BMPs

BMPs should also be implemented on commercial/multifamily/industrial lots and roadways, where possible during redevelopment or upgrades.

Rain garden adjacent to parking lot.

Commercial (and Multi Family/Industrial) Lots

In Appendix F, we described a number of potential BMPs that can be applied on commercial and multi-family lots. These include bioswales/rain gardens, green roofs, underground detention, and absorbent soils.

We recommend implementing bioswales along the edges of parking lots, while rain gardens can be located to receive runoff from parking lots and/or rooftops. Based on Metro Vancouver's Stormwater Source Control Design Guidelines (2012), bioswales and rain gardens should both be sized to at least 5% of the impervious area they service. This represents a 20:1 ratio of impervious area to bioswale/rain garden footprint. The guidelines provide additional recommendations regarding the detailed design and application of these BMPs.

Rain garden adjacent to buildings.

Where buildings have flat roofs, and occupy a large fraction of the total lot area, we recommend that green roofs be implemented. The standard range for green roof soil depths is 150 mm to 600 mm, as noted in the Stormwater Source Control Design Guidelines.

Absorbent soils should be implemented at a minimum depth of 450 mm as discussed in Metro Vancouver's recent Region-Wide Baseline for On-site Stormwater Management document (2017). In a typical commericial lot, medians between parking stalls and areas around the perimeter of buildings are good locations to add absorbant landscaping and rain gardens. Grading impervious surfaces to drain to pervious surfaces is recommended to help attenuate peak flows for small storm events.

Water quality treatment should be implemented for commercial or industrial lots that may generate higher levels of contaminants, to provide treatment before stormwater is discharged to the main system. Underground stormwater detention tanks can be implemented in conjuction with treatment devices to improve water quality and attenuate runoff.

Source controls implemented by The City should meet the release targets and storage requirements outlined in Table 5-3 to reduce stress on the storm sewer system. The release rates and storage requirements are estimated to mimic hypothetical natural peak runoff rates for a the 24 hour duration, 10-year period storm event (for current climatic conditions).

Table 5-3
Source Control Release Targets and Storage Targets

Minimum Required Storage Volume	Maximum Allowable Release Rate
120 m^3 / hectare	21 L/s / hectare

Roadways

There are a variety of road classifications within the study area, including local, collector, and arterial roadways consisting of 18 m, 20 m, and 24 m right-of-way widths respectively. As noted previously, road rights-of-ways present significant opportunities to implement BMPs because they are linear and are within the City's control. Further, since the City already has funding committed to road projects, these projects present an opportunity to incorporate BMP measures in a cost-effective manner. Rather than planning and funding Stormwater Low Impact Development projects in isolation, existing road projects under Delta's Neighborhood Road Improvements Plan can be modified to achieve LID goals. Road rights-of-way can incorporate a variety of BMPs depending on their width, including:

- Bioswales,
- Pervious pavement,
- Rain gardens,
- Absorbent landscaping combined with street trees, and
- Structural porous soils.

Where space allows, we recommend bioswales and rain gardens be built on the edges of local and collector roads, and in the center of arterial roads, to receive and treat runoff. Rather than using raised road medians on arterial roads to separate traffic, linear bioswales, depressed below the road surface, can be built to collect the runoff from the roadways, while providing aesthetic value. On streets with low traffic volumes, curb bulges, in which curbs are extended into the roadway for placement of rain gardens, can be effective in decreasing the impervious area of roadways while contributing to traffic calming measures. These BMPs will both filter out contaminants from the roadway runoff and attenuate peak flows. Pervious pavement is best used for sidewalks, as runoff on sidewalks has less total suspended solids content than roadways which can clog pavement pores and require increased maintenance.

BMPs should be encouraged on all projects as part of Delta's Neighborhood Road Improvements Plan. Details on roadside swale and rain garden design can be found in Delta's Design Guidelines Bylaw 7162 as well as Metro Vancouver's Stormwater Source Control Design Guidelines (2012).

For a full list of applicable BMPs to the study area and descriptions of each, see Appendix F.

Infiltration BMPs should not be considered above areas which exhibit potential slope stability hazards, such as the English Bluffs. We recommend infiltration BMPs be offset from the western and northern bluff areas by a minimum of 100 m. A qualified geotechnical or hydrogeological professional should confirm acceptability of proposed BMP locations for all cases, and confirm required setbacks from all slopes. In areas where infiltration is not feasible or practical, flow through (non-infiltration) BMPs can be used as an alternative, where all drainage from these systems is eventually directed back into the stormwater system. Flow through BMPs will not provide runoff volume reduction but will attenuate peak flows.

5.2.3 Summary of Recommended BMPs

Table 5-4 summarizes the recommended BMPs from Section 5.2.1 and 5.2.2 for quick reference for the City.

Table 5-4
BMP Recommendations

Residential Lots	Commercial/Multi-Family Lots
• Ensure all paved areas drain to a permeable surface and not directly to a roadway. • Limit impervious area to a maximum of 70% on each lot. • Disconnect downspouts from the storm system to drain to a permeable surface. • Increase the minimum absorbent topsoil depth to 450 mm. • Limit runoff to 40% of the 24 hour, 2-year return period rainfall (equivalent to 28 mm).	• Require pre-treatment of stormwater runoff for hydrocarbon and sediment removal. • Apply bioswales/rain gardens, green roofs, underground detention, and absorbent soils where possible. • Provide a minimum required storage volume of 120 m3 / ha with a maximum allowable release rate of 21 L/s/ha for a 24 hour duration, 10-year return period event. This release rate reflects the estimated peak flow rate under hypothetical natural conditions.

5.2.4 Impacts of BMPs in Tsawwassen

We completed an Extended Period Simulation (EPS) to assess the impacts of densification and development in the Tsawwassen area. For more details on this assessment of existing and future conditions, without application of mitigative measures, refer to Appendix F. This analysis provides information on the distribution of high flows and illustrates attenuation of runoff when comparing results between different model scenarios. In general, without application of source controls, future densification will decrease infiltration leading to increased runoff and peak flows. To assess the effectiveness of our recommended BMP measures in mitigating future densification, we updated our EPS model to account for these BMPs on single family lots and on commercial properties/roadways throughout the study area by altering the internal routing and storage parameters. We did not model BMPs in the sub-catchments in the English Bluffs area as they are not applicable due to potential risks of slope stability hazards arising due to excess infiltration, as noted in Delta's Design Guidelines. For this updated modelling exercise, we used one year of extended rainfall data (Summer 2010-2011).

Using the results from the EPS models, we created flow-duration-exceedance curves for the future condition with the application of BMPs. The results are presented on Figures 5-1 and 5-2, which also includes the flow-duration-exceedance curves for both the existing development condition and the future development conditions without BMPs. The reporting location for each curve is indicated on Map 5-2.

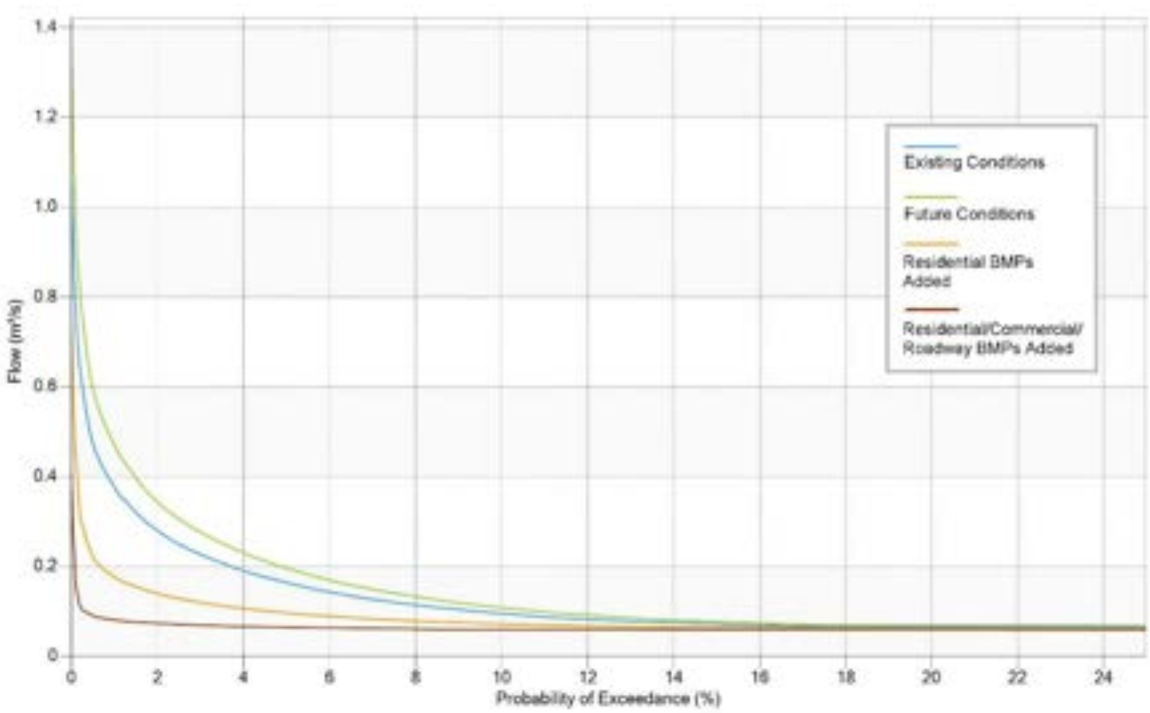

Figure 5-1
Outfall Ditch at 56 Street and 6 Avenue- D-1393

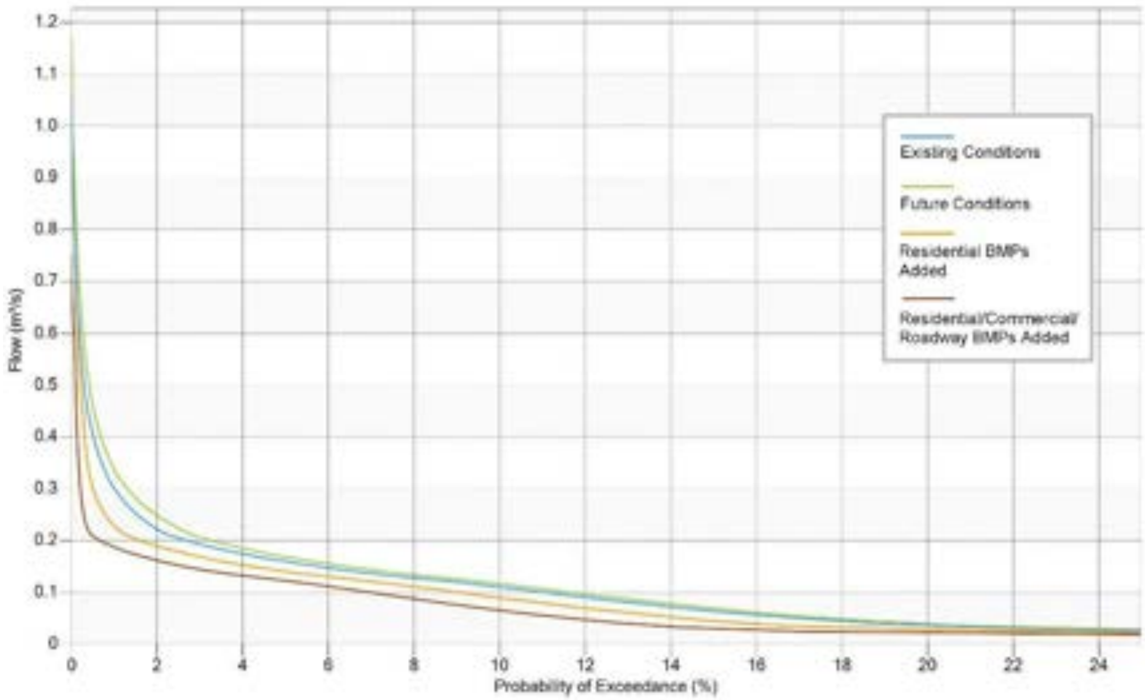

Figure 5-2
Outfall Ditch at Spyglass Crescent and 52 Street – D-1437

For both locations, it is clear from the EPS that the addition of BMPs reduce the duration and magnitude of high flows. For the outfall at 56 Street, flows in the 95th percentile (5% probability of exceedance) move from approximately 0.2 m^3/s in the future scenario to 0.07 m^3/s with all BMPs added. For the outfall at Spyglass Crescent, flows in the 95th percentile move from approximately 0.17 m^3/s in the future scenario to 0.12 m^3/s with all BMPs added. Even with future densification, implementing BMPs can have a net positive impact on the runoff conditions in the Tsawwassen area in comparison to existing conditions. Figure 3-3 illustrates example hydrographs for a sample rainfall event during the EPS scenario run for D-1393.

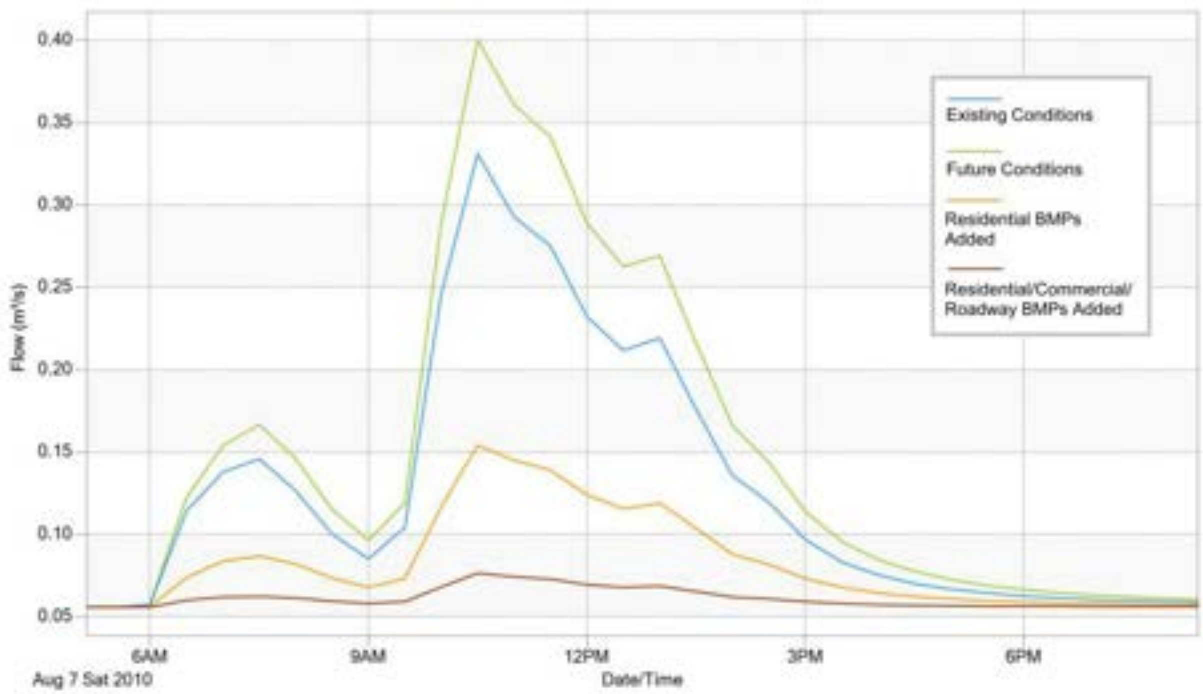

Figure 5-3
Example Hydrographs for D-1393

Figure 3-3 shows a significant decrease in flow volume (area under the curve) between future scenarios and scenarios with BMPs, illustrating the positive impact of adding BMPs to the system. BMPs allow for increased infiltration throughout the study area removing a large portion of runoff which would otherwise be routed downstream through the storm system.

5.3 ENVIRONMENTAL ENHANCEMENT OPPORTUNITIES

5.3.1 Water Quality Improvements

Upland Water Quality

Contaminants contained within urban runoff may be managed by stormwater BMPs (rain gardens, bioswales, infiltration facilities). However, the uplands are mostly built-out and are predominantly residential properties. It is very difficult to enforce or monitor the performance of stormwater management systems on residential lots. Therefore, the City should watch for opportunities involving larger-scale redevelopments in the uplands and apply rainwater management features to these developments.

The City's Tsawwassen Area Plan highlights policies and objectives that directly relate to improved water quality in runoff. For example, one such policy identifies the desire to maintain a 'garden theme' throughout Tsawwassen to promote the use of native vegetation on road rights-of-way and private developments. As a condition of redevelopment within the 'small town' centre, the plan encourages the development of parking lots that are aesthetically pleasing. This provides an opportunity to consider pervious pavers, as well as vegetated rain gardens, bioswales, or similar green infrastructure with attenuation, runoff reduction and water quality benefits.

Lowland Water Quality

The characteristics of the lowlands, including lack of shade and stagnant water conditions, will continue to cause water quality issues in the ditches. To address water quality issues associated with runoff from adjacent agricultural lands, a vegetated buffer strip should be provided along the ditches in the lowlands. This buffer will help filter contaminants, including nutrients and fecal coliforms from the agricultural fields, will shade the ditches to help moderate temperature, help prevent growth of instream aquatic vegetation, and will also serve as a corridor for small wildlife.

As noted in the table of enhancement projects (Section 5.1), further polishing of the water should be applied near the pump stations in the form of treatment wetlands. This would provide a final polishing of the water prior to discharge into the marine receiving environment, particularly at the 12th Avenue Pump Station and Brandrith Pump Station. Treatment wetlands are not feasible at the 3rd Avenue Pump Station given space constraints, however mechanical/chemical treatment options should be considered. Alternatively, we recommend changing the operation procedures of the pump station to discharge at high tides to increase flushing and dilution and reduce any aesthetic concerns on adjacent beaches.

5.3.1 Additional Enhancement Opportunities

During the review of existing information as part of the first stages of this ISMP, several potential opportunities to enhance and restore the environmental conditions in the study area were identified. Pursuing these opportunities whenever feasible will contribute to the general overall improvement of the watercourse / watershed health in the study area. These include:

- Maintain aquatic habitat where possible to provide habitat and nutrients for aquatic and semi-aquatic wildlife.
- Maintain ditch, watercourse, intertidal and marine habitat functionality (i.e. maintain or improve: flow, water levels, connectivity, riparian and intertidal vegetation).
- Complete any construction works within designated least harm/risk timing windows.
- Implement Best Management Practices including:
  - Standards and Best Practices for Instream Works[7].
  - Land Development Guidelines for the Protection of Aquatic Habitat[8].

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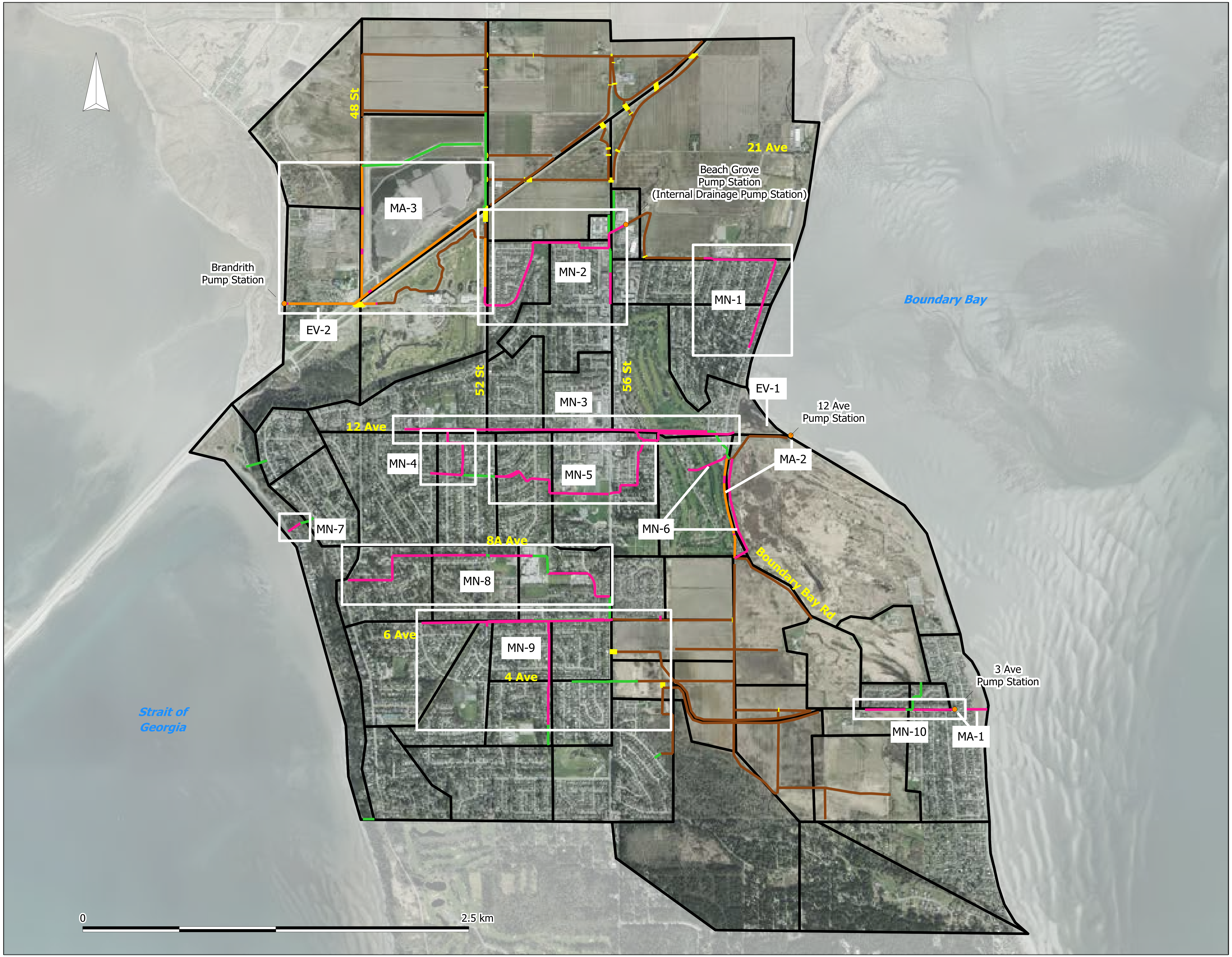
[7] B.C. Ministry of Water, Land and Air Protection. 2004. Standards and Best Practices for Instream Works. Available at: http://www.env.gov.bc.ca/wld/documents/bmp/iswstdsbpsmarch2004.pdf (accessed July 2016).

[8] Fisheries and Oceans Canada (DFO). 1993. Land Development Guidelines for the Protection of Aquatic Habitat. Available at: http://www.dfo-mpo.gc.ca/Library/165353.pdf (accessed July 2016).

    - Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia[9].
- Maintain and enhance structure and diversity of treed and shrubby ecosystems by:
    - Re-vegetating newly built areas to reduce surface runoff and improve rainwater retention.
    - Decreasing impermeable surfaces where possible and finding opportunities to reduce or mitigate hard surfaces.
    - Incorporating invasive species management, where necessary.
- Maintain riparian linkages to connect environmental areas by:
    - Considering green space corridor connectivity to enhance or restore wildlife habitat corridors.
    - Maintaining existing wildlife movement corridors.
- Plan and develop landscape as part of a sustainable ecological system by:
    - Considering the effects of climate change on the natural and built environment.
    - In new built-environments, directing surficial water flow to natural environments such as wetlands, green space corridors, or multi-storey forested habitat.
    - Constructing "catchment" ecosystems that will reduce runoff and retain rainwater and improve capacity for biodiversity.
    - Maintaining the health and vigour of existing vegetation and considering the occurrence or potential for spread of invasive plant species.
    - Incorporating habitat values for fish and wildlife, including species at risk, and maintaining habitat capacity for wildlife.
    - Managing topsoil to preserve existing topsoil condition to support vegetation and maintain rainwater infiltration.
    - Incorporating permeable surfaces (e.g., pathways) and planting vegetation to promote structural complexity and accommodate surface runoff.
- Building new green spaces where possible for recreational purposes. Protect areas adjacent and connected to the Boundary Bay Regional Park to protect the ecosystem in this area.

[9] B.C. Ministry of Environment. 2014. Develop with Care 2014. Environmental Guidelines for Urban and Rural Land Development in British Columbia. Available at: http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare/#Main (accessed September 2016).



LEGEND

- CULVERT
- DITCH
- STORM MAIN
- UPGRADED PIPE
- UPGRADED DITCH
- SUBCATCHMENTS
- xx-X UPGRADES ID

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	05-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

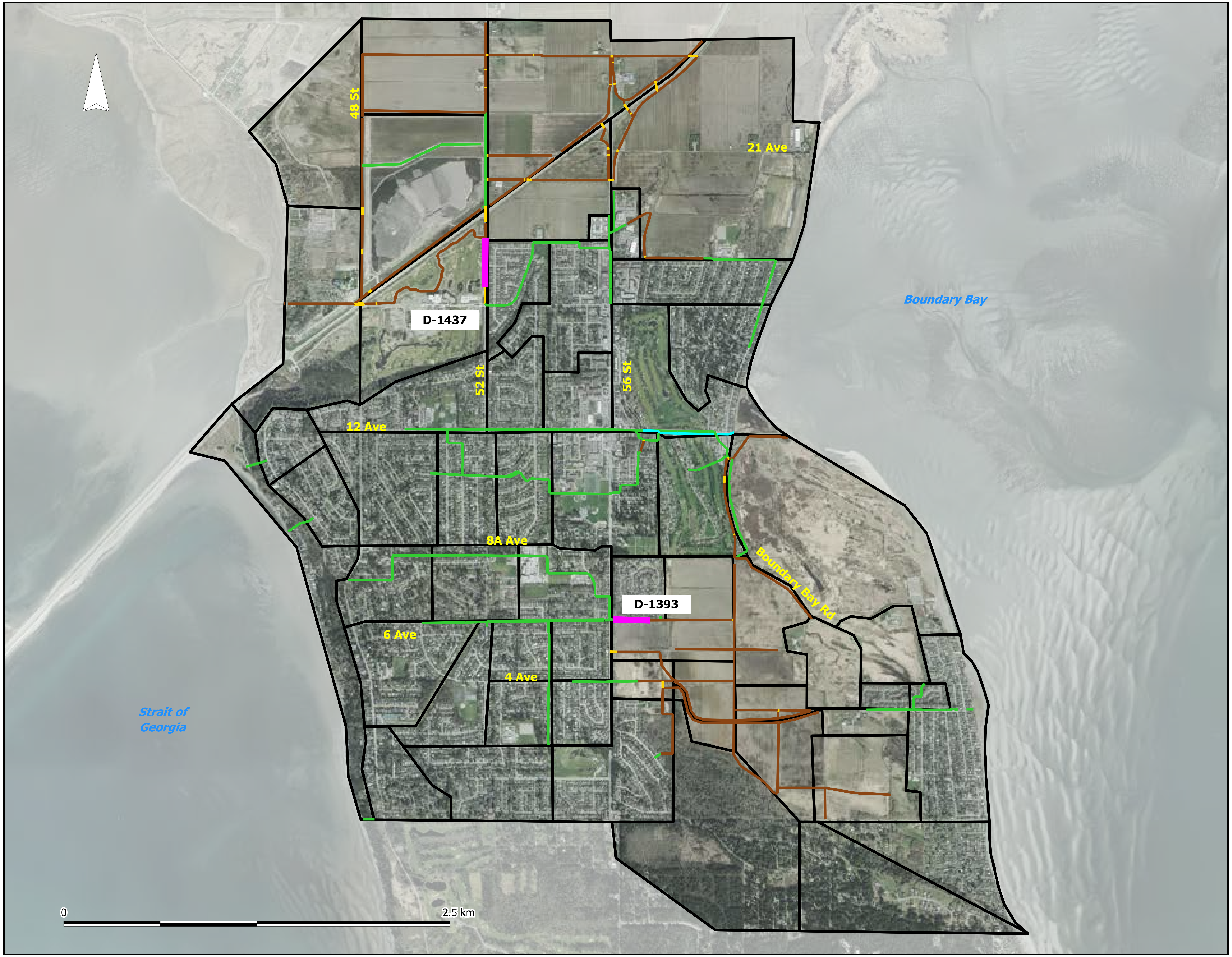
THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

LOCATION OF IMPROVEMENTS AND UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-1		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map



LEGEND

- REPORTING LOCATIONS
- CULVERT
- DITCH
- STORM GRAVITY MAIN
- PRESSURIZED STORM MAIN
- SUBCATCHMENTS

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		AM	14-06-17
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

REPORTING LOCATIONS FOR FDE CURVES

DRAWING NUMBER	REV. NO.	SHEET
MAP 5-2		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_figures_20180501_nv.map

6 Enforcement, Funding, and Monitoring Strategy

6.1 ENFORCEMENT STRATEGY

The City's implementation of the Tsawwassen ISMP's recommendations will require proactive and effective enforcement of the policy and regulatory aspects of the ISMP. We believe this requires both an enforceable regulatory framework, and community motivation to actively improve watershed health.

Several of the ISMP recommendations critical for supporting watershed health and responsible stormwater management are not supported or enforceable under the City's current bylaws, policies and design guidelines. For enforcement to be effective, we recommend the City update its existing policies, bylaws, and manuals to provide the necessary regulatory framework to support the implementation of these various measures in the study area.

We note that these documents are typically City-wide, and our recommendations must be considered in the context of recommendations arising from other City studies and plans.

To implement projects called out in the Implementation Strategy in Section 5.1, the following changes should be made to the **Delta Subdivision and Development Standards Bylaw No. 7162**:

- Soil depth for lawns is recommended to be a minimum of 150 mm. This should be updated to 450 mm to fulfill Metro Vancouver's new guidelines.
- Text should be added to require implementation of BMPs or set a limit to maximum outflow rates from lots to achieve runoff targets ("limiting runoff to 40% of the 1 in 2 year storm of 24 hour duration") as stated in Metro Vancouver's Baseline document (2017). The equivalent rainfall depth for Tsawwassen would be approximately 28 mm with an allowance for future climate change.
- Add in a requirement to disconnect downspouts on residential lots where infiltration capacity of the receiving soil has been confirmed to be sufficient for proper drainage.
- Add in a requirement for impervious surfaces to drain to permeable surfaces for residential lots.
- Design minor system components to the 10 year event, including a climate change allowance.
- Update IDF curves for climate change or make a note to design storm systems with an allowance for increased rainfall due to climate change.
- Require pre-treatment for hydrocarbon and sediment removal of stormwater runoff from industrial, multi-family, and commercial lots. Minimum required storage volume on these lots should be 120 m^3/hectare and maximum allowable release rate should be 21 L/s/hectare.
- Add more specific requirements and criteria on implementing stormwater BMPs (Section 5.2.16 of Drainage Schedule A), outline new requirements for residential properties.
- Reference Metro Vancouver Stormwater Source Control Design Guidelines (2012) for BMP design criteria.
- Provide clear guidance to designers as to how to incorporate climate change impacts into sizing of drainage infrastructure. Incorporation of climate change impacts in the design capacity (sizing) for

future infrastructure renewal is critical, and should be carried into asset management and capital plans immediately, even if specific projects are not yet formulated.

- Maximum acceptable runoff rates by land use should be included.
- Source control design criteria, including:
  - Maximum outflow rates per hectare of tributary area.
  - Rainfall capture targets (72% of 2-year return period, 24-hour duration rainfall, as per the draft Land Development Guidelines [DFO/MoE]).
  - Water quality objectives and a list of acceptable mechanisms to achieve these targets (bioswales, manufactured treatment units, constructed ponds/wetlands).
- Update design criteria for all open channel conveyance components, such as lowland ditches, to the 1:100 year design standard (including an allowance for climate change).
- Make reference to this ISMP and others in Delta to ensure designers take into account considerations specific to each ISMP study area.

In addition to the changes called out in this bylaw, the following bylaws in Delta will need to be revised to be consistent with the implementation strategy:

- **Delta Zoning Bylaw No. 2750:** Update to reflect new land use and development standards to minimize impervious coverage on lots and maintain native vegetation. More detailed and specific requirements should be included for areas which drain to the 12th Avenue or 3rd Avenue outfall to protect the Boundary Bay Regional Park and connected ecosystems.
- **Storm Sewers Regulation and Connection Charge Bylaw 5786:** Ensure language is provided such that downspouts can be disconnected from the storm system on existing lots and for development/redevelopment.
- **Official Community Plan Bylaw No. 3950:** Refer to ISMPs and include specific requirements on protecting against climate change impacts and implementing stormwater BMPs.
- **Soil Deposit and Removal Bylaw No. 7221:** Refer to ISMPs, ensure soil deposition is carried out in a manner to prevent stream contamination.
- **Pesticide Use Control Bylaw No. 6788:** Reference ISMPs and goals related to preventing contamination of downstream watercourses.
- Delta should create an erosion and sediment control bylaw to control releases of sediment to downstream areas and prevent negative impacts especially in the sensitive habitats of Boundary Bay Regional Park.

All bylaws related to stormwater management in Tsawwassen should refer to the ISMPs such that area specific recommendations can be enforced. See Appendix A, for descriptions of relevant content to stormwater management in these bylaws.

Delta should ensure building inspectors are trained to identify proper implementation of stormwater BMPs. For example, inspectors should identify lot grading is effectively routing runoff onto pervious surfaces and the required depth of topsoil is present.

6.1.1 Provincial

There are provincial acts which may affect the regulatory framework of stormwater management or watershed health within the study area. Those acts include the following:

- 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
- Fish Protection Act
- Fisheries Act
- Integrated Pest Management Act
- Public Health Act
- Riparian Areas Protection Act
- Water Sustainability Act
- Water Protection Act

6.1.2 Federal

There are federal acts that might influence stormwater management or watershed health in the study area. Those acts include the following:

- Canada Marine Act
- Canada Water Act
- Canada Wildlife Act
- Canadian Environmental Protection Act
- International Boundary Waters Treaty Act
- Fisheries Act
- Pest Control Products Act
- Species at Risk Act

Delta should work with the Tsawwassen First Nation to develop and implement consistent stormwater management planning strategies as responsibility for the Tsawwassen area drainage encompasses both jurisdictions. Similarly, drainage from Point Roberts ends up in the study area necessitating the City liaise and coordinate with Whatcom County Authorities.

6.2 FUNDING STRATEGY

A variety of funding sources exist within the City of Delta. Applicable funding sources are discussed in more detail above.

6.2.1 Municipal Funding

Development Cost Charges (DCC) Bylaw 7560

Provides provisions for Delta to implement development cost charges to provide funds for drainage upgrades for people who obtain approval for a subdivision or building permit. Table 6-1 below outlines the DCC allotted to drainage effective January 1, 2018:

Table 6-1
Development Cost Charges Allocated to Drainage

Type of Property	Portion Allotted to Drainage	DCC Rates
Low Density	$1,643	Per dwelling units
Townhouse	$890	Per dwelling units
Apartment	$548	Per dwelling units
Congregate Care	$546	Per sleeping unit
Commercial	$5.28	Per m^2 gross floor
Industrial	$36,959	Hectare gross site
Agriculture - Intensive	$10,266	Hectare gross site

Property Taxes (Outlined in Bylaw 5751)-

Property taxes contribute to funds available for drainage related expenditures. Table 6-2 below outlines the tax rates which pertain to each property class:

Table 6-2
Portion of Tax for Drainage

Property Class	Drainage Tax Rates (dollars of tax per $1000 taxable value)
Residential	0.1253
Utilities	2.1476
Supportive Housing	0.1253
Major Industry (Excludes eligible port properties)	1.5785
Light Industry	0.4664
Business and Other	0.4824
Recreation Property/Non-profit Organization	0.4063
Farm	1.0277

Land Owners and Private Developers

Land owners and private developers do not receive City funding to implement stormwater BMPs on private property. The cost of constructing, operating and maintaining source controls, riparian area buffers, stormwater detention or retention facilities, and off-site system upgrades necessitated as part of the development is the responsibility of land owners and developers. To promote widespread application of source controls throughout the study area, the City could offer incentives to encourage the application of BMPs.

6.2.2 Incentives

One-Time Rebates

While incentive programs are relatively low-cost to the City, they do result in lost revenue that would be otherwise used on capital projects. As such, we recommend that rebate-centered incentive programs be offered on a one-time basis to promote the initial establishment of source controls and awareness of their benefits.

We recommend that the City create a Stormwater Management Rebate Program to encourage land owners and developments to construct stormwater source control measures and detention and retention systems on their properties. In the initial stages of the project the approval process for rebates should be relatively easy to meet and administer. For example, a fixed rebate of a monetary value set by the City of Delta can be offered to participating land owners who show proof of on-site stormwater management control measures. Proof can take the form of a photo or receipt for constructed works. For the program to be effective, it will be important for the City to promote the inter-related benefits of stormwater management features, such as reduced municipal water requirements for landscaping and the insulation benefits of a green roof for industrial and commercial property owners.

Once the program is established, we recommend that the approval process for rebates be more thorough to ensure proper design and installation of works. The procedure will require more effort from both the City and the participant. Rebates should no longer be fixed, but be based on compliance with the approval process and projected reduction in total annual runoff volume. For example, participants could have to satisfy a sequence of steps as follows:

1. Submit to the City the conceptual design, including design drawings, engineering calculations and/or computer modelling of the proposed works.
2. Submit to the City detailed design drawings of the proposed works.
3. Submit to the City operation and maintenance plans of the proposed works.
4. Provide the City with a construction plan and schedule.
5. Facilitate inspection and monitoring by City of Delta inspectors.

Successful completion of the program will require proper introduction to developers and a thorough understanding of the approval process by those City of Delta staff administering or involved in the program.

Community Stormwater Programs

Delta has several community based programs already in place to promote stormwater management. Delta's rain garden program focuses on installing rain gardens in and around Delta roadways and at several elementary schools (The City of Delta, 2016a, Water Sustainability Action Plan for British Columbia, 2015). The Delta School Rain Garden Program has constructed, or is in the process of constructing, rain gardens at all 14 elementary schools in Delta (Fraser Basin Council, 2016)[10]. The rain gardens are constructed with the assistance of the School District and local community groups. There is a complementary rain gardener program targeted at students in grades 4 and 5 and supported by Delta's engineering department. The school rain gardens are maintained with the assistance of local streamkeeping groups (Fraser Basin Council, 2016)[17]. Delta also allows residents to adopt a rain garden in order to improve rain garden maintenance. The City should implement these programs in Tsawwassen schools.

Delta allows residents to sign out storm drain marking kits to paint yellow fish beside storm drains (The City of Delta, 2016e)[11]. The storm drains are marked with painted fish to improve awareness among residents that pollutants flowing into the storm drains can have a negative ecological impact. This program is also supported by Fisheries and Oceans Canada (Government of Canada, 2016)[12].

Delta makes rain barrels (including screen, faucets, overflow pipe and plug) available for residents to purchase for $70 each (The City of Delta, 2016b)[13].

Finally, Delta also runs tree planting programs. The Trees for Tomorrow program allows homeowners to request that one or two trees be planted on municipal land immediately adjacent to the side or front of their properties (The City of Delta, 2016c)[14]. Urban reforestation in Delta receives capital investment. The urban reforestation project plans to plant 5000 trees in Delta parks, boulevards, and medians over 5 years (The City of Delta, 2016d)[15]. The program recognizes the role trees play in helping to reduce the amount of pollution entering creeks and irrigation ditches through runoff, as well as the important role they play in erosion control.

6.2.3 Federal Funding

The federal government provides funding for infrastructure and environmental projects primarily through Infrastructure Canada and Environment Canada.

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[10] Fraser Basin Council. (2016). *Showcasing Successful Green Stormwater Infrastructure: Lessons from Implementation.* Metro Vancouver and Victoria: Fraser Basin Council.

[11] The City of Delta. (2016e). *What You Can Do*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/green-living/what-you-can-do

[12] Government of Canada. (2016). *Fisheries and Oceans Canada*. Retrieved September 13, 2016, from pac.dfo-mpo.gc.ca: http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/stormdrain-collecteur-eng.html

[13] The City of Delta. (2016b). *Rain Barrel Program*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/services/water-sewer/water-conservation/rain-barrel-program

[14] The City of Delta. (2016c). *Trees for Tomorrow*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/trees-for-tomorrow

[15] The City of Delta. (2016d). *Urban Reforestation Project*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/urban-reforestation-project

Although typically not as readily available as municipal funding sources, we highlight below some of the programs most applicable to the type of works recommended in this ISMP.

New Building Canada Plan

The New Building Canada Plan (NBCP) is a federal government program intended to support infrastructure projects across Canada. Much of the funding is intended for projects of national, regional, or local significance, and therefore may not be accessible for the projects associated with this ISMP; however, part of the NBCP is the Federal Gas Tax Fund, intended to provide municipalities with stable and predictable funding over the next ten years to support infrastructure projects. It is allocated on a per-capita basis to all municipalities across Canada and could be used for infrastructure upgrade projects in the study area.

We anticipate that within municipal governments such as the City of Delta, competition for these funds may not allow a significant investment in independent drainage projects. We strongly recommend the City push to have stormwater BMPs included in all infrastructure projects, where practical.

EcoAction Community Funding Program

The EcoAction Community Funding Program provides funds to non-profit community-based groups.

While the City of Delta is not eligible to apply for funding, community-based groups are. Community or environmental groups may apply for funding for various environmental enhancement projects. Minor terrestrial or riparian enhancement projects, such as the removal of debris jams and management of invasive species are the most likely types of projects to have success under this arrangement, and should be promoted by the City, and encouraged where possible to improve watershed health.

Green Municipal Fund

The Green Municipal Fund (GMF) is distributed through the Federation of Canadian Municipalities (FCM), but funded by the Government of Canada. The GMF funds municipal environmental initiatives, including plans, studies, and projects. Projects in the energy, transportation, waste and water sectors undergo a competitive process and are ultimately reviewed for approval or denial by the GMF Council.

The stormwater management projects supported by the fund must manage the majority of rainfall events for a community, which is the shared objective of source controls and stormwater BMPs. The funding is therefore directly relevant to the goals of this ISMP and should be applied for as applicable.

6.2.4 Provincial Funding

The British Columbia provincial government provides funding for community and stormwater management projects through the Ministry of Community, Sport and Cultural Development. Currently, the only applicable funding source is the Infrastructure Planning Grant Program, as the funds from all other relevant programs are fully allocated.

The Infrastructure Planning Grant Program provides grants up to $10,000 to assist in the development or improvement of long-term comprehensive plans. Existing projects (such as this ISMP) are ineligible for the funding. However, further studies in particular locations of concern within the study area, could be eligible.

6.3 MONITORING AND ADAPTIVE MANAGEMENT PLAN

In order to assess the effectiveness of stormwater management within with study area, the City should monitor key metrics that indicate the condition of the watershed. These metrics will track the condition of the watershed and identify areas of improvement as well as areas of degradation. This will indicate where enhancement projects and upgrades have been successful and will also highlight areas where additional mitigation is required.

In consultation with its members, Metro Vancouver has developed a Monitoring and Adaptive Management Framework (September 2014), which provides guidance on the minimum monitoring activities and response mechanisms for ensuring that ISMPs stay “on track” in meeting their objectives. This framework does not preclude the possibility of additional monitoring effort if the particulars of a watershed make it advisable.

Tsawwassen has no significant natural watercourses, upland drainage consists of an entirely piped system, and lowland drainage is predominantly through agricultural/road side ditches. As such, Metro Vancouver recommends monitoring water quality and in the piped system and lowland ditches only. However, we think it would be advisable to monitor flow in the piped system at key locations as well to assess the effectiveness of residential BMPs. These parameters will be the key performance indicators for the watershed.

We note the currently recommended sampling interval of 5 years will make it difficult to establish norms or trends on any particular watercourse. Acquiring sufficient data to establish norms will take many sampling periods, and the significance of individual measurements will be uncertain until the degree of variability has been established.

Accordingly, we recommend that hydrometric monitoring be carried out on a continuous basis on at least one of the major storm trunks. The advantage of a continuous monitor is the ability to record the response to large and infrequent events that may be missed with a periodic monitoring program.

Grab sampling for water quality offers similar concerns. Individual samples can miss specific events, such as the first flush during the onset of a storm, or long-term averages. Continuous sampling, preferably coinciding with flow monitoring on the same watercourse, will provide a more useful data record. However, in the case of water quality sampling, periodic installation of a portable sampling device may provide sufficient data.

Metric 1 – Continuous Hydrometric Monitoring
Hydrometric data provides insight into the actual response of the watersheds to rainfall events, which in turn will provide information on the effectiveness of recommended BMPs over time. Frequent monitoring periods are required to establish a reliable record for making representative assessments. We recommend

installing a permanent flow monitoring station at the outflow of the piped stormwater system at 56 Street and 6 Avenue to collect continuous data.

Measurement: Continuous water level and flow data:

Timing/Triggers: Data to be collected continuously on a permanent basis. Once every five years, data should be analysed to assess if goals are being met and parameters recommended in the AMF, as applicable to piped systems.

Goals: Mean annual flow/volumes – decrease
Peak flows and runoff volumes – decrease

Cost: $30,000 for initial setup and $5,000 annually for data collection, and maintenance.

Metric 2 – Water Quality Monitoring

Monitoring the water quality at key locations within the watersheds can provide insight into the success of the ISMP and identify areas of concern where mitigative measures may be required.

Metro Vancouver's AMF suggests water quality monitoring be done in low gradient, high gradient, and piped systems, with samples taken two periods per year – once in the dry season (July to August) and once in the wet season (November to December). The recommended sampling procedure is to collect 5 samples over a 30 day period on a weekly basis. The AMF recommends testing dissolved oxygen, temperature, turbidity, pH, conductivity, nitrate, E. coli, fecal coliforms, total iron, total copper, total lead, total zinc, and total cadmium.

Water quality monitoring should be completed at the inlet to the Brandrith Pump Station and 12th Avenue Pump Station to assess water quality in the lowland systems as well as the stormwater outlet at 56 Street and 6 Avenue to assess impacts of BMPs.

In addition to the primary constituents outlined above, Total Suspended Solids (TSS) should be monitored. Most water quality source controls are designed based on TSS removal efficiency. Therefore, information on TSS loading and removal efficiencies can assist in selecting source controls on future projects.

Testing for polycyclic aromatic hydrocarbons (PAH) is beneficial to monitor the performance of water quality devices, such as oil-water separators, but is relatively costly to implement. Without mandating stormwater source controls as a way of addressing historic contamination, the presence of PAH may not be actionable by the City. We recommend that PAH testing be completed at locations where distinct concerns are noted in the field (e.g. oily sheen on the surface of ditches, evidence of spills).

Measurement: Water quality monitoring of the following parameters:

- Dissolved oxygen
- Temperature
- Turbidity

- Total suspended solids
- pH
- Conductivity
- Nitrate
- *E. coli*
- Fecal coliforms
- Total iron, total copper, total lead, total zinc and total cadmium

Timing / Triggers: Two sampling periods per year (wet season and dry season) as per the AMF on a maximum repeated cycle of five years.

Cost: $8,000 per site per sampling period (including analysis and reporting).

Goals: Long term stability or improvement in water quality.

If the goals of the two metrics are not being met, the City should identify which stormwater and environmental BMPs have been put in place during the monitoring period. Depending on the BMPs that have been put in place, the City could review the items in the ISMP and take action on those which have not been completed, assess the enforceability of stormwater language in their bylaws, or complete an inspection program to assess degree of compliance of implementing BMPs throughout the study area.

REPORT

Closure

This report was prepared for the City of Delta to identify areas in the Tsawwassen Area in which stormwater management can be enhanced or improved. The assessment of drainage and environmental conditions in the watershed as well as recommendations for best management practices and drainage upgrades forms part of the broader Integrated Stormwater Management Plan for Tsawwassen.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering (B.C.) Ltd.

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Feb 4/2019

JS/MM/lp

Appendix A - Background Information

This appendix contains information from the Stage 1/2 and report. The appendix is organized as follows:

Section A1 outlines aquatic and terrestrial habitat.
Section A2 outlines the drainage network components.
Section A3 outlines stormwater regulations in delta.
Section A4 outlines plans and policies related to stormwater in Delta.

A1 AQUATIC AND TERRESTRIAL HABITAT

A1.1 FRESHWATER SYSTEM

Aquatic Habitat

The Brandrith catchment consists of a major agricultural irrigation-ditch network which collects water from upland residential and commercial (i.e. golf course, mall) areas. Fish habitat quality is poor as these ditches were constructed on estuarine lands with brackish water and have been developed for agricultural purposes[3]. Ditches in this catchment have varied flows, are often stagnant, and are prone to flooding and dewatering especially at the intertidal interface[3]. Furthermore, the catchment drains to the Brandrith Pump Station, which is a barrier to upstream fish migration. A habitat assessment in this area recently concluded that there was limited value fish habitat (lack of habitat and substrate diversity) and no characteristic features of salmonid-bearing stream habitat[3]. The South Fraser Perimeter Road (SFPR) Fish Habitat Impact Assessment, assessed the 64th Street ditch in this catchment and determined that it has low to moderate productive capacity, but has potential to contribute (e.g. food nutrients and water) to downstream habitats[16].

Aquatic habitat in the 12th Avenue catchment consists primarily of a major agricultural irrigation-ditch network in the lowland which receives drainage from a primarily piped drainage system in the large upland residential and commercial area with few ephemeral channels (Watercourse B) (Map 4-1). Flows from the agricultural lowlands drain through connecting ditches and channels to the 12th Avenue Pump Station located in Boundary Bay Park which is located in the northeast corner of the catchment and encompasses a large portion of the lowland. The 12th Avenue Pump Station outlets to Boundary Bay and is not passable to fish. A natural watercourse (Watercourse A) flows through Boundary Bay Regional Park and wildlife reserve (the Park) and drains to the pump station. Watercourse A has limited value fish habitat (fine substrate, dense vegetation growth in watercourse, poor water quality[2]).

[16] Coast River Environmental Services Ltd. 2006. South Fraser Perimeter Road Fish Habitat Impact Assessment. Prepared for the Ministry of Transportation. Available Online at http://www.delta.ca/docs/default-source/downloads/tfn/south-fraser-perimeter-road-fish-habitat-impact-assessment-.pdf?sfvrsn=8. Accessed Aug 2016.

The 3rd Avenue catchment also consists of major agricultural irrigation-ditches that flow from ephemeral watercourses (Watercourses C and D). Fish habitat quality is expected to be poor as these ditches flow into piped residential areas, have poor water quality [1,2], and drain out the 3rd Avenue Pump Station (*i.e.* a barrier to fish migration) to Boundary Bay.

The Strait of Georgia catchment is almost entirely piped underground or consists of small ephemeral ditches (swales). The catchment contains no notable fish habitat characteristics.

Riparian vegetation along ditch networks and watercourses is grass or shrub dominated with remnant trees along watercourses. Common riparian species include the introduced: Reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus armeniacus*), cutleaf evergreen blackberry (*Rubus lacinatus*), hard hack (*Douglas spirea*), English ivy (*Hedera helix*), and the native Nootka rose (*Cytisus scoparius*), red osier dogwood (*Cornus sericea*), cherry (*Prunus spp.*), red alder (*Alnus rubra*), willow (*Salix spp.*), and Douglas fir (*Pseudotsuga menziesii*)[3]. Although aquatic habitats are generally of poor or very poor quality to fish, riparian vegetation improves water quality, and provides habitat for amphibians, birds and other wildlife.

Fish Species

Fish observations and capture information is sparse for the study area. Within the Brandrith catchment, the brassy minnow (*Hybognathus hankinsoni*), redside shiner (*Richardsonius balteatus*), threespine stickleback (*Gasterosteus aculeatus*), common carp (*Cyprinus carpio*), peamouth chub (*Mylo cheilus*), brown catfish (*Ameiurus nebulosus*), and longnose sucker (*Catostomus catostomus*) have been documented[17]. Within the 12th Avenue catchment, common carp, threespine stickleback, brassy minnow and redside shiner have been documented[3]. Within Watercourse A, threespine stickleback has been documented in the vicinity of the 12th Avenue pump station[18] and brassy minnow has been documented further upstream west of Boundary Bay Road, approximately 150 m north of 8th Avenue[19]. In the 3rd Avenue catchment, the only fish presence documented was the threespine stickleback[7], and no fish have been documented within the Strait of Georgia catchment.

A1.2 MARINE SYSTEM

Marine Habitat

The study area is surrounded by a marine ecosystem including Boundary Bay with its foreshore to the east, and the Strait of Georgia (Pacific Ocean) with its foreshore (generally referred to as Roberts Bank) to the west. A variety of habitats are present in these marine ecosystems and are distributed based primarily on tidal and wave action. Habitats have been mapped by the Fraser River Estuary Management Plan and

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[17] City of Delta. 2003. Fish and Amphibian in Delta British Columbia: Species Occurrence and Habitat Utilization Study. 2001-2003 Data Report.

[18] British Columbia Ministry of Environment (MOE). 2016. Habitat Wizard database. Available at: www.env.gov.bc.ca/habwiz. Accessed Aug 2016.

[19] Community Mapping Network. 2015. Fraser River Estuary Management Program – Burrard Inlet Environmental Action Program. Available at: http://www.cmnbc.ca/atlas_gallery/fremp-bieap-habitat-atlas. Accessed Aug 2016.

Burrard Inlet[8] (Map 4-1). The marine ecosystems surrounding the study area include the following intertidal habitat types at the community level:

- Marsh (Brandrith catchment, 12th Avenue catchment)
- Sandflats (All catchments)
- Eelgrass (All catchments)
- Mudflats (12th Avenue catchment)

In addition to these habitat types, marsh habitats in the Brandrith and 12th Avenue catchments include several dendritic, tidally influenced channels connecting nearshore areas to other habitat types further offshore.

Eelgrass and sandflats are the most abundant habitat type and are present along most of the shoreline areas bordering the study area. Eelgrass is particularly abundant along the western coastline in offshore area adjacent to the Brandrith Pump station, and Strait of Georgia catchment.

The distribution and variety of these habitats form a marine ecosystem which provides highly diverse and valuable habitats for numerous fish and wildlife species. For example, eelgrass provides habitat for a variety of marine invertebrates and fish that are dependent on eelgrass beds for shelter, foraging and breeding habitat. These species, in turn, provide a food source for marine birds, migrating and wintering shorebirds, larger fish species, and marine mammals, and form an integral part of the larger ecosystem. Because of this, Boundary Bay and Roberts Bank have been designated as Wildlife Management Areas (WMA[20]) by the province of BC.

Fish Species

Marine fish documented in the Roberts Bank subtidal and intertidal habitats include at least 72 different species[6]. An intertidal forage fish spawning habitat study for the Boundary Bay Park beach determined that the beach was high quality spawning habitat for surf smelt (*Hypomesus pretiosus*) and Pacific sand lance (*Ammodytes hexapterus*)[21]. Surf smelt are an important part of the diet of the provincially blue-listed coastal cutthroat trout (*O. clarkii clarkii*) and bull trout (*Salvelinus confluentus*), and Pacific sand lance makes up a considerable proportion of the essential diet for juvenile salmon and the majority of the diet of Chinook salmon (*Onchorynchus tshawytscha*)[7]. Salmonid species previously documented in the marine habitat include juvenile pink (*O. gorbuscha*), chum (*O. keta*), Chinook, and cutthroat trout[4,6].

A1.3 TERRESTRIAL ENVIRONMENT

A summary of the terrestrial wildlife and vegetation in the study area is provided in this section. This includes the identification of typical wildlife and vegetation species and a list of rare or endangered wildlife

[20] Ministry of Environment. 2011. Parks and Protected Areas. Available at http://www.env.gov.bc.ca/lower-mainland/wildlife/recreation/park_areas.htm Accessed Aug 2016
[21] de Graaf, R.C. 2008. Boundary Bay Intertidal Forage Fish Spawning Habitat Project. Prepared for Friends of Semiahmoo Bay Society. Prepared by Emerald Sea Research & Consulting.

and plants that are known to occur in the area. This section is based on a desktop review of existing terrestrial conditions in the community of Tsawwassen and the Tsawwassen First Nation reserve, and incorporates terrestrial planning objectives from relevant documents to support the ISMP.

Information presented for the terrestrial environment was assembled from the following sources:

- *Tsawwassen First Nation Integrated Rain Water Management Plan – Environmental Overview*[22];
- *The City of Delta Official Community Plan – Schedule D.1: Tsawwassen Area Plan*[23];
- B.C. Conservation Data Centre Species and Ecosystems Explorer for potential occurrence of listed species[24]; and
- Government of British Columbia iMapBC database for known occurrences of listed species[25].

Land Use and Vegetation

The study area is located within the Moist Maritime Coastal Douglas-fir (CDFmm) biogeoclimatic zone[26], and is characterized by warm, dry summers and mild, wet winters. The study area has been altered from its natural condition by agricultural activities, community development, and municipal infrastructure. The vegetation in the area is heavily influenced by the maritime climate of the region. In general, the terrestrial environment of the study area can be defined under the following ecosystem classes:

- Agricultural;
- Forest, hedgerow, and riparian;
- Intertidal / mudflats; and
- Commercial / residential.

Agricultural lands in the study area are found in the Brandrith, 12th Avenue, and 3rd Avenue catchments. These lands are either fallow (dormant) or cropped and consist of tilled fields of grains, cereals, or vegetables[27] . Fallow fields are commonly dominated by grass and forb species. Although these areas are disturbed from their natural condition, they provide a permeable landscape for water and are often large in size.

Forest, hedgerow, and riparian areas in the study area are found in the Brandrith and 12th Avenue catchments, and consist of forest, shrub, or forb dominated lands. Forest areas are surrounded by agricultural, urban area, or commercial / residential development, and are fragmented from one another unless connected by a riparian corridor. Riparian corridors in the study area are often treed, with a dense shrub and forb dominated understorey. Hedgerows, typically trees and shrubs, are found alongside roads, ditches, and between fields. Common tree species in this ecosystem type include Douglas-fir, red alder,

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[22] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
[23] Schedule D.1: Tsawwassen Area Plan. Available on the internet at: https://delta.civicweb.net/filepro/documents/37999
[24] BC Conservation Data Centre available online at: http://a100.gov.bc.ca/pub/eswp/
[25] iMapBC available online at: http://maps.gov.bc.ca/ess/sv/cdc/
[26] Meidinger, D.V., and J. Pojar. 1991. *Ecosystems of British Columbia*. Research Branch. Special Report Series. Available on the Internet at: https://www.for.gov.bc.ca/hfd/pubs/Docs/Srs/Srs06.htm
[27] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.

paper birch, and western redcedar. Common shrub species include salal, tall Oregon grape, Himalayan blackberry, hard hack, English ivy, re-osier dogwood, willow, red elderberry and salmonberry. Common herb layer species include reed canarygrass, lady fern (*Athyrium filix-femina*), spiny wood fern (*Dryopteris expansa*), and skunk cabbage (*Lystichiton americanus*) in wetter sites. Forest, hedgerow, and riparian ecosystems are important in surface water flow and ground water retention as they capture and slow surface and ground water flow across the landscape.

Intertidal / mudflats are found on the shoreline of Boundary Bay and Roberts Bank. These areas are sparsely vegetated and heavily influenced by the changing tides. Ecosystems associated with the intertidal / mudflat areas are herb and forb dominated meadows, beach dunes, and saltgrass marsh. Common species found in the intertidal / mudflat areas include saltgrass species, salal, and reed canarygrass. A small wetland ecosystem is situated just south of Tsawwassen Drive South (UTM Zone 10U 492594, 5430288). Intertidal / mudflat ecosystems are important in water capture because they provide large expanses of permeable ground surface. Wetland ecosystems are important because they capture, retain, and improve water quality through natural filtration processes.

Commercial / residential areas are prominent and fragment the continuity of vegetated ecosystems across the study area. They are found throughout the study area, and are most highly concentrated in the 12th and 3rd Avenue catchment areas. Commercial / residential areas are characterized by hard surface development (i.e., roads, buildings) and are commonly impermeable, with patchy, fragmented green space along road sides and on private properties. Trees and shrubs growing in commercial / residential areas are a mix of native and cultivated species, within manicured lawns. These areas provide some connectivity of green space, but typically only in the tree canopy layer (i.e., ground cover is highly fragmented by roads and buildings). Two golf courses occur in the study area (Beach Grove Golf Course and Tsawwassen Springs Golf Course) and have patchy forest and shrubs with extensive areas of grass. Commercial / residential areas are largely hard surface, promoting surface water runoff and concentrating flows to ditches and storm water systems; however, green spaces with permeable surfaces within these areas capture water and return it to the ground water system.

Because of the mild and moist maritime climate, the study area has potential to support 104 provincially listed plant species. Two of those species have been identified near the study area and are federally listed under Schedule 1 of the Species at Risk public registry (Table A-1).

Table A-1
Federally Listed Plant Species Known to Occur Within 20 km of the Study Area

Common Name	Scientific Name	Habitat	BC List	SARA List
Streambank lupine	*Lupinus rivularis*	Along creeks and streambanks in sandy/gravelly substrates	Red	1- E (2002)
Vancouver Island beggarticks	*Bidens amplissima*	Wetland and shoreline areas with fluctuating water levels	Blue	1-SC (2001)

Source: Conservation Data Centre iMapBC database. available online at: http://a100.gov.bc.ca/pub/eswp/

[1] Red-listed species are indigenous species that are Extirpated, Endangered, or Threatened in B.C. Blue-listed species are indigenous species considered to be of Special Concern in B.C.

[2] E = Endangered: species facing imminent extirpation or extinction; T = Threatened: species that is likely to become endangered if limiting factors are not reversed; SC = Special Concern: species of special concern because of human activities or natural events.

Wildlife

The study area is rich in wildlife biodiversity, most notably for birds. Located along the Pacific Flyway, a major migratory corridor for birds, the study area has been described as part of a vital link for birds migrating on the Pacific Flyway. Habitat in the area provides suitable nesting, foraging, breeding, and overwintering habitat requirements for many species.

The Fraser River delta has been designated an Important Bird Area because it provides habitat for globally threatened bird species, birds with restricted breeding ranges, or globally limited breeding, wintering, and/or migratory bird habitat. The delta is important for its value in providing critical life requisites for species such as: trumpeter swans (*Cygnus buccinators*), tundra swans (*C. columbianus*), lesser snow geese (*Chen caerulescens*), Brandt's cormorant (*Phalacrocorax penicillatus*), and Atlantic brandt (*Branta bernicla*). Great blue herons (*Ardea herodias*) and shorebirds such as western sandpipers (*Calidris mauri*), dunlins (*Calidris alpina*), and black-bellied plovers (*Pluvialis squatorola*) are also reliant on these intertidal areas. Table 4-3 summarizes the list of birds observed during field surveys conducted near the study area[28].

The Boundary Bay Regional Park (on the foreshore of Boundary Bay in the 12th Avenue catchment) is an area that has provincial protection as a wildlife management area (WMA). No public access is permitted in this WMA, and it is an area important to migratory birds and for its value to overwintering birds. Similarly, the Roberts Bank WMA is an area of intertidal and nearshore subtidal habitat in the Fraser River delta. Intertidal habitats attract large numbers of shorebirds, ducks, gulls, herons, and birds of prey.

[28] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.

Table A-2
Bird Species Observed in the Study Area

Common Name	Scientific Name	Common Name	Scientific Name
Mallard	Anas platyrhynchos	American pipit	Anthus rubescens
Ring-necked pheasant	Phasianus colchicus	Orange-crowned warbler	Oreothlypis celata
Great blue heron	Ardea herodias	Spotted towhee	Pipilo maculatus
Bald eagle	Haliaeetus leucocephalus	Savannah sparrow	Passerculus sandwichensis
Northern harrier	Circus cyaneus	Fox sparrow	Passerella iliaca
Cooper's hawk	Accipiter cooperii	Song sparrow	Melospiza melodia
Red-tailed hawk	Buteo jamaicensis	Lincoln's sparrow	Melospiza lincolnii
Rough-legged hawk	Buteo lagopus	White-crowned sparrow	Zonotrichia leucophrys
Black-bellied plover	Pluvialis squatarola	Golden-crowned sparrow	Zonotrichia atricapilla
Killdeer	Charadrius vociferus	Dark-eyed junco	Junco hyemalis
Dunlin	Calidris alpina	Red-winged blackbird	Agelaius phoeniceus
Downy woodpecker	Picoides pubescens	Western meadowlark	Sturnella neglecta
Northern flicker	Colaptes auratu	Brewer's blackbird	Euphagus cyanocephalus
Northwestern crow	Corvus caurinus	House finch	Carpodacus mexicanus
Black-capped chickadee	Poecile atricapillus	American finch	Spinus tristis
Bewick's wren	Thryomanes bewickii	House sparrow	Passer domesticus
Winter wren	Troglodytes troglodytes	American wigeon	Anas americana
Marsh wren	Cistothorus palustris	Black-headed grosbeak	Pheucticus melanocephalus

Common Name	Scientific Name	Common Name	Scientific Name
Golden-crowned kinglet	Regulus satrapa	Green-winged teal	Anas crecca
American robin	Turdus migratorius	Short-eared owl	Asio flammeus
European starling	Sturnus vulgaris	Trumpeter swan	Cygnus buccinator

Source: *Tsawwassen First Nation Integrated Rainwater Management Plan*

Wildlife habitat in the study area is also suitable for small-to-large mammals, amphibians, reptiles, and turtles. Mice, voles, and adult amphibians will use habitats in the fallow or cropped agricultural fields and riparian areas in the 12th and 3rd Avenue and Brandrith catchments for forage or cover. These areas provide good hunting opportunities for birds of prey in the area, such as Cooper's hawk or red-tailed hawk in search of small mammals. Agricultural fields also provide good forage and cover opportunities for deer (*Odocoileus sp.*) and deer may be found throughout the study area, including the commercial / residential areas of the 12th Avenue catchment.

Forest, hedgerow, and riparian ecosystems provide suitable habitat for deer, as well as nesting and perching habitat for raptors, owls, and song birds. Riparian corridors are important habitats for wildlife movement across the landscape because they provide good cover and suitable forage for a wide range of species. The Pacific water shrew (*Sorex bendirii;* listed as Endangered under Schedule 1 of SARA) is known to occur within 20 km of the study area, and may be found in riparian or wetland habitats. Reptiles and amphibians will both occupy riparian habitats. The federally listed northern red-legged frog (*Rana aurora*) and painted turtle (*Chrysemys picta*) are known to occur within 20 km of the study area, and may be found in riparian or wetland ecosystems. Racoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) are known to use forested, hedgerow, riparian, and residential habitats for forage, cover, and movement. There is critical habitat under the Species at Risk Act for the Oregon forest snail (*Allogona townsendiana)* in the Southlands forest area.

Based on a search of the Conservation Data Centre Species and Ecosystems Explorer[29], 91 provincially listed wildlife species have potential to occur in the study area. The results of the Conservation Data Centre search for occurrences of federally listed wildlife species within 20 km of the study area is presented in Table A-3.

[29] Search query was area based for CDF biogeoclimatic zone and habitats found in the Study Area.

Table A-3
Federally Listed Wildlife Species Known to Occur Within 20 km of the Study Area

Species Group	Common Name	Scientific Name	Habitat	BC List	SARA List
Birds	Great blue heron, fannini subspecies	Ardea herodias fannini	Estuarine, Riparian	Blue	1-SC (2008)
Mammal	Pacific water shrew	Sorex bendirii	Riparian, Wetland	Red	1-E (2016)
Amphibian	Northern red-legged frog	Rana aurora	Riparian, Meadow, Wetland	Blue	1-SC (2015)
Turtle	Painted turtle – Pacific coast population	Chrysemys picta pop. 1	Riparian, Wetland	Red	1-E (2006)
Invertebrate	Dun skipper	Euphyes vestris	Forest, Agricultural, Meadow	Red	1-T (2013)
	Oregon forestsnail	Allogona townsendiana	Forest, Riparian, Wetland	Red	1-E (2005)

Source: Conservation Data Centre iMapBC database.

[1] Red-listed species are indigenous species that are Extirpated, Endangered, or Threatened in B.C. Blue-listed species are indigenous species considered to be of Special Concern in B.C.

[2] E = Endangered: species facing imminent extirpation or extinction; T = Threatened: species that is likely to become endangered if limiting factors are not reversed; SC = Special Concern: species of special concern because of human activities or natural events.

A2 DRAINAGE NETWORK

The drainage network for the study area was assembled based on the City of Delta's GIS data and our knowledge of the study area.

A2.1 CATCHMENTS

The study area is divided into four catchments based on the areas contributing to Brandrith Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station and the areas discharging to the Strait of Georgia.

For the purpose of this stormwater system analysis within ISMP, we divided the study area into 60 subcatchments (Map 2-3). The subcatchments in the urban areas were delineated based on areas contributing to major storm trunks (450 mm and larger) and a minimum area of approximately 20 ha for the majority of the subcatchments, which is an appropriate scale for a planning-level assessment.

A2.2 STORM DRAINS

Major storm drainage pipes, generally 450 mm diameter and larger, were identified and are shown on Map 2-3. These storm drains are predominantly located in the 12th Avenue catchment, and the remaining are in the 3rd Avenue catchment and Strait of Georgia catchment.

During model assembly, we made reasonable assumptions for the invert elevations of pipes with missing information based on nearby pipe inverts for hydraulic modelling. We took the following approach for missing data:

- If a pipe outlet invert elevation is missing and its downstream pipe inlet elevation is known, we used the downstream pipe inlet invert elevation for the missing invert data.
- If the above approach could not be taken, we assumed the pipe inverts based on the ground elevation (1-1.5 m below ground).

12th Avenue Catchment

On the north of 8a Avenue, two major drainage pipe alignments run east to west; along 12th Avenue and generally along 10a Avenue. These two lines interconnect at 50b Street via 51st Street and Ferguson Road. The 12th Avenue drainage pipes generally collect runoff from the 12th Avenue subcatchments north of 12th Avenue, and the 10a Avenue storm trunk collects runoff from the 12th Avenue subcatchments between 12th Avenue and 8a Avenue.

The storm network at the intersection of 12th Avenue and Ferguson Road where the two trunk lines tie in is complex. Downstream of the two lines, the flow is split into a gravity line which discharges into the channel upstream of the 12th Avenue Pump Station and a siphon line of varying pipe diameters from 750 mm to 1,350 mm which discharges to the foreshore. The 8a Avenue storm trunk discharges to open channel before it enters the storm pipe on 12th Avenue.

On the south of 8a Avenue, two major storm pipe alignments run east to west; generally, along immediately south of 8a Avenue and 6th Avenue. The 8a Avenue storm trunk generally collects runoff from the catchment area between 8a Avenue and 6th Avenue. The 6th Avenue storm trunk generally collects runoff from the catchment area south of 6th Avenue.

A storm main along 4th Avenue collects runoff from the area between 4th Avenue and 2nd Avenue and discharges to the Southlands area via 56th Street.

A storm trunk along Boundary Bay Road is currently proposed as part of our 12th Avenue Drainage Improvements project for The City of Delta.

3rd Avenue Catchment

The main storm trunk in the 3rd Avenue catchment follows the road alignment of 3rd Avenue. The storm drains to the 3rd Avenue Pump Station and discharges to Boundary Bay via 750 mm diameter CSP and HDPE drainage pipe.

Strait of Georgia

The Strait of Georgia catchment has three stormwater outfalls. They include the two outfalls north of 8a Avenue on TFN lands that drain the catchment area west of 48 and north of 8a Avenue, and the outfall at the US boarder that drains the area in the vicinity of English Buff Rd and US boarder.

In addition to the drainage outfalls, the hillside area west of English Buff Road drain directly to Strait of Georgia.

A2.3 CULVERTS

Using available data and mapping, we identified 39 culverts in the study area. Of these culverts, 29 culverts are Delta's responsibility and 10 culverts are within the Ministry of Transportation and Infrastructure's (MoTI) jurisdiction (i.e. Highway 17). The culvert inventory is presented as Table A-4 below. We note that the GIS data provided by Delta in the Highway 17 did not reflect the recent changes associated with the TFN developments and we updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

Table A-4
Culvert Inventory for Study Area

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
1	1,800	1	HDPE	48th Street	Brandrith	
2	1,500	1	concrete	48th Street	Brandrith	
3	200	1	concrete	48th Street	Brandrith	
4	900	1	concrete	52nd Street	Brandrith	
5	400	1	concrete	52nd Street	Brandrith	
6	1,200	1	HDPE	52nd Street	Brandrith	
7	900	1	CSP	52nd Street	Brandrith	driveway
8	600	1	CSP	52nd Street	Brandrith	driveway
9	525	1	CSP	52nd Street	Brandrith	driveway
10	600	1	CSP	52nd Street	Brandrith	driveway

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
11	600	1	CSP	52nd Street	Brandrith	driveway
12	1200	1	CSP	56th Street	Brandrith	north of Highway 17
13	900	1	concrete	56th Street	Brandrith	south of Highway 17
14	525	1	concrete	56th Street	Brandrith	driveway culvert
15	900	1	CSP	56th Street	Brandrith	driveway culvert
16	900	1	CSP	56th Street	Brandrith	driveway culvert
17	600	1	concrete	56th Street	Brandrith	driveway culvert
18	600	1	concrete	56th Street	Brandrith	driveway culvert
19	600	1	concrete	56th Street	Brandrith	
20	600	1	concrete	56th Street	Brandrith	crosses 21st Avenue at 56th Street
21	750	1	concrete	56th Street	12th Ave.	
22	1,200	1	HDPE	Highway 17	Brandrith	
23	1,800	1	CSP	Highway 17	Brandrith	
24	1,200	1	CSP	Highway 17	Brandrith	
25	600	1	CSP	Highway 17	Brandrith	
26	900	1	CSP	Highway 17	Brandrith	
27	900	1	CSP	Highway 17	Brandrith	
28	600	1	CSP	Highway 17	Brandrith	
29	600	1	CSP	Highway 17	Brandrith	
30	500 X 1200	2	concrete box	Boundary Bay Road	12th Ave.	east of 56th Street.
31	1,200	1	concrete	Boundary Bay Road	12th Ave.	utility access on west ditch
32	1,200	1	concrete	Boundary Bay Road	12th Ave.	utility access on west ditch
33	1,200	1	CSP	Miscellaneous Lowlands	Brandrith	
34	1,500	2	concrete	Miscellaneous Lowlands	Brandrith	
35	1,050	1	concrete	Miscellaneous Lowlands	Brandrith	

Culvert ID	Dimension (mm)	Number	Material	Road or local	Catchment	Notes/Description
36	600	1	PVC	Miscellaneous Lowlands	Brandrith	
37	2,200	3	CSP	Miscellaneous Lowlands	12th Ave.	discharge directly to Boundary Bay
38	1,200	1	concrete	Miscellaneous Lowlands	12th Ave.	on the current Southlands central ditch
39	1,200	1	concrete	Miscellaneous Lowlands	12th Ave.	on the current Southlands central ditch

48th Street

48th Street runs north-south on TFN lands and has 1 crossing culvert and 2 driveway culverts. A 1,800 mm diameter HDPE (Culvert 1) crosses the new 48th Street at Highway 17. The two driveway culverts are located north of Highway 17 and include a 1,500 mm diameter concrete culvert (Culvert 2) and 1,200 mm diameter concrete culvert (Culvert 3).

52nd Street

52nd Street between 12th Avenue and 28th Avenue is classified as Collector Road and it is one of the major roads in the study area. There are 3 crossing culverts; 900 mm diameter concrete (Culvert 4) and 400 mm diameter concrete (Culvert 5) and 1,200 mm diameter HDPE (Culvert 6), and 5 driveway culverts along 52nd Street; 900 mm diameter CSP (Culvert 7), 600 mm diameter CSP (Culvert 8), 525 mm diameter CSP (Culvert 9), 600 mm diameter CSP (Culvert 10) and 600CSP (Culvert 11).

56th Street

56th Street is the largest road in the study area, classified as Arterial Road, after Highway 17, and runs north-south from 28th Avenue to U.S. border.

In the Brandrith catchment, 56th Street has two crossing culverts; 1200 mm CSP (Culvert 12) north of Highway 17 and 900 mm concrete (Culvert 13) south of Highway 17. There are three driveway culverts along 56th Street north of Highway 17; 525 mm diameter concrete (Culvert 14) on the west side of 56th Street and two 900 mm CSP culverts (Culverts15 and 16) in series on the east side of 56th St.

There are two 600 mm diameter concrete driveway culverts in series (Culverts 17 and 18) along 56th Street south of Highway 17 on the west side of 56th Street. A 600 mm concrete diameter culvert (Culvert 19) along 56th Street provides continuity of the ditch around a fire hydrant. Another 600 mm diameter concrete culvert (Culvert 20) crosses 21st Avenue south of Highway 17. In the 12th Avenue catchment, a 750 mm diameter concrete culvert (Culvert 21) crosses 56th Street between 4th Avenue and 6th Avenue.

Highway 17

Highway 17 bisects the Brandrith catchment diagonally. The highway has seven culvert crossings. They include a 1,200 mm diameter HDPE (Culvert 22) and a 1,800 mm diameter CSP (Culvert 23) in parallel at 48th Street, a 1200 mm diameter CSP culvert (Culvert 24) at 52nd Street, a 600 mm diameter CSP (Culvert 25) between 52nd Street and 56th Street, a 900 CSP (Culverts 26) immediately west of 56th Street, a 900 CSP (Culvert 27), 600 CSP (Culvert 28) and 600 CSP (Culvert 29) east of 56th Street.

We note that the GIS data provided by Delta in the Highway 17 area is outdated and we updated the culvert data based on our IFC design drawings for the Highway 17 Tsawwassen Drive to 56th Street project (AE, 2014).

Boundary Bay Road

Boundary Bay Road defines the west boundary of Boundary Bay Regional Park and has one culvert crossing near 12th Avenue which consists of twin 500 mm x 1,200 mm box culverts (Culvert 30). This culvert conveys the majority of runoff from the 12th Avenue catchment area.

Along the west ditch of Boundary Bay Road, there are two culverts, 1,200 mm diameter concrete (Culvert 31) and 1,200 mm diameter concrete (Culvert 32) between 8a Avenue and 12th Avenue. They are not driveway culverts and we suspect they were constructed to maintenance access to utilities.

Lowlands

In addition to the culverts at major streets and highway, we identified culverts that are located in the lowlands.

In the Brandrith catchment, the lowland culverts include a 1200 mm diameter CSP (Culvert 33) north of Highway 17 between 52nd Street and 56th Street, a 1,500 mm diameter concrete (Culvert 34) crosses Springs Blvd south of Highway 17 and east 48th Street, 1,050 mm diameter concrete (Culvert 35) downstream of highway crossing culvert (Culver 27) and twin 600 PVC culverts (Culvert 36) north of 17A Avenue and east 56th Street.

In the 12th Avenue catchment, triplet 2,200 mm CSP culverts (Culvert 37) discharge directly to Boundary Bay. Other culverts include two 1,200 mm diameter concrete culverts (Culverts 38 and 39) along the main ditch that runs south to north in Southlands.

A2.4 PUMP STATIONS

The study area has four pump stations; Brandrith Pump Station, Beach Grove Pump Station, 12th Avenue Pump Station and 3rd Avenue Pump Station.

Brandrith Pump Station

The Brandrith pump station was originally built to accommodate runoff from a predominantly agricultural area in the mid-1980s. The station was upgraded in 1999 to increase pumping capacity. Until recently, the Brandrith pump station contained two vertically arranged 1.4 m^3/s submersible axial-flow pumps and one 0.3 m^3/s jockey pump, delivering a total capacity of approximately 3 m^3/s. The Brandrith Pump station has recently been upgraded to a total capacity of 5.4 m^3/s in order to accommodate increased flows from the TFN developments.

Beach Grove Pump Station

Beach Grove pump station located on 19th Avenue near 56th Street receives runoff from a portion of the Beach Grove subdivision, east of 56th Street between 12th Avenue and 17A Avenue. The pump station is an internal drainage pump station within the Brandrith catchment. The pump station discharges to a 1,200 mm concrete storm pipe. Record drawing indicates that the pump starts at 2.04 m and shuts off at 1.01 m. The capacity of this pump station is unknown at this time.

12th Avenue Pump Station

12th Avenue Pump Station, located on 12th Avenue at Boundary Bay, receives runoff from a significant portion of the uplands area. The pump station discharges to Boundary Bay via 600 mm diameter steel pipe. The outlet of the pipe has a flap gate.

The existing 12th Avenue Pump Station consists of two 0.35 m^3/s capacity pumps and one 0.95 m^3/s capacity pump, resulting in the existing total pump capacity of 1.65 m^3/s.

Under the parallel 12th Avenue Drainage Improvements project, Associated Engineering is currently engaged with Delta to upgrade the 12th Avenue Pump station to a proposed initial total capacity of 4.5 m^3/s.

3rd Avenue Pump Station

3rd Avenue Pump Station is located on the northwest corner of the intersection of 3rd Avenue and 67A Street. The pump station receives runoff via a 900 mm diameter concrete pipe and dischargers into 750 mm diameter pipe via a 1200 mm x 3050 mm (H x V) culvert.

The pump station was upgraded to a pumping capacity of 0.8 m^3/s in 2002.

A3 STORMWATER REGULATIONS IN DELTA

Several bylaws, acts, and regulations influence stormwater management and watershed health within the study area. Delta and Metro Vancouver bylaws apply throughout the study area with the exception of the Tsawwassen First Nation (TFN) lands. Tsawwassen First Nation’s plans, policies and regulations apply within their lands. TFN is also a member of Metro Vancouver and if they complete an entry agreement with the Metro Vancouver Sewerage and Drainage District (MVS&DD) then Metro Vancouver bylaws would apply within TFN lands.

The Fraser River Estuary Management Program (FREMP) previously had jurisdiction over the receiving water bodies and shorelines of the study area; however, FREMP was shut down in 2013. Many of FREMP's responsibilities were transferred to the Vancouver Fraser Port Authority (Port Vancouver). However, the study area is not in their jurisdiction.

Delta's 1989 Stormwater Management Design Manual[30] has been replaced by more recent regulations and policy such as Delta Subdivision and Development Standards Bylaw No. 7162. Finally, many federal and provincial acts have bearing on stormwater management in the Tsawwassen area.

A3.1 CITY OF DELTA

Delta Official Community Plan Bylaw No. 3950[31], 1985, Consolidated March 2015
This bylaw sets out policies for future development within Delta. Schedules A, D, and E are of particular importance to this ISMP and are discussed at length in section 0.

Delta Development Permit Area to Establish Streamside Protection and Enhancement Areas Bylaw No. 6349[32], 2005
This bylaw amends The City of Delta Official Community Plan bylaw (it is an addition to Schedule E) to establish protection areas for watercourses or sources of water. This bylaw is designed to "preserve, protect, restore, and enhance fish and wildlife, and their habitats, in and along streams." This is achieved by setting development standards that protect riparian areas and natural drainage patterns. The protection extends to ponds, lakes, rivers, creeks, brooks, ditches, springs, and wetlands. Watercourses may be considered whether or not they usually contain water. The streamside protection and enhancement area can extend anywhere from 5 to 30 m from the stream bank or top of a ravine depending on the streamside vegetation conditions.

Delta Subdivision and Development Standards Bylaw No. 7162[33], 2015
This bylaw sets development and design standards. Section 6 as well as Schedules A, B, and C are important components of the stormwater policy framework.

Section 6 pertains to water, sanitary sewers and drainage works and services. It includes an allowance for open ditch drainage systems in areas with agricultural zoning.

Schedule A specifies many design standards for the stormwater system, including storm mains (5.2.4), ditches (5.2.8), and culverts (5.2.9).

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[30] Dayton & Knight Consulting Engineers. (1989). City of Delta Stormwater Management Design Manual. Delta: City of Delta.
[31] The City of Delta. (1985). The City of Delta Offifical Community Plan Bylaw No. 3950. Consolidated March 2015.
[32] The City of Delta. (2005). Delta Development Permit Area to Establish Streamside Protection and Enhancement Areas Bylawy No. 6349.
[33] The City of Delta. (2015b). Delta Tree Protection and Regulation Bylaw No. 7415.

- Clause 5.2.3 includes the regulation that the design of a drainage system should not cross the boundaries shown on Delta's master drainage plan.
- Clause 5.2.12 in Schedule A states that all proposals for works affecting natural watercourses must be forwarded to the British Columbia Ministry of Environment (Fish and Wildlife Branch and Water Management Branch) as well as other applicable provincial and federal (e.g. Fisheries and Oceans Canada) agencies. Schedule A also encourages the use of stormwater best management practices (BMPs) to improve the quality of stormwater runoff, prevent surface drainage from flowing to adjacent lands, and reduce stormwater volumes.
- Clause 5.2.17 specifies design standards for many BMPs including absorbent landscapes, pervious paving, green roofs, on-site rain gardens, roadside swales, roadside rain gardens, roadside infiltration trenches, and street edge alternatives (Note: The use of stormwater BMPs is also discussed in Kerr Wood Leidal (2005)[34]. There are also several restrictions on the use of BMPs in the Tsawwassen area. Pervious paving, roadside swales, roadside rain gardens, and roadside infiltration trenches are not permitted in Tsawwassen English Bluff unless approved by the director of engineering. Roadside swales and roadside infiltration trenches are not recommended for Tsawwassen Central or Tsawwassen Boundary Bay Flat unless soil infiltration rates are demonstrated to be greater than 5 mm/hr or they are otherwise approved by the director of engineering).

Schedules B and C of the Delta Subdivision and Development Standards Bylaw contain supplementary specifications and supplementary drawings and maps respectively.

Delta Zoning Bylaw No. 2750[35], 1977, Consolidated December 2015

The Delta Zoning Bylaw sets standards for land use and development in the Tsawwassen area for each zoning category. It includes regulations pertaining to land use, landscaping, and construction including the types of facilities that may be constructed and how they are to be sited (including setback requirements). There are also regulations related to parking requirements and lot coverage. The zoning regulations have a significant impact on development density and the resulting impervious coverage.

Delta Storm Sewers Regulation and Connection Charge Bylaw No. 5786[36], 2000

This bylaw pertains to the use of storm sewers and applies connection charges to defray the cost of constructing piped drainage systems. The bylaw also states only unpolluted drainage waters should be discharged into the storm system.

Delta Soil Deposit and Removal Bylaw No. 7221[37], 2014

The Soil Deposit and Removal Bylaw identifies soil as an important resource in Delta. It imposes a permit requirement for the deposit or removal of soil on lands from Delta with some specified exemptions.

[34] Kerr Wood Leidal. (2005). *Stormwater Best Management Practices Integration Plan.* The City of Delta.
[35] The City of Delta. (1977). Delta Zoning Bylaw No. 2750. *Consolidated December 2015*.
[36] The City of Delta. (2000). Delta Storm Sewers Regulation and Connection Charge Bylaw No. 5786.
[37] The City of Delta. (2014). Delta Soil Deposit and Removal Bylaw No. 7221.

Delta Tree Protection and Regulation Bylaw No. 7415[38], 2015
With specified exceptions, this bylaw sets a permit requirement for any person to cut or otherwise cause the death of a tree. The bylaw also prohibits tree damaging activities and specifies measures for tree protection during development and construction.

Delta Pesticide Use Control Bylaw No. 6788[39], 2009
With specified exemptions, this bylaw prohibits the use of pesticides for the purpose of maintaining outdoor trees, shrubs, flowers or other ornamental plants, and turf on private or public lands within Delta.

A3.2 METRO VANCOUVER

Metro Vancouver bylaws apply to the study area; however, Metro Vancouver's role in governance related to stormwater management is generally more limited than that of the municipalities. Metro Vancouver most commonly provides policy guidance and assists the member municipalities with planning. The Stormwater Interagency Liaison Group (SILG) assists municipalities with sharing knowledge and experience related to sustainable stormwater management (Metro Vancouver, 2016b)[40]. Metro Vancouver also enforces the Integrated Liquid Waste Resource Management Plan (ILWRMP) to its member municipalities. This plan is the underlying mechanism for reviving development and implementation of ISMP.

Greater Vancouver Regional District Bylaw No. 1136[41], 2010
A bylaw to adopt a regional growth strategy for the Greater Vancouver Regional District (GVRD). The regional growth strategy for Metro Vancouver places a high level of importance on sustainability and maintaining a healthy natural environment. The plan outlines the following five goals:

- Create a compact urban area
- Support a sustainable economy
- Protect the environment and respond to climate change impacts
- Develop complete communities
- Support sustainable transportation choices

The regional growth plan links with other GVRD plans for housing, air quality, solid waste, finance, water, food systems, liquid waste, and parks and greenways. The development and expansion of sewerage services is discouraged in rural, agricultural, or conservation and recreation areas. The regional growth strategy promotes the development of integrated stormwater management plans.

Greater Vancouver Regional District Regional Parks Regulation Bylaw No. 1177[42], 2012, Consolidated April 2015

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[38] The City of Delta. (2015b). Delta Tree Protection and Regulation Bylaw No. 7415.
[39] The City of Delta. (2009). Delta Pesticide Use Control Bylaw No. 6788.
[40] Metro Vancouver. (2016a). *Minimum Requirements for Stormwater Management on Single-lot Residential Developments*. Retrieved September 13, 2016, from metrovancouver.org: http://www.metrovancouver.org/services/liquid-waste/consultations/stormwater-management-baseline/Pages/default.aspx
[41] Metro Vancouver. (2010a). Greater Vancouver Regional Distrrict Bylaw No. 1136.
[42] Metro Vancouver. (2012). Greater Vancouver Regional District Parks Regulation Bylaw No. 1777. Consolidated April 2015.

This bylaw is a consolidation of the regional parks bylaws for reference purposes. Those bylaws regulate the use of regional parks. Regional parks regulation is important because Boundary Bay Regional Park is an important conservation and recreation site located in the study area.

Greater Vancouver Sewerage and Drainage District Sewer Use Bylaw No. 299[43], 2007
This bylaw is a consolidation of the sewer use bylaw (299) and associated amendments. The bylaw regulates the use of both storm and sanitary sewers for members of the Greater Vancouver Sewerage and Drainage District (GVS&DD).

Minimum Requirements for Stormwater Management on Single Lot Residential Developments
Metro Vancouver is in the process of implementing new regulations regarding single lot residential developments (Metro Vancouver, 2016a)[44]. These regulations are to apply to single detached, duplex, and triplex homes. This regulation will apply where member municipalities do not have comparable regulations in place. The proposed regulations would require the use of a best management practice to improve runoff quality onsite and capture and infiltrate 40% of the 2-year, 24-hour storm. The requirements also stipulate that most developments shall not exceed 70% imperviousness, have a minimum topsoil depth of 450 mm and disconnect downspouts.

A3.3 TSAWWASSEN FIRST NATION

Land Use Planning and Development Act
This act outlines the zoning and building regulations for Tsawwassen First Nation. The zoning regulation includes minimum setbacks from watercourses. Also included are subdivision and development regulations that stipulate that parcel holders provide surface and underground drainage works (including collection, conveyance, and treatment) which are designed by a professional engineer.

Community Governance Act
The Community Governance Act provides regulation for public works, dikes and flood protection, and forest resources. It also governs soil deposit and removal under the Soil Deposit and Removal Regulation.

A4 PLANNING AND POLICIES

A4.1 OFFICIAL COMMUNITY PLAN

The City of Delta Official Community Plan (OCP), Bylaw No. 3950, establishes a vision for the future of Delta and describes related policy decisions. This ISMP should work within these policies and the OCP to enhance the vision outlined in the OCP. The OCP contains three sections of primary importance to the study area: Schedule A, Schedule D (Tsawwassen Community Plan), and Schedule E (Development Permit Area Guidelines and Requirements). This section will highlight the community development objectives and related policies that are most likely to influence stormwater management and watershed health in the study area.

[43] Metro Vancouver. (2007). Greater Vancouver Sewerage and Drainage District Sewer Use Bylaw No. 299.
[44] Metro Vancouver. (2010a). Greater Vancouver Regional Distrrict Bylaw No. 1136.

Schedule A

Objective: "Protect shoreline and riparian areas and maintain high standards for water quality."
The policy framework designed to meet water quality objectives includes the following:

- Work with other agencies to manage and monitor point source pollution and non-point source pollution into streams and Boundary Bay and Georgia Strait.
- Maintain water quality in groundwater aquifers.
- Develop an ISMP consistent with the regional Integrated Liquid Waste Resource Management Plan.

Objective: "Protect and enhance watercourses, ravines, forested uplands, wetlands, foreshore and marine areas as habitat for wildlife." This objective relates strongly to the wildlife components of the ISMP. The policies designed to meet this objective include the following:

- Take physical and environmental resource inventories of environmental assets.
- Implement streamside protection measures.
- Minimize habitat loss and fragmentation.
- Promote naturescaping to create new habitats for wildlife.
- Encourage the protection and reopening of natural watercourses.

Objective: "Balance the interests of agriculture, the protection of the environment and the co-operative management of the Fraser River delta ecosystem." Policies related to balancing agriculture and the environment will influence watershed health. The following policy is included under this objective:

- Encourage initiatives, including BMPs, to maintain water quality, hydrological, and soil conditions on agricultural land.

Objective: "Provide, maintain and renew a sustainable storm and sanitary sewer network to support the community's needs." The following policies related to this objective have the potential to affect stormwater management in the study area:

- Encourage the development and application of BMPs including limiting and mitigating impervious area, appropriate siting of buildings, and applying infiltration devices, open ditches and alternative street edge design.
- Support pilot projects for innovative and sustainable infrastructure design and explore the use of alternative development standards to reduce stormwater runoff.
- Encourage the preservation and enhancement of watercourses and riparian areas.
- Mitigate negative impacts of stormwater runoff from roads.
- Maintain and upgrade the agricultural irrigation system.

Objective: "Minimizing and planning for the impacts of climate change." Climate change will have a significant impact on the hydrological conditions in the study area; therefore, policy related to climate change adaptation is important to consider when creating an ISMP. On the subject of climate change, a report has been published on adapting to expected sea level rise in Delta[45]. The following policies are included in the OCP as means to meet this objective:

- Participate in senior government programs and initiatives that address climate change impacts and that help municipalities plan for local-scale impacts of climate change.
- Promote community awareness of climate change among all sectors and the public.

Objective: "Ensure that land use and development are undertaken in a manner consistent with municipal objectives for environmental sustainability." Implementing land use in an environmentally sustainable manner will include achieving stormwater management objectives. Some important policies related to this objective include the following:

- Require development applicants to complete a sustainability checklist.
- Plan for concentrated growth that discourages urban sprawl and minimizes impervious area.

Schedule D - Tsawwassen Community Plan

Schedule D sets out policy guidelines that will impact future land use in the Tsawwassen area. The following are some of the stated objectives and related policies which may influence stormwater management and/or watershed health.

Objective: "Preserve the semi-rural atmosphere of Tsawwassen, and protect and promote the identity of Tsawwassen." This objective should influence future land use. Some policies related to this objective are:

- Limit land use to farming and "open space" in the areas surrounding those which have already been developed.
- Promote the use of indigenous vegetation in road rights-of-way and private developments.
- Encourage the retention of special natural features and utilize semi-rural engineering practices for roads in the Beach Grove and Boundary Bay areas.
- Permit only single family residential development in the Highlands area.

Objective: "To create an attractive, viable, and cohesive town centre, with a "small town" atmosphere, that reflects the unique characteristics and varying lifestyles of the community, and which has a pedestrian environment and includes commercial, institutional and multiple family residential uses." The following policies are related to this objective:

- Focus growth, including the development of medium density housing, in and around the Tsawwassen town centre.
- Establish boundaries to limit the size of the town centre.

[45] Metro Vancouver. (2015). *Biennial Report: 2013-2014.* Intergrated Liquid Waste and Resource Management. Metro Vancouver.

Objective: "To provide a transition between the town centre and surrounding single family neighbourhoods, and to create an identifiable commercial focus in the town centre." This objective, closely related to the previous one, promotes development around the Tsawwassen town centre.

Objective: "To preserve the farmlands within the Southlands for agricultural uses…" The majority of the Southlands area, in the south-east corner of the study area, is to remain agricultural land.

Objective: "To enhance public enjoyment of the natural environment and to protect important habitat types." There are several policies related to this objective that may have significant influence on stormwater management or watershed health:

- Retain as many trees as possible and require two for one replacement of trees removed during development in zoning classified as commercial, multi-family residential, or more than two single-family units.
- Support the creation of nature parks in the Tsawwassen area and the expansion of Boundary Bay Regional Park.
- Protect farms, existing developments, wildlife habitat and other properties from deterioration caused by changes in drainage patterns or water table level.

There are additional relevant policies related to objectives for road works and engineering services:

- Limit the widths of major roads (56^{th} St.).
- Avoid further intrusion of roads and highways into farms to the north and east of the developed areas of Tsawwassen.
- Upgrade the drainage system as required to accommodate new development.

Schedule E – Development Permit Area Guidelines and Requirements

Schedule E of Delta's OCP sets out development criteria for specific regions within Delta. Within the study area the Entrance to Tsawwassen, Tsawwassen Town Centre, English Bluff, Boundary Bay Foreshore and the Southlands, and the Tsawwassen Golf and Country Club are all subject to Schedule E. Some of the guidelines and requirements relate to flood protection and protecting the natural environment. Schedule E also encourages the use of stormwater BMPs for some areas and contains the Streamside Protection and Enhancement Permit Area regulation.

Regulations for improvements to Tsawwassen Town Centre offer opportunities for the use of permeable pavers in pedestrian walkways and parking lots. There are requirements for the inclusion of trees in streetscaping and parking lots. The guidelines and regulations for the entrance to Tsawwassen borrow some of the guidelines from Tsawwassen Town Centre with additional requirements for flood protection, particularly north of 17A Avenue.

The guidelines for English Bluff focus on preventing damage to the natural environment and protecting development from hazardous conditions (such as mud flows, erosion, land slip, and subsidence) through siting and design control. Regulations prevent changes to density and encourage the preservation of existing natural drainage and vegetation.

The objectives for Boundary Bay Foreshore and the Southlands are to prevent damage to the natural environment and to protect development. The guidelines for these regions require any changes to natural drainage to be minimized. Flood protection regulations (based on the regulations established by the BC Ministry of Environment) prevent construction within 7.5 m of the natural boundary of any tidal area and within 6 m of any swamp, slough, pond, or ditch.

The development permit area regulations for the Tsawwassen Golf and Country Club (TG&CC) designate it as a buffer between the more developed lands to the south and more agricultural lands to the north. It should be noted that the land immediately to the north of the TG&CC has since been developed into the Tsawwassen Mills mall. The Tsawwassen Golf and Country club has also undergone development and is now the Tsawwassen Springs Golf Club. Significant residential development has occurred in the area around the course. Guidelines for the TG&CC include the preservation of mature trees, inclusion of plant material and landscape features, considering the use of green roofs, and maximizing the amount of landscaped area and permeable surfaces.

A4.2 TSAWWASSEN FIRST NATION

Tsawwassen First Nation policies and development initiatives will have a significant impact on stormwater management and watershed health within the study area. TFN lands are currently undergoing significant development, including the Tsawwassen Mills commercial development, the Enterprise Area residential development and future industrial development. The following documents are relevant to the development planning in TFN lands:

- TFN Land Use Plan (2009)
- TFN Zoning Regulation (2013)
- TFN South Neighbourhood Plan (2015)
- TFN Neighbourhood Plan (2016)

Future development and its impact on stormwater management is covered in detail in the TFN Integrated Rainwater Management Plan (IRMP) (Urban Systems, 2013). The IRMP expects much less development (and related changes in hydrology) in the Tsawwassen area outside of TFN lands. This is consistent with current Delta planning documents. There are also service agreements between Delta and TFN relating to drainage and irrigation services and dike maintenance Urban Systems, 2013, The City of Delta[46].

Notably, the City of Delta does not have authority on the TFN lands.

[46] Urban Systems. (2013). *Tsawwassen First Nation Integrated Rainwater Magement Plan.* Tsawwassen First Nation.

A4.3 POINT ROBERTS

The Southlands in the Tsawwassen area receives some drainage from uplands Point Roberts, U.S.A (Associated Engineering, 2014). Therefore, policy in Point Roberts has the potential to affect stormwater management in the Tsawwassen area. Significant development would have the potential to impact the volume of water draining into the Southlands; therefore, development policy is of particular concern. Whatcom County Chapter 20.72 – Point Roberts Special District establishes zoning bylaws for Point Roberts. This bylaw indicates an intention for Point Roberts to remain a rural area.

A4.4 INTEGRATED LIQUID WASTE RESOURCE MANAGEMENT PLAN

The Integrated Liquid Waste Resource Management Plan (ILWRMP) applies to Metro Vancouver and its member municipalities and outlines responsibilities and requirements for each. Requirements for the development of ISMPs are included in the ILWRMP. The ILWRMP is the evolution of the previously published Liquid Waste Management Plan (LWMP) which was first established in 2001 and included commitments by municipalities to create ISMPs. It was developed in accordance with the Canada-wide Strategy for the Management of Municipal Wastewater Effluent. The three primary goals of the ILWRMP are as follows:

- Protect public health and the environment
- Use liquid waste as a resource
- Effective and collaborative management

The ILWRMP discusses the development and implementation of infiltration management plans to ensure that wet weather inflows and infiltration are within targeted levels. As a part of the plan Metro Vancouver commits to working with municipalities to develop knowledge of watershed-based stormwater management approaches and identify improvements to related bylaws. The bylaws will require on-site rainwater management that meets either criteria from municipal ISMPs or regional criteria. The performance measures for the ILWRMP include beach closures and stream health indicators. The ILWRMP requires biennial reports from member municipalities, the latest of which was published in June 2015 (Metro Vancouver, 2015).

A4.5 COMMUNITY STORMWATER PROGRAMS

Delta has several community based programs. Delta's rain garden program focuses on installing rain gardens in and around Delta roadways and at several elementary schools (The City of Delta, 2016a; Water Sustainability Action Plan for British Columbia, 2015). The Delta School Rain Garden Program has constructed, or is in the process of constructing, rain gardens at all 14 elementary schools in Delta (Fraser Basin Council, 2016)[47]. The rain gardens are constructed with the assistance of the School District and local community groups. There is a complementary rain gardener program targeted at students in grades 4 and 5 and supported by Delta's engineering department. The school rain gardens are maintained with the

[47] Fraser Basin Council. (2016). *Showcasing Successful Green Stormwater Infrastructure: Lessons from Implementation.* Metro Vancouver and Victoria: Fraser Basin Council.

assistance of local streamkeeping groups (Fraser Basin Council, 2016)[17]. Delta also allows residents to adopt a rain garden in order to improve rain garden maintenance.

Delta allows residents to sign out storm drain marking kits to paint yellow fish beside storm drains (The City of Delta, 2016e)[48]. The storm drains are marked with painted fish to improve awareness among residents that pollutants flowing into the storm drains can have a negative ecological impact. This program is also supported by Fisheries and Oceans Canada (Government of Canada, 2016)[49].

Delta makes rain barrels (including screen, faucets, overflow pipe and plug) available for residents to purchase for $70 each (The City of Delta, 2016b)[50].

Finally, Delta also runs tree planting programs. The Trees for Tomorrow program allows homeowners to request that one or two trees be planted on municipal land immediately adjacent to the side or front of their properties (The City of Delta, 2016c)[51]. Urban reforestation in Delta receives capital investment. The urban reforestation project plans to plant 5000 trees in Delta parks, boulevards, and medians over 5 years (The City of Delta, 2016d)[52]. The program recognizes the role trees play in helping to reduce the amount of pollution entering creeks and irrigation ditches through runoff as well as the important role they play i

[48] The City of Delta. (2016e). *What You Can Do*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/green-living/what-you-can-do

[49] Government of Canada. (2016). *Fisheries and Oceans Canada*. Retrieved September 13, 2016, from pac.dfo-mpo.gc.ca: http://www.pac.dfo-mpo.gc.ca/sep-pmvs/sci-icp/stormdrain-collecteur-eng.html

[50] The City7 of Delta. (2016b). *Rain Barrel Program*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/services/water-sewer/water-conservation/rain-barrel-program

[51] The City of Delta. (2016c). *Trees for Tomorrow*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/trees-for-tomorrow

[52] The City of Delta. (2016d). *Urban Reforestation Project*. Retrieved September 13, 2016, from delta.ca: http://www.delta.ca/environment-sustainability/environmental-initiatives/trees/urban-reforestation-project

Appendix B – Water Quality Report

Date:	May 7, 2018	**File:**	2016-2283.020.003
To:	Corporation of Delta		
From:	Stacy Boczulak M.Sc., P.Ag., Rob Hoogendoorn, R.P.Bio.		
Project:	Tsawwassen ISMP		
Subject:	Water Quality Sampling		

MEMO

1 BACKGROUND

The aquatic habitat of watercourses in the Tsawwassen Integrated Stormwater Management Plan (ISMP) Study Area (Map 1) includes man-made drainage ditches and their associated riparian areas, and very few undeveloped, natural watercourses. Most of the ditches in the Study Area are disturbed, temporal, and not connected to fish-bearing streams. The ditches in the Study Area typically have poor water quality for fish, and fecal coliform bacteria are high within the 12th Avenue, 3rd Avenue[1], and Brandrith catchments[2].

The objective of the water quality sampling was to characterize current water quality conditions in a representative sub-sample of ditches within the Study Area for the Tsawwassen ISMP. Water quality information is useful for comparing to water quality objectives and criteria (i.e. for aquatic life), flagging threats to recreational water quality objectives, or providing baseline data for before-after development studies or climate change adaptation[3].

2 METHODS

Associated Engineering conducted water quality sampling in accordance with Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater (the AMF)[3]. Water quality sampling was conducted at four sites in open flowing ditches (Map 1) during two seasons: dry (July to August, 2016) and wet (November to December, 2015). During each season, 5 samples were collected from each site. Sites were located down-gradient within the catchments of the ISMP Study Area, with the exception of the Strait of Georgia catchment that had no open flowing channel or ditches available to sample. This site was moved up-gradient into the 12th Avenue catchment at the interface of residential and agricultural areas. The 12th Avenue catchment was chosen as it is the largest and most developed catchment within the Study Area.

Water quality sampling included in situ hand-held meter measurements and laboratory measurements of the following parameters:

- Water temperature (in situ);
- Dissolved oxygen (in situ);
- pH (in situ);
- Conductivity (in situ);
- Turbidity (in situ);
- Total metals (laboratory-measured);
- Nitrate-N (laboratory-measured);
- *Escherichia coli* (laboratory-measured); and
- Fecal coliforms (laboratory-measured).

[1] Corporation of Delta. 2009-2010. Pump Station Results and Corporation of Delta. 2013. BBAMP Field Data.
[2] Urban Systems. 2013. Integrated Rainwater Management Plan: Appendix C. Prepared for Tsawwassen First Nation.
[3] Metro Vancouver. 2014. Monitoring and Adaptive Management Framework for Stormwater.

3 RESULTS

We compared the in situ measurements and analytical sample results to federal or provincial approved and working water quality guidelines and criteria for the protection of freshwater aquatic life and to the AMF, as discussed below. The applicable water quality guidelines are as follows:

- Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Water Quality Guidelines for the Protection of Aquatic Life (the CCME Guidelines)[4];
- B.C. Ministry of Environment. 2010. Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture (the MOE Approved Guidelines)[5];
- B.C. Ministry of Environment. 2001. Water Quality Guidelines for Temperature[6]; and
- B.C. Ministry of Environment, Lands and Parks. 1998. Guidelines for Interpreting Water Quality Data[7].

3.1 General Parameters

Below we report the findings of water quality sampling from the dry and wet seasons, noting where there were exceedances of water quality guidelines. In some cases, we attempt to explain the cause of elevated concentrations.

pH

The pH ranged from 7.3 to 8.3 at the four sites within the Study Area (Table 1). All values were within the CCME Guidelines and the MOE Approved Guidelines for the protection of aquatic life. There were no trends in pH between sites or seasons.

Nitrate-N

The concentrations for Nitrate-N were low or below detection limit at all sites except the 12th Avenue up-gradient site in the wet season (Table 2). During the wet season, values at this site approached but did not exceed any guidelines. This site is in the vicinity of agricultural fields, and fertilizer runoff may explain the detectable nutrient levels.

Water Temperature

Water temperatures in the Study Area ranged from 15.1°C to 22.2°C in the dry season and from 6.8°C to 13.7°C in the wet season (Table 1). There were exceedances of the MOE Approved Guidelines and "unsatisfactory" temperatures according to the AMF for the dry season at all sites. Dry season temperatures were higher than the optimal temperature ranges for salmonid species and often above extreme temperature tolerances, as indicated in the MOE Water Quality Guidelines for Temperature. Salmonids are not expected in any catchments as there are barriers to fish passage (i.e. flap

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[4] http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/
[5] http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/water-quality-guidelines/approved-water-quality-guidelines
[6] http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html
[7] https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/intrptoc.htm

gates on pump stations). However, if the barriers to fish passage are removed in the future, warm summer temperatures may have an impact on rearing salmonids in the Strait of Georgia or Boundary Bay.

Conductivity

Conductivity values ranged between sites and seasons (Table 1). Conductivity was generally lowest in the 12th Avenue up-gradient site (100 – 261 µS/cm) and was very high at all other sites (350 – 24299 µS/cm). Conductivity at all sites were of the "needs attention" level according to the AMF. The Guidelines for Interpreting Water Quality Data (MELP 1998) indicate that natural waters normally vary between 50 and 1500 µS/cm. The elevated conductivity values found at all sites here may be due to an anthropogenic input of ions (dissolved metals or other dissolved solids) or to the salinity of lowland groundwater due to ocean influences in the Study Area.

Dissolved Oxygen

Concentrations of dissolved oxygen (DO) were low (i.e. <12.2 mg/L) at every site except the up-gradient site within the 12th Avenue catchment (Table 1). DO is essential to the respiratory metabolism of most aquatic organisms, like fish and aquatic invertebrates. DO affects the solubility and availability of nutrients (MOE 1998); therefore, low concentrations of DO can have negative implications on the productivity of aquatic ecosystems.

Concentrations were generally higher in the wet season at all sites, with values ranging from 2.9 to 12.2 mg/L, whereas dry season measurements ranged from 0.4 to 9.1 mg/L (Table 1). The higher concentrations in the wet season are partly due to the colder water temperatures, as oxygen is more soluble in colder water.

Turbidity

Turbidity was high within the Brandrith and 3rd Avenue catchments (ranging from 10 – 57 NTU and 12 – 2339 NTU respectively) (Table 1). In these catchments, most of the wet season turbidity readings were "of concern" according to the AMF. High turbidity increases the total available surface area of solids that bacteria can grow on, and can interfere with respiration of fish and invertebrates. The Guidelines for Interpreting Water Quality Data indicate that high turbidity reduces light penetration and photosynthetic abilities of submerged vegetation and algae and, in turn, may suppress secondary productivity.

Within the 12th Avenue catchment, turbidity was low and more favourable for aquatic life up-gradient (1.0 – 2.8 NTU) but increased further down-gradient (9– 15 NTU) (Table 1). Increased turbidity down-gradient is likely due to erosion causing an accumulation of sediment or dissolved solids down-gradient.

3.2 Microbiological Parameters

Water quality exceeded microbiological guidelines at every site. *E. coli* and total fecal counts were highest in the Brandrith catchment and, to a lesser extent, in the 3rd Avenue catchment (Table 2). Within the 12th Avenue catchment, *E. coli* and total fecal counts were lower up-gradient (only one exceedance) than down-gradient. High counts (i.e. >200 MPN/100 mL) are likely due to stagnant water at pump stations when the gates are closed and/or due to wildlife (i.e. duck) and dog use within Boundary Bay Park. High fecal and microbiological counts can have negative implications on any recreational users of the watercourses or downstream waterbodies that receive this water (i.e. Boundary Bay)[8]. Average values for microbiological parameters are presented below.

Site	Season	*E. coli* (MPN/100mL)	Total Fecal Coliforms (MPN/100mL)
Brandrith	Dry	8758*	48784*
	Wet	2132	3140
12th Avenue (up-gradient)	Dry	32	506*
	Wet	16	21
12th Avenue (down-gradient)	Dry	682	922*
	Wet	62	66
3rd Avenue	Dry	1633	1674*
	Wet	5038*	18509

* Mean is calculated from an unknown value (e.g. >24196 MPN/100mL)

3.3 Total Metals

Total antimony, arsenic, barium, beryllium, calcium, chromium, cobalt, lithium, magnesium, mercury, molybdenum, nickel, potassium, selenium, sodium, thalium, titanium, uranium and vanadium met the CCME Guideline and MOE Approved Guidelines for the protection of aquatic life (Table 2). There were very few exceedances of aquatic life guidelines for total boron, manganese, and silver.

Total aluminum concentrations ranged from 0.035 to 66.2 mg/L in the Study Area (Table 2). Total aluminum concentrations often exceeded the CCME Guideline and the MOE Approved Guideline at all sites in all seasons. As stated in the Guidelines for Interpreting Water Quality Data, aluminum is not considered a serious threat to aquatic health, except in aquatic ecosystems with low pH.

Total cadmium concentrations ranged from below detection limits (<0.000050 mg/L) to 0.00345 mg/L (Table 2). Concentrations in the 3rd Avenue catchment frequently exceeded the CCME Guidelines and at the "needs attention" level

[8] Note that the water quality testing done within Boundary Bay itself has shown no issues with bacterial counts to date.

according to the AMF. There were also CCME Guideline exceedances in the Brandrith catchment, and two exceedences (wet season) in the 12th Avenue catchment at the down-gradient site. As stated in the Guidelines for Interpreting Water Quality Data, cadmium can bioaccumulate and can cause toxic effects on aquatic life, if elevated. Other co-occurring heavy metals such as zinc and copper (discussed below) may increase cadmium's toxicity.

Total copper concentrations ranged from below detection limit (<0.0050 mg/L) to 0.1460 mg/L in the Study Area (Table 2). Total copper concentrations consistently exceeded the CCME Guidelines and the MOE Approved Guidelines at all sites in all seasons. Total copper in the 3rd Avenue and Brandrith catchments was found at a level that “needs attention” according to the AMF. In the 12th Avenue catchment there were only two concentrations at a level that “Needs attention” according to the AMF.

Total iron concentrations ranged from 0.233 to 158.0 mg/L within the Study Area (Table 2). Concentrations consistently exceeded the CCME Guideline at all sites except for sites within the12th Avenue catchment (only two exceedences at the down-gradient site). Many of the concentrations within the 3rd Avenue and Brandrith catchments were at levels classified as “needs attention”, according to the AMF.

Total lead concentrations ranged from below the detection limit (<0.0010 mg/L) to 0.0429 mg/L within the Study Area (Table 2). Concentrations exceeded CCME Guidelines and the MOE Approved Guideline, in three samples of the 3rd Avenue catchment. Two of these samples also were at the “need attention” level, according to the AMF.

Total zinc concentrations ranged from below the detection limit (0.025 mg/L) to 0.751 mg/L in the Study Area (Table 2). Concentrations exceeded CCME Guidelines within the 3rd Avenue and Brandrith catchments. Concentrations within the 3rd Avenue catchment exceeded MOE Approved Guidelines and were at a level classified as “needs attention”, according to the AMF. Within the 12th Avenue catchment, there were a few exceedances of the MOE Approved Guidelines. As stated in the Guidelines for Interpreting Water Quality Data, zinc can be toxic to aquatic organisms, particularly fish.

4 CONCLUSION

The ditches in the Study Area often have poor water quality for fish (i.e., high temperatures in the dry season, high conductivity, low dissolved oxygen, high turbidity, and high concentrations of certain metals) and may have implications on downstream areas of recreational use (i.e. high concentrations of fecal coliforms enter Boundary Bay). Many parameters exceeded several water quality guidelines (CCME and MOE Approved) and/or were at a levels classified by AMF as “needs attention”, “unsatisfactory”, or “of concern”.

Contributing factors to poor water quality include:

- Land development (residential, agricultural, and commercial) in the Study Area (increased nutrients, dissolved substances, microbiological growth, and metals);
- Stagnant water at pump stations of the Study Area (increased microbiological growth, reduced DO);
- Shallow, low-flowing ditches (increased temperatures, reduced DO); and
- Wildlife or waterfowl use (introduce fecal coliforms).

LEGEND

DRAINAGE FEATURES

- WATER QUALITY SAMPLING SITES
- PUMP STATION
- HABITAT COMPENSATION AREA
- SUBCATCHMENTS
- CULVERT
- STORM MAIN
- STORM SIPHON

WATERCOURSE

- SCHEDULE B
- SCHEDULE C
- UNCLASSIFIED

SCALE:	1:23,500		
PROJECT NO.	BUR_P_2016-2283	INITIAL	DATE
DRAWN		AD	13-12-16
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Delta

THE CORPORATION OF DELTA

TSAWWASSEN
INTEGRATED STORMWATER
MANAGEMENT PLAN

WATER QUALITY
SAMPLING SITES

DRAWING NUMBER	REV. NO.	SHEET
MAP 1		

Map File: \\s-bur-fs-01\projects\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_figures_20160807_ad.map

Table 2. Water Quality Monitoring Results (Laboratory Measured Parameters) Tsawwassen ISMP 2016

		Hardness ($CaCO_3$; mg/L)	Nitrate- N (mg/L)	Microbiology: *E. coli* (MPN/100mL)	Mean	Total Fecal Coliforms (MPN/100mL)	Mean	Total Metals (mg/L): Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)	Cobalt (Co)
CCME Guideline[c]		-	3	-	-	-	-	0.1	-	0.005	-	-	1.5	0.00009	-	0.001	-
BC Guideline[d]		-	3	77	-	200	-	0.05	-	0.005	-	-	1.2	***variable***	-	-	0.004
AMF Guideline[e]		-	3	-	-	200	-	-	-	-	-	-	-	0.00034	-	-	-
Brandrith Catchment																	
	16-Aug	2070	<0.50	649		>2419.6		0.072	<0.0020	0.0020	0.104	<0.025	1.19	<0.00010	180.0	<0.0020	<0.0020
	19-Aug	2370	<0.50	>2419.6		1600		0.286	<0.0020	0.0021	0.117	<0.025	1.44	<0.00010	197.0	<0.0020	<0.0020
Dry Season	23-Aug	2090	<0.50	2420	8758	7900	48784	0.180	<0.0010	0.0030	0.104	<0.025	1.23	<0.000050	168.0	<0.0010	0.00110
	26-Aug	761	<0.10	14100		92000		0.565	<0.00050	0.0094	0.067	<0.015	0.48	0.000101	69.0	0.0019	0.00171
	30-Aug	1330	<0.50	24200		140000		0.586	<0.0010	0.0024	0.075	<0.015	0.78	<0.000050	118.0	0.0018	0.00140
	4-Nov	246	<0.50	3080		7900		3.180	<0.00050	0.0048	0.036	<0.005	0.16	0.000121	50.0	0.0077	0.00370
	10-Nov	253	0.815	4610		2400		1.650	<0.00050	0.0051	0.027	<0.005	0.19	0.000121	48.7	0.0050	0.00398
Wet Season	18-Nov	264	0.912	480	2132	2400	3140	2.220	<0.00050	0.0047	0.027	<0.005	0.19	0.000123	51.2	0.0054	0.00363
	25-Nov	175	0.710	1190		1300		3.770	<0.00050	0.0043	0.028	<0.005	0.11	0.000147	37.3	0.0086	0.00382
	1-Dec	284	1.130	1300		1700		1.380	<0.00050	0.0038	0.029	<0.005	0.18	0.000070	51.6	0.0038	0.00267
12th Avenue Catchment (upgradient)																	
	16-Aug	37	0.366	26		>2419.6		0.050	<0.00050	0.0010	<0.020	<0.005	<0.10	<0.000050	11.2	<0.0005	<0.00050
	19-Aug	34	0.309	7		8		0.035	<0.00050	<0.0010	<0.020	<0.005	<0.10	<0.000050	10.2	<0.0005	<0.00050
Dry Season	23-Aug	49	0.560	6	32	5	506	0.071	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	15.3	<0.0005	<0.00050
	26-Aug	45	0.644	49		46		0.053	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	13.5	<0.0005	<0.00050
	30-Aug	39	0.363	72		49		0.046	<0.00050	0.0011	<0.020	<0.005	<0.10	<0.000050	11.9	<0.0005	<0.00050
	4-Nov	80	0.344	4		13		0.065	<0.00050	0.0013	0.026	<0.005	<0.10	<0.000050	22.9	0.0006	<0.00050
	10-Nov	77	2.510	9		13		0.062	<0.00050	0.0012	0.024	<0.005	<0.10	<0.000050	21.5	0.0005	<0.00050
Wet Season	18-Nov	73	2.420	14	16	4	21	0.111	<0.00050	0.0014	0.024	<0.005	<0.10	<0.000050	20.6	0.0006	<0.00050
	25-Nov	71	2.350	49		70		0.359	<0.00050	0.0019	0.026	<0.005	<0.10	<0.000050	20.0	0.0012	<0.00050
	1-Dec	76	2.390	5		5		0.068	<0.00050	0.0012	0.024	<0.005	<0.10	<0.000050	21.8	0.0006	<0.00050
12th Avenue Catchment (downgradient)																	
	16-Aug	890	<0.25	1050		>2419.6		0.084	<0.00050	0.0110	<0.020	<0.010	0.65	<0.000050	95.6	0.0009	0.00131
	19-Aug	49	0.493	365		170		0.106	<0.00050	0.0025	<0.020	<0.005	<0.10	<0.000050	13.4	<0.0005	<0.00050
Dry Season	23-Aug	1410	<0.25	387	682	350	922	0.632	<0.0010	0.0127	<0.050	<0.025	1.15	0.000054	122.0	0.0020	0.00250
	26-Aug	366	<0.10	1550		1600		0.768	<0.00050	0.0394	0.031	<0.005	0.29	<0.000050	47.8	0.0022	0.00720
	30-Aug	306	<0.10	60		70		0.403	<0.00050	0.0118	<0.020	<0.005	0.23	<0.000050	40.3	0.0011	0.00165
	4-Nov	227	<0.10	28		13		1.200	<0.00050	0.0047	0.020	<0.005	0.15	0.000132	40.2	0.0038	0.00252
	10-Nov	209	0.947	29		33		0.393	<0.00050	0.0036	<0.020	<0.005	0.13	0.000084	41.5	0.0018	0.00315
Wet Season	18-Nov	272	0.768	96	62	79	66	0.533	<0.00050	0.0034	<0.020	<0.005	0.18	0.000079	45.1	0.0021	0.00242
	25-Nov	190	0.784	122		170		1.030	<0.00050	0.0029	<0.020	<0.005	0.11	0.000096	37.8	0.0029	0.00214
	1-Dec	240	0.798	34		33		0.633	<0.00050	0.0036	<0.020	<0.005	0.15	0.000129	43.2	0.0024	0.00270
3rd Avenue Catchment																	
	16-Aug	138	0.011	17		>2419.6		0.501	<0.00050	0.0085	<0.020	<0.005	<0.10	<0.000050	35.6	0.0015	0.00077
	19-Aug	149	0.008	411		350		6.350	<0.00050	0.0134	0.048	<0.005	<0.10	0.000357	36.7	0.0142	0.00845
Dry Season	23-Aug	163	0.009	727	1633	1600	1674	6.390	<0.00050	0.0128	0.042	<0.005	<0.10	0.000316	40.3	0.0147	0.00776
	26-Aug	411	<0.025	5790		1600		62.6	<0.00050	0.0504	0.297	<0.005	0.24	0.002480	95.5	0.1340	0.07250
	30-Aug	486	<0.025	1220		2400		66.2	0.00055	0.0404	0.360	<0.005	0.34	0.003450	110.0	0.1540	0.08390
	4-Nov	395	<0.025	>24196		92000		7.140	0.00091	0.0254	0.101	<0.005	0.42	0.001180	89.2	0.0310	0.03320
	10-Nov	329	0.182	866		490		2.190	<0.00050	0.0118	0.039	<0.005	0.41	0.000362	68.8	0.0108	0.01070
Wet Season	18-Nov	311	0.332	29	5038	17	18509	4.200	<0.00050	0.0041	0.031	<0.005	0.39	0.000190	62.4	0.0105	0.00588
	25-Nov	248	0.306	93		31		5.490	0.00107	0.0053	0.033	<0.005	0.26	0.000174	51.6	0.0104	0.00666
	1-Dec	274	0.453	5		8		2.380	<0.00050	0.0039	0.022	<0.005	0.32	0.000128	54.4	0.0077	0.00440

		Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Magnesium (Mg)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Potassium (K)	Selenium (Se)	Silver (Ag)	Sodium (Na)	Thallium (Tl)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)
CCME Guideline[c]		***variable***	3	***variable***	-	-	-	0.00026	0.073	***variable***	-	0.001	0.00025	-	0.0008	-	-	-	0.03
BC Guideline[d]		0.002	-	***variable***	-	-	***variable***	***variable***	2	-	-	2	***variable***	-	-	-	-	-	***variable***
AMF Guideline[e]		0.011	5	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
Brandrith Catchment																			
	16-Aug	<0.0100	1.37	<0.0010	<0.050	393	0.942	<0.00020	0.0020	<0.010	89.0	<0.0010	<0.00020	2940	<0.00020	<0.050	0.00038	<0.150	<0.025
	19-Aug	<0.0100	2.05	<0.0010	<0.050	457	0.831	<0.00020	0.0031	<0.010	109.0	<0.0010	<0.00020	3670	<0.00020	<0.050	0.00052	<0.150	<0.025
Dry Season	23-Aug	<0.0050	2.82	<0.0010	<0.050	405	0.814	<0.00020	0.0015	<0.0050	94.0	<0.0010	<0.00010	3150	<0.00020	<0.050	0.00039	<0.150	<0.025
	26-Aug	0.0055	7.23	0.0015	<0.050	143	1.100	<0.00020	0.0014	<0.0050	36.3	<0.0010	<0.000050	992	<0.00020	<0.050	0.00021	<0.090	0.113
	30-Aug	<0.0050	1.78	<0.0010	<0.050	252	0.544	<0.00020	0.0014	<0.0050	60.1	<0.0010	<0.00010	1940	<0.00020	<0.050	0.00034	<0.090	0.018
	4-Nov	0.0185	6.56	0.0020	<0.050	29.4	0.311	<0.00020	0.0046	0.0206	17.5	<0.0010	<0.000050	143	<0.00020	0.119	0.00091	<0.030	0.037
	10-Nov	0.0161	5.21	0.0012	<0.050	31.9	0.324	<0.00020	0.0058	0.0212	18.1	<0.0010	<0.000050	160	<0.00020	0.075	0.00081	<0.030	0.026
Wet Season	18-Nov	0.0175	5.61	0.0012	<0.050	33.1	0.310	<0.00020	0.0053	0.0206	15.8	<0.0010	<0.000050	179	<0.00020	0.069	0.00095	<0.030	0.031
	25-Nov	0.0182	6.29	0.0022	<0.050	19.7	0.206	<0.00020	0.0047	0.0218	12.3	<0.0010	<0.000050	105	<0.00020	0.144	0.00096	<0.030	0.034
	1-Dec	0.0110	3.97	<0.0010	<0.050	37.6	0.353	<0.00020	0.0042	0.0151	16.4	<0.0010	<0.000050	218	<0.00020	<0.050	0.00093	<0.030	0.019
12th Avenue Catchment (upgradient)																			
	16-Aug	0.0047	0.186	<0.0010	<0.050	2.24	0.012	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	6	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	19-Aug	0.0034	0.184	<0.0010	<0.050	1.98	0.024	<0.00020	0.0013	<0.0050	<2.0	<0.0010	<0.000050	6	<0.00020	<0.050	<0.00020	<0.030	<0.0050
Dry Season	23-Aug	0.0040	0.228	<0.0010	<0.050	2.71	0.030	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	12	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	26-Aug	0.0051	0.202	<0.0010	<0.050	2.75	0.020	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	9	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	30-Aug	0.0121	0.169	<0.0010	<0.050	2.16	0.014	<0.00020	<0.0010	<0.0050	<2.0	<0.0010	<0.000050	8	<0.00020	<0.050	<0.00020	<0.030	<0.0050
	4-Nov	0.0049	0.193	<0.0010	<0.050	5.47	0.038	<0.00020	<0.0010	<0.0050	2.9	<0.0010	<0.000050	16	<0.00020	<0.050	<0.00020	<0.030	0.009
	10-Nov	0.0059	0.185	<0.0010	<0.050	5.58	0.042	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	14	<0.00020	<0.050	<0.00020	<0.030	0.008
Wet Season	18-Nov	0.0052	0.320	<0.0010	<0.050	5.25	0.072	<0.00020	<0.0010	<0.0050	2.7	<0.0010	<0.000050	13	<0.00020	<0.050	<0.00020	<0.030	0.009
	25-Nov	0.0268	0.504	<0.0010	<0.050	5.09	0.070	<0.00020	<0.0010	<0.0050	3.0	<0.0010	<0.000050	16	<0.00020	<0.050	<0.00020	<0.030	0.014
	1-Dec	0.0070	0.194	<0.0010	<0.050	5.2	0.043	<0.00020	<0.0010	<0.0050	2.6	<0.0010	<0.000050	37	<0.00020	<0.050	<0.00020	<0.030	0.007
12th Avenue Catchment (downgradient)																			
	16-Aug	<0.0025	1.160	<0.0010	<0.050	158	0.387	<0.00020	0.0011	<0.0050	49.1	<0.0010	<0.000050	1260	<0.00020	<0.050	0.00045	<0.060	<0.010
	19-Aug	0.0076	0.233	<0.0010	<0.050	3.62	0.028	<0.00020	<0.0010	<0.0050	2.1	<0.0010	<0.000050	10	<0.00020	<0.050	<0.00020	<0.030	0.014
Dry Season	23-Aug	<0.0050	2.660	<0.0010	<0.050	270	0.736	<0.00020	0.0013	<0.0050	85.0	<0.0010	<0.00010	2240	<0.00020	<0.050	0.00137	<0.15	<0.025
	26-Aug	0.0032	5.710	<0.0010	<0.050	59.8	3.720	<0.00020	0.0014	<0.0050	23.1	<0.0010	<0.000050	495	<0.00020	<0.050	0.00034	<0.030	0.008
	30-Aug	0.0019	1.670	<0.0010	<0.050	49.9	0.472	<0.00020	0.0010	<0.0050	16.7	<0.0010	<0.000050	392	<0.00020	<0.050	0.00021	<0.030	0.006
	4-Nov	0.0087	3.070	0.0011	<0.050	30.8	0.161	<0.00020	0.0021	0.0129	14.6	<0.0010	<0.000050	192	<0.00020	0.051	0.00036	<0.030	0.021
	10-Nov	0.0052	1.910	<0.0010	<0.050	25.5	0.277	<0.00020	0.0023	0.0143	13.0	<0.0010	<0.000050	139	<0.00020	<0.050	0.00030	<0.030	0.015
Wet Season	18-Nov	0.0052	2.010	<0.0010	<0.050	38.7	0.144	<0.00020	0.0024	0.0142	15.0	<0.0010	<0.000050	247	<0.00020	<0.050	0.00036	<0.030	0.009
	25-Nov	0.0065	2.050	<0.0010	<0.050	23.2	0.125	<0.00020	0.0018	0.0132	10.6	<0.0010	<0.000050	150	<0.00020	<0.050	0.00037	<0.030	0.013
	1-Dec	0.0056	2.060	<0.0010	<0.050	32.1	0.168	<0.00020	0.0021	0.0127	12.5	<0.0010	<0.000050	182	<0.00020	<0.050	0.00045	<0.030	0.013
3rd Avenue Catchment																			
	16-Aug	0.0055	2.650	<0.0010	<0.050	12	0.060	<0.00020	<0.0010	<0.0050	4.2	<0.0010	<0.000050	19	<0.00020	<0.050	0.00030	<0.030	0.006
	19-Aug	0.0142	17.1	0.0044	<0.050	14	0.226	<0.00020	0.0013	0.0152	4.8	<0.0010	<0.000050	19	<0.00020	0.274	0.00087	<0.030	0.054
Dry Season	23-Aug	0.0163	15.1	0.0049	<0.050	15.1	0.260	<0.00020	0.0014	0.0152	4.8	<0.0010	<0.000050	21	<0.00020	0.251	0.00089	<0.030	0.067
	26-Aug	0.1190	126.0	0.0348	0.078	41.9	1.770	0.00022	0.0032	0.1210	22.0	0.0015	0.000294	99	0.00037	1.740	0.00476	0.179	0.361
	30-Aug	0.1460	158.0	0.0429	0.098	51.5	2.210	<0.00020	0.0039	0.1440	26.0	0.0018	0.000364	108	0.00042	2.180	0.00498	0.257	0.517
	4-Nov	0.0925	151.0	0.0158	<0.050	41.8	1.600	<0.00020	0.0104	0.0565	34.1	<0.0010	0.000123	249	<0.00020	0.218	0.00289	0.107	0.751
	10-Nov	0.0165	46.1	0.0043	<0.050	38.2	0.625	<0.00020	0.0053	0.0221	32.6	<0.0010	0.000062	234	<0.00020	0.095	0.00107	0.040	0.212
Wet Season	18-Nov	0.0131	14.8	0.0024	<0.050	37.7	0.324	<0.00020	0.0025	0.0177	33.4	<0.0010	<0.000050	237	<0.00020	0.148	0.00069	<0.030	0.060
	25-Nov	0.0157	10.4	0.0025	<0.050	29	0.358	<0.00020	0.0073	0.0211	29.0	<0.0010	0.000064	141	<0.00020	0.185	0.00098	<0.030	0.041
	1-Dec	0.0094	8.6	0.0014	<0.050	33.7	0.232	<0.00020	0.0039	0.0148	30.5	<0.0010	<0.000050	179	<0.00020	0.107	0.00061	<0.030	0.027

Notes:

a) Dry season is defined as July-August and wet season is November-December according to Metro Vancouver's Monitoring and Adaptive Management Framework for Stormwater (MetroVan 2014).

b) See Map 1 for site locations and catchment boundaries

c) CCME guidelines for the protection of Aquatic Life

d) BC MOE Approved Water Quality Guidelines Aquatic Life, Wildlife and Agriculture

e) Based on Monitoring and Adaptive Management Framework

variable Guideline is a range of values based on calculation that relies on hardness, temperature and/or pH

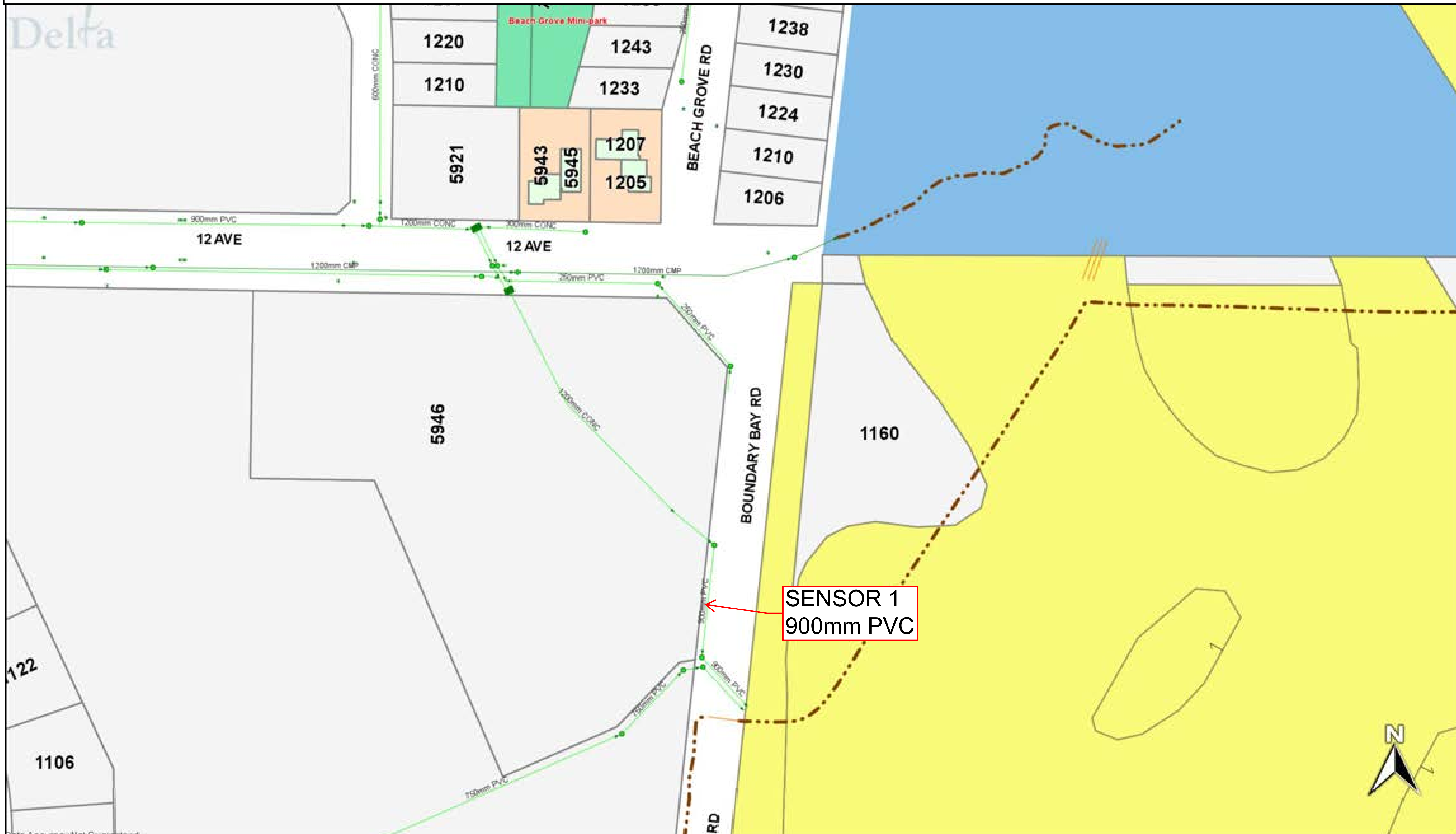
text Value Exceeds CCME Guidelines

text Value Exceeds BC Guidelines

text Value is "Unsatisfactory" , "of Concern" or "Needs Attention" as per the Adaptive Management Framework

Appendix C – Flow Monitoring

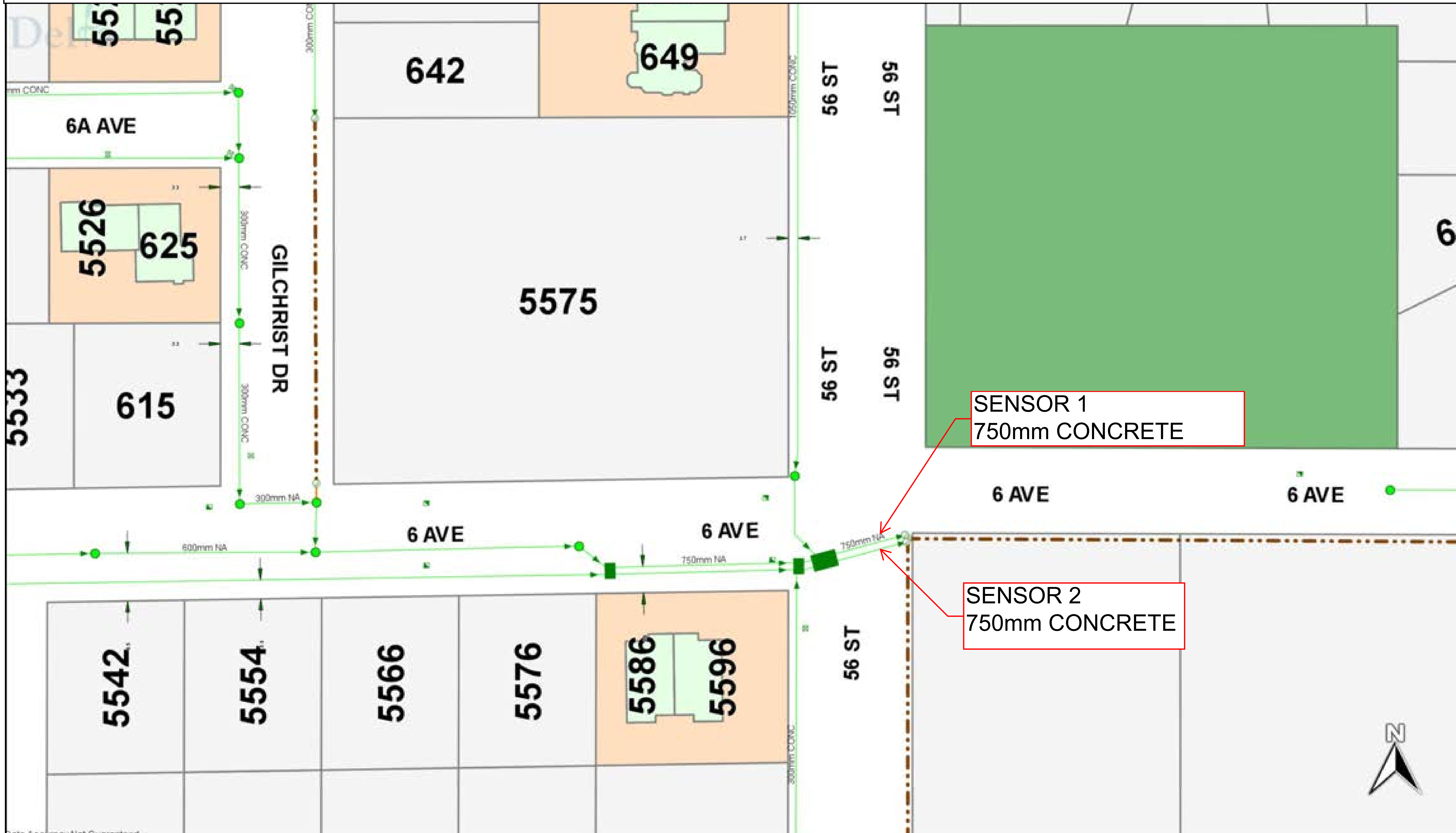
STREET MAP
SITE 1



40 m
100 ft

Oct/19/2016
Scale 1:1946

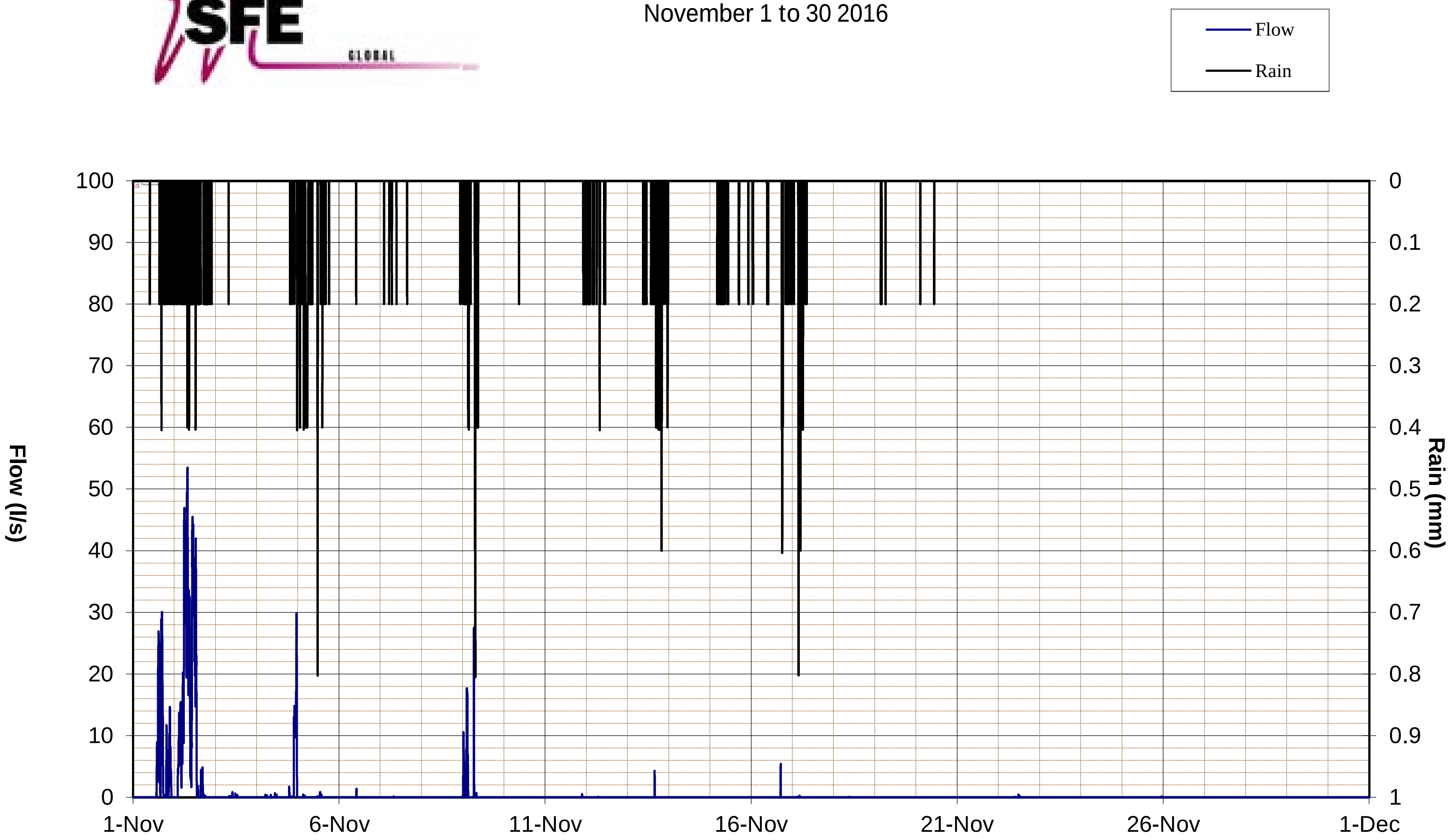
STREET MAP
SITE 2



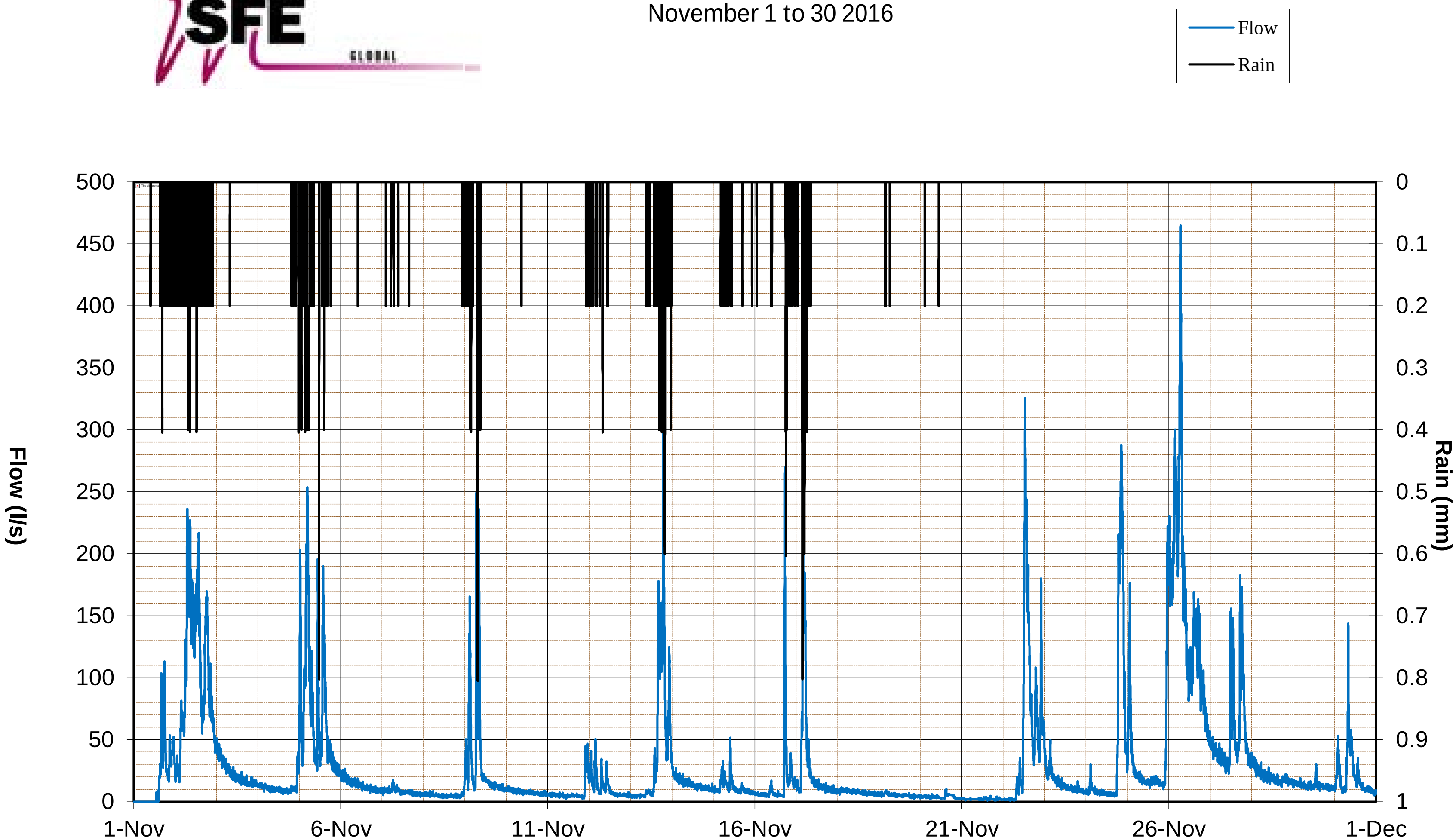
20 m
60 ft

Oct/19/2016
Scale 1:973

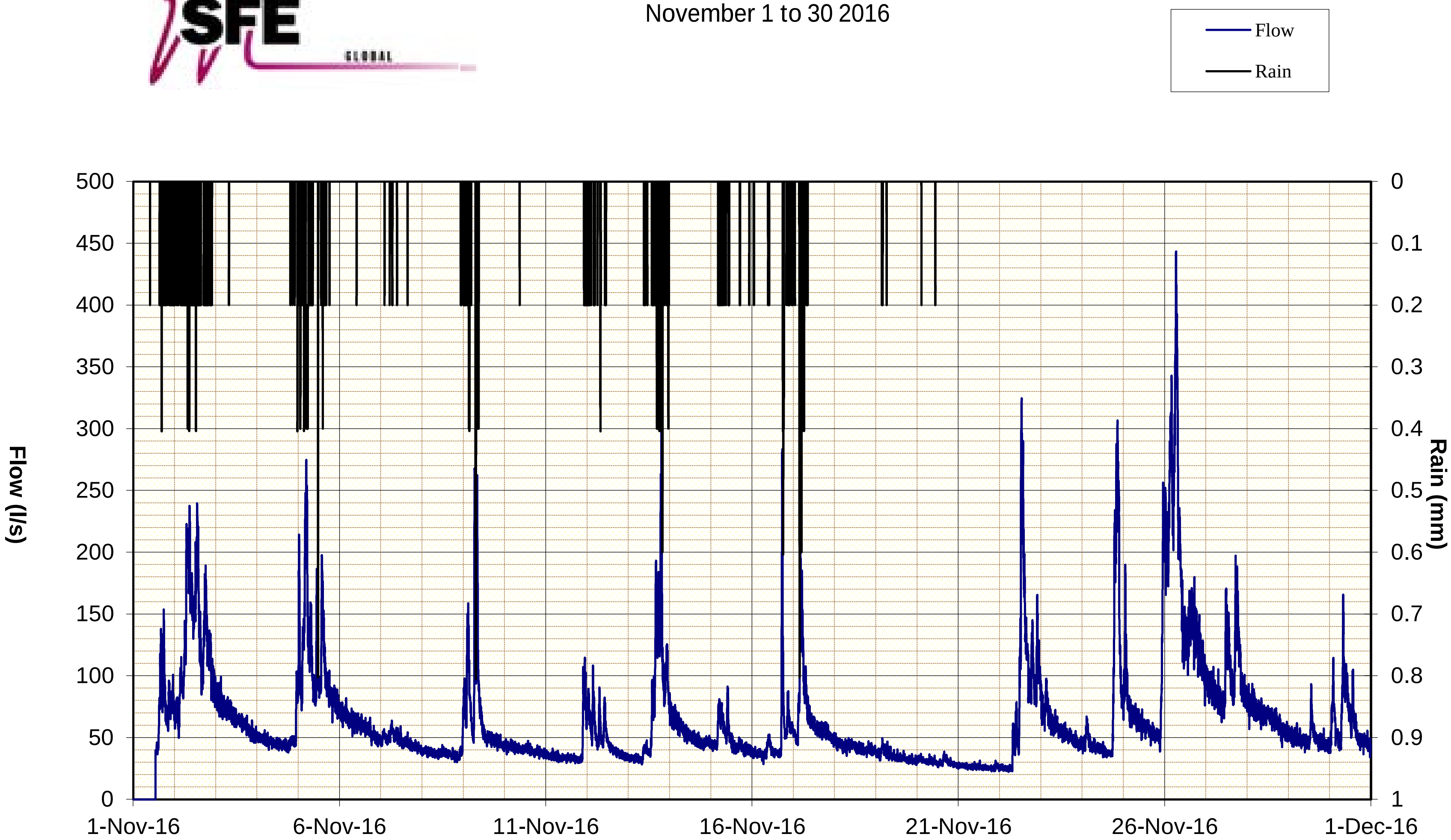
City of Delta (Tsawassen)
SFE Site #068F - 1 - 12th and Boundary Bay Road
November 1 to 30 2016



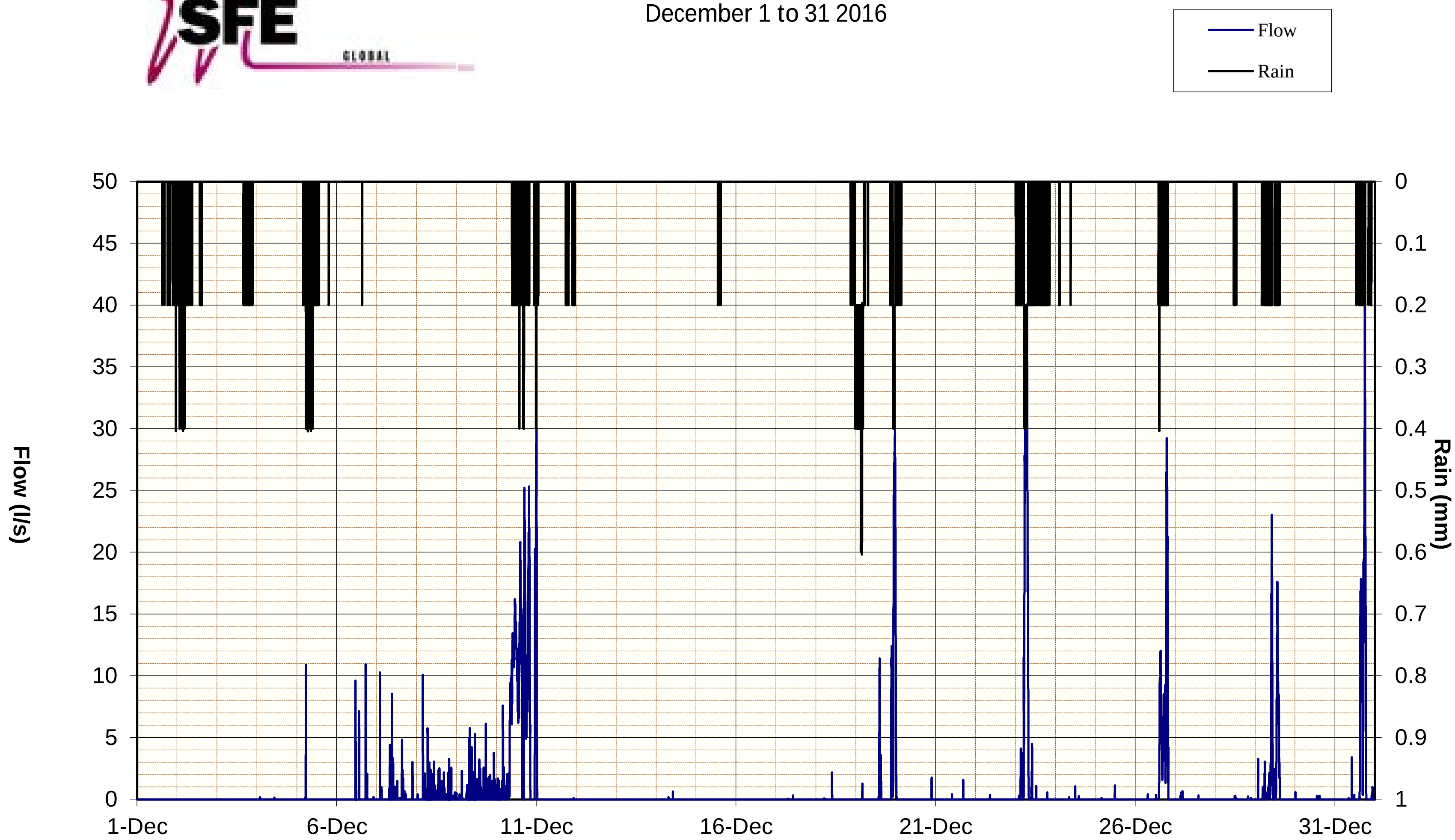
City of Delta (Tsawassen)
SFE Site #068F - 2 Left - 56th and 6th
November 1 to 30 2016



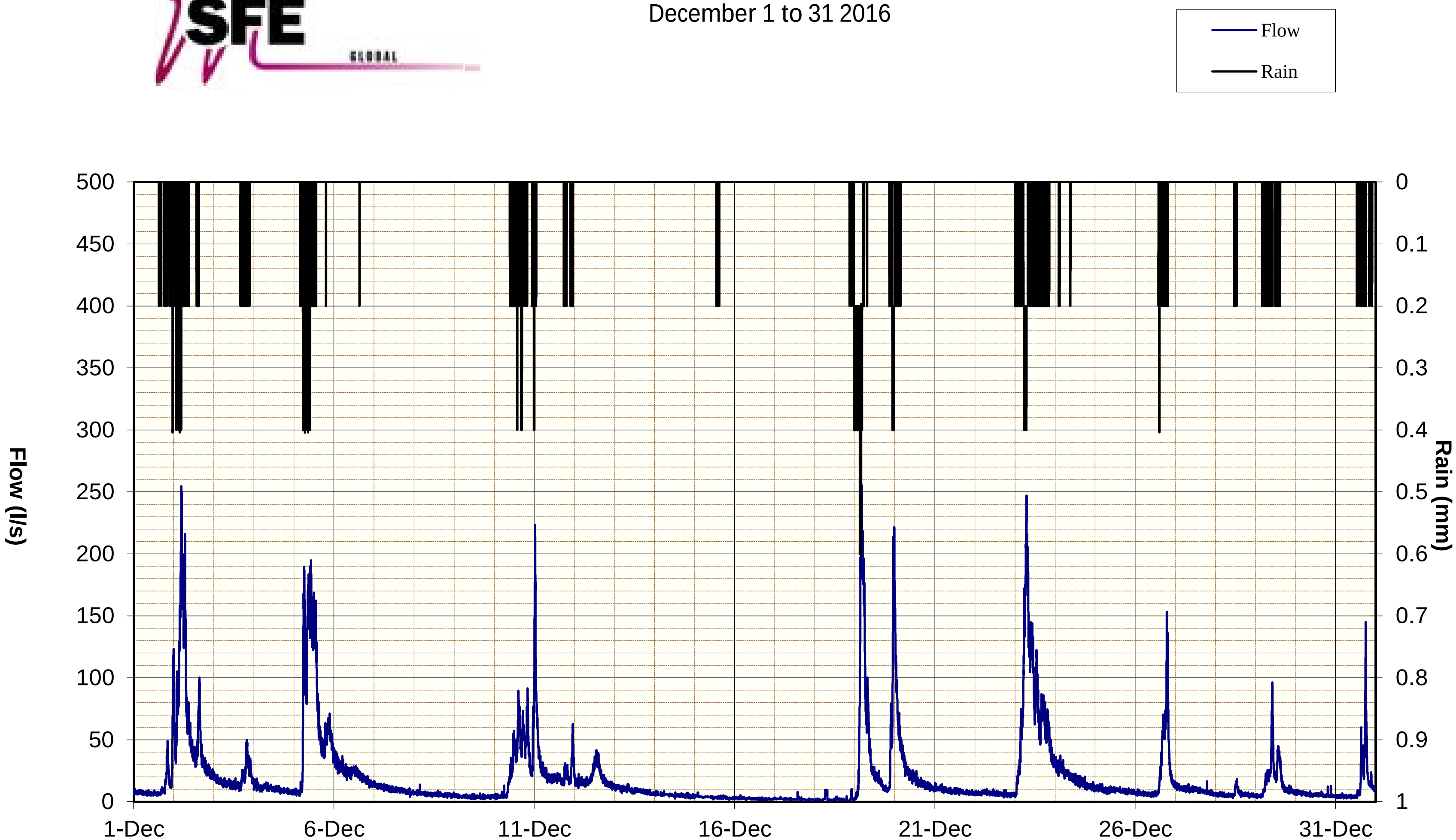
City of Delta (Tsawassen)
SFE Site #068F - 2 Right - 56th and 6th
November 1 to 30 2016



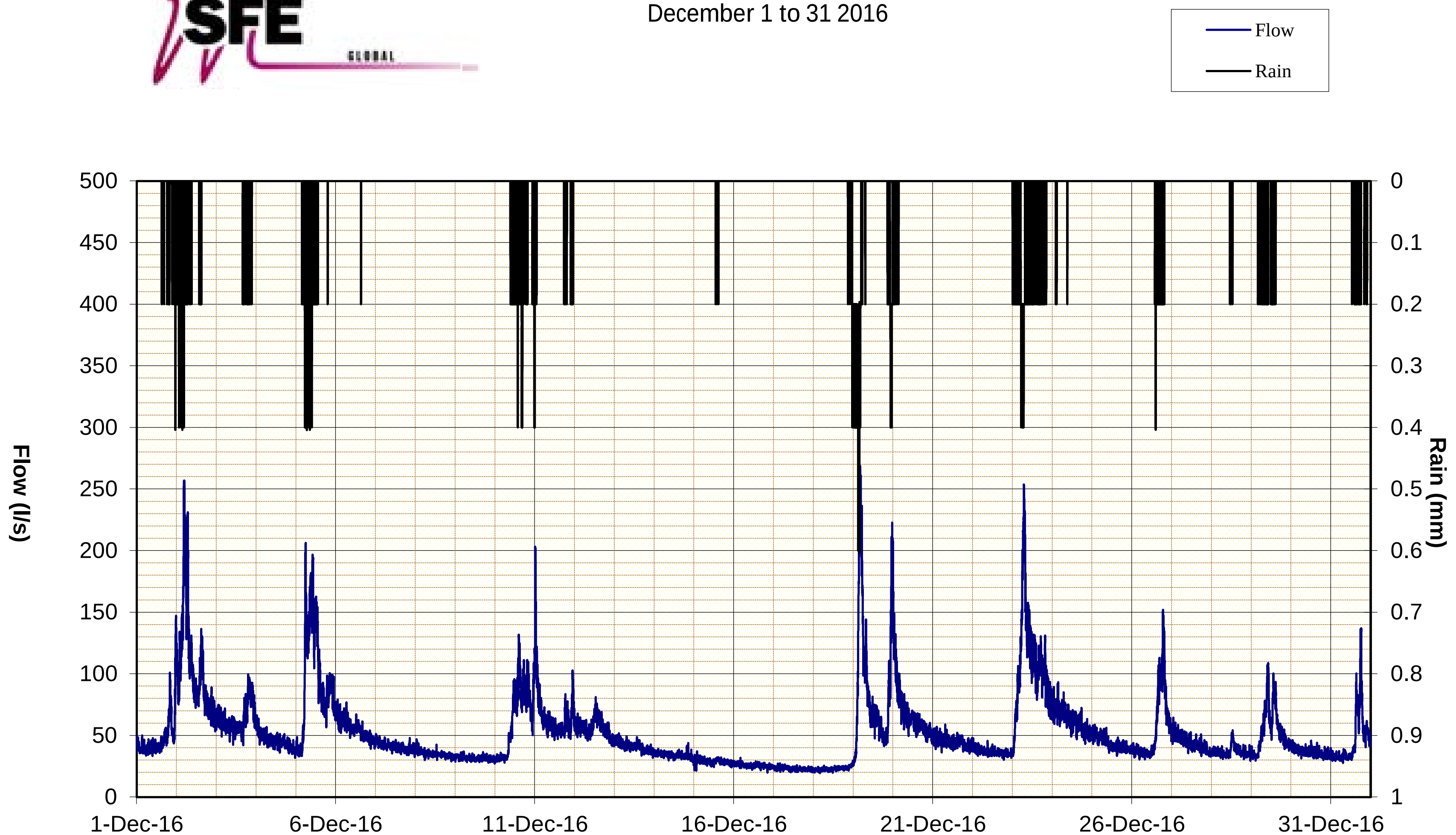
City of Delta (Tsawassen)
SFE Site #068F - 1 - 12th and Boundary Bay Road
December 1 to 31 2016



City of Delta (Tsawassen)
SFE Site #068F - 2 Left - 56th and 6th
December 1 to 31 2016



City of Delta (Tsawassen)
SFE Site #068F - 2 Right - 56th and 6th
December 1 to 31 2016



Appendix D – Hydrologic and Hydraulic Modelling

This appendix contains information from the Stage 3 report. The appendix is organized as follows:

D1 outlines the hydraulic modelling assessment.
D2 outlines the extended period simulation.
Following D1 and D2 we include long profiles illustrating system deficiencies (Figures D-1-D-8).

D1 HYDRAULIC MODELLING

D1.1 EXISTING CONDITION MODEL

Model Parameters

Subcatchment parameters including Horton infiltration rates, average slope, Manning's Roughness Coefficients for overland flow and depression storage were established based on air photos, LiDAR data, site visits and previous modelling efforts in the region. Table D-1 summarizes the key hydrologic parameters used in the model.

Table D-1
Hydrologic Model Parameters

Horton Infiltration Parameters	
Maximum Infiltration Rate (mm/hr)	3 (Lowlands) 5 (Uplands)
Minimum Infiltration Rate (mm/hr)	1 (Lowlands), 2.5 (Uplands)
Decay Constant (hr -1)	4.14
Drying Time (days)	7
Manning's Roughness Coefficient, n, for Overland Flow	
Impervious Surface (overland flow)	0.013
Pervious Surface (overland flow)	0.24
Depression Storage	
Impervious Surface (mm)	2.5
Pervious Surface (mm)	5

Table D-2 presents the hydraulic parameters assigned to the conduits within the model.

Table D-2
Conduit Properties

Manning's Roughness Coefficient, n, for Conduit Flow	
PVC	0.013
HDPE	0.013
Steel	0.013
Concrete	0.013
Corrugated Steel Pipe (CSP)	0.024
Ditches / Watercourses	0.035*

*Note: A Manning's n of 0.035 was chosen rather than 0.05 which would normally be applied to natural water courses. The majority of the open channels in this area are maintained agricultural ditches with fewer roughness features such as logs or boulders.

Rainfall Data

We developed design rainfall events for the 2-, 5-, 10-, 25-, 50-, and 100-year return period using the SCS Type IA curve and the IDF data for the Pebble Hill Reservoir rain gauge (ID:DT61) operated by Metro Vancouver. This rain gauge was selected due to its proximity to the study area and the period of record available. It is located in the southwest corner of the study area at an elevation of 51 m. The IDF data includes 13 years of data (from 1998 to 2010). The IDF curve is presented in in Figure D1-1.

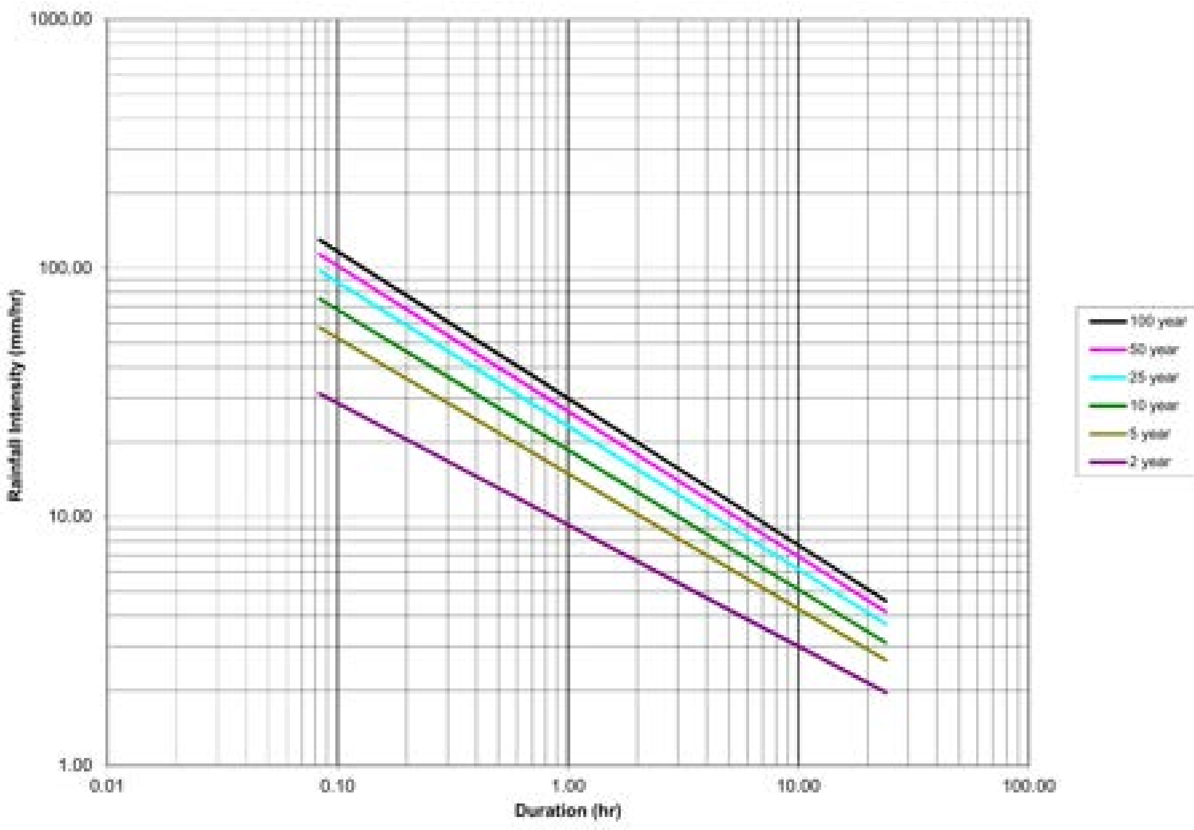


Figure D1-1
Pebble Hill Reservoir IDF Curves

Table D-3 presents the relevant coefficients for the Pebble hill IDF Curve.

Table D-3
Coefficient A and Exponent B for Pebble Hill Reservoir IDF Curve

	10-Year Return Period	100-Year Return Period
Coefficient A	18.598	29.948
Exponent B	-0.562	-0.590

We include an example of the 100-year storm event developed from this IDF curve for use in the model in Figure D1-2:

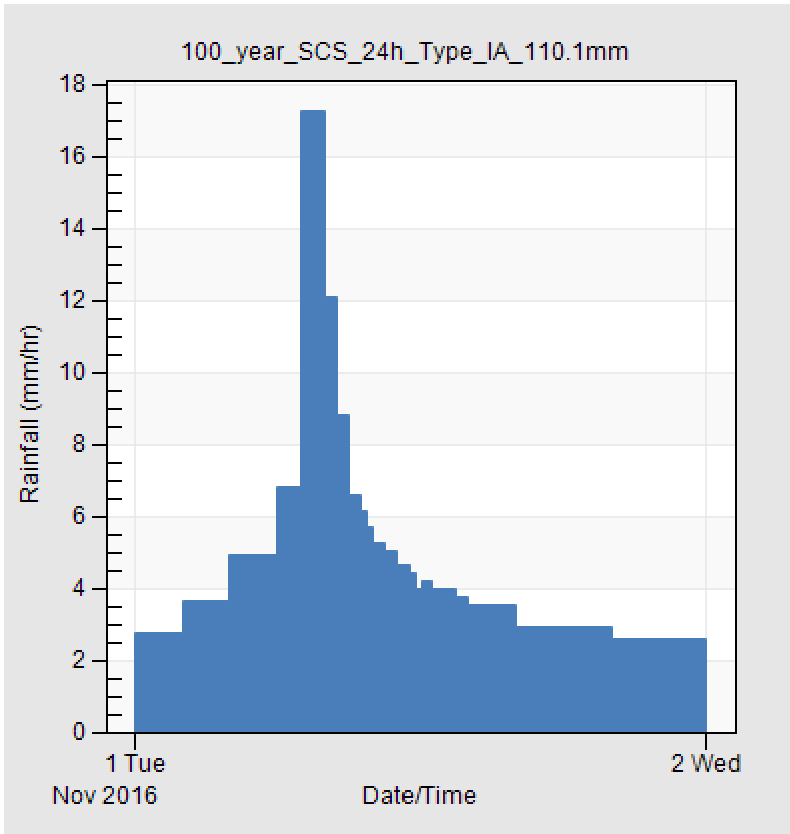


Figure D1-2
100-year, 24-hour Rainfall Event

Boundary Conditions and External Inflows

We added two subcatchments in the northern area of the model to account for the runoff that can be expected to contribute to the drainage along the north boundary of the study area. At the outfalls at the floodbox at Brandrith Pump Station (OF1) and the end of the storm siphon along 12 Avenue (OF5), we assumed fixed tidal conditions of high tide (1.8 m) to represent the worst-case tidal condition for the study area. The tidal information was taken from the Fisheries and Oceans Canada database. We assumed only free outfalls not controlled by pump stations would be affected by tides. The outfalls along English Bluffs (OF2, OF3, OF4) would not be significantly affected due to their steep gradient. We assume pump stations will be upgraded overtime to overcome future high tide conditions (OF6 and OF7).

Model Calibration

SFE completed flow monitoring near the intersection of Boundary Bay Road and 12 Avenue at the 900 mm PVC pipe (Site 1) and both of the 750 mm twinned concrete pipes at the intersection of 56 Street and 6 Avenue (Site 2). The figures in Appendix B show these locations in more detail. The flow monitoring was completed from November 1 to December 31, 2016. During this time, the peak flows measured during he storm events ranged from 50 L/s to 500 L/s. Associated Engineering processed the data and calibrated the existing condition model to match the flow distributions recorded at the flow monitoring locations. We used the sum of the two pipes at 56 Street for calibration as the other location did not have complete records over the monitoring period.

Figures D1-3 and D1-4 show the flow results from the model compared to the measured flows before and after calibration.

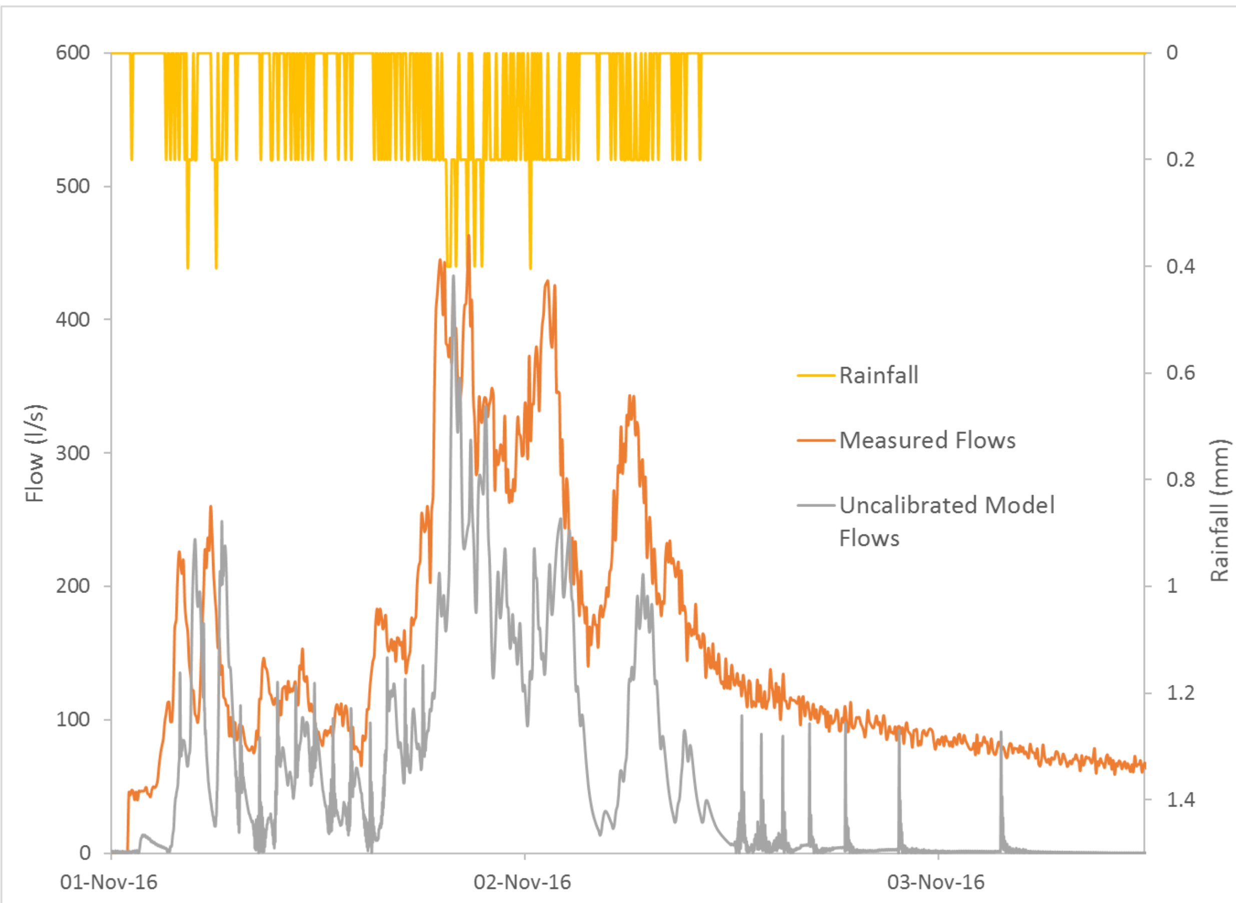


Figure D1-3
Comparison of Measured and Uncalibrated Model Flows (Site 2)

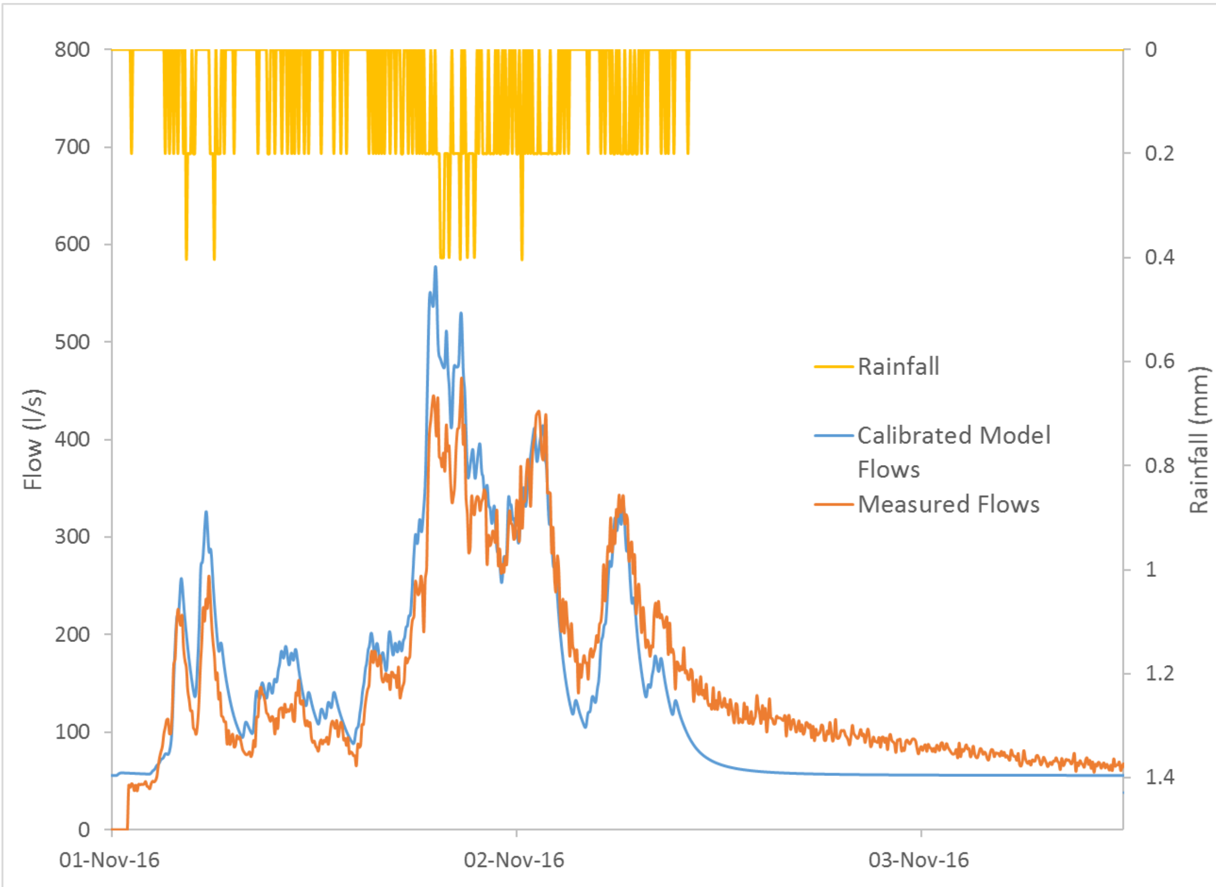


Figure D1-4
Comparison of Measured and Calibrated Model Flows (Site 2)

The uncalibrated model flows have significantly sharper, but lower peaks than the measured flows and underestimates the runoff volume. Additionally, the measured flows exhibit a base flow while the uncalibrated model does not.

To calibrate the model, we adjusted the hydrologic parameters affecting subcatchment runoff, most notably the effective impervious area. Although we originally assume single family residential areas to have 60% impervious cover, we changed this value to 40% to better correspond to the measured flows. To compensate for the resulting net decrease in surface runoff, we lowered the rates of infiltration for pervious surfaces to better replicate the watershed response during large storms. Additionally, we assigned base flows of approximately 0.6 L/s throughout the model to correspond the base flow measured by SFE. The calibrated hydrograph now closely replicates the measured flow events. Although the calibrated flow is overestimating the measured flows at the peaks, we did not feel that further reducing runoff rates was justifiable give the calibration event was relatively small. Runoff response does not scale linearly with the magnitude of an event.

Our calibrated model will give us more confidence in our model results for the smaller events. For larger events, however, additional calibration to larger storm events closer to the modeled event return period would be required to create an accurate representation of the watershed response.

D1.2 FUTURE CONDITION MODEL

We updated our Existing Condition Model to reflect future developments expected to occur within the study area. The purpose of this model is to identify the hydraulic impacts of future development. New deficiencies may occur as a result of future development, and existing deficiencies may be exacerbated.

Densification

In the existing condition model, we modelled all developments which were already approved and underway, including the Onni development in the TFN lands and the Southlands development. For the future condition, no new developments are planned, so for the most part, our land use condition and associated impervious values stayed the same. However, we assumed that as the housing stock is replenished overtime, houses will be built with bigger footprints and will have correspondingly greater impervious areas. To update our model to reflect this future densification, we increased the impervious percentage associated with the single family residential land use category from 40% to 50%.

Additionally, there is a portion of the northern point of Point Roberts which drains to the Tsawwassen Southlands area. As this area is zoned to be developed into rural residential housing, we modeled this area as fully developed into single family residential housing in our future condition.

Climate Change

The Lower Mainland can expect an increase in the frequency of storms as well as an increase in storm severity in the future due to climate change (Metro Vancouver[53], 2016). This increase in precipitation could have a significant effect on the drainage system performance in the Tsawwassen area. As such, we completed a screening level assessment of the effects of climate change on the rainfall in the area. We applied a percent increase to the total rainfall volume for the 24-hour storm proportional to increases found in a recent climate change study from the City of Surrey[54]. Given the similar climatic conditions between Tsawwassen and Surrey, using results of Surrey's updated IDF curves allows us to take advantage of data based on detailed regional downscaling. In the year 2080, Tsawwassen could experience a 50% increase in precipitation depending on the emissions scenarios we follow globally. We modelled this 50% increase for both the 10-year and 100-year event to assess the response of the current major and minor system to climate change.

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[53] Metro Vancouver. 2016. Climate Projections for Metro Vancouver. Available at: http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjections ForMetroVancouver.pdf (accessed February 2017).

[54] Dillon Consulting on Behalf of City of Surrey. 2015. Development of Future IDF Statistics for the City of Surrey.

Results are presented in Section 4.3. Figure D1-5 presents a comparison of our rainfall event adjusted for climate change to the original modelled event representing present day conditions.

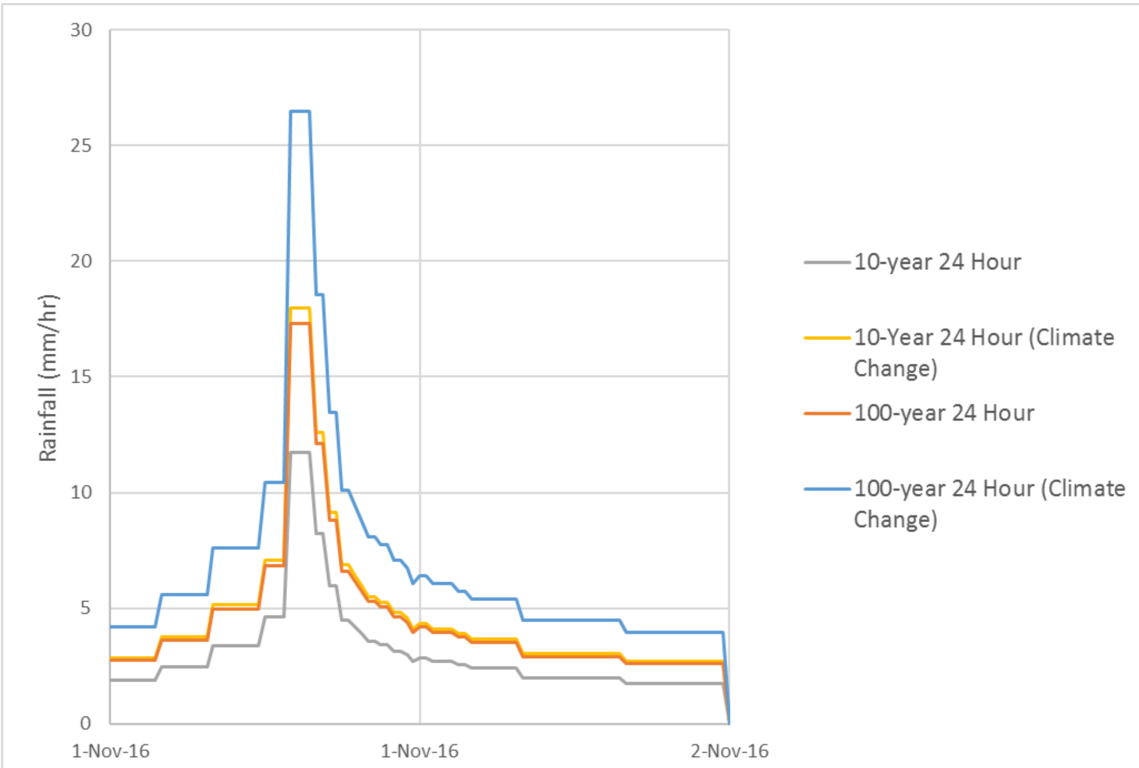


Figure D1-5
Comparison of Rainfall Events (with/without Climate Change)

D2 ASSESSMENT OF POTENTIAL IMPACTS

We ran a three-year continuous simulation of the drainage network to compare the existing and future conditions in the watershed. This allows us to analyze the potential impacts of development and densification in the Tsawwassen study area. The purpose of the simulation is to assess the impact of development on the hydrologic regime in natural watercourses. This provides an indication of changes in flow-duration characteristics following development.

D2.1 EXTENDED PERIOD RAINFALL DATA

We completed Extended Period Simulation (EPS) modelling for two scenarios. The first scenario was based on existing land use, while the second scenario was based on future land use. The modifications to the land use under future development conditions are the same as those used for the event-based models.

For both scenarios, the same hydraulic network and rainfall data were applied to the model. We used rainfall data spanning from June 1, 2010 to June 1, 2013 from the firehall rain gauge, as shown in Figure D2-1.

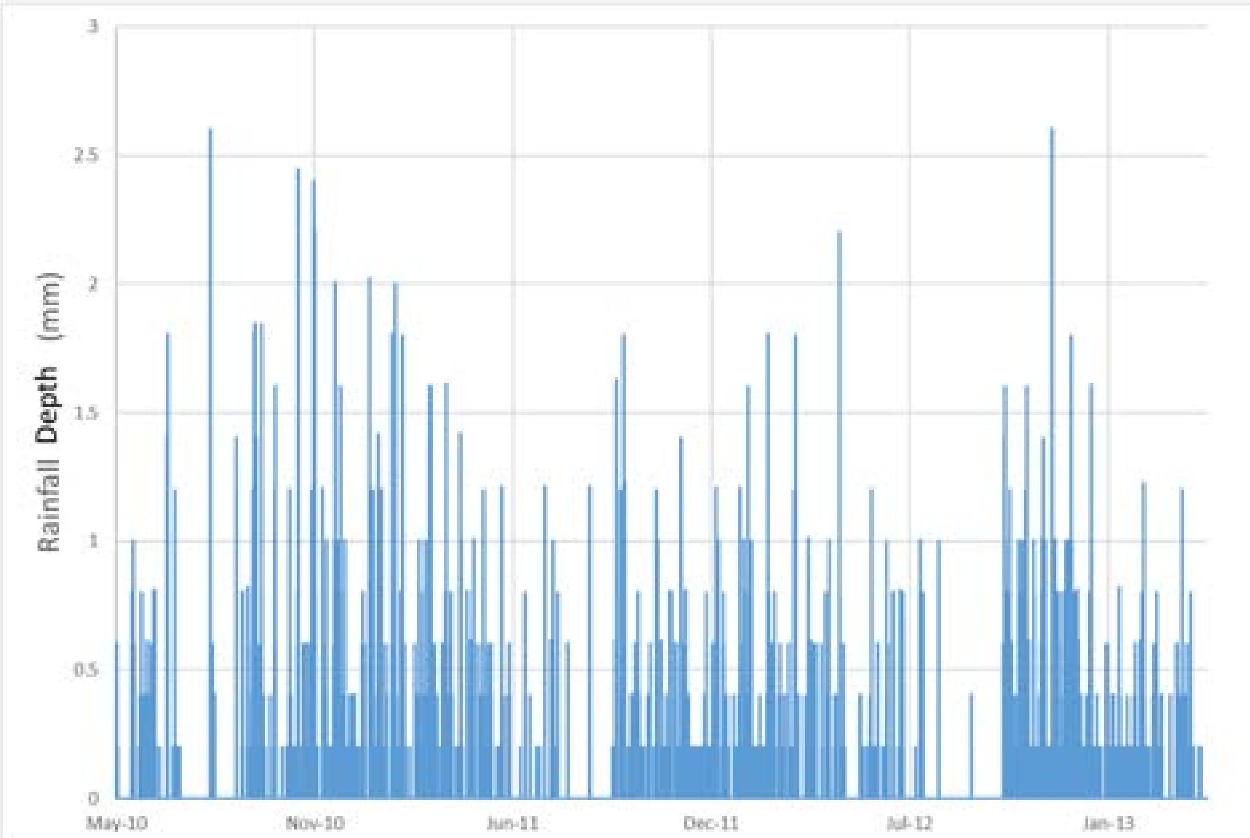


Figure D2-1
EPS Rainfall Data

D2.2 POTENTIAL IMPACTS OF DEVELOPMENT

Hydrological Impacts

The EPS modelling is based on recorded rainfall data over an extended period, not on synthetic design events. As such, it is representative of the typical rainfall events that occur within the study area, and therefore provides quantitative insight into the study area's response to development/densification, absent any mitigation measures such as source controls or BMPs.

The key hydrologic results from the EPS model are summarized in Table D-4.

Table D-4
Hydrologic Results from Extended Period Simulation Model

	Existing Development	Future Development	Change
Average Impervious Percent of Subcatchments (%)	39%	44%	14%
Total Runoff Volume (10^7 m^3)	1.4	1.6	12%
Average Total Infiltration of Subcatchments (mm)	1681	1585	-6%

The increased impervious area associated with the future development condition results in an increase in the total runoff volume. The increase in impervious area within the study area also reduces the total infiltration, as there is an increase in hard surfaces which cannot accommodate infiltration. These effects during the future development condition will cause formerly infiltrated water in the uplands single family residential areas to concentrate in downstream watercourses more quickly, if not managed with feasible source controls or BMPs.

We created flow-duration-exceedance curves at two locations in agricultural ditches to illustrate changes in flow regimes: one at the outlet of the storm main system at Spyglass Crescent and 52 Street (D-1437), and one at the outlet of the storm system at 56 Street and 6 Avenue (D-1393). The curves are presented in Figures D2-2 and D2-3, and the reporting location for each curve is indicated on Map 5-2. These curves represent the fraction of the total simulation time that a particular flow rate is exceeded in each watercourse.

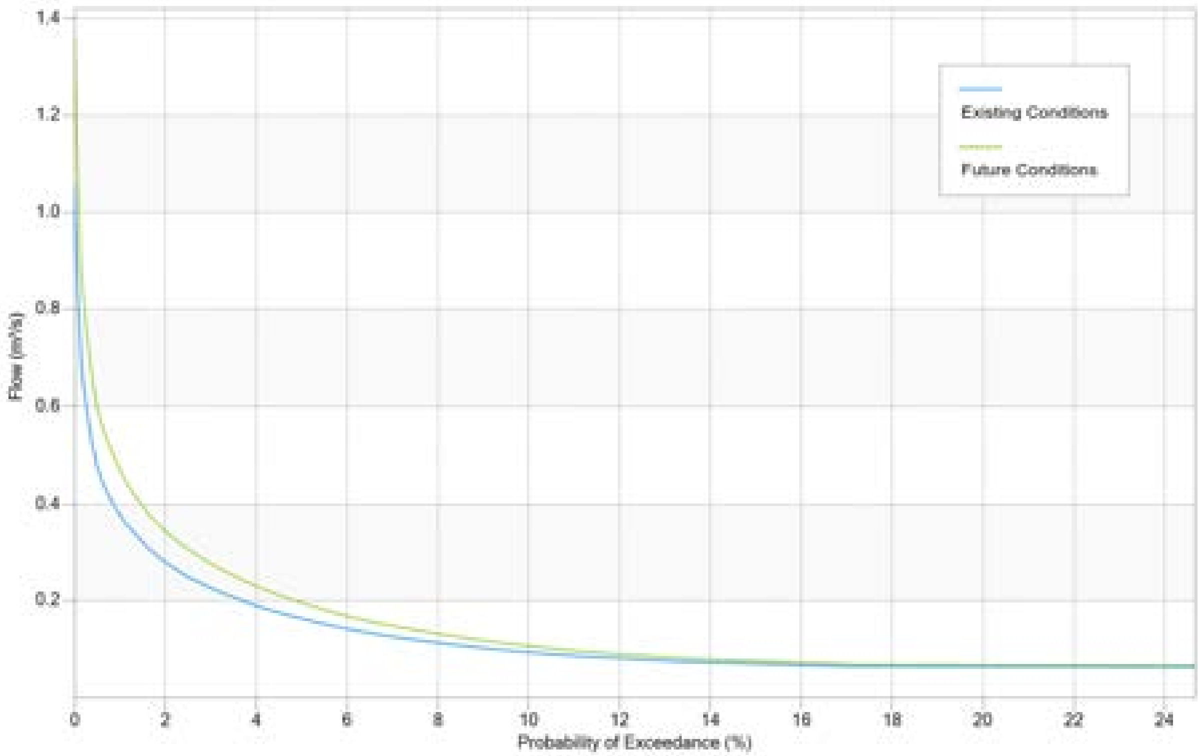


Figure D2-2
Flow Duration Exceedance Curve for D-1393

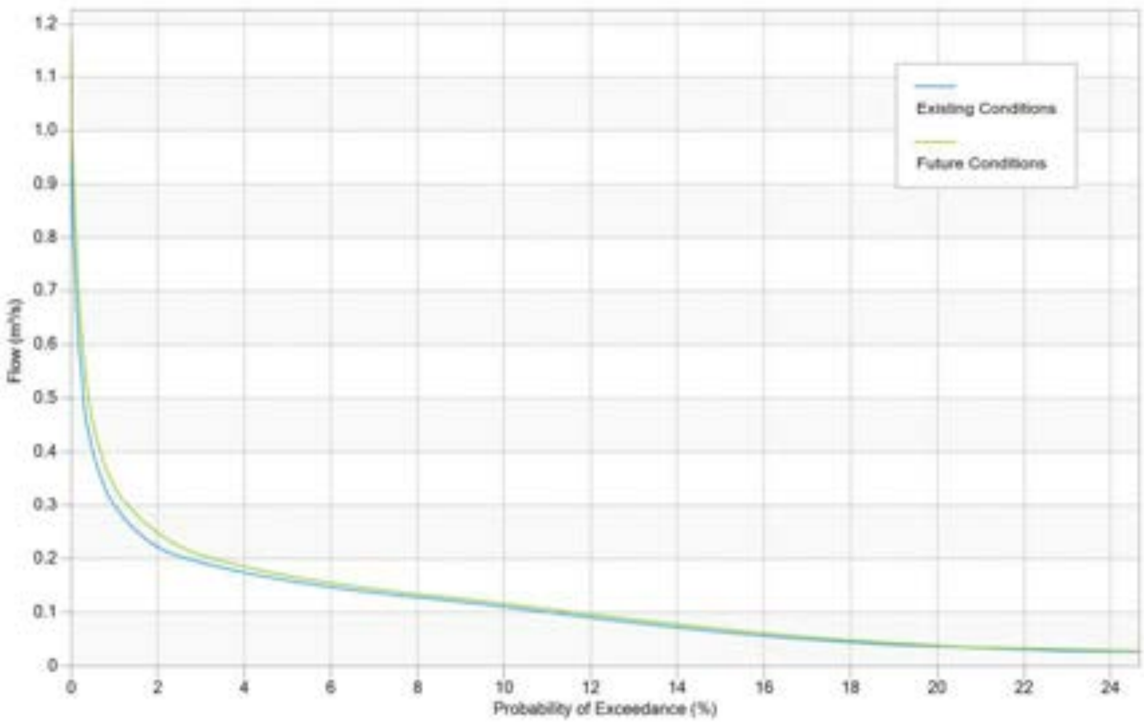
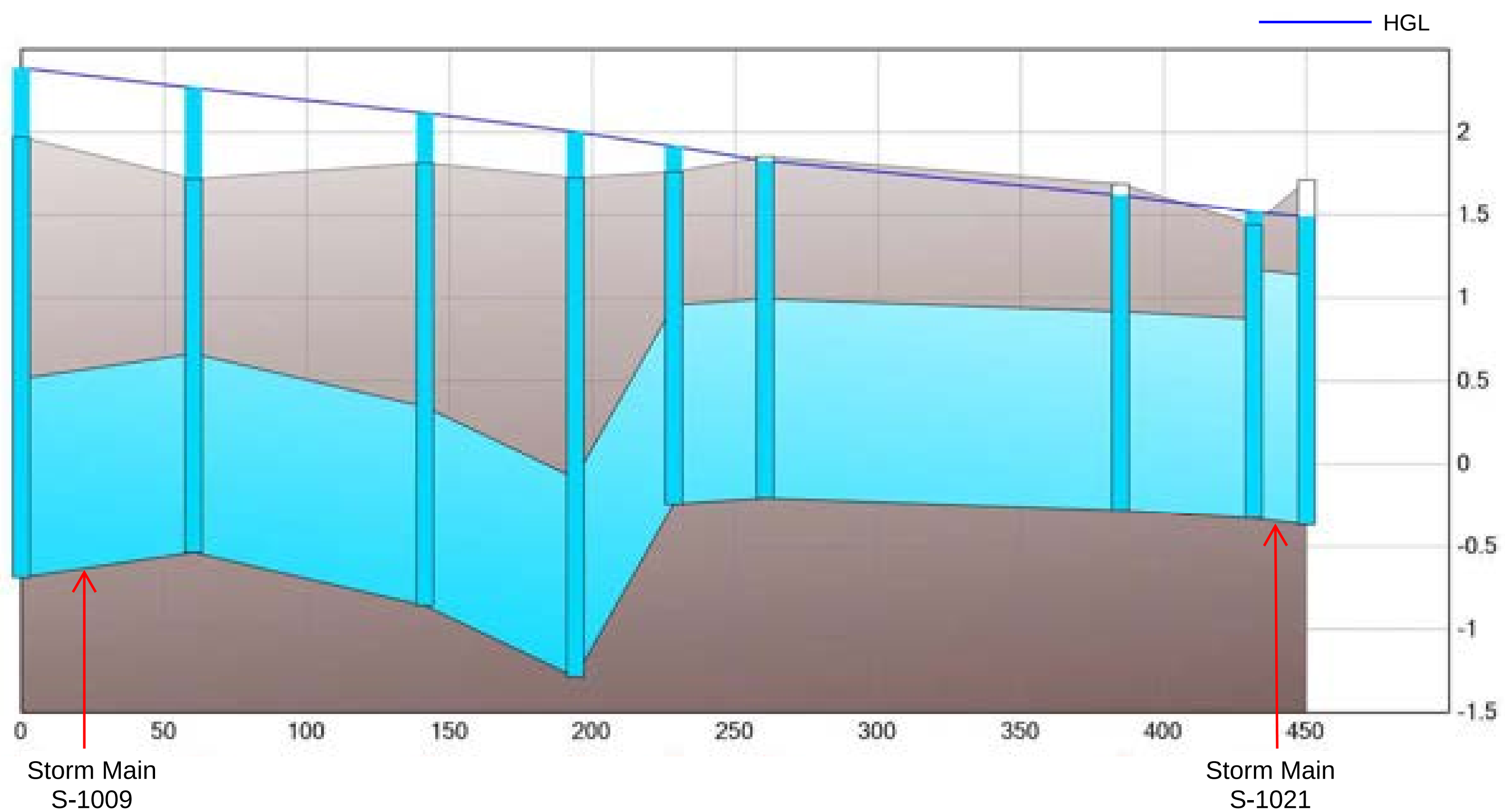


Figure D2-3
Flow Duration Exceedance Curve for D-1437

Under future development conditions, both ditches are subject to an increase in the occurrence of high frequency and duration flows. This is reasonable for both, given that a significant portion of the area draining into both ditches will be subject to densification and an increase in impervious area in the future conditions. We did not observe any significant change in the base/low flow conditions between the exiting and future development conditions.



PREPARED BY:

Associated Engineering

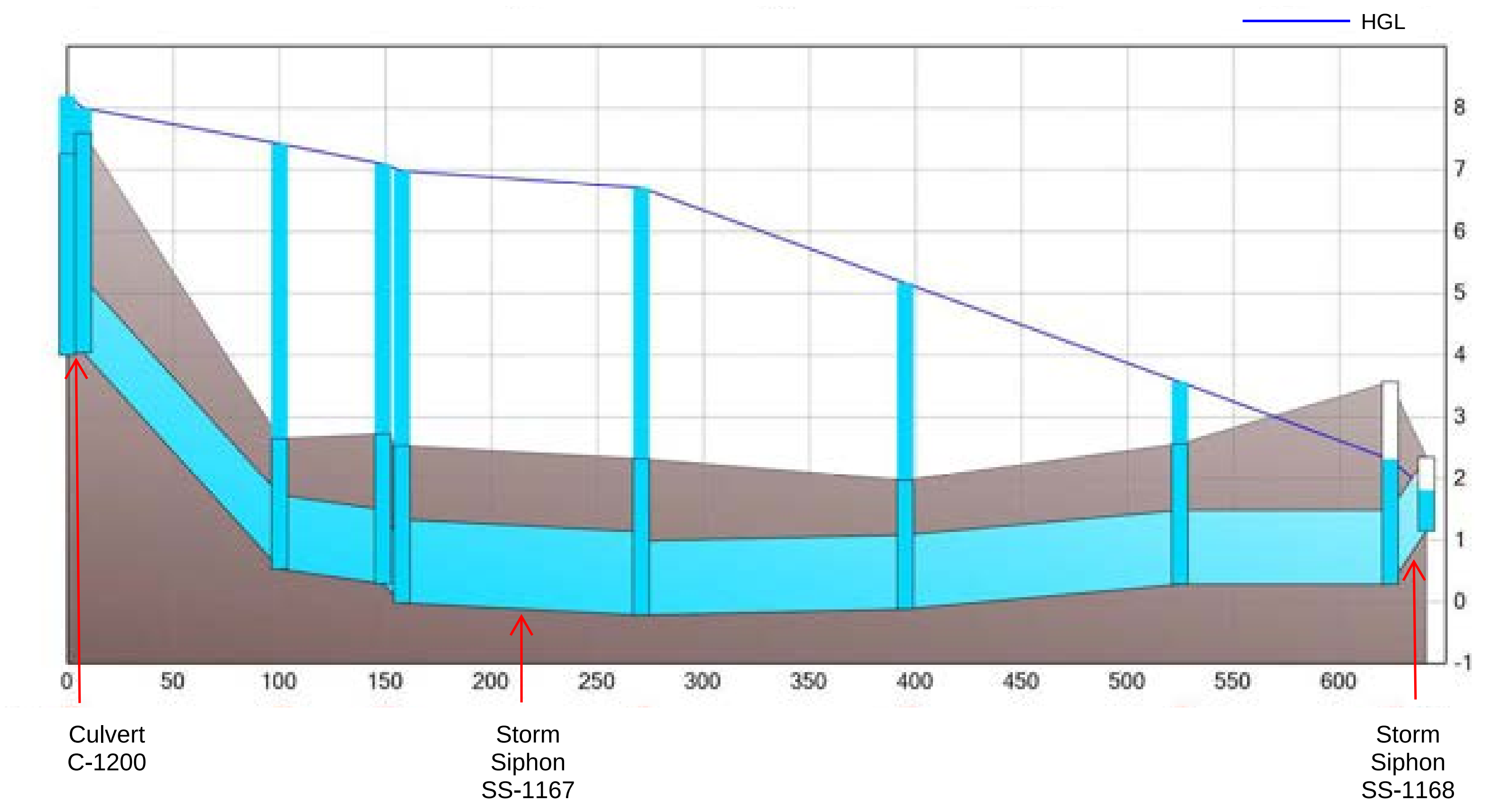
PREPARED FOR:

Delta

Figure D-2:
Existing Condition Deficiency D-2
Peak HGLs for 10-Year Design Event

PROJECT No: 20162283

DATE: APRIL 2018



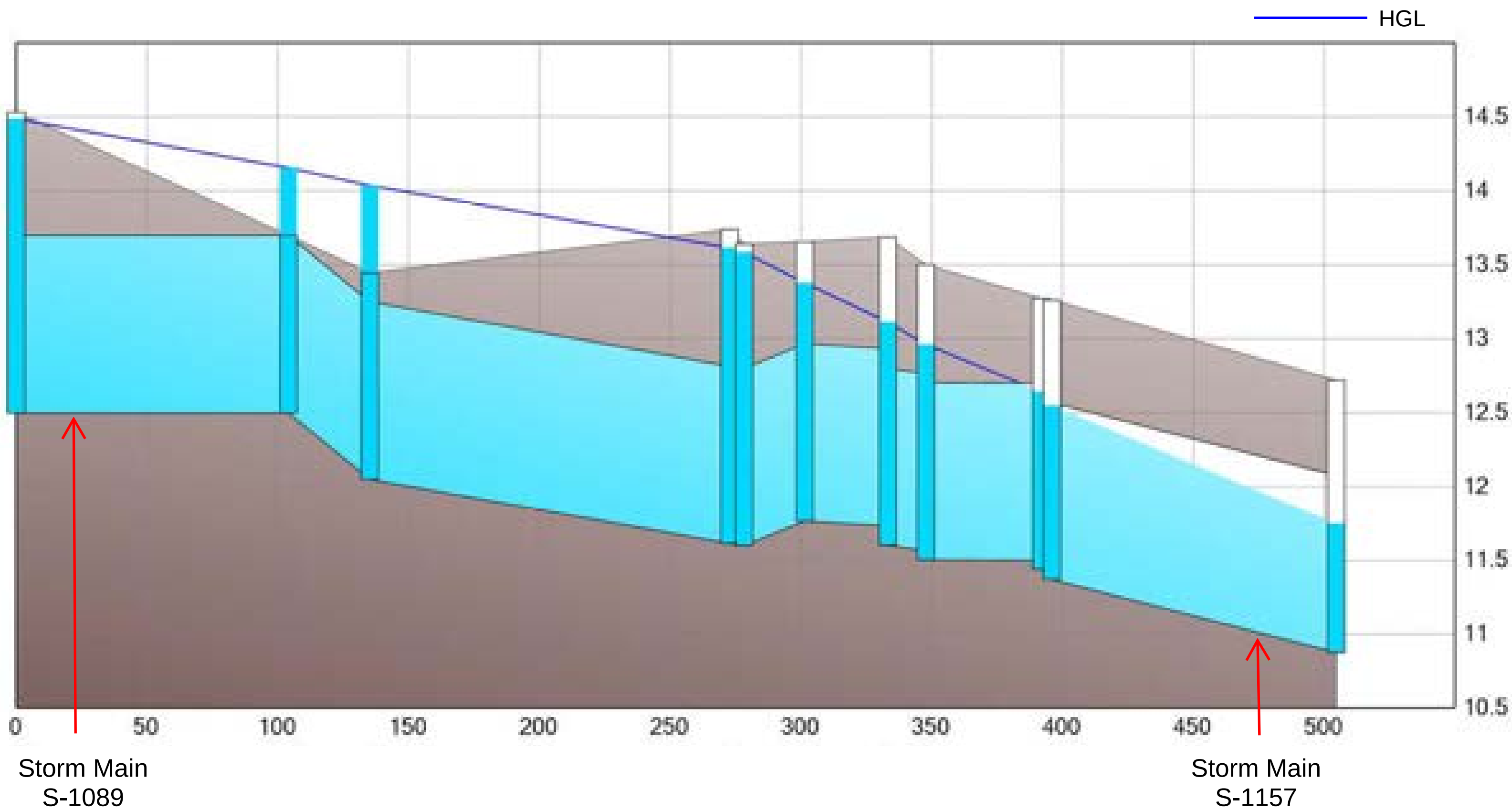
PREPARED BY: Associated Engineering

PREPARED FOR: Delta

Figure D-3:
Existing Condition Deficiency D-3
Peak HGLs for 10-Year Design Event

PROJECT No: 20162283

DATE: APRIL 2018



PREPARED BY:

Associated Engineering

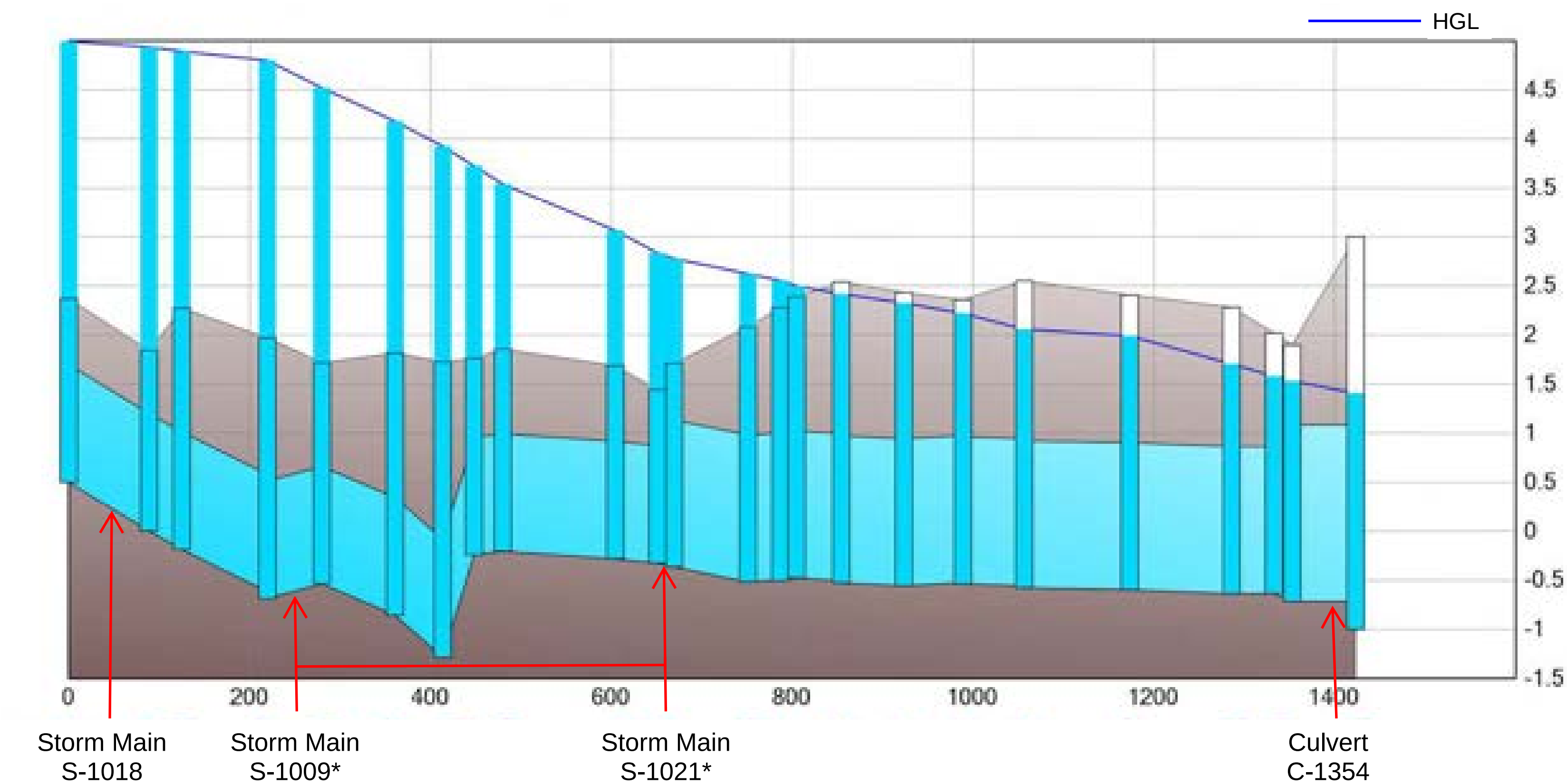
PREPARED FOR:

Delta

Figure D-4:
Existing Condition Deficiency D-4
Peak HGLs for 10-Year Design Event

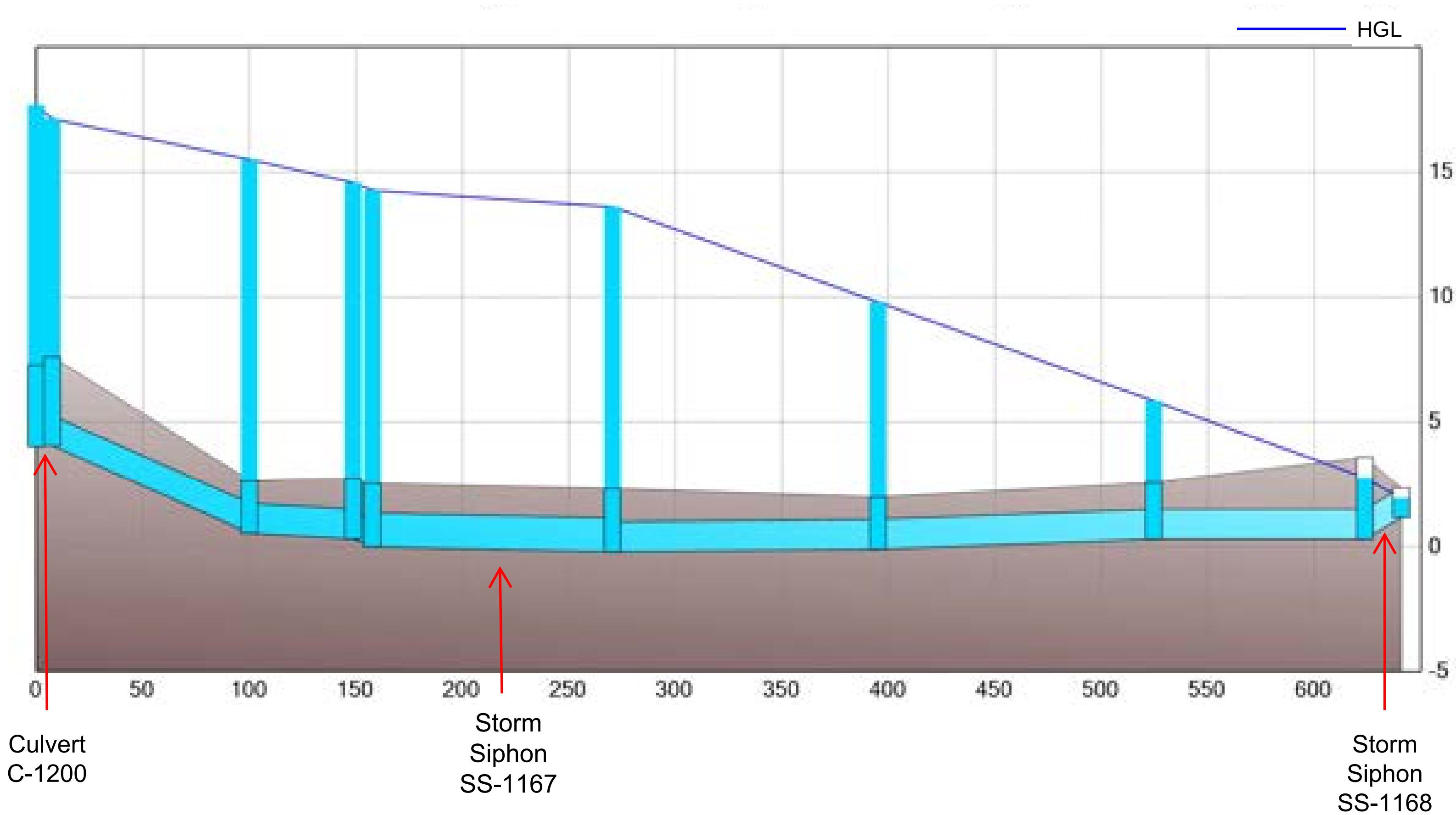
PROJECT No: 20162283

DATE: APRIL 2018



*Deficient under existing development conditions

PREPARED BY:	PREPARED FOR:		
Associated Engineering	Delta	Figure D-6: Peak HGLs for 10-Year Design Event Under Climate Change	PROJECT No: 20162283 DATE: APRIL 2018



PREPARED BY:

Associated Engineering

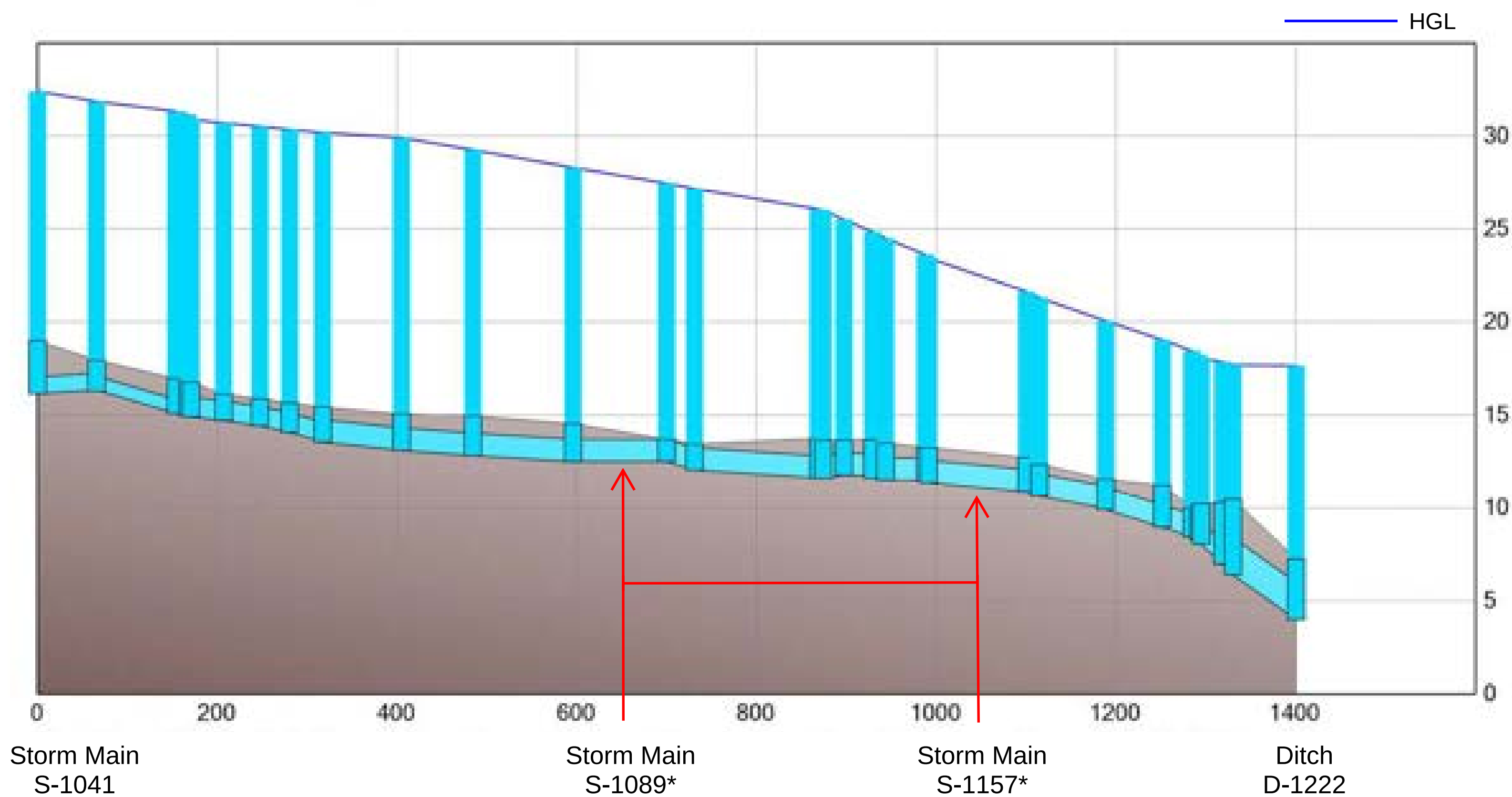
PREPARED FOR:

Delta

Figure D-7:
Peak HGLs for 10-Year Design Event
Under Climate Change

PROJECT No: 20162283

DATE: APRIL 2018



*Deficient under existing development conditions

PREPARED BY:

Associated Engineering

PREPARED FOR:

Delta

Figure D-8:
Peak HGLs for 10-Year Design Event Under Climate Change

PROJECT No: 20162283

DATE: APRIL 2018

Appendix E - System Upgrades

Table E-1
Minor System Upgrades

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
MN-1				
S-1297	427342	450	1200	15
S-1298	427343	450	1200	20
S-1299	427467	450	1200	106
S-1300	427468	450	1200	96
S-1301	427618	525	1200	9
S-1314	427344	450	1200	117
S-1316	427341	450	1200	20
S-1302	427621	525	1350	16
S-1303	427620	525	1350	2
S-1304	427619	525	1350	16
S-1305	427726	525	1350	13
S-1306	427730	525	1350	16
S-1307	427732	525	1350	13
S-1308	427731	525	1350	23
S-1309	427727	525	1350	16
S-1310	427729	525	1350	3
S-1311	427728	525	1350	23
S-1312	427725	525	1350	16
S-1313	427724	525	1350	55
S-1315	427617	525	1350	95
S-1317	427610	600	1350	90
S-1318	427609	600	1350	92

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1319	427599	600	1350	125
S-1320	427597	600	1350	56
S-1321	427598	600	1500	9
MN-2				
S-1006	1217146	685	750	37
S-1007	1217147	685	750	64
S-1005	427683	900	1050	104
S-1000	427490	1500	1200 x 1800	117
S-1001	427484	1500	1200 x 1800	47
S-1002	427485	1500	1200 x 1800	113
S-1003	427758	1200	1200 x 1800	53
S-1009	427557	1200	1200 x 1800	60
S-1010	427556	1200	1200 x 1800	81
S-1011	427745	1500	1200 x 1800	18
S-1012	427746	1500	1200 x 1800	49
S-1013	427649	1500	1200 x 1800	69
S-1014	427648	1500	1200 x 1800	65
S-1015	427647	1500	1200 x 1800	68
S-1018	434188	1200	1800	89
S-1020	427623	1200	1200 x 1800	36
S-1021	427750	1500	1200 x 1800	18
S-1022	427751	1200	1200 x 1800	47
S-1023	427756	1200	1200 x 1800	124
S-1024	427551	1200	1200 x 1800	32
S-1025	427749	1500	1200 x 1800	81
S-1026	427553	1200	1200 x 1800	34
S-1027	427560	1200	1200 x 1800	95
S-1028	427744	1500	1200 x 1800	36

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
C-1354	C-1218315	1200 x 1800	1200 x 2400	70
S-1247	C-1218315	1200 x 1800	1800 x 2100	20
MN-3				
S-1062	427023	450	675	43
S-1063	427014	450	675	107
S-1060	427029	600	750	16
S-1051	427055	600	900	69
S-1052	427056	600	900	80
S-1053	427057	600	900	14
S-1054	427039	450	900	38
S-1055	427046	450	900	46
S-1056	427044	450	900	87
S-1059	427030	450	900	69
S-1061	427028	450	900	22
S-1064	427024	450	900	81
S-1065	427021	450	900	27
S-1075	427053	600	900	73
S-1078	427086	750	900	15
S-1079	427084	750	900	78
S-1138	426900	480	900	102
S-1139	426909	600	900	18
S-1076	427093	750	1200	4
S-1077	427072	750	1200	74
S-1080	427092	750	1200	72
S-1081	427095	900	1200	12
S-1082	427091	750	1200	80
S-1119	427107	900	1200	59
S-1122	427105	900	1200	97

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1123	427103	900	1200	6
S-1125	427102	900	1200	82
S-1126	427101	900	1200	55
S-1136	427110	900	1200	57
S-1137	427112	900	1200	52
S-1140	426884	900	1200	15
S-1141	426894	750	1200	15
S-1144	426891	900	1200	27
S-1145	426890	900	1200	3
S-1146	426888	900	1200	39
S-1162	427209	900	1200	94
S-1164	427207	900	1200	99
S-1166	426901	900	1200	103
S-1244	936198	600	1200	47
SS-1245	426899	750	1200	114
C-1200	C-434907	1200	1500	8
S-1143	426905	1050	1500	9
S-1147	426898	1200	1500	93
S-1148	426886	1200	1500	49
SS-1142	936196	525	1800	4
SS-1161	427214	1200	2100	130
SS-1165	427208	1200	2100	125
SS-1167	426902	1350	2100	113
SS-1174	427213	1200	2100	99
SS-1168	427231	1200	2400	17
MN-4				
S-1043	426704	600	750	71
S-1044	427049	600	750	21

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1045	427051	600	750	22
S-1046	427050	600	750	15
S-1048	426703	600	750	21
S-1049	426697	600	750	58
S-1057	427035	450	750	97
S-1058	427026	600	750	73
S-1325	426686	600	750	93
S-1326	426872	450	750	102
S-1343	426684	500	750	13
MN-5				
S-1041	426712	900	1200	66
S-1042	426720	600	1200	31
S-1083	426738	1050	1200	41
S-1084	426739	1050	1200	36
S-1085	426742	750	1200	4
S-1086	426743	750	1200	13
S-1087	426721	750	1200	69
S-1088	426713	750	1200	88
S-1093	426745	1050	1200	37
S-1094	434166	1050	1200	33
D-1222	Ditch along Ferguson Road Leading into Pressurized system- Make into a Pipe	2 m wide ditch	1350	70
S-1120	426795	1200	1350	23
S-1133	426792	1200	1350	44
S-1134	426793	1200	1350	15
S-1135	426794	1200	1350	32

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1149	426887	1200	1350	12
S-1150	426929	1200	1350	24
S-1151	426928	1200	1350	3
S-1152	426927	1200	1350	8
S-1153	426925	1200	1350	33
S-1154	426933	1200	1350	63
S-1155	426806	1200	1350	74
S-1156	426807	1200	1350	14
S-1157	426796	1200	1350	109
S-1158	434220	1200	1350	4
S-1089	426773	1200	1500	104
S-1090	426771	1200	1500	111
S-1091	426772	1200	1500	79
S-1092	426750	1200	1500	88
S-1124	426776	1200	1500	31
S-1132	426777	1200	1500	138
MN-6				
S-1163	426939	750	900	60
S-1160	426951	750	900	74
S-1184	426953	750	900	103
S-1173	426950	750	900	31
S-1171	426957	750	900	7
S-1169	426958	750	900	23
S-1417	Crosses Boundary Bay Road near 8th avenue	1200	1200 (Add additional pipe beside existing 1200mm pipe)	98
S-1418	Along Boundary Bay Road near Jackson Way	1200	1200	216

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
			(Add additional pipe beside existing 1200mm pipe)	
S-1419	426310	1200	1200 (Add additional pipe beside existing 1200mm pipe)	141
S-1420	Along Boundary Bay Road near Jackson Way	1200	1200 (Add additional pipe beside existing 1200mm pipe)	114
S-1421	Along Boundary Bay Road near Jackson Way	1200	1200 (Add additional pipe beside existing 1200mm pipe)	147
MN-7				
S-1038	426311	600	1200	95
MN-8				
S-1071	426260	750	900	99
S-1277	426225	600	900	99
S-1278	426226	600	900	99
S-1279	426215	600	900	90
S-1280	426429	750	900	3
S-1281	426428	750	900	14
S-1282	426431	750	900	42
S-1283	426416	750	900	112
S-1284	426252	750	900	33
S-1285	426410	750	900	14
S-1286	426411	750	900	112
S-1287	426417	750	900	93
S-1288	426257	750	900	95
S-1290	426443	750	900	149

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1291	426441	750	900	93
S-1292	426440	750	900	100
S-1293	426258	750	900	84
S-1096	426354	900	1050	89
S-1097	426352	900	1050	15
S-1098	426351	900	1050	148
S-1099	426276	900	1050	155
S-1100	426263	900	1050	106
MN-9				
S-1030	426129	450	600	84
S-1031	426140	450	600	69
S-1032	426132	450	600	8
S-1033	426133	450	600	81
S-1034	426130	450	600	55
S-1035	426139	450	600	85
S-1067	426153	450	600	102
S-1069	426151	450	600	82
S-1070	426145	450	600	93
S-1072	426146	450	600	42
S-1073	426141	450	600	23
S-1074	426131	450	600	117
S-1294	426128	450	600	50
S-1322	426135	450	600	30
S-1264	425612	600	750	66
S-1265	425611	600	750	74
S-1267	425905	600	750	38
S-1268	426020	525	750	85
S-1269	426014	525	750	19

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1270	426016	525	750	18
S-1271	426015	525	750	9
S-1276	426053	600	750	106
S-1427	426207	450	750	14
S-1428	426206	450	750	16
S-1272	425608	600	750	106
S-1110	426195	600	750	7
S-1102	426186	600	750	47
S-1103	426185	600	750	39
S-1117	426162	450	900	5
S-1118	426164	750	900	162
S-1273	426159	750	900	68
S-1274	426160	750	900	13
S-1275	426057	750	900	70
S-1295	426124	450	900	122
S-1296	426122	450	900	113
S-1104	426192	750	1200	15
S-1106	426193	750	1200	15
S-1108	426199	750	1200	5
S-1109	426200	750	1200	5
S-1111	426197	750	1200	34
S-1113	426196	750	1200	34
S-1115	426179	750	1200	117
S-1116	426183	750	1200	84
MN-10				
S-1187	425936	600	900	111
S-1188	425935	600	900	80
S-1189	425934	600	900	82

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
S-1191	425942	900	1200	46
S-1192	425941	900	1200	3
S-1195	425956	900	1200	46
S-1196	425946	900	1200	76
S-1197	425947	900	1200	75
S-1198	425943	900	1200	15

Table E-2
Major System Upgrades

<table>
<tr><th>Model ID</th><th>City of Delta ID</th><th>Existing Diameter (mm)</th><th>Future Diameter (mm)</th><th>Length (m)</th></tr>
<tr><td colspan="5">MA-1</td></tr>
<tr><td>3rd_Outfall</td><td>434266</td><td>750</td><td>1500</td><td>49</td></tr>
<tr><td colspan="3">City of Delta ID</td><td colspan="2">Upgrades</td></tr>
<tr><td colspan="3">Pumps at 3rd Avenue Pump Station</td><td colspan="2">Triple capacity of all pumps</td></tr>
<tr><td colspan="5">MA-2</td></tr>
<tr><td>C-1364</td><td>435180</td><td>1050 x 1050</td><td>2400</td><td>13</td></tr>
<tr><td>C-1365</td><td>434761</td><td>1200</td><td>Two 2400 Culverts</td><td>49</td></tr>
<tr><td>C-1366</td><td>426617 / 426618</td><td>1200</td><td>Two 2400 Culverts</td><td>11</td></tr>
<tr><td>D-1378</td><td>437289</td><td>H: 2200
W: 3000
S: 1:1.5</td><td>H: 2200
W: 4000
S: 1:2</td><td>151</td></tr>
<tr><td>D-1377</td><td>437289</td><td>H: 1700
W: 3000
S: 1:1.5</td><td>H: 2200
W: 4000
S: 1:2</td><td>201</td></tr>
<tr><td>D-1376</td><td>437289</td><td>H: 1800
W: 3000
S: 1:1.5</td><td>H: 2200
W: 4000
S: 1:2</td><td>132</td></tr>
<tr><td>D-1375</td><td>437289</td><td>H: 1800
W: 3000
S: 1:1.5</td><td>H: 2200
W: 4000
S: 1:2</td><td>52</td></tr>
</table>

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
D-1374	437289	H: 1800 W: 3000 S: 1:1.5	H: 2200 W: 4000 S: 1:2	62
City of Delta ID		**Upgrades**		
Pumps at 12th Avenue Pump Station		Double capacity of all pumps		
MA-3				
C-1251	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1200*	*1800*	*63*
C-1250	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1800*	*2750*	*64*
C-1361	*Culvert below Highway 17 from 16th Avenue to Eagle Way*	*1050*	*1500*	*70*
C-1201	*Culvert Along 16th Avenue*	*1500*	*2400*	*13*
C-1344	*Culvert parallel to Highway 17*	*1800*	*2750*	*28*
C-1248	*Culvert parallel to Salish Sea Drive*	*1500*	*2400*	*38*
C-1249	*Culvert below Blue Heron Drive*	*1500*	*2400*	*53*
D-1435_2	Ditch along Eagle Way from Tsawwassen Drive to Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	428
D-1263	Ditch Along 16 Avenue	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	75

Model ID	City of Delta ID	Existing Diameter (mm)	Future Diameter (mm)	Length (m)
D-1437	Ditch parallel to 52 Street	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	354
D-1254	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	59
D-1345	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	57
D-1346_1	Ditch along Highway 17	H: 2000 W: 2000 S: 1:2	H: 2000 W: 4000 S: 1:2	881
D-1357	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	284
D-1356	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	220
D-1430	Ditch parallel to Salish Sea Drive	H: 1050 W: 1500 S: 1:2	H: 1050 W: 3000 S: 1:2	265

City of Delta ID	Upgrades
Pumps at Brandrith Pump Station	Double capacity of all pumps

**Culvert upgrades are indicated with italics.*

Table E-3
Minor System Upgrades: MN-1
Reference Figure E-1

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$32,000	$32,000
1.2	Erosion & Sediment Control Plan		1	LS	$16,000	$16,000
1.3	Traffic Planning		1	LS	$16,000	$16,000
1.4	Utility Relocation		1	LS	$10,000	$10,000
					Sub-Total - Section 1	**$74,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1297	15	LM	$2,137	$32,055
2.2	Supply & Install 1200mm Concrete Pipe	S-1298	20	LM	$2,137	$42,740
2.3	Supply & Install 1200mm Concrete Pipe	S-1299	106	LM	$2,137	$226,522
2.4	Supply & Install 1200mm Concrete Pipe	S-1300	96	LM	$2,137	$205,152
2.5	Supply & Install 1200mm Concrete Pipe	S-1301	9	LM	$2,137	$19,233
2.6	Supply & Install 1200mm Concrete Pipe	S-1314	117	LM	$2,137	$250,029
2.7	Supply & Install 1200mm Concrete Pipe	S-1316	20	LM	$2,137	$42,740
2.8	Supply & Install 1350mm Concrete Pipe	S-1302	16	LM	$2,658	$42,528
2.9	Supply & Install 1350mm Concrete Pipe	S-1303	2	LM	$2,658	$5,316
2.10	Supply & Install 1350mm Concrete Pipe	S-1304	16	LM	$2,658	$42,528
2.11	Supply & Install 1350mm Concrete Pipe	S-1305	13	LM	$2,658	$34,554
2.12	Supply & Install 1350mm Concrete Pipe	S-1306	16	LM	$2,658	$42,528
2.13	Supply & Install 1350mm Concrete Pipe	S-1307	13	LM	$2,658	$34,554
2.14	Supply & Install 1350mm Concrete Pipe	S-1308	23	LM	$2,658	$61,134
2.15	Supply & Install 1350mm Concrete Pipe	S-1309	16	LM	$2,658	$42,528
2.16	Supply & Install 1350mm Concrete Pipe	S-1310	3	LM	$2,658	$7,974
2.17	Supply & Install 1350mm Concrete Pipe	S-1311	23	LM	$2,658	$61,134
2.18	Supply & Install 1350mm Concrete Pipe	S-1312	16	LM	$2,658	$42,528
2.19	Supply & Install 1350mm Concrete Pipe	S-1313	55	LM	$2,658	$146,190
2.20	Supply & Install 1350mm Concrete Pipe	S-1315	95	LM	$2,658	$252,510
2.21	Supply & Install 1350mm Concrete Pipe	S-1317	90	LM	$2,658	$239,220
2.22	Supply & Install 1350mm Concrete Pipe	S-1318	92	LM	$2,658	$244,536
2.23	Supply & Install 1350mm Concrete Pipe	S-1319	125	LM	$2,658	$332,250
2.24	Supply & Install 1350mm Concrete Pipe	S-1320	56	LM	$2,658	$148,848
2.25	Supply & Install 1500mm Concrete Pipe	S-1321	9	LM	$3,151	$28,359
2.26	Supply & Install Manholes *					$525,538
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$3,153,228**
					Sub Total	**$3,227,228**
					Engineering (10%)	$323,000
					Contingency (40%)	$1,291,000
					Total	**$4,841,228**

Table E-4
Minor System Upgrades: MN-2
Reference Figure E-2

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$31,000	$31,000
					Sub-Total - Section 1	**$231,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 750mm Concrete Pipe	S-1006	37	LM	$1,318	$48,766
2.2	Supply & Install 750mm Concrete Pipe	S-1007	64	LM	$1,318	$84,352
2.3	Supply & Install 1050mm Concrete Pipe	S-1005	104	LM	$1,870	$194,480
2.4	Supply & Install 1200 x 1800mm Concrete Pipe	S-1000	117	LM	$5,698	$666,666
2.5	Supply & Install 1200 x 1800mm Concrete Pipe	S-1001	47	LM	$5,698	$267,806
2.6	Supply & Install 1200 x 1800mm Concrete Pipe	S-1002	113	LM	$5,698	$643,874
2.7	Supply & Install 1200 x 1800mm Concrete Pipe	S-1003	53	LM	$5,698	$301,994
2.8	Supply & Install 1200 x 1800mm Concrete Pipe	S-1009	60	LM	$5,698	$341,880
2.9	Supply & Install 1200 x 1800mm Concrete Pipe	S-1010	81	LM	$5,698	$461,538
2.10	Supply & Install 1200 x 1800mm Concrete Pipe	S-1011	18	LM	$5,698	$102,564
2.11	Supply & Install 1200 x 1800mm Concrete Pipe	S-1012	49	LM	$5,698	$279,202
2.12	Supply & Install 1200 x 1800mm Concrete Pipe	S-1013	69	LM	$5,698	$393,162
2.13	Supply & Install 1200 x 1800mm Concrete Pipe	S-1014	65	LM	$5,698	$370,370
2.14	Supply & Install 1200 x 1800mm Concrete Pipe	S-1015	68	LM	$5,698	$387,464
2.15	Supply & Install 1800mm Concrete Pipe	S-1018	89	LM	$3,394	$302,066
2.16	Supply & Install 1200 x 1800mm Concrete Pipe	S-1020	36	LM	$5,698	$205,128
2.17	Supply & Install 1200 x 1800mm Concrete Pipe	S-1021	18	LM	$5,698	$102,564
2.18	Supply & Install 1200 x 1800mm Concrete Pipe	S-1022	47	LM	$5,698	$267,806
2.19	Supply & Install 1200 x 1800mm Concrete Pipe	S-1023	124	LM	$5,698	$706,552
2.20	Supply & Install 1200 x 1800mm Concrete Pipe	S-1024	32	LM	$5,698	$182,336
2.21	Supply & Install 1200 x 1800mm Concrete Pipe	S-1025	81	LM	$5,698	$461,538
2.22	Supply & Install 1200 x 1800mm Concrete Pipe	S-1026	34	LM	$5,698	$193,732
2.23	Supply & Install 1200 x 1800mm Concrete Pipe	S-1027	95	LM	$5,698	$541,310
2.24	Supply & Install 1208 x 1800mm Concrete Pipe	S-1028	36	LM	$5,698	$205,128
2.25	Supply & Install 1200 x 2400mm Concrete Pipe	C-1354	70	LM	$7,467	$522,690
2.26	Supply & Install 1800 x 2100mm Concrete Pipe	S-1247	20	LM	$7,353	$147,060
2.27	Supply & Install Manholes *					$1,676,405.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$10,058,434**
					Sub Total	**$10,289,434**
					Engineering (10%)	$1,029,000
					Contingency (40%)	$4,116,000
					Total	**$15,434,434**

Table E-5
Minor System Upgrades: MN-3
Reference Figure E-3 & E-4

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$80,000	$80,000
1.2	Erosion & Sediment Control Plan		1	LS	$40,000	$40,000
1.3	Traffic Planning		1	LS	$40,000	$40,000
1.4	Utility Relocation		1	LS	$24,000	$24,000
					Sub-Total - Section 1	**$184,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 675mm Concrete Pipe	S-1062	43	LM	$1,204	$51,772
2.2	Supply & Install 675mm Concrete Pipe	S-1063	107	LM	$1,204	$128,828
2.3	Supply & Install 750mm Concrete Pipe	S-1060	16	LM	$1,318	$21,088
2.4	Supply & Install 900mm Concrete Pipe	S-1051	69	LM	$1,562	$107,778
2.5	Supply & Install 900mm Concrete Pipe	S-1052	80	LM	$1,562	$124,960
2.6	Supply & Install 900mm Concrete Pipe	S-1053	14	LM	$1,562	$21,868
2.7	Supply & Install 900mm Concrete Pipe	S-1054	38	LM	$1,562	$59,356
2.8	Supply & Install 900mm Concrete Pipe	S-1055	46	LM	$1,562	$71,852
2.9	Supply & Install 900mm Concrete Pipe	S-1056	87	LM	$1,562	$135,894
2.10	Supply & Install 900mm Concrete Pipe	S-1059	69	LM	$1,562	$107,778
2.11	Supply & Install 900mm Concrete Pipe	S-1061	22	LM	$1,562	$34,364
2.12	Supply & Install 900mm Concrete Pipe	S-1064	81	LM	$1,562	$126,522
2.13	Supply & Install 900mm Concrete Pipe	S-1065	27	LM	$1,562	$42,174
2.14	Supply & Install 900mm Concrete Pipe	S-1075	73	LM	$1,562	$114,026
2.15	Supply & Install 900mm Concrete Pipe	S-1078	15	LM	$1,562	$23,430
2.16	Supply & Install 900mm Concrete Pipe	S-1079	78	LM	$1,562	$121,836
2.17	Supply & Install 900mm Concrete Pipe	S-1138	102	LM	$1,562	$159,324
2.18	Supply & Install 900mm Concrete Pipe	S-1139	18	LM	$1,562	$28,116
2.19	Supply & Install 1200mm Concrete Pipe	S-1076	4	LM	$2,137	$8,548
2.20	Supply & Install 1200mm Concrete Pipe	S-1077	74	LM	$2,137	$158,138
2.21	Supply & Install 1200mm Concrete Pipe	S-1080	72	LM	$2,137	$153,864
2.22	Supply & Install 1200mm Concrete Pipe	S-1081	12	LM	$2,137	$25,644
2.23	Supply & Install 1200mm Concrete Pipe	S-1082	80	LM	$2,137	$170,960
2.24	Supply & Install 1200mm Concrete Pipe	S-1119	59	LM	$2,137	$126,083
2.25	Supply & Install 1200mm Concrete Pipe	S-1122	97	LM	$2,137	$207,289
2.26	Supply & Install 1200mm Concrete Pipe	S-1123	6	LM	$2,137	$12,822
2.27	Supply & Install 1200mm Concrete Pipe	S-1125	82	LM	$2,137	$175,234
2.28	Supply & Install 1200mm Concrete Pipe	S-1126	55	LM	$2,137	$117,535
2.29	Supply & Install 1200mm Concrete Pipe	S-1136	57	LM	$2,137	$121,809
2.30	Supply & Install 1200mm Concrete Pipe	S-1137	52	LM	$2,137	$111,124
2.31	Supply & Install 1200mm Concrete Pipe	S-1140	15	LM	$2,137	$32,055
2.32	Supply & Install 1200mm Concrete Pipe	S-1141	15	LM	$2,137	$32,055
2.33	Supply & Install 1200mm Concrete Pipe	S-1144	27	LM	$2,137	$57,699
2.34	Supply & Install 1200mm Concrete Pipe	S-1145	3	LM	$2,137	$6,411
2.35	Supply & Install 1200mm Concrete Pipe	S-1146	39	LM	$2,137	$83,343
2.36	Supply & Install 1200mm Concrete Pipe	S-1162	94	LM	$2,137	$200,878
2.37	Supply & Install 1200mm Concrete Pipe	S-1164	99	LM	$2,137	$211,563
2.38	Supply & Install 1200mm Concrete Pipe	S-1166	103	LM	$2,137	$220,111
2.39	Supply & Install 1200mm Concrete Pipe	S-1244	47	LM	$2,137	$100,439
2.40	Supply & Install 1200mm Concrete Pipe	SS-1245	114	LM	$2,137	$243,618
2.41	Supply & Install 1500mm Concrete Pipe	C-1200	8	LM	$3,151	$25,208
2.42	Supply & Install 1500mm Concrete Pipe	S-1143	9	LM	$3,151	$28,359
2.43	Supply & Install 1500mm Concrete Pipe	S-1147	93	LM	$3,151	$293,043
2.44	Supply & Install 1500mm Concrete Pipe	S-1148	49	LM	$3,151	$154,399
2.45	Supply & Install 1800mm Concrete Pipe	SS-1142	4	LM	$3,394	$13,576
2.46	Supply & Install 2100mm Concrete Pipe	SS-1161	130	LM	$4,205	$546,650
2.47	Supply & Install 2100mm Concrete Pipe	SS-1165	125	LM	$4,205	$525,625
2.48	Supply & Install 2100mm Concrete Pipe	SS-1167	113	LM	$4,205	$475,165
2.49	Supply & Install 2100mm Concrete Pipe	SS-1174	99	LM	$4,205	$416,295
2.50	Supply & Install 2400mm Concrete Pipe	SS-1168	17	LM	$4,769	$81,073
2.51	Supply & Install Manholes *					$1,323,516.20
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$7,941,097**
					Sub Total	**$8,125,097**
					Engineering (10%)	$813,000
					Contingency (40%)	$3,251,000
					Total	**$12,189,097**

Table E-6
Minor System Upgrades: MN-4
Reference Figure E-3

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$10,000	$10,000
1.2	Erosion & Sediment Control Plan		1	LS	$5,000	$5,000
1.3	Traffic Planning		1	LS	$5,000	$5,000
1.4	Utility Relocation		1	LS	$3,000	$3,000
					Sub-Total - Section 1	**$23,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 750mm Concrete Pipe	S-1043	71	LM	$1,318	$93,578
2.2	Supply & Install 750mm Concrete Pipe	S-1044	21	LM	$1,318	$27,678
2.3	Supply & Install 750mm Concrete Pipe	S-1045	22	LM	$1,318	$28,996
2.4	Supply & Install 750mm Concrete Pipe	S-1046	15	LM	$1,318	$19,770
2.5	Supply & Install 750mm Concrete Pipe	S-1048	21	LM	$1,318	$27,678
2.6	Supply & Install 750mm Concrete Pipe	S-1049	58	LM	$1,318	$76,444
2.7	Supply & Install 750mm Concrete Pipe	S-1057	97	LM	$1,318	$127,846
2.8	Supply & Install 750mm Concrete Pipe	S-1058	73	LM	$1,318	$96,214
2.9	Supply & Install 750mm Concrete Pipe	S-1325	93	LM	$1,318	$122,574
2.10	Supply & Install 750mm Concrete Pipe	S-1326	102	LM	$1,318	$134,436
2.11	Supply & Install 750mm Concrete Pipe	S-1343	13	LM	$1,318	$17,134
2.12	Supply & Install Manholes *					$154,469.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$926,818**
					Sub Total	**$949,818**
					Engineering (10%)	$95,000
					Contingency (40%)	$380,000
					Total	**$1,424,818**

Table E-7
Minor System Upgrades: MN-5
Reference Figure E-3

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$49,000	$49,000
1.2	Erosion & Sediment Control Plan		1	LS	$25,000	$25,000
1.3	Traffic Planning		1	LS	$25,000	$25,000
1.4	Utility Relocation		1	LS	$15,000	$15,000
					Sub-Total - Section 1	**$114,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1041	66	LM	$2,137	$141,042
2.2	Supply & Install 1200mm Concrete Pipe	S-1042	31	LM	$2,137	$66,247
2.3	Supply & Install 1200mm Concrete Pipe	S-1083	41	LM	$2,137	$87,617
2.4	Supply & Install 1200mm Concrete Pipe	S-1084	36	LM	$2,137	$76,932
2.5	Supply & Install 1200mm Concrete Pipe	S-1085	4	LM	$2,137	$8,548
2.6	Supply & Install 1200mm Concrete Pipe	S-1086	13	LM	$2,137	$27,781
2.7	Supply & Install 1200mm Concrete Pipe	S-1087	69	LM	$2,137	$147,453
2.8	Supply & Install 1200mm Concrete Pipe	S-1088	88	LM	$2,137	$188,056
2.9	Supply & Install 1200mm Concrete Pipe	S-1093	37	LM	$2,137	$79,069
2.10	Supply & Install 1200mm Concrete Pipe	S-1094	33	LM	$2,137	$70,521
2.11	Supply & Install 1350mm Concrete Pipe	D-1222	70	LM	$2,658	$186,060
2.12	Supply & Install 1350mm Concrete Pipe	S-1120	23	LM	$2,658	$61,134
2.13	Supply & Install 1350mm Concrete Pipe	S-1133	44	LM	$2,658	$116,952
2.14	Supply & Install 1350mm Concrete Pipe	S-1134	15	LM	$2,658	$39,870
2.15	Supply & Install 1350mm Concrete Pipe	S-1135	32	LM	$2,658	$85,056
2.16	Supply & Install 1350mm Concrete Pipe	S-1149	12	LM	$2,658	$31,896
2.17	Supply & Install 1350mm Concrete Pipe	S-1150	24	LM	$2,658	$63,792
2.18	Supply & Install 1350mm Concrete Pipe	S-1151	3	LM	$2,658	$7,974
2.19	Supply & Install 1350mm Concrete Pipe	S-1152	8	LM	$2,658	$21,264
2.20	Supply & Install 1350mm Concrete Pipe	S-1153	33	LM	$2,658	$87,714
2.21	Supply & Install 1350mm Concrete Pipe	S-1154	63	LM	$2,658	$167,454
2.22	Supply & Install 1350mm Concrete Pipe	S-1155	74	LM	$2,658	$196,692
2.23	Supply & Install 1350mm Concrete Pipe	S-1156	14	LM	$2,658	$37,212
2.24	Supply & Install 1350mm Concrete Pipe	S-1157	109	LM	$2,658	$289,722
2.25	Supply & Install 1350mm Concrete Pipe	S-1158	4	LM	$2,658	$10,632
2.26	Supply & Install 1500mm Concrete Pipe	S-1089	104	LM	$3,151	$327,704
2.27	Supply & Install 1500mm Concrete Pipe	S-1090	111	LM	$3,151	$349,761
2.28	Supply & Install 1500mm Concrete Pipe	S-1091	79	LM	$3,151	$248,929
2.29	Supply & Install 1500mm Concrete Pipe	S-1092	88	LM	$3,151	$277,288
2.30	Supply & Install 1500mm Concrete Pipe	S-1124	31	LM	$3,151	$97,681
2.31	Supply & Install 1500mm Concrete Pipe	S-1132	138	LM	$3,151	$434,838
2.32	Supply & Install Manholes *					$806,578.20
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$4,839,469**
					Sub Total	**$4,953,469**
					Engineering (10%)	$496,000
					Contingency (40%)	$1,982,000
					Total	**$7,431,469**

Table E-8
Minor System Upgrades: MN-6
Reference Figure E-4

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$24,000	$24,000
1.2	Erosion & Sediment Control Plan		1	LS	$12,000	$12,000
1.3	Traffic Planning		1	LS	$12,000	$12,000
1.4	Utility Relocation		1	LS	$8,000	$8,000
					Sub-Total - Section 1	**$56,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1163	60	LM	$1,562	$93,720
2.2	Supply & Install 900mm Concrete Pipe	S-1160	74	LM	$1,562	$115,588
2.3	Supply & Install 900mm Concrete Pipe	S-1184	103	LM	$1,562	$160,886
2.4	Supply & Install 900mm Concrete Pipe	S-1173	31	LM	$1,562	$48,422
2.5	Supply & Install 900mm Concrete Pipe	S-1171	7	LM	$1,562	$10,934
2.6	Supply & Install 900mm Concrete Pipe	S-1169	23	LM	$1,562	$35,926
2.7	Supply & Install 1200mm Concrete Pipe	S-1417	98	LM	$2,137	$209,426
2.8	Supply & Install 1200mm Concrete Pipe	S-1418	216	LM	$2,137	$461,592
2.9	Supply & Install 1200mm Concrete Pipe	S-1419	141	LM	$2,137	$301,317
2.10	Supply & Install 1200mm Concrete Pipe	S-1420	114	LM	$2,137	$243,618
2.11	Supply & Install 1200mm Concrete Pipe	S-1421	147	LM	$2,137	$314,139
2.12	Supply & Install Manholes *					$399,113.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$2,394,682**
					Sub Total	**$2,450,682**
					Engineering (10%)	$246,000
					Contingency (40%)	$981,000
					Total	**$3,677,682**

Table E-9
Minor System Upgrades: MN-7
Reference Figure E-5

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$3,000	$3,000
1.2	Erosion & Sediment Control Plan		1	LS	$2,000	$2,000
1.3	Traffic Planning		1	LS	$2,000	$2,000
1.4	Utility Relocation		1	LS	$1,000	$1,000
					Sub-Total - Section 1	**$8,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 1200mm Concrete Pipe	S-1038	95	LM	$2,137	$203,015
2.2	Supply & Install Manholes *					$40,603.00
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$243,618**
					Sub Total	**$251,618**
					Engineering (10%)	$26,000
					Contingency (40%)	$101,000
					Total	**$378,618**

Table E-10
Minor System Upgrades: MN-8
Reference Figure E-6

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$37,000	$37,000
1.2	Erosion & Sediment Control Plan		1	LS	$19,000	$19,000
1.3	Traffic Planning		1	LS	$19,000	$19,000
1.4	Utility Relocation		1	LS	$11,000	$11,000
					Sub-Total - Section 1	**$86,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1071	99	LM	$1,562	$154,638
2.2	Supply & Install 900mm Concrete Pipe	S-1277	99	LM	$1,562	$154,638
2.3	Supply & Install 900mm Concrete Pipe	S-1278	99	LM	$1,562	$154,638
2.4	Supply & Install 900mm Concrete Pipe	S-1279	90	LM	$1,562	$140,580
2.5	Supply & Install 900mm Concrete Pipe	S-1280	3	LM	$1,562	$4,686
2.6	Supply & Install 900mm Concrete Pipe	S-1281	14	LM	$1,562	$21,868
2.7	Supply & Install 900mm Concrete Pipe	S-1282	42	LM	$1,562	$65,604
2.8	Supply & Install 900mm Concrete Pipe	S-1283	112	LM	$1,562	$174,944
2.9	Supply & Install 900mm Concrete Pipe	S-1284	33	LM	$1,562	$51,546
2.10	Supply & Install 900mm Concrete Pipe	S-1285	14	LM	$1,562	$21,868
2.11	Supply & Install 900mm Concrete Pipe	S-1286	112	LM	$1,562	$174,944
2.12	Supply & Install 900mm Concrete Pipe	S-1287	93	LM	$1,562	$145,266
2.13	Supply & Install 900mm Concrete Pipe	S-1288	95	LM	$1,562	$148,390
2.14	Supply & Install 900mm Concrete Pipe	S-1290	149	LM	$1,562	$232,738
2.15	Supply & Install 900mm Concrete Pipe	S-1291	93	LM	$1,562	$145,266
2.16	Supply & Install 900mm Concrete Pipe	S-1292	100	LM	$1,562	$156,200
2.17	Supply & Install 900mm Concrete Pipe	S-1293	84	LM	$1,562	$131,208
2.18	Supply & Install 1050mm Concrete Pipe	S-1096	89	LM	$1,870	$166,430
2.19	Supply & Install 1050mm Concrete Pipe	S-1097	15	LM	$1,870	$28,050
2.20	Supply & Install 1050mm Concrete Pipe	S-1098	148	LM	$1,870	$276,760
2.21	Supply & Install 1050mm Concrete Pipe	S-1099	155	LM	$1,870	$289,850
2.22	Supply & Install 1050mm Concrete Pipe	S-1100	106	LM	$1,870	$198,220
2.23	Supply & Install Manholes *					$607,666.40
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$3,645,998**
					Sub Total	**$3,731,998**
					Engineering (10%)	$374,000
					Contingency (40%)	$1,493,000
					Total	**$5,598,998**

Table E-11
Minor System Upgrades: MN-9
Reference Figure E-7

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$41,000	$41,000
1.2	Erosion & Sediment Control Plan		1	LS	$21,000	$21,000
1.3	Traffic Planning		1	LS	$21,000	$21,000
1.4	Utility Relocation		1	LS	$13,000	$13,000
					Sub-Total - Section 1	**$96,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 600mm Concrete Pipe	S-1030	84	LM	$1,104	$92,736
2.2	Supply & Install 600mm Concrete Pipe	S-1031	69	LM	$1,104	$76,176
2.3	Supply & Install 600mm Concrete Pipe	S-1032	8	LM	$1,104	$8,832
2.4	Supply & Install 600mm Concrete Pipe	S-1033	81	LM	$1,104	$89,424
2.5	Supply & Install 600mm Concrete Pipe	S-1034	55	LM	$1,104	$60,720
2.6	Supply & Install 600mm Concrete Pipe	S-1035	85	LM	$1,104	$93,840
2.7	Supply & Install 600mm Concrete Pipe	S-1067	102	LM	$1,104	$112,608
2.8	Supply & Install 600mm Concrete Pipe	S-1069	82	LM	$1,104	$90,528
2.9	Supply & Install 600mm Concrete Pipe	S-1070	93	LM	$1,104	$102,672
2.10	Supply & Install 600mm Concrete Pipe	S-1072	42	LM	$1,104	$46,368
2.11	Supply & Install 600mm Concrete Pipe	S-1073	23	LM	$1,104	$25,392
2.12	Supply & Install 600mm Concrete Pipe	S-1074	117	LM	$1,104	$129,168
2.13	Supply & Install 600mm Concrete Pipe	S-1294	50	LM	$1,104	$55,200
2.14	Supply & Install 600mm Concrete Pipe	S-1322	30	LM	$1,104	$33,120
2.15	Supply & Install 750mm Concrete Pipe	S-1264	66	LM	$1,318	$86,988
2.16	Supply & Install 750mm Concrete Pipe	S-1265	74	LM	$1,318	$97,532
2.17	Supply & Install 750mm Concrete Pipe	S-1267	38	LM	$1,318	$50,084
2.18	Supply & Install 750mm Concrete Pipe	S-1268	85	LM	$1,318	$112,030
2.19	Supply & Install 750mm Concrete Pipe	S-1269	19	LM	$1,318	$25,042
2.20	Supply & Install 750mm Concrete Pipe	S-1270	18	LM	$1,318	$23,724
2.21	Supply & Install 750mm Concrete Pipe	S-1271	9	LM	$1,318	$11,862
2.22	Supply & Install 750mm Concrete Pipe	S-1276	106	LM	$1,318	$139,708
2.23	Supply & Install 750mm Concrete Pipe	S-1427	14	LM	$1,318	$18,452
2.24	Supply & Install 750mm Concrete Pipe	S-1428	16	LM	$1,318	$21,088
2.25	Supply & Install 750mm Concrete Pipe	S-1272	106	LM	$1,318	$139,708
2.26	Supply & Install 750mm Concrete Pipe	S-1110	7	LM	$1,318	$9,226
2.27	Supply & Install 750mm Concrete Pipe	S-1102	47	LM	$1,318	$61,946
2.28	Supply & Install 750mm Concrete Pipe	S-1103	39	LM	$1,318	$51,402
2.29	Supply & Install 900mm Concrete Pipe	S-1117	5	LM	$1,562	$7,810
2.30	Supply & Install 900mm Concrete Pipe	S-1118	162	LM	$1,562	$253,044
2.31	Supply & Install 900mm Concrete Pipe	S-1273	68	LM	$1,562	$106,216
2.32	Supply & Install 900mm Concrete Pipe	S-1274	13	LM	$1,562	$20,306
2.33	Supply & Install 900mm Concrete Pipe	S-1275	70	LM	$1,562	$109,340
2.34	Supply & Install 900mm Concrete Pipe	S-1295	122	LM	$1,562	$190,564
2.35	Supply & Install 900mm Concrete Pipe	S-1296	113	LM	$1,562	$176,506
2.36	Supply & Install 1200mm Concrete Pipe	S-1104	15	LM	$2,137	$32,055
2.37	Supply & Install 1200mm Concrete Pipe	S-1106	15	LM	$2,137	$32,055
2.38	Supply & Install 1200mm Concrete Pipe	S-1108	5	LM	$2,137	$10,685
2.39	Supply & Install 1200mm Concrete Pipe	S-1109	5	LM	$2,137	$10,685
2.40	Supply & Install 1200mm Concrete Pipe	S-1111	34	LM	$2,137	$72,658
2.41	Supply & Install 1200mm Concrete Pipe	S-1113	34	LM	$2,137	$72,658
2.42	Supply & Install 1200mm Concrete Pipe	S-1115	117	LM	$2,137	$250,029
2.43	Supply & Install 1200mm Concrete Pipe	S-1116	84	LM	$2,137	$179,508
2.44	Supply & Install Manholes *					$677,939.00
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$4,067,634**
					Sub Total	**$4,163,634**
					Engineering (10%)	$417,000
					Contingency (40%)	$1,666,000
					Total	**$6,246,634**

Table E-12
Minor System Upgrades: MN-10
Reference Figure E-8

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$12,000	$12,000
1.2	Erosion & Sediment Control Plan		1	LS	$6,000	$6,000
1.3	Traffic Planning		1	LS	$6,000	$6,000
1.4	Utility Relocation		1	LS	$4,000	$4,000
					Sub-Total - Section 1	**$28,000**
2.0	**Section 2 - Stormwater Infrastructure**					
2.1	Supply & Install 900mm Concrete Pipe	S-1187	111	LM	$1,562	$173,382
2.2	Supply & Install 900mm Concrete Pipe	S-1188	80	LM	$1,562	$124,960
2.3	Supply & Install 900mm Concrete Pipe	S-1189	82	LM	$1,562	$128,084
2.4	Supply & Install 1200mm Concrete Pipe	S-1191	46	LM	$2,137	$98,302
2.5	Supply & Install 1200mm Concrete Pipe	S-1192	3	LM	$2,137	$6,411
2.6	Supply & Install 1200mm Concrete Pipe	S-1195	46	LM	$2,137	$98,302
2.7	Supply & Install 1200mm Concrete Pipe	S-1196	76	LM	$2,137	$162,412
2.8	Supply & Install 1200mm Concrete Pipe	S-1197	75	LM	$2,137	$160,275
2.9	Supply & Install 1200mm Concrete Pipe	S-1198	15	LM	$2,137	$32,055
2.10	Supply & Install Manholes *					$196,836.60
	**Cost estimate for manholes is based on 20% of total pipe cost*					
					Sub-Total - Section 2	**$1,181,020**
					Sub Total	**$1,209,020**
					Engineering (10%)	$121,000
					Contingency (40%)	$484,000
					Total	**$1,814,020**

Table E-13
Major System Upgrades: MA-1
Reference Figure E-9

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$38,000	$38,000
1.2	Erosion & Sediment Control Plan		1	LS	$19,000	$19,000
1.3	Traffic Planning		1	LS	$19,000	$19,000
1.4	Utility Relocation		1	LS	$12,000	$12,000
					Sub-Total - Section 1	**$88,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		2.4	m^3	$1,200,000	$2,880,000
					Sub-Total - Section 2	**$2,880,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Supply & Install 1500mm Concrete Pipe	3rd_Outfall	49	LM	$18,000	$882,000
					Sub-Total - Section 3	**$882,000**
					Sub Total	**$3,850,000**
					Engineering (10%)	$385,000
					Contingency (40%)	$1,540,000
					Total	**$5,775,000**

Table E-14
Major System Upgrades: MA-2
Reference Figure E-10

	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$63,000	$63,000
					Sub-Total - Section 1	**$263,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		13.5	m³	$1,200,000	$16,200,000
					Sub-Total - Section 2	**$16,200,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Widen Ditch along Boundary Bay Road	D-1378	695	m³	$60	$41,700
3.2	Widen Ditch along Boundary Bay Road	D-1377	1813	m³	$60	$108,780
3.3	Widen Ditch along Boundary Bay Road	D-1376	1086	m³	$60	$65,160
3.4	Widen Ditch along Boundary Bay Road	D-1375	422	m³	$60	$25,320
3.5	Widen Ditch along Boundary Bay Road	D-1374	509	m³	$60	$30,540
3.6	Supply & Install 2400 mm Culvert	C-1364	13	LM	$33,000	$429,000
3.7	Supply & Install Two 2400 mm Culverts	C-1365	98	LM	$33,000	$3,234,000
3.8	Supply & Install Two 2400 mm Culverts	C-1366	22	LM	$33,000	$726,000
					Sub-Total - Section 3	**$4,660,500**
					Sub Total	**$21,123,500**
					Engineering (10%)	$2,113,000
					Contingency (40%)	$8,450,000
					Total	**$31,686,500**

Table E-15
Major System Upgrades: MA-3
Reference Figure E-11

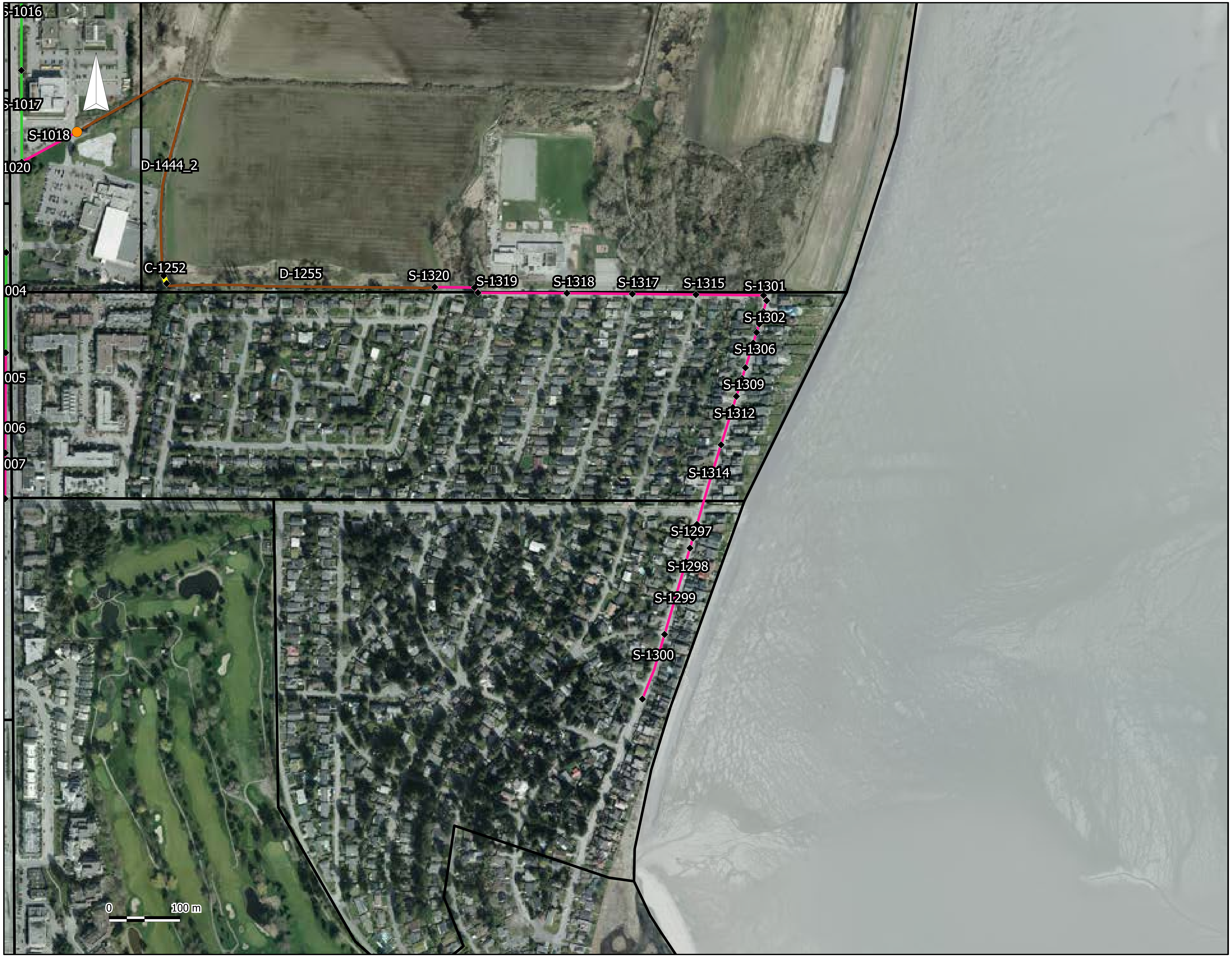
	Item	Model ID	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**					
1.1	Mobilization & Demobilization		1	LS	$100,000	$100,000
1.2	Erosion & Sediment Control Plan		1	LS	$50,000	$50,000
1.3	Traffic Planning		1	LS	$50,000	$50,000
1.4	Utility Relocation		1	LS	$71,000	$71,000
					Sub-Total - Section 1	**$271,000**
2.0	**Section 2 - Pump Station Upgrades**					
2.1	Increase Pump Capacity		11	m³	$1,200,000	$13,200,000
					Sub-Total - Section 2	**$13,200,000**
3.0	**Section 3 - Stormwater Infrastructure**					
3.1	Widen Ditch along Eagle Way	D-1435_2	1709	m³	$60	$102,540
3.2	Widen Ditch along 16 Avenue	D-1263	300	m³	$60	$18,000
3.3	Widen Ditch along 52 Street	D-1437	1414	m³	$60	$84,840
3.4	Widen Ditch along Highway 17	D-1254	235	m³	$60	$14,100
3.5	Widen Ditch along Highway 17	D-1345	227	m³	$60	$13,620
3.6	Widen Ditch along Highway 17	D-1346_1	3522	m³	$60	$211,320
3.7	Widen Ditch along Salish Sea Drive	D-1357	447	m³	$60	$26,820
3.8	Widen Ditch along Salish Sea Drive	D-1356	346	m³	$60	$20,760
3.9	Widen Ditch along Salish Sea Drive	D-1430	418	m³	$60	$25,080
3.10	Supply & Install 1800mm Culvert	C-1251	63	LM	$23,000	$1,449,000
3.11	Supply & Install 2750mm Culvert	C-1250	64	LM	$39,000	$2,496,000
3.12	Supply & Install 1500mm Culvert	C-1361	70	LM	$18,000	$1,260,000
3.13	Supply & Install 2400mm Culvert	C-1201	13	LM	$33,000	$429,000
3.14	Supply & Install 2750mm Culvert	C-1344	28	LM	$39,000	$1,092,000
3.15	Supply & Install 2400mm Culvert	C-1248	38	LM	$33,000	$1,254,000
3.16	Supply & Install 2400mm Culvert	C-1249	53	LM	$33,000	$1,749,000
					Sub-Total - Section 3	**$10,246,080**
					Sub Total	**$23,717,080**
					Engineering (10%)	$2,372,000
					Contingency (40%)	$9,487,000
					Total	**$35,576,080**

Table E-16
Environmental Enhancement Opportunity: EV-1

	Item	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**				
1.1	Mobilization & Demobilization	1	LS	$2,000	$2,000
1.2	Erosion & Sediment Control Plan	1	LS	$1,000	$1,000
1.3	Traffic Planning	1	LS	$1,000	$1,000
1.4	Utility Relocation	1	LS	$1,000	$1,000
				Sub-Total - Section 1	**$5,000**
2.0	**Section 2 - Wetlands**				
2.1	Construct/Expand Wetlands	1	LS	$200,000	$200,000
				Sub-Total - Section 2	**$200,000**
				Sub Total	**$205,000**
				Engineering (10%)	$21,000
				Contingency (40%)	$82,000
				Total	**$308,000**

Table E-17
Environmental Enhancement Opportunity : EV-2

	Item	Quantity	Unit	Unit Price	Cost
1.0	**Section 1 - General Requirements**				
1.1	Mobilization & Demobilization	1	LS	$2,000	$2,000
1.2	Erosion & Sediment Control Plan	1	LS	$1,000	$1,000
1.3	Traffic Planning	1	LS	$1,000	$1,000
1.4	Utility Relocation	1	LS	$1,000	$1,000
				Sub-Total - Section 1	**$5,000**
2.0	**Section 2 - Wetlands**				
2.1	Construct Wetlands	1	LS	$200,000	$200,000
				Sub-Total - Section 2	**$200,000**
				Sub Total	**$205,000**
				Engineering (10%)	$21,000
				Contingency (40%)	$82,000
				Total	**$308,000**



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LEGEND

- XXXX MODEL ID
- PUMP STATION
- CULVERT
- DITCH
- GRAVITY MAIN
- UPGRADED PIPE
- SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-1

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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Delta

THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-1 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-1		

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-2

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-2 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-2		

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Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

- XXXX — MODEL ID
- PUMP STATION
- CULVERT
- DITCH
- GRAVITY MAIN
- UPGRADED PIPE
- SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES MINOR SYSTEM UPGRADES: MN-3, MN-4, MN-5

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

MN-3 & MN-4 & MN-5 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-3		

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES MINOR SYSTEM UPGRADES: MN-3, MN-6

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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THE CITY OF DELTA

TSAWWASSEN AREA INTEGRATED STORMWATER MANAGEMENT PLAN

MN-3 & MN-6 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-4		

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LEGEND

XXXX MODEL ID
PUMP STATION
CULVERT
DITCH
GRAVITY MAIN
UPGRADED PIPE
SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-7

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-7 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-5		

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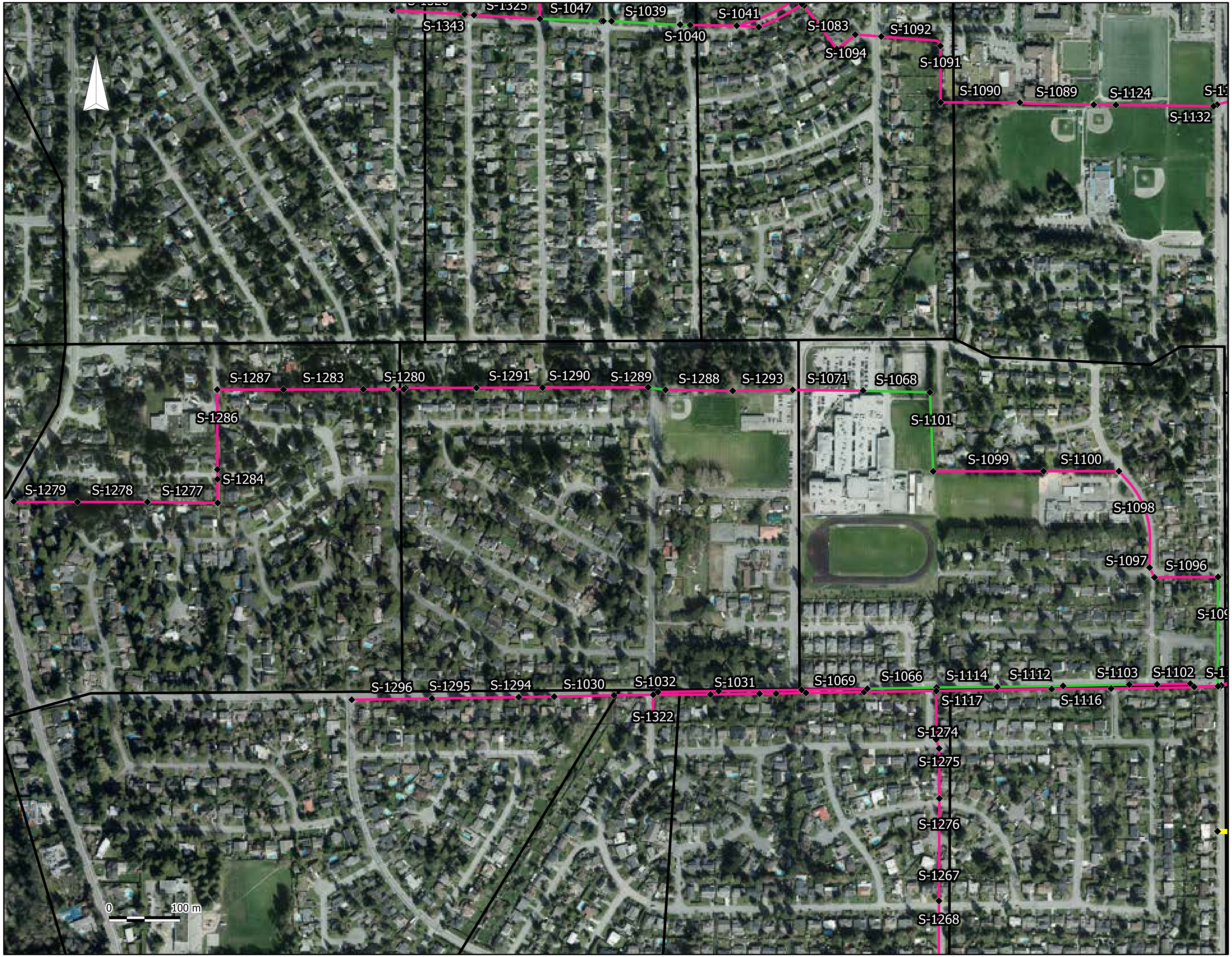

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-8

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-8 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-6		

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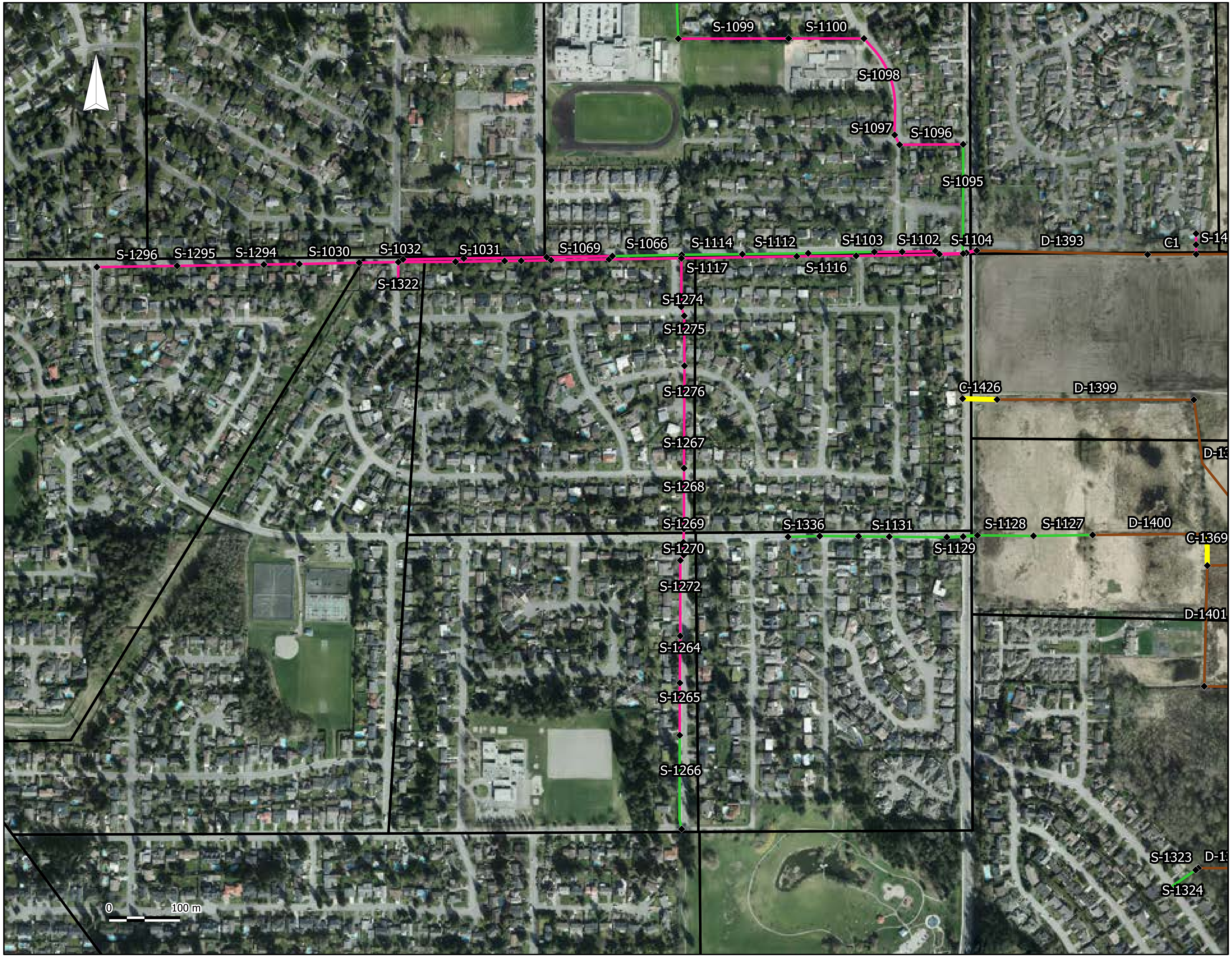

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-9

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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Delta

THE CITY OF DELTA

TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-9 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-7		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

XXXX	MODEL ID
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MINOR SYSTEM UPGRADES: MN-10

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	23-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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INTEGRATED STORMWATER
MANAGEMENT PLAN

MN-10 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-8		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

XXXX	MODEL ID
ABCD	PUMP STATION NAME
	PUMP STATION
	CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	UPGRADED DITCH
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-1

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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INTEGRATED STORMWATER
MANAGEMENT PLAN

MA-1 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-9		

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

XXXX	MODEL ID
ABCD	PUMP STATION NAME
	PUMP STATION
	CULVERT
	UPGRADED CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	UPGRADED DITCH
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-2

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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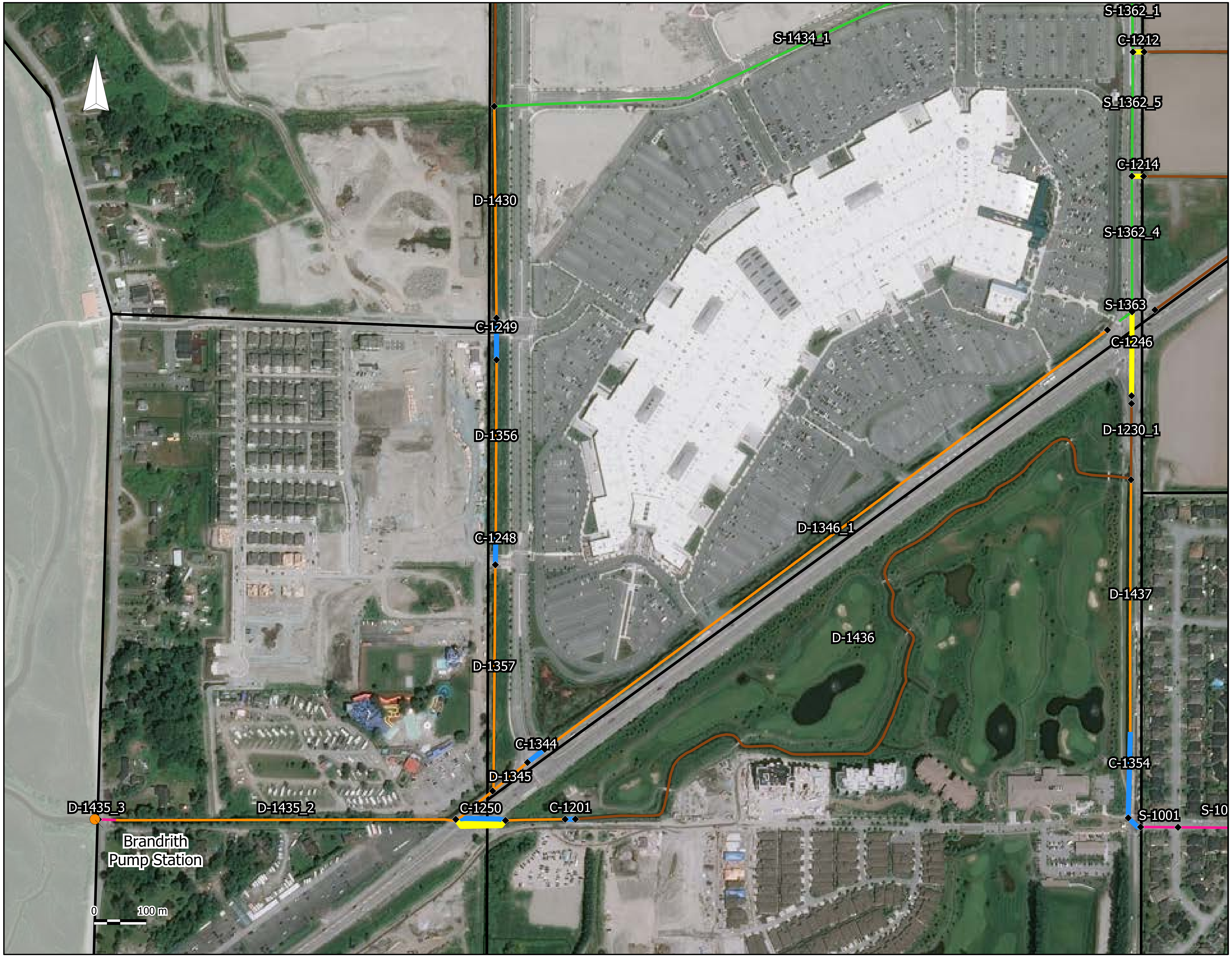
INTEGRATED STORMWATER
MANAGEMENT PLAN

MA-2 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-10		



Map File: P:\20162283\00_Tsaw_Area_ISMP\Working_Dwgs\010_GIS\map_del_tsaw_ismp_stage_5_appendix_E_figures_20180723.map

LEGEND

XXXX	MODEL ID
ABCD	PUMP STATION NAME
	PUMP STATION
	CULVERT
	UPGRADED CULVERT
	DITCH
	GRAVITY MAIN
	UPGRADED PIPE
	UPGRADED DITCH
	SUBCATCHMENTS

SEE APPENDIX E COST ESTIMATES
MAJOR SYSTEM UPGRADES: MA-3

SCALE:	AS SHOWN		
PROJECT NO.	2016-2283	INITIAL	DATE
DRAWN		NV	20-07-18
DESIGNED			
CHECKED			
APPROVED			
PROJECTION:	UTM ZONE 10N NAD 83		

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TSAWWASSEN AREA
INTEGRATED STORMWATER
MANAGEMENT PLAN

MA-3 UPGRADES

DRAWING NUMBER	REV. NO.	SHEET
MAP E-11		

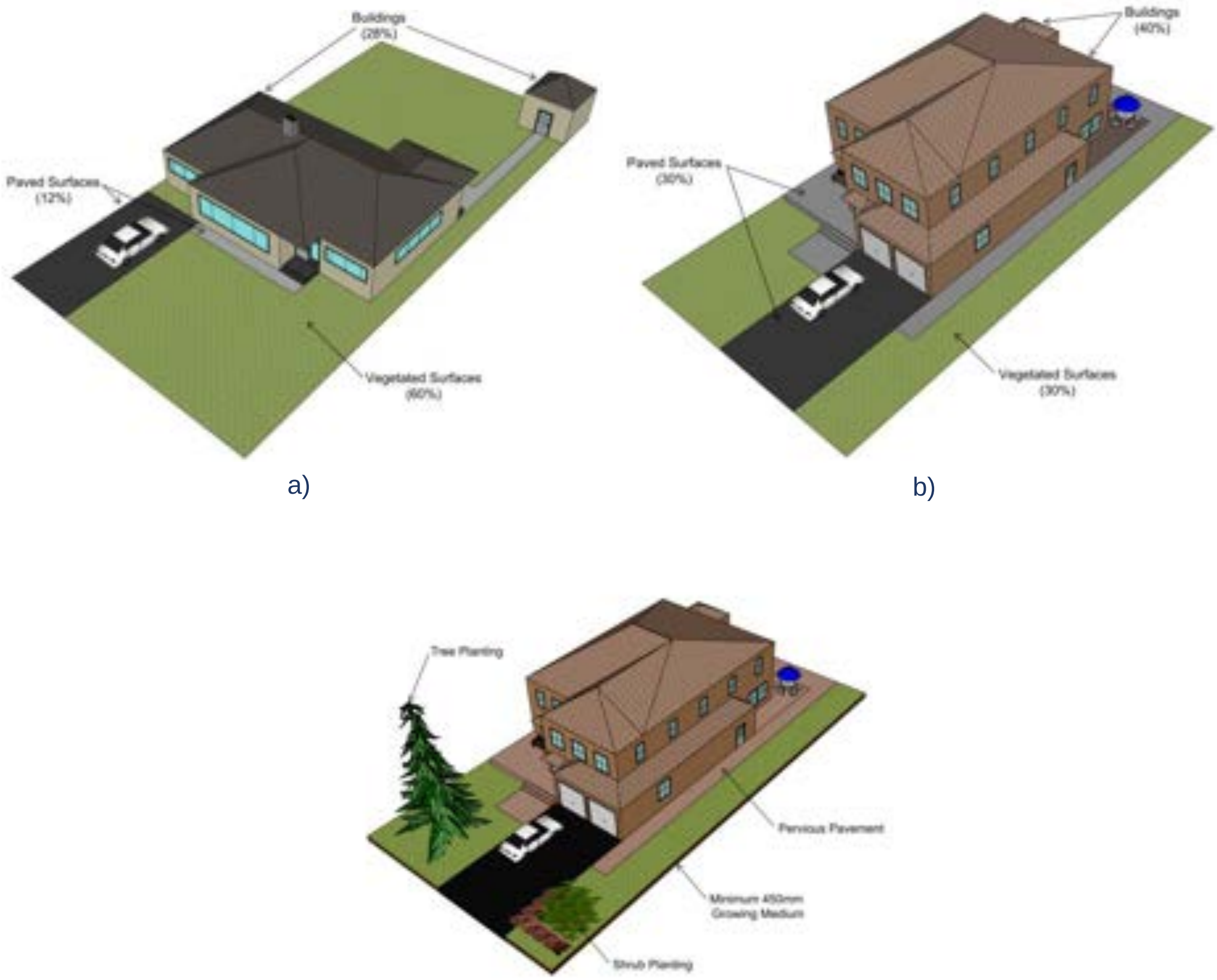
Appendix F - Description of Stormwater BMPs

This appendix outlines practical Best Management Practices (BMPs) with an assessment of their effectiveness in reducing flow and peak runoff for residential lots, industrial/commercial/multi-family lots, and roadways.

In general, BMP measures allow surface runoff to infiltrate back into the groundwater table or slow peak runoff by naturally attenuating flows. However, infiltration is only suitable in areas with underlying pervious soils such as sands or gravels, and in areas where the ground is not already saturated. The majority of the land use in Tsawwassen consists of residential areas, parks space, agricultural areas, with a small proportion of commercial/industrial/multi-family development.

F1 RESIDENTIAL LOTS

In Tsawwassen, residential areas contribute significantly to the net impervious area of the overall watershed. Older residential lots tend to have a relatively small building footprint, and a substantial proportion of pervious surface. In contrast, newly developed lots typically maximize building coverage, and include additional impervious features such as garages, sheds, concrete slab patios and larger driveways. Figure F-1 illustrates the general difference in lot configuration between old and new residential developments.



a) b)

c)

a) Older residential lot; b) Newly constructed / redeveloped residential lot;

c) Newly constructed / redeveloped residential lot with mitigative source controls / BMPs

Figure F-1
Residential Lot Layouts

As discussed above, our model calibration resulted in assigning an Effective Impervious Area (EIA) of 40% to single family residential areas to accurately represent downstream flow responses for the existing condition. An EIA of 40% should be achievable in future development scenarios even as impervious area increases as a result of densification through the implementation of BMPs. As such, all residential lots undergoing development or redevelopment should meet an EIA of 40% through the use of source controls. Further, vegetation should be planted and / or preserved.

The source controls that are most applicable to residential developments are described below.

F1.1 Disconnect Impervious Areas

In conventional drainage systems, impervious surfaces such as roads, driveways, parking lots, and roofs are connected directly into a conveyance system or receiving watercourse. Runoff from these impervious surfaces moves very rapidly and mobilizes and transports sediment and other pollutants. The result is very flashy flows with low times of concentration, high peak flow rates, large runoff volumes, and high pollutant mobility. These negative hydrologic impacts can be mitigated by disconnecting impervious areas from each other and the downstream pipe networks.

In some cases, residential roof leaders may be connected directly to the storm drainage system. Runoff originating from the roofs of these buildings is therefore unattenuated. During redevelopment of these lots, roof drains should be disconnected from the storm system, and instead discharged to pervious surfaces, such as lawns or gardens.

Disconnection can also include parking lots, roads, and other impervious surfaces; runoff can be directed to vegetated/pervious surfaces prior to arriving at a conventional drainage system. This approach will promote infiltration (subject to local soil conditions), evapotranspiration, and overland filtering. Even where runoff volumes are not significantly reduced, slowing of runoff provides downstream benefits in receiving streams, and is closer to a natural hydrologic regime.

The location, capacity, and soil conditions of each receiving vegetated area should be given careful consideration to ensure that directing impervious area runoff to pervious surfaces does not result in potential flooding or erosion.

Disconnecting impervious areas has good potential in medium and low density residential developments since there are generally green spaces available to receive runoff.

F1.2 Absorbent Landscaping and Growing Media

Absorbent landscaping acts like a sponge that retains rainfall, stores it temporarily, and then slowly releases it. Its primary purpose is to mimic the hydrologic function of undeveloped land on a developed site. It tends to have only a limited capacity, and will saturate and lose functionality during large rainfall events. Regardless, it is an appropriate measure to manage stormwater at the source, and is particularly effective for small, frequent rainfall events. Additionally, the filtration mechanism of the soil layer provides water quality benefits.

Absorbent landscapes typically consist of a layer of absorbent soil with vegetation such as shrubs and trees. The vegetation provides an additional function of supporting interception and evapotranspiration. Absorbent landscapes receive direct rainfall and runoff from small impervious surfaces (such as driveways, paths and patios). Additionally, roof downspouts can be directed such that they discharge to the absorbent landscape, rather than directly to other impervious surfaces or the storm drainage network.

Absorbent landscapes are easily applied (relative to other source controls) to existing residential lots, and provide aesthetic benefits for the community and individual homeowners. Vegetation can be selected such that it also supports backyard biodiversity and the increased presence of native plants. Required maintenance includes typical gardening activities such as weeding and replacing dead plants, as well as watering during extended dry periods. As well, an overflow should be considered, and should be inspected monthly and debris removed.

For the purpose of effective stormwater management, the depth of absorbent soils should be a minimum of 450 mm, and be comprised of soils with high organic content, such as sandy loam.

F1.3 Pervious Pavement

Pervious pavement provides an alternative to otherwise impermeable surfaces, such as driveways, walkways and patios. It consists of a paving system that allows rainfall to percolate into an underlying subgrade reservoir. If sufficient infiltration capacity exists in the subgrade or underlying soils, the water will be infiltrated. Otherwise, it can be discharged to the storm network through an underdrain.

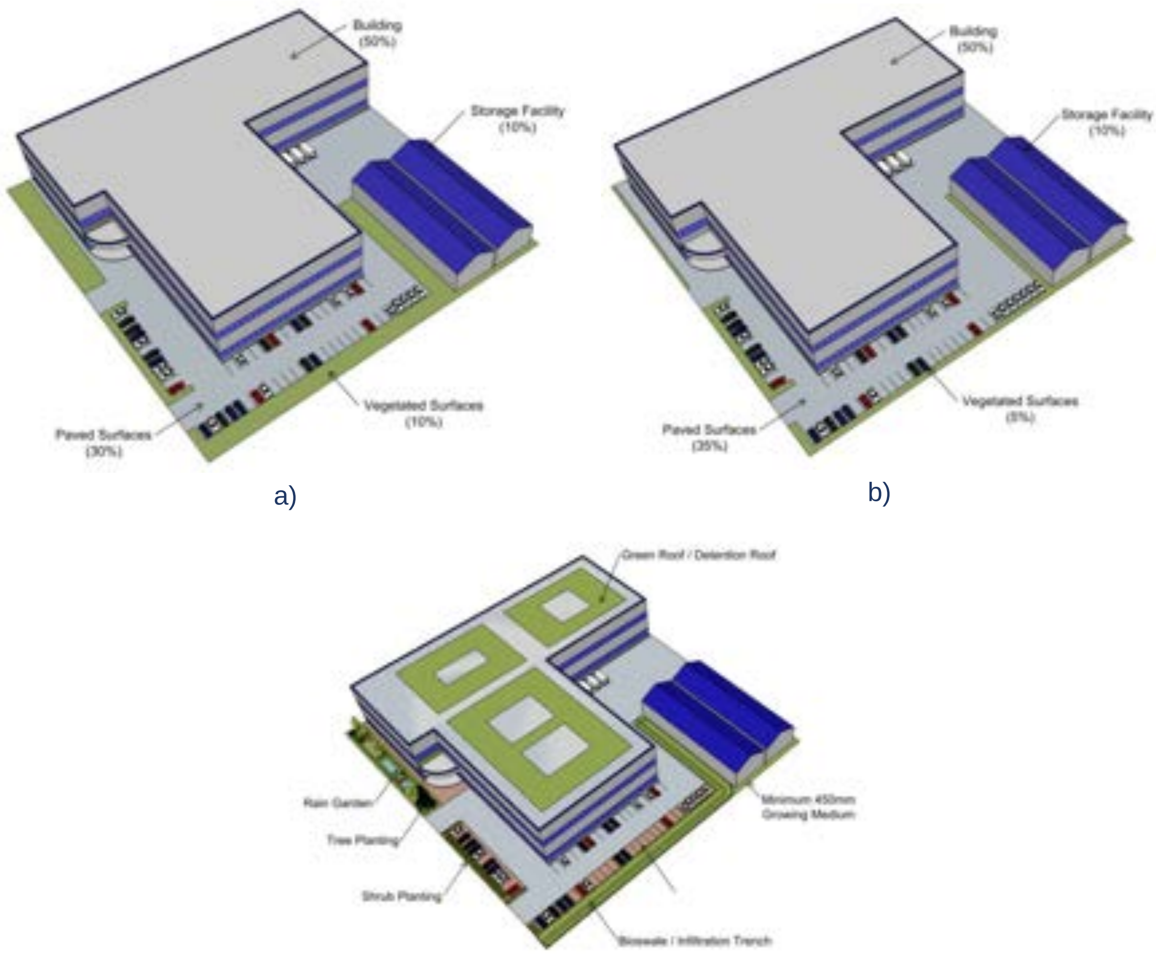
Metro Vancouver's Stormwater Source Control Guidelines (2012) suggests that pervious pavement can receive runoff from other impermeable areas, provided sediment loads are not excessively high. Pervious pavement can provide a reduction in peak flows and runoff volume, as well as some contaminant removal, and in certain areas assists in rehabilitating baseflows to natural watercourses via groundwater recharge.

Pervious pavement typically consists of five layers including the surface (porous asphalt / concrete, concrete / plastic grid pavers, concrete pavers installed with gapped joints), an aggregate bedding, open graded base, open graded sub base, and subsoil. Additionally, the use of a geotextile to prevent migration of fines into the base drainage courses is recommended. With relatively impermeable soils, a partial-infiltration configuration that includes an underdrain may be required.

On residential lots, pervious pavement provides excellent mitigation to the effects of driveway expansions, new walkways, porches and patios. Due to the relatively complicated nature of construction, however, individual home owners may be hesitant to install pervious pavement for these types of projects. Supplemental support and encouragement from the City may be necessary to maximize the implementation of pervious pavements in Tsawwassen.

F2 COMMERCIAL LOTS

Commercial lots (and multi-family/industrial developments) occupy a small percentage of the total land area but have a high proportion of impervious to pervious areas. As with residential lots, recently constructed commercial lots tend to have greater impervious coverage than older ones, as illustrated in Figure F-2. Bioswales, rain gardens and green roofs could feasibly be applied to 30% of total lot coverage if planned appropriately.



c)

a) Older industrial lot; b) Recently constructed / redeveloped industrial lot

c) Recently constructed / redeveloped industrial lot with mitigative source controls / BMPs

Figure F-2
Commercial Lot Layouts

The most applicable source controls for commercial lots are described below.

F2.1 Absorbent Soils

Absorbent soils are described in Section 6.1.2, and may be applied to landscape areas on industrial / commercial lots to achieve attenuation of runoff.

F2.2 Bioswales

Bioswales are shallow open channels that capture and convey stormwater runoff. They are typically comprised of a vegetated topsoil layer, a drain rock layer and a subgrade drain. In locations where stormwater treatment is a concern, as with industrial developments, bioswales provide stormwater treatment by assisting in the removal of Total Suspended Solids (TSS), heavy metals and some hydrocarbons.

Compared to a traditional piped drainage network, bioswales can significantly attenuate runoff received from impervious surfaces due to the relatively high roughness of the surface layer, the effect of temporary subsurface storage in the drain rock layer, and the promotion of shallow infiltration.

Bioswales can be implemented along the edges of parking lots and provide benefits to stormwater quality while lessening the strain on the City's piped drainage network.

F2.3 Green Roof

A green roof is a modified conventional roof that incorporates features such as planter boxes that support living vegetation. For the purposes of stormwater management, soil depth is typically 300 mm or less. Green roofs operate similar to absorbent landscaping by soaking up and temporarily retaining direct rainfall.

Buildings located on industrial lots tend to occupy a significant fraction of the total lot area and typically have flat roofs. This makes the implementation of green roofs practical and very effective for these areas.

Various studies have highlighted that green roofs provide extra insulation reducing heat transfer as well as improve the longevity of the roof structure by helping to protect the membrane from extreme temperature fluctuations (Metro Vancouver, 2012). With proper communication of these benefits, industrial property managers may be more inclined to support the inclusion of green roofs on their lots.

F2.4 Rain Gardens

Rain gardens are aesthetically pleasing landscape features designed to capture, detain, treat and infiltrate stormwater runoff. Rain gardens typically consist of 450 mm of absorbent topsoil supporting trees, shrubs and groundcover, overlying a drain rock reservoir. The soil and vegetative layers provide attenuation and treatment of water as it percolates and collects in the drain rock reservoir. If infiltration capacity in the drain rock reservoir is sufficient, the water will infiltrate. Otherwise, the water is directed into the storm drainage network either through an overflow catch basin at the surface or through a subdrain located in the drain rock layer.

Within industrial areas, rain gardens can provide a pleasant aesthetic feature while collecting and treating the majority of runoff generated from impervious surfaces such as parking lots or rooftops.

F2.5 Underground Detention

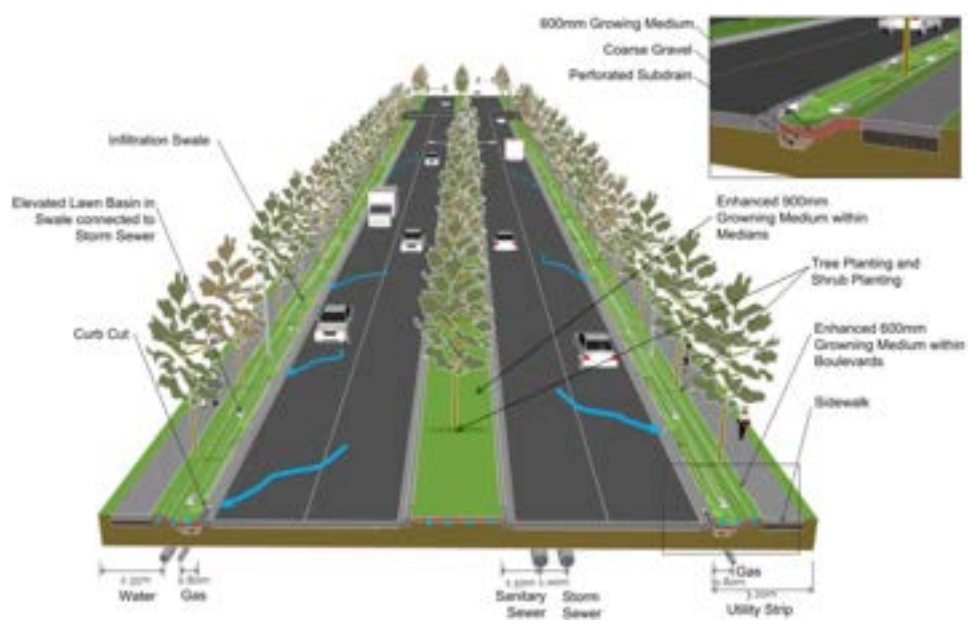
In commercial, industrial, and high density residential areas, detention storage can be provided as tanks located under parking or working areas and in urban residential areas within lawns or under driveways, preferably at the low point of each site.

These systems could be designed to provide both peak flow attenuation and volume reduction functions. To provide attenuation, storage units should be sized and configured with sufficient volume to retain a significant portion of the runoff for an extended period of time. They would require a flow control feature at the outlet to limit release rates. Water would be temporarily stored, and released at a slower rate, which would better mimic the slow percolation and concentration rates of the organic surficial soils and vegetation present under natural conditions. These units would require a bypass system, either external to the unit or an internal overflow, to ensure large design storms exceeding the unit capacity can be conveyed to the downstream system.

F3 ROADWAYS

The City should maximize the opportunity for implementing source controls by promoting inCity of sustainable stormwater management principles into all types of projects, including road construction / rehabilitation projects. Figure F-3 illustrates the potential configuration of roadway source controls to maximize hydrologic benefits across the study area. These measures should be implemented where possible. These roadside BMPs should only be implemented in areas not prohibited by the Delta Subdivision and Development Standards Bylaw No. 7162.

a)



b)

a) Local and collector roads; b) Arterial roads

Figure F-3
Road Right-of-Way Source Control Configurations

F3.1 Bioswales / Enhanced Ditches

The hydrologic benefits and typical structure of bioswales was discussed in Section 1.2.2.

Runoff from travelled lanes and parking areas can be directed to bioswales, rather than being immediately discharged into the storm drainage network. This provides for treatment of TSS, heavy metals and hydrocarbons, reducing the direct loading on the storm drainage network.

F3.2 Pervious Pavement

The hydrologic benefits and typical structure of pervious pavements were discussed in Section 1.1.3.

While pervious pavement should not be implemented in high-traffic areas due to potential structural concerns and ponding, sidewalks and parking lanes can utilize pervious pavement to attenuate runoff and promote shallow infiltration to the underlying soil.

F3.3 Rain Gardens

The hydrologic benefits and typical structure of rain gardens were discussed in Section 1.2.4.

Runoff from travelled lanes and parking lanes can be directed to rain gardens to provide treatment and runoff attenuation. Rain gardens can be placed at the downstream ends of bioswales to provide maximum treatment efficiency and runoff reduction. Rain gardens may be linear features or incorporated into curb bulges.

F3.4 Absorbent Landscaping and Street Trees

The hydrologic benefits and structure of absorbent landscaping were discussed in Section 1.1.2.

Absorbent landscaping can be employed in combination with street trees to support the City's ultimate tree canopy goals as well as the City's goal to provide aesthetically pleasing communities. Absorbent landscaping in a roadway context is best suited to the inclusion of street trees to maximize the hydrologic benefits. Trees can consist of coniferous or deciduous trees, and are most beneficial if they possess high leaf densities. Coniferous trees are preferred over deciduous trees, as leaf litter can restrict the absorption of the underlying soil, and their retention of foliage through the winter rainy season promotes maximum interception.

For maximum effectiveness, the growing medium should have a minimum depth of 450 mm. Analysis of the feasibility of street trees must consider implications to the surrounding pavement structures, as tree roots can damage concrete sidewalks and paved roads, although this effect can be mitigated by the use of structural soils.

Structural soils are soil media that can be compacted to meet pavement design and installation requirements while permitting adequate root growth. It is generally composed of gap-graded crushed stone, clay loam and a hydrogel stabilizing agent to bind the mixture together. It provides a root-penetrable, high strength pavement system that shifts design away from individual tree pits.

Structural soil can be located under the sidewalks adjacent to most arterial and local roads. By allowing roots to cover a greater area without damaging pavement structure, structural soil can reduce some of the drawbacks of street trees.

F4 CITY PARKS AND GREEN SPACES

F4.1 Stormwater Management Ponds

Stormwater management ponds are facilities designed to provide treatment of stormwater runoff through settling of sediment and pollutants and provide quantity control of peak flow through temporary storage. Stormwater management ponds should be employed to provide extended detention of runoff from urban development during large infrequent storm events. They should also be designed to detain and ensure the controlled release of runoff from all events up to and including the 100-year return period. Stormwater management ponds also control runoff and provide extended detention to runoff from small frequently occurring rainfall events, providing relief to downstream stormwater infrastructure and watercourses.

Stormwater management ponds should be located on City controlled property at the downstream end of the contributing drainage catchment, upstream of the receiving watercourse or drainage infrastructure.

When properly designed and managed, ponds can also function as attractive community amenities that provide recreation benefits and habitat for wildlife.