Old Logging Ditch and Burrow's Ditch

Integrated Stormwater Management Plan

REVISED DRAFT

CITY OF SURREY
the future lives here.

URBANSYSTEMS.
#2353 13353 Commerce Parkway
Richmond, BC, V6V 3A1
Phone: 604-273-8700
Fax: 604-273-8752

September, 2011
USL Reference No.: 1072.0176.01

URBANSYSTEMS

City of Surrey

Old Logging Ditch and Burrow's Ditch

Integrated Stormwater Management Plan (ISMP)

City Project #4809-0710

Final Report

Client: City of Surrey
Attention: Jeannie Lee, P.Eng.
14245 – 56th Avenue
Surrey, BC V3X 3A2

Prepared By: Urban Systems Ltd.
#2353 – 13353 Commerce Parkway
Richmond, BC V6V 3A1
Tel: (604) 273-8700
Fax: (604) 273-8752
Email: richmond@urban-systems.com

Jeffrey M. Rice, P.Eng.
Senior Water Resources Engineer / Project Manager

Contents

Appendices

List of Tables

List of Figures

Executive Summary

An Integrated Stormwater Management Plan (ISMP) for Old Logging Ditch/Burrow's Ditch

Old Logging Ditch and Burrow's Ditch lie in the south central part of Surrey, draining north from upland areas toward and through adjacent lowlands along the Nicomekl River. The study area, which totals 1,800 hectares, includes two important tributaries, Wills Brook and Morgan Creek, as well as several other watercourses and ditches. The lowlands are entirely within the Agricultural Land Reserve, while the upland areas are predominately low density, single family residential in character, though the southwest corner has undergone (and continues to undergo) densification with significant commercial and multi-unit residential development.

While the City of Surrey has completed neighbourhood planning for most of the upland area where development is expected to occur, the cumulative impact of development in these catchments has not been considered in any depth. The City of Surry retained Urban Systems, with its partners Dillon Consulting and Thurber Engineering, to develop an ISMP to investigate the cumulative impacts of development within these two watersheds.

The ISMP was completed in four stages:

Stage 1 What Do We Have?

Stage 1 involved collecting data on rainfall, water quality, infrastructure, etc., to complete the analysis.

Stage 2 What Do We Want?

Stage 2 involved identifying a vision for the watershed and assessing strategies to realize that vision.

Stage 3 How Do We Put It Into Action?

Once clear direction had been set in Stage 2, the next stage was to develop recommendations and an implementation plan.

Stage 4 How Do We Stay On Target?

Implementing an ISMP is an ongoing process. To make sure the City stays on track, key performance targets, a monitoring program, an assessment plan and an adaptive management process were developed in Stage 4.

Assessment and Analysis

The development of this ISMP involved the following analytical components:

- **Land use Review** – Existing and future land use conditions were reviewed using recent aerial photography as well as the City's Zoning Bylaw, Official Community Plan, and related Neighbourhood Concept Plans.

- **Policy, Regulations and Standards Review** – Existing key City policies, regulations (by-laws) and standards were reviewed with an eye towards identifying potential revisions that could enhance stormwater management within the Study Area.

- **Environmental Review** – Existing aquatic and terrestrial habitat conditions within the Study Area were assessed through a desktop review supplemented by field investigation.

- **Hydrogeological and Geotechnical Review** – A high-level assessment of groundwater conditions and surficial geology was conducted through a review of available documentation, including well records. Stream bank stability and erosion were assessed through a document review supplemented by field investigation.

- **Hydrologic and Hydraulic Review** – Both hydrologic and hydraulic conditions under several scenarios (including existing and future land use conditions) were simulated for the upland areas of the catchments. Significant effort was directed towards assessing the cumulative impact of previously recommended improvements from prior NCP servicing plans. This approach allowed the long-term impact of Best Management Practices/Low Impact Development (BMPs/LID) on existing watercourses to be fully assessed. In addition, estimates of runoff pollutant loads to the local watercourses were developed for existing and future conditions.

Results

Development within the catchments to date has primarily been low to medium density single family residential, though commercial and higher density residential development has occurred in the southwest corner of the Study Area; lower density land uses are generally anticipated for the future as well. Stormwater management practices which were implemented along with the development appear to provide some protection for watershed health, and the most recent local neighbourhood plans are recommending more on-site stormwater controls which will further enhance this protection. These controls are consistent with the City's current directions for stormwater management which emphasize traditional flood and erosion control as well as water quality and management of runoff "at the source".

The modeling performed for the project assessed and confirmed the efficacy of these controls for maintaining watercourse hydrology and meeting water quality objectives. Specifically, a combination of on-site source controls (for runoff peak and volume control) and detention storage (for runoff peak control) was found to protect creeks and downstream agricultural land. On-site controls, which emphasize the use of infiltration and evapo-transpiration to manage rainfall, also provide significant benefits with respect to recharging groundwater, watercourse base flow maintenance and water quality.

In general, infiltration-based on-site controls can be used throughout the Study Area, with two specific exceptions. Infiltration should not be used in the transition zone between the uplands and the lowland agricultural lands nor closer than 15 metres to creek banks; infiltration should not be used in areas of poorly drained soils, notably the area bounded by 166 Street, Highway 15, 30 Avenue and 26 Avenue.

Recommendations

Based on the ISMP results, it is recommended that the City take a number of actions to help ensure the environmental health of local watercourses and mitigate flood risks in Old Logging Ditch and Burrow's Ditch catchments. All recommendations were grouped into seven categories:

- **Environmental Protection and Enhancement** – Projects generally intended to mitigate or enhance in-stream conditions for fish and wildlife.

- **Municipal Infrastructure** – Projects to improve the functioning of the City's stormwater collection, conveyance, control, treatment and discharge systems; this includes upgrades to existing storm drains, construction of new trunk storm drains, detention ponds and runoff treatment systems, and replacement of inadequately sized culverts.

- **Instream Improvements** – Projects to repair erosion that directly impacts property or other local infrastructure such as roads.

- **Pilot Projects –** Small scale projects intended to demonstrate the applicability and effectiveness of innovative stormwater controls.

- **Planning and Analysis** – Activities and tasks to enhance the City's understanding of local streams and storm systems, to evaluate the success of past actions, and to determine the feasibility of undertaking additional actions or adapting to changed conditions.

- **Policy and Regulation** – Development and adoption of changes to bylaws, guidelines and other regulatory tools.

- **Public Education and Outreach** – Programs and activities intended to educate the public, developers, contractors and others about stormwater management and its benefits to the Old Logging Ditch and Burrow's watershed.

Details of key recommendations are provided in the tables and figures below. **Table E-**1 lists recommended maximum discharge rates for runoff, by area within the Old Logging Ditch and Burrow's Ditch catchments. Table **E-2** summarizes the recommendations for new development and re-development on-site stormwater management. Recommendations for infrastructure improvements are listed in **Table E-3** with locations for the various improvements shown on **Figure E-1**. Recommendations for in-stream aquatic habitat improvements are shown on **Figure E-2**; these projects should be undertaken as and when opportunities arise in conjunction with new development or other City initiatives.

The total cost of capital improvements listed in **Table E-3** is about $20.85 million. Approximately $12.6 million of this is recommended to be spent over the next five years, primarily to correct existing problems or shortcomings identified in this ISMP; approximately $6.8 represent improvements that should be implemented when development is ready.

Table E-1: Recommended Maximum Discharge Rates

Catchment Areas	Maximum discharge rate (l/s/ha)		Comments
	2 year storm event	5 year storm event	
Morgan Creek	8	11	Encompasses business park development.
Morgan Creek N. of 32nd Avenue.	6	8	Covers most of the upland section of the Morgan Creek catchment
Wills Brook N. of 32nd Avenue.	4	6	Covers most of the upland section of the Wills Brook catchment
Old Logging Ditch N. of 32nd Avenue.	5	7	Since only low-density single-family development is expected to occur in these catchments, these maximum discharge rates would primarily be used for long-term monitoring purposes.

Table E-2: Recommendations for On-Site Stormwater Management Measures
For New Development and Re-Development Sites

Category	Recommendation	Reference
Development Requirements		
Single Family Residential Development < 50% Total Impervious Area (TIA)	• Place 300 mm of amended growing media ("topsoil") in all lawn areas • Disconnect roof leaders	Table 5
Single Family Residential Development > 50% TIA; Multi-Family/Commercial/Industrial/Active Park Space	• Disconnect roof leaders and discharge to ground or on-site control features • For areas subject to high vehicle use, provide and maintain oil/water separator(s) • Meet minimum discharge and on-site retention criteria: o Min. discharge: Varies by location; see Table E-1 o Retention volume: 300 m3/ha	
Road Rights-of Way	• Meet minimum discharge and on-site retention criteria: o Min. discharge: Varies by location; see Table E-2 o Retention volume: 300 m3/ha	
Building Expansions	• Meet minimum discharge and on-site retention criteria: o Min. discharge: Varies by location; see Table E-2 o Retention volume: 300 m3/ha	

Table E-3: Recommendations for Infrastructure Capital Improvements 2011-09-19 ISMP

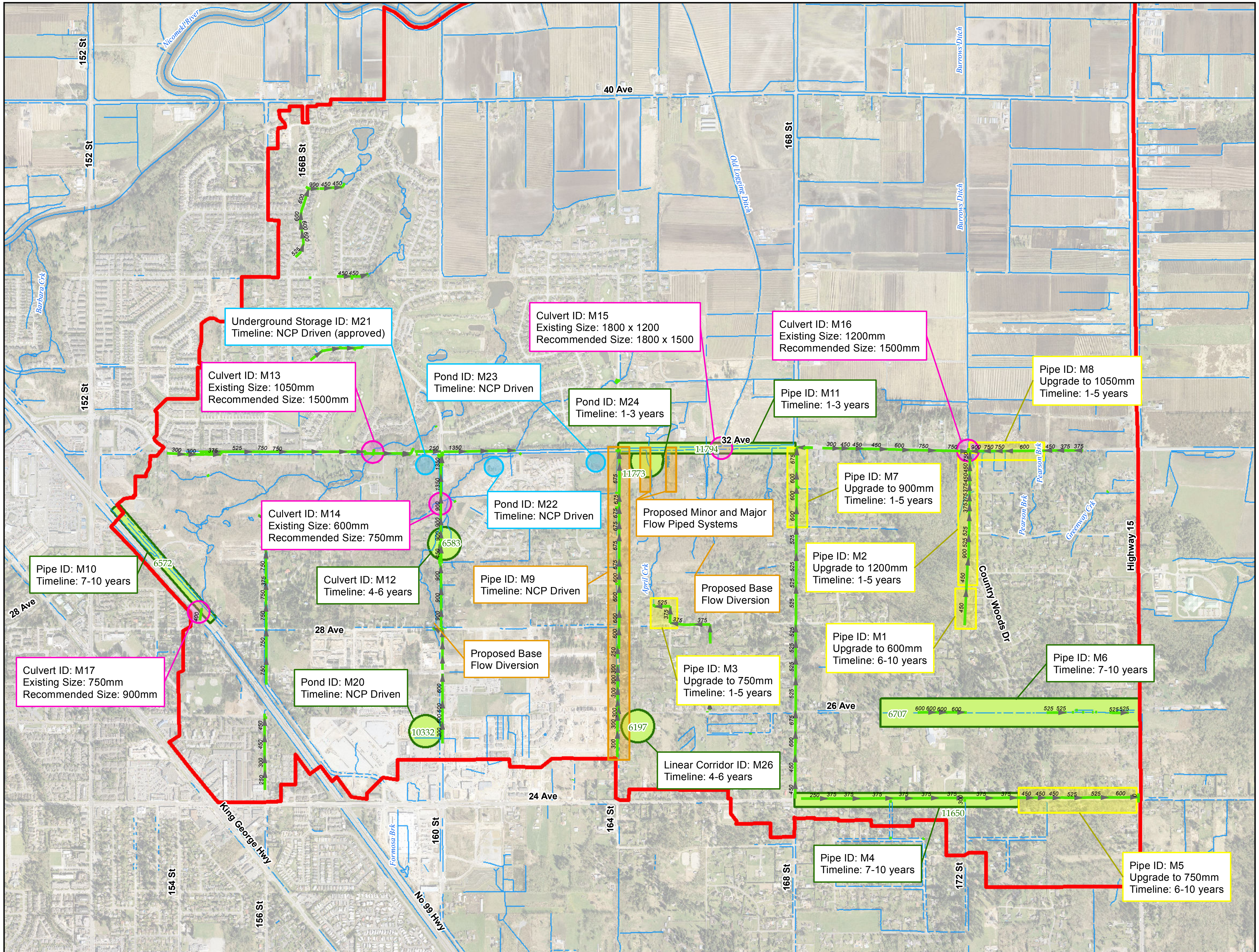
Project # (See Figure E-1)	Description	Recommended Timing			Estimated Capital Cost**
		Within 5 years	Beyond 6 Years	When Required for Development	
M2	172 St. concrete trunk storm sewer - 640 m of 1200 mm diameter	X			$ 1,459,000
M3	166 St. concrete trunk storm sewer - 150 m of 750 mm diameter	X			$ 220,000
M4	24 Ave. concrete trunk storm sewer (Currently included in the 10 year Servicing Plan)	X			$ 494,000
M6	26 Ave. concrete trunk storm sewer (Currently included in the 10 year Servicing Plan)	X			$ 7,802,000

M7	168 St. concrete trunk storm sewer - 375 m of 900 mm diameter	X			$ 866,000
M8	32 Ave. concrete trunk storm sewer - 330 m of 1050 mm diameter	X			$ 851,000
M11	32nd Ave trunk and creek works: 20 m 900mm+110m 1200mm – (Currently included in the 10 year Servicing Plan)	X			$ 422,900
M13	Morgan Creek at 32nd Avenue - culvert upgrade - 30.5 m of 1500 mm diameter	X			$ 115,000
M14	Wills Brook at 16th St - culvert upgrade - 12 m of 750 mm diameter	X			$ 45,000
M15	Old Logging Ditch at 32nd Avenue - box culvert upgrade - 19.5 m of 1800 mm x 1500 mm (Currently included in the 10 year Servicing Plan)	X			$ 140,000
M16	Burrow's Ditch at 32nd Avenue - culvert upgrade - 15 m of 1500 mm diameter	X			$ 100,000
M17	Morgan Creek at Highway 99 - culvert upgrade - 120 m of 900 mm diameter	X			$ 100,000
M10	Croydon Dr: 029-031 Ave- 630 m of 1200mm trunk sewer (Currently included in the 10 year Servicing Plan)		X		$ 1,089,000
M12	160th St/030 Ave: Upgrade culvert crossing for future peak flows		X		$ 45,000
M18	Culvert upgrades to improve fish accessibility (to be determined through detailed stream assessments)		X		$30,000 per culvert
M1	172 St. concrete trunk storm sewer - 160 m of 600 mm diameter			X	$ 227,000
M5	24 Ave. concrete trunk storm sewer - 375 m of 750 mm diameter			X	$ 765,000
M9	164th St trunk storm sewer upgrade –300 m of 600 mm diameter and 500 m of 675 mm diameter			X	$ 1,486,000
M20	Community Detention Pond -Volume 3000 cu.m. (Originally identified in the North Grandview Heights NCP)			X	$ 1,306,000

M21	Detention Pond -Volume 450 cu.m. (Originally identified in the North Grandview Heights NCP)			X	$ 183,000
M22	Detention Pond -Volume 600 cu.m. (Originally identified in the North Grandview Heights NCP)			X	$ 244,000
M23	Detention Pond -Volume 500 cu.m. (Originally identified in the North Grandview Heights NCP and currently in the 10 year Servicing Plan)			X	$ 204,000
M24	Detention Pond -Volume 1800 cu.m. (Originally identified in the North Grandview Heights NCP and currently in the 10 year Servicing Plan)			X	$ 729,000
M25	Detention Pond -Volume 3400 cu.m. (Originally identified in the North Grandview Heights NCP)			X	$ 1,388,000
M26	Detention Pond -Volume 3200 cu.m. (Originally identified in the North Grandview Heights NCP)			X	$ 319,000
	Miscellaneous Erosion Protection and Ravine Works (Currently in the 10 year Servicing Plan)		X		$245,600

*See **Figure E-1** for locations

**Capital cost includes construction, engineering and administrative costs, as well as a 35% contingency.



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Recommended Infrastructure Improvements

Figure E-1

Legend

- Existing Trunk System
- Culvert Upgrade
- Pipe Upgrade
- North Grandview Heights NCP - Pipe Upgrade
- North Grandview Heights NCP - Pond/Storage
- City of Surrey 2010 Ten Year Plan - Pipe, Culvert, and Pond/Storage
- Catchment Boundary

Note: Exact location of recommended ponds still to be determined.

N

0 250 500 750 1,000
Metres

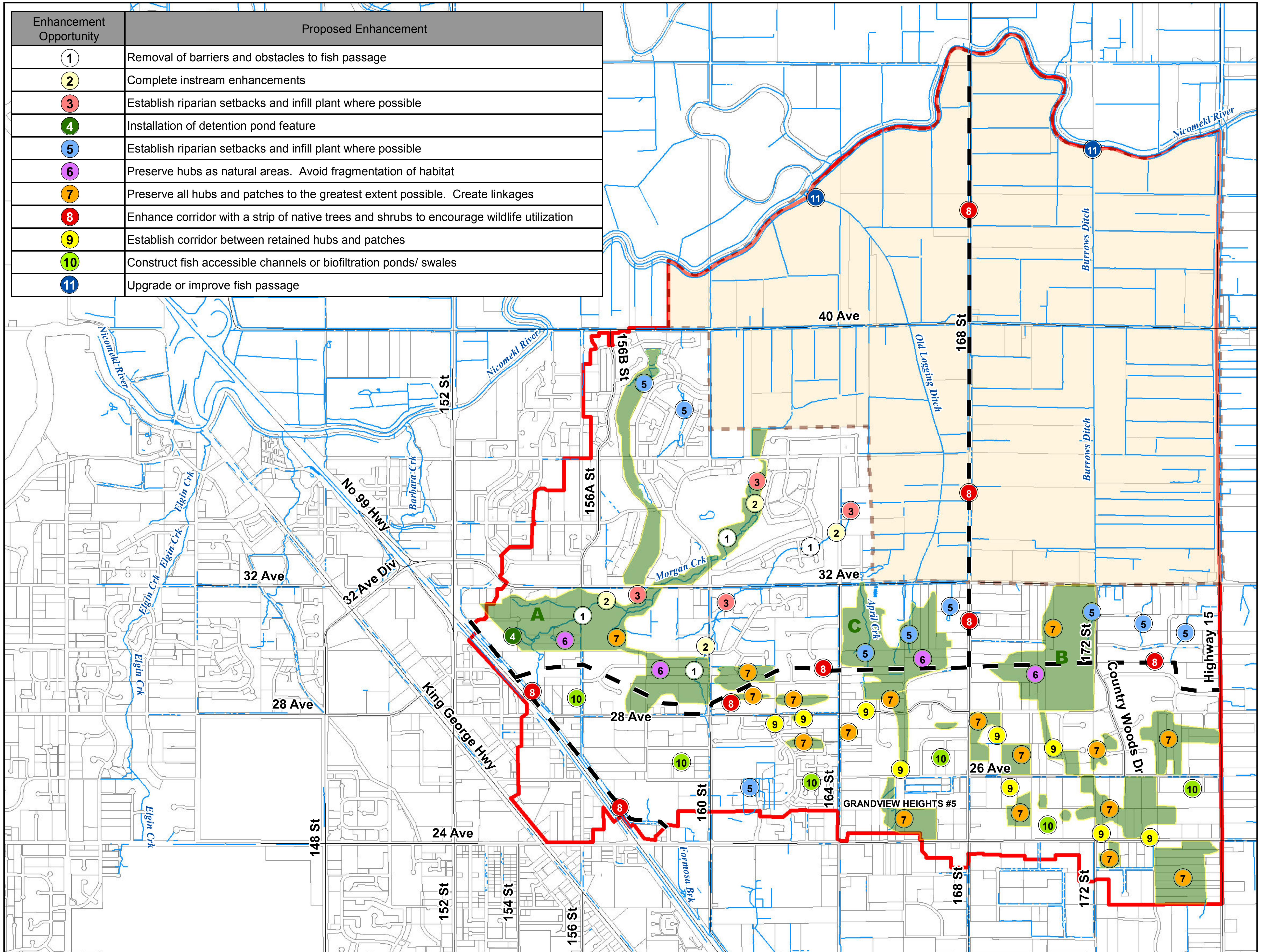
URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\FigureE1_RecommendedInfrastructureImprovements.mxd Last updated by: bpauls on September 19, 2011 at 10:18:35 AM

Enhancement Opportunity	Proposed Enhancement
1	Removal of barriers and obstacles to fish passage
2	Complete instream enhancements
3	Establish riparian setbacks and infill plant where possible
4	Installation of detention pond feature
5	Establish riparian setbacks and infill plant where possible
6	Preserve hubs as natural areas. Avoid fragmentation of habitat
7	Preserve all hubs and patches to the greatest extent possible. Create linkages
8	Enhance corridor with a strip of native trees and shrubs to encourage wildlife utilization
9	Establish corridor between retained hubs and patches
10	Construct fish accessible channels or biofiltration ponds/ swales
11	Upgrade or improve fish passage



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Recommended Aquatic and Terrestrial Enhancement Opportunities

Figure E-2

Legend

- Prioritized Enhancement Opportunity (see Table 4 for additional information)
- Watercourse
- North Grandview/Coast Meridian Multi-use Corridor
- Agricultural Land Reserve
- Terrestrial Hub
- Catchment Boundary

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

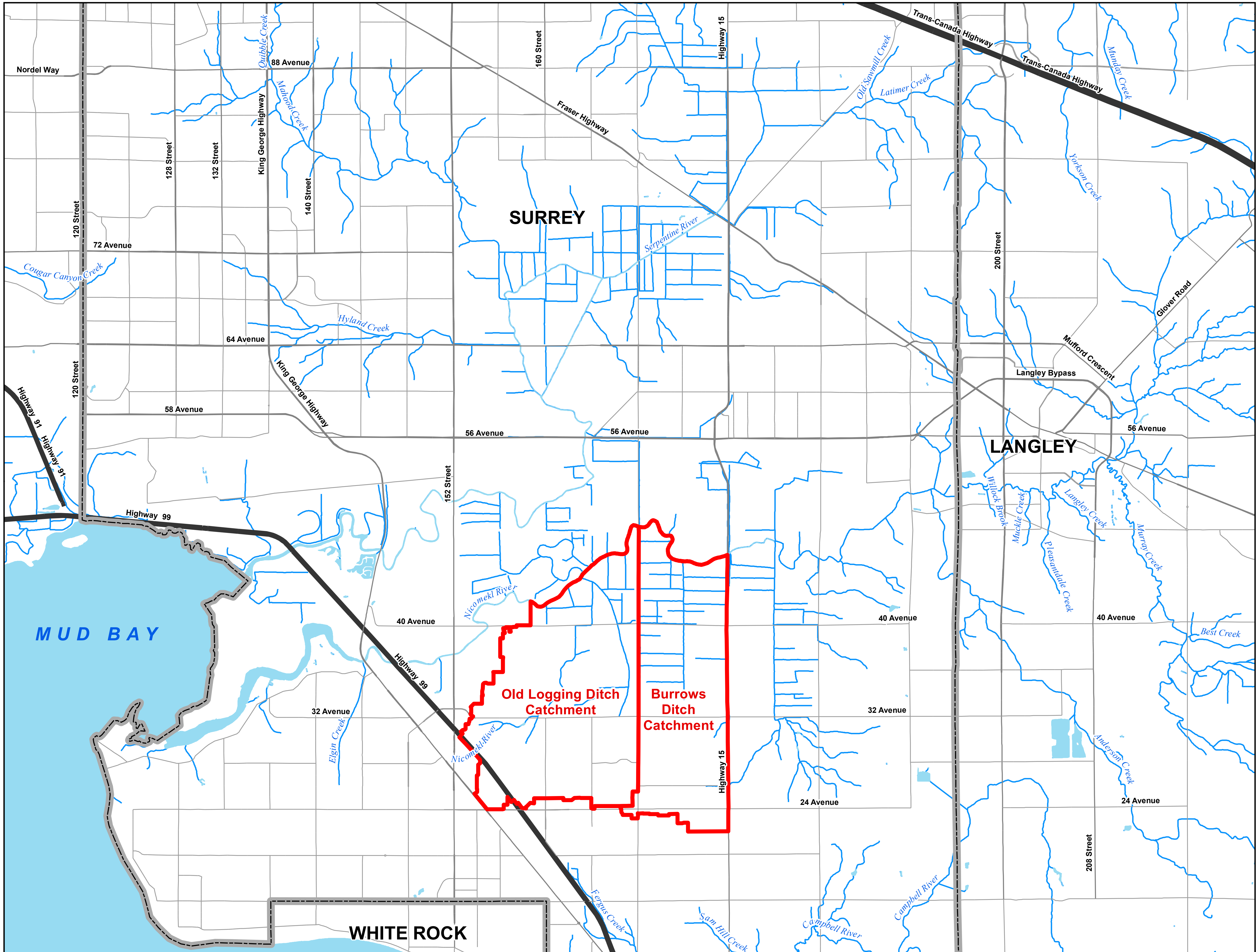
1072.0176.01

1 Introduction

1.1 Project Description

Old Logging Ditch and Burrow's Ditch lie in the south central part of Surrey, draining north from upland areas toward and through adjacent lowlands along the Nicomekl River. The study area, which totals 1,800 hectares, includes two important tributaries, Wills Brook and Morgan Creek, as well as several other watercourses and ditches. The lowlands are entirely within the Agricultural Land Reserve, while the upland areas are predominately low density, single family residential in character, though the southwest corner has undergone (and continues to undergo) densification with significant commercial and multi-unit residential development.

While the City of Surrey has completed neighbourhood planning for most of the upland area where development is expected to occur, the cumulative impact of development in these catchments has not been considered in any depth. The City of Surry retained Urban Systems, with its partners Dillon Consulting and Thurber Engineering, to develop an Integrated Stormwater Management Plan (ISMP) to investigate the cumulative impact of development within these two watersheds. The general location of the Study Area is shown in **Figure 1** and a more detailed map of the Study Area is shown in **Figure 2**.



Old Logging Ditch/ Burrows ISMP

General Location Map Figure 1

Legend

- Road
- Freeway
- Watercourse
- Waterbodies
- City of Surrey Boundary
- Study Area/Catchment Boundary

N

0 750 1,500 2,250 3,000

Metres

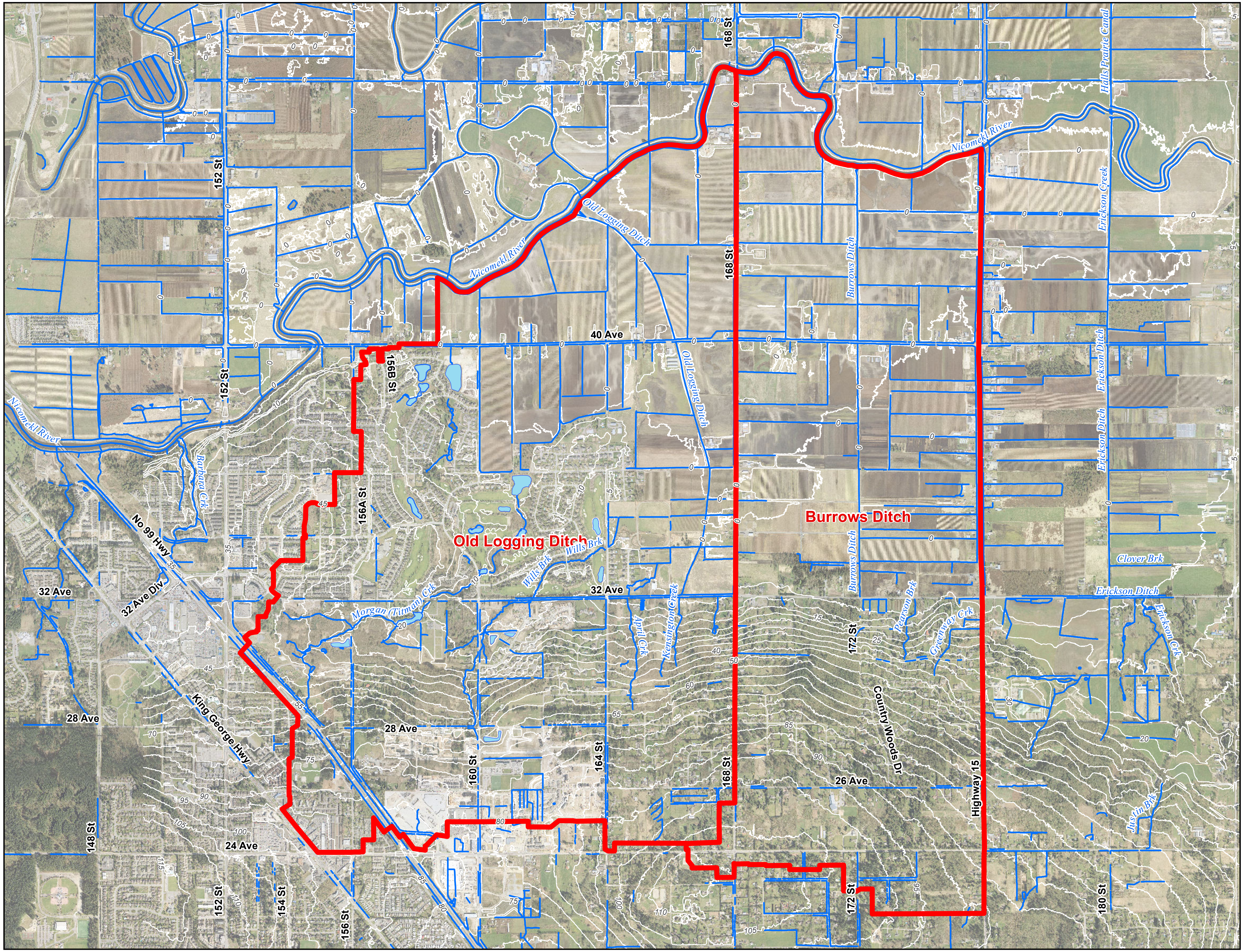
CITY OF SURREY the future lives here.

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure01_GeneralLocationMap.mxd Last updated by: bpauls on September 14, 2011 at 1:58:14 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Study Area Overview Figure 2

Legend

- Watercourse
- Contours - 5m
- Existing Detention Pond
- Catchment Boundary

Note:
Orthophoto captured during Spring, 2009.

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure02_StudyAreaOverview.mxd Last updated by: bpauls on September 14, 2011 at 1:58:31 PM

1.2 The ISMP Process

This ISMP has been developed to meet the Greater Vancouver Regional District (GVRD, now referred to as Metro Vancouver) ISMP Terms of Reference Template (Kerr Wood Leidal Associates, 2005), but in a way that is tailored to the City's unique characteristics and needs. Metro Vancouver's terms of reference template for integrated stormwater management planning is an important guiding document for the preparation of this ISMP. Thus, we have cross-referenced the specific clauses of that template with project work; see **Appendix A** for a summary of this cross referencing. This ISMP has been developed in four stages as outlined in the graphic below.

Stage 1 What Do We Have?

Stage 1 involved collecting data on rainfall, water quality, infrastructure, etc., to complete the analysis.

Stage 2 What Do We Want?

Stage 2 involved identifying a vision for the watershed and assessing strategies to realize that vision.

Stage 3 How Do We Put It Into Action?

Once clear direction had been set in Stage 2, the next stage was to develop recommendations and an implementation plan.

Stage 4 How Do We Stay On Target?

Implementing an ISMP is an ongoing process. To make sure the City stays on track, key performance targets, a monitoring program, an assessment plan and an adaptive management process were developed in Stage 4.

Figure 3: ISMP Process

1.2.a Analysis

The development of this ISMP involved the following four analytical components:

- **Land use review** – Existing and future land use conditions were reviewed using recent aerial photography as well as the City's Zoning Bylaw, Official Community Plan, and related Neighbourhood Concept Plans.

- **Environmental review** – Existing aquatic and terrestrial habitat conditions within the Study Area were assessed through a desktop review supplemented by field investigation.

- **Hydrogeological and geotechnical review** – A high-level assessment of groundwater conditions and surficial geology was conducted through a review of available documentation, including well records. Stream bank stability and erosion were assessed through a document review supplemented by field investigation.

- **Hydrologic and hydraulic modeling** – Both hydrologic and hydraulic conditions under several scenarios (including existing and future) were modeled using MIKE SHE and MIKE 11. This approach allowed the long-term impact of BMPs/LID on existing watercourses to be fully assessed.

Through discussions with the City, for purposes of this ISMP, the formulation of stormwater management strategies focuses on the upland areas only. Strategies for the Agricultural Land Reserve (ALR) lands have not been included.

1.2.b Consultation

This ISMP has involved the following consultation activities:

- Meetings with staff from Engineering/drainage
- Three (3) consultative and review meetings with interdepartmental staff

1.3 Report Outline

This ISMP is organized into the following six sections:

Section 1 – Introduction

Section 2 – What do we have? Includes a review of the existing hydrologic, hydraulic, hydrogeologic, environmental, land use conditions within the Study Area. As well, there is a brief review of current City policies, regulations and bylaws regarding stormwater management.

Section 3 – What do we want? Establishes a vision and objectives for the catchments, assesses alternative management strategies, and proposes recommendations.

Section 4 – How do we put it into action? Proposes recommendations on financing, development requirements, and enforcement.

Section 5 – How do we stay on target? Proposes a long-term process for monitoring and assessing the progress of plan implementation.

Section 6 – Conclusion Provides a summary of the main findings of the ISMP.

This ISMP also includes several appendices that contain technical information that supports the recommendations. References to relevant appendices are made throughout.

2 What do we have?

This Section provides an overview of existing land use, environmental, hydrogeologic, hydrologic, and hydraulic conditions within the Study Area. As well, there is a brief review of the City's current regulatory framework for stormwater management.

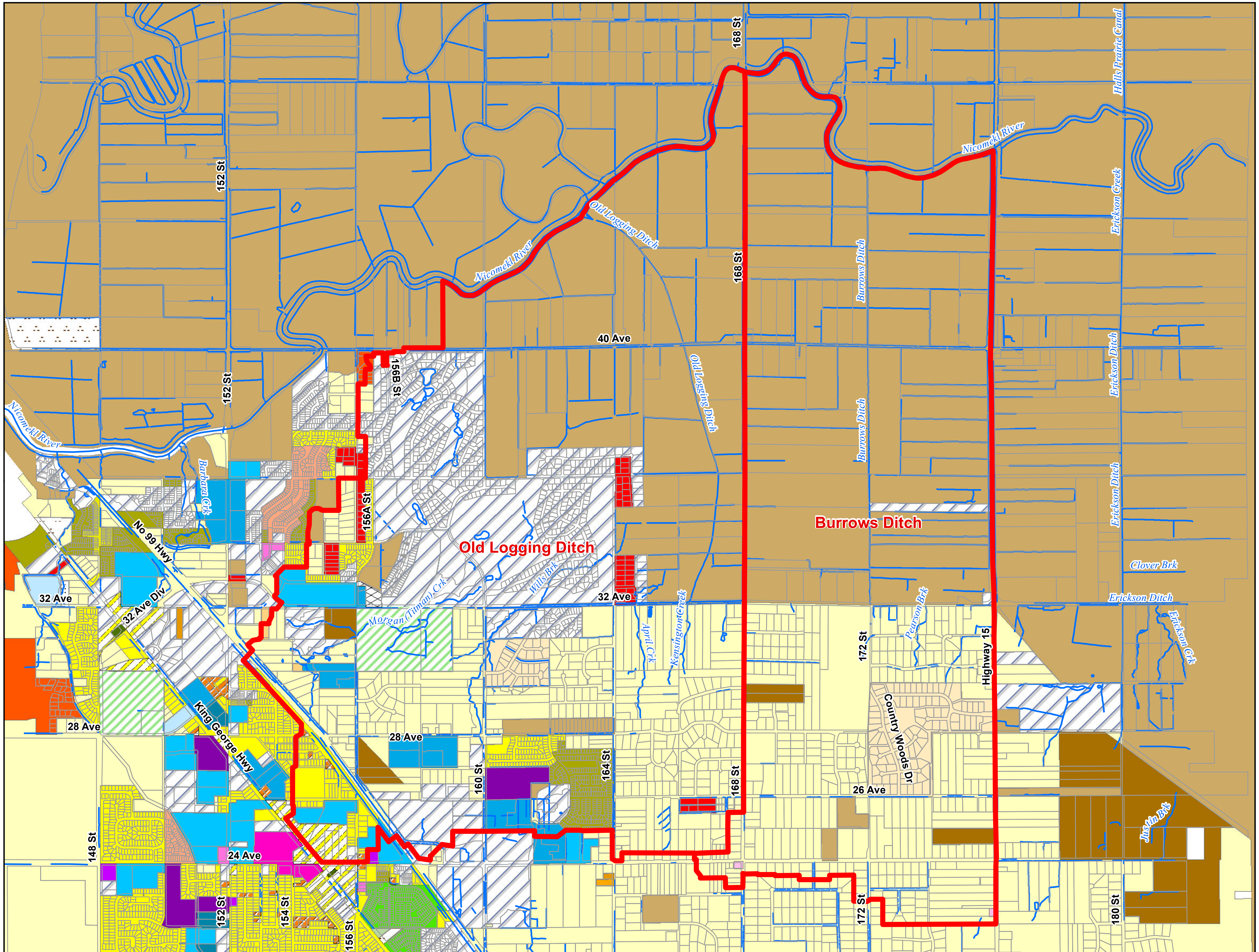
2.1 Land use

2.1.a Existing Land Use

As shown on the aerial photograph (**Figure 2**), the Old Logging Ditch catchment is the most developed part of the Study Area. The Burrow's Ditch catchment is less developed, encompassing only agricultural or suburban residential development. The existing land use pattern within the Old Logging Ditch/Burrow's catchment is largely determined by the City of Surrey Zoning Bylaw No. 12000, which regulates land use within the City. As shown on **Figure 4**, most of the existing development is residential or agricultural. There is also a commercial development in the south-west corner of the Study Area near Highway 99 and 26 Avenue.

The Study Area also currently contains a number of small parks within established neighbourhoods, as well as the Gardens of Gethsemani Cemetery (located south of 32 Avenue and East of 156 Street), which provides the most significant amount of green space within the western portion of the Old Logging Ditch catchment. The Rosemary Heights Business Park, which has not yet been developed, also currently provides substantial open space around Morgan Creek and Wills Brook. In the eastern part of the Study Area, the most significant intact green space is the large stand of mature trees west of 172 Street. As well, existing large residential lots provide substantial green space throughout the Study Area; however, many of these lots are slated for future densification.

One significant indicator of urban development's impact on watercourses is the fraction of the land that is covered by impervious surfaces (buildings, roads, parking lots, etc.). In the Cascadia region of North America (essentially, northern California, Oregon, Washington and BC), the current wisdom is that deterioration in watercourse health accelerates when 10% or more of a watershed is covered by impervious surfaces. Under existing conditions, the total impervious area (TIA) fraction is 32.4% and 16.2% for Old Logging Ditch and Burrows Ditch catchments, respectively. Some of these impervious surfaces do not produce runoff that reaches streams directly or via storm sewers. Accounting for this reduction in "connected" impervious surfaces, the "effective" impervious area (EIA) fraction is 20.8% and 10.0% for Old Logging Ditch and Burrows Ditch catchments, respectively. In the case of the Study Area, this reduction is primarily a result of the City's current policy of requiring that roof leaders on single family residential homes be discharged to ground, not to storm sewers. City staff has indicated that the compliance rate on this policy is not very good, and for purposes of the ISMP, a compliance rate of 50% (of all single family residential lots) has been used.



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Current Zoning Figure 4

Legend

- Catchment Boundary
- Waterways

Zoning

- General Agricultural
- Intensive Agricultural
- Local Commercial
- Neighbourhood Commercial
- Community Commercial
- Comprehensive Development
- Self-Service Gasoline Station
- Combined Service Gasoline Station
- Highway Commercial/Industrial
- Tourist Accomodation
- Agro Industrial
- Business Park
- Light Impact Industrial
- Assembly Hall 1
- Assembly Hall 2
- Cemetery
- Acreage Residential Gross Density
- Single Family Residential Gross Density
- Half Acre Residential Gross Density
- One Acre Residential
- Single Family Residential
- Single Family Residential (9)
- Single Family Residential (12)
- Half Acre Residential
- Multiple Residential (10)
- Multiple Residential (15)
- Multiple Residential (30)
- Multiple Residential (45)
- Multiple Residential (70)
- Duplex Residential
- Manufactured Home Residential
- Special Care Housing 2
- Suburban Residential

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure04_CurrentZoning.mxd Last updated by: bpauls on September 14, 2011 at 2:32:04 PM

2.1.b Future Land Use

Future land development within the Study Area will be guided by Surrey's Official Community Plan (OCP), which contains the City's long-term land use planning objectives, as well as related General Land Use Plans (GLUPs) and Neighbourhood Concept Plans (NCPs), which provide more detailed land use plans for specific areas. OCP details are shown on **Figure 5,** whereas NCP and GLUP details are shown on **Figure 6**.

Most of the future development within the Study Area is expected to occur within those areas covered by an NCP. The NCPs with the Study Area that hold the most development potential are:

- **Rosemary Heights Business Park NCP**

  This NCP calls for low-impact industrial development (i.e., business parks) as well as live/work development, and also includes a creek preservation area. None of this area has been developed.

- **Morgan Heights NCP**

  This NCP is primarily residential, calling for a range of residential development (with densities from 6 units per acre (upa) to 10 upa). This neighbourhood has yet to fully develop, but build-out is expected within the near future.

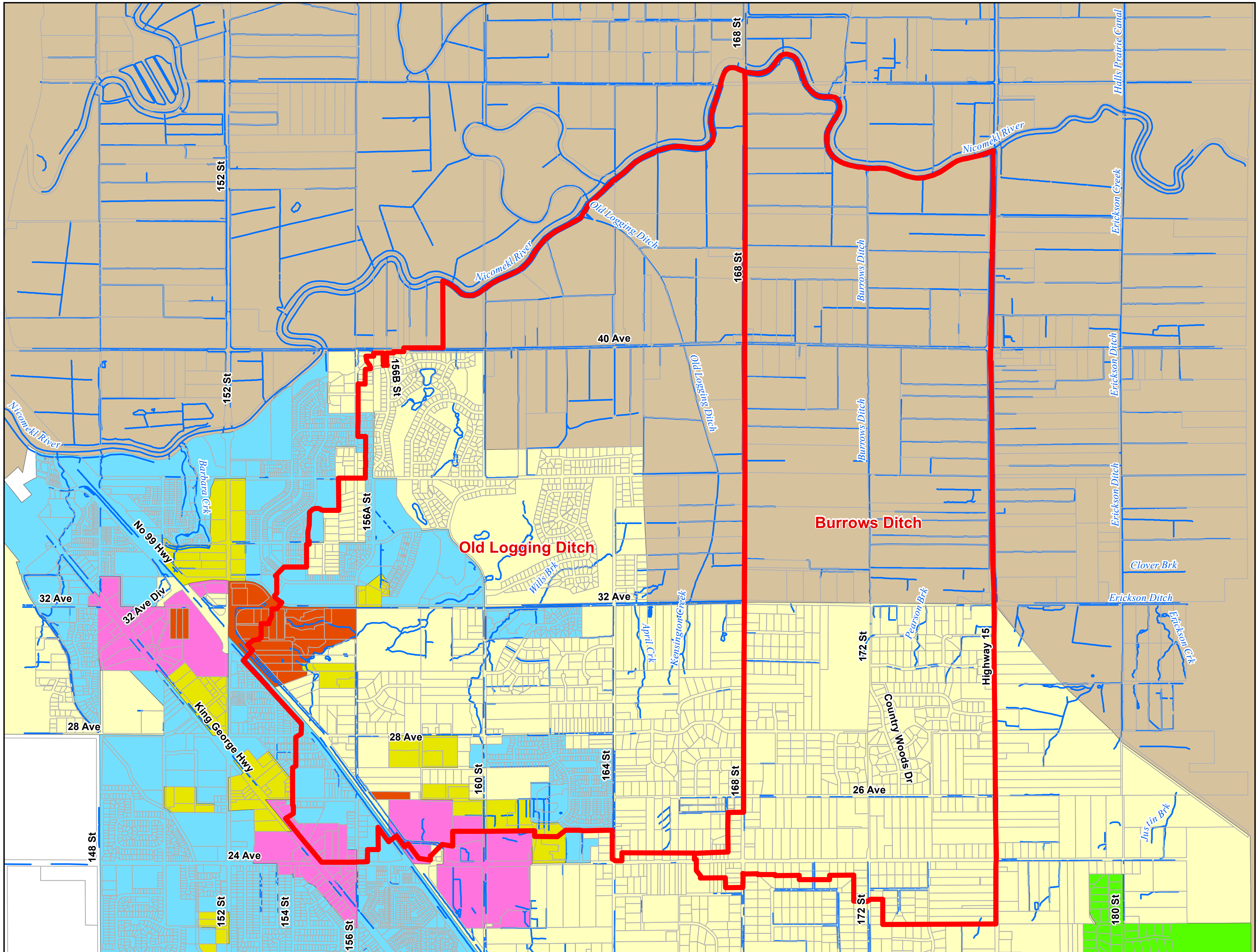
- **North Grandview Heights NCP**

  This NCP primarily calls for a mix of relatively low-density residential development (from 1 upa to 8 upa), preserving many of the existing one-acre/half-acre residential areas, with some multi-family housing along the westernmost edge of the NCP; major areas of this NCP have not yet been developed. North Grandview Heights holds the most development potential within the Study Area (see **Figure 7**).

- **Highway 99 Local Area Plan**

  The Study Area includes a small portion of the Highway 99 Local Area Plan, which includes **Business Park/Light Industrial** and **Commercial** land use designations. The Business Park/Light Industrial designation provides for business park uses as well as light impact industrial uses that are entirely enclosed within a building. The Commercial designation allows a wide range of commercial uses, from large format retail to drive-thrus. This area has not yet been developed.

As well, a very small part of the Grandview Heights NCP #2 overlaps with the south-east corner of the Old Logging Ditch catchment, and calls for mixed-use residential/ commercial development (what will be the commercial centre for the neighbourhood).



![City of Surrey logo] CITY OF SURREY the future lives here.

Old Logging Ditch/ Burrows ISMP

OCP Map Figure 5

Legend

- Watercourse
- Catchment Boundary

OCP

- Agricultural
- Commercial
- Industrial
- Urban Residential
- Suburban Residential
- Multiple Residential
- Town Centre
- Rural

N

0 250 500 750 1,000

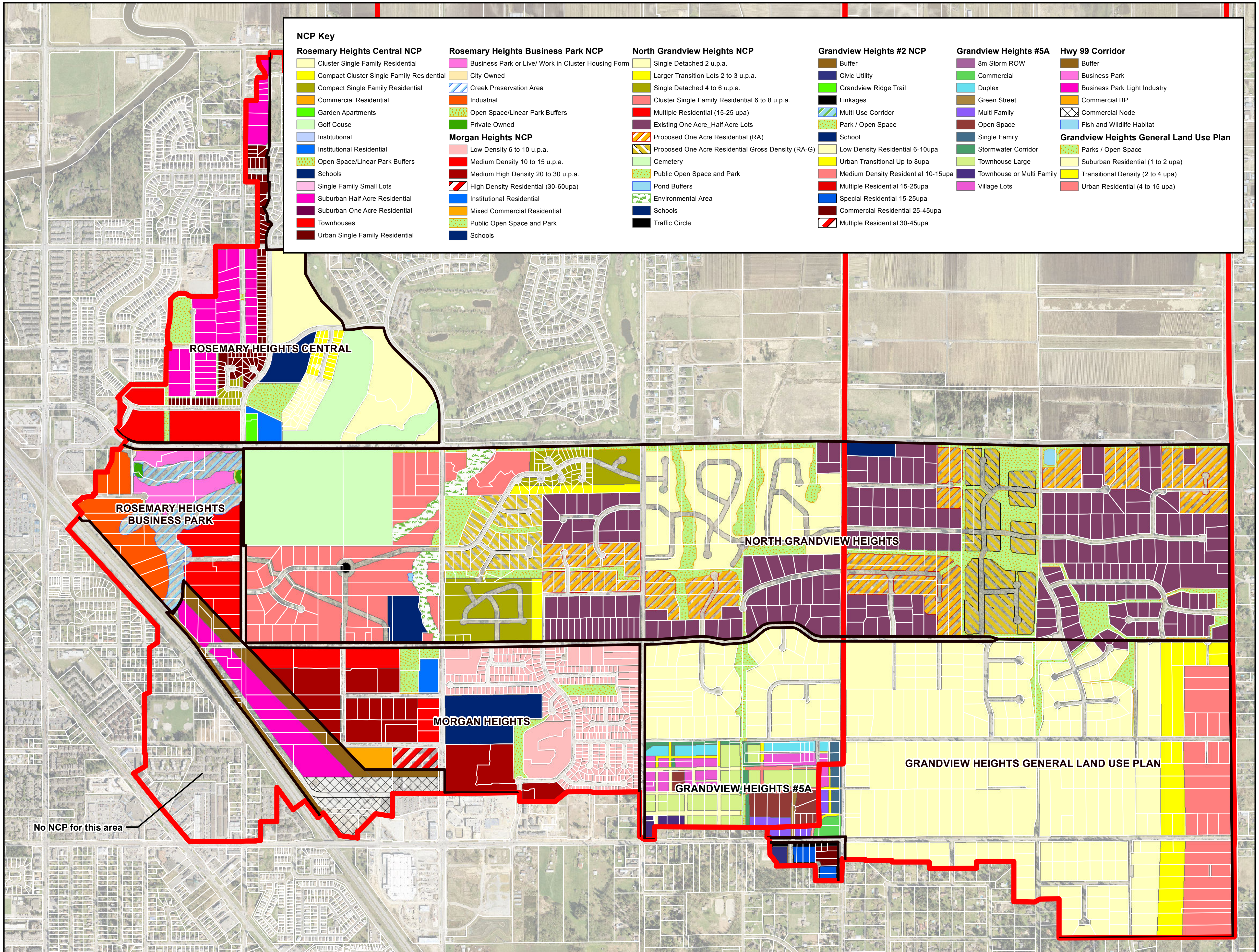
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure05_OCP.mxd Last updated by: bpauls on September 14, 2011 at 2:34:33 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Neighbourhood Concept and General Land Use Plans Figure 6

Legend

Catchment Boundary

NCP Boundaries

N

0 200 400 600 800

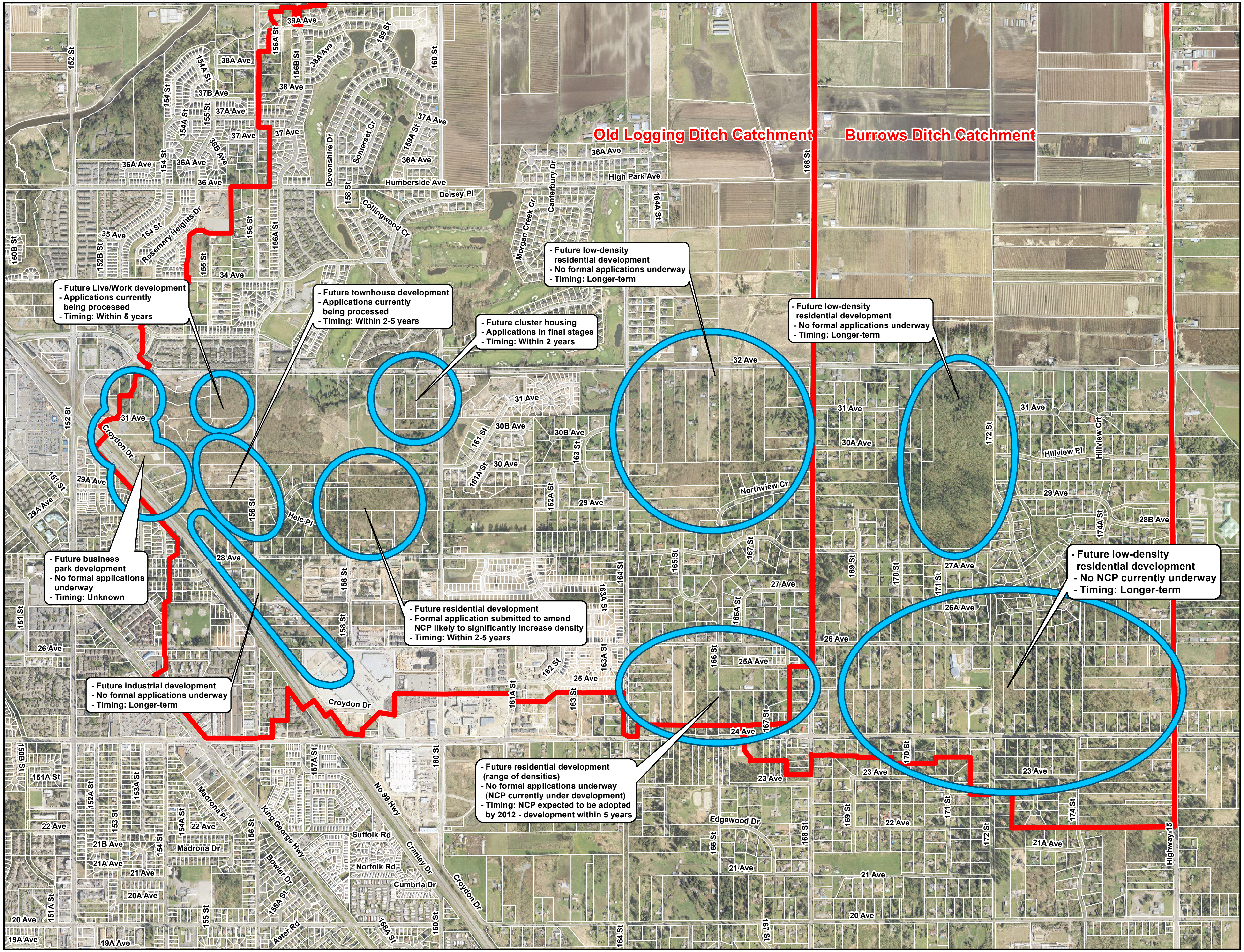
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure06_NeighbourhoodConcept_and_GeneralLanduseP lans.mxd Last updated by: bpauls on September 14, 2011 at 4:10:22 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Areas With Significant Development Potential Figure 7

Legend

Catchment Boundary

Development Potential Areas

N

0 200 400 600 800

Metres

URBANSYSTEMS.

1072.0176.01

As well, the City is currently in the process of updating or developing the following plans that fall within the Study Area:

- **Grandview Heights NCP 5A (from 164 Street to 168 Street between 26 Avenue and 24 Avenue)** – Stage 1 of this NCP has been approved and Stage 2 is expected to be completed by the end of this year (2011) or early next year. NCP 5A plans for a range of residential development, from large lot duplex or single-family lots (2-10 upa) to high-density multi-family development (30-45 upa). This area is expected to begin developing within the next five years.

- **Grandview Heights NCP #2 (Sunnyside Heights)** – The Study Area also encompasses a small corner of the Sunnyside Heights NCP, which was completed in 2010. The Study Area includes most of the NCP's commercial node, which comprises mixed-use residential/commercial uses, and also encompasses a small amount of civic uses (for a water reservoir). It is unknown when this portion of the neighbourhood will develop.

Under full build-out future conditions as described above, the estimated TIA fraction is 47.9% and 38.6% for Old Logging Ditch and Burrows Ditch catchments, respectively. Accounting for reduction in "connected" impervious surfaces, the estimated future EIA fraction is 31.0% and 25.2% for Old Logging Ditch and Burrows Ditch catchments, respectively. This accounts for continued requirement to discharging single family residential roof leaders to ground; it does not account for application of any other BMPs or recommendations that will be discussed **Sections 4 and 5** of this ISMP report

Parks and Open Space

The Rosemary Heights Business Park NCP calls for the preservation of riparian areas around Morgan Creek and Wills Brook; however, much of the current green space in this area will be lost to development. The North Grandview Heights NCP also calls for the protection of riparian areas around creeks and includes plans for parks (mix of active and passive) throughout the NCP area. However, only a portion of the stand of mature trees west of 172 Street will be preserved as park space. The North Grandview Heights NCP includes plans for a multi-use corridor along the future Grandview Interceptor (sewer) right-of-way to connect active park space with natural protected areas. See **Figure 6** for future parks and open space.

2.2 Environmental Conditions

With respect to environmental conditions, the Study Area can be generally split between upland (primarily) residential and lowland (primarily) agricultural areas. Aquatic and terrestrial habitats within these two zones are distinctly different. For example, the lowlands are characterized by the presence of numerous constructed linear channels aligned along property lines and roadways, generally with limited riparian vegetation. Most if not all of the ditches in the lowlands north of 32 Avenue are designated Class A or Class A(O) water courses, meaning that fish (both salmonid and non-salmonid) are (potentially) present at all or some times, respectively (see **Figure 8**). Water quality can be poor, especially during the summer when dissolved oxygen may be quite low, and “coarse” fish represent the predominant resident fish. Salmonids tend to use the channels only as migratory corridors to the more desirable upland stream habitat. Terrestrial habitat in the lowlands has also been altered by the presence of agricultural land uses and generally lacks important wildlife habitat.

By contrast, the uplands present a mix of channel types, both natural (or generally so) and constructed (linear ditches mostly along roadways), often with significantly larger riparian vegetation zones than found in the lowlands.

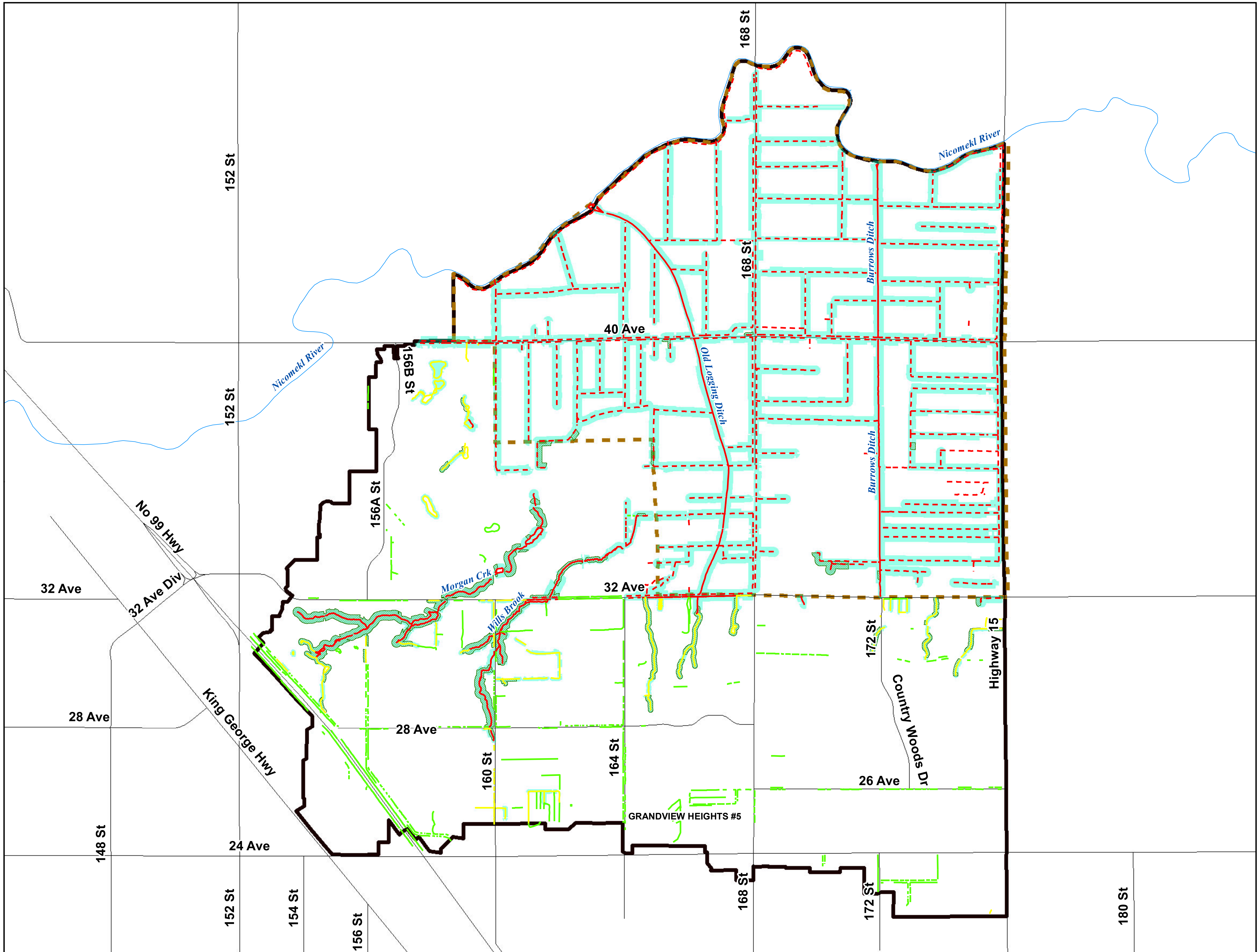
The entire lengths of Morgan Creek and Wills Brook are designated Class A, that is, both salmonid and non-salmonid species are (potentially) present year round. Though perhaps not exhibiting the highest quality habitat, these ditches and creeks represent significant fisheries resources within the City. In general, water quality could be expected to be better here than in the lowlands. Similarly, the terrestrial habitat in the uplands tends to be more intact, providing a greater variety and extent of both hubs and interconnections.

Overall, the health of each catchment and the Study Area as a whole has been somewhat compromised by both upland residential and commercial development and by lowland agricultural land use. Plotting the % RFI vs. % EIA as shown in **Figure 9** indicates that despite these impacts, both watersheds may be experiencing moderate health. It should be noted that the observed B-IBI values may be indicative of impairment in watershed health however. The impacts to habitat are more significantly demonstrated in the lowland agricultural areas where limited riparian vegetation and linear channels generally lacking in complexity provide limited value for important salmonid species. The lack of large contiguous vegetated areas also compromises the value of the lowlands as terrestrial habitat. The uplands, with its more intact riparian vegetation, channels retained on natural alignments, and intact terrestrial hubs with interconnected corridors, provides the best habitat, from both a terrestrial and aquatic perspective, in the Study Area. Focusing on the uplands, which have more intact riparian vegetation, some channels with natural (or near natural) alignments and intact terrestrial hubs and interconnecting corridors, there appear to be excellent opportunities to maintain and / or enhance watershed health through application of appropriate management practices; these are described in **Appendix B**, which contains the environmental report.

CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Watercourse Classification and Riperian Areas Figure 8



Legend

Watercourse

Watercourse Classification

Class A (red-coded):
Year-round salmonid presence.
Non-salmonid species also present.

Class A (O) (red-dash):
Inhabited during overwintering periods by salmonids. Non-salmonid species present year-round.

Class B (yellow-coded):
Provides food and nutrient value to downstream fish populations.
No potential for fish presence.

Class C (green-coded):
No fish presence. Does not provide food or nutrient value to fish bearing watercourses.

Catchment Boundary

Agricultural Land Reserve Boundary

Intact Riparian Vegetation

Riparian Setbacks

N

0 250 500 750 1,000
Metres

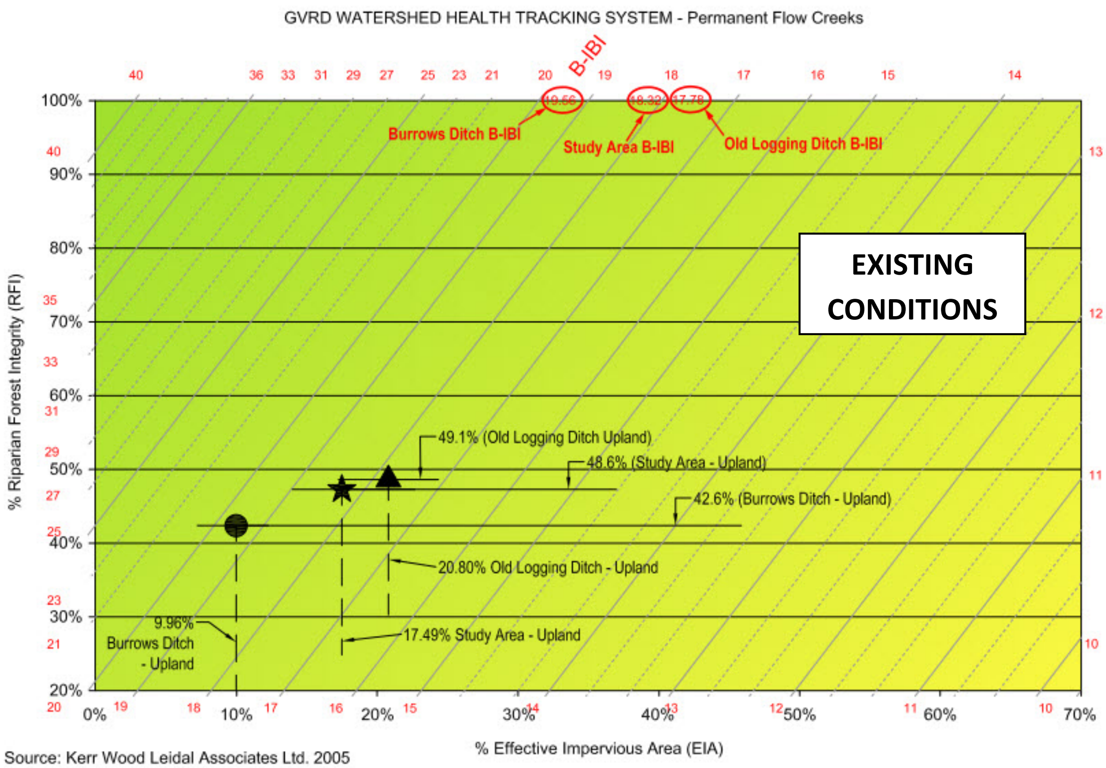
URBANSYSTEMS.

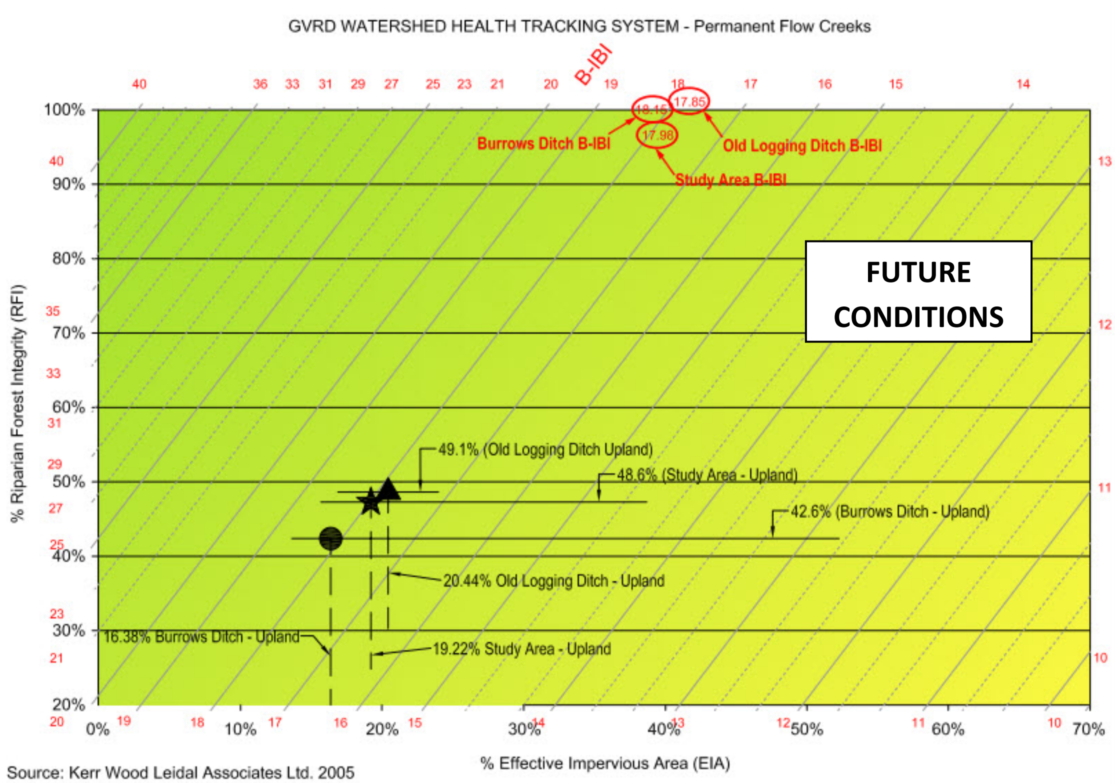
DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure08_WatercourseClassification_and_RiperianAreas.mxd Last updated by: bpauls on September 14, 2011 at 4:38:31 PM

Figure 9: Watershed Health Tracking System





2.3 Water Quality Conditions

2.3.a Instream Conditions

Conventional water quality parameters including temperature, pH, conductivity, dissolved oxygen (DO), and turbidity were measured at 6 locations (4 in the uplands and 2 in the lowlands) across the Old Logging Ditch and Burrow's Ditch watershed. Given the timing of the field assessment (i.e., December), water quality results are not definitive as per the maximum effort outlined in Clause 13 – Water and Sediment Quality Analysis of the ISMP Template. However, conventional water quality parameters for the 6 sampling locations were found to be generally within acceptable guideline levels for freshwater aquatic life (Province of British Columbia, 2006 – see **Appendix B**).

The following was found:

- Temperature readings varied slightly at each of the 6 sampling locations, and were generally found to be quite cool due to the near freezing ambient air temperature at the time of the field assessment.
- Levels of pH measured across the Study Area were found to be slightly acidic, ranging from 6.8 to 5.06. The pH level at Morgan Creek near Morgan Creek Way was found was the lowest of all sites (5.06),below guidelines for freshwater aquatic life. The low pH observed at this location is likely due to the large amount of leaf litter and organic matter present within the wetted portion of the creek during the time of the field assessment.
- Dissolved oxygen levels measured were found to be within recommended levels for salmonid species.
- Old Logging Ditch and Burrow's Ditch displayed similar pH, conductivity, and dissolved oxygen levels. Given that both these ditches are long, wide agricultural drainage channels, similar water quality values are to be expected. Turbidity levels measured for the two channels were similar, with Old Logging Ditch measuring 18.6 NTUs and Burrow's Ditch measuring 13.2 NTUs.

Lowland water quality of the Study Area may directly affect salmonid presence within the lowland and upland regions. During summer months, poorer lowland water quality (high temperatures and low DO) could restrict salmonid occupancy to upland reaches of the Study Area. Low DO, high temperatures, and poor substrate material may also limit spawning and rearing habitat within the catchment (New East Consulting Services Limited, 1996). Non-salmonid species such as threespine stickleback, minnows, and redside shiner can withstand poorer water quality and are common throughout the Study Area's lowland region.

Another factor affecting water quality within the lowland is runoff from agricultural fields which could contain fertilizers and pesticides (ECL Envirowest Consultants Limited, 1994). In addition, water quality could be affected by the withdrawal of water or the introduction of Nicomekl River water by local irrigation districts.

Previous water quality sampling programs concluded the following:

- Many of the small drainage channels within the lowland area displayed poor water quality, with high dissolved oxygen (DO) and temperatures levels (City of Surrey & Dillon Consulting Limited, 2002).

- Established Class A watercourses, including Morgan Creek (in the uplands) and Old Logging Ditch (in the lowlands), were found to have moderate water quality during the 2001 summer sampling program, with good DO levels, but moderate to high temperatures.

2.3.b Runoff Quality

There is no runoff quality data available for the Study Area. A desktop estimation of pollutant loading in stormwater runoff based on land use within the uplands areas only was developed; the results are described in Section 2.8.j. Unless managed, increases in runoff pollutant loadings from the uplands will only exacerbate water quality conditions in the lowlands.

2.4 Hydrogeologic Conditions

Significant investigation of the hydrogeological conditions of the catchments was completed as a part of previous studies, notably the North Grandview Heights NCP, in the late 1990's and early 2000's. These earlier studies were reviewed as part of this ISMP and their general results and understandings were confirmed. In addition, limited site investigations confirmed water course bank and bed conditions.

The general surficial geology of the study area is closely aligned with the topography. Deep deposits of peat, organic silt and silty clay over river sands or sands and gravel characterize the lowlands; shallow to deep deposits of mixed sands, silts and clays underlain by silt and clay characterize the uplands. Although some areas act as aquitards, they generally do not completely inhibit groundwater recharge.

The hydrogeology of the catchments is complex, incorporating a number of perched aquifers and a significant deep aquifer, with upland recharge and lowland discharge. The deep aquifer is likely connected with the major regional White Rock aquifer which lies west of the area. Groundwater flow is predominantly to the north-north east, with discharge to the lowlands. This is evident from the number of reported artesian wells generally lying close to 32 Avenue, which roughly coincides with the uplands-lowlands boundary. Infiltrated runoff in the upland areas will supply the recharge zone of either or both the shallow and deep aquifer systems, depending on local soil permeability and percolation potential.

As shown on **Figure 10**, the soils in the uplands areas are generally well drained and are potentially suitable for runoff infiltration. The most significant exception is a large contiguous area of poorly drained soils roughly bounded by 166 Street and Highway 15, on the west and east, and by 30 Avenue and 26 Avenue on the north and south; this area is not suitable for infiltration-based stormwater facilities. Other unsuitable areas generally lie at the transition from uplands to lowlands. In these areas, perforated underdrains would be needed with infiltration-based stormwater facilities to prevent surface ponding.

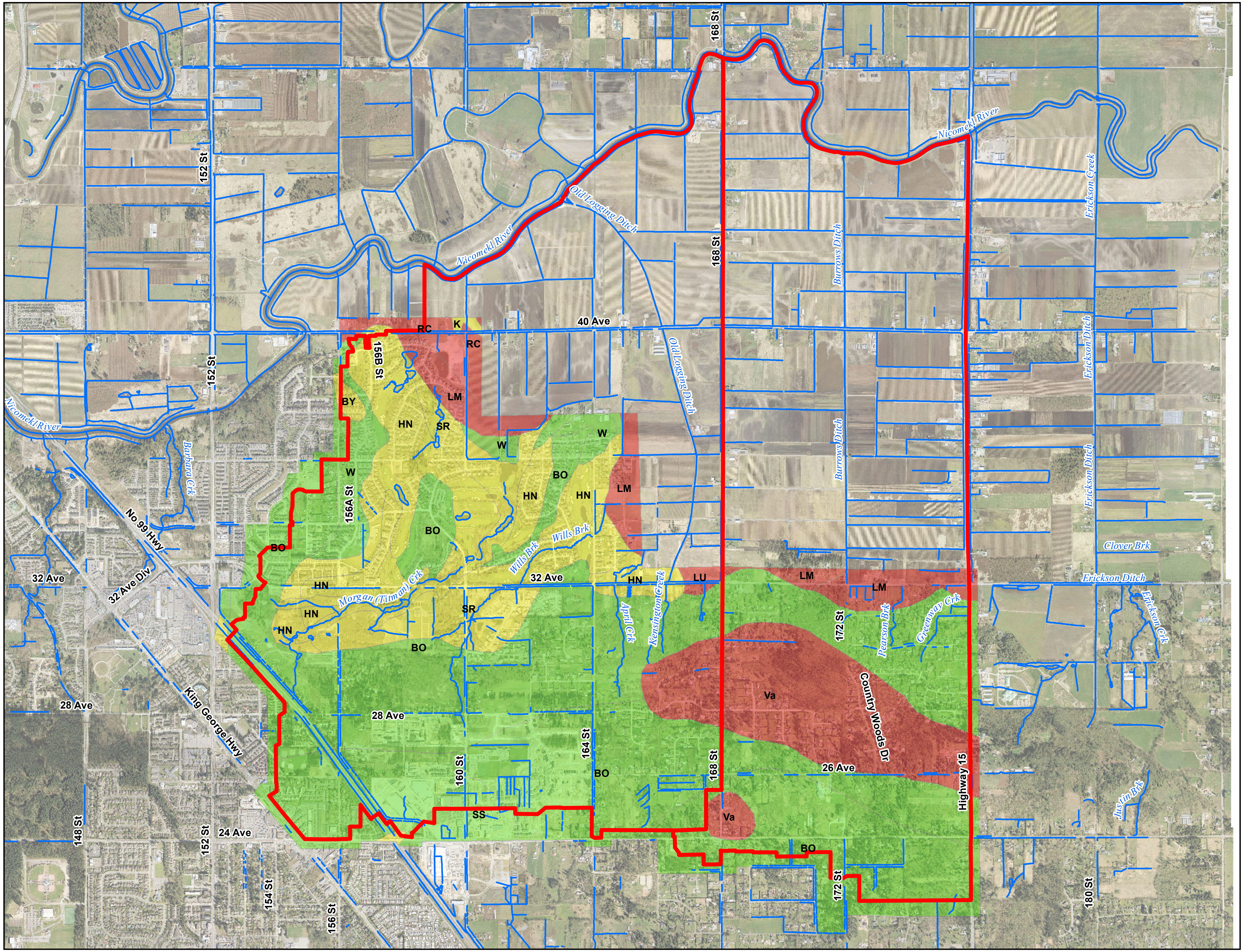
Coupled with assessments made as a part of previous studies, investigation of the creeks at a dozen sites indicates that the creeks do not generally exhibit significant widespread erosion. Some areas of current concern do exist nonetheless, as represented by the several capital improvement projects included in the City's 10-year capital plan.

Based on current understandings, two key conclusions from the hydrogeological and geotechnical investigation are:

- Runoff infiltration, for example from rain gardens, bioswales or subsurface rock galleries, is generally feasible throughout much of the upland areas of the catchments, except in those areas classified as poorly draining (see **Figure 10**); and
- The upland creeks do not exhibit widespread bank instabilities at this time, but could in the future if runoff is not adequately managed.

Site conditions must be confirmed prior to installing infiltration-based stormwater facilities at any specific location within the watersheds. In all circumstances, it is recommended that such systems be located at least 15 metres from top of creek banks to reduce the risk of bank instability.

Appendix D contains a copy of the hydrogeological report.



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Surficial Soils Figure 10

Legend

- Watercourse
- Catchment Boundary

Soil Drainage Conditions*

- Very Poor
- Moderately Well
- Well

* Note: Soil data clipped to hydrology model boundaries.

Soil data source: Soils of the Langley-Vancouver Map Area, 1980, Ministry of Environment.

N

0 250 500 750 1,000

Metres

URBANSYSTEMS.

1072.0176.01

2.5 Drainage System Conditions

This section briefly describes the existing drainage systems serving the Study Area and the drainage systems previously proposed for future development through the City's planning efforts. Analysis of hydrologic and hydraulic conditions and assessment of stormwater management alternatives is discussed in Section 2.8.

2.5.a Existing Conditions

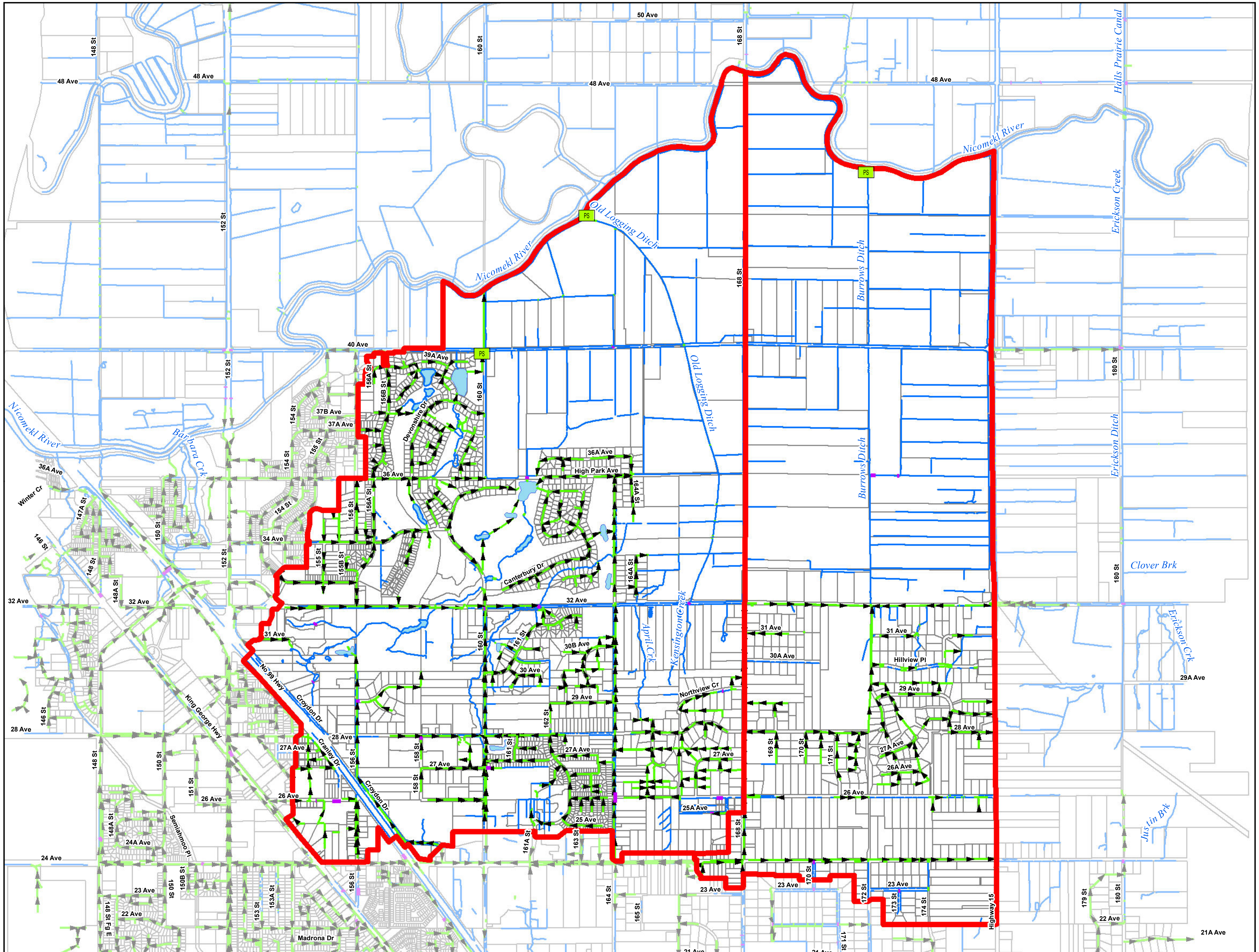
Old Logging Ditch has three primary tributaries: Morgan Creek, Wills Brook, and April Creek. Another creek named West Creek or (Morgan Creek) (New East Consulting, 1996) located on the south side of 40th Avenue discharges into Old Logging Ditch via Morgan Creek. All of these creeks are within the Upland catchments and the average gradient of these creeks lies between 1% and 5%. There are several on-line and off-line ponds located in this catchment. These ponds serve multiple purposes including stormwater detention, irrigation, aesthetics, and aquaculture. Considering the scope of this ISMP, the major focus was on the ponds that provide significant detention. Based on available information, three on-line detention ponds were identified along Morgan Creek and one on-line detention pond with an off-line subsidiary pond was identified along West Creek. The West Creek ponds discharge into the lowlands through a pump station located at the intersection of 40th Avenue and 160th Street.

Compared to the Old Logging Ditch catchment, the Burrow's Ditch catchment has fewer open channels and ditches. Most of the existing development is connected to the City's closed piped system that ultimately discharges into Burrow's Ditch at the lowlands on the north side of 32nd Avenue. No stormwater detention ponds were identified in this catchment.

Figure 11 shows the existing stormwater infrastructure within the Old Logging Ditch and Burrow's Ditch Upland catchments. As shown, all drainage from the uplands areas eventually reached a pump station, one each for Morgan Creek, Old Logging Ditch and Burrow's Ditch; pump is required only when the Nicomekl River is at peak stages.

Appendix E contains a table showing all of the drainage works recommended in the City's 2010-2019 10 Year Servicing Plan.

Figure 12 and **Table 1** identify drainage issues and concerns previously noted in the various NCPs. In the uplands, potential creek sensitivity to erosion and minor flooding in limited areas due to undersized drainage infrastructure were noted as issues; however, the NCPs did not identify any existing major flooding or significant erosion issues in the uplands. In the lowlands, a number of flooding issues were identified, some of which were noted as being caused or exacerbated by upland development and undersized infrastructure.



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Existing Stormwater Infrastructure Figure 11

Legend

- PS Pump Stations
- Culvert
- Mains
- Watercourse
- Cadastral
- Existing Detention Pond
- Study Area Catchment Boundary

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

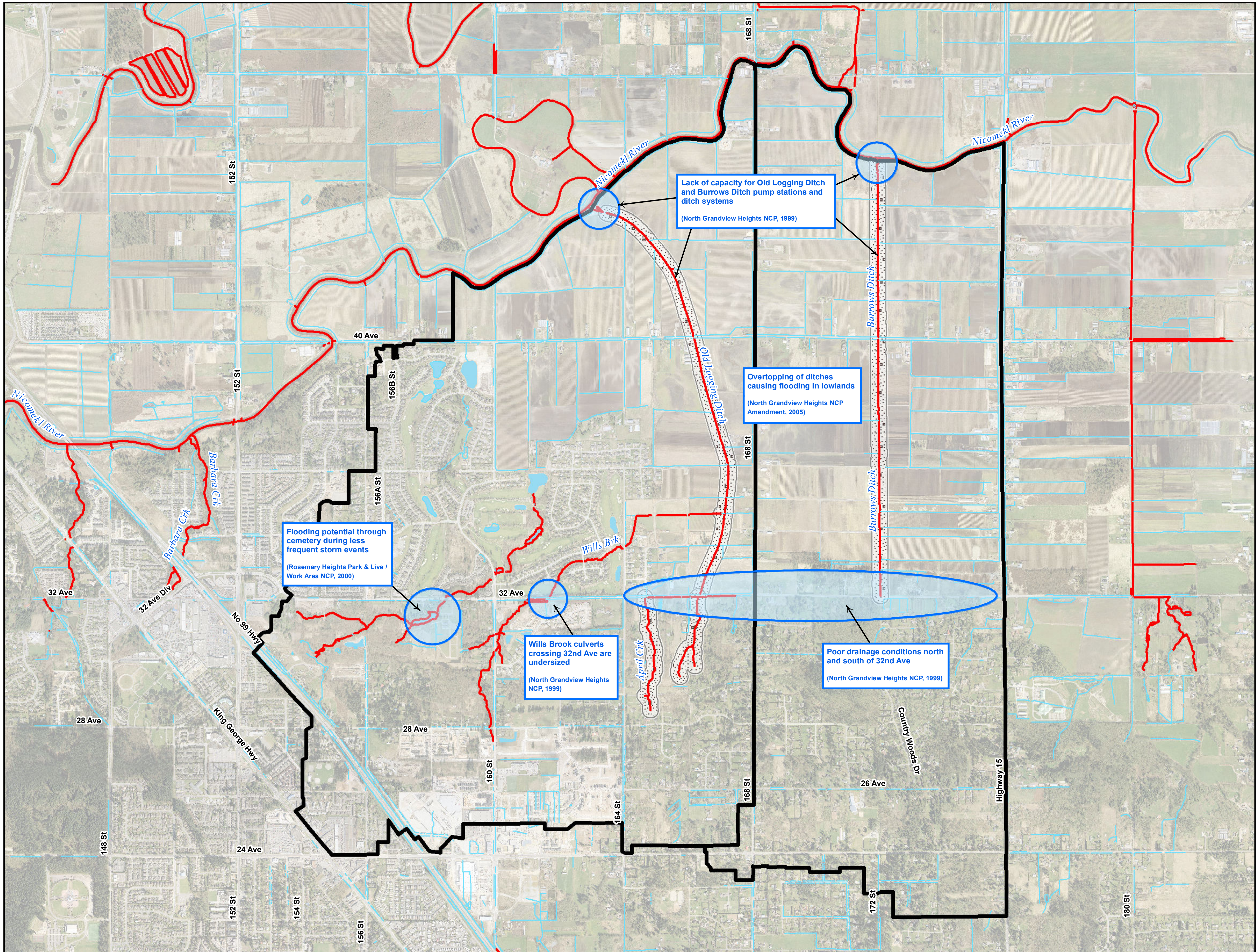
DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure11_ExistingStormwaterInfrastructure.mxd Last updated by: bpauls on September 14, 2011 at 4:59:54 PM

Table 1: Existing Drainage Issues and Concerns (as identified in current NCPs)

Plan or Study	Title	Grandview Heights General Land Use Plan	Grandview Heights #1 (Morgan Heights) NCP	Rosemary Heights Central NCP	Rosemary Heights Park & Live / Work Area NCP	Grandview Heights #5A	North Grandview Heights NCP	North Grandview Heights NCP 2005 Amendment
	Date	2005	2005	1996	2000	2010 (draft only)	1999	2005
Existing Problems or Issues Cited	**Flooding**			• Area subject to tidal fluctuations. • Existing sewer on 152nd Street, between the 32nd Avenue diversion and 34th Avenue, is under capacity for the existing conditions. • Existing sewer on 152nd Street between 36th Avenue to the Nicomekl River is under capacity and required replacement. • Barbara Creek is sensitive to erosion. • Nicomekl River at 40th Avenue is subject to frequent flooding.	• Existing storm sewers on 152nd Street and/or 32nd Avenue experience surcharge and flooding. • Flooding potential through the Gardens of Gethsemani Cemetery under less frequent storm events.		• Flooding in the lowlands located north of the NCP. • Many springs and overland paths. • The capacity of the ditch system and pumping capacities of the Old Logging Ditch and burrows Ditch pump stations are of concern. • Poor drainage conditions south of 32nd Avenue and lowlands. • Wills Brook culverts crossing 32nd Avenue are extremely undersized.	• In the lowlands there is overtopping of the ditches and flooding into the lowlands.
	Watercourse Erosion / Deposition		• Ongoing erosion north of 32 Avenue in April Creek, Wills Brook and its tributaries.	•	• Morgan Creek is sensitive to erosion.		• Wills Brook, Old Logging Ditch, April Creek, Morgan Creek and other upland watercourses have been identified as very sensitive ecosystems to the impacts of increased flow. • Sedimentation of Lowland Ditches. • April Creek and Kensington Creek experience erosion, sedimentation, and long duration lowland flood control.	



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Existing Drainage Issues and Concerns Identified in NCP's Figure 12

Legend

- Watercourse Sensitive to Increased Flow
- Watercourse
- Specific Drainage Issues
- Stream Erosion Noted
- Stream Sedimentation Noted
- Existing Ponds
- Catchment Boundary

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

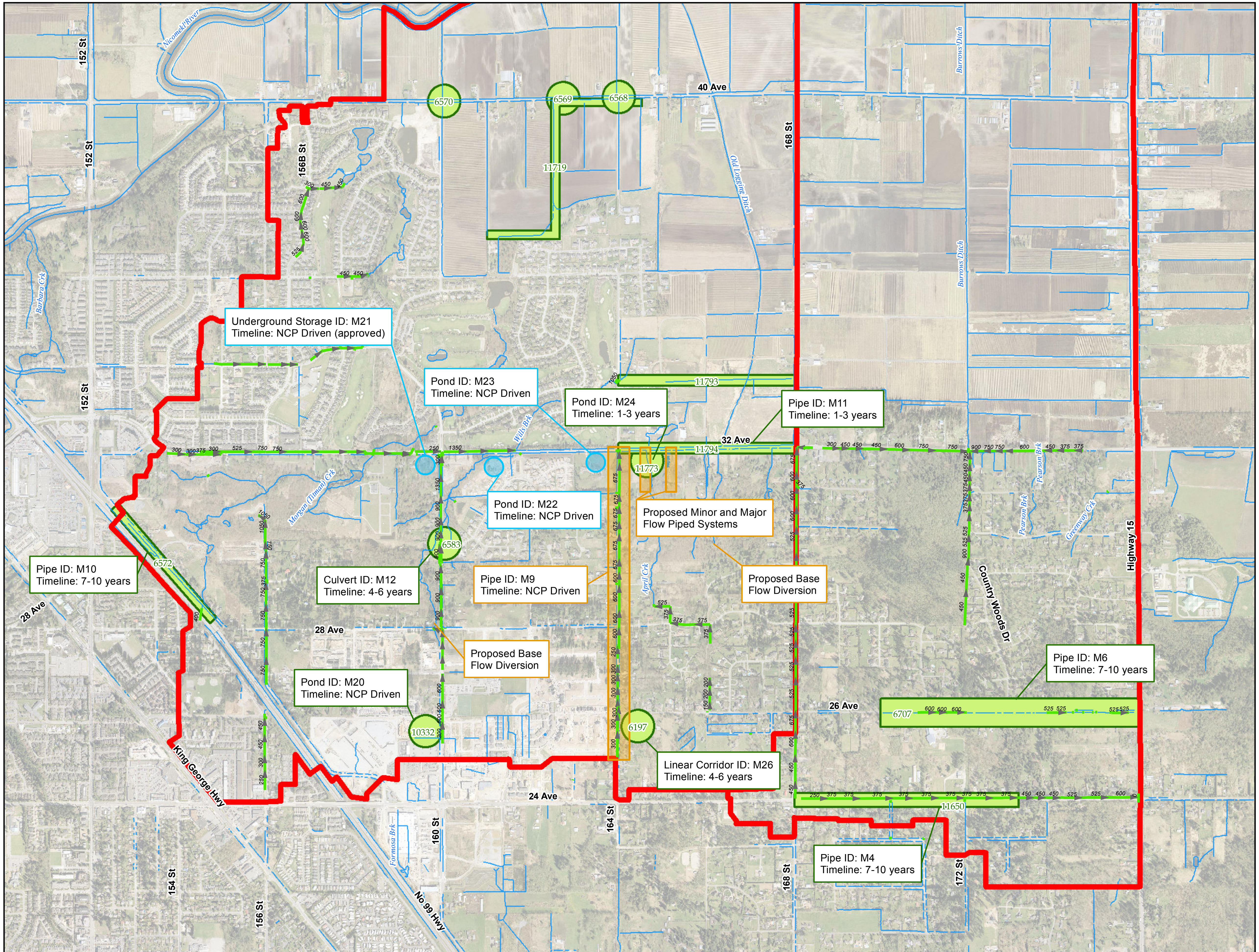
2.5.b Future Conditions

To support future development, the current NCPs and the GLUP have proposed several regional stormwater management measures within the Study Area. These have generally been incorporated in the City's 10-Year Servicing Plan which also identifies planned culvert upgrades, major and minor system upgrades, base flow diversions, erosion and ravine works, and detention ponds. **Figure 13** shows currently proposed drainage infrastructure improvements and **Figure 14** shows currently proposed instream improvements per the NCPs and the 10 Year Servicing Plan.

The NCPs have also included recommendations for use of best management practices (BMPs) and low impact development (LID) measures, such as:

- Disconnected roof leaders for single family residential lots;
- 300 mm topsoil;
- Infiltration trench;
- Green street;
- Reduced road width;
- Bioswales; and
- Reduced lot grading.

It is noted that the City has for quite some time already required disconnected roof leaders on single family residential lots, though staff has indicated that the compliance rate is quite low.



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Previously Proposed Drainage Infrastructure Improvements Figure 13

Legend

Existing Storm Trunk System

Proposed Drainage Infrastructure Upgrades

North Grandview Heights NCP - Pipe Upgrade

North Grandview Heights NCP - Pond/Storage*

City of Surrey 2010 Ten Year Plan - Pipe, Culvert, and Pond/Storage

Catchment Boundary

*Note: Pond locations to be determined.

N

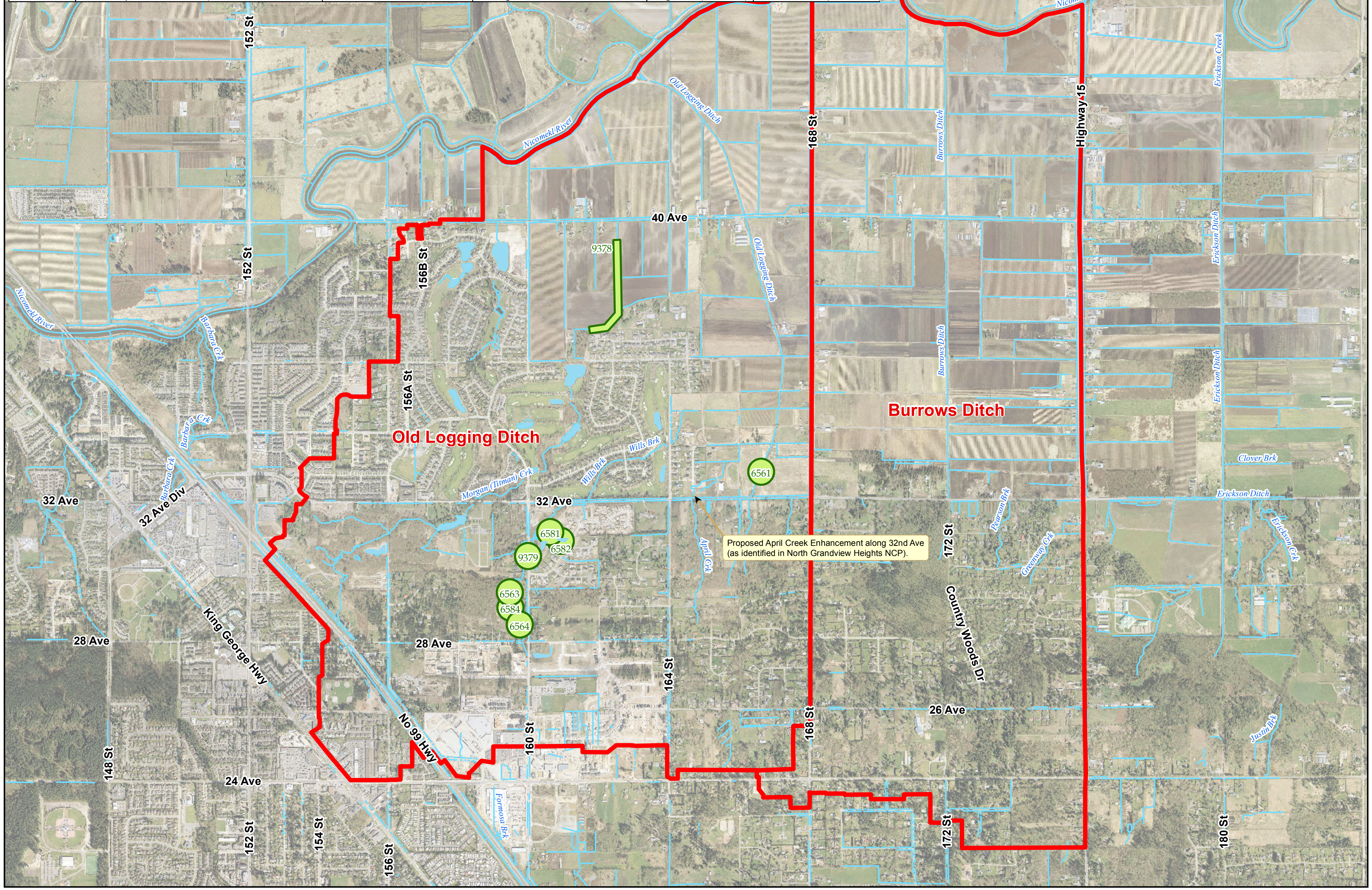
0 250 500 750 1,000

Metres

URBANSYSTEMS.

1072.0176.01

PROJECT NO	PROJECT NAME	PROJECT LOCATION	PROGRAM DESCRIPTION	LRP PRIORITY	NONGROWTH COST	GROWTH COST
6561	Erosion protecton	167 St / 033 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	60000
6563	Erosion protecton	159 St / 029 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	10000
6564	Erosion protecton	160 St / 028 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	10000
6581	Remove stm outall and stablize banks	161 St / 031 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	60000
6582	Remove culvert and stabilize banks	161 St / 031 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	60000
6584	Remove box culvert and stabilize banks	159 St / 029 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	2	10000
9378	2 sites (ID=TTMN-1,2; risk=L)	Titman Creek: 164 St / 040 Ave	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	26002	0
9379	Over-steep bank at 160 St.; (Site ID=TTMN-3; Risk=	near 3024 - 160 St	Drainage - Erosion & Ravine Works	Long Term (7 - 10 Yrs)	9602	0



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Previously Proposed Instream Improvements* Figure 14

Legend

- 2010 Ten Year Plan - Streamworks
- Watercourse
- Catchment Boundary

* As identified in currently adopted NCPs and in the City's 10-year Servicing Plan.

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure14_PreviouslyProposedInstreamImprovements.mxd Last updated by: bpauls on September 15, 2011 at 8:29:09 AM

2.6 Current Policy, Regulations, and Standards

The City has a number of policies, bylaws and guidelines that directly or indirectly provide context and ultimately affect or provide direction for stormwater management efforts in the Study Area. In the paragraphs that follow, several key aspects of these policies, by-laws and regulations are highlighted.

2.6.a Sustainability Charter

The Sustainability Charter is the City's overarching policy document that promotes social, cultural, environmental, and economic sustainability. In terms of stormwater management, the Sustainability Charter encourages the use of sustainable stormwater management practices, reducing imperviousness, controlling erosion and sedimentation, and promoting overall environmental protection. All of these actions are included under the Environmental Sustainability Pillar.

2.6.b Official Community Plan

The City's Official Community Plan By-Law, 1996, No. 12900 sets the overall policy context for the City since all bylaws adopted after the OCP must be consistent with it. In addition to regulating future land use, which is the main purpose of the OCP, the OCP also includes several policies that relate directly to stormwater management and environmental protection. The OCP includes policies to enhance agricultural viability by properly managing water use and drainage. These policies require stormwater runoff from upland areas to be managed in a way that reduces water quality degradation and flooding on lowland agricultural areas. The OCP also includes policies to regulate the stormwater impacts of land development more generally. All land development must properly control sedimentation and erosion, and maintain water quality and natural flow patterns.

2.6.c Drainage Design Standards

The City's "Design Criteria Manual" (May 2004) provides the basis for drainage (and stormwater) design throughout the City. For example, pertinent to stormwater management, general infrastructure servicing requirements are listed in the Manual's Table 2.1 and standard pavement and sidewalk widths are shown in Table 2.2 of the Manual (with alternative standards shown in Table 2.3), by land use zone in all cases. Most upland areas within the Old Logging Ditch and Burrow's Ditch catchments are zoned residential or commercial, and thus must meet the drainage system requirements specified in the Manual.

The basic servicing objectives specified in the Manual are:

- Provide minor system conveyance capacity for up to the 5-year frequency storm event
- Provide major system conveyance capacity for up to the 100-year frequency storm event, to minimize damage to life and property

- In water courses where erosion is an issue, apply attenuation of peak flows to the more restrictive of:
  - Reducing the 5-year frequency post-development peak flow to 50% of the 2-year frequency post-development peak flow; or
  - Reducing the 5-year frequency post-development peak flow to the 5-year frequency pre-development peak flow.
- Maintain a flood control and drainage system in lowlands to satisfy ARDSA standards.

Other critical servicing objectives include:

- Protect properties from flooding due to the 100-year frequency peak flow (200-year frequency peak flow in major floodplains, such as the Nicomekl River)
- Protect properties, both private and public, from groundwater emergence due to development

2.6.d Erosion and Sediment Control By-Law

Since 2006, the City has had an erosion and sediment control (ESC) by-law (By-Law No. 16138), regulating activities during construction that could affect the City's drainage system including its streams. The key prohibition is that sediment or sediment-laden water may not be discharged into the City's drainage systems at greater than 75 mg/L of Total Suspended Solids (TSS) (Part II, Section 1 of the By-Law). For small-scale construction (less than 2,000 m^2), this target must be satisfied and best management practices (BMPs) must be used as a means to satisfy the prohibition. For larger-scale construction (greater than 2,000 m^2), an ESC permit application must be made (though it can be waived by the City) that provides details that will lead to meeting the performance target. "Construction" as used in the by-law applies to construction of buildings as well as on-site landscaping work; in other words, any work that could generate soil erosion and potentially yield sediment in the City's drainage systems.

Vegetation cover is a natural stormwater control, minimizing wash-off of sediment in streams and storm sewers. The ESC By-Law recognizes this and requires the use of BMPs, specifically, the retention of existing vegetation and ground cover "where possible" and revegetation of disturbed areas "as soon as practically possible".

While this by-law specifically applies to construction-related activities, it nonetheless could be seen as a minimum unofficial target for post-construction runoff discharges as well.

2.6.e Building Bylaw

By-Law 9011 (adopted in 1987), commonly called the "Building By-Law", contains several provisions particularly pertinent to runoff management. Three key items related to site drainage (Section 24 of the By-Law) are noted. First, when the City's Building Inspector designates a site for "zero increase in runoff", the owner must install and maintain *"for all times"* on-site retention systems. Second, when fill is placed on a site, measures must be taken to prevent runoff from discharging on adjacent properties. Third, unless approved by the City's Building Inspector, roof leads ("rainwater leaders") must discharge to a splash pad at grade and *not* into a weeping tile or a main storm discharge system.

2.6.f Tree Protection By-Laws

The City has two tree protection bylaws. Tree Cutting Bylaw 1979, No 5835 prohibits cutting, removing, breaking, injuring or in any other way destroying or damaging any tree, shrub, plant, turf, sod, or flower on City property without the City's authorization. The City's other tree protection bylaw, Tree Preservation Bylaw 2006, No. 16100, applies to all areas of the City and prohibits the cutting, removal, and damage of trees that are listed as protected without a permit. "Protected trees" include, among others, specific species, trees of a certain size (with a diameter at breast height of 30 centimetres or more), as well as specimen quality trees.

2.6.g Stormwater Drainage Regulation and Charges By-Law

The City's Stormwater Drainage Regulation and Charges By-Law, 2008, No. 16610, is a key regulatory tool for drainage and stormwater management within the City, specifying the conditions under which connections and discharges can be made to the City's drainage system (including ditches and streams, along with detention ponds, pumping stations and the like). It includes provisions related to floodplain management, on-site stormwater management, cost recovery for drainage works, prohibited discharges, and inspection and monitoring requirements. Several pertinent provisions are noted here:

- Fill placement or movement on a property must not interfere with ground drainage patterns or induce flooding without authorization.
- On-site stormwater management facilities are required on newly created land parcels when prescribed in neighborhood plans, master drainage plans, ISMPs or servicing agreements. The owner of the property where an on-site facility has been installed must (1) ensure that it is accessible, (2) maintained in good condition and (3) functions as designed. Further, for commercial and industrial properties, proof of maintenance or operation reports must be submitted for approval at the time of issuance or renewal of a business license.
- Facilities to remove grease, oil and sand are required on the building drains from all commercial, industrial and multi-family sites. The facilities must be located so as to be readily and easily accessible for cleaning and inspection, and the owner must maintain them in operable and functional state. The City may prescribe maintenance requirements (manner; frequency) and may require periodic proof of maintenance from the owner.
- Discharge to the City's drainage system of prohibited or hazardous wastes (as defined by the *BC Environmental Management Act*) and of sediment or sediment-laden water is prohibited (see also Section 2.6.d, ESC By-Law). Discharge to the City's drainage system of "anything that contravenes" the Federal Fisheries Act is also prohibited.

- A connection charge is imposed and levied on new connections to the drainage system. Further a drainage parcel tax is imposed and levied on all parcels of land which are directly or indirectly serviced by the City's drainage system; the magnitude of the tax is in part a function of each property's land use category as set in the City's Drainage Parcel Tax By-Law, 2001, No. 14593.
- Penalties are described for violations of the By-Law, with fines of $100 to $10,000 possible; further, each day a violation persists, may be considered a separate violation. In some cases, service may be shut off.

2.6.h Subdivision and Development By-Law

Regulation of development within the City is accomplished through the Surrey Subdivision and Development By-Law. With respect to stormwater, it defines the level of service expected within the City, as well as providing mechanisms for funding of those aspects of servicing that are better done on a neighborhood or regional basis, such as construction of large stormwater detention ponds. Some key provisions that affect or could affect stormwater management include:

- Requires a developer, if so directed, to prepare a stormwater control plan (Part II, Section 10(i))
- Requires a developer, except in certain circumstances or when cash-in-lieu is allowed, to dedicate to the City 5% of the land as parkland (Part III, Sections 13 through 15)
- Requires a developer, if so directed, to set aside and convey to the City land and facilities to provide for detention storage, when so directed by the City (Part V, Section 25(a))
- Provides that detention facilities, if compatible, may be located with other public recreation facilities (Part V, Section 25(b))
- Establishes drainage service requirements for all land uses within the City; allows use of open drainage systems and/or French drain systems in certain areas and requires use of open shallow swale drainage systems in the West Panorama Ridge neighborhood (Schedule A, Table 1)
- Establishes standard pavement widths and number of sidewalks for various road classifications, for all land uses within the City (Schedule A, Tables 2 and 3 of the Subdivision and Development By-Law)

2.7 Opportunities and Constraints

Though there is a significant amount of development present in the Study Area uplands (TIA about 32% and 16% in Old Logging Ditch and Burrow's Ditch upland areas, respectively), nonetheless there is also a fair amount of both riparian and non-riparian forest areas and of reasonably healthy natural water courses. This suggests the possibility that maintenance and enhancement of catchment health may be possible, through application of targeted management tools and implementation of a variety of stormwater controls.

Using the existing conditions reviews as a springboard, a list of potential opportunities for stormwater management in the Study Area was generated. **Table 2** shows these opportunities along with a list of some of the challenges or constraints that may hinder the implementation of those opportunities. The viability and effectiveness of these opportunities were explored as part of Stage 3.

Table 2: Opportunities and Constraints

Opportunities	
• Allow density bonuses for implementing LID • Construct fish friendly pump stations at Old Logging and Burrow's Ditches at Nicomekl River • Create public parks and natural amenities; integrate with natural stormwater features • Daylight storm sewers in uplands (primarily Burrow's Ditch catchment) • Design all storm features to also be public amenities • Encourage (or perhaps require) use of pervious materials for parking lots • Encourage use of green roofs • Enhance stormwater infiltration, where appropriate • Establish strong public education program; provide signage re: environment/stormwater management • Implement fish habitat protection program - make this a feature of the catchments • Improve or optimize detention pond performance, esp. for water quality control • Improve riparian corridors through lowlands - Old Logging and Burrow's Ditch • Improve water quality in creeks • Improve/ create fish access along Morgan Creek (confirm location of all barriers) • Install instream enhancements (Morgan Creek upstream of 32nd Avenue) • Set aside 6-8% of land for stormwater management • Undertake terrestrial and aquatic enhancements to lower Morgan (Titman) Creek • Undertake stream restoration work in uplands	• Provide incentives to install absorbent landscaping and trees on existing developed lots • Provide municipal water supply (to reduce groundwater removal) in areas still relying on wells • Reconfigure roads as "green" during re-development • Reconstruct (or confirm reconstruction) of Wills Brook • Reduce long-term creek erosion through volume control measures • Reduce storm drain installation; replace with ditches • Removal / enhancement at Morgan Creek - barrier removed at cemetery pond • Remove fish barriers in all Class A watercourses in Study Area • Require 200-300 mm (min.) amended topsoil for all new development • Require disconnected roof leaders and encourage installation of rain barrels • Restore riparian habitat on golf course • Retain riparian setbacks at Morgan Creek & Wills Brook; also enhance size of setback where possible • Limit removal of trees during construction; require greater number of replacements • Link wildlife corridors • Promote increased cluster development / limit development • Preserve large wooded area near 32nd and 172nd as an intact wildlife hub. (Possibly purchase land for park creation.)
Constraints	
• ALR designation may constrain enhancement strategies in the lowlands • Enhancements within golf course site may not be well-received by the golf course owners • Established land use plans may limit possibilities; significant land use/servicing changes would require an NCP amendment • Difficulty of obtaining insurance liability for green roofs • Lack of authority (or appropriate regulations) to impose retroactive actions on existing development • Limited financial resources to implement recommendations; particularly limited sources of revenue to remediate existing issues • Long-term maintenance issues - Who is responsible? Frequency of required maintenance? Cost? • Need compelling reasons in order to impose new land use regulations that limit development • Often difficult to quantify the benefits of some recommendations	• Opposition to any new development in some cases • Opposition to retroactive measures on private property • Possible topographic constraints upstream, limiting fish access • Potential loss of development potential; unsupportive development community • Potentially difficult to argue for "working backwards" with daylighting and restoration • Private land ownership • Some areas not suitable for infiltration-based BMPs • Unsupportive residents • Challenges to acquire adequate ROW for stream corridors

2.8 Hydrologic and Hydraulic Analysis

This section of the ISMP report briefly describes the hydrologic and hydraulic analysis that was undertaken and presents the pertinent results. **Appendix C** provides a fuller description of the modeling process including details such as model assumptions, soil infiltration rates and boundary conditions; the appendix also contains a complete set of hydrograph plots to illustrate the results which are summarized in this section.

Typically analysis is performed on "pre-development" and "post-development" land use conditions then scenarios are applied to the post-development condition from which recommendations for a drainage or stormwater management strategy are drawn. Through discussion with City staff, it was determined to use the existing land use conditions in lieu of pre-development conditions.

As noted previously, the Study Area has developed to date under the guidance of a series of NCPs and a GLUP that have recommended significant stormwater controls; unless altered by this ISMP, new development within these areas will continue to occur under the guidance of the adopted NCPs, applying the previously recommended controls. Thus, through discussions with City Staff, it was determined to focus the ISMP's post-development analysis on assessing whether these previously implemented and recommended controls can be expected to work as anticipated. Once that was accomplished, the modeling was used to confirm or update trunk sewer and culvert sizing, as well as to establish Study Area-wide minimum base flows for watercourses and maximum release rates for properties.

Modeling was accomplished with the MIKE SHE software package. MIKE SHE is a physically-based, 2-dimensional hydrologic model with distributed parameters. MIKE SHE simulates overland flow, groundwater flow, interception and infiltration, evapo-transpiration and unsaturated surficial soil flow. It conceptualizes the watershed as a series of individual grid cells, with each cell capable of accommodating different land uses, elevations, soils types, vegetation types and climate parameters. Rain, snow and mixed rain/snow events can be modeled. MIKE SHE was used in the analysis to allow assessment of the interactions of surface and sub-surface flow which drive long-term flow conditions in watercourses and broad-scale assessment of the use of BMPs, including source controls and detention ponds. Watercourses, pipes and related hydraulic structures were modeled with an associated model called MIKE 11.

The modeling boundary covers the entire uplands area; the lowlands that form the northern part of the Old Logging Ditch and Burrows Ditch catchments were not modeled as a part of this ISMP.

The model was calibrated to flow records from the Morgan Creek Pump Station, which serves a well-established and nearly fully developed section of the Study Area. Unfortunately, only very limited data was available for much less developed sections of the Study Area, sufficient to use only as a basic check on the calibration that was able to be done. This model can be considered sufficiently accurate for purposes of an ISMP; comparison of results will be more reliable than absolute result values.

2.8.a Land Use Scenarios

As noted in the previous section, the modeling analyzed two land use scenarios:

- **Existing Conditions** – Existing land use (based on current zoning information and aerial photography); and
- **Future Conditions** – Land use as proposed in the various NCPs and the Grandview Heights GLUP.

2.8.b Design Storms

A range of design storm events plus a continuous precipitation series of ten years were simulated for the ISMP analysis. The design storm events cover the various requirements and considerations of the City's design guidelines:

- 2-year recurrence design storm (various durations to 24 hours);
- 5-year recurrence design storm (various durations to 24 hours);
- 100-year recurrence design storm (various durations to 24 hours);
- 10-year, 5-day winter season storm(ARDSA); and
- 10-year, 2-day growing season storm (ARDSA).

The design storms were combined with two different soil moisture conditions (winter saturated conditions; summer average saturated conditions) and a single set of downstream boundary conditions (average levels in all creeks; average tide level in the Nicomekl). **Appendix C** provides additional details.

2.8.c Stormwater Management Scenarios

The following five stormwater management scenarios were modeled in order to assess the impact of various stormwater measures recommended by NCPs and the GLUP.

- **Existing Conditions** – Existing stormwater management measures as follows:
  - On-line and off-line detention ponds as currently installed; and
  - Disconnected roof leaders for 50% of existing single family residential lots.
- **Future Conditions (Scenario IIa)** – In addition to the existing stormwater management measures, the following measures were applied as previously proposed in the various NCPs/GLUP; as will be discussed this is the recommended management approach of this ISMP:
  - Off-line detention ponds;
  - Disconnected roof leaders for 100% of the new single family residential lots;

- Multi-family, commercial and industrial lots served by on-site source controls; and
- Absorbent topsoil (300mm) for lawns and boulevards.

- **Future Conditions (Scenario IIb)** – The following stormwater management measures as proposed in the various NCPs/GLUP; this scenario demonstrates the impact of poor compliance to the requirement to discharge roof leaders to ground:
  - Off-line detention ponds;
  - Disconnected roof leaders for 50% of the single family residential lots;
  - Multi-family, commercial and industrial lots served by on-site source controls; and
  - Absorbent topsoil (300mm) for lawns and boulevards.
- **Future Conditions (Scenario IIc)** – The following stormwater management measures as proposed in the various NCPs/GLUP; this scenario demonstrates the impact of not using absorbent topsoil on lawns:
  - Off-line detention ponds;
  - Disconnected roof leaders for 100% of the single family residential lots;
  - Multi-family, commercial and industrial lots served by on-site source controls; and
  - No absorbent topsoil**.**
- **Future Conditions (Scenario IId)** – The following stormwater management measures as proposed in the various NCPs/GLUP; this scenario demonstrates the impact of eliminating detention ponds:
  - No Off-line detention ponds
  - Disconnected roof leaders for 100% of the single family residential lots;
  - Multi-family, commercial and industrial lots served by on-site source controls; and
  - Absorbent topsoil.

2.8.d Results for Stormwater Management Scenario Modeling

Peak Flows in Watercourses: Table 3 shows the computed peak flows in five locations around the Study Area. The locations were chosen to capture flows from the areas which will undergo new development in the future. 1-hour duration storm results are shown for the 2-year, 5-year and 100-year recurrence design storms. **Appendix C** provides a full set of hydrograph plots for all design storm events that were modeled.

Table 3: Comparison of Peak Discharges for Stormwater Management Scenarios

	Peak Discharge for Short Duration (1 hour) Design Storms (in m^3/s)														
	2-Year Storm					5-Year Storm					100-Year Storm				
Management Scenario	Existing	IIa	IIb	IIc	IId	Existing	IIa	IIb	IIc	IId	Existing	IIa	IIb	IIc	IId
Morgan Creek U/S of 32 Avenue	0.65	0.69	0.69	0.83	0.69	1.06	1.10	1.10	1.33	1.10	2.33	2.28	2.28	2.80	2.28
Morgan Creek D/S of 32 Avenue	0.84	0.93	0.93	1.17	0.93	1.43	1.51	1.51	1.88	1.51	2.82	2.78	2.78	3.12	2.78
Wills Brook D/S of 32 Avenue	0.78	0.42	0.42	0.57	0.61	1.26	0.80	0.80	0.94	1.07	2.76	2.09	2.09	2.50	2.36
Old Logging Ditch D/S of 32 Avenue	1.21	0.78	0.91	1.46	0.85	1.87	1.33	1.65	2.05	1.39	4.26	3.32	3.52	5.02	3.30
Burrow's Ditch D/S of 32 Avenue	0.60	0.30	0.38	0.90	0.30	0.93	0.45	0.55	1.33	0.45	2.04	1.09	1.24	2.94	1.09

NOTES: Cells with values less than "Existing condition" are highlighted; lowest values for "Future condition" are underlined.

Stormwater Management Scenarios:

Scenario:	Detention Ponds?	Single Family Residential Roof Leader Disconnect Rate	BMPs for All Multi-Family, Commercial and Industrial Land Uses?	Absorbent Topsoil for Lawns?
IIa	Y	100%	Y	Y
IIb	Y	50%	Y	Y
IIc	Y	100%	Y	N
IId	N	100%	Y	Y

The effect of different Best Management Practices and/or Low Impact Development measures on the stream flows is clearly evident in the flow hydrographs. However, the extent of impact varies depending on the proposed land use changes in the contributing areas. For example, absorbent topsoil seems to be the most effective measure in mitigating the impact of future development in the Old Logging Ditch and Burrow's Ditch watersheds. The Morgan Creek and Wills Brook subwatersheds are nearly built out and opportunity to apply topsoil and disconnected roof leaders is limited. Therefore the incremental benefit is not as apparent, for these subwatersheds as they are in the remaining subwatersheds in the overall study area. The majority of the proposed NCP ponds are located in the Wills Brook watershed. Thus, the effect of ponds in reducing the peak flows is clearly evident in this subwatershed.

Maximum Runoff Volumes: Table 4 shows the computed runoff volumes at the same watercourse locations noted for peak flows. Generally longer duration storms yield larger runoff volumes; thus, 24-hour duration design storm results are shown on this table.

Table 4: Comparison of Total Runoff Volumes for Stormwater Management Scenarios

	Peak Discharge for Long Duration (24 hour) Design Storms (in m^3)														
	2-Year Storm					5-Year Storm					100-Year Storm				
Management Scenario	Existing	IIa	IIb	IIc	IId	Existing	IIa	IIb	IIc	IId	Existing	IIa	IIb	IIc	IId
Morgan Creek D/S of 32 Avenue	31,000	28,080	28,080	31,230	28,080	30,680	30,620	30,630	33,960	30,630	51,010	47,290	47,290	51,400	47,290
Wills Brook D/S of 32 Avenue	29,850	27,540	27,540	29,340	27,630	30,110	28,690	28,690	30,580	28,790	46,840	43,950	43,950	43,060	44,040
Old Logging Ditch D/S of 32 Avenue	33,270	36,060	37,800	44,000	36,530	46,100	39,400	41,920	47,920	39,380	65,620	58,170	62,140	68,020	59,870
Burrow's Ditch D/S of 32 Avenue	18,840	16,460	17,650	22,960	16,460	24,270	18,370	19,780	24,950	18,370	33,900	27,680	29,920	34,720	28,680

NOTES: Values rounded to nearest 10 m^3

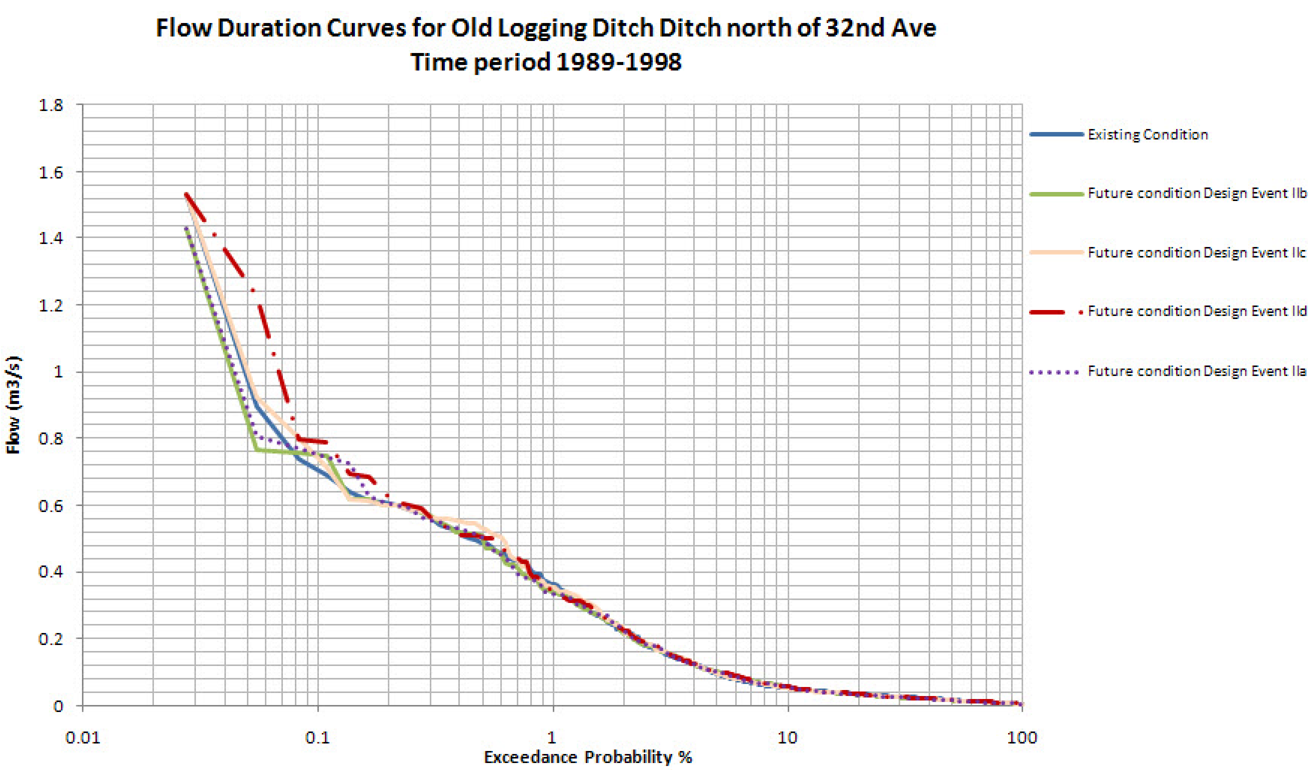
Cells with values less than "Existing condition" are highlighted; lowest values for "Future condition" are underlined

Stormwater Management Scenarios:

Scenario:	Detention Ponds?	Single Family Residential Roof Leader Disconnect Rate	BMPs for All Multi-Family, Commercial and Industrial Land Uses?	Absorbent Topsoil for Lawns?
IIa	Y	100%	Y	Y
IIb	Y	50%	Y	Y
IIc	Y	100%	Y	N
IId	N	100%	Y	Y

The peak runoff volumes from the proposed developed sites are expected to increase if no mitigation measures are undertaken. However, with the NCP proposed ponds and LIDs, future flows are reduced close to the existing condition. As observed, 'disconnected roof leaders' alone cannot reduce the impact of future development. The implementation of 'absorbent topsoil' or similar measures is required to mitigate future development impacts on the streams.

Long-Term Impact on Watercourses: One way to assess the long-term impact of changes in hydrology on a watercourse is to perform a flow duration analysis. For the ISMP, 10 years of rainfall data was used to simulate 10 years of stream flow. The resulting data is plotted as a flow duration curve to show the percentage of time that flow is equal to, or less than, various values. Assuming that the reference condition represents a relatively healthy aquatic system then, ideally when stormwater management controls are applied, the flow duration curve will change very little from that of the reference condition. The flow duration curve for Burrow's Ditch is shown here; the results for the other watercourses (Morgan Creek, Wills Brook and Old Logging Ditch) are very similar. The curves for all five locations are in **Appendix C.**



In general, the positive benefit of BMP/LID in preserving base flows and maintaining the peak flows close to existing condition is clearly evident in the flow duration curves. It is also observed that for less frequent but high flow events, reliance on traditional detention ponds without LID cannot mimic the flow duration pattern of the existing development condition. Despite the limited application of onsite LIDs (disconnected roof leader and absorbent topsoil), in future, modeling suggests that the streams within the Old Logging Ditch and Burrow's Ditch watersheds will be capable of maintaining the flow condition close to existing conditions.

Recommended Management Scenario: The following conclusions are drawn from the assessment:

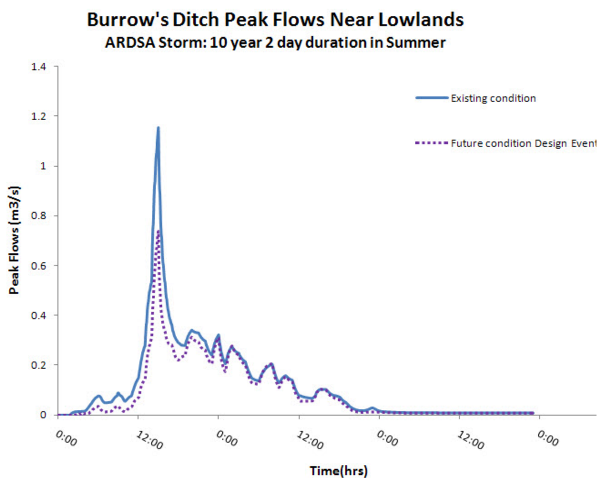
- Discharge of roof leaders to ground is an effective method of stormwater management, particularly for small storms; while a 50% compliance rate appears to still provide significant benefits, full benefits are not realized without a higher compliance rate.
- Installation of absorbent topsoil (300mm) in residential lawns and boulevards is a very effective method to reach stormwater management goals.
- The stormwater management servicing plans, as recommended by the various NCPs and GLUP within the Old Logging Ditch and Burrow's Ditch catchments are able to satisfy City design guidelines as long as low impact on-site controls are applied to all properties.

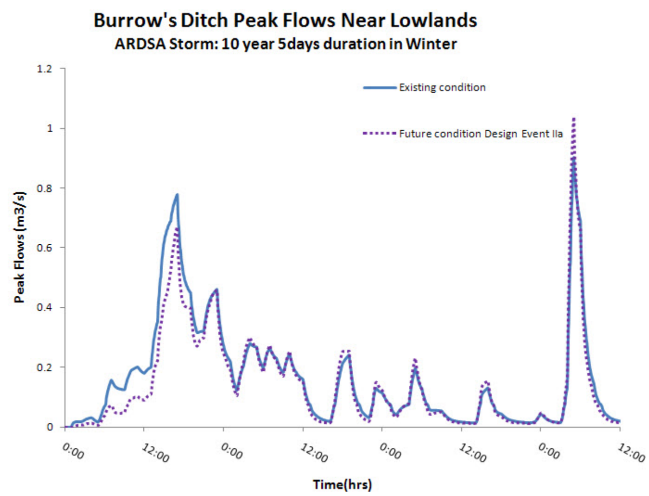
On balance, we recommend the continued application of stormwater Management Scenario IIa within the catchments. This approach places a high premium on on-site source controls. The very simple control represented by installation of absorbent topsoil provides significant benefits and it can be applied easily to single family residential lots, thus eliminating the on-site facilities that such homeowners must maintain.

Using Management Scenario IIa as a base, impacts on lowlands and infrastructure improvements were assessed.

2.8.e Impact of Development on the Lowlands

One of the major concerns with regards to upland development is the potential for increased flooding and erosion in downstream lowlands. According to the City's current drainage policy, drainage in the lowlands should follow the provincial ARDSA (Agri-food Regional Development Subsidiary Agreement) criteria that requires flooding be limited to 2 days during a 2 day 1:10 year summer storm event and 5 days during a 5-day 1:10 year winter storm event. However, the City of Surrey has reduced the 2 days to 1.8 days in the summer. Since the lowlands were not modeled during this study, induced lowlands flooding was evaluated by how well the future hydrographs (Scenario IIa) matched the existing hydrographs. One sample, for Burrow's Ditch, is shown here; plots for all locations (Morgan Creek, Wills Brook, Old Logging Ditch and Burrow's Ditch as they enter the lowlands) are found in **Appendix C**.





The 10 year 2 day summer event hydrographs demonstrate comparatively stronger influence of BMPs/LIDs than the 10 year 5 day winter event. This is expected because in summer, the initial moisture condition of the soil is low and the BMPs/LIDs would response better during a storm event. While in winter, the soil is generally saturated and near the lowlands, the water table is high. Thus, the effectiveness of BMPs/LIDs is less evident compared to summer condition. Nonetheless, all hydrographs are closely matched when the recommended Management Scenario is applied (IIa).

2.8.f Base Flow Estimation

Field measured base flow values were not available for the current study. The hydrogeologic assessment report for the North Grandview Heights areas (Piteau Associates, 1998) previously reported base flows for the West Creek, Morgan Creek, Wills Brook and April Creek. However, the report did not include base flows for Old Logging Ditch and Burrow's Ditch. Therefore, the 10 year simulated flow results (Scenario IIa) were used to estimate the base flows in the watercourses. Low flow conditions during summer are generally the most critical from a fisheries perspective, thus summer flows with 90% exceedance probability or more over the ten year period were considered to represent closely the existing base flows. **Table 5** shows the estimated base flows for the watercourses.

Table 5: Estimated Base Flows (Summer) and Allowable Release Rates

Location	Minimum Estimated Base Flow	Allowable Release Rates	
		2-year Storm	5-Year Storm
Morgan Creek U/S of 32 Avenue	7 L/s	8 L/s/ha	11 L/s/ha
Morgan Creek D/S of 32 Avenue	12 L/s	6 L/s/ha	8 L/s/ha
Wills Brook D/S of 32 Avenue	16 L/s	4 L/s/ha	6 L/s/ha
Old Logging Ditch D/S of 32 Avenue	7 L/s	5 L/s/ha	7 L/s/ha
Burrow's Ditch D/S of 32 Avenue	4 L/s	2 L/s/ha	3 L/s/ha

2.8.g Allowable Discharge Rates

To provide erosion protection in the creeks and flood protection in the lowlands, allowable discharge rates from the sub-catchments in the Study Area were estimated based on the ISMP modeling. Some of the previous NCPs also recommended maximum release rates. The Grandview Heights #1 (Morgan Heights) NCP (2005) and the North Grandview Heights NCP (2005) both recommended a 9 l/s/ha release rate for the 2 year event and 15 l/s/ha for the 5 year event to protect Old Logging Ditch and the lowlands. The Rosemary Heights Park and Live/Work Area NCP (2000) recommended a 7.2 l/s/ha release rate for the 5 year event. **Table 5** shows the proposed allowable release rates.

As the basis for these recommendations, both Provincial and DFO criteria were assessed. The DFO criteria recommends reduction of post development flows to pre-development flows for the 6 month 24 hour, 2 year 24 hour, and 5 year 24 hour precipitation events. The Provincial guidelines recommend storing 50% to 100% of MAR runoff and release at a rate that approximates the natural forested condition. In the present case, the existing condition was considered as the base condition (instead of pre-development condition) and post-development peak flows are restricted such that they do not exceed the existing peak flows for frequently occurring storm events (2 year and 5 year storm events). Generally, the more stringent of the two criteria (Provincial or DFO) became the basis for the recommended discharge rates.

2.8.h Trunk System Capacity

Table 6 shows the estimated existing and future peak flows in the trunk systems of the Study Area, after applying the recommended management scenario (IIa). The peak flows were estimated such that the contributing area at any particular location is close to 20 ha or more. As expected, for most of the areas, future flows increased significantly due to development intensification. Seven (7) trunk systems, all of which currently exist, are identified for upgrading to accommodate the 100-year recurrence design runoff.

Table 6: Evaluation of Trunk Sewer Capacity

Storm Main Location	Main Size (mm)	Capacity (m^3/s)	Existing 100-year Flow (m^3/s)	Future 100-year Flow (m^3/s)	Deficient in Existing Condition?	Deficient in Future condition?	Recommended Upgrade Size (mm)
168 St	675	1.65	2.326	3.037	yes	yes	900
32nd Ave between 176th and 172nd St	900	0.57	0.656	0.822	yes	yes	1050
24THAVE	450	0.35	0.376	0.768	yes	yes	750
166TH ST	525	0.31	0.45	0.798	yes	yes	750
172NDST	750	1.01	1.333	2.688	yes	yes	750
32nd Ave between 172nd St and 168th St	750	0.94		0.4	yes	yes	750
164ST	300	0.28	0.086	0.029	no	no	
164th St	675	2.25	0.15	0.29	no	no	
164th St	900	3.12	0.23	0.37	no	no	
156ST	1050	0.86	0.281	0.283	no	no	
156St	750	0.35		0.267	no	no	
24THAVE	375	0.25	0.166	0.25	no	no	
24THAVE	600	0.80	0.442	1.134	no	no	
166TH ST	375	0.22	0.044	0.114	no	yes	600
160TH ST	600	0.88	0.075	0.075	no	no	
160TH ST	900	5.71	2.05	1.629	no	no	
160TH ST	1350	3.99	2.744	2.219	no	no	
160TH ST (32nd Ave W of WB)	1350	2.39	2.612	1.815	no	no	
168ST	600	0.95	0.531	0.874	no	no	
168ST	525	1.38	0.856	1.234	no	no	
172NDST	450	0.78	0.668	1.247	no	no	
32nd Ave W of Morgan Creek	750	1.79	0.181	0.124	no	yes	1200

NOTE: Trunk sewers deficient for existing conditions are recommended for replacement in near-term (1-5 years); if deficient only for future conditions, replacement is recommended beyond 5 years or when triggered by development.

2.8.i Culvert Assessment

Nine existing culverts were modeled in the hydraulic network. The evaluation of peak flows was conducted for these culverts using the 100-year storm events under the existing and future development (IIa) scenarios. The results of the culvert assessment are summarized in **Table 7**. The simulated stream profiles did not show any overtopping of banks in the vicinity of these culverts; minor localized backwater effect was observed in all cases.

Table 7: Culvert Assessment

Creek Name	Culvert Crossing	Existing Size (mm)	Length (m)	No	Capacity (m3/s)	Existing Peak Flows 100y-1h (m^3/s)	Future Peak Flows 100y-1h (m^3/s)	Adequate for hydraulic purpose?	Recommended Size (mm)
Morgan Creek	32nd Avenue	1050	30.5	1	1.4	2.567	3.036	No	1500
Wills Brook	160th St (North of 161th St)	600	12	1	0.35	0.359	0.482	No	750
Old Logging Ditch	32nd Avenue	1800X1200	19.5	1	3.78	4.252	5.317	No	1800X1500
Burrows Ditch	32nd Avenue	1200	15	1	2	2.02	3.055	No	1500
Morgan Creek	HWY 99	750	120	1	0.6	0.626	0.62	No	900
Wills Brook	32nd Avenue	1800X1200	10	1	3.78	2.909	2.614	Yes	
Wills Brook	Cross Creek Crt.	1350	16	2	5.2	3.065	2.785	Yes	
Wills Brook	164th St	3050X1350	25	1	7.6	3.312	3.021	Yes	
Wills Brook	160th Street (South of 161 St)	750	12	1	0.6	0.145	0.174	Yes	

NOTE: Upsizing may be applied at time of design to provide fish passage capabilities

As shown, five (5) culverts were found to be under capacity and are recommended for upgrade.

2.8.j Surface Runoff Quality

The assessment of stormwater runoff quality for the Old Logging Ditch and Burrow's Ditch watersheds included a desktop estimation of pollutant loading by stormwater runoff based on land use. This includes typical pollutants such as Total Suspended Solids (TSS), Phosphorus, Nitrogen, Fecal Coliforms, Oil and Grease, Zinc (Zn) and Copper (Cu). A screening-level tool was used to assess predicted pollutant loads associated with stormwater runoff and identify future application of treatment practices. The method requires minimal data input, all of which was readily available for this preliminary water quality assessment:

- Drainage (catchment) area(s)
- Impervious cover – % Imperviousness was estimated based on existing and future land use type
- Pollutant concentrations – Event mean concentrations are based on data collated by researchers in the U.S.; we focused on a few pollutants, as representative of the spectrum of potential contaminants in runoff: Total Suspended Solids (TSS); Total Nitrogen; Dissolved Phosphorus; Total Copper; Total Zinc; and Bacteria (specifically, Fecal Coliforms).

To estimate annual pollutant loadings, seven basic land use categories were assigned within each catchment, then pollutant concentrations associated with those land use categories were applied. This method was applied to both existing and future conditions. Considering the land use type of the study catchments, TSS, Oil & Grease, Zn and Cu are selected for demonstrating the potential change in pollutant loading due to development. TSS is often used as the surrogate measure of water quality. High levels of TSS can damage fish and aquatic invertebrates and degrade instream habitat where the material settles onto gravel and cobble substrates. Copper and Zinc are the primary metals of concern because of their adverse impacts on fisheries. Copper interferes with fish sensory systems related to predator avoidance, juvenile growth and migratory success. Zinc alters behavior, blood and serum chemistry, impairs reproduction and reduces growth.

Table 8 shows annual loadings (kg) of TSS, Oil & Grease, Zn and Cu for both existing and future (with and without BMPs) conditions. The increase in pollutant loading for the Burrow's Ditch watershed is quite significant compared to the corresponding increase for the Old Logging Ditch watershed. This is due to the fact that the Burrow's Ditch watershed, which currently has little development, is expected to undergo relatively significant development in the future. In contrast, the Old logging Ditch watershed is nearly built out.

Table 8: Annual Pollutant Loadings

	Annual Pollutant Load (Kg/yr)			
	Total Suspended Solids (TSS)	**Oil & Grease**	**Total Zinc**	**Total Copper**
Existing Conditions	154,060	19,020	263	44
Future Conditions (without application of BMPs)	286,130	36,640	484	80
Future Condition (Scenario IIa)	171,130	19,820	300	51

NOTE: Rounded to nearest 10 Kg if value > 100 Kg and to nearest 1 Kg if < 100 Kg

3 What do we want?

This Section establishes a vision for the catchments, assesses alternative management strategies, and proposes recommendations.

3.1 Vision and Objectives

In the year 2030,

The Old Logging Ditch uplands, where the majority of development is currently located, has been restored; fish are present in the upper reaches of both Morgan Creek and Wills Brook; ravines and stream banks have been stabilized, and the quality of runoff discharging into local watercourses has been significantly improved. In the Burrow's Ditch uplands, which are currently less developed, streams and other existing environmental assets have been protected and enhanced. In the lowlands, agricultural productivity has been preserved through successful stormwater management in the uplands.

In order to fulfill this vision, the following objectives for stormwater management are proposed:

Objective 1: To protect agricultural activity in the lowlands.

Objective 2: To reduce flooding and erosion risks.

Objective 3: To improve the quality of runoff discharging into local watercourses to protect and enhance fisheries values.

Objective 4: To maintain intact riparian areas and, where possible, increase riparian setbacks.

Objective 5: To maintain significant areas of intact wildlife habitat and, where possible, increase wildlife habitat.

Objective 6: To maintain natural amenity uses and, where possible, incorporate amenity values into stormwater infrastructure.

Objective 7: To maintain minimum stream base flows to protect and enhance fisheries values.

Objective 8: To balance the needs of development with environmental values.

Objective 9: To provide stormwater management in a cost-effective manner.

3.2 Proposed Performance Targets

The City of Surrey's Design Manual outlines four basic criteria to be followed by any proposed drainage plan. However, depending on the nature of the development and existing site constraints, these design criteria might have to be modified, resulting in deviations from the City's performance targets. The key aspects of the City's current drainage policy are shown in **Table 9**.

In general, stormwater management measures proposed by the established NCPs and the GLUP follow the City's basic criteria. For the current ISMP, all of the proposed measures were comprehensively reviewed to predict the cumulative impact of upland development on the existing hydrology, aquatic and terrestrial habitat, and last but not least, the lowlands. The general performance criteria used throughout the ISMP analysis are also shown in **Table 9** and reflect the City's current criteria.

Table 9: Design Criteria

Focus Area	City of Surrey Design Manual Criteria	Criteria Used in this ISMP
Minor conveyance system	Design minor conveyance system for 1:5 year storm event	Design minor conveyance system for 1:5 year storm event
Major drainage system	Ensure adequate capacity of major drainage infrastructure for 1:100 year storm event to minimize damage to life and property;	City's criteria plus: • Ensure upstream and downstream areas are not adversely affected by flooding or erosion as a result of upgrading culverts.
Erosion	If erosion is a concern, follow the more stringent of the following: • Control the 5-year post-development flow to 50% of the 2-year post-development rate; or • Control the 5-year post-development flow to the 5-year pre-development flow rate;	City's criteria Note: Since the detention ponds already proposed by the NCPs were found to be adequate, no additional detention ponds were proposed; therefore, these criteria were not re-assesed in this ISMP.
Lowlands	Maintenance of a flood control and drainage system in the lowlands that meets provincial guidelines for agriculture in floodplains (ARDSA);	City's criteria Note: Since a full analysis was not conducted as part of this ISMP, the following criteria were used: maintain post-development peak discharges into the lowlands as close as feasible to existing levels for the 10-year 5-day winter and 10-year 2-day summer storm events (ARDSA storms).
Water Quality	No established criteria	Improve, or avoid deterioration of, the water quality of watercourses receiving runoff from the development areas, through the application of stormwater Best Management Practices (BMPs) or on-site Low Impact Development measures (LID)
Base Flows	No established criteria	At a minimum, maintain existing base flow during low-flow season; if current base flow is not adequate, base flow diversions will be proposed
Peak Flows	No established criteria	Post-development peak flows in the streams not to exceed existing peak flows for the 2-year, 5-year and 100-year recurrence events

3.3 Proposed Actions for a Sustainable Future

All recommended projects and initiatives have been grouped into seven categories:

- **Environmental Protection and Enhancement** – projects generally intended to mitigate or enhance in-stream conditions for fish and wildlife.

- **Municipal Infrastructure** – projects to improve the functioning of the City's stormwater collection, conveyance, control, treatment and discharge systems; this includes upgrades to existing storm drains, construction of new trunk storm drains, detention ponds and runoff treatment systems, and replacement of inadequately sized culverts. **Figure 16** shows the locations for the recommended municipal infrastructure improvements.

- **Instream Improvements** – projects to repair erosion that directly impacts property or other local infrastructure such as roads (since proposed and currently proposed instream improvements are the same, see **Figure 14** for a map of proposed instream improvements).

- **Pilot Projects –** small scale projects intended to demonstrate the applicability and effectiveness of innovative stormwater controls.
- **Planning and Analysis** – activities and tasks to enhance the City's understanding of local streams and storm systems, to evaluate the success of past actions, and to determine the feasibility of undertaking additional actions or adapting to changed conditions.
- **Policy and Regulation** – development and adoption of bylaws, guidelines and other regulatory tools.
- **Public Education and Outreach** – programs and activities intended to educate the public, developers, contractors and others about stormwater management and its benefits to the Old Logging Ditch and Burrow's watershed.

The following initial steps were taken to develop priorities:

- **Step 1 – Identify projects to be funded by developers (as opposed to the City)**

  The first step was to identify those projects required exclusively for growth, and that would be entirely funded by the development community. It is expected that the development community will pay for these projects through works and services agreements or development cost charges (DCCs). Since the City will not be responsible for the costs associated with constructing these projects, these projects will occur as development proceeds, independent of the City's implementation plan for City-funded projects.

- **Step 2 – Prioritize City-funded initiatives**

  The second step was to categorize the remaining City-funded initiatives as "near-term" or "mid-to long- term". Near-term initiatives are those that should be undertaken within the next five years; mid- to long-term projects would be undertaken in six plus years. High priority projects are, logically, recommended to be undertaken in the near-term, whereas lower priority projects are recommended to be undertaken further in the future, although factors come into play in each case.

  While there were exceptions, in general, the priority timing was defined using these guides:

  - **Near-Term (1–5 years) –** High priority initiatives are those initiatives that exhibit one or more of these characteristics:

    - Generate information that will affect the delivery of subsequent projects or execution of subsequent initiatives;
    - Result in policies, procedures or regulations that will affect future development
    - Address significant existing flooding or erosion issues;
    - Address significant fish habitat issues;
    - Correspond to works in an area with significant development pressure;
    - Are high-profile and have significant "educational" value; or
    - Significantly reduce discharge of pollutants in runoff.

  - **Mid- to Long-Term (6+ years) –** Priority initiatives in this category are those that:

    - Result in moderate improvements to water quality;
    - Correspond to works in an area with moderate development pressure;
    - Respond to a local interest in the project; or
    - Would generate new and useful information for the City.

Recommended projects and initiatives are shown in **Table 10** and **Figures 15** and **16**. Further details on environmental initiatives are included in **Appendix B** and details regarding recommended municipal infrastructure upgrades are shown in **Appendix C**. No changes are recommended to proposed infrastructure contained in adopted City plans or the 10 Year Capital Plan; however, a small number of additions are recommended.

3.4 Cost Estimates

Cost estimates for the proposed municipal infrastructure improvements are shown in **Table 10**. These cost estimates include cost estimates developed for the current ISMP, cost estimates revised for the proposed NCPs and cost estimates provided in the City's 2010 ten year Servicing Plan. The revised cost estimates were developed using monthly cost history from the "Engineering News Record" (ENR) construction cost index between 1990 and 2010.

3.4.a Storm Sewer Upgrades

Cost estimates were originally provided for some of the storm sewer upgrade works listed in the City's 2010 ten year servicing plan. We recommend these projects remain in the capital works program and the cost estimates have been updated to reflect the most up to date costs. Cost estimates for the storm sewer upgrade proposed in the current ISMP were developed using the unit rates provided by the City of Surrey in February, 2010. Detailed cost estimates are shown in **Appendix F**.

3.4.b Detention Facilities

Seven detention facilities were proposed in the North Grandview Heights NCP and two of them are included in the City's 2010 ten year servicing plan. Cost estimates for the North Grandview Heights NCP proposed detention facilities were upgraded to reflect the 2010 cost using the escalation factor derived from the ENR construction cost index. The cost estimates for the two detention facilities shown in the 2010 ten year servicing plan were remained same assuming the 2010 cost estimates are up to date. No additional detention facilities are proposed as part of this ISMP. Detailed cost estimates are shown in **Appendix F**.

3.4.c Conveyance Works

The City of Surrey's 2010 ten year servicing plan included capital works that consist of conveyance works along Old Logging Ditch and along 34th Avenue Ditch between 164th Street and 166th Street. The cost estimates for these items have not changed and are shown in **Appendix F**.

3.4.d Erosion and Sediment Control Works

The City of Surrey's 2010 ten year servicing plan included erosion and sediment control works in several ditches as part of their long term (7-10 years) plan. **Appendix F** shows the estimated costs for these works.

Table 10: Recommended Initiatives and Costs

ID	Watershed Location	Category	Recommendation	Schedule: 0-5 Years	Schedule: 6+ Years	Schedule: Timing Driven by Development	Estimated Cost (June 2010)	Funding Source	Directly Addresses Local Flooding and Erosion Risks?	Environmental Benefit
E1	Old Logging Ditch	Env'l Protection & Enhancement	Entire Morgan Creek and Wills Brook systems - removal of barriers and obstacles to fish passage	✓			TBD	Stormwater Utility	N	Improves fish access to good quality spawning and rearing habitat
E2	Old Logging Ditch	Env'l Protection & Enhancement	Entire Morgan Creek and Wills Brook systems - complete instream enhancements	✓			$ 50,000	Stormwater Utility	N	Improves fish habitat
E3	Old Logging Ditch	Env'l Protection & Enhancement	Entire Morgan Creek and Wills Brook systems - establish riparian setbacks and infill plant where possible	✓			$20/sq.m	Stormwater Utility/Developer Contribution	N	Improves fish access to good quality spawning and rearing habitat
E4	Old Logging Ditch	Env'l Protection & Enhancement	Morgan Creek headwaters - installation of detential pond feature	✓			$204,000 for a 500 cu. m. pond	Stormwater Utility	N	Improves instream conditions (including water quality) during low flow conditions. Improve fish habitat.
E5	Old Logging Ditch	Env'l Protection & Enhancement	All upland watercourses other than Morgan Creek and Wills Brook - establish riparian setbacks and infill plant where possible	✓			$20/sq.m	Stormwater Utility/Developer Contribution	N	Increased riparian structure, function and diversity; Improves water quality
E6	Old Logging Ditch	Env'l Protection & Enhancement	Terrestrial hubs A, B, and C - preserve hubs as natural areas; avoid fragmentation of habitat	✓			TBD	Stormwater Utility/Developer Contribution	N	Improves wildlife habitat
E7	Old Logging Ditch	Env'l Protection & Enhancement	All terrestrial hubs and patches - perserve all hubs and patches to the greatest extent possible. Create linkages.		✓		TBD	Stormwater Utility/Developer Contribution	N	Improves wildlife habitat
E8	Old Logging Ditch	Env'l Protection & Enhancement	North Grandview/Coast Meridian Multi-Use Corridor - enhance corridor with a strip of native trees and shrubs to encourage wildlife utilization.		✓		$307,000 (for 2 trees/lin.m)	Stormwater Utility/Developer Contribution	N	Improves wildlife habitat
E9	Old Logging Ditch	Env'l Protection & Enhancement	All terrestrial hubs and patches - establish corridors between retained hubs and patches.		✓		TBD	Stormwater Utility/Developer Contribution	N	Improves wildlife habitat
E10	Old Logging Ditch	Env'l Protection & Enhancement	All uplands development - create Class A or Class B habitat during land development.			✓	TBD	Developer Contribution	N	Improves wildlife habitat
E11	Old Logging Ditch	Env'l Protection & Enhancement	Old Logging Ditch and Burrows Ditch outlets to Nickomeckl River - upgrade or improve fish passage.		✓			Stormwater Utility	N	Improve fish access to good quality spawning and rearing habitat
M1	Old Logging Ditch	Municipal Infrastructure	172 St. concrete trunk storm sewer - 160 m of 600 mm diameter			✓	$ 227,000	DCCs	Y	
M2	Old Logging Ditch	Municipal Infrastructure	172 St. concrete trunk storm sewer - 640 m of 1200 mm diameter	✓			$ 1,459,000	Stormwater Utility	Y	

Table 10: Recommended Initiatives and Costs

ID	Watershed Location	Category	Recommendation	Schedule: 0-5 Years	Schedule: 6+ Years	Schedule: Timing Driven by Development	Estimated Cost (June 2010)	Funding Source	Directly Addresses Local Flooding and Erosion Risks?	Environmental Benefit
M3	Old Logging Ditch	Municipal Infrastructure	166 St. concrete trunk storm sewer - 150 m of 750 mm diameter	✓			$ 220,000	Stormwater Utility	Y	
M4	Old Logging Ditch	Municipal Infrastructure	24 Ave. concrete trunk storm sewer - Included in the 10 year Servicing Plan	✓			$ 494,000	Stormwater Utility	Y	
M5	Old Logging Ditch	Municipal Infrastructure	24 Ave. concrete trunk storm sewer - 375 m of 750 mm diameter			✓	$ 765,000	DCCs	Y	
M6	Old Logging Ditch	Municipal Infrastructure	26 Ave. concrete trunk storm sewer - Included in the 10 year Servicing Plan	✓			$ 7,802,000	Stormwater Utility/DCCs	Y	
M7	Old Logging Ditch	Municipal Infrastructure	168 St. concrete trunk storm sewer - 375 m of 900 mm diameter	✓			$ 866,000	Stormwater Utility	Y	
M8	Old Logging Ditch	Municipal Infrastructure	32 Ave. concrete trunk storm sewer - 330 m of 1050 mm diameter	✓			$ 851,000	Stormwater Utility	Y	
M9	Old Logging Ditch	Municipal Infrastructure	164th St trunk storm sewer upgrade –300 m of 600 mm diameter and 500 m of 675 mm diameter			✓	$ 1,486,000	DCCs	Y	
M10	Old Logging Ditch	Municipal Infrastructure	Croydon Dr: 029-031 Ave- 630 m of 1200mm trunk sewer - included in the 10 year Servicing Plan		✓		$ 1,089,000	DCCs	Y	
M11	Old Logging Ditch	Municipal Infrastructure	32nd Ave trunk and creek works: 20 m 900mm+110m 1200mm - included in the 10 year Servicing Plan	✓			$ 422,900	DCCs	Y	
M12	Old Logging Ditch	Municipal Infrastructure	160th St/030 Ave: Upgrade culvert crossing for future peak flows		✓		$ 45,000	DCCs	Y	
M13	Old Logging Ditch	Municipal Infrastructure	Morgan Creek at 32nd Avenue - culvert upgrade - 30.5 m of 1500 mm diameter	✓			$ 115,000	Stormwater Utility	Y	
M14	Old Logging Ditch	Municipal Infrastructure	Wills Brook at 16th St - culvert upgrade - 12 m of 750 mm diameter	✓			$ 45,000	Stormwater Utility	Y	
M15	Old Logging Ditch	Municipal Infrastructure	Old Logging Ditch at 32nd Avenue - box culvert upgrade - 19.5 m of 1800 mm x 1500 mm - included in the 10 year Servicing Plan	✓			$ 140,000	Stormwater Utility	Y	

Table 10: Recommended Initiatives and Costs

ID	Watershed Location	Category	Recommendation	Schedule 0-5 Years	Schedule 6+ Years	Schedule Timing Driven by Development	Estimated Cost (June 2010)	Funding Source	Directly Addresses Local Flooding and Erosion Risks?	Environmental Benefit
M16	Old Logging Ditch	Municipal Infrastructure	Burrow's Ditch at 32nd Avenue - culvert upgrade - 15 m of 1500 mm diameter	✓			$ 100,000	Stormwater Utility	Y	
M17	Old Logging Ditch	Municipal Infrastructure	Morgan Creek at Highway 99 - culvert upgrade - 120 m of 900 mm diameter	✓			$ 100,000	Stormwater Utility	Y	
M18	Old Logging Ditch	Municipal Infrastructure	Culvert upgrades to improve fish accessibility (to be determined through detailed stream assessments)		✓		$30,000 per culvert	Stormwater Utility	N	Improves fish access to good quality spawning and rearing habitat
M19	Old Logging Ditch	Municipal Infrastructure	Conduct proactive O&M to ensure that recommended stormwater management infrastructure (especially BMPs) function properly.			✓	In house costs		Y	Improves instream conditions
M20	Old Logging Ditch	Municipal Infrastructure	Community Detention Pond -Volume 3000 cu.m. Potential location west of 160th St - included in the North Grandview Heights NCP			✓	$ 1,306,000	Stormwater Utility/DCC	Y	Improves instream conditions and protect lowlands
M21	Old Logging Ditch	Municipal Infrastructure	Detention Pond -Volume 450 cu.m. Potential location near 32nd Ave and 160th St - included in the North Grandview Heights NCP			✓	$ 183,000	Stormwater Utility/DCC	Y	Improves instream conditions and protect lowlands
M22	Old Logging Ditch	Municipal Infrastructure	Detention Pond -Volume 600 cu.m. Potential south of 32nd Ave and east of Wills Brook - included in the North Grandview Heights NCP			✓	$ 244,000	Stormwater Utility/DCC	Y	Improves instream conditions and protect lowlands
M23	Old Logging Ditch	Municipal Infrastructure	Detention Pond -Volume 500 cu.m. Potential south of 32nd Ave and 164th St. - included in the North Grandview Heights NCP/10 year Servicing Plan			✓	$ 204,000	DCCs	Y	Improves instream conditions and protect lowlands
M24	Burrow's Ditch	Municipal Infrastructure	Detention Pond -Volume 1800 cu.m. Potential location near April Creek - included in the North Grandview Heights NCP/10 year			✓	$ 729,000	DCCs	Y	Improves instream conditions and protect lowlands
M25	Old Logging Ditch	Municipal Infrastructure	Detention Pond -Volume 3400 cu.m. Potential location south of 28th Ave - included in the North Grandview Heights NCP			✓	$ 1,388,000	Stormwater Utility/DCC	Y	Improves instream conditions and protect lowlands
M26	Old Logging Ditch	Municipal Infrastructure	Detention Pond -Volume 3200 cu.m. Potential location east of 164th St.- included in the North Grandview Heights NCP			✓	$ 319,000	DCCs	Y	Improves instream conditions
S1 (6582)	Old Logging Ditch	Erosion and Ravine Works	Remove culvert and stabilize banks - included in the 10 year Servicing Plan		✓		$ 60,000	DCCs	Y	Improves instream conditions
S2(9378)	Old Logging Ditch	Erosion and Ravine Works	2 sites (ID=TTMN-1,2; risk=L) - included in the 10 year Servicing Plan		✓		$ 26,002	Stormwater Utility	Y	Improves instream conditions

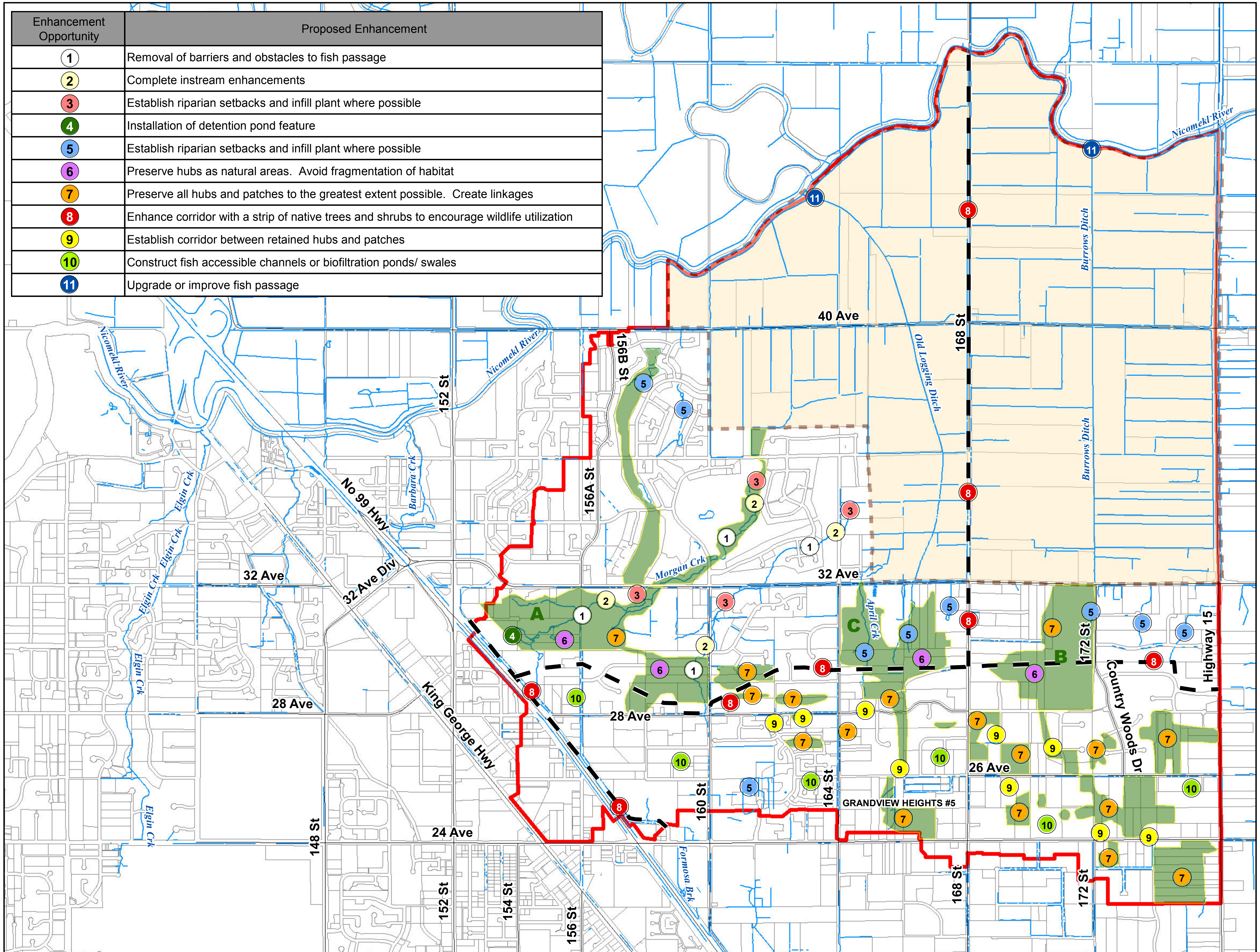
Table 10: Recommended Initiatives and Costs

ID	Watershed Location	Category	Recommendation	Schedule			Estimated Cost (June 2010)	Funding Source	Directly Addresses Local Flooding and Erosion Risks?	Environmental Benefit
				0-5 Years	6+ Years	Timing Driven by Development				
S3(6581)	Old Logging Ditch	Erosion and Ravine Works	Remove stm outfall and stablize banks - included in the 10 year Servicing Plan		✓		$ 60,000	DCCs	Y	Improves instream conditions
S4(6584)	Old Logging Ditch	Erosion and Ravine Works	Remove box culvert and stabilize banks - included in the 10 year Servicing Plan		✓		$ 10,000	DCCs	Y	Improves instream conditions
S5(6561)	Old Logging Ditch	Erosion and Ravine Works	Erosion protection - included in the 10 year Servicing Plan		✓		$ 60,000	DCCs	Y	Improves instream conditions
S6(6563)	Old Logging Ditch	Erosion and Ravine Works	Erosion protection - included in the 10 year Servicing Plan		✓		$ 10,000	DCCs	Y	Improves instream conditions
S7(6564)	Old Logging Ditch	Erosion and Ravine Works	Erosion protection - included in the 10 year Servicing Plan		✓		$ 10,000	DCCs	Y	Improves instream conditions
S8(9379)	Old Logging Ditch	Erosion and Ravine Works	Over-steep bank at 160 St.; included in the 10 year Servicing Plan		✓		$ 9,602	Stormwater Utility	Y	Improves instream conditions
PP1	Either	Pilot Projects	To be discussed with the City.						N	Improves instream conditions
PA1	Both	Planning & Analysis	Complete an assessment of all existing detention ponds for hydraulics and water quality treatment.	✓			$7,500/ pond	Stormwater Utility	Potentially	Improves water quality
PA2	Both	Planning & Analysis	Entire Morgan Creek and Wills Brook Systems - conduct detailed assessments of entire channel looking for perched culverts, anthropogenic fish barriers, debris jams, etc., as well as for opportunities for instream enhancement.	✓			$8,000 (for visually inspecting both channels)	General Revenue	N	Improves fish access
PA3	Both	Planning & Analysis	Conduct flow monitoring on Morgan Creek, Wills Brook, Old Logging Ditch, and Burrow's Ditch.	✓			$10,000 to install (per location)	Stormwater Utility	N	Improves instream conditions
PA4	Both	Planning & Analysis	Update this ISMP analysis with flow monitoring data.	✓			$ 50,000	Stormwater Utility	N	Refine recommendations for improving instream conditions
PA7	Both	Planning & Analysis	Conduct water quality monitoring (twice per year - summer and winter).	✓			$5,000/year per location	Stormwater Utility	N	Improves water quality
PA8	Both	Planning & Analysis	Intall a rain gauge centrally within the study area.	✓			$5,000 to install	Stormwater Utility	N	

Table 10: Recommended Initiatives and Costs

ID	Watershed Location	Category	Recommendation	Schedule: 0-5 Years	Schedule: 6+ Years	Schedule: Timing Driven by Development	Estimated Cost (June 2010)	Funding Source	Directly Addresses Local Flooding and Erosion Risks?	Environmental Benefit
PA9	Both	Planning & Analysis	Continue ravine assessments (every three years).	✓			$xx per assessment (to confirm with City based on costs of current ravine assessment program)	Stormwater Utility	Y	
PA10	Both	Planning & Analysis	Every four years, conduct a comprehensive review of available data (from monitoring efforts) for adaptive management purposes.	✓			$ 35,000	Stormwater Utility	Y	Improve instream conditions
PR1	Both	Policy & Regulation	Make the following amendments to the Zoning Bylaw: - extend maximum impervious area regulations to all zones - encourage the use of bioswalses, wetlands, rain gardens, etc. for stormwater managment in landscape design Improve strategies to promote cluster development	✓			$ 20,000	Stormwater Utility	N	Improve instream conditions by enhancing base flow and improving water quality
PR2	Both	Policy & Regulation	Make the following amendments to the Subdivision and Development Bylaw -require development to meet recommended minimum on-site detention targets and maximum discharge rates -require adherence to stormwater management standards for all development - currently, the Bylaw exempts small scale building permit applications -specifically require the use of on-site BMPs -require all land uses to disconnect roof leaders -require all single-family developments to install 300 mm of absorbent growing media -establish standards for public rights-of-way re: detention targets and BMPs	✓			$ 30,000	Stormwater Utility	N	Improve instream conditions by enhancing base flow and improving water quality
PR3	Both	Policy & Regulation	Make the following amendments to the Building Bylaw: -require 300 mm of absorbent growing media in single family areas -require disconnected roof leaders for all development -establish an inspection system for topsoil and roof leaders	✓			In house costs	Stormwater Utility	N	Improve water quality and instream conditions.
PE1	Both	Public Education & Outreach	Prepare an annual report on watershed health for Council and the public (every fourth year, the report should reflect the comprehensive review).	✓			In house costs	Stormwater Utility	N	
PE2	Both	Public Education & Outreach	Develop a public education program re: stormwater management (specifically re: on-lot BMPs and disconnected roof leaders).	✓			$ 25,000	Stormwater Utility	N	Improve water quality and instream conditions.

Enhancement Opportunity	Proposed Enhancement
1	Removal of barriers and obstacles to fish passage
2	Complete instream enhancements
3	Establish riparian setbacks and infill plant where possible
4	Installation of detention pond feature
5	Establish riparian setbacks and infill plant where possible
6	Preserve hubs as natural areas. Avoid fragmentation of habitat
7	Preserve all hubs and patches to the greatest extent possible. Create linkages
8	Enhance corridor with a strip of native trees and shrubs to encourage wildlife utilization
9	Establish corridor between retained hubs and patches
10	Construct fish accessible channels or biofiltration ponds/ swales
11	Upgrade or improve fish passage



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Recommended Aquatic and Terrestrial Enhancement Opportunities Figure 15

Legend

- Prioritized Enhancement Opportunity (see Table 4 for additional information)
- Watercourse
- North Grandview/Coast Meridian Multi-use Corridor
- Agricultural Land Reserve
- Terrestrial Hub
- Catchment Boundary

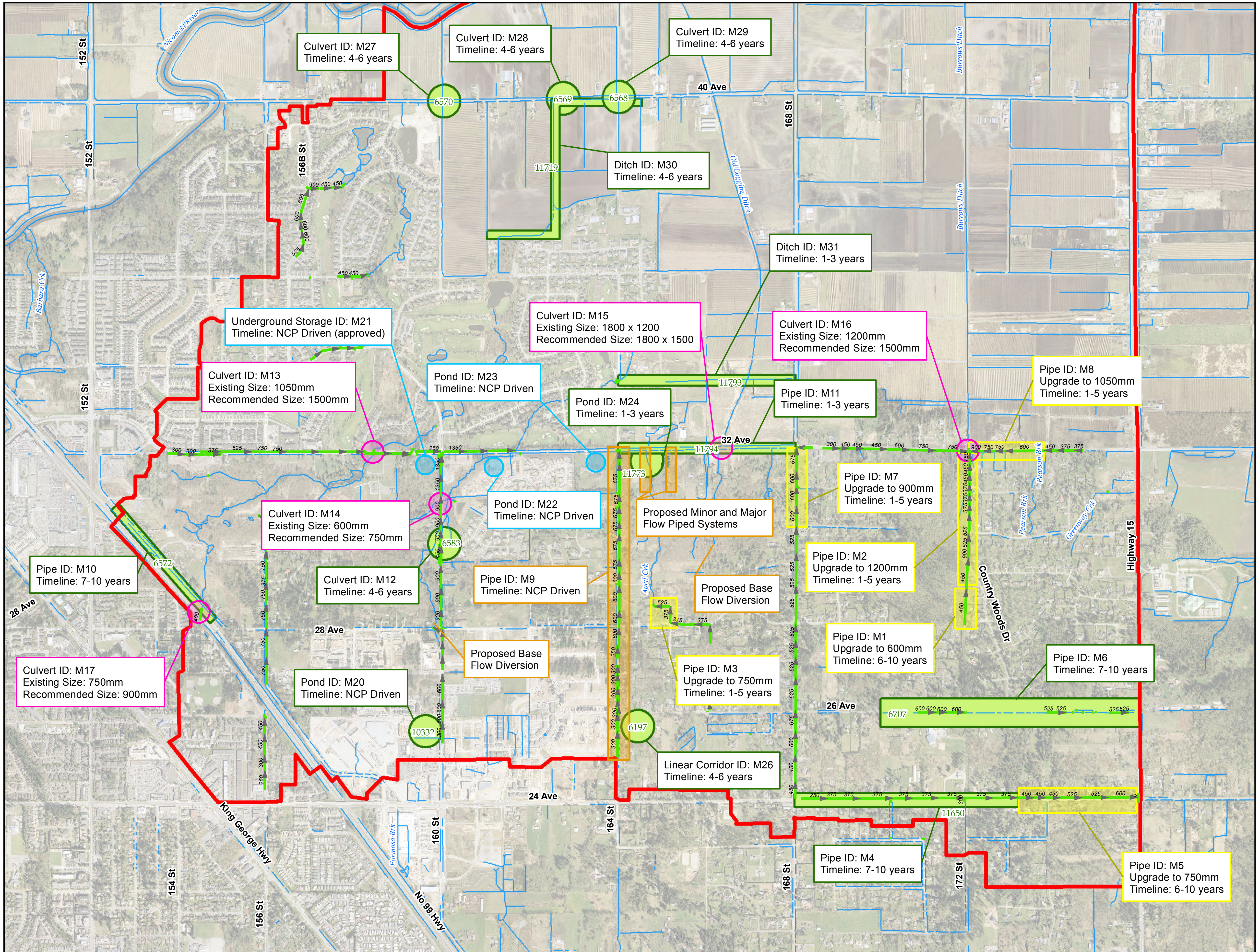
N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Recommended Infrastructure Improvements

Figure 16

Legend

- Existing Trunk System
- Culvert Upgrade
- Pipe Upgrade
- North Grandview Heights NCP - Pipe Upgrade
- North Grandview Heights NCP - Pond/Storage
- City of Surrey 2010 Ten Year Plan - Pipe, Culvert, and Pond/Storage
- Catchment Boundary

Note: Exact location of recommended ponds still to be determined.

N

0 250 500 750 1,000

Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure16_RecommendedInfrastructureImprovements.mxd Last updated by: bpauls on September 16, 2011 at 9:12:59 AM

4 How do we put it into action?

This Section outlines recommendations on financing, development requirements, and enforcement.

4.1 Financing

Table 10 in the previous Section indicates a potential funding source for each recommended project and initiative. Potential sources of funding are:

Infrastructure Funding

- **Development cost charges (DCCs)** – Only municipal infrastructure projects needed to support growth and which could be considered "trunk" elements are eligible for inclusion in the City's DCC program. The following stormwater projects would be eligible DCC projects (provided they are needed to service new development):
  - Trunk sewers that drain more than 20 ha (as per City policy)
  - Community detention ponds
  - Large-scale BMPs
- **Works and services** – Smaller scale works (works and services) will be the responsibility of the developer.
- **Stormwater utility** – Those stormwater projects that are not growth-related will be funded through the City's stormwater utility.

Environmental Enhancement

- **5% parkland dedication** – The City is authorized to ask developers for 5% of a single-family subdivision for parkland dedication.
- **Parkland DCCs** – In some cases, the City may be able to add parkland (needed to serve new development) in its DCC program.
- **Negotiated/developer contributions** – The City may be able to negotiate with developers to provide certain environmental enhancements through the development process.

Grants are also a potential source of funding for the recommended initiatives; however, grants are uncertain and should not be relied upon.

4.2 Development Requirements

For new development, it is recommended that the City establish requirements based on land use and on impervious surface coverage. As discussed in **Section 3**, these requirements are based on the hydrologic modeling completed for the ISMP (see **Table 11** for a summary).

4.2.a Minimum Retention Volumes

To provide minimum base flow in streams and protect the lowlands, a retention volume of 300 m^3/ha is recommended. The proposed 300 m^3/ha retention volume is in line with the recommendation of the Grandview Heights #5 NCP (250 m^3 of retention per hectare of development). The Grandview Heights #1 (Morgan Heights) NCP, recommended 45 m^3/ha communal on-site detention for single family development and 120 m^3/ha for communal or on-site detention, retention and/or infiltration.

4.2.b Maximum Discharge Rates

In addition to on-site retention, maximum discharge rates are listed for the major creek systems and the Old Logging Ditch and the Burrow's Ditch (see also **Figure 17**). These provide both erosion protection in the creeks and flood protection in the lowlands. Some of the previous NCPs also recommended maximum release rates. The Grandview Heights #1 (Morgan Heights) NCP (2005) and the North Grandview Heights NCP (2005) both recommended a 9 l/s/ha release rate for the 2 year event and 15 l/s/ha for the 5 year event to protect Old Logging Ditch and the lowlands. The Rosemary Heights Park and Live/Work Area NCP (2000) recommended a 7.2 l/s/ha release rate for the 5 year event.

4.2.c Single-Family Development (TIA< 50%)

For new single-family development with a maximum total impervious area of 50%, it is recommended that developers provide 300 mm of absorbent growing media (sometimes referred to as amended topsoil) and disconnect roof leaders to ground rather than to the storm drain collection system in the streets (as per the City's current Design Manual). At 50% impervious area, these sites are expected to be able to meet both Provincial and DFO on-site detention criteria through requirements to install absorbent growing media and disconnect roof leaders. No further requirements would be made for this type of development. The size of each lot and the total number of lots within the single-family subdivision would be irrelevant – this simplified approach would apply so long as each individual lot had a total impervious area of less than 50%.

This simplified approach should be relatively straightforward for developers to implement and for the City to administer. This approach should also provide developers with an incentive to reduce total impervious area by using porous pavement, for example. The Engineer of Record should verify in writing that the absorbent growing media meets the requirements of the Guidelines and has been properly installed and that roof leaders discharge to ground not to a storm sewer.

The City may also want to consider developing a detailed checklist for absorbent growing media requirements that could be used at the plan review stage. A sample checklist for absorbent growing media requirements is added in **Appendix G**.

In addition, homeowners should be encouraged to incorporate other stormwater source controls into their properties such as:

- Maintenance (or retention) of high tree cover densities;
- Rain gardens; and
- Permeable pavement for driveways, walkways and patios.

Design of these additional controls should be completed in accordance with Metro Vancouver's "Stormwater Source Control Design Guidelines 2005" (Lanarc, et al, 2005)

In the eastern portion of the Burrow's Ditch watershed (enclosed by 26th Avenue to the south, 31st Avenue to the north, 166th Street to the west and Highway 15 to the east) that does not have conditions conducive to infiltration, perforated storm drains should be installed to reduce ponding as this area develops.

4.2.d Multi-Family, Commercial, Institutional, Industrial, and an Active Park Space

It is recommended that these types of developments be required to:

- Disconnect roof leaders;
- Meet specific performance targets for on-site runoff storage and release rates (see **Table 111** and
- Table **12** respectively). See **Appendix C** for details on minimum runoff volumes to be retained on-site and maximum allowable discharge rates;
- Provide communal detention as recommended in adopted NCPs and GLUP;
- Provide water quality treatment for any specific high risk contaminants associated with that site's land use activities, e.g., oil capture/removal for gas service stations, if required by the City; and
- Promote the use of landscape-based stormwater source controls that provide water quality improvement and emphasize infiltration and evapotranspiration of rainwater during minor storms (e.g., absorbent growing media, rain gardens, bioswales, and porous pavement)

The specific mix of source control methods will be up to each site owner, thus allowing integration into the site's overall architectural and landscaping concept. Designs should be done in accordance with Metro Vancouver' "Stormwater Source Control Guidelines 2005".

These recommendations are in line with the stormwater management strategies outlined in the various NCPs and GLUP for the area.

The Engineer of Record should verify in writing that all BMPs have been designed in accordance with the Guidelines and properly installed.

As well, the City should consider expanding its list of requirements for a Stormwater Control Plan to require developers to:

- Provide more detailed information on the location and dimensioning of low-impact management initiatives;
- Use continuous modelling and flow duration curves (existing and post development) to demonstrate the impact of the proposed development; and
- Provide a discussion of how the proposed stormwater management approach will address water quality treatment.

Similar to the restriction noted in the section on single family development, in the eastern portion of the Burrow's Ditch watershed, that does not have conditions conducive to their use, infiltration-based low impact BMPs must be constructed with perforated subdrains.

4.2.e Development within Public ROWs

As shown in **Table 11**, detention targets have also been established for public rights-of-way by road type (which influences the amount of runoff and pollutants generated). At a minimum, all road cross-sections should include swales constructed with absorbent growing media to depths of 300 mm in portions planted in grass and 450 mm in portions planted with shrubs or trees. Swales should be designed not only to control the volume of runoff flowing off the roadway, but to also provide water quality treatment. The City also has the option to reduce runoff volumes by reducing the width of paved surfaces within the road right-of-way.

The neighbourhood plan for Grandview Heights NCP #2 contemplates the widespread use of green corridors and infiltration-type storm drains to minimize the number of required detention ponds and improve water quality in that neighbourhood. In the future, this same approach may be considered for new development in the Old Logging Ditch/Burrow's watershed; however, the practicality of this approach should be tested first within Grandview Heights NCP #2.

4.2.f Building Expansions (for all land uses)

All renovations to buildings, including additions of sidewalks, driveways and parking areas, that increase impervious area to more than 50% should manage all runoff generated from the impervious area on the lot according to the recommended targets for on-site retention (300 m^3/ha) and allowable maximum discharge rates.

4.2.g Runoff Quality

Control of the generation and washoff of non-point source (NPS) pollutants in rainwater are readily addressed through the use of low impact BMPs as recommended in the previous sections. Most importantly, reduction in the total annual volume of runoff, which will occur as the result of using infiltration- and evapotranspiration-based BMPs, is a critical first step in minimizing NPS pollution. Further, BMPs that provide for settling, soil contact and vegetative uptake will provide significant runoff quality benefits. Specific recommendations follow.

For public infrastructure:

- provide low impact biofiltration systems (bioswales; rain gardens) and, where feasible, narrower streets and/or porous asphalt parking lanes, for as many streets as possible;
- install perforated storm drain systems in all new developments;
- provide all storm drain catch basins with deep sumps (at least 450mm) and hooded outlets;
- provide detention ponds with treatment features to optimize treatment for rainfall depths up to and including the MAR (approximately 60 mm); and

- perform desktop assessments of the watersheds' existing ponds and optimize treatment capabilities as needed.

For new single family residential development:

- provide 300 mm of amended growing media for lawns;
- disconnect roof leaders; and
- encourage use of permeable materials for driveways, walks and patios;

For all other types of new development:

- provide 300 mm of amended growing media for lawns;
- use low impact BMPs to provide treatment and infiltration (where allowable); and
- for areas subject to high automobile use, including gas service stations, and for other commercial, industrial, and institutional sites required by the City, provide oil/water separator facilities, or equivalent.

One area within the Burrow's Ditch upper watershed has been noted as unsuitable for infiltration of runoff. In this area, low impact BMPs may be used for water quality control, but only when provided with a perforated underdrain system. The underdrains intercept runoff before it is infiltrated to soil and redirects it to the City's storm drains. While this means that runoff volume will not be reduced, it does mean that runoff will have been provided treatment through contact with soil prior to eventual discharge to the local watercourse.

It is absolutely critical that BMPs be maintained and replaced over time in order to obtain the desired runoff treatment.

Appendix H provides a summary of suggested various BMPs that can be implemented by developers and the City as specific sites are developed. In general, the suitability of each of the listed BMPs will depend on the specific, local circumstances of each development.

Table 11: Recommended Development Requirements

	Disconnect roof leaders	300 mm of absorbent growing media	Min. retention volume	Max. discharge rate	Other requirements
Single Family (TIA < 50%)	✓	✓	n/a	n/a	n/a
Single-Family (TIA > 50%), Multi-Family, Commercial, Institutional, Industrial, Active Park Space	✓	Optional	300 m^3/ha	See Table 12	Incorporate on-lot BMPs where appropriate
Building expansions	n/a	Optional	300 m^3/ha	See Table 12	n/a
Public Rights-of-Way					
Local (20 m RoW)	n/a	✓	0.6 m^3/lin.m.	n/a	For future consideration: infiltration type storm drains and green corridors as recommended in Grandview Heights NCP #2
Collector (24 m RoW)	n/a	✓	0.7 m^3/ lin.m.	n/a	
Arterial (34 m RoW)	n/a	✓	1.0 m^3/ lin.m.	n/a	

Table 12: Recommended Discharge Rates

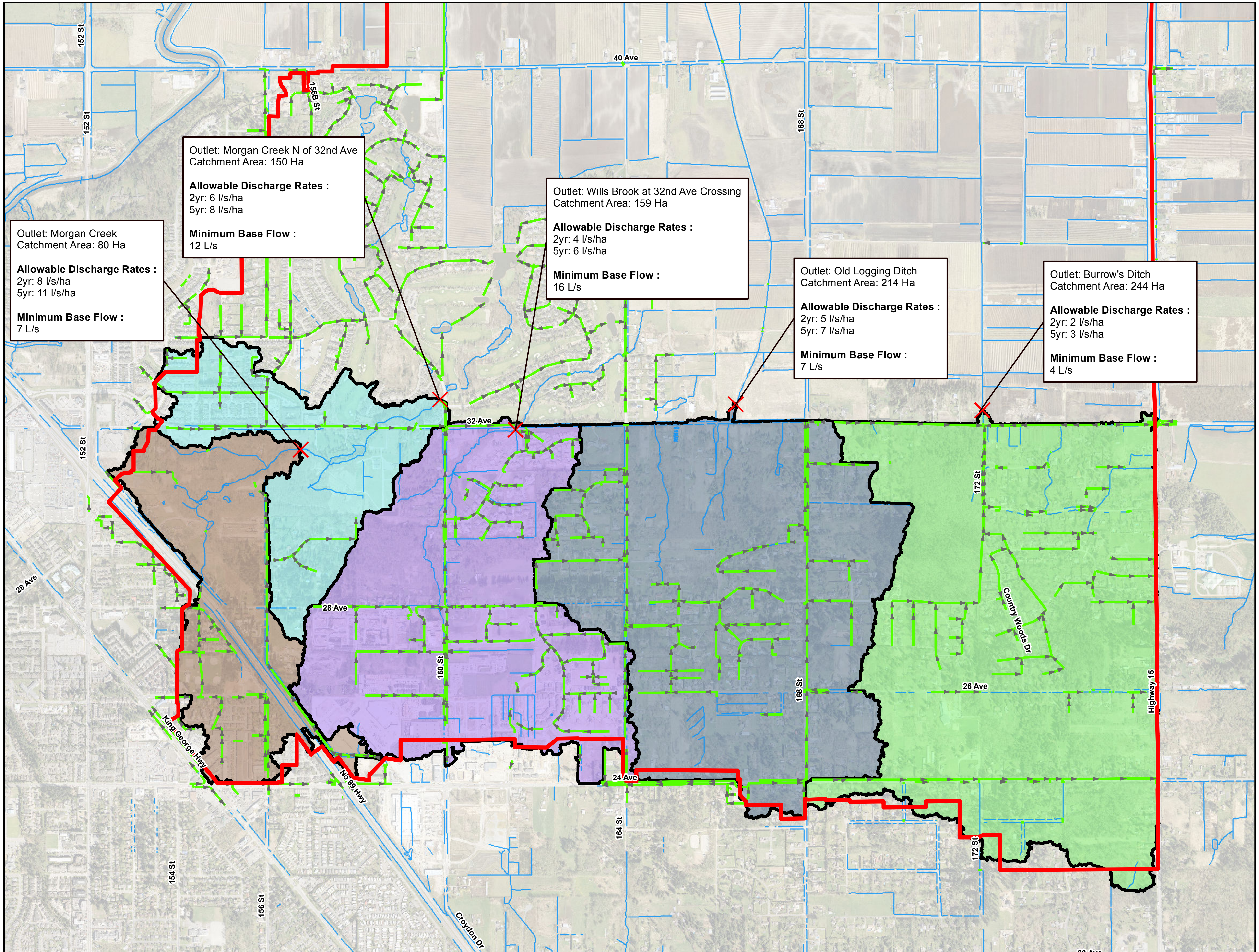
Catchment Areas	Maximum discharge rate (l/s/ha)		Comments
	2 year storm event	5 year storm event	
Morgan Creek	8	11	Encompasses business park development.
Morgan Creek N. of 32nd Avenue.	6	8	Covers most of the upland section of the Morgan Creek catchment
Wills Brook N. of 32nd Avenue.	4	6	Covers most of the upland section of the Wills Brook catchment
Old Logging Ditch N. of 32nd Avenue.	5	7	Since only low-density single-family development is expected to occur in these catchments, these maximum discharge rates would primarily be used for long-term monitoring purposes.
Burrow's Ditch N. of 32nd Avenue.	2	3	

CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Recommended Allowable Discharge Rates/Minimum Base Flow Requirements*

Figure 17



Legend

- Catchment Outlets
- Drainage Mains
- Waterways
- Catchment Boundary

*Based on continuos similation modeling (see text).

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2011_09_15_FinalReport\Figure17_RecommendedAllowableDischargeRates_MinBaseFlow.mxd Last updated by: bpauls on September 16, 2011 at 9:26:15 AM`

4.3 Enforcement Strategy

To help ensure compliance with the requirements for installing on-lot BMPs, absorbent growing media, and disconnecting roof leaders, the City could move forward with the following:

- **Education program –** The City may consider delivering education programs for the public, developers/builders, as well as City staff (especially the building department) to explain the requirements for on-lot BMPS, absorbent growing media, and disconnected roof leaders. This education program should not only provide an explanation of these requirements, but should also explain the importance of a low-impact approach to stormwater management.
- **Register on-lot BMPs on title –** To help ensure that on-lot BMPs are maintained indefinitely, on-lot BMPs and their associated O&M plans should be registered on title.
- **Sign-off by engineer of record/provision of receipts –** All required on-lot BMPs as well as absorbent growing media and disconnected roof leaders should be signed off by the engineer of record. The City may also require developers to adopt the approach used by the City of Portland, Oregon in regard to absorbent growing media. Portland requires developers to submit a receipt for the soil used on the site (the receipt must show quantity and type), from a certified soil vendor. During the construction process, the owner must then show the receipt or pay to have the site's soil tested. Absorbent growing media inspection could be completed as part of the lot grading inspection.
- **Building permit for increasing impervious area –** Any substantial increase to a lot's impervious area, whether through building expansion or paving, should be managed through the building permit process. Home owners/builders should be required to obtain building permits not only for the building expansion (as is currently the practice), but also for any change to the lot that increases impervious area beyond 65%. In these cases, stormwater management should be a requirement of the building permit; alternatively, the City may be able to amend its Stormwater Drainage Regulation and Charges Bylaw to make the same requirements without having to rely on the building permit process.
- **Groundwater seepage policy** - The City may consider adopting an internal policy to review groundwater seepage at the time of development approvals. Although an official policy does not currently exist, the City does require trench drains behind sidewalks, roads, detention walls, etc., where springs and groundwater emergence are a known concern.
- **Complaint based enforcement –** The City could rely on a complaint based system to enforce these requirements; however, the effectiveness of this approach would be highly dependent on the level of understanding City residents have about the importance of stormwater management. This approach would need to include a public education component.

- **Random audits for compliance –** The City of Portland conducts random audits to check that roof leaders are disconnected and that on-lot BMPs have been installed and are functioning properly. The City may consider establishing a similar program.
- **Fines –** In addition to establishing random audit and/or complaint-based enforcement systems, the City may also want to consider establishing specific fines for not meeting on-lot stormwater management requirements.

The City may also consider increasing its administration/inspection fee to ensure that any additional costs to administer and inspect new stormwater management requirements are fully funded by developers.

5 How do we stay on target?

This Section outlines a long-term process for monitoring and assessing the progress of plan implementation.

5.1 Monitoring and assessment program

The monitoring and assessment program is divided into two main components:

1. **Watershed Health and Flooding Monitoring** (see **Table 13)** – this component establishes a monitoring program for various indicators that have a direct impact on the health of the Old Logging Ditch and Burrow's Ditch watersheds or on flooding. For example, this portion of the monitoring program deals with such issues as water quality and pipe capacity directly.

2. **Development Requirements Monitoring** (see **Table 14**) – this component establishes a monitoring program to ensure that development requirements are being met. This monitoring is about checking compliance with City bylaws and policies (e.g., bylaws mandating disconnection of roof leaders). Implementation of City bylaws and policies clearly has an impact on watershed health and flooding, but these implementation targets are not indicators of watershed health or flooding directly.

Table 13: Watershed Health and Flood Monitoring

Indicator #	Indicator	Target	Adaptive Management Program				
			Monitor			Situation that necessitates further action	Examples of 'why' target(s) is not being met
			Items	Frequency	Cost		
WF1	Status of public stormwater infrastructures (trunk storm sewers, culverts, detention ponds)	• No flooding/surcharging during minor storms (up to 5 year) • No debris jam at or near culverts • Minimize sedimentation at pond bottoms. • Safe conveyance of runoff during major storms (100 year)	Monitor at least the following as per the City's current approach: ✓ Pipe capacity ✓ Debris flow ✓ Sedimentation in detention ponds ✓ Surcharging; flooding	As per City's current approach	As per City's current approach	As per City's current approach	• Insufficient O&M activity? • Increased imperviousness? • Ponds not properly designed?
WF2	Frequency, duration and extent of lowland flooding	• Satisfy the ARDSA criteria • Maintain the recommended discharge rates in the current ISMP	✓ Water level monitoring at lowlands (water gauge) ✓ Stream flow monitoring at the intersection of each of Morgan Creek, Wills Brook, Old Logging Ditch, and Burrow's Ditch between lowlands and uplands (flow monitor)	Take at least one reading during each of low flow and high flow seasons	$1,000/site	Significant flood risks observed through monitoring	• Inadequate detention and flow rate control in the Uplands? • Increased imperviousness in the Uplands? • Not following the recommended discharges rate in the current ISMP? • Sedimentation in the lowland ditches?
			✓ Flood exceedance frequency	Record as needed	In-house costs		
WF3	Water quality in Morgan Creek, Wills Brook, Old Logging Ditch and Burrow's Ditch	• DO • pH • Temperature • Turbidity Follow Ministry of Environment's approved water quality guidelines, 2006 edition. (http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html#2)	✓ WQ monitoring at one or more locations along each of Morgan Creek, Wills Brook, Old Logging Ditch, and Burrow's Ditch	Twice per season – once during low flow conditions and once during high flow conditions	Instrument Rental: • Labour and equipment rental cost: $210/test site	Water quality parameters not being met; investigate potential corrective action after 3 or 4 exceedances per year over a three-year period	• Ponds not properly designed? • Stormceptors/Oil –grit separators not properly working? • Increased imperviousness? • BMPs not properly followed? • Lack of adequate shade in the creeks?
		• Polyaromatic hydrocarbons • Total Suspended Solids (TSS) • Oil and Grease • Trace metals (incl. zinc and copper) • Fecal Coliform • Total Nitrogen Follow Ministry of Environment's approved and working water quality guidelines (http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html#2 and http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html#table1)	✓ At least one test site in the Old Logging Ditch watershed and one in the Burrow's Ditch watershed	For two years, annually during low flow and high flow seasons. Depending on the extent of dilution in the high flow seasons, decision will be made whether to continue monitoring in both the seasons or only in low flow season.	• Testing and labour cost: $500/sample	Water quality parameters not being met; investigate potential corrective action after 2 exceedances per year over the proposed two-year period	

WF4	Riparian forest integrity/ecological health	• Benthic Index of Biotic Integrity (B-IBI)	✓ Testing at one site in the Old Logging Ditch watershed and one site in the Burrow's Ditch watershed	Once per year	• Testing and labour cost: $3200 (total $1,600 per site)	B-IBI values indicating consistent deterioration trend; RFI values shown not to be increasing; healthy and structured native understory and canopy not developing; significant invasive species presence	
		• Riparian Forest Integrity (RFI)	✓ Desktop analysis with aerial photos	Every 4 years	$1,400		
		• Healthy riparian setbacks (e.g., well-structured shrub layer, tree canopy, no invasive species)	✓ Visual inspection at two representative sites along each watercourse	Every two years	$1,750 for all sites (based on sites no more than 100m in length)		
WF5	Status of wildlife habitat	• Maintain/restore intact hubs and corridors	✓ Visual inspection	Every 4 years	$1,750	Inspection indicates that hubs and corridors are being impacted by adjacent land use	
WF6	Stream conditions	• Maintain minimum base flow[1] as recommended in the current[2] ISMP. ▪ Morgan Creek ▪ Wills Brook ▪ Old Logging Ditch ▪ Burrow's Ditch • Minimize stream widening/ downcutting • Maintain/restore stream complexity	✓ Rainfall monitoring	Continuous monitoring with one rain gauge for both the watersheds	$5,000 for installation	n/a	• Not following recommended LID measures in the current ISMP? • Not following the recommended discharges rates in the current ISMP? • Not maintaining the minimum setback criteria?
			✓ Stream flow/water level monitoring in uplands at the Morgan Creek, Wills Brook, Old logging Ditch and Burrows Ditch. ✓	Take at least one reading during each of low flow and high flow conditions	$5,000 for installation/site		
			✓ Channel stability, substrate condition, instream sedimentation monitoring along Morgan Creek and Wills Brook.	Every 3 years to coordinate with City's existing ravine assessment program.	As per City's current ravine assessment cost.	Significant erosion	

[1] Recommended targets were previously noted in Interim Report #3; a reference map will be included with the ISMP report to show these minimum base flows.
[2] The use of the word "current" assumes that the requirements of the ISMP may be adjusted over time as part of the adaptive management program.

Table 14: Development Requirements Monitoring

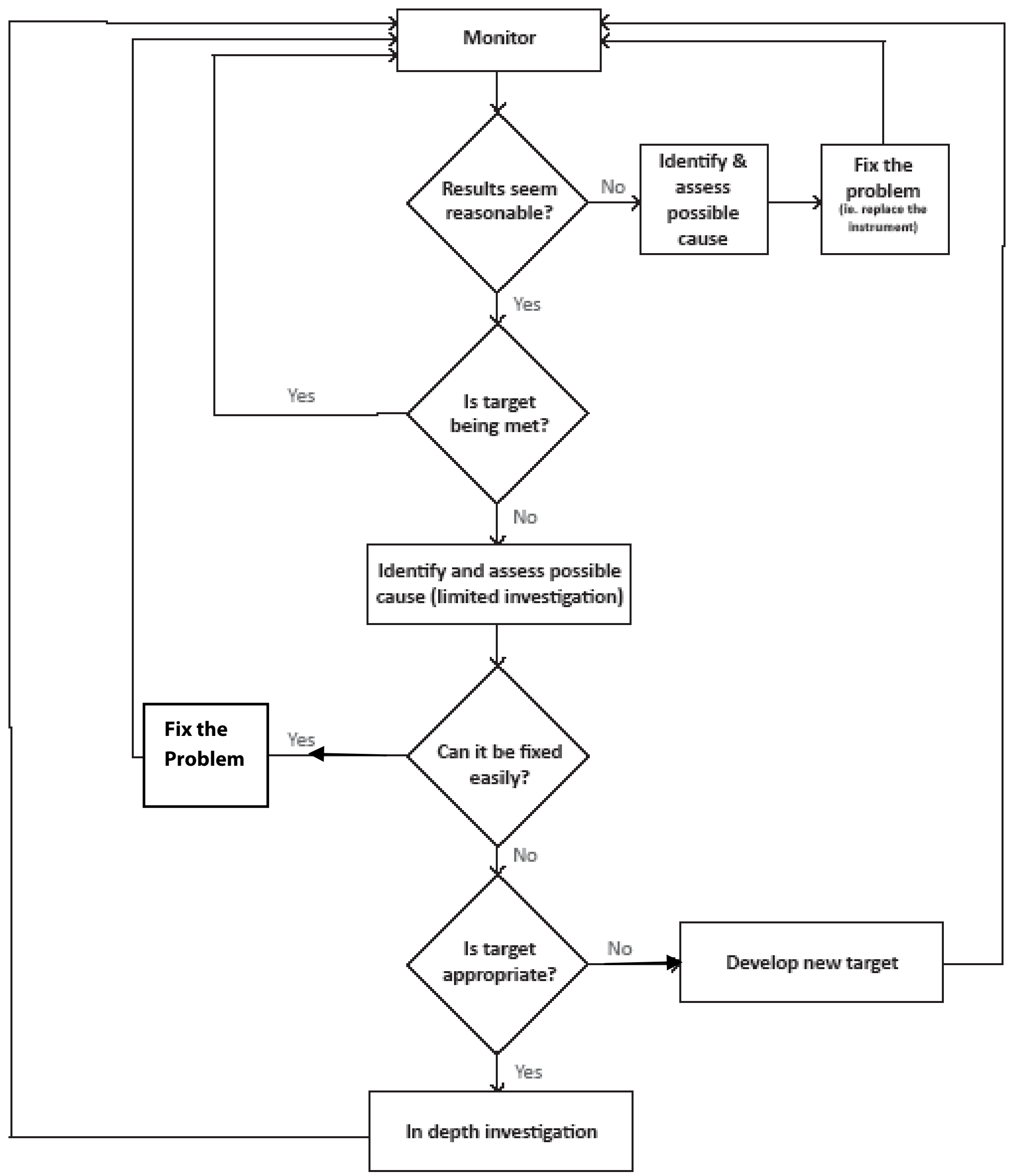
Indicator #	Indicator	Target	Adaptive Management Program				
			Monitor			Situation that necessitates further action	Examples of 'why' target(s) is not being met
			Item	Frequency	Cost		
DR1	Distribution of hydrologic processes by land use type	• Maintain the discharge limits as recommended in the current ISMP • Maintain the on-site retention volume criteria per land use type as recommended in the current ISMP • Compliance with City regulations regarding landscaping, tree planting, and tree preservation / planting	✓ Require sign-off by engineer of record that runoff managed as required ✓ Require sign-off by landscape architect for landscaping	• At time of development approvals (possibly introduce drainage requirements linked to building occupancy - through Stormwater Drainage Regulation and Charges Bylaw) • Representative sample checked for compliance every 4 years[3]	In-house costs	Non-compliance of greater than 10% (based on a representative sample taken every 4 years)	• Recommendations not being followed during design? • Lack of enforcement? • Lack of communication and/or education about requirements? • Poor construction/installation or maintenance of BMPs?
DR2	Status of low impact development measures	• Disconnected roof leaders for residential, commercial, industrial, active park spaces • 300 mm absorbent growing medial	✓ Require sign-off by engineer of record for roof leaders and absorbent growing media installation ✓ Require receipts for absorbent growing media ✓ Inspect absorbent growing media when lot grading is inspected	• At time of development approvals (possibly introduce drainage requirements linked to building occupancy - through Stormwater Drainage Regulation and Charges Bylaw) • Representative sample checked for compliance every 4 years	In-house costs	Non-compliance of greater than 10% (based on a representative sample taken every 4 years)	• Not following recommended LID measures in the current ISMP? • Topsoil not properly installed? • Lack of enforcement? • Lack of communications?
DR3	Management of additional impervious area due to additional site development (e.g., building expansion, paving)	• If building expansion, deck construction, paving, etc. results in an existing site having more than 65% total impervious area, discharge rates and on-site retention criteria recommended in current ISMP must be met	✓ Require building permit for any development activity that increases impervious area (including paving) ✓ Require sign-off by engineer of record that runoff managed as required	• At time of development approvals (possibly introduce drainage requirements linked to building occupancy - through Stormwater Drainage Regulation and Charges Bylaw) • Representative sample checked for compliance every 4 years	In-house costs	Non-compliance of greater than 10% (based on a representative sample taken every 4 years)	• Not following requirements to manage additional runoff due to building expansion, paving? • Lack of enforcement? • Lack of communications?

[3] The recommendation is for site visits to a representative sample, say 10-15%, of all lots developed during the previous four years. At a minimum, during the site visit, checks would be made on (1) depth of amended growing media, (2) roof leader disconnection, (3) visual check on presence and general condition of surface BMPs (e.g., rain gardens) and (4) confirmation of installation of subsurface BMPs (e.g., drain rock systems). For the latter item, original site plans or drawings, as submitted to the City at time of development, would have to be pulled and reviewed during the visit.

5.2 Adaptive Management Process

The **Monitoring and Assessment Process** is outlined by the flowchart on the following page (**Figure 18**). This is a standard process involving monitoring, checking results, and then taking appropriate action. As shown in **Tables 13** and **14**, action is not required each and every time a target is not met. Rather, action is only required at certain trigger points (e.g., if a target is not met "x" times within a year). This approach will help ensure that the City makes the best use of limited resources to address the most significant issues within these watersheds.

Figure 18: Monitoring and Assessment Process



Since the ultimate objective of this ISMP is to improve instream conditions, it is recommended that the City monitor flow conditions in various watercourses to assess the effectiveness of this plan. For long-term monitoring purposes, the maximum discharge rates included in

Table **15** have been converted to show target flow rate ranges. The City should consider monitoring flow rates at least every five years (and covering both low and high flow conditions) and more frequently as catchments develop. The target flow rates are shown in **Table 15** as well as in **Figure 17**.

The range was selected considering the peak flows during ARDSA storms (for both summer and winter) and peak flows for 2 year storms such that in the lower end, minimum channel flows can be maintained and in the upper end, flooding or erosion potential is not exacerbated. Providing a range for monitoring purposes also recognizes the inherent uncertainly with an uncalibrated model and varying site conditions.

Table 15: Target Flow Rates

Discharge Point	Target Flow Rates (m^3/s)		Minimum Base Flow (l/s)
	2 year storm event	5 year storm event	
Morgan Creek	0.5 – 0.8	0.6 – 1.2	7
Morgan Creek N. of 32nd Avenue.	0.6 – 1.2	0.9 – 1.6	12
Wills Brook N. of 32nd Avenue.	0.5 – 0.9	0.9 – 1.4	16
Old Logging Ditch N. of 32nd Avenue.	0.6 – 1.3	1.0 – 1.9	7
Burrow's Ditch N. of 32nd Avenue.	0.2 – 0.7	0.5 – 0.7	4

6 Conclusion

Old Logging Ditch and Burrow's Ditch are typical of many watersheds in Surrey, exhibiting the general impacts of urban development but not so seriously as to fully impair them as environmental resources or to have generated excessive flooding or creek erosion. Past planning efforts, as primarily expressed in the various applicable land use plans, appear to have laid a credible foundation for watercourse protection and flood control, if not in detail at least in overall perspective. Still, an overarching watershed vision has been lacking; this Integrated Stormwater Management Plan (ISMP) provides that vision, encapsulated in nine objectives. **Table 16** summarizes just how the recommendations of the ISMP address these objectives, through a focus on the use of low impact best stormwater practices and various riparian and in-stream enhancements and through long-term implementation of an adaptive management plan.

One very interesting finding of the analysis performed for the ISMP has been that, with some adjustments, implementation of the stormwater-related recommendations of the current GLUP and NCPs should maintain and enhance hydrologic conditions within the local streams as well as avoid unwanted flooding in the downstream agricultural lowlands. The most significant adjustment is a heightened emphasis on the use of low impact best management practices that focus on infiltration and evapotranspiration of rainwater wherever possible. Over time, this emphasis will yield more stable and healthier base stream flows in the area's watercourses. To piggyback on anticipated healthier base stream flow conditions, the ISMP has identified riparian and in-stream aquatic habitat improvements that can enhance the fisheries and general environmental values of the watercourses.

In addition to the heightened emphasis on maintaining hydrologic functions of the watersheds, the ISMP recognizes that the remaining urban runoff can carry environmental pollutants into receiving waters. The same low impact best management practices chosen to maintain hydrologic function, also tend to provide high levels of runoff treatment.

Finally, a critical role of the ISMP has been to outline implementation, monitoring and adaptive management actions to allow the City to continue forward with improving and maintaining watershed health in Old Logging Ditch and Burrow's Ditch catchments.

Table 16: Recommendations and Objectives

Recommendations	Objective
Reduce the rate and volume of runoff into the lowlands by: • Establishing maximum discharge rates into the lowlands for new development (all but SF lots with TIA < 50%) • Establish a monitoring program with target flow rates • Establish minimum on-site detention criteria for new development • Requiring 300 mm of amended growing media on new SF lots with TIA <50% • Requiring the disconnection of roof leaders (for all new development)	**Objective 1:** To protect agricultural activity in the lowlands.
Minimize run-off into streams and discharge into the City drainage system: • Establishing minimum on-site detention criteria for new development • Requiring 300 mm of amended growing media on new SF lots with TIA <50% • Requiring the disconnection of roof leaders (for all new development) Upgrade drainage infrastructure, including • Detention ponds • Minor and major conveyance system	**Objective 2:** To reduce flooding and erosion risks.
Promote infiltration and enhance water quality: • Encouraging the use of BMPs/LID • Requiring 300 mm of amended growing media on new SF lots with TIA <50% • Establish a monitoring program with target flow rates	**Objective 3:** To improve the quality of runoff discharging into local watercourses to protect and enhance fisheries values.
Infill plant riparian areas	**Objective 4:** To maintain intact riparian areas and, where possible, increase riparian setbacks.
• Protect wildlife corridors • Create linkages between greenspaces	**Objective 5:** To maintain significant areas of intact wildlife habitat and, where possible, increase wildlife habitat.
• Protect wildlife corridors • Create linkages between greenspaces	**Objective 6:** To maintain natural amenity uses and, where possible, incorporate amenity values into stormwater infrastructure.

Recommendations	Objective
• Promote infiltration (as above) • Minimize run-off (as above) • Establish a monitoring program with target base flows	**Objective 7:** To maintain minimum stream base flows to protect and enhance fisheries values.
Maintain proposed land uses, while improving riparian areas and protection/creating wildlife habitat.	**Objective 8:** To balance the needs of development with environmental values.
Provide recommended initiatives that focus on the key issues in the watershed.	**Objective 9:** To provide stormwater management in a cost-effective manner.

Appendix A

Summary of Tasks for Integrated Stormwater Management Planning (GVRD Template)

SUMMARY OF TASKS FOR
INTEGRATED STORMWATER MANAGEMENT PLANNING*

GVRD CLAUSE		OBJECTIVE(S)	Applicable Old Logging Ditch / Burrows ISMP Task #
1	Establish Framework	• To identify clearly the goals and objectives of the ISMP • To obtain an understanding of the issues and develop an appropriate study approach and scope • To establish which template clauses are applicable and determine the level of effort required • To establish applicable regulatory requirements (i.e., to determine which DFO approval letter is required)	Task 1.07 Task 1.08 Task 2.01 Task 2.08
2	Mapping / Information Gathering	• To obtain, review and evaluate all current and historical information, mapping, reports, plans and other pertinent data on the watershed	Task 1.01 Task 1.02 Task 1.08
3	Hydrometric Data and EIA Calculation	• To collect precipitation and stream flow data • To measure at least two significant rainfall events in the winter during saturated soil conditions, two in the spring or summer during dry soil conditions, and summer base flows • To collect sufficient information to determine the existing effective impervious area (EIA) of the basin	Task 1.01
4	Drainage System Inventory	• To establish a solid understanding of the watershed's physical characteristics • To identify opportunities and constraints for flood and stormwater management measures	Task 1.01 Task 1.04 Task 1.06
5	Hydrogeology / Geotechnical Assessment	• To identify sub-surface flow regimes, soil types, infiltration opportunities • To determine the sub-surface catchment area and base flow potential • To evaluate the groundwater flow regime as it relates to stream base flows • To identify ravine instabilities, and areas throughout the watershed designated as geotechnically significant • To identify areas in the watershed where infiltration should be minimized or prohibited	Task 1.05 Task 2.04
6	Land Use Information **	• To identify existing and future land use, and review land use plans and policies • To identify land use planning constraints and opportunities	Task 1.03

* "Based on "Template for Integrated Stormwater Management Planning 2005," prepared for Greater Vancouver Regional District by Kerr Wood Leidal Associates Ltd, December 2005.

GVRD CLAUSE		OBJECTIVE(S)	Applicable Old Logging Ditch / Burrows ISMP Task #
7	Agricultural Lands	• To identify agricultural lands • To establish level of flood protection and drainage requirements	Task 1.03
8	Recreational / Amenities	• To identify opportunities for existing and potential recreational trails, creek daylighting, riparian corridor relocation or enhancement, wetlands and other stormwater related amenities	Task 1.03
9	Aquatic Species and Habitat Inventory	• To identify aquatic species abundance and diversity, important habitat of the watershed, and opportunities for environmental enhancement	Task 1.04
10	Riparian Corridor Assessment	• To determine the extent and quality of existing and potential riparian corridors	Task 1.04
11	Terrestrial Species and Habitat Assessment	• To incorporate the findings of previous studies identifying important non-riparian habitat and other biological elements • To determine and protect the role of the riparian forest and aquatic habitat with non-riparian habitat and species	Task 1.04
12	Benthic Community Sampling	• To measure the aquatic health of the creek system • To establish a baseline for comparison of future years	Task 1.04
13	Water and Sediment Quality Analysis	• To determine if the watershed is representative of "typical" watersheds with similar impervious areas and land uses • To recommend future water quality assessment programs should water quality results exceed recommended guidelines, or fall outside what is considered "typical" for similar watersheds	Task 1.04
14	Base Plan Mapping (GIS Database)	• To geographically depict all information for quick and easy access, understanding, interpretation and analysis	Task 1.01 Task 1.03 Task 1.04 Task 1.05 Task 1.09

GVRD CLAUSE		OBJECTIVE(S)	Applicable Old Logging Ditch / Burrows ISMP Task #
15	Existing Stormwater Program Review	• To define the municipality's existing practices and needs related to stormwater policies such as bylaws/enforcements, design standards, operation and maintenance practices, public education, equipment and staff training	Task 1.05 Task 1.07 Task 2.06
16	Hydrological Analysis	• To develop a useful tool to simulate the watershed's hydrologic response, determine effective impervious area, estimate design flows and volumes, determine the impact of development, assess mitigative alternatives, and size recommended facilities	Task 1.06 Task 2.03
17	Hydraulic Analysis	• To assess flooding extent, depth and duration • To determine the conveyance capabilities of the existing and future drainage system (channels, drainage ditches, and structures) and size upgrades, if required • To the assess the hydraulic functioning storm sewer systems • To determine structural deficiencies in the storm sewer systems	Task 1.06
18	Channel Erosion	• To identify sections of the watercourse channel that are, or will be, susceptible to erosion from flows <<Q2 to Q100 • To identify mitigation measures for existing and future development conditions	Task 1.06 Task 2.04
19	Agricultural Assessment	• To assess and mitigate agricultural flooding and poor drainage	Task 1.05 Task 1.06 Task 2.04
20	Natural Hazard Assessment	• To identify and recommend mitigative measures for natural hazard areas (i.e. debris flows, etc) • To identify potential impacts of natural hazards on the drainage collection system • To identify areas where the stormwater plan may yield or worsen geotechnical hazards	Task 2.04
21	Land Use Sensitivity Analysis **	• To explore the impacts of modified development densities and location options • To make recommendations on land use (if required) that may eventually be incorporated into the GVRD's Livable Regional Plan and/or a municipality's OCP/NCP planning process during the next update	Task 1.07 Task 2.02 Task 2.06
22	Recreation and Public Access Analysis	• To assess walkways, greenways and access points along stream corridors as a public amenity and for public education • To integrate with Parks and Recreation Plans	Task 2.02

GVRD CLAUSE		OBJECTIVE(S)	Applicable Old Logging Ditch / Burrows ISMP Task #
23	Environmental Parameters **	• To determine the effective impervious area and riparian forest integrity for existing and future development scenarios as proposed • To plot the parameters on the GVRD Watershed Health Tracking System so as to show the potential impact of unmitigated future development	Task 2.03
24	Ecological Health Analysis	• To quantify the ecological health of the watercourse at key locations • To quantify the ecological impacts of changing land use densities, riparian corridors, development standards, and source controls, LID measures and regional BMPs	Task 2.03
25	Flood / Erosion Management Alternatives	• To investigate improvements and structural alternatives to alleviate flooding and erosion problems • To investigate environmental mitigation and/or enhancement, if required	Task 2.04 Task 2.05 Task 2.08
26	Land Use Alternatives **	• To prepare alternative development scenarios as a result of the land use sensitivity analysis that was performed in Clause 21 that address land use location and densities, riparian corridor locations and setbacks, ESAs, public trails and other stormwater amenities • To investigate low impact development standards potentially applicable to various land use designations and the resulting reduction in effective impervious area	Task 1.07 Task 2.02 Task 2.06 Task 2.08
27	Stormwater Management Alternatives	• To investigate stormwater management alternatives to minimize the impacts of land development • To incorporate the LID strategies developed in Clause 26	Task 1.07 Task 2.05 Task 2.06 Task 2.08
28	Water Quality Alternatives	• To identify measures to mitigate point and non-point source water quality problems on impervious areas	Task 2.04 Task 2.05 Task 2.08
29	Evaluate Alternatives	• To evaluate alternatives for flood / erosion management, land use, land development standards, stormwater management, and water quality management in an integrated way with consideration for health and safety, environmental impacts, costs, and public acceptance	Task 2.07 Task 2.08
30	Stormwater	• To develop a Stormwater Program that includes recommended practices, bylaws, standards, etc.	Task 3.08

GVRD CLAUSE		OBJECTIVE(S)	Applicable Old Logging Ditch / Burrows ISMP Task #
	Program		
31	Integrated Stormwater Management Plan	• To develop an ISMP plan that strives to achieve a fisheries no-net-loss • To address the impact of stormwater management on relevant community values, including recreation, agriculture, fisheries, greenways, heritage, archaeology, safety, transportation, economics, property values, flood protection, affordability, the environment and related issues	Task 3.04 Task 3.05 Task 3.06
32	Implementation Strategy	• To develop a strategy and timeline for the proposed works • To identify and evaluate various financial alternatives to fund and implement ISMP • To evaluate the implementation timing of the proposed works and strategies and ensure that the health of the watershed will be maintained as stated by the ISMP watershed health objectives	Task 3.01 Task 3.02 Task 3.03 Task 3.07
33	Integrate with Municipal Plans	• To make recommendations to be considered in OCPs, NCPs, Parks and Recreation plans, Strategic Transportation plans, etc.	Task 3.03 Task 3.08
34	Adaptive Management	• To establish and monitor watershed health and state using performance indicators (B-IBI scores, EIA and riparian forest integrity) • To adapt the ISMP implementation strategy if needed to achieve no-net-loss of watershed health	Task 4.01 Task 4.02 Task 4.03 Task 4.04
35	Report	• To document the study process and findings	Task 1.09 Task 2.09 Task 4.05 Task 4.06 Task 3.10

** Iterative Process

Acronyms:

B-IBI	Benthic Index of Biotic Integrity
DFO	Fisheries and Oceans Canada
EIA	Effective Impervious Area
ESA	Environmentally Sensitive Area
GIS	Geographic Information System
GVRD	Greater Vancouver Regional District (or MetroVancouver)
ISMP	Integrated Stormwater Management Plan
LID	Low Impact Development
NCP	Neighborhood Concept Plan
OCP	Official Community Plan

Appendix B

Environmental Report (including BC Water Quality Guidelines)

BURROWS DITCH AND OLD LOGGING DITCH INTEGRATED STORMWATER MANAGEMENT PLAN

Existing Conditions Report and Enhancement Opportunities – Environment (Final)

September 2011

Submitted to:

City of Surrey
14245-56th Avenue
Surrey, BC
V3X 3A2
Attention: Ms. Jeannie Lee

Submitted by:

Dillon Consulting Limited
Suite 510 – 3820 Cessna Drive
Richmond, BC
V7B 0A2

Project No. 09-2507

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

APPENDICES

1.0 INTRODUCTION

The Burrows Ditch and Old Logging Ditch watersheds support a variety of aquatic and terrestrial habitats from the impacted agricultural lowlands north of 32nd Avenue to the more intact upland habitat to the south. Aquatic habitat is provided by constructed linear roadside and agricultural ditches in addition to the more naturalized upland channels. Terrestrial habitat is provided by intact vegetated hubs linked by a series of corridors throughout both watersheds.

This report provides a summary of the existing habitat conditions supported within the catchment area of each watershed, including the important Old Logging Ditch tributaries of Wills Brook and Morgan Creek. To determine the existing conditions, a desktop review of existing background information was completed and supplemented by a field investigation to fill gaps identified during the literature review. The information obtained concentrated on the environmentally focused clauses outlined in Metro Vancouver's Template for Integrated Stormwater Planning 2005 draft report. Specifically, those clauses that provide relevant information as to the existing environmental condition within both watersheds consist of the following:

- Clause 9 Aquatic Species and Habitat Inventory
  - Fish presence, channel and riparian characteristics, fish passage barriers, and spawning/rearing habitat for salmonids.
- Clause 10 Riparian Corridors Assessment
  - Calculation of intact riparian vegetation (% Riparian Forest Integrity) and extent/structure of riparian corridors.
- Clause 11 Terrestrial Species and Habitat Assessment
  - Wildlife presence and extent/location of wildlife hubs and corridors.
- Clause 12 Benthic Community Sampling
  - Interpretation of existing benthic invertebrate diversity and abundance data to determine aquatic health.
- Clause 13 Water and Sediment Quality Analysis
  - Determination of water and sediment quality parameters that may be affecting aquatic habitat.
- Clause 23 Environmental Parameters
  - Determination of watershed health based on intact riparian forest and impervious area within each watershed. Watershed health has also been predicted for future conditions.

This summary of existing habitat conditions supported within both watersheds can be utilized as a baseline for comparisons to environmental conditions and ecological health as the watersheds develop in the future. It also serves to identify areas of environmental sensitivity and importance in order to act as a tool to direct that future development in such a way as to sustain critical aquatic and terrestrial habitat.

A map indicating the Study Area and its regional context within the Lower Mainland is provided in **Figure 2-1**.

2.0 METHODOLOGY

2.1 Fisheries/Aquatic Assessment

The fisheries and aquatic habitat assessment of the Old Logging Ditch and Burrows Ditch systems consisted of a review of available literature and regional specific databases. Contact was made with a local streamkeeper group as well. The City of Surrey Mapping On-line System (COSMOS) was used to obtain fish classification and fish species information for the Study Area.

An overview field evaluation and sampling program was conducted on December 10^{th} and 11^{th}, 2009. The overview investigation was intended to provide additional information related to fish habitat, fish presence, and general water quality of the Burrows Ditch and Old Logging Ditch systems. Surveys were carried out by a two-person crew and involved an aquatic habitat assessment, water quality sampling, and fish capture study at several sites (see **Figure 2-2**). The sampling protocol for the fisheries and aquatic habitat assessment incorporated B.C. Resource Information Standards Committee standards and procedures.

The sampling locations for the fish and aquatic habitat assessment were selected based on existing information, site physiography, and resemblance to the “typical” habitat found at each respective watercourse. Sampling locations were associated with both constructed habitats (*e.g.* Burrows Ditch and Old Logging Ditch) and stream tributaries within the Burrows and Old Logging Ditch Study Area (*e.g.* Morgan Creek and Wills Brook).

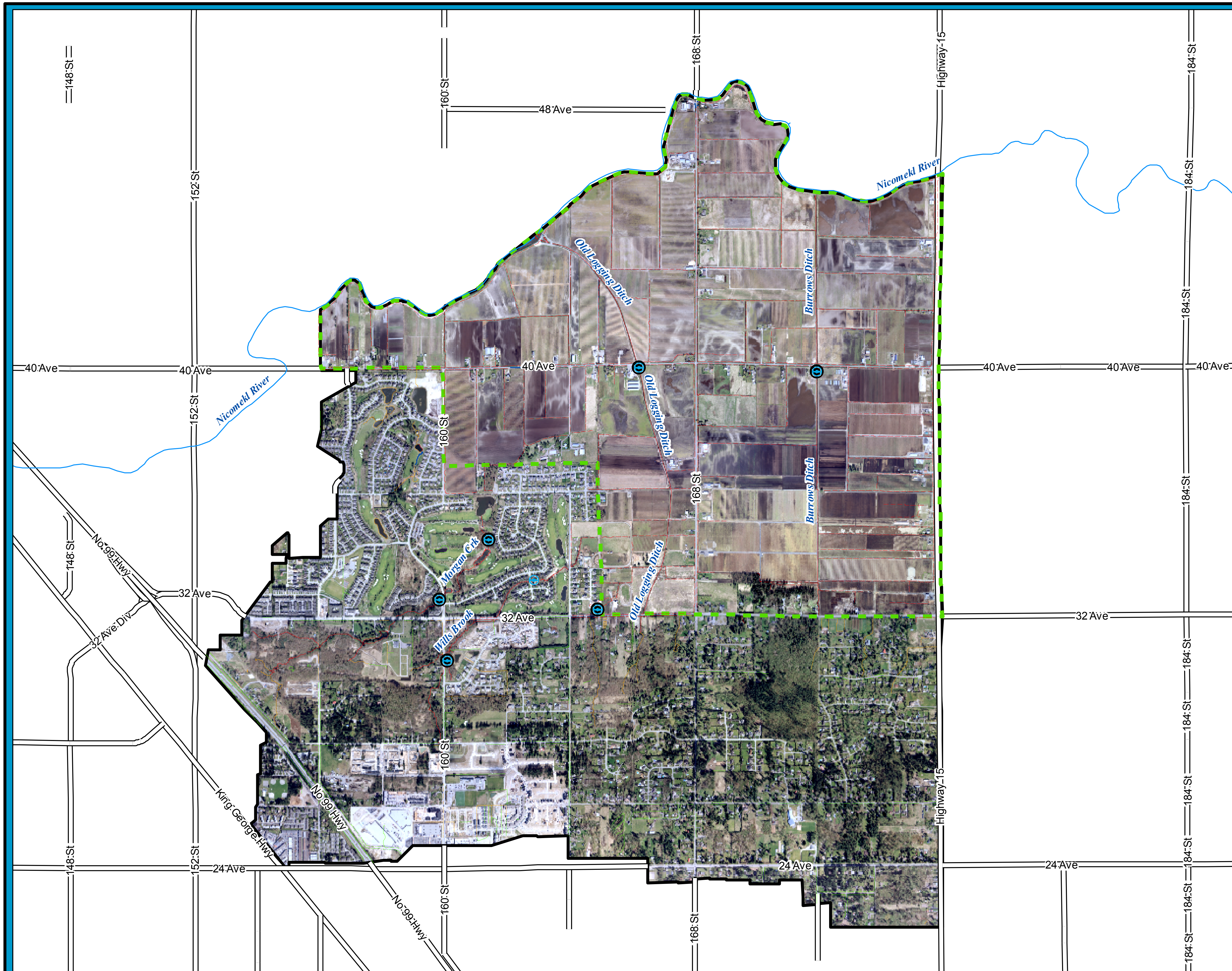
The fisheries and aquatic habitat assessment included a qualitative assessment of existing habitats (*e.g.*, channel characteristics/morphology, watercourse substrates, and instream and riparian attributes), fish species presence/absence, and connectivity to known fish habitat.

Fish composition was examined to obtain information on the condition of aquatic and riparian habitats and to assist in the identification of potentially sensitive elements of fish habitat. Fish composition information was also deemed important for the evaluation of overall sensitivities of fish species to potential changes in water quality or quantity that might result from future development within the Study Area.

A fish capture study was completed with the use of baited G-style minnow traps. All traps were set for a minimum of 24 hours and all collected fish were enumerated and identified to species and released alive at their point of capture. Baited minnow traps were placed in 7 locations within the Burrows Ditch and Old Logging Ditch systems. Sampling locations are described in **Figure 2-2** and **Table 2-1** below.

Furthermore, a fish barrier assessment was conducted in conjunction with the fisheries and aquatic habitat assessment in December 2009 in an effort to identify and map any potential fish passage barriers and identify the most ecologically significant fish barriers within the Study Area.


CITY OF
SURREY
the future lives here.
Figure 2.1:
Project Location
Legend
Study Area
Parks
Legal Lot Boundary
WHALLEY
CITY CENTRE
GUILDFORD
FLEETWOOD
NEWTON
CLOVERDALE
Burrows/Old Logging Ditch Study Area
SOUTH SURREY
WHITE ROCK
KEY MAP
NOT TO SCALE
N
W
E
S
Meters
2,000 1,000 0 2,000 4,000
Project Name: Burrows/Old Logging Ditch ISMP
Map Created By: 42aph
Map Checked By: 42lkd
Date Created: JAN-2010
Date Modified: AUG-2010
File Path G:\CAD\092507\GIS_Data
Source: www.Geogratis.com & COSMOS
DILLON CONSULTING



CITY OF SURREY
the future lives here.

Figure 2.2: Project Area and Field Assessment Locations

Legend

- Agricultural Land Reserve Boundary
- Study Area
- Fish Sample Location
- Water Quality Assessment Location

Watercourse Classification

- Class A (red-coded) watercourse - Year-around salmonid presence. Non-salmonid species also present.
- Class A(O) (red-dashed) watercourse - Inhabited during overwintering periods by salmonids. Non-salmonid species present year-round.
- Class B (yellow-coded) watercourse - Provides significant food and nutrient value to downstream fish populations. No potential for fish presence.
- Class C (green-coded) watercourse - No fish presence. Does not provide significant food and nutrient value to downstream fish populations.
- Unknown Watercourse

N W E S

Meters

500 250 0 500 1,000

Project Name:	Burrows/Old Logging Ditch ISMP
Map Created By:	42aph
Map Checked By:	42lkd
Date Created:	JAN-2010
Date Modified:	AUG-2010
File Path	G:\CAD\092507\GIS_Data

Source: COSMOS & Urban Systems

DILLON CONSULTING

Table 2-1: Fisheries and Aquatic Habitat Survey Locations, December 2009

Major Drainage	Site	Stream / Creek	Location
Old Logging Ditch	1	Old Logging Ditch	North and south sides of 40th Avenue
	2	Unnamed Roadside Ditch	North side of 32nd Avenue, east of 164th Street
	3	Morgan Creek	Accessed from Morgan Creek Way
	4	Morgan Creek	Accessed from Morgan Creek Crescent
	5	Wills Brook	East side of 160th Street
	6	Wills Brook	East side of Crosscreek Court
Burrows Ditch	7	Burrows Ditch	North and south sides of 40th Avenue

The riparian habitat of the 4 main fish-bearing watercourses within the Study Area was assessed at 6 sampling locations (Sites 1 and 3 through 7 as listed in **Table 2-1**). Species composition, approximate width of the riparian zone, approximate percent of riparian streamside cover, and riparian quality were estimated and recorded.

To determine the percent riparian forest integrity (% RFI), the Streamside Protection Regulation (SPR) was applied. Streamside Protection and Enhancement Areas (SPEAs), the areas linking aquatic and terrestrial ecosystems adjacent to a stream, were determined for all fish-bearing (Class A and A(O)) and non-fish bearing (Class B) watercourses within the Study Area. Widths/setbacks of the SPEAs varied depending on fish presence and the presence of permanent structures adjacent to a watercourse. Following the determination of the SPEA setbacks, intact riparian vegetation within the SPEAs was identified. The % RFI was calculated based on the existing intact and established forested riparian areas within the SPEA and the total area of the SPEA. SPEAs and existing riparian vegetation were estimated through aerial photographic interpretation and the use of existing background and field assessment information. The RFI is based on calculated estimated values obtained through the use of ArcGIS.

Conventional water quality parameters including temperature, pH, conductivity, dissolved oxygen (DO), and turbidity were measured at 6 locations across the Old Logging Ditch and Burrows Ditch watersheds (Sites 1 through 5 and Site 7 as listed in **Table 2-1**). Water quality parameters were measured using hand-held water quality metres. When direct access to the wetted edge of a watercourse was not attainable, as was the case at Old Logging Ditch and Burrows Ditch, a large bucket was used to collect water for sampling purposes.

Given the timing of the field assessment, water quality results are not definitive as per the maximum effort outlined in Clause 13 – Water and Sediment Quality Analysis of Metro Vancouver's Template for Integrated Stormwater Planning, 2005.

2.2 Terrestrial Assessment

The terrestrial habitat assessment component was based on a review of available published information, unpublished records, and site visits. Information on occurrences of red- and blue-listed animals species found in the vicinity of the Study Area was obtained from the B.C. Conservation Data Centre (CDC) website. The federal Species at Risk and BC Ecosystems Explorer websites were also reviewed.

Site visits were conducted December 10^{th} and 11^{th}, 2009 at seven (7) locations within the Study Area. Surveys involved general "walk-through" assessments of potential high quality habitats within the Study Area. Wildlife was identified by visual observation, calls, tracks, feeding sign, feces and other signs.

3.0 EXISTING HABITAT CONDITIONS

3.1 Aquatic Habitat and Species

The aquatic ecosystem in the Burrows Ditch and Old Logging Ditch systems provides habitat for a variety of fish species. Fish species presence within the Study Area is influenced by migration patterns within the Nicomekl River. Further details regarding fish and aquatic habitat within the Study Area are discussed below.

3.1.1 Watercourse Classification

All watercourses within the Study Area drain north into Old Logging Ditch or Burrows Ditch prior to discharging to the Nicomekl River. Watercourses are classified based on the presence of salmonid (salmon and trout species) as well as so-called "coarse" fish (*e.g.* threespine stickleback (*Gasterosteus aculeatus*), redside shiner (*Richardsonius balteatus*), etc.) and the contribution of food and nutrient value to downstream fish populations. Four watercourse classifications help to guide development, planning, operations and maintenance works, and restoration activities within the City of Surrey (HB Lanarc & Raincoast Applied Ecology, 2009):

- Class A (red-coded) watercourse – Year-round salmonid presence. Non-salmonid species also present.
- Class A(O) (red-dash) watercourse – Inhabited during overwintering periods by salmonids. Non-salmonid species present year-round.
- Class B (yellow-coded) watercourse – Provides significant food and nutrient value to downstream fish populations. No potential for fish presence.
- Class C (green-coded) watercourse – No fish presence. Does not provide significant food and nutrient value to downstream fish populations.

Watercourse classifications within the Study Area are indicated on **Figure 2-2**.

3.1.2 Fish Presence and Aquatic Habitat

3.1.2.1 Nicomekl River

North of the Study Area, the Nicomekl River is the largest watercourse influencing the Burrows Ditch and Old Logging Ditch systems. The river flows west through Surrey before entering Mud Bay approximately 8 km downstream of the western Study Area boundary. The Nicomekl River is red-coded

(Class "A") according to the City of Surrey Classification System. As discussed, red-coded habitats include features that support salmonid species year-round. The Freshwater Fisheries Society of BC's online "Fish Wizard" database indicated that the lower reaches of the Nicomekl River are occupied by three species of anadromous salmon (Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*)), and two species of resident trout (cutthroat (*O. clarki clarki*) and rainbow (*O. mykiss*)). Both cutthroat and rainbow trout can also be anadromous. One species of char (Dolly Varden (*Salvelinus malma*)) is also reported from this reach of the river. Several coarse fish species also occupy the Nicomekl River including brassy minnow (*Hybognathus hankinsoni)*, flathead chub (*Platygobio gracilis)*, lamprey (*Lampetra* sp.*)*, peamouth chub (*Mylocheilus caurinus*), prickly sculpin (*Cottus asper*), pumpkinseed *(Lepomis gibbosus)*, redside shiner, starry flounder (*Platichthys stellatus)*, threespine stickleback, and yellow perch (*Perca flavescens*).

No fisheries or aquatic habitat data was collected for the Nicomekl River during the December 2009 surveys due to its occurrence outside of the Study Area boundary.

3.1.2.2 Burrows Ditch

Burrows Ditch lies within the Agricultural Land Reserve (ALR) and is aligned east of 168th Street and west of Highway 15. Burrows Ditch receives local drainage from the upland slopes to the south of 32nd Avenue. In mid-December 2009, flow within the ditch was slow and conveyed north to the Nicomekl River. Burrows Ditch was designed with moderately steep banks and a trapezoidal cross section. Substrates were comprised of fines and organics with an average wetted width and depth of approximately 3.5 m and 1.5 m respectively. Riparian vegetation consisted primarily of invasive vegetation such as Himalayan blackberry (*Rubus discolor*), and reed canary grass (*Phalaris arundinacea*).

Background fish habitat information indicates that Burrows Ditch contains salmonid species year round and is classified as a Class "A" watercourse by COSMOS. Documented fish species present within Burrows Ditch include coho salmon, cutthroat trout, redside shiner, threespine stickleback, pumpkinseed, goldfish (*Carassius auratus*), and fathead minnow (*Pimephales promelas*) (ECL Envirowest 1994). Dillon's recent fish sampling program within Burrows Ditch in December 2009 confirmed the presence of threespine stickleback, pumpkinseed, and redside shiner. Overall fish habitat in Burrows Ditch is considered to be of low quality and value. Low discharge volumes and poor water quality may inhibit utilization by salmonids during summer months, although salmonids are known to travel through the ditch to more suitable spawning and rearing habitats upstream.

No fish barriers are known to occur within Burrows Ditch although it is suspected that a floodbox gate exists at the confluence with the Nicomekl River that may present a complete or partial barrier to fish during summer months. The floodbox was scheduled for replacement in the summer of 2010; however, improved fish access was not a component of the proposed works. As such, improved access will have to be incorporated during the next round of maintenance/upgrading of the pump station and ancillary infrastructure.

3.1.2.3 Old Logging Ditch

As with Burrows Ditch, Old Logging Ditch lies within the ALR and is aligned north of 32nd Avenue approximately parallel to 168th Street. Old Logging Ditch receives local drainage from the upland slopes to the south of 32nd Avenue. Flow in the Old Logging Ditch system is generally conveyed north towards the Nicomekl River. Old Logging Ditch contained moderately steep banks and a trapezoidal cross section. Substrates were comprised of fines and organics with an average wetted width and depth of approximately 3.5 m and 3 m at the time of survey. Riparian vegetation consisted of hardhack (*Spirea douglasii)*, Himalayan blackberry, and reed canary grass.

Old Logging Ditch is identified as a Class A watercourse and is red-coded (supports salmonids on a year-round basis) according to COSMOS. Previous fish sampling programs in Old Logging Ditch have documented the presence of coho salmon, cutthroat trout, rainbow trout, threespine stickleback, redside shiner, and carp (*Cyprinus carpio*) (New East Consulting, 1996). Fish sampling within Old Logging Ditch in December 2009 confirmed the presence of threespine stickleback. Although no salmonids were collected during the December 2009 fish capture study, salmonids are known to migrate through the system to upstream spawning and rearing habitats. Overall fish habitat in Old Logging Ditch is considered to be of low quality and value.

Two fish barriers are documented within Old Logging Ditch. An outlet structure associated with a pond south of 32nd Avenue presents a complete barrier to fish during all times while a floodbox gate at the confluence with the Nicomekl River presents a complete barrier to fish during summer months (New East Consulting, 1996). As with the floodbox on Burrows Ditch, the floodbox on Old Logging Ditch was scheduled for replacement in the summer of 2010; however, improved fish access was also not a component of the proposed works.

3.1.2.4 Morgan Creek

The Morgan Creek lowland reach occurs north of 32nd Avenue within the ALR while the upland reach is found to the south of the ALR boundary. Both reaches of Morgan Creek are Class A (red-coded) according to COSMOS, although fish distribution is likely dictated by the availability of suitable habitats and the locations of fish barriers.

A fish and aquatic habitat assessment of the lowland reach (north of the ALR boundary) of Morgan Creek was conducted at two sites adjacent to the Morgan Creek Golf Course (see **Figure 2-2**). At both sites, stream velocities were slow to moderate and conveyed northeast towards Old Logging Ditch. Substrates within the lowland reach of Morgan Creek consisted predominantly of silt and clay with minor amounts of fine gravel in some sections. Wetted widths varied between 1 and 5 meters due to the presence of ponded segments associated with the Morgan Creek golf course. Streamside habitat complexity at both sites consisted of an approximately 15 m wide riparian corridor consisting of red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), western red cedar (*Thuja plicata*), and black cottonwood (*Populus trichocarpa* ssp. *balsamifera*).

Documented fish presence in lower Morgan Creek includes cutthroat trout, fathead minnow, and threespine stickleback. Background information indicates that lower Morgan Creek is utilized by salmonids as a migration corridor to upland spawning and rearing habitats although this remains unconfirmed. Dillon's fish sampling program in Morgan Creek north of 32nd Avenue in December 2009 confirmed the presence of threespine stickleback. Overall fish habitat in lower Morgan Creek is considered to be of low to moderate quality and value.

The upland reach of Morgan Creek consists of two stream tributaries located at the headwaters of the Old Logging Ditch watershed system. Morgan Creek originates within the forest block, roadside ditches, and residential lots south of 32nd Avenue between Croyden Drive and 156th Street. Both tributary channels convey flow northeast towards 32nd Avenue. Background information indicates that the headwater tributaries of Morgan Creek are relatively low to moderate gradient streams contained within steeply incised ravines with bank heights of 2-4 m. Substrates in both tributaries are dominated by clay and gravel with varying amounts of decomposing organic matter. Streamside riparian habitat is well-developed in both tributaries and contains predominantly red alder and paper birch (*Betula papyrifera*) with an understory consisting of salmonberry (*Rubus spectabilis*), vine maple (*Acer circinatum*), red elderberry (*Sambucus racemosa*), and fern species (Strix, 2000).

No fish capture data exists for the headwaters of Morgan Creek. Background information and previous fish capture studies suggest that all fish species are precluded from the headwaters of Morgan Creek due to the presence of a fish barrier at the outlet of the Gardens of Gethsemani cemetery pond (New East Consulting, 1996). Below the pond, the system is documented to sustain both resident and anadromous populations of salmonids. No fish or aquatic habitat assessment of the Morgan Creek headwaters was conducted due to private property access limitations. Background documents suggest that fish habitat in the headwaters of Morgan Creek is considered to be of high quality and value.

Some access and enhancement work has been completed on Morgan Creek during previous years. The culvert conveying the channel under 32nd Avenue was retrofitted with a larger diameter box culvert at its outlet north of the road in 2000. The box essentially functioned as a covered pool and included instream gravels to add some complexity and to provide a substrate for benthic invertebrate recruitment. The culvert was also made fish passable with the installation of a weir at its outlet. In addition, instream complexing in the form of a series of step pools and large woody debris was installed downstream of the culvert. Riparian planting was also completed downstream.

A privately owned floodbox gate and pump station at the confluence with Old Logging Ditch likely presents a complete barrier to fish during summer months.

3.1.2.5 Wills Brook

The Wills Brook lowland reach is found north of 32nd Avenue while the upland reach resides south of 32nd Avenue and immediately east and west of 160th Street. The Wills Brook upland drains the forest block and residential properties in the southern portion of the Study Area. Flow is conveyed northeast approximately paralleling 160th Street and is connected hydraulically with Old Logging Ditch at

32nd Avenue. Substrates in Wills Brook were comprised of coarse gravel and cobble with an average wetted width and depth of approximately 1.5 m and 0.1 m respectively. Instream habitat complexity was primarily provided by riparian cover, undercut banks, and large and small woody debris. Riparian vegetation consisted of salmonberry, vine maple, willow (*Salix* spp.), and bracken fern (*Pteridium aquilinum*). Overhanging vegetation consisted of big leaf maple, red alder, and black cottonwood.

Wills Brook is identified as a Class "A" watercourse by COSMOS. Documented fish presence within Wills Brook includes coho salmon and cutthroat trout (New East Consulting, 1996). Fish sampling within Wills Brook at 160th Street in December 2009 confirmed the presence of cutthroat trout. Overall fish habitat in Wills Brook is considered to be of high quality and value within the uplands and of medium to low quality in value north of 32nd Avenue.

Background information indicated that several fish barriers in the form of driveway culverts occurred along Wills Brook near 160th Street. (New East Consulting, 1996). However, it is suspected that these barriers have since been removed as a result of recent and ongoing fish enhancements in the vicinity.

3.1.2.6 Other Study Area Watercourses

Numerous red-coded linear agricultural ditches flow within the ALR portion of the Study Area boundary. These ditches exhibit similar streamside habitat and water quality values as the Burrows Ditch and Old Logging Ditch systems. Salmonids have been documented to migrate through these ditches to more suitable spawning and rearing habitats upstream. Fish habitat values within these agricultural ditches are considered to be of low quality with the exception of the linear road side ditch north of 32nd Avenue. Salmonid spawning and rearing habitat values within the north 32nd ditch were recently enhanced from the approximate 16500 block eastward to Old Logging Ditch. The enhancements consisted of the construction of a meandering channel complexed with large woody debris (LWD), constructed pool-riffle sequences, and "lunker" structures. Fish barriers were removed to promote fish migration. Riparian planting was also completed as a component of the works.

Additional upland watercourses include several non-fish bearing Class B and C ephemeral and permanent streams that drain the southern slopes of the Study Area south of 32nd Avenue. A pond outlet representing a fish barrier on April Creek south of 32nd Avenue is documented although this was not confirmed during the December 2009 survey due to property access constraints.

3.1.2.7 Summary of Fish Collection

Four (4) species of fish (threespine stickleback, redside shiner, pumpkinseed, and cutthroat trout) were collected during the 2009 field investigation. Threespine stickleback was the most abundant and widely distributed fish species collected within the Study Area watercourses. Three cutthroat trout were collected in Wills Brook. No other salmonids were captured in any other watercourses within the Study Area during the December 2009 surveys. **Table 3-1** summarizes the fish collection results by location.

Table 3-1: Fish Collection Summary for the Burrows Ditch and Old Logging Ditch Systems

Fish Species Collected	Location				
	Old Logging Ditch	Burrows Ditch	Wills Brook	Morgan Creek	Ditch at 32nd Ave
Threespine stickleback *(Gasterosteus aculeatus)*	5	5	-	51	No fish captured
Pumpkinseed *(Lepomis gibbosus)*	-	1	-	-	
Redside Shiner (*Richardsonius balteatus*)	-	2	-	-	
Cutthroat Trout (*Oncorhynchus clarki clarki*)	-	-	3	-	

3.1.2.8 Summary of Barriers to Fish Passage

Background information on fish barriers was collected in conjunction with the fisheries habitat assessment in an effort to identify and map any potential fish passage barriers and identify the most ecologically significant fish barriers in the Study Area. Several potential fish passage obstructions were identified on several watercourses. Potential fish barriers in the Study Area represent artificial barriers in the form of culverts, floodbox gates, or outlets/inlets associated with on-line ponds. Information about location and type of each barrier/obstacle in the Study Area is outlined in **Table 3-2** (New East Consulting 1996).

Table 3-2: Potential Fish Barriers in the Burrows Ditch and Old Logging Ditch Systems

Watercourse	Description
Old Logging Ditch	Floodbox gate at the confluence with the Nicomekl; presents a complete barrier to fish during summer months.
	On-line pond south of 32nd Avenue; presents a complete barrier to fish.
Morgan Creek	Privately owned floodbox gate and pump station at the confluence with Old Logging Ditch; presents a complete barrier to fish during summer months.
	On-line pond at Gardens of Gethsemani cemetery outlet pond; presents a complete barrier to fish.
Unnamed Roadside Ditch North of 32nd Avenue	Driveway culverts and pond outlet structures; may have been removed during recent enhancements on-site.

3.1.3 Riparian Corridor Assessment

Riparian vegetation serves a variety of functions in helping to maintain the quality of fish habitat. Vegetation along the banks of a watercourse provides:

- Shade;
- A natural filter of surface water before it enters a watercourse;
- Bank stabilization;
- Nutrient contribution through leaf fall and insect drift; and
- Shelter and habitat diversity in the form of large woody debris (downed trees and decaying tree stumps).

Riparian habitat and riparian corridor quality varied significantly between the watercourses located within agricultural land (lowlands) and residential land (uplands). The riparian quality of the lowland agricultural channels was significantly less than the quality of channels within the upland residential areas. Differences in quality between these areas are attributed to the width of the riparian zone, connectivity, and streamside riparian cover. Agricultural channels were found to have narrower riparian corridors, less diverse vegetation, higher invasive plant species encroachment, and lower streamside riparian cover. Upland channels in residential areas were found to have larger riparian corridors, diverse native vegetation, and higher streamside riparian cover. Both riparian zones in the lowland and upland areas of the catchment areas were found to support a variety of bird species (See **Section 3.2.1** for more information).

A map indicating intact riparian vegetation is provided in **Figure 3-1**. The following outlines the distinctive features and qualities of the riparian habitat within the Study Area.

3.1.3.1 Nicomekl River

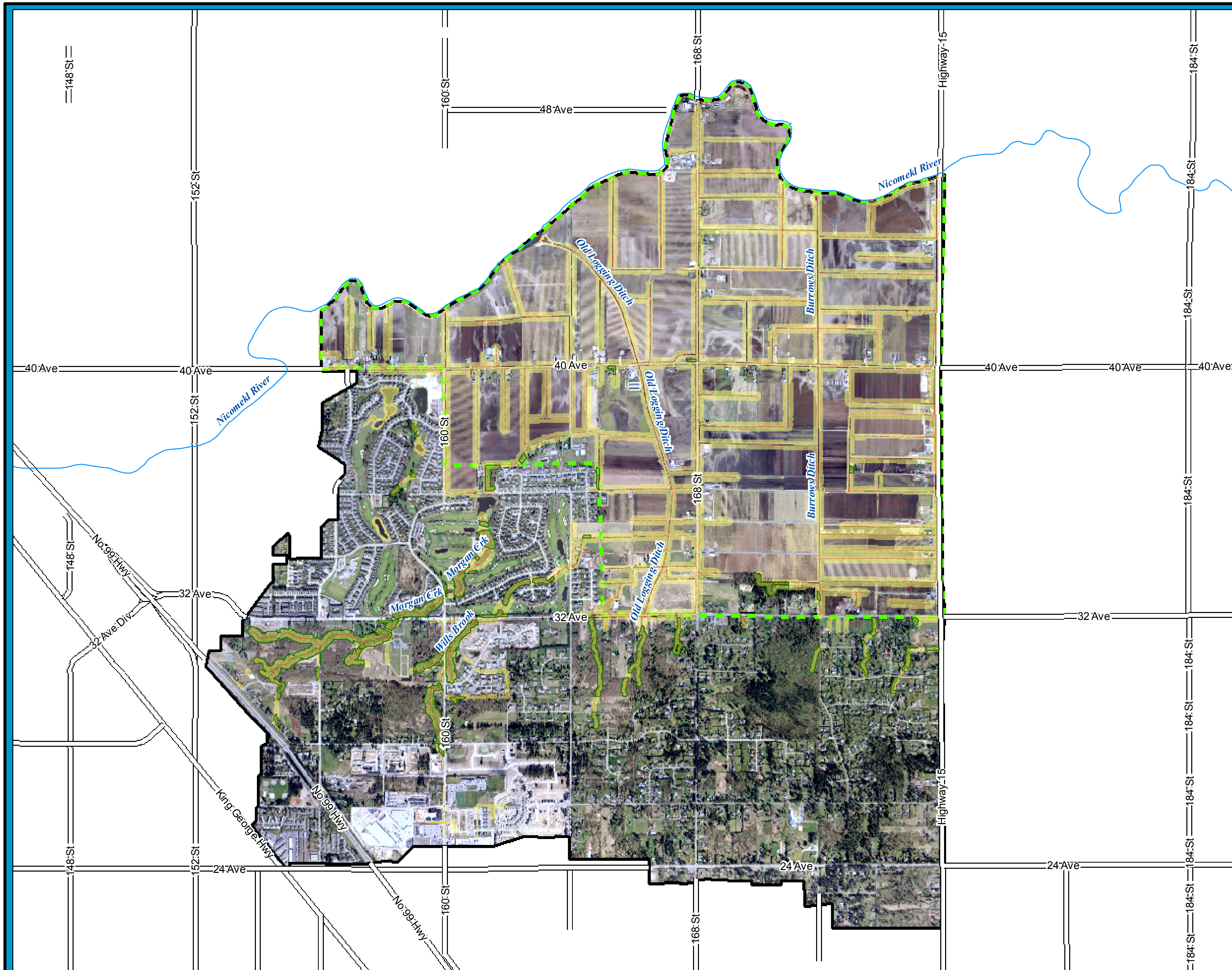
The Nicomekl River does not provide a significant riparian habitat contribution to the Old Logging Ditch and Burrows Ditch watersheds. The riparian zone of the Nicomekl River varies in width up to approximately 15 m and is vegetated mainly by invasive Himalayan blackberry and reed canary grass, as well as native vegetation clusters of hardhack. No significant riparian habitat exists along the length of the Nicomekl River that occurs north of the Study Area.

3.1.3.2 Burrows Ditch

At 40th Avenue, the riparian zone extends approximately 2 to 5 metres from the top of bank on both sides of Burrows Ditch (**Photo** 3-1). Vegetation observed in December of 2009 consisted of red alder, Himalayan blackberry, hardhack, and reed canary grass. Other riparian species present within the riparian zone of Burrows Ditch include salmonberry and willow species (ECL Envirowest Consultants Limited, 1994). Invasive species were prevalent on both banks of the channel at the 40th Avenue road culvert.

CITY OF SURREY
the future lives here.

Figure 3.1: Riparian Forest Integrity



Legend

- Study Area
- Agricultural Land Reserve Boundary
- Riparian Setbacks
- Intact Riparian Vegetation
- Watercourse

Watercourse Classification

- Class A (red-coded) watercourse - Year-around salmonid presence. Non-salmonid species also present.
- Class A(O) (red-dashed) watercourse - Inhabited during overwintering periods by salmonids. Non-salmonid species present year-round.
- Class B (yellow-coded) watercourse - Provides significant food and nutrient value to downstream fish populations. No potential for fish presence.

N
W E
S

Meters

520 260 0 520 1,040

Project Name: Burrows/Old Logging Ditch ISMP
Map Created By: 42aph
Map Checked By: 42lkd
Date Created: JAN-2010
Date Modified: JAN-2010
File Path G:\CAD\092507\GIS_Data

Source: COSMOS & Urban Systems

DILLON CONSULTING

Riparian canopy and understory cover was found to be limited at 40th Avenue. Clusters of native vegetation are present along the length of Burrows Ditch and provide small areas of overhanging vegetation. Invasive vegetation is dominant along Burrows Ditch and provides minimal canopy cover to the edge of the channel. Riparian coverage is moderate at the southern extent of Burrows Ditch, from 200 metres north of 32nd Avenue.

Photo 3-1: Riparian vegetation on the east bank of Burrows Ditch at 40th Avenue

3.1.3.3 Old Logging Ditch

Old Logging Ditch and Burrows Ditch were found to have similar riparian corridor habitats. The width of the riparian zone for Old Logging Ditch ranged from approximately 6 m to 14 m at 40th Avenue and was bound by agricultural lands on both banks. Prevalent vegetation observed at this location consisted of hardhack, Himalayan blackberry, and reed canary grass. Other species such as willow and salmonberry have also been observed along Old Logging Ditch (City of Surrey & Dillon Consulting Limited, 2002). Invasive Himalayan blackberry and reed canary grass were common within the riparian zone. Riparian coverage of Old Logging Ditch consisted of overhanging invasive species and limited clusters of native vegetation and established deciduous tree species.

3.1.3.4 Morgan Creek

Riparian habitat along Morgan Creek displayed moderate value at the two assessment locations within the upland region, with wide riparian zones, diverse riparian vegetation, and ample streamside cover. Riparian zone width at Morgan Creek near Morgan Creek way varied from approximately 15 m to 25 m with prevalent canopy species consisting of red alder, black cottonwood, bigleaf maple, and western red cedar. Prevalent understory species consisted of willow, salmonberry, and Himalayan blackberry.

At the Morgan Creek Crescent site, the width of the riparian zone was approximately 15 m to 65 m. Canopy vegetation consisted primarily of red alder while the understory vegetation consisted of vine maple, Pacific ninebark (*Physocarpus capitatus*), salmonberry, sword fern (*Polystichum munitum*), bracken fern, and fringe cup (*Tellima grandiflora*). At this location, the intact riparian vegetation provided a wide, accessible corridor for the movement of wildlife (**Photo 3-2**).

The majority of Morgan Creek flows through the Morgan Creek Golf Course and the Gardens of Gethsemani Cemetery. Riparian habitat within the cemetery was generally intact and was comprised mainly of deciduous species. Within the golf course property, riparian habitat varied in width and was fragmented in some areas by manufactured landscapes and access pathways.

Photo 3-2: Riparian vegetation and habitat at Morgan Creek, approximately 55 metres west of Morgan Creek Crescent

3.1.3.5 Wills Brook

The riparian habitat quality of Wills Brook was found to be similar to that of Morgan Creek. At the assessment location on the east side of 160th Street within the upland region, riparian vegetation consisted of a variety of canopy and understory species. Canopy species included western red cedar, red alder, bigleaf maple, and black cottonwood. Prevalent understory species consisted of vine maple, willow, salmonberry, Himalayan blackberry (near the roadside), and bracken fern. The width of the riparian zone at this location ranged from approximately 28 to 36 metres, providing a wide area of intact riparian vegetation. Canopy coverage at this location was high at approximately 50 to 60%. The quality of the riparian corridor along Wills Brook was moderate to high, with low corridor fragmentation. Riparian habitat along Wills Brook was fragmented due to the presence of 160th Street and to a somewhat lesser degree, the large residential properties west of 160th Street.

3.1.3.6 Other Riparian Habitat within the Study Area

Agricultural drainage channels within the lowland region had similar riparian habitats to Old Logging Ditch and Burrows Ditch, with invasive species (Himalayan blackberry and reed canary grass) dominating the riparian zone and native vegetation clusters of hardhack and salmonberry occurring amongst the invasive vegetation. Red elderberry, rose (*Rosa* sp.), red alder, western red cedar and Douglas-fir (*Pseudotsuga menziesii*) have also been documented along agricultural drainage channels that feed into Old Logging Ditch (City of Surrey & Dillon Consulting Limited, 2002). Riparian zone widths of agricultural drainage channels varied across the lowland portion of the Study Area but were generally smaller than Old Logging Ditch and Burrows Ditch and in some cases were extremely small given the presence of adjacent land utilized for agriculture. Contribution of the agricultural drainage channels to riparian corridor connectivity was low.

Within the upland region of the Old Logging Ditch and Burrows Ditch watersheds, several Class B watercourses also provide high quality riparian habitat in addition to Morgan Creek and Wills Brook. South of 32nd Avenue between 164th and 168th Street, three Class B watercourses flow south through intact riparian habitat mainly comprised of deciduous canopy species. These riparian areas provide corridors for the movement of species to the south, where many of the larger terrestrial hubs are found (See **Section 3.2** for more information).

Other watercourses within the upland region include the Class B ponds and smaller channels which flow through the northern portion of the Morgan Creek Golf Course. Riparian habitat is significantly limited at this location.

3.1.3.7 Riparian Forest Integrity

Percent riparian forest integrity (% RFI) was calculated for the Study Area as a whole and for the Burrows Ditch and Old Logging Ditch catchments. Three calculations were performed to obtain estimated % RFI values for the total, lowland and upland areas. Nine % RFI values derived for the Study Area are presented in **Table 3-3**.

Table 3-3: Percent Riparian Forest Integrity Values for the Study Area

Watershed		% RFI
Study Area	Total Study Area	10.2
	Lowland RFI	0.7
	Upland RFI	48.6
Burrows Ditch	Total RFI	2.4
	Lowland RFI	1.0
	Upland RFI	42.6
Old Logging Ditch	Total RFI	16.9
	Lowland RFI	0.003
	Upland RFI	49.1

In 1999, the Greater Vancouver Regional District (GVRD) developed the "GVRD Watershed Classification System" to classify and predict watershed health (Kerr Wood Leidal Associates Limited, 2005). This system, based on the influence that RFI and Total Impervious Area (TIA) have on a watershed, classified a watershed as "excellent", "good", "fair" and "poor". According to the GVRD Watershed Classification System, a decrease in RFI and an increase in TIA will show a decline in watershed health (Kerr Wood Leidal Associates Limited, 2005).

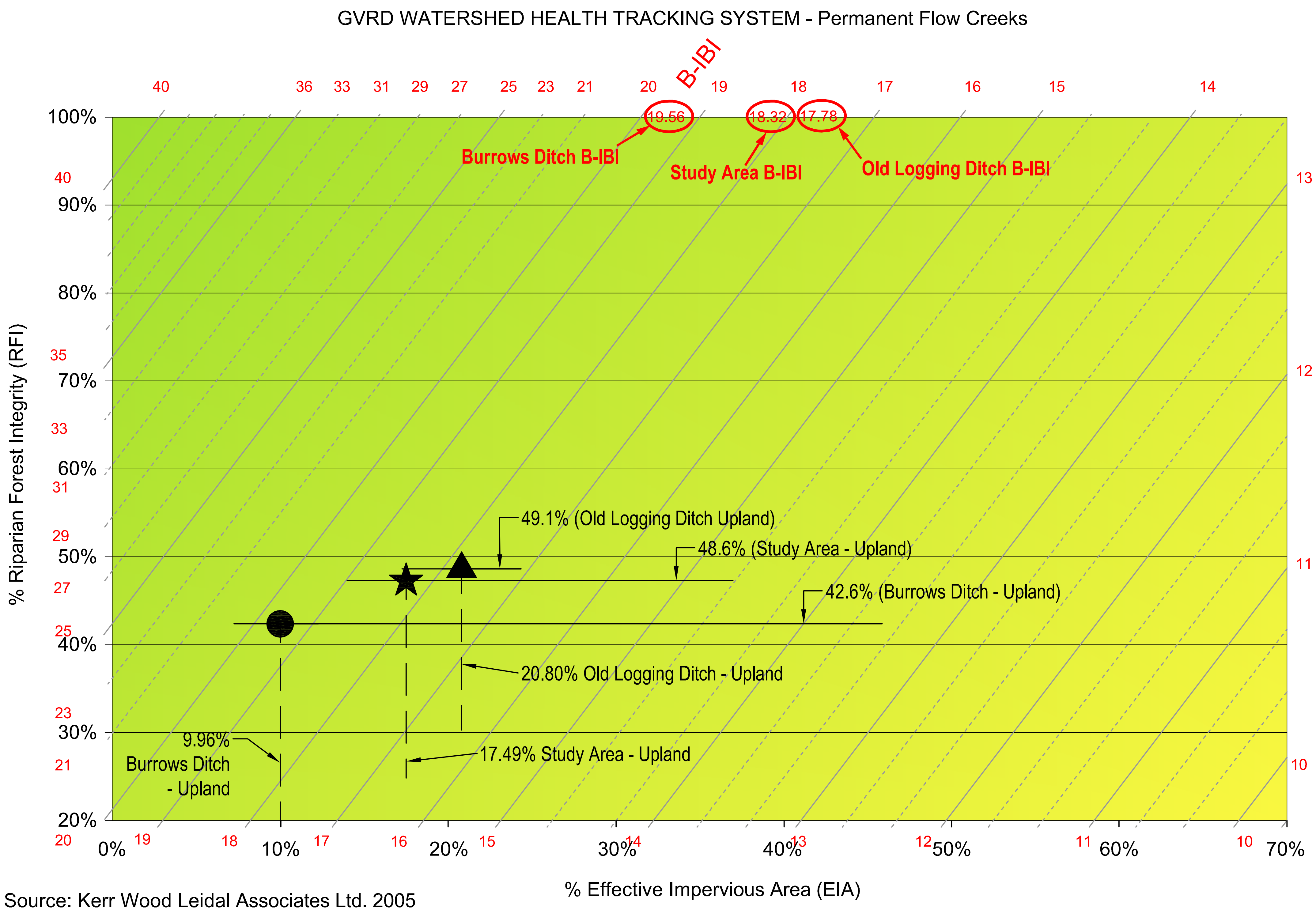
The 1999 classification system has since been discontinued and Kerr Wood Leidal Associates Limited proposed a new Watershed Health Tracking System in 2005. The 2005 tracking system does not utilize separate classifications (good, bad, etc.) and incorporates predictive Benthic Index of Biotic Integrity (B-IBI scores (see **Section 3.1.4** for further discussion) to determine watershed health. The 2005 tracking system can be used as a predictive tool to measure the health of a watershed over time. Similar to the 1999 system, a high % RFI value and a low % TIA value will signify a watershed is in very good health. Instead of using distinct boundaries to classify watershed health, the 2005 system assigns "very good health" to watersheds with high % RFI values and low % TIA values and "poor health" to watersheds with low % RFI and high % TIA.

Under the 2005 tracking system, a % RFI value is not considered if it is below a 20% threshold. As shown in **Table 3-3**, only the values for the upland areas can be utilized as % RFI values in determining health of the watershed as they are above the 20% threshold. Low % RFI values for the lowland region are attributed to agricultural land use comprising a significant portion of the area. Existing intact riparian forest vegetation was more prominent in the upland region of the catchment area, especially in areas south of 32nd Avenue.

The estimated % RFI values have been plotted against the percent Effective Impervious Area (% EIA) of the Study Area, Burrows Ditch, and Old Logging Ditch as seen in **Figure 3-2** to indicate existing conditions. Additionally, **Figure 3-3** indicates % EIA vs. % RFI for predicted future conditions. For future conditions, we have assumed that the % RFI will not change. Note that % EIA was utilized rather than % TIA as outlined in the preceding discussion given that % EIA can provide a truer indication of overall conditions. % EIA values for the Study Area were provided by Urban Systems Limited.

CITY OF SURREY
the future lives here.

Figure 3.2: Graph of % Riparian Forest Integrity vs % Effective Impervious Area



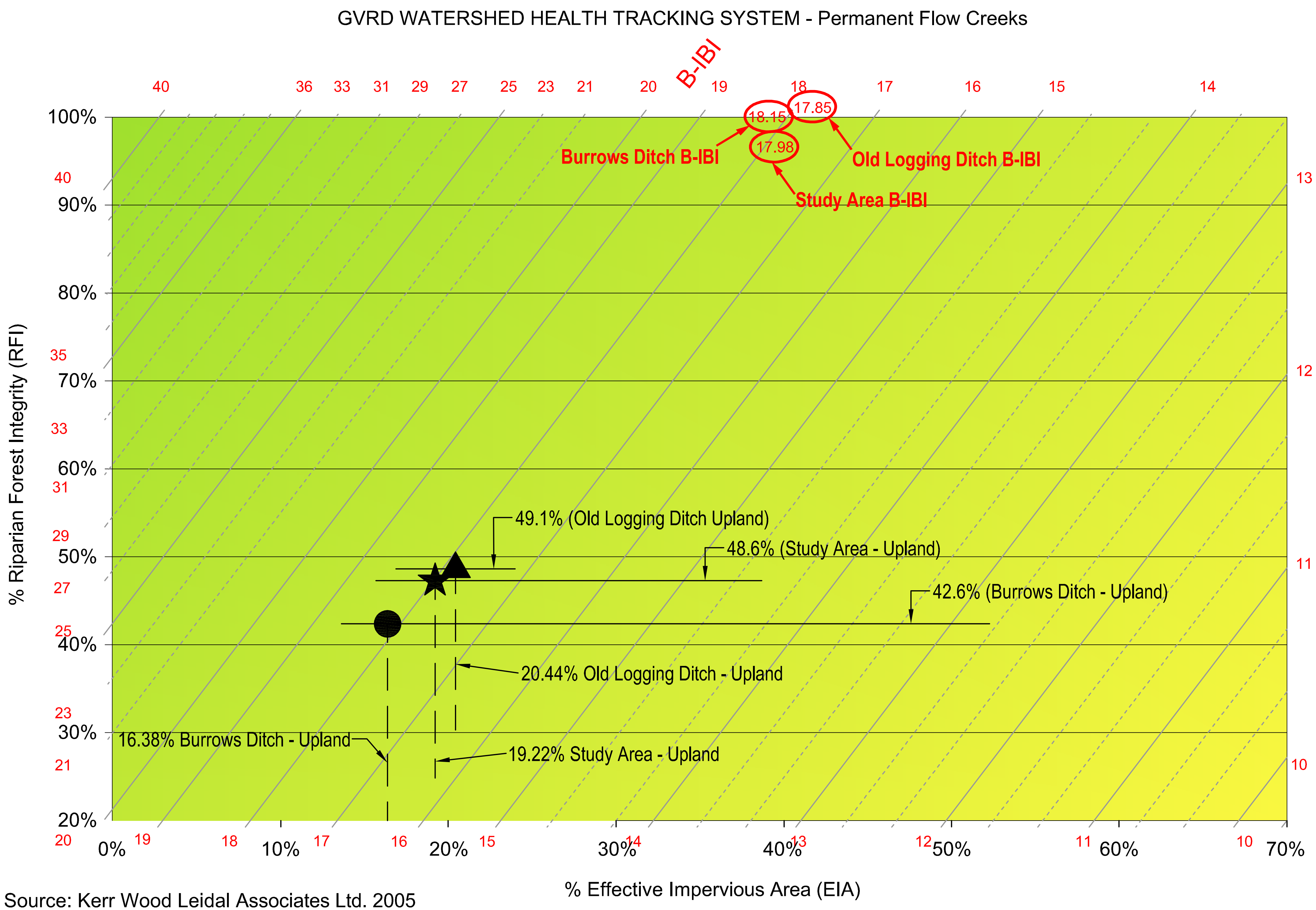
Source: Kerr Wood Leidal Associates Ltd. 2005

Legend

- ★ Study Area
- ▲ Old Logging Ditch
- ● Burrows Ditch

Project Name:	Burrows/Old Logging Ditch ISMP
Map Created By:	42aph
Map Checked By:	42nrg
Date Created:	JAN-2010
Date Modified:	SEPT-2011
File Path	G:\CAD\092507\

DILLON CONSULTING



Source: Kerr Wood Leidal Associates Ltd. 2005

CITY OF SURREY
the future lives here.

Figure 3.3:
Graph of % Riparian Forest Integrity vs % Effective Impervious Area for Future Conditions

Legend

★ Study Area

▲ Old Logging Ditch

● Burrows Ditch

Project Name:	Burrows/Old Logging Ditch ISMP
Map Created By:	42aph
Map Checked By:	42nrg
Date Created:	JAN-2010
Date Modified:	SEPT-2011
File Path	G:\CAD\092507\

DILLON CONSULTING

As outlined in **Figure 3-2**, the values of % RFI vs. % EIA generally fall within the lower left corner of the health tracking system graph, which may indicate moderate watershed health. The health of the upland regions of Burrows Ditch and Old Logging Ditch is similar, with Burrows Ditch having slightly lower % RFI as well as a lower % EIA than Old Logging Ditch. The upland area of the Burrows Ditch watershed contains many of the large intact terrestrial hubs within the Study Area (See **Section 3.2** for more information). The upland region of the Old Logging Ditch watershed has a higher % EIA and a higher % RFI than Burrows Ditch.

For future conditions, there is almost no change in % EIA and therefore limited potential for changes in watershed health for Old Logging Ditch. However, there is a significant increase in % EIA for Burrows Ditch which may predict a reduction in overall watershed health as development proceeds.

Predictive B-IBI scores for the Study Area, Burrows Ditch, and Old Logging Ditch uplands range from 17.78 to 19.56 under current conditions as indicated in **Figure 3-2.** The values range from 17.85 to 18.15 for future conditions as indicated on **Figure 3-3**. (See **Section 3.1.4** for more discussion on B-IBI). Predictive B-IBI values for current and future conditions are slightly higher than actual B-IBI values obtained from the spring of 2006 to 2008 for the Burrows Ditch and Old Logging Ditch systems as indicated in Section 3.1.4 below.

3.1.4 Benthic Communities

An alternative method for assessing the health of a stream or watershed is to determine the structure and diversity of the benthic macroinvertebrate community, which serves as an important biological indicator. Benthic invertebrates, or streambed insects, can be used to provide an indication of the health of a stream or watershed (HB Lanarc & Raincoast Applied Ecology, 2009) given their diverse and abundant nature, their sensitivity to human disturbance, and the ease in their identification and sampling (Kerr Wood Leidal Associates Limited, 2005). A multimetric rating system entitled the “Benthic Index of Biotic Integrity (B-IBI)” measures benthic communities and assigns a score to a watershed or stream based on the presence or absence of benthic invertebrates (Kerr Wood Leidal Associates Limited, 2005). This monitoring was initiated as a tool as part of the Integrated Stormwater Management Plan process. The B-IBI combines multiple indicator metrics into a single numerical index based on comparing observed biological and ecological patterns to region-specific expectations. Each metric is some measure of the biotic assemblage data, such as taxonomic richness, indicators of ecological function or relative abundance of a certain taxonomic or trophic group. The multimetric B-IBI score can be used to quickly rank watercourses in terms of quality, management/restoration priority, etc. The disadvantage to using a multimetric score such as the B-IBI is that the details of what is occurring in the system may be overlooked. Each metric on its own offers specific information that can be useful in assessing the quality of the system.

The 10-metric B-IBI reflects conditions of the Pacific Northwest and scores the health of a watershed on a scale of 10 to 50. Benthic invertebrate sampling was not conducted as part of the December 2009 field assessment and thus background information has been utilized to describe the benthic community of the Study Area.

A B-IBI score of 10 can indicate poor watershed health while a score of 50 can indicate excellent health, An extremely healthy watershed with a score of 50 is expected to be found in a pristine, untouched area which has never experienced logging, whereas an unhealthy watershed with a score of 10 is likely to be found in a highly developed area with a high level of impervious area. Watersheds with high B-IBI scores are likely to be inhabited by salmonid species while lower scoring watersheds are likely to have fewer species of fish and lower densities of salmonids (Kerr Wood Leidal Associates Limited, 2005).

It should be noted that the B-IBI system and the interpretation of its data is based on mountain streams and is not necessarily comparable to streams and ditches found within suburban watersheds such as Burrows Ditch and Old Logging Ditch. As such, making qualitative comments that a system is experiencing “poor” or “excellent” health based on a low or high score can be inaccurate. Nevertheless, it is a tool that can be used to predict trends in overall watershed health by providing a starting point for B-IBI values. From this starting point, an upward trend can be indicative of improving health through the application of BMPs for example. Similarly, a downward trend in B-IBI values could be indicative of worsening health resulting from development and an increase in effective impervious area.

In the spring of 2006 through 2009, the City of Surrey conducted benthic invertebrate sampling at a variety of watercourse across Surrey, including Old Logging Ditch and Burrows Ditch. The total B-IBI scores for these two watersheds were found to be low, indicating that the two systems may have poor watershed health (**Table 3-4**). Out of the two watersheds, Old Logging Ditch was found to have the lowest B-IBI score in the spring of 2008 with a rating of 10. The decrease in B-IBI observed at Old Logging Ditch could be attributed to increased residential development in the upland reaches of the watershed. Over the course of the 3-year sampling program, both streams did not achieve scores higher than 16.

Table 3-4: Total B-IBI Scores for Old Logging Ditch and Burrows Ditch

Watercourse	Spring of 2006	Spring of 2007	Spring of 2008	Spring of 2009
Old Logging Ditch	14	16	10	15
Burrows Ditch	14	16	16	15

Source: Raincoast Applied Ecology & City of Surrey 2006, 2007, and 2008 Benthos Monitoring for Old Logging Ditch and Burrows Ditch and City of Surrey Metrics Report.

Given the drawbacks associated with the B-IBI system as outlined above, discussion of some of the individual metrics and what that indicates regarding the health of the Old Logging and Burrows watersheds has been included.

The B-IBI metrics included in the 2006 Surrey Benthic Invertebrate Sampling Program were:

- Total number of taxa (abundance);
- Number of Ephemeroptera taxa;
- Number of Plecoptera taxa;
- Number of Trichoptera taxa;

- Number of long-lived taxa;
- Number of intolerant taxa;
- Percent of tolerant individuals;
- Percent of predator individuals;
- Numbers of clinger taxa; and
- Percent dominance.

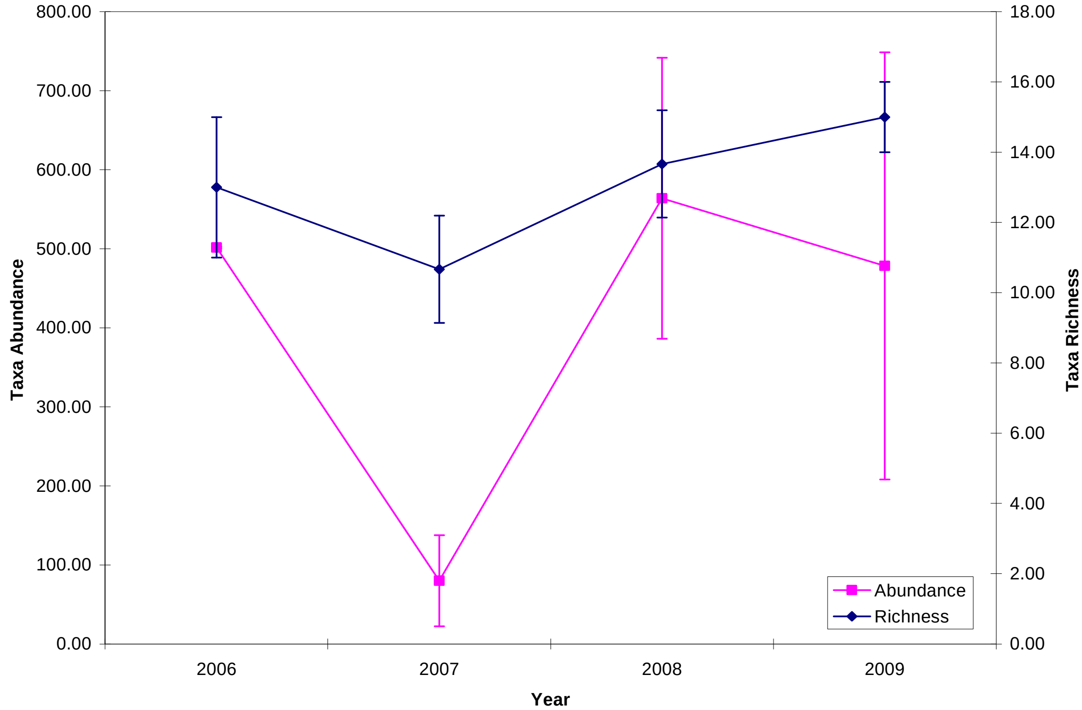
Two sites were sampled from 2006 to 2009, Morgan Creek and Burrows Ditch. At each site samples were collected and processed in triplicate. The mean value of those sub-samples is used in the following discussion.

3.1.4.1 Morgan Creek

For Old Logging Ditch, the B-IBI scores for 2006 to 2009 indicate that the watercourse may be impaired or degraded and has not improved much over the 4 years of sampling. As described in the 2006 report, this watercourse is buffered from residential development by riparian vegetation to the top-of-bank. Both banks in the area of the sampling site appeared stable. It is described as shallow with coarse gravel and sand as the dominant substrate. Juvenile coho were observed in Spring 2006 at the site and the morphology around the sampling site is indicative of pool habitat.

The degraded score this site received warrants future examination. Looking at the total number of taxa (sample abundance), it has remained relatively constant from 2006 to 2009, with the exception of a steep decline in 2007. This decline in 2007 also impacted the taxa richness at the site, however it rebounded to 2006 levels by 2009 (**Figure 3-4**).

Figure 3-4: Taxa Abundance at Morgan Creek



TOLD

Metrics generally used to indicate impaired systems include % Worm (Oligochaeta, Nematoda and Turbellaria), % Midge (Chironomidae), and % Dominants. Conversely, metrics such as % EPT (Ephemeroptera, Plecoptera, Trichoptera) can indicate good water and habitat quality.

Looking at the percentage of Oligochaeta in the 2006-2009 samples, the relatively low numbers would indicate the site is unimpaired. However, the coarse gravel and sand substrate are not the soft, organically-enriched sediments Oligochaeta prefer and may explain the lack of abundance.

A predominance of midges (Chironomidae) generally indicates poor water quality. However, interpreting abundances of Chironomidae should be undertaken with caution as this Family has a wide tolerance range for changes in water quality. The data provided in the Metrics Report for this project included Chironomidae as a group, rather than providing lower taxonomic identification. The percentage of Chironomidae varied significantly from year to year, but shows a trend of increasing abundance.

Percentage of EPT is a common metric widely used to quickly determine high quality stream environments. Good concentrations of these 3 groups indicate adequate dissolved oxygen and a general lack of suspended solids. In 2007 and 2009, this site displayed fair numbers of EPT taxa, but that percentage was significantly lower in 2006 and 2008.

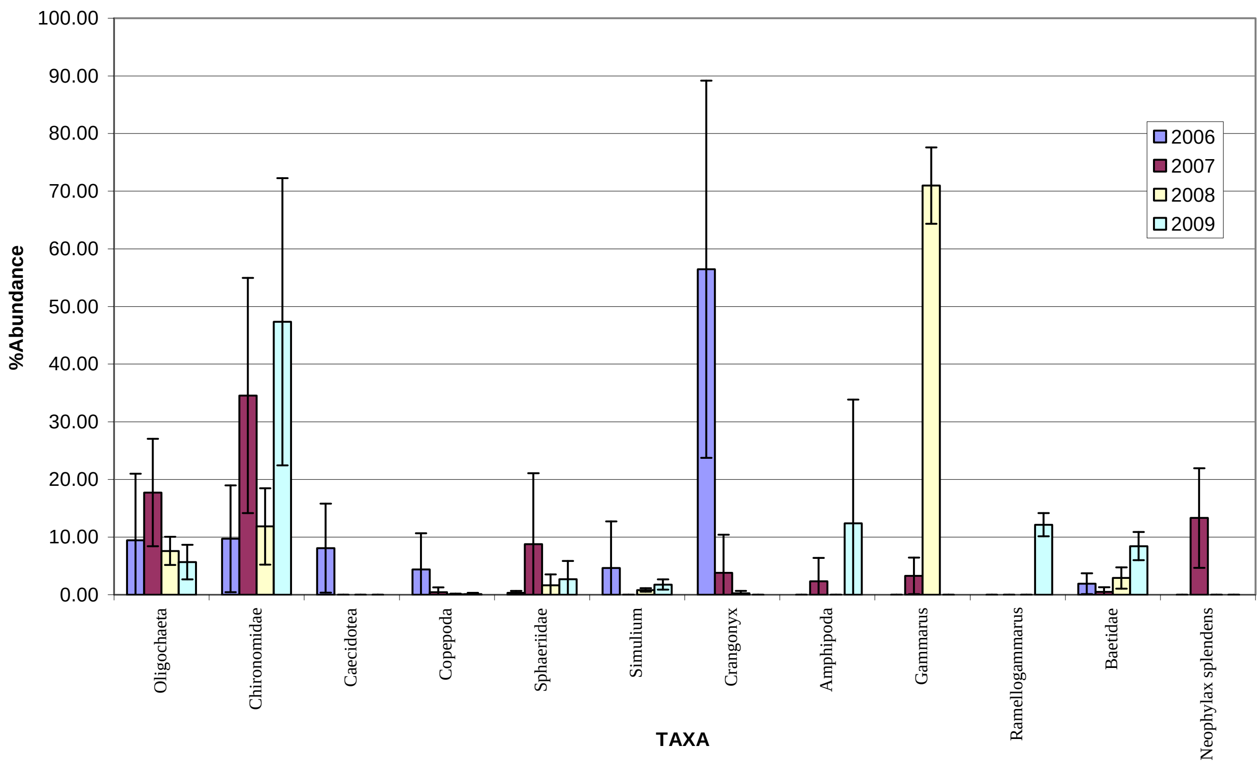
Regardless, if a few taxa are found to dominate the assemblage it is likely that a disturbance has occurred within the population of those species who have specific preferences for food or habitat. These "specialist" species will often be replaced by those that are opportunistic. A metric in the B-IBI, percent dominance is calculated by adding the number of individuals in the three most abundant taxa. Over the 4 year sampling period, this percentage was never below 61% and went as high as 94% in one sub-sample.

Signs of Improvement

There is no question that the site sampled in Morgan Creek is an impaired site. The site is dominated by only a few taxa that are generally found to be tolerant of pollution and opportunistic in nature. However, there was a slight trend towards improvement observed in the data over the years. As seen in

Figure 3-5, in 2006 there were more taxa present and in greater numbers that are known to be tolerant. In 2009, although we still see approximately 50% of taxa dominated by tolerant groups (mostly Chironomidae), there begins to be more taxa that display sensitivity to pollution (Amphipoda, Baetidae). With the large and conflicting changes from year-to-year at the site, it is recommended that the site continue to be monitored on an annual basis to determine trends.

Figure 3-5: Percent Abundance at Morgan Creek



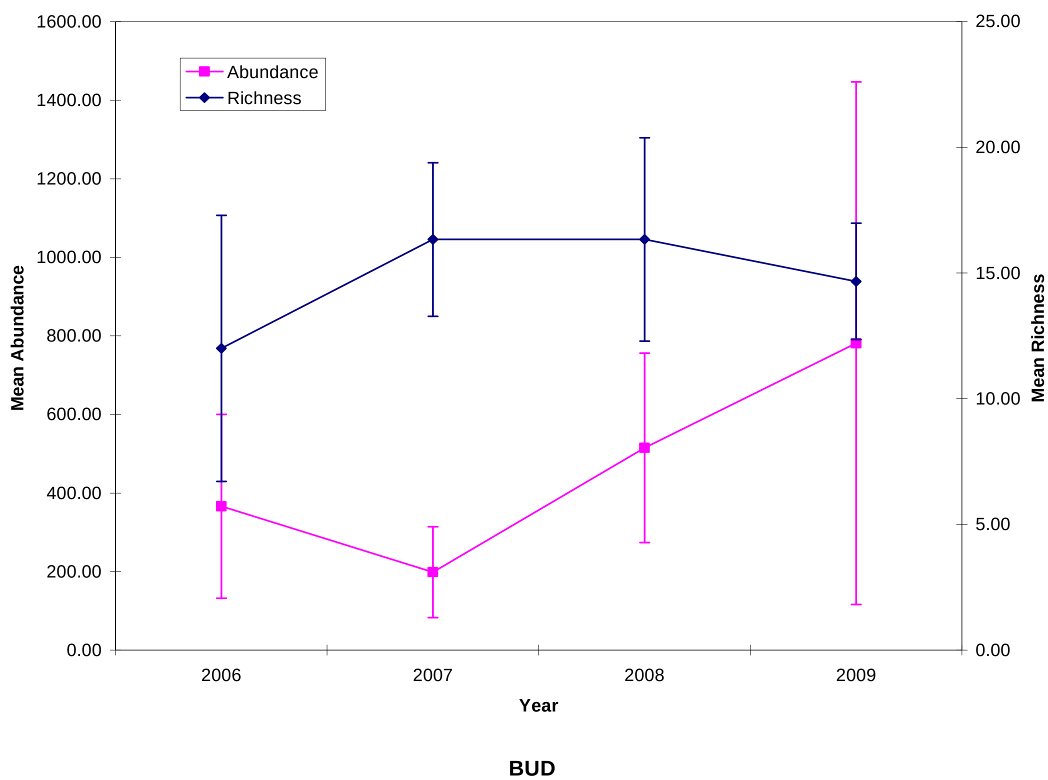
TOLD

3.1.4.2 Burrows Ditch

For Burrows Ditch, the B-IBI scores for 2006 to 2009 indicate that the watercourse may be impaired or degraded and has not improved over the 4 years of sampling. As described in the 2006 report, this watercourse has limited riparian vegetation and on the right bank the vegetation was cleared to the water level for new access road construction. The left bank appeared stable and the right bank was slightly eroded due to sloughing as a result of brush clearing adjacent to the channel. The dominant substrate was defined as sand and fine gravel.

The lower score this site received warrants future examination. Looking at the total number of taxa (sample abundance), it has remained relatively constant from 2006 – 2009, with the exception of a small decline in 2007. This decline in 2007 did not appear to impact the taxa richness at the site as a slight increase was noted (**Figure 3-6**). This may correspond to the decrease in Chironomids and the increase in Gammarus and Polycelis.

Figure 3-6: Taxa Abundance at Burrows Ditch



Looking at the percentage of Oligochaeta in the 2006-2009 samples, the numbers would indicate the site is possibly impaired. However, the coarse gravel and sand substrate are not the soft, organically-enriched sediments Oligochaeta prefer and may explain the lack of abundance. The number of Oligochaeta increased in 2008; however this may be attributable to the low numbers of Chironomidae and Polycelis.

As previously discussed, a predominance of midges (Chironomidae) generally indicates poor water quality. However, interpreting abundances of Chironomidae should be undertaken with caution as this Family has a wide tolerance range for changes in water quality. The percentage of Chironomidae varied significantly from year to year, but shows a trend of decreasing abundance.

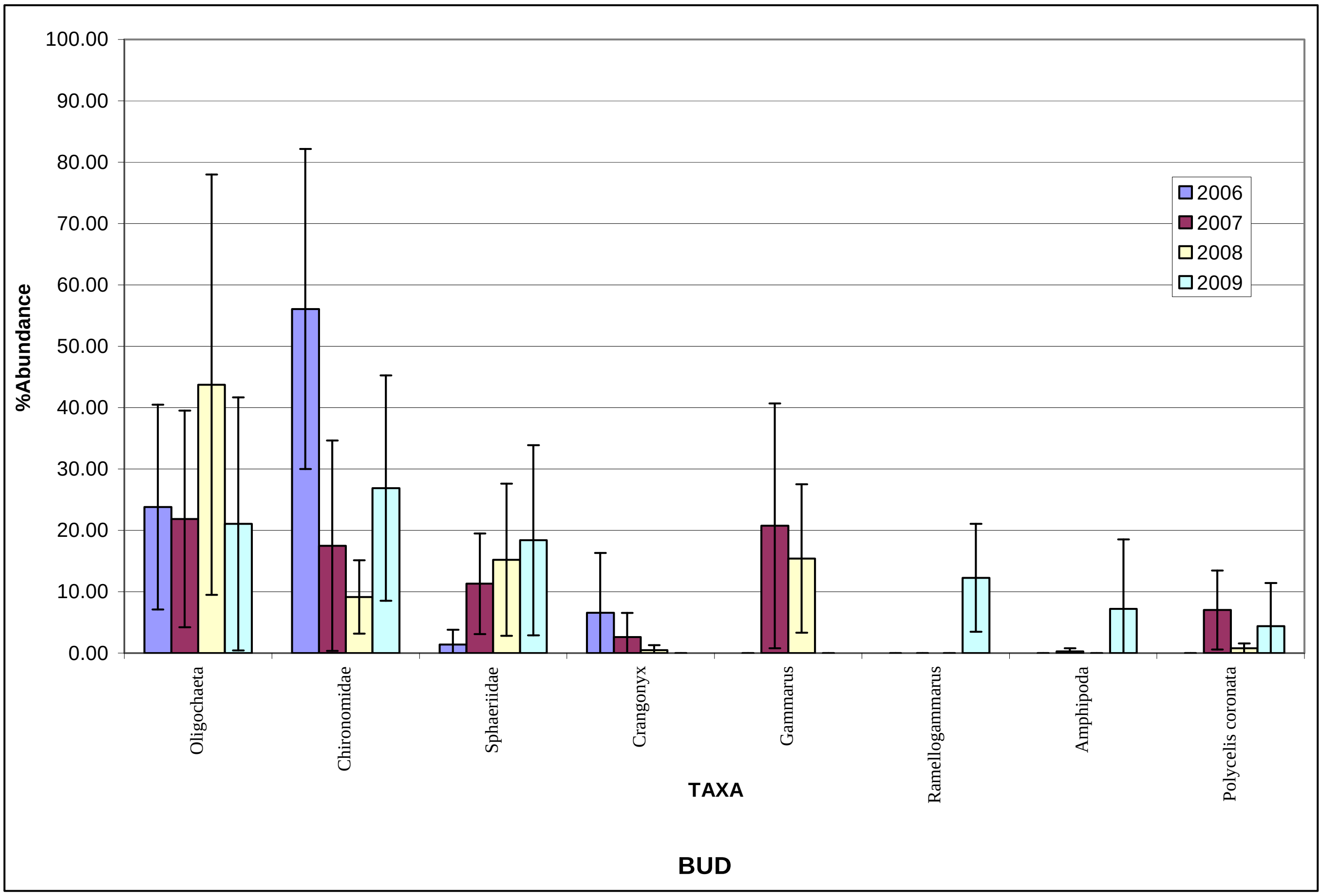
Percentage of EPT is a common metric widely used to quickly determine high quality stream environments. In 2007, this site displayed fair numbers of EPT taxa, but that percentage declined significantly in the subsequent years.

Regardless, if a few taxa are found to dominate the assemblage it is likely that a disturbance has occurred within the population of those species who have specific preferences for food or habitat. These "specialist" species will often be replaced by those that are opportunistic. A metric in the B-IBI, percent dominance is calculated by adding the number of individuals in the three most abundant taxa. Over the 4 year sampling period, this percentage was never below 62% and went as high as 95% in one sub-sample.

Signs of Improvement

There is no question that the site sampled in Burrows Ditch is an impaired site. The site is dominated by only a few taxa that are generally found to be tolerant of pollution and opportunistic in nature. However, there was a slight trend towards improvement observed in the data over the years. As seen in **Figure 3-7**, in 2006 there were more taxa present and in greater numbers that are known to be tolerant. In 2009, although we still see approximately 50% of taxa dominated by tolerant groups, there begins to be more taxa that display sensitivity to pollution (Amphipoda, Polycelis). With the large and conflicting changes from year-to-year at the site, it is recommended that the site continue to be monitored on an annual basis to determine trends.

Figure 3-7: Percent Abundance in Burrows Ditch



3.1.5 Water Quality

Conventional water quality parameters for the 6 sampling locations were found to be generally within acceptable guideline levels for freshwater aquatic life (Province of British Columbia, 2006). **Table 3-5** outlines the parameters sampled for each of the sampling locations. Water quality measured as part of the "Old Logging Ditch/Morgan Creek Functional Feasibility Study for Lowlands" in 2001 found that many of the small drainage channels within the lowland area displayed poor water quality, with high dissolved oxygen (DO) and temperatures levels (City of Surrey & Dillon Consulting Limited, 2002). Established Class A watercourses, including Morgan Creek (in the uplands) and Old Logging Ditch (in the lowlands), were found to have moderate water quality during the 2001 summer sampling program, with good DO levels, but moderate to high temperatures.

Table 3-5: Conventional Water Quality Parameters Measured within the Old Logging Ditch and Burrows Ditch Watersheds

Water Quality		Sampling Location*					
Water Quality Parameter	**Unit**	**Old Logging Ditch**	**Burrows Ditch**	**32nd Ave, east of 164th**	**Morgan Creek at Morgan Creek Way**	**Morgan Creek at Morgan Creek Crescent**	**Wills Brook**
Temperature	°C	2.7	2.5	6.7	4.4	2.2	3.7
pH	-	6.07	6.06	6.7	5.06	6.47	6.8
Conductivity	mS	0.31	0.33	0.27	0.25	0.19	0.27
Dissolved Oxygen	ppm	6.3	7	7.2	6	7.1	7.8
Turbidity	NTU	18.6	13.2	3	5.12	5.29	5.72

See **Figure 2-1: Project Location for sampling locations**

Temperature readings varied slightly at each of the 6 sampling locations. Generally, water temperatures were found to be quite cool due to the near freezing ambient air temperature at the time of the field assessment. The unnamed watercourse on the north side of 32nd Avenue, east of 164th Street was found to have the highest water temperature (6.7°C) of all sites sampled.

Levels of pH measured across the Study Area were found to be slightly acidic, ranging from 6.8 to 5.06. The pH level at Morgan Creek near Morgan Creek Way was found was the lowest of all sites (5.06), below guidelines for freshwater aquatic life. The low pH observed at this location is likely due to the large amount of leaf litter and organic matter present within the wetted portion of the creek during the time of the field assessment.

Dissolved oxygen levels measured were found to be within recommended levels for salmonid species. DO levels at Wills Brook, Morgan Creek at Morgan Creek Crescent, and the unnamed tributary on the north side of 32nd Avenue were found to be above 6.0. At these locations, run and riffle sequences were present within the streams, likely helping to increase the DO level (**Photo 3-3**). Wills Brook was found to have the highest DO level (7.8). During the field assessment, Wills Brook was the only watercourse in which cutthroat trout were sampled (See **Section 3.1.2** for more information on fish sampling). Moderate DO levels were found at Morgan Creek and Old Logging Ditch during the December field assessment.

Old Logging Ditch and Burrows Ditch displayed similar pH, conductivity, and dissolved oxygen levels. Given that these ditches are both long, wide, agricultural drainage channels, similar water quality parameters are to be expected. Turbidity levels measured for the two channels were similar, with Old Logging Ditch measuring 18.6 NTUs and Burrows Ditch measuring 13.2 NTUs.

Lowland water quality of the Study Area may directly affect salmonid presence within the lowland and upland regions. During summer months, poorer lowland water quality (high temperatures and low DO) could restrict salmonid occupancy to upland reaches of the Study Area. Low DO, high temperatures, and poor substrate material may also limit spawning and rearing habitat within the catchment (New East Consulting Services Limited, 1996). Non-salmonid species such as threespine stickleback, minnows, and redside shiner can withstand poorer water quality and are common throughout the Study Area’s lowland region (See **Section 3.1.2** for more information). Another factor affecting water quality within the lowland is runoff from agricultural fields which could contain fertilizers and pesticides (ECL Envirowest Consultants Limited, 1994). In addition, water quality could be affected by the withdrawal of water or the introduction of Nicomekl River water by local irrigation districts.

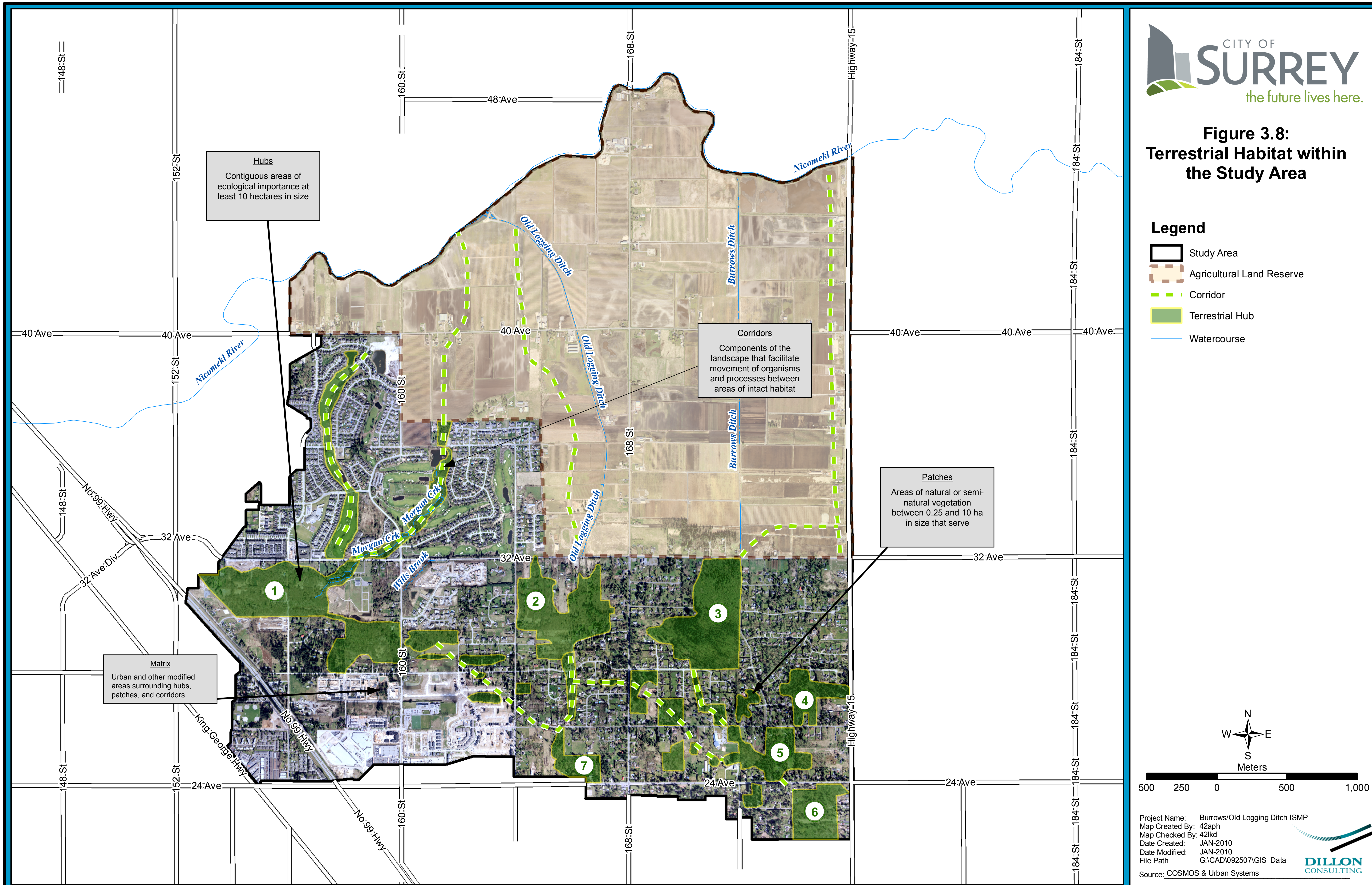
Photo 3-3: Run and riffle sequences observed at Wills Brook, approximately 15 metres east of 160th Street

3.2 Terrestrial Habitat and Species

3.2.1 Habitat Overview – Wildlife Hubs, Patches and Corridors

The Study Area is located within the Moist Maritime Coastal Douglas-fir (CDFmm) and Very Dry Maritime Coastal Western Hemlock (CWHxm1) biogeoclimatic zones. Given the existing agricultural and residential land uses, the vegetative climax community typical of these zones is not expected to occur.

Terrestrial habitats within the Study Area are composed of hubs, patches, and corridors within a matrix of residential and agricultural properties. Upland areas located south of 32nd Avenue and west of Morgan Creek Drive are dominated by forested woodlots and residential development. Several large forested hubs and smaller woodlot patches occur in this area. Defined as contiguous areas of forested habitat greater than 10 hectares in area, forest hubs are considered the most significant terrestrial habitat feature within the Study Area uplands. Patches are areas of natural or semi-natural vegetation between 0.1 and 10 hectares in size. Patches within the Study Area were associated with upland habitats south of 32nd Avenue. Corridors within the Study Area are portions of the landscape that facilitate movement of organisms and processes between upland and lowland habitats (Raincoast, 2009). **Figure 3-8** illustrates all hubs, patches, and corridors identified within the Study Area boundary.



CITY OF SURREY
the future lives here.
Figure 3.8:
Terrestrial Habitat within the Study Area
Legend
Study Area
Agricultural Land Reserve
Corridor
Terrestrial Hub
Watercourse
Hubs
Contiguous areas of ecological importance at least 10 hectares in size
Corridors
Components of the landscape that facilitate movement of organisms and processes between areas of intact habitat
Patches
Areas of natural or semi-natural vegetation between 0.25 and 10 ha in size that serve
Matrix
Urban and other modified areas surrounding hubs, patches, and corridors
Nicomekl River
Old Logging Ditch
Burrows Ditch
Morgan Crk
Wills Brook
48 Ave
40 Ave
32 Ave
24 Ave
148 St
152 St
160 St
168 St
184 St
Highway 15
No 99 Hwy
King George Hwy
32 Ave Div
1
2
3
4
5
6
7
N
W
E
S
Meters
500
250
0
500
1,000
Project Name: Burrows/Old Logging Ditch ISMP
Map Created By: 42aph
Map Checked By: 42lkd
Date Created: JAN-2010
Date Modified: JAN-2010
File Path G:\CAD\092507\GIS_Data
Source: COSMOS & Urban Systems
DILLON CONSULTING

One greenway in particular, the North Grandview Heights/Coast Meridian Multi-use corridor, has been partially constructed with some sections still in the planning stage. When completed, the corridor will link the eastern and western portions of the Study Area along the approximate 28th/29th Avenue right-of way. It will also run along the Croyden Drive alignment adjacent to Highway 99 as well as north along 168th Street from 29th Avenue to the Nicomekl River. It is expected that this corridor will serve to facilitate wildlife passage throughout the Study Area, particularly as it will link some of the existing hubs and patches.

Seven forested hubs associated with upland habitats south of 32nd Avenue were identified during the December 2009 terrestrial habitat surveys. Deciduous woodlot hubs represent the most common type of terrestrial habitat hubs within the Study Area uplands. Deciduous hubs are dominated by red alder, black cottonwood, bigleaf maple, and paper birch. Coniferous hubs contain predominantly Douglas-fir with some western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*) and western red cedar. The hubs could also be comprised of mixed deciduous/coniferous species.Error! Reference source not found.Understory vegetation is relatively well-developed and includes common species such as red huckleberry (*Vaccinium parvifolium*), trailing blackberry (*Rubus ursinus*), sword fern, spiny wood fern (*Dryopteris expansa*) dull Oregon-grape (*Mahonia nervosa*) baldhip rose (*Rosa gymnocarpa*), common snowberry (*Symphoricarpos albus*), Pacific dogwood (*Cornus nuttallii*) and oceanspray (*Holodiscus discolor*). These second and third growth forest hubs provide critical habitat for numerous wildlife species (Strix, 2000).

In addition to upland terrestrial habitats, large acreages of agricultural land dominate the lowland sub-basin to the north of 32nd Avenue within the Study Area. In general, vegetation species within these lowland agricultural areas consist of native and non-native species adapted to disturbed sites such as hardhack, Himalayan blackberry, and reed canary grass. The lowland agricultural areas north of 32nd Avenue provide habitat for waterfowl and small mammals including the Townsend's vole (*Microtus townsendii*), an important prey species for many species of raptors, coyote (*Canis latrans*), and the blue-listed Great Blue Heron *fannini* subspecies (*Ardea herodias* ssp. *fannini*) (Strix, 2000).

3.2.2 Wildlife Species Presence

Wildlife habitat in the Study Area has been significantly impacted by agricultural activity and residential development. Wildlife utilization in some areas within the Study Area is likely restricted to species that are adapted to urban environments such as coyotes, passerines, rodents and raccoons. Other small mammals such as voles and shrews, mice, and bats are expected. Larger mammals including black-tailed deer (*Odocoileus hemionus* ssp. *columbianus*) utilize the upland hubs of the Study Area at certain times. Additionally, neo-tropical migratory birds, raptors, waterfowl, woodpeckers, rodents, and other mammals also inhabit the Study Area.

Amphibian species likely to inhabit the Study Area include Pacific tree frog (*Hyla regilla*), the blue-listed red-legged frog (*Rana aurora*), rough-skinned newt (*Taricha granulosa*), long-toed salamander (*Ambystoma macrodactylum*), northwestern salamander (*Ambystoma gracile*), ensatina (*Ensatina eschscholtzi*), and western red-backed salamander (*Plethodon vehiculum*). The latter two species do not require water for breeding, and are thus expected to be present in the larger, undisturbed woodlots of the Study Area. Reptiles consisting of all three species of garter snake (common (*Thamnophis sirtalis*), northwestern (*T. ordinoides*), and western terrestrial (*T. elegans*)), are expected to occur (Strix, 2000).

Documented species within the Study Area include coast mole (*Scapanus orarius),* coyote, Townsend's vole, and gray squirrel (*Sciurus carolinenis*), numerous neo-tropical migratory birds, as well as year-round residents such as Barn Owl (*Tyto alba*), Red-tailed Hawk (*Buteo jamaicensis*), Coopers Hawk (*Accipiter cooperii*), and Great Blue Heron (Strix, 2000).

The December 2009 field surveys documented several over-wintering and resident bird species including Pygmy Nuthatch (*Sitta pygmaea*), numerous waterfowl (Canada Goose (*Branta canadensis*), Snow Goose (*Chen caerulescens*), Mallard ducks (*Anas platyrhynchos*), Bufflehead (*Bucephalia albeola*)) Chestnut-backed Chickadee (*Parus rufescens*), Pileated Woodpecker (sign – *Dryocopus pileatus*), Varied Thrush (*Ixoreus naevius*), Great Blue Heron, and Song Sparrow (*Melospiza melodia*). The relatively low number of bird species seen is likely due to the winter timing of the surveys.

3.2.3 Rare Element Species

A review of the CDC's online database indicated that there are no known occurrences of provincially listed species within the Study Area. A review of the provincial BC Species and Ecosystem Explorer generated a list of 149 rare element species within the Coastal Western Hemlock biogeoclimatic zone, many of which could be supported by habitat provided in the Study Area. Although there is potential for some of these species to occur, previous agricultural disturbance and heavy residential use of the upland habitats would likely preclude the occurrence of many of these species. However, there is moderate potential for species-at-risk to occur within the remaining intact forest hubs within the Study Area (Madrone, 2008). Forest hubs with both wooded and open habitats are the most sensitive environmental features with the highest value within the Study Area boundary.

No rare element species or communities were observed during the December 2009 field assessments. Species that have been reported or are expected to occur within the vicinity of the Burrows Ditch and Old Logging Ditch Study Area are summarized below.

3.2.3.1 Birds

Band-tailed Pigeon (*Columba fasciata)* a blue-listed species, may breed in coniferous or mixed woodlots throughout year. The Barn Owl, a provincially blue-listed species and a species of special concern under the federal *Species at Risk Act* is documented to occur in several areas within the Study Area boundary. Barn Owls likely forage in old field habitat and roost in adjacent woodlots or agricultural buildings. The Great Blue Heron *fannini* subspecies is blue-listed provincially and of special concern federally, and is documented to forage in agricultural lowlands and associated ditches within the Study Area, particularly during winter months. Similarly, the blue-listed Short-eared Owl (*Asio flammeus*) may forage within lowland agricultural areas. Another owl, the Western Screech-owl (*Otus kennicottii),* may potentially occur in wooded areas within the Study Area (Strix, 2000).

3.2.3.2 Mammals

Suitable wetland habitat with associated riparian areas for the Pacific water shrew (*Sorex bendirii*), a provincially red-listed species, is present within the forested uplands of the Study Area. Townsend's big-eared bat (*Corynorhinus townsendii*), a provincially blue-listed species, has the potential to utilize wooded areas within the Study Area. Trowbridge's shrew (*Sorex trowbridgii*), also a blue-listed species, is likely a common resident in wooded habitats throughout the Study Area (Strix, 2000).

3.2.3.3 Reptiles and Amphibians

Both the red-legged frog (*Rana aurora*), a provincially blue-listed species, and the western toad (*Bufo boreas*), a species of special concern federally, may occupy wetland or wooded areas within the Study Area. Although rarely sighted in the Lower Mainland due to its secretive and subterranean habits, suitable habitat for the rubber boa (*Charina bottae*) exists in the upland forested habitats within the Study Area (Strix, 2000).

4.0 SUMMARY AND CONCLUSION

In general, the Burrows Ditch and Old Logging Ditch watersheds can be demarcated between upland residential and lowland agricultural areas. Aquatic and terrestrial habitat within these two areas is distinctly different in both watersheds and the Study Area as a whole.

Aquatic habitat within the lowlands is typically represented by constructed linear channels aligned along property lines and road shoulders. These channels generally provide Class A(O) habitat which can demonstrate poor water quality, particularly during the summer months, and very limited intact riparian vegetation (and therefore low % RFI). Resident fish presence in the lowlands is usually exhibited by so-called "coarse" fish. Salmonids tend to use the lowland watercourses only as migratory corridors to access the more desirable habitat supported in the upland areas.

Upland aquatic habitat is a mixture of watercourses within their natural alignments and linear ditches aligned along property lines and road shoulders. Classifications include Class A, B, and C habitat. In general, water quality within these habitats is expected to be improved due to the presence of significant retained riparian vegetation adjacent to the watercourses. Resident salmonid presence is to be expected within the upland reaches of Class A habitat along with the presence of "coarse" fish species. Class B habitat, while not supporting resident fish populations, is expected to provide a significant source of food and nutrients to fish-occupied downstream reaches.

B-IBI values in both watersheds were generally low from 2006-2009. A number of factors could have contributed to these results including the impacts to Riparian Forest Integrity, particularly in the lowland agricultural areas, deleterious substances within road runoff, and sediment from upland residential developments. It should also be noted that comparing % RFI to % EIA utilizing the Watershed Health Tracking System outlined in Metro Vancouver's Template for Integrated Stormwater Management Planning generated predicted B-IBI values between 17.78 to 19.56 for current conditions and 17.85-18.15

for future conditions. Additional analysis of the metrics used to determine the B-IBI scores indicated that both the Old Logging Ditch and Burrows Ditch systems were exhibiting signs of impairment.

Terrestrial habitat is significantly more intact within the upland reaches of both watersheds. The lowland areas are largely lacking in important wildlife habitat as a result of agricultural land use. As a result, wildlife utilization is expected to be limited to generalist species such as waterfowl, numerous species of passerines (perching birds) and mammals such as raccoon, coyote and any number of rodent species. Intact wildlife hubs, patches and corridors within the upland habitat provide significantly greater habitat value to both watersheds. The hubs and patches provide refugia for species with more specialized habitat requirements. The intact corridors, especially riparian habitat adjacent to watercourses, provide important connectivity between hubs so that these more specialized species may carry out their required life functions. The more intact upland habitat also provides a greater variety of habitat such that there is a greater potential for the presence of rare-element species.

In general, the overall health of each watershed and the Study Area as a whole has been compromised by residential development and agricultural land use. The impacts to habitat are more significantly demonstrated in the lowland agricultural areas where limited riparian vegetation and linear channels generally lacking in complexity provide limited value for important salmonid species. The lack of large contiguous vegetated areas also compromises the value of the lowlands as terrestrial habitat. The uplands, with its more intact riparian vegetation, channels retained on natural alignments, and intact terrestrial hubs with interconnected corridors, provides the best habitat, from both a terrestrial and aquatic perspective, in the Study Area.

There are a number of enhancement opportunities that can be undertaken in both the terrestrial and aquatic habitat of the two watersheds. These opportunities are discussed in detail in **Appendix A**.

5.0 REFERENCES

City of Surrey Benthic Metrics Report. 2006-2009.

City of Surrey & Dillon Consulting Limited. 2002. Old Logging Ditch / Morgan Creek, Functional Feasibility Study for Lowlands. Final Report (Appendix).

Columbia Basin Research. 2002. University of Washington Columbia Basin Research Salmon Web. Accessed January 2010 from: http://www.cbr.washington.edu/salmonweb/bibi/biomonitor.htm

Conservation Data Centre. 2010. British Columbia Species and Ecosystems Explorer. Accessed January 2010. Website at http://a100.gov.bc.ca/pub/eswp/reports.do?index=1.

ECL Envirowest Environmental Consultants. 1994. Biophysical Assessment of Watercourses Draining Lands North of 32nd Avenue Between 168th and 176th Street, Surrey, BC. Prepared for City of Surrey.

Freshwater Fisheries Society of BC "Fish Wizard" website, 2010 at http://www.fishwizard.com/

HB Lanarc & Raincoast Applied Ecology. 2009. City of Surrey Ecosystem Management Study Book 1 Main Report - Draft August 2009.

Kerr Wood Leidal Associates Limited. 2005. Template for Integrated Stormwater Management Planning 2005 - Submission of Draft Report. Prepared for the Greater Vancouver Regional District.

Madrone Environmental Services Ltd. September 30, 2008. Environmental Assessment Review Grandview Heights.

New East Consulting Services Limited. 1996. Morgan Creek / Old Logging Ditch Master Drainage Plan. Prepared for City of Surrey, Engineering Department.

Province of British Columbia. 2006. British Columbia Approved Water Quality Guidelines 2006 Edition. Retrieved January 2010 from: http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html

Raincoast Applied Ecology & City of Surrey. n.d. City of Surrey 2006, 2007, and 2008 Benthos Monitoring for Old Logging Ditch and Burrows Ditch.

Raincoast Applied Ecology and HB Lanarc August 2009. City of Surrey DRAFT Ecosystem Management Study. Main Report.

Strix Environmental/Dillon Consulting Limited. February 10, 2000. Rosemary Heights Business Park and Live/Work Area Neighbourhood Concept Plan.

APPENDIX A

ENHANCEMENT OPPORTUNITIES

INTRODUCTION

Development within the Burrows Ditch and Old Logging Ditch watersheds has the potential to significantly impact both aquatic and terrestrial habitat either directly or indirectly. Direct impacts can include a loss or degradation of habitat through the removal of vegetation, culverting/infilling of watercourses or scouring of channels through an increased discharge of runoff. Indirect impacts can include a loss of habitat connectivity (either aquatic or terrestrial) and a decrease in water quality to the detriment of fish and benthic invertebrates. However, as development proceeds, these impacts can be lessened, eliminated or potentially improved through the retention and enhancement of existing habitat features or the construction of new habitat wherever possible. Through retention and enhancement, the City of Surrey can protect environmental values while at the same time creating liveable, functional neighbourhoods with a wide variety of public amenities.

This section identifies a series of potential enhancement opportunities for both aquatic and terrestrial habitat that can be implemented within the Study Area. The identified opportunities are concentrated primarily within the uplands given the limited potential for implementation of enhancements within the agricultural lowlands.

PRIORITIZATION OF ENHANCEMENT OPPORTUNITIES

A series of enhancement opportunities were identified and developed for the Study Area (see **Table 1** below for a prioritized list). These opportunities were then prioritized based on a number of factors including the legislation governing habitat protection (*e.g.* the *Fisheries Act*), the relative importance of the habitat being protected, and the feasibility of implementation. It should be stressed that the enhancement opportunities listed will serve to offset the effects of development and could potentially improve habitat value and connectivity and, in that sense, may be considered important. However, it is recognized that development within the watersheds is inevitable and, as such, the list attempts to strike a balance by prioritizing opportunities that protect the most important habitat features, are feasible to complete from a cost perspective, and can be completed over the next several years. The locations of the proposed enhancements are indicated on **Figure 1** below.

As shown in **Table 1**, the Wills Brook and Morgan Creek systems were given the highest priority. This was done for several reasons, not the least of which was that development surrounding watercourses is strictly regulated by several pieces of federal and provincial legislation including the *Fisheries Act*, the *Water Act*, and the Riparian Areas Regulation. In addition, both creeks are accessible to salmonids for at least a portion of their lengths and are to a greater or lesser extent still located within their original alignments. Access improvement, instream enhancements, and riparian plantings would provide a significant benefit to the salmonid populations utilizing the watersheds for rearing and spawning.

Table 1: Prioritized List of Aquatic and Terrestrial Habitat Enhancement Opportunities

Enhancement Opportunity	Location(s)	Proposed Enhancement	Potential Methodology(s)	Notes / Reference
1	Entire Morgan Creek and Wills Brook systems	Removal of barriers and obstacles to fish passage	Conduct a detailed assessment of entire channel looking for perched culverts, anthropogenic barriers (*e.g.* cemetery pond), debris jams, etc. Install new culverts, fish ladders, and weirs to allow for fish access to entire system. Remove jams.	a
2	Entire Morgan Creek and Wills Brook systems	Complete instream enhancements	Add instream complexing (boulder clusters, LWD, gravel, riffles), install weirs, construct ponds. Improve fish habitat in conjunction with access improvements (see Enhancement Opportunity 1).	1 / a
3	Entire Morgan Creek and Wills Brook systems	Establish riparian setbacks and infill plant where possible	Establish setbacks consistent with the *Streamside Protection Regulation* and infill plant with native species using the City's Restoration Prescriptions. Would require negotiation with private land owners (*e.g.* Morgan Creek Golf Course).	1 / a, b
4	Morgan Creek headwaters	Installation of detention pond feature	Explore potential for construction of detention/biofiltration pond feature, potentially in conjunction with future Rosemary Heights Business Park. Potential to treat water and supplement base flow to downstream reaches.	1 / a
5	All upland watercourses other than Morgan Creek and Wills Brook	Establish riparian setbacks and infill plant where possible	Establish setbacks consistent with the *Streamside Protection Regulation* and infill plant with native species using the City's Restoration Prescriptions. Would require some negotiation with private land owners.	1, 2 / a, b
6	Terrestrial hubs A, B and C	Preserve hubs as natural areas. Avoid fragmentation of habitat	Acquire land not already in City's possession. Designate as "Environmental Area" consistent with North Grandview Heights NCP. Leave in a natural state with limited or no maintenance.	1, 3 / a
7	All terrestrial hubs and patches	Preserve all hubs and patches to the greatest extent possible. Create linkages	Retain as much of the hubs and patches as possible given designated land use. Create linkage through Subdivision/Zoning/Development Permit stages.	1, 4 / a
8	North Grandview / Coast Meridian Multi-use Corridor	Enhance corridor with a strip of native trees and shrubs to encourage wildlife utilization	Include a strip of native vegetation to provide cover for terrestrial species to facilitate movement through Study Area.	a
9	All terrestrial hubs and patches	Establish corridors between retained hubs and patches	Retain or establish corridors with native vegetation to provide cover for terrestrial species.	a
10	All upland developments	Create Class A or Class B habitat during land development	When subdivision and land development occur, explore the potential to construct accessible Class A habitat or, where fish access is not possible, construct biofiltration swales/ponds to treat adjacent runoff before discharging the fish-occupied waters.	
11	Old Logging Ditch and Burrows Ditch outlets to Nicomekl River	Upgrade or improve fish passage	Install fish-friendly pump station with floodboxes upgraded to improve fish passage during next stage of maintenance / improvement.	5 / b

Notes and References

1 Implementation of these opportunities would have added benefit of improving water quality.

2 In conjunction with establishment of setbacks, designate all watercourses (Class A and B) as “Creek Preservation Area” as indicated on Rosemary Heights Business Park NCP. North Grandview Heights NCP designates Class B watercourses as “Public Open Space and Park”. “Creek Preservation Area” potentially has a greater level of protection.

3 Hubs are large contiguous woodlots with significant habitat value in isolation of other hubs. Additionally, hubs link the upland areas to the ALR. Priority order of retention is Hub A (links to wildlife corridor through Morgan Creek golf course, as well as Morgan Creek and Wills Brook riparian zones), Hub B (links upland areas to ALR, serves as linkage for smaller terrestrial patches in southeast corner of Study Area and the Erickson system to the east) and Hub C.

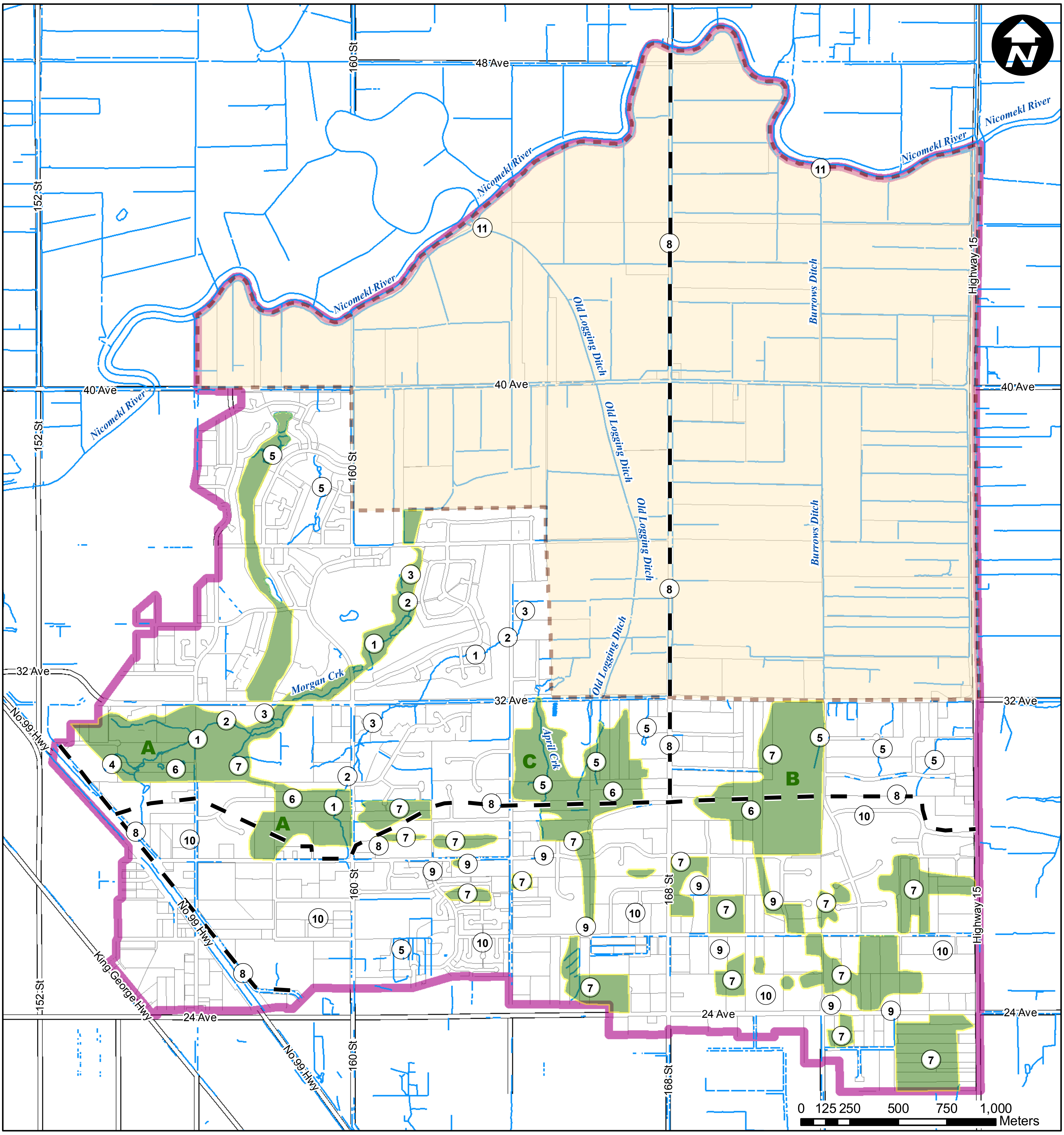
4 Designated land use likely precludes retaining hubs and patches in their entirety. Therefore, retain as much as possible and retain land for linkage between larger hubs and patches.

5 The pump stations currently allow access although it is somewhat restricted. Greater utilization by salmonid species, particularly coho, can be expected with improved access.

a Strix Environmental Consulting / Dillon Consulting Limited, 2000

b New East Consulting Services, 1996

Old Logging Ditch and Burrows Ditch Systems
Aquatic and Terrestrial Enhancement Opportunities



Enhancement Opportunity	Proposed Enhancement
1	Removal of barriers and obstacles to fish passage
2	Complete instream enhancements
3	Establish riparian setbacks and infill plant where possible
4	Installation of detention pond feature
5	Establish riparian setbacks and infill plant where possible
6	Preserve hubs as natural areas. Avoid fragmentation of habitat
7	Preserve all hubs and patches to the greatest extent possible. Create linkages
8	Enhance corridor with a strip of native trees and shrubs to encourage wildlife utilization
9	Establish corridor between retained hubs and patches
10	Construct fish accessible channels or biofiltration ponds/ swales
11	Upgrade or improve fish passage

Legend

- 1 Prioritized Enhancement Opportunity
- Terrestrial Hub
- Agricultural Land Reserve
- Watercourse
- Catchment Area
- North Grandview/ Coast Meridian Multi-use Corridor

CITY OF SURREY the future lives here. URBANSYSTEMS. DILLON CONSULTING

The remaining watercourses within the Study Area were prioritized next due to the requirement to protect fish habitat as per the above-referenced legislation and their potential to improve water quality in fish-occupied reaches.

Terrestrial enhancement opportunities were prioritized next. Given the considerably lower level of protection afforded to terrestrial habitat in existing legislation, it was determined that as much as the existing hubs and patches provide important habitat for a wide variety of species, the potential to protect them in their entirety was considerably diminished. In addition, the wildlife species most likely to be present are expected to be those that are well-adapted to living in urban/suburban environments so ongoing development may not be as detrimental to their survival as the protection of watercourses would be to salmonid species, which are currently under pressure in British Columbia. A review of background information indicated that some rare-element species could utilize the terrestrial habitat onsite for at least a component of their life requirements. These species may be afforded some protection under the federal *Species at Risk Act* and further assessment may be required to determine if critical habitat is present.

All the above-described opportunities explore the potential to protect and enhance existing habitat. Opportunity 10 was prioritized next as the works are more about creating new habitat, where and if possible, during the development process.

The final opportunity identified was the upgrading of the Old Logging Ditch and Burrows Ditch pump station floodboxes to improve fish access. Given that replacement of the floodboxes was scheduled for the summer of 2010 and that access improvements were not contemplated at that time, the next maintenance or replacement of the floodboxes will likely not occur for a number of years in the future. As such, this opportunity has been given the lowest priority.

DISCUSSION OF ENHANCEMENT OPPORTUNITIES

Enhancement Opportunity 1

Opportunity 1 consists of the removal of barriers and obstacles to fish access throughout the Morgan Creek and Wills Brook channels. These two creeks provide the best potential habitat for rearing and spawning of salmonids within the upland sections of the Study Area. Fish access has been confirmed through at least a portion of the channels and the removal of anthropogenic and naturally occurring barriers/obstacles would provide a considerably larger habitat area to support resident salmonid populations. Please note that for the purposes of this discussion, barriers prevent access to upstream reaches under all flow conditions whereas obstacles restrict access under certain flow conditions (generally during low-flow periods) or at least impede upstream access.

Opportunity 1 can be accomplished through the completion of a detailed assessment from the confluence of the Morgan and Wills systems with Old Logging Ditch to their origins at Croyden Drive and 28th Avenue respectively. Some obstructions have previously been identified, such as the privately owned floodbox at the confluence of Old Logging Ditch with Morgan Creek which acts as an obstacle. The online pond within the Gardens of Gethsemani cemetery on the south side of 32nd Avenue is thought to be a barrier to fish access to upstream reaches. Other obstructions may be present, such as the culvert conveying Wills Brook under 160th Street which was observed to be "perched" with its invert above the downstream water level.

Once the barriers and obstacles have been identified, a series of instream works can be completed that may provide access to the entirety of the two channels. Works can consist of the replacement of perched culverts with larger diameter culverts with their inverts backwatered under all flow conditions, the installation of baffles within existing culverts to provide refugia for fish migrating upstream, instream weirs or step pools to allow access to culverts or over obstructions, fish ladders, and the physical removal of anthropogenic or naturally occurring blockages. All of these proposed works would require permitting under the *Fisheries Act* and *Water Act* and the application of standard Best Management Practices.

Enhancement Opportunity 2

In conjunction with the removal of obstructions from Wills Brook and Morgan Creek, a series of instream enhancements could be implemented to improve habitat values and the ability of the channels to support salmonids. Please note that although this is given second priority on the list, it should be conducted simultaneously with Opportunity 1 as there is little point in improving access if the sections of channel made available do not provide suitable rearing habitat.

Instream enhancements may include, but not be limited to, the following:

- Boulder clusters within the wetted perimeter of the channel consisting of round rock piled to create cover within their interstitial spaces;
- Large Woody Debris (LWD) consisting of log tangle structures and/or rootwads cabled to the bank and partially submerged within the wetted perimeter would provide cover and refugia for fish;
- The weirs, step pools and fish ladders referenced in Opportunity 1 would also create pool habitat which is utilized by salmonid species for cover and refugia from flow;
- The construction of ponds where local topography allows. Ponds could be complexed with boulder clusters and LWD to provide cover and refugia and instream vegetation for food/nutrient input and water quality improvements. Any ponds constructed should provide a minimum depth of 300 mm and preferably more to provide adequate cover. Additionally, the enhancement of existing ponds such as are found within the golf course could also be completed;
- The construction of "lunker" structures which essentially mimic naturally occurring undercut banks which are frequently used by salmonids for cover; and
- The placement of gravel to provide spawning habitat where adequate flow is present. The gravel could also be placed in such a way as to create riffles which serve to improve water quality as a result of surface agitation mixing with the air to increase dissolved oxygen levels within the water column.

Please note that gravel placement could be accomplished by placement of particularly sized gravel at select locations with the intention of having that gravel mobilize downstream during higher flow events. The gravel would be sized to target specific salmonid species, likely coho salmon, cutthroat trout and rainbow trout in these systems. The determination of the volume of gravel to be placed and at what location could be determined through the implementation of hydraulic modelling. A pilot project recently initiated by the City may provide some indication of this process in the near future.

Enhancement Opportunity 3

Infill planting with native species along the Morgan Creek and Wills Brook riparian setbacks would greatly serve to improve overall habitat value. Riparian vegetation provides numerous benefits to instream habitat including:

- Provides shade which subsequently improves water quality due to higher dissolved oxygen presence in cooler waters;
- Bank stability that reduces erosion and the subsequent sedimentation of the watercourse;
- Acts as a source of LWD;
- Provides a food and nutrient input as a source of leaf litter deposition and insect drift; and
- Filters out pollutants being conveyed to the channel either overland or by subsurface flow.

Infill planting can be completed in areas where setbacks have been established utilizing either the Streamside Protection Regulation protocols or, where subdivision is occurring, the Riparian Areas Regulation. The planting could be included as a requirement of the subdivision process. Alternatively, some riparian areas could be enhanced if the City enters into an agreement with a landowner to install vegetation. Installation could be completed either by a landscape contractor or through City environmental programs (*e.g.* SHaRP).

At a minimum, it is suggested that a 5 metre vegetated buffer be retained along the top-of-bank of the channels. It is recognized that the public will often attempt to access creeks due to their aesthetic value. Riparian vegetation can be damaged as a result. For this reason, it may be practical to create gaps in any infill planting to focus access to a select few points such that impacts to the remaining vegetation can be minimized.

It should be noted that there are Restrictive Covenants (RCs) in place along portions of Morgan Creek and Wills Brook within the Morgan Creek Golf Course north of 32nd Avenue. A review of the RC document provided by the City indicated in part that "the Owner shall not, without the prior written consent of the Wildlife Manager either: (i) cut down, trim, defoliate, alter, remove or in any was tamper with work on any trees, shrubs, plants, bushes, ground cover vegetation or any other plant life in the Environmental Management Area". A review of the aerial photograph on COSMOS from April 2009 indicated that some impacts to the riparian setback had occurred within the RC. Specifically, these impacts consist of the following:

- The RC was utilized as a part of the fairway on the 36A Avenue alignment west of 159A Street on Morgan Creek;
- Portions of the RC along Morgan Creek downstream of Morgan Creek Way were utilized as fairway; and

- Portions of Wills Brook between 32nd Avenue and 164th Street have also been encroached on by the golf course.

Given the existence of the RC, it may be possible to encourage the golf course to re-establish riparian vegetation in those areas, assuming that no previous agreement for the removal of vegetation has been obtained from the Wildlife Manager.

A review of the April 2009 aerial photograph also indicated that portions of the greenbelt on Morgan Creek between 32nd Avenue and Morgan Creek Way are lacking in significant riparian vegetation.

Enhancement Opportunity 4

Previous assessments conducted within Morgan Creek have indicated that summer base flows can be extremely low. This can potentially have a negative impact on downstream fish populations as a source of clean, oxygenated water would be compromised. It may also result in a lowering of water depth which could reduce cover and the availability of rearing habitat. The construction of the Rosemary Heights Business Park will require some form of stormwater management given the anticipated increase in impervious surface that is likely to develop. If feasible, a detention pond could be constructed that would have several benefits to fish habitat if it can be engineered to allow a steady flow of clean, oxygenated water to downstream reaches during low flow periods. The water quality can be improved if the pond includes a healthy buffer of riparian vegetation, instream vegetation such as a cattail bench and sufficient depth to reduce surface warming from penetrating to the pond invert. An additional benefit would be to enhance the pond with complexing elements and to make it accessible to fish.

Enhancement Opportunity 5

Similar to the infill planting proposed for Morgan Creek and Wills Brook, Opportunity 5 would have the benefit of providing improved water quality and overall fish habitat value. Setbacks would be consistent with the Streamside Protection Regulation and the minimum requirements of the Riparian Areas Regulation. It can be achieved as a requirement of the subdivision process.

It should be noted that the Class B watercourses referenced in the North Grandview Heights NCP are designated as “Public Open Space and Park”. A greater level of protection may be possible if these channels are designated as “Creek Preservation Areas” similar to the designation in the Rosemary Heights Business Park NCP. There might be some benefit in extending the “Creek Perseveration Area” designation to Wills Brook as well.

Enhancement Opportunity 6

Terrestrial Hubs A, B and C are the largest and most intact forested blocks in the uplands and provide habitat for a number of terrestrial wildlife species. They also provide connectivity throughout the upland area, particularly when linked to the numerous small forested patches in the southeast corner of the Study Area. They also serve to link the uplands to the ALR lands to the north. Retention of these hubs in their entirety, if possible, would add a significant benefit to terrestrial habitat resources.

Enhancement Opportunity 7

Given the numerous forested patches present within the Study Area, their retention would provide habitat for numerous wildlife species, particularly if retained with Hubs A, B and C as referenced in Opportunity 6. The creation of linkages through the construction of multiuse corridors between the patches would serve as migratory habitat throughout the Study Area and to other habitat to the south and east. Linkages could also be made to retained riparian zones and the ALR.

Enhancement Opportunity 8

The North Grandview/Coast Meridian Multi-use Corridor is planned for the approximate 29th Avenue alignment, along Croyden Drive and north from 29th Avenue along 168th Street. Given that it is well-along in the planning phase with some sections already constructed, there may be potential to add a strip of vegetation that would provide cover for wildlife species and encourage its use as a corridor for movement throughout and beyond the Study Area. On its current proposed alignment, the Multi-use Corridor links Terrestrial Hubs A, B and C as indicated in **Figure 1**. The City is currently acquiring the land or working with developers to have the land dedicated through the development process. Funding is being provided either through amenity contributions or is being funded by the City as a capital cost.

Enhancement Opportunity 9

Regardless of the extent of the forested hubs and patches that are retained, there may be some potential to create linkages between the remaining sections during the development process. As with the North Grandview Corridor discussed above, this would create linkages and encourage terrestrial wildlife migration throughout the Study Area.

The remaining forested patches are concentrated in the central part of the uplands and southeast corner of the Study Area. The developments proposed as part of the Grandview Heights #5 and Grandview Heights General Land Use Plan encompass the majority of the remainder of these patches. Proposed zoning for the land is currently mixed density residential and low density residential for Grandview Heights #5 and Grandview Heights General respectively. Given the type of development proposed, there is an opportunity to retain at least a portion of the patches and create linkages between them both within the proposed development areas and to the retained patches immediately outside of the development areas. Similarly to the North Grandview/Coast Meridian Corridor, this can be funded through amenity contributions and the capital budget.

Enhancement Opportunity 10

Given the land use proposed for the uplands, stormwater management will be a critical element to be incorporated as development proceeds. Depending on the location of any development, it may be possible to acquire land and incorporate new fish habitat into the stormwater design. The habitat could be made fish accessible if closer to 32nd Avenue. Fish habitat further upslope would likely not be fish accessible due to topography but could include biofiltration elements to improve water quality to fish-occupied reaches downslope.

Enhancement Opportunity 11

The Old Logging Ditch and Burrows Ditch floodboxes at the Nicomekl River were scheduled for replacement in the summer of 2010. Improved fish access was not a component of the proposed design. It is recommended that the access through the floodboxes be improved when maintenance or replacement is next required.

TABLES FROM BC MINISTRY OF ENVIRONMENT
WATER QUALITY GUIDELINES 2006

Table 4. Average 30-day Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg/L of Nitrogen)

Temperature (T) in degrees Celsius

pH	T=0.0	T=1.0	T=2.0	T=3.0	T=4.0	T=5.0	T=6.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.8	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.2	2.08	2.05	2.02	1.99	1.97	1.95	1.92
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131

Temperature (T) in degrees Celsius

pH	T=7.0	T=8.0	T=9.0	T=10.0	T=11.0	T=12.0	T=13.0
6.5	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.6	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.7	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.8	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.9	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.0	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.1	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.2	1.90	1.88	1.86	1.85	1.83	1.81	1.80
7.3	1.90	1.88	1.86	1.85	1.83	1.82	1.80
7.4	1.90	1.88	1.87	1.85	1.83	1.82	1.80
7.5	1.91	1.88	1.87	1.85	1.83	1.82	1.81
7.6	1.91	1.89	1.87	1.85	1.84	1.82	1.81
7.7	1.91	1.89	1.87	1.86	1.84	1.83	1.81
7.8	1.63	1.62	1.60	1.59	1.57	1.56	1.55
7.9	1.38	1.36	1.35	1.34	1.33	1.32	1.31
8.0	1.16	1.15	1.14	1.13	1.12	1.11	1.10
8.1	0.922	0.914	0.906	0.899	0.893	0.887	0.882
8.2	0.736	0.730	0.724	0.718	0.714	0.709	0.706
8.3	0.588	0.583	0.579	0.575	0.571	0.568	0.566
8.4	0.471	0.467	0.464	0.461	0.458	0.456	0.455
8.5	0.377	0.375	0.372	0.370	0.369	0.367	0.366
8.6	0.303	0.301	0.300	0.298	0.297	0.297	0.296
8.7	0.244	0.243	0.242	0.241	0.241	0.240	0.240
8.8	0.197	0.197	0.196	0.196	0.196	0.196	0.196
8.9	0.160	0.160	0.160	0.160	0.160	0.161	0.161
9.0	0.131	0.131	0.131	0.131	0.132	0.132	0.133

Temperature (T) in degrees Celsius

pH	T=14.0	T=15.0	T=16.0	T=17.0	T=18.0	T=19.0	T=20.0
6.5	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.134	0.135	0.128	0.121	0.114	0.108	0.102

1. The average of the measured values must be less than the average of the corresponding individual values.

2. Each measured value is compared to the corresponding individual values.

3. No more than one in five of the measured values can be greater than 1.5 x the corresponding guidelines values.

Reference 3

Table 5. Maximum Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life

Temperature (T) in degrees Celsius

pH	T=0.0	T=1.0	T=2.0	T=3.0	T=4.0	T=5.0	T=6.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681

Temperature (T) in degrees Celsius

pH	T=7.0	T=8.0	T=9.0	T=10.0	T=11.0	T=12.0	T=13.0
6.5	26.2	26.0	25.7	25.5	25.2	25.0	24.8
6.6	25.5	25.2	25.0	24.7	24.5	24.3	24.1
6.7	24.6	24.4	24.1	23.9	23.7	23.5	23.3
6.8	23.6	23.4	23.1	22.9	22.7	22.5	22.3
6.9	22.5	22.2	22.0	21.8	21.6	21.4	21.3
7.0	21.1	20.9	20.7	20.5	20.3	20.2	20.0
7.1	19.7	19.5	19.3	19.1	18.9	18.8	18.7
7.2	18.1	17.9	17.8	17.6	17.4	17.3	17.2
7.3	16.5	16.3	16.2	16.0	15.9	15.7	15.6
7.4	14.8	14.7	14.5	14.4	14.2	14.1	14.0
7.5	13.1	13.0	12.9	12.7	12.6	12.5	12.4
7.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9
7.7	9.92	9.83	9.73	9.65	9.57	9.50	9.43
7.8	8.48	8.40	8.32	8.25	8.18	8.12	8.07
7.9	7.17	7.10	7.04	6.98	6.92	6.88	6.83
8.0	6.02	5.96	5.91	5.86	5.81	5.78	5.74
8.1	4.80	4.75	4.71	4.67	4.64	4.61	4.59
8.2	3.83	3.80	3.76	3.74	3.71	3.69	3.67
8.3	3.06	3.03	3.01	2.99	2.97	2.96	2.94
8.4	2.45	2.43	2.41	2.40	2.38	2.37	2.36
8.5	1.96	1.95	1.94	1.93	1.92	1.91	1.91
8.6	1.58	1.57	1.56	1.55	1.55	1.54	1.54
8.7	1.27	1.26	1.26	1.25	1.25	1.25	1.25
8.8	1.03	1.02	1.02	1.02	1.02	1.02	1.02
8.9	0.833	0.832	0.831	0.831	0.832	0.834	0.838
9.0	0.681	0.681	0.681	0.682	0.684	0.688	0.692

Temperature (T) in degrees Celsius

pH	T=14.0	T=15.0	T=16.0	T=17.0	T=18.0	T=19.0	T=20.0
6.5	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	23.9	23.8	23.6	23.5	23.3	23.3	23.2
6.7	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.37	9.31	9.26	9.22	9.18	9.15	9.12
7.8	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.698	0.704	0.711	0.720	0.729	0.740	0.752

Table 16. Summary of Water Quality Guidelines for Nitrogen

Water Use	Nitrate mg/L as nitrogen	Nitrite mg/L as nitrogen	Ammonia (total) mg/L as nitrogen
Fresh Water Aquatic Life - maximum	200 mg/L (maximum)	0.06 mg/L (maximum) when the chloride is less than 2 mg/L – also see Table 17	See Tables 4 and 5
Fresh Water Aquatic Life - average	Less than or equal to 40 mg/L (average)	Less than or eual to 0.02 mg/L (average) when the chloride is less than 2 mg/L – also see Table 17	See Tables 4 and 5
Wildlife	100 mg/L (maximum)	10 mg/L (maximum)	None proposed

1. The average value is calculated from at least 5 weekly samples taken in a period of 30 days.

2. Where nitrate and nitrite are present, the total nitrate+nitrite nitrogen should not exceed these values.

3. These levels are too high for some amphibians. For example the 96-h LC_{50} for the eastern American toad is 13.6 mg/L N.

4. Chronic effects are observed at lower levels, 5 to 10 mg/L N (reference 27)

Reference 3

Table 9. Summary of Water Quality Guidelines for Copper

Water Use	**30-day averages µg/L total copper**	**Maximum µg/L total copper**
Raw Drinking Water Supply	—	500 µg/L
Fresh Water Aquatic Life (when average water hardness as $CaC0_3$ is less than or equal to 50 mg/L)	less than or equal to 2µg/L	(0.094(hardness)+2) µg/L (hardness as mg/L CaCO3)
Fresh Water Aquatic Life (when average water hardness as $CaC0_3$ is greater than 50 mg/L)	less than or equal to 0.04 (mean hardness) µg/L	(0.094(hardness)+2) µg/L (hardness as mg/L CaCO3)
Wildlife	None proposed	300 µg/L
Livestock Water Supply	None proposed	300 µg/L
Irrigation Water Supply	None proposed	200 µg/L
Recreation and Aesthetics	None proposed	1000 µg/L
Marine and Estuarine Aquatic Life	less than or equal to 2 µg/L	3 µg/L

1. The average is calculated from at least 5 weekly samples taken in a period of 30 days.

2. When detailed knowledge on the the bioavailable forms of copper is available, the form of copper in the guidelines for aquatic life can be modified, as justified by the data.

3. If natural background levels exceed the guidelines for aquatic life, the increase in total copper above natural levels to be allowed, if any, should be based on site-specific data.

Reference 6

Table 25. Summary of Aquatic Life and Sediment Guidelines for Polycyclic Aromatic Hydrocarbons (PAHs)

PAH	Fresh Water (chronic)	Fresh Water (phototoxic)	Sediments (Fresh Water)
Naphthalene	1 µg/L	NR	0.01 µg/g
Methylated naphthalene	NR	NR	NR
Acenaphthene	6 µg/L	NR	0.15 µg/g
Fluorene	12 µg/L	NR	0.2 µg/g
Anthracene	4 µg/L	0.1 µg/L	0.6 µg/g
Phenanthrene	0.3 µg/L	NR	0.04 µg/g
Acridene	3 µg/L	0.05 µg/L	1 µg/g
Fluoranthene	4 µg/L	0.2 µg/L	2 µg/g
Pyrene	NR	0.02 µg/L	NR
Chrysene	NR	NR	NR
Benz[a]anthracene	0.1 µg/L	0.1 µg/L	0.2 µg/g
Benzo[a]pyrene	0.01 µg/L	NR	0.06 µg/L

1. NR — not recommended due to insufficient data

2. *sediment containing 1% organic carbon

Reference 16

Table 33. Recommended Guidelines for Zinc

Water Use	Guideline (µg/L Total Zinc)
Freshwater Aquatic Life - maximum concentration — water hardness less than or equal to 90 water hardness equal to 100 water hardness equal to 200 water hardness equal to 300 water hardness equal to 400	use the equation 33 + 0.75 x (hardness - 90) — 33 40 115 190 265
Freshwater Aquatic Life - 30-day average concentration — water hardness less than or equal to 90 water hardness equal to 100 water hardness equal to 200 water hardness equal to 300 water hardness equal to 400	use the equation 7.5 + 0.75 x (hardness - 90) — 7.5 15 90 165 240

1. When the ambient zinc concentration in the environment exceeds the guideline, then further degradation of the ambient or existing water quality should be avoided.

2. These are instantaneous maximums.

3. Averages are of five weekly measurements taken over a 30-day period.

4. Water hardness is measured as mg/L of $CaCO_3$.

Reference 31

Appendix C

Hydrologic Report (including Runoff Pollutant Loadings Analysis)

Table of Contents

1 Hydrologic and Hydraulic Model Development

1.1 Introduction

Hydrologic and hydraulic modeling for the Old Logging Ditch and Burrow's Ditch watersheds proceeded through the following steps:

Model development
Model calibration, verification and validation (to a limited extent due to lack of adequate data)
Development of Design Scenarios
Review of Model Results
Finalization of Recommended Strategies

The MIKE-SHE model, developed by the Danish Hydraulic Institute, was used for the hydrologic analysis and MIKE-11 was used for the hydraulic analysis. MIKE-SHE is a powerful, physically-based hydrologic model with distributed parameters. MIKE-SHE includes process models for overland flow, groundwater flow, interception and infiltration, evapo-transpiration, and unsaturated flow. It conceptualizes the watershed as a series of individual grid cells, with each cell capable of accommodating different land uses, elevations, soils, and climate parameters. MIKE-SHE can simulate stream flows resulting from varying forms of precipitation: rain, snow, and mixed rain and snow.

MIKE SHE couples with a stand-alone, 1-D hydro-dynamic model, MIKE-11, which is used to model stream networks and associated hydraulic structures. The coupling of the MIKE-11 and MIKE-SHE models allow the overland flow, sub-surface flow and groundwater flow modules of the MIKE-SHE model to interact with the MIKE-11 model. The dynamic interaction between the two models provides a more realistic representation of the hydrologic/hydraulic processes exist in an urban watershed.

1.2 Model Development

1.2.a Catchment Boundary and Model Domain

The catchment boundary and the model domain for the study area are shown in **Figure 1**. Both Old Logging Ditch and Burrow's Ditch watershed include lowlands. For the current modeling, lowlands were not included; however, the lowland boundary condition was included and impact on lowlands was investigated. As shown in the figure, the model domain (or boundary) is not exactly same as the catchment boundary. In MIKE SHE, the model domain should extend (at a minimum) two cell sizes beyond the catchment boundary. Besides, ground water boundary condition and boundary condition of the receiving water bodies need to be considered. If the groundwater zone underneath the catchment area interact with areas outside the catchment boundary or the aquifer extends beyond the catchment boundary, the model domain should be extended. In this instance, the model domain was extended 200 m to the north beyond the catchment boundary to incorporate the lowland boundary condition and for other sides; the typical distance of two cell sizes was maintained.

1.2.b Model Grid

The MIKE SHE model conceptualizes a watershed as a series of discrete square cells, each of which can have its own set of model parameters (elevation, soils, land use, etc.) associated with it. **Figure 2** presents the grid approximation of the watershed generated by the MIKE SHE program. The topography of the Old logging ditch and Burrow's ditch is moderately steep, gradually merging into the lowlands. To utilize the LIDAR data to its fullest extent and replicate the topographic conditions, a finer grid size is appropriate. However, there is limitation in computational power and time and thus, a cell size of 40 m by 40 m were used in the model that maintains reasonable computational time. The selected grid size simulates the hydrologic and hydraulic condition in a reasonable manner. Total model domain is **1151.4 ha** and a total of **7433** cells were used.

1.2.c Topography

The Study Area includes approximately 988 ha of uplands from both Burrows Ditch and Old Logging Ditch catchments. The topographic data for the model was developed using the LiDAR (Light Detection and Ranging) information received from the City. The data points were evenly spaced in 1 meter intervals, and represented the ground surface only. A continuous ground surface with a 1 meter cell-size resolution was built using ArcGIS and this was imported into MIKE SHE to build the upper boundary of the model. In MIKE SHE, the topography defines the drainage surface for overland flow and is also used as the top elevation of both the unsaturated (UZ) module and the saturated (SZ) module.

Using the bilinear interpolation method in MIKE SHE, the model surface consists of 40m X 40m grid cells was developed from the DEM. The bilinear interpolation method essentially takes the average of the values of the four closest points (2 along the X axis and 2 along the Y axis) to the centroid of the cell as the cell elevation.

1.2.d Soils

The Geological Survey of Canada's generalized surficial geology mapping of the area indicates three major surficial geological units in the Uplands; Capilano Sediments (Cd and Cb) and

Vashon Drift (Va). The Lowlands comprises of Post Glacial Salish sediments (SAb). Cd mostly consists of stony to stoneless silt and clay with minor amounts of sand and silt underlain by till. Similarly Cb consists of medium to coarse sand underlain by silt and clay. More than two third of the Uplands is covered by Cb and Cd. The rest of the study area consists of Va, which is glacial till containing lenses and interbeds of glaciocustrine stony silt.

The "Soils of the Langley-Vancouver Map Area, Vol 3" indicates a number of soil types including the Bose, Boosey, Heron, Cloverdale, Whatcom, Lumbum, Richmond, Summer, Triggs, Lulu and Sunshine. The dominant soil type in the area is Bose soil. Bose soils are moderately well to well drained, and rapidly pervious in the upper gravelly part but slowly pervious in the compact glacial till or glaciomarine underlay. They have low water holding capacity and after a prolonged rain, telluric seepage along the surface of the dense compact subsoil is usual. Poorly drained soils including Boosey, Heron, Lumbum, and Triggs are present in the low lying areas along the 32nd Ave (of the Langley-Vancouver Map Area, Vol 3). Near the lowland, the water table is high. An area enclosed by 166th St and 176th St in the E-W direction and by 26th Ave and 31st Ave in the N-S direction also contains poorly drained soil. Considering the scope of the current work, a soil map was developed based on the drainage characteristics of the soil and is shown in **Figure 3**.

1.2.e Unsaturated Zone

In the unsaturated zone module of MIKE SHE, The Green Ampts method was used to estimate the flow exchange between the overland and unsaturated zone. Different soil parameters such as saturated water content, field capacity, wilting point, saturated hydraulic conductivity and soil suction values were used to estimate the unsaturated flow. During the calibration process using limited flow data (the Morgan Creek flow data at the 160th St. crossing), the saturated hydraulic conductivity was found to be most sensitive among different parameters. **Table 1** presents the parameters that resulted in modeled flows that closely match with the measured flows.

1.2.f Saturated Zone

Due to lack of sufficient groundwater information, one aquifer was considered for the entire watershed. The aquifer characteristics were taken from the hydrogeology report (Piteau Associates Engineering Ltd., 1998). The aquifer depth was set at 8 m below the ground. During the calibration process, the sensitivity of the aquifer depth was investigated and 8 m depth resulted in modeled flows that closely match the observed flows. The initial potential head for the aquifer was estimated after observing the condition of the simulated groundwater table over a period of one year.

For the groundwater zone, along the borders with the lowlands, 'fixed head' boundary was considered at 0.5 m below ground. 'No flux' boundary was considered for the boundaries with neighboring Erickson Creek Watershed and Fergus Creek Watershed. This means that there is no groundwater interaction (flow) occurring through the catchment boundaries. **Table 2** shows the different characteristics of the simulated aquifer.

1.2.g Land use

The land use information for existing condition and future condition were obtained from the City's existing zoning map and neighborhood concept plan (NCP) maps. Using the zoning information in conjunction with the ortho photos, the total impervious area and pervious areas were estimated for both existing and future conditions. For example, if a site in the NCP is designated as 'single family residential 2-4 upa (unit per acre)', the total impervious area was estimated based on a typical single family residential site with 2-4 upa or similar in the City of Surrey. That way, it was possible to mimic the imperviousness that is close to reality.

Directly Connected Impervious Area

The total impervious area per development lot is divided into two types: directly connected to the storm sewer system and not directly connected to the storm sewer system. According to City of Surrey's building by-law, all single family residential lots should have disconnected roof leaders. This means, instead of conveying the total impervious area runoff directly to the City's storm system, the runoff from the roofs flow on the pervious ground and is allowed to infiltrate and/or evaporate and finally discharge into the storm system. However, it is understood that not all single family lots follow the bylaw strictly. Thus, based on discussion with the City, it was decided that for modeling purpose, 50% of the existing single family residential lots will have 'disconnected roof leaders'. Other types of land uses i.e. multifamily housing, commercial, industrial, institutional are considered to have 'connected roof leaders'.

For future condition, it was assumed that the existing bylaw will be enforced and possibly expanded to multifamily residential, commercial, industrial and active park spaces. Thus, in the future condition model it was assumed that all the above mentioned lots have 'disconnected roof leaders'.

Vegetation

Based on available information, the existing vegetation in the Old Logging Ditch and Burrows Ditch catchment can be classified into seven (7) groups. Interception and evapo-transpiration are the two hydrologic aspects that depend on vegetation type. Thus, for each vegetation type, the model requires leaf area index (LAI) and root depth (RD) values. Leaf Area Index (LAI) is the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows. Root depth presents the typical root depth for each vegetation type below the ground. These values were selected from existing literature. **Table 3** shows the different values of RD and LAI.

Manning's M

In MIKE SHE, the surface roughness characteristics is represented by Manning's 'M' that is equivalent to the Stickler roughness coefficient. It is the inverse of roughness coefficient Manning's 'n', typically used in overland flow estimation. **Table 4** shows the different Manning's 'M' used in the model.

Depression Storage

The depression storage is the amount of water that will fill up the existing depressions before the overland flow starts. For existing condition, nominal depression storage of 0.5 mm was assumed for every cell. For future condition, same depression storage was assumed when NCP proposed land use changes, detention ponds and other infrastructure changes were considered.

To simulate the on-site infiltration storage by the proposed absorbent topsoil that varies in depth based on land use type, the depression storage was used in the current study. In MIKE SHE, the depression storage is subjected to evaporation and infiltration, which is similar to the way absorbent topsoil is expected to function. In a real setting, runoff infiltrates into the absorbent topsoil and evaporates with time. Two different on-site detention criteria were investigated in the analysis; the Provincial criteria and the Department of Fisheries and Oceans criteria. The more stringent of the two was selected for the current study, which is the Provincial criterion. **Table 5** shows the detention storage values for different land use types.

Evapo-transpiration

The annual water balance summary reported in the 'Hydrogeological Assessment for the North Grandview Heights Area General And NCP Servicing Plans' (1998) included the estimated monthly potential evapo-transpiration for Surrey's Sunnyside area. The Thornthwaite method (Thornthwaite, 1948) was used to estimate the potential evapo-transpiration. This method is based on monthly average temperature values, which were taken from the 30-year long recorded data (1960-1990) from the Surrey Municipal Hall station. Compared to the monthly average rainfall from the 30 year recorded data, monthly evapo-transpiration exceeds rainfall from May to September indicating no significant recharge during that period. On an annual basis, approximately 50% of the total precipitation returns to the environment via evapo-transpiration.

1.2.h Rainfall Data

There are two Metro Vancouver rain gauges that could be used for this study: Surrey Municipal Hall and White Rock STP. Since the municipal hall gauge was used as the basis for work in nearby Fergus Creek and, more specifically, in the servicing plan for Grandview Heights #2, this was used here as well. The Surrey Municipal Hall rain gauge has T 36 years of hourly rainfall data, covering the period 1963 to 1998. The most current 20 years of data was used in the continuous modeling simulation for the ISMP. Besides continuous simulation, design storms were developed to use in the model based on the IDF information published in the City's Drainage manual.

Considering the interaction with lowlands, the ARDSA storms were also used to investigate flooding potential in the lowland caused by the upland development. Based on the information available in the City's Drainage manual, the growing season hyetograph was taken from the Pitt Meadows STP Rainfall Gauge and the winter season hyetograph was taken from the Surrey Municipal Hall Rainfall Gauge. **Table 6** to **Table 9** show different rainfall data for different storm durations.

1.2.i Hydraulic Components

Figure 4 shows the overall existing stormwater infrastructure for the study area. **Figure 5** shows the selected streams and ditches used in the MIKE 11 model. Morgan Creek, April Creek, Wills Brook, and West Creek are the major creeks in the Study Area. Besides these, Old Logging Ditch, Burrows Ditch, ditches along 32nd Avenue, ditches along 176th St, and ditches along 26th Avenue are being modeled. Typically cross sections were created from the digital elevation model at every 40-60 m interval. Cross sections at smaller interval were created whenever deemed necessary. **Figure 6** shows typical cross sections of creeks and road side ditches.

Ten culverts were modeled in both the existing and future condition model. Culvert information was derived from City's GIS database and As-built drawings. Due to lack of information about the culvert underneath Highway 99, a limited site survey was conducted to retrieve the information necessary for modeling. Significant numbers of on-line and off-line ponds exist in the study area; mostly in the Old Logging Ditch watershed. Considering the direct impact of on-line ponds on the stream flow condition, three on-line ponds on Morgan Creek and one on-line pond on West Creek were modeled in the existing condition. The ponds information (i.e. pond area, depth, volume, inlet and outlet condition) were taken from orthophotos, old reports and As-built drawings. For the future condition, detention ponds proposed in the NCPs were incorporated in the model; however detailed information was not available other than the detention volume.

A pump station is located at the southwest corner of 40th Avenue and 160th St. This is known as the West Creek Pump station. Based on the As-built drawings, the pump station has one lead pump and one lag pump. The lead pump starts at 1.0 m water elevation and stops at 0.70 m water elevation. The lag pump starts at 1.05 m water elevation and stops at 0.70 m water elevation. The total pumping capacity of the two pumps is 0.9 cms.

1.2.j Initial/Boundary Conditions

In all instances the initial overland water depth were set at a depth of 0.0 mm. The initial ground water depth was estimated based on one year model simulation. In order to mimic the initial condition for different model scenarios, all models were initialized with appropriate seasonal hydrologic condition. For wet weather condition, models were initialized with simulated hydrologic condition for December and for summer, models were initialized with simulated hydrologic condition for the month of June.

There are six discharge locations in the study area. The boundary water levels at these locations were approximated based on existing studies, As-built drawings of the pump station and cross-section of the creeks. **Table 10** shows the different boundary conditions at the six discharge locations.

1.3 Model Calibration and Validation

Limited information was available for model calibration and validation. Daily stream flow data was available at the Morgan Creek and 160th Street crossing starting from 1996 to 2008. The model was calibrated using the 1997 rainfall data between December 16th and December 30th. **Figure 7** shows the modeled flows and the recorded flows. The modeled data was reasonably close to the recorded data. The rainfall data between February 24th and March 26th of 1997 was used to validate the model, as shown in **Figure 8**. Again, reasonably good match was observed between recorded flows and simulated flows.

No flow or water level data prior to this study was available for the Old Logging Ditch or Burrow's Ditch. Thus, water level gauges were installed in March 2010 by the City (upon request from Urban Systems) at two locations; Old Logging Ditch at the 32nd Avenue crossing and Burrow's Ditch at the 32nd Avenue crossing. The locations were chosen such that the discharge into the lowlands can be measured. However, the gauge at the Old Logging Ditch was damaged due to road construction. The Burrow`s Ditch gauge collected three months of water level data (March to May, 2010). Using the As-built drawing of the culvert where the gauge was located, the gauge readings were converted to water elevations. Due to data limitation, the gauge data were only used as a check to make sure that the model inputs are reasonable and provide reasonable results.

2 Development of Design Scenarios

Two main design events were modeled:

- **Design Event I – Existing Conditions**
- **Design Event II– Future Conditions**

Together, these two Design Events will provide the City with a good understanding of how future development might change the hydrologic behaviour of the watersheds relative to existing conditions. Each Design Event is defined by a combination of three components:

- **Land Use Scenario** - land use assumptions
- **Stormwater Management Scenario** – stormwater management approaches (e.g., detention facilities, minor/major conveyance, and BMPs)
- **Hydrologic/Hydraulic Conditions** – the design storms, initial conditions and boundary conditions.

2.1 Land Use Scenarios

The following two land use scenarios have been used in the modeling:

- **Existing Conditions** – Existing land use (based on current zoning information and aerial photography).
- **Future Conditions** – Land use as proposed in the various NCPs and the Grandview Heights General Land Use Plan (GLUP).

2.2 Stormwater Management Scenarios

Since all of the currently adopted NCPs already outline stormwater management approaches, the NCP recommendations were used as the basis for the future condition scenarios (**Figure 9**). This gives the opportunity to assess the cumulative impact of the NCP proposed land use and associated stormwater management strategies at the watershed scale. In an attempt to understand the sensitivity of each of the BMP/LID measures, three other probable design scenarios were developed. These includes stormwater management scenario with 50% single family residential lots with disconnected roof leaders instead of 100%, with no absorbent topsoil and no NCP proposed ponds. In the following sections, comparison of runoff volumes, flow hydrographs and flow duration curves are presented including all the above scenarios to demonstrate the incremental benefit of the proposed BMP/LIDs. However, for the remaining analysis, future condition with NCP proposed BMP and LID was considered only for comparison with the existing condition.

The following five stormwater management scenarios will be modeled:

- **Existing Conditions** – Existing stormwater management measures as follows:
  - On-line and off-line detention ponds
  - Disconnected roof leaders (for 50% of existing single family residential lots)
- **Future Conditions (IIa)** – The following stormwater management measures as proposed in the various NCPs/GLUP:
  - Off-line detention ponds
  - Disconnected roof leaders (for 100% of the residential, commercial, industrial lots; institutional to have connected roof leaders)
  - Absorbent topsoil
- **Future Conditions (IIb)** – The following stormwater management measures as proposed in the various NCPs/GLUP:
  - Off-line detention ponds
  - Disconnected roof leaders (for 50% of the single family residential lots; multifamily, commercial, industrial and institutional to have connected roof leaders)
  - Absorbent topsoil
- **Future Conditions (IIc)** – The following stormwater management measures as proposed in the various NCPs/GLUP:
  - Off-line detention ponds
  - Disconnected roof leaders (for 100% of the residential, commercial, industrial lots; institutional to have connected roof leaders)
  - No absorbent topsoil
- **Future Conditions (IId)** – The following stormwater management measures as proposed in the various NCPs/GLUP:
  - No Off-line detention ponds
  - Disconnected roof leaders (for 100% of the residential, commercial, industrial lots; institutional to have connected roof leaders)
  - Absorbent topsoil

2.3 Hydrologic/Hydraulic Conditions

Hydrologic and hydraulic models were developed for existing and future scenarios and assessed model results in the light of existing design criteria/guidelines. The design criteria/guidelines include the City’s existing drainage criteria as well as the Provincial and Federal Best

Management Practices guidelines. A compilation of the existing drainage criteria/guidelines is presented in **Table A.2** (**Appendix A**). **Table 11** identifies the hydrologic/hydraulic conditions modeled for each Design Event.

3 Evaluation of Existing and Future Conditions

- The assessment of existing and future drainage condition focused on the following issues:
- Capacity of the trunk system
- Capacity of the culverts
- Impact on lowlands
- Impact on stream flows
- Surface runoff quality

The City's standard design criterion for minor systems is to support runoff from the 1:5 year storm event. The major system is designed for storms exceeding the 1:5 year storm up to 1:100 year storm to provide safe conveyance of runoff and to minimize damage to life and property. The North Grandview Heights NCP recommends that, due to steep gradients, north/south trunk drainage routes within the NCP area should be designed for the 100-year storm event. The same is recommended for the east/west trunk systems. Thus, we assumed that the north-south and east-west trunks will be designed for the 100-year storm event and we presented the flows generated by the 5-year and 100-year storm events.

For the future condition scenario, changes in land use and stormwater management measures were considered according to the proposed NCPs and GLUP. The City's 10-Year Servicing Plan also identifies planned culvert upgrades, major and minor system upgrades, base flow diversions, erosion and ravine works, and detention ponds. **Figure 9** shows currently proposed infrastructure improvements per the NCPs and the 10 Year Servicing Plan. The NCPs also recommend best management practices and low impact development (LID) measures. Some of these LID measures are:

- Disconnected roof leaders for single family residential lots
- 300 mm topsoil
- Infiltration trench
- Green street
- Reduced road width
- Bioswales

- Reduced lot grading

From the different LID measures mentioned above, disconnected roof leaders and absorbent soil on lawns were considered in the current future condition model. The reasons behind selecting these two are:

- Disconnecting roof leaders is an easily implemented option.
- Based on our past experience, the application of topsoil is also an easily implemented option and provides a significant stormwater management benefit that helps achieve the desired stormwater management target.

The capacity assessment of trunk systems completed in the following section considers only the disconnection of roof leaders. This is due to the fact that trunk systems are designed for major storm events, whereas topsoil (or any other LID measure) is typically designed for minor storm events.

3.1 Trunk System Capacity

Table 12 shows the estimated existing and future peak flows in the trunk systems. The peak flows were estimated at certain locations along the trunk system such that the contributing area at any particular location is close to 20 ha or more. To assess the maximum capacity of the existing trunk, a simplified analysis was completed using Manning`s flow equation. Five year and one hundred year storm events with thirty minutes, one hour and two hour durations were used in the MIKE SHE/MIKE 11 models to determine the maximum peak flows in the trunk systems for existing and future conditions. As expected, for most of the areas, future flows increased significantly due to development intensification. **Table 13** identifies those trunks with insufficient capacity along 24th Avenue, 32nd Avenue between 172nd St and 176th St, 166th St, 168th St and 172nd St. **Figure 9** shows the contributing areas, and location of flow measurement and identifies the trunks with insufficient capacity.

3.2 Culvert Assessment

Ten existing culverts were modeled in the hydraulic network. The evaluation of peak flows was conducted for these culverts for the 5-year and 100-year storm events under the existing and future development scenarios. The results of the culvert assessment are summarized in **Table 14**.

Peak flows through the following five culverts for a 100-year storm event exceeded the estimated peak flow capacity (assuming inlet control) of the culverts:

- Morgan Creek at 32nd Avenue (M13)
- Morgan Creek at the HWY 99 crossing (M17)
- Wills Brook at 160th St (M14)

- Old Logging Ditch at 32^{nd} Avenue (M15)
- Burrow's Ditch at 32^{nd} Avenue (M16)

However, the modeled stream profiles did not show any overtopping to banks in the vicinity of the culverts. Minor localized backwater effect was observed in all cases. The 10 Year Servicing Plan includes the Old Logging Ditch culvert at 32^{nd} Avenue to be upgraded. However, detailed information about this proposed upgrade is not available. **Table 14** shows the recommended culvert sizes based on peak flow capacity. A more detailed analysis would be required if these culverts are considered for upgrade/replacement.

3.3 Peak Flows in the Streams

The primary focus of the current integrated stormwater management plan is on the upland areas where significant development has either taken place or in progress. Thus, it is important to estimate the increase in stream flows caused by the development. Generally, peak flows tend to be higher for shorter duration storms. Considering the size of the contributing catchment areas of the Morgan Creek, Wills Brook, Old Logging Ditch and Burrow's Ditch, 1-hour duration storms for different return periods were considered to estimate peak flows. The flow locations were selected based on future development condition and are shown in **Figure 11**. The flow hydrographs are shown in **Figures 12-17**.

Effect of different Best Management Practices and/or Low Impact Development measures on the stream flows is clearly evident in the flow hydrographs. However, the extent of impact varies depending on the proposed land use changes in the contributing areas. For example, absorbent topsoil seems to be the most effective measure in mitigating the impact of future development in the Old Logging Ditch and Burrow's Ditch watersheds. The Morgan Creek and Wills Brook watersheds are nearly built out and opportunity to apply topsoil and disconnected roof leaders is limited. Therefore the incremental benefit of LID's is not apparent as they are in the Old Logging Ditch and Burrow's Ditch watersheds. Majority of the NCP proposed ponds are located in the Wills Brook watershed. Thus, the effect of ponds in reducing the peak flows is clearly evident in this watershed.

3.4 Maximum Runoff Volumes

Table 15 shows the maximum runoff volumes at four selected locations immediately downstream of the proposed NCPs. Generally longer duration storms yield larger runoff volumes. Thus, 24-hour duration storm was considered for estimating the maximum runoff volumes from the proposed developed sites for different design events.

The peak runoff volumes from the proposed developed sites are expected to increase if no mitigation measures are undertaken. However, with the NCP proposed ponds and LIDs, future flows are reduced close to the existing condition. As observed, 'disconnected roof leaders' alone cannot reduce the impact of future development. The implementation of 'absorbent topsoil' or similar measures is required to mitigate future development impacts on the streams.

3.5 Impact of Development on the Lowlands

One of the major concerns of the upland development is the potential of flooding and erosion in the lowlands. According to the City's current drainage policy, drainage in the lowlands should follow the provincial ARDSA (Agri-food Regional Development Subsidiary Agreement) criteria that requires flooding be limited to 2 days during a 2 day 1:10 year summer storm event and 5 days during a 5-day 1:10 year winter storm event. However, the City of Surrey has reduced the 2 days to 1.8 days in the summer. For the current ISMP study, four locations were selected (as shown in Figure 18) where the Morgan Creek, Wills Brook, Old Logging Ditch and Burrow's Ditch enter the lowlands. Figures 19-20 show the peak flow hydrographs at those locations for existing condition and future development condition with NCP proposed BMPs and LIDs. The 10 year 2 day summer event hydrographs demonstrate comparatively stronger influence of BMPs/LIDs than the 10 year 5 day winter event. This is expected because in summer, the initial moisture condition of the soil is low and the BMPs/LIDs would response better during a storm event. While in winter, the soil is generally saturated and near the lowlands, the water table is high. Thus, the effectiveness of BMPs/LIDs is less evident compared to summer condition.

3.6 Assessment of Long Term Impact on Streams

Continuous simulation was conducted using the 10 year rainfall data from the Surrey Municipal Hall rain gauge. The data used was hourly rainfall data and covers the period between 1989-1998. Five reference locations were selected (Figure 11) along Morgan Creek, Wills Brook, Old Logging Ditch and Burrow's Ditch for long term flow duration analysis. Figures 21 (i-v) show flow-duration curves for different design scenarios. The curves show how the application of BMP and/or LID affects the flow condition in the streams.

In general, the positive benefit of BMP/LID in preserving base flows and reducing the peak flows close to existing condition is clearly evident for 10% or more times over the period of ten years. It is also observed that for less frequent but high flow events, reliance on traditional detention ponds without LID cannot mimic the flow duration pattern of the existing development condition. Despite the limited application of onsite LIDs (disconnected roof leader and absorbent topsoil), in future, the streams within the Old Logging Ditch and Burrow's ditch watersheds seem to be able to maintain the flow condition close to existing condition.

3.7 Base Flow Estimation

No field measured base flow values were available for the current study. The hydrogeologic assessment report for the North Grandview Heights areas (Piteau Associates, 1998) reported base flows for the West Creek, Morgan Creek, Wills Brook and April Creek. However, the report did not include base flows for Old Logging Ditch and Burrow's Ditch. Therefore, the 10 year simulated flow data were investigated to estimate the base flows in the creeks mentioned above. Flows for summer and winter were investigated separately. Considering the low flow condition during summer to be critical from fisheries perspective, summer flows with 90% exceedance probability or more over a period of ten years (1989-1998) was considered to closely represent the existing base flow. **Figure 22** shows the estimated base flows for different creeks.

3.8 Allowable Discharge Rates

To provide erosion protection in the creeks and flood protection in the lowlands, allowable discharge rates from different catchments in the Old Logging Ditch and Burrow's Ditch were estimated. These allowable release rates are shown in **Figure 23**. Some of the previous NCPs also recommended maximum release rates. The Grandview Heights #1 (Morgan Heights) NCP (2005) and the North Grandview Heights NCP (2005) both recommended a 9 l/s/ha release rate for the 2 year event and 15 l/s/ha for the 5 year event to protect Old Logging Ditch and the lowlands. The Rosemary Heights Park and Live/Work Area NCP (2000) recommended a 7.2 l/s/ha release rate for the 5 year event. As the basis for these recommendations, both Provincial and DFO criteria were assessed. The DFO criteria recommends reduction of post development flows to pre-development flows for the 6 month 24 hour, 2 year 24 hour, and 5 year 24 hour precipitation events. The Provincial guidelines recommend storing 50% to 100% of MAR runoff and release at a rate that approximates the natural forested condition. In the present case, the existing condition was considered as the base condition (instead of pre-development condition) and post-development peak flows are restricted such that they do not exceed the existing peak flows for frequently occurring storm events (2 year and 5 year storm events). Generally, the more stringent of the two criteria (Provincial or DFO) became the basis for the recommended discharge rates. However, for any particular location, if it was not possible to satisfy any of the two criteria, existing peak flow was considered as the maximum discharge rate.

4 Surface Runoff Quality

The assessment of stormwater runoff quality for the Old Logging Ditch and Burrow's Ditch watersheds included a desktop estimation of pollutant loading by stormwater runoff based on land use. This includes typical pollutants such as Total Suspended Solids (TSS), Phosphorus, Nitrogen, Fecal Coliforms, Oil and Grease, Zinc (Zn) and Copper (Cu). A screening-level tool was used to assess predicted pollutant loads associated with stormwater runoff and identify future application of treatment practices. The method requires minimal data input, all of which was readily available for this preliminary water quality assessment:

- Drainage (catchment) area(s)
- Impervious cover – % Imperviousness was estimated based on existing and future land use type
- Pollutant concentrations – Event mean concentrations are based on data collated by researchers in the U.S.; we focused on a few pollutants, as representative of the spectrum of potential contaminants in runoff: Total Suspended Solids (TSS); Total Nitrogen; Dissolved Phosphorus; Total Copper; Total Zinc; and Bacteria (specifically, Fecal Coliforms).

To estimate annual pollutant loadings, seven basic land use categories were assigned within each catchment, then pollutant concentrations associated with those land use categories were applied. This method was applied to both existing and future conditions. Considering the land use type of the study catchments, TSS, Oil & Grease, Zn and Cu are selected for demonstrating the potential change in pollutant loading due to development. TSS is often used as the surrogate measure of water quality. High levels of TSS can damage fish and aquatic invertebrates and degrade instream habitat where the material settles onto gravel and cobble substrates. Copper and Zinc are the primary metals of concern because of their adverse impacts on fisheries. Copper interferes with fish sensory systems related to predator avoidance, juvenile growth and migratory success. Zinc alters behavior, blood and serum chemistry, impairs reproduction and reduces growth.

Figures 24 and **25** show annual loadings (kg) of TSS, Oil & Grease, Zn and Cu for both existing and future conditions. The increase in pollutant loading for the Burrow's Ditch watershed is quite significant compared to the corresponding increase for the Old Logging Ditch watershed. This is due to the fact that the Burrow's Ditch watershed, which currently has little development, is expected to undergo relatively significant development in the future. In contrast, the Old logging Ditch watershed is nearly built out.

Table 1
Soil Parameters

Soil type based on Drainage Characteristic	Water Content at saturation	Field capacity	Wilting Point	Saturated Hydraulic Conductivity (m/s)	Soil Suction at wetting front (m)
Well drained Soil	0.45	0.2	0.08	$4 X10^{-6}$	-0.1
Medium to well drained Soil	0.40	0.3	0.2	$1 X 10^{-7}$	-0.2
Poorly drained soil	0.47	0.4	0.26	$1 X 10^{-8}$	-0.25

Table 2
Aquifer Characteristics

	Depth of Aquifer	Horizontal Hydraulic Conductivity (m/s)	Vertical Hydraulic Conductivity (m/s)	Specific Yield	Specific Storage (1/m)
Aquifer	8 m below ground	$5 X 10^{-5}$	$2 X 10^{-7}$	0.2	0.0001

Table 3
Vegetation Parameters

Vegetation type	Leaf Area Index	Root Depth (mm)
Agricultural	2	152.4
Deciduous	5.3	685.8
Evergreen	5.5	685.8
Mixed	3	685.8
Modified	2	152.4
Old Field/Rough Pasture	2.5	152.4
Shrub	2.1	152.4
Others	2	152.4
Golf course	2	152.4

Table 4
Manning's 'M'

Surface type	Manning's 'M'
Deciduous/Evergreen	3
Agricultural/Shrub/Golf Course	5
Old Field/Rough Pasture	10
Mixed	13
Modified/Others	20
Impervious	100

Table 5 Depression Storage for Different Land use Types

Considering Surrey Municipal Hall Rain gauge, the Mean Annual Rainfall amount is 60 mm [Ref: 2010-01-20-MASSCRVE-SMH.xls]

50% of the MAR is 30 mm

Capture volume by Topsoil 60 mm
(30% porosity, 1.5 Factor of safety)
300mm X 30% / 1.5 = 60 mm

Single family landuse types	Proposed Category	%IA	Proposed depression storage (mm) (the difference in storage	Area (ha) A	Pervious area (ha)		Equivalent Depression Storage= A * D / A	Target Capture volume (mm)- Metro Van Criteria	Detention Volume per landuse m3/ha	Is 300 mm adequate?
								30		
1. 1-2 upa	Category 1	40		159.65	95.79		50.00	47895		yes
			30							
2. 2 upa		39	30	23.48	14.3228		49.18	7044	300	yes
			30							
3. 2-3 upa		40	30	1.98	1.188		50.00	594		yes
			30							
4. 2-4 upa		46	30	14.01	7.5654		55.56	4203		yes
			30							
5. 4-6 upa	Category 2	50	30	9.42	4.71		60.00	2826		yes
			30						300	
6. 6-8 upa		57	30	24.74	10.6382		69.77	7422		no
			30							
	Category 3	65	30	22.23	7.7805		85.71	6669		no
7. 4-15 upa			30							
8. Village lots 4-6 upa	**Category 2**	57	30	4.21	1.8103		69.77	1263		no
			30							
9. One acre residential 1-2 upa	**Category 4**	16	30	15.49	13.0116		35.71	4647		yes
			30							
10. One acre residential gross density 1-2 upa	**Category 4**	16	30	13.32	11.1888		35.71	3996		yes
			30							
			30							
Multifamily /Commercial/others			30							
Duplex	Category 5	65	30	2.19	0.7665		85.71	657		no
Multi Family	Category 5	65	30	2.88	1.008		85.71	864		no
Multiple Residential (15-25 upa)	Category 5	65	30	8.28	2.898		85.71	2484		no
Special Residential 15-25upa	Category 5	65	30	1.97	0.6895		85.71	591	300	no
Townhouse Large	Category 5	65	30	6.99	2.4465		85.71	2097		no
Townhouse or Multi Family	Category 5	65	30	1.28	0.448		85.71	384		no
Schools	Category 6		30					0		
Business Park, Live/Work cluster Housing Fo	Category 7	90	30	4.94	0.494		300.00	1482		no
Commercial Residential 25-45upa	Category 7	90	30	0.77	0.077		300.00	231		no
Industrial	Category 7	90	30	11.23	1.123		300.00	3369		no
Commercial	Category 8	95	30	0.82	0.041		600.0000	246		no
				329.88				98964		

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\D3-Models-Spreadsheets\Spreadsheets\Analysis_for_int_rep_4\[2010_08_20_Depression_Storage_Estimation_table 5.xls]det_sr_mar_al

Old Logging Ditch/Burrows Ditch ISMP

Project # 1072.0176.01

Table 6.0

RAINFALL HYETOGRAPHS			**1:2**	**YEAR STORM INTENSITY -**				**Surrey Municipal Hall**					
	MODIFIED AES SHORT STORM (mm/hr)						**AES LONG STORM (mm/hr)**				**SCS Type 1A**		
Rain (mm)	7.2	10.4	14.9	0.0	21.5	0.0		26.5	0	0	38.1		54.8
Duration	30min	1hour	2hour	3hour	4hour	5hour	Duration	6hour	8hour	10hour	12hour	Duration	24hour
Time (min)							Time (min)					Time (min)	
0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	9.50	6.24	4.47	0.00	3.35	0.00	10	3.18	0.00	0.00	0.96	20	1.10
10	15.55	7.49	4.47	0.00	3.09	0.00	20	3.18	0.00	0.00	0.96	40	1.10
15	18.14	11.23	5.36	0.00	3.22	0.00	30	3.18	0.00	0.00	0.96	60	1.10
20	21.59	11.23	5.36	0.00	3.22	0.00	40	3.71	0.00	0.00	1.92	80	1.37
25	12.95	12.48	8.05	0.00	3.86	0.00	50	3.70	0.00	0.00	1.92	100	1.37
30	9.02	13.73	8.05	0.00	3.86	0.00	60	3.70	0.00	0.00	1.92	120	1.37
35		17.47	8.05	0.00	3.86	0.00	70	4.79	0.00	0.00	2.30	140	1.64
40		13.73	8.05	0.00	3.86	0.00	80	4.77	0.00	0.00	2.30	160	1.64
45		9.98	8.94	0.00	5.80	0.00	90	4.77	0.00	0.00	2.30	180	1.64
50		8.74	8.94	0.00	5.80	0.00	100	4.25	0.00	0.00	2.69	200	1.92
55		7.49	9.83	0.00	5.80	0.00	110	4.23	0.00	0.00	2.69	220	1.92
60		4.99	9.83	0.00	5.80	0.00	120	4.25	0.00	0.00	2.69	240	1.92
65		0.00	12.52	0.00	5.15	0.00	130	4.25	0.00	0.00	3.45	260	2.47
70		0.00	12.52	0.00	5.15	0.00	140	4.23	0.00	0.00	3.45	280	2.47
75		0.00	9.83	0.00	5.15	0.00	150	4.25	0.00	0.00	3.45	300	2.47
80		0.00	9.83	0.00	5.15	0.00	160	6.36	0.00	0.00	4.61	320	3.29
85		0.00	7.15	0.00	7.09	0.00	170	6.36	0.00	0.00	4.61	340	3.29
90		0.00	7.15	0.00	7.09	0.00	180	6.36	0.00	0.00	4.61	360	3.29
95		0.00	6.26	0.00	7.09	0.00	190	4.79	0.00	0.00	6.53	380	4.66
100		0.00	6.26	0.00	7.09	0.00	200	4.77	0.00	0.00	6.53	400	4.66
105		0.00	5.36	0.00	7.09	0.00	210	4.77	0.00	0.00	6.53	420	4.66
110		0.00	5.36	0.00	7.09	0.00	220	4.77	0.00	0.00	8.06	440	5.75
115		0.00	3.58	0.00	7.09	0.00	230	4.77	0.00	0.00	8.06	460	5.75
120		0.00	3.58	0.00	7.09	0.00	240	4.77	0.00	0.00	8.06	480	5.75
125		0.00		0.00	9.02	0.00	250	4.79	0.00	0.00	6.14	500	4.38
130		0.00		0.00	9.02	0.00	260	4.77	0.00	0.00	6.14	520	4.38
135		0.00		0.00	9.02	0.00	270	4.77	0.00	0.00	6.14	540	4.38
140		0.00		0.00	9.02	0.00	280	4.25	0.00	0.00	4.99	560	3.56
145		0.00		0.00	7.09	0.00	290	4.23	0.00	0.00	4.99	580	3.56
150		0.00		0.00	7.09	0.00	300	4.25	0.00	0.00	4.99	600	3.56
155		0.00		0.00	7.09	0.00	310	4.25	0.00	0.00	4.61	620	3.29
160		0.00		0.00	7.09	0.00	320	4.23	0.00	0.00	4.61	640	3.29
165		0.00		0.00	5.15	0.00	330	4.25	0.00	0.00	4.61	660	3.29
170		0.00		0.00	5.15	0.00	340	3.70	0.00	0.00	3.84	680	2.74
175		0.00		0.00	5.15	0.00	350	3.72	0.00	0.00	3.84	700	2.74
180		0.00		0.00	5.15	0.00	360	3.67	0.00	0.00	3.84	720	2.74
185		0.00			4.51	0.00	370		0.00	0.00	3.07	740	2.19
190		0.00			4.51	0.00	380		0.00	0.00	3.07	760	2.19
195		0.00			4.51	0.00	390		0.00	0.00	3.07	780	2.19
200		0.00			4.51	0.00	400		0.00	0.00	3.45	800	2.47
205		0.00			3.86	0.00	410		0.00	0.00	3.45	820	2.47
210		0.00			3.86	0.00	420		0.00	0.00	3.45	840	2.47
215		0.00			3.86	0.00	430		0.00	0.00	2.30	860	1.64
220		0.00			3.86	0.00	440		0.00	0.00	2.30	880	1.64
225		0.00			2.58	0.00	450		0.00	0.00	2.30	900	1.64
230		0.00			2.58	0.00	460		0.00	0.00	3.07	920	2.19
235		0.00			2.58	0.00	470		0.00	0.00	3.07	940	2.19
240		0.00			2.58	0.00	480		0.00	0.00	3.07	960	2.19
245		0.00				0.00	490			0.00	2.30	980	1.64
250		0.00				0.00	500			0.00	2.30	1000	1.64
255		0.00				0.00	510			0.00	2.30	1020	1.64
260		0.00				0.00	520			0.00	1.92	1040	1.37
265		0.00				0.00	530			0.00	1.92	1060	1.37
270		0.00				0.00	540			0.00	1.92	1080	1.37
275		0.00				0.00	550			0.00	1.53	1100	1.10
280		0.00				0.00	560			0.00	1.53	1120	1.10
285		0.00				0.00	570			0.00	1.53	1140	1.10
290		0.00				0.00	580			0.00	1.92	1160	1.37
295		0.00				0.00	590			0.00	1.92	1180	1.37
300		0.00				0.00	600			0.00	1.92	1200	1.37
		0.00					610				1.53	1220	1.10
		0.00					620				1.53	1240	1.10
		0.00					630				1.53	1260	1.10
		0.00					640				1.53	1280	1.10
		0.00					650				1.53	1300	1.10
		0.00					660				1.53	1320	1.10
		0.00					670				1.92	1340	1.37
		0.00					680				1.92	1360	1.37
		0.00					690				1.92	1380	1.37
		0.00					700				1.53	1400	1.10
		0.00					710				1.53	1420	1.10
		0.00					720				1.53	1440	1.10
Rain (mm)	7.23	10.4	14.9	0	21.47	0		26.5	0	0	38.1		54.8

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\D3-Models-Spreadsheets\Spreadsheets\Rainfall\[2010-01-20-MASSCRVE-SMH_table5-6-7.xls]2yr

Old Logging Ditch/Burrows Ditch ISMP
Project # 1072.0176.01

Table 7.0

RAINFALL HYETOGRAPHS **1:5 YEAR STORM INTENSITY - Surrey Municipal Hall**

	MODIFIED AES SHORT STORM (mm/hr)						AES LONG STORM (mm/hr)				SCS Type 1A		
Rain (mm)	10.7	14.4	19.9	0.0	27.2	0.0		32.6	0	0	44.6		60.8
Duration	30min	1hour	2hour	3hour	4hour	5hour	Duration	6hour	8hour	10hour	12hour	Duration	24hour
Time (min)							Time (min)					Time (min)	
0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	14.06	8.64	5.97	0.00	4.24	0.00	10	3.91	0.00	0.00	1.12	20	1.22
10	23.01	10.37	5.97	0.00	3.92	0.00	20	3.91	0.00	0.00	1.12	40	1.22
15	26.85	15.55	7.16	0.00	4.08	0.00	30	3.91	0.00	0.00	1.12	60	1.22
20	31.96	15.55	7.16	0.00	4.08	0.00	40	4.56	0.00	0.00	2.25	80	1.52
25	19.17	17.28	10.75	0.00	4.90	0.00	50	4.55	0.00	0.00	2.25	100	1.52
30	13.35	19.01	10.75	0.00	4.90	0.00	60	4.56	0.00	0.00	2.25	120	1.52
35		24.19	10.75	0.00	4.90	0.00	70	5.89	0.00	0.00	2.70	140	1.82
40		19.01	10.75	0.00	4.90	0.00	80	5.87	0.00	0.00	2.70	160	1.82
45		13.82	11.94	0.00	7.34	0.00	90	5.87	0.00	0.00	2.70	180	1.82
50		12.10	11.94	0.00	7.34	0.00	100	5.22	0.00	0.00	3.15	200	2.13
55		10.37	13.13	0.00	7.34	0.00	110	5.20	0.00	0.00	3.15	220	2.13
60		6.91	13.13	0.00	7.34	0.00	120	5.22	0.00	0.00	3.15	240	2.13
65			16.72	0.00	6.53	0.00	130	5.22	0.00	0.00	4.04	260	2.74
70			16.72	0.00	6.53	0.00	140	5.20	0.00	0.00	4.04	280	2.74
75			13.13	0.00	6.53	0.00	150	5.22	0.00	0.00	4.04	300	2.74
80			13.13	0.00	6.53	0.00	160	7.82	0.00	0.00	5.40	320	3.65
85			9.55	0.00	8.98	0.00	170	7.82	0.00	0.00	5.40	340	3.65
90			9.55	0.00	8.98	0.00	180	7.82	0.00	0.00	5.40	360	3.65
95			8.36	0.00	8.98	0.00	190	5.89	0.00	0.00	7.64	380	5.17
100			8.36	0.00	8.98	0.00	200	5.87	0.00	0.00	7.64	400	5.17
105			7.16	0.00	8.98	0.00	210	5.87	0.00	0.00	7.64	420	5.17
110			7.16	0.00	8.98	0.00	220	5.87	0.00	0.00	9.44	440	6.38
115			4.78	0.00	8.98	0.00	230	5.87	0.00	0.00	9.44	460	6.38
120			4.78	0.00	8.98	0.00	240	5.87	0.00	0.00	9.44	480	6.38
125				0.00	11.42	0.00	250	5.89	0.00	0.00	7.19	500	4.86
130				0.00	11.42	0.00	260	5.87	0.00	0.00	7.19	520	4.86
135				0.00	11.42	0.00	270	5.87	0.00	0.00	7.19	540	4.86
140				0.00	11.42	0.00	280	5.22	0.00	0.00	5.84	560	3.95
145				0.00	8.98	0.00	290	5.20	0.00	0.00	5.84	580	3.95
150				0.00	8.98	0.00	300	5.22	0.00	0.00	5.84	600	3.95
155				0.00	8.98	0.00	310	5.22	0.00	0.00	5.40	620	3.65
160				0.00	8.98	0.00	320	5.20	0.00	0.00	5.40	640	3.65
165				0.00	6.53	0.00	330	5.22	0.00	0.00	5.40	660	3.65
170				0.00	6.53	0.00	340	4.56	0.00	0.00	4.49	680	3.04
175				0.00	6.53	0.00	350	4.58	0.00	0.00	4.49	700	3.04
180				0.00	6.53	0.00	360	4.52	0.00	0.00	4.49	720	3.04
185					5.71	0.00	370		0.00	0.00	3.59	740	2.43
190					5.71	0.00	380		0.00	0.00	3.59	760	2.43
195					5.71	0.00	390		0.00	0.00	3.59	780	2.43
200					5.71	0.00	400		0.00	0.00	4.04	800	2.74
205					4.90	0.00	410		0.00	0.00	4.04	820	2.74
210					4.90	0.00	420		0.00	0.00	4.04	840	2.74
215					4.90	0.00	430		0.00	0.00	2.70	860	1.82
220					4.90	0.00	440		0.00	0.00	2.70	880	1.82
225					3.26	0.00	450		0.00	0.00	2.70	900	1.82
230					3.26	0.00	460		0.00	0.00	3.59	920	2.43
235					3.26	0.00	470		0.00	0.00	3.59	940	2.43
240					3.26	0.00	480		0.00	0.00	3.59	960	2.43
245						0.00	490			0.00	2.70	980	1.82
250						0.00	500			0.00	2.70	1000	1.82
255						0.00	510			0.00	2.70	1020	1.82
260						0.00	520			0.00	2.25	1040	1.52
265						0.00	530			0.00	2.25	1060	1.52
270						0.00	540			0.00	2.25	1080	1.52
275						0.00	550			0.00	1.80	1100	1.22
280						0.00	560			0.00	1.80	1120	1.22
285						0.00	570			0.00	1.80	1140	1.22
290						0.00	580			0.00	2.25	1160	1.52
295						0.00	590			0.00	2.25	1180	1.52
300						0.00	600			0.00	2.25	1200	1.52
							610				1.80	1220	1.22
							620				1.80	1240	1.22
							630				1.80	1260	1.22
							640				1.80	1280	1.22
							650				1.80	1300	1.22
							660				1.80	1320	1.22
							670				2.25	1340	1.52
							680				2.25	1360	1.52
							690				2.25	1380	1.52
							700				1.80	1400	1.22
							710				1.80	1420	1.22
							720				1.80	1440	1.22
Rain (mm)	10.7	14.4	19.9	0	27.2	0		32.6	0	0	44.6		60.8

Old Logging Ditch/Burrows Ditch ISMP

Project # 1072.0176.01

Table 8.0

RAINFALL HYETOGRAPHS **1:100 YEAR STORM INTENSITY - Surrey Municipal Hall**

	MODIFIED AES SHORT STORM (mm/hr)						AES LONG STORM (mm/hr)					SCS Type 1A		
Rain (mm)	19.8	25.5	32.9	0.0	0.0	0.0		49.4	0	0				82.4
Duration	30min	1hour	2hour	3hour	4hour	5hour	Duration	6hour	8hour	10hour	12hour	12hour	Duration	24hour
Time (min)							Time (min)						Time (min)	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	25.95	15.30	9.87	0.00	0.00	0.00	10	5.93	0.00	0.00	0.00	0.00	20	1.65
10	42.47	18.36	9.87	0.00	0.00	0.00	20	5.93	0.00	0.00	0.00	0.00	40	1.65
15	49.56	27.54	11.84	0.00	0.00	0.00	30	5.93	0.00	0.00	0.00	0.00	60	1.65
20	58.99	27.54	11.84	0.00	0.00	0.00	40	6.92	0.00	0.00	0.00	0.00	80	2.06
25	35.38	30.60	17.77	0.00	0.00	0.00	50	6.90	0.00	0.00	0.00	0.00	100	2.06
30	24.65	33.66	17.77	0.00	0.00	0.00	60	6.91	0.00	0.00	0.00	0.00	120	2.06
35		42.84	17.77	0.00	0.00	0.00	70	8.92	0.00	0.00	0.00	0.00	140	2.47
40		33.66	17.77	0.00	0.00	0.00	80	8.89	0.00	0.00	0.00	0.00	160	2.47
45		24.48	19.74	0.00	0.00	0.00	90	8.89	0.00	0.00	0.00	0.00	180	2.47
50		21.42	19.74	0.00	0.00	0.00	100	7.91	0.00	0.00	0.00	0.00	200	2.89
55		18.36	21.71	0.00	0.00	0.00	110	7.88	0.00	0.00	0.00	0.00	220	2.89
60		12.24	21.71	0.00	0.00	0.00	120	7.91	0.00	0.00	0.00	0.00	240	2.89
65			27.64	0.00	0.00	0.00	130	7.91	0.00	0.00	0.00	0.00	260	3.71
70			27.64	0.00	0.00	0.00	140	7.88	0.00	0.00	0.00	0.00	280	3.71
75			21.71	0.00	0.00	0.00	150	7.91	0.00	0.00	0.00	0.00	300	3.71
80			21.71	0.00	0.00	0.00	160	11.86	0.00	0.00	0.00	0.00	320	4.94
85			15.79	0.00	0.00	0.00	170	11.86	0.00	0.00	0.00	0.00	340	4.94
90			15.79	0.00	0.00	0.00	180	11.86	0.00	0.00	0.00	0.00	360	4.94
95			13.82	0.00	0.00	0.00	190	8.92	0.00	0.00	0.00	0.00	380	7.00
100			13.82	0.00	0.00	0.00	200	8.89	0.00	0.00	0.00	0.00	400	7.00
105			11.84	0.00	0.00	0.00	210	8.89	0.00	0.00	0.00	0.00	420	7.00
110			11.84	0.00	0.00	0.00	220	8.89	0.00	0.00	0.00	0.00	440	8.65
115			7.90	0.00	0.00	0.00	230	8.89	0.00	0.00	0.00	0.00	460	8.65
120			7.90	0.00	0.00	0.00	240	8.89	0.00	0.00	0.00	0.00	480	8.65
125				0.00	0.00	0.00	250	8.92	0.00	0.00	0.00	0.00	500	6.59
130				0.00	0.00	0.00	260	8.89	0.00	0.00	0.00	0.00	520	6.59
135				0.00	0.00	0.00	270	8.89	0.00	0.00	0.00	0.00	540	6.59
140				0.00	0.00	0.00	280	7.91	0.00	0.00	0.00	0.00	560	5.36
145				0.00	0.00	0.00	290	7.88	0.00	0.00	0.00	0.00	580	5.36
150				0.00	0.00	0.00	300	7.91	0.00	0.00	0.00	0.00	600	5.36
155				0.00	0.00	0.00	310	7.91	0.00	0.00	0.00	0.00	620	4.94
160				0.00	0.00	0.00	320	7.88	0.00	0.00	0.00	0.00	640	4.94
165				0.00	0.00	0.00	330	7.91	0.00	0.00	0.00	0.00	660	4.94
170				0.00	0.00	0.00	340	6.91	0.00	0.00	0.00	0.00	680	4.12
175				0.00	0.00	0.00	350	6.94	0.00	0.00	0.00	0.00	700	4.12
180				0.00	0.00	0.00	360	6.85	0.00	0.00	0.00	0.00	720	4.12
185					0.00	0.00	370		0.00	0.00	0.00	0.00	740	3.29
190					0.00	0.00	380		0.00	0.00	0.00	0.00	760	3.29
195					0.00	0.00	390		0.00	0.00	0.00	0.00	780	3.29
200					0.00	0.00	400		0.00	0.00	0.00	0.00	800	3.71
205					0.00	0.00	410		0.00	0.00	0.00	0.00	820	3.71
210					0.00	0.00	420		0.00	0.00	0.00	0.00	840	3.71
215					0.00	0.00	430		0.00	0.00	0.00	0.00	860	2.47
220					0.00	0.00	440		0.00	0.00	0.00	0.00	880	2.47
225					0.00	0.00	450		0.00	0.00	0.00	0.00	900	2.47
230					0.00	0.00	460		0.00	0.00	0.00	0.00	920	3.29
235					0.00	0.00	470		0.00	0.00	0.00	0.00	940	3.29
240					0.00	0.00	480		0.00	0.00	0.00	0.00	960	3.29
245						0.00	490			0.00	0.00	0.00	980	2.47
250						0.00	500			0.00	0.00	0.00	1000	2.47
255						0.00	510			0.00	0.00	0.00	1020	2.47
260						0.00	520			0.00	0.00	0.00	1040	2.06
265						0.00	530			0.00	0.00	0.00	1060	2.06
270						0.00	540			0.00	0.00	0.00	1080	2.06
275						0.00	550			0.00	0.00	0.00	1100	1.65
280						0.00	560			0.00	0.00	0.00	1120	1.65
285						0.00	570			0.00	0.00	0.00	1140	1.65
290						0.00	580			0.00	0.00	0.00	1160	2.06
295						0.00	590			0.00	0.00	0.00	1180	2.06
300						0.00	600			0.00	0.00	0.00	1200	2.06
							610				0.00	0.00	1220	1.65
							620				0.00	0.00	1240	1.65
							630				0.00	0.00	1260	1.65
							640				0.00	0.00	1280	1.65
							650				0.00	0.00	1300	1.65
							660				0.00	0.00	1320	1.65
							670				0.00	0.00	1340	2.06
							680				0.00	0.00	1360	2.06
							690				0.00	0.00	1380	2.06
							700				0.00	0.00	1400	1.65
							710				0.00	0.00	1420	1.65
							720				0.00	0.00	1440	1.65
Rain (mm)	19.75	25.5	32.9	0	0	0		49.4	0	0	0.0	0		82.4

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\D3-Models-Spreadsheets\Spreadsheets\Rainfall\[2010-01-20-MASSCRVE-SMH_table5-6-7.xls]100yr

Table 9.1 : ARDSA STORM for SUMMER SEASON

Site: Pitt Meadows STP Rainfall Gauge

Hour	10-year growing season 2-day duration hourly precip (mm)
1	1.07
2	0.83
3	1.24
4	0.41
5	0.66
6	1.07
7	1.24
8	0.44
9	0.66
10	1.24
11	0.41
12	1.07
13	1.9
14	3.39
15	6.38
16	12.02
17	3.38
18	2.97
19	2.39
20	2.69
21	3.52
22	3.11
23	2.69
24	2.03
25	3.35
26	1.43
27	2.85
28	2.22
29	1.82
30	1.03
31	1.19
32	1.98
33	1.98
34	0.79
35	1.59
36	1.19
37	0.31
38	0.58
39	0.58
40	1.16
41	0.97
42	0.58
43	0.58
44	0.31
45	0
46	0
47	0.36
48	0.36

Table 9.2: ARDSA Storm for Winter Season

Site: Surrey Municipal Hall Rainfall Gauge

Hour	10-yr winter season 50day duration hourly precip (mm)
1	0.68
2	1.67
3	0.3
4	0.68
5	0.53
6	0.15
7	1.29
8	2.12
9	1.14
10	1.14
11	2.12
12	1.97
13	1.58
14	1.96
15	3.94
16	6.58
17	6.43
18	7.11
19	3.77
20	3.92
21	2.38
22	2.9
23	4.19
24	4.11
25	1.69
26	1.54
27	0.61
28	2.2
29	2.8
30	2.27
31	1.36
32	2.57
33	1.81
34	1.28
35	2.37
36	1.23
37	1.23
38	0
39	0
40	0
41	0
42	1.67
43	2.49
44	2.18
45	0
46	0
47	0
48	1.87
49	0.93
50	0.41
51	0
52	0.72
53	0.72
54	2.37
55	0.72
56	0
57	0.41
58	0.41
59	0
60	0
61	0
62	0
63	0
64	1.85
65	1.34

66	0
67	0.21
68	0
69	0
70	0
71	0
72	0.41
73	0.62
74	0
75	0
76	0
77	2.06
78	10.08
79	5.04
80	0.93
81	0.41
82	0.21
83	0
84	0
85	0
86	0
87	0.27
88	0
89	0
90	0
91	0
92	0
93	0
94	0
95	0
96	0.27
97	0.95
98	1.49
99	0
100	0.68
101	0
102	0.27
103	0.95
104	0
105	0
106	0.68
107	1.49
108	1.9
109	0
110	0
111	0
112	0
113	0
114	0
115	0
116	1.9
117	2.58
118	2.99
119	1.9
120	1.36

Table 10
Boundary water levels

Discharge Location	Boundary water levels (m)
West Creek P.S	0.215
Morgan Creek	-1.2
Wills Brook	1.0
Old Logging Ditch	0.0
Burrow's Ditch	0.264
176th St at 32nd Avenue	0.6
164th St at High park	2.6

Table 11: Design Events

Design Event Label	Land Use	Stormwater Management	Hydrologic/Hydraulic Conditions		
			Storm Event	Initial Condition	Boundary Condition
Design Event I *Existing Conditions*	Existing land use	IIa Existing stormwater management infrastructure that includes: • Minor and major storm mains • Detention ponds • Water quality ponds • Ditches • Pump station	1. 2 year design storm for 1, 2, 24 hour durations	Ground condition representing winter period saturation	Average water Levels in the Creeks and average tide level in Nicomekl river
			2. 5-year design storm for 1, 2, 24 hour durations		
			3. 100-year design storm for 1, 2, 24 hour durations		
			4. 10-year 5-day winter season storm		
			5. 10 year 2-day duration growing season storm	Ground condition representing summer period	
			6. Continuous simulation 1989-1998	Ground condition representing winter period saturation	

Design Event Label	Land Use	Stormwater Management	Hydrologic/Hydraulic Conditions		
			Storm Event	Initial Condition	Boundary Condition
Design Event II ***Future Conditions***	Future land use based on neighbourhood concept plans	IIa Existing stormwater management infrastructure and the following stormwater management strategies as proposed in NCPs: • Detention ponds • Minor and major storm mains • 100% disconnected roof leaders for single family and multifamily residential land use type, commercial and industrial land use type. • Absorbent topsoil for lawns	1. 2 year design storm for 1, 2, 24 hour durations	Ground condition representing winter period saturation	Average water Levels in the Creeks and average tide level in Nicomekl river
			2. 5-year design storm for 1, 2, 24 hour durations		
			3. 100-year design storm for 1, 2, 24 hour durations		
			4. 10-year 5-day winter season storm		
			5. 10 year 2-day duration growing season storm	Ground condition representing summer period	
			6. Continuous simulation 1988-1998	Ground condition representing winter period saturation	
		IIb Existing stormwater management infrastructure and the following stormwater management strategies as proposed in NCPs: • Detention ponds • Minor and major storm mains • <u>50% disconnected roof leaders for single family residential land use type only</u>. Other land use types have connected roof leaders. • Absorbent topsoil for lawns.	1. 2 year design storm for 1, 2, 24 hour durations	Ground condition representing winter period saturation	Average water Levels in the Creeks and average tide level in Nicomekl river
			2. 5-year design storm for 1, 2, 24 hour durations		
			3. 100-year design storm for 1, 2, 24 hour durations		
			4. 10-year 5-day winter season storm		
			5. 10 year 2-day duration growing season storm	Ground condition representing summer period	
			6. Continuous simulation 1988-1998	Ground condition representing winter period saturation	
		IIc Existing stormwater management infrastructure and the following stormwater management strategies as proposed in NCPs: • Detention ponds • Minor and major storm mains • 100% disconnected roof leaders for single family and multifamily residential land use type, commercial and industrial land use type. • <u>NO absorbent topsoil for lawns.</u>	1. 2 year design storm for 1, 2, 24 hour durations	Ground condition representing winter period saturation	Average water Levels in the Creeks and average tide level in Nicomekl river
			2. 5-year design storm for 1, 2, 24 hour durations		
			3. 100-year design storm for 1, 2, 24 hour durations		
			4. 10-year 5-day winter season storm		
			5. 10 year 2-day duration growing season storm	Ground condition representing summer period	
			6. Continuous simulation 1988-1998	Ground condition representing winter period saturation	

		IId Existing stormwater management infrastructure and the following stormwater management strategies as proposed in NCPs: • No Detention ponds • Minor and major storm mains • 100% disconnected roof leaders for single family and multifamily residential land use type, commercial and industrial land use type. • Absorbent topsoil for lawns.	1. 2 year design storm for 1, 2, 24 hour durations	**Ground condition representing winter period saturation**	
			7. 5-year design storm for 1, 2, 24 hour durations		
			8. 100-year design storm for 1, 2, 24 hour durations		
			9. 10-year 5-day winter season storm		
			10. 10 year 2-day duration growing season storm	**Ground condition representing summer period**	
			11. Continuous simulation 1988-1998	**Ground condition representing winter period saturation**	

Table 12

Peak Flows in the Trunk Systems

Storm Main Location in Model	Chainage	Main Size (mm)	Capacity (m3/s)	EX Q-5	FT-Q-5	EXQ-100	FT-Q-100	Deficient in EX cond for 5 yrs?	Deficient in EX cond for 100 yrs?	Deficient in Future cond for 5 years?	Deficient in Future cond for100 years?	Recommend Replacement?1-5yr if deficient in EX cond	Recommend Replacement?6-10yr or depends on development application (if deficient in FT cond)
168 St	1151.7	675	1.65	1.067	1.338	2.326	3.037	no	yes	no	yes	Y	
32nd Ave between 176th and 172nd St	776.13	900	0.57	0.231	0.298	0.656	0.822	no	yes	no	yes	Y	
24THAVE	910	450	0.35	0.118	0.323	0.376	0.768	no	yes	no	yes	Y	
166TH ST	670.29	525	0.31	0.151	0.32	0.45	0.798	no	yes	no	yes	Y	
172NDST	610	750	1.01	0.652	1.222	1.333	2.688	no	yes	yes	yes	Y	
32nd Ave between 172nd St and 168th St	628.1	750	0.94		0.045		0.4	no	yes	yes	yes	Y	
164ST	200	300	0.28	0.001	0.005	0.086	0.029	no	no	no	no		
164th St	520	675	2.25	0.07	0.116	0.15	0.29	no	no	no	no		
164th St	700	900	3.12	0.08	0.13	0.23	0.37	no	no	no	no		
156ST	620.42	1050	0.86	0.131	0.129	0.281	0.283	no	no	no	no		
156St	200.25	750	0.35				0.267	no	no	no	no		
24THAVE	335	375	0.25	0.06	0.08	0.166	0.25	no	no	no	no		
24THAVE	1310	600	0.80	0.107	0.491	0.442	1.134	no	no	no	no		
166TH ST	200	375	0.22	0.022	0.046	0.044	0.114	no	no	no	yes		Y
160TH ST	250.05	600	0.88	0.009	0.017	0.075	0.075	no	no	no	no		
160TH ST	700	900	5.71	0.933	0.445	2.05	1.629	no	no	no	no		
160TH ST	1500.18	1350	3.99	1.084	0.741	2.744	2.219	no	no	no	no		
160TH ST (32nd Ave W of WB)	1735.3	1350	2.39	1.176	0.567	2.612	1.815	no	no	no	no		
168ST	250	600	0.95	0.161	0.432	0.531	0.874	no	yes	no	no		
168ST	855.409	525	1.38	0.243	0.583	0.856	1.234	no	no	no	no		
172NDST	225	450	0.78	0.326	0.589	0.668	1.247	no	no	no	no		
32nd Ave W of Morgan Creek	1097.5	750	1.79	0.085	0.064	0.181	0.124	no	no	no	yes		Y
								no	no	no	no		

URBANSYSTEMS.

Table 13

Recommended Trunk Sizes

Storm Main Location in Model	Chainage	Main Size (mm)	Capacity (m3/s)	EX Q-5	FT-Q-5	EXQ-100	FT-Q-100	Recommended size (mm)	Recommended Length (m)
				m3/s	m3/s	m3/s	m3/s		
168 St	1151.7	675	1.65	1.067	1.338	2.326	3.037	900	375
32nd Ave between 176th St and 172nd St	776.13	900	0.57	0.231	0.298	0.656	0.822	1050	330
24THAVE	910	450	0.35	0.118	0.323	0.376	0.768	750	575
24THAVE	1310	600	0.80	0.107	0.491	0.442	1.134	750	375
166TH	670.29	525	0.31	0.151	0.32	0.45	0.798	750	825
172NDST	225	450	0.78	0.326	0.589	0.668	1.247	750	150
172NDST	610	750	1.01	0.652	1.222	1.333	2.688	600	160
								1200	640

Table 14
Culvert Assessment

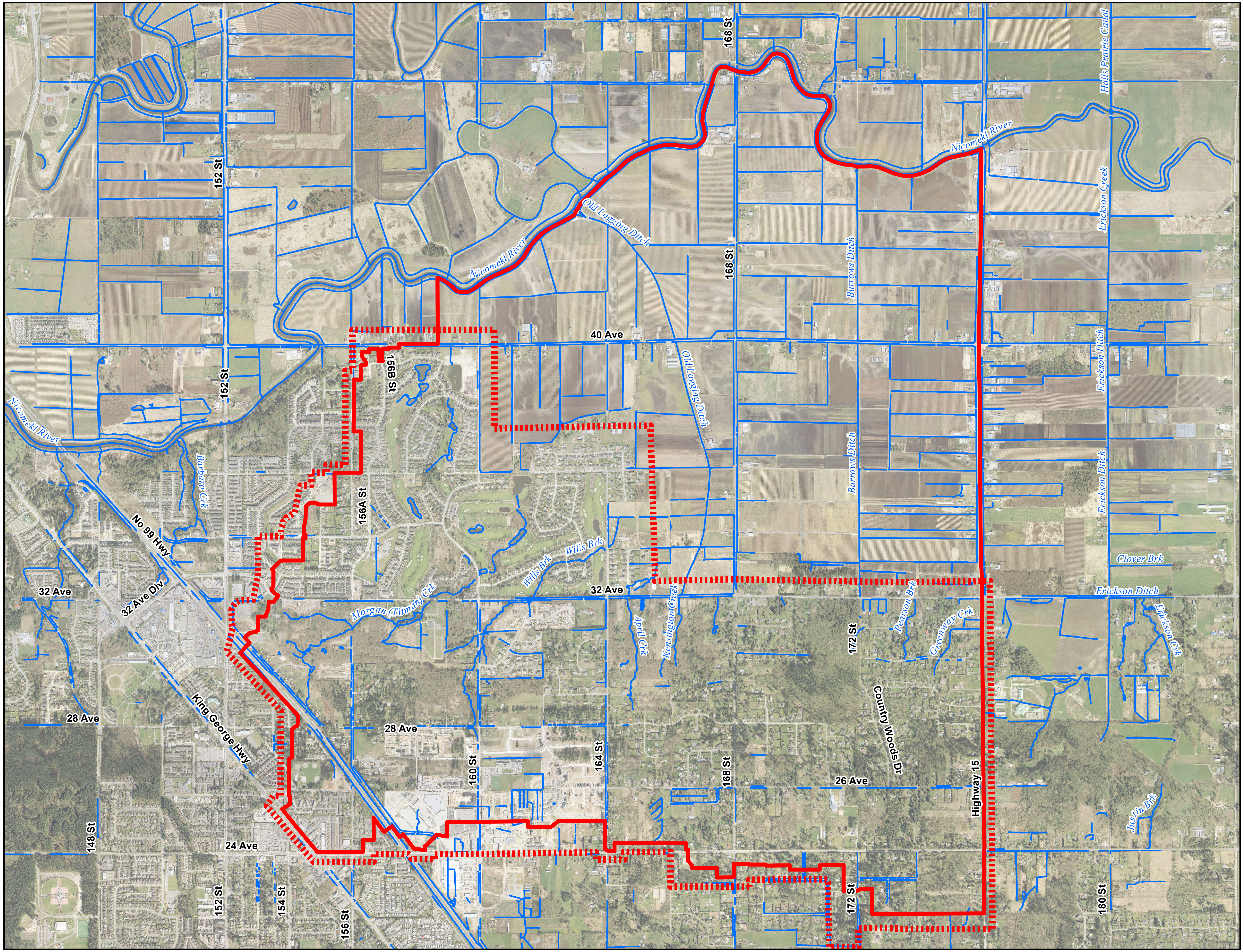
Creek Name	Culvert Crossing		Culvert ID	Existing Size (mm)	Length (m)	No	Capacity (m3/s)	Existing Peak Flows (m^3/s) 5y-1h	100y-1h	Future Peak Flows (m^3/s) 5y-1hr	100y-1h	Is adequate for hydraulic purpose?	Is adequate for environmental purpose?	Recommended Size (mm)
Morgan Creek	32nd Avenue	MG2	M9	1050	30.5	1	1.4	1.21	2.567	1.659	3.036	No	Will be decided based on proposed detail environmental assessment. Improvements may be needed to make the culverts fish accessable. Thus, a L.S cost of $30,000 is anticipated for each culvert.	1500
Wills Brook	160th St (North of 161th St)	WB4	M10	600	12	1	0.35	0.18	0.359	0.234	0.482	No		750
Old Logging Ditch	32nd Avenue	OLD1	M11	1800X1200	19.5	1	3.78	1.865	4.252	2.229	5.317	No		1800X1500
Burrows Ditch	32nd Avenue	BRW1	M12	1200	15	1	2	0.919	2.02	1.431	3.055	No		1500
Morgan Creek	HWY 99	MG1	M13	750	120	1	0.6	0.296	0.626	0.293	0.62	No		900
Wills Brook	32nd Avenue	WB1	M14	1800X1200	10	1	3.78	1.345	2.909	0.996	2.614	Yes		
Wills Brook	Cross Creek Crt.	WB5	M15	1350	16	2	5.2	1.429	3.065	1.076	2.785	Yes		
Wills Brook	164th St	WB2	M16	3050X1350	25	1	7.6	1.549	3.312	1.16	3.021	Yes		
Wills Brook	160th Street (South of 161 St)	WB3	M17	750	12	1	0.6	0.066	0.145	0.087	0.174	Yes		

Table 15

Peak Runoff Volumes at Four Locations (Long Duration Storm Events)

													Peak Runoff Volume (m^3)		
Location	2 yr- 24 hr design storm					5 yr - 24 hr design storm					100 yr - 24 hr design storm				
	Existing	Future Design Event IIa	Future Design Event IIb	Future Design Event IIc	Future Design Event IId	Existing	Future Design Event IIa	Future Design Event IIb	Future Design Event IIc	Future Design Event IId	Existing	Future Design Event IIa	Future Design Event IIb	Future Design Event IIc	Future Design Event IId
Morgan Creek to the north of 32nd Ave	31009	28078	28078	31234	28078	30682	30617	30626	33962	30627	51006	47294	47294	51401	47294
Wills Brook to the north of 32nd Ave	29850	27538	27538	29335	27626	30112	28694	28694	30576	28787	46835	43949	43949	46056	44039
Old Logging Ditch to the north of 32nd Ave	33165	36058	37800	44004	36532	46097	39398	41919	47923	39381	65615	588167	62143	68024	59870
Burrow's Ditch to the north of 32nd Ave	18837	16464	17652	22962	16464	24269	18373	19799	24954	18373	33899	27679	29917	34715	27679

URBANSYSTEMS®



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Catchment Boundary / Model Domain Figure 1

Legend

- Waterway
- Catchment Boundary
- Model Domain

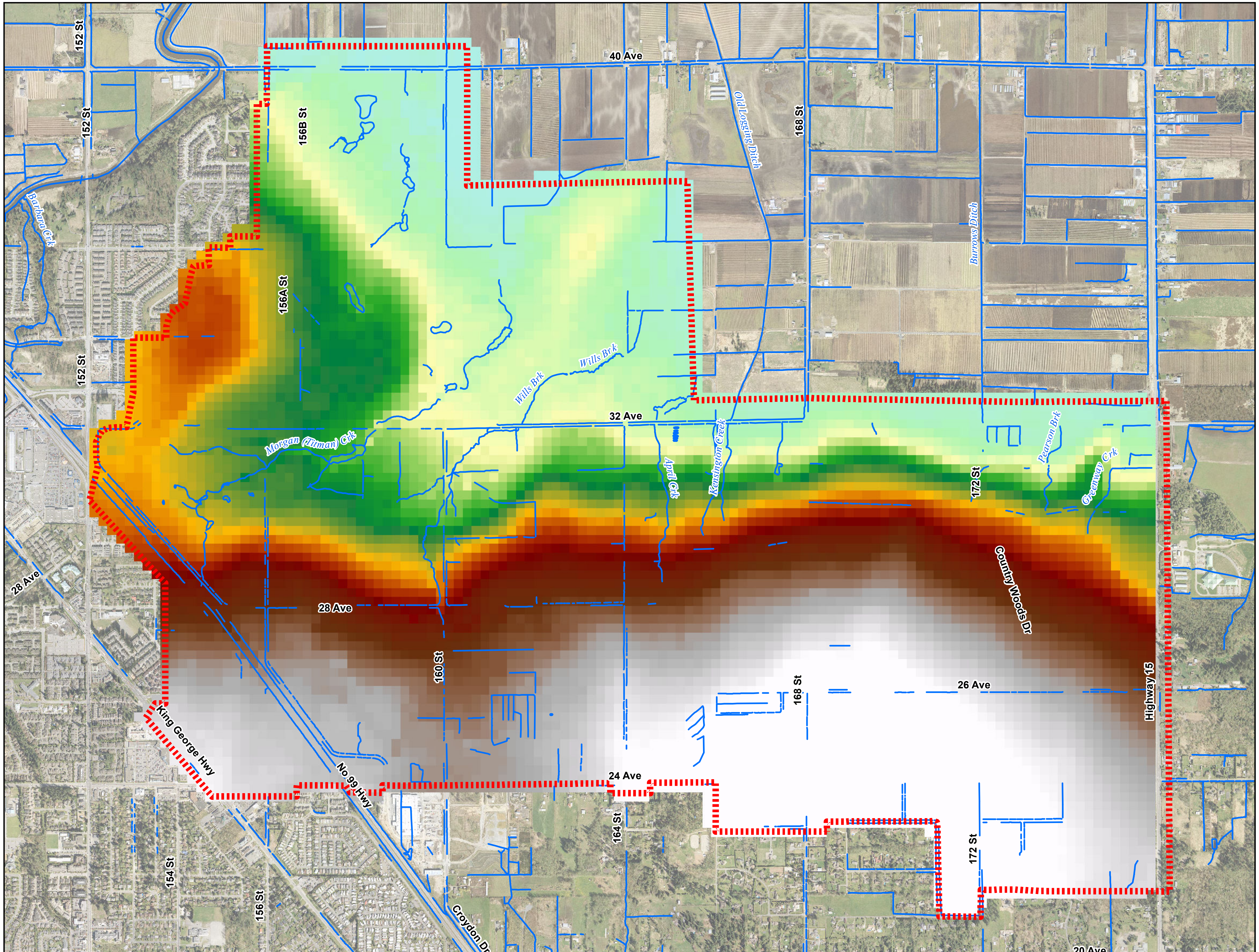
Note:
Orthophoto captured during Spring, 2009.

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

1072.0176.01



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Model Topography
Figure 2

Legend

Waterway

Model Domain

Elevation (m)

High : 115 m

Low : -0.8 m

N

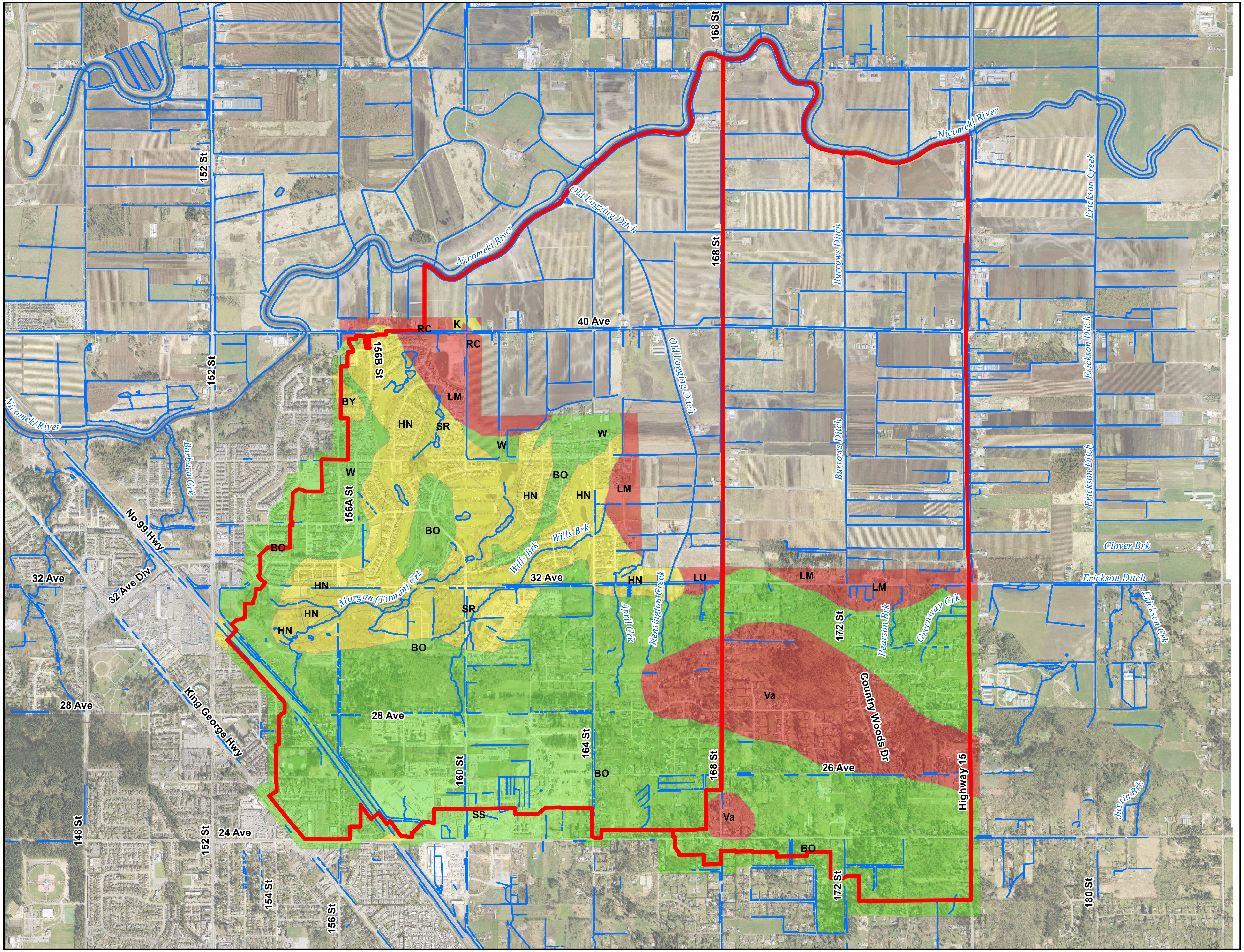
0 125 250 375 500

Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01



Old Logging Ditch/ Burrows ISMP

Surficial Soils Figure 3

Legend

- Waterway
- Catchment Boundary

Soil Drainage Conditions*

- Very Poor
- Moderately Well
- Well

* Note: Soil data clipped to stormwater model boundaries.

Soil data source: Soils of the Langley-Vancouver Map Area, 1980, Ministry of

N

0 250 500 750 1,000

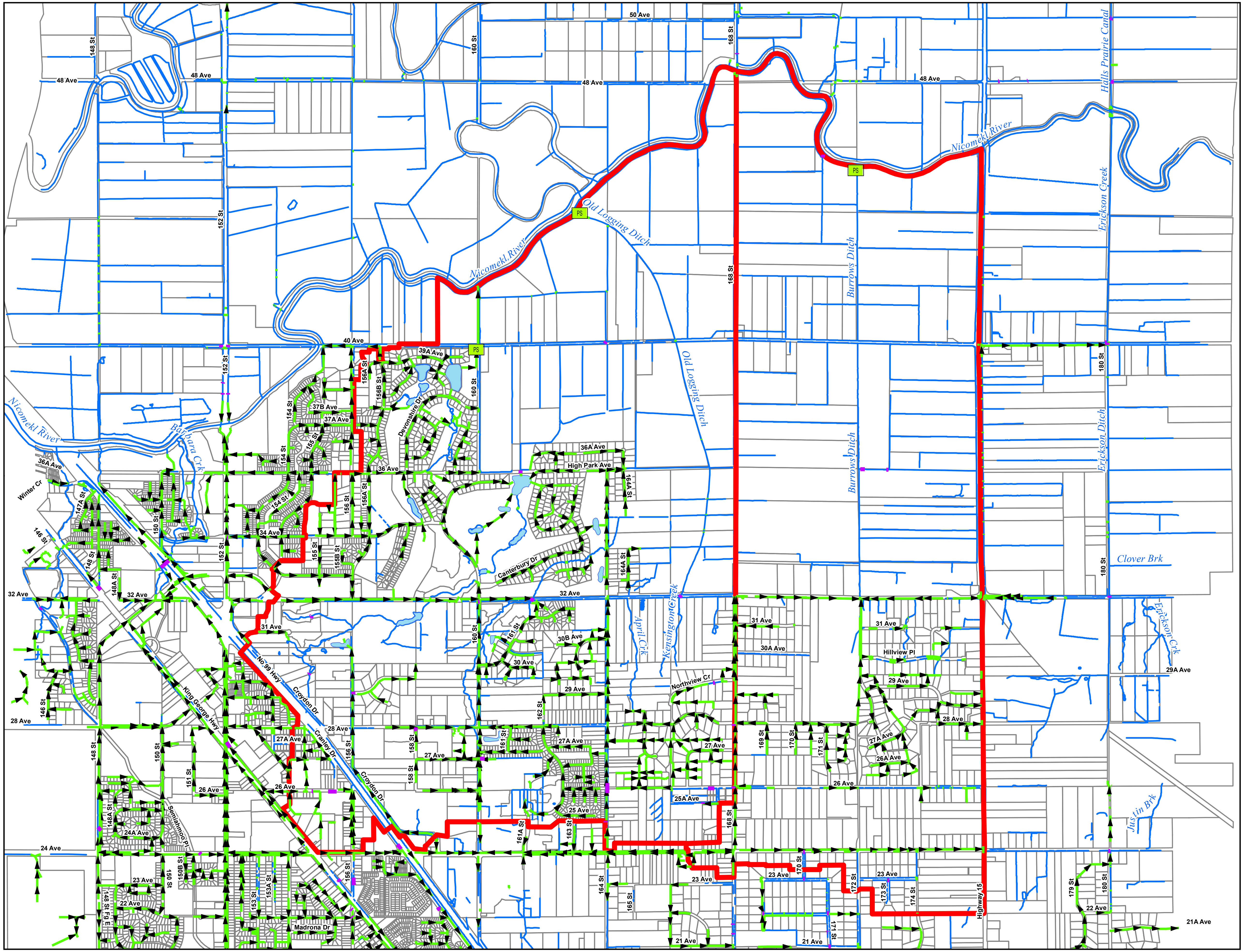
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2010_08_26_FinalReport_TechnicalAppdx\Figure03_SurficialSoils.mxd Last revised by: bpauls on 26/08/2010 at 12:59:13 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Existing Stormwater Infrastructure
Figure 4

Legend

- Pump Stations
- Culvert
- Mains
- Waterways
- Cadastral
- Detention Pond
- Study Area Catchment Boundary

N

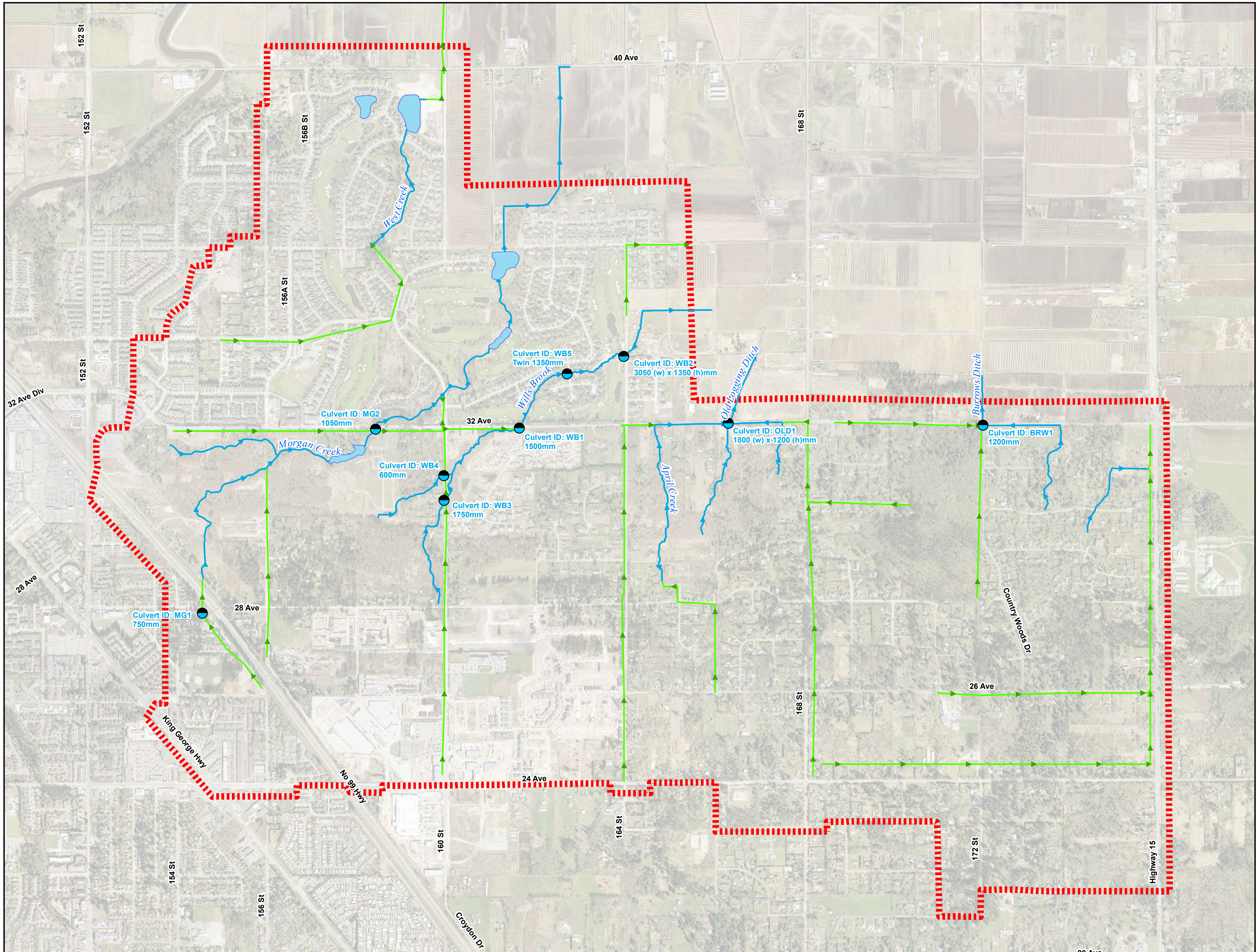
0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2010_08_26_FinalReport_TechnicalAppdx\Figure04_ExistingStormwaterInfrastructure.mxd Last revised by: bpauls on 26/08/2010 at 1:11:00 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Modeled Conveyance Systems Figure 5

Legend

- Modeled Culvert
- Modeled Natural Channel
- Modeled Pipe
- Modeled Pond
- Model Domain

N

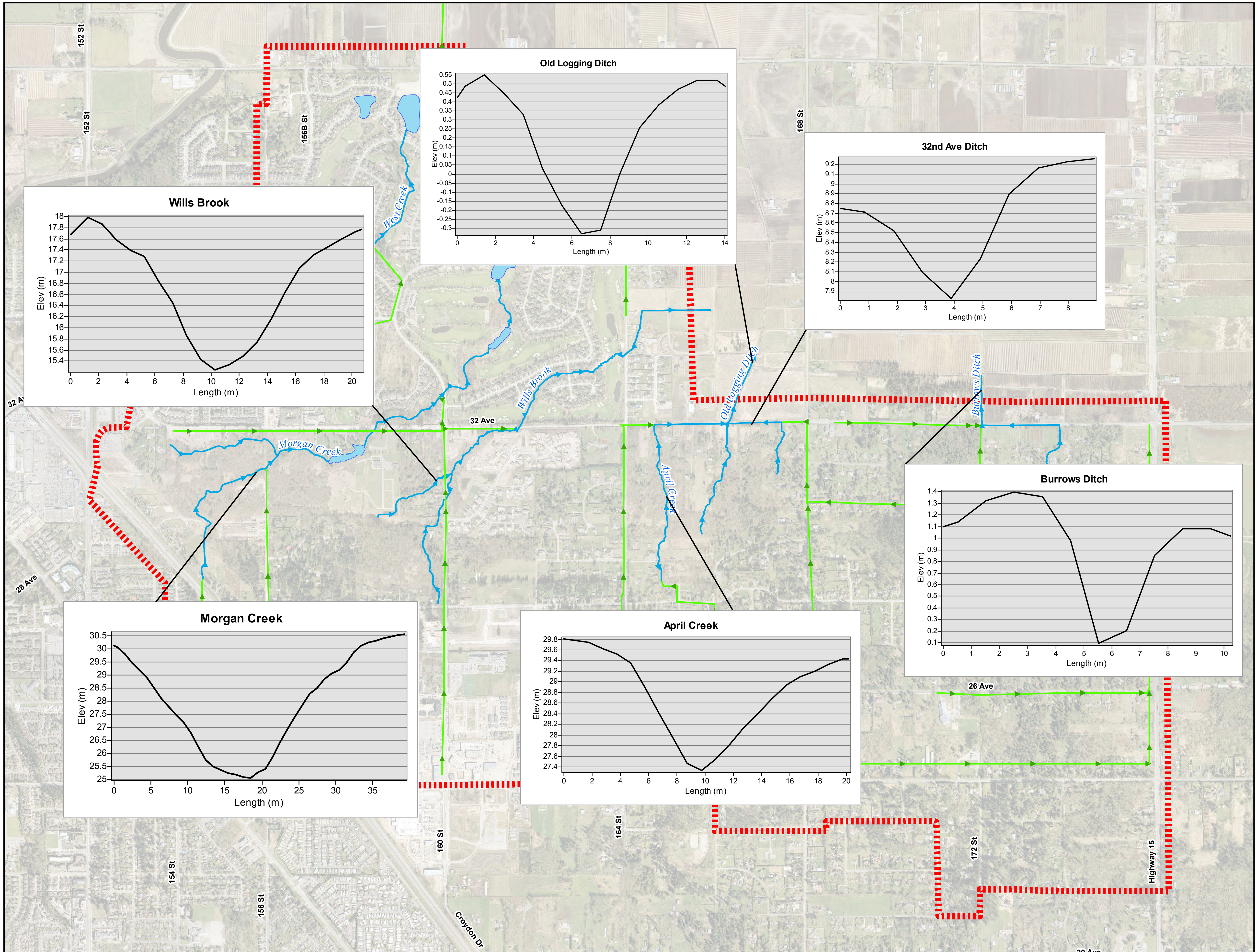
0 250 500 750 1,000

Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Typical Cross Sections Figure 6

Legend

- Modeled Natural Channel
- Modeled Pipe
- Modeled Pond

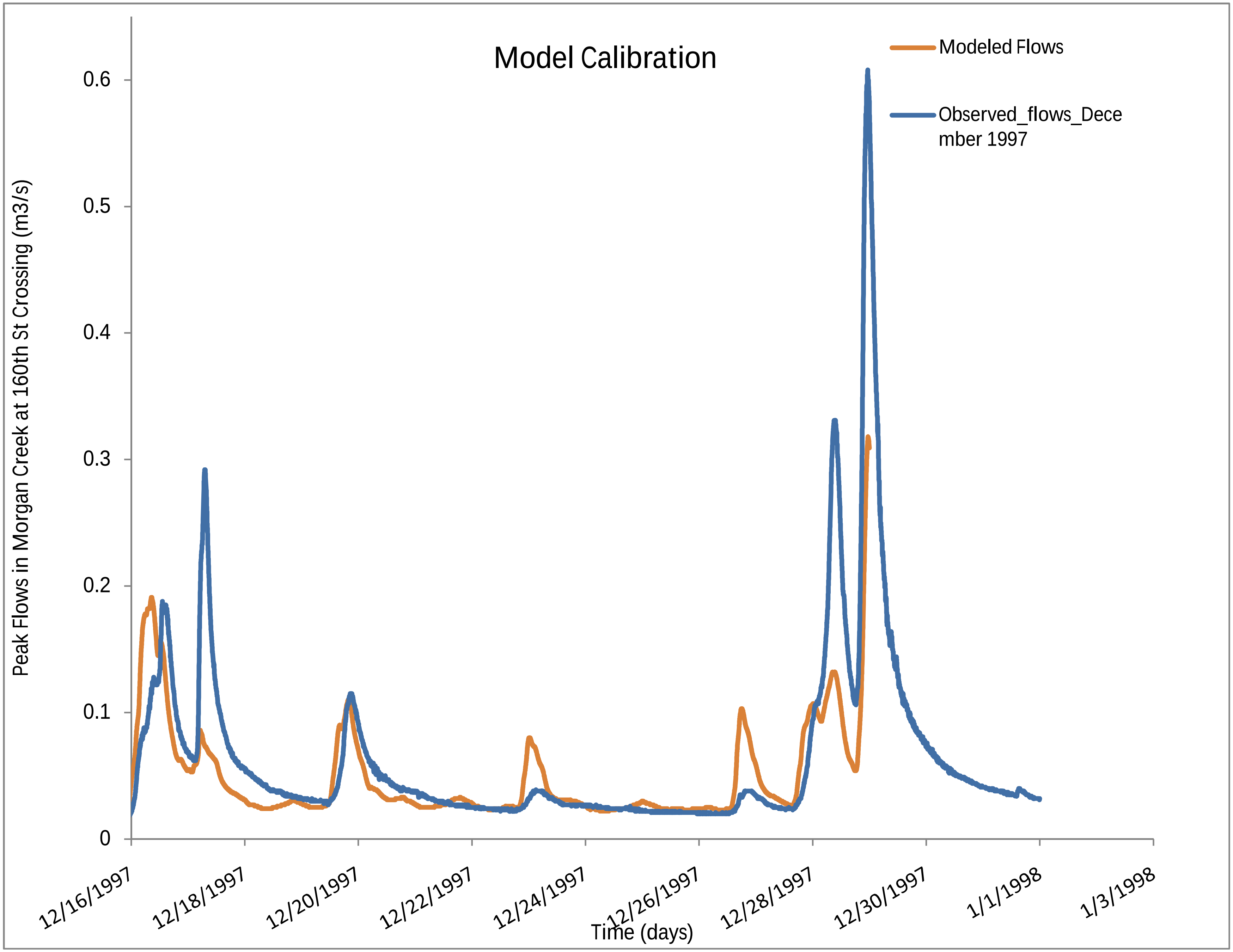
N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

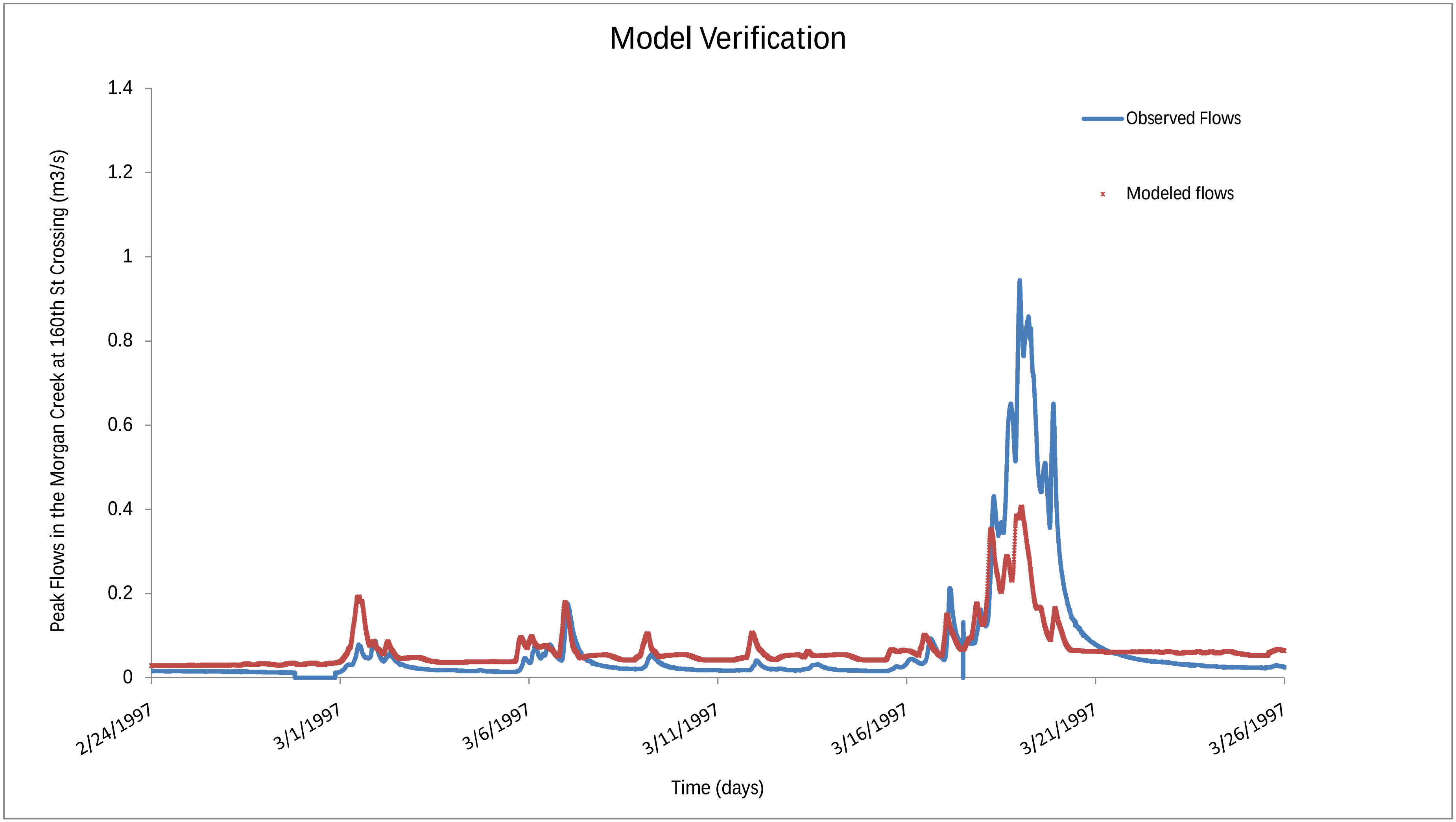
1072.0176.01

Figure 7

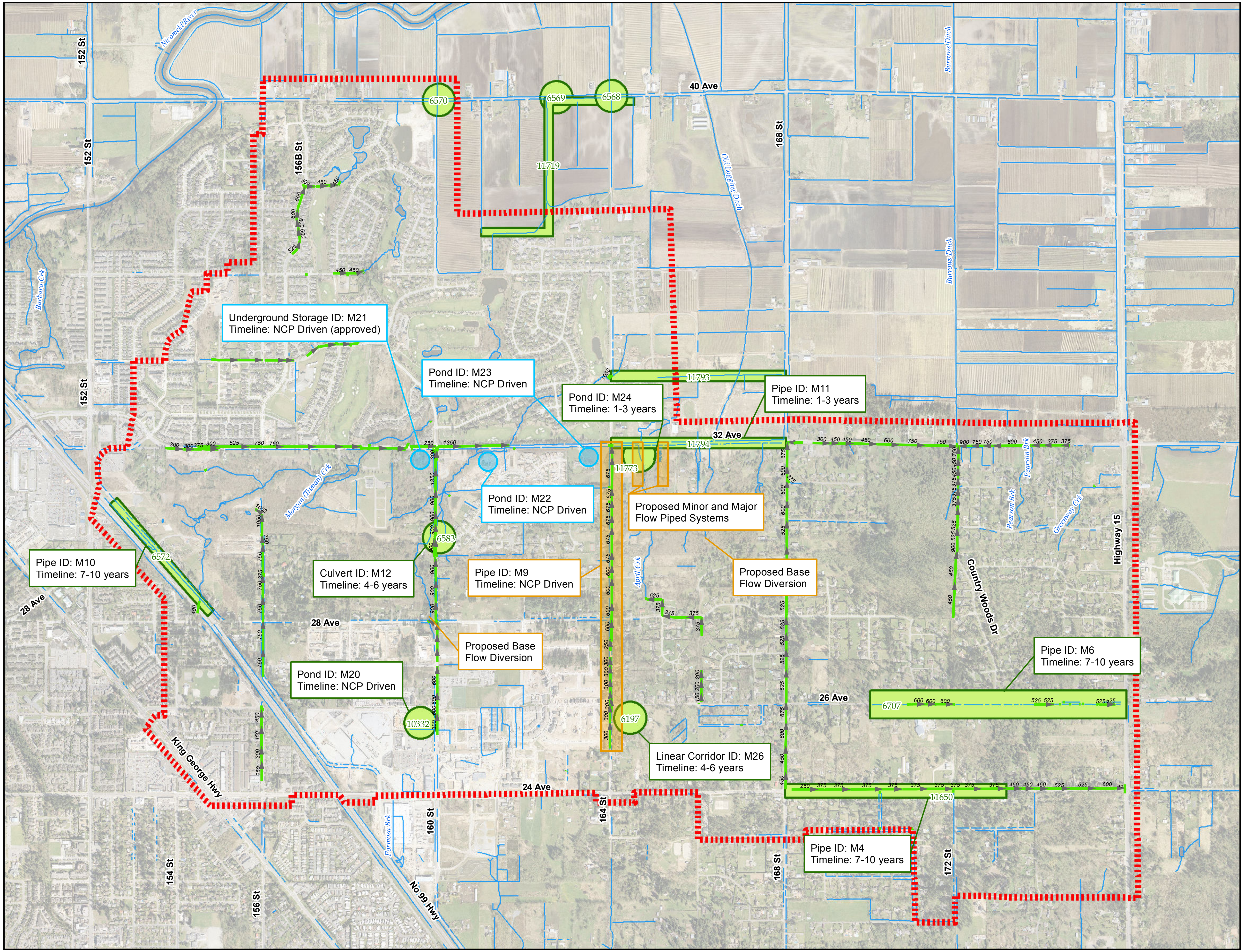


Model Calibration
Modeled Flows
Observed_flows_December 1997
Peak Flows in Morgan Creek at 160th St Crossing (m3/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
12/16/1997
12/18/1997
12/20/1997
12/22/1997
12/24/1997
12/26/1997
12/28/1997
12/30/1997
1/1/1998
1/3/1998
Time (days)

Figure 8



Model Verification
Observed Flows
Modeled flows
Peak Flows in the Morgan Creek at 160th St Crossing (m3/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2/24/1997
3/1/1997
3/6/1997
3/11/1997
3/16/1997
3/21/1997
3/26/1997
Time (days)



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Infrastructure Proposed in Current City Plans

Figure 9

Legend

- Existing Trunk System

Proposed Infrastructure Upgrades

- North Grandview Heights NCP - Pipe Upgrade
- North Grandview Heights NCP - Pond/Storage
- City of Surrey 2010 Ten Year Plan - Pipe, Culvert, and Pond/Storage
- Model Domain

Note: Exact location of recommended ponds still to be determined.

N

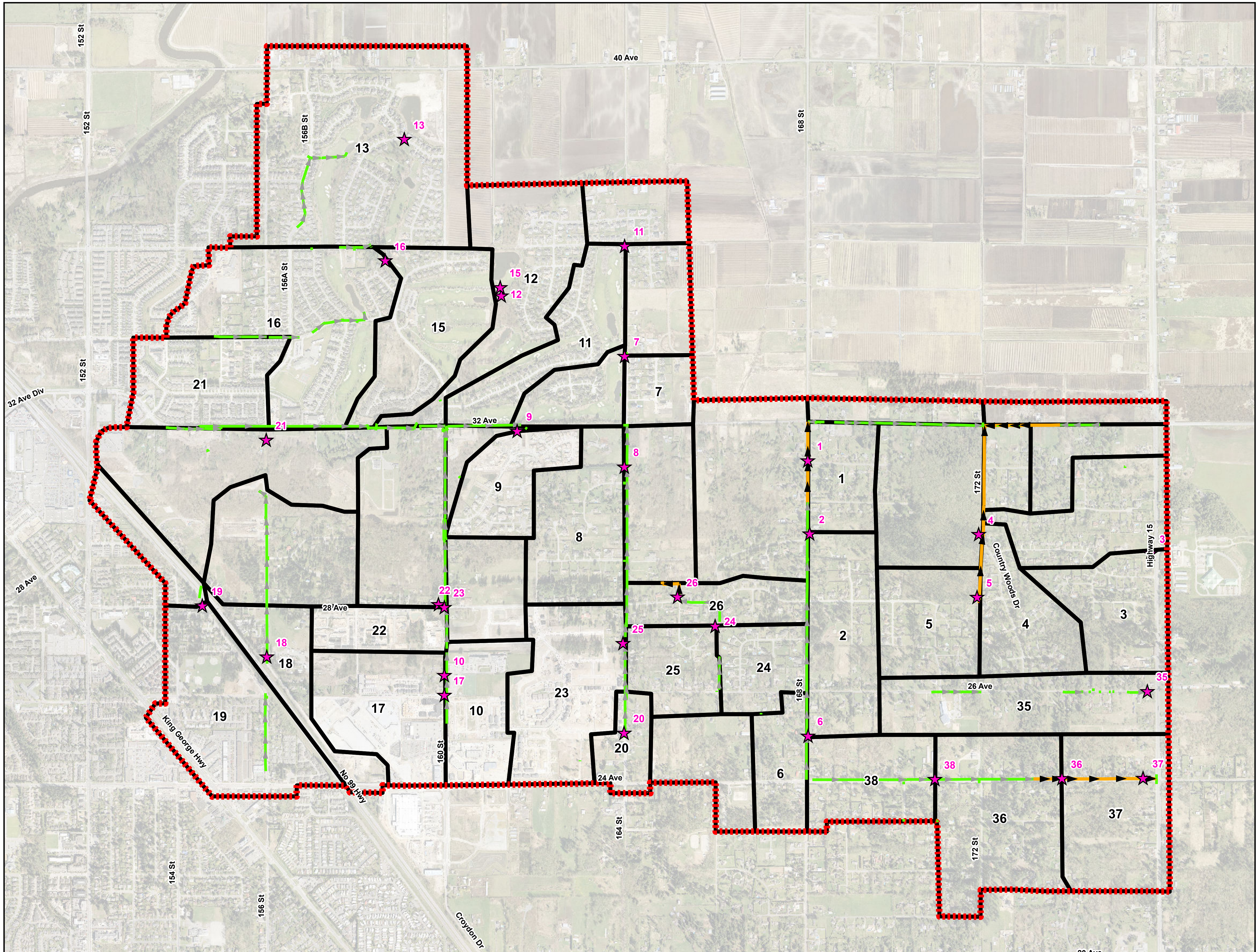
0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2010_08_26_FinalReport_TechnicalAppdx\Figure09_InfrastructureProposedCurrentCityPlans.mxd Last revised by: bpauls on 26/08/2010 at 2:02:48 PM



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Sub Catchments for Trunk Capacity Designation

Figure 10

Legend

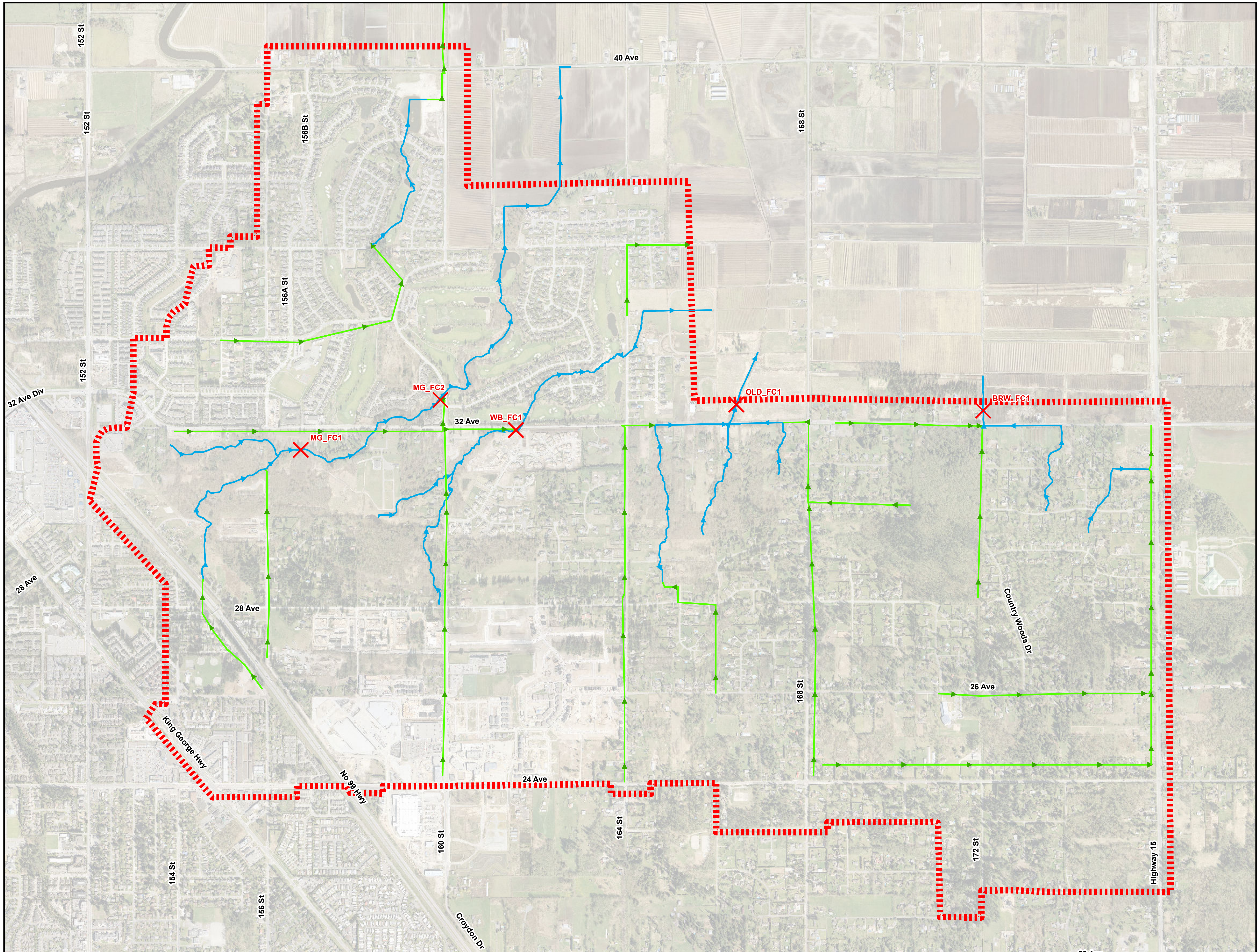
- Drain Code Outlets
- Trunk System
- Trunks with Insufficient Capacity
- Model Domain
- Sub-Catchment Boundary

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

1072.0176.01



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Flow Measurement Locations

Figure 11

Legend

- Flow Locations
- Modeled Natural Channel
- Modeled Pipe
- Model Domain

N

0 250 500 750 1,000
Metres

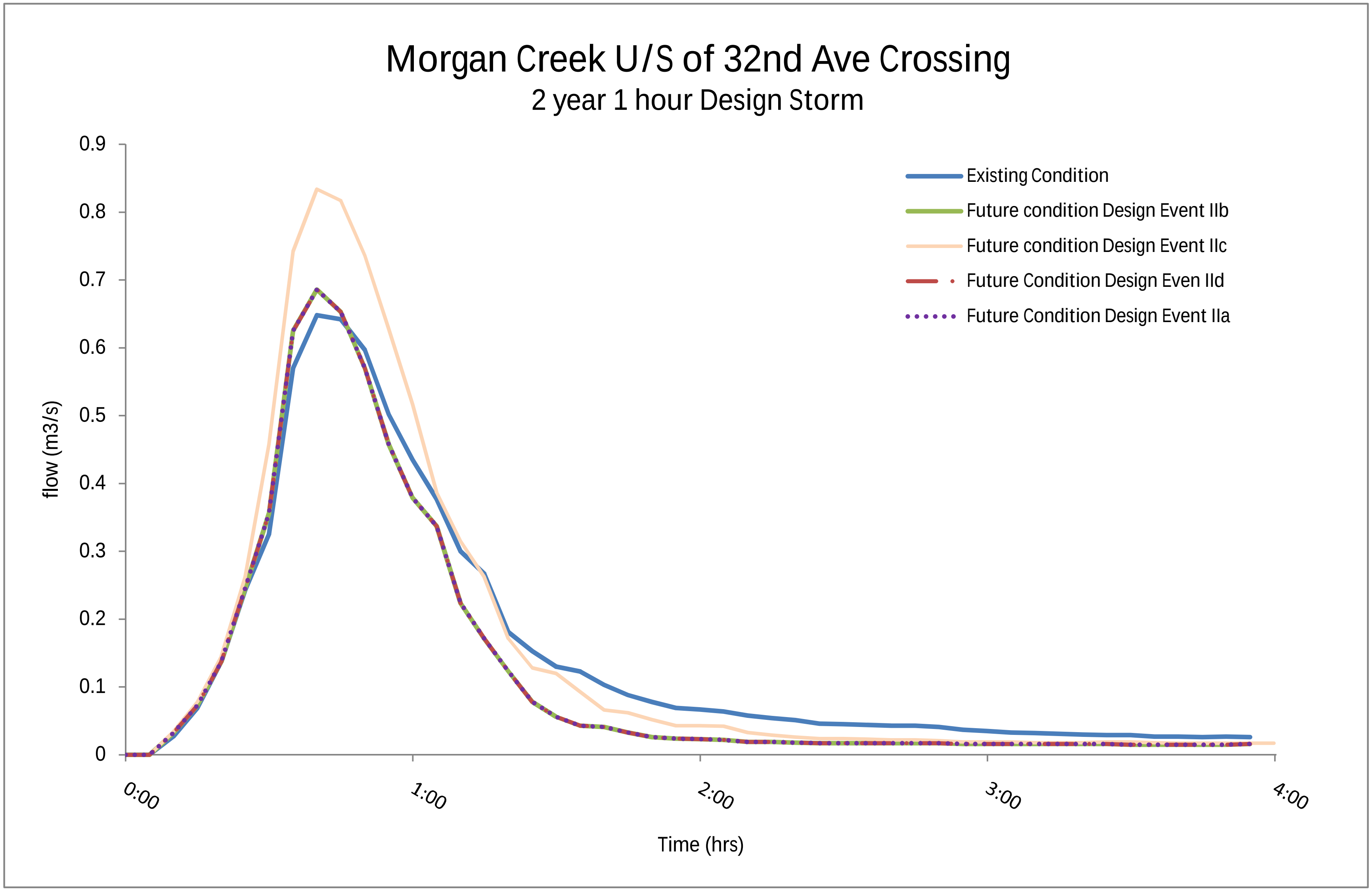
URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

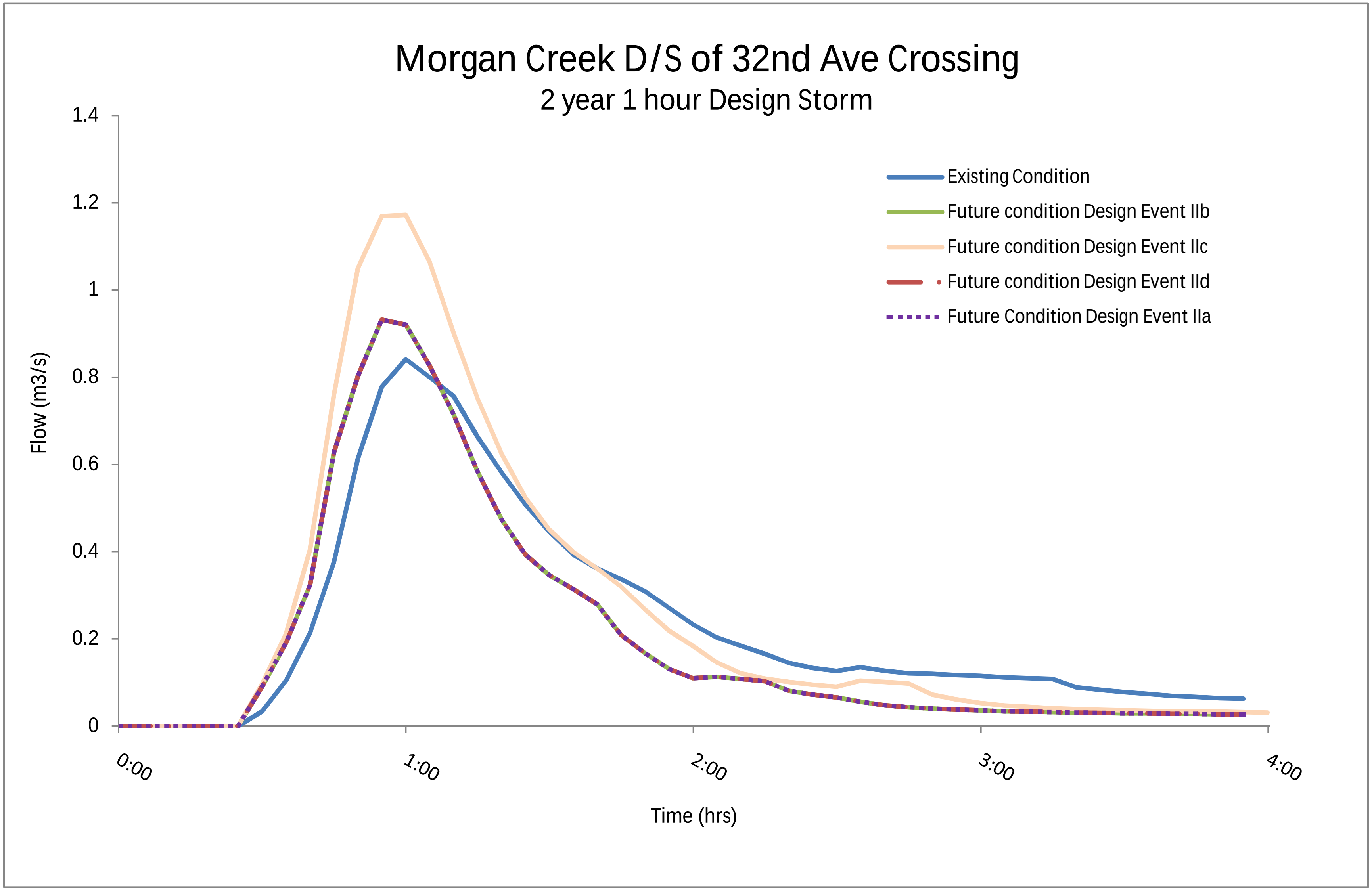
U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2010_08_26_FinalReport_TechnicalAppdx\Figure11_FlowLocations.mxd Last revised by: bpauls on 27/08/2010 at 9:26:12 AM

Figure 12(i)



Morgan Creek U/S of 32nd Ave Crossing
2 year 1 hour Design Storm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
flow (m3/s)
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future Condition Design Even IId
Future Condition Design Event IIa

Figure 12(ii)



Morgan Creek D/S of 32nd Ave Crossing
2 year 1 hour Design Storm
Flow (m3/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 12(iii)

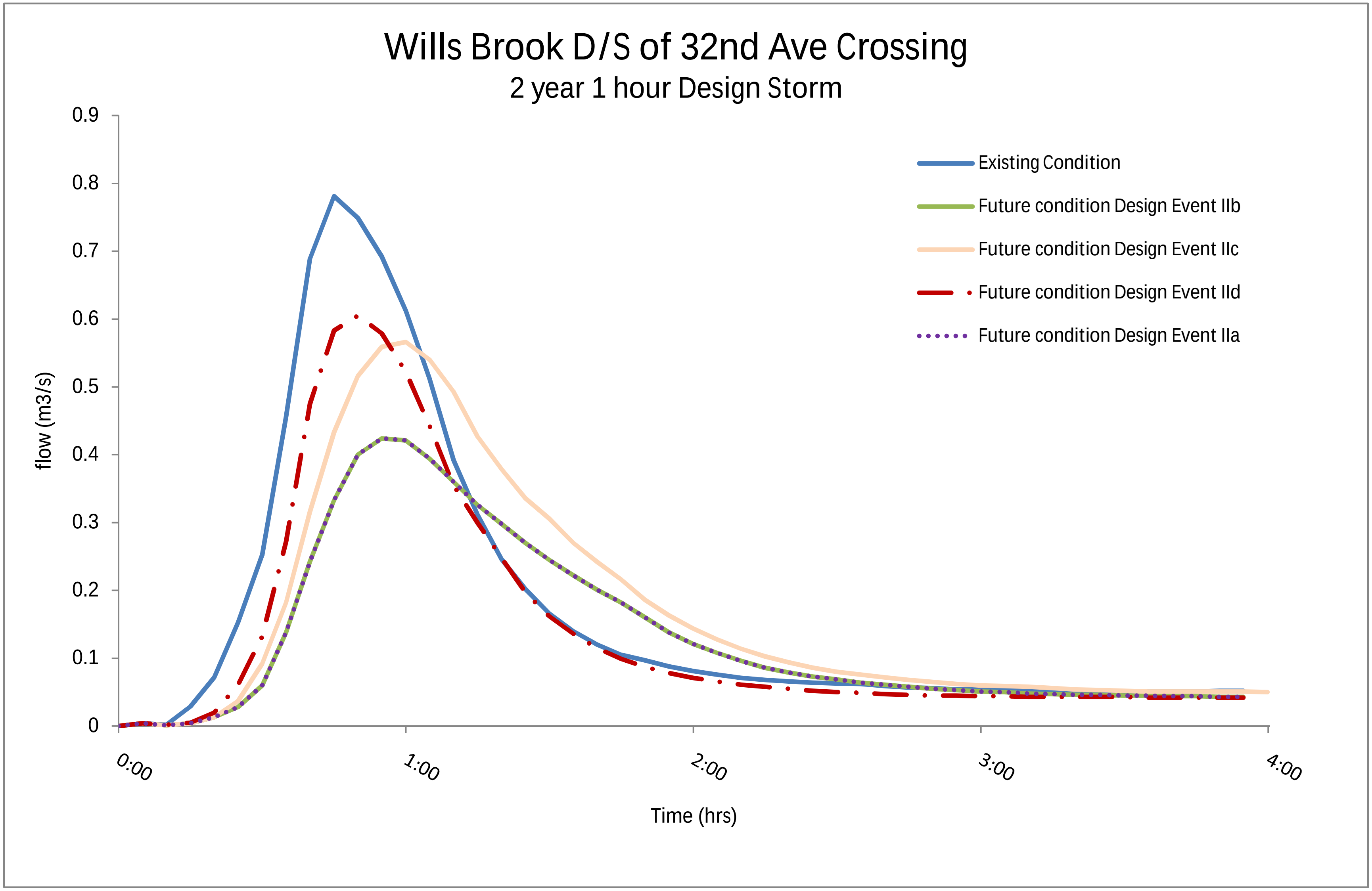
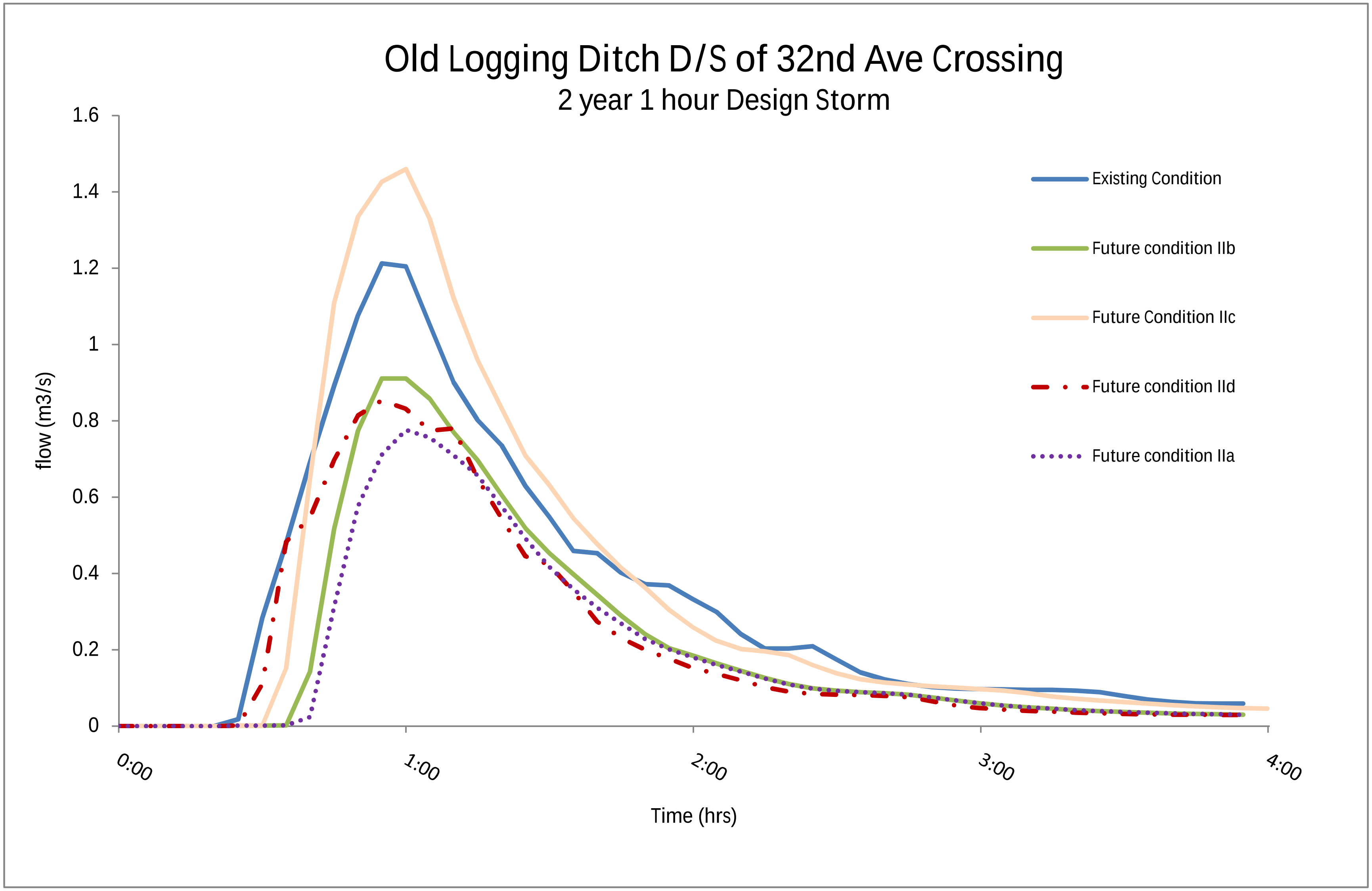
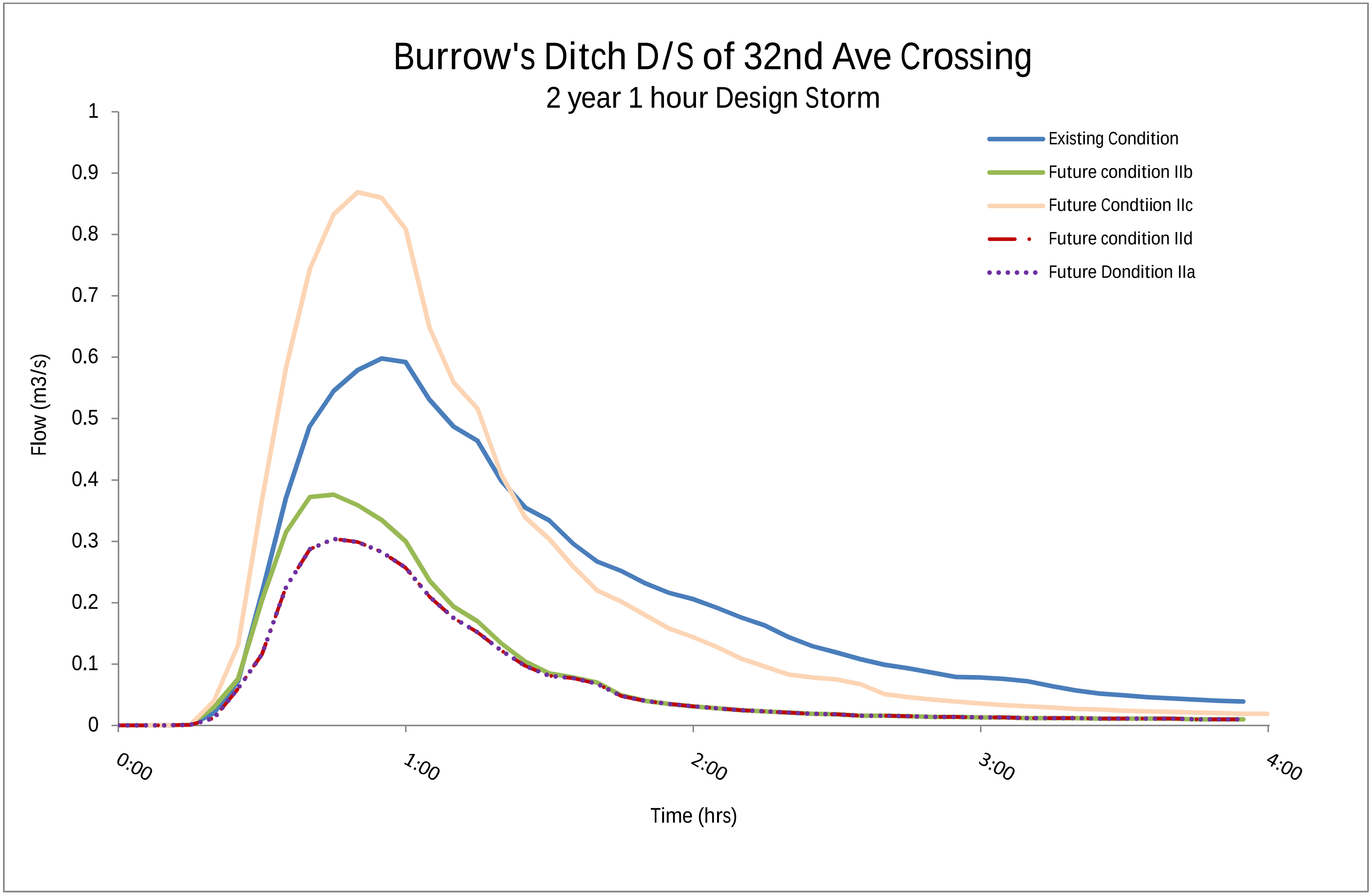


Figure 12(iv)



Old Logging Ditch D/S of 32nd Ave Crossing
2 year 1 hour Design Storm
flow (m3/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future Condition IIc
Future condition IId
Future condition IIa

Figure 12(v)



Burrow's Ditch D/S of 32nd Ave Crossing
2 year 1 hour Design Storm
Flow (m3/s)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future Condtiion IIc
Future condition IId
Future Dondition IIa

Figure 13(i)

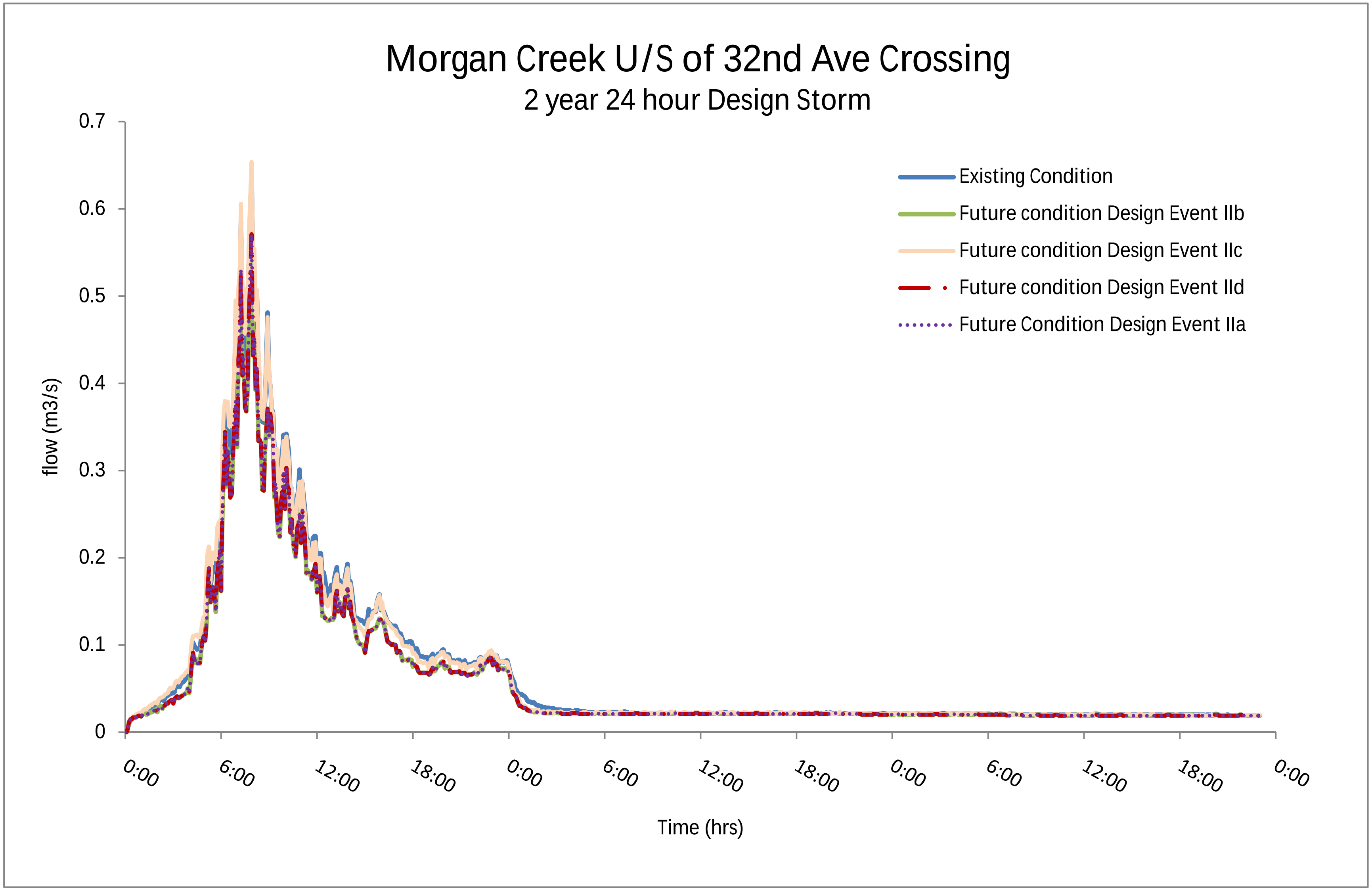
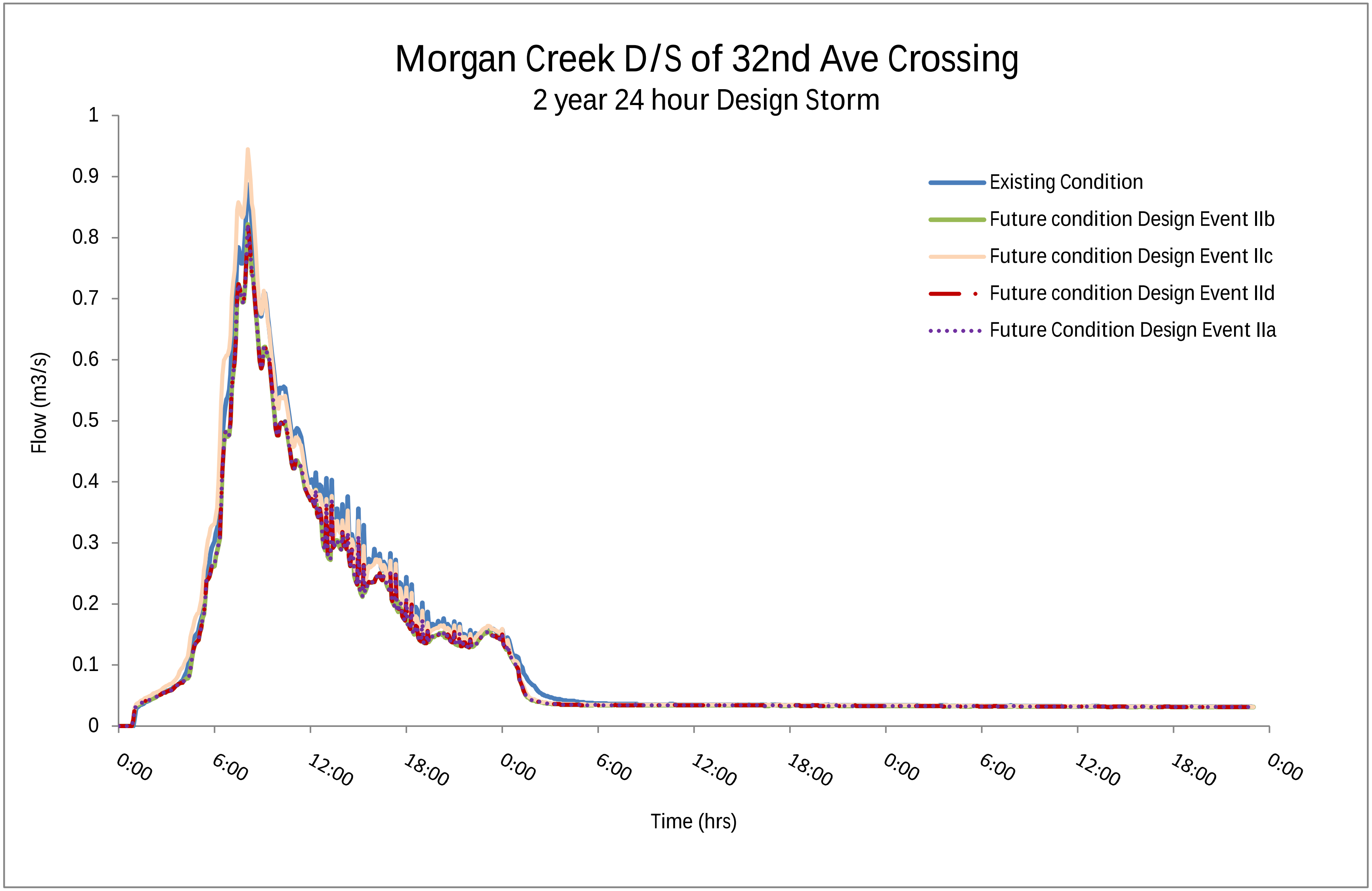

Morgan Creek U/S of 32nd Ave Crossing
2 year 24 hour Design Storm
flow (m3/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 13(ii)



Morgan Creek D/S of 32nd Ave Crossing
2 year 24 hour Design Storm
Flow (m3/s)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 13(iii)

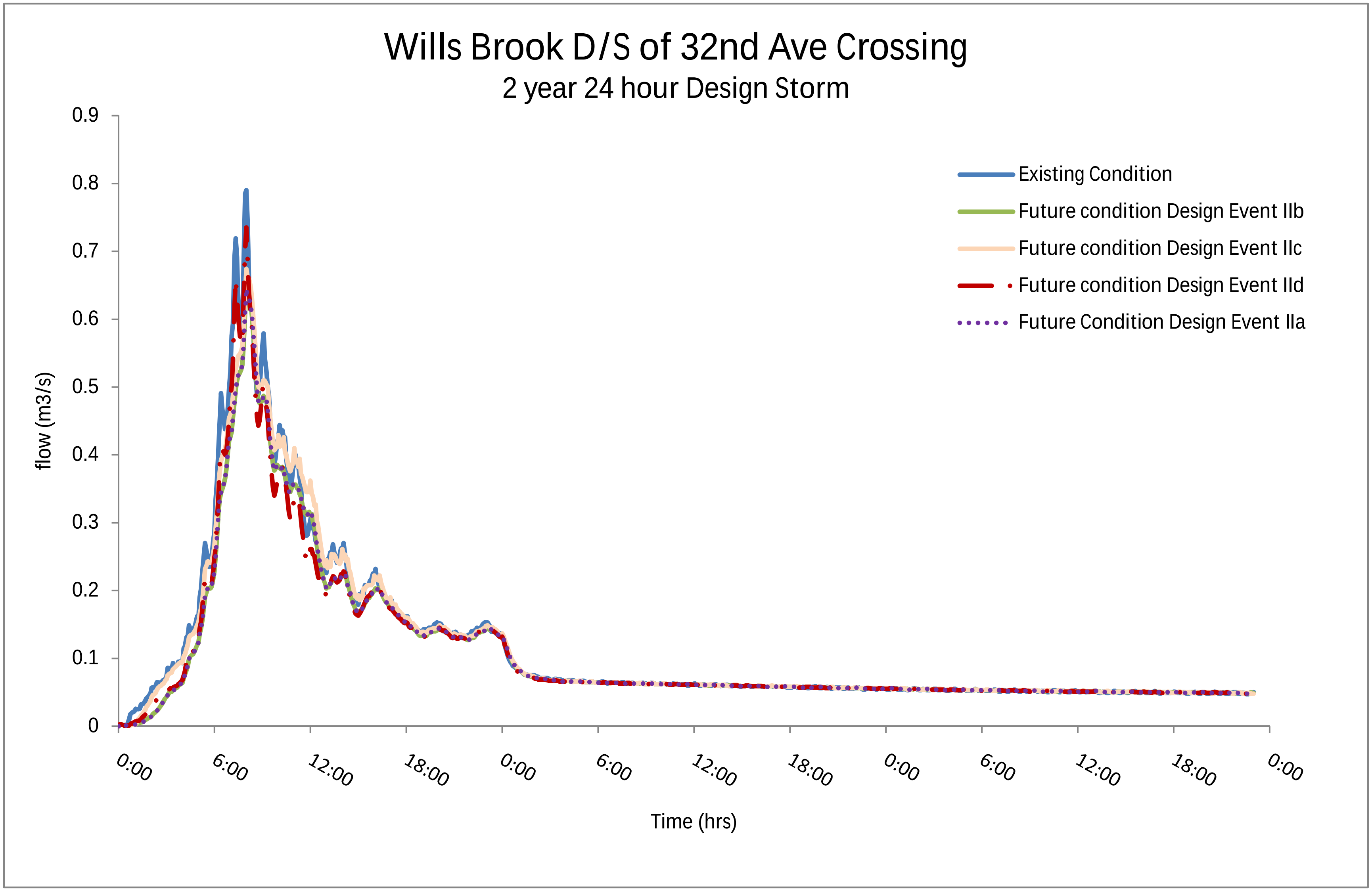
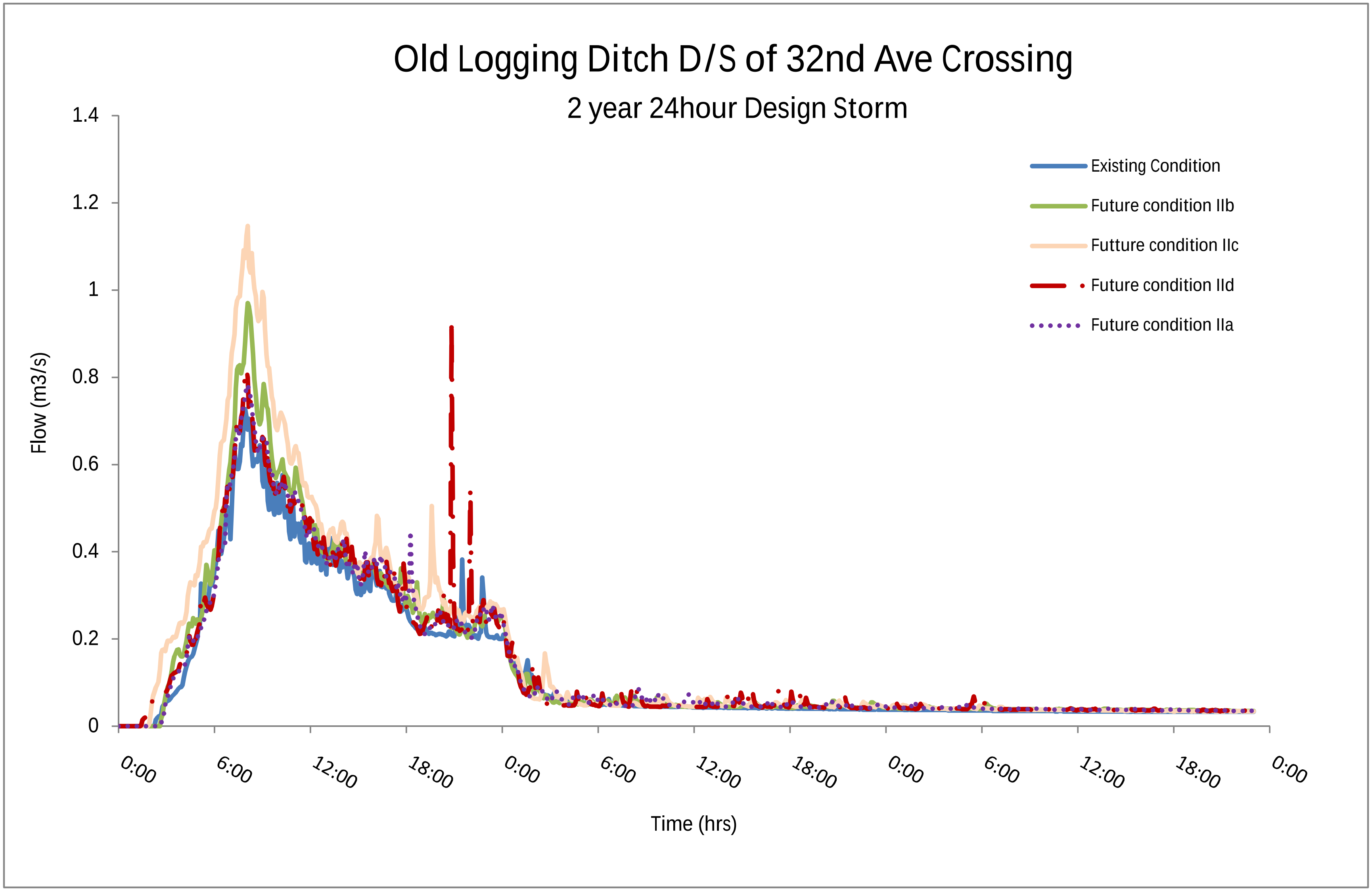
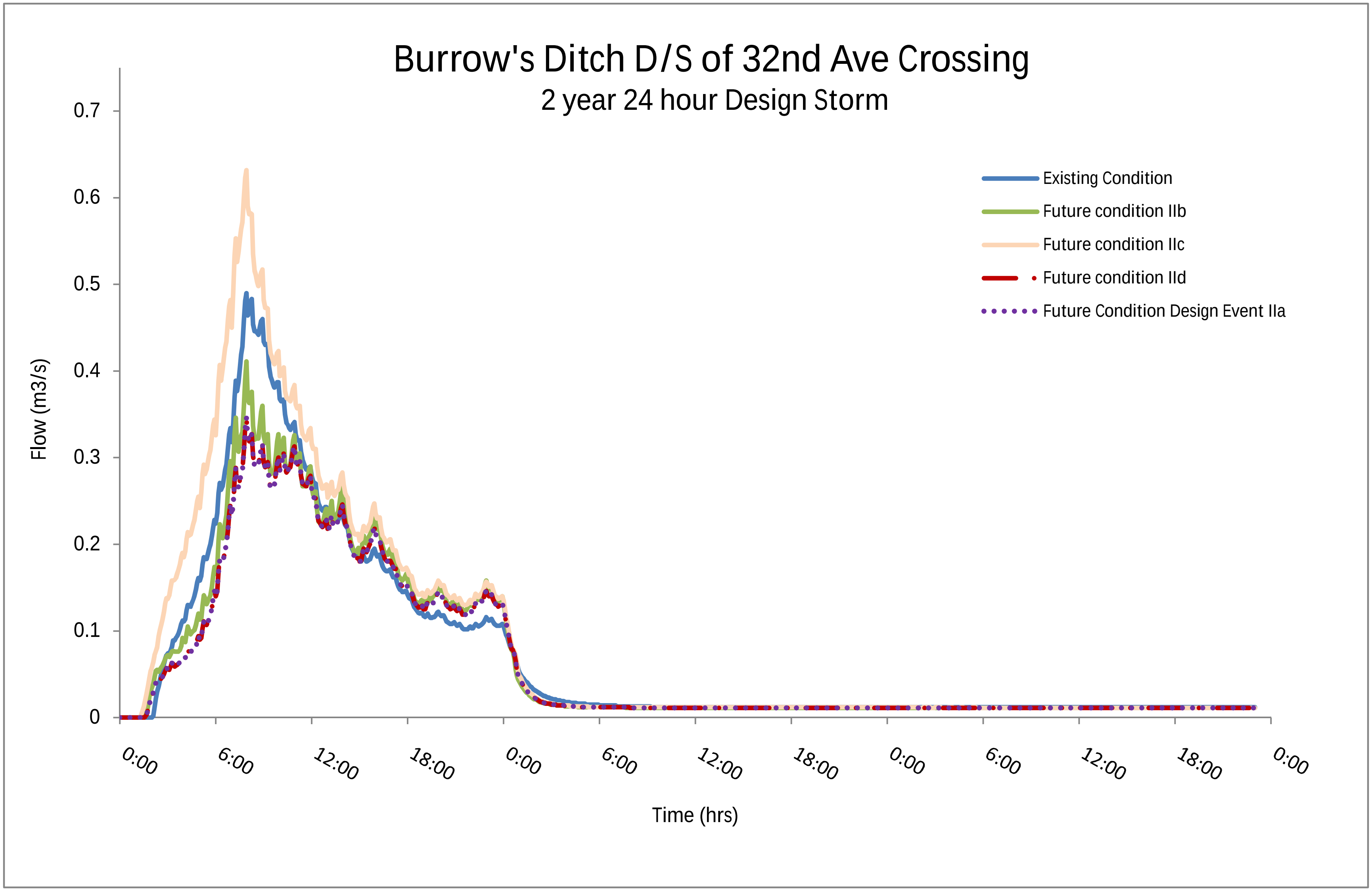


Figure 13(iv)



Old Logging Ditch D/S of 32nd Ave Crossing
2 year 24hour Design Storm
Flow (m3/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)
Existing Condition
Future condition IIb
Futture condition IIc
Future condition IId
Future condition IIa

Figure 13(v)



Burrow's Ditch D/S of 32nd Ave Crossing
2 year 24 hour Design Storm
Flow (m3/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future Condition Design Event IIa

Figure 14(i)

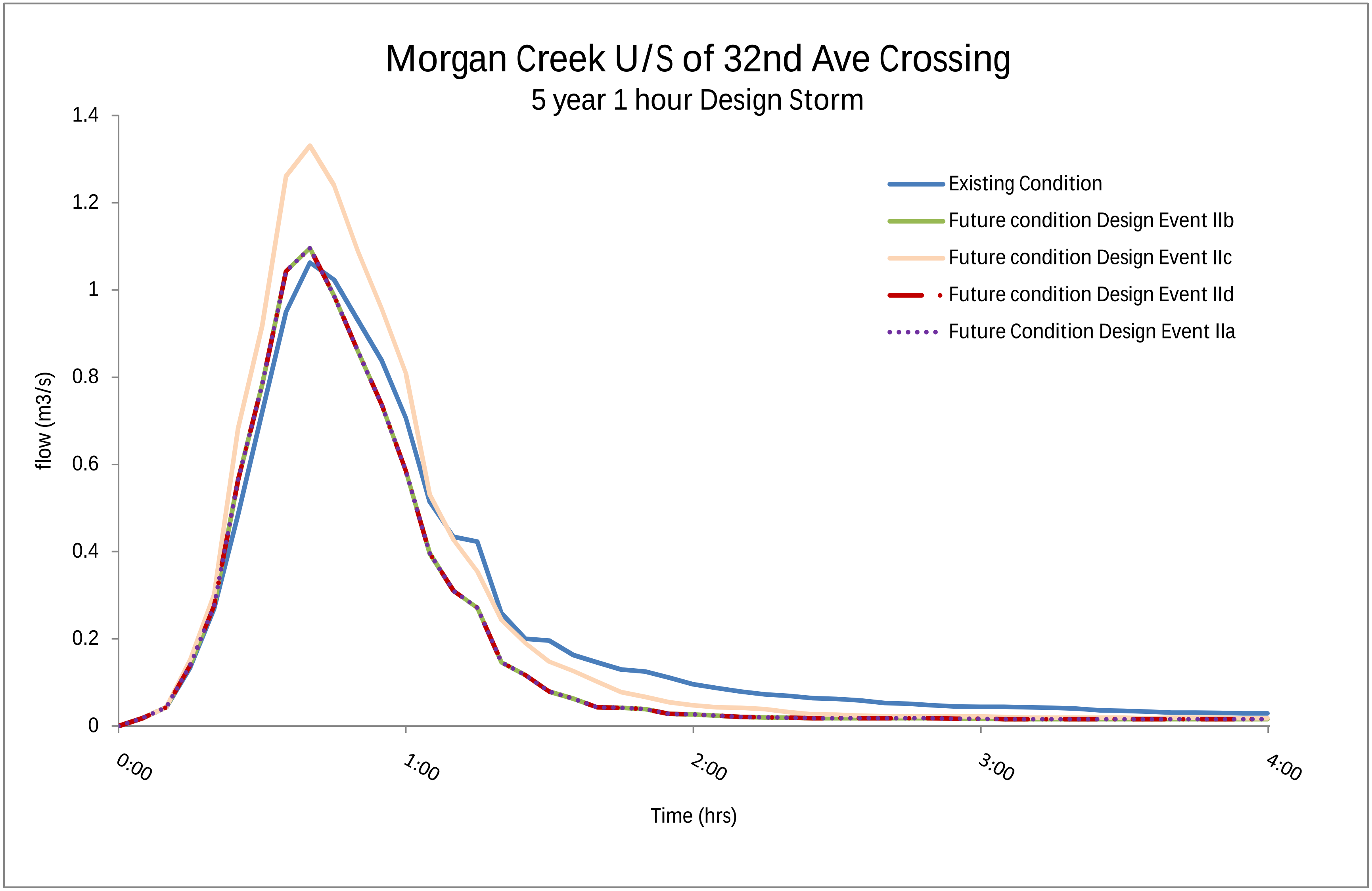
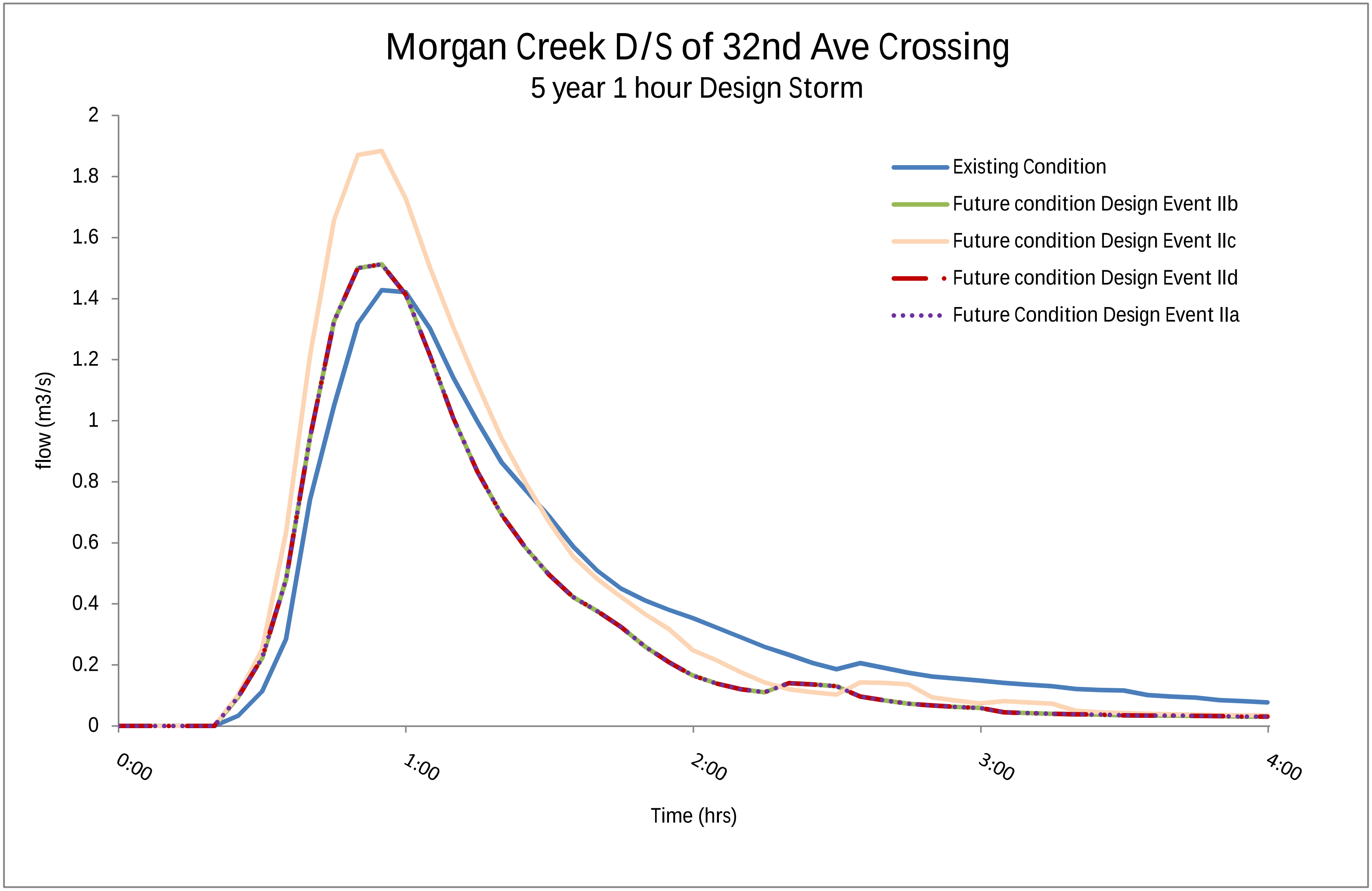

Morgan Creek U/S of 32nd Ave Crossing
5 year 1 hour Design Storm
1.4
1.2
1
0.8
0.6
0.4
0.2
0
flow (m3/s)
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 14(ii)



Morgan Creek D/S of 32nd Ave Crossing
5 year 1 hour Design Storm
flow (m3/s)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 14(iii)

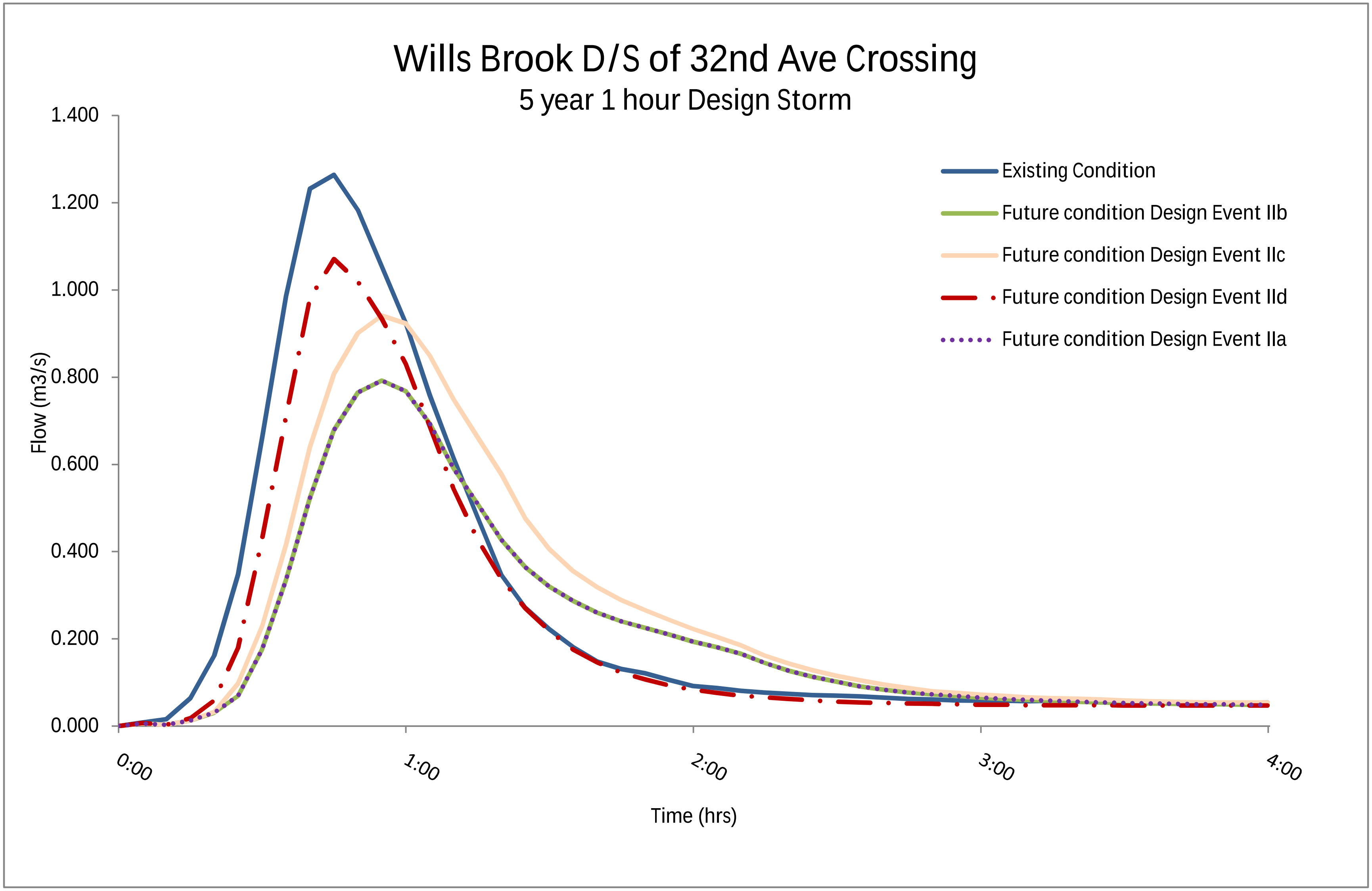


Figure 14(iv)

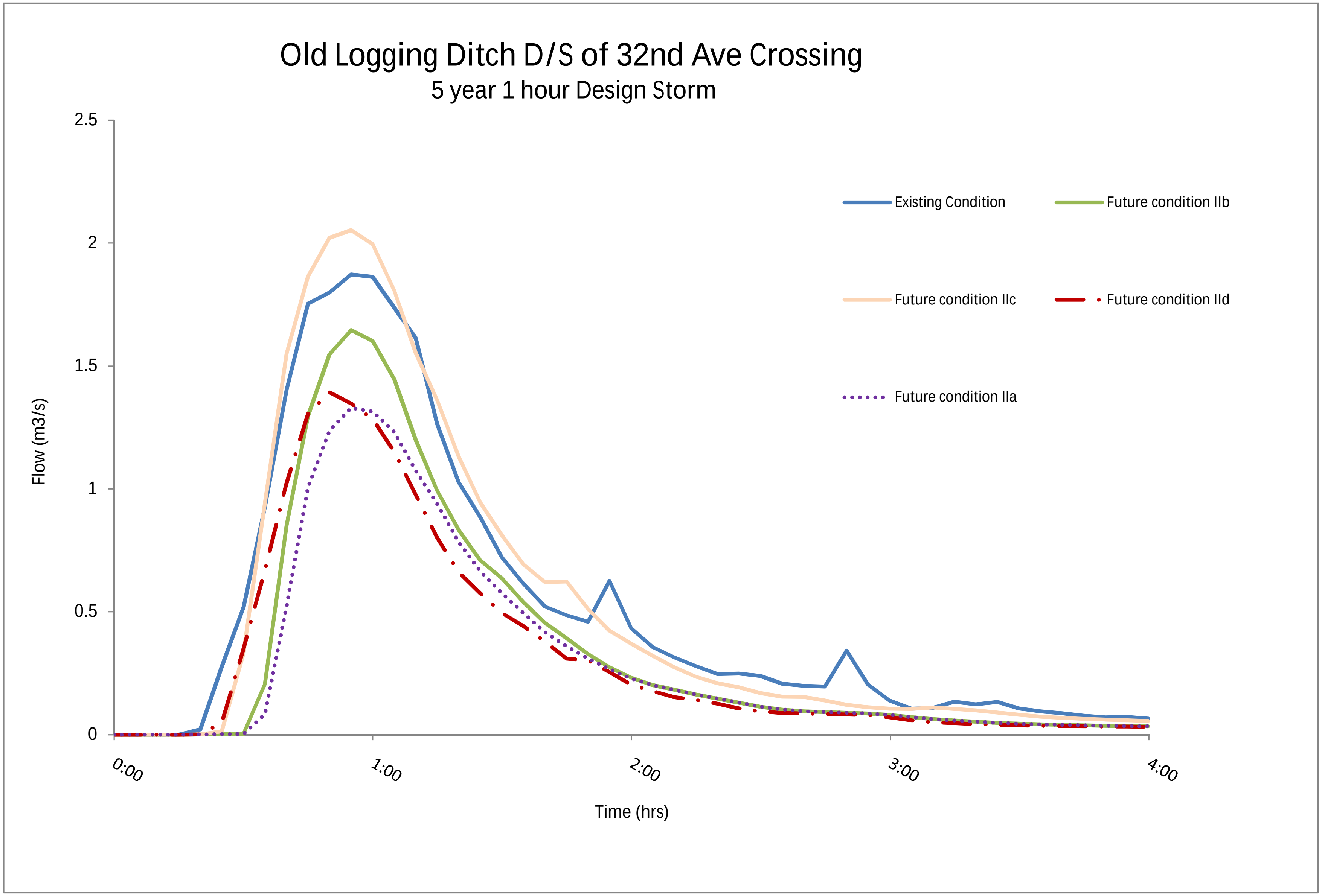
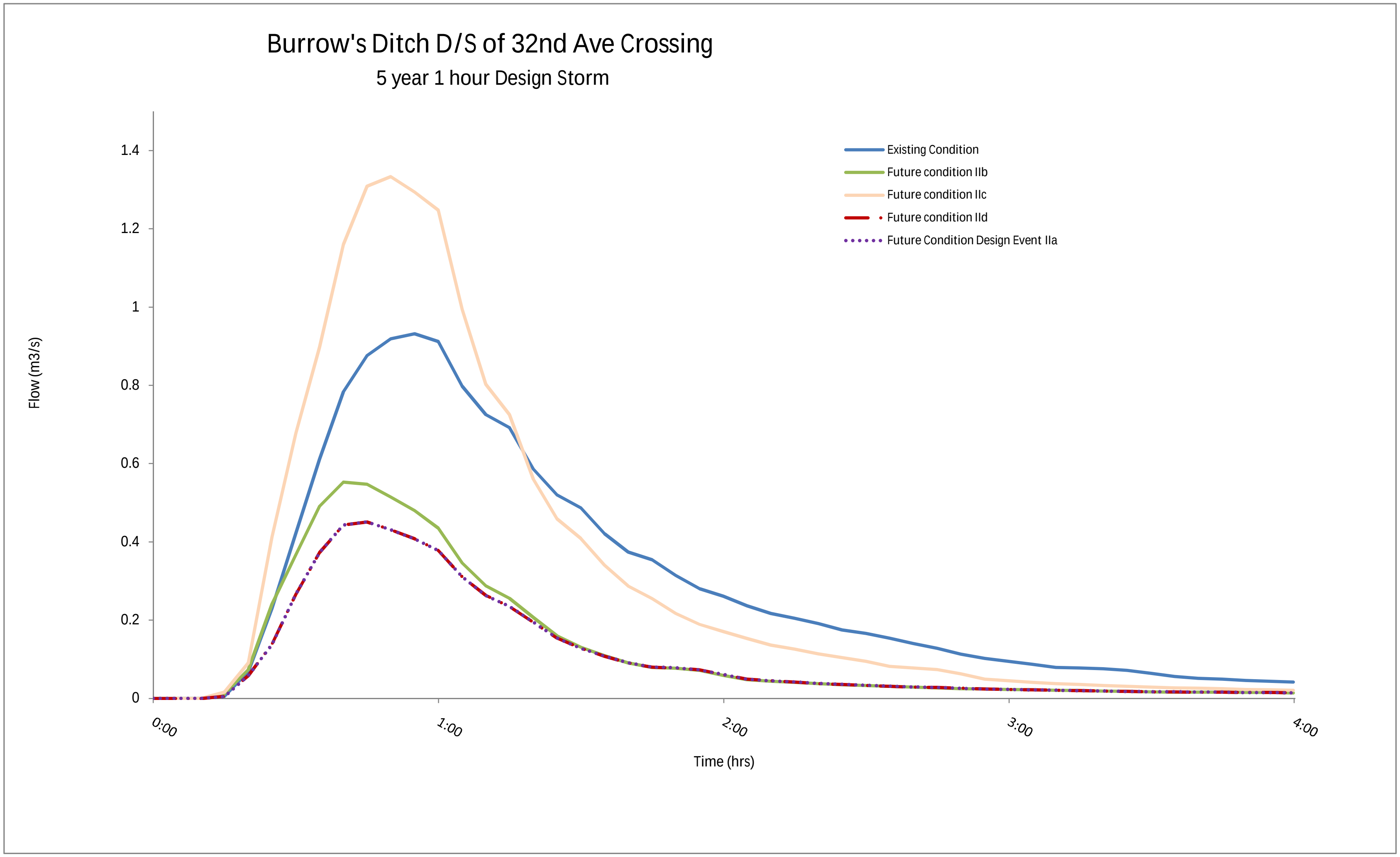
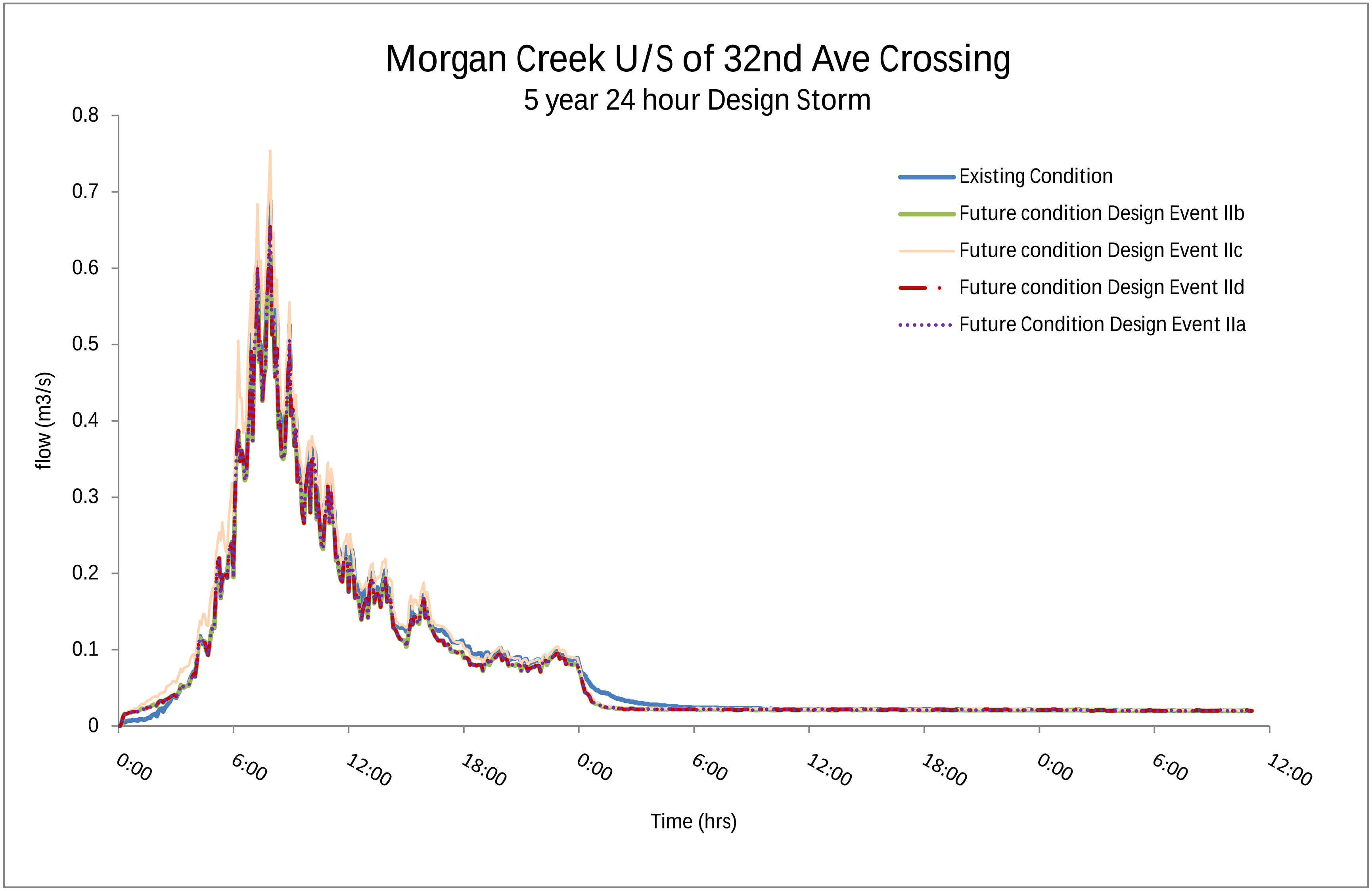

Old Logging Ditch D/S of 32nd Ave Crossing
5 year 1 hour Design Storm
2.5
2
1.5
1
0.5
0
Flow (m3/s)
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future condition IIa

Figure 14(v)



Burrow's Ditch D/S of 32nd Ave Crossing
5 year 1 hour Design Storm
Flow (m3/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future Condition Design Event IIa

Figure 15(i)



Morgan Creek U/S of 32nd Ave Crossing
5 year 24 hour Design Storm
flow (m3/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 15(ii)

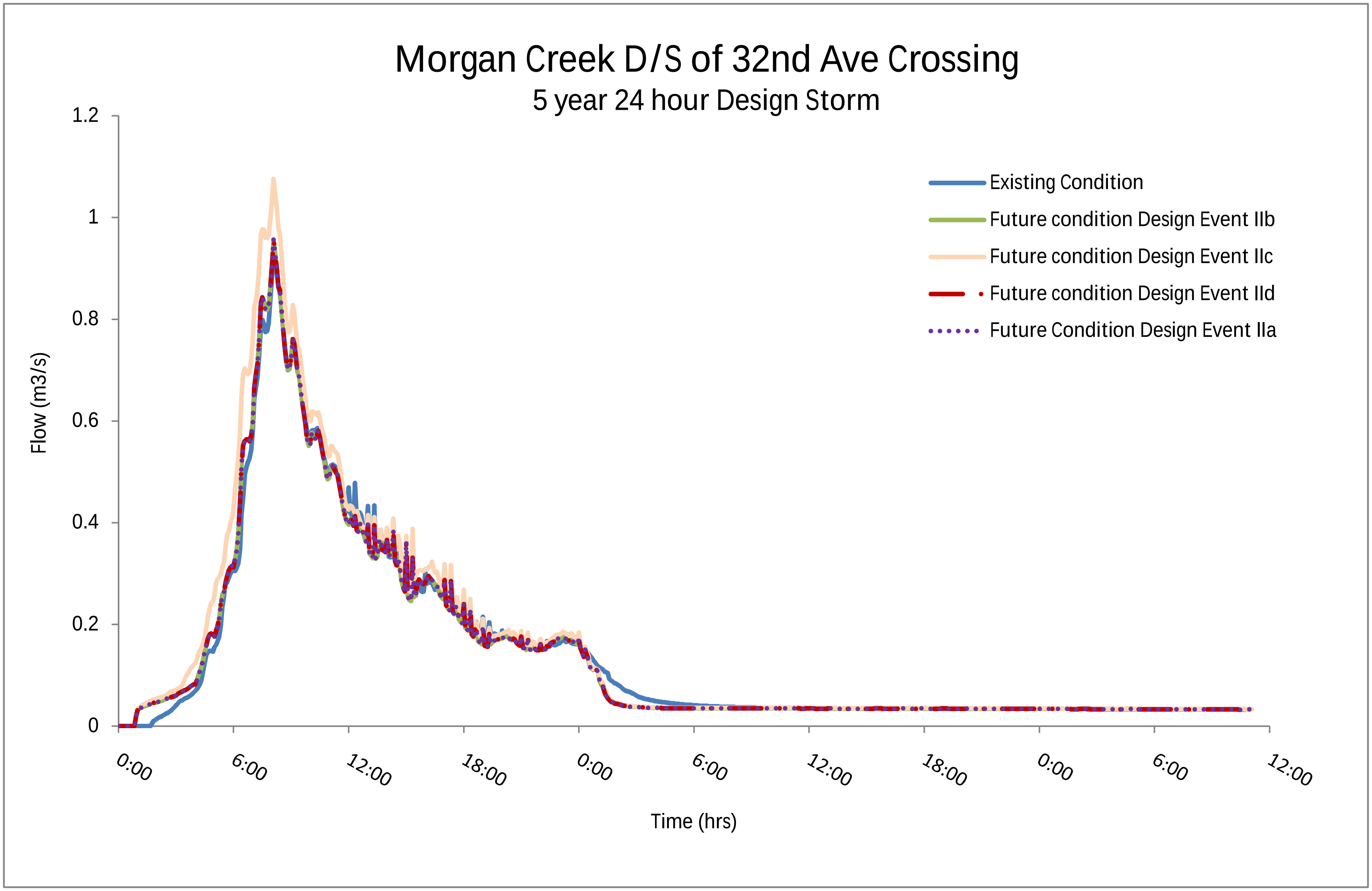

Morgan Creek D/S of 32nd Ave Crossing
5 year 24 hour Design Storm
Flow (m3/s)
1.2
1
0.8
0.6
0.4
0.2
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 15(iii)

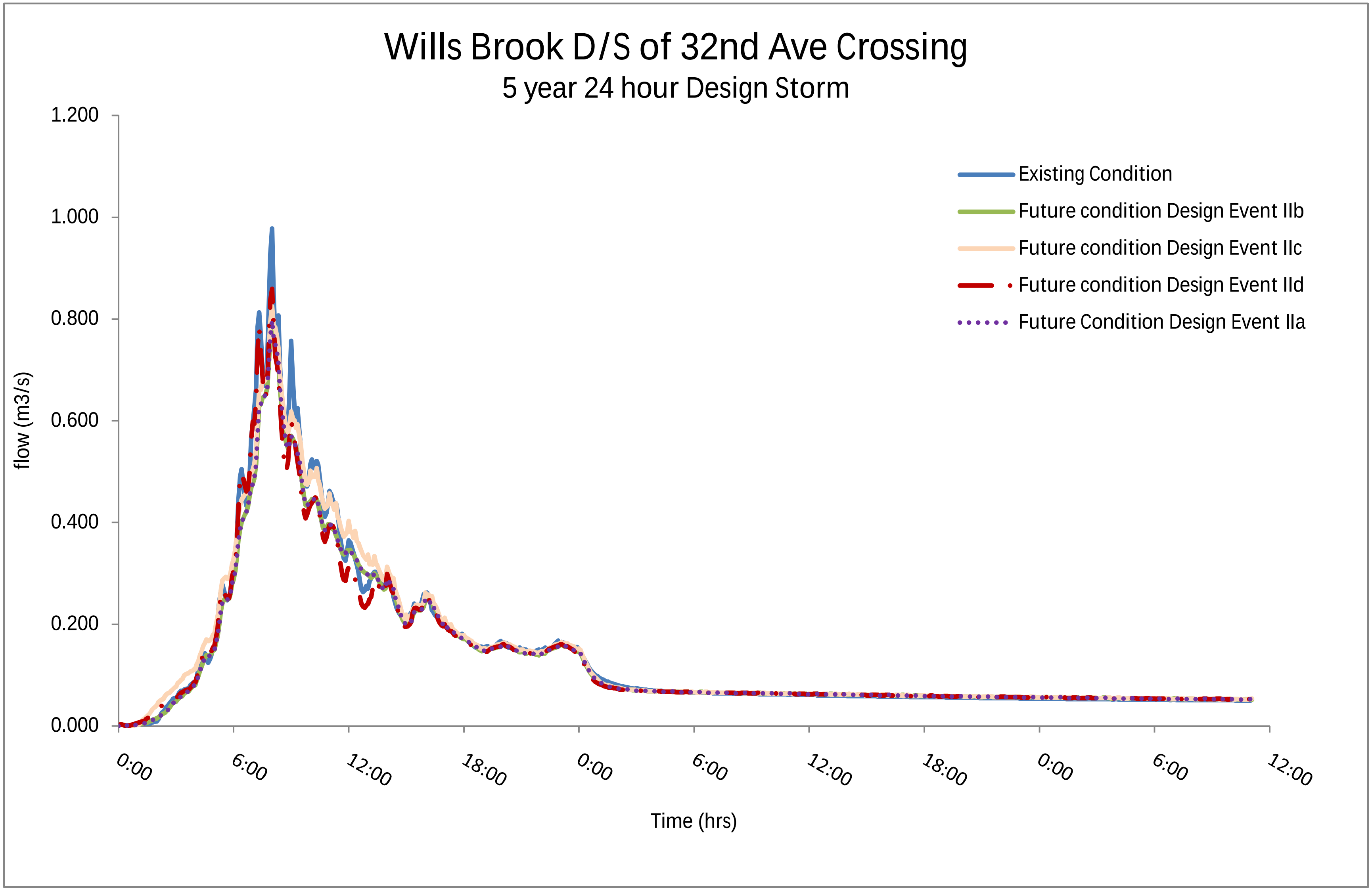
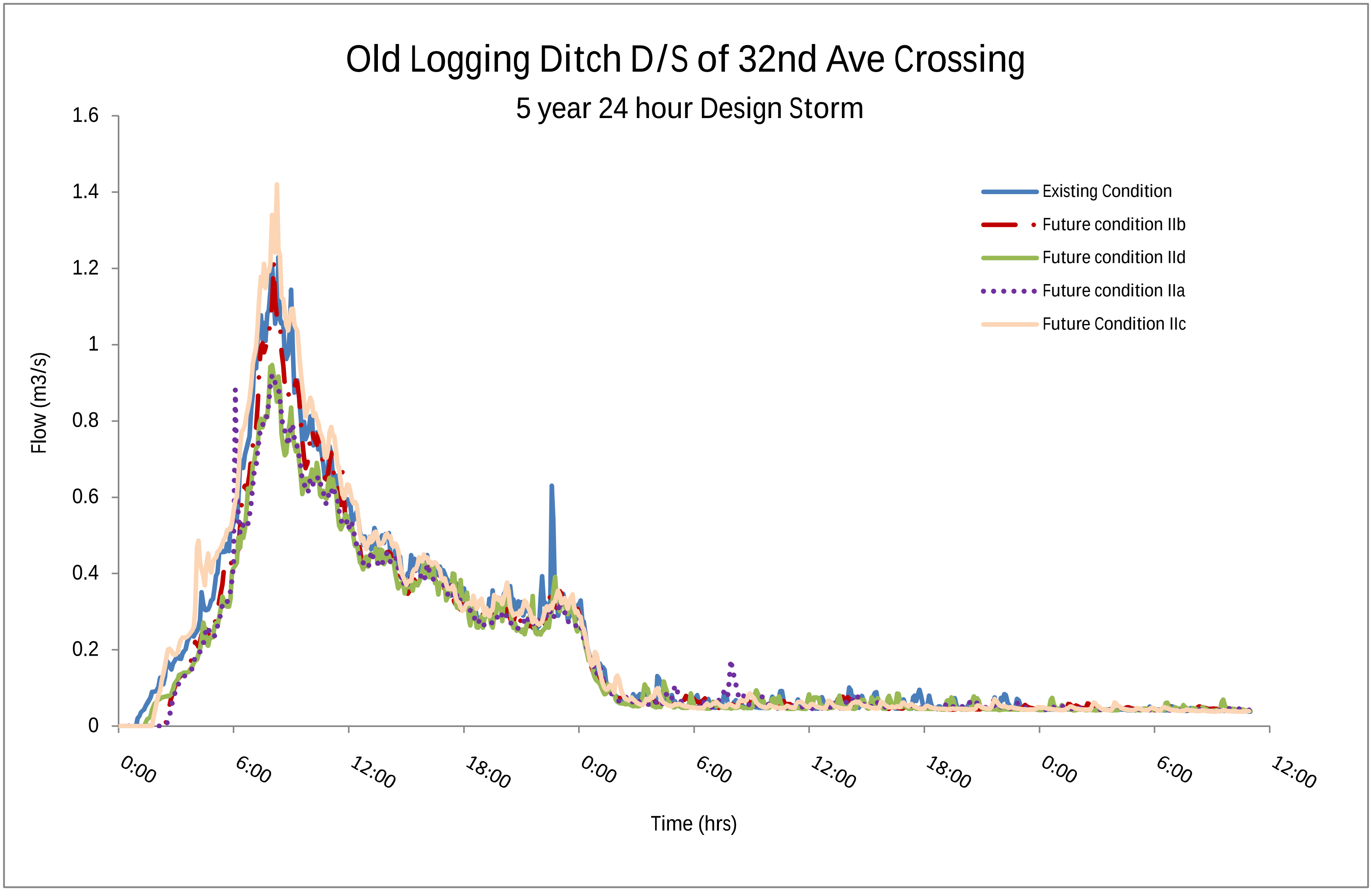
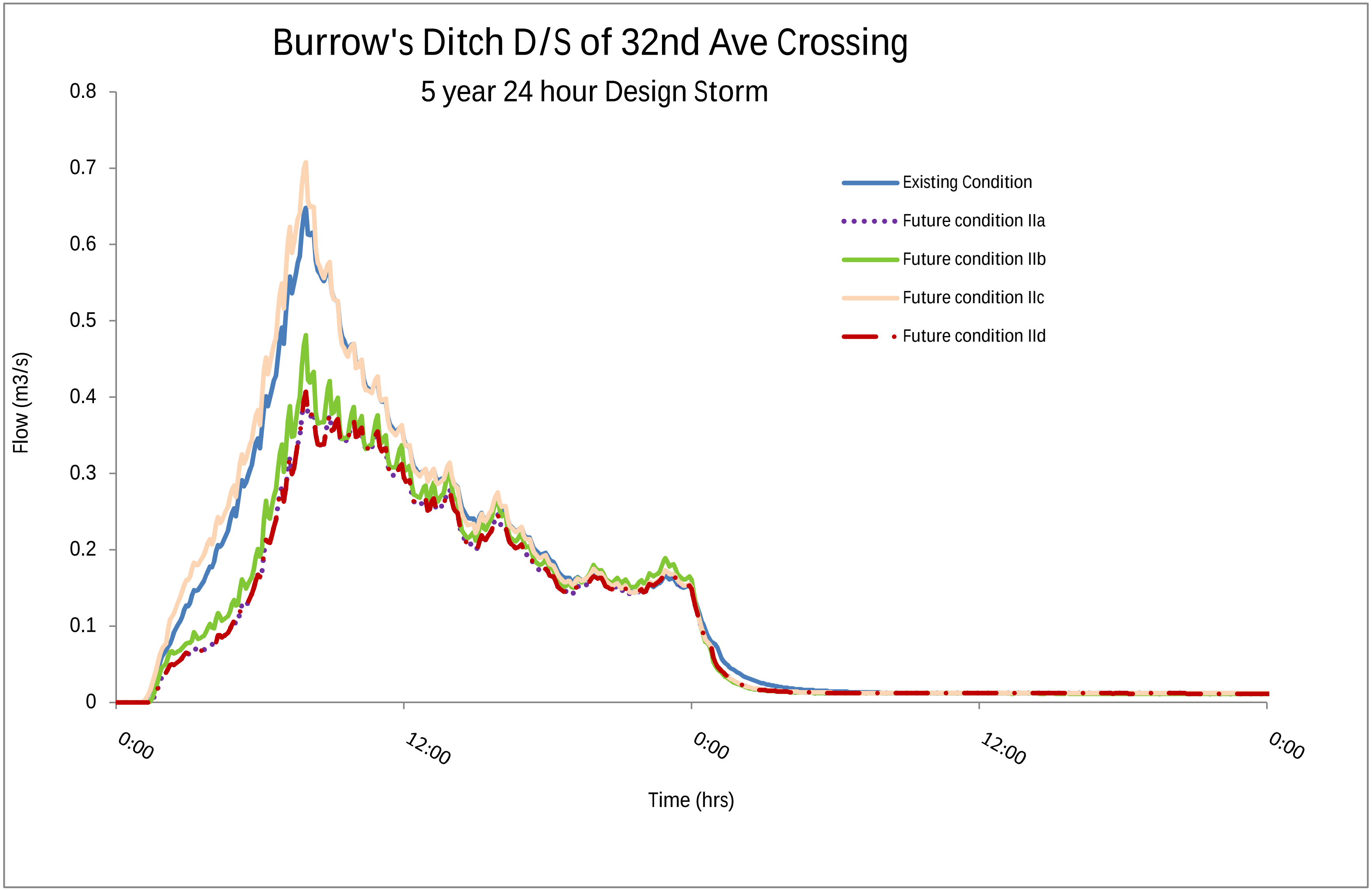


Figure 15(iv)



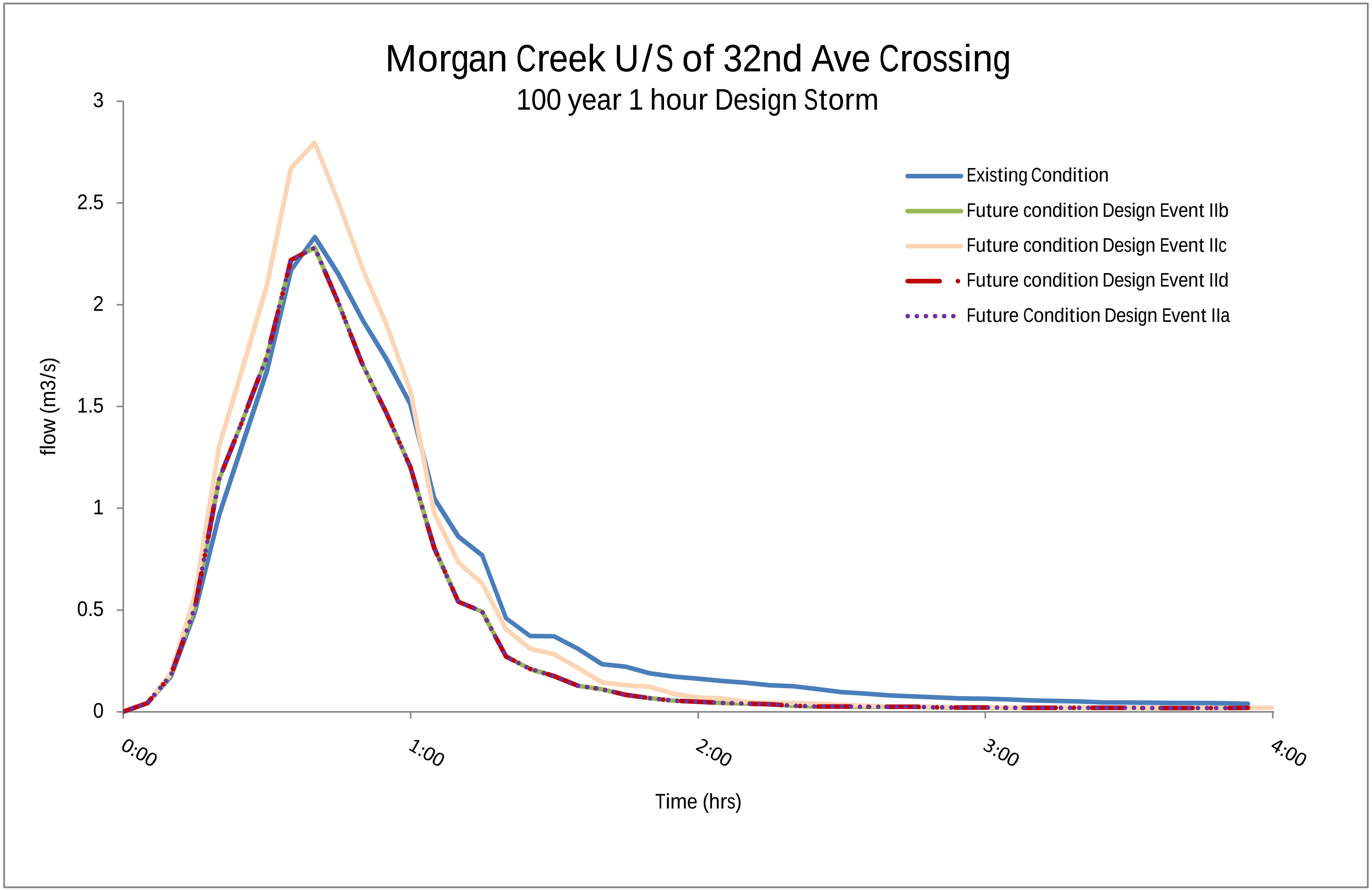
Old Logging Ditch D/S of 32nd Ave Crossing
5 year 24 hour Design Storm
Flow (m3/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IId
Future condition IIa
Future Condition IIc

Figure 15(v)



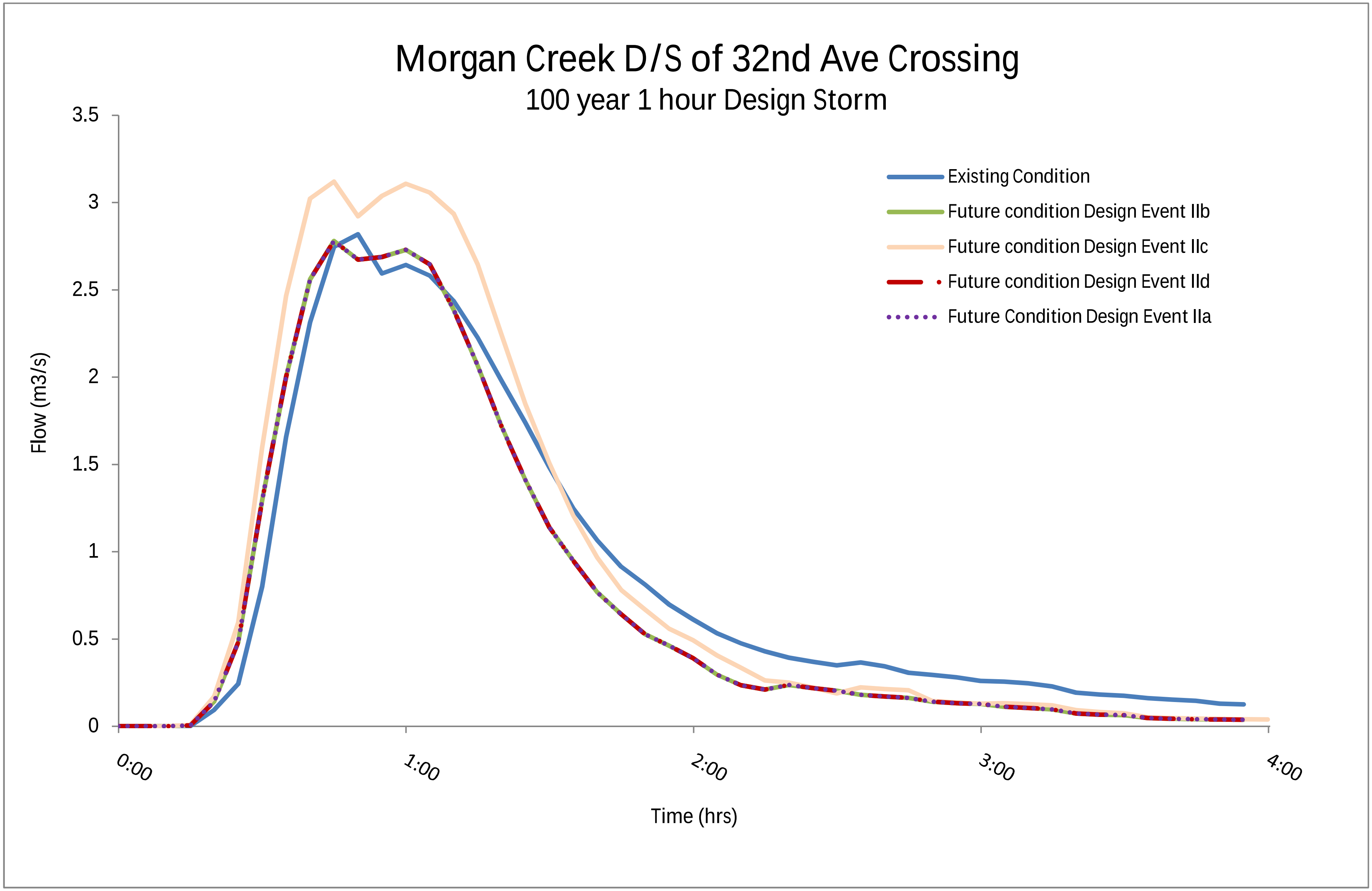
Burrow's Ditch D/S of 32nd Ave Crossing
5 year 24 hour Design Storm
Flow (m3/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0:00
12:00
0:00
12:00
0:00
Time (hrs)
Existing Condition
Future condition IIa
Future condition IIb
Future condition IIc
Future condition IId

Figure 16(i)



Morgan Creek U/S of 32nd Ave Crossing
100 year 1 hour Design Storm
flow (m3/s)
3
2.5
2
1.5
1
0.5
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 16(ii)



Morgan Creek D/S of 32nd Ave Crossing
100 year 1 hour Design Storm
Flow (m3/s)
3.5
3
2.5
2
1.5
1
0.5
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 16(iii)

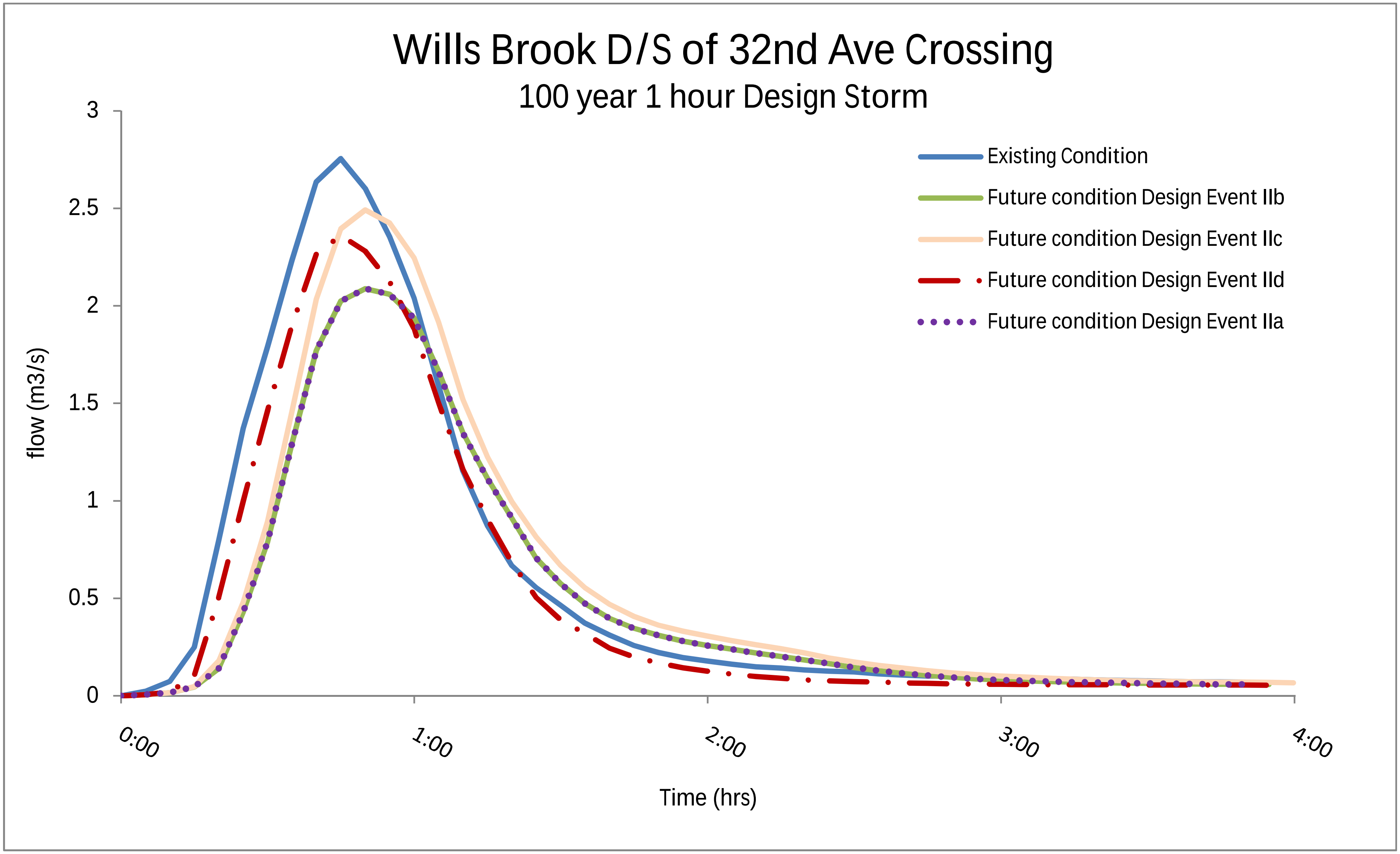


Figure 16 (iv)

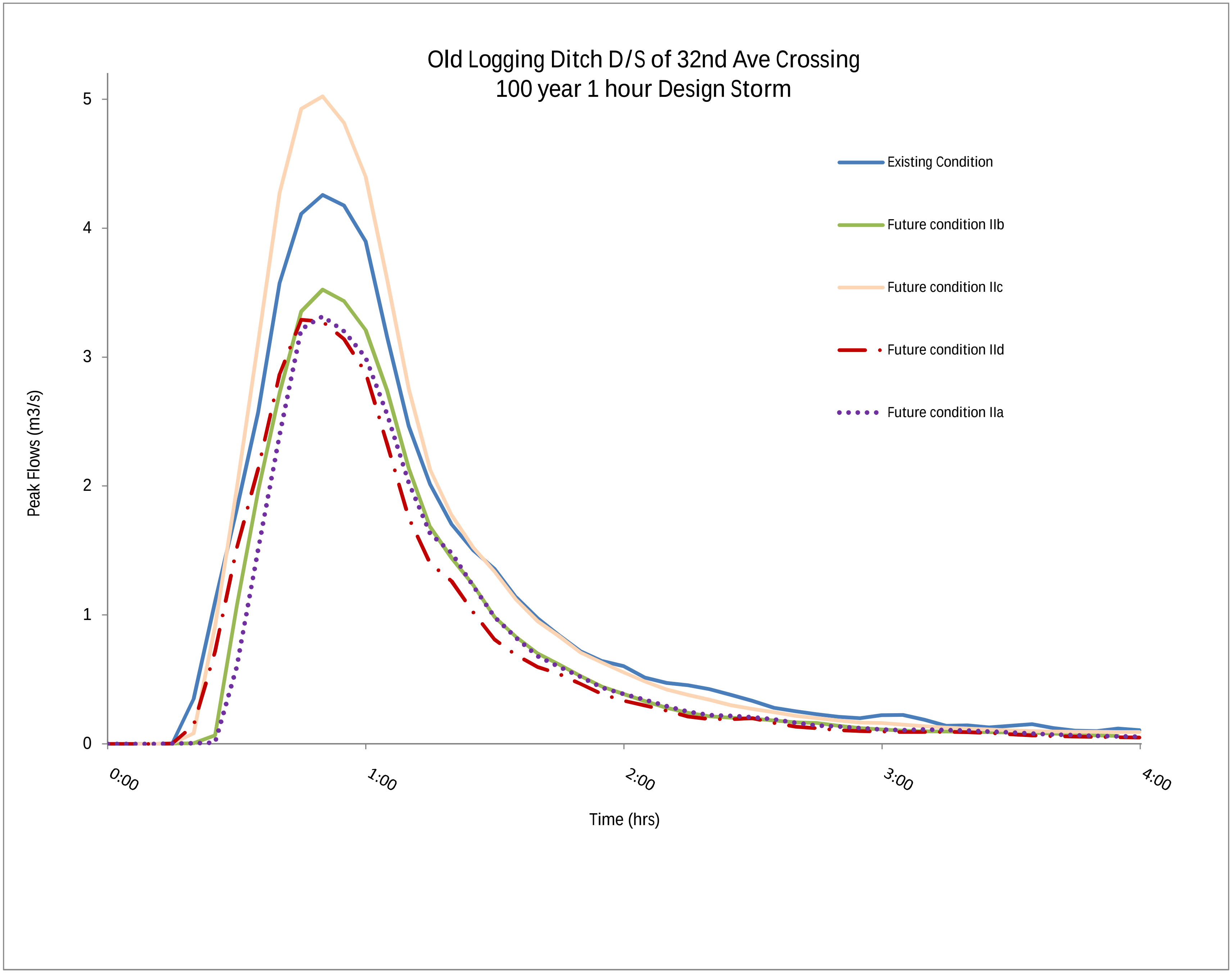
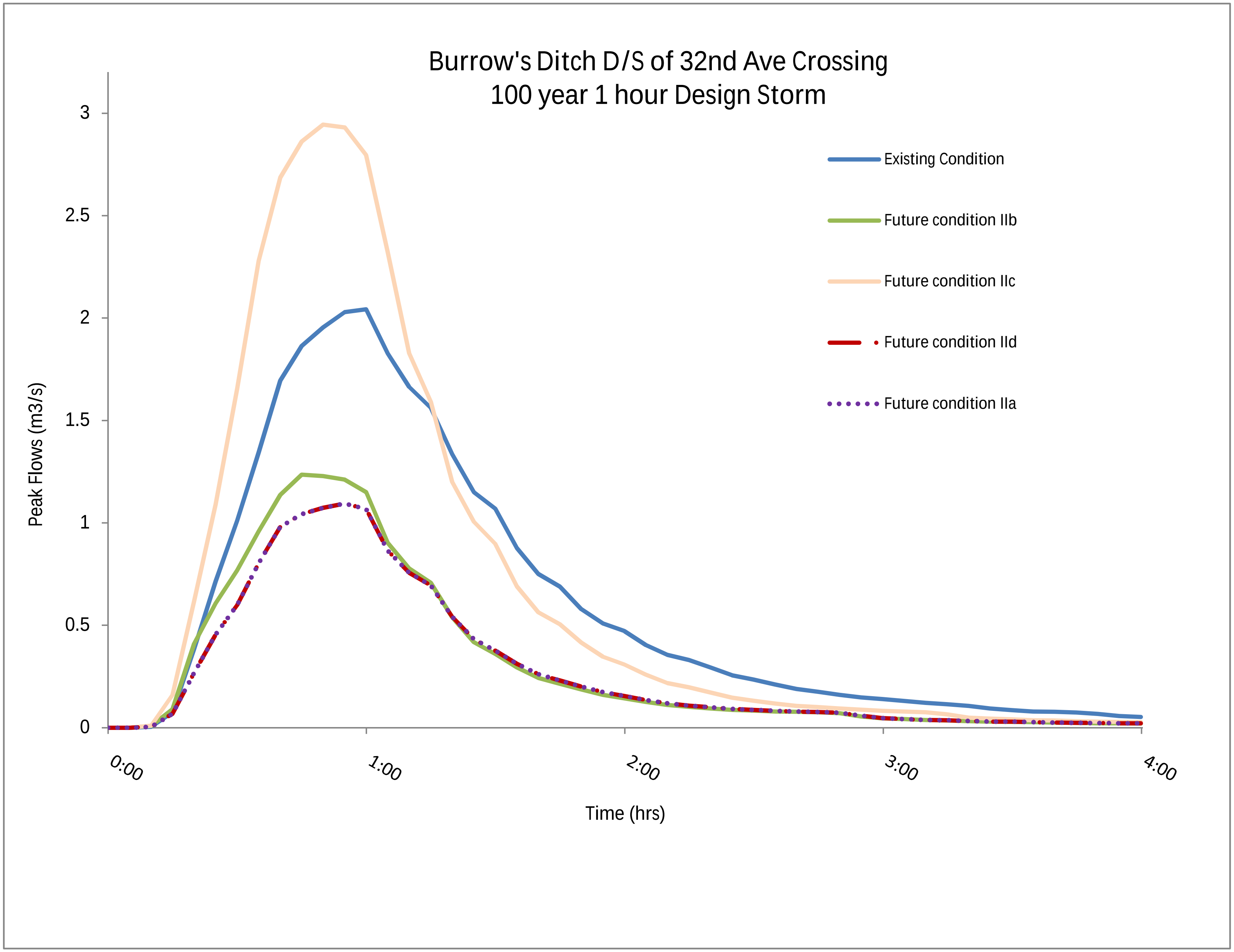

Old Logging Ditch D/S of 32nd Ave Crossing
100 year 1 hour Design Storm
Peak Flows (m3/s)
0
1
2
3
4
5
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future condition IIa

Figure 16 (v)



Burrow's Ditch D/S of 32nd Ave Crossing
100 year 1 hour Design Storm
Peak Flows (m3/s)
3
2.5
2
1.5
1
0.5
0
0:00
1:00
2:00
3:00
4:00
Time (hrs)
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future condition IIa

Figure 17(i)

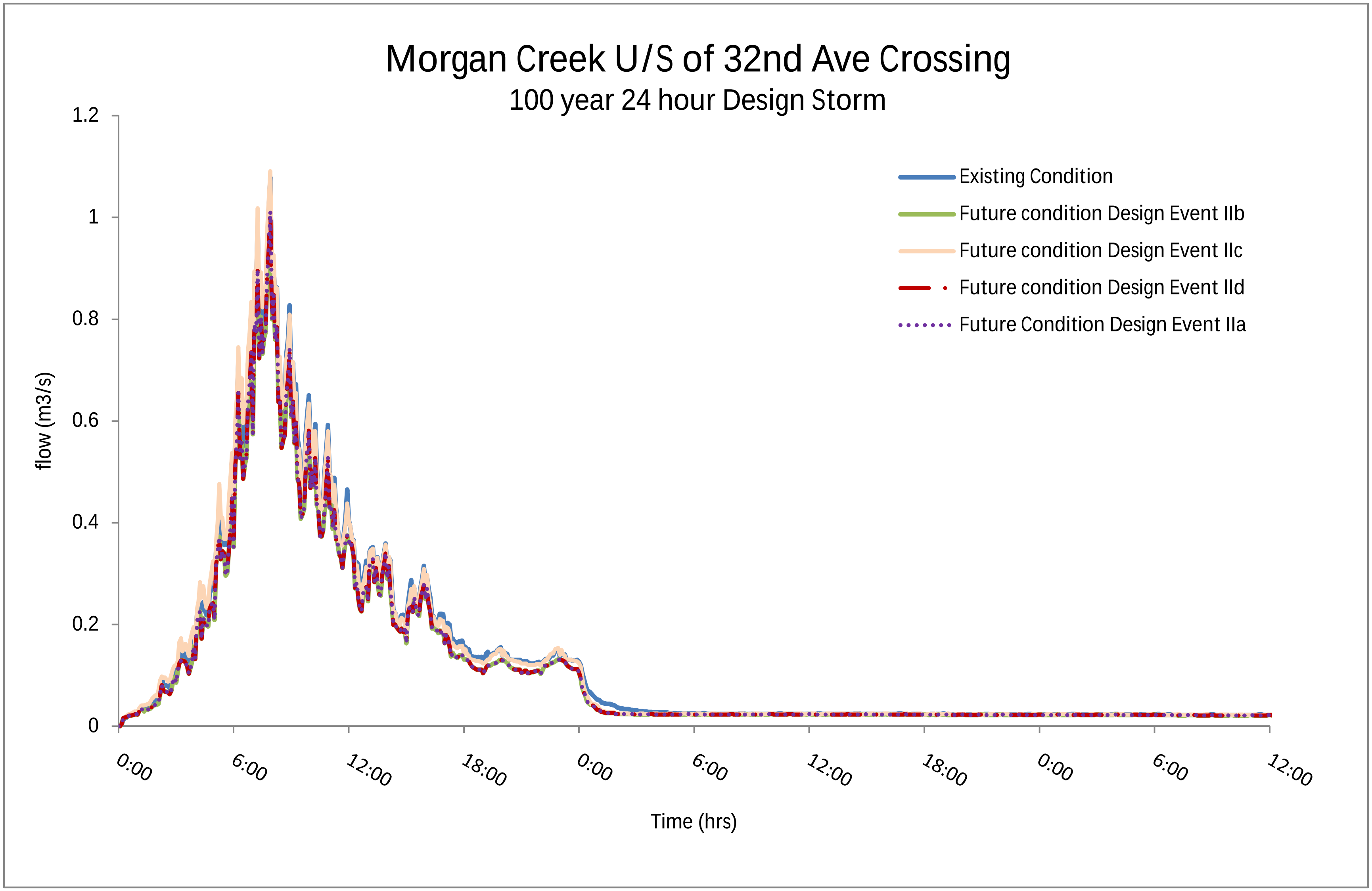

Morgan Creek U/S of 32nd Ave Crossing
100 year 24 hour Design Storm
1.2
1
0.8
0.6
0.4
0.2
0
flow (m3/s)
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
Time (hrs)
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 17(ii)

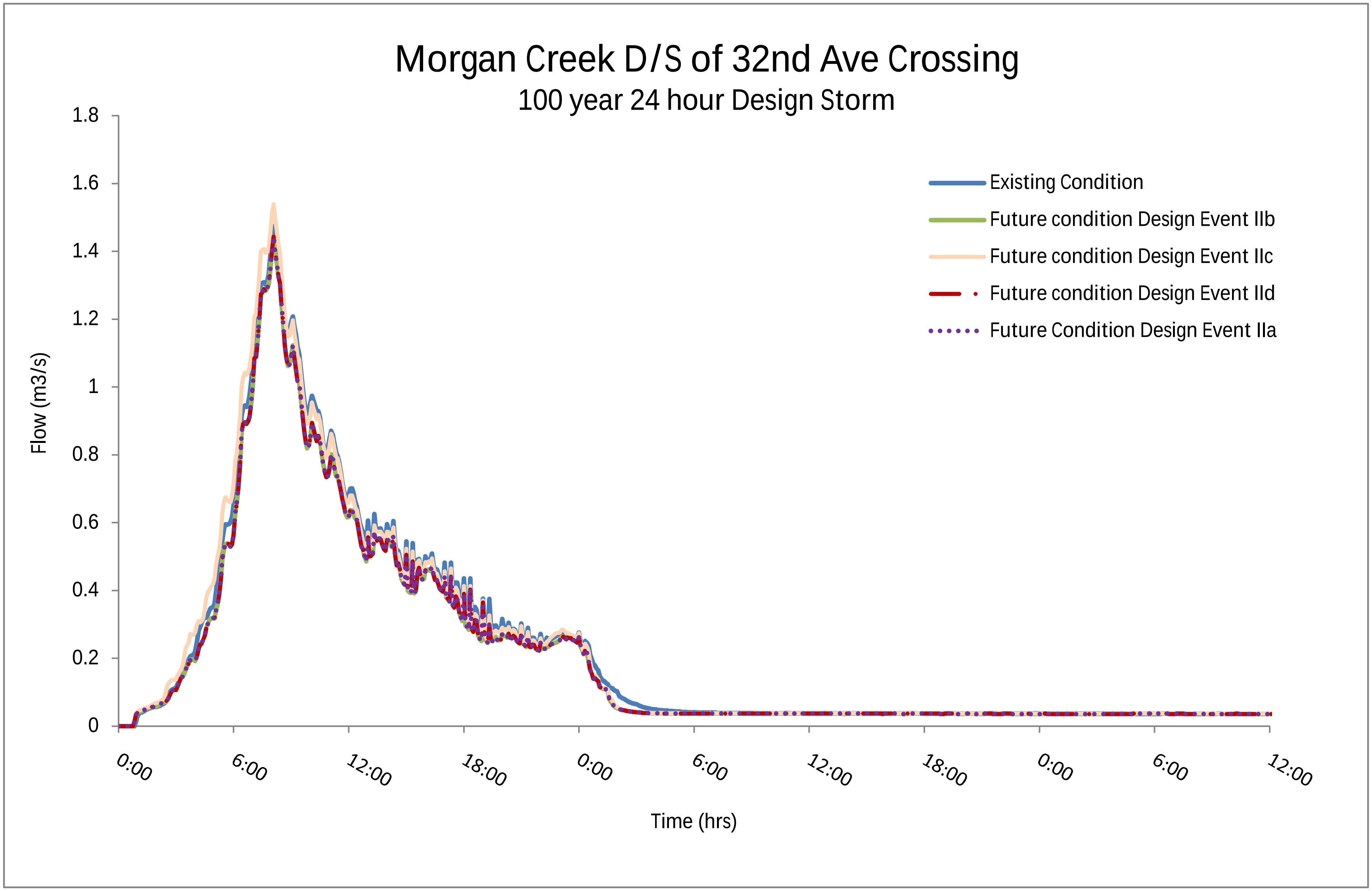

Morgan Creek D/S of 32nd Ave Crossing
100 year 24 hour Design Storm
Flow (m3/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
Time (hrs)

Figure 17(iii)

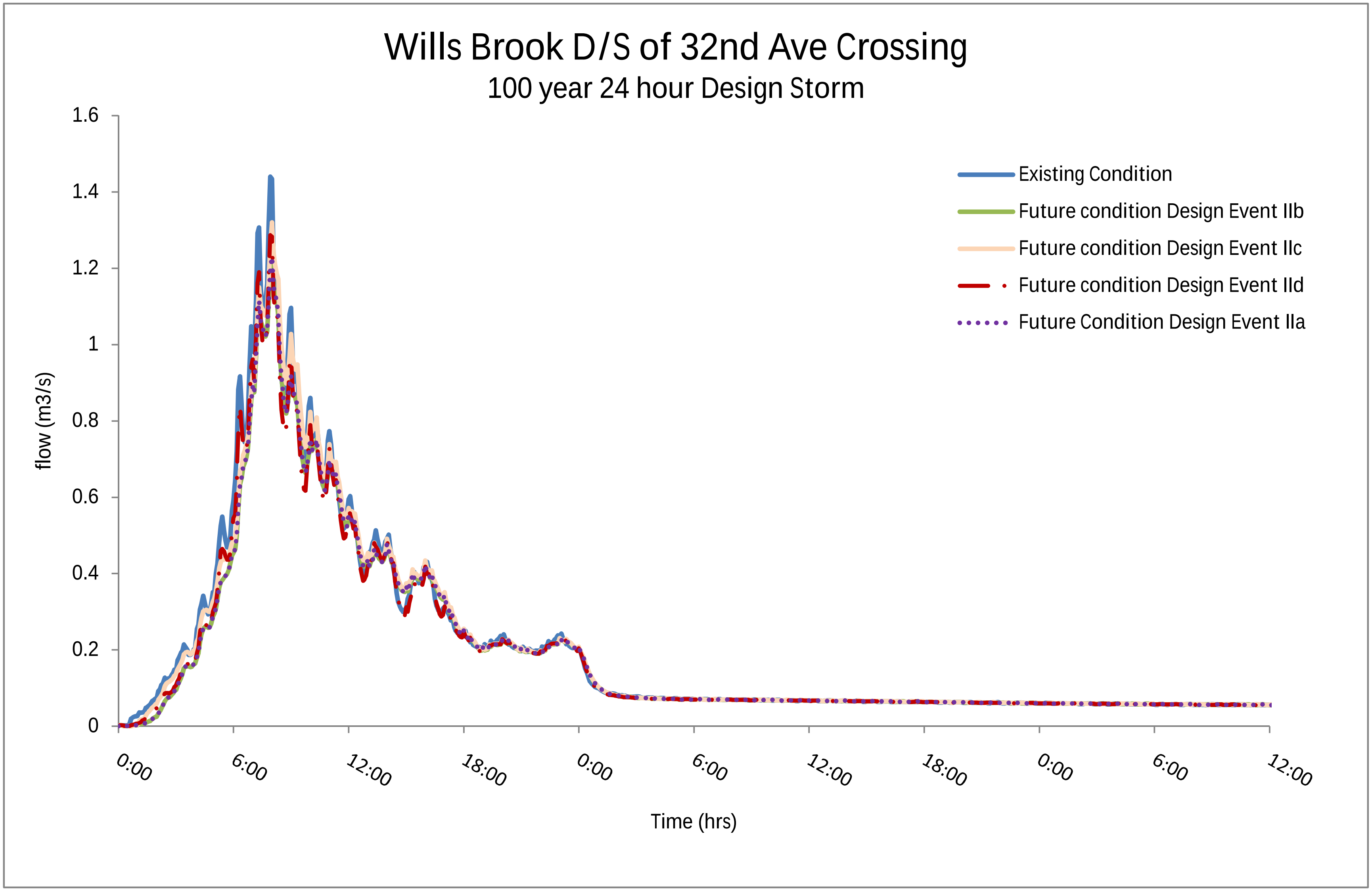
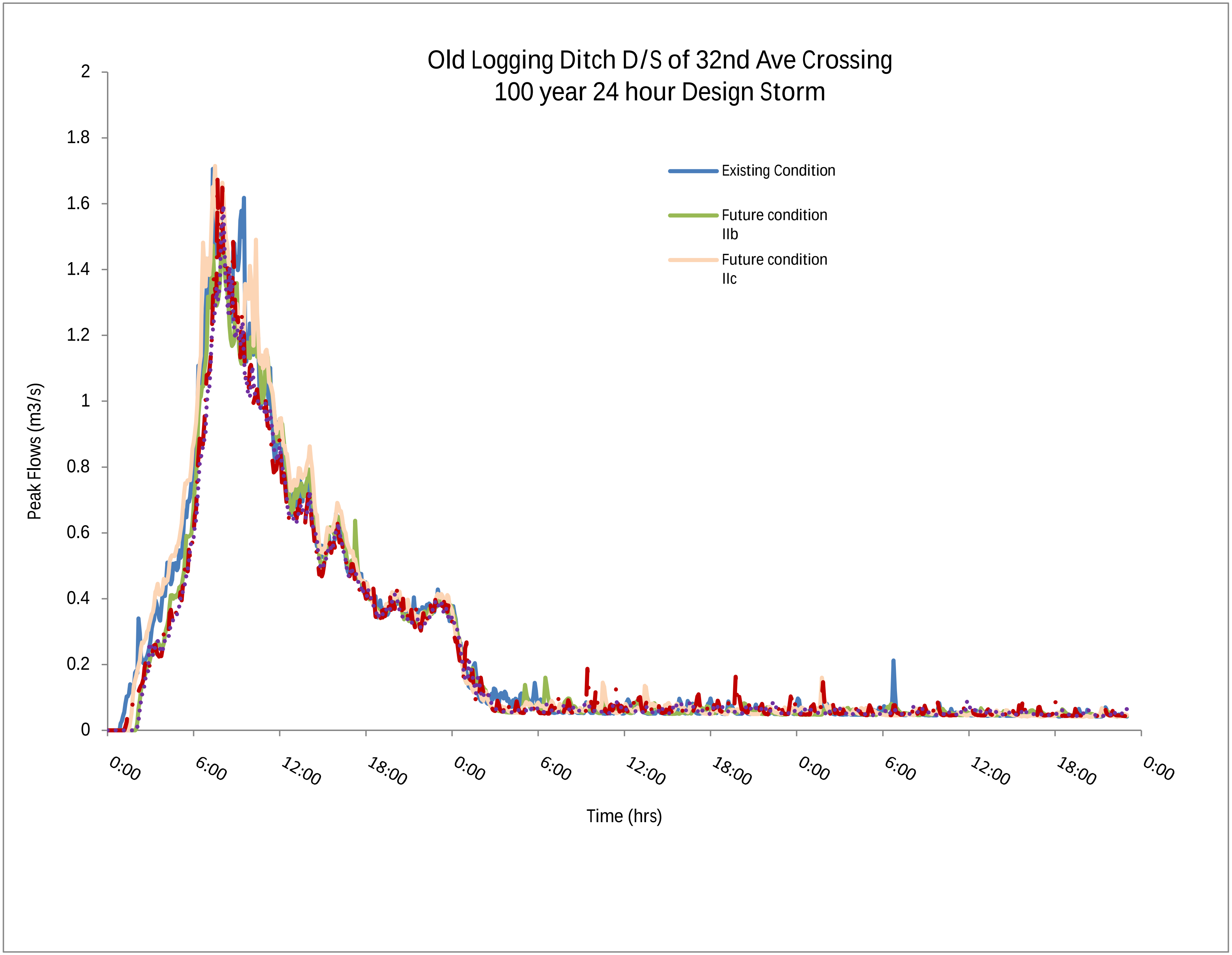
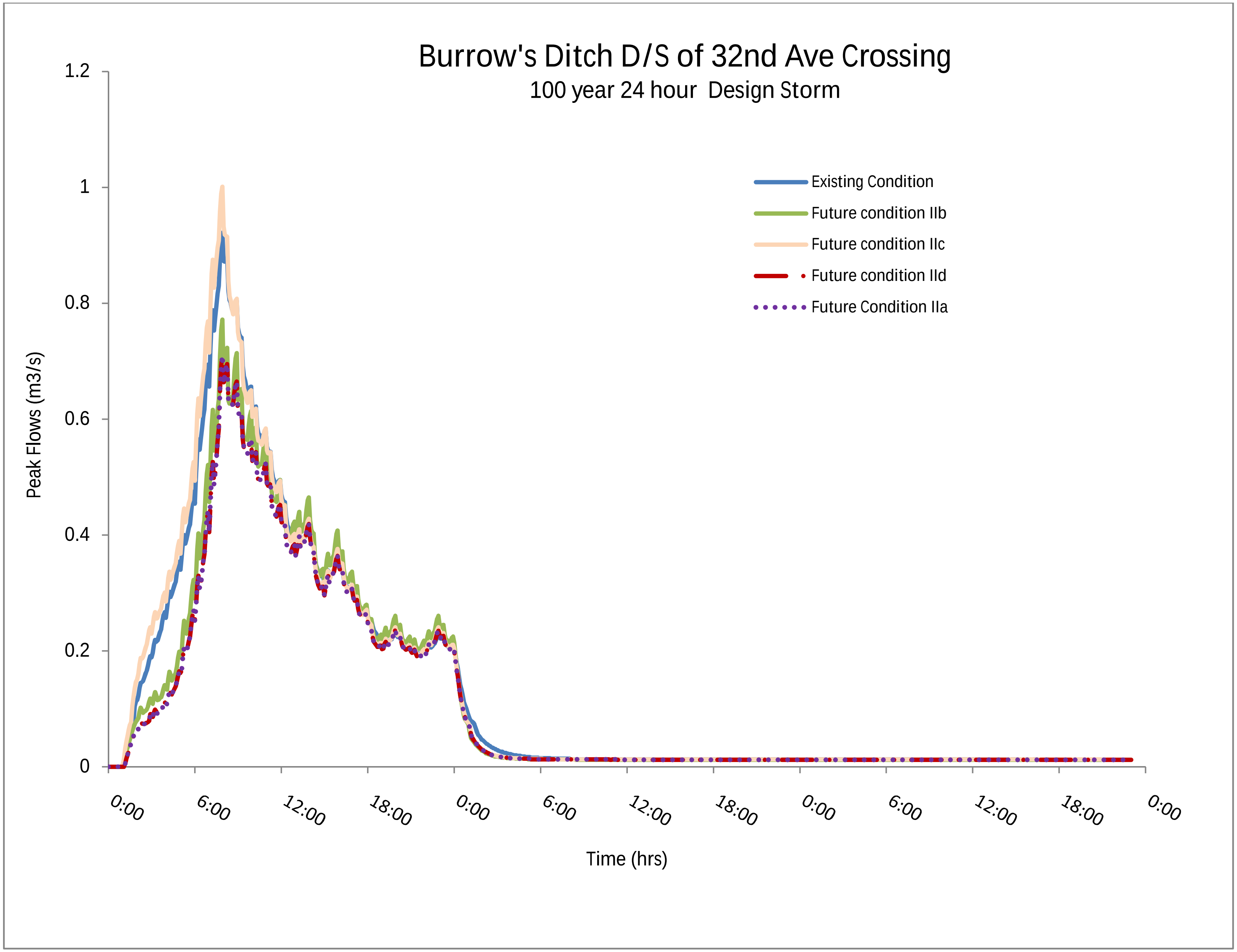


Figure 17 (iv)

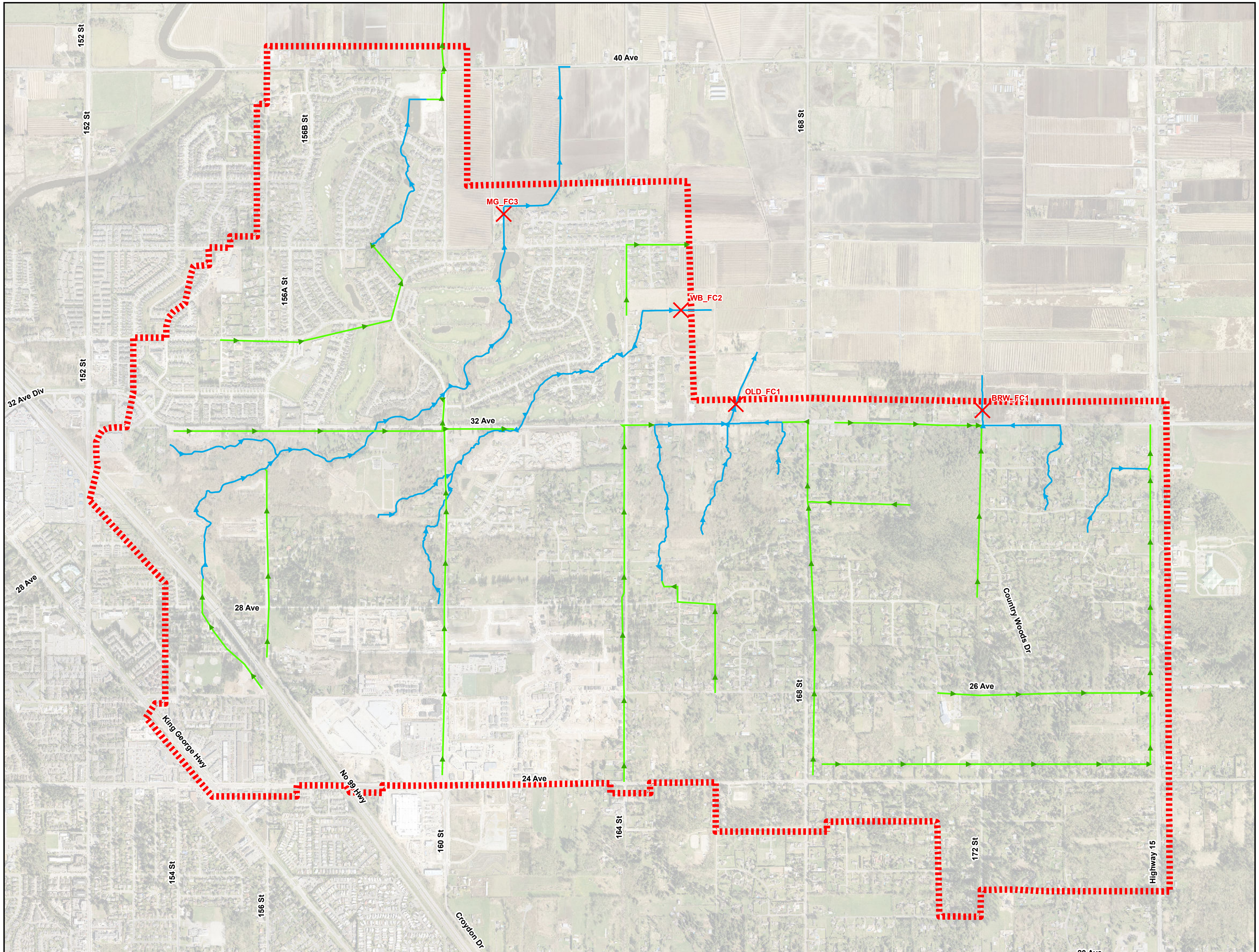


Old Logging Ditch D/S of 32nd Ave Crossing
100 year 24 hour Design Storm
Existing Condition
Future condition IIb
Future condition IIc
Peak Flows (m3/s)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)

Figure 17 (v)



Burrow's Ditch D/S of 32nd Ave Crossing
100 year 24 hour Design Storm
Peak Flows (m3/s)
1.2
1
0.8
0.6
0.4
0.2
0
Existing Condition
Future condition IIb
Future condition IIc
Future condition IId
Future Condition IIa
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
6:00
12:00
18:00
0:00
Time (hrs)



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

ARDSA Flow Measurement Locations

Figure 18

Legend

- ARDSA Flow Locations
- Modeled Natural Channel
- Modeled Pipe
- Model Domain

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\GIS\Projects\mxds\2010_08_26_FinalReport_TechnicalAppdx\Figure18_ARDSA_FlowLocations.mxd Last revised by: bpauls on 27/08/2010 at 9:01:36 AM

Figure 19(i)

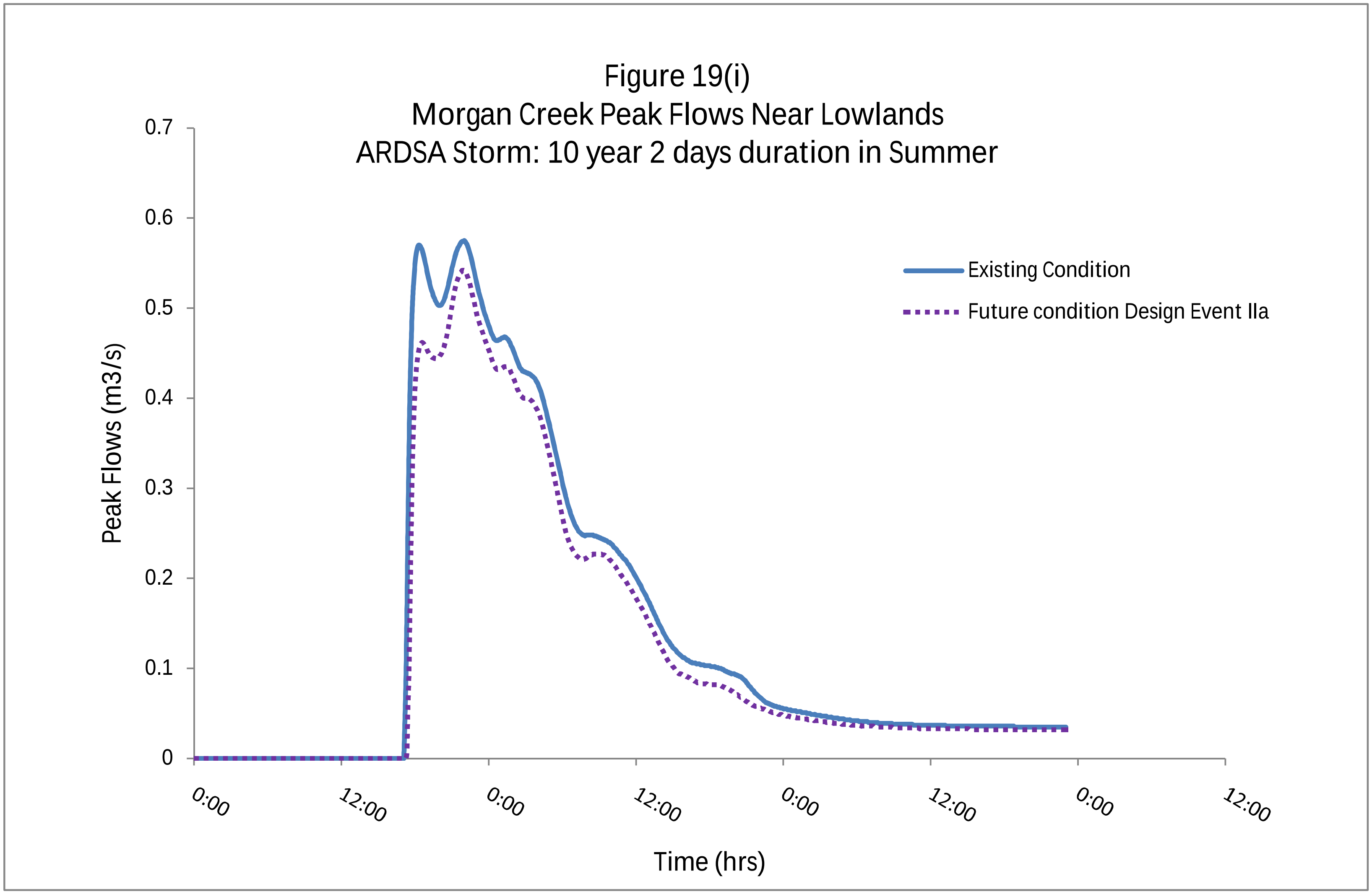


Figure 19(i)
Morgan Creek Peak Flows Near Lowlands
ARDSA Storm: 10 year 2 days duration in Summer
Peak Flows (m3/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Existing Condition
Future condition Design Event IIa
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time (hrs)

Figure 19(ii)

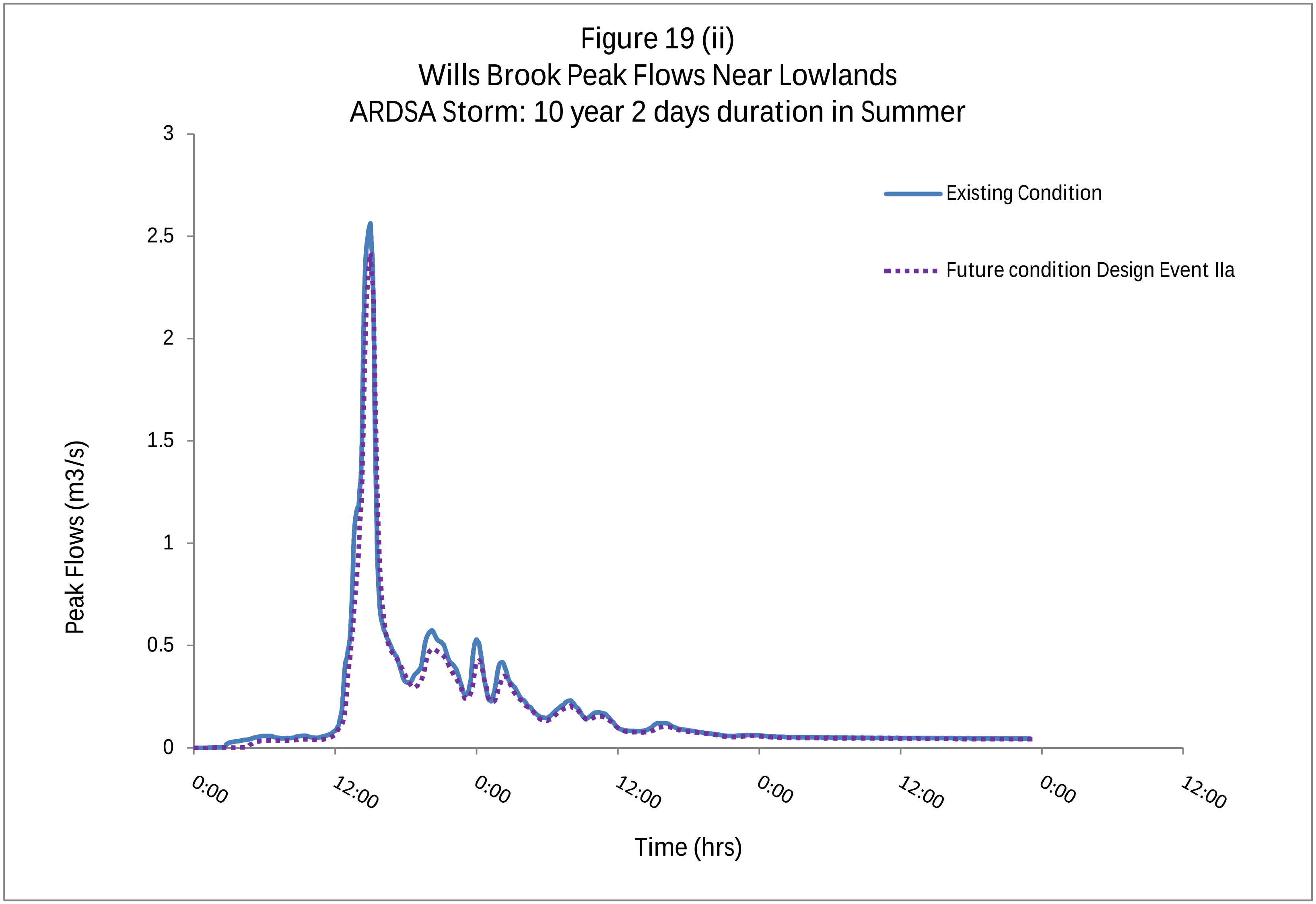


Figure 19 (ii)
Wills Brook Peak Flows Near Lowlands
ARDSA Storm: 10 year 2 days duration in Summer
Peak Flows (m3/s)
3
2.5
2
1.5
1
0.5
0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time (hrs)
Existing Condition
Future condition Design Event IIa

Figure 19(iii)

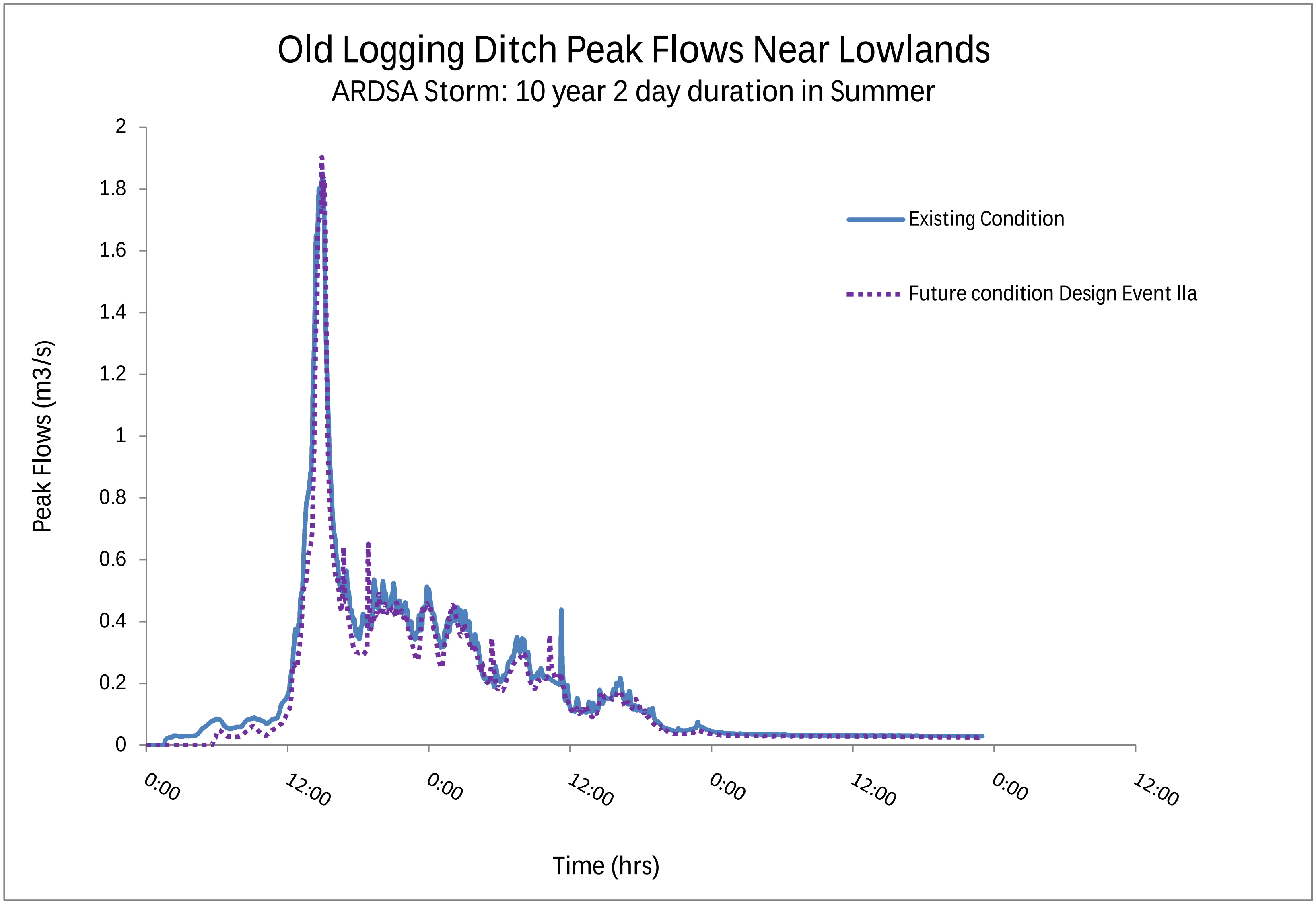
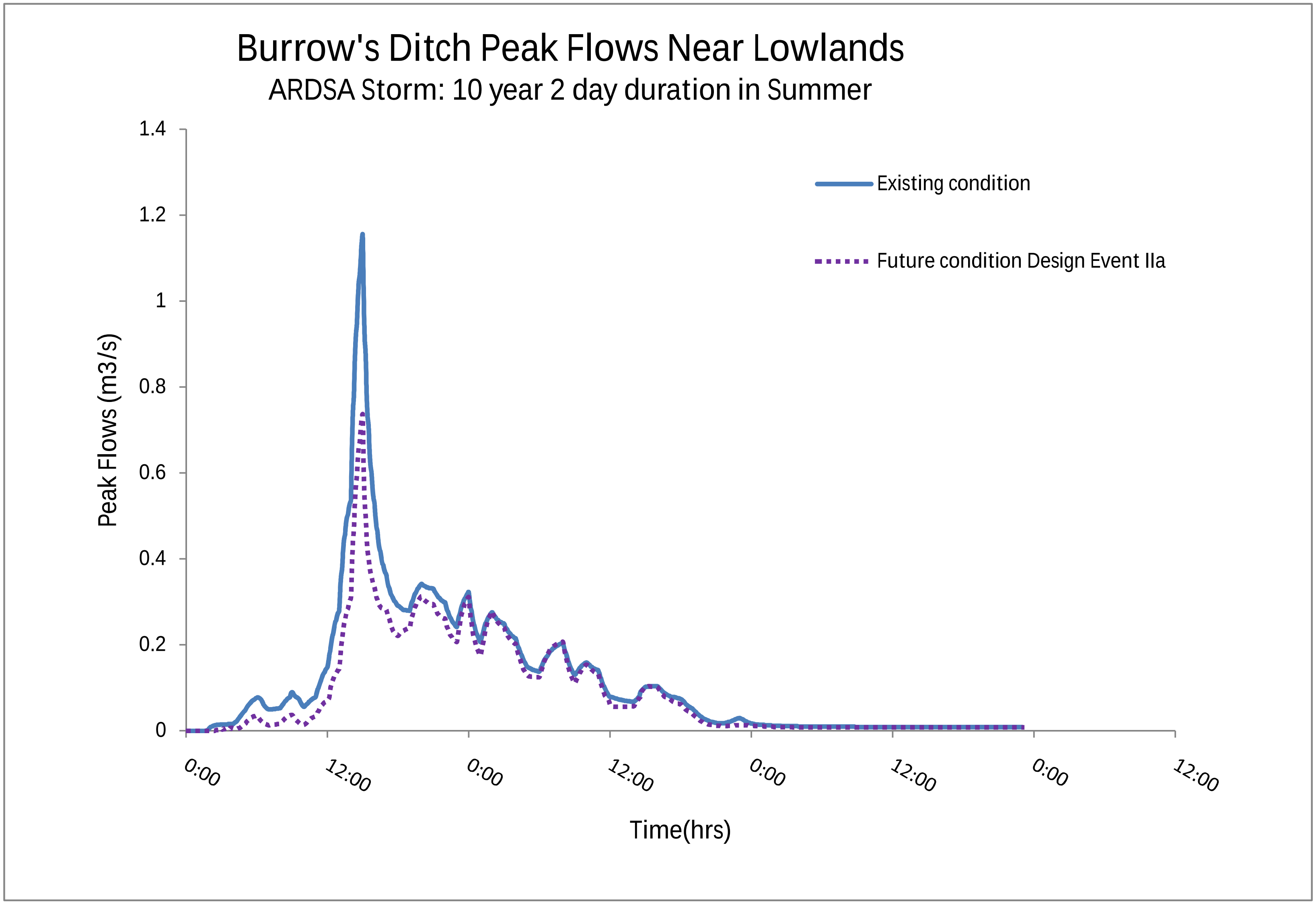


Figure 19(iv)



Burrow's Ditch Peak Flows Near Lowlands
ARDSA Storm: 10 year 2 day duration in Summer
Peak Flows (m3/s)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time(hrs)
Existing condition
Future condition Design Event IIa

Figure 20(i)

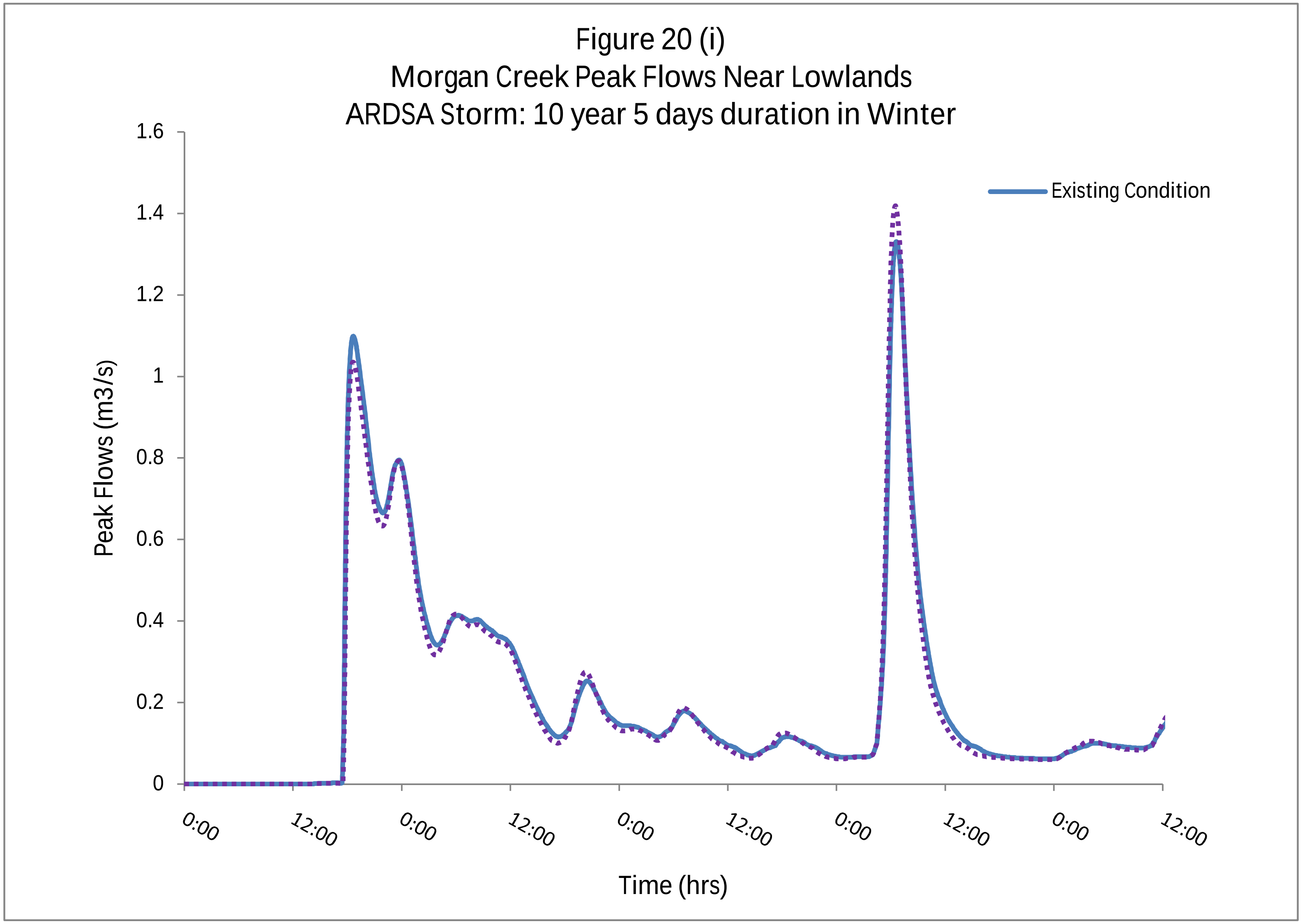
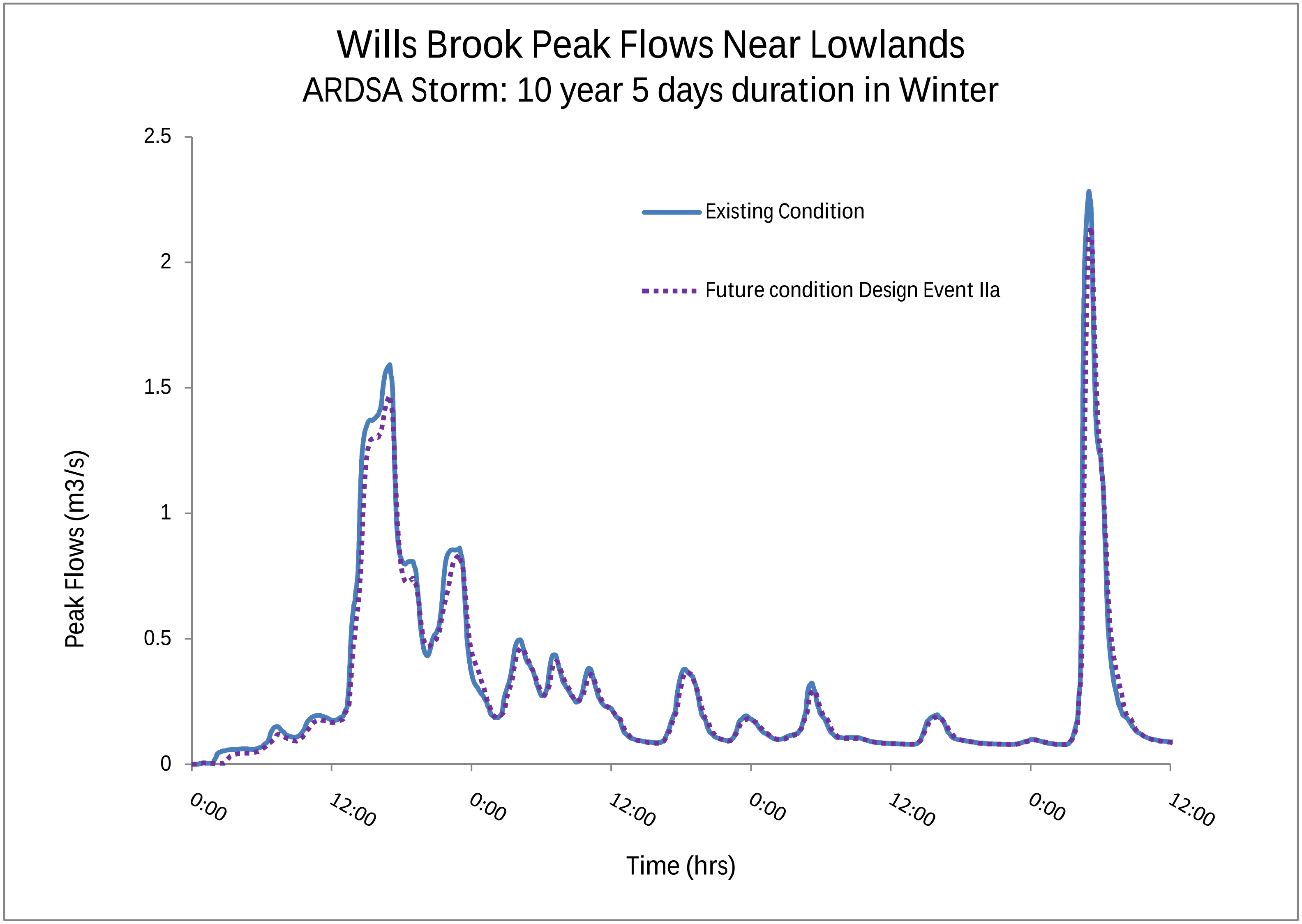


Figure 20 (i)
Morgan Creek Peak Flows Near Lowlands
ARDSA Storm: 10 year 5 days duration in Winter
Existing Condition
Peak Flows (m3/s)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time (hrs)

Figure 20(ii)



Wills Brook Peak Flows Near Lowlands
ARDSA Storm: 10 year 5 days duration in Winter
Existing Condition
Future condition Design Event IIa
Peak Flows (m3/s)
2.5
2
1.5
1
0.5
0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time (hrs)

Figure 20(iii)

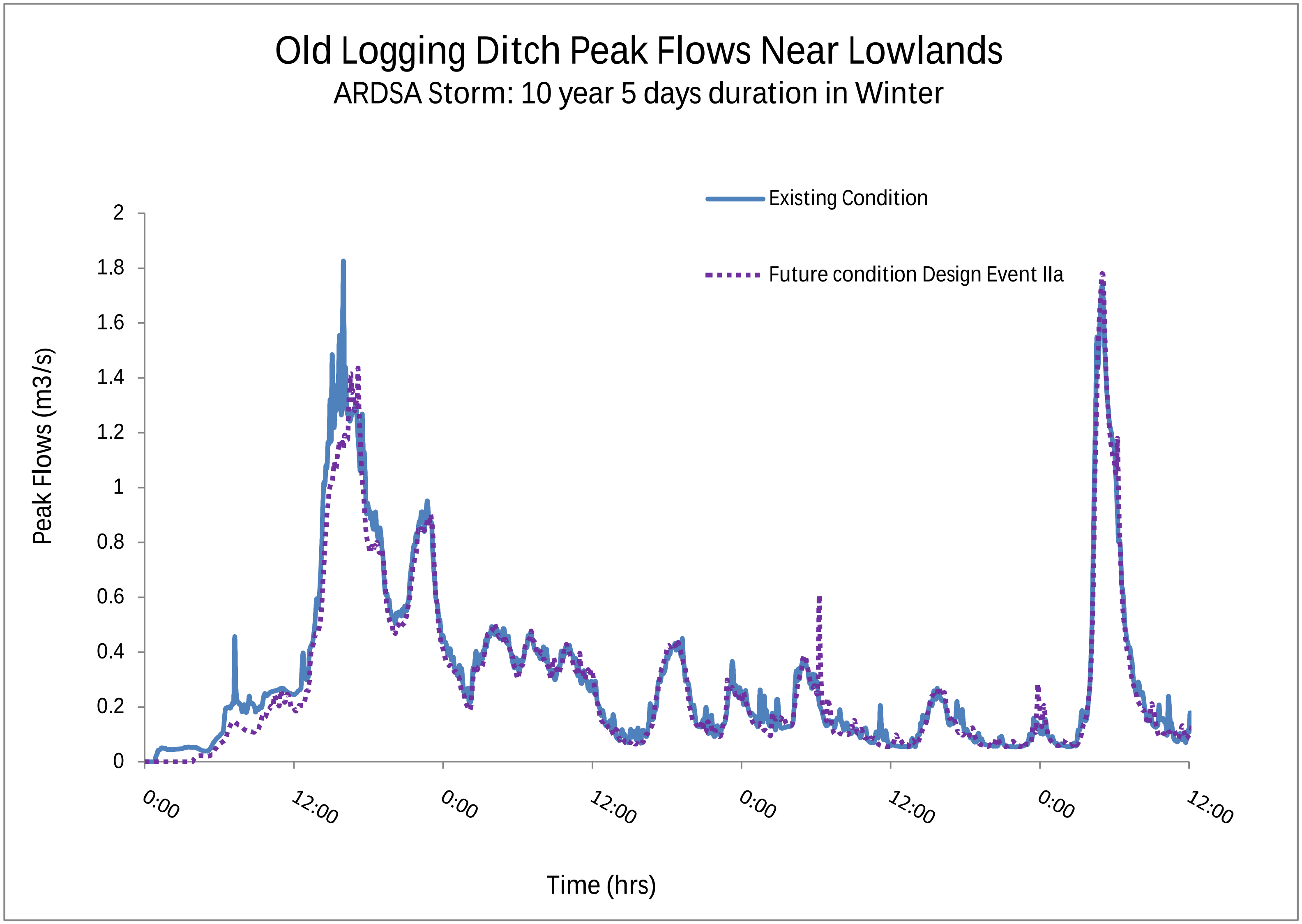


Figure 20(iv)

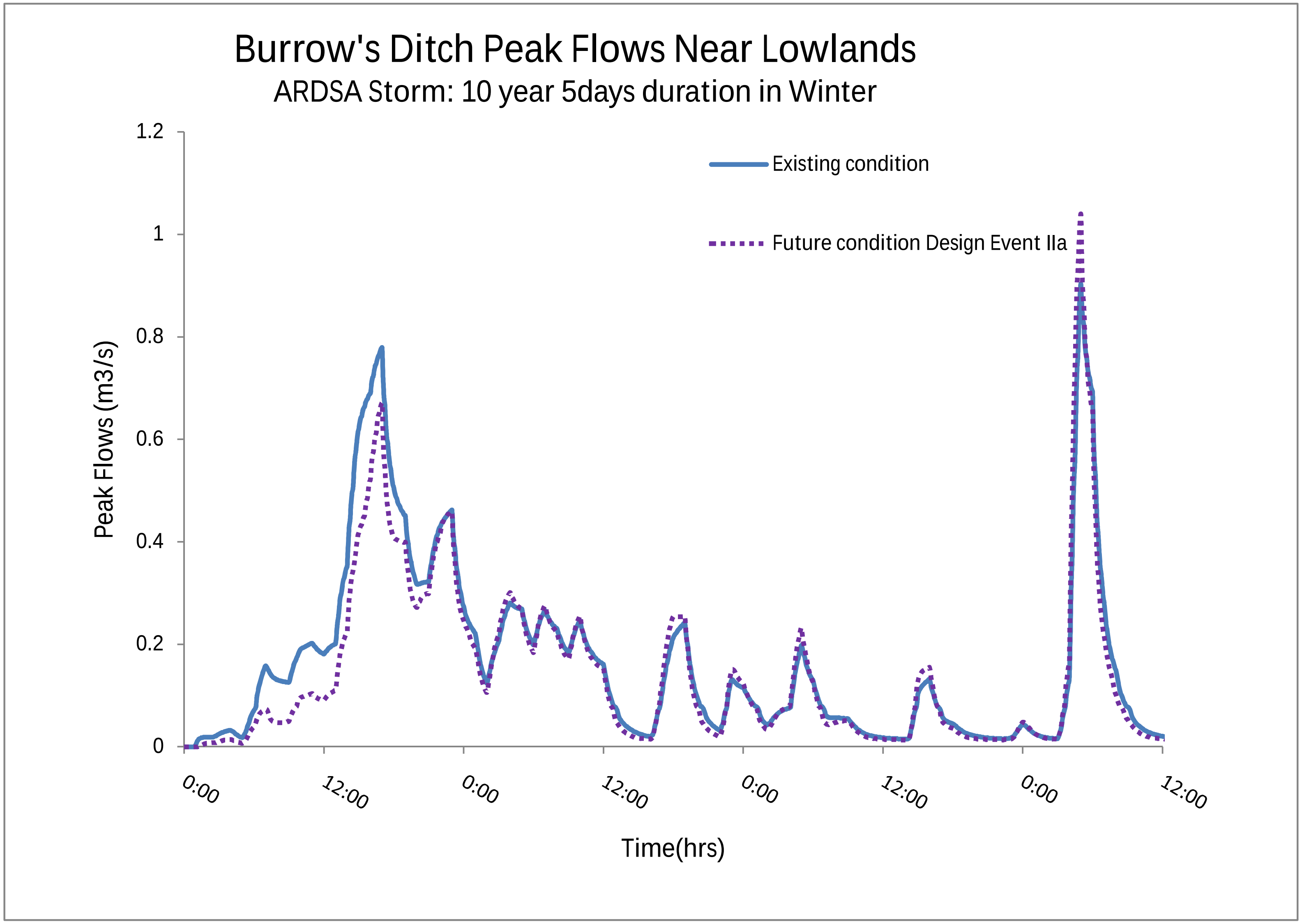
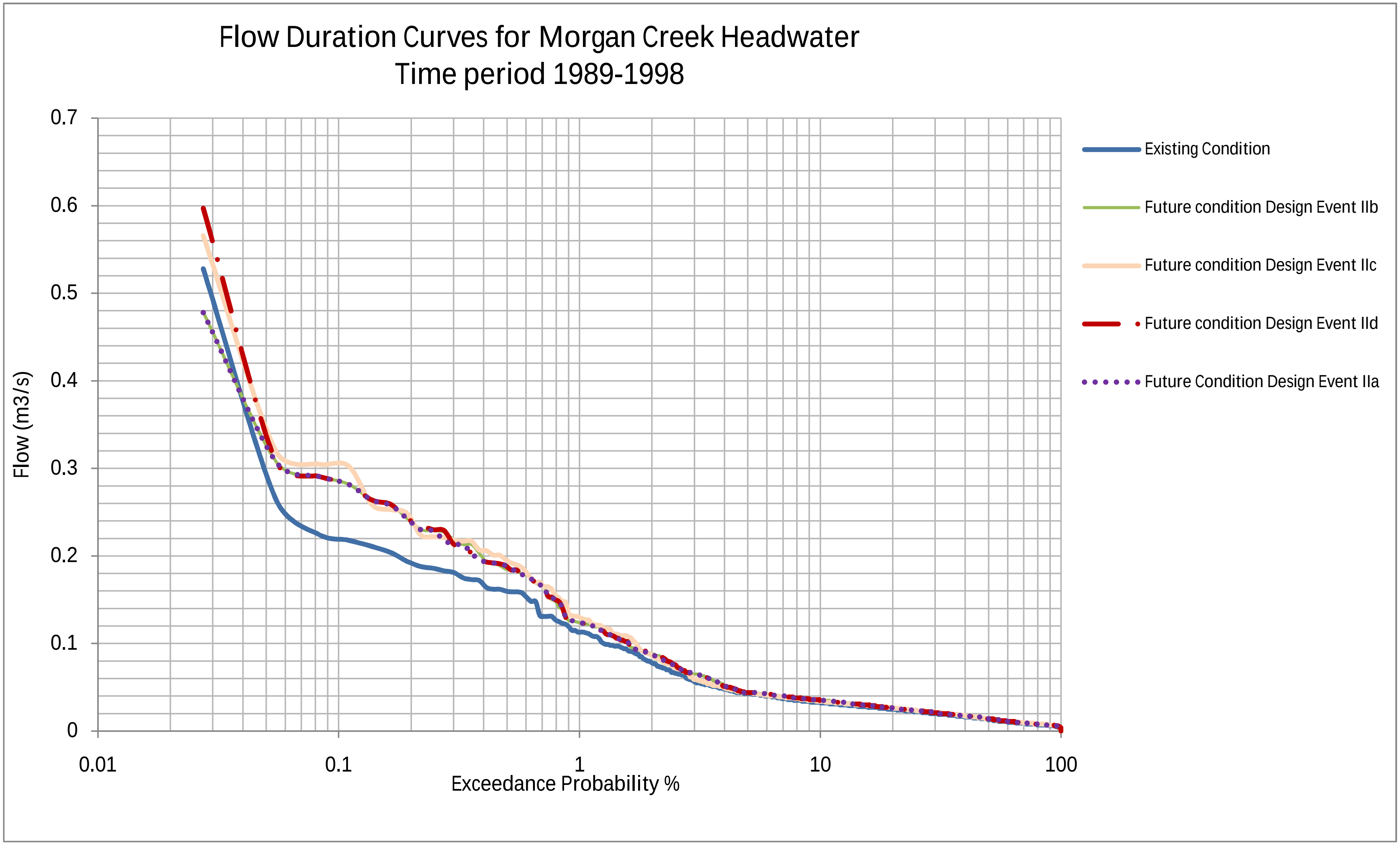

Burrow's Ditch Peak Flows Near Lowlands
ARDSA Storm: 10 year 5days duration in Winter
Peak Flows (m3/s)
1.2
1
0.8
0.6
0.4
0.2
0
Existing condition
Future condition Design Event IIa
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time(hrs)

Figure 21 (i)



Flow Duration Curves for Morgan Creek Headwater
Time period 1989-1998
Flow (m3/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01
0.1
1
10
100
Exceedance Probability %
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future Condition Design Event IIa

Figure 21(ii)

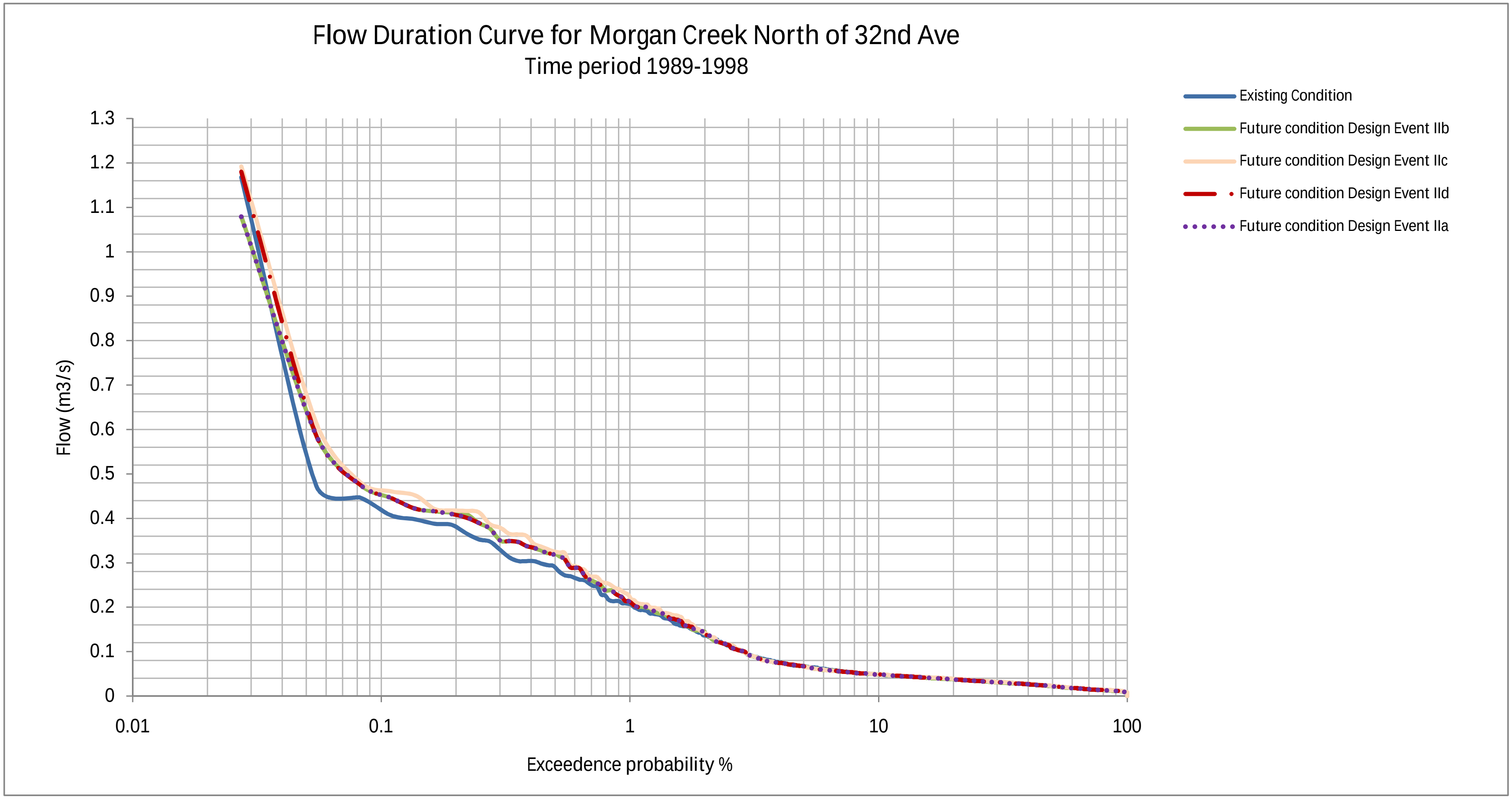

Flow Duration Curve for Morgan Creek North of 32nd Ave
Time period 1989-1998
Flow (m3/s)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.01
0.1
1
10
100
Exceedence probability %
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future condition Design Event IIa

Figure 21 (iii)

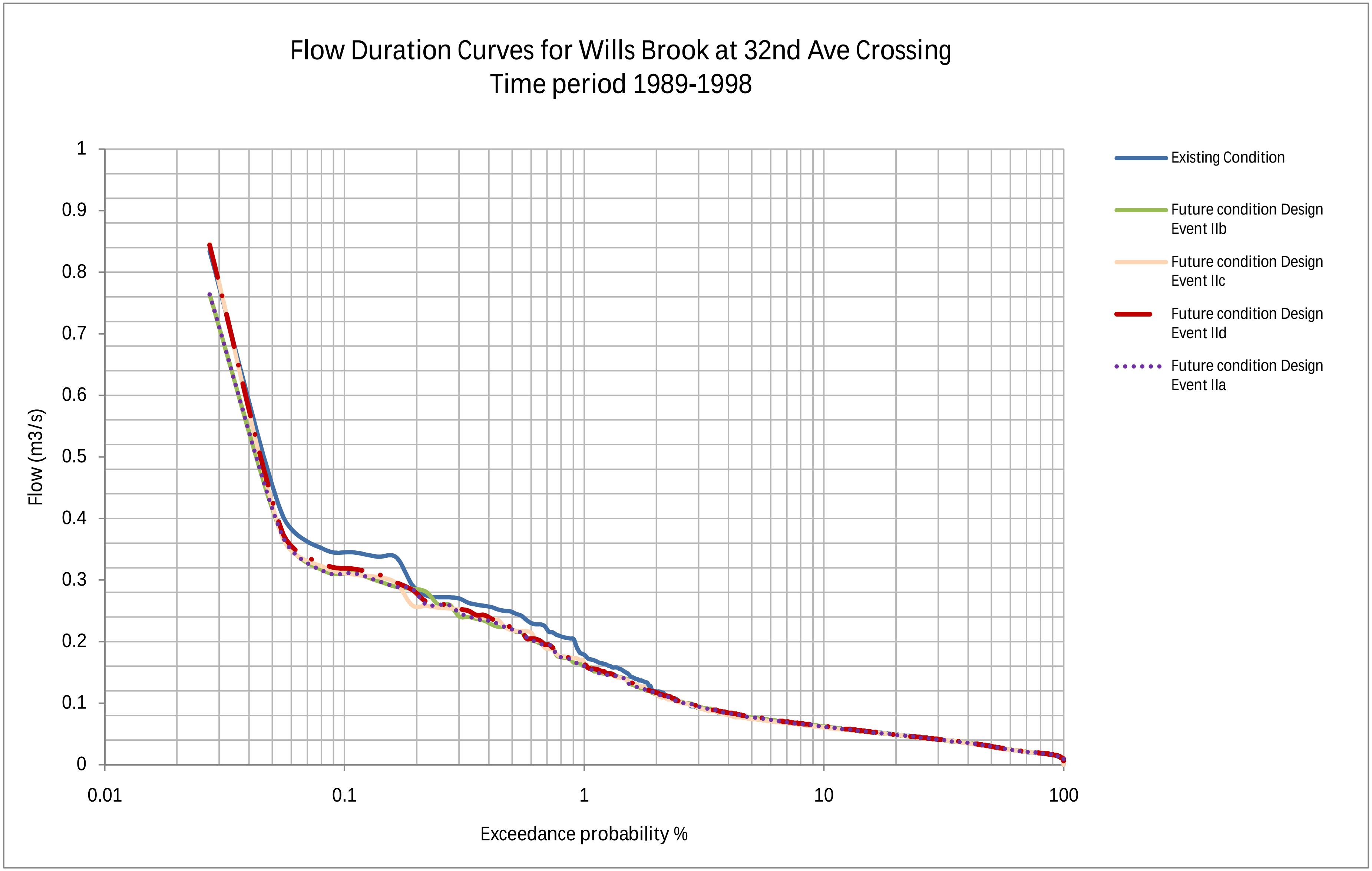
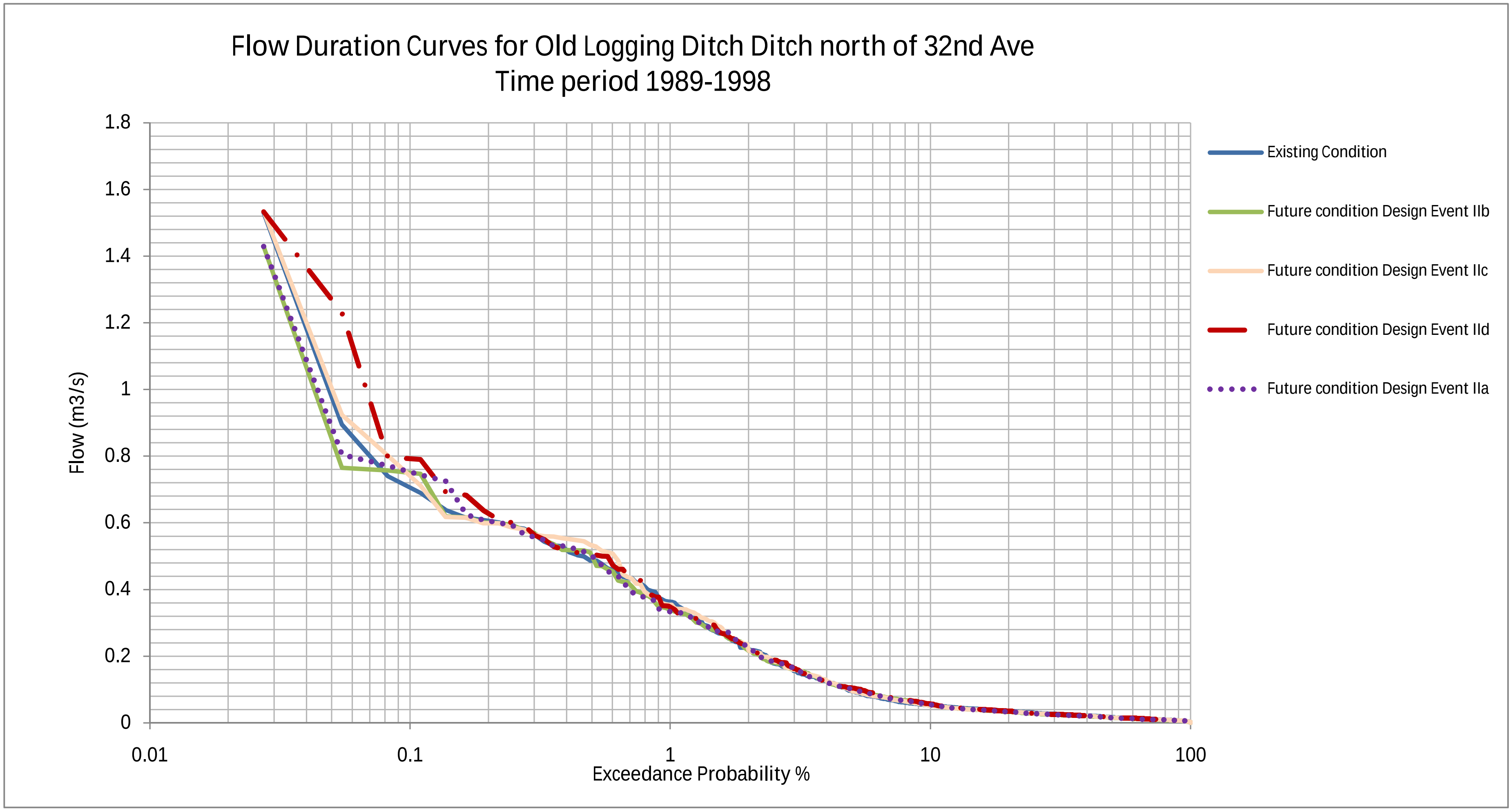
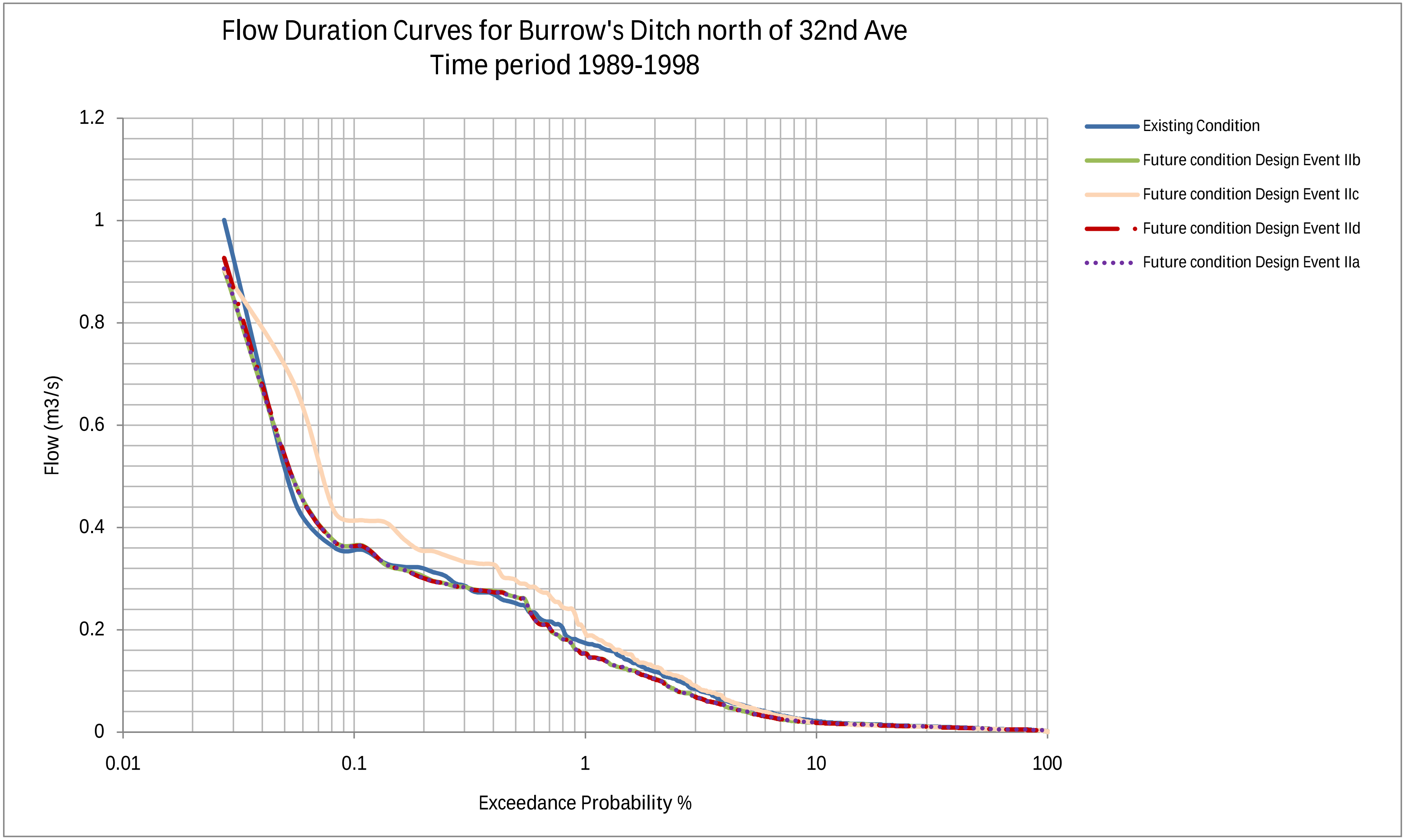


Figure 21 (iv)

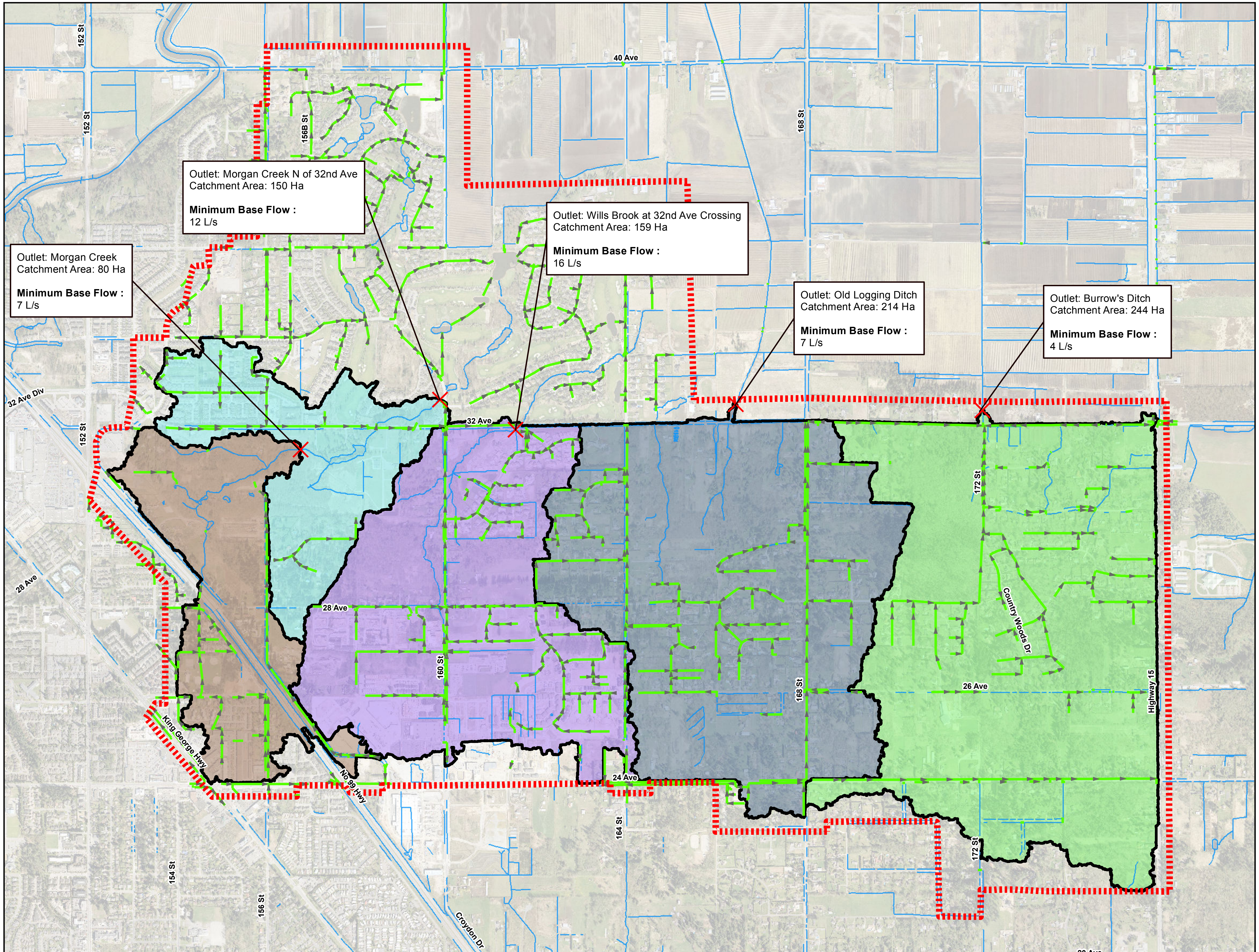


Flow Duration Curves for Old Logging Ditch Ditch north of 32nd Ave
Time period 1989-1998
Flow (m3/s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.01
0.1
1
10
100
Exceedance Probability %
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future condition Design Event IIa

Figure 21 (v)



Flow Duration Curves for Burrow's Ditch north of 32nd Ave
Time period 1989-1998
Flow (m3/s)
1.2
1
0.8
0.6
0.4
0.2
0
0.01
0.1
1
10
100
Exceedance Probability %
Existing Condition
Future condition Design Event IIb
Future condition Design Event IIc
Future condition Design Event IId
Future condition Design Event IIa



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Minimum Base Flow Requirements*

Figure 22

Legend

- Catchment Outlets
- Drainage Mains
- Waterways
- Model Domain

*Based on model simulation between 1988 and 1998.

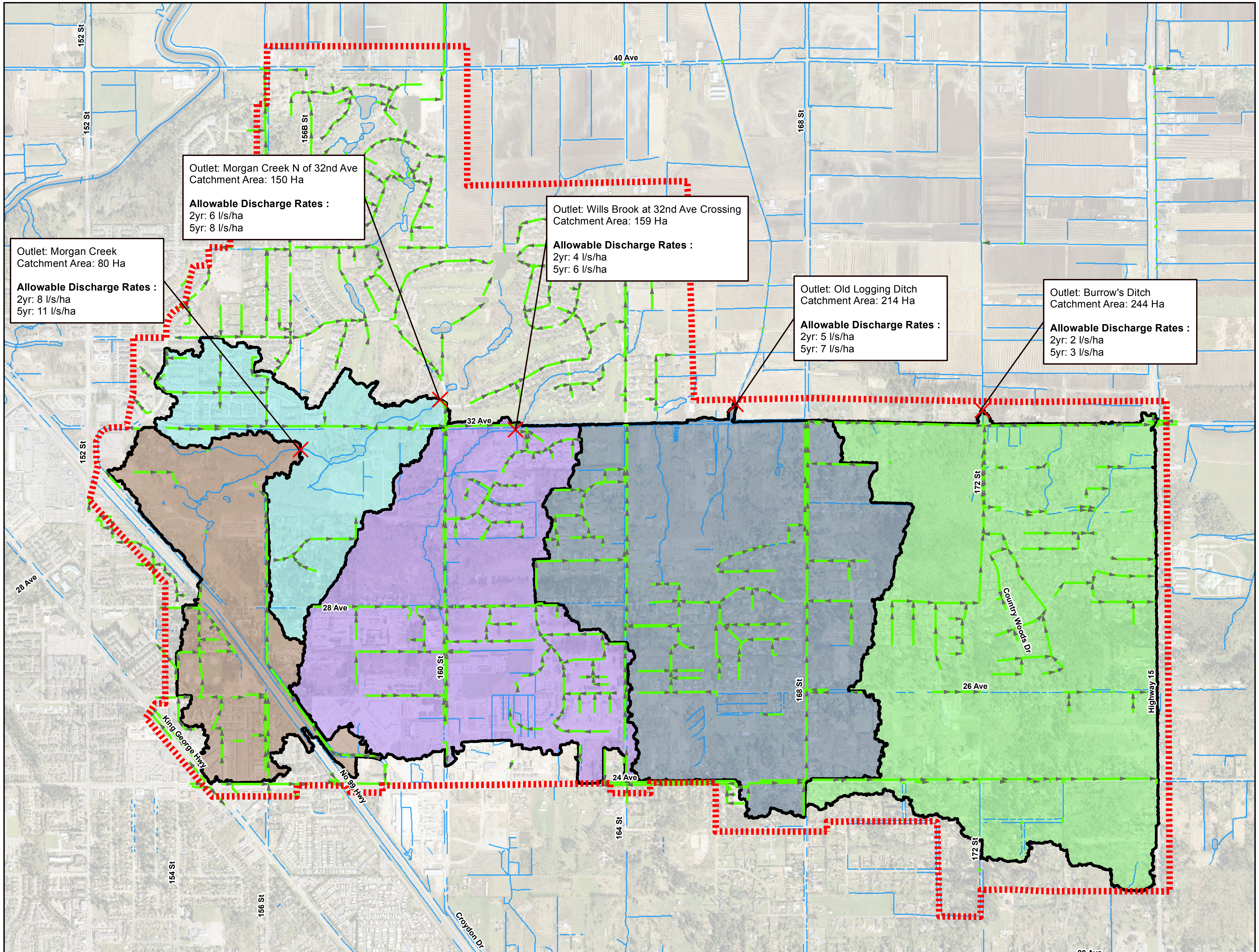
N

0 250 500 750 1,000

Metres

URBANSYSTEMS.

1072.0176.01



CITY OF SURREY
the future lives here.

Old Logging Ditch/ Burrows ISMP

Allowable Discharge Rates*

Figure 23

Legend

- Catchment Outlets
- Drainage Mains
- Waterways
- Model Domain

*Based on model simulation between 1988 and 1998.

N

0 250 500 750 1,000
Metres

URBANSYSTEMS.

DATA PROVIDED BY CITY OF SURREY. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

1072.0176.01

Figure 24(a) OLD LOGGING DITCH WATERSHED POLLUTANT LOADING

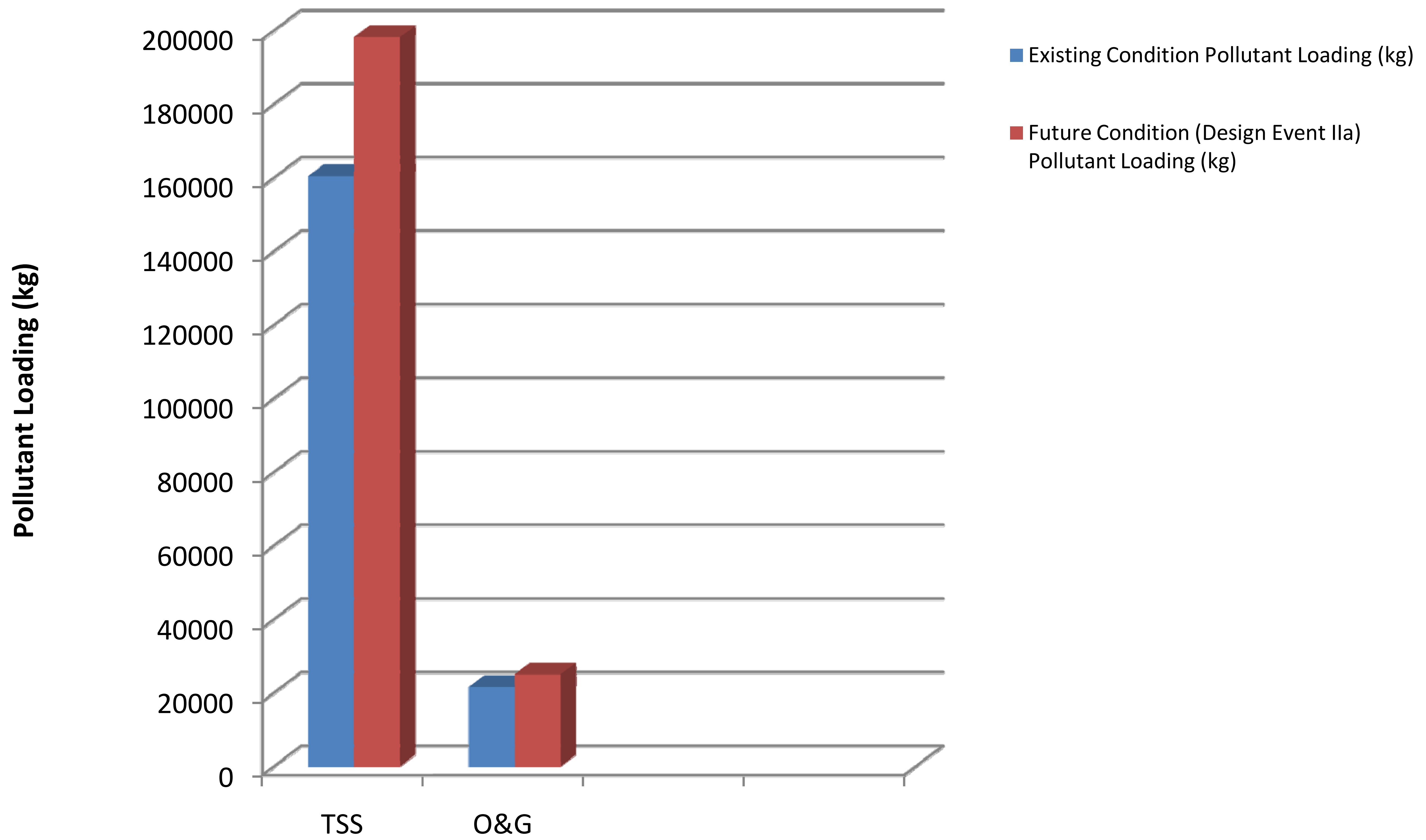


Figure 24(b) BURROWS DITCH WATERSHED POLLUTANT LOADING

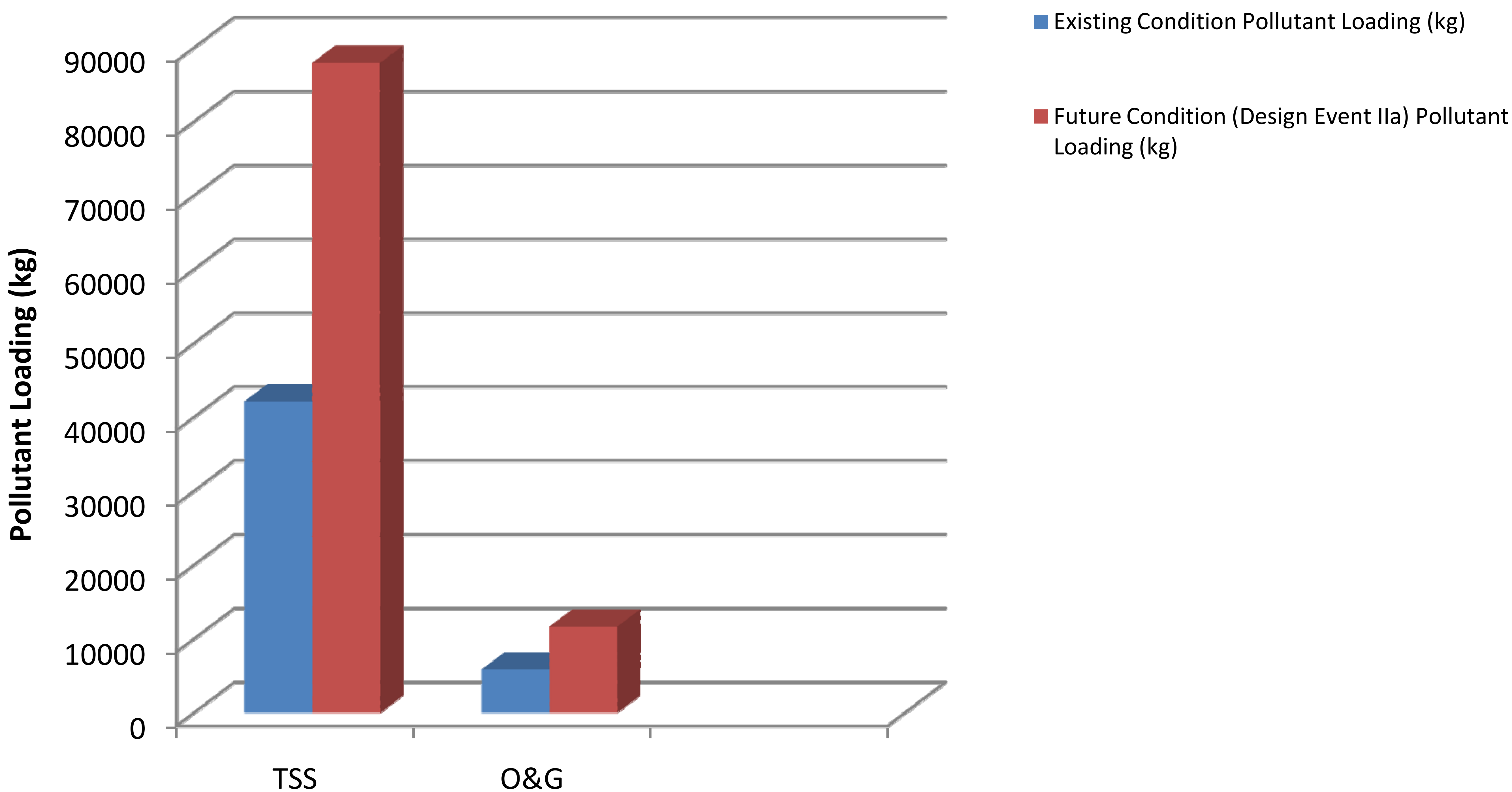
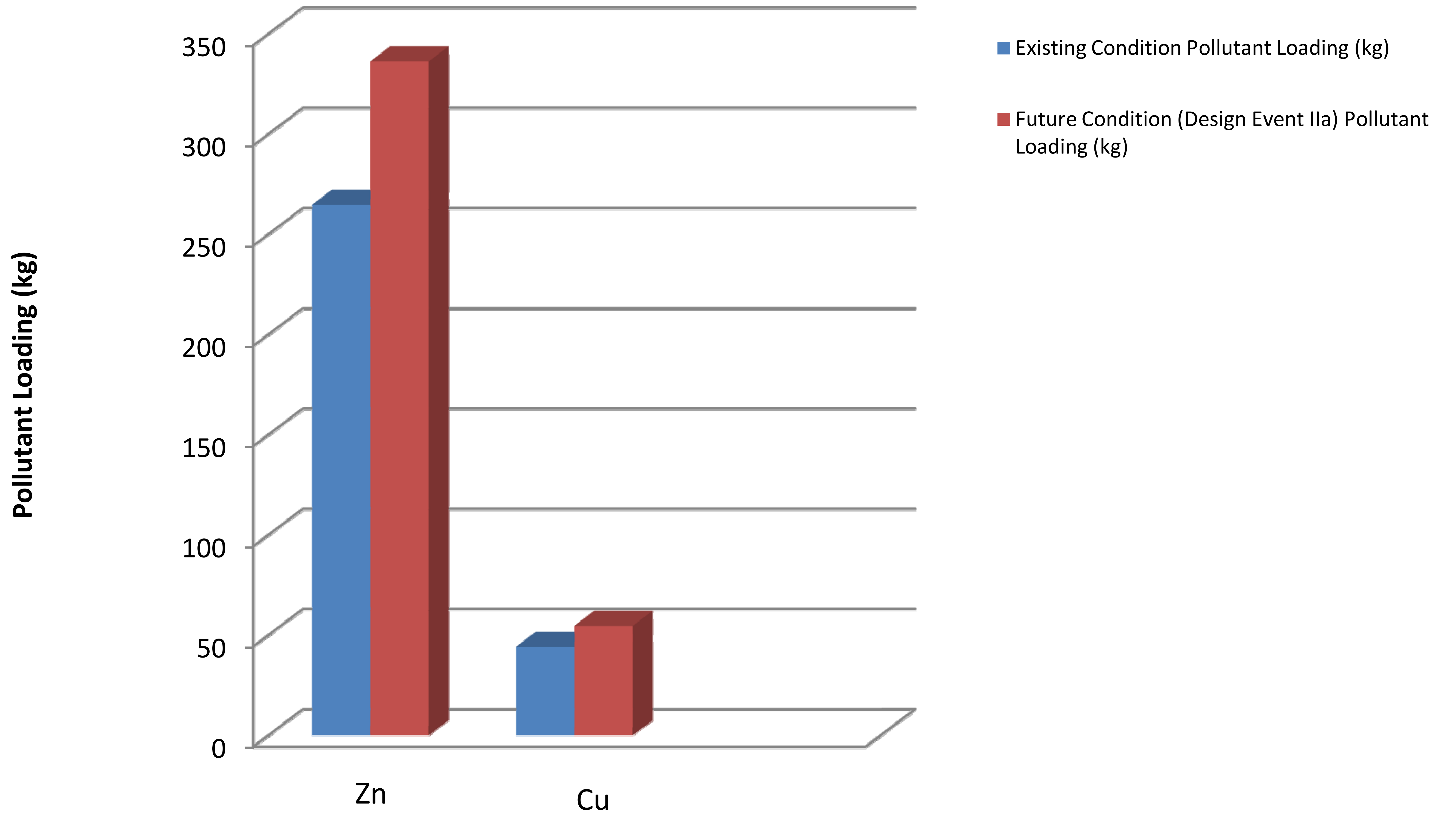


Figure 25(a) OLD LOGGING DITCH WATERSHED POLLUTANT LOADING



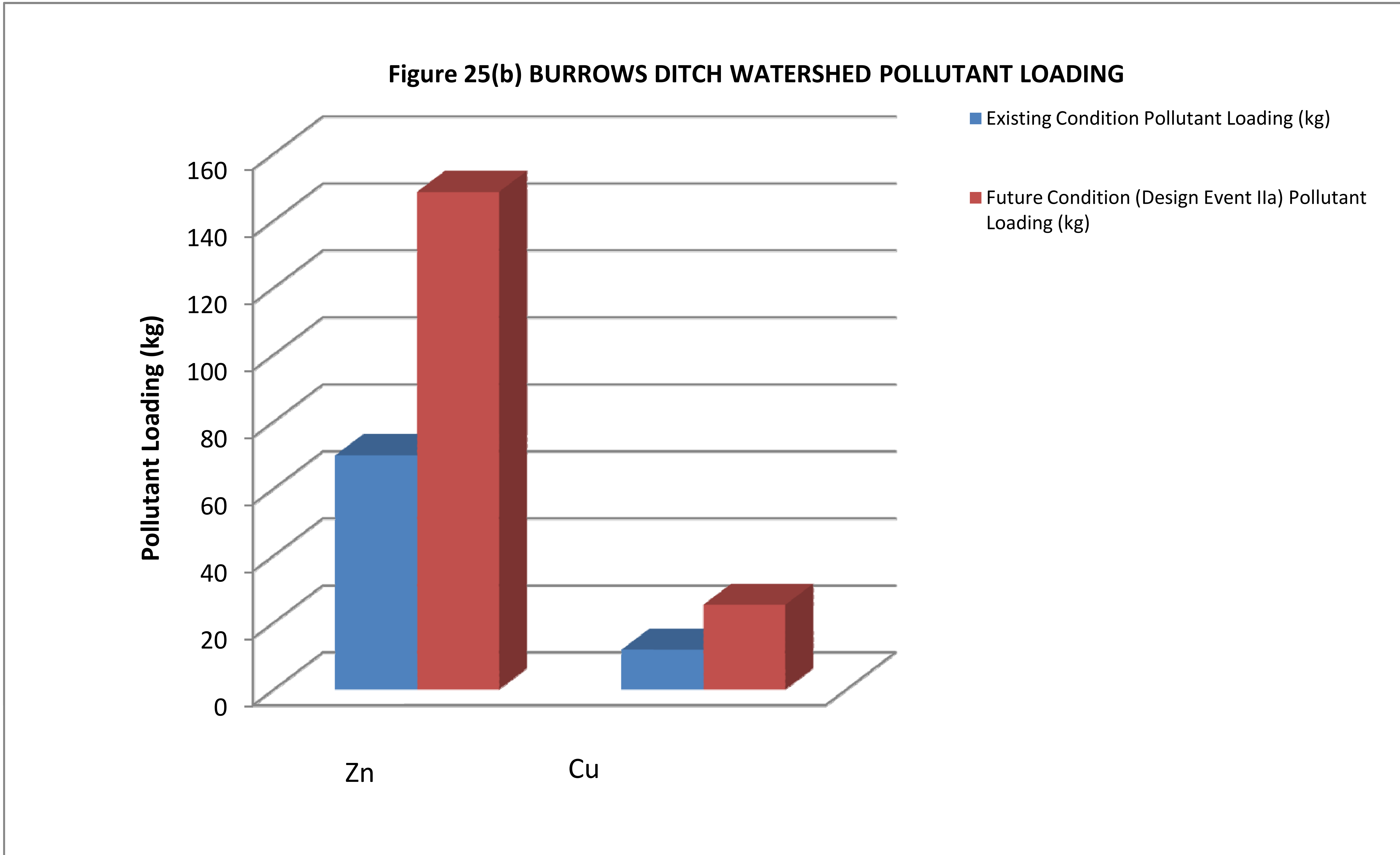


Figure 25(b) BURROWS DITCH WATERSHED POLLUTANT LOADING
Existing Condition Pollutant Loading (kg)
Future Condition (Design Event IIa) Pollutant Loading (kg)
Pollutant Loading (kg)
160
140
120
100
80
60
40
20
0
Zn
Cu

Appendix D

Hydrogeologic Report

August 24, 2010 File: 17-610-134

Urban Systems Ltd.
2353 13353 Commerce Parkway
Richmond, BC
V6V 3A1

Attention: Mr. J.M. Rice, P.Eng.
Senior Water Resource Engineer

OLD LOGGING AND BURROWS DITCHES - ISMP
GEOTECHNICAL AND HYDROGEOLOGICAL ASSESSMENT -
STAGE 1 REPORT

Dear Sirs:

Following our project status review meeting on January 25, we are pleased to submit this Stage 1 report on geotechnical and hydrogeological aspects of the study.

Use of this report is subject to the enclosed Statement of General Conditions.

1. WORK PROGRAM

Work completed for preparation of this report comprises the following:

- Review of previous reports made available for the study, including:
  - Piteau Associates Engineering Ltd. (Piteau's) November 1998 report to Urban Systems Ltd. (USL) and the City of Surrey entitled *Hydrogeological Assessment for the North Grandview Heights Area – General and NCP Servicing Plans*. Figures 11 and 12 from this report, showing a hydrogeologic profile and the shallow groundwater flow systems, respectively, were missing from Piteau's report and have not yet been provide by the City.
  - USL's summary of Piteau's findings presented in Section 8 of the report to the City of Surrey entitled *North Grandview Heights – General Area and Neighbourhood Concept Engineering Plan* dated November 1998.

Suite 200, 1445 West Georgia Street, VANCOUVER, B.C., Canada V6G 2T3 T.604-684-4384 F.604-684-5124 www.thurber.ca
VANCOUVER • VICTORIA • KAMLOOPS • SQUAMISH • EDMONTON • CALGARY • FORT McMURRAY • TORONTO

  - Dillion Consulting Limited (Dillon)'s August 2002 report to City of Surrey entitled *Old Logging Ditch/Morgan Creek Functional Feasibility Study for Lowlands.*
  - Review of New East Consulting Services Ltd.'s November 1996 report to the City of Surrey entitled *Morgan Creek/Old Logging Ditch – Marsh Drainage Plan.*
- Compilation and analysis of well records from the BC Water Resources Atlas (BCWRA). These records do not reflect all of the wells installed in the study area and the quality of the records varies.
- Review of the Geological Survey of Canada (GSC) mapping of surficial geology shown on Map 1484A.
- Inspection of stream channels in the study area at selected locations and sampling and testing of stream bed materials.

2. SURFICIAL GEOLOGY OF STUDY AREA

The GSC's generalized surficial geology mapping of the study area is reproduced on Dwg. 17-610-134-1 in Appendix A. Three geological units are identified, described as follows by the GSC:

SAb: Post Glacial Salish Sediments – Peat, organic silt and silty clay deposits up to 10m thick in lowland areas, generally overlying Fraser River sediments (sand or sand and gravel).

Cb: Capilano Sediments – A raised beach deposit of medium to coarse sand 1 to 5 m thick underlain by silt and clay.

Cd: Capilano Sediments – A marine and glaciomarine stony to stoneless silt and clay with minor amounts of sand and silt, underlain by Vashon Drift. The unit includes till-like deposits, contains marine shells and is normally less than 3 m thick, but can be up to 10 m thick in upland areas.

Va: Vashon Drift – Glacial till containing lenses and interbeds of glaciolacustrine stoney silt.

As indicated on the Drawing, Unit SAb covers about 50% of the study area, mainly in the lowland area, and Capilano Sediments (Units Cb and Cd) most of the remainder. The contact between these 2 units is gradational over the study area. Unit Cd acts as an aquitard that inhibits but does not completely prevent infiltration of surface water. The Vashon Drift unit is found only in the southeast quadrant of the study area. The Capilano Sediments and Vashon Drift are found primarily in the uplands.

3. HYDROGEOLOGY

3.1 Water Wells

3.1.1 General

BCWRA water well records indicate that 182 wells were installed in the study area. A TEL identification number has been assigned to each well. The records are not included in this report but have been forwarded to USL. Well locations with the TEL identification number are shown on Dwgs. 17-610-134-2 and -3 in Appendix A. It is not known how many of these wells are still in active use.

For analysis of well records, the study area has been divided at 32 Avenue into a lowland area to the north and upland area to the south. The results of the analysis are summarized in Table 1. Additional comments are presented below.

As reported by Piteau (1998), the City has installed a piped water system in parts of the study area and many property owners have abandoned their wells. Some property owners still use wells for domestic purposes because they:

- Prefer the taste of well water over chlorinated piped water.
- Use it to provide water in areas where it would be expensive to provide piped water.
- Use it for special purposes such as aquaculture, irrigation and flows into ornamental ponds.

3.1.2 Well Construction Methods and Well Depths

In terms of well construction, 96 wells are known to have been drilled, 20 dug and 66 completed by unknown methods. Ninety-eight wells were completed in the upland area and 84 in the lowland area. Well depth information is available for 97 upland wells and 75 lowland wells. All of the wells which are less than 10 m deep are in the upland area. In the 10 to 100 m depth range, the wells are roughly equally divided between the upland and lowland areas. Sixteen of the 19 wells more than 100 m deep are in the lowland area. Twenty wells were dug to depths of between 3 and 13 m.

3.1.3 Static Water Levels

Static water levels in the wells were reported for 102 wells and ranged from artesian to 54 m depth. Reported static water levels are shown on Dwg. 17-610-134-4 by colour coding. In 45 wells, distributed between the upland and lowland areas, the water level was within 10 m of the ground surface. Of the remaining 40 non-artesian wells, entirely located in the upland area, 27 wells reported depths to water of 10 to 30 m and 13 reported more than 30 m.

3.1.4 Non-Artesian Wells

The locations of non-artesian wells, colour coded to indicate reported yield, are shown on Dwg. 170-610-134-5. Yields were reported by the driller at the time of well construction for 91 wells, comprising 52 upland wells and 39 lowland wells. No yield data is available for the remaining 74 wells. Yields ranged from 0.5 to 700 gpm with 21 reporting low yield up to (5 gpm), 56 moderate yield (5 to 25 gpm), 9 high yield (25 to 100 gpm) and five with a yield of over 100 gpm. Five of the very high yield wells are located in the upland area and of these, 3 are distributed along 32 Avenue at the upland - lowland contact. The highest yield well (No. 92), located in the Morgan Creek area towards the northern edge of the upland area and immediately south of 32 Avenue, reported a yield of 700 gpm.

Overall, it appears that wells sunk into the lower parts of the north-facing slopes of the Grandview Heights typically return moderate yields fairly consistently from well depths in the range 20 to 50 m.

3.1.5 Artesian Wells

Thirty-eight wells were reported to have artesian flows during installation. However, 21 of those wells had very low artesian flow and appear to have been completed as pumped wells. The location of the 17 artesian wells, colour coded to indicate reported yield, are shown on Dwg. 17-610-134-6. Eleven of the wells are in the lowland area, and six in the uplands. Five wells recorded low flows (<1 gpm), 5 recorded moderate flows (1 to 10 gpm), 3 recorded high flows (10 to 30 gpm) and 4 recorded (very) high flows in excess of 30 gpm. Wells at the contact between the upland and lowland areas (around 32 Avenue) recorded most of the moderate or high artesian flows.

Well 89 located roughly 100 m south of Well 92 in the Morgan Creek area, produced an artesian flow of 1700 gpm.

3.2 Hydrogeological Conditions

3.2.1 General

The discussion presented in this section is primarily based on information presented in Piteau (1998) and USL (1998) supplemented by interpretation of the well results presented in Section 3.1.

The wide range of well yields and depths in the study area suggests a complex hydrogeological system incorporating a number of perched aquifers and a significant deep aquifer with upland recharge and lowland discharge areas. The hydrogeological system is illustrated on the enclosed Figures 8.1.2.2 and 8.1.2.3 from Piteau (1998) and described below.

The deep aquifer comprises a series of hydraulically connected sand units which are likely to be connected with the major regional White Rock aquifer west of the study area. Productive wells targeting this deep aquifer were typically constructed to depths of around 20 to 50 m although some were in excess of 100 m deep. Secondly, throughout the low permeability Capilano Sediments above the deep aquifer, there are localised, confined, perched aquifers. A relatively thin surficial layer of moderately permeable colluvium also allows groundwater flow.

In terms of deep aquifer water balance, it is considered that the upland area, extending towards White Rock outside the study area boundary, forms an area of aquifer recharge. Groundwater flows predominantly towards the north-northeast to discharge in the lowlands. Sufficient hydraulic head is consistently developed around the upland / lowland area contact and most of the reported artesian wells occur close to 32 Avenue. Locally, the shallow aquifer could be less consistent and potentially ephemeral, responding more directly to infiltration and exhibiting low levels or even drying up in summer months in relatively isolated segments of the aquifer.

In summary, the key elements to note in relation to hydrogeological conditions in the study area are:

- A deep, stable aquifer and a shallow, less consistent perched aquifer system resulting from the presence of permeable zones within the low permeability soil units of the Capilano Sediments.

- Groundwater flow generally to the north-northeast.
- Groundwater discharge in the lowland area.

3.2.2 Stormwater Impacts on Hydrogeological System

Stormwater flows entering the hydrogeological system in upland areas will supply the recharge zone of the shallow and / or deep aquifer system, depending on the input location and soil permeability / percolation potential. Low permeability soils in the upland area will retard infiltration into the shallow aquifer and drainage plans should be targeted to accommodate increased surface runoff in low permeability zones after intense rainfall. Stormwater entering the upland area aquifers will move hydraulically down-gradient toward the lowlands area in a generally north-northeast direction. Where permeable layers intercept the ground surface, seeps and springs will form and stormwater flows will contribute directly to stream baseflows. In periods of intense rainfall, a rise in hydraulic head will occur at the upland / lowland interface, producing an increase in artesian flows. Static water levels could be expected to rise marginally in the lowland discharge zone.

In the lowland area, static water levels are close to ground level and the management of stormwater flows over the lowland area is more critical. Stormwater flows, again, will be retained near-surface where the Capilano Sediments exhibit low permeability and potentially pond where peaty soils dominate. Close attention will need to be paid to elevation controls on balancing ponds, weir structures and ditches. In intense periods of rainfall, the low hydraulic gradient in the lowland area means longer retention periods of high water levels prior to natural draining.

4. STREAM CHANNEL OBSERVATIONS

4.1 Previous Assessment

Piteau (1998) carried out a site reconnaissance along accessible portions of 3 streams in the study area to observe site and slope conditions. Site locations were described as follows:

- On the upper reaches of Morgan Creek west of 156 Street, south of 31 Avenue (Site GT1) and south of 32 Avenue (Site GT2).
- On April Creek, 150 m north of 28 Avenue (Site GT3) and immediately south of 32 Avenue (Site GT4).

- The upper 100 m of Kensington Creek, upstream of its confluence with Old Logging Ditch.

Inspection Sites GT1 through GT4 are shown approximately on Dwg. 17-610-134-7.

Piteau's comments on geotechnical characteristics of these 3 streams were as follows:

- At Site GT1 on Morgan Creek, the stream had a silt/sand/gravel substrate. The stream bed and 4 m high banks were stable.
- At Site GT2 on Morgan Creek, the stream had a sand/gravel substrate. The 5 m high banks were well vegetated with no apparent instability, except for minor undercutting which exposed firm, grey silt with some fine sand and clay.
- At Site GT3 on April Creek, the channel was incised about 0.5 m into the underlying glacial till, but no significant bank instability was observed.
- At Site GT4 on April Creek, the stream channel was poorly incised with low banks with no apparent instability.
- Stream flow was discontinuous in the section of Kensington Creek traversed through swampy ground. No bank instability was reported.

4.2 Current Assessment

Twelve sites on stream channels in the study area were inspected during the current study. Site locations are shown on Dwg. 17-610-134-7. Stream bed material was sampled at seven of the sites and subjected to laboratory gradation tests. Gradation results are included in Appendix B. Descriptions of the sites are as follows:

Site 1 – Upstream Reach of Morgan Creek

This site is believed to be in the vicinity of the Piteau's site GT1, located about 1 km upstream of the culvert at 32 Avenue. Low banks with a gravel substrate were observed. The stream bed sample contained 1% fines (percent passing No. 200 sieve).

Site 2 – Morgan Creek, 600 m upstream of 32 Avenue culvert

This is believed to be in the vicinity of Piteau's Site GT2. There is a settling pond upstream of the sampling site with the discharge flowing in a channel with 2 to 3 m high, stable banks. The stream bed sample was taken at the confluence of where the pond outflow and Morgan Creek. The sample contained 4% fines.

Site 3 – Morgan Creek at 32 Avenue

6 m high, tree- and brush-covered banks show no signs of instability. A stream bed sample obtained from the culvert intake area contained 3% fines.

Site 4 – Morgan Creek at Morgan Creek Way

The creek is 8 m wide upstream of the bridge, widening into a large pond downstream, with low, stable banks in both areas.

Site 5 – Wills Brook at 28 Avenue

6 m high, tree- and brush-covered, stable banks exist on both sides of the road. Many fallen trees are evident on the upstream side.

Site 6 – Wills Brook at 160 Street

This is a low bank area with no signs of instability.

Site 7 – Wills Brook at 32 Avenue

South of 32 Avenue, Wills Brook has been channelled as part of a subdivision development with 2 m high banks and boulders and tree stumps in the channel. No instability was noted. A stream bed sample obtained from the culvert intake area contained 2% fines.

Site 8 – April Creek at 32 Avenue

At 32 Avenue, this is a small creek flowing under the road in two 300 mm diameter pvc pipes. No bank instability was noted. A stream bed sample obtained from the culvert intake area contained 1% fines.

Site 9 – Old Logging Ditch at 32 Avenue

On the south side of 32 Avenue, flow into the culvert originates with roadside ditch flows from the east and west sides. At the culvert outlet, the flow is joined by a major ditch flow from the west before flowing north into

Old Logging Ditch. No bank instability was noted. A stream bed sample obtained from east flowing ditch on the north side at the confluence with the culvert outflow contained 1% fines.

Site 10 – Old Logging Ditch at 40 Avenue

The stream is 5 m wide at this location with low banks. No bank instability was noted.

Site 11 – Burrows Ditch at 32 Avenue

Very low flow was observed at the culvert intake, derived from Pearson Brook. The flow was considerably higher at the outlet, presumably due to storm sewer discharges. The upstream channel is heavily vegetated but downstream, the channel is incised 1 m into peat. The stream bed was sampled about 15 m downstream of the culvert outlet. The sample contained 0.3% fines

Site 12 –Burrows Ditch at 40 Avenue

Burrows Ditch at this location had a low flow in a stable, low bank channel. The culvert was installed under the road and the flow was directed into the south side roadside ditch flowing east.

5. ENGINEERING EVALUATION

5.1 Infiltration

Surface water infiltration may be considered in all of the upland area covered by Units Cb and Cd. This can comprise rock pits for house roof and perimeter drainage, rain gardens and perforated drains incorporated into drainage swales. Except at specific sites, slope stability due to infiltration is unlikely to be a problem considering that the ground slope is moderate in the upland area, varying from about 8% from 32 Avenue to El. 50 m and only 4% at higher elevations. However, we recommend that infiltration systems be located no closer than 15 m to the top of bank to ensure bank stability.

5.2 Stream Bank Stability and Erosion Potential

No areas of significant bank instability along creeks in the study area with a potential for future erosion or requiring immediate remedial work were identified during the current study. However, the City has identified 4 locations in the study area which will require erosion protection in the next 7 to 10 years at a total estimated cost of $140,000. The sites are identified as follows:

159 Street at 29 Avenue
160 Street at 28 Avenue (Wills Brook)
161 Street at 31 Avenue (Wills Brook)
167 Street at 33 Avenue (Old Logging Ditch)

We have not inspected these locations but expect them to exhibit minor instability at present.

5.3 Provision of Municipal Water Supply

Provision of an enhanced municipal water supply in the study area with a consequent reduction in removal of groundwater by domestic wells would increase the potential for infiltration of surface water without affecting slope stability.

We trust that this letter is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours very truly,
Thurber Engineering Ltd.

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA D. SMITH

Dave Smith, P.Eng.
Principal
DS/cw

THURBER ENGINEERING LTD.

STATEMENT OF GENERAL CONDITIONS

1. STANDARD OF CARE

This study and Report have been prepared in accordance with generally accepted engineering or environmental consulting practices in this area. No other warranty, expressed or implied, is made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report which is of a summary nature and is not intended to stand alone without reference to the instructions given to us by the Client, communications between us and the Client, and to any other reports, writings, proposals or documents prepared by us for the Client relative to the specific site described herein, all of which constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. WE CANNOT BE RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to us by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the document, subject to the limitations provided herein, are only valid to the extent that this Report expressly addresses proposed development, design objectives and purposes, and then only to the extent there has been no material alteration to or variation from any of the said descriptions provided to us unless we are specifically requested by the Client to review and revise the Report in light of such alteration or variation or to consider such representations, information and instructions.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT OUR WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS WE MAY EXPRESSLY APPROVE. The contents of the Report remain our copyright property. The Client may not give, lend or, sell the Report, or otherwise make the Report, or any portion thereof, available to any person without our prior written permission. Any use which a third party makes of the Report, are the sole responsibility of such third parties. Unless expressly permitted by us, no person other than the Client is entitled to rely on this Report. We accept no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without our express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel, may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and this report is delivered on the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to us. We have relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, we cannot accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by us. We are entitled to rely on such representations, information and instructions and are not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

(see over . . . .)

c) Design Services: The Report may form part of the design and construction documents for information purposes even though it may have been issued prior to the final design being completed. We should be retained to review the final design, project plans and documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the report recommendations and the final design detailed in the contract documents should be reported to us immediately so that we can address potential conflicts.

d) Construction Services: During construction we must be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RISK LIMITATION

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause an accidental release of those substances. In consideration of the provision of the services by us, which are for the Client's benefit, the Client agrees to hold harmless and to indemnify and defend us and our directors, officers, servants, agents, employees, workmen and contractors (hereinafter referred to as the "Company") from and against any and all claims, losses, damages, demands, disputes, liability and legal investigative costs of defence, whether for personal injury including death, or any other loss whatsoever, regardless of any action or omission on the part of the Company, that result from an accidental release of pollutants or hazardous substances occurring as a result of carrying out this Project. This indemnification shall extend to all Claims brought or threatened against the Company under any federal or provincial statute as a result of conducting work on this Project. In addition to the above indemnification, the Client further agrees not to bring any claims against the Company in connection with any of the aforementioned causes.

7. SERVICES OF SUBCONSULTANTS AND CONTRACTORS

The conduct of engineering and environmental studies frequently requires hiring the services of individuals and companies with special expertise and/or services which we do not provide. We may arrange the hiring of these services as a convenience to our Clients. As these services are for the Client's benefit, the Client agrees to hold the Company harmless and to indemnify and defend us from and against all claims arising through such hirings to the extent that the Client would incur had he hired those services directly. This includes responsibility for payment for services rendered and pursuit of damages for errors, omissions or negligence by those parties in carrying out their work. In particular, these conditions apply to the use of drilling, excavation and laboratory testing services.

8. CONTROL OF WORK AND JOBSITE SAFETY

We are responsible only for the activities of our employees on the jobsite. The presence of our personnel on the site shall not be construed in any way to relieve the Client or any contractors on site from their responsibilities for site safety. The Client acknowledges that he, his representatives, contractors or others retain control of the site and that we never occupy a position of control of the site. The Client undertakes to inform us of all hazardous conditions, or other relevant conditions of which the Client is aware. The Client also recognizes that our activities may uncover previously unknown hazardous conditions or materials and that such a discovery may result in the necessity to undertake emergency procedures to protect our employees as well as the public at large and the environment in general. These procedures may well involve additional costs outside of any budgets previously agreed to. The Client agrees to pay us for any expenses incurred as the result of such discoveries and to compensate us through payment of additional fees and expenses for time spent by us to deal with the consequences of such discoveries. The Client also acknowledges that in some cases the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed and the Client agrees that notification to such bodies by us will not be a cause of action or dispute.

9. INDEPENDENT JUDGEMENTS OF CLIENT

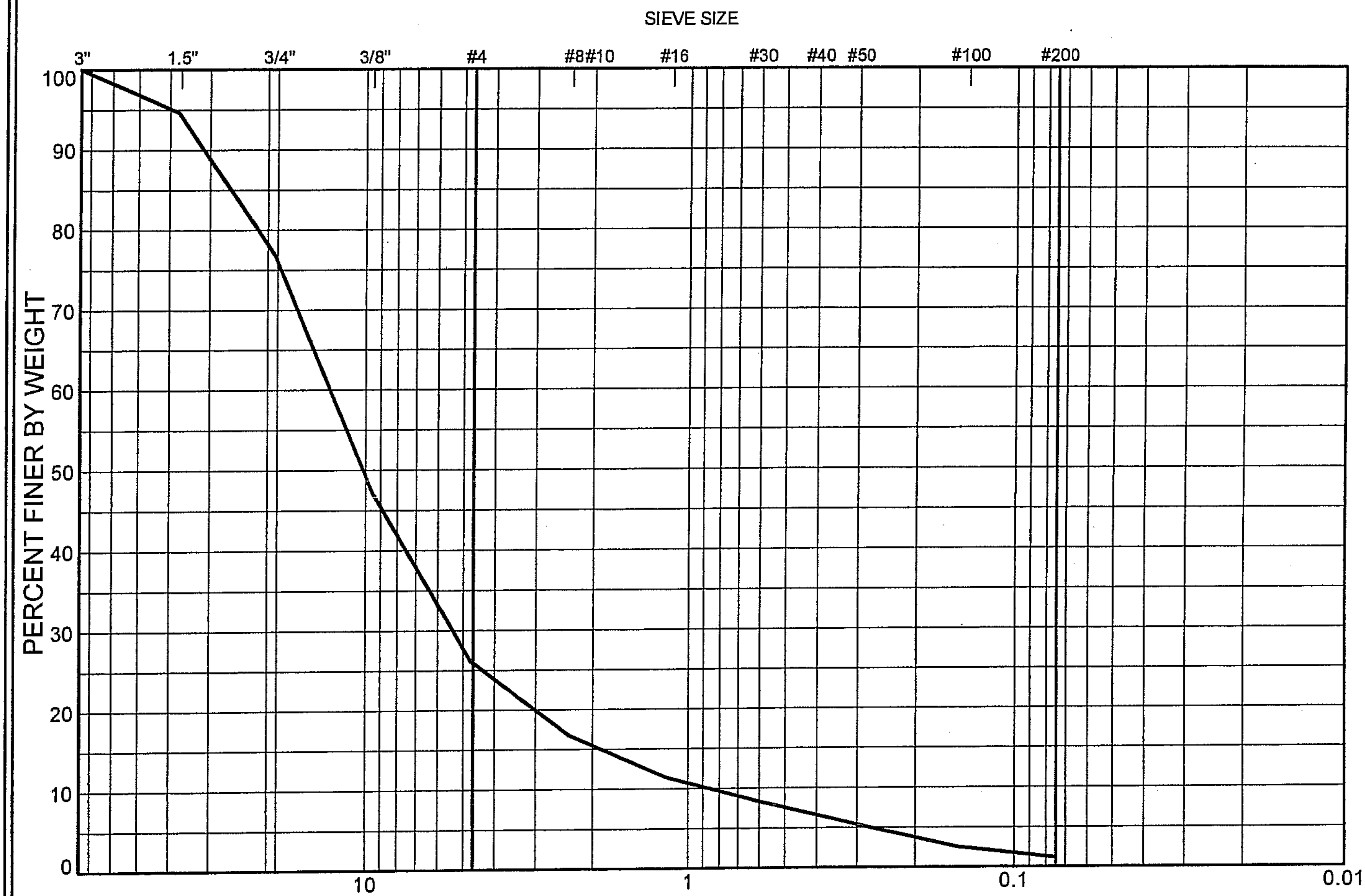
The information, interpretations and conclusions in the Report are based on our interpretation of conditions revealed through limited investigation conducted within a defined scope of services. We cannot accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

Appendix A

DRAWINGS

Appendix B

GRADATION TEST RESULTS



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 1 - See Comments
Sample: See Description
Sample Depth: N/A
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM/KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**73.9%**
Sand	**25.0%**
Fines	**1.2%**
Moisture Content	%
D10	**0.868**
D30	**5.395**
D60	**12.837**
Cu	**14.78**
Cc	**2.61**

Sieve Size		Percent Passing
inches	mm	
3	75	**100.0**
1.5	37.5	**94.6**
0.75	19	**76.8**
0.375	9.5	**47.1**
#4	4.75	**26.1**
#8	2.36	**16.7**
#16	1.18	**11.4**
#30	0.6	**8.3**
#50	0.3	**5.4**
#100	0.15	**2.6**
#200	0.075	**1.2**

Description: Sandy GRAVEL with trace of silt (GW).
Comments: Morgan Creek - Upstream Reach

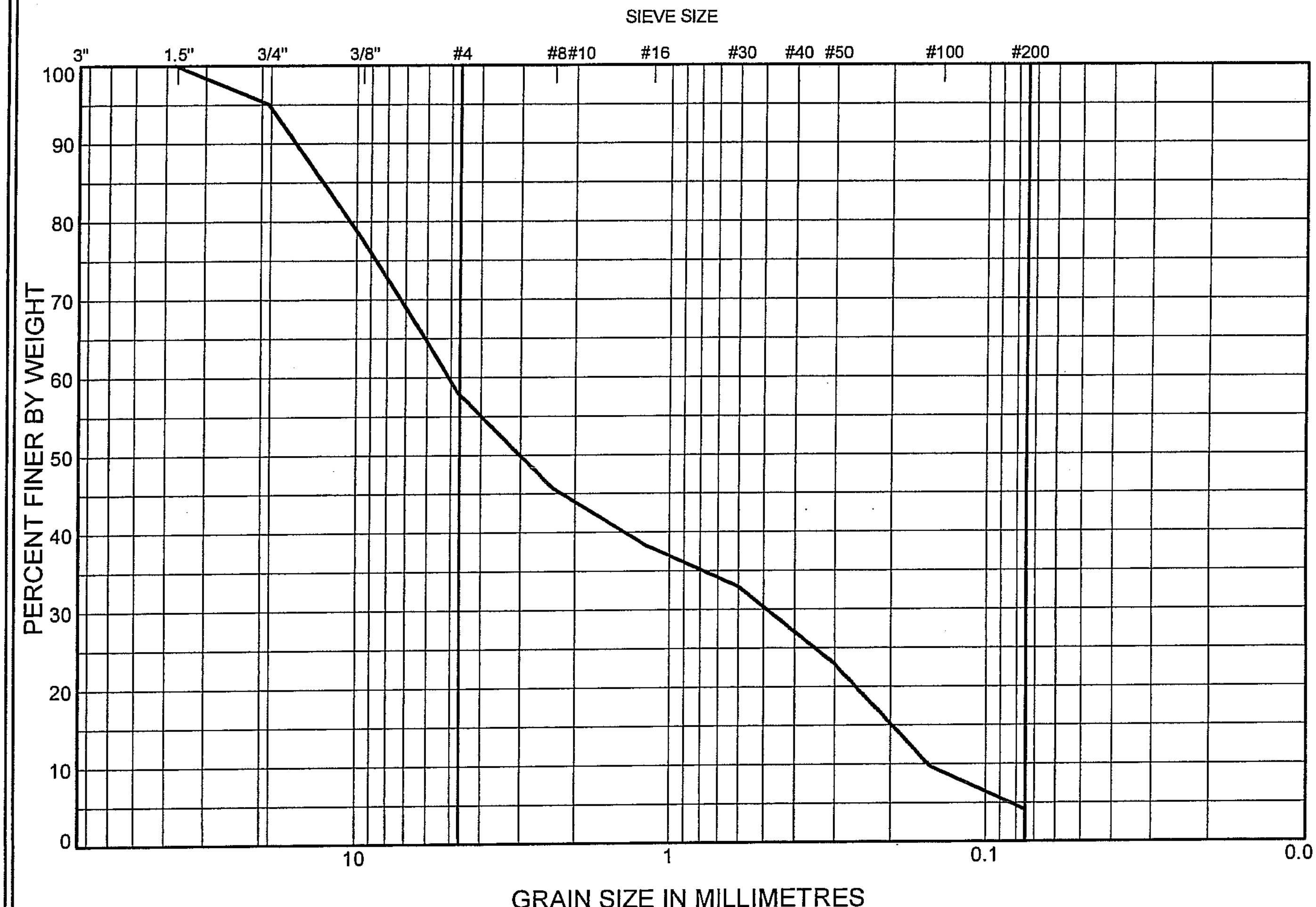
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134

GRAIN SIZE (HW) 17-610-134.GPJ CAN_LAB.GDT 3/8/10- THURBER BC.GLB



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 2 - See Comments
Sample: See Description
Sample Depth: 0.0 m
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM/KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**41.9%**
Sand	**54.0%**
Fines	**4.1%**
Moisture Content	%

D10	**0.153**
D30	**0.49**
D60	**5.083**
Cu	**33.27**
Cc	**0.31**

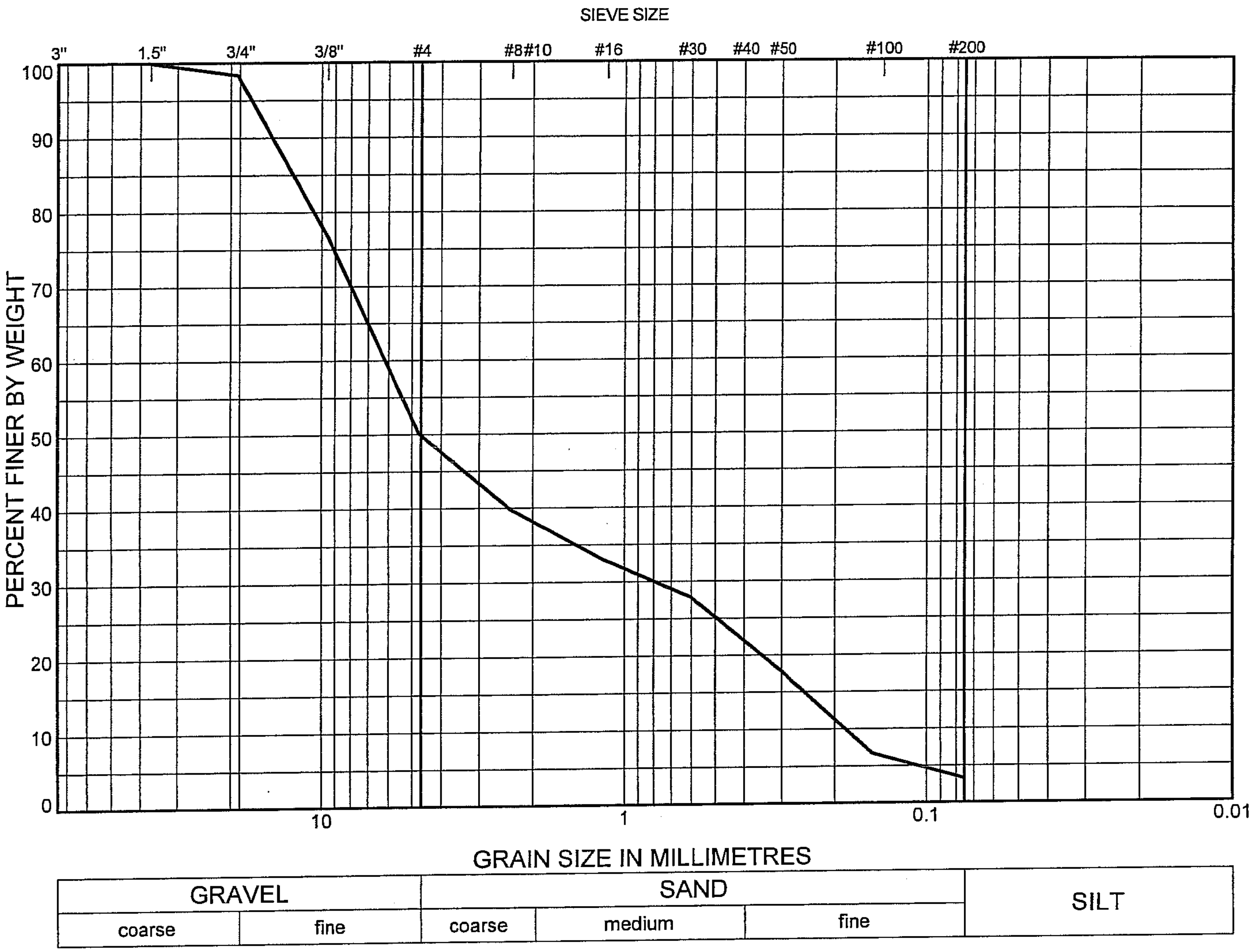
Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**95.0**
0.375	9.5	**77.5**
#4	4.75	**58.1**
#8	2.36	**45.7**
#16	1.18	**38.2**
#30	0.6	**32.9**
#50	0.3	**22.9**
#100	0.15	**9.6**
#200	0.075	**4.1**

Description: GRAVEL & SAND with trace of silt (GP/SP).
Comments: Morgan Creek - 600 m Upstream of 32 Avenue Culvert

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134



Sample Location:	Site 3 - See Comments
Sample:	See Description
Sample Depth:	N/A
Date Sampled:	March 2, 2010
Sampled By:	TM/HMW
Date Received:	March 2, 2010
Date Tested:	March 3, 2010
Tested By:	TM
Test Method:	ASTM C136 and C117
Specification:	

Gravel	49.9%
Sand	46.9%
Fines	3.2%
Moisture Content	%
D10	0.185
D30	0.798
D60	6.153
Cu	33.28
Cc	0.56

Sieve Size		Percent Passing
inches	mm	
3	75	
1.5	37.5	**100.0**
0.75	19	**98.4**
0.375	9.5	**76.6**
#4	4.75	**50.1**
#8	2.36	**39.7**
#16	1.18	**33.0**
#30	0.6	**27.8**
#50	0.3	**17.8**
#100	0.15	**6.6**
#200	0.075	**3.2**

Description: SAND & GRAVEL with trace of silt (SP/GP).

Comments: Morgan Creek at 32 Avenue - Culvert Intake Area

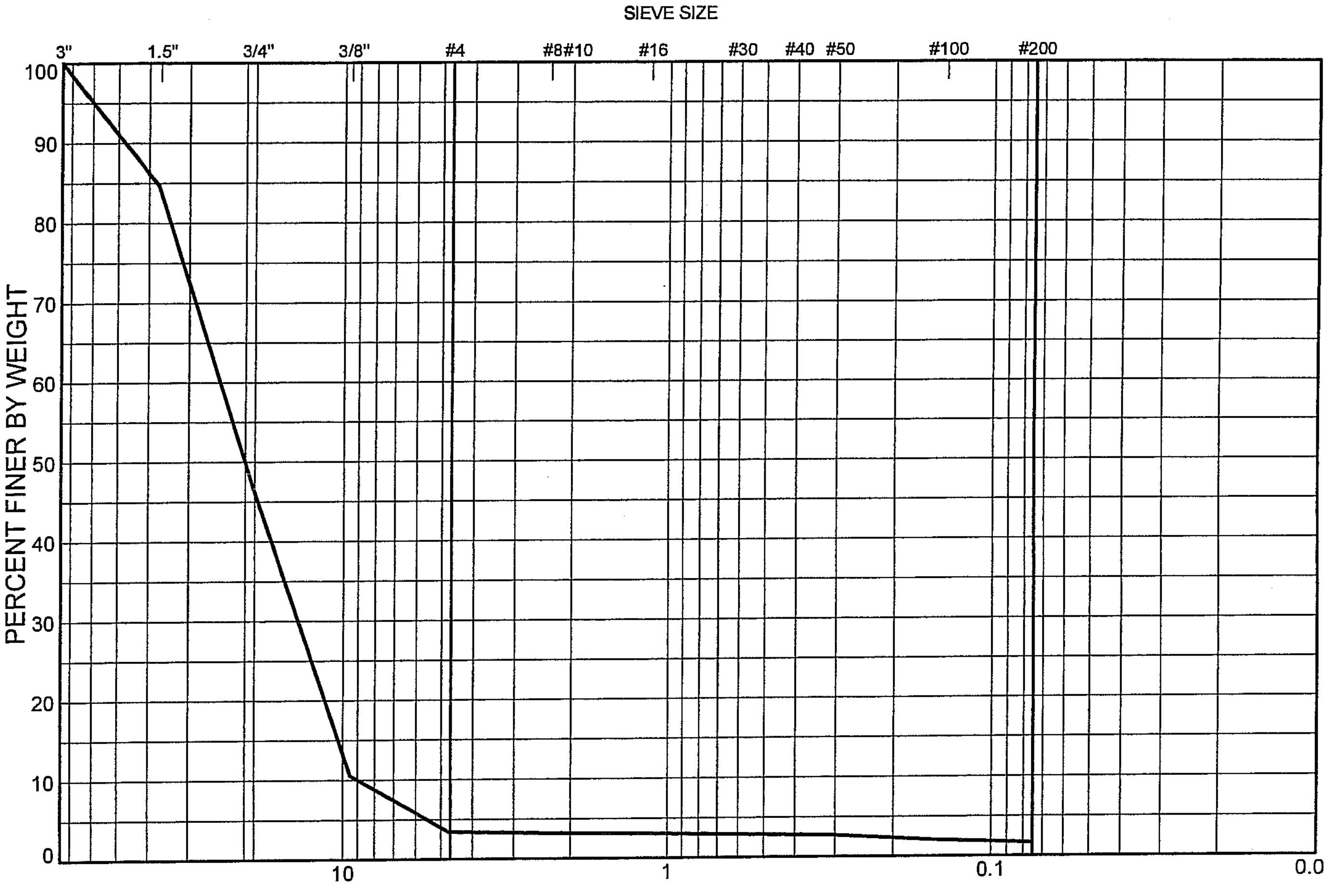
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER

Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 7 - See Comments
Sample: See Description
Sample Depth: N/A
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM
Test Method: ASTM C136 and C117
Specification:

Gravel	96.6%
Sand	1.8%
Fines	1.7%
Moisture Content	%

D10	9.021
D30	13.74
D60	23.98
Cu	2.66
Cc	0.87

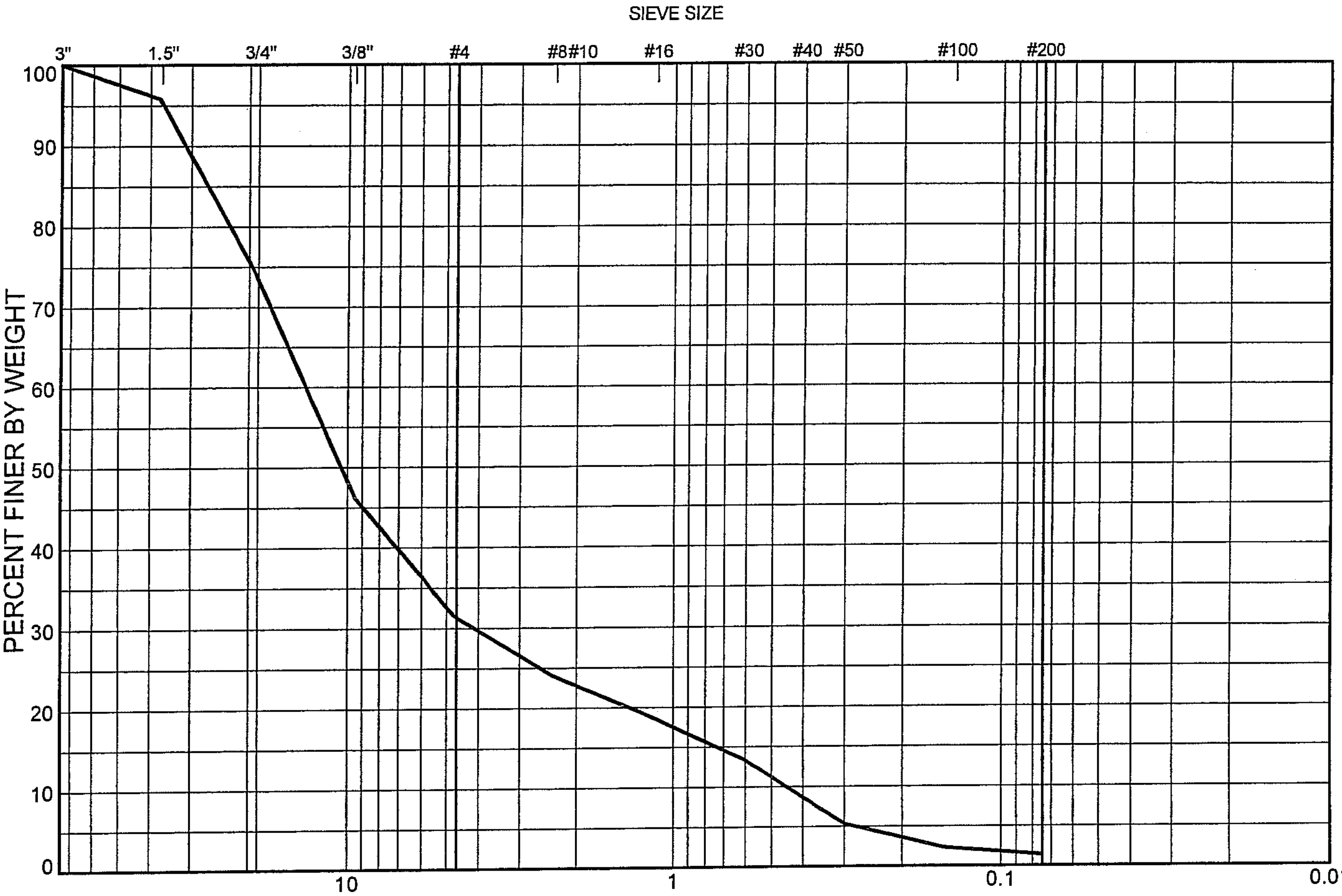
Sieve Size		Percent Passing
inches	mm	
3	75	100.0
1.5	37.5	84.8
0.75	19	47.1
0.375	9.5	10.5
#4	4.75	3.4
#8	2.36	3.2
#16	1.18	3.1
#30	0.6	2.9
#50	0.3	2.7
#100	0.15	2.1
#200	0.075	1.7

Description: GRAVEL with traces of silt and sand (GP).
Comments: Wills Brook at 32 Avenue - Culvert Intake Area

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 8 - See Comments
Sample: See Description
Sample Depth: N/A
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM
Test Method: ASTM C136 and C117
Specification:

Gravel	**68.5%**
Sand	**30.1%**
Fines	**1.4%**
Moisture Content	%

D10	**0.451**
D30	**4.135**
D60	**13.379**
Cu	**29.68**
Cc	**2.84**

Sieve Size inches	Sieve Size mm	Percent Passing
3	75	**100.0**
1.5	37.5	**95.8**
0.75	19	**74.1**
0.375	9.5	**46.3**
#4	4.75	**31.5**
#8	2.36	**24.0**
#16	1.18	**18.9**
#30	0.6	**13.3**
#50	0.3	**5.3**
#100	0.15	**2.3**
#200	0.075	**1.4**

Description: Sandy GRAVEL with trace of silt (GW).
Comments: April Creek at 32 Avenue - Culvert Intake Area

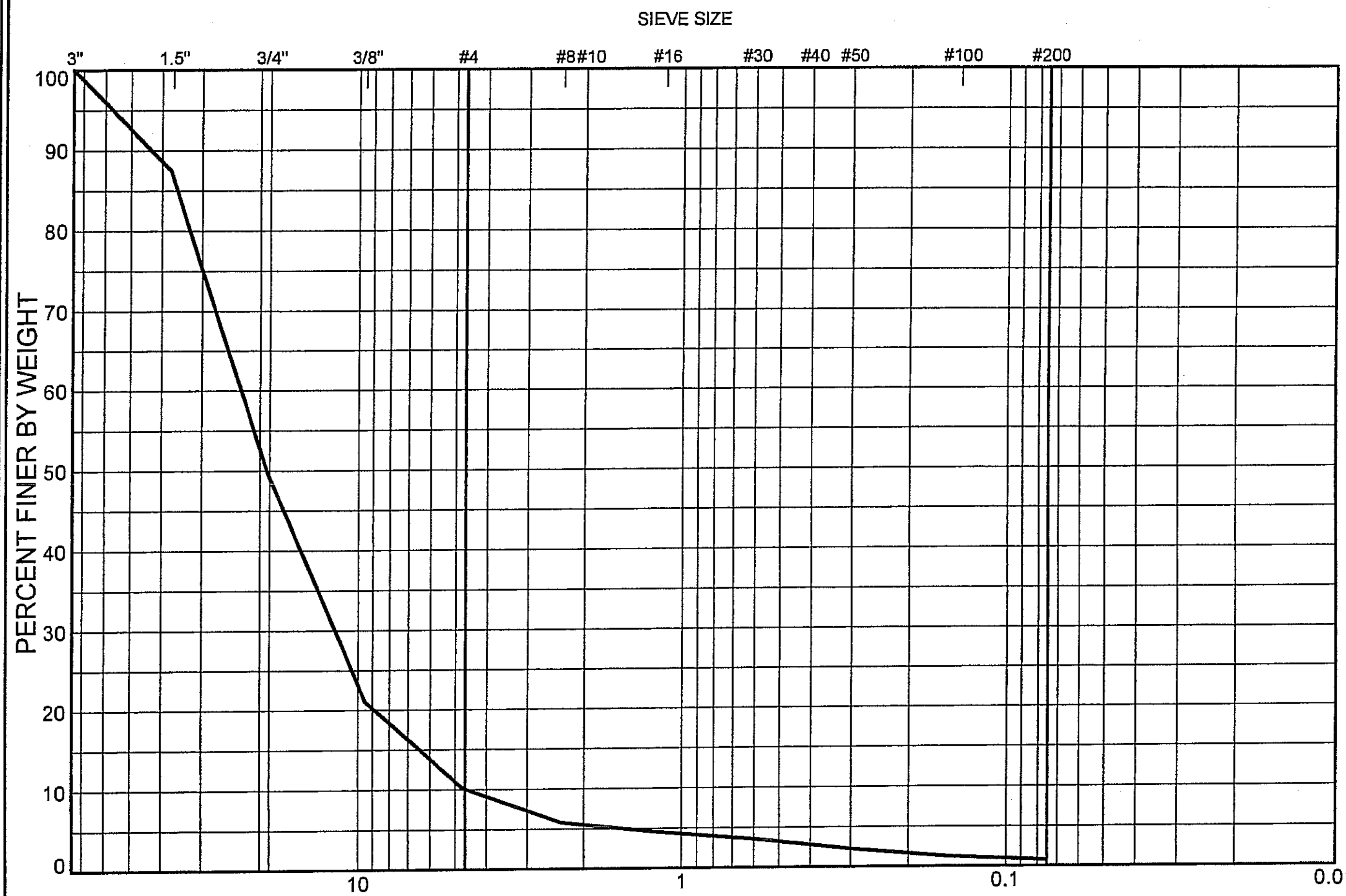
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134

GRAIN SIZE (HW) 17-610-134.GPJ CAN_LAB.GDT 3/8/10- THURBER BC.GLB



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 9 - See Comments
Sample: See Description
Sample Depth: N/A
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM
Test Method: ASTM C136 and C117
Specification:

Gravel	**89.9%**
Sand	**9.4%**
Fines	**0.8%**
Moisture Content	%

D10	**4.639**
D30	**11.786**
D60	**22.821**
Cu	**4.92**
Cc	**1.31**

Sieve Size		Percent Passing
inches	mm	
3	75	**100.0**
1.5	37.5	**87.4**
0.75	19	**49.9**
0.375	9.5	**21.0**
#4	4.75	**10.1**
#8	2.36	**5.8**
#16	1.18	**4.5**
#30	0.6	**3.6**
#50	0.3	**2.3**
#100	0.15	**1.2**
#200	0.075	**0.8**

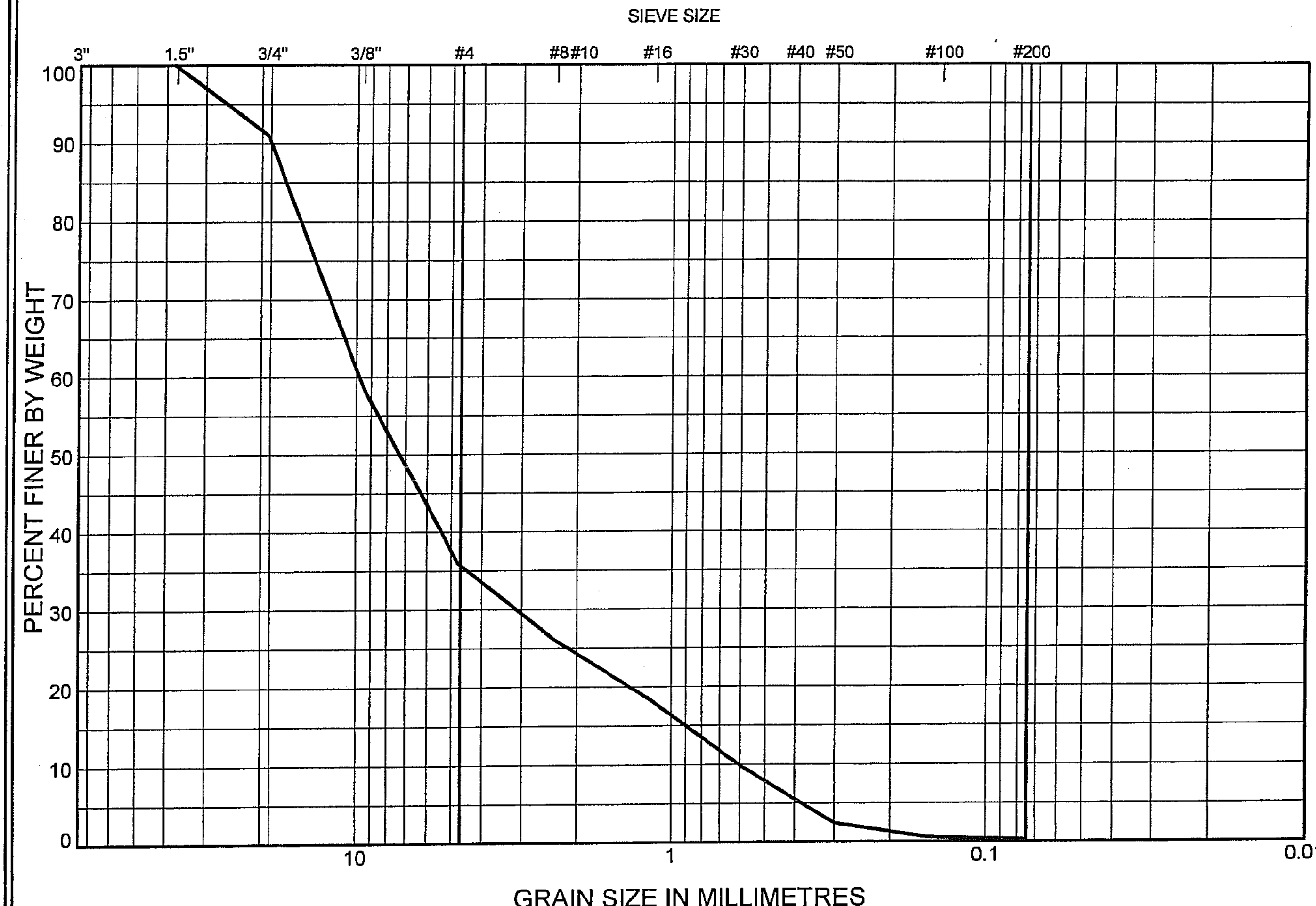
Description: GRAVEL with traces of silt and sand (GW).
Comments: Old Logging Ditch at 32 Avenue - Culvert Outlet Area

The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134



GRAVEL		SAND			SILT
coarse	fine	coarse	medium	fine	

Sample Location: Site 11 - See Comments
Sample: See Description
Sample Depth: N/A
Date Sampled: March 2, 2010
Sampled By: TM/HMW
Date Received: March 2, 2010
Date Tested: March 3, 2010
Tested By: TM/KM
Test Method: ASTM C136 and C117
Specification:

Gravel	**64.1%**
Sand	**35.6%**
Fines	**0.3%**
Moisture Content	%

D10	**0.608**
D30	**3.116**
D60	**9.801**
Cu	**16.13**
Cc	**1.63**

Sieve Size (inches)	Sieve Size (mm)	Percent Passing
3	75	
1.5	37.5	**100.0**
0.75	19	**91.0**
0.375	9.5	**58.5**
#4	4.75	**35.9**
#8	2.36	**26.1**
#16	1.18	**18.4**
#30	0.6	**9.8**
#50	0.3	**2.4**
#100	0.15	**0.6**
#200	0.075	**0.3**

Description: Sandy GRAVEL with trace of silt (GW).
Comments: Burrows Ditch at 32 Avenue - 15 m Below Culvert Outlet

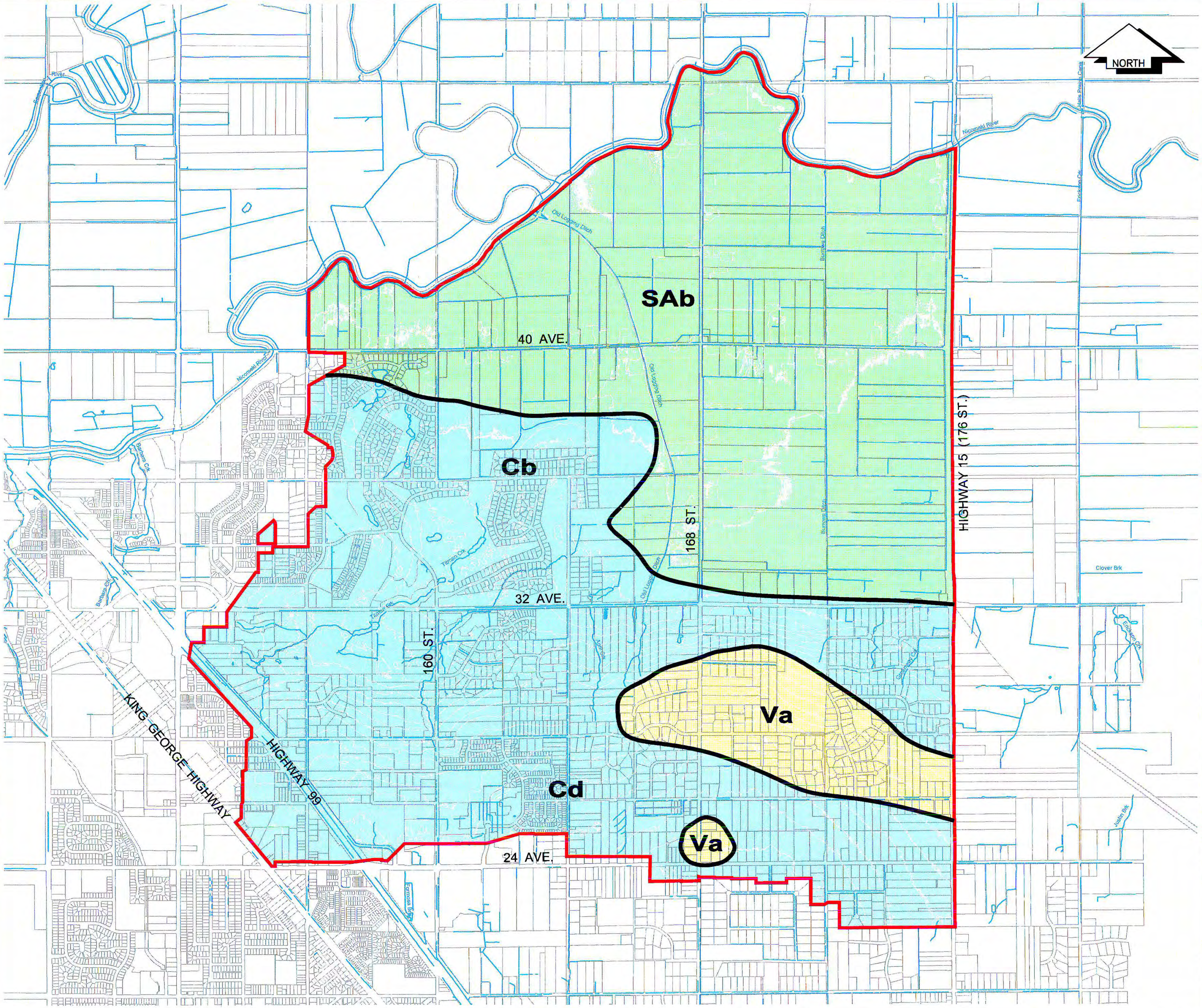
The results are for the sole use of the designated client only. This report constitutes a testing service only and does not represent any interpretation or opinion regarding the specification compliance or material suitability. Engineering interpretation will be provided by Thurber upon request.

THURBER
Thurber Engineering Ltd.
#200 - 1445 West Georgia St.
Vancouver, B.C. V6G 2T3
Telephone: (604) 684-4384
Fax: (604) 684-5124

GRAIN SIZE DISTRIBUTION

CLIENT: Urban Systems Ltd.
PROJECT: Old Logging and Borrows Ditches ISMP
FILE NO.: 17-610-134

S:\CAD Files\ACADDATA\PROJECTS\17\VED02563.dwg



NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. SURFICIAL GEOLOGY TAKEN FROM GSC MAP 1484A.
3. FOR DESCRIPTION OF SOIL UNITS REFER TO REPORT.
4. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.

LEGEND:

STUDY AREA BOUNDARY

200 0 500 1,000m

SCALE 1:25,000

URBAN SYSTEMS LTD.

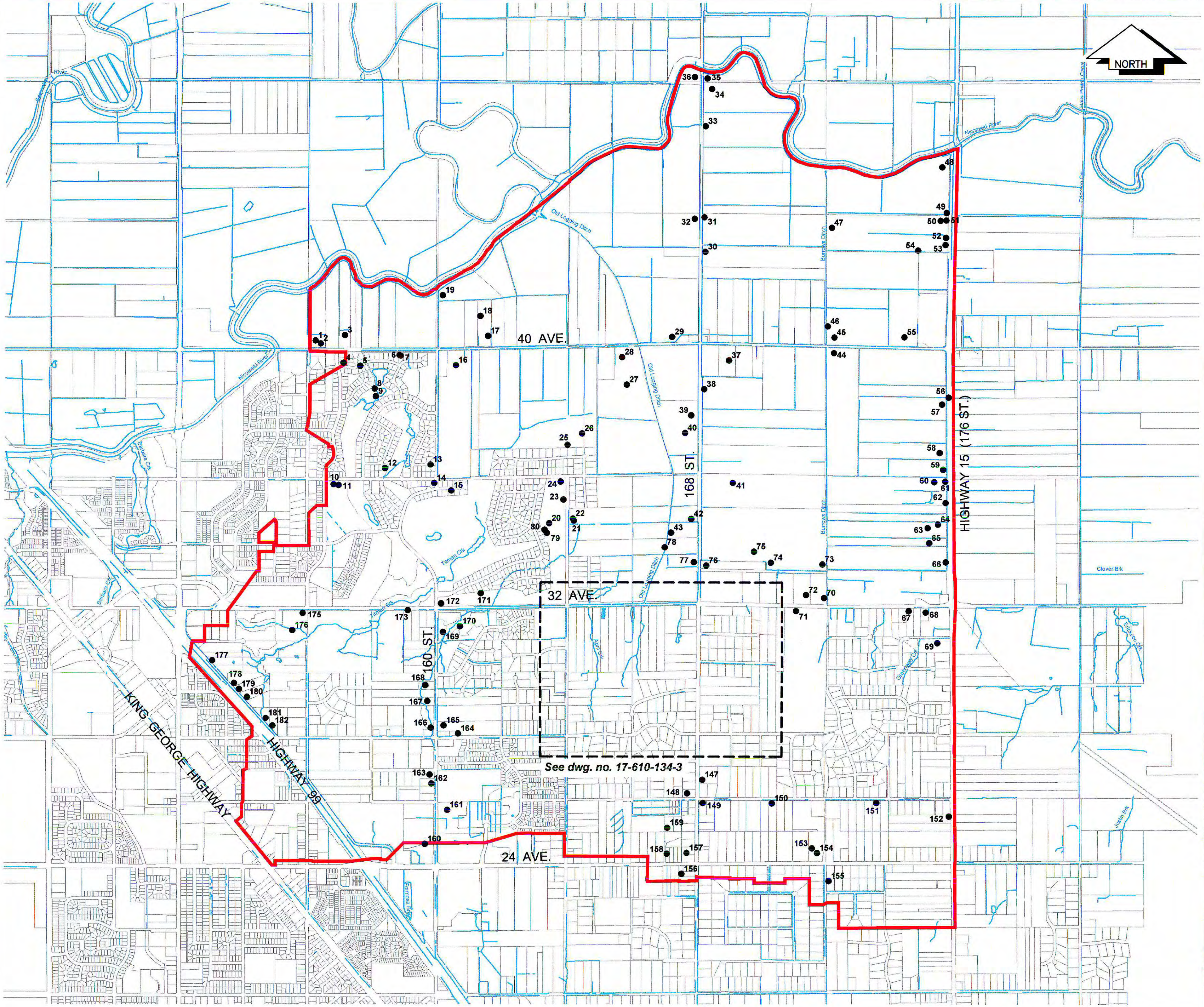
SURFICIAL GEOLOGY

OLD LOGGING AND BURROWS DITCHES ISMP — SURREY, B.C.

THURBER ENGINEERING LTD.
GEOTECHNICAL · ENVIRONMENTAL · MATERIALS

ENGINEER:	DRAWN:	APPROVED:
DS	DRB/KM	
DATE: DECEMBER 24, 2009	SCALE: AS SHOWN	DRAWING No. 17-610-134-1

S:\CAD Files\ACADDATA\PROJECTS\17\VED02563.dwg



NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.

LEGEND:

STUDY AREA BOUNDARY

41 — WELL NUMBER

└ WELL LOCATION (APPROXIMATE)

200 0 500 1,000m

SCALE 1:25,000

URBAN SYSTEMS LTD.

WELL LOCATION PLAN

OLD LOGGING AND BURROWS DITCHES ISMP — SURREY, B.C.

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS

ENGINEER:	DRAWN:	APPROVED:
DS	DRB/KM	
DATE: DECEMBER 24, 2009	SCALE: AS SHOWN	DRAWING No. 17-610-134-2

S:\CAD Files\ACADDATA\PROJECTS\17\VED02563.dwg

NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.

LEGEND:

41 ——— WELL NUMBER

WELL LOCATION (APPROXIMATE)

50 0 100 200m

SCALE 1:5,000

URBAN SYSTEMS LTD.

DETAIL FOR UPPER LOGGING DITCH AREA WELL LOCATION PLAN

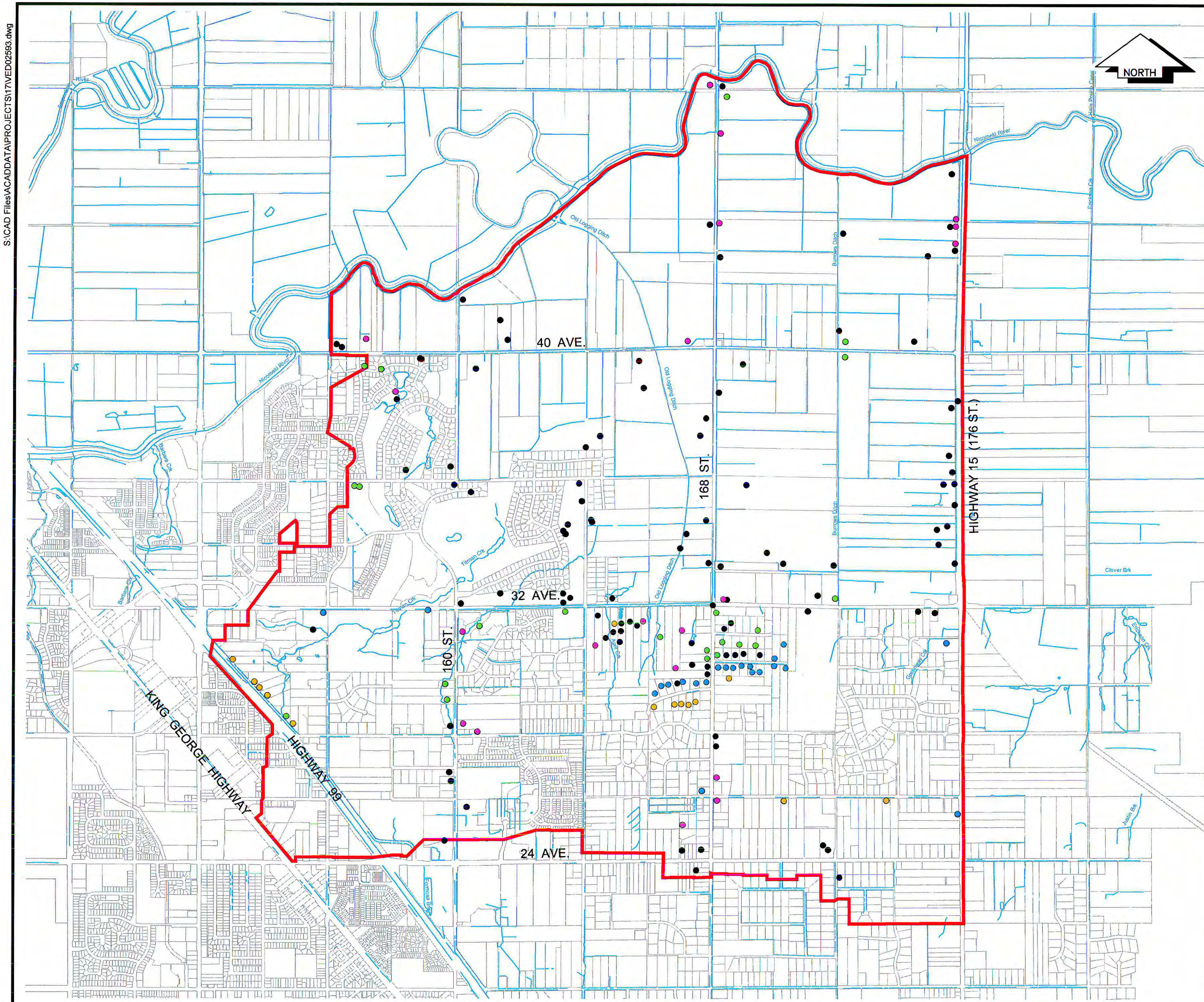
OLD LOGGING AND BURROWS DITCHES ISMP

SURREY, B.C.

THURBER ENGINEERING LTD.

GEOTECHNICAL • ENVIRONMENTAL • MATERIALS

ENGINEER: DS	DRAWN: DRB/KM	APPROVED:
DATE: DECEMBER 24, 2009	SCALE: AS SHOWN	DRAWING No. 17-610-134-3



NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.
3. ONLY WELLS WITH STATIC WATER LEVEL IN WELL RECORDS ARE COLOUR CODED.

LEGEND:

STUDY AREA BOUNDARY

DEPTH TO GROUNDWATER TABLE (m)

- < 2
- 2 - 10
- 10 - 30
- > 30

200 0 500 1,000m

SCALE 1:25,000

URBAN SYSTEMS LTD.

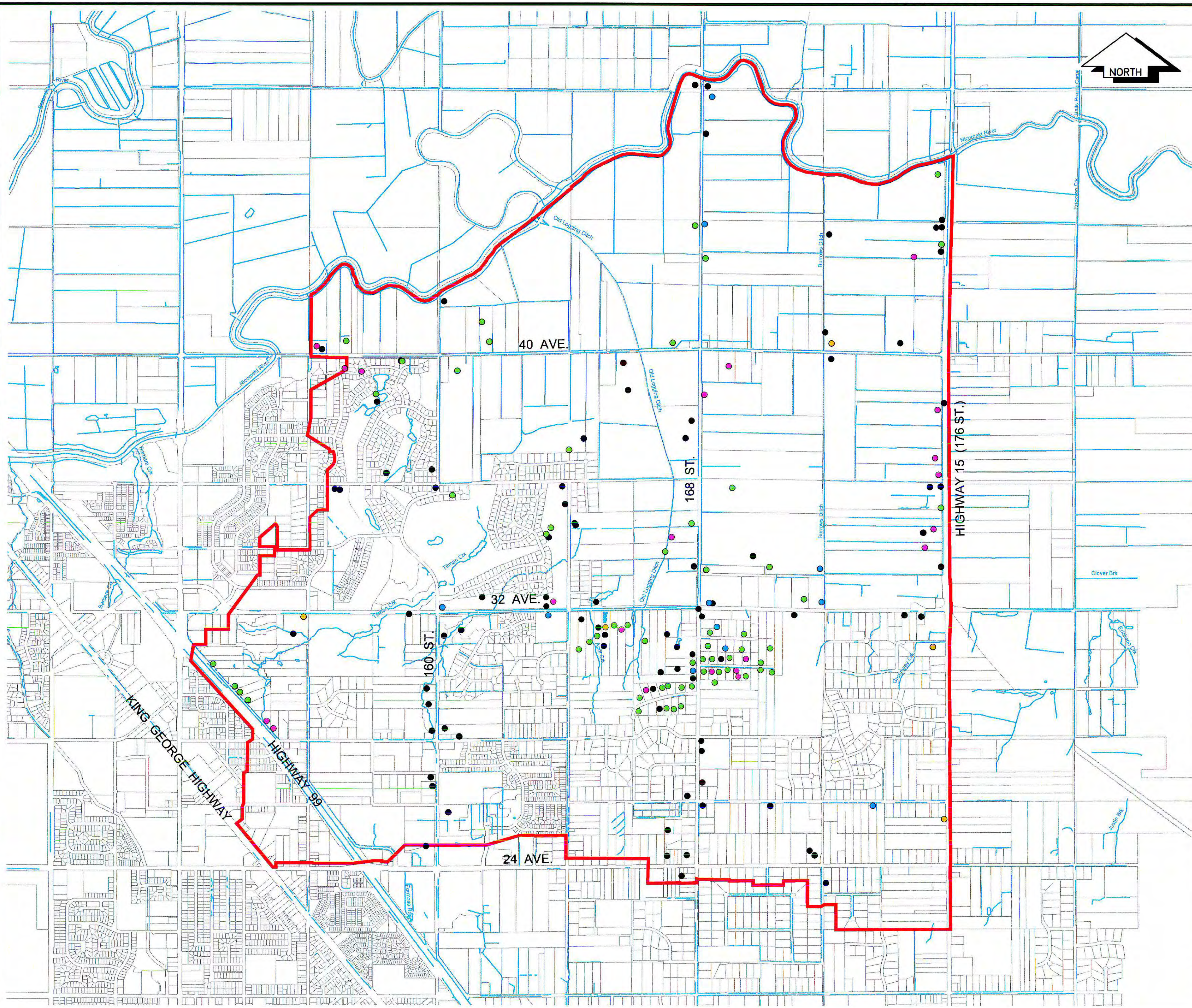
STATIC WATER LEVELS REPORTED IN WELL RECORDS

OLD LOGGING AND BURROWS DITCHES ISMP — SURREY, B.C.

THURBER ENGINEERING LTD.
GEOTECHNICAL ◦ ENVIRONMENTAL ◦ MATERIALS

ENGINEER : AB/DS	DRAWN : KM	APPROVED :
DATE : MARCH 19, 2010	SCALE : AS SHOWN	DRAWING No. 17-610-134-4

S:\CAD Files\ACADDATA\PROJECTS\17\VED02593.dwg



NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.
3. ONLY WELLS INTERPRETED TO BE PUMPED WELLS FROM WELL RECORDS ARE COLOUR CODED.

LEGEND:

STUDY AREA BOUNDARY

WELL YIELD (gpm)

- < 5
- 5 - 25
- 25 - 100
- > 100

200 0 500 1,000m

SCALE 1:25,000

URBAN SYSTEMS LTD.

NON - ARTESIAN WELL LOCATIONS AND YIELDS

OLD LOGGING AND BURROWS DITCHES ISMP

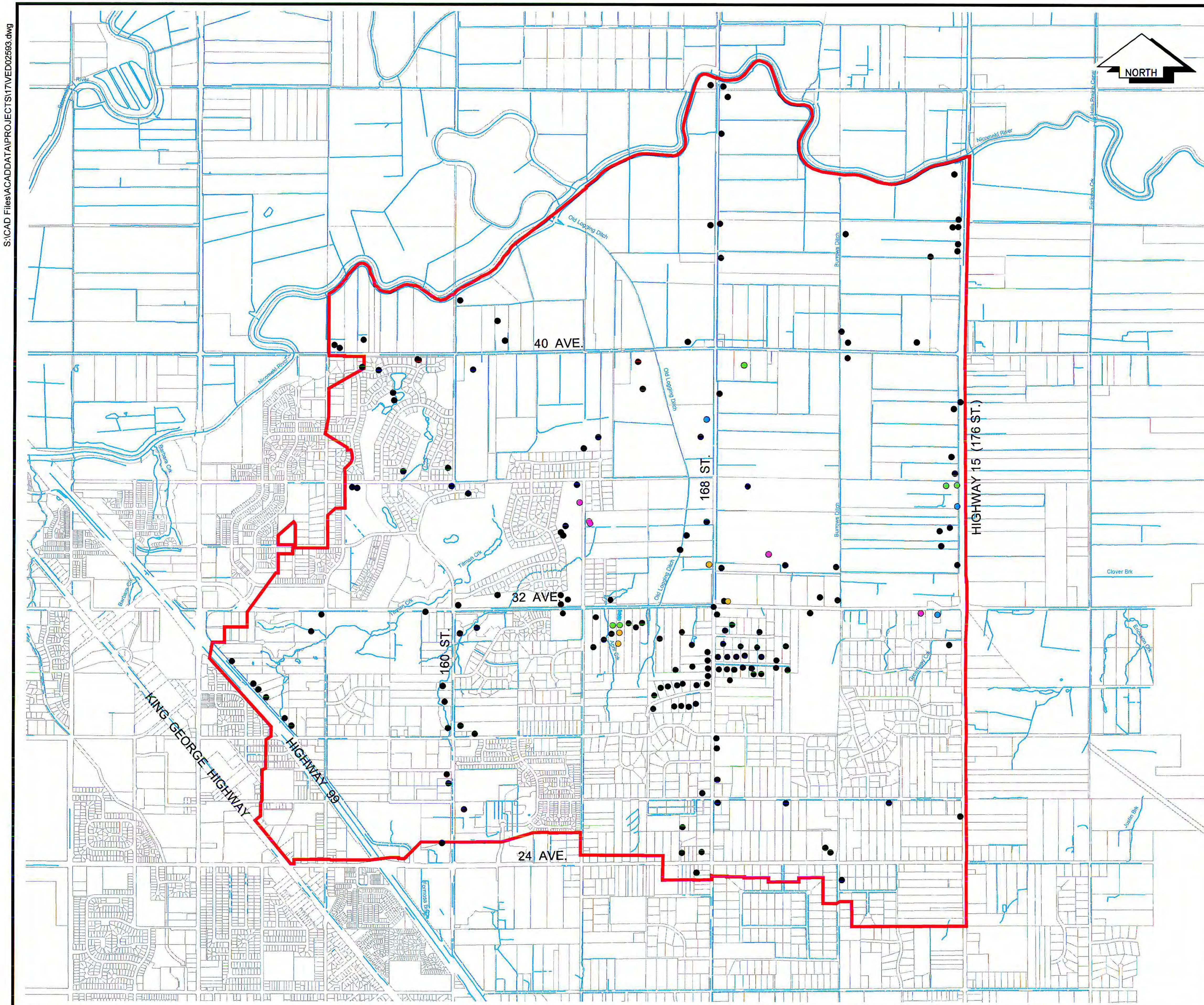
SURREY, B.C.

THURBER ENGINEERING LTD.

GEOTECHNICAL • ENVIRONMENTAL • MATERIALS

ENGINEER :	DRAWN :	APPROVED :
AB/DS	KM	
DATE : MARCH 19, 2010	SCALE : AS SHOWN	DRAWING No. 17-610-134-5

S:\CAD Files\ACADDATA\PROJECTS\17\VED02593.dwg



NOTES:

1. BASE PLAN PROVIDED BY URBAN SYSTEMS LTD.
2. DRAWING TO BE READ IN CONJUCTION WITH THURBER ENGINEERING LTD. REPORT.
3. ONLY WELLS INTERPRETED TO BE ARTESIAN FROM WELL RECORDS ARE COLOUR CODED.

LEGEND:

STUDY AREA BOUNDARY

WELL YIELD (gpm)

- < 1
- 1 - 10
- 10 - 30
- > 30

200 0 500 1,000m

SCALE 1:25,000

URBAN SYSTEMS LTD.

ARTESIAN WELL LOCATIONS AND YIELDS

OLD LOGGING AND BURROWS DITCHES ISMP — SURREY, B.C.

THURBER ENGINEERING LTD.
GEOTECHNICAL = ENVIRONMENTAL = MATERIALS

ENGINEER: AB/DS	DRAWN: KM	APPROVED:
DATE: MARCH 19, 2010	SCALE: AS SHOWN	DRAWING No. 17-610-134-6

Appendix E

Drainage Improvements in the City's Current 10-Year Servicing Plan

Currently Listed Improvement Projects within Study Area
(Per City's 2010-2019 10 – Year Servicing Plan)

Category	Project ID	Project Name	Project Location	Priority	Total Cost
Lowland & Dyking Works	11719	Old Logging Ditch Conveyance Works	Old Logging Ditch	4-6 yrs	$410,000
Exist System Upgrade	11650	Storm Sewer upgrade	024 Ave / 168 St	7-10 yrs	$493,700
Trunk System	6568	Culvert upgrade 15m of 1800mm diameter	164 St / 040 Ave	4-6 yrs	$54,000
Trunk System	6569	Culvert upgrade 7m of 1800mm diameter	163 St / 040 Ave	4-6 yrs	$54,000
Trunk System	6570	Culvert upgrade with flap gate 12m of 600mm diameter	160 St / 040 Ave	4-6 yrs	$36,000
Trunk System	6572	630m of 1200mm trunk sewer	Croydon Dr: 029 – 031 Ave	7-10 yrs	$1,089,000
Trunk System	6583	Upgrade culvert crossing for future peak flows	160 St / 030 Ave	4-6 yrs	$45,000
Trunk System	6707	Trunk Storm Sewer and Detention Pond	026 Ave: 170 – 176 St	7-10 yrs	$7,802,000
Trunk System	11793	770m ditch	034 Ave: 164 St to 166 St	1-3 yrs	$388,900
Trunk System	11794	32 Ave Trunk & Creek Works: 20m-900mm + 110m-1200mm	032 Ave: 164 to 166 St	1-3 yrs	$422,900
Community Detention	6197	Community Detention Pond	164 St / 026 Avenue	4-6 yrs	$2,690,000
Community Detention	10332	Detention Pond G 3200 cu.m.	028 Ave / 160 St	NCP Driven	$1,095,000
Community Detention	11773	Pond F: 1800 cu.m.	032 Ave / 166 St (April Crk)	1-3 yrs	$616,000
Erosion & Ravine Works	6561	Erosion protection	167 St / 033 Ave	7-10 yrs	$60,000
Erosion & Ravine Works	6563	Erosion protection	159 St / 029 Ave	7-10 yrs	$10,000
Erosion & Ravine Works	6564	Erosion protection	160 St / 028 Ave	7-10 yrs	$10,000
Erosion & Ravine Works	6581	Remove stm outfall and stabilize banks	161 St / 031 Ave	7-10 yrs	$60,000
Erosion & Ravine Works	6582	Remove culvert and stabilize banks	161 St / 031 Ave	7-10 yrs	$60,000
Erosion & Ravine Works	6584	Remove box culvert and stabilize banks	159 St / 029 Ave	7-10 yrs	$10,000
Erosion & Ravine Works	9378	Over-steep bank, 2 sites	Titman Creek: 164 St / 040 Ave	7-10 yrs	$26,000
Erosion & Ravine Works	9379	Over-steep bank at 160 St.	Near 3024 160 St	7-10 yrs	$9600
TOTAL Estimated Cost for Drainage Improvements					**$15,442,100**

Appendix F

Cost Estimate Details

Old Logging Ditch/Burrow's Ditch ISMP
Class D Construction Cost Estimate (DRAFT)

	DESCRIPTION		UNIT	Proposed Implementation time period years	QUANTITY	Construction Location	UNIT PRICE	AMOUNT
172 Street Trunk Storm Sewer								
	Concrete storm sewer							
M1	600mm dia.	600	lin.m.	6+	160	collector	$ 1,416	$ 227,000
M2	1200mm dia.	1200		1-5	640	collector	$ 2,279	$ 1,459,000
166 Street Trunk Storm Sewer								
	Concrete storm sewer							
M3	750mm dia.	750	lin.m.	1-5	150	local	$ 1,469	$ 220,000
24 Avenue Trunk Storm Sewer								
	Concrete storm sewer							
M4	Included in the 2010 10 year servicing plan	750	lin.m.	6+	995	Arterial		$ 493,741
M5	750mm dia.	750		6+	550	Arterial	$ 2,040	$ 1,122,000
26 Avenue Trunk Storm Sewer								
	Concrete storm sewer							
M6	Included in the 2010 10 year servicing plan	750	lin.m.	6+	1185	Collector		$ 7,802,002
168 St Trunk Storm Sewer								
	Concrete storm sewer							
M7	900mm dia.	900	lin.m.	1-5	375	Arterial	$ 2,310	$ 866,000
32nd Avenue								
	Concrete storm sewer							
M8	1050mm dia.	1050	lin.m.	1-5	330	Arterial	$ 2,579	$ 851,000
164th St Trunk Storm Sewer								
M9	Recommended in the Grandview Heights #1 NCP; however no detail information is available.							
Croydon Drive: 029 - 031 Ave.								
M10	Included in the 2010 10 year servicing plan; 630 m of 1200 mm trunk sewer	1200		6+	630	Local	$ 1,729	$ 1,089,000
32nd Ave trunk and creek works								
M11	Included in the 2010 10 year servicing plan; 20 m 900mm and 110m 1200mm	1200		1-5	130	Arterial	3253	$ 422,900
	Grand Total							**$ 14,552,643**

Notes:

1 Trunk costs based on unit rates provided by City of Surrey 16-Feb-2010
2 Total cost does not include GST/HST.
3 The cost estimates included in the 2010 10 year servicing plan were shown as they are. No changes have been made.

OLD LOGGING DITCH /BURROW'S DITCH ISMP
CULVERT COST ESTIMATE (DRAFT)

								Existing Peak Flows (m^3/s)		Future Peak Flows (m^3/s)					
Creek Name	**Culvert Crossing**	Culvert ID in the model	**Culvert ID**	**Existing Size (mm)**	**Length (m)**	**No**	**Capacity (m3/s)**	**5y-1h**	**100y-1h**	**5y-1hr**	**100y-1h**	**Is adequate for hydraulic purpose?**	**Is adequate for environmental purpose?**	**Recommended Size (mm)**	**Culvert Cost (Hydraulic)**
Wills Brook	160th Street (South of 161 St)	WB3	M12	750	12	1	0.6	0.066	0.145	0.087	0.174	Included in the 10 year servicing plan	Included in the 10 year servicing plan	detail information not available	$45,000
Morgan Creek	32nd Avenue	MG2	M13	1050	30.5	1	1.4	1.21	2.567	1.659	3.036	No	Will be decided based on proposed detail environmental assessment. Improvements may be needed to make the culverts fish accessable. Thus, a L.S cost of $30,000 could be anticipated for each culvert.	1500	$115,000.00
Wills Brook	161th St)	WB4	M14	600	12	1	0.35	0.18	0.359	0.234	0.482	No		750	$45,000.00
Old Logging Ditch	32nd Avenue	OLD1	M15	1800X1200	19.5	1	3.78	1.865	4.252	2.229	5.317	No		1800X1500	$140,000.00
Burrows Ditch	32nd Avenue	BRW1	M16	1200	15	1	2	0.919	2.02	1.431	3.055	No		1500	$100,000.00
Morgan Creek	HWY 99	MG1	M17	750	120	1	0.6	0.296	0.626	0.293	0.62	No		900	$100,000.00
Wills Brook	32nd Avenue	WB1		1800X1200	10	1	3.78	1.345	2.909	0.996	2.614	Yes			
Wills Brook	Cross Creek Crt.	WB5		1350	16	2	5.2	1.429	3.065	1.076	2.785	Yes			
Wills Brook	164th St	WB2		3050X1350	25	1	7.6	1.549	3.312	1.16	3.021	Yes			
Ditch	160th St / 40th Ave	?	M27	?	12	1	?	?	?	?	?	Included in the 10 year servicing plan	Included in the 10 year servicing plan	600	$36,000.00
Ditch	163 St / 40th Ave	N/A	M28	?	7	1	?	N/A	N/A	N/A	N/A	Included in the 10 year servicing plan	Included in the 10 year servicing plan	1800	$54,000.00
Ditch	164th St / 40th Ave	N/A	M29	1500	15	1	?	N/A	N/A	N/A	N/A	Included in the 10 year servicing plan	Included in the 10 year servicing plan	1800	$54,000.00

Assumptions:

Assumed Aluminized steel pipe

Assumed cost per unit meter of culvert: 750 mm -$115; 900 mm-$135; 1200mm-$240; 1500mm-$300;1800mm-$385;2000 mm - $500; 2100 mm - $500.

Assumed excavation and backfill cost/unit meter of culvert: 750mm-$150; 900mm-$150; 1200mm-$180; 1500mm-$270; 1800mm-$400; 2000mm-$550;2100mm-$550.

Assumed lump sum Isolation cost: 750mm to1200mm-$10,000; 1500mm to 2100mm- $20,000.

Assumed Lump sum surface restoration cost: 750mm-$4000; 900mm-$5000; 1200mm-$6000; 1500mm-$7500; 1800mm-$10,000; 2000mm-$15,000; 2100mm-$15,000.

Assumed mobilization cost= 15% of (Culvert cost+Excavation and backfill cost+Isolation cost+Surface restoration cost)

Base Construction Cost=Culvert cost+Excavation and backfill cost+Isolation cost+Surface restoration cost+Mobilization cost

Contingency = 35% of Base Cost

Administration during construction = 10% of Base Cost

Engineering = 15% of Base Cost

Total Esitmated Cost= Base construction cost+ Contingency+Administration cost +Engineering cost

The 'Site Improvment Contingency' includes such things as headwalls, retaining wall, or local channel improvements. It is assumed that all works would not extend more than 6 m beyond the limit of the culvert

Total Esitmated Cost with Site improvement contingency= Total estimated cost+site improvement contingency

U:\Projects_VAN\1072\0176\01\D-Drafting-Design-Analysis\CostEstimate\FinalReport_CostEstimates\[2010_08_24_culvert_cost.xls]cost

Old Logging Ditch/Burrow's Ditch ISMP
Class D Construction Cost Estimate (DRAFT)

		DESCRIPTION	UNIT	Proposed Implementation time period years	QUANTITY	Construction Location		UNIT PRICE	AMOUNT
Old Logging Ditch Conveyance Works									
M30		Included in the 2010 10 year servicing plan; drainage - lowland & dyking, approximately 1300m.	lin.m	4-6	1300	Old Logging Ditch			$ 410,000
34th Ave Ditch Upgrade (164 St - 166 St)									
M31		Included in the 2010 10 year servicing plan; 770m of ditch	lin.m	1-3	770	34th Ave			$ 388,900
		Grand Total							**$ 798,900**

Notes:

1. costs based on 2010 10 year servicing plan provided by City of Surrey
2. Total cost does not include GST/HST.

Old Logging Ditch/Burrow's Ditch ISMP
Class D Construction Cost Estimate (DRAFT)

PROJECT_NO	PROJECT_NAME	PROJECT_LOCATIO	PROGRA	LRP_YR	LRP_PRIORITY	NONGROWTH	GROWTH_COST
6582 (S1)	Remove culvert and stabilize banks	161 St / 031 Ave	Drainage	2010	Long Term (7 -	2	60000
9378 (S2)	2 sites (ID=TTMN-1,2; risk=L)	Titman Creek: 164 S	Drainage	2010	Long Term (7 -	26002	0
6581 (S3)	Remove stm outfall and stablize banks	161 St / 031 Ave	Drainage	2010	Long Term (7 -	2	60000
6584 (S4)	Remove box culvert and stabilize banks	159 St / 029 Ave	Drainage	2010	Long Term (7 -	2	10000
6561 (S5)	Erosion protection	167 St / 033 Ave	Drainage	2010	Long Term (7 -	2	60000
6563 (S6)	Erosion protection	159 St / 029 Ave	Drainage	2010	Long Term (7 -	2	10000
6564 (S7)	Erosion protection	160 St / 028 Ave	Drainage	2010	Long Term (7 -	2	10000
9379 (S8)	Over-steep bank at 160 St.; (Site ID=TTMN-3; Risk=	near 3024 - 160 St	Drainage	2010	Long Term (7 -	9602	0

Old Logging Ditch / Burrow's Ditch ISMP
Class D Construction Cost Estimate (DRAFT)

#	ID	Source	Pond Location	Pond volume (cu.m)	Total Cost as shown in City's 10 yr Servicing Plan/North Grandview Heights NCP/Grandview Heights #1 NCP	Total Cost Updated to reflect 2010 costs (using ENR Construction index 1990 to present)
1	M20	North Grandview Heights NCP	W of 160th St	3200	$1,104,000	$1,306,000
2	M21	North Grandview Heights NCP	32nd Ave and 160th St	450	$154,000	$183,000
3	M22	North Grandview Heights NCP	S of 32nd Ave and E of Wills Brook	600	$206,000	$244,000
4	M23	North Grandview Heights NCP/10 year Servicing Plan	32nd Ave and 164th St	500	$172,000	$172,000
5	M24	North Grandview Heights NCP/10 year Servicing Plan	April Creek	1800	$616,000	$616,000
6	M25	North Grandview Heights NCP	S of 28th Ave	3400	$1,173,000	$1,388,000
7	M26	North Grandview Heights NCP (City's 10 year servicing plan recommends a detention pond in close proximity to this pond. So we assume they are the same and thus included the cost that is shown in the 10 year servicing plan)	E of 164th St	3200	$269,000	$319,000

Notes:

1 Based on current information from the City, M21 has now been approved as an underground storage tank. However, the cost still reflects the pond assumption.

2 Based on current information from the City, M26 is planned to be a linear corridor instead of a detention pond. Since not enough informaiton is available, it is still inlcuded in the table. However, the cost does not reflect the proposed change.

3 M20 and M25 were proposed in the North Grandview Heights without any costs associated with them. Therefore, a unit cost of $345 was used to estimate the total cost and then the total cost was updated. The unit cost was derived from the other pond costs.

Appendix G

City of Seattle Topsoil Requirements

Green Stormwater Infrastructure on Private Property:

Post Construction Soil Management

November 30, 2009

This Client Assistance Memo (CAM) is designed to help applicants meet the City of Seattle Stormwater Code Green Stormwater Infrastructure (GSI) requirements for Post Construction Soil Quality and Depth. Obtain a copy of the Construction Stormwater Control Plan/Post Construction Soil Management (CSC/PCSM) Plan at the DPD drainage desk.

Refer to CAM 530, *Managing Stormwater in Seattle* before continuing with this CAM. It is an essential resource for designing, constructing and completing GSI and is referenced throughout this CAM.

This CAM covers:

- What is healthy soil and why does it matter?
- What are the Post Construction Soil Management requirements?
- What are the Post Construction Soil Management options?
- How are custom amendment rates calculated?
- How are the Post Construction Soil Requirements documented on the CSC/PCSM Plan sheet?
- What inspections are required for GSI Post Construction Soil Management?
- How are inspections scheduled?
- Where can material suppliers and installers be found?
- What other resources and contacts are available?

What is healthy soil and why does it matter?

Naturally occurring soil (undisturbed), soil organisms, and vegetation provide important stormwater management functions, including water infiltration and storage, and nutrient, sediment, and pollutant removal.

These functions are largely lost when native soils and vegetation are stripped and replaced with minimal soil and sod. Not only are these important stormwater management functions lost, but these landscapes become pollution-generating surfaces due to compaction, increased use of pesticides and fertilizers, concentration of pet wastes, and pollutants from adjacent roads and driveways.

While restoring a minimum soil quality and depth is not the same as preserving naturally occurring soil and vegetation, it does improve onsite stormwater management and water quality.

Amending construction-disturbed soils with compost re-establishes a healthy soil ecosystem, which provides increased treatment of pollutants and sediments. It also supports healthy plant growth, minimizing the need for fertilizers and pesticides, thus reducing pollution through prevention.

What are the Post Construction Soil Management requirements?

In the City of Seattle, all new construction sites subject to clearing, grading, or compaction that have not been covered by impervious surface, incorporated into a drainage facility, or engineered as structural fill or slope shall, at project completion, meet post construction soil quality and depth requirements. Only the areas of the sites where existing vegetation and/or soil are disturbed or compacted must be restored.

A minimum 8-inch depth of compost amended soil or imported topsoil shall be placed in all areas of the project site that have been disturbed during construction. Before the soil is placed, the subsoil must be scarified (loosened) at least 4 inches deep, with some incorporation of the amended soil into the existing subsoil shall be achieved to avoid stratified layers.

City of Seattle
Department of Planning & Development
Michael McGinn, Mayor Diane Sugimura, Director
700 5th Avenue, Suite 2000
P.O. Box 34019
Seattle, WA 98124-4019
(206) 684-8600
Printed on totally chlorine free paper made with 100% post-consumer fiber

Figure 1 - Cross Section of Turf Soil Amendment

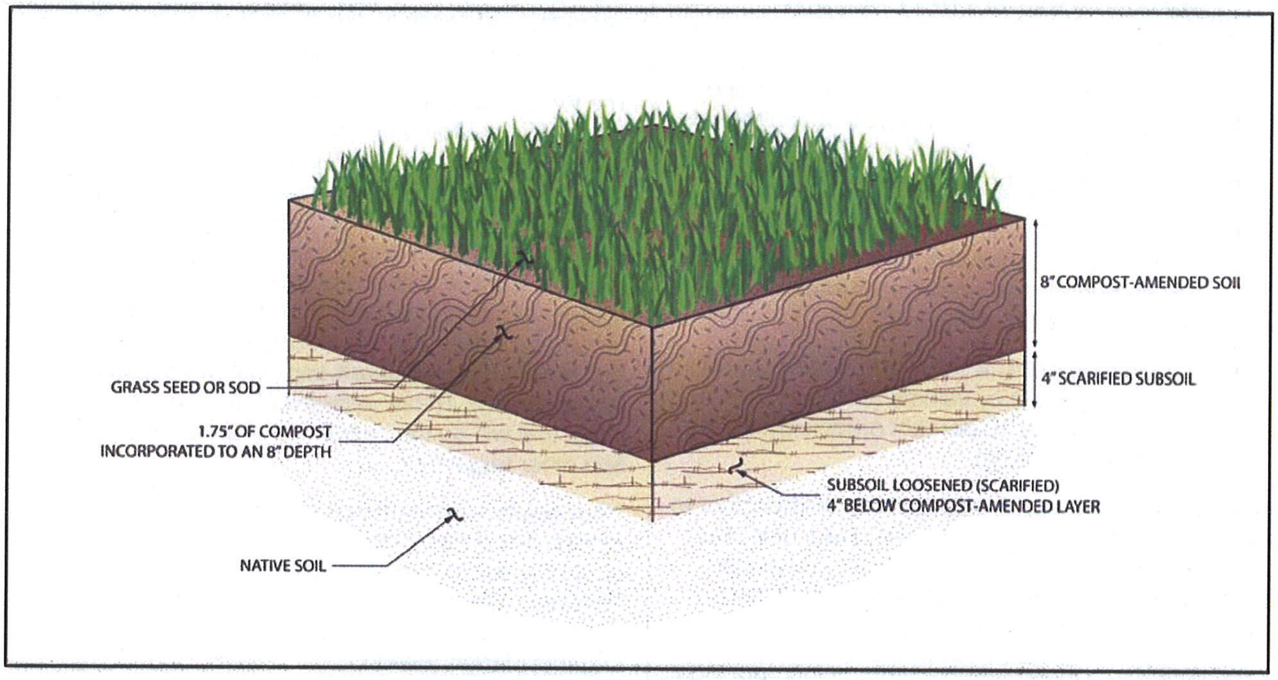
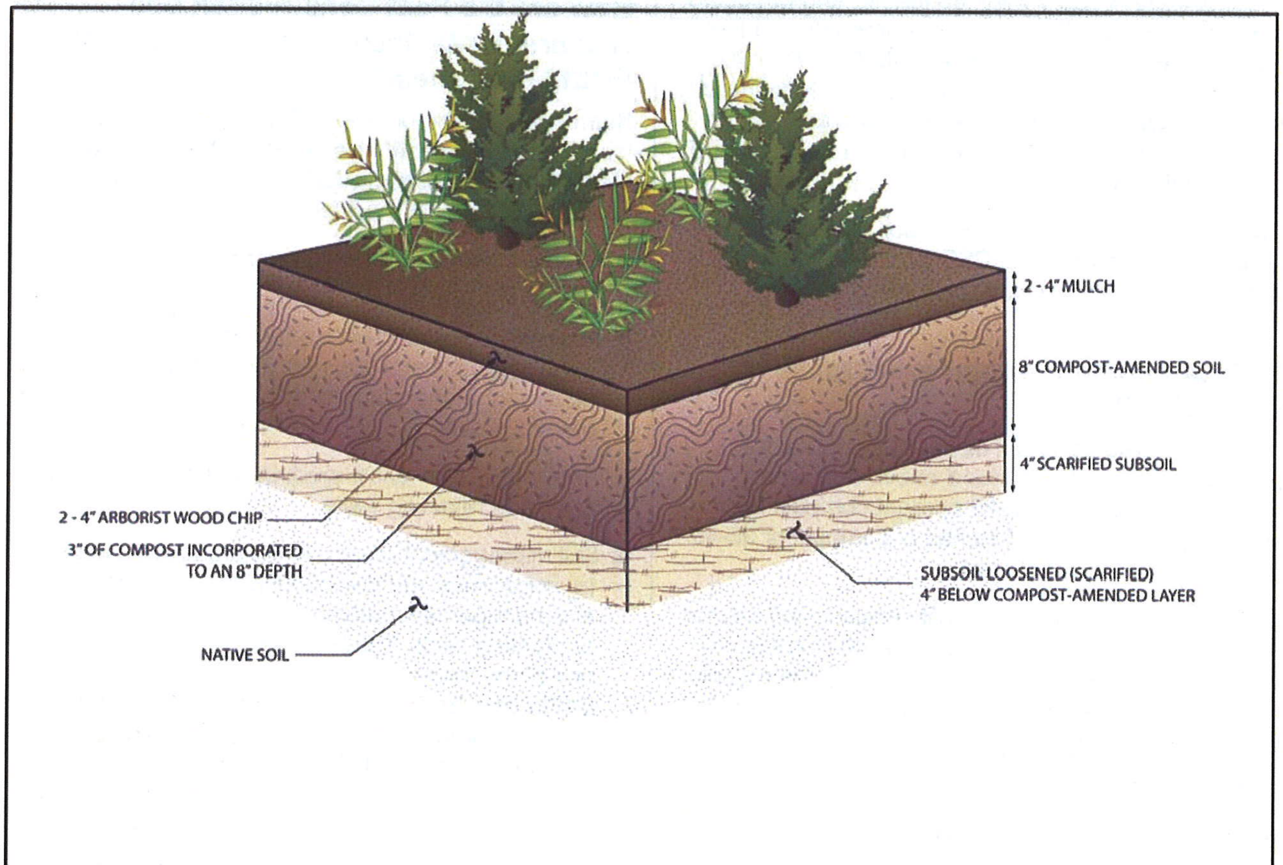


Figure 2 - Cross Section of Planting Bed Soil Amendment



tions" above). Delineate each soil management area with a dark, clear line and note the square footage of each area.

- Construction stormwater control (CSC) measures - also known as Temporary Erosion and Sedimentation Control (TESC) - show CSC measures that will be used to contain the site during construction. Use the standard detail symbols shown on the CSC/PCSM Plan Sheet.

Complete the Soil Management Plan Worksheet **http://www.seattle.gov/dpd/Codes/Stormwater-GradingandDrainageCode/Forms/default.asp** on the CSC/PCSM Plan Sheet. Show the square footage of each Soil Management Area, and do the calculations to show how much compost, amended topsoil, and mulch will be brought onto the site. The DPD site inspector must see delivery tickets equaling those totals, and inspect the soil, before the project can pass final inspection.

Access to Information

Links to electronic versions of DPD **Client Assistance Memos (CAMs), Director's Rules**, and the **Seattle Municipal Code** are available on the "Publications" and "Codes" pages of our website at **www.seattle.gov/dpd**. Paper copies of these documents, as well as additional regulations mentioned in this CAM, are available from our Public Resource Center, located on the 20th floor of the Seattle Municipal Tower at 700 Fifth Ave. in downtown Seattle, (206) 684-8467.

Site Final Inspection

The final site inspection shall occur prior to the building permit final approval.

Builder Requirements:	Inspector Requirements:	Notes
Have the approved plan set onsite	Evaluate permanent erosion control	This inspection cannot be conducted without the approved plan set
Know the impervious square footage per plan	Measure required impervious surface	
Show how Non-disturbed areas have been protected throughout construction	Verify Non-disturbed areas remained protected throughout construction	No storage, vehicle traffic, clearing, grading, or other impacts are allowed on Non-disturbed areas
Provide original delivery tags of compost, topsoil and mulch showing supplier, quantity, type of material, and delivery location	Verify compost, topsoil, and mulch came from an approved supplier. Make sure that total quantities meet or exceed the required amount shown on the approved CSC/Post Construction Soil Plan Sheet	
Based on the approved CSC/Post Construction Soil Management Plan Sheet, ensure that the site has been properly amended and planting beds/turf areas are planted Be prepared to dig holes (one cubic foot in size) where the Inspector designates, to verify mulch, topsoil/compost and scarified subgrade	Choose locations of test holes to be dug in both planting beds and turf areas. Verify profile of mulch, topsoil/compost and scarified subgrade Test several locations with a "rod penetrometer" probe to verify 12 inches of probe penetration. The probe should be driven easily solely by the weight of the Inspector to a depth of 12 inches below the mulch layer	The test holes and 12-inch probe test should verify 8 inches of topsoil/compost soil mix, and 4 inches of scarified (loosened) subgrade There shall be a minimum of 2 inches and maximum of 4 inches of mulch on top of the topsoil/compost mix in planting beds. Mulch shall be kept 1-2 inches away from the trunks of all trees
Follow the CSC/PCSM Plan in the approved plan set and provide scaled redline of any changes made to this approved plan set	Ensure the CSC/PCSM Plan has been followed and that any and all changes were approved and properly documented on the plan sheet	
Schedule additional inspections as needed	Assess the need for additional inspections	

Post-Construction Soil Quality and Depth

This checklist is intended to highlight items critical to the performance of post-construction soil quality and depth that need to be addressed in the design plans and verified by a City of Seattle (COS) Seattle Public Utilities (SPU) plan reviewer or a designated representative.

Some items have detailed requirements that may not be explicitly stated; refer to the Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual (Manual) for specifics. Resources and their links are listed at the bottom of this checklist.

Technology Description
Post-construction quality and depth provides improved onsite management of stormwater flow and water quality. It involves amending the disturbed soils with compost in the post development landscape to help re-establish a healthy soil ecosystem. This BMP is required for all sites.

Design Requirements (Manual Volume 3, Section 4.4.3)

	Review Item
☐	1. Plans indicate that areas of vegetation and soil that will be left undisturbed are protected from compaction and materials storage during construction
☐	2. For all areas where soil and vegetation will be disturbed, plans indicate that at least one of the following will be implemented:
	▪ Site topsoil or subsoils will be amended either at default "pre-approved" rates or at custom calculated rates to meet the soil quality guidelines (described below) based on engineers' tests of the soil and amendment. The amendment rates are submitted. The default pre-approved rates are:
	▫ In planting beds, 3 inches of compost is tilled in to an 8 inch depth
	▫ In turf areas, 1.75 inches of compost is tilled in to an 8 inch depth
	▪ Existing topsoil will be stockpiled during grading and replaced prior to planting. It must be demonstrated that stockpiled soil meets organic matter or depth requirements, otherwise it will require amendment, which shall be stated on the plans.
	▪ Topsoil is imported and the following specifications are provided on the plans
	▫ For planting beds, a mix by volume of 35 percent compost with 65 percent mineral soil is pre-approved to achieve the requirement of a minimum 8 percent organic matter by loss-on-ignition test
	▫ For turf areas, a mix by volume of 20 percent compost with 80 percent mineral soil is pre-approved to achieve the requirement of a minimum 4 percent organic matter by loss-on-ignition test
	▫ Subsoil shall be scarified 4 inches below amended layer to produce 12-inch depth of un-compacted soil
	▪ For all areas where soil and vegetation will be disturbed, plans require the following:
	▫ Subsoil shall be scarified 4 inches below amended layer to produce 12-inch depth of un-compacted soil
	▫ After planting, 2 to 4 inches of arborist wood chip or compost mulch shall be applied to planting beds.
	▪ Soil quality guidelines

	▫ **Topsoil shall have an organic matter content by the loss-on-ignition test** of a minimum 8 percent dry weight in planting beds, and a minimum 4 percent organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil
	▫ **Topsoil layer shall have a minimum depth of 8 inches**
	▪ **Plans indicate that the compost must meet the definition of "Composted Materials"** in WAC 173-350 section 220
☐	3. A **soil management plan is submitted that includes:**
	▪ **A site map showing areas to be fenced and left undisturbed during** construction, and areas that will be amended at the turf or planting bed rates
	▪ **Calculations of the amounts of compost, compost amended topsoil, and** mulch to be used on the site

Resources:

- Green Stormwater Infrastructure (GSI) website (specifications, CADD drawings, plant lists, links to other resources)
  http://www.seattle.gov/util/greeninfrastructure

- Seattle Right-of-Way Improvements Manual
  http://www.seattle.gov/transportation/rowmanual/manual/

- Stormwater Code, **Director's Rules (Manual** and GSI to MEF), Client Assistance Memos (CAMs), GSI and flow control calculators for pre-sized facilities
  http://www.seattle.gov/dpd/Codes/StormwaterCode/Overview/default.asp

Appendix H

Example Best Management Practices for Use in OLD/BD

Stormwater Best Management Practices (BMPs)

Item	Stormwater BMP	Photo	Stormwater Management Objectives			Opportunities	Constraints	Capital Costs (to be updated for final ISMP)	Maintenance Requirements
			Peak Flow Reduction	Volume Control	Water Quality				
1	Roof Leader Disconnection		X			Increases travel time of runoff to discharge point (which reduces peak flow); may reduce runoff volume through infiltration/retention (if directed to pervious area and infiltrated).	Pools or saturated areas may develop if overland drainage paths are ill defined or soil conditions are not conducive to infiltration.	low	Periodically inspect downspouts to ensure that flow to grass or planter box is unimpeded. Remove debris and repair damaged pipes as needed. Check splash blocks or rocks and repair, replace or replenish as necessary.
2	Planter Box		X	X	X	Increases travel time of runoff; water quality benefits (plant and soil uptake of pollutants, lower runoff water temperature); some retention/detention capacity; improved aesthetics.	Additional cost for drain rock gallery below soil; typically limited to treating only roof runoff (unless set flush with adjacent sidewalk, pavement, etc).	medium (capital costs of $24,000 U.S. per acre of impervious area, plus 2-8% of total cost for annual maintenance)	Prune and weed bi-annually or as needed to remove and replace any dying, dead or overgrown plants or shrubs that may interfere with planter operation. Remove any fallen leaves, accumulations of sediment, litter, and debris. Inspect planter box structure periodically, and after major storm events, to ensure structural integrity of the box. Planter box should drain within 3-4 hours after a storm event. Till or replace soil (specify sandy loam), as necessary. Periodically inspect the overflow pipe to make sure that it can safely convey excess flows to a storm drain. Repair or replace any damaged or disconnected piping.
3	Extensive Green Roof		X	X	X	Suitable for large roof areas and roof slopes up to 30 degrees; low maintenance after initial plant establishment; research indicates that green roofs have same or longer life than conventional roof (15-20 years); little to no need for irrigation after initial plant establishment; often suitable for retrofit projects; access to roof can be accommodated.	Limited choice of plants (native species only); not typically used as a recreational space; potential insurability issues.	medium ($30-$45/m^2 systems are available; typically $75-$90/m^2 more than conventional roof system)	Irrigate during dry weather as necessary to establish grass / keep alive and occasionally weed vegetation. Avoid use of pesticides and fertilizers or use environmentally friendly products. It is advisable to occasionally inspect for leaks near abutting vertical walls, roof vent pipes, outlets, air conditioning units, perimeter areas, etc. Typically $15-20/m^2 /year
4	Intensive Green Roof		X	X	X	Greater diversity of plants and habitats (native and non-native species); good insulation; aesthetically pleasing; often used as a recreational/employee amenity area.	Can be significant additional weight loading on roof; often a need for irrigation system to sustain plants; higher capital and maintenance costs over extensive roof; potential insurability issues.	high ($450-$3,500 U.S./m^2)	Similar to typical landscaping requirements; long-term maintenance of plant and soil materials; typically $15-20/m^2/year; may be more if extensive irrigation is required.
5	Rain Garden		X	X	X	Effective treatment and removal of suspended solids, metals, nutrients and hydrocarbons; groundwater recharge potential if pervious soils are present; micro-scale habitat and reduction of urban "heat island" effects; aesthetic benefits.	Requires relatively flat slopes to be able to optimize water quality treatment through the system; requires modest land area.	medium ($18,000-$20,000 U.S. per impervious acre)	Conduct monthly inspections as follows: Inspect rain garden for obstructions, sediment accumulation and ponded water. If ponded water does not drain within 24 hours, remove surface soils and replace with sand. Inspect inlets for channels, exposure of soils, or other evidence of erosion. Maintain vegetation on a biannual schedule. Prune and weed, as needed. Remove and replace any dead or diseased vegetation. Avoid use of pesticides and fertilizers or use environmentally friendly products. Inspect and, if needed, replace mulch before the wet season begins. The entire area may need mulch replacement every two to three years, although spot mulching may be sufficient when there are random void areas.
6	Bioswale		X	X	X	Water quality benefits (plant and soil uptake of pollutants, lower runoff water temperature); stormwater can be detained by providing additional ponding and/or subsurface storage, and infiltrated if pervious soils are present; aesthetic benefits; ideal for treating runoff from parking lots / roads.	Additional costs for drain rock gallery and perforated underdrain pipe below swale; not recommended for areas with high sediment loads; not appropriate where water table or bedrock is shallow.	medium ($300 - $550 per m^2)	Main objective is to maintain a dense, healthy vegetated cover. Mow and irrigate during dry weather to extent necessary to keep vegetation alive. Avoid use of pesticides and fertilizers or use environmentally friendly products. Inspect vegetated swales monthly: Confirm ponded flow drains within 24 hours after a rainfall. If water ponds more than 24 hours then regrading may be necessary. Inspect vegetated swale bi-annually for erosion and sediment/debris accumulation. Sediment accumulating near culverts and in channels should be removed when it builds up to 75 millimeters (3 inches) at any spot, or if it covers the vegetation.; Annual Maintenance cost for 900 ft^2 area is about $200 USD(2005).
7	Grass Swale		X	X	X	Water quality benefits; stormwater can be detained by providing additional ponding and/or subsurface storage, and infiltrated if pervious soils are present; ideal for treating runoff from parking lots / roads; less expensive than bioswale.	"Rural" look; pollutant uptake not as effective as bioswale; possible tripping hazard for pedestrians.	low ($200 - $300 per m^2)	Irrigate during dry weather as necessary to establish grass and maintain it in good condition. Mow grass when the height exceeds 3". Conduct monthly inspections and take following actions as required: Remove obstructions and trash. Confirm ponded flow drains within 24 hours after a rainfall event (if ponding observed for longer than 24 hours, grading required to improve drainage). Identify and correct any erosion problems. Avoid use of pesticides and fertilizers or use environmentally friendly products; annual maintenance cost is about $0.75 USD(1997) per linear foot.
8	Porous Pavement		X	X	X	Reduces generation of stormwater runoff; research indicates reduction in snow accumulation due to geothermal warming through pores; lifespan 15-20 years when properly designed/constructed/maintained; groundwater recharge potential if pervious soils present; pollutant removal; possible aesthetic improvement if pavers used; useful in parking lots (stalls), driveways, road shoulders, sidewalks, other low traffic areas.	Not recommended for high traffic volume areas, areas with high levels of dust or sediment washoff, steep profile grades; pavement clogging possible if not properly maintained; effectiveness limited by suitability of subsoils, drainage characteristics and groundwater conditions.	Typically 10-15% higher than traditional asphalt; porous asphalt (PA) = $55 - $90/m$^{2:}$ porous concrete = PA + $15-$60/m$^{2:}$ grass/gravel pavers = PA + $30-$55/m$^{2:}$ interlocking concrete paving blocks = PA + $50-$120/m$^{2:}$	The overall maintenance goal for porous pavement is to prevent clogging of the void spaces within the surface material. The surface of porous pavements must not be sealed or repaved with non-porous materials if it is to continue to function. Monthly inspections should be conducted to ensure that the pavement area is clean of debris and dewaters between storms. (Source: WMI, 1997). Also the area should be swept quarterly and annually inspected for deterioration or spalling.
9	Reduce Impervious Area		X	X	X	Direct reduction in impervious area equates to less stormwater runoff generated and more pervious area available for retention and infiltration.	Practicality in application depends on intended land use(s).	Depends on extent of implementation; e.g. conventional storm sewer system cost may be reduced in scope if less runoff is generated (smaller pipe sizes)	Typically more maintenance required for non-pervious surfaces (usually related to landscape costs).

Stormwater Best Management Practices (BMPs)

10	Rainwater Harvesting and Reuse		X	X		Reduces peak and volume of stormwater runoff; lowers building water demands (and costs) as water can be used for toilets, air conditioning / cooling systems & irrigation; rain barrels and cisterns come in several shapes that can be selected to match building form.	Requires additional infrastructure to store and distribute "grey water"; size limitations (max volume = 10,000 gallons for cisterns and 100 gallons for rain barrels); overflow systems to storm or sanitary system are required.	low Rain barrels = $100-$150 U.S. ea.; Cisterns = $150 to $10,000 U.S. ea.	Bi-annual inspection for clogging and part replacements; cisterns should also undergo water quality assessments for fecal coliform, bacterial, sediment, heavy metals and annual sediment removal = $750-$1250 per year; maintenance costs will vary if grey water distribution system is introduced.
11	Amended Soils		X	X	X	Water quality benefits; recharge groundwater table; / infiltrate if pervious soils are present; aesthetic benefits (healthier plants / grasses).	Additional design consideration for steep slope areas; organic content reduces over time.		Visually inspect (at least annually) amended soils for signs of compacted soils, waterlogged soils, or diseased vegetation. If an issue is apparent, conduct a routine soil infiltration rate analysis to confirm then undertake the following corrective actions as required: Aerate soil extensively. Till organic amendments into the soil for a depth of several inches and restabilize the site. Remove diseased vegetation and replace with healthy vegetation.; Annual maintenance cost for 1/4 acre area is about $125 USD(2005).
12	Underground Detention/Infiltration System		X		X	Reduces peak of stormwater runoff and helps settle out suspended solids.	Presence of bedrock and/or groundwater table; infiltration capacity of native soils (for infiltration system); topographic constraints; large footprint area.		Annually remove trapped floatables and accumulated sediments from within the system. Proprietary traps and filters associated with stormwater storage units should be maintained as recommended by the manufacturer. Sediments are best removed mechanically rather than by flushing to avoid flushing sediments downstream into native waters. Any structural repairs required to inlet and outlet areas should be addressed on an as needed basis.
13	Infiltration Trench		X	X	X	Recharge groundwater table. Used for sites 5 acres or less, such as parking lots, roofs and highways. Good for small sites where little land is available as they can be incorporated into landscaping.	Requires relatively flat slopes to be able to diffuse water over its length and optimize water quality treatment through the system		The following procedures should be conducted annually or as needed: Cleaning and removing debris after major storm events(>2" rainfall). Mowing and maintaining upland vegetated areas. Sediment cleanout. Repairing or replacing stone aggregate. Maintaining inlets and outlets. Removing accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been lost should be done on a 4-year cycle.

Item Sources:

1 Urban Systems Ltd. City of Surrey. "Hyland Creek Integrated Stormwater Management Plan." BMP Matrix. 2006.
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf

2 State of Rhode Island. Department of Environmental Management. "Best Management Practices for Urban Sites." http://72.14.253.104/search?q=cache:oCPSh99_i4YJ:www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/udm3.pdf+best+management+practices+cost+green+roofs&hl=en&ct=clnk&cd=4
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf

3,4 EPA Office of Water. "Low Impact Development for Big Box Retailers." November 2005.
Fairfax County. "LID BMP Fact Sheet." 1.5 Green Roofs. February 2005. July 2007. www.lowlimpactdevelopment.org/fairfax
Ryerson University. City of Toronto. "Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto." October 2005. www.toronto.ca/greenfoofs/
State of Rhode Island. Department of Environmental Management. "Best Management Practices for Urban Sites." http://72.14.253.104/search?q=cache:oCPSh99_i4YJ:www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/udm3.pdf+best+management+practices+cost+green+roofs&hl=en&ct=clnk&cd=4
Low Impact Development Urban Design Tools Website. "Green Roofs". http://www.lid-stormwater.net/greenroofs_maintain.htm

5 State of Rhode Island. Department of Environmental Management. "Best Management Practices for Urban Sites." http://72.14.253.104/search?q=cache:oCPSh99_i4YJ:www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/udm3.pdf+best+management+practices+cost+green+roofs&hl=en&ct=clnk&cd=4
Urban Systems Ltd. City of Surrey. "Hyland Creek Integrated Stormwater Management Plan." BMP Matrix. 2006.
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf

6 EPA Office of Water. "Low Impact Development for Big Box Retailers." November 2005.
Urban Systems Limited.City of Surrey. *Hyland Creek Integrated Stormwater Management Plan* . BMP Matrix. 2006.
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf

7 EPA Office of Water. "Low Impact Development for Big Box Retailers." November 2005.
Urban Systems Limited.City of Surrey. *Hyland Creek Integrated Stormwater Management Plan* . BMP Matrix. 2006.
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf
US Green Building Council. "Grassy Swales". http://www.usgbcnorthtexas.org/library/landscaping/Grassy_Swales.pdf
San Mateo County. "San Mateo Countywide Water Pollution Prevention Program" http://www.flowstobay.org/p2business/pdfs/Chapter_8_Operation_and_Maintenance.pdf

8 US Department of Transportation: Federal Highway Administration (FHA). Stormwater BMPs in an Ultra-Urban Setting. Section 3.7 Porous Pavement. 1996. July 2007. www.fhwa.dot.gov/environment/ultraurb/
Urban Systems Limited, Stayte Road Reconstruction - Phase II. Closing Tender Prices, July 2006
State of Rhode Island. Department of Environmental Management. "Best Management Practices for Urban Sites." http://72.14.253.104/search?q=cache:oCPSh99_i4YJ:www.dem.ri.gov/programs/bpoladm/suswshed/pdfs/udm3.pdf+best+management+practices+cost+green+roofs&hl=en&ct=clnk&cd=4
The Stormwater Manager's Resource Center. "Stormwater Management Fact Sheet: Porous Pavement" http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm

9 Fairfax County.LID BMP Fact Sheet. February 2005. July 2007. www.lowlimpactdevelopment.org/fairfax

10 New England Centre for Environmental Industry and Technology. Environmental Protection Agency. http://www.epa.gov/Region1/assistance/ceitts/stormwater/techs/stormceptor.html
Rainwater Management Ltd. Email to Pete Law. "Stormwater." August 1, 2007.

11 Fairfax County. "LID BMP Fact Sheet - Soil Amendments" http://www.lowimpactdevelopment.org/ffxcty/5-1_soilamendments_draft.doc

12 Duluth Streams, Lake Superior. "Underground storage." http://www.duluthstreams.org/stormwater/toolkit/underground.html

13 Hamilton County, Tennessee. "BMP Maintenance Guidelines and Inspection Checklists." http://www.hamiltontn.gov/WaterQuality/bmps/12.1.pdf
Michigan Department of Environmental Quality. "Infiltration Trench". http://www.deq.state.mi.us/documents/deq-swq-nps-it.pdf

Capital cost provided by Cambie Roofing and Drainage Contractors. Telephone discussion. August 1, 2007.

Appendix I

References

Aplin & Martin Consultants Ltd. September 2005. North Grandview Heights Neighbourhood Concept Plan – Storm Drainage Report.

City of Surrey & Dillon Consulting Limited. 2002. Old Logging Ditch / Morgan Creek, Functional Feasibility Study for Lowlands. Final Report (Appendix).

City of Surrey Engineering Department. May 2004. Storm Drainage System Design Criteria Manual.

City of Surrey. June 2005. Grandview Heights General Land Use Plan.

Dillon Consulting. August 2002. Old Logging Ditch/Morgan Creek Functional Feasibility Study For Lowlands.

ECL Envirowest Environmental Consultants. 1994. Biophysical Assessment of Watercourses Draining Lands North of 32nd Avenue Between 168th and 176th Street, Surrey, BC. Prepared for City of Surrey.

Kerr Wood Leidal Associates Ltd. 2005. Template for Integrated Stormwater Management Planning 2005. Prepared for Greater Vancouver Regional District.

Lanarc Consultants Ltd., Kerr Wood Leidel Associated Ltd., and Goya Ngan. April 2005. Stormwater Source Control Guidelines 2005. Prepared for the Greater Vancouver Regional District (now Metro Vancouver).

New East Consulting Services Ltd. November 1996. Morgan Creek/Old Logging Ditch Master Drainage Plan.

Piteau Associates. November 1998. Hydrogeological Assessment for the North Grandview Heights Area General and NCP Servicing Plans.

Stantec Consulting. September 2005. Grandview Heights Area Neighbourhood Concept Plan #1 – Morgan Heights.

UMA Engineering Ltd. December 2002. Erickson Creek and Burrows Ditch Functional Plan Project 4802-702P.

Urban Systems Ltd. September 1996. Rosemary Heights Neighbourhood Concept Plan – Stage Two Plan,

Urban Systems Ltd, Dillon Consulting Ltd, and Strix Environmental Consulting. February 2000. Rosemary Heights Business Park & Live/Work Area Neighbourhood Concept Plan.

Urban Systems. January 11, 1999. North Grandview Heights Neighbourhood Concept Plan.

Urban Systems. October 1996. Rosemary Heights Central Neighbourhood Concept Plan.