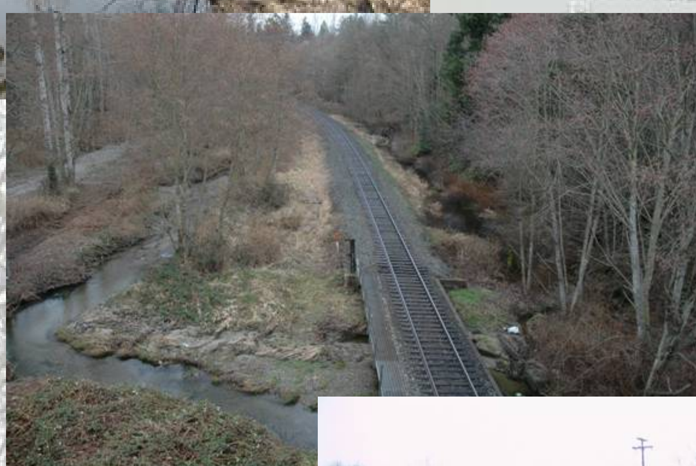
Cougar Creek/Northeast Interceptor Canal

INTEGRATED STORMWATER MANAGEMENT PLAN
FINAL REPORT

JUNE 2009



Cougar Creek/Northeast Interceptor Canal Integrated Stormwater Management Plan Report

June 2009

Submitted to:
The Corporation of Delta
Engineering Department
4500 Clarence Taylor Crescent
Delta, BC V4K 3E2

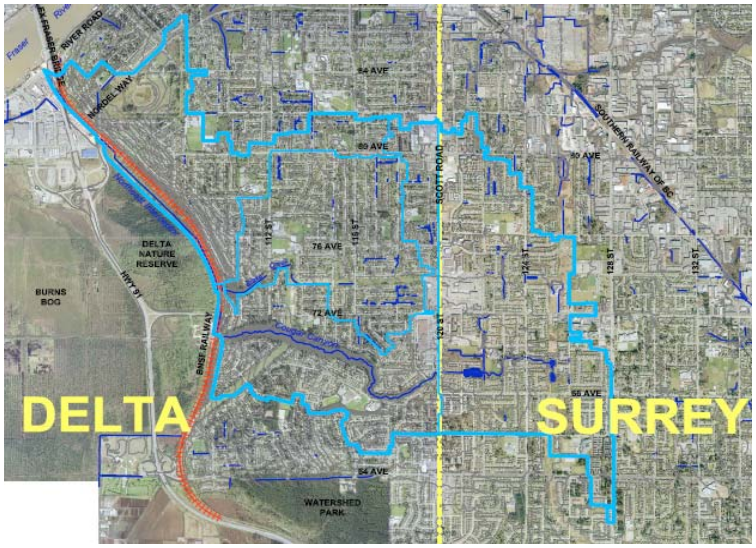
Submitted to:
City of Surrey
Engineering Operations Department
14245 – 56th Avenue
Surrey, BC V3X 3A2

Submitted by:
Dillon Consulting Limited
130 – 10691 Shellbridge Way
Richmond, BC V6X 2W8

Project Nos.: 06-6904 and 06-6987

EXECUTIVE SUMMARY

Cougar Creek/Northeast Interceptor Canal
Integrated Stormwater Management Plan – A Health Card and Executive Summary



The goal of the Integrated Stormwater Management study is to develop a plan for the Cougar Creek and Northeast Interceptor Canal (NEIC) watershed shown on the map that considers the natural resource features and provides for future uses that will protect and enhance, where feasible, the environmental conditions.

To fully understand the watershed, a number of investigations were undertaken to analyse the significant changes which occurred over the recent past within the study area in land use, hydrology, water quality and riparian corridors.

EXISTING CONDITIONS

<u>Land use</u>

The primary processes contributing to watershed changes are urbanization. The continued conversion of pervious areas, such as natural areas and large rural lots with older homes, towards newly and more intensively developed areas with increased impervious surfaces (*e.g.*, roads and roof tops) has drastically changed the watershed characteristics. A 1940 aerial photo shows that the watershed was experiencing minimal development, with small farms and was largely forested. Impervious surfaces were minimal.

Almost the entire watershed has now been developed with the exceptions of the NEIC and the Blake and Cougar Creek ravines. As a result, the total impervious surface area now stands at 58.9% and 60.4% for Surrey and Delta respectively. Like virtually all watersheds in Delta and Surrey, development within the Cougar Creek/NEIC watershed is continuing with increasing pressure on the few remaining greenfield sites and redevelopment and densification of existing residential and commercial areas of the catchment. The current impervious surface estimates are expected to further increase in future by the proposed developments and re-developments.

<u>Cougar Creek and North East Interceptor Canal</u>

Upper Cougar catchment: Most of the area is serviced by stormwater pipes that feed into retention ponds in the headwaters area. The upper portion of the Cougar Creek watershed within Surrey has mild ground and creek bed slopes with creek depths ranging from 1 to 3 m to top-of-bank. The average slope down to 122nd Street and 69th Avenue is mild, ranging from 1% to 3.75%.

Cougar Canyon catchment: Downstream of the Surrey-Delta border at Scott Road the creek changes, flowing at a higher velocity through an erosion prone region consisting of close to 5.5% grades, followed by a deposition area at Westview Drive and a backwater zone along the Canal near the Fraser River. The upper reach is characterized by steep canyon slopes from Nicholson Road to Westview Drive. There are numerous storm water outfalls within this reach mostly from the north side of the canyon, but the creek also receives inflow from a number of springs along the canyon slopes from groundwater. The hydraulics of the Cougar Creek canyon system is characterized as deep, wide, and hydraulically steep; consequently the capacity of the creek to convey high flows is adequate. These high flows in a hydraulically steep channel result in high erosive velocities.

Northeast Interceptor Canal: The 3.3 km long man-made Canal serves as the outlet for Cougar Creek. It has a very flat gradient and the water levels in the Canal can be subject to backwater effects from the Fraser River. Over the past years a number of construction activities have taken place along or across the Canal, such as in-stream works by the Burlington Northern Santa Fe (BNSF) Railway to increase discharge capacity in the Canal, the construction and removal of stream crossings, and a series of cleanup activities by the Corporation of Delta and local schools.

In addition to the Cougar Creek flows, the Canal receives stormwater from residential areas to the east via Blake Creek and from nine storm outfalls. In the vicinity of the Canal near its outlet is Burns Bog, an environmentally sensitive area located on the Fraser River flood plain. During high water conditions the Canal can overtop and inundate the Bog and its low lying areas.

Flooding and Erosion

As the Cougar Creek catchment has developed over the years, stormwater runoff has increased in intensity, frequency and duration into Cougar Creek and the Canal. Smaller rainfall events that may have produced very little runoff in Cougar Creek are now resulting in higher flows that occur more frequently for the same storm events. These increases in small runoff events often account for the majority of long-term movement of sediment and consequently are the most deterministic of the geomorphic stability of the stream channels.

Past records do not show any private homes being affected by the occasional flooding. However, with increasing frequency, flooding occurs as Cougar Creek turns northwards into the Canal. The Canal reach that parallels the railway tracks to the east has a limited cross-section that is unable to convey all flows within the top-of-bank. As a result, flood stages of the channel rise to the railway track bed causing the railway to suspend operations until after the storm passes. A significant portion of the flood flows are naturally diverted southwards along the east side of the railway tracks.

During large rainfall events, flows from the Canal upstream of the rail crossing have been observed to overtop the rail line (especially in the upper end of the Canal downstream of the Westview Drive culvert) due to the limited hydraulic conveyance capacity in the NEIC channel. The BNSF Railway has experienced line closures annually for the last four years and has overtopped historically throughout its length.

Another potential problem caused by the occasional flooding of the railway tracks is the contamination of the ballast by the sediments carried by the floodwaters. The Canal can also overtop its banks and flood Burns Bog, discharging urban runoff into the environmentally sensitive area.

An additional cause of flooding is the floating debris which collects at many of the culvert and trash rack entrances and could significantly reduce the conveyance capacity.

Cougar Creek and the manmade Canal are now undergoing significant changes, due to the rapid rate of development, and the channelization started in the early 1960s. Neither watercourse has had sufficient time to adjust to the resulting changes in flows and sediment loads, and to reach equilibrium. Natural stream stability would not be achieved until the watercourses develop a stable dimension, pattern and profile and as a result would neither aggrade nor degrade. As such, the initiation of bank stabilization projects at selected locations within the Canyon would provide temporary stability until a stable dimension developed.

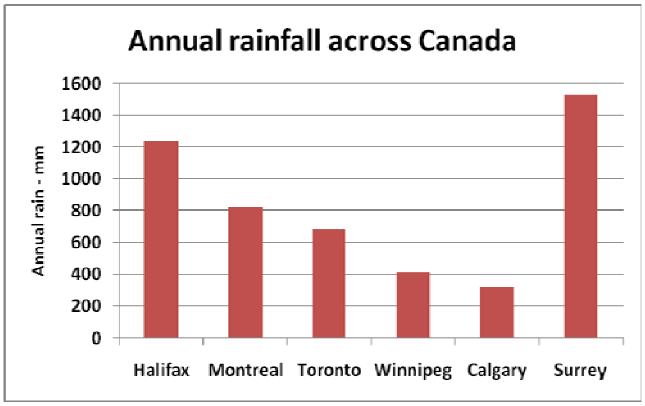
Most of the soils forming the open watercourses are made up of dense silty sand and gravel, very dense interbedded silt and sand with dropstones, and very dense sand. However, the Cougar Creek soils do not fit well into the highly erodable soil classes, unless exposed to high velocity flows in excess of 1 m/s.

Sedimentation and the resulting detrimental effects on channel capacities and fish habitat is a major problem. A sediment trap was constructed at the outlet of Cougar Creek at the downstream end of the steep canyon east of Westview Drive to collect the sediment before it enters the slow-moving shallow Canal to permit the removal of the sediment. Annual removal of the sediment appears to be inadequate to remove all the material deposited by Cougar Creek in the sediment trap.

Increased sediment transport appears to have occurred based on the recent increased frequency of cleaning the sediment trap. The increasing volumes of sediment being moved indicates the possibility that high urban runoff-induced erosion is occurring through the Cougar Canyon reach and it appears that it needs cleaning after each major storm event. Significant portions of the fines are also being deposited downstream throughout the Northeast Interceptor Canal. Given the ongoing erosion, works intended to stabilize the walls within the Canyon may be justified.

Hydrology

The rainfall-runoff process in the Cougar Creek and Canal watershed is strongly influenced by the high precipitation observed at the Surrey rainfall gauge located at the Municipal Offices. As shown, the annual total rainfall in the study area is one of the highest in Canada.



The very limited Cougar Creek flow data observed during the 2001-2005 period at the Nicholson Road gauge showed that the creek can respond very rapidly to high intensity rainfall events. The highest peak flow of 7.74 m^3/sec was observed in October 2003.

Water quality

Limited water quality sampling has been undertaken by Delta along Cougar Creek and the Canal. The half dozen samples collected at Nicholson Road, the Lyon Road walkway, Westview Road and in the Canal cover the ten-year period between 1983 and 1993. During the study, two sets of water quality samples were taken, one set during low flow conditions during a dry period, and one following a period of rainfall during moderate flow conditions at three locations: Nicholson Road, Westview Drive and Nordel Drive. The results show a reduction in the pollutant concentrations moving downstream along Cougar Creek and the Canal, but none of the parameters showed excessively high concentration.

Generally, the pollutant concentrations observed are very similar to those observed in other parts of the Metro Vancouver area or reported for other North American urban areas. A review of the average TSS concentration data, usually adopted as a good indicator, suggests that the highest concentration of total suspended sediment concentration was observed at the upper end of Cougar Creek. As the flow moves downstream along the creek, the concentration drops markedly even before it reaches Westview Drive, resulting in an average TSS concentration less than half of the value observed at Nicholson Road. When compared to the original watershed conditions, the current annual runoff increased three-fold and the annual load by seven-fold in a typical year.

Fisheries and benthic conditions

The Cougar Creek watershed is the most productive salmonid habitat in the Corporation of Delta, supporting a significant number of both salmonid and so-called “coarse” fish (*e.g.*, threespine stickleback) species. The reaches within Delta provide both spawning and rearing habitat with the most natural reaches located within the Cougar and Blake Creek ravines.

Riparian habitat

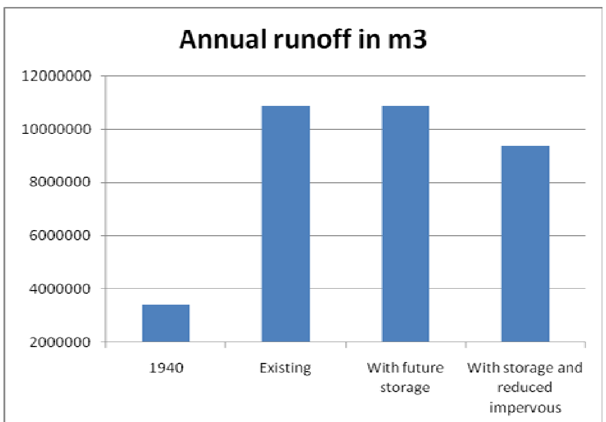
Riparian vegetation has been severely compromised within the City of Surrey. Vegetation is largely restricted now to a narrow strip along both sides of the channel. It consists of a relatively young assemblage of mixed deciduous and coniferous species with a mature understory consisting of a mixture of native and non-native species. Analysis of aerial photos taken in 2001 and 2006 indicates that although the extent of the vegetation has not increased significantly, it appears to be maturing. This would obviously provide a greater benefit to the channel.

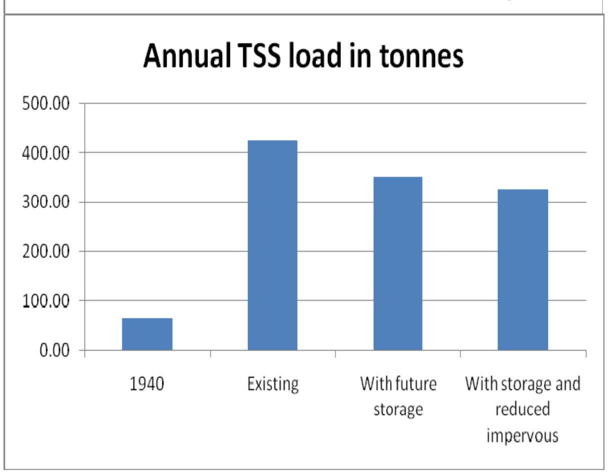
There has also been significant impact to the riparian community within Delta, which appeared to start with residential development in the 1960s. The development has continued such that throughout much of the upland reaches near the Cougar Creek ravine, residential development extends to near, or in some cases below, the top-of-bank of the ravine. The presence of the ravine has the benefit of restricting development potential such that the riparian community is largely intact, with a well-developed canopy and understory structure.

The riparian community within the reaches of the Canal is largely intact, with trails and sanitary sewer/rail infrastructure being the primary impacts. However, vegetation is compromised as a result of industrial development to the east of the Alex Fraser Bridge. In some cases, industrial properties extend right to the top-of-bank.

ANALYSIS OF EXISTING AND FUTURE WATERSHED CONDITIONS

A computer model was developed to analyze existing and future watershed conditions. The existing condition model confirmed frequent flooding along the Canal downstream of Westview Drive, the overtopping of the railway tracks and the spilling of flood waters into Burns Bog. A future land use scenario was also tested with the computer model based on estimates of increases in site coverage over the next 15 to 20 years. As the watershed is already heavily developed, the future land use scenario showed only small increases in flows and even smaller increases in water elevations or velocities, when compared to the existing condition land use scenario.





Major changes that have occurred during the past decades as a result of the rapid rate of development, resulting in significant increases in runoff and pollutant loads generated in the watershed.

The attached graph illustrates the substantial increase in annual runoff in an average year between the 1940 undeveloped watershed and existing conditions. Future efforts to reduce the volume of runoff could only result in small reduction. Similarly, the Total Suspended Solids predicted by the model showed substantial increases compared to the 1940 conditions, and small reduction in potential future pollutant loads.

The model also predicted high velocity flows along the steep section of the Cougar Creek Canyon, where a number of erosion vulnerable sites have been observed.

Out of the nine alternative remediation measures investigated, the following three were selected and recommended for consideration as part of the IMSP:

- Channel improvements along the Canal downstream of Westview Drive, either Option #2 or Option #3, for an estimated cost of $0.3 to $0.4 million. The final selection will depend on the BNSF's future plan on twinning the railway tracks and on DFO's input on potential environmental constraints.
- Erosion protection along the two sections of the creek system which showed the most advanced state of undercutting: i) #7, adjacent to Ridgewood Place, and ii) #13, adjacent to Canyon Crescent (Option #8), for an estimated cost of $50,000.
- Introduction of Low Impact Development (LID) concept to manage rainfall at the source, minimizing the hydrologic impact of new developments (Option #6). This is a long-term approach which will require a change in site planning practices for new developments or re-developments.

In addition to the three remedial measures, the recommended Integrated Stormwater Management Plan contained a number of management components summarized in the table below.

Summary of Integrated Stormwater Management Plan	
Objective	**Recommended management component**
SHORT TERM REMEDIAL AND REHABILITATION MEASURES	
Alleviate existing and potential erosion and flooding concerns.	• Improve flow capacity of Canal in the vicinity of Westview Drive to reduce flooding (Option #2 or #3). • Complete a detailed survey of erosion conditions at Sites #7 and #13, for two consecutive years, followed by a mitigation measure as required (Option # 8).
LONG TERM STORMWATER MANAGEMENT MEASURES FOR NEW AND RE-DEVELOPMENTS	
Minimize destruction of property and natural resources from flooding and erosion generated by developments Control runoff to reduce the flood risk threatening life and property	• Design the major and minor system to meet runoff volume and peak flow targets. • Adopt appropriate SWM facilities in new developments and re-developments to control runoff volume, peak flows, water quality and erosion for all design events, where feasible. • Prepare a floodplain mapping study for Cougar Creek and the Canal to establish flood plain limits. • Adopt LID concepts for future developments. Where feasible, the predevelopment hydrologic cycle components, in particular the base flow component, should be maintained. • As part of operation/maintenance, remove channel constrictions such as log and debris jams and sediment depositions.
LONG TERM RIPARIAN CORRIDOR MANAGEMENT	
Protect stream morphological and fluvial character and prevent increase in erosion and deposition. Restore eroding stream banks to a stable condition.	• Regular monitoring of potential erosion sites. • Provide erosion protection as required. • Municipalities to prepare a long-term planting program.
Ensure that hydrogeological functions are preserved	• Encourage infiltration of stormwater where feasible. • Maintain or enhance existing base flows.
Protect aquatic ecosystem and maintain/enhance aquatic habitat	Suggested list of fish habitat compensation projects to protect stream corridors: • Remove accumulated sediments from the Cougar system downstream of Westview Drive. • Remove debris jam barriers from Cougar Canyon. • Maintain existing habitat diversity. • Construct fish habitat in the Canal. • Aquatic protection to be based on resident fish community and habitat conditions. • Provide fish habitat compensation sites, where needed. • Provide appropriate riparian setbacks. • Implement strict erosion/sediment control during construction activities. • Enhance riparian vegetation upstream of Scott Road. • Purchase setbacks within industrial properties and construct off-line ponds north of Nordel Way, where space permits. • Undertake clearing and grubbing of invasive vegetation from Cougar Creek headwaters and replace with native vegetation. • Relocate existing channel to the dry pond at Khalsa School and plant native vegetation. • Investigate opportunities for securing habitat credits to offset future habitat losses.
LONG TERM LAND USE PLANNING AND CONTROL	
Ensure that new developments or re-developments incorporate the most appropriate development form and mitigation measures necessary to protect the natural features and functions.	• Develop strategies based on LID concepts for developing or redeveloping i) existing large developed areas, ii) existing park and school sites, iii) vacant lands and green sites, and iv) infill developments. • Parks, green spaces and schools could present future opportunities for watershed enhancement facilities (rain gardens, biofilters). • Delta/Surrey to continue to explore enhancement opportunities on larger greenfields. • Environmental Implementation Reports should be part of development applications. • Prepare a set of proposed guidelines for retrofitting drainage facilities. • Establish owner incentive programs and density bonus systems. • Create neighbourhood plans where infill developments are expected. • Consider adopting environmental friendly erosion protection measures. • Ensure that the planned Greenway stream corridor will minimize flooding and erosion risks. • Adopt long-term riparian setbacks for re-development sites. • Encourage enhancement of Hydro Park RoW and Cougar Creek Park detention ponds to improve fish habitat. • Explore opportunities to manage greenfields, such as tree retention, introduction of new or retrofitting of existing stormwater management facility incorporating green policies for roads and public rights-of-way. • Include monitoring requirements in subdivision agreements. • Review existing road sweeping programs. • Identify areas to be preserved for recreational opportunities, and these areas to be integrated in future planning.
IMPLEMENTATION MEASURES	
Long-term tasks to assist in the integration of stormwater management and land use planning and the protection and enhancement of the stream environment.	• Monitoring required for larger facilities. • Regular on-site construction inspection. • Prepare a brief Operation and Maintenance Manual. • Prepare administration protocols to manage the approval, inspection and monitoring of BMPs. • Delta to prepare erosion and sediment control by-laws. • Review/update design criteria/specifications, enact floodplain regulation. • Public information and consultation on stormwater management. • Adopt recommended SWM policies and by-laws, and undertake enforcement. • Funding and financial planning review.

TABLE OF CONTENTS

TABLES

FIGURES

LIST OF PHOTOS

APPENDICES

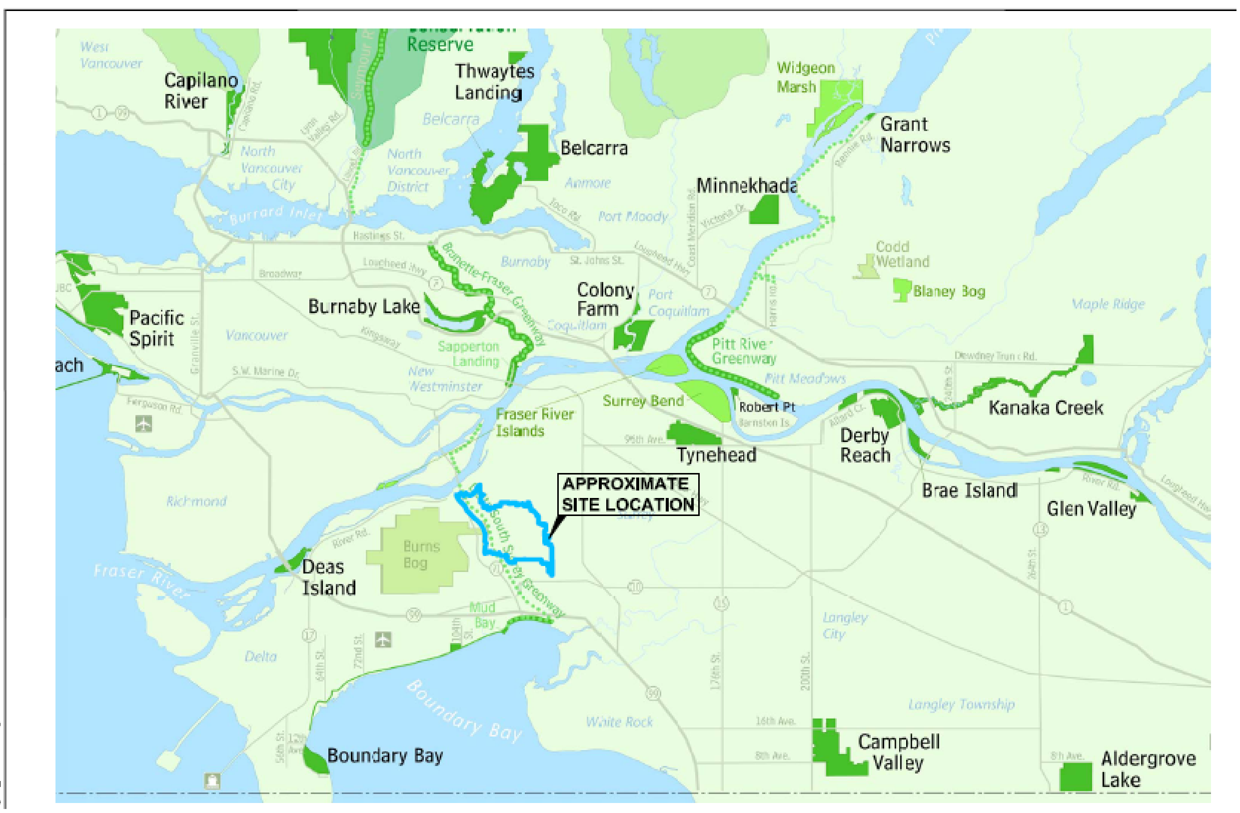
1.0 INTRODUCTION

1.1 Background

With the rapid population growth in the Lower Mainland resulting in significant changes to stormwater runoff patterns, degradation of our urban watersheds is expected to accelerate unless effective stormwater controls are introduced. Metro Vancouver (formerly the Greater Vancouver Regional District, GVRD) and its member municipalities have committed to implementing Integrated Stormwater Management Plans (ISMPs) under the umbrella of the Liquid Management Waste Plan to manage stormwater flows in a manner that preserves the physical and biological values of our existing watercourses and addresses a range of needs of affected communities. This new approach in watershed-based assessment was developed to maintain or improve watershed health while managing issues such as flooding, erosion and environmental values. A number of such ISMP studies have been completed or are under preparation within Metro Vancouver.

The purpose of the study is to develop a comprehensive and integrated storm water management plan which will set out a sustainable strategy for storm water management in the Cougar Creek and North East Interceptor Canal watershed. A key map of the study area location is shown below in **Figure 1-1.**

Figure 1-1: Key Map



The integrated plan will seek to improve the overall watershed system by minimizing the risk of flooding, preserving aquatic and riparian habitats and delineating effective and affordable watercourse improvement programs.

A number of goals and objectives have been developed as part of the study process which need to be met to achieve the overall study purpose. These goals and objectives relate to the management of the natural resources within the study area, including aquatic and terrestrial resources, flood and erosion control, and surface and groundwater resources. The study framework developed was based on the understanding of the study area ecological conditions and the hydrologic, hydraulic and hydrogeologic processes, and included the assessment of the watershed characteristics, natural processes and human activities.

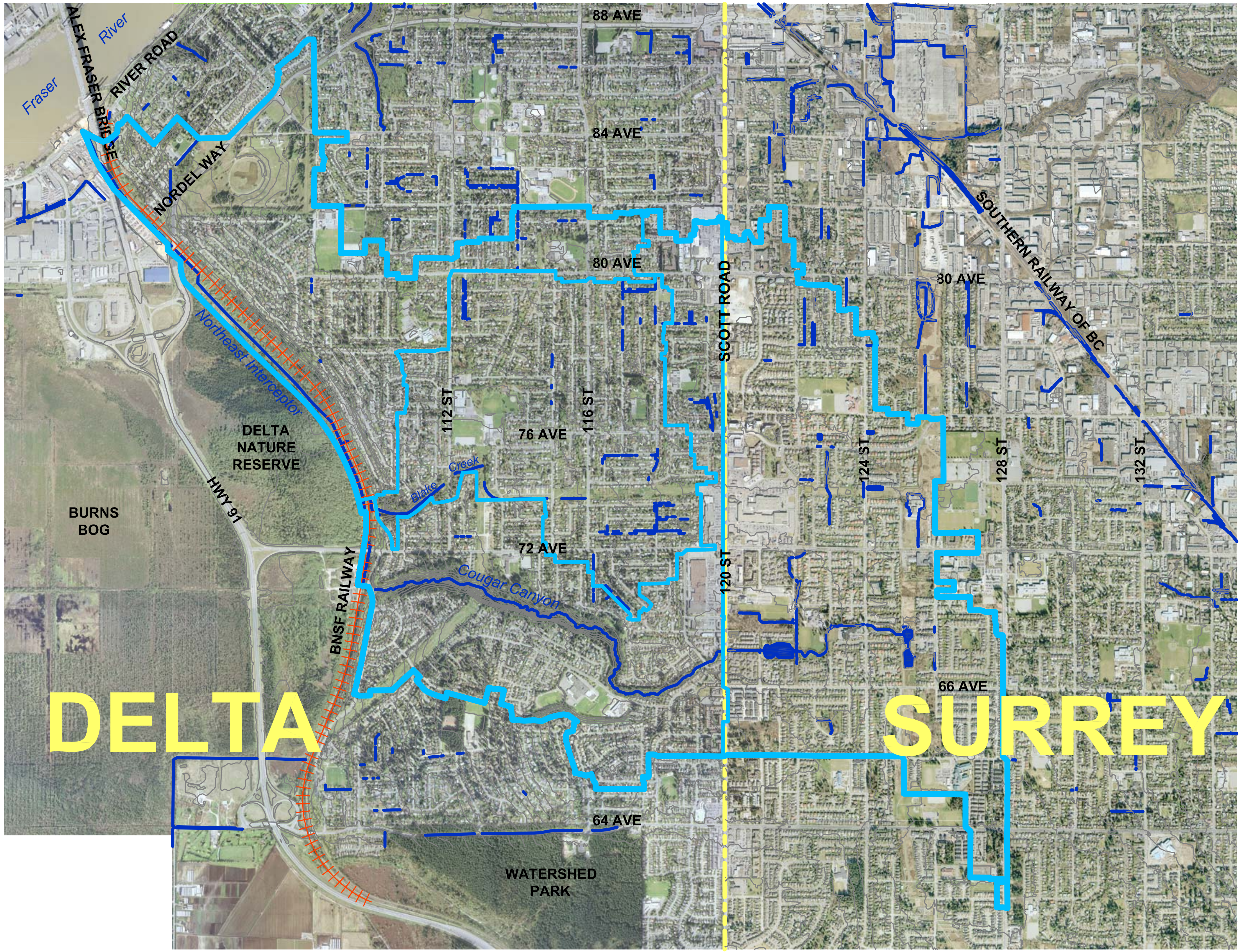
The Cougar Creek and Northeast Interceptor Canal (NEIC) watershed encompasses parts of two municipalities. The headwaters are located in the City of Surrey, and the creek enters the Corporation of Delta at Scott Road and 69th Avenue. The study area shown on **Figure 1-2** provides an overview of the Cougar Creek watershed, its boundaries and sub-catchments.

1.2 Planning Context

The Cougar Creek/NEIC watershed has experienced rapid growth since the late 1970s. Over the past four decades the mainly farm lands and wooded watershed has changed into urban land uses.

Changes in development, the type of land use, and past stormwater practices has precipitated the need for a comprehensive planning approach. The proposed ISMP will integrate past watershed assessments, master drainage plan, stormwater plan and municipal plan processes in one document to address the stormwater impacts on the community and the environment. The context for completing an ISMP has evolved considerably over the past decade. Master Drainage Plans (MDPs) previously focused mainly on water management, with lesser emphasis on other critical values such as water quality, aquatic habitat, and attributes of the watershed that were inextricably linked to stormwater. The new ISMP process recognizes the integrated setting of urban watersheds and requires that water management strategies be considered in the context of a “bigger picture”. The ISMP focus is on the integration of stormwater management and land use planning and forms an integral component of a local government’s land development and growth management strategy recognizing that upstream activities (land use change) have downstream consequences (flood risk and environmental risk).

This ISMP report is intended to provide key direction, strategies and specific actions for the Corporation of Delta and the City of Surrey towards managing stormwater from a changing watershed in the context of an integrated framework. Options for the improvement of stormwater management are evaluated with regard to environmental impacts and opportunities, benefits, and capital and annual operating costs. This ISMP report also provides prioritization of potential capital intensive projects on stormwater infrastructure to key areas of the watershed, while deferring expenditures in other areas until those needs become more urgent.



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

DATE JUNE 2009	PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
	TITLE AERIAL VIEW OF WATERSHED	FIGURE NO. 1-2

FileName:g:\cad\066904\066904-figures-ismp.dwg

1.3 Study Goal and Objectives

Based on the municipal objectives and policies, the following set of study goals and objectives were developed:

The study goal is to:

Develop an integrated management plan for the Cougar Creek and Northeast Interceptor Canal watershed that considers the natural resource features and provides for future uses that will protect and enhance, where feasible, the environmental conditions.

The City of Surrey adopted the following development objectives relevant to the ISMP study (City of Surrey, Design Criteria Manual, 2004):

- Maintain performance capacity and condition integrity of the existing drainage system.
- Provide adequate servicing infrastructure to all newly developing areas and minimize downstream adverse impacts.
- Adopt a financially stable long-term capital, operation, and maintenance program for drainage needs.
- Protect the physical integrity of watercourse / creeks, their banks and floodplains.
- Control the sediment loadings and erosion potential resulting from clearing of land for development and other construction activity.
- Minimize detrimental impact on aquatic life and wildlife habitats along watercourses.

The following study objectives were based on the study goal, and a review of local development objectives.

<u>Minimize Threat to Life and the Destruction of Property from Flooding:</u>

- Alleviate existing and potential drainage, erosion and flooding concerns.
- Control runoff to reduce the flood risk threatening life and property.
- Adopt appropriate land use control and development standards to prevent development in flood prone and erosion hazard areas.

<u>Protect and Enhance Aquatic Habitat and Stream Corridors</u>

- Ensure that new developments or re-developments incorporate the most appropriate development form and mitigation measures necessary to protect the natural features and functions.
- Protect stream morphological and fluvial character and prevent increases in erosion and deposition. Where practical restore eroding stream banks to a stable condition.
- Restore, rehabilitate or enhance water quality. Prevent the accelerated enrichment of the Cougar Creek/NEIC system from urban runoff.
- Ensure that hydrogeological functions are preserved.

- Maintain and enhance aquatic habitat.
- Provide appropriate buffers to watercourses and valley lands to maintain their biological health.
- Ensure that the recreational potential of the Cougar Creek/NEIC corridor is maintained and fully developed.
- Develop a cost effective strategy for municipal capital improvements and improve community awareness of watershed issues.

1.4 Study Approach and Report Structure

The study approach was designed to address the three most important questions:

- ***What do we have?*** **-** understanding the watershed issues and identifying the stormwater-related objectives for the watershed. These objectives define what the ISMP is striving to achieve.
- ***What do we want?*** **-** setting realistic performance targets and developing strategies to achieve the watershed objectives and to guide the selection of site specific design solutions.
- ***How do we get there?*** **-** developing an ISMP Implementation Program and implementing the appropriate site designs to achieve performance targets that suit local objectives and conditions.

The report describes in detail the major phases of the study:

Chapter 1.0 **INTRODUCTION**
Goals and objectives

Chapter 2.0 **REVIEW OF EXISTING WATERSHED CONDITION**
Review of Existing Information
Existing Watershed Conditions

Chapter 3.0 **MODELLING OF EXISTING CONDITION**
Hydrological Model
Input Data
Calibration and Validation
Hydraulic Model
Modelling of Existing Conditions

Chapter 4.0 **ALTERNATIVE REMEDIAL MEASURES**
Alternative Remedial Measures
Modelling of Alternative Remedial Measures

Chapter 5.0 **RECOMMENDED ISMP**
Target Setting
Integrated Stormwater Management Plan
Alternative SWM Practices for New Developments
Implementation Plan

Chapter 6.0 **REFERENCES**

2.0 REVIEW OF EXISTING WATERSHED CONDITIONS

2.1 Existing Reports

A number of past reports relating to the Cougar Creek/NEIC watershed were reviewed during the study. These included the following two Master Drainage Plans:

- *North Delta Fraser Drainage Area and Boundary Bay Drainage Area - Master Drainage Plans (1989) by Dayton and Knight Ltd.* This study provided drainage plans for a number of watersheds within North Delta including Cougar Creek and the Northeast Interceptor Canal. As was customary during the 1980s, environmental considerations within the MDP were not comprehensively covered; and
- *Cougar Creek Master Drainage Plan (1996) and Cougar Creek Drainage Study (1996) by M.M. Dillon Limited.* With an increasing awareness of the impact of development and land use planning on stormwater drainage through the 1990s, the two studies integrated environmental and land use planning concerns with engineered solutions to reduce watershed degradation.

A number of other studies within specific disciplines were also reviewed:

- *Benthic Studies (1993 to 1999) by Rob Rithaler (Corporation of Delta).* These studies evaluated the benthic community utilizing a number of biotic indices to measure the richness and diversity of invertebrate taxa within the creek substrates. In general, the results indicated that there was an impairment of the benthic invertebrate community during the course of the study. This impairment likely resulted from decreased water quality due to high peak flows and the discharge of deleterious substances to the channel;
- *Cougar Creek Flow Analyses (2000 to 2005).* A depth gauge installed at the Nicholson Road culvert was utilized to determine the flows within Cougar Creek. The flow data was subsequently used in the calibration and running of the hydraulic modeling for the watershed; and
- *Preliminary Designs for Northeast Interceptor Canal by Delcan (1994) and Klohn-Crippen (1997).* These studies analyzed the "congested" hydraulics of Cougar Creek at Westview Drive and the head reaches of the Northeast Interceptor Canal. Various works were proposed to provide a more efficient hydraulic regime through these reaches to mitigate flooding of the BNSF Railway line and the Metro Vancouver Greenway path to the west of the BNSF line.

A more detailed list of reports reviewed during the study is presented in the References (Section 6)**.**

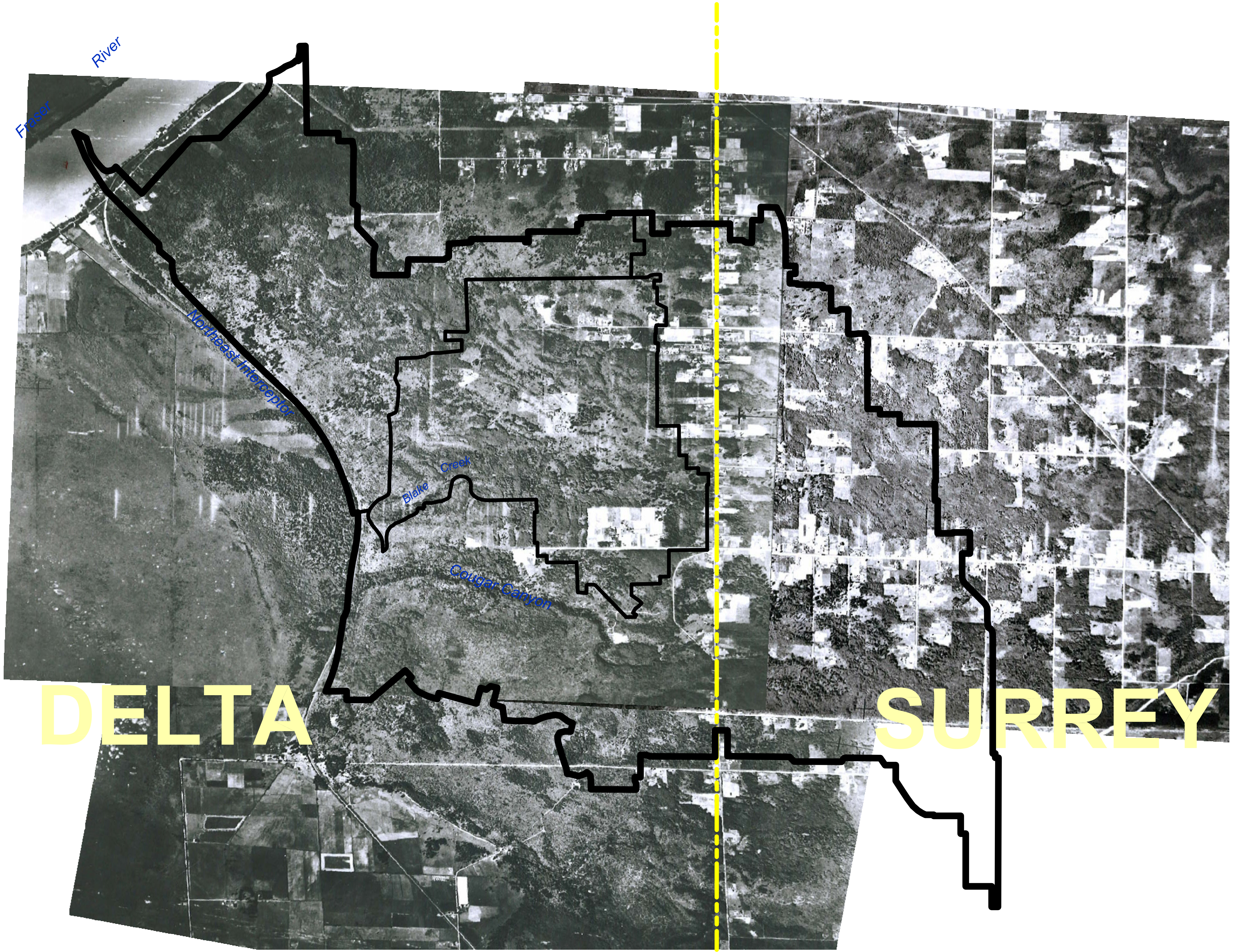
2.2 Historical Changes in the Watershed

A review of the historical aerial photos dating back to 1940 demonstrated a rapid rate of growth within the watershed. **Figure 2-1 - Figure 2-4** illustrate watershed conditions in 1940, 1962, 1984 and 2006. The photos show a large increase in development commencing in the 1960s to nearly a "complete" development stage. Some of the more obvious features identified from these photos are:

- 1940 – (**Figure 2-1**). The watershed was experiencing minimal development and was largely forested. There was a limited road network. Development tended to consist of what may have been small farms or large suburban lots. Impervious surfaces were minimal.

- 1962 – (**Figure 2-2**). Although still well-forested, the watershed began to experience significantly greater road development by the early 1960s. Smaller residential lots were also being developed although the percentage of impervious surface was still relatively low.
- 1984 – (**Figure 2-3**). A very large alteration in the watershed occurred between the 1960s and 1980s. An extensive network of roads was constructed mainly for small residential lots and commercial development along Scott Road, particularly within Delta. Forested or well-vegetated areas were generally restricted to the Northeast Interceptor Canal, the Blake and Cougar Creek ravines, and the upper reaches of the creek within Surrey. Impervious surface increased significantly during this time frame.
- 2006 – (**Figure 2-4**). The development of the remaining vegetated portions of the watershed in Surrey was the most significant occurrence between the 1980s and today. Almost the entire watershed has now been developed with the exceptions of the Canal and the Blake and Cougar Creek ravines. As a result the total impervious surface area now stands at 58.9% and 60.4% for Surrey and Delta respectively.

Please note that due to the inherent inaccuracies in the older aerial photographs, boundaries cannot be scaled consistently from **Figure 2-1** to **Figure 2-4**.



LEGEND
- WATERSHED
- WATERSHED (SUBDIVIDED)
- DELTA/ SURREY BORDER

SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

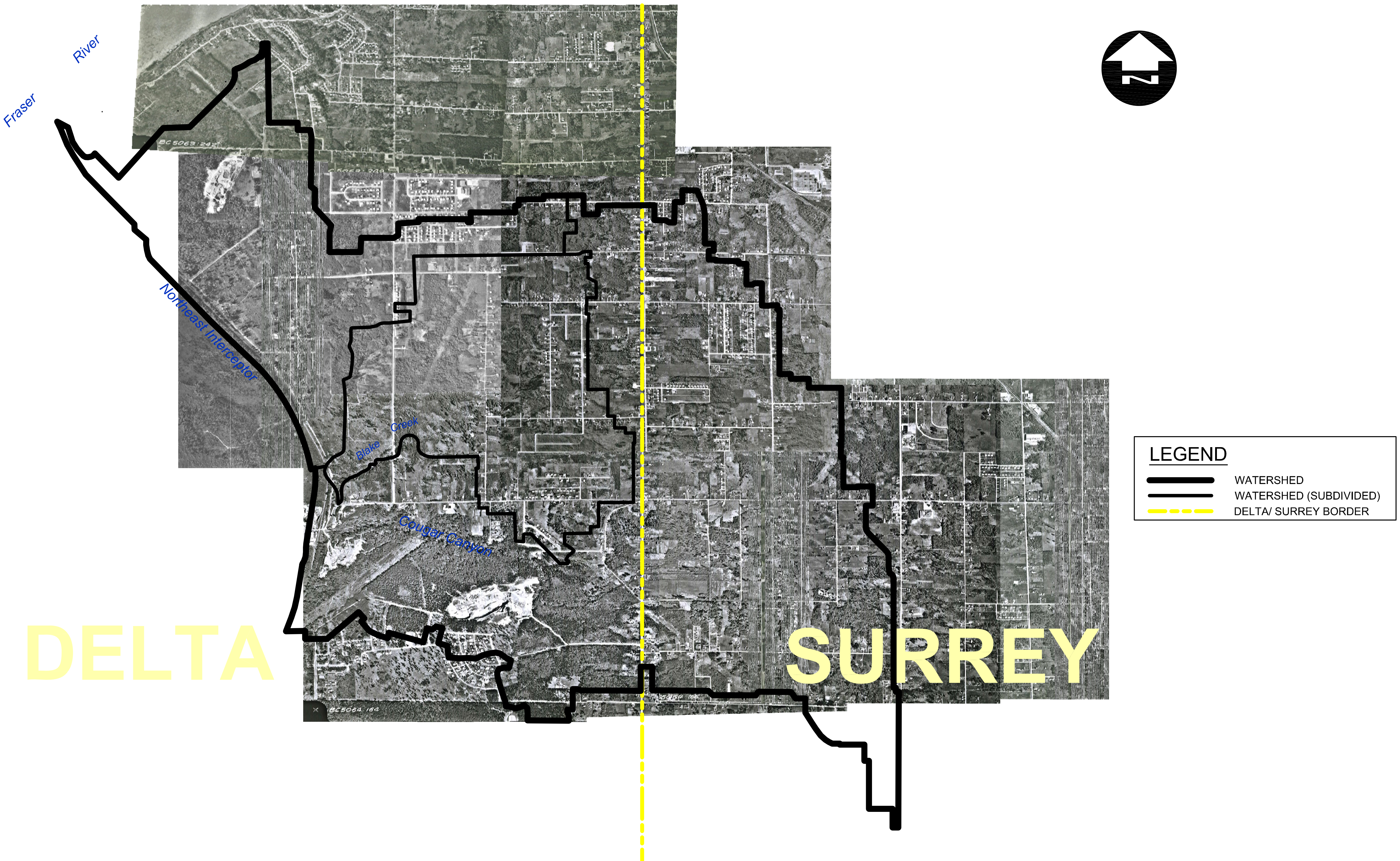
APPROXIMATE SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

PROJECT	COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN
PROJECT NO.	06-6904
TITLE	1940 AERIAL PHOTO
FIGURE NO.	2-1
DATE	JUNE 2009

FileName:g:\cad\066904\066904-figures-historic_ortho.dwg



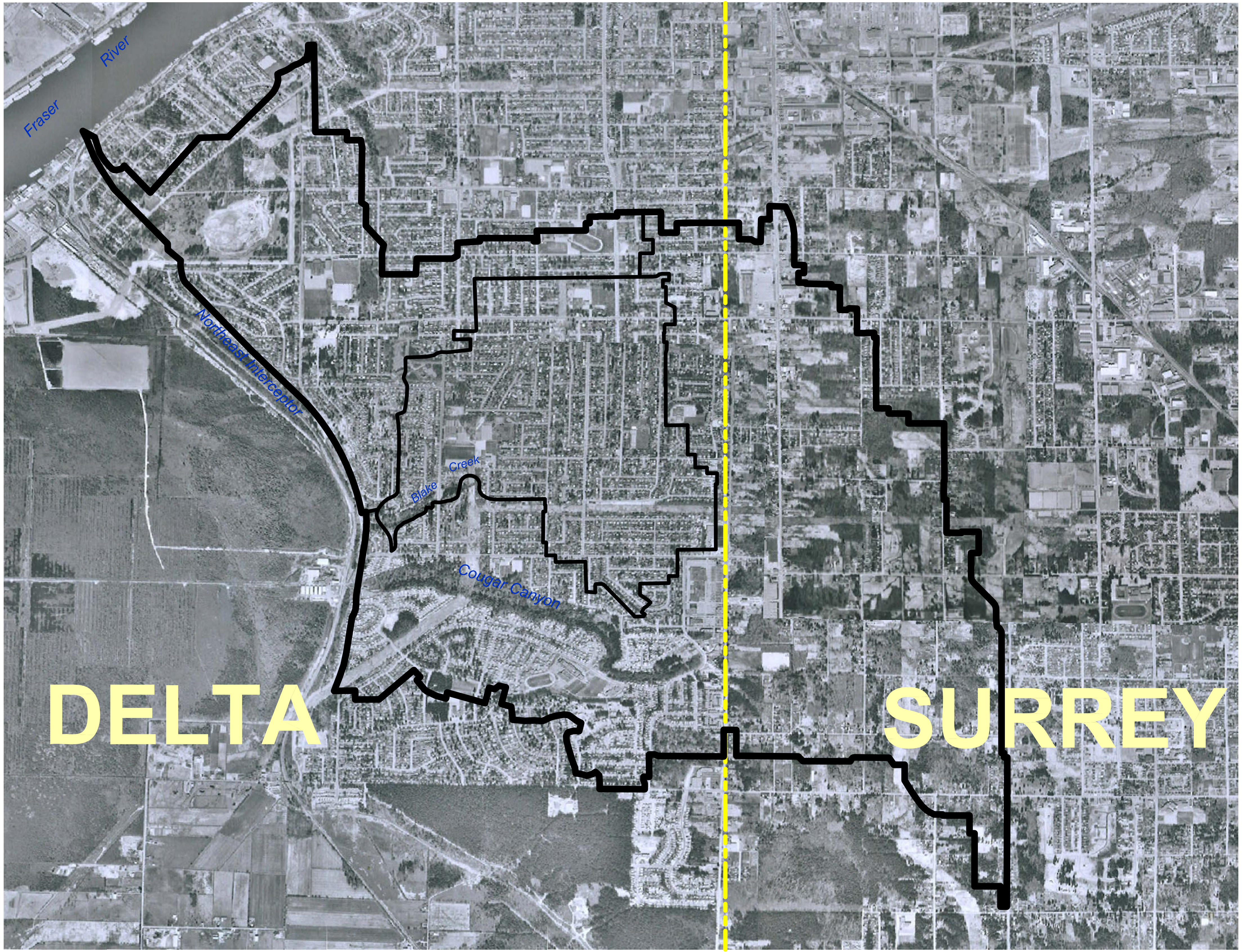
SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

APPROXIMATE SCALE 1:25,000

0 250 750 1250m

DATE JUNE 2009	PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
	TITLE 1962 AERIAL PHOTO	FIGURE NO. 2-2

FileName:g:\cad\066904\066904-figures-historic_ortho.dwg



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

APPROXIMATE SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

DATE JUNE 2009

PROJECT

COUGAR CREEK
INTEGRATED STORMWATER MANAGEMENT PLAN

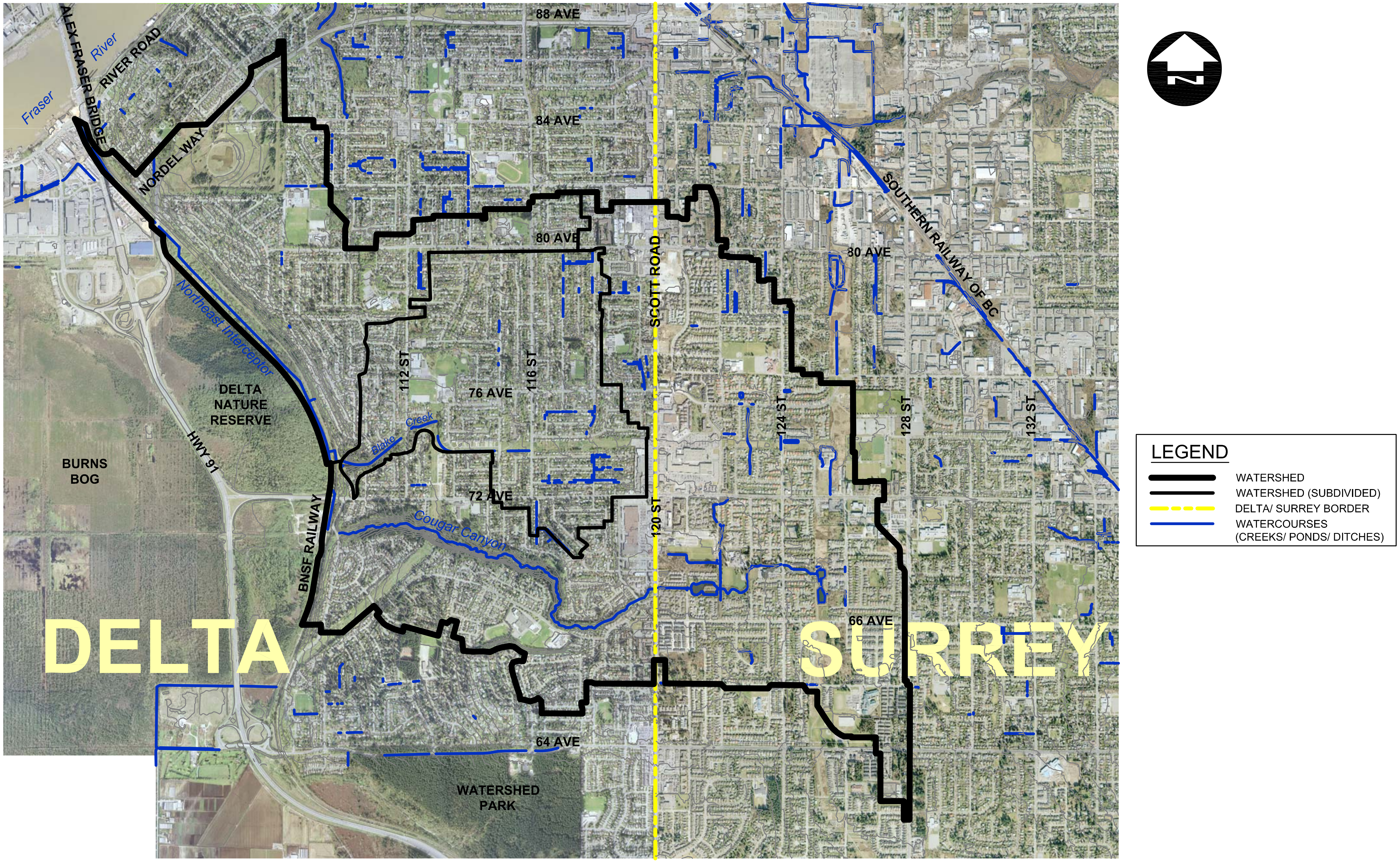
TITLE

1984 AERIAL PHOTO

PROJECT NO. 06-6904

FIGURE NO. 2-3

FileName:g:\cad\066904\066904-figures-historic_ortho.dwg



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

APPROXIMATE SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING	PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE JUNE 2009	TITLE 2006 AERIAL PHOTO	FIGURE NO. 2-4

FileName:g:\cad\066904\066904-figures-historic_ortho.dwg

2.3 Existing Watershed Conditions

The potential impact of drainage from uncontrolled development on the environment is well documented in the literature. A summary of the potential detrimental effects observed in the study area are presented in **Table 2-1**.

Table 2-1: Summary of Potential Impacts on the Environment

Type of impact	Effects
Hydrologic impacts	• Increase in duration, frequency and magnitude of peak flows, increased risk of flooding • Decrease of base flows, detrimental effect on aquatic resources • Potential change in groundwater level, and its effect on water supply
Soils erosion impacts	• Increased rates and volumes of soils erosion • Increased amount of soil transported to watercourses, increased risk of flooding and damaging aquatic habitat
Hydraulic impacts	• Increased flood levels, increased risk of flooding • Change in flow velocities and change in bank erosion
Geomorphologic impacts	• Change in flow depth, and channel dimensions • Change in sediment loads • Change in channel formations
Water quality impacts	• Change in water quality: pollutant concentration and load • Change in sediment quality • Change in benthic community
Terrestrial and aquatic biota impacts	• Loss of fish habitats • Loss of riparian vegetation • Losses or reduction in native plants • Losses of animal species and linkages • Disruption between components of the terrestrial ecosystem
Socio-economic impacts	• Risk of loss of life and property • Loss of agricultural resources • Increased cost of erosion control, flood control, water supply and treatment • Loss of recreational facilities • Loss of aesthetics • Loss of biodiversity

The following pages summarize the general conditions of the watershed based on the review of background information and site inspection. The Cougar Creek/NEIC watershed is located within two adjacent municipalities; the Cougar Creek portion is located on the western most edge of Surrey, and it forms the headwaters for the watershed near 75th Avenue and 122A Street. The Surrey portion of the watershed is bounded by Scott Road to the west, 128th Street to the east, 80th Avenue to the north and 64th Avenue to the south. The creek then flows parallel to Scott Road to 70th Avenue where it combines with two other tributaries before entering the Cougar Creek detention pond.

The original outlet of Cougar Creek has been changed in the 1940s mainly by the construction of the railway line. A relatively narrow and long diversion channel, named the North East Interceptor Canal, was constructed with an outlet to the Fraser River. This artificially created outlet canal was built with a very mild slope and is prone to tidal influences from the Fraser River.

2.3.1 Land Uses

The primary process contributing to watershed changes in the Cougar Creek/NEIC drainage area is urbanization. The continued conversion of pervious areas such as natural areas, large rural lots with older homes, and other areas which have been constrained from development to date, towards newly and more intensively developed areas with increased impervious surfaces (*e.g.*, roads and roof tops) has drastically changed the watershed characteristics. There are also concerns with respect to the removal of existing trees and vegetation resulting from development that also decreases permeability throughout the watershed over time.

Like virtually all watersheds within the municipal boundaries of Delta and Surrey, development within the Cougar Creek/NEIC watershed has continued with increasing pressure for development of the few remaining greenfield sites and redevelopment and densification of existing residential and commercial areas of the catchment. Anticipated developments such as Delsom Estates on Nordel Way, North Delta Inn re-development and the South Fraser Perimeter Highway provide bona fide examples of development/redevelopment initiatives. These recent and additional future land use changes, and the cascading watershed issues that accompany them, have driven the need for the development of an ISMP.

Land use within the Cougar Creek watershed is primarily single-family residential with scattered concentrations of multi-family developments (both townhouses and apartments) and commercial properties (predominately along the Scott Road corridor). The north-western sector near the mouth of the Northeast Interceptor Canal accommodates some industrial development and along almost the entire western edge are portions of Burns Bog and Nature Reserve areas.

A rapid increase of impervious areas took place since 1979 as a result of new and infill developments primarily in the Cougar Creek headwaters catchment. This includes single dwelling developments mainly in the southeastern areas of the watershed between 64th Avenue to 68th Avenue from 124th Street to 128th Street and along 126th Street between 68th Avenue and 72nd Avenue, the development of townhouses and commercial space along the Scott Road corridor, and densification of existing urban areas through "two-lot splits".

The total watershed area is 1192 ha; of this total 394.6 ha is located in Surrey and 797.4 ha in Delta. The impervious areas are very similar: Delta 60.37% and Surrey 58.92%. A breakdown of the different land use categories in hectares are presented in **Table 2-2** below:

Table 2-2: Breakdown of Existing Land Uses [1]

Land use	Surrey	Delta	Total
Urban	175.89	298.74	474.64
Multifamily	105.77	136.16	241.93
Suburban [2, 3]	81.89	-	81.89
Industrial	0.39	36.11	36.51
Park	0.00	79.05	79.05
Road [4]	-	202.41	202.41
Agriculture	0.00	18.07	18.07
Commercial	24.45	26.84	51.29
Unclassified [5]	6.24	-	6.24
Total	**394.64**	**797.39**	**1192.03**

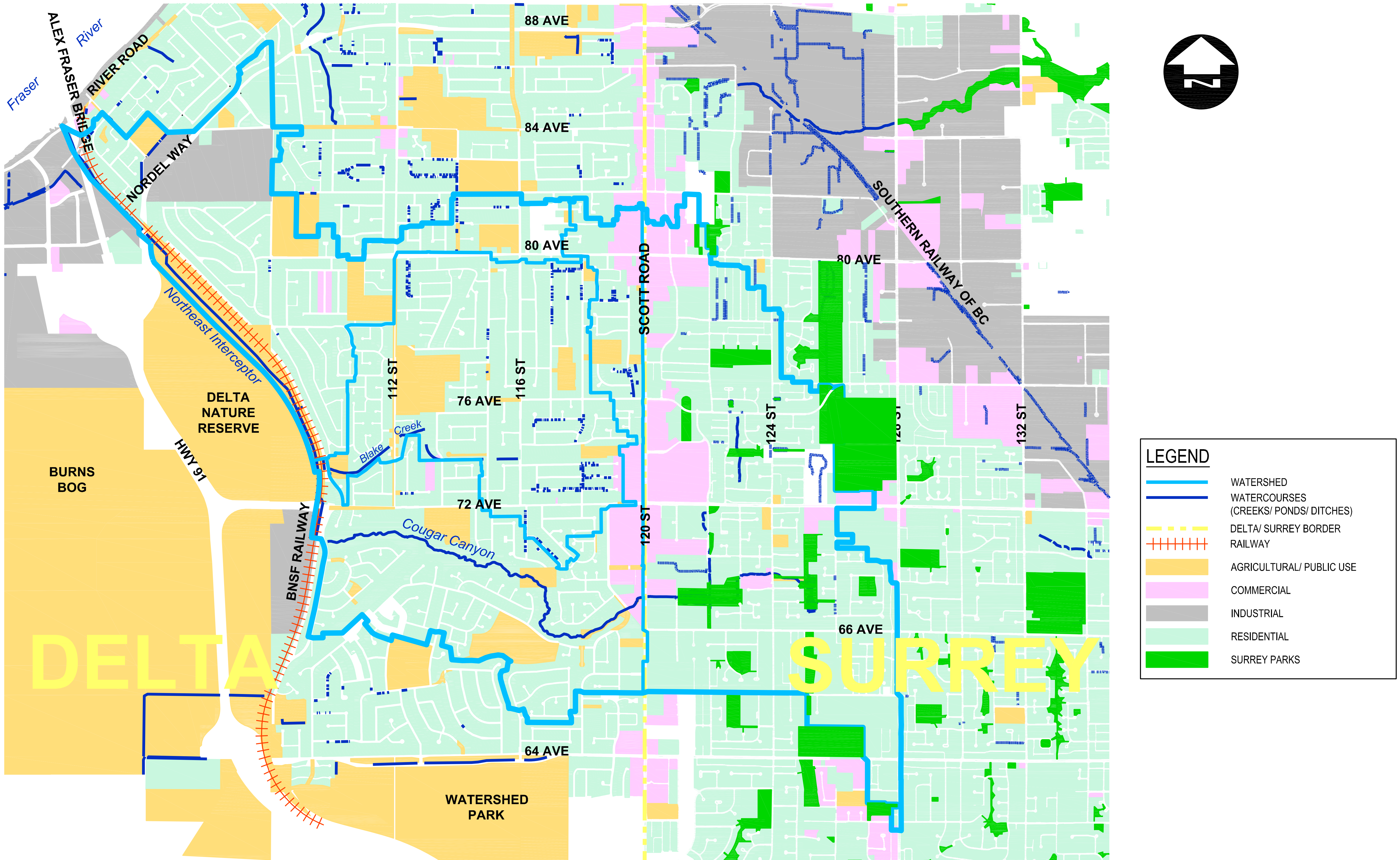
1. Data obtained from Surrey's and Delta's Official Community Plans.
2. Suburban designation within Surrey includes areas for Parks.
3. Suburban designation is not utilized within the Corporation of Delta.
4. Road designation included as components of other land use designations within Surrey.
5. Unclassified designation within Surrey only. Exact land use not known within these areas.

Figure 2-5 provides a map of the existing land uses within the Cougar Creek/NEIC watershed.

Data was also collected to illustrate future development conditions. According to the latest population projections for Surrey/White Rock/Delta the current population of 536,000 is expected to grow to 766,000 (25%) by the year 2031. Generally, there is limited opportunity to extend the existing development areas within the study limits. However, future infilling and re-development could change the drainage characteristics of the Cougar Creek/NEIC system, unless proper stormwater management practices are incorporated in the design.

2.3.2 Erosion and Sedimentation

Cougar Creek is located within a canyon draining highlands in Delta and Surrey. Downcutting of the streambed under natural conditions was relatively slow, progressing in a "geologic" time scale. Cougar Creek and the manmade Canal are now undergoing significant geomorphological changes, due to the rapid rate of development since the early 1960s. Neither watercourse has had sufficient time to adjust to the resulting changes in flows and sediment loads, and to reach equilibrium. Natural stream stability is achieved when the watercourses develop a stable dimension, pattern and profile and as a result neither aggrade nor degrade. This ongoing process could be assisted by designing and constructing a 'natural channel' that could form part of a future stable stream system.



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

PROJECT	COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE JUNE 2009	TITLE LAND USE MAP	FIGURE NO. 2-5

FileName:g:\cad\06904\06904-figures-ismp.dwg

Most of the soils forming the open watercourses are:

- Silty sand and gravel, dense;
- Interbedded silt and sand with dropstones, very dense; and
- Sand, very dense.

Some of the soil types are prone to erosion but none of the Cougar Creek soils fit well into the highly erodable soil classes, as shown in the **Table 2-3**.

Table 2-3: Cougar Creek/NEIC Watershed Soil Types

Prime location	Soil Name	Soil type	Erodability
Near the upper reaches of the Cougar Creek canyon	Late Glacial	Silty sand and gravel, dense	Moderately erodable, pebbles and cobbles reduce potential
Near Cedarbrook Place	Till	Silty sand and gravel, very dense	Resists erosion, very dense stream bed with cohesive properties visible
On the Commonwealth Crescent alignment	Silt	Interbedded silt and sand with dropstones, very dense	Moderately erodable. Appears to be variable over short distances.
On the 115A Street alignment	Quadra Sand or Colebrook Grave;	Sand, very dense	Erodable. Lack of cohesion leaves the sand erodable to concentrated flows even though very dense.
On the Newport Place alignment	Quadra Marine Interbedded Fine Sand and Silt	Interbedded sand and silt, very dense	Less erodable than the overlying sand due to the cohesive nature of the silt

Generally, the erosion could be caused by:

1. surface water flow over the crest of the slope;
2. groundwater seepage out of the slope; and
3. stream flow at the toe of the slope.

In the case of the Cougar Creek and the Canal, the stream flow component appears to be the most influential cause of erosion.

While erosion is a natural process, the erosion issues identified in this report are confined to sites where private property is at risk and where acceleration of the erosion processes from urbanization is possibly a contributor of these emerging risks. The Cougar Creek canyon slopes are steep and located within dense to very dense glacial materials. Instabilities can be expected on such steep slopes during very wet periods, particularly when the slopes are altered during development or local drainage is concentrated. Fill placed on slopes is particularly sensitive to instability during wet periods. In addition, natural changes in stream course within the Canyon will lead to undercutting of the banks and instabilities.

The current encroachment of landowners into the riparian land uses can create serious problems, especially within the Cougar Creek Canyon. Fill has been placed by landowners particularly in the backyards along the south bank of Cougar Creek. The fill has often been placed on material that may render fill areas unstable after heavy precipitation events. There are also concerns respecting illegal dumping of materials and garbage over the bank and in the riparian areas which may impact the integrity of riparian areas along the watercourses throughout the watershed.

Steep canyon slopes along several reaches of Cougar Creek are now emerging as a significant risk not only to private property owners, but also the Corporation of Delta. Fill placed on, or at the top of, these slopes can be particularly sensitive to instability during periods of precipitation/runoff.

Almost all, if not all of the eroding slopes are eroding due to undercutting of the canyon slope by stream activity, followed by slope failure and/or ravelling. The slopes fail to an over-steeped angle. Therefore, even if the stream migrates away from the toe of the slope, there will be long-term continuing slope degradation, until the slope reaches an angle of repose (1.5 H: 1 V or shallower).

Examination of the geologic profile indicates that the stream is held up by the till and underlying laminated stony silt and sandy silt within the upper reaches of the canyon. The stream gradient increases through the Quadra sand which first become exposed on the approximate 116th Street alignment. Many of the largest erosion scars are within this sand unit. Although the sand is very dense, it is susceptible to erosion under the influence of flowing water.

The Canal was excavated into Fraser River Delta materials. The Delta is composed of overbank silts and fine sands overlying channel or pro-delta sand deposits. Peat deposits are present at some locations. The largest example of a peat deposit in the region is adjacent to Burns Bog. Most of the channel banks are therefore silt deposits. Some sand and fine gravel on the stream bed were transported to the Canal from the adjacent slopes. During flooding events, flow in the Canal is often overbank, spreading over wide areas, so that elevated velocities and steep gradients resulting in extensive erosion do not develop. The most significant erosion is caused by the flow into the channel from surrounding flood plain areas.

Erosion within the Canal is generally not a stability concern. The primary issue related to erosion is the loss of carrying capacity resulting from deposition of material resulting from erosion within the Canyon. The larger material is largely intercepted in the sediment basin at the base of the Canyon. However, finer material can be carried to the Canal and the larger material can also be carried if regular maintenance of the sediment basin does not occur.

Typical potential bank failure modes and instabilities observed are: 1) colluvial slides, 2) undercutting and slab regression, 3) fill placement, 4) terrace instability, and 5) bank and bed erosion. These instabilities are discussed below:

1. *Colluvial Slides:* Most of the higher slopes of Cougar Canyon are very dense granular material. In this dense state, the slopes are stable at relatively steep angles (>35^{o}). However, over time, the near surface material under the forces of wetting and drying, freezing and thawing, and oxidation loosen so that they are metastable at these steep slopes. These loose materials (colluvium) move slowly downslope. If stream action is removing these materials at the toe of the slope, the process

could be ongoing. Where not removed, the colluvium could build in front of the dense material until a stable angle for the colluvium is created. However, during this process, a very wet period or seismic loading could destabilize the colluvium, resulting in a larger slide. This process may be enhanced if the colluvium is less permeable than the intact material so that it creates a dam for seepage draining from the very dense intact material. Old scars are visible at locations along the Canyon walls that are most probably the result of this process. Ridges and embayments are common along canyon walls. The colluvium with this topographic setting will develop thicker sections in the embayments. During wet periods, runoff is also focussed into the embayments promoting failure of the colluvium downslope in the embayment due to elevated piezometric levels in the colluvium. Although no such areas were observed, such conditions almost certainly could exist in the Canyon.

2. *Undercutting and Slab Regression*: This type of mass movement results from erosion at the toe of the slope and resulting failure of the oversteepened slope. Such undercutting and failure of the slope in dense sand, and sand and gravel results in small slab failures regressing up the slope at very steep slope angles. After the stream moves away from the toe of the slope, the slope ravels to a long term stable slope angle. It is often during this phase that the movement reaches the crest of the slope. There are several of these features where Cougar Creek cuts down through the erodable material, all on the left bank, between the pedestrian overpass and the elementary school at Lyon Road. This is the most common active bank feature in the valley and is a major source of sediment load for the stream.

Photo 1: Large Slope Erosion with Houses near Slope Crest, an Example of Undercutting and Slab Regression.

Photo 2: The Largest Eroded Slope in Cougar Canyon, an Example of Undercutting and Slab Regression

3. *Fill Placement Causing Oversteepening*. It has been relatively common practise in the past to place fill over the slope crest of a ravine during property development (lot levelling and basement excavation). This can provide not only a level building lot, but also provide additional level yard. However, this fill material was almost always pushed or dumped into place with no compaction and often contains wood. This practise results in a very loose material near the slope crest, which is at the angle of repose under dry conditions. During wet weather, this material is susceptible to saturation and failure. This fill at the crest of the slope also over-steepens the existing slope, which had previously come into equilibrium with the environmental conditions at the flatter angle. The overall slope is therefore potentially at risk. As this was a building activity, generally the residential structure is near the potential failure.

   Some fills were noted in both Surrey and Delta, but in areas where the Canyon was relatively shallow. In these areas, the greatest threat is temporary stream blockage as a result of fill failure. Little risk to structures is anticipated. The presence of fill at slope crests was not investigated during the field traverse in the deeper sections of the Canyon due to both time constraints and property access rights. It is probable that several lots will have fills, as that would have been a normal practise.

Photo 3: Probable Area of Fill Placement on North Bank

4. *Terrace Instability*: Movement of thin terrace deposits was observed along the stream, due to undercutting of loose to dense terrace deposits and potentially enhanced by rotting of buried organic debris. One of these features was observed downstream of Nicholson Road. The undulating surface and tilting trees were cited as evidence of ground movement in this area. Although some older slope movement may have occurred at this location, the surface features at this site as well as at other terrace sites downstream may also be due to rotting of wood debris. In all cases observed, there was no risk to structures from this ground movement.
5.

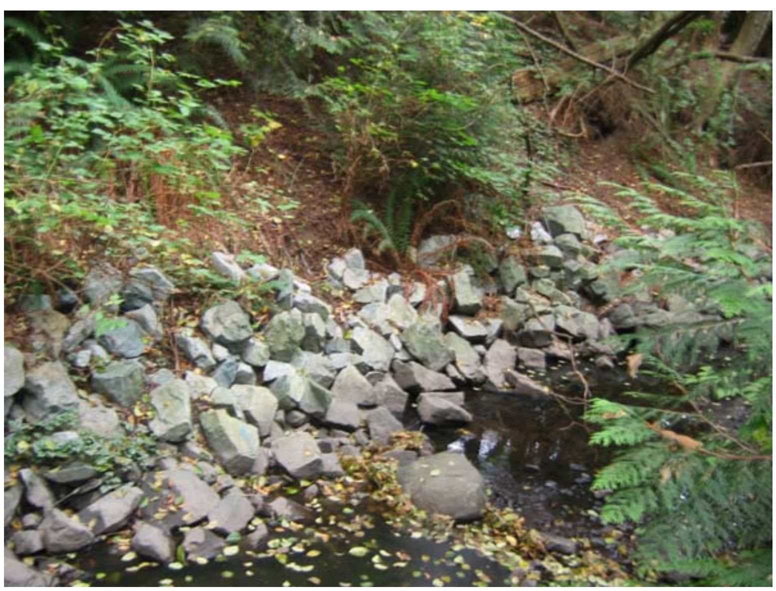


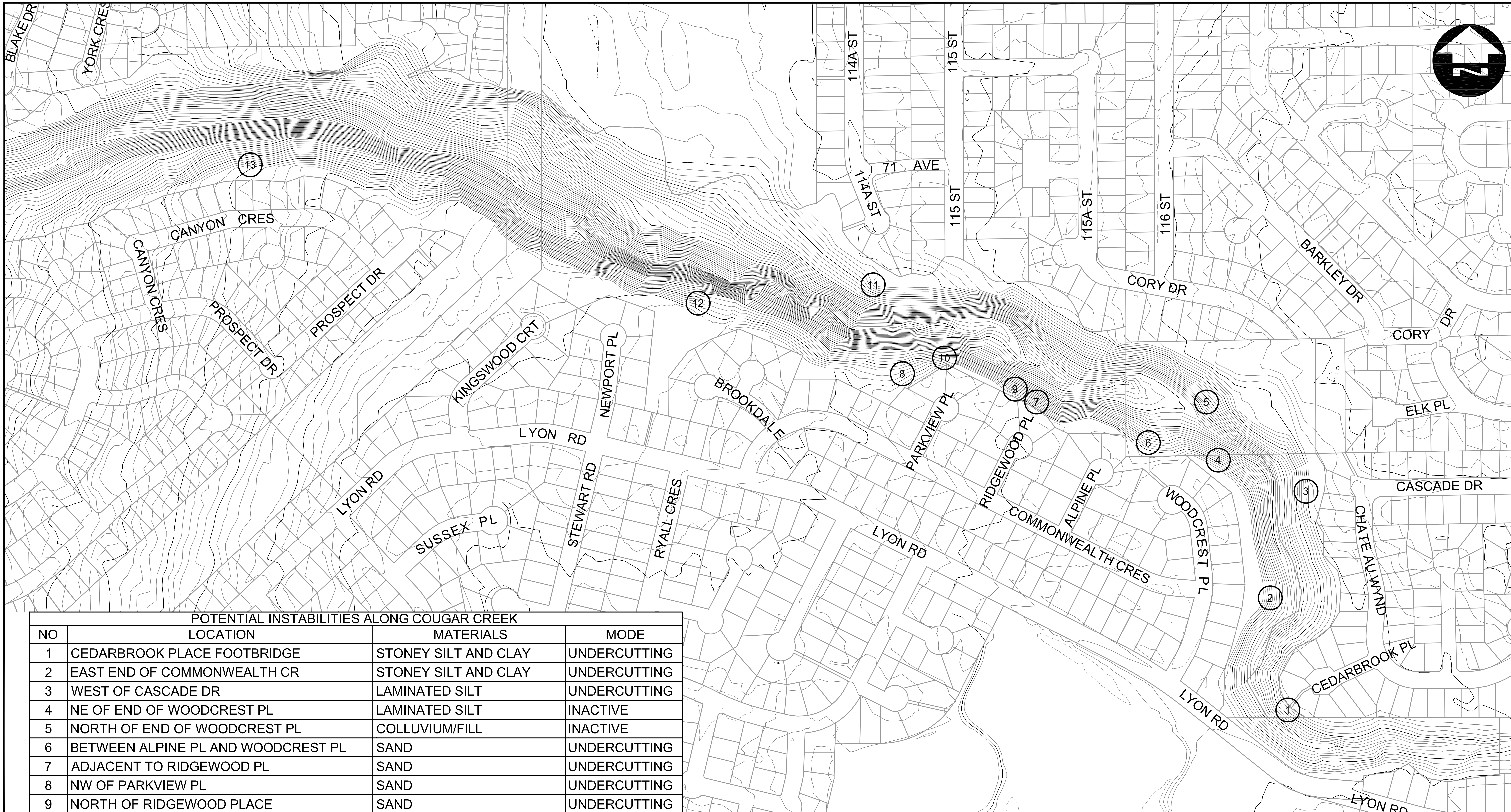
Photo 4: Example of Area of Terrace Instability with Stabilization Works

6. Bank and Bed Erosion: At several sites downstream of Nicholson Road, Cougar Creek appears to be slowly downcutting. The erosion activity may be related to climate and/or development that increases peak stream flows. This activity generally contributes sediment to the stream bed. In addition, related stream bank erosion provides additional sediment source. Where stream bank erosion impacts Canyon slopes, slope instabilities as noted in point 3, above is observed.

Photo 5: Erosion into Terrace on Right Bank

Potential instabilities observed were caused by streambed down cutting, terrace bank erosion and minor undercutting over the length of Cougar Creek downstream of Nicholson Road and are summarized in **Table 2-4** and located on **Figure 2-6**. There are three inactive cases**,** and ten active sources of stream sediment. Of those ten, numbers 7 and 13 are the largest, with number 7 having the highest scarp, and with the scarp closest to residential dwellings.

Number 5 is on a slope composed of very loose material, probably fill. Older trees common in the valley are missing on this slope. There are no dwellings near the crest of this slope.



POTENTIAL INSTABILITIES ALONG COUGAR CREEK

NO	LOCATION	MATERIALS	MODE
1	CEDARBROOK PLACE FOOTBRIDGE	STONEY SILT AND CLAY	UNDERCUTTING
2	EAST END OF COMMONWEALTH CR	STONEY SILT AND CLAY	UNDERCUTTING
3	WEST OF CASCADE DR	LAMINATED SILT	UNDERCUTTING
4	NE OF END OF WOODCREST PL	LAMINATED SILT	INACTIVE
5	NORTH OF END OF WOODCREST PL	COLLUVIUM/FILL	INACTIVE
6	BETWEEN ALPINE PL AND WOODCREST PL	SAND	UNDERCUTTING
7	ADJACENT TO RIDGEWOOD PL	SAND	UNDERCUTTING
8	NW OF PARKVIEW PL	SAND	UNDERCUTTING
9	NORTH OF RIDGEWOOD PLACE	SAND	UNDERCUTTING
10	NORTH OF PARKVIEW PLACE	SAND	INACTIVE
11	SOUTH OF 114A STREET	SAND	UNDERCUTTING
12	BETWEEN BROOKDALE AND NEWPORT PL	SAND	UNDERCUTTING
13	ADJACENT TO CANYON CR	SAND	UNDERCUTTING

APPROXIMATE SCALE 1:4,000

0 40 120 200m

SOURCE: BASE MAP PROVIDED BY THE CITY OF SURREY.

DILLON CONSULTING

DATE JUNE 2009

PROJECT
COUGAR CREEK
INTEGRATED STORMWATER MANAGEMENT PLAN

TITLE
LOCATION OF CHANNEL INSTABILITIES

PROJECT NO.
06-6904

FIGURE NO.
2-6

FileName:g:\cad\06904\06904-figures-master-drainage.dwg

Table 2-4: Potential Instabilities Along Cougar Creek

No	Location	Materials	Mode
1.	Cedarbrook Place footbridge	Stoney silt and clay	Undercutting
2.	E. end of Commonwealth Cr	Stoney silt and clay	Undercutting
3.	W of Cascade Dr	Laminated silt	Undercutting
4.	ENE of end of Woodcrest Pl	Laminated silt	Inactive
5.	N of end of Woodcrest Pl	Colluvium/fill	Inactive
6.	Between Alpine Pl and Woodcrest Pl	Sand	Undercutting
7.	Adjacent to Ridgewood Pl	Sand	Undercutting
8.	NW of Parkview Pl	Sand	Undercutting
9.	North of Ridgewood Place	Sand	Undercutting
10.	North of Parkview Place	Sand	Inactive
11.	South of 114A Street	Sand	Undercutting
12.	Between Brookdale and Newport Pl	Sand	Undercutting
13.	Adjacent to Canyon Crt	Sand	Undercutting

An assessment of potential erosion was also conducted within Blake Creek. Some bank protection has been placed near 112th Street and appears to be functioning well. Further upstream at the culvert discharge, slopes are steep. These slopes are in the less erodable Vashon and Upper pre-glacial deposits and appear to be functioning well.

Finally, there are also some erosion issues within the Canal downstream of the BNSF Bridge. Flood flows have caused the formation of gullies along the Metro Vancouver bicycle path. This is a concern for Metro Vancouver and area residents as well as the Corporation of Delta.

The significant erosion process in the upper portion of the watercourse resulted in a similar rate of sedimentation. To reduce the sedimentation in the Canal, a sediment trap was constructed at the outlet of Cougar Creek at the downstream end of the steep canyon east of Westview Drive to collect the sediment before it enters the slow moving shallow Canal and to permit the removal of the sediment. This sediment sump been cleaned out the following number of times in recent years:

2004 – September 29th and December 21st
2005 – none
2006 – April
2007 – Jan 30th and April 11th

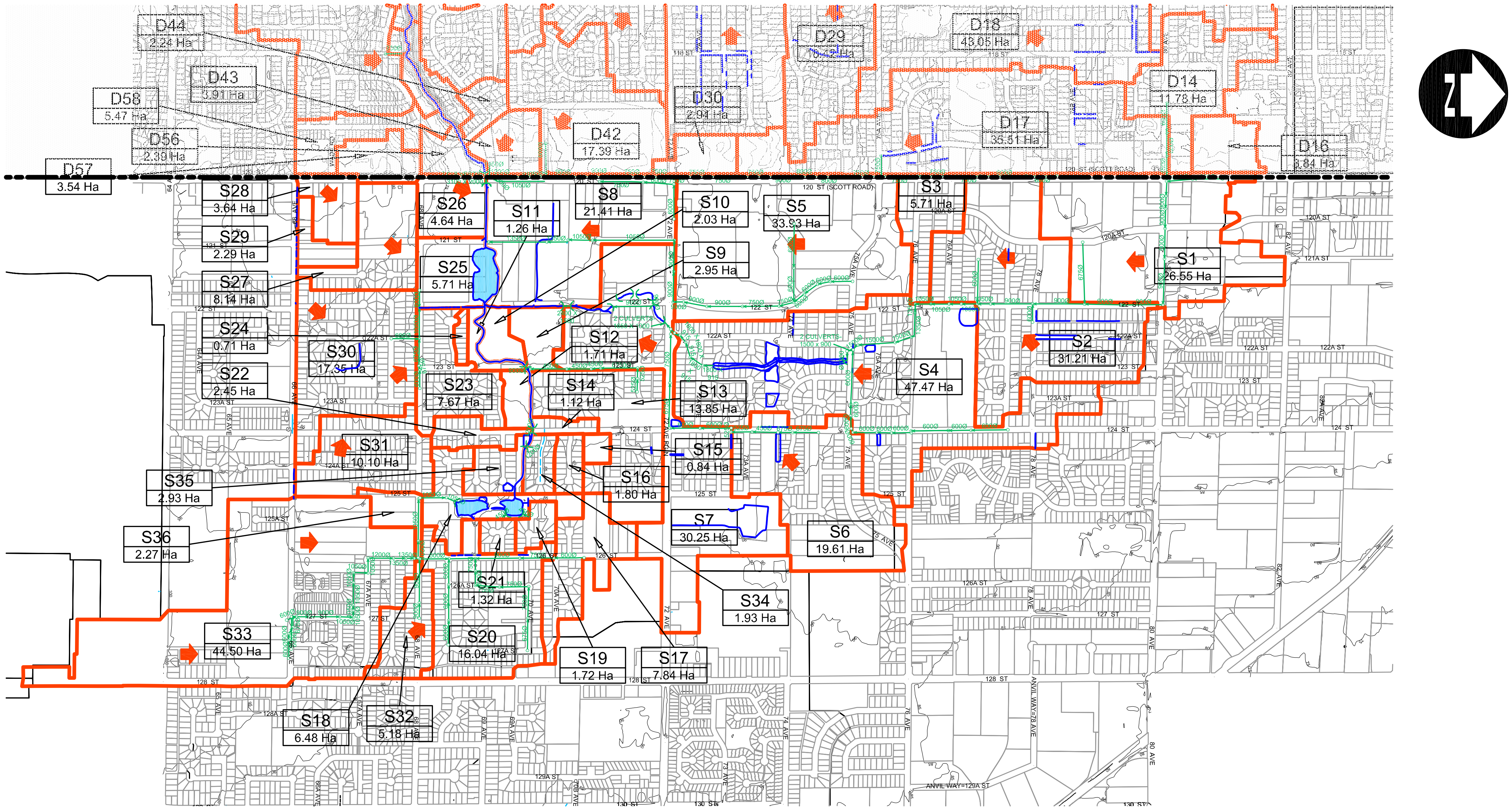
It is estimated that the sediment sump can trap approximately 300 m^3 of sediment. A review of past cleaning practices indicates that a marked increased in sediment transport has occurred over the past years based on the recent increased frequency of cleaning the sediment trap. The increasing volumes of sediment being moved indicates the possibility that higher urban runoff volume and intensity of peak flows occurring through the Cougar Canyon reach create the increase in erosion/sedimentation and as a result the facility would require cleaning after each major storm event.

2.3.3 Surface Drainage and Hydrology

<u>Major-Minor System</u>

Surface waters within the study area are drained by closed storm drain systems with outlets to Cougar Creek, the Canal or its tributaries. Almost all the old open drains have been replaced by conduits during the urbanization phase. The existing storm sewer system comprised of a major-minor system was sized to convey a 1 in 5-year or 1 in 10-year storms and is shown on **Figure 2-7** for Surrey and **Figure 2-8** for Delta.

Starting in the late 1970s, new developments within the study area were required to provide stormwater detention facilities to limit the flow to pre-development conditions for the 1:5 year or 1:10 design event. As a result, close to 30 small detention facilities exist in the watershed, most providing a very limited control of runoff from small drainage areas. An analysis of these small ponds showed that the storage facilities fill up very quickly even by a 2-year storm. For any larger events the ponds are ineffective and would let runoff pass downstream uncontrolled. These limited storage facilities may provide some temporary settling of pollutants discharged by the urban runoff, however, subsequent runoff events could re-suspend the previously settled particles.



LEGEND

- MUNICIPAL BOUNDARY
- OPEN CHANNEL/ DITCHES
- WET PONDS
- 600Ø STORM MAIN
- MINOR SYSTEM FLOW DIRECTION
- SUBCATCHMENT BOUNDARY
- MAJOR SYSTEM FLOW DIRECTION
- D1 SUBCATCHMENT NAME
- 13.45 Ha SUBCATCHMENT AREA

APPROXIMATE SCALE 1:15,000

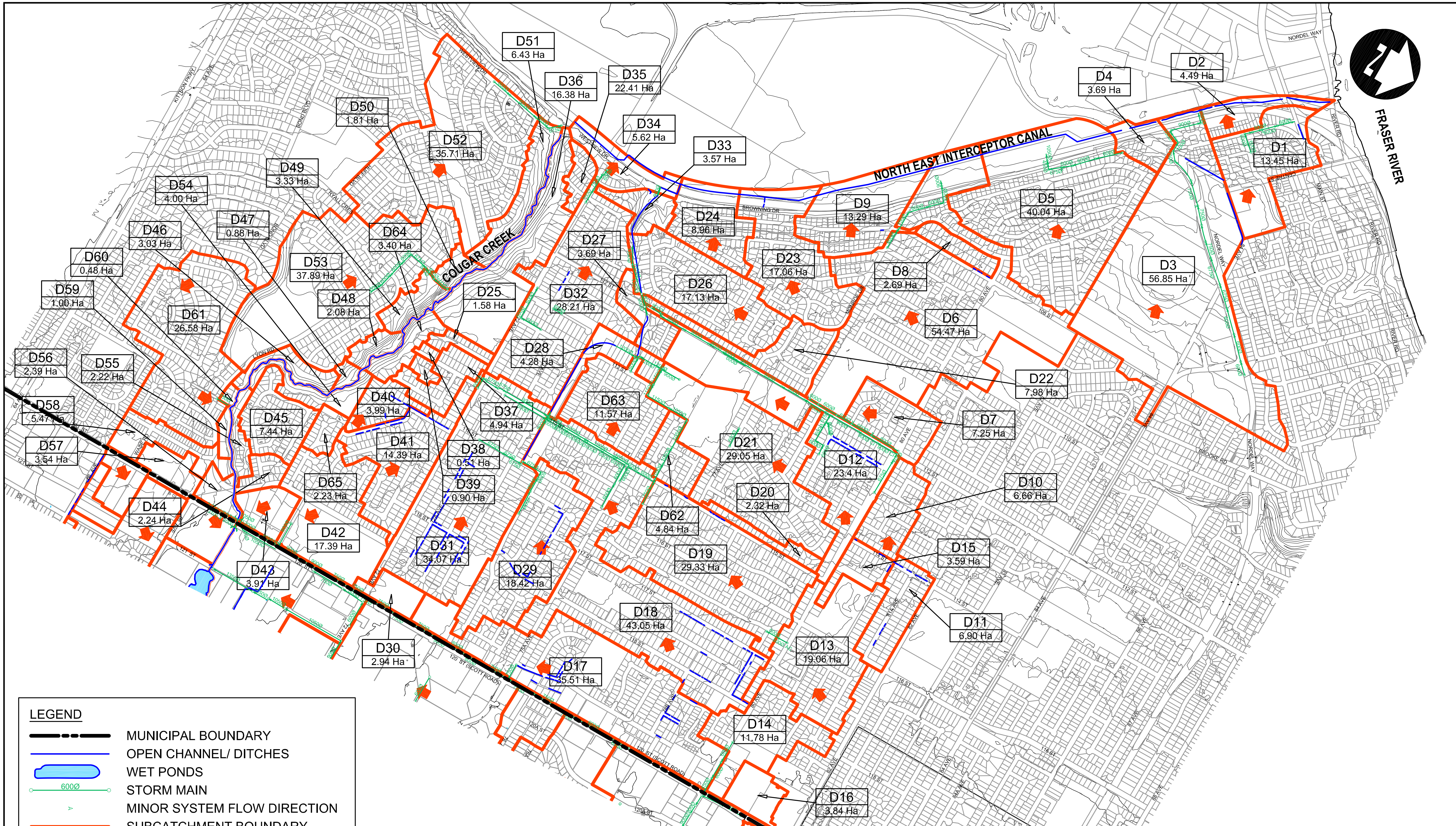
0 150 450 750m

SOURCE: BASE MAP PROVIDED BY THE CITY OF SURREY.

DILLON CONSULTING

	PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE JUNE 2009	TITLE MAP OF MAJOR MINOR SYSTEM - SURREY	FIGURE NO. 2-7

FileName:g:\cad\06\6904\06904-figures-master-drainage.dwg



SOURCE: BASE MAP PROVIDED BY THE COOPERATION OF DELTA.

DILLON CONSULTING

PROJECT: COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN		PROJECT NO. 06-6904
DATE: JUNE 2009	TITLE: MAP OF MAJOR MINOR SYSTEM - DELTA	FIGURE NO. 2-8

FileName:g:\cad\06904\06904-figures-master-drainage.dwg

The three more significant existing storage facilities within the watershed listed in **Table 2-5** are shown on **Figure 2-9**.

Table 2-5: Storage Facilities

Name	Storage m^3	Drainage area ha	Unit Area Storage mm	Unit Area Release Rate L/s/ha
Cougar Creek Park	15,732	328.92	10.5	17.7
Hydro ROW	18,823	85.35	22.1	19.8
Soccer Dry Pond	11,858	33.93	34.9	63.2
Total	46,413	362.85	12.8	

Open Watercourses

Drainage conditions in the Cougar Creek/NEIC watercourses are summarized below.

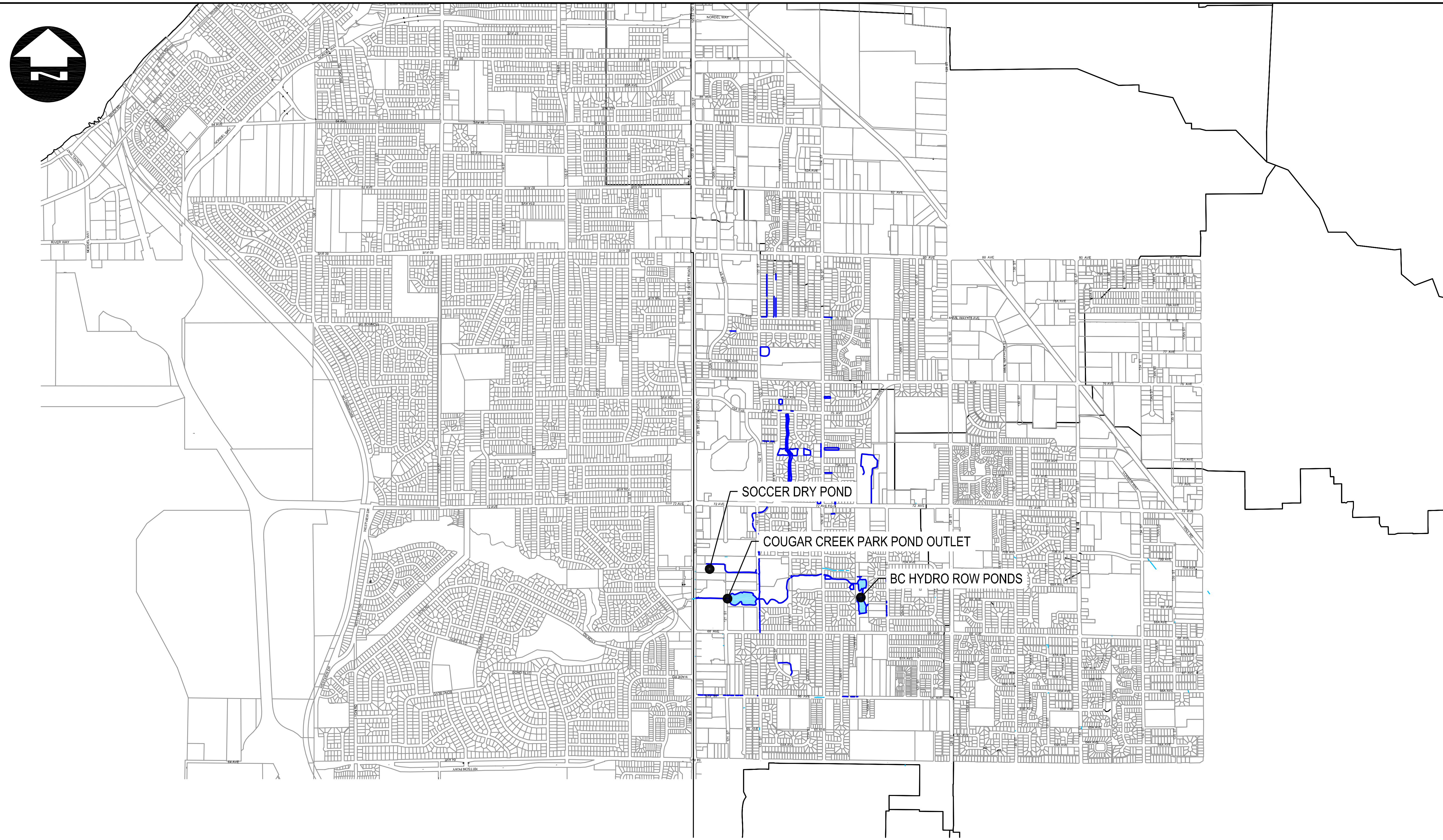
Upper Cougar Catchment:

Most of the area is serviced by stormwater pipes that feed into one of the retention ponds in the headwaters area. There are two retention ponds within the BC Hydro RoW along the 125th Street corridor, another large pond within Cougar Creek Park, and another dry pond located within the soccer pitch next to the Scott Road Temple. The ponds within the park and Hydro right-of-way are accessible to salmonids and provide good rearing habitat.

The upper portion of the Cougar Creek watershed within Surrey has mild ground and creek bed slopes with a creek depths ranging from 1 to 3 m to top-of-bank. The average slope down to 122nd Street and 69th Avenue is mild, ranging from 1% to 3.75 %.

Cougar Canyon Catchment:

Downstream of the Surrey-Delta border at Scott Road the creek changes, flowing at a higher velocity through an erosion prone region consisting of close to 5.5% grades, followed by a deposition area at Westview Drive and a backwater zone along the Canal near the Fraser River. This reach is characterized by steep canyon slopes from Nicholson Road to Westview Drive. The average gradient through the Canyon is 2.8%. There are numerous storm water outfalls within this reach mostly from the north side of the Canyon. The creek also receives groundwater inflow from a number of springs along the Canyon slopes – approximate locations of springs coincide with Capilano Formation, Vashon glacio-marine deposits, at the base of the Quadra sand, and near the western end of the canyon.



SOURCE: BASE MAP PROVIDED BY THE CITY OF SURREY.

APPROXIMATE SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

PROJECT	COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN
PROJECT NO.	06-6904
TITLE	LOCATION OF MAJOR PONDS
FIGURE NO.	2-9
DATE	JUNE 2009

FileName:g:\cad\06\6904\06904-figures-master-drainage.dwg

The hydraulics of the Cougar Creek canyon system is characterized as deep, wide, and hydraulically steep. The capacity of the creek to convey high flows is adequate especially at the Canyon sections where the ravine walls are up to 30 m deep. The Canyon experiences high flows from large and/or intense rainstorm events as a result of a nearly-fully urbanized upstream catchment. These high flows in a hydraulically steep channel result in high erosive velocities. The Cougar Creek Canyon flows drain into the Westview Drive pipe arch culvert crossing and into the start of the Canal.

Blake Creek Catchment:

Most of this residential area collects storm water through pipes and swales. The main collector channel for Blake Creek is along the Mader Lane corridor between 73rd Avenue and 74th Avenue. This unnamed ditch is fed by the local storm sewer system and experiences rapid and large increases in flow during even moderate rain events. The Blake Creek canyon descends towards the Canal at a 7.1% grade (a 50 m drop over a 700 m length) with inflows from six stormwater outfalls. Blake Creek along these reaches also receives groundwater from springs.

Northeast Interceptor Canal:

The 3.3 km long man-made Canal serves as the outlet for Cougar Creek. It has a very flat gradient and the water levels in the Canal can be subject to backwater effects from the Fraser River. Over the past years a number of construction activities took place along or across the Canal, such as in-stream works by the BNSF to increase discharge capacity, the construction and removal of stream crossings, and a series of cleanup activities by the Corporation and local schools. The Metro Vancouver sanitary trunk sewer also acts as a constraint on the Canal.

In addition to the Cougar Creek flows, the Canal receives stormwater from residential areas to the east from nine storm outfalls. This includes runoff from the new Delsom development at the intersection of Nordel Way and 84th Avenue. There are also groundwater inputs from the eastern slopes into the Interceptor. Estimates range from 4 L/s to 8 L/s.

In the vicinity of the Canal near its outlet is Burns Bog, an environmentally sensitive area located on the Fraser River flood plain. During high water conditions the Canal can overtop its banks and inundate the Bog and its low lying areas.

Any investigation of existing and future conditions along the Canal has to consider the various interests within and adjacent to the Canal's Right–of-Way, such as:

- BNSF Railway
- Metro Vancouver Sanitary (formerly known as GVS&DD)
- Terasen Gas (formerly known as BC Gas)
- BC Hydro Transmission line
- Water main
- Municipal storm sewers

Past Flooding

The Cougar Creek flows under its previous natural conditions would drain into the Delta Nature Reserve and Burns Bog before discharging into the Fraser River. The construction of the BNSF rail line and the Canal changed the natural flow regime of the creek and created an effective sediment trap upstream of the rail crossing.

The hydraulics of the Canal can be generally characterized as undersized and having flat slopes that frequently floods mainly at locations where the banks are very low. Flooding in the past was limited to the area near the railway bridge, further downstream adjacent to the wetlands and near the Tilbury Rail Crossing. Overflows have been observed into the adjacent Delta Nature Reserve during significant rain events. The Corporation of Delta completed some channel improvement works and installed two box culverts near the railway bridge in the recent past.

The channel capacity of the Canal between the pipe arch culvert crossing west of Nordel Way and the BNSF Bridge crossing has a low bankfull capacity due to the shallow depth of flow, small channel cross-section, and low gradients. This portion of the Canal has much lower capacities than the remaining system, creating flood vulnerable areas where the creek could overtop its banks and flood adjacent land.

During large rainfall events, flows from the Canal upstream of the rail crossing have been observed to overtop the rail line (especially in the upper end of the Canal downstream of the Westview Drive culvert) due to the limited hydraulic conveyance capacity in the channel. The channel section in this portion of the Canal is restricted by the close proximity of Westview Drive to the east and the rail line to the west. During large rainfall events, flows in the Canal between the rail line crossing and the Alex Fraser Bridge often overtop the service road to the west. Also, increased flood risk has developed on the Cougar Creek reach west of Westview Drive. Another potential problem caused by the occasional flooding of the railway tracks is the contamination of the ballast by the sediments carried by the floodwaters. The railway has experienced line closures annually for the last four years and has overtopped historically throughout its length. The Canal can also overtop its banks and flood Burns Bog discharging polluted urban runoff into this environmentally sensitive area.

Floating debris which collects at many of the culvert and trash rack entrances could significantly reduce the conveyance capacity.

Past records do not show any private homes being affected by the occasional flooding along Cougar Creek. However, with an increasing frequency, flooding does occur where Cougar Creek turns northwards into the Canal. A section of the Canal reach that parallels the tracks to the east has a limited cross section that is unable to convey all flows within the top-of-bank.

As the Cougar Creek catchment has developed over the years, computer estimates indicated increased stormwater runoff produced by the increase in development. This process resulted in increased intensity, frequency and durations of discharges in Cougar Creek and the Canal. Smaller rainfall events that may have produced very little runoff from mainly undeveloped surfaces are now resulting in higher flows that occur more frequently for the same storm events. These increases in relatively small runoff events often account for the majority of long-term movement of sediment and consequently are the most deterministic of the geomorphic stability of the stream channels.

Low Flows

Summer low flows along the Cougar Creek/NEIC system have decreased since 1997. A review of local summer and spring rainfall indicates a decrease in the number of rainy days with a corresponding decrease in summer base flows. As a result, the contribution of groundwater becomes more critical to the quality of water and fish habitat throughout the catchment. Unfortunately, some of the past development practices and storm water management strategies may have altered the groundwater recharge and discharge mechanisms to the detriment of the aquifer system.

Sedimentation

Sedimentation is a major issue in the lower reaches of the system, most notably along the Canal. Erosive forces and urban development have conveyed a significant sediment load which has settled in the low-gradient reaches of the Canal. As a result, the capacity of the Canal has been severely compromised. Flows from the hydraulically steep Cougar Creek canyon enter the flatter gradient of the Canal. Transported sediments and gravels eroded from the Canyon are deposited upstream of the Westview Drive culvert or just downstream in the upstream end of the Canal. The accumulation of sediments and gravel over time has aggraded the Canal, further reducing channel capacity.

Structures Crossing the Watercourses

A detailed survey was carried out along the watercourses to obtain information on all structures, such as bridges, culverts and outfalls. **Table 2-6** summarizes the survey data only for bridges and culvert crossings, the information needed for the computer modelling. A more detailed table with all surveyed information is presented in the **Appendix A.** The table also includes a numerical code for the condition of the structure; the condition of structure ranked from 1 to 5, where 1 = very poor condition and 5 = very good condition.

Table 2-6: List of Structures Modeled

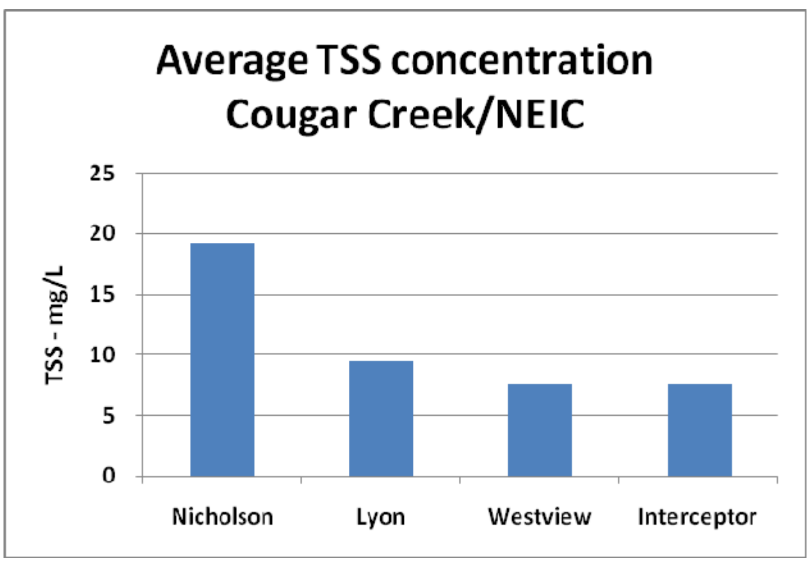
#	Location*	Description of Structure	Material	Condition	# of Structures	Diameter of size of opening	Height	Width	Dist.(m)	Photos	Comments
1	River Road	Circular culverts	corrugated steel	4	4	1.2m	2.3 m	2.9 m	0	1 to 13	Mill bridge 27m away, 4 round culverts at River Road, 7m grizzly and storm outfall on upstream side of River Road. Vertical bagwall on left bank of upstream side
2	Adjacent to trail	Box culvert	concrete	5	2		3 m	3 m	26	14, 16, 17	Square box culverts, open bottoms, concrete baffles throughout. Located under railroad
3	Adjacent to trail	Bridge	wood	3	1 bridge 1 debris trap		3.8 m	9.8 m	197	16	4.9 m upstream of culvert inlet
5	Under trail	Circular culverts	corrugated steel	2.5	1	1.2 - 1.5 m			245	23 to 25	Vegetation overgrown on culvert, some debris located on inlet side
7	Adjacent to trail	Circular culverts	corrugated steel	2.5	1	3 m			561	32 to 36	Right bank has linear concrete wall, most likely part of sanitary structure, culvert more elliptical in shape, debris buildup at inlet side
8	NEIC Canal	None						Wetted: 1.8 m Bankfull: 2 m	719	37 to 42	BFH: 0.4m, Depth of water 0.8m. Beaver dams located on main channel and tributary channel. Cross section not completed due to dams and too much water
9	Adjacent to trail	Bridge	wooden	3	1		0.9 m	1.8 m	1210	43 to 46	Wooden bridge crossing canal. Length of bridge: 18.5 m. Broken on one end, with heavy vegetation on upstream side (willows)
13	Adjacent to trail	Bridge	wooden	5	1		0.9m	1.8 m	1717	57 to 60	Wooden bridge crossing. Length of bridge: 9.4 m. Wetland located 5m NE from canal
19a	Adjacent to trail	Train bridge	concrete	5	1		2.3 m	7.4 m	2390	88 to 96	Train bridge located 12.5 m from Cougar Creek to the NNE. ~40 m upstream of bridge there was a change to a cobble substrate
20	Tributary to Cougar Creek	Culvert	corrugated steel	5	3	1.0 m			2720	97 to 100	3 culverts feed into tributary which flows under train bridge.
21	Adjacent to trail	Bridge	wooden	5	1		1.3 m	1.5 m	2788	101 to 103	Length of bridge: 6.8 m. FS = 264 degrees W. Cross-section details below
23	Under trail	Culvert	corrugated steel	5	1	0.6 m			2939	108 to 110	Culvert located 22.4m upstream of structure #22. Plugged at both inlet and outlet. 12.4 m from culvert outlet to Cougar Creek. FS = 267 degrees
25	Near trail	Train bridge	concrete	5	1		1.1 m		2937	116 to 118	Length of bridge: 15 m. There is an outfall on the right bank of creek.
27	Past 72nd Ave	Culvert	corrugated steel	1	1	0.8 m			3091	123 to 126	Culvert is falling apart. Length is undetermined.
28	Westview Drive	Ellipse	corrugated steel	4	1	4 m			3177	127 to 129	Large elliptical culvert under Westview Drive

2.3.4 Water Quality

During the study, two sets of water quality samples were taken, one set during low flow conditions during a dry period, and one following a period of rainfall during moderate flow conditions at three locations: Nicholson Road, Westview Drive and Nordel Drive. **Appendix B** presents the results of the water quality monitoring. Generally, the results show a reduction in the pollutant concentrations moving downstream along Cougar Creek and the Canal, but none of the parameters showed excessively high concentration.

Limited water quality sampling has been undertaken by the Corporation of Delta along Cougar Creek and the Canal over a ten-year period between 1983 and 1993. Half a dozen samples were collected at Nicholson Road, the Lyon Road walkway, Westview Drive and in the Canal. Generally, the observed pollutant concentrations were very similar to those observed in other parts of the Metro Vancouver area or reported for other North American urban areas. A review of the limited number of samples taken by Delta plotted on **Figure 2-10** suggests that the average Total Suspended Solids (TSS) concentration data observed along Cougar Creek and the Canal system is the highest at the upper end of Cougar Creek and as the flow moves downstream along the creek, the concentration drops markedly even before it reaches Westview Drive, resulting in an average TSS concentration less than half of the value observed at Nicholson Road. This trend was also identified in the 2008 samples. The recent introduction of an Erosion and Sediment Control bylaw in Surrey will assist in future control of sedimentation in the Canal.

Figure 2-10: Average TSS Concentrations at Four Sample Sites



Significant research has been done over the past decade to characterize stormwater quality. The prime source of pollutants in urban areas listed in the technical literature is mainly from atmospheric deposition, automotive exhaust emission and fluids, corrosion of metal surfaces, and vegetative matter. Urban runoff from residential developments may contain a variety of dilute contaminants such as suspended solids, chloride from road salt, oil and grease, metals, pesticide residues, bacteria (*E. coli*) and viruses. Generally, with the exception of the dissolved constituents (nitrogen, salt), most contaminants are attenuated by filtration during transport through the soils. Without appropriate mitigative measures (*e.g.*, the City's

Erosion and Sediment Control bylaw), pollutant loads have the potential to impact receiving stream and habitat quality.

A comprehensive analysis of local stormwater quality was reported by Metro Vancouver in 2003. The report is based on stormwater quality data collected between 1993 and 1997 and contains useful information on typical stormwater characters and loadings of contaminants applicable to the Metro Vancouver area. However, the data and the results did not differentiate between different types of land uses; instead the data represented catchments with total impermeable area ranging from 35% to 75%, similar to the Cougar Creek/NEIC watershed.

A very comprehensive list of pollutant loads generated by different land uses reported in the literature is presented in **Table 2-7** to assist in estimating pre- and post-development pollutant loads for selected parameters. The data represents event mean concentrations monitored across North America. The potential surface water quality impacts caused by urbanization can be assessed qualitatively by considering parameters of urban runoff that are recognized as suitable indicators. The table also lists Metro Vancouver results and the few observations taken at Nicholson Road by the Corporation of Delta.

Generally, in the design of stormwater management facilities, only one or two key indicators, such as Total Suspended Solids (TSS) made up of street dirt and wind-blown deposition and, depending on the water quality, Total Phosphorus (TP) is considered.

Table 2-7: Mean Pollutant Concentration Generated by Different Land Uses

Land Use	Primary Indicators		Secondary Indicators					Metals					
	TSS (mg/L)	TP (mg/L)	BOD (mg/L)	COD (mg/L)	TKN (mg/L)	TDS (mg/L)	TN (mg/L)	Cd (ug/L)	Cr (ug/L)	Cu (ug/L)	Pb (ug/L)	Ni (ug/L)	Zn (ug/L)
Forested wetland	19.0	0.2	4.1	29.4	0.6	52.0	1.1	0.5	2.8	5.3	3.0	4.7	22.9
Cropland Pasture	19.2	0.2	4.2	29.7	0.6	52.0	1.1	0.5	2.9	5.4	3.1	4.7	23.5
Upland forest	19.7	0.2	4.3	30.4	0.7	52.0	1.1	0.5	2.9	5.6	3.2	4.7	24.8
Urban open	20.0	0.2	4.4	30.7	0.7	52.0	1.1	0.5	2.9	5.7	3.2	4.7	25.4
Utilities	20.7	0.2	4.6	31.7	0.7	52.0	1.2	0.5	3.0	6.0	3.4	4.8	27.5
Low-density residential	22.1	0.2	5.0	33.4	0.8	52.0	1.2	0.5	3.1	6.5	3.8	4.8	31.2
Med-density residential	30.5	0.2	7.5	43.5	1.1	52.0	1.7	0.6	3.8	9.7	6.1	5.0	59.4
Institutional	41.9	0.3	11.3	56.7	1.5	52.0	2.4	0.6	4.5	14.7	9.9	5.3	112.9
High-density residential	47.7	0.3	13.3	63.1	1.7	52.0	2.7	0.7	4.9	17.3	12.0	5.4	145.9
Multifamily residential	47.7	0.3	13.3	63.1	1.7	52.0	2.7	0.7	4.9	17.3	12.0	5.4	145.9
Commercial	54.2		15.7	70.1	2.0		3.1	0.7	5.3	20.4	14.5	5.5	188.7
Highways	57.8		17.0	74.0	2.1	1.3	3.3	0.7	5.5	22.1	16.0	5.5	214.6

Land Use	Primary Indicators		Secondary Indicators					Metals						
	TSS (mg/L)	TP (mg/L)	BOD (mg/L)	COD (mg/L)	TKN (mg/L)	TDS (mg/L)	TN (mg/L)	Cd (ug/L)	Cr (ug/L)	Cu (ug/L)	Pb (ug/L)	Ni (ug/L)	Zn (ug/L)
Industrial	57.8		17.0	74.0	2.1	1.3	3.3	0.7	5.5	22.1	16.0	5.5	214.6
Metro Vanc.	*44*	*0.14*	*5*	*34*	*0.8*	-	-	*0.24*	*2.3*	-	*11.7*	-	*73*
Nicholson Rd	*19*	-	*9*	*17*	*20*	-	-	*Min.*	*-.*	*10*	*10*	*4.7*	*31*

Reference: CH2M Hill, 2000. Technical Memorandum on Urban Stormwater Pollutant Assessment for North Carolina Department of Environment and Natural Resources.

2.3.5 Fisheries

The Cougar Creek watershed is the most productive salmonid habitat in the Corporation of Delta, supporting a significant number of both salmonid and so-called “coarse” fish (*e.g*., threespine stickleback) species. The Cougar Creek reaches within Delta provide both spawning and rearing habitat with the highest value habitat located within the Cougar and Blake Creek ravines. Within the City of Surrey, Cougar Creek is only one of many productive salmonid watercourses. However, there is significant value found within the ponds and reaches of the creek in Surrey. In particular, the pond in Cougar Creek Park would provide significant and productive rearing habitat.

According to the Freshwater Fisheries Society of BC’s on-line “FishWizard” database, Cougar Creek supports a variety of fish species including Chinook salmon, coho salmon, cutthroat trout, peamouth chub, sculpin and threespine stickleback. Other reports (Delcan 1994) identify rainbow trout as being present within system. Up until 2007, the Cougar Creek Streamkeepers group released coho into Cougar Creek from their incubator box within the ravine, in numbers ranging from approximately 8,000 to 13,000 fry each year (Pete Willows, *pers. comm.*). All indications are that returns to date have not been significant although some coho spawners may be present. In the last two years, the streamkeepers have switched to chum releases after consultation with Fisheries and Oceans Canada. It is felt that perhaps the system does not provide sufficiently good habitat to support coho given that they tend to remain instream for a year after emergence before going to sea. Chum, on the other hand, move to sea almost immediately upon emergence and would be less likely to be subjected to stresses potentially present within Cougar Creek. In the last two years, chum releases have ranged from 10,000 to 50,000 in number with approximately 1,000 coho smolts (*i.e.*, ready to go to sea) being released within that same time frame.

Chinook salmon have been observed primarily within rearing habitat near the confluence with the Fraser River. Chum salmon are also present within the channel, which may reflect the efforts of the Cougar Creek Streamkeepers. Delcan (1994) reported that coho salmon spawning habitat was located from 2.5 km to 4.5 km upstream of the confluence with the Fraser River. More specifically, the spawning habitat extends from near the confluence of the Northeast Interceptor Canal with Blake Creek to the Cougar Creek ravine.

From a fish habitat perspective, the accessible reaches of Cougar and Blake Creeks within their respective ravines provide the greatest habitat value within the watershed. These reaches demonstrate high complexity with a varied substrate ranging from sand to boulder, a natural meander pattern and significant cover from overhanging vegetation and large woody debris. Based on site assessments, the majority of salmonid spawning habitat found within the Cougar Creek system is found here, although some potential spawning habitat has been observed within the Northeast Interceptor Canal, but it extends only as far as the confluence with Blake Creek.

The remainder of the Cougar Creek system does not provide spawning habitat for salmonids due to a lack of suitable gravel, although it does provide functional rearing habitat. Rearing is likely limited within the Northeast Interceptor Canal, as it has become largely infilled with sediment such that depth and other cover features are significantly lacking. Salmonid utilization would be predominantly adult migration in order to reach the identified spawning habitat within the Cougar and Blake ravines, or for smolts to out-migrate to the Fraser River.

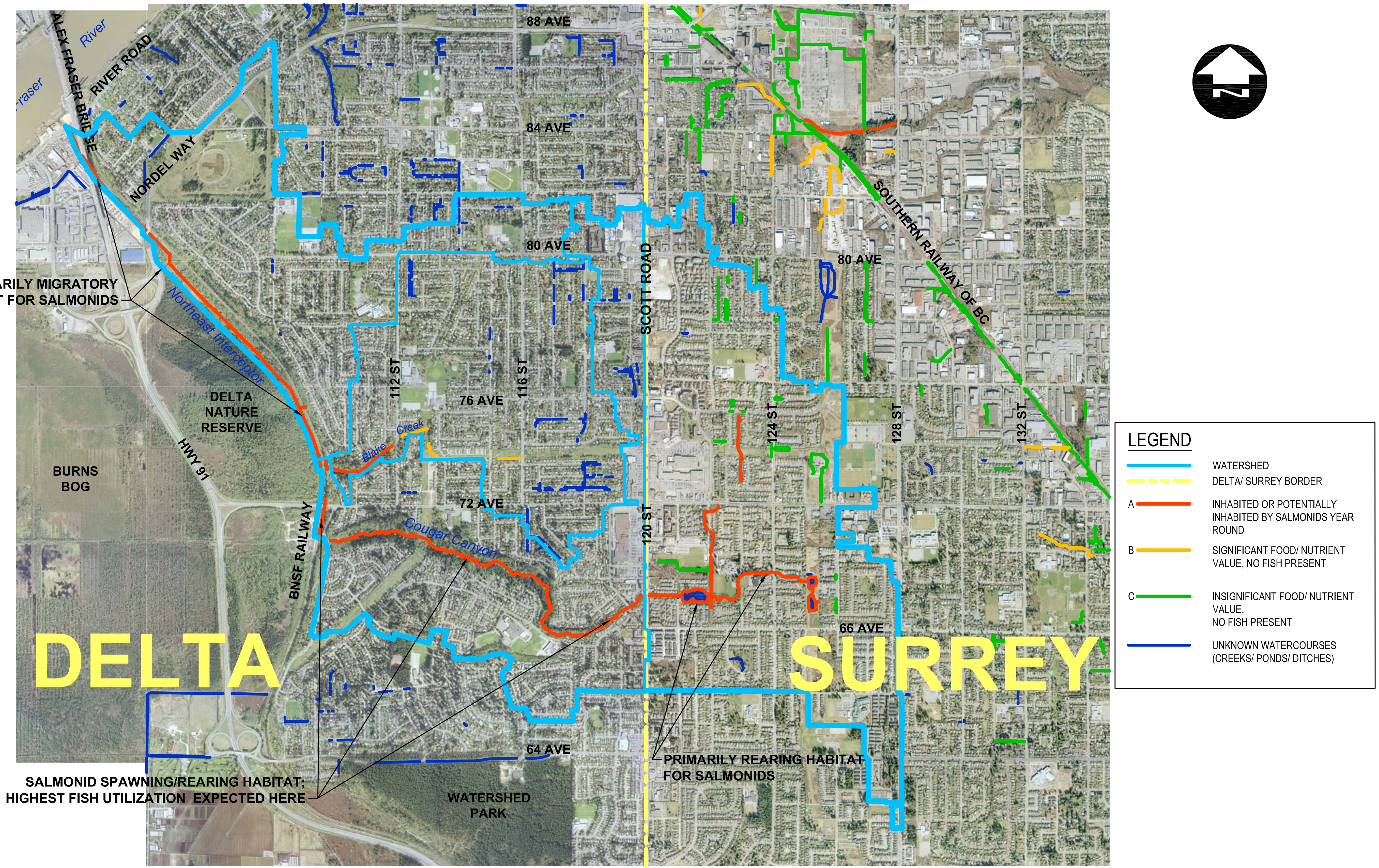
Given that information contained in previous reports was restricted to the determination of presence/absence of fish species and that salmonids are released by the local streamkeeper group, it is difficult to determine what population sizes may be.

Figure 2-11 provides an illustration of the stream classifications within the watershed. This report utilizes the City's classification system where Cougar Creek and the majority of Blake Creek are identified as Class A habitat (inhabited or potentially inhabited by salmonids year-round). This is very similar to the Corporation's system which would identify these same reaches as "Schedule A – Salmonids".

2.3.6 Riparian Vegetation

Figure 2-12 provides a spatial presentation of the riparian corridor assessment. This consists of a comparison of the historic (including manmade) or potential 30-metre setback from the top-of-bank or from the top of the ravine bank to the amount of significant (*i.e.*, intact tree and shrub habitat) riparian vegetation still within that setback. Riparian vegetation has been severely compromised within the City of Surrey. Vegetation is largely restricted to a narrow strip along both sides of the channel. The vegetation assemblage consists of relatively young mixed deciduous and coniferous species with a mature understory consisting of both native and non-native species. Analysis of aerial photos taken in 2001 and 2006 indicate that although the extent of the vegetation has not increased significantly, it appears to be maturing. This would provide a greater benefit to the channel through more shading and greater bank stability amongst other factors. It should be noted that vegetation adjacent to some of the detention ponds appears to have increased significantly, particularly at 121st Street and at the south pond within the BC Hydro right-of-way north of 68th Avenue.

There has also been significant impact to the Cougar Creek riparian community within Delta, which appeared to start with the residential development in the 1960s. Development has continued such that throughout much of the upland reaches adjacent to the Cougar Creek ravine, residential development extends to near, or in some cases below, the top-of-bank of the ravine. The presence of the ravine has the



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

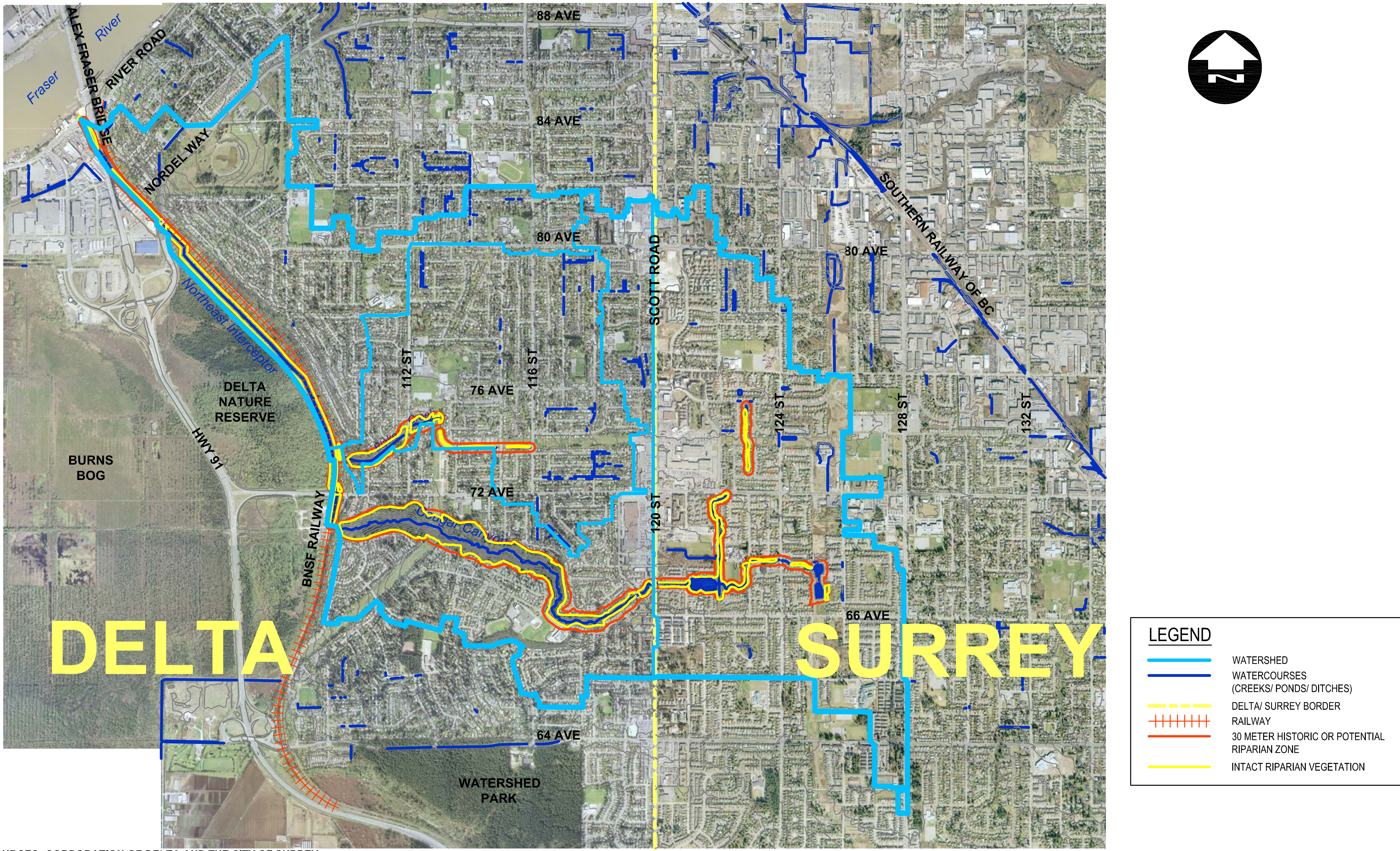
SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

PROJECT	COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE JUNE 2009	TITLE STREAM CLASSIFICATION	FIGURE NO. 2-11

FileName:g:\cad\066904\066904-figures-ismp.dwg



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

PROJECT	COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN
PROJECT NO.	06-6904
TITLE	RIPARIAN CORRIDOR
FIGURE NO.	2-12
DATE	JUNE 2009

FileName:g:\cad\066904\066904-figures-ismp.dwg

benefit of restricting development potential such that some aspects of the riparian community are largely intact, including a well-developed canopy and understory structure (within the ravine limits). The riparian community within the reaches of the Canal is largely intact, with trail and rail infrastructure being the primary impacts. Vegetation adjacent to the Canal is also compromised as a result of industrial development east of the Alex Fraser Bridge. In some cases, industrial properties extend up to the top-of-bank.

Aerial photography was used to assess the riparian integrity (intact riparian vegetation) between 1940 and 2006. **Table 2-8** below provides a summary of intact riparian vegetation within a designated 30 m buffer from the top-of-bank or top-of-ravine of all portions of the Cougar and Blake Creek systems. When reviewing this data, the following should be noted:

- The total setback and intact riparian areas are approximate due the marginal errors on the historic air photos, inconsistent capturing perspective, and photo quality;
- The Canal did not exist until after 1963 and has been excluded from consideration until 1982. For this reason there is a significant increase in the 30 m setback area between pre-1963 and 1982;
- Setback and intact riparian boundaries were delineated from air photo interpretations;
- There is a substantial increase in the setback area from the 1980s to 2006 due to channel realignment and the creation of new watercourses along property lines; and
- Aerial imagery was missing for a portion of the watershed for 1940 and 1963. As such, the areas of the subcatchments have only been calculated where all the information is present.

Table 2-8: Summary of the Estimated Intact Riparian Vegetation – m^2

	Year							
	1940		1963		1982		2006	
	30 m Setback Area	Intact Riparian Area	30 m Setback Area	Intact Riparian Area	30 m Setback Area	Intact Riparian Area	30 m Setback Area	Intact Riparian Area
NEIC	N/A	N/A	N/A	N/A	159,538	31,228	168,061	97,490
Blake Creek					71,200	31,663	92,878	46,982
Cougar Canyon					487,535	323,341	445,459	310,882
Upper Cougar					113,499	48,100	187,990	63,306
Total Area:	**558,159**	**403,432**	**599,863**	**423,688**	**831,771**	**434,331**	**894,388**	**518,660**

N/A = Not Available

The values indicated in **Table 2-8** were utilized to generate Percent Riparian Forest Integrity (%RFI) from the 1940s to the present as detailed in **Table 2-9** below. %RFI is determined by measuring the intact vegetation within a setback zone set at 30 metres from the top-of-bank of the channel or ravine. The percentage of intact vegetation constitutes the %RFI and is one indicator of overall watershed health. A progressively decreasing %RFI is indicative of progressive riparian habitat health impacts within the

Cougar Creek watershed. **Table 2-9** presents the %RFI values for the entire watershed and its four catchments for select years.

Table 2-9: Riparian Forest Integrity - %

<table>
<tr><th rowspan="2">Catchment/Subcatchment</th><th colspan="4">Year</th></tr>
<tr><th>1940</th><th>1963</th><th>1982</th><th>2006</th></tr>
<tr><td>Entire Watershed</td><td>72.3%</td><td>70.6%</td><td>52.2%</td><td>58.0%</td></tr>
<tr><td>Northeast Interceptor Canal</td><td rowspan="4">n/a</td><td rowspan="4">n/a</td><td>19.6%</td><td>50.6%</td></tr>
<tr><td>Cougar Creek ravine</td><td>66.3%</td><td>69.8%</td></tr>
<tr><td>Upper Cougar Creek</td><td>42.4%</td><td>33.7%</td></tr>
<tr><td>Blake Creek</td><td>44.5%</td><td>50.6%</td></tr>
</table>

The %RFI showed a very slight decrease between 1940 and 1963, likely as a result of the beginnings of the development of the road network and suburban subdivisions. There was a significant decrease between 1963 and 1982 due to the large-scale development that occurred during that time. The entire catchment shows some recovery between 1982 and 2006 likely as a result of the vegetation maturing.

From 1982 to 2006 there was an increase in %RFI for all subcatchments except for Upper Cougar Creek. This increase was in some cases significant as evidenced by the increase at the Northeast Interceptor Canal and can likely be explained as post-construction maturing/re-establishment of vegetation. The %RFI decrease within the Upper Cougar Creek subcatchment is likely a result of development that has occurred subsequent to 1982. It should be noted however, that although the %RFI may have decreased within the Upper Cougar Creek catchment (*i.e.*, within Surrey), that overall riparian area has increased through the creation of new channels. It should also be noted that many of the ditches within the Upper Cougar Creek catchment were constructed agricultural ditches within suburban farmland prior to the development observed in the 1980s. The riparian vegetation that was adjacent to these agricultural ditches should not be considered “historic”.

Riparian vegetation along the reaches near the confluence of the Northeast Interceptor Canal with the Fraser River consists of a narrow setback of young trees and shrubs. Local industrial and recreational land uses have affected the riparian zones, as in some places development is at or immediately adjacent to the top-of-bank of the watercourse.

Riparian integrity improves significantly upstream along the Canal through the Delta Nature Reserve and the Delta/Metro Vancouver Lands. Vegetation through this area consists of stands of mixed young and mature forest, with younger species dominating immediately adjacent to the Canal. A well-developed shrub layer is also present adjacent to the Canal; although it has been significantly impacted throughout extensive portions of this reach due to the local trail system and the construction of the Metro Vancouver sanitary trunk sewers.

The riparian canopy and understory are well-developed through the Cougar Creek ravine between Westview Drive and Nicholson Road even though residential development extends to at or near the top of the ravine bank throughout significant portions of this reach. The width of the ravine has served to insulate the creek channel from development. The Blake Creek ravine downstream of the 113th Avenue alignment exhibits similar characteristics.

The riparian vegetation in the upper reaches of both Cougar and Blake Creeks has been severely impacted due to residential and commercial development. Throughout the majority of these channel reaches development extends to at or near the top-of-bank.

Overall, there was a general reduction in the %RFI from the 1940s to the present time. The lowest %RFI was experienced in the 1980s as a result of the large-scale development that occurred in the late 1970's/early 1980's and was approximately 20% lower than in the 1940s. Even after recovery resulting from maturing vegetation, the %RFI today is still approximately 15% lower than in the 1940s. There has been an impairment of riparian function as a result. However, given the level of present development, the decrease in %RFI could have been more dramatic. This number has been held higher than expected as a result of the development constraints placed on the setback zone by the Cougar Creek ravine.

The higher than expected %RFI is not necessarily an indicator that the health of the watershed has not been overly affected, however. The large-scale development that has occurred, along with the increasing intensity of storm events, has resulted in erosion and impaired water quality which likely have had a significantly greater impact on the health of the Cougar Creek system than the %RFI might indicate.

It should be noted that existing bylaws and regulations in both the City and the Corporation provide a level of protection to existing riparian areas as discussed in **Appendix E**.

2.3.7 Benthic Conditions

A previous benthic assessment conducted within the Cougar Creek watershed indicated that there has been a progressive decrease in water quality and a subsequent impact to the density and diversity of the benthic community.

Two main metrics for measuring watershed health have been utilized in this report: Benthic Index of Biotic Integrity (B-IBI) and Total Impervious Area (TIA) measured against % Riparian Forest Integrity. B-IBI is considered to be the "most appropriate" indicator (Kerr Wood Leidal 2005). As stated in the KWL report "benthic macroinvertebrates are diverse and abundant in streambed substrates, sensitive to human disturbance associated with patterns of land use, and are relatively easy to sample and identify". Sampling has shown a strong correlation between an increase in TIA and a decrease in B-IBI.

Comparison of TIA vs. %RFI is also a good indicator of overall watershed health and can be used to predict the impacts of development within a watershed without the implementation of storm water management measures.

1993 – 1999 Benthic Invertebrate Study

Benthic invertebrate sampling was conducted within the Cougar Creek watershed from 1993 to 1999 (Rithaler 2003). The results of the assessment were analyzed using a variety of statistical tools. Discussion of the results is provided below.

Rithaler utilized a method developed in 1988 by W.L. Hilsenhoff referred to as the Hilsenhoff or Family Biotic Index (FBI). The FBI is based on categorizing macroinvertebrates into categories at the family level depending on their response to organic pollution (Mandaville 2002) with 0 being the most intolerant and 10 being the most tolerant. Rithaler used a reverse FBI where a lower value was indicative of a negative impact on the benthic invertebrate community. The results of the assessment demonstrated that during the study a “decreasing index indicates an increasing impairment to the benthic community structure due to deteriorating water quality.” The trend from 1994 through 1999 indicated a decreasing index for “all families” grouped together and “all families excluding gastropods”. Despite this trend however, it should be noted that the unadjusted FBI values ranged from 3.64 to 4.50, which is indicative of “very good” water quality with “possible slight organic pollution”.

A second analytical tool utilized by Rithaler was the Shannon Diversity Index (H) which is used to calculate aquatic and terrestrial biodiversity, where an increase in the number and distribution of taxa is indicative of an increase in H. In other words, a higher H value demonstrates a favourable condition for benthic invertebrates. In the case of Rithaler’s study, H was fairly consistent from 1994 to 1996 for both “all families” and “all families excluding gastropods”. However, there was a noticeable decrease in H between 1996 and 1997. The H value recovered slightly in 1998 and 1999 but not to the peaks demonstrated in 1995 and 1996. This is potentially indicative of a significant pollution incident or compromised water quality between the 1996 and 1997 sampling efforts that severely impacted the benthic community, particularly those families less tolerant of pollution.

A third metric utilized by Rithaler was %EPT (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]), which are three taxonomic groups generally recognized as “intolerant groups” and are essentially synchronous with the use of benthic macroinvertebrates to evaluate water quality. In general, habitats with higher counts of EPT insects tend to have cleaner, cooler and more oxygenated water.

Rithaler found that when considering “all families excluding gastropods”, there was a consistent decrease from 1994 to 1999, indicative of a decrease in water quality. When gastropods were included in the calculations, there was considerably greater variability with a large jump occurring between 1995 and 1996. Values levelled off and declined between 1996 and 1999.

Rithaler’s study indicated that there was a precipitous decrease in the mean number of individuals per sample day between 1994 and 1995, possibly as a result of a significant pollution event or some other decrease in water quality. The numbers recovered somewhat between 1995 and 1999, but were still well below 1994 levels.

Finally, Rithaler also analyzed Taxa Richness (TR) which “indicates the health of the community through its diversity, and increases with increasing habitat diversity, suitability, and water quality” (Manndaville 2002). Results indicate a decrease in TR from 1994 to 1997 recovered only slightly between 1997 and 1999. Rithaler indicated that this was indicative of deteriorating water quality.

Note that the Rithaler study was a draft data report and did not provide analysis, methodology or discussion of natural variability. As such, there could be significantly variability in the values of the above-described metrics which may lend itself to different interpretations of the data. This data cannot be compared to the benthic information collected as a component of this study. The collection methodology was sufficiently different thus rendering any comparison meaningless.

The data collected as part of the 2007 component of this study is intended to serve as the start of a baseline data set that will be added to over time. Over the long-term, comparisons of year-to-year benthic-invertebrate data will allow the overall health of the Cougar Creek watershed to be tracked.

2007 Benthic Invertebrate Study

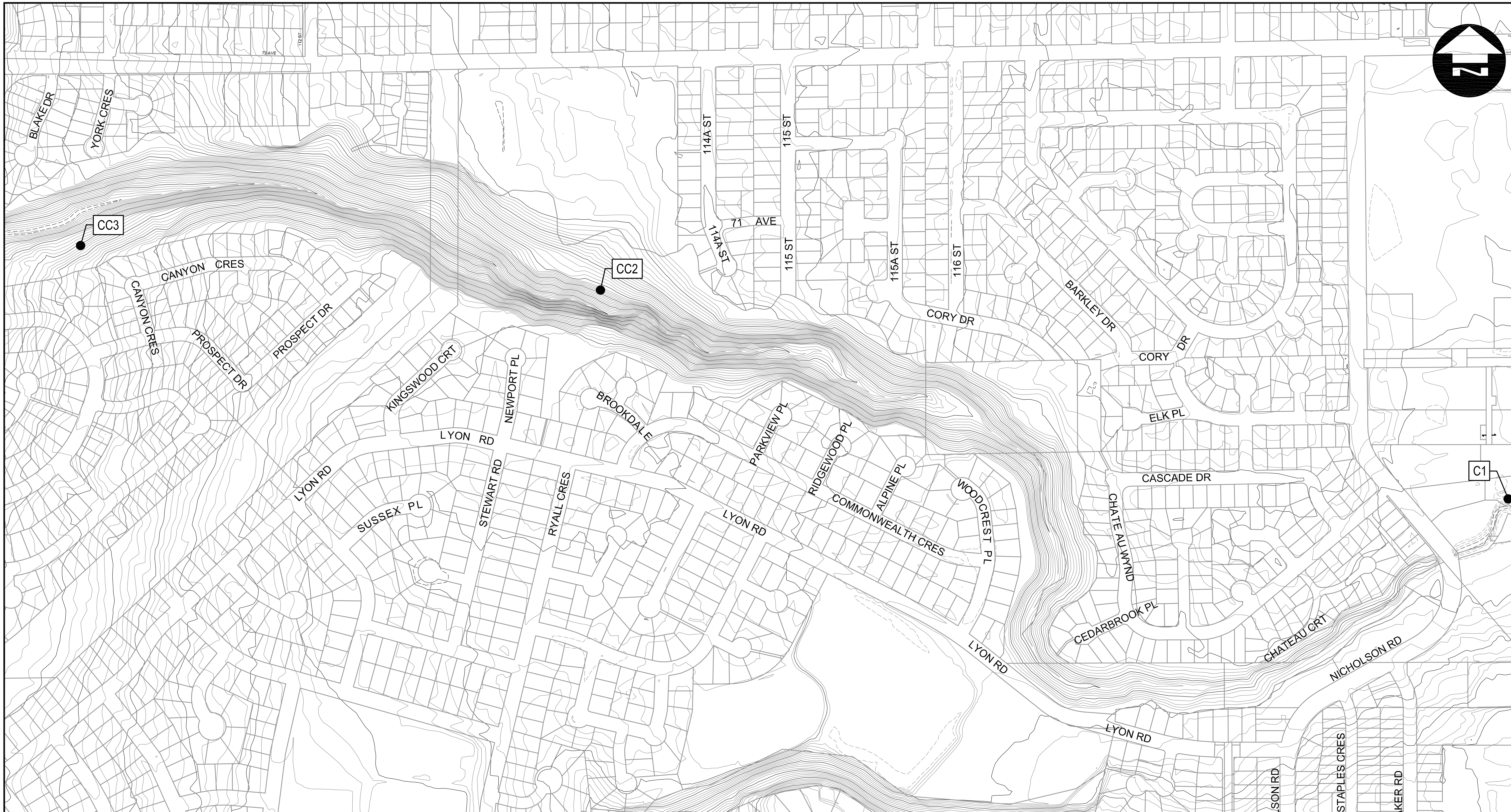
Benthic-invertebrate sampling was completed at three locations within the Cougar Creek watershed on May 11th, 2007. (**Figure 2-13** – Map showing Benthic Invertebrate sampling locations). The most upstream site (C1) was located immediately west (downstream) of 120th Street near the Delta / Surrey border. This site has been sampled as part of the City of Surrey's benthic invertebrate sampling program since 2005. The middle site (CC2) was located within the ravine, and coincided with one of Rithaler's study locations (Rithaler 2003). The most downstream site (CC3) was located ~100m upstream of the sediment sump located east of Westview Drive. Photos and detailed information for each site is provided below:

Site C1

Cougar Creek immediately west of 120th Street is a linear channel with low flow generally observed in the spring sampling season. The channel exhibited a wetted width of ~2.5m and a bankfull width of ~3m. Average water depth at the time of sampling was 5-10cm. The substrate consisted of hardpan clay with a short section of gravel. Garbage was observed within the creek at this location. The water was slightly turbid at the time of sampling and a high level of algae was observed. Riparian vegetation in the area consisted of manicured vegetation and shrubs on the north (right) bank, and shrubs and mature trees on the south (left) bank (**Photographs 6 and 7**).

Photo 6: Site C1 – Looking Upstream

Photo 7: Site C1 – Looking Downstream



SOURCE: BASE MAP PROVIDED BY THE CORPORATION OF DELTA.

APPROXIMATE SCALE 1:5,000

0 50 150 250m

DILLON CONSULTING

	PROJECT: COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE: JUNE 2009	TITLE: BENTHIC INVERTEBRATE SAMPLING LOCATIONS	FIGURE NO. 2-13

FileName:g:\cad\06904\06904-figures-master-drainage.dwg

Site CC2

The 'middle' sample site was located within a deep ravine with extensive and established riparian vegetation on both sides of the creek (**Photographs 8 and 9**). The creek at this location exhibited run/riffle/pool complexes, with large boulders and large woody debris. Wetted width ranged from 2-6m, with a bankfull width of 8-12m. Water depth was ~10cm at the time of sampling. The substrate was clean, ~80% embedded, and consisted of boulders, cobble and coarse gravel.

Photo 8: Site CC2 – Looking Upstream

Photo 9: Site CC2 – Looking Downstream

Site CC3

Cougar Creek approximately 100m upstream (east) of the sediment sump at Westview Drive is a wide, meandering channel that exhibits run/riffle/pool complexes (**Photographs 10 and 11**). An intact, established riparian vegetation buffer exists on both sides of the creek, consisting of a deciduous canopy with extensive shrub understory. The cobble-dominated substrate is clean, and ~60% embedded. Wetted width ranged from ~2-4m, with a bankfull width of 8-12m. Wetted depth was ~15cm (~30-40cm in pools) at the time of sampling.

Photo 10: Site CC3 – Looking Upstream

Photo 11: Site CC3 – Looking Downstream

Conventional water quality parameters were measured at each site using handheld water quality meters. Measured parameters are presented in **Table 2-10** and include: temperature (C); pH; turbidity (NTUs); conductivity (mS); and dissolved oxygen (mg/L).

Table 2-10: Conventional Water Quality Parameters Measured at Each Site

	C1	CC2	CC3
Temperature (C)	14.8	10.9	10.9
pH	6.86	7.2	7.12
Turbidity (NTUs)	22.70	0.84	1.96
Conductivity (mS)	0.18	0.15	0.17
Dissolved Oxygen (mg/L)	10.2	10.0	10.2

No major anomalies in water quality parameters were identified at any of the sample sites. The parameters were within acceptable levels for freshwater aquatic life (BC Water Quality Guidelines 2006). Water temperature and turbidity were higher at site C1 compared to the other two sites, and pH, conductivity and dissolved oxygen were very similar at all sites.

Benthic-invertebrate samples were collected according to a standard protocol developed and used within the City of Surrey since 1999. This protocol predates the GVRD (Metro Vancouver) sampling protocol (EVS 2003), and was developed through extensive consultation with Federal and Provincial regulatory agencies, municipal government and public interest groups. This sampling methodology is consistent with the "Salmon Web" field sampling protocol developed in Washington State (Salmon Web 2004).

A total of three replicate samples were collected from riffle habitat at each site. The samples were collected using a 250μm mesh Surber sampler and were transferred to labelled water-tight plastic containers. They were preserved with 10% formalin and were further sealed with duct-tape around the lid of the container. Each sample was processed separately (*i.e.,* not pooled). The samples were sent to qualified taxonomists at Biologica Environmental Services Ltd. (Victoria, BC) for detailed taxonomic analysis.

Upon arrival at the laboratory, the samples were transferred from 10% formalin to 70% ethanol and were split using a plankton splitter to produce representative sub-samples to facilitate timely sorting and identification. Rose Bengal stain was added, and all organisms in the sub-sample were enumerated and identified to Lowest Practical Taxonomic Level (LPTL) by trained taxonomists. If organism fragments were present, only anterior regions were enumerated to prevent overestimating the abundance of organisms in the sample. A list of references used during the taxonomic identification process is provided in Appendix G.

Data received from the taxonomists was initially screened and all "non-benthic groups" (based on Mandaville 2002) were removed from the data set. Mandaville includes a comprehensive list of benthic groups, including tolerance values and feeding habit based on a number of reference documents including: Hilsenhoff 1987; Bode *et al.* 1996; Hauer and Lamberti 1996; Barbour *et al.* 1999; and Bode *et al.* 2002.

B-IBI scores were calculated for each site according to the Metro Vancouver protocol (EVS 2003). This protocol involved the use of a pre-defined B-IBI 'calculator' in the form of an Excel worksheet which had been standardized for watercourses in the Greater Vancouver area.

The Metro Vancouver B-IBI score can range from a minimum of 10 to a maximum of 50, with higher scores more indicative of good overall stream health. The B-IBI is comprised of 10 indices, including:

- total number of taxa;
- number of mayfly (Ephemeroptera) taxa;
- number of stonefly (Plecoptera) taxa;
- number of caddisfly (Trichoptera) taxa;
- number of long-lived taxa;
- number of intolerant taxa;
- percent of tolerant individuals;
- percent of predator individuals;
- number of clinger taxa; and
- percent dominance.

A B-IBI score was calculated for each of the three samples collected at each site, and then averaged to provide a mean B-IBI score (+/- standard deviation) for each site. Results of the B-IBI calculations are provided in Appendix G.

A summary of mean B-IBI scores is provided in **Table 2-11**. This table also includes results from site C1 for 2005 and 2006.

Table 2-11: B-IBI Values for the Three Cougar Creek Sites

Sample Site	Year	Replicate Riffle B-IBIs			Mean B-IBI*	(+/- SD)
		1	2	3		
C1	2005	16	16	16	16	(0.0)
	2006	14	10	12	12	(2.0)
	2007	12	12	12	12	(0.0)
CC2	2007	12	14	12	13	(1.2)
CC3	2007	12	14	12	13	(1.2)

* Mean B-IBI is the average of the three individual riffle B-IBIs.

B-IBI scores for all three Cougar Creek sites were very similar in 2007. In general, the B-IBI scores within the Cougar Creek watershed were quite low, indicating relatively poor stream health. However, it should be noted that B-IBI scores generated with this protocol cannot be compared to the standards generated by Metro Vancouver's sampling protocol given that Metro Vancouver samples in a different order of stream and during the summer (as compared to May for the sampling conducted for this report). A comparison of mean B-IBI scores at site C1 from 2005 to 2007 can be made as the sampling protocol was consistent. Sampling indicated that there was a decrease in scores between 2005 and 2006. There appeared to be no change in B-IBI scores between 2006 and 2007 at site C1. Variation (standard deviation) within each site was quite low, indicating that separate riffles within each site do not exhibit considerable differences (*i.e*. lack of patchiness) in terms of benthic invertebrate communities.

A review of the community composition at each site may allow for inferences about water quality and overall stream health. For example, most Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa (*i.e*. EPT taxa) are sensitive to environmental stress (Plafkin *et al.* 1989). Therefore, an observed decline in the number of EPT taxa can infer a decrease in overall stream health. An increase in oligochaetes may indicate nutrient enrichment and/or a change in the substrate towards more soft-substrate conditions. An increase in the proportion of pollution-tolerant chironomids is associated with declining water quality (Plafkin *et al.* 1989).

Site C1 was dominated by oligochaetes, and to a lesser extent, chironomids and copepods. Very low numbers of EPT taxa were observed at this site. The high proportion of oligochaetes in the community is consistent with the substrate, which is primarily comprised of hardpan clay at this location. High numbers of chironomids and low numbers of EPT taxa may indicate impaired water quality; however this may also be reflective of a lack of suitable substrate and habitat niches for EPT taxa at this site.

Sites CC2 and CC3 were quite similar in terms of community composition. Similar to site C1, both CC2 and CC3 were dominated by oligochaetes, and to a lesser extent, chironomids and copepods. Both these sites exhibited very low numbers of EPT taxa; however, they exhibited high abundance of Ephemeroptera individuals. The higher abundance of Ephemeroptera at these sites compared to site C1 may indicate that these sites have better water quality or contain more habitat niches for Ephemeroptera.

It should be noted that the B-IBI scores generated by this study should not be compared to scores achieved utilizing Metro Vancouver’s sampling protocol given that Metro’s protocol is designed for watercourses with different characteristics. Should comparisons be made this does not necessarily indicate that conditions are either improving or worsening.

This data should be considered a starting point for a long-term assessment of B-IBI scores within the Cougar Creek ravine. Further sampling conducted over a period of several years utilizing the same protocol described above may demonstrate if overall watershed health is changing. It may also demonstrate the efficacy of any of the possible management alternatives discussed in this report, assuming they are implemented.

2.3.8 Summary of Stream Corridor Conditions

The overall influence of urbanization has progressively resulted in changes in base flows, water quality and the general health of the riparian corridor. Base flow through the Cougar Creek channel is limited during the dry summer months, reducing habitat availability for fish during this period. This effect is more pronounced in the upper reaches of the channel where there are fewer sources of input. The increased impervious surface coverage resulted in new sources of pollutants and deleterious substances discharging into the stream, negatively impacting fish and fish habitat. As a result, the overall ability of the channel to support a viable population of salmonids is compromised by the siltation and scour of spawning areas, the loss of riparian integrity, and degraded water quality. **Table 2-12** summarizes conditions observed along the creek corridor.

Table 2-12: Summary of Observed Stream Corridor Conditions

Location	Observations	Constraints
Headwaters and Upper Reaches	123rd St and 124th St. Average channel width 2.2 m, height 0.5 m. Substrate fines and sand. Good canopy of Douglas fir, western hemlock, broadleaf maple and willow, also riparian shrub and groundcover. 124th St gabion in good condition	Erosion present in select locations. Low rating for salmonid habitat. Encroachment of private property owners to the creek bed is being experienced throughout the Cougar Headwaters sub-catchment. In some cases, retaining walls and fill material appear to have been placed below the top-of-bank of the channel. This has severely compromised the riparian integrity and function of the system
Upstream of Nicholson Road	Upstream of Nicholson creek contained in man-made channel. Creek enters the municipal park and forms an online pond. Good tree canopy coverage. A number of small tributaries enters the creek. Good salmonid habitat rating.	In the past beaver activity and debris jams were observed.
Cougar Canyon	Creek contained in a steep ravine. Average width 10 m and 8 m height at the ravine. Good tree canopy. Substrate made up of gravel, cobbles and sand. At the upstream end of the reach the channel width decreases to 4 m and a height of 2.5 m. Instream substrate and canopy the same as downstream. Good salmonid habitat rating. Local property owners have built up to, and in some cases, below the top-of-bank of the Canyon ravine.	Prone to form log and debris jams. Shopping carts, oil drums and logs were observed in the past preventing fish passage. Significant erosion in places. This compromises water quality through sedimentation of downstream reaches. The erosion is also resulting in the loss of riparian vegetation, as the supporting substrates are being washed away. However, the trees that are falling into the channel provide fish habitat in the form of large woody debris. Erosion sites may require erosion protection but any application of hard lining of the channel should not impact habitat. In some cases, owners appear to have placed fill within the Canyon or have removed vegetation to improve views. This has resulted in potentially increased instability along the Canyon wall. Riparian Forest Integrity has been compromised.
Canal	The Canal is a manmade channel. At the mouth it is 20 m wide with fines dominating the substrate composition. 80 m upstream four 1,160 mm CSP with flap gates convey flows. Average width 5 m with 3.5 m high banks. Good canopy cover. Further upstream boulders and gravels form the substrate. Three weirs were installed to control velocities. Blake Creek Ravine discharges into the Canal. Substrate changes to mainly sands and loose gravel.	Past evidence of beaver activity. Low salmonid habitat rating. Extensive siltation not only affects the hydraulic conductivity of the channel, but also the quality of habitat. Siltation occurs mainly around the BNSF reach serving as a sediment source for habitat downstream. The channel is largely infilled downstream of Westview Drive such that there is minimal cover for salmonids and other fish. As a result, the Canal provides minimal rearing habitat and would be utilized primarily as a migratory corridor to more favourable habitat in the Canyon and upstream reaches or for outmigrating smolts.

2.3.9 Geology

The Cougar Creek valley is shallow in Surrey and in the upper reaches in Delta near Scott and Nicholson Roads. Within the Cougar Canyon reach, the streambed initially declines slowly westward before increasing in slope and descending rapidly into a high-sided ravine with a wider valley floor than is found in the upstream reaches. Following is a brief description of the surficial geology.

In Surrey and the east end of Cougar Creek in Delta, the stream channel is developed in late glacial till-like materials, probably deposited as glacial marine and reworked as relative sea level fell. These are mapped as raised beach deposits of the Capilano Formation (Cb). These materials are relatively loose, and generally are poorly sorted, so they are moderately erodable.

The steam bed slowly declines westward into very dense glacial tills downstream of the footbridge near Cedarbrook Place. These are mapped as Vashon Drift Lodgement till (Va). These lodgement tills are very poorly sorted and very dense. They are not very erodable.

Underlying the till is laminated stony silt and sandy silt. These materials are probably marine interbedded fine sand and silt. As they have been loaded by the last glaciation, they are very dense. The high density and fines content results in material that is not very erodable.

The stream valley descends rapidly downstream through sand with some sand and gravel. This is mapped as Quadra glaciofluvial deposits (PVb). The Quadra sand is erodable, due to the grain size distribution, even though the deposit is very dense. Underlying the Quadra glaciofluvial deposits are Quadra marine interbedded fine sand to clayey silt (PVc) or Cowichan Head deposits. These finer grained materials are less erodable than the overlying sand.

Underlying these silts is the Watershed Park Aquifer, interpreted by Gartner Lee as Pre-Semiahmoo pre-glacial outwash deposits. Although there is no obvious evidence, this aquifer material is expected to be erodable.

On the slopes of both Cougar Creek Canyon and Blake Creek, colluvial material accumulates as the result of wetting and drying, freeze/thaw and other weathering processes. The colluvium is very loose and erodable.

Underlying the Cougar Creek streambed are alluvial materials. These are also present underlying terrace features within the Canyon. Generally, these alluvial materials are moderately erodable.

Fill materials are probably present as a result of land development practices in the area. This would include fill placement at the top of slopes and in gully features.

At Watershed Park, Gartner Lee have interpreted the sequence as Quadra Sand from elevations of 50 to 35 m, underlain by glaciomarine or interglacial marine deposits from 35 to 5 m, which in turn is underlain by the Watershed Park Aquifer. At Cougar Creek Canyon, the sequence is very similar with Quadra sand from approximately 54 m to 30 m, underlain by glaciomarine or interglacial marine deposits below 30 m.

The base of pre-Quadra marine deposits is not well defined, but is expected to be above 5 m elevation and perhaps as high as 20 m.

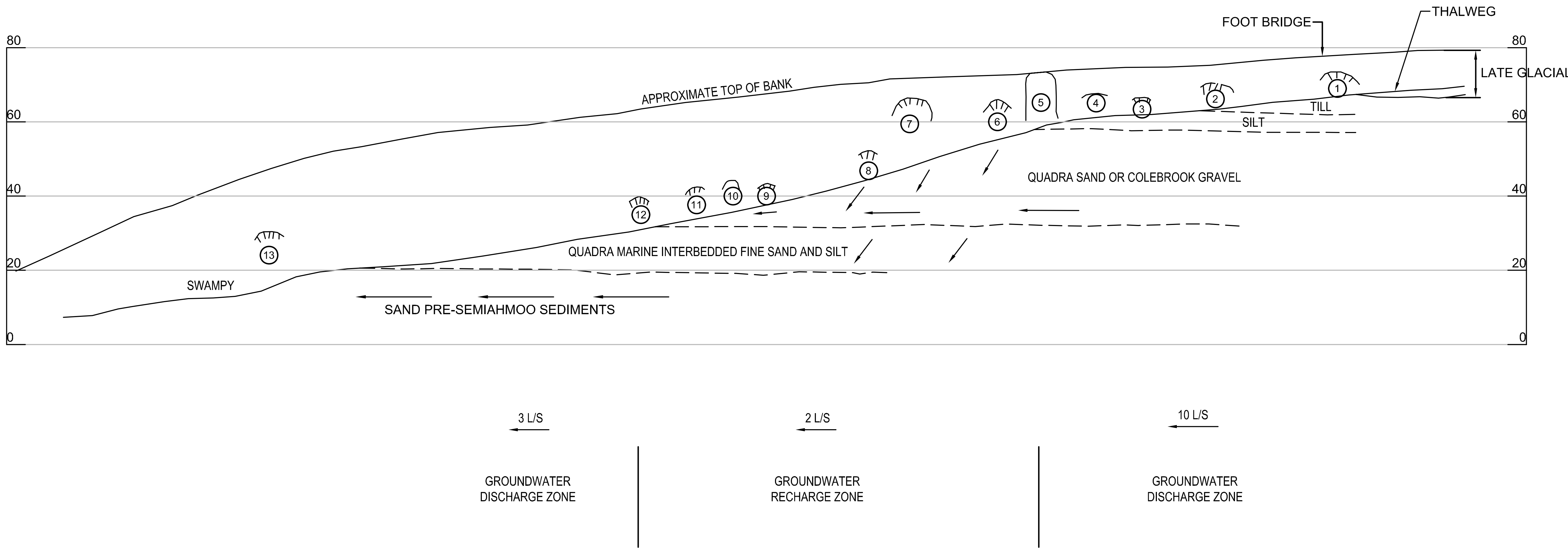
The Blake Creek ravine, although shorter and entirely within Delta, cuts downward and westward through similar materials. The lower reach of Blake Creek is much steeper than Cougar Creek and in general has a much smaller watershed.

Figure 2-14 shows a profile of the geology for the Cougar Creek ravine downstream of the pedestrian crossing at Cedarbrook Place to Westview Drive. All significant eroded areas are located within this section of the ravine.

2.3.10 Aquifer Description

Groundwater conditions in the area were investigated by Gartner Lee (2004) in respect to development of the groundwater resource at Watershed Park. Water available for runoff and infiltration enter the surficial soil, primarily mapped as Capilano Formation raised beach deposits. In these materials, groundwater will probably flow laterally towards stream channels, ditches and utility trenches. Some of this water may discharge to Cougar Creek from storm drains. The distance that lateral flow dominates is expected to be relatively small as flow will be moving vertically through the underlying Vashon tills and into the Quadra Sand. Similarly, some lateral flow is expected at the base of the Quadra Sand towards the stream channels. At some distance away from discharge points vertical flow to the underlying aquifer material will dominate. Groundwater in the lower aquifer is pumped at Watershed Park, discharges from springs and artesian wells at the toe of the slope and most probably discharges into Cougar Creek and into the marshes west of the uplands.

Following are descriptions of the three components of the groundwater flow system at Cougar Creek based on the work by Gartner Lee and a field traverse undertaken as part of this analysis on September 12, 2007, during a relatively dry spell.



SCALE: NOT TO SCALE

DILLON CONSULTING

DATE JUNE 2009

PROJECT
COUGAR CREEK
INTEGRATED STORMWATER MANAGEMENT PLAN

TITLE
GEOLOGY PROFILE

PROJECT NO. 06-6904

FIGURE NO. 2-14

FileName:g:\cad\066904\066904-figures-ismp.dwg

<u>Surficial Aquifer:</u>

Gartner Lee described this aquifer as Capilano Sediments. This aquifer represents the shallow, surficial flow system. They further noted that they expect this aquifer to provide seasonal baseflow to the upper reaches of streams. In Cougar Creek, this discharge would occur in areas where the glacial till (Vashon Drift Lodgement till, Va) and underlying pro-glacial silts underlies the stream. This occurs upstream of a site adjacent to Elk Place. This aquifer may also provide short term flow to perimeter drains which discharge to storm sewers and to backfill along utility corridors, including storm drains. Most of the catchment would therefore discharge to the creek. As water recharges this formation and discharges not only to surface but to the deeper aquifers, most of the water discharging to the stream would be expected to arrive from nearby areas, with more distant recharge migrating to the deeper aquifers. The catchment area is approximately 7 km^2. Gartner Lee estimated that 48 mm to 106 mm per annum of groundwater recharge would enter this aquifer and the mid-depth aquifer below. For a first order estimate half of this recharge was assumed to be within this surficial aquifer. The contribution to stream flow would therefore average 5 L/s to 12 L/s. During the measurements taken on September 12, 2007, flows increased from 2 L/s at Nicholson Road to 10 L/s adjacent to Elk Place, an increase of 8 L/s. Flows measured in the fall of 2000 indicate the Cougar Creek flows at Nicholson Road are relatively low (<10 L/s) much of the time, with high flows responsive to storm events. Little groundwater contribution is therefore expected upstream of Nicholson Road.

<u>Mid Depth Aquifer:</u>

Gartner Lee described this aquifer as Colebrook Gravel/Quadra Sand. They interpret that the base of this aquifer at Watershed Park is at an elevation of about 35 m. At Cougar Creek Canyon, the base is closer to 30 m**.** Over most of the stream thalweg in Quadra Sand, the stream bed is above the water table, resulting in a net loss of stream flow, from 10 L/s adjacent to Elk Place to 3 L/s north of Kingswood Crescent, a loss of 7 L/s. Most of the discharge from this unit would be expected to the creek near the base of the unit from about 0.5 to 1 km upstream of the railway. Gartner Lee estimated that 48 mm to 106 mm of groundwater recharge would report to this aquifer and the surficial aquifer above. For a first order estimate half of this recharge was assumed to be within this mid-depth aquifer. This aquifer is not expected to discharge to the well field. The catchment area is therefore expected to be larger, perhaps in the order of 3 km^2. Therefore, from 2 L/s to 5 L/s of groundwater was estimated to discharge to Cougar Creek from this aquifer, some from the stream bed and some from the valley walls.

<u>Watershed Park Aquifer:</u>

Gartner Lee (2004) described this aquifer as pre-Semiahmoo sediments at or near sea level. Discharge from this aquifer to Cougar Creek is probably occurring in the lower 400 m of the Canyon (upstream of the rail right-of-way). This is based on the measured groundwater levels in this aquifer at Watershed Park, the anticipated groundwater flow directions in the aquifer, the presence of swampy areas and increase in stream flow. Gartner Lee presented a map illustrating the expected boundaries of the recharge area for the Watershed Park wells. The recharge area covers more than 50% of the Cougar Creek watershed. The recharge area for this component of flow is probably limited to 0.5-1.0 km^2. Gartner Lee estimate that recharge reporting to the Watershed Park Aquifer is 196 mm/yr to 254 mm/yr. With that recharge, contribution to base flow (occurring into the lower 400 m of the stream channel) at the railway would range from 3 L/s to 8 L/s. Total dry season flow at the railway crossing is therefore expected to be 8 L/s to 16 L/s. Flow observed in the creek on September 12, 2007 would support the lower end of this estimate.

Additional discharge from this aquifer will occur in the Northeast Interceptor Canal downstream of the Canyon. Based on a similar model to the above, about 7 to 13 L/s is expected to discharge from the aquifer per kilometre. However, only a small component of that flow is expected to discharge to the Canal. If 20% were to report over about 3 km, the contribution would be 4 L/s to 8 L/s.

Groundwater Discharge Summary:

Estimated net groundwater contributions to Cougar Creek flows are summarized in **Table 2-13.** It is clear that groundwater discharge to the creek predominates from Nicholson Road downstream about 0.9 km, that the stream loses flow to the groundwater system downstream for the next 0.6 km and that the stream gains in the lowest 0.9 km. It is also clear that the stream gains along the Northeast Interceptor Canal, although the increase in the flow rate due to groundwater discharge is not as well defined.

Table 2-13: Summary of Groundwater Interaction in Cougar Creek/NEIC

Distance from railway bridge (km)	Gains (L/s)	Losses (L/s)	Dry Season flow (L/s)
2.4 (Nicholson Road)	-	-	2
2.4 – 1.5	8	-	10
1.5 – 0.9	-	5	3
0.9 – 0 (railway)	9	-	12 (8 – 16)
0 – 3	6	-	18 (12 – 24)

2.4 Regulations and Policies

The Official Community Plans of Surrey and Delta provide an extensive list of stormwater related policies, reproduced below.

Surrey (Official Community Plan By-Law No 12900)

- Protect and enhance the aquatic environment of the Fraser, Nicomekl, Serpentine, and Campbell Rivers, as well as creeks and aquifers throughout the City and along the City's ocean shoreline.
- Preserve ravines and watercourses in their natural state, and wherever possible, link them with green spaces to develop a continuous network of the natural environment throughout and between the developed areas of the City. These networks may provide for public access where such access is not detrimental to the environment.
- Recognize the need to minimize hazards of floodplains on development by locating low intensity land uses (*e.g.*, agriculture, parks, etc.) in the floodplains and regulating any development in the floodplains in accordance with provincial regulations.
- Coordinate with adjacent municipalities in addressing cross-boundary environmental issues such as runoff, drainage, and protection of environmentally sensitive areas.
- Provide adequate control of sedimentation and erosion in runoff water during construction.

- Attempt to maintain water quality, base flows and the natural flow pattern in any receiving watercourse to avoid flood damage and to protect aquatic biota (vegetation and wildlife) and habitats.
- Manage the quality and quantity of stormwater runoff to help protect and enhance aquatic habitats.
- Protect the quality and integrity of ecosystems, including air, land, water and biota (vegetation and wildlife) and, where quality and integrity have diminished, encourage restoration to healthy conditions.
- Identify and endeavor to protect Fisheries Sensitive Zones (instream aquatic habitats, out-of-stream habitat features, side channels, wetlands, riparian areas).

Delta (Official Community Plan 3950)

- Develop Integrated Stormwater Management Plans and require the use of integrated stormwater management practices consistent with the regional Liquid Waste Management Plan.
- Use development permit guidelines and bylaws to ensure that appropriate measures are taken when development occurs in potentially hazardous areas such as along slopes, bluffs or ravines, and in flood prone areas.
- Provide major and minor system flow path for new development and where upgrades or major road improvements occur.
- Promote the development and application of best management practices for infrastructure servicing residential, commercial, industrial and agricultural properties (*e.g.* limiting and mitigating impervious area, appropriate siting of buildings and application of infiltration devises, open ditches and alternative/innovative street edge design) where appropriate.
- Support pilot projects for innovative and sustainable infrastructure design and explore the use of alternative development standards to reduce storm water runoff.
- Encourage preservation of watercourses and enhancement of riparian environments through local planning projects, erosion mitigation and runoff-management projects.
- Work to mitigate negative environmental impacts of stormwater runoff from roads into storm water systems.
- Meet acceptable engineering standards for drainage and flood risk in urban areas.
- Provide flood protection to all 1 in 200-year return period levels, from sea and river induced flooding.

2.5 Public Consultation

A number of meetings on the current health and future of the Cougar Creek watershed were conducted during the preparation of the ISMP, and prior to the analysis of the management of alternatives. In addition, an Open House was held to solicit views and opinions from the general public. Stakeholder concerns and issues were identified and incorporated in the preparation of the Integrated Stormwater Management Plan.

The purpose of these meetings was to:

- obtain input as to the issues and concerns regarding the watershed and to hear suggestions with respect to watershed management; and
- present preliminary findings and recommendations for review and comment by the stakeholders.

First Stakeholders Meeting

The initial stakeholders meeting was held on February 7, 2007. The purpose of the meeting was to focus on identifying issues, key concerns and ways to improve the management of the Cougar Creek watershed from the point of view of the stakeholders involved in managing and maintaining the watershed.

The meeting was attended by staff from the Corporation of Delta, City of Surrey, Burlington Northern Santa Fe Railway, Cougar Creek Streamkeepers, Fisheries and Oceans Canada, the South Fraser Perimeter Road project team, Greater Vancouver Regional District and the Dillon project team. Each stakeholder group presented a summary of concerns, issues, future plans and potential solutions to the problems caused by excessive storm flows within the watershed. There was recognition that there were many challenges in the watershed facing the implementation of stormwater impact mitigation practices due to potentially competing interests. Some of the options for stormwater mitigation were seen as potentially limiting on the activities of other stakeholders.

However, there was also consensus that there was potential for the various stakeholder groups to work together to implement some of the proposed solutions in such a way that stakeholder activities would not be significantly impacted. The general view of most stakeholders was that that the watershed is mostly developed; hence, there are only limited opportunities for future greenfield developments within the watershed. Future plans could only include a limited number of stormwater infrastructure capital cost projects. The ISMP will need to foster “ownership” from watershed stakeholders through inclusive and “educational” consultation designed to facilitate their involvement in future changes and management.

Additional discussions were also held with other stakeholders as summarized in the following sections.

City of Surrey Enhancement Projects

The City of Surrey has completed several enhancement projects within the Cougar Creek watershed. Since 1997, most of the suggested enhancements in Dillon’s 1996 reports have been implemented by the City costing millions of dollars, including expansion of the original stormwater detention pond in Cougar Creek Park, changed controls at all ponds, and construction of ponds within the BC Hydro right-of-way. Instream works have included the installation of both wetland and riparian vegetation at the detention ponds in the BC Hydro right-of-way during the spring over the last several years. In addition, the cleaning of a channel and the installation of riparian vegetation was completed south of 68th Avenue in a previously unidentified channel in the Hydro right-of-way. Also, the City of Surrey’s Salmon Habitat Restoration Program (SHaRP) has conducted some planting works within the Cougar Creek watershed over the past several years. These various projects would have the cumulative effect of improving water quality, adding a food/nutrient input to downstream reaches, improving conveyance capacity and slowing runoff into receiving watercourses. Large scale works would be required to see a quantifiable improvement in the system, however.

Corporation of Delta Erosion Remediation

Remedial measures were installed in the Canyon in 2006 on behalf of the Corporation of Delta. A total of three sites were a component of this program. They were located approximately 400 m downstream of Nicholson Road, at the pedestrian bridge crossing at Cougar Creek Elementary School and approximately 350 m upstream of Westview Drive.

The works downstream of Nicholson Road consisted of the removal of a tree debris jam that was deflecting flow against the south bank of the channel. The trees were winched to the south bank, cabled in place and anchored in such a way as to deflect potentially erosive flows toward the centre of the channel.

The works at the pedestrian bridge crossing consisted of the removal of a debris jam that was deflecting flow against the north bank. The jam consisted of large boulders and trees. The boulders were moved against the north and south banks of the channel while the trees were removed to above the high water mark.

The works upstream of Westview Drive consisted of the removal of a debris jam that was deflecting flow up against the south bank of the channel. The debris jam was removed and the trees cabled and anchored to the toe of the south slope and angled in such a way as to promote the deflection of flow away from the south bank.

There is anecdotal evidence that these projects led to a brief reduction in the volume of sediment and gravel discharging downstream given that there was a reduced requirement to removal gravel from the sump immediately upstream of Westview Drive. However, clean outs of the sump have subsequently increased to pre-installation frequencies. Ongoing review of the erosion remediation projects is recommended as a result.

In addition to these works, bank stabilization was undertaken in the upper reaches of the ravine downstream of Nicholson Road in the mid-1990s. Slumping of the south bank was occurring due to an increase in erosive flow. Riprap stabilization was placed along the eroded areas. In addition, instream enhancements consisting of a log weir, spawning gravel and boulder clusters were also installed.

The Corporation confirmed that the sediment sump upstream of Westview Drive has not been expanded in size since its construction in the mid 1990s, except there has been some adjustments done to the isolation system.

Burns Bog Conservation Society Input

The Burns Bog Conservation Society (BBCS) expressed a number of concerns, primarily related to the Burns Bog/Northeast Interceptor Canal interface. Of primary concern is maintaining the bog ecosystem in its current state as much as is possible. In order to accomplish this, the nutrient input regime (*i.e.,* nutrient poor) should be maintained in its current state. Nutrient rich waters discharging from the Northeast Interceptor Canal during flood events could alter the bog ecosystem and should be minimized. At the same time however, too much restriction of the flow of these waters into the bog could lead to a reduction in the water level to the detriment of the bog. As such, maintaining the spillover at its current rate is the most prudent idea given that the current ecosystem has adapted to existing conditions.

Other concerns expressed by the BBCS include the presence of trees within the bog. Trees tend to shade the peat moss critical to the bog ecosystem and reduce or prevent its establishment. Dead trees tend to discharge nutrients as they decompose. Removal of these trees is seen by the BBCS as providing a benefit to the ecosystem of the bog. At the same time, they recognize the values of trees, particularly along the eastern edge of the bog, as they can intercept nutrient rich flood water from the NEIC and prevent its discharge to the bog. There is recognition that a difficult balance must be achieved.

Removal of invasive species such as holly, blackberry and policeman's helmet is also seen as a net benefit to the bog ecosystem.

Finally the discharge of sediment and pollutants from the NEIC is seen as a detriment the fisheries resource supported in the Cougar Creek system given the effects on water quality and the reduction in cover/capacity within the NEIC. Mitigation of these impacts is seen as a benefit to the bog ecosystem.

Cougar Creek Streamkeepers

The Cougar Creek Streamkeepers are fully supportive of any efforts to reduce urban runoff and increase infiltration and tree canopy cover. Their suggestions for improving the watershed conditions included:

- Adopt Best Management Practices to improve overall watershed health;
- The need for additional or improved hatchery facilities;
- Purchase property (residential lots) for use as infiltration zones, lagoons, carbon sinks and recreational facilities;
- Improve the capacity and water release control at the upper Cougar Creek detention ponds in Surrey;
- Utilize medians, boulevards etc. as infiltration zones;
- All development/redevelopment to provide tree canopy and 100% infiltration through the use of vegetation, rain gardens, green roofs etc.;
- Utilize fiscal incentives/disincentives via the taxation system to encourage more tree cover and less impervious surface;
- Encourage engineers to design systems that increase infiltration rather than discharging directly to the storm sewer;
- Promote the implementation of storm water management by making it a visible issue for the public; and
- Establish measurable goals for runoff quantity and water quality through the implementation of a monitoring program.

Metro Vancouver

The main concern of the Metro Vancouver Planning staff is the preservation of the water quality in Burns Bog. Although the Bog needs periodical flooding, the nutrient-rich runoff from the Cougar Creek catchment should not be mixed with bog waters as this will have a negative impact on the unique habitat within the bog.

Metro Vancouver Parks staff are concerned mainly with the opportunities to reduce the risks of flooding along the Northeast Interceptor Canal as flood events are usually accompanied by rising floodwaters that move westward over the pathway into the Delta Nature Reserve forests along the west side of the path. This often results in gullies being formed over the pathway.

Another issue raised was the initiative to develop and complete the Regional Greenway along the existing utility right-of-way. Concerns as to its design (*e.g.,* height, surface materials) have been raised and should be included as part of a comprehensive strategy for the area along the rights-of-way for Metro Vancouver, the railway and Burns Bog. There was also the suggestion raised by several stakeholders that the foot of Cougar Canyon west of the railway tracks should be explored for the possible location of a recreational "node" encompassing a staging area, interpretive ponds and a formalized pedestrian railway crossing. It was suggested that stormwater management features could be part of the node and cross-utilized for recreational purposes.

Metro Vancouver Sewerage staff concerns are to maintaining 24-hour access to their sewerage lines; hence, any proposals that mitigate flooding along the Northeast Interceptor Canal would be positively received by Metro Vancouver (Sewerage).

Metro Vancouver staff expressed their concern with the problem area north of the 72nd Avenue overpass. Creek infilling over the years has lead to a reduction in capacity which has led to flooding. Typically their access road is flooded at least once per year, damaging a 200-300 m section of the road. Current plans consist of annual road rehabilitation and nothing else. Future plans are to link with the Parks greenway but that continues to be delayed due to other priorities. It will be a long-term issue as funding and other issues are taking priority. There are no plans to do any crossings or linkages. Twinning has been completed from River Road south to Colebrook Road past 128th Street in Surrey.

The Gateway Program has identified the Cougar Creek system as a major source of compensation opportunities through the Environmental Impact Assessment studies completed for the South Fraser Perimeter Highway. Their program identified habitat improvements within the Delta Nature reserve including enhancement of the riparian barriers, and expansion of aquatic habitat. It should be noted that while Gateway has not committed to the installation of compensatory habitat, they are considering it.

BNSF Railway

BNSF Railway staff expressed concerns over the impact of development in the watershed, the perceived increases in flood flows along Cougar Creek and the impacts of these increased flows on the operations of the railway. They are receptive to any improvements that would reduce the risk of flooding along the railway. There are future plans to twin the existing railway. For safety reasons BNSF strongly discourages pedestrians crossing their right-of-way; it was suggested to plant vegetation barriers to discourage pedestrian access. Any future plans to introduce a greenway along the railway tracks could further increase the potential for informal crossings.

<u>Department of Fisheries and Oceans (DFO)</u>

Department of Fisheries and Oceans (DFO) staff was supportive of efforts to explore opportunities to mitigate impacts to Cougar Creek and its tributaries. They felt it was important that cohesion of effort would be maintained with the multiplicity of stakeholders to avoid addressing issues within the watershed on a "piecemeal" basis.

<u>Terasen Gas</u>

Terasen Gas representatives pointed out that they have two concerns regarding the operation of their system: transmission pipelines and distribution lines.

The transmission pipelines located in a small portion of the watershed's north and west boundaries are constantly monitored for erosion and flooding but have not experienced any major issues to date. They noticed seasonal flooding in the bog west of Hwy 91. There are no current plans to add to the existing transmission pipelines within their existing right-of-way.

However, Terasen Gas has extensive distribution gas lines running throughout the watershed including around the watercourses. Planning for work adjacent to, or crossing of, these is driven by customer growth and the need to upgrade/repair existing infrastructure. This is difficult to forecast. These works, if and when required, would be done in accordance to Best Management Practices and with adherence to all applicable regulatory requirements.

2.6 Summary of Existing Conditions

Our initial review of past reports, feedback from stakeholders and analysis of the data collected identified the following overriding concerns:

- Increased potential for flooding and erosion/sedimentation in light of increased development and redevelopment in the catchment and climate change in the Pacific Northwest region;
- The perceived negative effect of development and associated impacts (including stormwater) on the abiotic and biotic components of the natural environment of the watershed;
- The need for the Corporation of Delta and the City of Surrey to comply with the Metro Vancouver requirements for ISMPs prior to any further investments into the drainage infrastructure in the Cougar Creek/NEIC watershed;
- The critical need to integrate the understanding of current conditions in the watershed including land use, the drainage network, and values of the natural environment to ensure that recommended management strategies of the ISMP are justified in the most current watershed context, which can therefore be accurately evaluated as to their potential benefits; and

- The importance of integrating issues related to new development and re-development within the watershed with the municipal planning process and potentially with the broader context of the Official Community Plans (OCPs) and Zoning/Development By-laws for both the Corporation and the City.

Table 2-14 summarizes the existing conditions in the Cougar Creek/NEIC watershed.

Table 2-14: Summary of Existing Conditions in the Cougar Creek/NEIC Watershed

Issues	Summary observations
Flooding/flow conveyance	Old open drains have been replaced by storm sewers.
	Upper portion of Cougar in Surrey: mild slopes (1%-3.75%), depth 1-3 m.
	Flood risk west of Westview Drive, frequent closure of BNSF tracks.
	Decreased summer flows along the system.
	Cougar Canyon catchment: average 2.8% slope (up to 5.5%) from Nicholson Road to Westview. 8 storm outfalls. Inflow from springs.
	Blake Creek catchment: steep 7.1% gradient, discharges into the Canal. Ditch along Mader Lane between 73rd and 74th Avenue experiences rapid and large increase in flows. Six outfalls.
	The Canal is flat 0.25% gradient, nine outfalls, groundwater input from east 4-8 L/s.
	The Canal's flow capacity has been constrained by railway structures, infrastructure access and crossings.
Erosion/sedimentation	Sedimentation in Cougar Canyon east of Westview Drive.
	Steep slopes in Cougar Creek.
	Downstream of Surrey boundary: 5.5 % slopes, higher velocity and erosion prone.
	Sedimentation at the backwater zone in the Canal.
	Approximately 20 erosion sites, two serious.
Fish habitat	Cougar Creek supports a number of fish, including salmonids.
	Spawning habitat extends from near the confluence of the Canal with Blake Creek to the Cougar Creek ravine.
	Two Upper Cougar catchment ponds have access to salmonids.
Riparian corridor	Riparian vegetation has been severely compromised within the City of Surrey. Vegetation is largely restricted to a narrow strip along both sides of the channel.
	Vegetation at some of the detention ponds appears to have increased significantly, particularly at 121st Street and at the south pond within the BC Hydro right-of-way north of 68th Avenue.
	The riparian community within the reaches of the Canal is largely intact, with trail and rail infrastructure being the primary impacts. Vegetation is compromised as a result of industrial development to the east of the Alex Fraser Bridge.
	Riparian vegetation improves significantly proceeding upstream along the Canal through the Delta Nature Reserve and the Delta/Metro Vancouver Lands.
	The riparian vegetation in the upper reaches of Cougar and Blake Creeks has been severely impacted due to residential and commercial development.
	The riparian canopy and understory are well-developed through the Cougar Creek ravine between Westview Drive and Nicholson Road.

Issues	Summary observations
Groundwater	Groundwater discharge to the creek predominates from Nicholson Road downstream about 0.9 km, then the stream loses flow to the groundwater system downstream for the next 0.6 km, and then stream gains in the lowest 0.9 km. The stream gains along the Canal.
Benthic Invertebrates	Low taxa richness may be indicative of impaired water quality due to high peak flows and discharge of deleterious substances in urban runoff.

3.0 MODELING OF EXISTING WATERSHED CONDITION

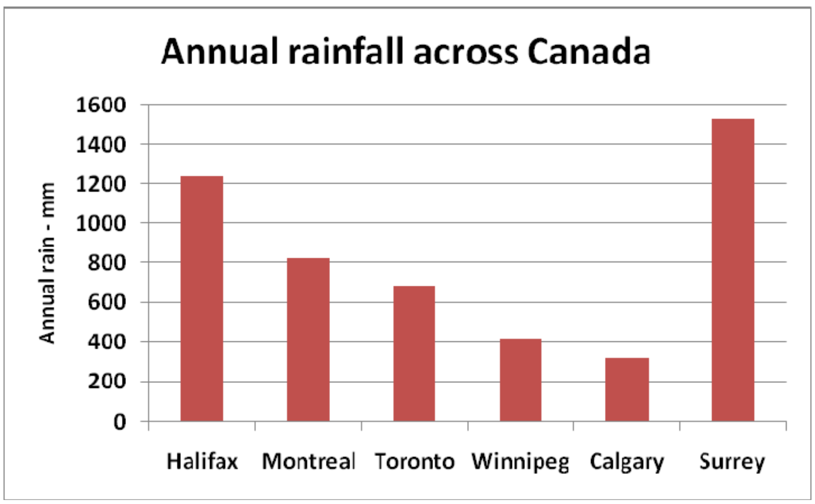
3.1 Rainfall Analysis

The knowledge of local rainfall data is essential to analyze the rainfall/runoff relationship in the watershed and to develop different future stormwater management scenarios for the ISMP. Concurrent and continuous records of rainfall and stream flow data can provide a picture of the characteristic rainfall-runoff response in the watershed and can assist in the calibration and verification of the hydrology/hydraulic computer model.

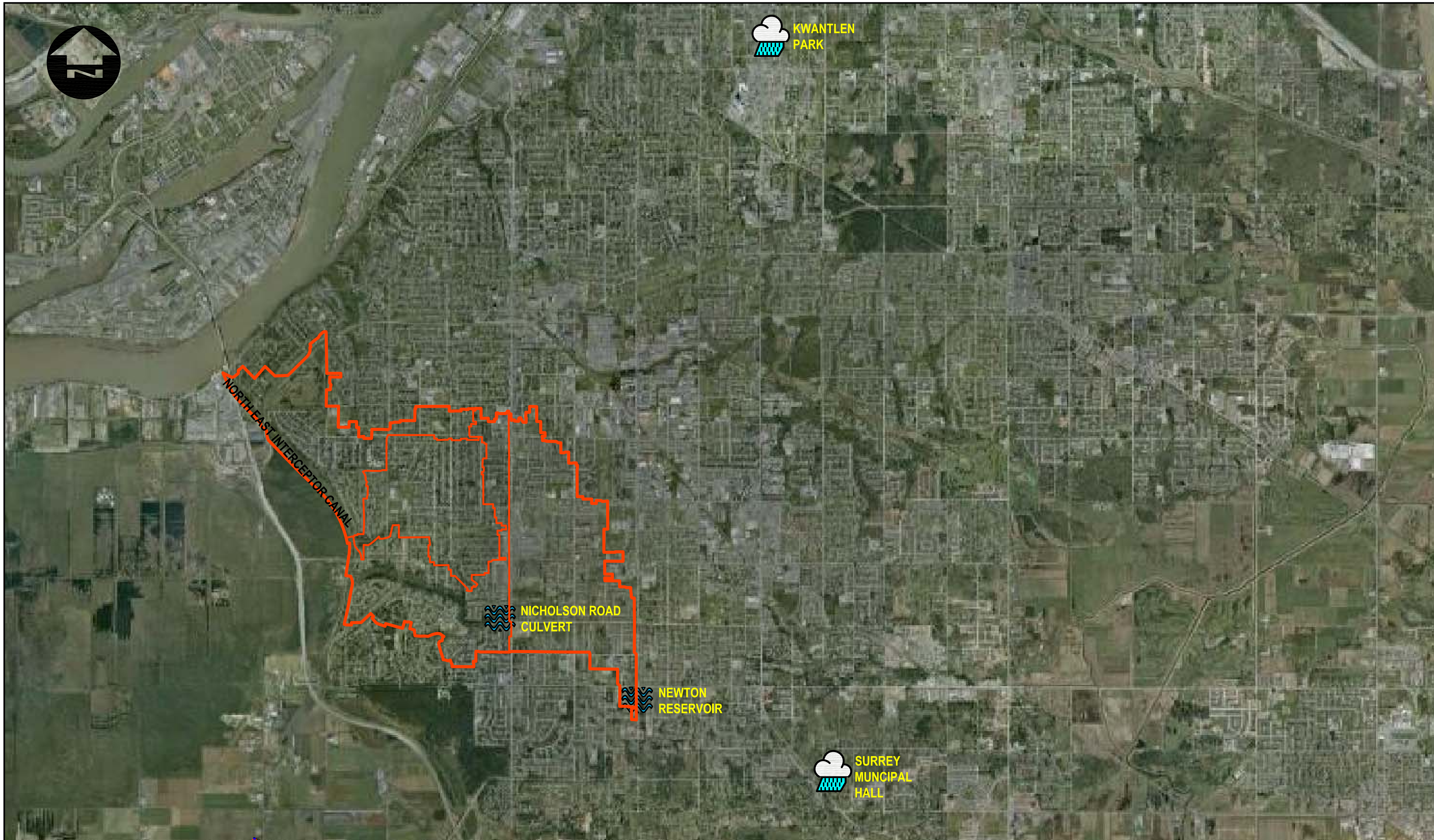
Due to lack of stream flow observations in the area long term, local rainfall data was used to simulate different stream flow events.

Local rainfall data was selected for the analyses as the climate conditions in the study area are unique when compared to the rest of Canada. **Figure 3-1** illustrates the range of long term annual average rainfall values observed across Canada, with the Surrey Kwantlen gauge showing the highest annual rainfall.

Figure 3-1: Long Term Annual Rainfall across Canada



Two long-term rain gauges were selected to provide the study area rainfall statistics: Municipal Hall and Kwantlen Park, and one short-term station located at the Newton Reservoir, shown on **Figure 3-2** and listed in **Table 3-1**



LEGEND

FLOW GAUGE

RAINFALL GAUGE

APPROXIMATE SCALE 1:50,000

0 500 1500 2500m

SOURCE: BASE MAP FROM GOOGLE EARTH PRO

DILLON CONSULTING	PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE JUNE 2009	TITLE LOCATION OF RAINFALL AND STREAM FLOW GAUGES	FIGURE NO. 3-2

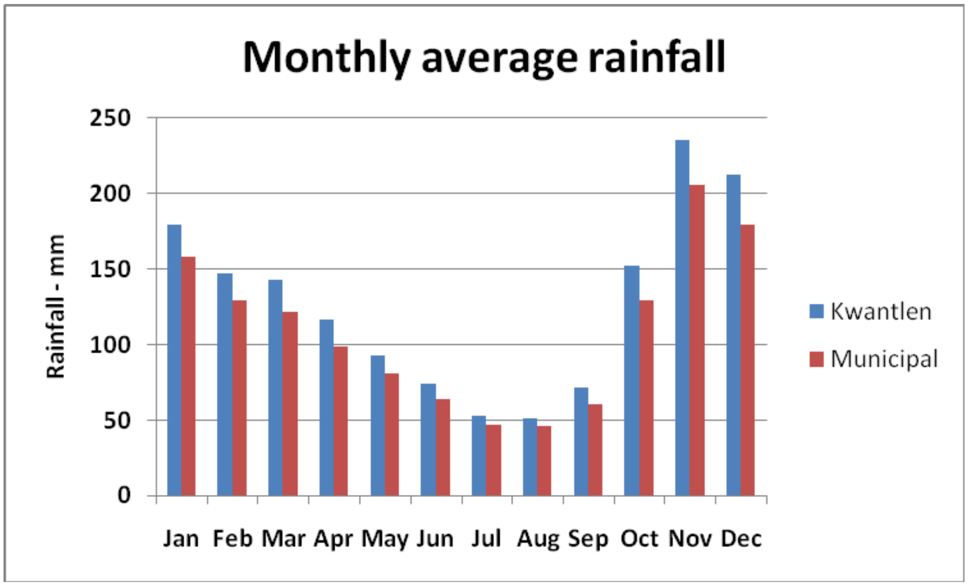
FileName:g:\cad\0669040\06904-figures-master-drainage.dwg

Table 3-1: Rainfall Data Used in the Study

Name	Operation	30 year average precipitation
Surrey Municipal Hall	1962 to date	1585.9 mm
Surrey Kwantlen Park	1960 to date	1370.1 mm
Newton Reservoir	Short term	N/A

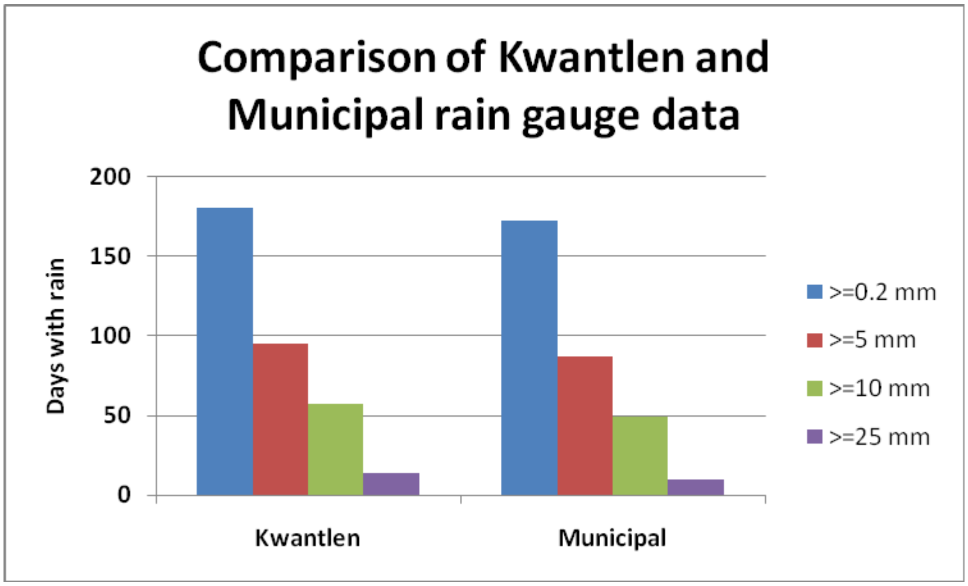
A comparison of average monthly rainfall at the two long-term gauges plotted on **Figure 3-3** shows a similar pattern; high winter rainfall period from November to January and the low summer months from May to September.

Figure 3-3: Monthly Average Rainfall at Surrey Municipal and Kwantlen Gauges



A second analysis of the long-term data recorded at the two gauges examined the number of days with >=2 mm, >=5 mm, >= 10 mm and >=25 mm of rain as shown on **Figure 3-4**. This resulted in very similar patterns.

Figure 3-4: Comparison of Days with Rain at the Two Gauges



3.2 Cougar Creek Flow Analysis

A flow gauge was established by Delta in September 2000 at the upstream end of the Nicholson Road culverts as shown on **Figure 3-2** by installing a sonic depth probe to record Cougar Creek flows at one minute intervals. Continuous flow data is available for the period September 2000 to December 2005. The gauge observes flows from a 475.9 ha drainage area.

The total observed local rainfall based on the Kwantlen rain gauge data and the total flow at the Nicholson Road gauge are compared for the years 2003 and 2004 to estimate the average annual runoff coefficient in **Table 3-2**. The relatively high impermeable area of the watershed is reflected by the high runoff coefficients.

Table 3-2: Total Rain and Runoff Observed at the Nicholson Road Gauge

Year	Total rain		Total flow - m^3	Runoff %
	mm	m^3		
2003	1327	6,315,193	3,700,315	58.5
2004	1422	6,767,298	4,327,167	64.0

The annual maximum observed peak flows for the five years of flow data are shown in **Table 3-3.**

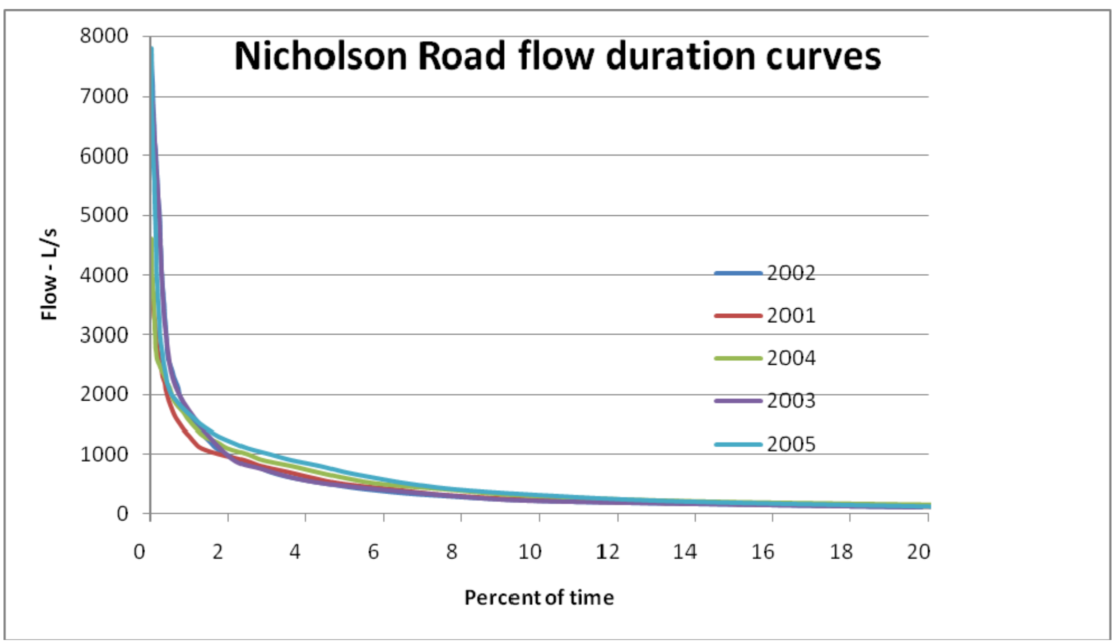
Table 3-3: Annual Peak Flows at Nicholson Road Gauge

Year	Peak flow m^3/s
2001	3.99
2002	2.69
2003	7.74
2004	4.67
2005	7.10

The highest peak flow of 7.74 m^3/s was observed in October 2003. This high peak was preceded by a very dry September and two rain events of about 20 mm each in early October. Based on data from the Surrey Municipal Hall gauge, the October 2003 event consisted of two large rainstorms, the first a 3-day event from October 15th to 17th with a 72-hour rainfall total of 244 mm, and the second from October 19th to 21st with a total rainfall of 64 mm. The first storm exceeded a 100-year 24-hour event, which has a total rainfall of about 100 mm. The daily rainfall of 158 mm on October 16th is likely greater than a 200-year 24-hour rain event. It is important to note that the above frequency estimates of rainfall may not reflect the frequency of the corresponding flows.

To further investigate the flow characteristics of Cougar Creek at the gauge site, flow-duration curves were developed for the 2001 to 2005 data showing cumulative percent of time for different flows. These curves can be used to assess the flow and erosion characteristics in the Cougar Creek/NEIC system. **Figure 3-5** presents the results of the five years of data analysis.

Figure 3-5: Flow Duration Curves at Nicholson Road Gauge



Generally, the five curves show a similar flow-duration distribution. Flows in excess of 1,000 L/s only occur 2%-3% of the time in a year. Based on the five years of Nicholson Road flow data, flow duration estimates were prepared for flows up to 1000 L/s for wet and dry years as indicated in **Table 3-4**.

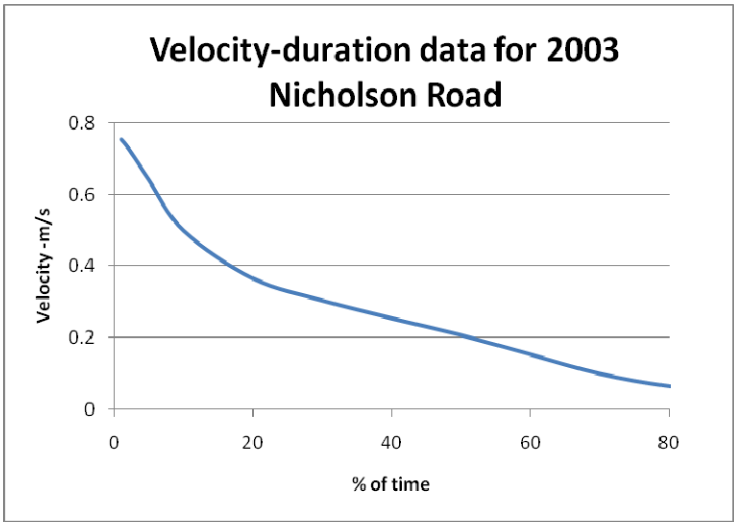
Table 3-4: Flow Duration for Flows <1000 L/s

Nicholson Road flow – exceeded by % of time		
Flow – L/s	**dry year**	**wet year**
100	20	26
200	10	14
300	7	10
400	6	8
500	5	7
600	4	6
700	3	5
800	2.5	4
900	2.2	3.5
1000	2	3

The data also showed that generally base flow in the creek ranges from 15 L/s - 30 to L/s in the winter months and 6 L/s to 10 L/s in the summer months. Flow in the creek responds to a rainfall event once the rainfall exceeds approximately 6 mm.

The Nicholson Road flow data also includes velocity estimates at the gauge site located at the entrance of the culvert. To illustrate the frequency of observed flow velocities, a velocity-duration graph was prepared for the Nicholson Road location based on the 2003 data as shown on **Figure 3-6**. Generally, the velocities are rather low, less than 1 m/s, influenced by the potential backwater effect caused by the culvert entrance.

Figure 3-6: Velocity-Duration Graph for 2003



3.3 Hydrologic Analysis – Single Event Modelling

An assessment of the potential impacts of the existing and future developments on the surface water system was undertaken using computer simulation. The selected model was used to analyze single event storms with different return period, followed by a continuous modelling of all rainfall events observed in a year.

3.3.1 Introduction

The primary purpose of modelling for flood management purposes is to assess the conveyance capacity of drainage facilities. Two types of hydrologic modelling were used in the flow simulation: 'single event modelling' and 'continuous simulation'. Single event was used for flood risk assessment, while continuous modelling was used for the analysis of rainfall/runoff capture, storage and outflow control. A hydraulic model was used to simulate flow routing in open channels to determine flow depth and velocities.

The single event modelling started with the analysis of existing conditions along the creeks based on existing land use, then future land use conditions were modelled, followed by a series of analyses to determine the impact of alternative remedial measures.

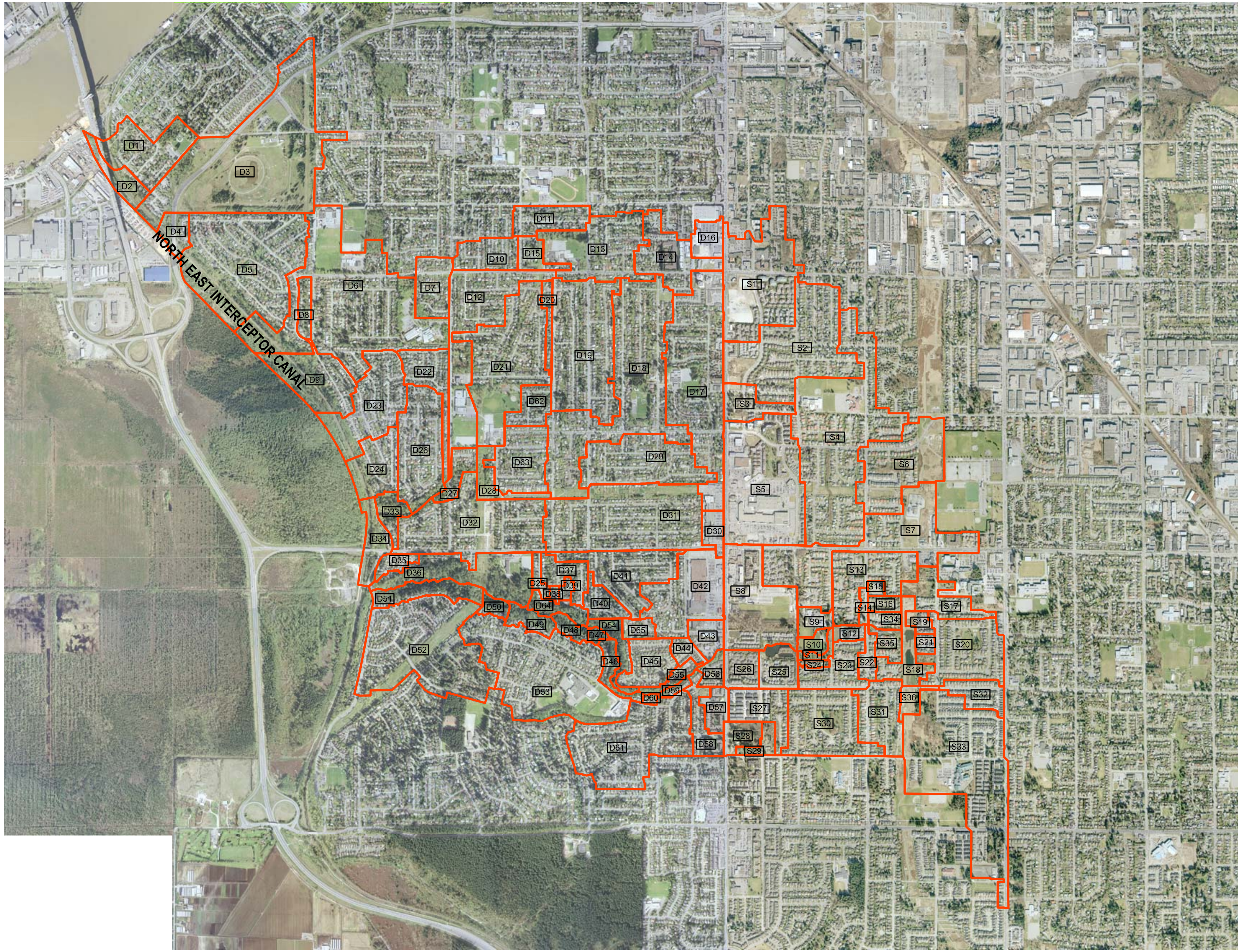
The US EPA Storm Water Management Model (EPA SWMM) was selected to represent the hydrologic and hydraulic characteristics of the catchment and drainage features. This dynamic rainfall-runoff simulation model can be used for single event or continuous simulation of runoff. The hydrologic and hydraulic responses for both existing watershed conditions and after implementation of remedial measures were simulated by the model.

The following description presents a summary of the model input data, development and calibration results. Remedial measure scenarios and options are presented and their effects on Cougar Creek and NEIC flows and water levels are discussed. A more detailed description of the model is presented in **Appendix C.**

3.3.2 Input Data

Catchments

The study area was subdivided into sub-catchments, lumped and delineated on the basis of the location of discharge into the main drainage system (storm sewers, ditches, and creek) and topographic information and drainage patterns. A total of 101 sub-catchments were delineated as shown on **Figure 3-7** and incorporated in the EPA SWMM model. For a complete list of the sub-catchments see **Appendix C.** Characteristic parameters to represent the drainage of the various sub-catchments in the study area were determined. These parameters include catchment size, imperviousness ratio, subcatchment width, slope and roughness, depression storage coefficients, and Horton's infiltration parameters. To characterize the drainage of subcatchment areas, the following aspects were taken into account in determining model parameters.



LEGEND

COUGAR CREEK SUBCATCHMENTS

SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

SCALE 1:25,000

0 250 750 1250m

DILLON CONSULTING

DATE JUNE 2009

PROJECT
Cougar Creek
INTEGRATED STORMWATER MANAGEMENT PLAN

TITLE
SUBCATCHMENT AREAS

PROJECT NO.
06-6904

FIGURE NO.
3-7

FileName:g:\cad\066904\066904-figures-ismp.dwg

The average imperviousness ratio for each sub-catchment was calculated based on representative imperviousness ratios for various land use types using digital files of current land-use zoning information of the study region obtained from the City and the Corporation. ArcGIS was used to determine the areal proportion of the various land use types for each subcatchment. The average impervious ratio per sub-catchment was calculated by weighting representative impervious ratios for each land use type on an area basis. Initial values of impervious ratios for both the City of Surrey and the Corporation of Delta were derived from values provided in Table 5-3(h) of the City of Surrey's Engineering Department Design Criteria Manual (2004). Calibrated impervious ratio values used in the model are shown in **Table 3-5.**

Table 3-5: Representative Impervious Ratios

Land use Class	Impervious ratio
Single- Family	0.60
Multi-Family	0.65
Suburban	0.40
Industrial	0.90
Park	0.05
Road	1.00
Agriculture	0.05
Commercial	0.90

Based on the above, the portion of the Cougar Creek/NEIC watershed within Surrey was estimated to have an overall imperviousness of approximately 58.9%. The portion of the Cougar Creek watershed within Delta was estimated to have an overall imperviousness of approximately 60.4%. The percent imperviousness and area sizes for each modelled subcatchment is listed in **Appendix C.**

Park spaces or road-only areas for the City of Surrey are not segregated in the land use zoning classification as is done in the Corporation of Delta. These park spaces are incorporated into other land uses. Some areas in Surrey were unclassified and were assumed to have an average impervious ratio of 0.50. The Corporation of Delta includes both urban and suburban areas as single family residential.

The initial values for the remaining sub-catchment parameters were chosen to be physically realistic and in general agreement with experience and engineering practice including:

- Values for subcatchment widths were determined based on recommendations made in the SWMM User's Manual and experience gained from various other studies.
- Representative values from other studies were used for Manning's overland sheet flow roughness coefficients. A slope of one percent was used to represent the average subcatchment grading.
- Depression storage losses of 2.5 and 6.0 mm were used for the impervious and pervious area, respectively. These losses correspond to values suggested in literature.

<u>Infiltration</u>

The Horton infiltration method was used in the hydrologic model to represent the local soil infiltration component. The following parameters were used:

- Max infiltration rate 44.76 mm/hr
- Min infiltration rate 6.73 mm/hr
- Decay constant 1.78 (1/hr)
- Drying time 7 days

These parameters were refined thorough subsequent calibration.

<u>Existing Drainage System</u>

Storm sewer trunks in the Cougar Creek watershed discharge at various outfalls located along Cougar Creek, Blake Creek, and the Northeast Interceptor Canal as shown on the major-minor system maps, **Figure 2-7** and **Figure 2-8.** The storm sewer system layout, connectivity, invert and surface elevations, and conduit shape and dimensions were determined from block profiles, sewer plans, and digital data provided by the City of Surrey and Corporation of Delta. The extent of the system modelled in EPA-SWMM was based on the contributing lumped subcatchment areas to reduce computational time. Local losses, such as those that occur at manholes and culverts, were incorporated based on literature values presented by Marsalek (1985) and the Denver Regional Council of Governments (1969).

Existing stormwater management facilities that provided flow attenuation in the Cougar Creek system were also modelled. The pond facilities that were modelled included the Cougar Creek Park wet pond, the Cougar Park East wet ponds south of Serpentine Greenway Park (BC Hydro Utility RoW), and the soccer field dry pond in Kabaddi Park (north of Cougar Creek Park). Stage-storage-discharge relationships were obtained from the previous MDP study (Dillon 1996) or from as-built drawings available from the City of Surrey. Culvert and pipe information was obtained from both the City and the Corporation. Information on the Nicholson Road culvert was obtained from various previous flow monitoring reports prepared for the Corporation.

Hydraulic data of channel or ditch cross-sections and structures for Cougar Creek and the NEIC were obtained from the survey undertaken as part of the study and from past reports (Delcan 1994; Klohn-Crippen 1997; Dillon 1995; and Dillon 1996). The dimensions and configurations of the various hydraulic structures were visually confirmed in the field. Hydraulic roughness of the channel and conduits and inlet/outlet loss values were taken from estimates based on field observations and from the previous studies.

<u>Rainfall Data-Single Event Modeling</u>

Two types of rainfall data are required for estimating the different return period stormwater discharges: single event return period storms for the 2-, 5-, 10- and 100-year events, and continuous rainfall data for the calibration of the computer model. **Table 3-6** lists the range of storm events adopted for the hydrologic and hydraulic analyses.

Table 3-6: Summary of Rainfall Criteria

Component	Storm events
Urban drainage, minor system	6 months, 1:2 year, 1:5 year and 1:10 year storm event based on the Chicago distribution using 12, 24 and 48 hour durations
Urban drainage, major system	1:100 year event based on the Chicago distribution using 12, 24 and 48 hour durations

For single event modelling, a series of design storms were generated for the existing condition to estimate the water depths and flows at critical locations for various return periods. Two local rain gauges were selected to provide the study area rainfall statistics: Municipal Hall and Kwantlen Park.

Rainfall design storm hyetographs were developed by prorating the Environment Canada Atmospheric Environment Services (AES) data obtained from the two Surrey stations. Storm durations of 12, 24 and 48 hours were simulated for each return period (6 months, 2, 5, 10 & 100 years). AES Type design storm distributions were used for 1 and 2 hour design storms while the SCS Type II design storm distribution was used for the 6, 12, 24 and 48 hour storms. **Table 3-7** lists the design storm rainfall intensities and volumes for the various return period events and storm durations. The intensities of Municipal and Kwantlen rainfall were calculated using the equation provided by Surrey Design Manual. The 6 months intensities were calculated by extrapolation.

Table 3-7: Design Rainfall Intensities (mm/hr) and Depths (mm)

Duration	0.5 year		2 year		5 year		10 year		100 year	
Minutes	**Intensity**	**Depth**	**Intensity**	**Depth**	**Intensity**	**Depth**	**Intensity**	**Depth**	**Intensity**	**Depth**
5	26.55	2.21	34.62	2.88	55.03	4.59	68.63	5.72	111.37	9.28
10	19.45	3.24	24.99	4.17	38.10	6.35	46.71	7.79	73.49	12.25
15	16.21	4.05	20.65	5.16	30.74	7.68	37.31	9.33	57.65	14.41
30	11.88	5.94	14.91	7.46	21.30	10.65	25.42	12.71	38.12	19.06
60	8.70	8.70	10.77	10.77	14.77	14.77	17.33	17.33	25.23	25.23
120	6.37	12.74	7.77	15.55	10.24	20.48	11.83	23.66	16.73	33.45
360	3.89	23.36	4.64	27.84	5.74	34.45	6.46	38.79	8.74	52.46
720	2.85	34.20	3.35	40.21	3.99	47.85	4.42	53.04	5.82	69.80
1440	2.09	50.16	2.42	58.07	2.77	66.49	3.02	72.59	3.88	93.01
2880	1.53	73.60	1.75	83.88	1.93	92.45	2.07	99.43	2.59	124.13

Rainfall Data-Continuous Event

For the EPA SWMM model calibration a third rainfall gauge was used located at the Newton Reservoir in the Surrey. For this gauge, a series of observed 15-minute rainfall data were used for the year 2004 that coincides with the available stream flow data at Nicholson Road. The observed total rainfall at the Newton Reservoir was 1210.8 mm for the period between January 1 and December 30, 2004. The Newton Reservoir hyetograph for 2004 is illustrated in **Figure 3-8** and monthly rainfall totals are listed in **Table 3-8.**

Figure 3-8: Newton Reservoir Hyetograph for 2004

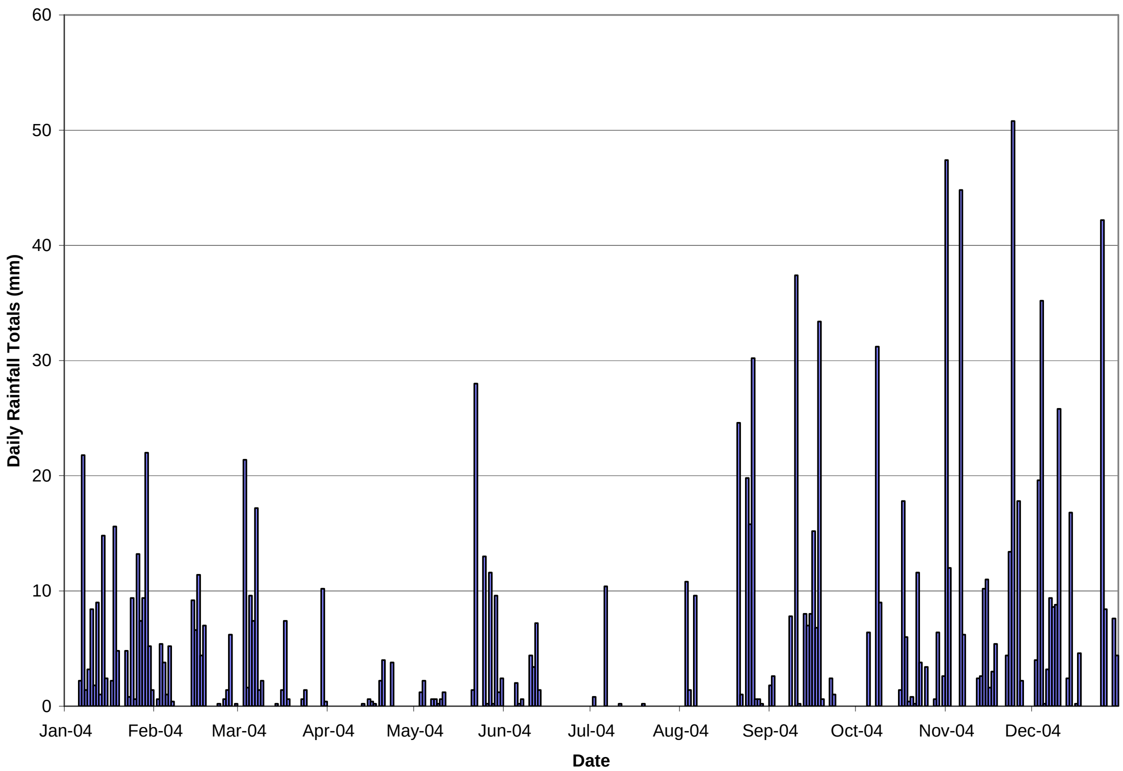


Table 3-8: Monthly Totals of Observed Rainfall at Newton Reservoir 2004

Month	Rainfall (mm)	Month	Rainfall (mm)
January	162.8	July	11.6
February	63.6	August	114.6
March	83.0	September	132.2
April	11.4	October	101.6
May	74.2	November	235.2
June	19.2	December	201.4

3.3.3 Hydrologic Model Calibration and Validation

The purpose of the model calibration was to adjust the model input parameters to more accurately simulate observed hydrologic conditions, and increase accuracy in the simulation of different scenarios.

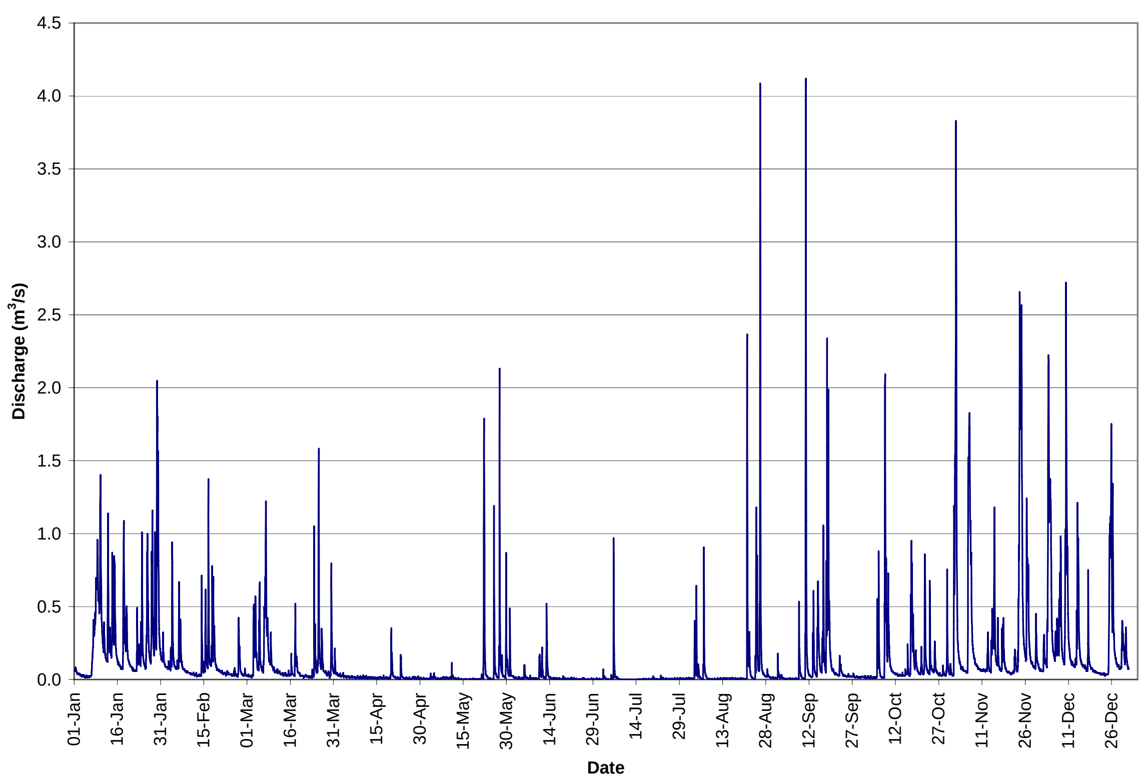
Model calibration was performed by simulating the runoff by the EPA SWMM model of the Cougar Creek watershed draining to the Nicholson Road culverts. The total catchment area upstream of the Nicholson Road culverts is estimated to be 475.9 ha with an overall imperviousness percentage of 62.6%.

Simulated flows were compared against observed flows at the Nicholson Road culvert. The model calibration was limited to the available period of observed stream flow and rainfall data for the 2004 calendar year. For the purposes of model simulation, the November 2004 period was chosen due to the wide range of flows that were observed. An iterative procedure of parameter evaluation and refinement was used in combination with comparing the simulated and observed flows in various ways, as described below. The goodness of fit between the observed and simulated data was evaluated by a "weight of evidence" approach that considered:

- annual water balance volumes;
- flow duration curves;
- hydrographs for November 2004 storms; and
- maximum annual peak flows.

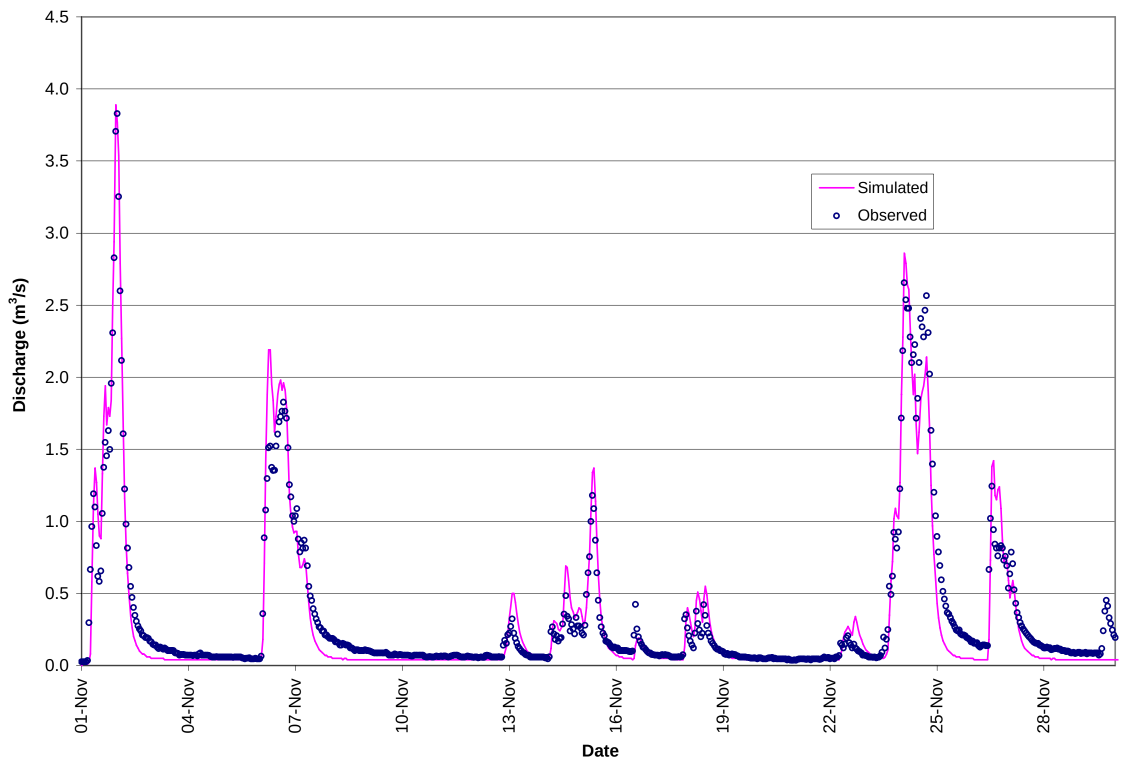
The observed stream flow data at the Nicholson Road culvert gauge is reported in 15-minute intervals and is averaged into hourly intervals for presentation purposes as shown in **Figure 3-9.**

Figure 3-9: Cougar Creek Flows Observed at Nicholson Road Culvert - 2004



The subcatchment parameters that were adjusted during calibration were slope, representative catchment width, surface roughness, depression storage coefficients, and Horton's infiltration parameters. A comparison of simulated and measured hydrographs for November 2004 is shown on **Figure 3-10.** The two hydrographs show a good visual fit of the simulated hydrograph for the November 2004 period compared with the observed flow record. The modelled peak flows and hydrograph response matched closely with observed with some deviation on the receding or falling limb of the runoff event. Comparisons of the modelled 2004 simulation illustrated that, in general, the simulated hydrograph response matched the observed.

Figure 3-10: Nicholson Road Simulated and Observed Flows for November 2004



The annual water balance for the 2004 modelled year was within 10% of observed estimated flow volumes. The simulated runoff volume was 911 mm over the catchment basin size of 475.9 ha compared with the observed runoff volume of 825 mm.

Based on the calibration and validation results, the Cougar Creek/NEIC model parameters can be deemed reasonably calibrated and can be used to analyze existing and future flood flow conditions. The representative general subcatchment parameters were thus transferred to the rest of the Cougar Creek model.

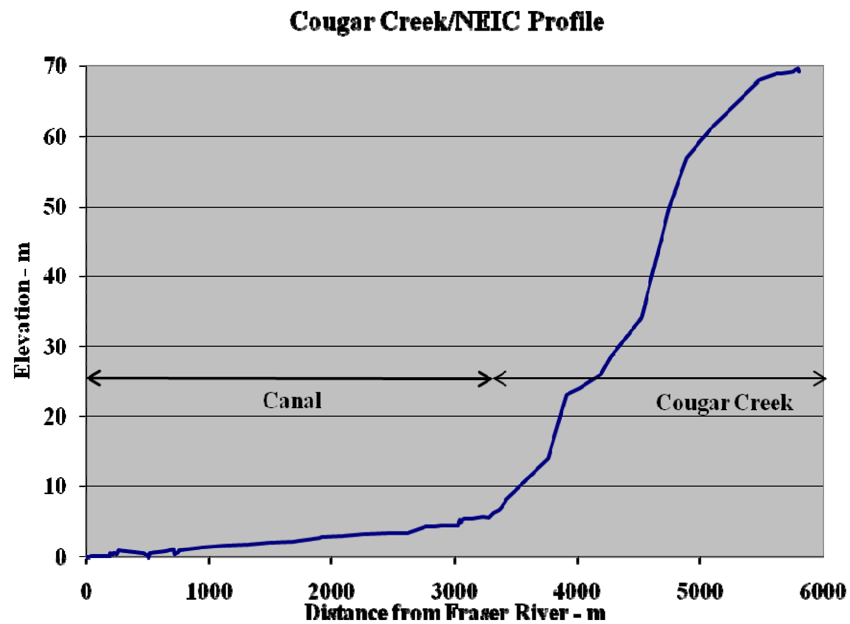
3.3.4 Existing System Modelling

The purpose of the existing system modelling is to establish flows, flood elevations and velocities along Cougar Creek and the Northeast Interceptor Canal representing existing conditions. The EPA SWMM model was used to compute flows, velocities and backwater elevations.

The Fraser River Hydraulic Model report (NHC 2006) indicated that for extreme flood events (*i.e.*, the 1 in 200 year flood), water levels in the lower 28 km of the Fraser River (including downstream of the Alex Fraser Bridge) are governed by winter high tides and storm surges versus freshet discharge from the river. At the mouth of the NEIC, just downstream of the Alex Fraser Bridge, the extreme winter design event water level made up of a 1:200 year flood inflow from the Fraser River is estimated to be 3.00 m GSC. The effect of the boundary condition starting level can influence water levels more than 2 km upstream.

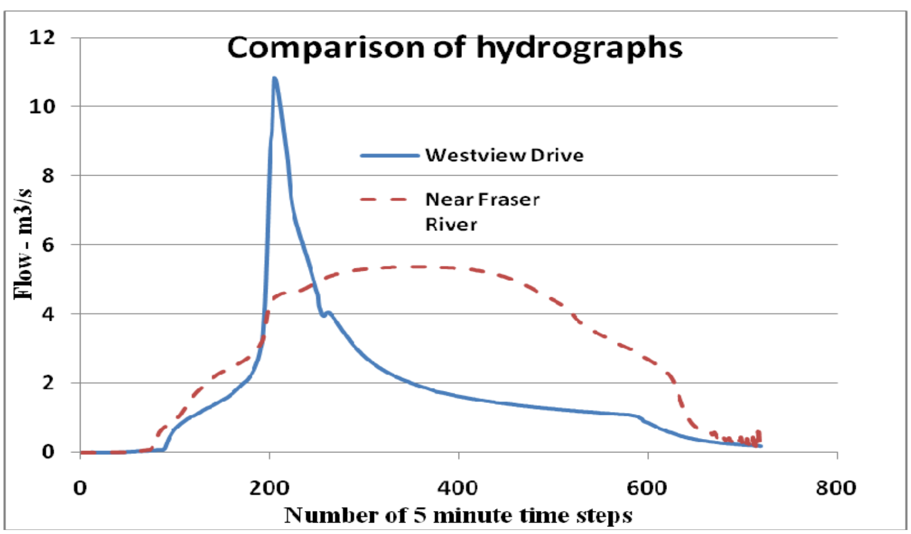
Water level conditions at or near a junction of two rivers depend on whether the floods would be generated by two independent flood events, or by the same event. In the case of the Fraser River and the NEIC the flood producing events are totally independent. Therefore, the “design” water level should be based on the higher of a 1) high water level in the Fraser River and the mean annual flood in the Canal, or 2) on a more frequent water level in the Fraser River and the selected frequency flood event in the Canal. The first alternative would result in a high water elevation of 3.0 m backing up in the Canal extending over a distance of approximately 2 km, while the second alternative would be based on a series of computer analyses of the 6 months, 2-, 5-, 10- and 100-year floods generated over the Cougar Creek/NEIC watershed with a more frequent water level at the Fraser River. For the more frequent Fraser River level the 95th percentile December and January water level of 1.5 m observed in the Fraser River at the Port Mann Bridge was selected (NHC, 2004), since large rainstorms in the lower Fraser Valley typically occur in the winter. This water level was adjusted by reducing it to elevation 1.2 m to allow for the drop in water level between Port Mann Bridge and River Road elevations. This estimate includes the effects of tides. Mean tidal water levels in the Fraser River at the NEIC is estimated to be 0.3m GSC. The hydraulic computations were strongly influenced by the dramatic change in the bed gradients where the steep Cougar Creek discharges into the Canal, which has a very flat gradient. **Figure 3-11** illustrates the bed profiles of the two different reaches.

Figure 3-11: Bed Profile of the Cougar Creek/NEIC System



The computer results showed that once the high flows pass the steep gradient of Cougar Creek and enter the Canal, which has a very flat gradient, the Canal would not be capable of conveying the high flows; instead it would store the flood volume temporarily in the open channel and behind crossings, and release it to the Fraser River in lower flood peaks but over a longer duration. **Figure 3-12** illustrates this phenomenon by comparing hydrographs at Westview Drive near the bottom of Cougar Creek and near the outlet to Fraser River.

Figure 3-12: Comparison of Hydrographs near the Outlets of Cougar Creek and the Canal



Three different storm durations were modelled (12-, 24- and 48-hours) for the 6-months, 2-, 5-, 10- and 100-year events and in all cases the 48-hour event provided the highest flows and flood elevations at

Westview Drive and at the Fraser River outlet. The 12-hour event provided the highest velocities. **Tables 3.9** and **3.10** provide the output from the 48-hour event, **Table 3.11** provides the output from the 12-hour event, but all results of the simulation are presented in **Appendix C.**

Table 3-9, **Table 3-10** and **Table 3-11** present a summary of computed peak flows, flood elevations and velocities along the Cougar Creek/NEIC system.

Table 3-9: Summary of Peak Flows Predicted by the Model

Location	Chainage	Return period				
		6-months	2-year	5-year	10-year	100-year
Cougar Creek	**m**	**Flows - m^3/s**				
Cougar Creek Pond, u/s	6012.7	3.14	3.53	4.01	4.18	4.23
Scott Road culvert, d/s	5764.4	3.66	4.29	5.42	5.96	7.19
Nicolson Road culvert, d/s	5623.4	3.75	4.42	5.58	6.13	7.45
Catchment boundary of D48/D47	4749.4	4.32	5.25	6.55	7.38	10.80
Catchment boundary of D50/D51	4198.4	4.91	6.05	7.70	9.00	14.21
Canal						
Westview Drive culvert, d/s	3317.0	5.31	6.56	8.45	9.88	15.05
	3282.5	5.33	6.59	8.49	9.94	15.14
BNSF crossing inlet, u/s	3075.1	5.33	6.58	8.45	9.86	15.13
	2888.3	5.69	7.04	9.09	10.66	14.73
Terasen Gas pipeline culvert, u/s	760.2	2.53	2.54	2.55	2.55	2.54
	642.4	2.75	2.85	3.04	3.20	3.42
Metro Vancouver culvert, u/s	517.7	2.74	2.84	2.97	3.06	3.13
Steel lined canal, u/s	269.1	2.80	2.92	3.11	3.24	3.43
Twin box culvert, u/s	222.3	2.94	3.11	3.40	3.61	4.12
River Road culvert, u/s	46.5	2.94	3.11	3.40	3.60	4.09

Table 3-10: Summary of Flood Elevations Predicted by the Model

Location	Chainage	Return period				
		6-months	2-year	5-year	10-year	100-year
Cougar Creek	**m**	**Water surface elevations- m**				
Cougar Creek Pond, u/s	6012.7	71.07	71.13	71.21	71.26	71.37
Scott Road culvert, d/s	5764.4	70.12	70.20	70.33	70.39	70.53
Nicolson Road culvert, d/s	5623.4	69.84	69.89	69.97	70.01	70.08
Catchment boundary of D48/D47	4749.4	50.58	50.63	50.68	50.71	50.82
Catchment boundary of D50/D51	4198.4	27.16	27.25	27.36	27.44	27.69

Location	Chainage	Return period				
		6-months	2-year	5-year	10-year	100-year
Canal	**m**					
Westview Drive culvert, d/s	3317.0	7.33	7.41	7.52	7.60	7.82
	3282.5	7.19	7.25	7.33	7.38	7.55
BNSF crossing inlet, u/s	3075.1	6.04	6.18	6.37	6.51	6.90
	2888.3	5.61	5.72	5.87	5.95	6.13
Terasen pipeline culvert, u/s	760.2	2.47	2.49	2.50	2.51	2.52
	642.4	2.06	2.10	2.16	2.20	2.22
Metro Vancouver culvert, u/s	517.7	2.03	2.08	2.14	2.18	2.20
Steel lined canal, u/s	269.1	1.56	1.58	1.61	1.64	1.69
Twin box culvert, u/s	222.3	1.43	1.45	1.49	1.51	1.57
River Road culvert, u/s	46.5	1.30	1.31	1.33	1.35	1.38

Table 3-11: Summary of Velocities Predicted by the Model

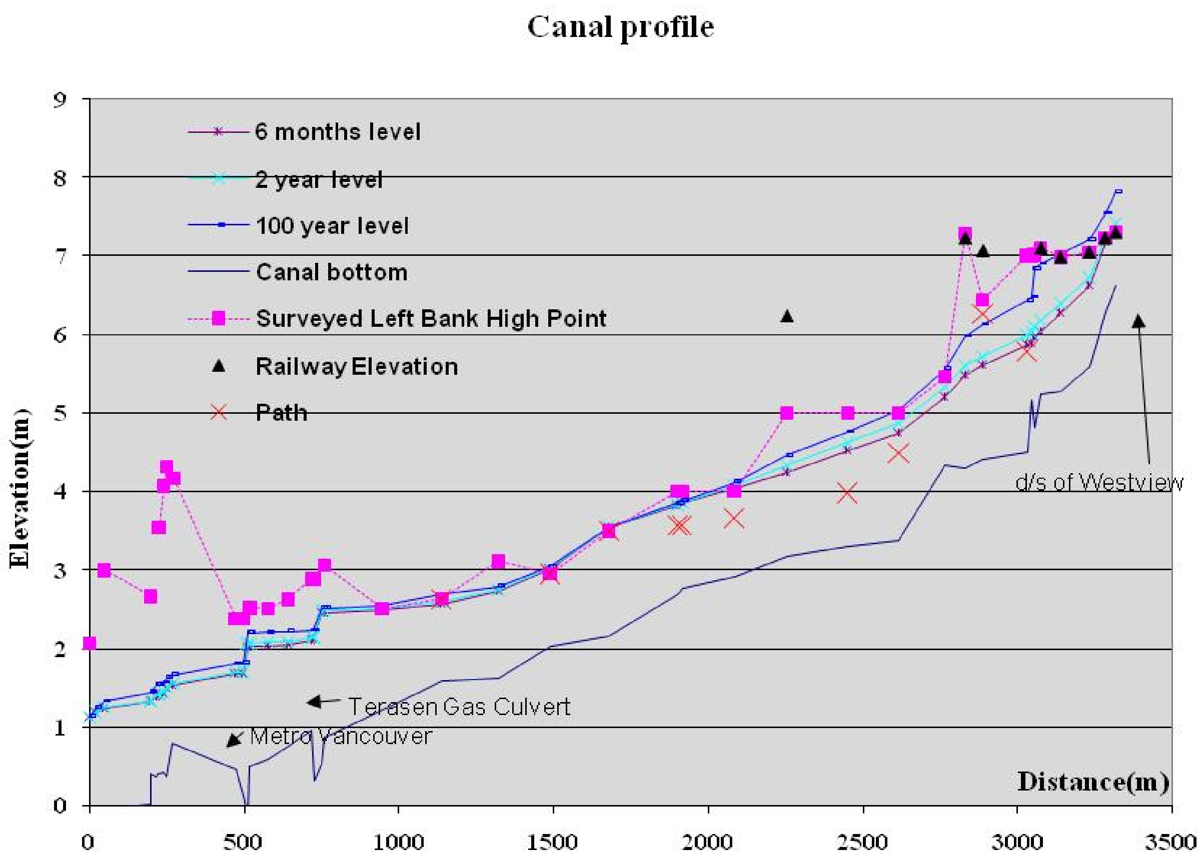
Location	Chainage	Return period				
		6-months	2-year	5-year	10-year	100-year
Cougar Creek	**m**	**Velocities - m/s**				
Cougar Creek Pond, u/s	6012.7	1.12	1.15	1.25	1.24	1.09
Scott Road culvert, d/s	5764.4	0.88	0.88	0.88	0.88	0.88
Nicolson Road culvert, d/s	5623.4	0.82	0.89	1.02	1.08	1.20
Catchment boundary of D48/D47	4749.4	3.85	4.06	4.33	4.46	4.77
Catchment boundary of D50/D51	4198.4	2.57	2.60	2.83	2.99	3.36
Canal						
Westview Drive culvert, d/s	3317.0	1.25	1.39	1.58	1.71	2.09
	3282.5	0.74	0.76	0.81	0.84	0.91
BNSF crossing inlet, u/s	3075.1	1.05	1.06	1.07	1.08	1.09
	2888.3	1.14	1.14	1.14	1.14	1.16
Terasen pipeline culvert, u/s	760.2	0.35	0.35	0.35	0.35	0.36
	642.4	0.49	0.49	0.51	0.52	0.51
Metro Vancouver culvert, u/s	517.7	0.27	0.27	0.27	0.27	0.27
Steel lined canal, u/s	269.1	0.81	0.82	0.83	0.83	0.83
Twin box culvert, u/s	222.3	0.44	0.45	0.47	0.49	0.52
River Road culvert, u/s	46.5	0.52	0.54	0.58	0.61	0.67

3.4 Model Prediction on Flooding and Erosion – Existing Conditions

Flooding

The model predicted flooding of the railway tracks downstream of Westview Drive, at several locations along the Canal spilling into Burns Bog, and along the foot path even by the 6-month storm event. **Figure 3-13** shows the profile of the Canal between Westview Drive and the outlet, with bed, left bank elevations and the 6-months, the 2- and the 100-year flood elevations. The model confirmed the observed flood vulnerabilities at the above locations. A more detailed analysis of the flooding locations is presented in **Chapter 4,** Remedial Measures**.**

Figure 3-13: Canal Profile



Erosion

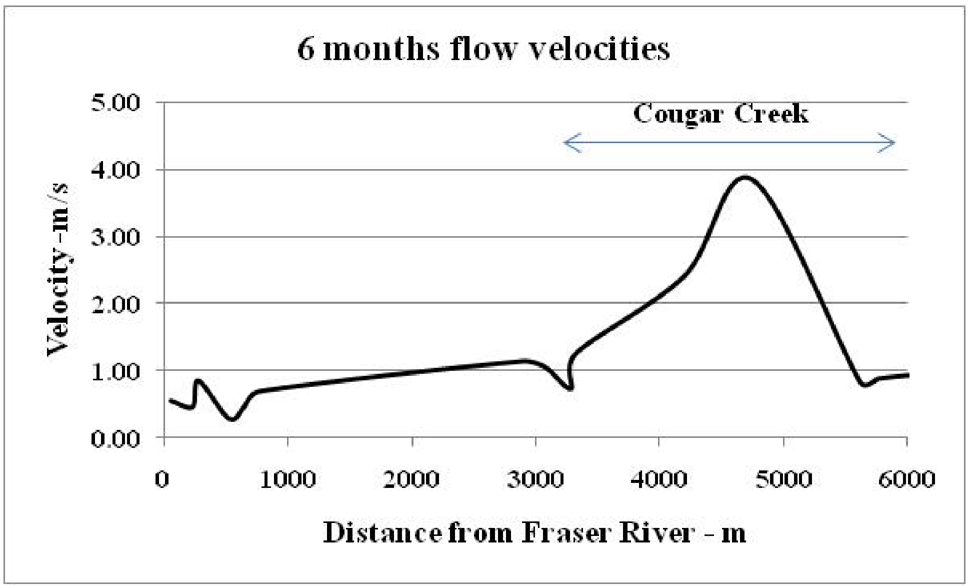
To assess the erosion vulnerable reaches along the Cougar Creek/NEIC system, simulated velocities summarized in **Table 3-11** can be compared with the maximum permissible velocities for different soil types listed in **Table 3-12**.

Table 3-12: Typical Non-Erodable Velocities

Soil material	Non-erodable velocities
Fine sand, colloidal	0.8 m/s
Sandy loam, non-colloidal	0.8 m/s
Silt loam, non-colloidal	0.9 m/s
Loam	1.0 m/s
Stiff clay, alluvial silts	1.5 m/s
Fine gravel	1.8 m/s

Generally, the velocities in the Canal are below the non-erodable velocities, while along the steep Cougar Canyon they are above the non-erodable velocities. Assuming a maximum non-erodable velocity of 1 m/s for the Cougar Creek and the Canal soils, the model predicted excessive average velocities even for the 6 months flows along the Cougar Canyon as shown on **Figure 3-14.**

Figure 3-14: Flow Velocities along Cougar Creek and the Canal



3.5 Existing Conditions in the Cougar/NEIC System with Future Land Use

3.5.1 Future Land Use Assumptions

The existing Cougar Creek/NEIC model was adjusted to simulate the affect of future development. The future development scenario selected in the computer analysis represents the "worst" scenario, assuming that the past practice of redeveloping with higher densities and site coverage would prevail. Properties/lands were identified within the Cougar Creek/NEIC catchment area in Delta and Surrey that have a potential to redevelop to higher densities and site coverage, thereby increasing stormwater runoff. The purpose of the modelling was to estimate the effect of these higher density developments on future runoff, and to identify alternative stormwater management techniques to control runoff.

The method for estimating future land use and site coverage was based on available information for each of the two municipal areas. A summary of the impervious area estimates are presented for both municipal areas within the watershed in **Appendix D.**

In the calculation a number of assumptions had to be made:

Delta

- Existing older commercial developments are estimated to be redeveloped to a level that will increase the hard surface coverage from the existing to 20% more.
- Future multi-family and townhouse development sites are estimated to have a site coverage of 45% (buildings, roofs and covered parking)
- Residential lands currently zoned RS1and RM1 could expect an increase of about 15% in total site coverage due to infill development within the next 15-20 years.
- Residential lands currently zoned RS2, RS3 and RS4 could expect an increase of about 10%.

Using a 2006 air photo, current zoning maps and the North Delta Land Use Plan, properties and designated areas were identified and numbered on a large air photo. Each site and number corresponded to an estimated increase in the site coverage (%) that could occur within the next 15-20 years. Most sites are underdeveloped and can be expected to densify over the years.

The North Delta catchment area is generally developed with varying types and sizes of residential subdivisions. Many subdivisions (particularly those zoned RS1, RM1, RS2, RS3 and RS5) consist of larger lots (0.4 ha) and can be expected to eventually be redeveloped over time. For these residential areas, estimates were made across the catchment based on the type of residential zone and the likelihood that areas within the zone would experience redevelopment via “infill”.

Surrey

Using a 2007 air photo along with current zoning maps and future land use maps (Official Community Plan Map, West Newton North NCP map and West Newton South NCP map), properties were identified and numbered on the large air photo. Each site and number corresponds to an estimated increase in the site coverage (%) that could occur within the next 15-20 years. Some sites are underdeveloped and can be expected to densify over the years and some sites are greenfield and can be expected to be fully developed.

Several assumptions apply to this analysis as follows:

- Existing older commercial developments are estimated to be redeveloped to a level that will increase the hard surface coverage from the existing to 20% more.
- Greenfield commercial sites (designated but undeveloped) are estimated to be developed to a level that will increase the hard surface coverage from the existing to either 40% or 60% more depending on the current site coverage.

- Future single family development sites are estimated to have a site coverage of 50%.
- Future multi-family development sites are estimated to have a site coverage of 40% (all are based on Surrey's Zoning Bylaw requirements).

3.5.2 Future Land Use Model Results

The results of the Future Land Use scenario showed only a small increase in flows and even smaller increases in water elevations or velocities, when compared to the existing land use scenario. **Table 3-13** compares the water elevations for both scenarios.

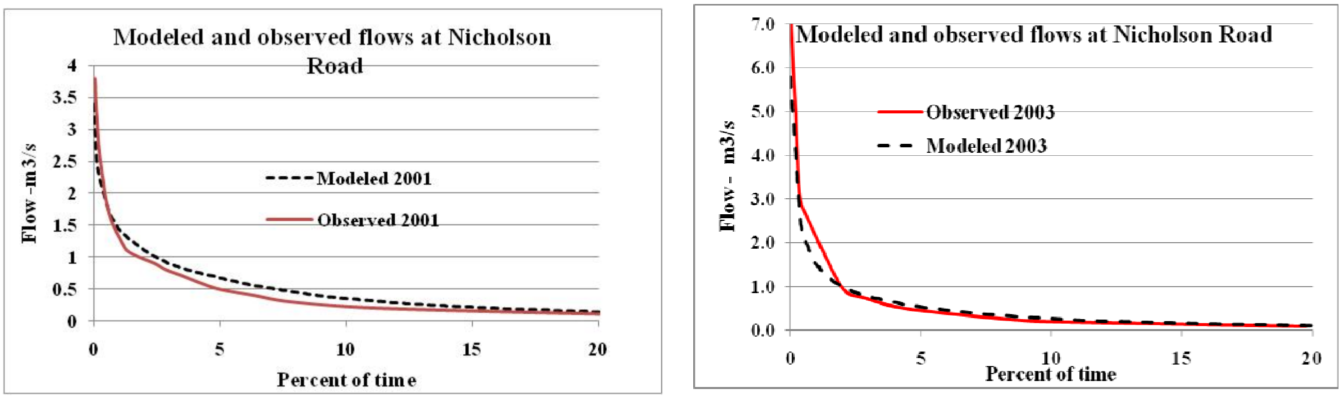
Table 3-13: Summary of Existing and Future Land Use Flood Elevations Predicted by the Model

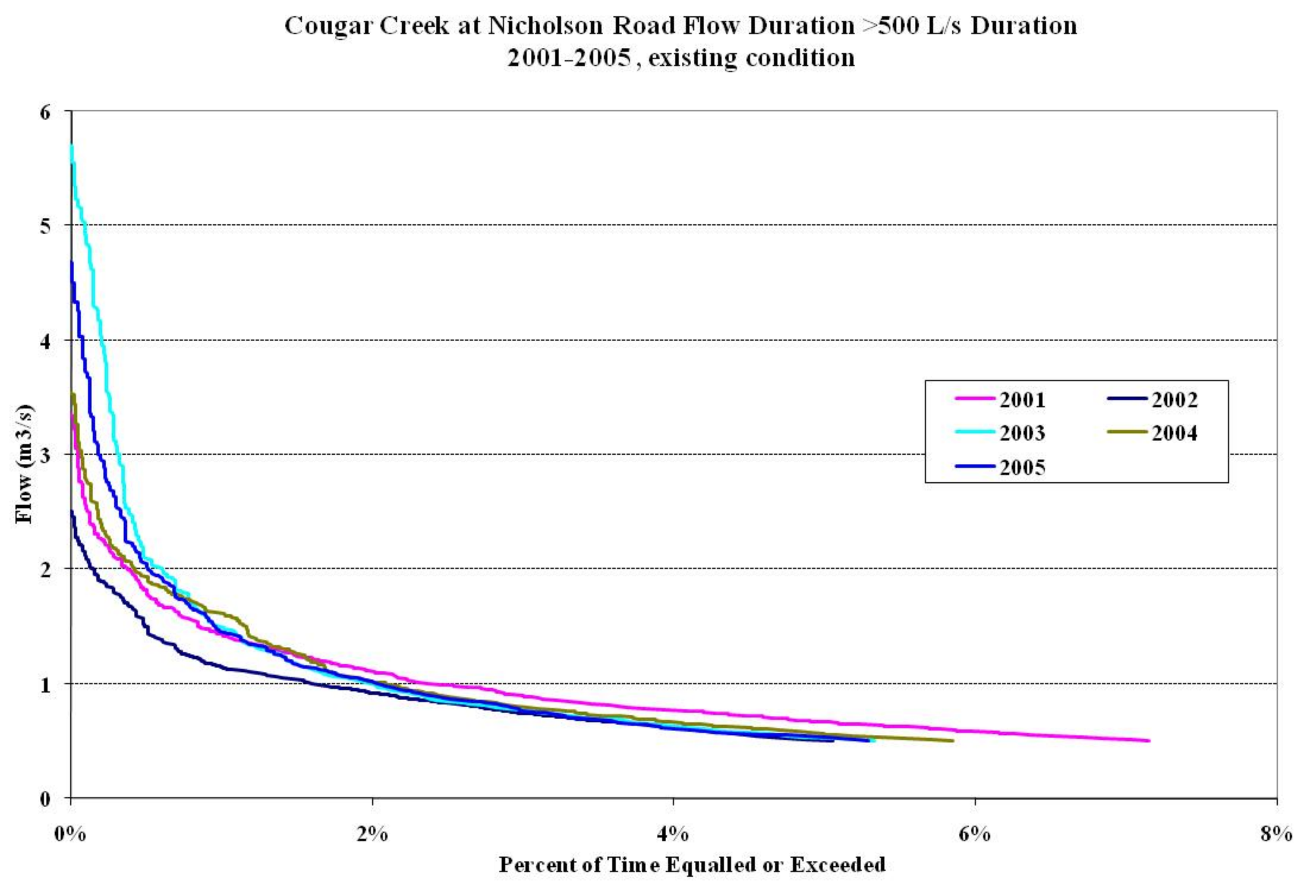
Location	Existing	*Future*	Existing	*Future*	Existing	*Future*
	6-months	*6-months*	10-year	*10-year*	100-year	*100-year*
Cougar Creek	**Water surface elevations - m**					
Cougar Creek Pond, u/s	71.07	*71.09*	71.26	*71.28*	71.37	*71.38*
Scott Road culvert, d/s	70.12	*70.14*	70.39	*70.41*	70.53	*70.55*
Nicolson Road culvert, d/s	69.84	*69.85*	70.01	*70.02*	70.08	*70.10*
Catchment boundary of D48/D47	50.58	*50.59*	50.71	*50.72*	50.82	*50.83*
Catchment boundary of D50/D51	27.16	*27.17*	27.44	*27.45*	27.69	*27.70*
Canal						
Westview Drive culvert, d/s	7.33	*7.34*	7.60	*7.60*	7.82	*7.83*
	7.19	*7.20*	7.38	*7.39*	7.55	*7.55*
BNSF crossing inlet, u/s	6.04	*6.05*	6.51	*6.53*	6.90	*6.90*
	5.61	*5.62*	5.95	*5.96*	6.13	*6.13*
Terasen pipeline culvert, u/s	2.47	*2.49*	2.51	*2.51*	2.52	*2.52*
	2.06	*2.15*	2.20	*2.22*	2.22	*2.23*
Metro Vancouver culvert, u/s	2.03	2.13	2.18	*2.20*	2.20	*2.22*
Steel lined canal, u/s	1.56	1.60	1.64	1.65	1.69	1.69
Twin box culvert, u/s	1.43	1.46	1.51	1.52	1.57	1.57
River Road culvert, u/s	1.30	1.32	1.35	1.36	1.38	1.39

3.6 Continuous Modelling

The purpose of continuous modelling is to gain a better understanding how the entire flow events could affect the creeks, especially the erosion/sedimentation process. For the analyses, the Newton reservoir rainfall data for 2001 - 2006 was used and processed in 15 minute time steps. To test the accuracy of the model, observed flow-duration curves at the Nicholson Road culvert were compared with the modelled flow-duration values. The results showed very similar flow distributions, as shown on the two examples plotted on **Figure 3-15** for 2001 which was a relatively dry year with lower peak flows and for 2003 which had the highest observed flows.

Figure 3-15: Comparison of Observed and Modeled Flow Duration Curves for 2001 and 2003





The calibrated continuous model was run for the 2001-2005 period to simulate five years of runoff in the Cougar Creek/NEIC system. The resulting flow-duration curves incorporate the storage effect of existing stormwater management facilities located upstream. The five year plot shows similar pattern for the five years of flows at Nicholson Road; generally a peak flow of 1 m^3/s is only exceeded approximately 2 % of the time (approximately half a day) in a year.

The model showed the beneficial effect of ponds in reducing the incoming peak flows. Examples of the reduction are shown on **Table 3-14**.

Table 3-14: Flood Peak Reduction by Ponds

Pond	Flood Event-year	Reduction in peak - %
Soccer pond	1:5	33%
	1:100	74%
Cougar Creek pond	1:5	13%
	1:100	5%
B.C. Hydro	1:5	57%
	1:100	44%

3.7 Water Quality Assessment

Significant research has been done over the past decade to characterize stormwater quality. The prime source of pollutants in urban areas listed in the technical literature is from atmospheric deposition, automotive exhaust emission and fluids, corrosion of metal surfaces, and vegetative matters. Urban runoff from residential developments may contain a variety of dilute contaminants such as suspended solids, chloride from road salt, oil and grease, metals, pesticide residues, bacteria (*E. coli*) and viruses. Generally, with the exception of the dissolved constituents (nitrogen, salt), most contaminants are attenuated by filtration during transport through the soils. Without appropriate mitigative measures, pollutant loads have the potential to impact receiving stream and habitat quality.

To assess the potential effect of development on the water quality, annual pollutant loads were estimated first to reflect existing conditions, followed by estimates of changes in annual pollutant loads from the original natural conditions of the 1940s to projected pollutant loads for different future conditions. The purpose of the analysis was to obtain a better understanding of the differences between existing and future runoff volumes and water quality and to identify the potential beneficial effects of control measures to be introduced as part of the development plan.

The potential surface water quality impacts caused by urbanization can be assessed qualitatively by considering parameters of urban runoff that are recognized as suitable indicators. A spreadsheet model was used to estimate the annual Total Suspended Solids pollutant loads for past, existing and future development conditions. Generally, TTS is selected as a major indicator of the various urban pollutants present in stormwater. The model uses published pollutant event mean concentration values (mg/L) for each land use category to estimate total annual pollutant loads entering the watercourses.

Four scenarios were analyzed to illustrate the changes in annual runoff and TSS loads:

- Prior to urbanization (1940 conditions);
- Existing conditions;
- Future development scenario with storage facilities at all residential areas capable to settle 50% of the incoming pollutant load; and
- Future development based on the LID concept, capturing all rainfall events by infiltration up to 10 mm without releasing the runoff downstream.

For the future land use scenarios it was assumed that eventually all urban runoff from residential areas will be controlled by storage facilities, which will settle 50% of the load. It was assumed that for industrial and commercial areas there will not be any suitable land to capture and store the urban runoff. The purpose of the future scenario runs was to illustrate the increase in flows and pollutant load, if the additional future developments and re-developments would fail to adopt the rigorous stormwater controls as suggested in the ISMP Targets. The following is a summary of the water quality spreadsheet computations. **Figure 3-16, Figure 3-17, Figure 3-18**, and **Figure 3-19** are sample plots of results predicted by the model.

Figure 3-16: Annual Runoff in m^3

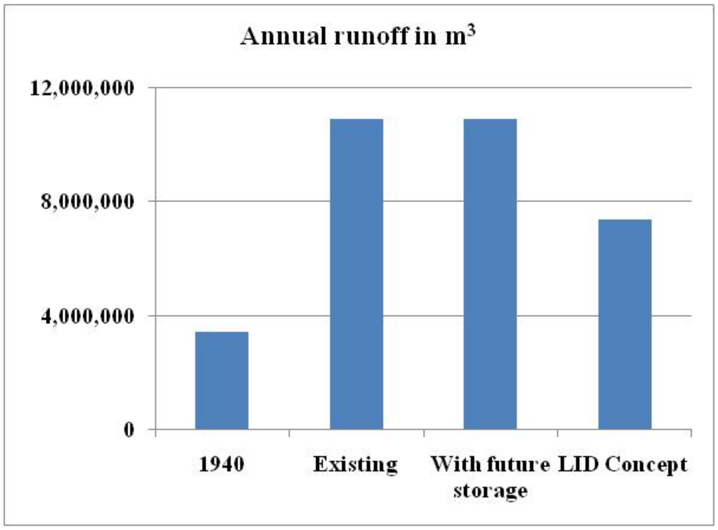
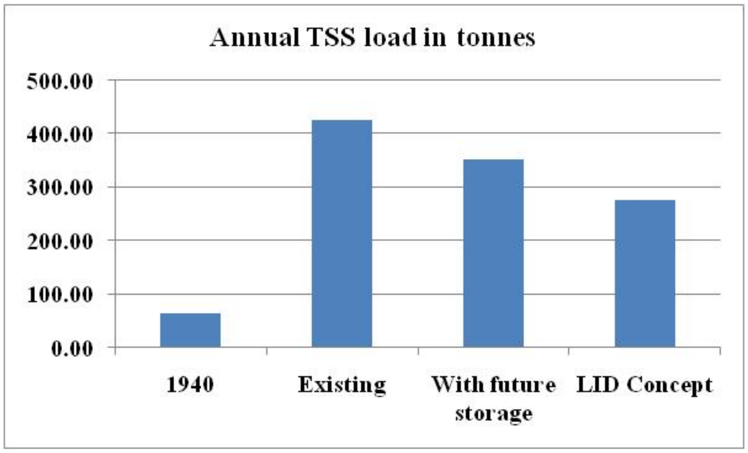


Figure 3-16 shows the significant increase in annual runoff volumes caused by the past decades of urbanization. This increase is the result of impermeable surfaces discharging a much higher percent of rainfall runoff under current development conditions than during the pre-developed conditions. As the future scenario storage facilities would only provide a temporary storage to settle particles, the total annual runoff volume would be identical to the existing scenario.

Figure 3-17: Annual TSS Load in Tonnes



The Total Suspended Solid (TSS) estimates illustrated on **Figure 3-17** also shows large increases in the annual loads over the past years. This large increase is due to the combination of higher concentrations of TSS and higher runoff volumes generated in urban areas. The model also showed that even with stringent future runoff control from residential areas, the total annual TSS load cannot be lowered to approach the 1940 conditions. When considering the total load estimates, it is important to emphasize that the total does not include the substantial bedload movement in the creek. For example the sediment trap at the bottom of the Cougar Creek Canyon can accommodate a similar load of sediment, an amount which is deposited at least annually.

The TP and Zn annual load estimates shown on **Figure 3-18** and **Figure 3-19** show very similar results.

Figure 3-18: Annual TP Load in Tonnes

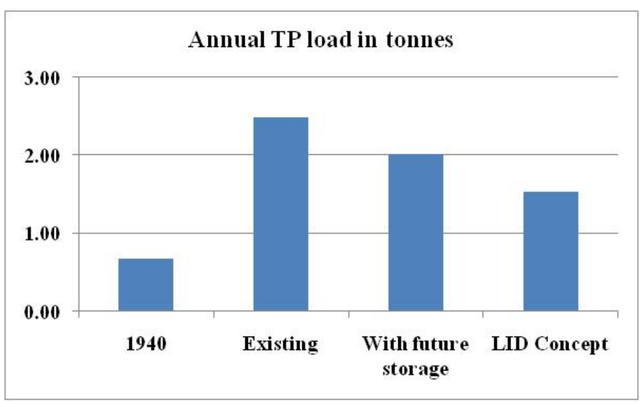
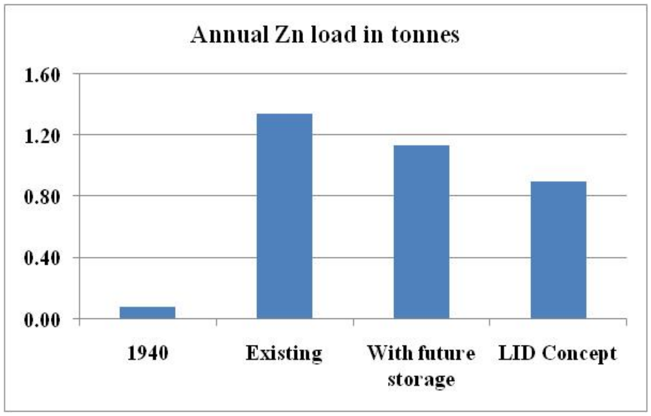


Figure 3-19: Annual Zn Load in Tonnes



A review of the water quality estimates suggests that even with the most advanced stormwater management facilities in place, future runoff volumes and pollutant loads would not be able to replicate the 1940 pre-development conditions in the watershed. However, in the long-term as areas become re-developed and rigorous stormwater controls are introduced under the LID concept, both the runoff and pollutant loads could be reduced from the existing condition estimates, thereby reducing the risk of flooding, erosion and pollutant discharges.

4.0 ALTERNATIVE REMEDIAL MEASURES

This chapter presents a screening of alternative remedial scenarios designed to reduce the existing and future flooding, erosion and environmental damages caused by urban runoff. Chapter 5 presents a long list of additional management practices recommended to be adopted as part of the ISWMP.

A "do nothing" alternative would result in a continued increase in flooding and erosion/sedimentation along the Cougar Creek and the Canal until the system would adjust to the climate and land use changes and eventually would reach an equilibrium.

4.1 Remedial Measures

The objectives of the analysis of alternative remedial measures are to:

- Provide a minimum acceptable level of service in the watercourses
- Analyze alternative remedial measures and recommend appropriate measure(s)
- Recommend acceptable strategies to deal with environmental and fisheries issues
- Consider both initial and long-term costs in the analysis
- Prioritize recommended improvements

The following is a list of alternative remedial measures reviewed, a number of which were selected for computer simulation to determine the potential beneficial effects.

1. Diversion of urban drainage
2. Relief open channel
3. Channel improvements
4. Increased storage capacity
5. Berming the Canal banks
6. Changes in land use development plans and the use of Low Impact Development (LID)
7. Increase tree canopy cover
8. Erosion protection
9. Provide additional flood storage at the Bog

As most of the Cougar Creek/NEIC watershed is already heavily developed, there is a need to review short–term remedial alternatives to be applied even before any long-term developments could introduce strict control of stormwater in future.

4.1.1 Option #1 - Diversion of Urban Drainage along 72nd Avenue to the Canal

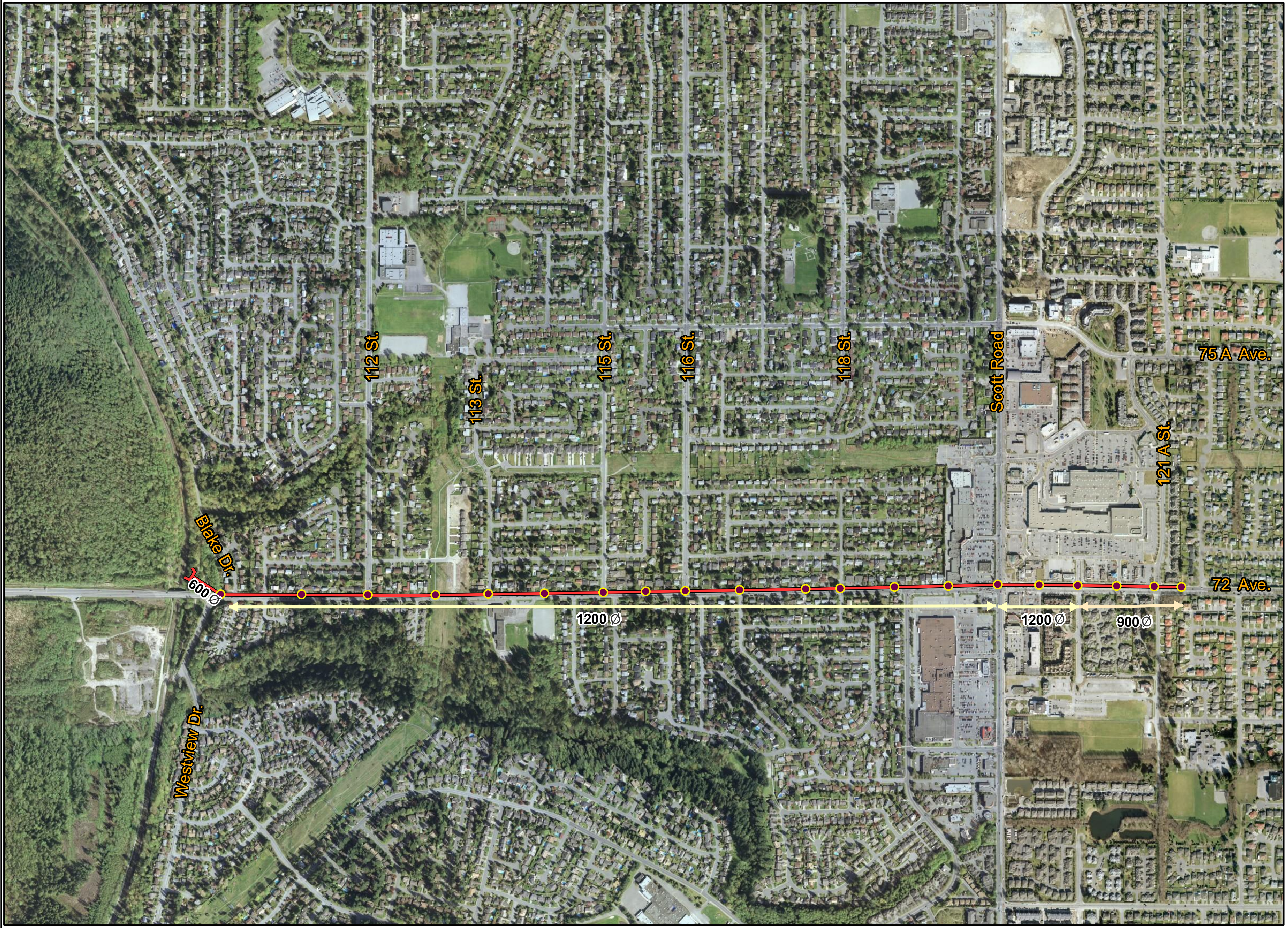
Option #1 shown on **Figure 4-1** proposes to divert a significant portion of the available stormwater flows from north of 72nd Avenue via a new 2.56 km long constructed stormwater trunk line directed west along 72nd Avenue beginning at 122nd Street and draining west to an outfall just upstream of the BNSF Bridge. Approximately 50% of the total storm sewer flows from a 218.6 ha catchment area would be diverted at the intersections of 72nd Avenue at Scott Road, 72nd Avenue at 121st Street, and 72nd Avenue at 122nd Street to the new storm trunk. This trunk line would replace existing local storm lateral sewer lines and would be sized from 900 mm and 1200 mm diameter circular concrete pipes. The new trunk would discharge to a new outfall into the Canal just upstream of the BNSF Bridge. However, a portion of the existing storm drainage would continue to discharge into the Canal to provide the necessary base flows.

Option #1 would reduce the amount of discharges through the steep Cougar Creek Canyon conveying the stormwater to the Canal but would not reduce the peak discharges downstream of the BNSF Bridge since the diverted flows would not be attenuated through the Cougar Creek Canyon.

The benefit of this option would be to reduce the peak flow and total volume of runoff draining through the Cougar Creek Canyon and thereby reducing the rate of erosion in the Canyon. This reduction would also represent a reduction in sediment deposited in the Canal, thereby providing a reduced risk of flooding, fish habitat destruction and reduced risk of flooding of the rail line downstream of the Westview Drive culvert.

The construction of Option #1 would result in a significant disruption to traffic flow on a major roadway (72nd Avenue) that could require the closure of at least one lane of traffic and affecting cross street traffic from 122nd Street west to Westview Drive. At the time of detailed design, various construction methods could be investigated such as pipe jacking to reduce disruption at the intersections (although the size of the pipe might preclude pipe jacking).

The construction cost of Option #1, based on a method of open-cut & shoring, is estimated to be approximately $8,238,000. If pipe-jacking is used at high traffic intersections, the capital costs would increase. Estimates provided for all options are intended for planning purposes and actual construction costs should be based on subsequent detailed designs.



SCALE 1:10,000

0 85 170 340 510 680

Meters

DILLON CONSULTING

DATE

JUNE 2009

PROJECT

COUGAR CREEK
INTEGRATED STORMWATER MANAGEMENT PLAN

PROJECT NO.

06-6904

TITLE

MAP OF DIVERSION ROUTE ALONG
72nd AVENUE TO THE CANAL

FIGURE NO.

4-1

An alternative diversion route was also examined that could reduce the impact on traffic including routing flows from the next available public right-of-way access to the north at 75th Avenue. This alternative route would run west along 75th Avenue to 116th Street, south to the green space north of 73rd Avenue, west to the green space between 112th Street and 113th Street, south to 72nd Avenue and outfall to the Canal west of Blake Drive. However, this alignment would be longer in length, would receive significantly less flows from a smaller catchment area (roughly 100 ha) than the previous option, and would not provide as much benefit in the reduction of flows in Cougar Creek and would prevent any base flow supplement. Overall, the benefit of this option is reduced Cougar Creek Canyon flows at up to the upstream end of the Canal but once the diversion route joins the Canal the flows would be the same as now. Downstream of the outlet of the diversion channel the flows would be unaltered.

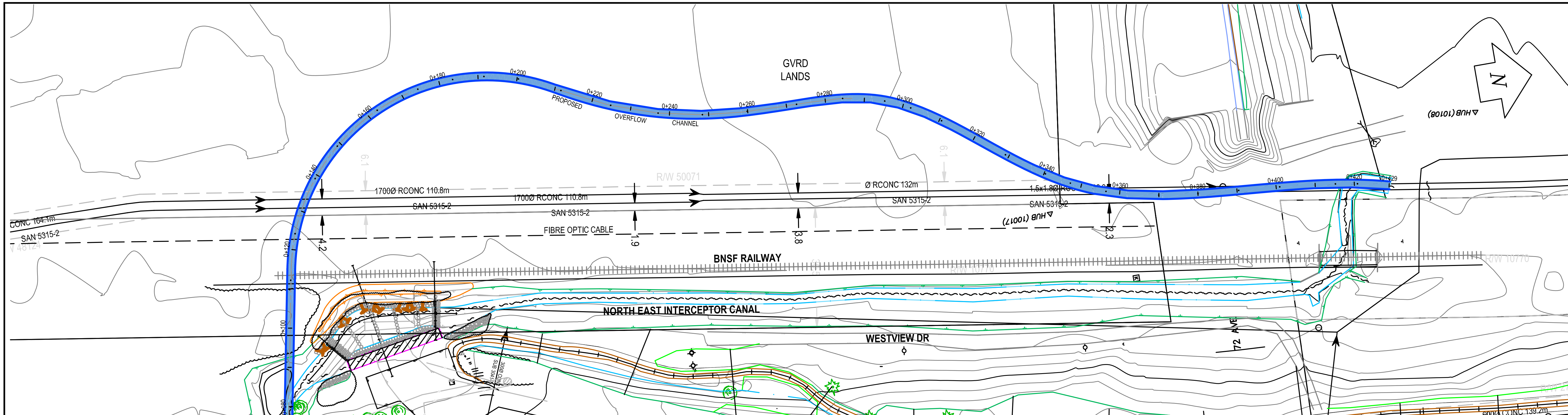
Conclusion. Option # 1 is extremely expensive to construct. Also, there are only limited benefits derived from the flow reduction in the Cougar Canyon, a section of the creek where no flood risk has been reported. However, this option could reduce the erosion rate in the steep section of the Cougar Canyon. **Because of the high cost and limited benefits, Option #1 is not recommended as a viable alternative remedial measure.** Instead, local erosion protection at sites requiring attention would provide a significantly less expensive solution.

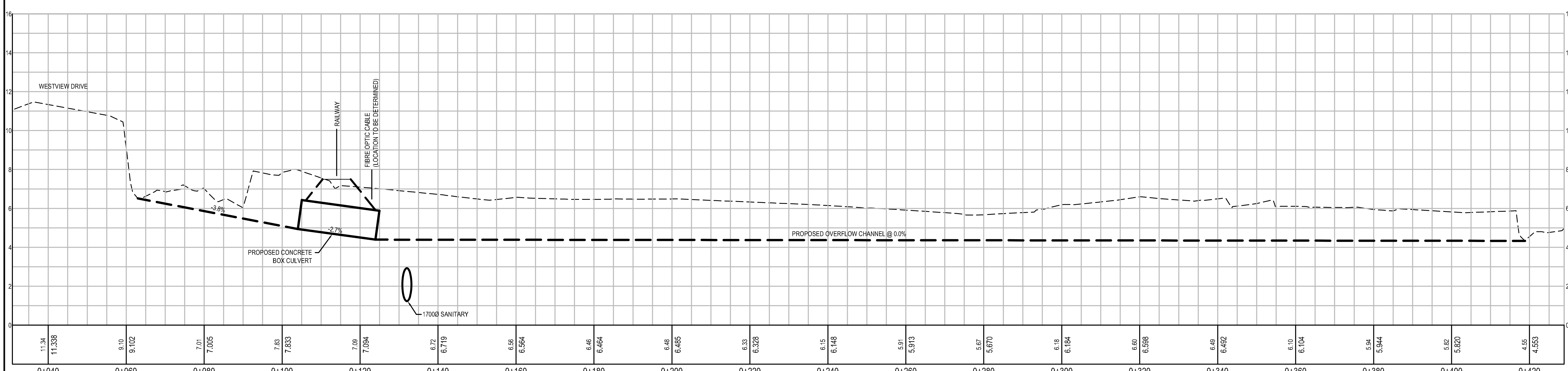
4.1.2 Option #2 - Relief Open Channel

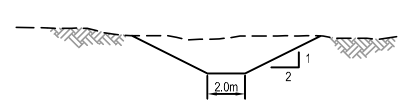
Option #2 shown on **Figure 4-2** proposes to divert a portion of Cougar Creek flows downstream of the Westview Drive culvert via an open channel and under the railway tracks in a new 2400 x 1500 mm concrete box culvert. Flows through this culvert would be directed north via a new constructed channel on the west side of the railway tracks and would re-join the Canal just downstream of the railway bridge crossing. The diversion channel would be sized to carry flows up to the 10-year frequency event and would allow low flows and base flows to continue in the existing channel of the Canal, but would direct a large portion of higher flows through the new culvert and unlined channel. It is also recommended that a small portion of the existing NEIC channel be lowered by 0.4m in the vicinity of the Old Fison's access (approximate chainage 3+200 to 3+300) to have a consistent gradient and to assist in lowering water levels adjacent to the railway tracks.

A significant portion of sediment and gravel that is currently conveyed past the Westview Drive culvert would also be discharged during high flows. This new channel could act as a sediment trap due to the flat slopes that would need to be periodically cleaned out. The proposed relief channel and culvert crossing is approximately 400 m in total length with an average slope of 0.0066 m/m. The channel would have a 2 m bottom width, an average depth of 2.0 m, and 2:1(H:V) side slopes. The box culvert would be approximately 20 m long and have a slope of 1.0%. The estimated cost of the construction is $0.40 million, excluding any additional cost of handling the railway traffic during construction.

Option #2 would permit flows on both sides of the railway line downstream of the Westview Drive culvert until the Canal crosses the railway line under the existing railway bridge. This option reduces water levels locally but does not address water levels or flows downstream of the bridge. **Table 4-1** compares the simulated flood elevations for existing land use condition with Option #2.







(A) PROPOSED CHANNEL SECTION
SCALE : NOT TO SCALE

FileName:g:\cad\066904\design\channel design\066904-proposed-channel.dwg

DILLON CONSULTING	PROJECT: COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN		PROJECT NO. 06-6904
DATE: JUNE 2009	TITLE: MAP OF DIVERSION AT THE UPSTREAM END OF THE CANAL		FIGURE NO. 4-2

Table 4-1: Simulated Flood Levels for Existing Conditions and with Option #2

Location	Chainage	Existing 6-months	*Option 6-months*	Existing 10-year	*Option 10-year*	Existing 100-year	*Option 100-year*
Cougar Creek	**m**	**Water surface elevations- m**					
Cougar Creek Pond, u/s	6012.7	71.07	*71.07*	71.26	*71.26*	71.37	*71.37*
Scott Road culvert, d/s	5764.4	70.12	*70.12*	70.39	*70.39*	70.53	*70.53*
Nicolson Road culvert, d/s	5623.4	69.84	*69.84*	70.01	*70.01*	70.08	*70.08*
Catchment boundary of D48/D47	4749.4	50.58	*50.58*	50.71	*50.71*	50.82	*50.82*
Catchment boundary of D50/D51	4198.4	27.16	*27.16*	27.44	*27.44*	27.69	*27.69*
Canal							
Westview Drive culvert, d/s	3317	7.33	*6.91*	7.60	*7.12*	7.82	*7.30*
	3282.5	7.19	*6.81*	7.38	*6.99*	7.55	*7.15*
BNSF crossing inlet, u/s	3075.1	6.04	*5.95*	6.51	*6.36*	6.90	*6.71*
	2888.3	5.61	*5.60*	5.95	*5.94*	6.13	*6.17*
Terasen pipeline culvert, u/s	760.2	2.47	*2.47*	2.51	*2.51*	2.52	*2.52*
	642.4	2.06	*2.06*	2.20	*2.20*	2.22	*2.22*
Metro Vancouver culvert, u/s	517.7	2.03	*2.03*	2.18	*2.18*	2.20	*2.20*
Steel lined canal, u/s	269.1	1.56	*1.56*	1.64	*1.64*	1.69	*1.69*
Twin box culvert, u/s	222.3	1.43	*1.43*	1.51	*1.51*	1.57	*1.57*
River Road culvert, u/s	46.5	1.30	*1.30*	1.35	*1.35*	1.38	*1.38*

As expected Option #2 does not affect flow conditions upstream of the relief channel. In the vicinity of the structures at Westview Drive and the railway culvert, the relief channel would lower the water levels sufficiently to provide flood protection up to the 10-year event at the flood vulnerable location in the vicinity of the railway bridge and railway track.

Conclusion. Although the estimated $0.40 million construction cost for the relief channel may not be high, the total cost of this alternative with the costs of track protection and handling the rail traffic during construction needs to be balanced with the costs of continued service disruptions due to flooding and overtopping of the railway. Also, the cost estimate was based on the assumption that no additional land costs would occur.

It is recommended that Option #2 should be considered as a feasible alternative to reduce flooding along the Canal, together with Option #3, presented below. The final selection should not be made until discussions with the BNSF would determine their future plans of twinning the tracks. Option #2 would need to consider the possible moving the path/trail that currently exists along this route. Potential conflicts with the sanitary sewer line running along the west side of the BNSF tracks would also need to be considered in the design to ensure that there is enough cover and downcutting

is prevented. Prior to the selection Option #2 or Option #3 an Environmental Assessment will have to determine the affect of the remedial measures on the aquatic habitat.

4.1.3 Option #3 - Channel Improvements along the Canal

The reaches where most of the flow constrictions exist are along the Canal. The existing condition computer model predicted overtopping at several locations even by the 6-month flood. The highest risk of flooding is downstream of the Westview Drive culvert and at the vicinity of the railway bridge, (approximate chainage 3+100 m to 3+300 m). Option #3 proposes to improve the Canal capacity by lowering the bed invert, and by increasing the channel cross-section area to safely discharge flows up to the 100-year 48-hour event without overtopping the railway tracks, as shown on **Figure 4-3**. **Table 4.2** compares the simulated flood elevations for existing land use condition with Option #3.

Figure 4-3: Canal Profile with Option # 3

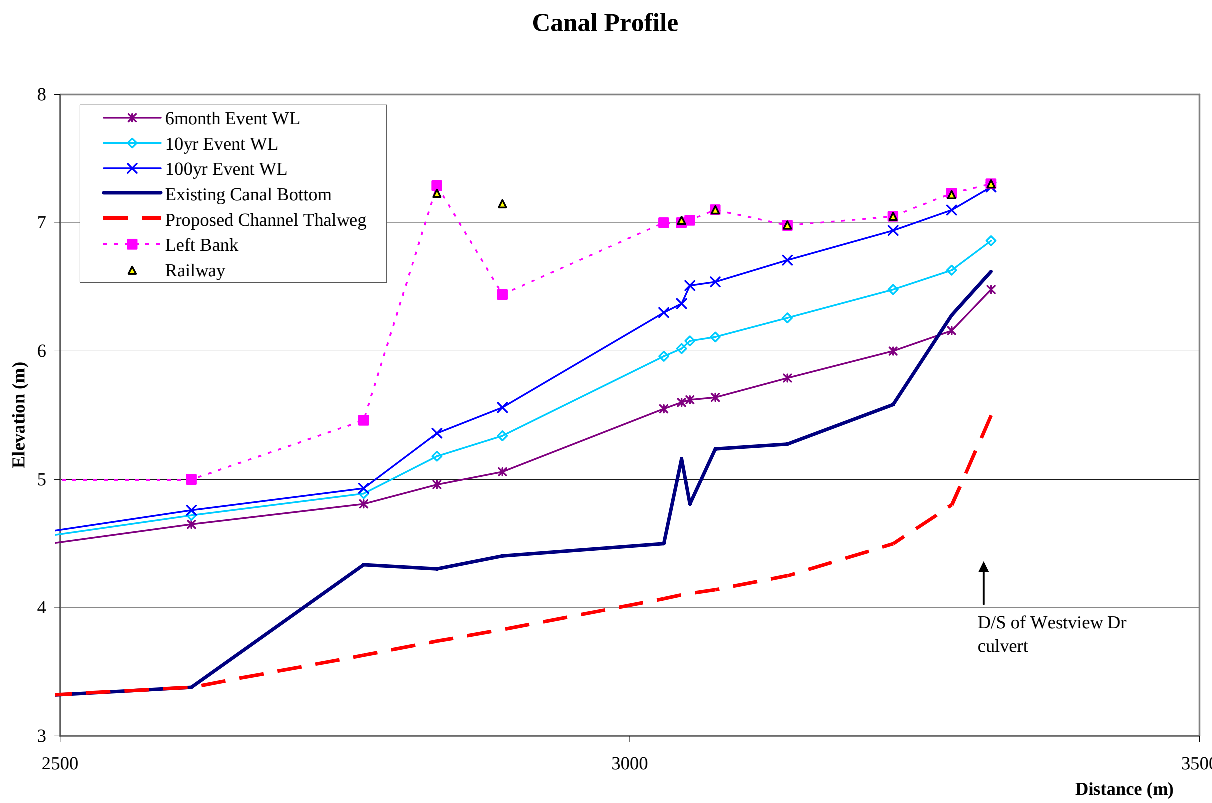


Table 4-2: Simulated Flood Levels for Existing Conditions and with Option #3

Location	Chainage	Existing	*Option*	Existing	*Option*	Existing	*Option*
		6-months	*6-months*	10-year	*10-year*	100-year	*10- year*
Cougar Creek	**m**	**Water surface elevations- m**					
Cougar Creek Pond, u/s	6012.7	71.07	*71.07*	71.26	*71.26*	71.37	*71.37*
Scott Road culvert, d/s	5764.4	70.12	*70.12*	70.39	*70.39*	70.53	*70.53*
Nicholson Road culvert, d/s	5623.4	69.84	*69.84*	70.01	*70.01*	70.08	*70.08*
Catchment of boundary D48/D47	4749.4	50.58	*50.58*	50.71	*50.71*	50.82	*50.82*
Catchment of boundary D50/D51	4198.4	27.16	*27.16*	27.44	*27.44*	27.69	*27.69*
Canal							
Westview Drive culvert, d/s	3317	7.33	*6.48*	7.60	*6.86*	7.82	*7.28*
	3282.5	7.19	*6.16*	7.38	*6.63*	7.55	*7.10*
BNSF crossing inlet, u/s	3075.1	6.04	*5.64*	6.51	*6.11*	6.90	*6.54*
	2888.3	5.61	*5.06*	5.95	*5.34*	6.13	*5.56*
Terasen pipeline culvert, u/s	760.2	2.47	*2.47*	2.51	*2.51*	2.52	*2.52*
	642.4	2.06	*2.06*	2.20	*2.20*	2.22	*2.22*
Metro Vancouver culvert, u/s	517.7	2.03	*2.04*	2.18	*2.18*	2.20	*2.20*
Steel lined canal, u/s	269.1	1.56	*1.56*	1.64	*1.64*	1.69	*1.69*
Twin box culvert, u/s	222.3	1.43	*1.43*	1.51	*1.51*	1.57	*1.57*
River Road culvert, u/s	46.5	1.30	*1.30*	1.35	*1.35*	1.38	*1.38*

A more detailed survey of the area would establish the extent of the excavation required and the structural conditions at the railway bridge. Prior to undertaking this option, a geotechnical study would be required to identify the soils along the Canal and to establish stable cross-sections and bed profiles. Also, it is recommended to establish the local water table to ensure that during periods of high groundwater levels the capacity of the improved Canal section would not be compromised. This alternative is only viable with lowering of the bridge invert.

Option #3 would very likely involve impacting the valley wall as it would cut into or “shave” off some of the east embankment slopes to provide the required channel conveyance expansion, and would therefore require a detailed geotechnical investigation. Also, lowering of the channel at the bridge would involve additional bridge abutment works that when finished could raise the cost to be similar to the cost of constructing a new bridge.

It is estimated that the cost of this channel improvement would be in the order of $0.30 million, including survey, engineering, excavation and disposal, excluding structural works, if required. Both Options #2 and #3 could achieve relatively the same flood control results for nearly the same cost but there are more inherent long term slope failure risks for Option #3.

Conclusion. **Channel improvements downstream of Westview Drive and in the vicinity of the railway bridge is a feasible alternative and is recommended for further consideration, together with Option #2 as it would reduce the risk of flooding at the most vulnerable location.** However, before undertaking any channel improvements, consultation with the BNSF will be required to investigate any future plans for twinning the track and with DFO to review the environmental constraints and potential impacts on the local fishery before undertaking such remedial measures.

A second alternative of Option #3 was also considered but rejected. This second alternative could provide flood protection further downstream along the Canal and prevent flood waters spilling into the Bog, but a more extensive channel improvement program would be required over a distance of almost 2 kilometres length. This extended program would include an improved channel to retain low flows in a 1 m wide section, but it would increase the channel capacity by adding a 6.0 m wide floodplain bench and increase the total channel depth by constructing a containment berm with a 4.0 m top width downstream of the railway bridge. Sections of the channel exposed to frequent flows would be lined with riprap or equivalent bioengineering techniques to provide erosion protection. Other areas not subject to frequent inundation would be re-vegetated. The containment berm would reduce flooding over the Metro Vancouver service road and overflows into the Delta Nature Reserve and Burns Bog. In addition to the channel improvements this alternative could include the replacement of Terasen Gas Pipeline crossing and Metro Vancouver culverts with twin 2400 mm wide x 1500 mm high concrete box culverts constructed with fish baffles at each crossing with a minimum slope of 1% or an equivalent bridge opening.

The cost of this more extensive alternative is estimated to be approximately $1 million not including the cost of relocating the service road or any land costs. Although it could provide a hydraulically more efficient solution, the construction of these extensive channel improvements could create two significant environmental problems.

The first concern involves the significant disruption of the existing Canal section which is a important salmonid migratory habitat. Local channel improvements have been undertaken in the past by the BNSF near the railway bridge. The purpose of the improvement was to protect the tracks from flooding and sediment deposition using ecology blocks. The blocks were only partially successful as at times the company had to place the main track out of service. An alternative to improve the capacity of the Canal section was turned down due to the sensitive fish habitat. Transport Canada noted in the last inspection that they are not satisfied with the existing ecology blocks. This suggests that any works in the Canal which could disturb fish habitat may not be permitted.

The second concern involves the upsetting of the water balance in Burns Bog. By providing a more “efficient” conveyance system, the existing spilling of the Canal during high flows into the adjacent Bog would cease to exist.

Conclusion. **This second alternative of Option #3 is not recommended due to its high costs, its lack of providing flood protection further upstream along the Canal and railway tracks, and its potential adverse environmental impacts.**

4.1.4 Option #4 - Increased Storage Capacity

The existing storage capacity of the three major ponds draining a total of 448.2 ha catchment area is 46,413 m^3 (See **Table 2-5**), which represents only the equivalent of approximately 13 mm runoff. Option #4 proposes to increase pond storage capacities and reduce pond outlet discharges at three ponds in the upper Cougar Creek basin to reduce flows and velocities in Cougar Creek. There are only three ponds providing any significant flood attenuation in the catchment and they are located in upper Cougar Creek in the City of Surrey. The Delta part of the watershed has much less opportunity to provide new storage facilities. These ponds are the Cougar Park East Wetponds (north and south cells) in the BC Hydro ROW at 125th Street and 74th Avenue, the Cougar Creek Park Wetpond and the Drypond in the Kabaddi Park soccer field. To reduce the peak flows and velocities into Cougar Creek from these ponds, the storage capacity must also increase as outlet discharges increase. To test the effectiveness of this option, outlet discharge relationships for each were optimized on a conceptual basis to maximize the 1:100 year (Surrey flood criterion) 12-hour event water levels and to limit the active ponding depth to 1.5 m. The expansion designs do not include any forebay facility, although the expansion of the Cougar Creek Park wetpond could be considered as a new forebay upstream of the existing forebay.

Smaller dry ponds located in the Upper Cougar Creek catchment in Surrey provide some flow attenuation. The largest of these smaller ponds, located at 74th Avenue and 122A Street can be effective for attenuation of small rainfall events such as the 6-month 48-hour rainfall event. During the 1:10 year 48-hour rainfall event, the small dry pond east of Cougar Creek surcharges and during the 1:100 year 48-hour rainfall event, both ponds were surcharging as indicated by scenario tests in the model.

These small detention ponds were not found to have any beneficial reduction in flows when examining flows downstream of the Cougar Creek Park Wetpond. Peak flows were observed to increase marginally at this location due primarily to superposition of outflow hydrograph peaks and flow travel time and to the small catchment areas to the ponds relative to the overall catchment. There was also no opportunity to expand these ponds and thus these small ponds were not included further in the analysis.

The Cougar Creek Park Pond was assumed to expand into the area to the east and south of the existing soccer pitch where the existing creek channel currently runs (See **Figure 4-4**, **Figure 4-5** and **Figure 4-6**). These two ponds would be hydraulically connected by a submerged culvert under 122nd Street. The available space for wet pond construction was restricted in efforts to minimize impacts to the existing playing fields. The existing pathway to the north of the creek would require replacement. Design elevations were based on the existing pond. Stage-area-storage-discharge relationships for the existing facilities were derived from as-built drawings available from the City.

SCALE 1:1,500

0 12.5 25 50 75 100

Meters

DILLON CONSULTING

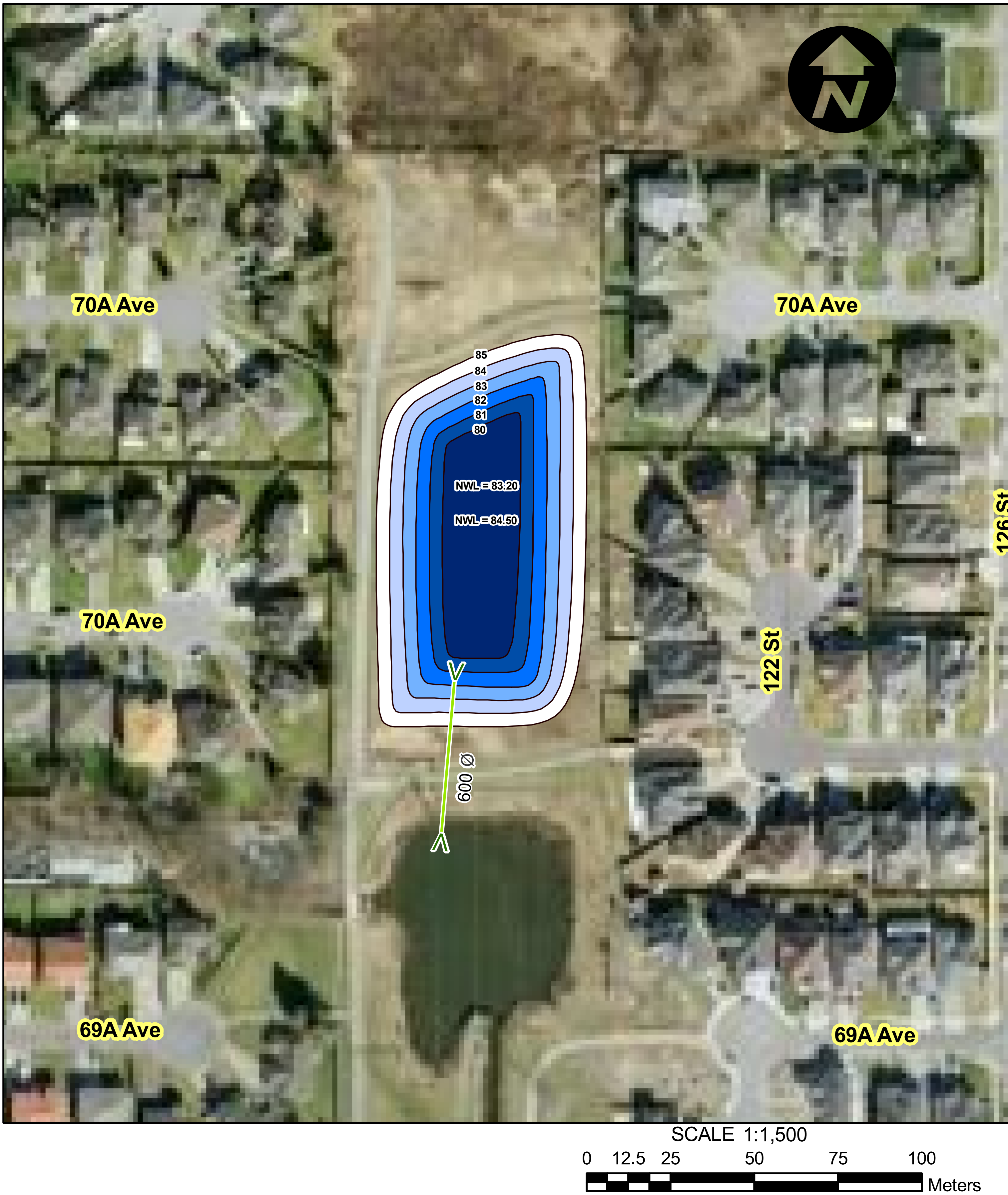
DATE JUNE 2009

PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN

TITLE COUGAR PARK POND

PROJECT NO. 06-6904

FIGURE NO. 4-4



DILLON CONSULTING

PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN		PROJECT NO. 06-6904
DATE JUNE 2009	TITLE COUGAR PARK EAST NORTH CELL EXPANSION	FIGURE NO. 4-5

DILLON CONSULTING

PROJECT

COUGAR CREEK
INTEGRATED STORMWATER MANAGEMENT PLAN

PROJECT NO.

06-6904

DATE

JUNE 2009

TITLE

COUGAR PARK EAST SOUTH CELL EXPANSION

FIGURE NO.

4-6

The expansion of the Cougar Park East Pond (BC Hydro ROW wet pond) was assumed to expand in both the north and south directions into the adjacent green spaces. The north cell expansion would require a separate cell due to the presence of a sanitary sewer line running east-west from 70th Avenue. These two cells would be hydraulically connected by a submerged pipe. Design elevations were based on the existing pond. The south cell expansion would expand into an existing dugout pond south of the south pond cell. This dugout does not appear to be hydraulically connected to the Cougar Park East pond.

Stage-area-storage-discharge relationships for the existing facilities were derived from “as-built” drawings available from the City. It is estimated that the combined storage at the ponds could be increased from the existing 46,000 m^3 to 93,000 m^3, which still represent only a 20 mm runoff from the upstream catchments. (See **Table 4-3).** For more details of the stage storage data see **Appendix C.** Reductions in flows from the Cougar Park East pond in the BC Hydro ROW would provide a further restriction in flows from the Cougar Creek Park wetpond since the two ponds act in series.

Expansion of the existing Cougar Creek East and Cougar Creek Park ponds would provide significant attenuation of Surrey’s total catchment area (363 ha) draining to these ponds. Expansion of the Cougar Creek Park pond would reduce unit area release rates from 17.7 L/s/ha to 8.4 L/s/ha and increase the unit area storage from 10.9 mm to 16.2 mm based on nearly doubling the storage capacity. Expansion of the Cougar Creek East ponds would reduce unit area release rates from 19.8 L/s/ha to 7.4 L/s/ha and increase the unit area storage from 22.1 mm to 42.5 mm based on nearly doubling the storage capacity. There is a small increase in release rates from the soccer dry pond due to reduced backwater effects downstream of the soccer pond outlet.

Table 4-3: Expansion of Storage Facilities

Name	Expanded Pond Storage Capacity m^3	Drainage area ha	Unit Area Storage mm	Unit Area Release Rate L/s/ha
Cougar Creek Park	44,862	328.92	19.6	8.4
Hydro ROW	36,308	85.35	42.5	7.4
Soccer Dry Pond	11,858	33.93	34.9	73.9
Total	**93,028**	**362.85**	**25.6**	

The cost of Option #4 is estimated to be approximately $1.7 million for the Cougar Creek Park pond expansion and $1.8 million for the East Cougar Park pond expansions for a total of $3.5 million. These estimates do not include the cost of land (if applicable) or any landscaping.

The potential benefits provided by the addition of stormwater storage are flood and erosion protection, and improved water quality downstream. **Table 4-4** presents the results of the computer simulation to predict the water levels with the assumed additional storage in place. When compared to existing conditions, the reduction in water levels is minimal downstream of the storage facilities. Downstream of Scott Road, reductions in velocities in Cougar Canyon are an average of 10% lower at the upper end of the Canyon with diminishing reductions at the lower end of the Canyon. At the Westview Drive and railway culverts which are the most flood vulnerable locations there are virtually no benefits to be gained by the additional storage.

Table 4-4: Simulated Flood Levels for Existing Conditions and with Option # 4

Location	Chainage	Existing	*Option 4*	Existing	*Option 4*	Existing	*Option 4*
		6-months	*6-months*	10-year	*10-year*	100-year	*100-year*
Cougar Creek	**m**	**Water surface elevations- m**					
Cougar Creek Pond, u/s	6012.7	71.07	*71.18*	71.26	*71.39*	71.37	*71.47*
Scott Road culvert, d/s	5764.4	70.12	*69.98*	70.39	*70.25*	70.53	*70.45*
Nicolson Road culvert, d/s	5623.4	69.84	*69.75*	70.01	*69.93*	70.08	*70.06*
Catchment boundary of D48/D47	4749.4	50.58	*50.54*	50.71	*50.69*	50.82	*50.81*
Catchment boundary of D50/D51	4198.4	27.16	*27.11*	27.44	*27.41*	27.69	*27.67*
Canal							
Westview Drive culvert, d/s	3317	7.33	*7.29*	7.6	*7.57*	7.82	*7.81*
	3282.5	7.19	*7.15*	7.38	*7.36*	7.55	*7.53*
BNSF crossing inlet, u/s	3075.1	6.04	*5.96*	6.51	*6.46*	6.90	*6.89*
	2888.3	5.61	*5.55*	5.95	*5.92*	6.13	*6.13*
Terasen pipeline culvert, u/s	760.2	2.46	*2.46*	2.51	*2.51*	2.52	*2.52*

To analyze the potential benefits in reducing erosion, the continuous model was run for all the observed rainfall events in 2003. **Figure 4-7** and **Figure 4-8** show the simulated velocity-duration graphs for existing conditions and with the increased pond storage in place for two locations along Cougar Creek. The velocity plots were limited to velocities of 1 m/s or higher, as this value has been assumed as the erosion threshold velocity when erosion begins. Both graphs illustrate that in 2003 only 0.2% of the time (approximately 14 hours) did the velocity exceed the threshold value in the Canyon at chainage 4749.4 m, while further downstream only 0.1 % of the time (7 hours) was the 1 m/s velocity exceeded. The analysis also confirmed that in order to control the very high flows, the ponds would store the runoff volume and release it later but at an increased rate of flow.

Figure 4-7: Velocity-Duration at Alpine Place

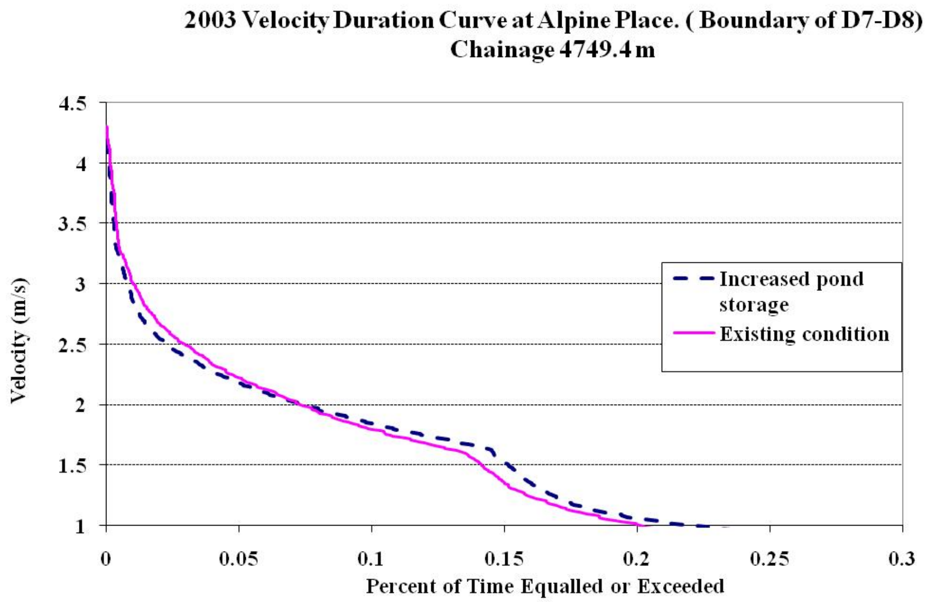
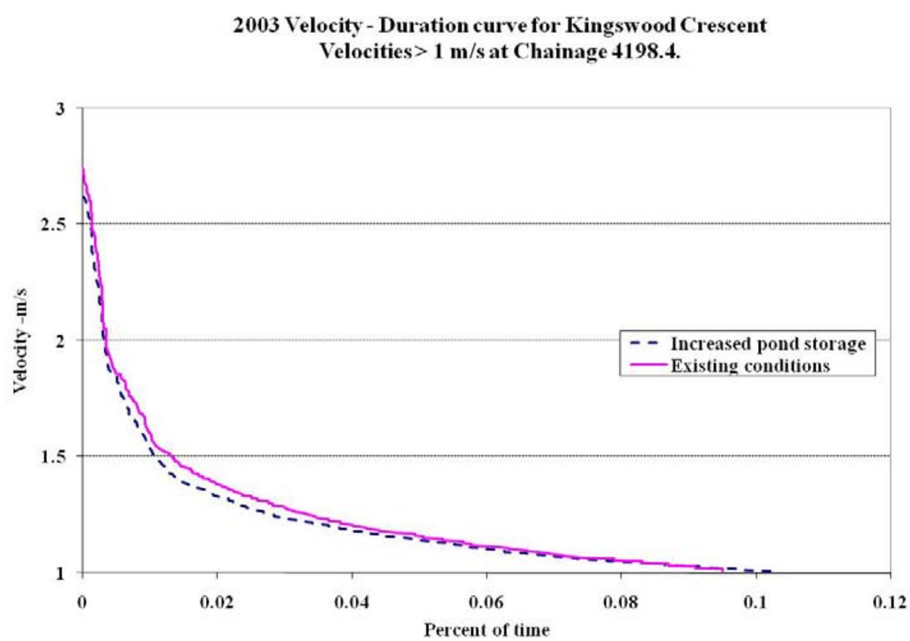


Figure 4-8: Velocity-Duration at Kingswood Crescent



Finally, the water quality benefits predicted from increased storage is shown in **Table 4-5** based on the annual loading estimates reported in Chapter 3.7, Water Quality Assessment. The analysis assumed a long-term land use alternative with runoff control at all residential areas capable to reduce the annual load by 50%, a scenario far in excess of the limited increase in storage facility assumed in Option # 4.

Table 4-5: Annual Pollutant Load Estimates at the Canal Outlet to the Fraser River

Land use conditions	Annual loads in a typical year - tonnes			Annual runoff in a typical year
	TSS	TP	Zn	Million m^3
Pre-urban (1940)	64.46	0.68	0.08	3.3
Existing conditions	425.23	2.49	1.34	10.8
With additional storage	351.71	2.01	1.14	10.8
With LID concept	275	1.54	0.9	7.3

Even with the assumed runoff controls at all urban developments, the effect of the storage on the total annual pollutant loads would be very limited, showing a reduction of 15% to 20% compared to existing conditions. It is important to point out that the installation of storage facilities would not reduce the total annual runoff, unless accompanied by infiltration facilities introduced under a future LID land use concept.

Conclusion. The increase in upstream storage capability in the Cougar Creek watershed would provide only limited flood, erosion and water quality control benefits, for an estimated cost of $3.5 million. The reduced flood peaks released by the combined storage would not benefit the flood vulnerable areas located well downstream on the Canal. Similarly, the erosion vulnerable reaches in the Cougar Creek and Cougar Canyon would receive only a minimal relief in velocity reduction from the additional storage. Any local erosion protection work would be able to provide a better protection for a fraction of the cost. The provision of the additional storage could provide some minimal additional opportunities for passive recreation around the facility, but could further increase the summer water temperature in the pond.

Based on the limited benefits and the high cost, Option #4 is not recommended as a short-term solution. In the long term, when more of the existing developments become re-developed, the introduction of infiltration facilities with stormwater ponds should be re-examined.

4.1.5 Option #5 - Berming the Canal Banks

Both existing and future condition modelling scenarios showed frequent overtopping of the Canal. By constructing a berm on the west side of the Canal, the spilling of floodwaters could be stopped. Raising the embankment by approximately 1 m could prevent the spill. All construction would be outside the Canal and therefore fish habitat would not be affected. However, the future water balance of the Nature Reserve and the Burns Bog would be altered. Another important drawback of this alternative is that it will not provide any flood relief upstream near Westview Drive and at the flood vulnerable railway tracks. The potential benefit provided by the berm would be very limited but the environmental damages could be significant.

The Burns Bog Conservation Society (BBCS) expressed a number of concerns, primarily related to the Burns Bog/Northeast Interceptor Canal interface. Of primary concern is maintaining the Bog ecosystem in its current state as much as possible. In order to accomplish this, the relatively low nutrient input regime should be maintained in its current state. Nutrient rich waters discharging from the Canal during flood events could alter the Bog ecosystem and should be minimized. At the same time however, too much restriction of the flow into the Bog could lead to a reduction in the water level to the detriment of the bog. According to the BBCS maintaining the spillover at its current rate is the most prudent approach given that the current ecosystem has adapted to existing conditions.

Conclusion. **Option # 5 is not recommended due to lack of flood control benefits and the potential harmful effects it may have on Burns Bog.**

4.1.6 Option #6 - Changes in Land Use Development Plans (LID)

Option # 6 proposes to implement low impact development (LID) techniques to provide source control throughout the catchment to reduce the amount of runoff at the source for both new, existing, and redevelopment areas.

This would be accomplished by:

- reducing the development's effective or directly connected impervious area;
- better site design of new subdivision developments to optimize road layouts and reduce overall pavement and impervious surfaces;
- reducing the amount of runoff ultimately generated that would drain to end-of-pipe stormwater management facilities;
- capturing and reusing some of the runoff at the source for irrigation and grey-water uses;
- treating some of the runoff by infiltrating into the soil, interception by vegetation, evapotranspiration and/or evaporation back into the atmosphere in shallow depression storage areas; and
- Stormwater source control would also help to restore natural hydrologic functions such as infiltration, interception, evapotranspiration, and depression storage that can be distributed through the site.

To analyse the effect of LID on the runoff, two different scenarios were modelled. The first one, Option #6a was based on the recommendations in the B.C. Stormwater Planning Guidebook (2002) to adopt a three-tier management approach (Tiers A, B and C) to manage stormwater for a wide spectrum of rainfall events relative to the mean annual rainfall (MAR).

<u>Option 6a</u>

The three Tiers recommended in the MOE Guidebook are:

Tier A: to reduce the runoff volume by capturing the small, frequent storm events using on-lot or on-street source control facilities to return rainfall to natural hydrologic pathways.

Tier B: to control and reduce the rate of runoff discharging into natural drainage systems released at a rate that mimics natural rates. Tier B events in an urbanized basin generate the majority of significant flows in watercourses that are responsible for accelerating the channel morphological changes due to the increased frequency and magnitude of runoff from large storm events. Tier B events can be controlled by increasing the amount of source controls above the Tier A rainfall capture target or by runoff flow controls such as detention pond and wetland facilities.

Tier C: to provide flood risk management by safely containing and conveying stormwater from extreme storms up to the 100-year event to reduce risks to public safety and property by ensuring there is adequate overland flow and conveyance capacity.

Management of Tier A events requires rainfall capture by source control methods. Tier B can also be accomplished by source control measures by capturing rainfall volumes greater than the Tier A rainfall capture target.

These measures include permeable pavement or other structural landscape areas, absorbent landscapes, providing rain barrels and cisterns, green roofs, rain gardens/bioretention areas, infiltration basins and infiltration trenches. A wide range of literature and information on LIDs and Stormwater Source Controls is publicly available; some more relevant ones are listed in the References.

For Tier A rainfall management, a rainfall capture target for source control is recommended to be 50% of MAR since approximately 90% of all rainfall events are less than 50% of the MAR. The MAR can be approximated with the 24-hour 2-year rainfall event. The 24-hour 2-year rainfall event for the catchment is just under 60 mm and 50% of this value is 30 mm. Based on the above, the target source control capture of 30 mm will need to be either infiltrated or captured by the implementation of source control LID measures. For Tier B events, the recommended goal is to detain the additional rainfall volume up to the MAR, or in this case, up to an additional 30 mm.

The actual implementation would be achieved over the long run as the area redevelops and new developments meet stormwater management goals as outlined in the Stormwater Planning guidebook (MOE 2002).

For example, the City of Chilliwack has set source volume control targets for both Tier A and Tier B events. For Tier A control, 60 mm of rainfall, or the MAR, would be captured on pervious areas (such as green spaces) and 30 mm would be captured on impervious areas (lots, roads, etc). For Tier B, the next 30 mm of rainfall would be captured on pervious areas and in impervious areas, sufficient storage provided to detain runoff, and released at a rate replicating natural rates.

For the source control target of 30 mm from impervious areas, all roof tops from residential areas would need to be directed to infiltration chambers or infiltration trenches sized with a capture volume equivalent to the total roof area multiplied by the design depth of the infiltration facility.

Incorporating a rain barrel program for rainwater harvesting and re-use under LID could also help reduce runoff. Driveway pavements should be converted to permeable pavers or other structurally supportive permeable surfaces. Road-side swales or subsurface perforated sewer pipes and dry wells should be used to infiltrate road drainage.

For commercial and industrial areas, intensive green roof systems could be used. Where this is not possible, runoff from roof areas should be directed to cisterns for water re-use or infiltrated in infiltration trenches, bioretention swales, and absorbent landscapes. Runoff from parking lots could also be directed to infiltration trenches, bioretention swales, and absorbent landscapes. Paved areas that are not subject to heavy traffic could be using permeable pavers.

Infiltrating source controls from paved areas in industrial areas would require case-by-case assessments based on the intensity and type of industrial activity to prevent groundwater contamination.

Two scenarios were explored that varied the degree of implementation of source control LIDs to examine the impact on flows and water levels in the Canal. The first scenario assumes that the depression storage for approximately 30% of the Cougar Creek catchment is increased by 30 mm representing the total source control volume captured in LIDs over the catchment for the impervious portions of the catchment and by 60 mm for the pervious undeveloped portions of the catchment such as parks.

The source control methodology for Option #6a proposes to follow Chilliwack's guideline of source control capture of 30 mm on developed areas and source control capture of 60 mm on undeveloped areas (where possible). For the source control target of 60 mm on pervious undeveloped areas, an absorbent soil layer of 300 mm was assumed with a void ratio of 0.2. Since most of the Cougar Creek catchment is developed, a staged or tiered approach would be required in implementing source control LIDs since affecting change over 30% of the watershed will take time.

The second alternative modelled under Option #6a is a more pragmatic level of what extent source control LIDs could be implemented within the foreseeable future in the catchment (*i.e.*, next 50 years) for new and redevelopment projects. This second alternative assumes that the depression storage for approximately 15% of the Cougar Creek catchment is increased by 30 mm representing the total source control volume captured in LIDs over the catchment for the impervious portions of the catchment and by 60 mm for the pervious undeveloped portions of the catchment.

In either scenario, it is recommended that the following measures should be considered for residential, commercial, and industrial land use areas for new and redevelopment areas:

1. Infiltration trench or chamber - Impervious areas such as residential roof tops would be directed to an equivalent in-ground infiltration trench that would equate to 30 mm over the catchment. An underground infiltration chamber facility could provide more storage with a smaller footprint;
2. Bioretention facilities - should have a minimum facility depth of 500 mm and a surface ponding depth of 150 mm (where possible). Bioretention roadside swales should have rock check dam structures to lessen slopes and promote infiltration;
3. Green roof - should have an absorbent layer thickness of 300 mm;
4. Permeable pavers - would require a reservoir base course sized to capture a minimum of 30 mm of rainfall;
5. Absorbent landscaping in the form of an amended soil mix would require a minimum thickness of 300 mm over the pervious portion of the lot; and

6. Rainwater harvesting using rain barrels and cisterns for non-potable re-use using a target of 300 m^3 of storage per hectare of roof coverage.

LID source control measures should follow design guidelines as outlined in the GVRD's "Stormwater Source Control Design Guidelines" (GVRD, 2005) referencing the appropriate measure and site specific conditions (*e.g.*, grading/slope, dimensions, soils, groundwater and bedrock presence, dimensions, catchment area suitability, etc.). For instance, bioretention areas could be positioned in steeper areas of up to 5% to 10% (GVRD, 2005) if properly terraced.

Table 4-6 presents the results of the 15% and 30% increases in depression storage scenarios for the 6-months and 100-year flood events. The computer predicted very small reduction in flood levels.

Table 4-6: Comparison of 6-months and 100-year Water Elevations with Increases in Depression Storage in 15% and 30% of the Watershed

Location	Chainage	Existing	*15%*	*30%*	Existing	*15%*	*30%*
		6-months	*6-months*	*6-months*	100-year	*100-year*	*100-year*
Cougar Creek	**m**	**Water surface elevations- m**					
Cougar Creek Pond, u/s	6012.7	71.07	*71.06*	*71.03*	71.37	*71.37*	*71.34*
Scott Road culvert, d/s	5764.4	70.12	*70.11*	*70.09*	70.53	*70.51*	*70.49*
Nicolson Road culvert, d/s	5623.4	69.84	*69.83*	*69.82*	70.08	*70.08*	*70.06*
Catchment boundary of D48/D47	4749.4	50.58	*50.58*	*50.57*	50.82	*50.81*	*50.80*
Catchment boundary of D50/D51	4198.4	27.16	*27.16*	*27.14*	27.69	*27.67*	*27.63*
Canal							
Westview Drive culvert, d/s	3317	7.33	*7.33*	*7.31*	7.82	*7.80*	*7.77*
	3282.5	7.19	*7.19*	*7.18*	7.55	*7.53*	*7.50*
BNSF crossing inlet, u/s	3075.1	6.04	*6.03*	*6.00*	6.9	*6.89*	*6.89*
	2888.3	5.61	*5.60*	*5.58*	6.13	*6.13*	*6.13*
Terasen pipeline culvert, u/s	760.2	2.46	*2.46*	*2.43*	2.52	*2.52*	*2.52*
	642.4	2.05	*2.05*	*2.02*	2.22	*2.22*	*2.22*
Metro Vancouver culvert, u/s	517.7	2.03	*2.02*	*2.00*	2.2	*2.20*	*2.20*
Steel lined canal, u/s	269.1	1.53	*1.53*	*1.52*	1.67	*1.67*	*1.66*
Twin box culvert, u/s	222.3	1.40	*1.40*	*1.38*	1.54	*1.54*	*1.53*
River Road culvert, u/s	46.5	1.24	*1.24*	*1.23*	1.33	*1.33*	*1.32*

A comparison of the runoff volumes between existing conditions and with the two scenarios tested also showed a small reduction, similar to the changes in water levels.

Option 6b

The second scenario considered in Option #6 (#6b) investigated the effect of reducing the total directly-connected impervious area (DCIA) through various measures including directing downspouts from single family and multifamily developments onto landscaped areas, and directing sheet flow runoff onto green spaces, and/or bioretention rain gardens and rain barrels. The amount of reduction in DCIA would also depend on the available green space in the lots. Higher density developments such as row town homes and small single-family lots in high density subdivisions would have limited opportunity to redirect existing roofs and paved areas to landscaped areas to be effective at reducing DCIA.

The amount of DCIA reduction in the catchment is dependant on the actions of individual landowners and developers and would require policy of enforcement and/or incentives. For new developments, some form of policy or financial incentive would be required to gear development design to minimize the direct connection of impervious areas to the drainage collection system (*e.g.,* ditches, storm sewers, and street curbs leading to catchbasins). Redevelopment projects should be required to have a DCIA of the lot reduced by 50% of the previous site's DCIA. Existing developments should be given a financial incentive to reduce their DCIA such as tiered sewer utility rates as a function of DCIA area. However, this would require a comprehensive GIS analysis of all lots and cataloguing and incorporating this into the property assessments database system.

A reasonable long-term goal might be to have a total catchment reduction of 20% to 30% of the total impervious area. The DCIA for road areas was not assumed to be reduced although some retrofit opportunities may exist in some portions of the catchment to reduce the total paved surface area in large existing cul-de-sacs. Commercial and industrial areas comprise a smaller proportion of the total catchment and would see limited retrofitting opportunities. Some parking spaces in commercial areas that are seldom used could be converted to pervious pavers with a reservoir base course and a modest reduction of 5% in DCIA was assumed.

It is unknown what percentage of the impervious land in the catchment is directly connected. For the purposes of this assessment, a 10% to 15% reduction of directly connected impervious area was assumed to be feasible depending on the various land uses. However, additional reduction may be feasible but would require a thorough assessment and inventory of existing downspout connections. **Table 4-7** lists the impervious values used to represent reduced DCIA.

Table 4-7: Reduction in Representative Impervious Ratios

Land Use Classification	Reduction	Reduced Impervious Ratio
Single-Family/Urban	0.15	0.45
Multi-Family	0.10	0.55
Suburban	0.10	0.30
Commercial	0.05	0.85

Higher reduction of impervious ratios may be a possibility but would likely be an ideal solution rather than reflecting reality as technical implementation issues and public acceptance factor into the success of such a program.

Since the majority of the existing watershed is already developed, the opportunities for reducing DCIA are limited. For new developments, imposing low DCIA requirements on the limited number of possible sites and the small overall relative area of greenfield development locations within the catchment would not significantly affect the overall catchment DCIA.

For existing land uses, it is unlikely that all roof downspouts can be retrofitted or redirected to drain to green spaces, rain gardens, and rain barrels; additionally, there is a limited capacity for storing and infiltrating runoff. Driveways and walkways draining to the stormwater collection system could be retrofitted with interceptor cross-slope drains to direct runoff to green spaces. Alternatively, permeable pavers and pavements or reducing driveway widths to driving strips could be retrofitted into existing sites or be implemented in redevelopment projects. A rain barrel sales program for residential homes would be effective at reducing 15 to 30% of DCIA from individual residential lots. Homeowner acceptance/participation would moderate that overall reduction in DCIA.

Larger existing roofs can be retrofitted to green roofs but would be an expensive undertaking and would likely require structural improvements to the building should such an undertaking be carried out for a roof replacement. Green roofs would be much easier to be incorporated in a new redevelopment project.

In the analysis it was assumed that the overall percent impervious for the Delta portion of Cougar Creek would be reduced to 52.8% from the existing value of 60.4% and the Surrey portion of Cougar Creek would be reduced to 47.2% from the existing value of 58.9%. **Table 4-8** shows the estimated water elevations for existing conditions for Option 6b.

Table 4-8: Estimated Water Elevations for Existing Conditions and for Reduced Directly Connected Impervious Areas

Location	Chainage	Existing	*Option*	Existing	*Option*	Existing	*Option*
		6-months	*6-months*	10-year	*10-year*	100-year	*100-year*
Cougar Creek	**m**	**Water surface elevations - m**					
Cougar Creek Pond, u/s	6012.7	71.07	*70.95*	71.26	*71.2*	71.37	*71.36*
Scott Road culvert, d/s	5764.4	70.12	*70.05*	70.39	*70.34*	70.53	*70.5*
Nicholson Road culvert, d/s	5623.4	69.84	*69.79*	70.01	*69.97*	70.08	*70.06*
Catchment boundary of D48/D47	4749.4	50.58	*50.55*	50.71	*50.69*	50.82	*50.79*
Catchment boundary of D50/D51	4198.4	27.16	*27.11*	27.44	*27.38*	27.69	*27.63*
Canal							
Westview Drive culvert, d/s	3317	7.33	*7.28*	7.60	*7.54*	7.82	*7.77*
	3282.5	7.19	*7.15*	7.38	*7.34*	7.55	*7.50*
BNSF crossing inlet, u/s	3075.1	6.04	*5.95*	6.51	*6.41*	6.9	*6.88*
	2888.3	5.61	*5.53*	5.95	*5.89*	6.13	*6.12*

Location	Chainage	Existing 6-months	*Option 6-months*	Existing 10-year	*Option 10-year*	Existing 100-year	*Option 100-year*
Terasen pipeline culvert, u/s	760.2	2.46	*2.43*	2.51	*2.5*	2.52	*2.52*
	642.4	2.05	*2.02*	2.19	*2.16*	2.22	*2.22*
Metro Vancouver culvert, u/s	517.7	2.03	*2 .00*	2.17	*2.14*	2.20	*2.20*
Steel lined canal, u/s	269.1	1.53	*1.52*	1.62	*1.60*	1.67	*1.66*
Twin box culvert, u/s	222.3	1.40	*1.38*	1.48	*1.46*	1.54	*1.53*
River Road culvert, u/s	46.5	1.24	*1.24*	1.29	*1.28*	1.33	*1.32*

A comparison of runoff volumes also showed similar results of small reduction in volumes between existing conditions and with the reduced directly connected impervious area scenario.

Conclusion. **It is recommended to adopt the LID concept using the Three Tier management approach and the reduction of the indirectly connected impermeable area at the time of future developments and re-developments, therefore this option is more suitable as a long-term solution.**

As the concept is centred on capturing the more frequent runoff events, Option 6a is not effective to control higher flows, velocities and the resulting erosion caused by the more infrequent events. The LID concept is more effective in controlling runoff from the more frequent events. Option 6b, based on the reduction of directly connected impervious areas on its own is ineffective, therefore this approach is only recommended if formed as part of a future LID development plan.

4.1.7 Option #7 - Increase in Tree Canopy

Awareness of the benefits of increasing tree canopy cover in an urban setting has been growing in recent years. Many studies (City of North Vancouver 2004; CMHC 2007) have described the cost-benefit of urban forestry on stormwater runoff reduction as well as other net benefits (*i.e.*, reduced energy use, improved air quality, increased CO_2 capture, and aesthetic & socio-economic benefits). Various studies have indicated that total interception values estimated for trees in a variety of cities have ranged from 500 L to 5000 L annually per typical large street tree. Studies have shown that broadleaf evergreens and conifers intercept more than deciduous where winter precipitation patterns are dominant (CNV 2004). Xiao et al. (1998) estimated that only 2% of annual rainfall in Sacramento’s urban forest was intercepted due to the winter rainfall pattern observed and the predominance of non-evergreen trees.

Xiao et al. (1998) indicates that for flood event analyses (2-year to 200-year) of an urban forest, leaf-off interception estimates varied from 2.4% to 9.9% (1.5 mm to 1.9 mm) of observed precipitation events while leaf-on interception was 4.9% to 19.7% (2.6 mm to 3.6 mm). Spittlehouse (1998) indicates that based on three sites in BC that had predominantly spruce, fir, hemlock, and pine over a range of elevations, the average interception was between 4 mm for low canopy density forests and up to 10 to 15 mm for young coastal forests. The CHMC study (2007) indicates that two Canadian studies have shown that interception ranges from 2 mm to 8 mm depending on the tree type. Based on a literature review completed for Toronto, an increase in tree canopy from 25% to 50% could result in an average potential reduction in annual runoff between 10%-20%.

The City of Seattle has estimated that its overall urban forest canopy cover is approximately 18% with a goal of increasing that amount to 30%. Seattle is planning to plant over 649,000 trees over 30 years at a cost of $114 million (or $175/tree) plus annual maintenance costs.

Portland has an overall canopy cover of 26% with a goal of increasing that to 47% for residential areas and 12% for industrial/commercial areas. American Forests (2007) recommend guidelines for tree canopy cover goals for urban catchments of 25% to 60% impervious area with a recommended goal of 40%.

Without an analysis of existing canopy cover in the Surrey and Delta portions of the Cougar Creek catchment, it is assumed that the current overall canopy cover for the entire catchment based on a cursory review is approximately 20%. Based on the above, using an assumed canopy cover target of 30% and an average interception value of 3 mm, approximately 3600 m^3 of additional rainfall per storm event could be intercepted over the 1192 ha catchment. This roughly translates to 0.3 mm over the entire developed catchment and is represented as an increase in depression storage for both the impervious and pervious areas of 2.8 mm and 6.3 mm, respectively.

Based on the above and assuming that the trees planted have a target crown diameter of 5 m, it is estimated that approximately 60,800 trees would be required to increase the canopy cover in the catchment by 10%. Costs will vary depending on the tree, location, and size of tree planted. Using an assumed average cost of $200 for purchasing, planting, staking, and mulching for a 5 cm calliper coniferous tree, the total cost would be $12,142,000, excluding annual maintenance costs. Using a target crown diameter of 10 m the number of trees for a 10% canopy cover increase would be reduced to 15,200 and the total cost thus reduces to $3,036,000, excluding annual maintenance costs. Planting younger trees would significantly reduce costs but would not see any significant benefits until further into the future (>10 years).

One concern regarding tree coverage was expressed by the Burns Bog Conservation Society (BBCS) on the presence of trees within Burns Bog. Trees tend to shade the peat moss critical to the Bog ecosystem and reduce or prevent its establishment. Dead trees tend to discharge nutrients as they decompose. Removal of these trees is seen by the BBCS as providing a benefit to the ecosystem of the Bog. However, it is important to recognize the values of trees, particularly along the eastern edge of the Bog, as they can intercept nutrient rich flood water from the Canal and prevent its discharge to the Bog. There is a recognition by stakeholders that a difficult balance must be achieved.

Conclusion. **Option #7 is expensive and would provide only modest stormwater benefits. However, it is recommended that the municipalities should prepare a long-term tree planting program (approximate cost $10,000), which could assist in the control of stormwater quantity, quality, air quality and would provide visual benefits as well to local residents.**

4.1.8 Option #8 - Erosion Protection

Protection of erosion sites appears to have a low priority, except in cases where there is a risk of structural failure or blockage of a creek channel. Potential unstable sections along Cougar Creek have been identified in Chapter 2.3.2, **Table 2-4**. The two sections which showed the most advanced state of undercutting were i) #7, adjacent to Ridgewood Place, and ii) # 13, adjacent to Canyon Crescent.

There are several erosion protection measures that can be applied locally within Cougar Creek that could provide alternatives to, or supplementation of, the flood control alternatives reviewed.

- Bioengineering for toe-of-slope protection: “Softening” of traditional hard engineering solutions can include the cabling of woody debris within the wetted perimeter of the channel, dressing hard solutions with topsoil or “riprap grout” to provide a planting medium, and the creation of “eco-pockets” of soil;
- “Green wall” technology: Green walls include such products as “Deltalok”, “Filtrexx” and “Sierrascape”, which have a planting medium placed within which provides a medium for grass and other vegetation. “Sierrascape” walls would be particularly effective in high erosion zones. These grass walls can be supplemented with live-stakes of willow or red-osier dogwood to enhance the vegetative component; and
- Monitoring: Rather than provide any erosion protection measures, monitoring of potentially problematic sites could be initiated. Monitoring may indicate that protective measures may not be required in the short-term which would allow the City or Corporation to direct funds to areas of the watershed where the implementation of remedial works were more pressing.

In most cases these cost estimates are only order of magnitude estimates as a more detailed site-specific investigation would be required to determine the most appropriate approach and level of effort required.

For erosion sites we have assumed an average cost of $25,000 each to provide bank protection over a small area. Some sites with more difficult access or requiring more extensive treatment will be subject to higher costs.

In addition to flood control and erosion protection, channel reaches have been identified as being particularly deficient in base flow during dry periods.

It is estimated that the combined cost of undertaking a remedial measure at the two sites would be in the order of $50,000, including a more detailed site assessment, but excluding any potential land costs.

Conclusion. **It is recommended that a Design Brief be prepared for the two sites by a qualified soil mechanic expert to investigate the most effective erosion protection method, land requirement and construction costs, before undertaking the project.**

4.1.9 Option #9 - Provide Additional Flood Storage at the Bog

This option was suggested during our stakeholders meeting. The environmental disadvantages described in Options #3 and #5 above far outweigh the limited flood control benefits downstream of the Bog.

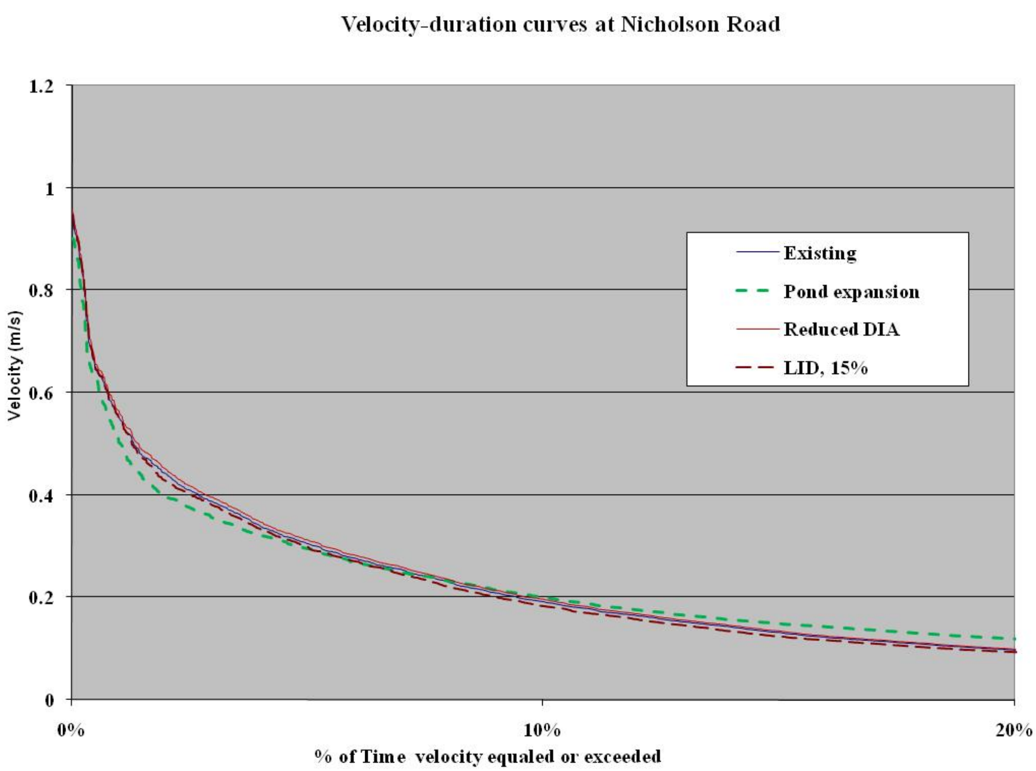
Conclusion. **Option #9 is not recommended.**

4.1.10 Velocity Reduction and Changes in Water Balance

A review of the single event and continuous modelling identified the effectiveness of various alternatives modelled. In addition to the above analyses of the nine options, velocity reduction and changes in water balance were compared.

Velocity reduction by the alternatives modelled showed minimal changes. **Figure 4-9** compares the velocity-duration distribution at Nicholson Road for existing conditions and for three different management alternatives.

Figure 4-9: Velocity-Duration Curves for Different Management Alternatives at Nicholson Road



The effectiveness of the alternatives can also be illustrated by reviewing the annual water balance components. **Table 4-9** illustrates the water balance (in mm) for 2003 as predicted by the continuous model for the Nicholson Road location. While the pond expansion alternative would result in the same total runoff volume assuming a future land use scenario, reduced DIA or the adoption of LID measures would be able to reduce the total runoff to a varying degree.

Table 4-9: Water Balance Components at Nicholson Road for Different Management Scenarios

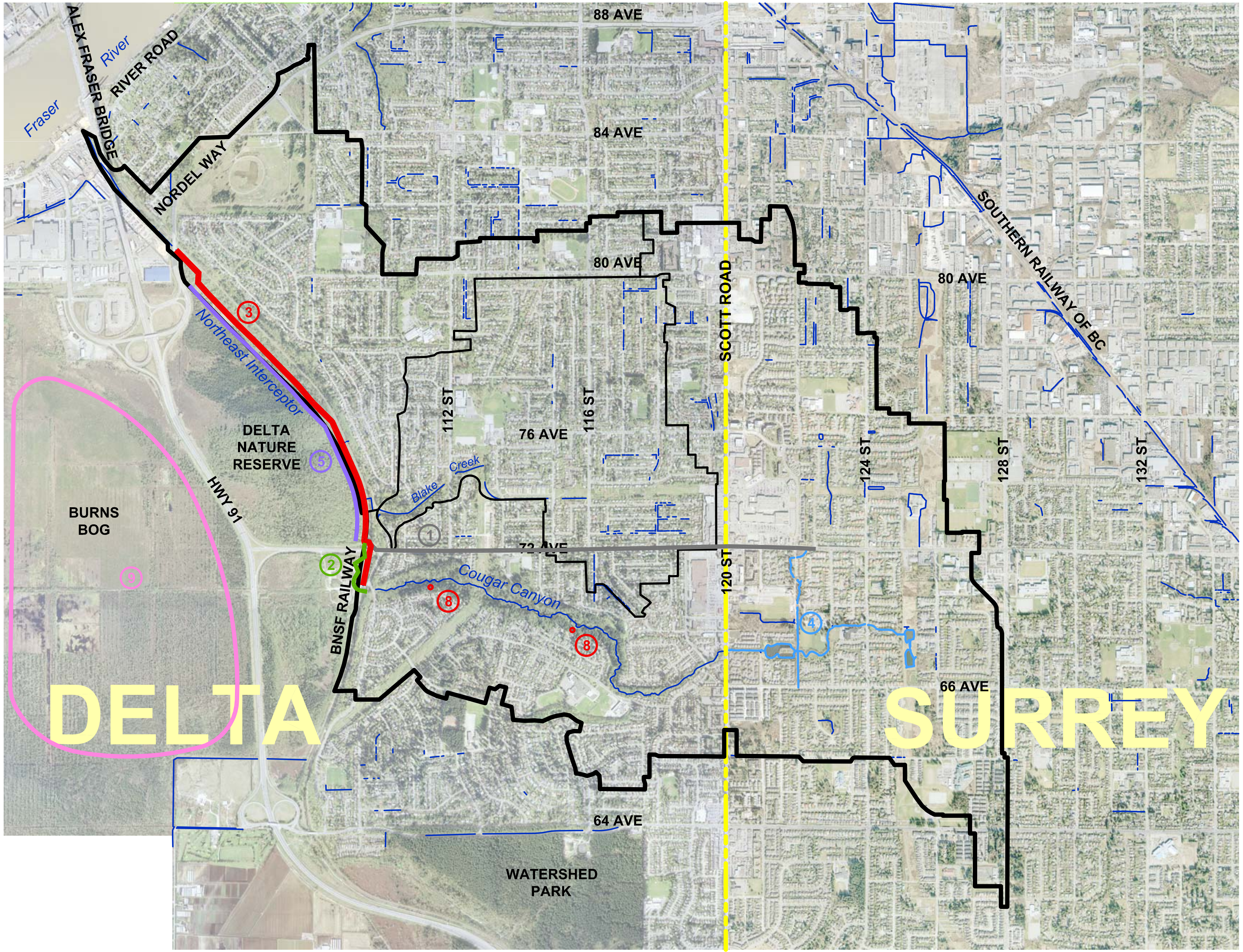
Component	Existing land use (mm)	Future land use (mm)	Option #4 pond expansion (mm)	Option #6 reduced DIA (mm)	Option #6 LID, 30% (mm)	Option #6 LID, 15% (mm)
Precipitation	1078	1078	1078	1078	1078	1078
Runoff	527	551	551	448	461	502
Evaporation	137	141	141	123	183	160
Infiltration	413	384	384	506	404	413

4.2 Summary of Alternative Remedial Measures

Table 4-10 summarizes the various alternative remedial measures shown on **Figure 4.10**. Generally, the alternatives had limited capacity to reduce the flood levels in the short term below existing conditions.

Table 4-10: Alternative Remedial Measures

#	Alternative	Advantages	Disadvantages	Applicability	Comment
1	Diversion of urban drainage	Can bypass flood and erosion vulnerable areas	Expensive. May require substantial land. Potential increase in flows, erosion risk downstream	Applicable for underground sewers. No space for open channel, only for relief sewer	Not recommended Cost $8.2 million
2	Relief open channel	Can bypass flood and erosion vulnerable areas	May require substantial land. Potential increase in flows, erosion risk downstream of outlet	Space may be available at the outlet of Cougar creek	Potential short term alternative. Cost $0.4 million, or
3	Channel improvements	Minimum land requirements. Provides stable channel, reduces flooding, erosion and sedimentation	Usually benefits only local conditions	Applicable for both Cougar Creek and NEIC	Potential short term alternative. Cost $0.3 million
4	Increased storage capacity	Could be multi-purpose for flood, water quality and erosion control	Expensive, effective only if capturing larger drainage area	Have limited application by retrofitting existing facilities and may require expensive land	Potential long term alternative. Cost $3.5 million
5	Berming the Canal banks	Low initial cost. May not affect fish habitat.	Increase in flood levels if flood plain decreased, space requirement could be an issue, water balance of Bog could be adversely affected	Limited to NEIC area	Not recommended
6	Changes in land use development plans (LID)	Can reduce directly connected impermeable areas, and may provide dense vegetation cover	Not effective in the short term. Require more research to determine long term effects	Not applicable in the short term	Recommended long term alternative
7	Increase tree canopy cover	Reduction in runoff, increase in infiltration	Not very effective	Not recommended on its own	Potential long term alternative. Prepare long-term tree plantation plan. Cost $ 10,000
8	Erosion protection	Minimum land requirements. Provides stable channel, reduces erosion and sedimentation	Usually benefits only local conditions	Applicable to existing erosion prone sites	Recommended short term alternative Cost $50,000
9	Provide additional flood storage at the Bog	May improve water quality discharge downstream into Fraser River	May damage local environment. Will not provide any benefit to upstream flood, and erosion risk areas	Not recommended unless an environmental assessment is completed before considering this alternative	Not recommended



SOURCES: CORPORATION OF DELTA AND THE CITY OF SURREY

APPROXIMATE SCALE 1:25,000

0 250 750 1250m

LEGEND

- WATERSHED
- WATERSHED (SUBDIVIDED)
- DELTA/ SURREY BORDER
- WATERCOURSES (CREEKS/ PONDS/ DITCHES)

SUMMARY OF REMEDIAL ALTERNATIVES

#	Alternative	Comment
1	Diversion of urban drainage	Not recommended
2	Relief open channel, $0.5 Million	Potential short term alternative
3	Channel improvements, $0.3 Million	Potential short term alternative
4	Increased storage capacity	Potential long term alternative
5	Berming the Canal banks	Not recommended
6	Changes in land use development plans (LID)	Recommended long term alternative
7	Increase tree canopy cover	Potential long term alternative
8	Erosion protection Cost $50,000	Recommended short term alternative at Sites # 7 and 13.
9	Provide additional flood storage at the Bog	Not recommended unless an environmental assessment is completed before selecting this alternative

DILLON CONSULTING

DATE JUNE 2009

PROJECT COUGAR CREEK INTEGRATED STORMWATER MANAGEMENT PLAN

TITLE SUMMARY OF REMEDIAL MEASURES

PROJECT NO. 06-6904

FIGURE NO. 4-10

FileName:g:\cad\06690406904-figures-option-summary.dwg

5.0 RECOMMENDED ISMP

Following a review of remedial measures and the selection of the three recommended short term alternatives in Chapter 4, this chapter presents a detailed description of the Integrated Stormwater Management Plan. An outline of the proposed Plan including relevant chapter numbers is presented on **Figure 5-1.**

5.1 Target Setting

A review of existing conditions in the Cougar Creek/NEIC watershed clearly indicated that the majority of the watershed is already heavily urbanized. The resulting increase in stormwater runoff, erosion/sedimentation and the reduction in water quality has deteriorated the conditions in the watercourses and will continue to do so unless adequate measures are taken. The following ISMP was developed based on the vision that stormwater should be managed on a watershed basis treating rainwater and snowmelt as a resource to be utilized to improve the health of the watershed's watercourses and enhance the natural environment. The goal is to reduce and ultimately eliminate the adverse effects of stormwater runoff on the natural environment in a timely and sustainable manner, and achieve a measurable improvement in the health of watersheds.

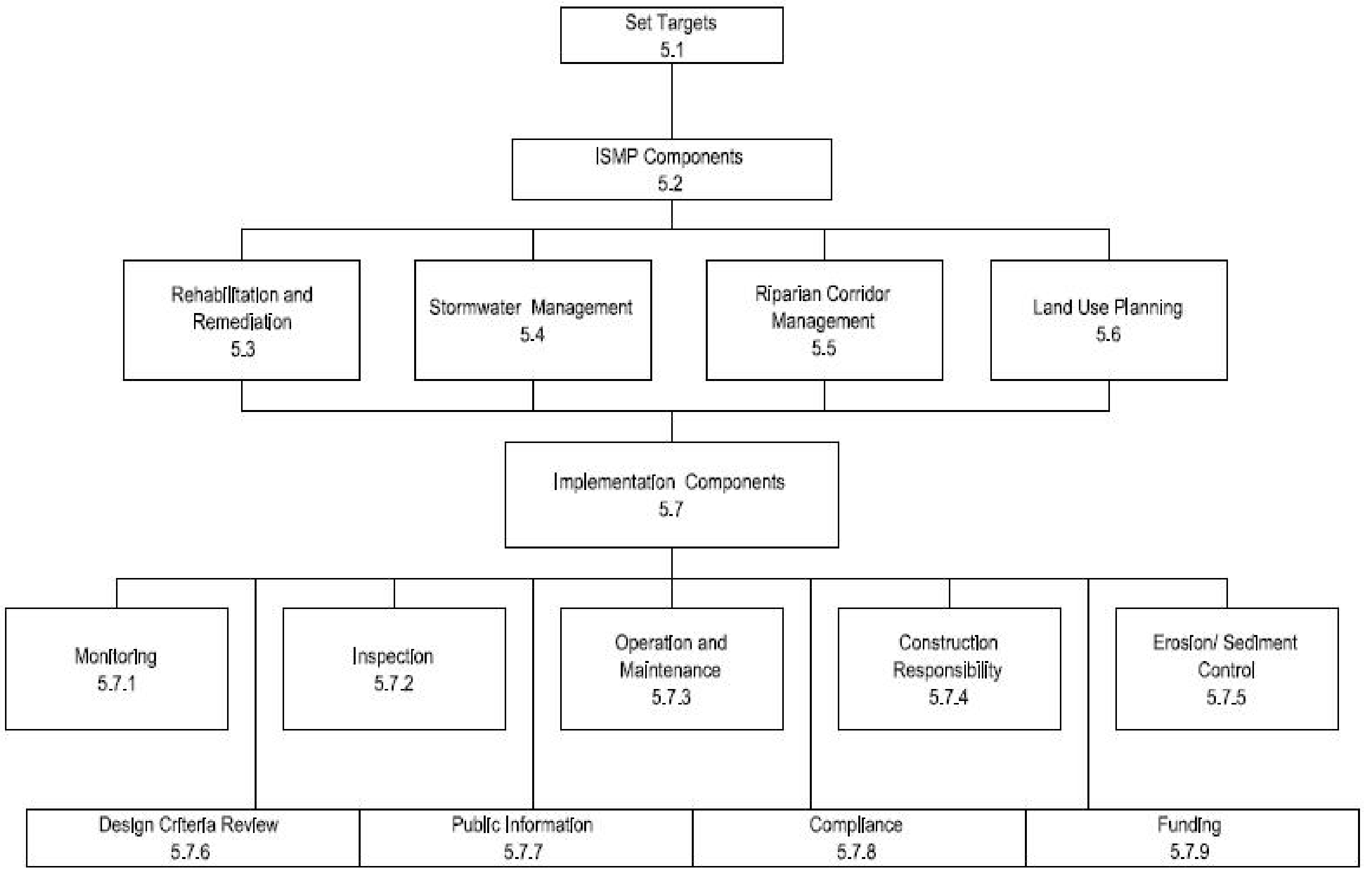
Even if the existing land development practices incorporating traditional stormwater management practices are maintained, environmental conditions would continue their present downward trend, resulting in further erosion/sedimentation, degradation in water quality and a potential increase in flooding. By accommodating urban growth without additional remedial programs, even the status quo could not be maintained.

To guide the implementation of the ISMP, a set of performance targets have been developed for approval agency staff and developers for measuring the progress and the success of the ISMP. In setting ISMP targets, considerations were given for the existing developed conditions and for measures requiring increased stormwater control for new developments and re-developments in stormwater management.

<u>Runoff Volume</u>

The following are the recommended runoff control targets for the Cougar Creek/NEIC watershed based on the approach recommended in the British Columbia Stormwater Planning Guidebook. The targets are based on the fact that the watershed is already developed and the watercourses are experiencing significant changes compared to the original natural channel conditions, a process which may continue in future until the watercourses could adapt to a new regime condition.

Integrated Stormwater Management Plan Flow Chart



DILLON CONSULTING	PROJECT: NORTH DELTA INTEGRATED STORMWATER MANAGEMENT PLAN	PROJECT NO. 06-6904
DATE: MARCH 2009	TITLE: INTEGRATED STORMWATER MANAGEMENT PLAN FLOW CHART	FIGURE NO. 5-1

FileName:g:\cad\066904\06904-figures-master-drainage.dwg

It is well known that stormwater quantity and quality impacts are the result of uncontrolled urban runoff from impervious surfaces. North American research shows that once the impervious surface in a watershed exceeds 10% of the total area, stormwater related impacts become noticeable in a watershed. In ideal circumstances, developments should be planned and constructed to simulate a watershed with not more than 10% total impervious area. As runoff from a natural and un-developed surface is usually very low when compared to runoff from impermeable surfaces, the B.C Guidebook suggests limiting the total runoff volume from a new development to 10% or less of the total rainfall volume as a reasonable runoff target. This means that 90% of the rain falling on the watershed would be infiltrated, released through evapotranspiration or reused.

In watersheds already heavily developed this target could not be achieved. This low target could be compared to the observed runoff in Cougar Creek at the Nicholson Road gauge, where the annual runoff represents approximately 60% of the total annual rainfall. Therefore, it is clear that the 10% target could not be reached for the entire Cougar Creek/NEIC watershed, but could be applied for site-specific larger new developments with opportunities to provide the necessary control to meet this low target. However, it is also important to consider maintaining adequate flow conditions in the Cougar Creek/NEIC system with its healthy salmonid population. Therefore the runoff volume target of 10% should be applied for larger new developments, where feasible. Every effort should be made to reduce the total runoff in the Cougar Creek/NEIC watershed.

New developments should utilize Low Impact Development technologies. The applicant should demonstrate that they have applied LID to achieve a minimum 90% runoff control of the mean annual runoff. For re-developments or small site-specific new developments, the applicant should demonstrate that the maximum feasible runoff control has been applied.

Runoff Rate

The target for erosion control according to the B.C Guidebook should be based on channel forming flow rates, thereby limiting the rate of flow in a natural channel to reduce the risk of erosion/sedimentation and thereby degrading the aquatic habitat. Observations of natural streams across North America identified the mean annual flood (MAF) representing the bank-full flows acting as the channel-forming flow. In absence of long-term flow data, the MAF is usually expressed as the runoff by the mean annual rainfall (MAR) event, which is estimated to be approximately 60 mm for the study area. The Guidebook suggests adopting the mean annual flood under natural undeveloped conditions as a suitable target for runoff rate. The Cougar Creek regime has gone through substantial changes from its natural conditions over the past 50 years due to the rapid rate of development which resulted in a significant increase in flows, velocities and runoff volumes. Therefore, any target for runoff rate control based on the natural condition mean annual flood would not be feasible or affordable. In addition, the Canal is not a natural watercourse and therefore the channel forming flow principle would not strictly apply.

Another target for erosion control adopted in B.C. applies to storage facilities, requiring that the duration of flow releases from a storage facility not exceed the duration of erosion causing flows for the 2-year event, or control post-development flows to pre-development levels for the 6-months, 2-year and 5-year events. A similar target is stated in the Surrey Servicing Objective, which states that where erosion is a concern, the more stringent of the two following criteria should apply:

i. control the 5-year post-development flow to 50% of the 2-year post-development rate; or
ii. control the 5-year post-development flow to 5-year pre-development flow rate.

Runoff targets for new developments or re-development areas should require the control of runoff rate to existing rates for a range of flow conditions, such as the 2-, 5-, 10-, 25-, 50- and 100-year events to control the risk of flooding and erosion. For flood protection, no building should be damaged by the 1 in 100 year storm event.

Where feasible, over-control should be achieved thereby reducing the post-development peak flows below the pre-development level.

For storm sewer sizing the major-minor system approach should be adopted, using the 5-10 year criteria for the minor system. Consideration should be given to using a 1 in 25-year storm for high value commercial or industrial development and for business areas. For flows in excess of the minor system capacity, the major system should carry flows up to the 100-year event.

Channel Capacities

While Cougar Creek has ample capacity to discharge high flows through the deep and steep gradient Canyon section, the capacity of the Canal is restricted by the flat gradient and small cross-sections and undersized crossings**.** It is recommended to adopt a 1 in 10-year flow as an interim target for the Canal capacity. For the long-term the Canal capacity should be increased to carry flows up to the 1 in 100-year event, to match the flood plain criteria adopted by Surrey. It is recommended that the two municipalities undertake a Flood Plain Mapping study of the Canal and the Cougar Creek system, starting at the Fraser River in Delta and extending the study into the headwaters in Surrey. The purpose of the Flood Plain Mapping Study would be to establish accurate 100-year and 200-year flood lines based on detailed field surveys.

Water Quality

When managing runoff for water quality impacts, the control of more frequent and smaller rainfall events are usually selected for targets. This approach is based on the fact that the percentage of annual precipitation for very large events is relatively small, and the construction cost of storage facilities to control runoff based on extreme rainfall events would be prohibitive. This approach still provides partial benefit for larger storms as storage facilities can continue to control pollutants from the first portion of the larger storm's runoff.

Where no source control is feasible the target should be to maintain pre-development water quality, or control peak flows up to the post-development 6-months (70% of 2-year 24-hour) event. At a minimum, the water quality discharged from a new or re-developed area should utilize LID approach to improve the water quality in the streams. There is a need for the Corporation to develop a new bylaw to control water quality from new developments.

Another source of potential pollutants entering the streams is at construction sites. While the city of Surrey has an existing by-law for the control of erosion and sedimentation at construction sites, a similar by-law would be required for Delta.

Aquatic System

Targets to protect the health of the aquatic system are based on indicators such as relative changes in instream condition or in the Benthic Index of Biological Integrity (B-IBI). The B-IBI score is influenced by a number of factors related to water quality. Generally, the poorer the water quality, the lower the B-IBI score. Low water quality can be caused by excessive flow leading to erosion, untreated road runoff, and a lack of riparian cover. In addition, excessive depth over riffle habitat can have a negative impact on the B-IBI score.

Most species of fish can withstand higher exposure of elevated levels of TSS, but impairment will occur when sediment exposure increases beyond threshold values which are a function of both the sediment concentration and its duration. Sediment concentration in a receiving stream below 25 mg/L would result in few ill effects regardless of the duration. For typical runoff events lasting less than 4 hours, moderate impacts would occur at about 200 mg/L, and for duration of more than 10 hours, a concentration of 1,000 mg/L could result in major impacts.

There are opportunities for enhancement of existing aquatic vegetation which could promote improved water quality through “biological polishing”. The implementation of measures to improve water quality could improve the overall B-IBI score. Measures that could be implemented in this regard include:

- Detention in the watershed to prevent high “flashy” flow;
- The use of biofiltration ponds/systems to remove pollutants; and
- The establishment of more riparian cover to provide bank stability slows the discharge of flow to the channel and provides a food/nutrient input.

The B-IBI index has a numerical range of 10 to 50, with 10 being very poor stream condition and 50 being excellent stream condition. In setting a target for stream health, a value of 28-36 (or “fair” stream condition) is recommended. There is considerable debate in regards to this valuation system however. The sites used to establish the target stream condition ranges may not be repeatable in the conditions found within watercourses in Surrey or Delta. As such, it may not be possible to achieve a “fair” stream condition in the short term using the existing B-IBI system. In general, the City and the Corporation should strive to achieve a rating that is a high as possible.

Additional long-term targets to protect the health of the watershed related to the riparian system could include:

- Preserving/establishing a 30 m wide riparian corridor along Cougar Creek where possible; and
- Adopting a long-term target of a minimum of 5% of the MAF, as a base flow where feasible. Based on limited flow data observed at the Nicholson Road gauge, the estimated MAF is 5.2

m^3/s, and the minimum observed flow is approximately 0.1 m^3/s, less than the suggested 5% target. Future base flow enhancement projects may include a reduction in impervious surfaces, flow releases from upstream ponds, and introduction of infiltration facilities.

Table 5-1 provides a summary of stormwater management targets.

Table 5-1: Summary of Stormwater Management Targets

Stormwater management component	Target
Drainage, flood protection-minor system	5- to 10-year return period event
Drainage, flood protection - major system	Drainage system to carry the 100-year return period event with only minimal damage to public and private property
Watercourse floodway	Up to 100-year event
Stormwater control-volumetric reduction of more frequent events < 50% of MAR	Capture 90% of total rain from impermeable surfaces and release only 10% of total rain runoff volume. For redevelopments or small site-specific new developments apply the maximum feasible runoff control.
Stormwater control-volumetric reduction of infrequent storms	Retain 50% of MAR volume (30 mm). Release rate to approximate natural condition runoff rates to control erosion. Ensure that the total release flow will not exceed 10% of total rain. For redevelopments or small site-specific new developments apply the maximum feasible runoff control.
Stormwater control-peak flows	For new developments control to existing rates for the 2-, 5-, 10-, 25-, 50- and 100-year events
Canal capacity	Interim target 1 in 10-year peak flow, for the long-term adopt the 1 in 100-year event, No development permitted within the 1 in 200-year flood plain.
Detention storage	In addition to the 30 mm source control, detain the next 30 mm and release it at pre-development (undeveloped) rates.
Water quality treatment	Fully treated at site where no source control is feasible to maintain pre-development quality, or control up to the post-development 6-months (70% of 2-year 24-hour event) peak flow.
Receiving system erosion control	Duration of release flows from storage facility not to exceed the duration of erosion-causing flows for the 2-year event, or control post-development flows to pre-development levels for 6-month, 2-year and 5-year events.
Receiving system sediment control	Control runoff to maintain pre-development TSS
Aquatic system	Preserve or establish the 30 m wide corridor long Cougar Creek where feasible. Maintain base flow in streams at a minimum of 5% of the MAF.

5.2 ISMP Components

The Integrated Stormwater Management Plan was developed to provide guidance for the future management of the Cougar Creek/NEIC watershed to meet the goals and objectives described in Chapter 1. The initial characterization of the watershed identified current conditions and how the watershed functions under existing conditions. A subsequent task focused on analyzing alternative remedial measures for both existing and future land use conditions.

The following is a description of the proposed ISMP based on the carrying capacity of the watershed under the existing pressures on the environment, with the understanding that as the human activities and pressures would increase in future, the carrying capacity of the local habitat could be further reduced. The management strategy must recognize that human activities have changed the original natural habitat and conditions and activities in the watershed will continue to reflect society's requirements for the need for orderly urban development without causing further deterioration to the local environment.

The scope of the management strategy developed was broad based to include the various technical and administrative tools that are needed to undertake successful land use and resource management measures.

The various recommended tasks for the ISMP are presented under the following subheadings:

1. *Short-term remediation and rehabilitation measures to protect residents from flooding and erosion*.
2. *Medium- and long-term management alternatives to protect or enhance the resiliency of the watershed and stream systems*.

- Stormwater management measures for new developments or re-developments to control and where feasible to enhance the hydrologic functions and flow conditions related to surface water flows and water quality.
- Riparian corridor management measures to protect and enhance riparian systems.
- Land use planning and development control measures to guide long-term future urban land use in a manner that recognizes the natural heritage resources.
- Implementation measures to provide approval agencies the necessary tools to adopt and process development applications.

The following is a more detailed description of the remedial and management control measures, listing first the two short-term remediation measures reviewed in Chapter 4, followed by a long list of recommended Management Alternatives.

5.3 Remediation and Rehabilitation of Existing Conditions

A review of existing conditions in Chapter 2 identified the two major issues facing the Cougar Creek/NEIC system: flooding at the lower end of the Cougar Creek/Upper Canal region and erosion along the steep Cougar Creek Canyon. A number of remedial measures to control flows designed to reduce flood and erosion risks were analyzed in Chapter 4. The estimated construction and operation/maintenance costs for some of those remedial measures were very high. The high costs combined with the absence of reports on past flood damages (except those reported by the BNSF), poor water quality, or significant erosion suggests that no expensive remedial measures should be considered as high priority items.

The following is a list of the recommended two short-term remedial measures.

Flood Control

The railway tracks and the adjacent low lying areas could be protected from frequent flooding by channel improvement. The most practical flood control alternative to remedy the existing flooding situation at the vicinity of Westview Drive and the railway tracks is to improve the channel capacity in the area and thereby to provide protection up to a 100-year flood event. This alternative is subject to future plans by the BNSF to twin the tracks, in which case the reconstructed railway beds should be raised above the 100-year flood elevation.

As discussed in **Chapter 4** under Options #2 and #3, before undertaking any channel improvements consultation with the railway company will have to establish any future plans for twinning the track and with DFO to review the environmental constraints and potential impacts on the local fisheries resource.

The computer modelling confirmed that there would be no need to replace the existing culverts for hydraulic reasons. For example twinning of GVRD or Terasen culverts and/or channel improvements (cleaning out/correcting thalweg in locations of adverse slopes) would have a small effect on water levels in the Canal. Currently, the 1:100 year 48-hour water levels are below the overtopping elevations crossing the GVRD and Terasen culverts.

Erosion Control

Erosion hazard exists through channel migration caused by high runoff resulting in a potential risk of loss of natural habitat and property. Where there are well-defined channels these migrations could cause toe erosion, reduced slope stability and possible failure of the banks. To address these conditions, vulnerable stream corridors have been identified. The two most significant areas of erosion within the Canyon are located adjacent to Ridgewood Place and Canyon Crescent (Sites #7 and #13 in **Chapter 2, Table 2-4.**

Assessment of these sites described in Option #8 indicated that there is a “good chance” of failure risk although not likely in the near future. This failure could extend to the existing house on the site should the ongoing erosion continue or worsen.

It is suggested that the Corporation of Delta complete a detailed survey of the crest of the ravine at both sites. The survey should then be repeated a year later to determine if there has been any movement of the crest toward the house. The surveys could be repeated over the course of several years to assess the progress of the failure which in turn will allow the Corporation the time to develop a timeline and methodology for repair. Repair of the failure can be accomplished through the addition of fill material to the existing scar, the armouring of the toe-of-slope, or moving the creek away from the toe. The recommendation to initiate survey and potential mitigation of the ongoing erosion at the two sites could be repeated for any of the erosion scars currently existing in the Cougar Creek Canyon. For regular maintenance recommendations see Implementation Chapter 5.7.3.

5.4 Management Alternatives - Stormwater Management for New or Re-Developments

The objective in employing stormwater management measures for new developments and redevelopments is to improve the health of the local environment by encouraging healthy watersheds and watercourses.

For existing developed areas there are only limited opportunities available to introduce effective stormwater management facilities. For new or redeveloping areas any stormwater management facility selected must ensure that the proposed development will not increase the frequency and intensity of flooding, erosion/sedimentation or further degrade the environment.

The information presented in this chapter is based on the latest technical literature and on Dillon's experience in the planning, design, construction and operation/maintenance of stormwater management facilities.

The current trend in urban development advocates the hierarchy of preferred stormwater Best Management Practices (BMPs) based on the philosophy that source controls be assessed first and end-of-pipe last. **Table 5-2** summarizes the latest techniques available to control urban runoff in developing areas under the following four categories:

i) Source Controls.
ii) Conveyance (system) Controls.
iii) End of pipe Controls.
iv) Miscellaneous Controls.

It is important to note that the ultimate selection of recommended measures is dependent on reach-specific characteristics, sensitivities and functionalities present within the study area. Experience suggests that the best strategy in selecting suitable BMPs for a specific development is to avoid environmentally sensitive areas and consider the applicability of the site to accommodate the selected BMP. The selection of the appropriate alternative must be based on technical, environmental and financial consideration as well as on the cumulative effects of the stormwater management system and on the acceptability by the public.

Table 5-2: Alternative Stormwater Best Management Practices

SOURCE CONTROL	CONVEYANCE CONTROL	END OF PIPE CONTROL	MISCELLANEOUS MEASURES
• Disconnect roof leader and foundation drain • Reduced lot grading • Roof top storage • Porous paving • Raingarden • Biofilter	• Grassed swale • Pervious pipe • Diversion/relief conduit • Pervious catchbasin	• Wet or dry storage pond • Artificial wetland • Infiltration trench/basin • Buffer • Filter • Oil and grit separator	• Land use regulation • Litter control • Recycling programs • Waste control programs • Spill response • Hazardous material handling • Street sweeping • Road salt management • Public education

A more detailed discussion on the various Best Management Practices, their applicability, advantages and disadvantages and effectiveness are presented in **Appendix H.**

There are constantly new SWM control techniques being developed, mainly for water quality control; therefore it is recommended to encourage demonstration projects on private lands, such as the use of permeable paving, new oil and grit separators, phosphorus removal facilities, etc.

A number of competing and conflicting factors have to be addressed when selecting the appropriate BMP for new development areas. Generally, all BMPs have limitations and therefore no single alternative will achieve the desired quantity and quality control. Instead, in most applications a train of BMPs will have to be applied. Physical constraints of the site, environmental conditions, construction and long-term operation and maintenance costs, and aesthetics are all important considerations which will affect the design criteria selection process.

The following four-step process is recommended in the selection of the best BMP for future new developments or redevelopments within the study area.

Step 1 – Selection of Design Criteria

The first task in the design process is to establish the design criteria of BMPs and establish a set of design criteria applicable for a particular site.

Table 5-3 summarizes the suggested criteria for the control of quantity, quality, erosion and base flow recharge for different site conditions.

Table 5-3: Selection of BMP Design Criteria for New Developments

Control	Target Criteria	Guidelines
Flood and water quantity	5 -10 year storm event	Minor drainage system
	100 – year storm event	Major drainage system
Water quality	In absence of source control	Treat 90% of annual rain falling on impervious surfaces
	Storage facility sizing	Treat the 6-month rain falling on impervious areas
Erosion	Control 6-month, 2-year and 5-year events	Control post development flows to predevelopment level.
Baseflow	Where feasible, the pre-development hydrologic cycle components should be maintained.	None

Step 2 –Screening of BMP Alternatives for New Developments

A screening tool has been developed to compare the capabilities and limitations of each BMP. This initial assessment matrix is presented in **Table 5-4**. The following group of factors were considered in the selection of an appropriate BMP or group of BMPs for new developments:

1. BMPs control capability: water quantity, quality, and erosion control, recharge and habitat protection capabilities
2. Site applicability: slope of land, local soils, location of bedrock and water table, size of drainage area

3. Capability of the BMP to act as a stand-alone control facility or to be used only as part of a treatment train

From the above analysis a short list of alternative BMPs can be prepared. **Table 5-4** shows each matrix component whether it can be effective, have only limited benefits or it is not recommended.

Table 5-4: Stormwater Management BMPs – Initial Assessment Matrix

TYPE OF BMP	Control of					Slope		Soils infiltration		Bed rock		Water table		Drainage area		Treatment
	Quantity	Quality	Erosion	Recharge	Habitat	0-5%	6-10%	>15mm/h	<15mm/h	<1m	>1m	<1m	>1m	<5ha	>5ha	train only*
SOURCE CONTROL																
Reduced lot grade																Yes
Roof leader disconnection																Yes
Roof storage						N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes
Sump pump														N/A	N/A	Yes
CONVEYANCE CONTROL																
Grassed swale																Yes
Perforated pipe																
END-OF-PIPE CONTROL																
Extended wet pond																
Extended dry pond																
Wetland																
Infiltration																Yes
Permeable pavement																Yes
Forested buffer																Yes
Filters strip																Yes
Sand filter																Yes
Separator																Yes
Bio-retention																Yes

Legend
- Can be effective
- Limited benefits
- Not recommended

*** BMPs used mainly as part of a treatment train**

Step 3 –Shortlist of Alternative BMPs

To derive a short list, a number of additional conditions have to be considered by considering additional constraints:

1. Capability to remove pollutants:
   To assist in the selection of BMPs, a list was prepared as shown in **Table 5-5** on the various BMPs capability to remove the most common pollutants considered in stormwater management:

   - Total Suspended Solids (TSS) is the most common indicator.
   - Nutrient treatment column indicates the TP and TN removal capabilities of each BMP.
   - Metals include those observed in urban runoff: lead, copper, chromium, zinc and cadmium.
   - Bacterial removal column describes the capability to remove bacteria in urban runoff.

Table 5-5: Estimated Pollutant Removal Rates for Different BMPs

BMPs	Removal Rates (%) for Water Quality Parameters Assuming Ideal Conditions				
	TSS	TP	TN	Metals	Bacteria
Wet pond	80	50	35	60	70
Wetland	80	50	30	40	80
Infiltration	90	70	50	90	90
Filters	85	60	40	70	35
Swales, biofilters	85	40	50	70	Negl.
Oil & Grit Separators	<40	<5	<5	No data	No data
Porous pavement	Negl	80	80	No data	90

2. Space requirement: BMPs space requirement can range from 2%-5% of drainage area for storage facilities, to 10% or more for swales. Based on the current land use within the study area, space available for stormwater management is very limited.
3. Environmental considerations: loss of aquatic habitat and riparian vegetation, inhibiting the passage of aquatic fauna, potential for causing sediment build-up or starvation in downstream watercourses, and increasing downstream water temperature are all relevant.
4. Health and safety issues: injury, drowning, skin irritations and infections, mosquito borne diseases, odours, risk to maintenance staff and general public. These issues are only applicable for structural alternatives such as ponds and wetlands.

Step 4- Final Selection of BMPs

The final selection criteria should include estimate of long-term operation/maintenance costs and community acceptance. Before the final selection is made, environmental regulations and permit requirements for the municipalities of Surrey and Delta must be considered.

Stormwater Management for Infill Developments and Retrofits

Stormwater management in infill areas requires a special consideration when selecting design criteria and suitable alternative BMPs. Generally, small infill areas provide limited opportunity to introduce many of the alternative BMPs reviewed. The focus of this section is on infill areas of less than 5 hectares in size where storm sewer infrastructure already exists. For infill areas in excess of 5 ha there should be more opportunity to introduce other alternative BMPs. Although the development of a relatively small infill area may not have a significant impact, the development of several individual sites can have a significant cumulative effect on the watershed.

Infill developments with no stormwater management facility should be discouraged. As a minimum criterion, a 5 mm rainfall event should be retained at the site. Only where on-site control may be ineffective or impractical because of physical constraints, off-site control should be considered. In some circumstances the City or Corporation should request financial contribution toward the development of a stormwater management facility at another location, preferably in the same watershed.

Only infill developments consisting of one new residential lot discharging into an existing storm sewer should be permitted to proceed without any BMPs, other than basic good housekeeping measures.

When considering the need for stormwater management for infill areas, a number of factors have to be assessed:

- Proposed land use;
- Infrastructure capacity;
- Opportunities of retrofitting existing stormwater management systems; and
- Site conditions, such as soil percolation level, slopes, vegetation, aquifer and bedrock location.

A list of alternative BMPs available for infill developments is listed in **Table 5-6**.

Table 5-6: List of Alternative BMPs Suitable for Infill Development

BMP	Control	Comment
Roof leader to pervious surface	Peak flow	Where physically feasible
Rooftop storage	Peak flow	Flat roof only
Parking lot	Peak flow	Dependent on site grades
Super pipes, underground storage	Peak flow	Dependent on sewer invert levels
Pervious pipe	Quantity and quality	Dependent on soils
Swales	Quality	Dependent on soils
Infiltration trench	Quality	Dependent on soils and water table
Filters	Quality	Generally feasible
Oil and grit separators	Spills and some quality	Generally feasible
Storage ponds	Quantity and quality	Generally not feasible
Wetlands	Quantity and quality	Generally not feasible

Older runoff control structures constructed prior to the introduction of BMPs were designed to control flooding. Retrofitting is the process by which these existing structures are modified to serve a water quality improvement function as well. Retrofitting can improve the multi-use function (flood peaks, velocities, pollutant loadings) and appearance of existing facilities, enhance the useful life of the BMP, and reduce the operation and maintenance costs. In many instances retrofitting could also be considered to improve an existing water quality BMP.

Opportunities to retrofit at the source such as roof top storage on flat roofs with or without vegetated cover are very limited in the study area. The most effective retrofitting would involve existing detention ponds. Basins designed primarily for flood protection can be retrofitted to provide additional benefits by providing extended detention with permanent pool in place to control the outflow and to possibly incorporate forebays at the inlet and outlet for enhanced settlement of suspended solids.

Another possibility for retrofitting could involve infiltration measures at locations such as medians, parking area and roadside swales, where soil permeability and groundwater depth are sufficient.

Operation and maintenance form an important part in the longevity and aesthetic functioning of stormwater management facilities. Different types of facilities require different maintenance activities and therefore, costs can vary with both type and size. Typical operation/maintenance costs are shown in **Table 5-7.** Prices for operation and maintenance activities are usually reported either as unit price or as percentage of construction costs as indicated.

Table 5-7: Typical Operation/Maintenance Costs

Type of facility	Interval years	Unit	Price
Wet ponds			
• Vegetation maintenance	4	ha	$4,000
• Sediment removal, front end loader	Varies	m^3	$25
• Sediment removal, manual	Varies	m^3	$150
• Sediment disposal, off-site (non-toxic)	Varies	m^3	$500
Inspection	Annual	Per structure	$100
Infiltration basin or trench	2	ha	$5,000

The annual operation and maintenance cost for wet ponds have been reported to be 4%-5% of the capital costs.

5.5 Management Alternative - Riparian Corridor Management

The maintenance of a healthy aquatic ecosystem through riparian corridor management is another objective the ISMP should address in order to prevent further deterioration of riparian integrity and provide enhancement opportunities where feasible. Erosion, water quality, and base flow are the most important components of riparian corridor management.

The Cougar Creek/NEIC system is continually adjusting its stream dimensions to accommodate the fluctuating discharge and sediment transport. Bank erosion and sedimentation (which are natural processes unless chronic or ongoing) is occurring as a result; therefore channel enhancement through management options is needed at the affected area described under Rehabilitation and Remediation in Section 5.3 to mitigate the erosion and sedimentation issues and to provide a resilient channel system.

In the longer term, regular inspection of the stream corridor should be carried out to monitor potential erosion sites. Where necessary, environmentally friendly protection methods should be applied, such as bioengineering or greenwalls.

The quality of urban runoff and the potential method of treatment can have a considerable impact on the quantity and quality of the runoff entering the Cougar/NEIC system not only during high flows but also at low flow conditions. Surface runoff in the heavily urbanized watershed is collected and conveyed by an extensive stormwater system. Existing land development has altered the relationship between surface and subsurface flows through the high percentage of paved areas. Any further reduction in the subsurface flows can further impact on fish and fish habitat by reducing base flow levels. It is recommended that new developments and re-developments should aim to reproduce the hydrologic cycle to pre-development level, in particular to maintain base flows.

The riparian vegetation along the Cougar Creek/NEIC system has been impacted by past development. The degree varies from reach to reach and can exhibit a complete removal of vegetation or a reduction of the riparian vegetation to a narrow strip, or areas where the riparian corridor remains intact. Depending on local stream conditions, the aim is to provide a minimum width of a riparian zone. Where an adequate riparian zone can be established, the vegetative canopy could assist in some control of surface runoff quantity and quality entering the stream system.

It is recognized that long-term hydraulic and fisheries enhancements are needed along the corridor. Examples of potential fish habitat compensation or enhancement opportunities in the catchment include:

i. Removal of accumulated sediment from the NEIC downstream of the Westview Drive culvert to the BNSF Bridge in order to restore some of the lost hydraulic capacity. Complexing elements (logs, rootwads, and crib structures) could be added to improve rearing habitat capability;

ii. Construction of fish habitat between the NEIC and BNSF RoW. New habitat could potentially consist of offline ponds or back channels with a wetland component. Storm flows could be directed to the new habitat where the wetland vegetation would provide biofiltration of contaminants;

iii. Construction of a channel from Westview Drive south along the east side of the BNSF RoW to convey peak flows. Based on flood control alone, this alternative could not be justified, only if this area could be complexed and developed to act as wetland or channel;

iv Explore limited opportunities to daylight sections of Blake Creek;

v. Continual assessment of Cougar Canyon for debris jam barriers, and alter or remove debris jams to ensure fish access to upstream reaches;

vi. Enhancement of reaches of Cougar Creek currently lacking in riparian vegetation primarily in the more developed areas upstream of the Canyon near Scott Road in Delta, and adjacent to the reaches in Surrey;

vii. Purchasing setback within industrial properties near Nordel Way to develop as riparian setback. Currently, industrial development extends to at or near the top-of-bank throughout a large part of this section of the channel;

viii. Construction of off-line ponds north of Nordel Way where space permits for food/nutrient contributions and improved water quality;

ix. Clearing and grubbing invasive vegetation species (*e.g.*, Himalayan blackberry, Japanese knotweed) from the Cougar Creek headwaters and replacement with native vegetation;

x. Relocation of the channel to the dry detention pond at the Khalsa School on 124th Street. Plant the area with native riparian vegetation;

xi. Future fish habitat compensation/enhancement projects expected in the watershed arising from habitat losses associated with the proposed South Fraser Perimeter Highway and other developments;

xii. In addition to identifying potential compensation sites, opportunities exist for securing “habitat credits” and “banking” to offset future habitat losses. Complexing alternatives of the Northeast Interceptor Canal channel alignment and morphology were investigated to determine if an increase in the quantity and quality of habitat was feasible. One alternative would include a 2.0 km reach of the Northeast Interceptor Canal from north of 72nd Avenue to Nordel Way, which can be re-constructed into a meandering channel of 2.4 km length. Moreover, the channel can be designed to be continuous with the forest so this scheme will also serve as a flooding buffer. These works could result in an additional 1,200 m^2 of aquatic habitat and take advantage of intact vegetated habitat. Further habitat improvements can be realized through the replacement of the current flap gate arrangement (to a side-mounted flap gate) at the flood box to facilitate easier entry of fish into the Cougar system from the Fraser River;

xiii. In some areas of the Canyon, significant erosion was noted at the toe-of-slope. Traditional "hard" engineering solutions (typically riprap sized to resist flow) are often utilized to provide the required level of protection. However, these solutions could result in a loss of overall habitat productivity and complexity. There are numerous solutions which can be applied to these eroded areas that provide the required level of protection while at the same time retaining or even increasing habitat values. These solutions could include:

- "Living wall" technology (*e.g.,* Filtrexx, Deltalok Sierrascape) that incorporates vegetation within an erosion resistant wall;
- Riprap grout, a seeded compost mixture which can be blown into riprap to provide a planting medium;
- Large round boulders that provide the required bank stabilization while at the same time retaining interstitial spaces for fish cover; and
- Log cribs and revetments that provide stability, resistance to flow and create cover for fish.

xiv. There is a consideration by BNSF to add another bridge in the vicinity of the Westview culverts to improve flow capacity and reduce the risk of overtopping.

All these potential solutions would require an engineer's approval to ensure that they would be effective in the conditions typically found within the system.

A limited opportunity for the enhancement of recreational facilities within the riparian corridor is available in the watershed. Within the Canyon there is a desire to maintain the natural character of the ravine. Further downstream Metro Vancouver is considering an integrated design of a greenway stream corridor. These planned corridor improvements must be conducted in a manner that ensures that flooding and erosion risks are minimized along the Cougar Creek/NEIC as the greenway improvements are designed and implemented. Participants at the stakeholder meetings voiced the need to design the greenway in a manner that will limit access to the stream. Thus, consideration should be given to constructing defined pedestrian crossings that will keep dogs and pedestrians out of the watercourse.

5.6 Management Alternative - Land Use Planning and Control

One of the most effective methods of long-term control of stormwater is the adoption of new approaches to development. Existing information suggests that future land uses could involve increased site coverage for a number of commercial sites.

5.6.1 General Approach to Control the Extent of Impermeable Surfaces – Adoption of Low Impact Development Concept

There is a need to change past site planning practices when developing or re-developing in future within the Cougar Creek/NEIC subwatershed. One of the latest stormwater management approaches is to adopt Low Impact Development (LID) to manage rainfall at the source using distributed decentralized small-scale controls. The goal of the new LID approach is to permit full development first by minimizing the hydrologic impacts through new site design and by providing controls to mitigate any disturbances to the hydrologic regime.

A successful LID design is capable of maintaining or approximating a site's predevelopment hydrology by using the latest design techniques to store, detain, infiltrate, and filter urban runoff close to its source. These features are the building blocks of LID; however, many of the other components of the urban environment have the potential to serve as part of LID. This includes not only the use of open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment / revitalization projects.

The key to LID is to retain the natural drainage functions. Instead of rapidly draining the site in underground storm sewers, low impact development employs various planning tools and control practices to preserve the natural hydrologic functions of the watershed. Simple tools, such as reduction in effective impermeable area, maintenance of infiltration capacity, provision of storage and extended time of concentration are alternative ways to achieve the goal of LID. Training on the principles and benefits of LID should be considered for municipal staff.

The LID approach will require more flexible regulations than permitted by most existing zoning ordinances. To ensure that the LID approach will provide optimum environmental and economic benefits, new environmentally sensitive and flexible zoning options will be needed. If LID becomes a requirement then changes to the zoning bylaw and Official Community Plan may be required.

The Land Development control process for a site should start with the identification of sensitive areas where no development should take place, such as flood plains, wetlands, steep slopes, buffers, setbacks, highly pervious and sensitive habitat areas. The remaining areas could be considered for the definition of the development envelope.

When selecting land cover a number of simple techniques should be introduced, such as:

- Minimize the total impervious area, use reduced road width, on-site parking, sidewalks and driveways;
- Minimize directly connected impervious areas;
- Maintain wherever possible existing topography and flow path;
- Disconnect impervious areas to the extent feasible and increase opportunities for infiltration;
- Minimize site disturbance and tree removal;
- Utilize highly permeable soils for infiltration;
- Flatten slopes to slow down the surface runoff;
- Increase flow path;
- Increase sheet flow;
- Increase roughness of surfaces to slow down flows and increase infiltration;
- Use of swales;

- Reduce curbs and gutters;
- Use of vegetative filter strips;
- Roof leader disconnection and re-direction to permeable surfaces;
- Use of rain barrels;
- Roof storage for industrial or commercial developments;
- Rain gardens;
- Bioretention;
- Revegetation;
- Use of permeable paving;
- Use of wetlands; and
- Capture and store rainwater for irrigation.

5.6.2 Future Strategies for Redevelopment of Existing Developed Areas

Specific strategies should be adopted for existing developed areas such as shopping centres and industrial sites, existing parks, green spaces and school sites, vacant lands or greenfield sites, and for existing residential areas or lots that have redevelopment potential. Outlined below are some potential strategies to manage development/redevelopment initiatives toward improving storm water management practices and enhancing the watershed. It is important that all new development designs adopt the stormwater management targets presented in the ISMP.

Existing Large Developments

The watershed contains numerous large developments such as shopping centres, industrial buildings/lots, schools and some large multi-family sites of varying ages. These developments typically contain large parking lot and roof surfaces. Many of these are aging and may redevelop within the next 10-15 years. To ensure that these sites are redeveloped in a manner that reduces or eliminates surface runoff and to take advantage of all opportunities to manage storm water in accordance with the objectives of this ISMP and other storm water requirements, well-documented policies and defined requirements should be put in place.

As commercial and industrial land shortages are eminent within the Lower Mainland, redevelopment of the existing shopping centres along Scott Road, local shopping precincts throughout the watershed and under-utilized industrial sites in the north west sector of the watershed can be expected to be redeveloped. Many of theses sites are characterized by large expanses of pavement or impervious parking areas and roofs. Opportunities to implement LIDs and BMPs at the site level should be pursued.

Existing Vacant Lands or “Green-field” Sites

There is a limited number of green-field or undeveloped sites within the watershed. The largest site involves the Delsom lands and it is noted that substantial work has gone into preparing and designing storm water-related sustainable development standards for the varying types of development approved for these lands. Other new developments on larger sites in Delta could be implemented using these established standards through the rezoning and subdivision/development permit processes in conjunction with “low impact development standards” incorporated into municipal subdivision and development guidelines and by-laws that could be applied to the entire watershed/municipality.

Similarly, Surrey has undertaken considerable work and established sustainable development standards, particularly through the East Clayton Neighbourhood Concept Plan process and most recently, through its “Sustainability Charter”. In addition, “green street” and other storm water management standards have been pursued through the Grandview Heights Neighbourhood Concept Plan (Area #2) process.

Infill Development

There are opportunities and challenges in pursuing enhanced storm water management initiatives in existing developed residential areas within the watershed. The older neighbourhoods typically are based upon 7,200 square foot (or larger) lots and contain relatively small homes compared to newer homes built since the mid-80’s. Consequently, due to high consumer demands for single family homes and densification trends, these neighbourhoods can be expected to redevelop, likely through “two-lot splits” or duplex and 2 units per lot redevelopment projects. Many lots may experience the replacement of small homes (*i.e.*, 30% lot coverage) to large homes (*i.e.*, 60% lot coverage) with or without secondary suites and coach houses. Along with this redevelopment or “infill” will come new driveway construction and landscaping and potentially some municipal road retrofits (*i.e.*, curb/gutter replacement, repaving, etc.). The watershed can expect to experience the redevelopment of larger 1960s single-family lots. The challenge is to secure the opportunity when redevelopment occurs with new neighbourhood-wide and on-site drainage systems that maximize natural infiltration through Low Impact Developments (LIDs) and Best Management Practices (BMPs) at the site level:

In Delta it is difficult to require SWM measures on single family lots except through zoning and development standards. It is essential to develop a strategy to accommodate this redevelopment while ensuring that new and enhanced storm water management techniques are incorporated into new building and redevelopment site plans. Statutory requirements are typically not managed through Development Permits. Therefore, storm water related strategies must be implemented through rezoning, subdivision and policy means. In Delta, Development Permits can be used for landscaping requirements.

Existing Park/Greenspace and School Site Areas

The extent of existing parks systems within the study area is shown on **Figure 2-5** in Chapter 2. Discussions were undertaken with the Surrey and Delta Parks Departments in regards to future recreational uses for the Cougar Creek system.

The Corporation of Delta’s Department of Parks, Recreation and Culture indicated there are no additional plans for the Cougar Creek system. The Municipality is not planning to create any linkages with the Metro Vancouver or Surrey park systems, nor do they currently have any plans to construct trails or expand on the existing trail system. The intention is to leave Cougar Creek as a natural area where public access is not encouraged.

The City of Surrey's Department of Parks, Recreation and Culture indicated that the portion of Cougar Creek oriented in an east/west direction (*i.e.*, from the Scott Road culvert to the detention ponds in the BC Hydro RoW) is considered "high priority" for recreational use. The whole of the open water channel system in the watershed is considered "high priority" from a drainage perspective. The intention is to create a linkage with the Greenways corridor currently located within the BC Hydro RoW. There is little likelihood of creating a linkage with the Cougar Creek Canyon in Delta. Ideally, Surrey Parks would like to establish this BC Hydro linkage in the relative short-term.

Surrey Parks is also intending to increase riparian setbacks along Cougar Creek if possible. It is recognized that this will likely have to occur when redevelopment occurs. As such, the timeline to establish these increased setbacks is likely 20-40 years in the future. Fisheries and Oceans Canada has indicated their support to establish new setbacks in concert with redevelopment. Increased setbacks could be enhanced with the planting of native riparian vegetation to improve habitat quality as well as assist with slowing discharge of runoff to the Cougar Creek system. Surrey Parks would also like to enhance the proposed linkage as a wildlife corridor. The intention is to enhance the corridor and the BC Hydro Greenway with nurse logs, brush piles, shrubs, edge habitat etc. to encourage wildlife utilization. Trees could also be planted where there was no possibility of interfering with overhead transmission lines.

Finally, Surrey Parks would like to encourage enhancement of the detention ponds in the Hydro RoW and Cougar Creek Park to improve fish habitat. Enhancement could include the installation of cattail and other aquatic vegetation around the perimeter as well as the installation of water tolerant shrub species. This would have the benefit of enhancing the aesthetic value of the ponds but would also serve to remove pollutants from entering the Cougar Creek system, provide bank stability, provide a food/nutrient input and increase overall biodiversity and complexity.

Parks, green spaces and school sites could present future opportunities for watershed enhancement facilities in the form of rain gardens, bio-filtration areas and other storm water catchment and infiltration initiatives. There are no plans to construct any structures within or adjacent to the channel riparian area at this time.

While the majority of the urban lands within the watershed have been developed, there are opportunities to manage land use and development/redevelopment on some larger "greenfield" sites that have not yet been built out to their full capacity and on existing large commercial/industrial developments. It is recommended that Delta/Surrey continue with what is being done and explore enhancement opportunities where possible, such as:

a) Incorporate sustainable drainage and tree retention strategies to minimize the impact of additional storm water runoff on the watershed;

b) Enhance storm water management practices within existing green spaces in both the Corporation and the City and on school sites that have open space areas (including playing fields and parking lots);

c) Improve the storm water management system through the redevelopment or retrofitting of existing large developments such as in commercial developments (and their parking lots) along

Scott Road and within large municipal facilities (*i.e.*, recreation centres). This is especially true for the older developments that can be expected to redevelop within the next 10 years; and

(d) Incorporate “green” polices and standards for roads, boulevards and pathways/trails on public rights-of-way throughout the watershed.

Environmental Impact Report

Any proponent of an urban land use change should demonstrate how the proposed development would meet the requirements outlined in the Cougar Creek/NEIC ISMP. It is recommended that an Environmental Impact Report (EIR) should accompany a development application to demonstrate that the various stormwater management, infiltration, and environmental issues have been addressed.

The purpose of the EIR is to characterize and analyse the natural heritage features and functions and to determine and address the potential impacts of a proposed development application, including servicing requirements. An integral part of the EIR report would be the description of the control of stormwater management. The preparation of an EIR would assist in the development of the Draft Plan of the proposed development to ensure that the requirements of the ISMP are met and that the site characteristics are understood, to provide the information necessary for processing of the Draft Plan and to provide conditions of agencies approval.

The objectives to be fulfilled by the EIR are to:

- Demonstrate how the requirements set out in the ISMP are being fulfilled;
- Provide sufficient level of conceptual design to ensure that the various components of the natural environment and infrastructure can be implemented as envisaged in the ISMP;
- Ensure servicing requirements for the areas external to the Draft Plan are adequate;
- Identify details regarding any potential development constraints or conflicts and how they are to be resolved;
- Provide any further implementation details as needed;
- Streamline the Draft Plan approval process; and,
- Facilitate the development of Draft Plan conditions.

5.6.3 Consideration for Future Planning and Engineering Studies

The computer analysis described in Chapter 3 showed that permitting higher density developments in future without adequate control of stormwater would result in increases in flows and risk of erosion. It is recommended that the principles of Low Impact Development described in the ISMP should be adopted for the Cougar Creek/NEIC watershed. To assist in the implementation of these principles the following planning and engineering tasks should be undertaken as a follow up to the ISMP study.

- A set of proposed guidelines/specifications for retrofitting on-site drainage could be prepared based on the LID concepts, such as green roofs, swales and infiltration areas, enhanced landscaping, tree cover and parking surface materials, described in the ISMP.
- Under Surrey's existing Development Permit process, the guidelines could be adopted as part of the development permit area requirements for commercial and industrial sites and would therefore be implemented at the time that a development permit is applied for and issued. Similarly, Delta may wish to explore options for establishing Development Permit Areas within which the guidelines would apply to new developments/redevelopments.
- Owner incentive programs and ways to communicate the initiative to property owners could be established at the time the Development Permit Areas are proposed and enacted.
- A density bonus system could be put in place (as an amendment to the zoning by-laws) that requires additional housing units or lot redevelopment to implement low impact standards and on-site water retention before a second unit or lot can be approved.
- In areas where infill development is currently active or expected to be active soon, a program could be put in place to create new or amended neighbourhood plans. These could be "short form" plans focused on creating more sustainable established neighbourhoods within the watershed. The plans would consist of policy documents adopted by Council and would contain policies pertaining to redevelopment. The plans would involve community consultation and review which would also serve to educate and inform the public, property owners and the building/development industry about low impact development requirements on a neighbourhood (or sub-neighbourhood) basis in the watershed.
- An area planning process should consider measures that control stormwater runoff and incorporate rain water management strategies such as:
    - for areas with large expansive parking lots and roofs to prepare a plan of alternative stormwater controls.
    - Sites which may pose a "problem" associated with existing drainage within the watershed, or where there is a need and feasible opportunity for drainage management facilities, should be identified and prioritized.
    - Areas should be designated or flagged as potential retrofit areas for enhanced storm water management facilities and/or redevelopment practices through redevelopment.
    - Similarly, areas that may experience infill residential development should be identified by delineating these areas on a map and describe them in general terms.
    - The study should explore the option of creating an "overlay" infill management area within which certain guidelines/redevelopment standards for infill developments (*e.g.*, lot coverage, landscaping, trees, pavement, etc.) must be adhered to. This would constitute a more informal approach and involve the adoption of new policies or guidelines. The study should identify and map all parks, protected areas and school sites within the watershed, and also which of these sites present an opportunity to install drainage facilities that could improve the watershed.
    - An area planning process should consider measures that control stormwater runoff and incorporate rain water management strategies, such as the Cougar Creek Elementary Rain Garden Project, ponds, bio-filtration areas, tree planting, and parking lot retrofits.
    - Identify areas to be preserved for recreational opportunities, and these areas should be integrated in future planning.

- An engineering study should address the possibilities of retrofitting some of the existing small storage ponds located in the upper Cougar Creek watershed to water quality Best Management Practices.
- A review of the existing road sweeping practices should be undertaken by both municipalities to aim for a reduction in urban pollutants entering the watercourses.
- Identify areas to be preserved for recreational opportunities. These areas should be integrated in future planning.

5.7 Implementation of the Plan

Implementation of the recommended ISMP tasks will take place over a number of years. Construction of the recommended remedial measures could be undertaken over a relatively short time frame, but the integration of stormwater management with land use planning involves a considerably longer timeline, as many of the recommended tasks will have to be coordinated at some future date when new developments or re-developments would take place within the watershed. It takes a considerable time for a stream to adjust to any stream preservation and restoration programs. For this reason ongoing monitoring and assessment of progress should form an important part of a long-term ISMP. This will ensure an effective blending of policy, science and site design to achieve the protection of property, water quality and habitat.

The implementation part of the Cougar Creek/NEIC Integrated Stormwater Management Plan consists of the following nine components:

1 Monitoring;
2 Construction inspection;
3 Operation and maintenance;
4 Construction responsibilities;
5 Erosion and sediment control at construction sites;
6 Review of design criteria and specification;
7 Public information and consultation;
8 Compliance and enforcement; and
9 Funding.

The following is a brief description of the recommended implementation tasks.

5.7.1 Monitoring

Monitoring could be required for large facilities that will be part of municipal infrastructure. Also, current municipal monitoring programs should be continued and improved where appropriate (*e.g.* water quality monitoring along Cougar Creek.)

5.7.2 Construction Inspection

To ensure an efficient long-term operation and maintenance program each municipality should undertake an extensive inspection program during the construction phase. Regular on-site inspection is important to ensure that the approved temporary and permanent stormwater management plan and design are properly implemented. Visual inspection of all BMP facilities would ensure that the facility has been built according to approved design.

Important elements of the inspection program are:

- Inspect sediment control, diversion and BMP structures during and following installation;
- Inspect sites following severe rainstorm or snow melts events;
- Final inspection nearing completion, to ensure that temporary control measures have been removed, stabilization of the site is complete, major-minor system is in proper condition and the grading agrees with the design;
- All inspections should be documented in a report, listing the name of the inspector, date and time, comments on compliance; and
- Municipality to develop uniform Inspection Forms.

The developer should be given the choice to build the final BMP first to also act as a control during construction, or construct first a temporary facility.

5.7.3 Operation and Maintenance - Watercourses and Stormwater Management Facilities

High sediment rates carried by Cougar Creek and the Canal have added considerable volume of gravel and finer material deposits to the system. As a result, the hydraulic capacity of the channel has decreased. Removal of gravel and sediment and clearing of debris, would improve the hydraulic capacity of the channel, especially in the flat Canal sections. In-stream works will have to be carried out involving local dyking, diversion and pumping which may create temporary interference with the flow and the local environment. The timing and the activity in the creeks will have to be approved in consultation with DFO to ensure meeting regulatory requirements and to minimize the damage to the aquatic environment.

Trapping the sediment at a central location with easy access by machinery to remove the material has been considered in the past. The existing sediment pond located at the downstream end of the steep Cougar Canyon reach has a very limited capacity and needs frequent cleaning. Past plans to increase the storage volume, or to construct additional storage sites have not materialized.

Stormwater Management facilities designed for the conveyance and control of flow, water quality and erosion/sedimentation require a high level of maintenance.

To ensure effective operation, long life and compatibility with the local urban and natural environment, conveyance systems and stormwater control facilities must be monitored, inspected and maintained regularly. Public agencies responsible for stormwater management should continue taking great interest in these local facilities after the planning, design and construction stages. The lack of a regularly scheduled program of maintenance and operation reduces the effectiveness of a stormwater management system and often results in adverse environmental impacts that may be difficult and costly to correct. Without an assured source of funds, well-trained staff and suitable equipment required for operational activities in stormwater control, little can be achieved in developing an ongoing operation and maintenance program.

Municipalities have a number of concerns with respect to operation and maintenance of storm water management facilities. These concerns are focussed on four different issues.

- Safety and liability involved in the operation of various storm water management facilities;
- Downstream environmental effects of quantity and quality control facilities;
- Aesthetic considerations; and
- Funding for future operation and maintenance activities.

The goal of the operation and maintenance program is to ensure within an economic framework, an acceptable standard of stormwater management and BMP facilities in terms of structural and public safety, aesthetic effectiveness, and convenience.

The main objectives of the Operation and Maintenance program are:

- to protect and prolong the useful life of facilities;
- to identify, repair and rehabilitate structures; and
- to provide a sound basis for a management system for the planning and funding of the operation, maintenance and rehabilitation of facilities.

All three aspects of a stormwater management facility: design, construction and long-term maintenance are equally important to ensure a long useful life and high performance. A municipality should have adequate opportunities to provide input into the design and construction phases, before undertaking the long-term maintenance program. **Table 5-8** illustrates the various stages of planning and development, when a municipality should be given an opportunity to review and comment on the proposed SWM policies, design, or to carry out inspections and an efficient maintenance program.

Table 5-8: Municipal Input to Stormwater Management

Phase	Municipal Input	Output
Official Community Plan	Formulation of SWM policy and land use plan	Official Plan with generalized SWM policies
Neighbourhood Concept Plan	SWM targets, goals, objectives, BMP requirements	Neighbourhood Concept Plan with specific SWM policies
Draft Plan of Subdivision and Site Plan	Stormwater management plan, preliminary design review	Approved development plan with condition of draft plan approval, including SWM requirements
Final Design	Design review of SWM facilities	Certificate of Approval
Construction	Inspection of SWM facilities	Facility in place
Assumption	Clearing of deficiencies	Municipal ownership
Post-Construction	Operation and maintenance	Annual programs

Past experience and our inspection of the open watercourses indicates that floating debris, refuse and sediment deposition can cause severe flow constriction at locations, mainly in the Canal. It is suggested that a brief Operation and Maintenance Manual be prepared for Cougar Creek and the NEIC. The municipalities should consult in the development of the Manual.

5.7.4 Construction Responsibilities

Responsibility for the construction of stormwater management facilities is usually shared by the developers and the municipality. The following is the recommended share of responsibilities:

New developments in a presently undeveloped catchment area: it is the developers' responsibility to pay for all the runoff control measures whether located on the lot (at the source) or along the conveyance system or at the receiving system. The stormwater management system must be capable of controlling the runoff events as described under the ISMP targets.

New developments in partially developed areas: it is a shared responsibility between the developers and the municipality. Normally, the developer would be responsible for the on-lot and source control, while the cost of controlling larger storm events should be shared with the municipality.

Redevelopments in a fully developed area: it would be the developers' responsibility to control stormwater within the lot and at the source, while the municipality would be responsible for the rest of the stormwater management system.

5.7.5 Erosion and Sediment Control at Construction Sites

The City of Surrey has an existing by-law for the control of erosion and sedimentation at construction sites. A similar by-law should be developed in Delta. These by-laws should be fully applicable to development activities in the Cougar Creek/NEIC watershed, and contractors would be responsible for all on-site sediment control measures. Construction activities should not be relying on municipal control facilities as part of their sediment control plans.

5.7.6 Review of Design Criteria and Specifications

The current drainage/stormwater management design criteria summarized below are similar for both municipalities.

Surrey Servicing Objectives

The planning for drainage systems which meet the needs of growth must meet four basic criteria which form the fundamental aspects of the City's Drainage Policy:

- A minor system conveyance capacity up to the 1:5-year return period storm to minimize inconvenience of frequent surface runoff.
- A major system conveyance capacity up to the 1:100-year return period storm to provide safe conveyance of flows to minimize damage to life and property. Same criteria to be used for flood plain delineation for the Cougar Creek/NEIC system.
- Where erosion is a concern, to the more stringent of the two following criteria:
    - 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.
- Maintenance of a flood control and drainage system in the lowlands that meets provincial guidelines for agriculture in floodplains (ARDSA).

Delta Design Criteria

- Minor system criteria: 10-year storm, but consideration will be given to using 5-year storm for low-density residential areas. For high value commercial or industrial areas, a 25-year storm is recommended.
- Basement floor elevation located close to storm sewer outfall should be a minimum 0.3 m above the 100-year flood elevation.
- Major system designed for the 100-year flood and no buildings should be damaged by the 100-year storm.

It is recommended that the recently developed B.C. Storm Water Management Policy and Design Manual recommendations should also be applied to the design of local SWM facilities. However, the overall objectives of the Cougar Creek/NEIC Integrated Watershed Management Plan, particularly the recommendations to control runoff, should be followed.

An administration protocol to manage design approval, construction inspection and monitoring of BMPs for new developments and re-developments is required for both municipalities.

Flood Plain Regulations

One of the most effective preventive measures in controlling flood related damages is the control of development or filling of land vulnerable to flooding. Flood Plain Maps based on detailed survey would identify the area subject to flooding under a Design Flood, which usually is based on the provincial 200-year flood event.

It is recommended that a Flood Plain Mapping program should be undertaken for the Cougar Creek/NEIC system based on a 200-year flood criterion. Once the computer generated flood elevations are transposed to a detailed contour map, the area inundated by the 200-year flood should be declared as Flood Plain and no development or fill should be permitted. The accompanying Design Note should also address under what conditions re-development would be permitted in the flood plain.

5.7.7 Public Information and Consultation

Watershed protection and enhancement has not typically been on the public agenda nor are most residents aware of the impact of land use, development and landscaping on the health of the watershed. There are opportunities to increase public awareness and local practices to create “buy in” and increase knowledge about storm water management.

Consideration should be given to inform the public on stormwater management facilities. More particularly to their purpose, cost of construction and operation/maintenance, on problems such as debris and weeds, future programs, contact names and telephone numbers.

Photo 12: Cougar Canyon Elementary School Raingarden

5.7.8 Compliance and Enforcement

Education

Area property owners should be aware of the effect of changes in land uses, in particular the role of on-site features in stormwater management and its effect on the general health of the watershed. It is recommended that such education campaigns should be repeated at periodic times as turnover in property ownership will occur over time.

Proposed Stormwater Management Policies

Following the analysis of the Cougar Creek/NEIC watershed a set of stormwater management policies should be developed incorporating the existing policies of the two municipalities. These policies summarized in **Table 5-9** represent broad statements of intent with respect to the direction for stormwater management and should not be regarded as guidelines or targets, nor can they be quantified. The policies are intended to be applicable to the entire watershed draining through Cougar Creek and the Canal. It is important that these recommended policies be adopted by both municipalities, as one municipality cannot adopt policies to apply beyond its jurisdiction.

It is recommended that the stormwater management goals and linkage between the objectives and policies should be articulated in OCPs and Area Plans/NCPs.

Municipal Sustainability Policies, By-laws and Development Standards, both new and existing, should be pursued and refined to ensure they are easily implemented and practical. Both Surrey and Delta have taken proactive approaches to applying sustainable development practices at both the site level and municipal-wide.

Table 5-9: Recommended Municipal Stormwater Management Related Policies

#	POLICIES
Stormwater Quality and Quantity Policies	
1	Minimize flood hazards by regulating any development in the floodplains in accordance with relevant provincial regulations. Provide flood protection up to the 1 in 200-year return period levels from river flooding.
2	Require the use of integrated stormwater management practices consistent with the regional Liquid Waste Management Plan.
3	Use development permit guidelines and bylaws to ensure that appropriate measures are taken when development occurs in potentially hazardous areas, such as along slopes, bluffs or ravines, and in flood prone areas.
4	Manage, and reduce to the extent possible, the volume of stormwater entering the sewer system to minimize the quantity and quality impact on receiving waters.
5	Surface and sub-surface water quality should not to be degraded. Implement pollution prevention measures, which protect the quality of urban runoff.
6	Implement Best Management Practices to control runoff quantity, quality and erosion/sedimentation.
7	Strive to detain or retain stormwater at lot level.
8	Require the property owner of BMP facilities, located on their own land, to be responsible for future maintenance.
9	Implement infiltration Best Management Practices, to the extent that soil conditions and groundwater levels permit, to mitigate the adverse impacts of stormwater.
10	Mitigate negative environmental impacts of stormwater runoff from roads into the storm water system.
11	Meet acceptable engineering standards for drainage and flood risk in urban areas.
12	Promote and encourage the development of new stormwater management technologies and pilot projects that improve the quality of urban runoff.
13	Source Controls at the lot level are the preferred method for controlling urban runoff. Infiltration methods shall be utilized, to the extent subsoil conditions permit.
14	Conveyance Controls, such as infiltration systems, should be implemented to the extent site conditions and subsoil conditions permit.
15	Where roadside ditches exist, these ditches should be retained and enhanced where feasible.
16	End-of-Pipe Controls should be implemented at the storm sewer outfall where Source Control and Conveyance Controls are unable to achieve the necessary level of stormwater quality and quantity control. Spill containment devices will be required for all facilities where the discharge is to surface or is infiltrated.
Natural Area Protection Policies	
17	Rehabilitate degraded aquatic and terrestrial habitat, including riparian areas using natural and native species.
18	Preserve the natural heritage system and riparian areas, which sustain aquatic and terrestrial habitats as a balanced ecosystem.
19	Enhance riparian areas by planting native vegetation along banks and creating canopy cover to control water quantity and erosion and to improve water quality.

#	POLICIES
20	Preserve, re-establish and rehabilitate vegetative cover in the natural and urban areas to maintain hydrologic and environmental benefits.
21	Locate new infrastructures outside natural areas and valleys.
22	Renewal of infrastructure in ways which have the least impact on natural areas and wildlife.
23	Site new stormwater management facilities to respect the natural heritage features.
24	Encourage private stewardship of valleys, ravines and natural areas, which support water quality improvements and optimized runoff control.
Major-Minor Drainage Systems Policies	
25	Ensure flows that exceed the capacity of the Minor Drainage System are directed away from buildings.
26	Preserve, re-establish and rehabilitate valley lands and watercourses.
27	Rehabilitate watercourses using the best available technology, such as “natural channel design” and bioengineering techniques.
28	Preserve watercourses in their natural location.
29	Strive to ensure all valleys and watercourse lands come into Municipal ownership, if possible.
30	Eliminate sanitary sewer cross connections.
Development Policies – Developers Role	
31	The Municipality will require the owners of lands, submitting development applications to: Provide a Stormwater Management Plan for development applications that are based on achieving the level of control consistent with the Integrated Stormwater Management Plan, and an Environmental Impact Report which demonstrates that the proposed development minimizes the impact on riparian areas.
32	Construct and monitor erosion and sediment controls on sites, which have the potential to discharge sediments to downstream sewers and/or water bodies.
Public Involvement and Municipalities’ Role	
33	Disseminate information and educational material to residents, businesses and community stakeholders so that they can understand the impacts of urban runoff.
34	Develop public education and participation activities to include all communities.
35	Encourage and assist volunteers, including non-governmental organizations (NGOs) to undertake projects that support the restoration, rehabilitation and reclamation of natural wetlands, watercourses, valleys, ravines, and aquatic and terrestrial habitat.
36	Encourage property owners to voluntarily implement urban runoff control measures, where requirements cannot be imposed.
37	Delta and Surrey to co-ordinate all stormwater management activities within the Cougar Creek/NEIC watershed.
38	Make dedicated funding available to finance stormwater management initiatives.

A number of proposed By-Laws are listed in **Appendix E.**

Streamside Protection Regulations

In July of 1997, the Provincial government passed the *Fish Protection Act* to help ensure that fish have sufficient water and habitat for the future in regions of the Province where development was happening at a rapid pace. The Act authorized the Province to “establish policy directives regarding the protection and enhancement of riparian areas” in residential, commercial and industrial areas.

Subsequently, the Provincial government adopted the Streamside Protection Regulation (SPR) in January of 2001 "to protect streamside protection and enhancement areas from residential, commercial and industrial development" as these streamside areas are important to maintain the form and function of fish habitat. These streamside protection and enhancement areas or SPEAs are defined as "an area adjacent to a stream that links aquatic to terrestrial ecosystems and includes both the riparian area vegetation and the adjacent upland vegetation that exerts an influence on the stream". SPEAs are determined based on the existing or potential streamside vegetation conditions, whether or not the channel is fish-bearing and the flow regime within non-fish bearing streams (*i.e.*, permanent or ephemeral). Under the terms and conditions of the SPR, the width of the SPEA can range from 5 metres up to 30 metres.

The City of Surrey uses the SPR in the determination of SPEAs for new commercial, industrial or residential development within its municipal boundaries. The Corporation of Delta has passed its own bylaw governing setbacks (No.6349 Streamside Protection and Enhancement Area, Development Permit Area), where the setbacks are largely determined using the terms and conditions of the SPR in regards to existing or potential vegetation, fish presence and flow regime. Delta has added another element to the determination of setbacks where ravines greater than 60m width (excluding the floodplain) are provided protection of "at least" 10 metres from the top of the ravine. Both the City's use of the SPR and the Corporation's bylaw meet the minimum requirements of the Provincial Riparian Areas Regulation.

5.7.9 Funding and Financial Planning

It is recommended as a long-term implementation tool, the Corporation and the City should undertake a funding and financial planning review in order to prepare and adopt new funding policies for stormwater management infrastructure activities.

A review of Canadian and U.S. practices in funding mechanisms identified a number of key issues which can influence the adoption and selection of funding mechanisms for SWM. These are:

- Delays or cancellation of SWM programs;
- Lack of capability to predict annual operating and capital budgets;
- Lack of long-term planning;
- Existing funding mechanisms are regarded as unfair or not equitable;
- Missing of opportunities to achieve cost-effective solutions in SWM;
- Lack of relevant policies needed to prioritize projects;
- Lack of policies for debt issues and emergency reserves; and
- Lack of public understanding and involvement in SWM funding.

A wide range of opportunities are available to a municipality to fund stormwater management activities. These include:

User charges - User charges are payments by property owners for use of a public infrastructure. This mechanism can be used to recover the cost of construction and operation/maintenance of a stormwater infrastructure. The underlying philosophy of user charges is that those who use the service should pay for the service, thereby shifting the burden of payments from the tax-paying public to the users of the infrastructure and services.

Development charges **-** Development charges are paid by a developer of new properties or in some cases of re-developed properties. These payments are used as contribution towards the capital cost of servicing new developments or redevelopments.

Sewer surcharges on water bills **-** Sewer surcharge can be incorporated in the water rate, but as a separate entity. Frequently, the surcharges are expressed as a percentage of the water rate, or as a flat rate.

Property taxes **-** Revenues collected by municipalities from property taxes can be allocated to specific purposes, including the financing of storm sewer construction, operation and maintenance.

Stormwater utility fees **-** Linking storm water utility fees to the impervious lot coverage could provide an incentive to reduce total runoff and encourage site specific environmentally sensitive management.

It is recommended that a series of criteria should be considered when selecting the most appropriate funding mechanism for a municipality, as summarized in **Table 5-10** below.

Table 5-10: Funding Issues and Criteria

Criteria	Issue
Authority	The municipality should have the legal authority to set up a funding mechanism for stormwater management.
Financial impact	There should be no significant financial impact on owners.
Flexibility	The selected funding mechanism should be flexible to allow future modification, if needed.
Adequacy	The funding mechanism should be predictable and sufficient to cover the costs of stormwater management.
Fairness	The collection of funds should be equitable and just.
Political support	The funding of stormwater management should have a wide political support.

It is recommended that a short list of one or two funding mechanisms should be selected for detailed review. Once the short list has been agreed upon by all the stakeholders, the preferred alternative should be selected and a detailed report prepared on the chosen funding mechanism(s). The next step in the selection process would involve the preparation of a detailed cost and financing model. A multi-year revenue modelling exercise should be conducted to determine the adequacy and affordability of the selected funding mechanism(s).

Part of the Implementation Program would be the requirement for a Financial Plan which outlines the land acquisition and capital financing of the stormwater management facilities. The Plan should outline negotiation procedures with the developer/owner during zoning changes, land exchange, density bonuses, and adjustments of existing Development Charges. Also, the Plan should address regulatory issues, such as the role of various regulatory tools, zoning negotiations, development permits for protection of the natural environmental, ecosystems and biodiversity, tree protection bylaws, watercourse protection bylaws, and engineering standards and specifications. The Plan should ensure that the regulatory tools would work together, without overlap or excessive red tape.

Table 5-11 summarizes the study objectives and the components of the recommended Integrated Stormwater Management Plan.

Table 5-11: Summary of Integrated Stormwater Management Plan

Summary of Integrated Stormwater Management Plan	
Objective	**Recommended management component**
SHORT-TERM REMEDIAL AND REHABILITATION MEASURES	
Alleviate existing and potential erosion and flooding concerns.	• Improve flow capacity of the Canal in the vicinity of Westview Drive to reduce flooding (Option #2 or #3) • Complete a detailed survey of erosion conditions at Sites # 7 and #13, for two consecutive years, followed by a mitigation measure as required (Option # 8).
LONG-TERM STORMWATER MANAGEMENT MEASURES FOR NEW AND RE-DEVELOPMENTS	
Minimize destruction of property and natural resources from flooding and erosion generated by developments Control runoff to reduce the flood risk threatening life and property	• Design the major and minor system to meet runoff volume and peak flow targets. • Adopt appropriate SWM facilities in new developments and re-developments to control runoff volume, peak flows, water quality and erosion for all design events, where feasible. • Prepare a floodplain mapping study for Cougar Creek and the Canal to establish flood plain limits. • Adopt LID concepts for future developments. Where feasible, the predevelopment hydrologic cycle components, in particular the base flow component, should be maintained. • As part of operation/maintenance, remove channel constrictions, such as log and debris jams and sediment depositions.
LONG-TERM RIPARIAN CORRIDOR MANAGEMENT	
Protect stream morphological and fluvial character and prevent increase in erosion and deposition. Restore eroding stream banks to a stable condition.	• Regular monitoring of potential erosion sites. • Provide erosion protection as required. • Municipalities to prepare a long-term planting program.
Ensure that hydrogeological functions are preserved	• Encourage infiltration of stormwater where feasible. • Maintain or enhance existing base flows.
Protect aquatic ecosystem and maintain/enhance aquatic habitat	Suggested list of fish habitat compensation projects to protect stream corridors: • Remove accumulated sediments from the Cougar system downstream of Westview Drive. • Remove debris jam barriers from Cougar Canyon. • Maintain existing habitat diversity. • Construct fish habitat in the Canal. • Aquatic protection to be based on resident fish community and habitat conditions. • Provide fish habitat compensation sites, where needed. • Provide appropriate riparian setbacks. • Implement strict erosion/sediment control during construction activities. • Enhance riparian vegetation upstream of Scott Road. • Purchase setbacks within industrial properties and construct off-line ponds north of Nordel Way, where space permits. • Undertake clearing and grubbing of invasive vegetation from Cougar Creek headwaters and replace with native vegetation. • Relocate existing channel to the dry pond at Khalsa School and plant native vegetation. • Investigate opportunities for securing habitat credits to offset future habitat losses.
LONG-TERM LAND USE PLANNING AND CONTROL	
Ensure that new developments or re-developments incorporate the most appropriate development form and mitigation measures necessary to protect the natural features and functions	• Develop strategies based on LID concepts for developing or redeveloping i) existing large developed areas, ii) existing park and school sites, iii) vacant lands and green sites, and iv) infill developments. • Parks, green spaces and schools could present future opportunities for watershed enhancement facilities (rain gardens, biofilters). • Delta/Surrey to continue to explore enhancement opportunities on larger greenfields. • Environmental Implementation Reports should be part of development applications. • Prepare a set of proposed guidelines for retrofitting drainage facilities. • Establish owner incentive programs and density bonus systems. • Create neighbourhood plans where infill developments are expected. • Consider adopting environmental friendly erosion protection measures. • Ensure that the planned Greenway stream corridor will minimize flooding and erosion risks. • Adopt long-term riparian setbacks for re-development sites. • Encourage enhancement of Hydro Park RoW and Cougar Creek Park detention ponds to improve fish habitat. • Explore opportunities to manage greenfields, such as tree retention, introduction of new or retrofitting of existing stormwater management facility incorporating green policies for roads and public rights-of-ways. • Include monitoring requirements in subdivision agreements. • Review existing road sweeping programs. • Identify areas to be preserved for recreational opportunities, and these areas to be integrated in future planning.
IMPLEMENTATION MEASURES	
Long-term tasks to assist in the integration of stormwater management and land use planning and the protection and enhancement of the stream environment	• Monitoring required for larger facilities • Regular on-site construction inspection • Prepare a brief Operation and Maintenance Manual • Prepare administration protocols to manage the approval, inspection and monitoring of BMPs • Delta to prepare erosion and sediment control by-laws • Review/update design criteria/specification, enact floodplain regulation • Public information and consultation on stormwater management • Adopt recommended SWM policies and by-laws, and undertake enforcement • Funding and financial planning review

6.0 REFERENCES

American Forests. 2007. Setting Urban Tree Canopy Goals. http://www.americanforests.org/resources/urbanforests/treedeficit.php. (last accessed August 2007).

Armstrong J.E. and S.R. Hicock. GSC Map 1484A. Surficial Geology New Westminster.

B.C Water, Land and Air Protection, Stormwater Planning Guidebook, 2002.

Bruce Geotechnical Consultants Inc. Cougar Creek Drainage Study, Geotechnical Assessment. December 19, 1995.

Canadian Housing and Mortgage Corporation (CMHC). 2007. Urban Forestry. Website http://www.cmhc-schl.gc.ca/en/inpr/su/waco/alstmaprrepr/ alstmaprrepr_006.html. (last accessed July 2007)

City of Coquitlam. 2005. City of Coquitlam Low Impact Development Policy & Procedures Manual.

City of North Vancouver. 2004. Urban Forest Master Plan Phase II – Street Tree Master Plan Backgrounder.

City of Seattle. 2006. Urban Forest Management Plan.

City of Surrey, Storm Drainage System Design Criteria Manual, 2004.

Corporation of Delta, Cougar Creek Flow Analysis September 200- December 2005

Dayton & Knight, North Delta Fraser Drainage Area and Boundary Bay Drainage Area Master Drainage Plan 1989

Dayton & Knight. Corporation of Delta Stormwater Management Design Manual, Draft 1989.

Delcan. Preliminary Design Report North East interceptor Canal, 1994.

Denver Regional Council of Governments, Urban Storm Drainage Criteria Manual 1969

Dillon Consulting Limited. Cougar Creek Drainage Master Plan, 1996.

Dillon Consulting Limited. Cougar Creek Drainage Study, 1996.

Donigian, A.S. Jr. 2002. Watershed Model Calibration and Validation: The HSPF Experience. WEF National TMDL Science and Policy 2002, November 13-16, 2002. Phoenix, AZ. WEF Specialty Conference.

Gartner Lee Limited. Delta Watershed Park Preliminary Aquifer Assessment. Prepared for Corporation of Delta. October 2004.

Gilmore, Suzanne. May 2002. Benthic Macro-Invertebrate population difference between sand and cobble substrates in the Arroyo Seco Watershed. Central Coast Watershed Studies, The Watershed Institute, Earth Systems Science and Policy, and California State University Monterey Bay. Website at http://science.csumb.edu/~ccows/ccows/pubs/class_reports/ArroyoSecoBMI_Gilmore.pdf

Greater Vancouver Regional District (GVRD). 2005. Stormwater Source Control Design Guidelines 2005.

Greater Vancouver Sewerage and Drainage District (GVS&DD) 1999. Liquid Waste Management Plan Stormwater Management – Best Management Practices Guide for Stormwater.

Kerr, Wood, Leidal. Template for Integrated Stormwater Management-Template, 2006

Ker, Wood, Leidal. Flood Management Study Draft 2007.

Klohn-Crippen. North East Interceptor Canal Improvements, Draft Pre-design Report 1997.

City of North Vancouver – Methodology and Procedures. Center for Urban Forest Research. Pacific Northwest Research Station. USDA Forest Service.

Marsalek, J. "Head Losses at Selected Sewer Manholes". Environmental Hydraulics Section, Hydraulics Division, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario, 1985.

North American Benthological Society. 2008. History of the EPT Taxa Richness Metric website at http://www.benthos.org/Bulletin/bull1302.htm.

Northwest Hydraulic Consultants (NHC). Lower Fraser River Hydraulic Model-Final Report, 2006.

Prince George’s County Department of Environmental Resources (PGDER). 1999. Low Impact Development Design Strategies – An Integrated Design Approach. Programs and Planning Division.

Puget Sound Action Team (PSAT). 2005. Low Impact Development – Technical Guidance Manual for Puget Sound.

Puget Sound Action Team. 2003. Natural Approaches to Stormwater Management – Low Impact Development in Puget Sound.

Roesner, L. A., J. A. Aldrich, and R. E. Dickinson. 1988. Storm Water Management Model User's Manual Version 4: EXTRAN Addendum, U.S. Environmental Protection Agency (USEPA).

Ron Macdonald, Estimated Urban Runoff Character and Contaminant Loadings in the GVRD, 2003.

Rossman, L.A. 2004. Storm Water Management Model User's Manual Version 5.0. National Risk Management Research Laboratory. Office of Research and Development. U.S. Environmental Protection Agency (USEPA).

Spittlehouse, David L. 1998. Rainfall Interception in Young and Mature Conifer Forests In British Columbia. Proc. 23rd Conf. on Agricultural and Forest Meteorology, 2-6 November 1998, Albuquerque, N.M. American Meteorological Society, Boston, MA.

US Environmental Protection Agency (USEPA). 2000. Low Impact Development (LID) – A Literature Review. EPA-841-B-00-005.

Water Pollution from Urban Stormwater Runoff in the Brunette River Watershed, B.C. 1998.

West Coast Environmental Law, Smart By-Laws, 2003.

West Coast Environmental Law, The Green Buildings Guide 2006.

Xiao, Q., E. G. McPherson, J. R. Simpson, and S. L. Ustin. 1998. Rainfall Interception by Sacramento's Urban Forest. Center for Spatial Technologies and Remote Sensing. University of California, Davis.

APPENDIX A
STRUCTURAL SURVEY SUMMARY

Appendix A: List of Structures within Northeast Interceptor Canal

#	Location*	Description of Structure	Material	Condition**	# of Structures	Diameter of size of opening	Height	Width	Dist.(m)	Photos	Comments
1	River Road	Circular culverts	Corrugated steel	4	4	1.2m	2.3 m	2.9 m	0	1 to 13	Mill bridge 27 m away, 4 round culverts at River Road, 7 m grizzly and storm outfall on upstream side of River Road. Vertical bag wall on left bank of upstream side
2	Adjacent to trail	Box culvert	Concrete	5	2		3 m	3 m	26	14, 16, 17	Square box culverts, open bottoms, concrete baffles throughout. Located under railroad
3	Adjacent to trail	Bridge	Wood	3	1 bridge 1 debris trap		3.8 m	9.8 m	197	16	4.9 m upstream of culvert inlet
4	Adjacent to trail	Alex Fraser Bridge Infrastructure	Concrete and steel	5	1		2.0 m	4.8 m		18 to 22	Concrete, open-bottomed with steel sides
5	Under trail	Circular culverts	Corrugated steel	2.5	1	1.2 - 1.5 m			245	23 to 25	Vegetation overgrown on culvert, some debris located on inlet side
6	NE side of canal	Concrete culvert	Concrete	5	2	0.5 & 1 m				26 to 31	Water from culverts flows overtop GVRD sanitary main
7	Adjacent to trail	Circular culverts	Corrugated steel	2.5	1	3 m			561	32 to 36	Right bank has linear concrete wall, most likely part of sanitary structure, culvert more elliptical in shape, debris build-up at inlet side
8	NEIC Canal	None						Wetted: 1.8 m Bank full: 2 m	719	37 to 42	BFH: 0.4 m, Depth of water 0.8 m. Beaver dams located on main channel and tributary channel. Cross section not completed due to dams and too much water
9	Adjacent to trail	Bridge	Wooden	3	1		0.9 m	1.8 m	1210	43 to 46	Wooden bridge crossing Canal. Length of bridge: 18.5 m. Broken on one end, with heavy vegetation on upstream side (willows)
10	Adjacent to trail	Small channel	Earth				0.7 m			47 to 49	Small channel draining lowland pond located on NE side
11	Under trail	Pipe	PVC	5	1	0.3 m				50 to 53	Pipe crosses under trail, drains area on the SW side of trail. Pipe length = 6 m. FS = 212 degrees
12	Under trail	Pipe	Corrugated Steel	1	1	0.3 m				54 to 56	Pipe located into trail and under mid-channel. Located 29 m upstream of structure #11
13	Adjacent to trail	Bridge	Wooden	5	1		0.9 m	1.8 m	1717	57 to 60	Wooden bridge crossing. Length of bridge: 9.4 m. Wetland located 5 m NE from canal
14	Under trail	Pipe	Steel	4	1	0.3 m				61 to 65	Length of pipe 7.3 m. Pipe located 2.8 m of structure #13 (bridge). FS 222 degrees SW
15	Under trail	Pipe	PVC	5	1	0.2 m				66 to 69	Length of pipe 6.37 m. Pipe located 18.1 m upstream of structure #14. Drainage for ditch on opposite side of trail
16	Under trail	Pipe	PVC	5	1	0.23 m				70 to 74	Length of pipe 5.1 m. Recently replaced. FS = 224 degrees
17	Under trail	Pipe	Unknown	2	1	<0.3 m				75 to 76	Length of pipe ~ 5.3 m. Difficult to view pipe, possibly steel
18	Under railroad track	Culvert	Corrugated steel	4	1	0.8 m				77 to 83	Culvert located 18 m from Canal. FS = 80 degrees E. Length of culvert = 9.3 m
19a	Adjacent to trail	Train bridge	Concrete	5	1		2.3 m	7.4 m	2390	88 to 96	Train bridge located 12.5 m from Cougar Creek to the NNE. ~40 m upstream of bridge there was a change to a cobble substrate
20	Tributary to Cougar Creek	Culvert	Corrugated steel	5	3	1.0 m			2720	97 to 100	3 culverts feed into tributary which flows under train bridge
21	Adjacent to trail	Bridge	Wooden	5	1		1.3 m	1.5 m	2788	101 to 103	Length of bridge: 6.8 m. FS = 264 degrees W
22	Under trail	Culvert	Corrugated steel	5	1	0.9 m				104 to 107	Length of culvert 6.1 m. FS 303 degrees NW. Fish (CT) located at outlet to Cougar Creek ~ 5.5 m away from trail
23	Under trail	Culvert	Corrugated steel	5	1	0.6 m			2939	108 to 110	Culvert located 22.4 m upstream of structure #22. Plugged at both inlet and outlet. 12.4 m from culvert outlet to Cougar Creek. FS = 267 degrees
25	Near trail	Train bridge	Concrete	5	1		1.1 m		2937	116 to 118	Length of bridge: 15 m. There is an outfall on the right bank of creek
26	Near train bridge	Culvert	Concrete	4 to 4.5	1	0.8 m				119 to 122	Outfall located 3 to 3.5 m from creek and 15 m from bridge. FS from W bank = 120 degrees
27	Past 72nd Ave	Culvert	Corrugated steel	1	1	0.8 m			3091	123 to 126	Culvert is falling apart. Length is undetermined
28	Westview Drive	Ellipse	Corrugated steel	4	1	4 m			3177	127 to 129	Large elliptical culvert under Westview Drive

APPENDIX B

WATER QUALITY SAMPLES TAKEN IN FEBRUARY, MARCH AND APRIL 2008

Appendix B: Water Quality Samples Taken in February and March 2008

SITE		Nicholson	Westview	Nordel	Nicholson	Westview	Nordel
CANTEST ID		802220420	802220421	802220423	803190858	803190859	803190860
Date Sampled		22/02/2008	22/02/2008	22/02/2008	18/03/2008	18/03/2008	18/03/2008
Parameter	Units	DRY WEATHER CONDITIONS			MODERATE FLOW CONDITIONS		
Hardness (Total) $CaCO_3$	mg/L	77.9	71.8	67.1	52.4	50.6	43.4
Total Suspended Solids	mg/L	2	< 1	1	6	< 1	2
Total Aluminum Al	mg/L	0.13	0.048	0.15	0.27	0.079	0.11
Total Antimony Sb	mg/L	< 0.0002	0.0002	< 0.0002	0.0005	0.0003	0.0002
Total Arsenic As	mg/L	0.0004	0.0011	0.001	0.0017	0.0018	0.0013
Total Barium Ba	mg/L	0.023	0.018	0.019	0.017	0.012	0.013
Total Beryllium Be	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Bismuth Bi	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Boron B	mg/L	0.02	0.02	0.01	0.01	0.01	0.01
Total Cadmium Cd	mg/L	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004	< 0.00004
Total Calcium Ca	mg/L	22.9	20.8	19.6	15.5	14.7	12.7
Total Chromium Cr	mg/L	0.001	0.0019	0.0007	0.0018	0.0016	0.0012
Total Cobalt Co	mg/L	< 0.0002	< 0.0002	0.0002	0.0003	< 0.0002	< 0.0002
Total Copper Cu	mg/L	0.0024	0.0022	0.0024	0.0037	0.0033	0.0034
Total Iron Fe	mg/L	0.32	0.12	0.5	0.39	0.15	0.37
Total Lead Pb	mg/L	0.0006	0.0002	0.0009	0.0009	0.0004	0.0007
Total Lithium Li	mg/L	0.0004	0.0003	0.0005	0.0009	0.0009	0.0082
Total Magnesium Mg	mg/L	5	4.82	4.4	3.29	3.38	2.83
Total Manganese Mn	ug/L	0.052	0.01	0.066	0.052	0.0077	0.046
Total Mercury Hg	mg/L	< 0.02	< 0.02	< 0.02	< 0.00002	< 0.00002	< 0.00002
Total Molybdenum Mo	mg/L	0.0004	0.0004	0.0003	0.0008	0.0005	0.0003
Total Nickel Ni	mg/L	0.0011	0.0008	0.001	0.0012	0.0007	0.0008
Total Phosphorus P	mg/L	< 0.03	< 0.03	0.03	0.03	< 0.03	< 0.03
Total Potassium K	mg/L	1.84	1.86	1.67	1.46	1.46	1.25
Total Selenium Se	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Silicon Si	mg/L	6.03	6.48	6.61	3.9	4.27	4.32
Total Silver Ag	mg/L	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005
Total Sodium Na	mg/L	20.1	16.8	15.5	10.8	9.81	9.76
Total Strontium Sr	mg/L	0.159	0.129	0.125	0.103	0.09	0.081
Total Tellurium Te	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Thallium Tl	mg/L	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Total Thorium Th	mg/L	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Total Tin Sn	mg/L	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Total Titanium Ti	mg/L	0.0047	0.002	0.006	0.009	0.0024	0.0036

SITE		Nicholson	Westview	Nordel	Nicholson	Westview	Nordel
CANTEST ID		802220420	802220421	802220423	803190858	803190859	803190860
Date Sampled		22/02/2008	22/02/2008	22/02/2008	18/03/2008	18/03/2008	18/03/2008
Parameter	Units	DRY WEATHER CONDITIONS			MODERATE FLOW CONDITIONS		
Total Uranium U	mg/L	< 0.0001	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001
Total Vanadium V	mg/L	0.0007	0.0008	0.0009	0.001	0.0009	0.001
Total Zinc Zn	mg/L	0.009	0.005	0.01	0.014	0.007	0.009
Total Zirconium Zr	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Monocyclic Aromatic Hydrocarbons							
Benzene	ug/L	< 0.1	< 0.1	< 0.1	< 0.0001	< 0.0001	< 0.0001
Ethylbenzene	ug/L	< 0.1	< 0.1	< 0.1	< 0.0001	< 0.0001	< 0.0001
Toluene	ug/L	< 0.1	< 0.1	< 0.1	0.0002	< 0.0001	< 0.0001
Xylenes	ug/L	< 0.1	< 0.1	< 0.1	< 0.0001	< 0.0001	< 0.0001
Volatile Hydrocarbons VHw6-10	ug/L	< 100	< 100	< 100	< 0.1	< 0.1	< 0.1
VPHw	ug/L	< 100	< 100	< 100	< 0.1	< 0.1	< 0.1
Styrene	ug/L	< 0.1	< 0.1	< 0.1	< 0.0001	< 0.0001	< 0.0001

Sample ID CANTEST ID Date Sampled		Nicholson 804280206 28/04/2008	Westview 804280208 28/04/2008	Nordel 804280209 28/04/2008
Parameter	Units			
Nitrate and Nitrite N	mg/L	0.48	0.59	0.7
Nitrate N	mg/L	0.46	0.58	0.68
Nitrite N	mg/L	0.017	0.015	0.018
Total BOD	mg/L	< 10	< 10	< 10
Chemical Oxygen Demand	mg/L	< 20	< 20	< 20

APPENDIX C
COMPUTER MODELING

EPA SWMM Model Description

The EPA Storm Water Management Model (EPA SWMM) is a comprehensive dynamic rainfall-runoff simulation model that uses real and hypothetical storm events (hyetographs) with other meteorological data and system information to generate water quantity and quality results that can vary spatially as well as temporally. It is a comprehensive mathematical model that is used widely throughout the world in the analysis of complex hydrologic, hydraulic and water quality problems for urban (and rural) areas. EPA SWMM, and its variants, have been used extensively for the simulation of surface runoff, transport of runoff through complex open-channel and closed conduit drainage networks (storm, sanitary and combined sewer systems), floodplain analysis, storage and treatment of runoff, estimation of urban pollutant build-up and wash-off, soil erosion and sediment transport, and receiving water impacts (through a linkage to the receiving water quality impact model EPA WASP). Single-event and continuous simulations can be performed throughout the entire EPA SWMM model. The model is suited to simple order of magnitude screening models, overall watershed and site planning assessments, more detailed drainage analysis and design, and operational applications (real-time controls and notifications).

The EPA SWMM model was originally developed in 1969-1971 primarily to address pollution problems due to combined sewer overflows. EPA SWMM and its variants are capable of analyzing all aspects of urban water quantity and quality and are considered by many in the engineering community to be the model of choice for comprehensive hydrologic and hydraulic analyses of the urban drainage systems in North America.

Version 5 of the model, EPA SWMM5, used in this study has been completely redeveloped with a complete graphical user interface for the input and presentation of model results.

Subcatchment Characteristics

Subcatchments were lumped and delineated on the basis of the location of discharge into the main drainage system (storm sewers, ditches, and creek) and topographic information and drainage patterns. A total of 101 subcatchments were delineated and modelled in the EPA SWMM model.

Characteristic parameters to represent the drainage of the various sub-catchments in the study area were determined. These parameters include catchment size, imperviousness ratio, subcatchment width, slope and roughness, depression storage coefficients, and Horton's infiltration parameters. To characterize the drainage of subcatchment areas, the following aspects were taken into account in determining model parameters:

The average imperviousness ratio for each subcatchment was calculated based on representative imperviousness ratios for various land use types using digital files of current land-use zoning information of the study region obtained by the City and the Corporation. ArcGIS was used to determine the areal proportion of the various land use types for each subcatchment. The average impervious ratio per subcatchment was calculated by weighting representative impervious ratios for each land use type on an area basis. Initial values of impervious ratios for both the City of Surrey and the Corporation of Delta were derived from values provided in Table 5.3(h) of the City of Surrey's Engineering Department Design Criteria Manual (2004). Calibrated impervious ratio values used in the model are shown in Table 1.

Table 1: Representative Impervious Ratios

Land Use Classification	Impervious Ratio
Single-Family/Urban	0.60
Multi-Family	0.65
Suburban	0.40
Industrial	0.90
Park	0.05
Road	1.00
Agricultural	0.05
Commercial	0.90

Based on the values presented in Table 1, the portion of the Cougar Creek watershed within Surrey was estimated to have an overall imperviousness of approximately 58.9%. The portion of the Cougar Creek watershed within Delta was estimated to have an overall imperviousness of approximately 60.4%. The percent imperviousness and area sizes for each modelled subcatchment is listed in Table 2.

Table 2: Subcatchment Parameters

Catchment ID	Total Area (ha)	% Imperviousness	Catchment ID	Total Area (ha)	% Imperviousness
Delta Subcatchments			D52	35.71	67.1%
D1	13.45	55.0%	D53	37.89	51.6%
D2	4.49	74.3%	D54	3.03	50.0%
D3	56.85	22.0%	D55	2.22	47.0%
D4	3.69	69.0%	D56	2.39	64.5%
D5	40.04	57.5%	D57	3.54	59.0%
D6	54.47	47.9%	D58	5.47	73.2%
D7	7.25	72.3%	D59	1.00	41.6%
D8	2.69	60.0%	D60	0.48	58.4%
D9	13.29	37.4%	D61	26.58	69.6%
D10	6.66	69.0%	D62	4.84	73.5%
D11	6.90	68.7%	D63	11.57	71.9%
D12	23.41	57.7%	D64	3.40	40.0%
D13	19.06	58.0%	D65	2.23	60.9%
D14	11.78	72.1%	**Surrey Subcatchments**		
D15	3.59	66.8%	S1	26.55	64.8%
D16	3.84	90.0%	S2	31.21	60.8%
D17	35.51	83.5%	S3	5.71	56.2%
D18	43.05	65.7%	S4	47.47	57.8%
D19	29.33	78.0%	S5	33.93	77.3%
D20	2.32	66.6%	S6	19.61	51.2%
D21	29.05	52.8%	S7	30.25	56.3%
D22	7.98	71.2%	S8	21.41	58.5%

Catchment ID	Total Area (ha)	% Imperviousness	Catchment ID	Total Area (ha)	% Imperviousness
D23	17.06	61.2%	S9	2.95	40.9%
D24	8.96	58.7%	S10	2.03	40.0%
D25	1.58	79.1%	S11	1.26	43.1%
D26	17.13	55.0%	S12	1.71	65.0%
D27	3.69	69.4%	S13	13.85	63.4%
D28	4.28	64.0%	S14	1.12	62.3%
D29	18.42	74.4%	S15	0.84	90.0%
D30	2.94	88.6%	S16	1.80	60.0%
D31	34.07	72.2%	S17	7.84	51.0%
D32	28.21	80.2%	S18	6.48	51.8%
D33	3.57	24.0%	S19	1.72	60.0%
D34	5.62	67.9%	S20	16.04	58.7%
D35	2.24	69.2%	S21	1.32	60.0%
D36	16.38	37.0%	S22	2.45	59.4%
D37	4.94	72.6%	S23	7.67	60.0%
D38	0.51	82.3%	S24	0.71	60.0%
D39	0.90	67.2%	S25	5.71	57.3%
D40	3.99	71.9%	S26	4.64	64.0%
D41	14.39	73.5%	S27	8.14	59.7%
D42	17.39	82.0%	S28	3.64	43.7%
D43	3.91	80.1%	S29	2.29	40.0%
D44	2.24	77.0%	S30	17.35	58.1%
D45	7.44	74.0%	S31	10.10	52.8%
D46	4.00	11.7%	S32	5.18	63.4%
D47	0.88	15.2%	S33	44.50	52.6%
D49	2.08	45.0%	S34	1.93	60.0%
D50	3.33	45.0%	S35	2.93	64.4%
D51	1.81	40.0%	S36	2.27	45.5%

Park spaces or road-only areas for the City of Surrey are not segregated in the land use zoning classification as is done in the Corporation of Delta. These park spaces are incorporated into other land uses. Some areas in Surrey were unclassified and were assumed to have an average impervious ratio of 0.50. The Corporation of Delta includes both urban and suburban areas as single family residential.

The initial values for the remaining subcatchment parameters were chosen to be physically realistic and in general agreement with experience and engineering practice:

- Values for subcatchment widths were determined based on recommendations made in the SWMM User's Manual and experience gained from various other studies;

- Representative values from other studies were used for Manning's overland sheet flow roughness coefficients. A slope of one percent was used to represent the average subcatchment grading;
- Depression storage losses of 2.5 and 6.0 mm were used for the impervious and pervious area, respectively. These losses correspond to values suggested in literature; and
- Horton's infiltration parameters of 44.76 mm/hr and 6.73 mm/hr were used for the initial and ultimate infiltration capacity according to Horton's formula. A value of 1.78 hr^{-1} was used for the recession coefficient. These Horton parameters are typical for soils that are Hydrological Soil Type C (*e.g.*, clay loam, loam, silty loam) and were observed to provide reasonable calibration volumes. The Horton's infiltration parameters presented previously in the Cougar Creek Drainage Study (Dillon, 1996) were examined but did not provide enough rainfall during the calibration exercise.

Hydraulic System

Storm sewer trunks in the Cougar Creek watershed discharge at various outfalls located along Cougar Creek, Blake Creek, and the North East Interceptor Canal. The storm sewer system layout, connectivity, invert and surface elevations, and conduit shape and dimensions were determined from block profiles, sewer plans, and digital data provided by the City of Surrey and Corporation of Delta. The extent of the system modelled in EPA-SWMM was based on the contributing lumped subcatchment areas to reduce computational time. Local losses, such as those that occur at manholes and culverts, were incorporated based on literature values presented by Marsalek (1985) and the Denver Regional Council of Governments (1969).

Hydraulic data of channel or ditch cross-sections and structures for Cougar Creek and the NEIC were obtained from previous studies (Delcan, 1994; Klohn-Crippen, 1997; Dillon, 1995; and Dillon, 1996). The dimensions and configurations of the various hydraulic structures in the NEIC were visually confirmed in the field. Hydraulic roughness of the channel and conduits and inlet/outlet loss values were taken from estimates from the previous studies or from estimates based on field observations. It is recommended that an updated and thorough hydraulic survey be performed to more accurately predict hydraulic performance of the NEIC and to represent changes in the channel due to sediment erosion and aggrading and as well as any changes in the hydraulic structures.

Cougar Creek Park Storage Modeling

The proposed stage storage relationship for the Cougar Creek Park expansion is listed in **Tables 3 and 4.**

Table 3: Stage-Area-Storage-Discharge Relationship – Cougar Creek Park Wetpond (Existing and Possible Expansion)

Elevation	Total Depth	Existing				Expansion			
		Area	Total Storage	Active Storage	Discharge	Combined Area	Total Storage	Active Storage	Discharge
(m)	(m)	(m^2)	(m^3)	(m^3)	(m^3/s)	(m^2)	(m^3)	(m^3)	(m^3/s)
67	0	1380	0	0	0	4220	0	0	0
69	2	6262	7642	0	0	12216	16436	0	0
70	3	9526	15536	0	0	17210	31149	0	0
70.15 (NWL)	3.15	9923	16995	0	0	17871	33780	0	0
71	4	12179	26388	9393	3.034	21619	50563	33568	1.061
72.5 (HWL)	4.5	13178	32727	15732	8.960	23556	61857	44862	3.136

Table 4: Stage-Area-Storage-Discharge Relationship – Cougar Park East Wetpond (Existing and Possible Expansion)

Elevation	Total Depth	Existing				Expansion			
		Area	Total Storage	Active Storage	Discharge	Combined Area	Total Storage	Active Storage	Discharge
(m)	(m)	(m^2)	(m^3)	(m^3)	(m^3/s)	(m^2)	(m^3)	(m^3)	(m^3/s)
80	0	1880	0	0	0	3986	0	0	0
81	1	2702	2291	0	0	6095	5040	0	0
82	2	3879	5581	0	0	8806	12490	0	0
83 (NWL)	3	7091	11066	0	0	13791	23789	0	0
84	4	9179	19201	8135	0.742	17873	39621	15832	0.056
85 (HWL)	5	12197	29889	18823	7.530	23079	60097	36308	0.565

APPENDIX D

LAND REDEVELOPMENT ANALYSIS – SURREY AND DELTA CATCHMENTS

Purpose

The purpose of this exercise was to identify properties/lands within the Cougar Creek catchment area that have a potential to redevelop to higher densities and site coverage, thereby increasing stormwater runoff. The data was used in the hydrologic computer model for the project.

SURREY
Methodology

Using a 2007 air photo along with current zoning maps and future land use maps (Official Community Plan Map, West Newton North NCP map and West Newton South NCP map), properties were identified and numbered on the large air photo. Each site and number corresponds to an estimated increase in the site coverage (%) that could occur within the next 15-20 years. Some sites are underdeveloped and can be expected to densify over the years and some sites are greenfield and can be expected to be fully developed. The sites outlined in red refer to commercial/institutional/industrial redevelopment sites and those outlined in brown refer to residential redevelopment sites.

Some Assumptions

Several assumptions apply to this analysis as follows:

- Existing older commercial developments are estimated to be redeveloped to a level that will increase the hard surface coverage from the existing to 20% more.
- Greenfield commercial sites (designated but undeveloped) are estimated to be developed to a level that will increase the hard surface coverage from the existing to either 40% or 60% more depending on the current site coverage.
- Future single family development sites are estimated to have a site coverage of 50%.
- Future multi-family development sites are estimated to have a site coverage of 40% (all are based on Surrey's Zoning Bylaw requirements).

Site Listing for Surrey

Commercial Site No.	Existing Land Use	Future Land Use	Increase in Site Coverage
1	CD Zone, under utilized (72nd Ave & 125th St)	More commercial	20%
2	PA Zone, under utilized (72nd Ave & 124th St)	More institutional or other development	20%
3	C8 Zone, under utilized	More commercial	20%
4	CD Zone, Temple, under utilized	More institutional, residential	40%
5	C8 Zone, vacant greenfield	Commercial	60%
6	C8 Zone, vacant, greenfield	Commercial	60%
7	Greenfield, Scott Road	Commercial	60%
8	C8 Zone, under utilized	Commercial	20%

Residential Site No.	Existing Land Use	Future Land Use	Estimated Site Coverage
1	Undeveloped (West Newton North NCP)	Multi-family	45%
2	Vacant, greenfield (West Newton North NCP)	Single family lots	50%
3	Undeveloped (West Newton South NCP)	Townhouses	45%
4	Vacant, greenfield (Scott Rd & 66th Ave)	Multi-family	45%
5	Undeveloped (125th St & 66th Ave)	Single family lots	50%
6	Undeveloped (126th St & 68th Ave)	Single family lots	50%
7 & 7a	Vacant, greenfield	Single family lots	50%
8	Vacant, greenfield (122nd St & 70th Ave)	Single family lots	50%
9	Undeveloped (Strawberry Hill East)	Single family lots	50%
10	Undeveloped (124th St)	Single family lots	50%
11	Greenfield & large lots (Scott Rd)	Multi-family	45%
12	Vacant, greenfield	Multi-family	45%
13	Vacant, greenfield	Multi-family	45%

DELTA

Methodology

The method for estimating future land use and site coverage for the hydrologic model has two components as follows:

1. Using a 2006 air photo along with current zoning maps and the North Delta Land Use Plan, properties and designated areas were identified and numbered on the large air photo. Each site and number corresponds to an estimated increase in the site coverage (%) that could occur within the next 15-20 years. Most sites are underdeveloped and can be expected to densify over the years. The sites outlined in red refer to commercial redevelopment sites and those outlined in brown refer to residential and mixed use redevelopment sites.
2. Compared with Surrey, the North Delta catchment area is generally developed with varying types and sizes of residential subdivisions. Many subdivisions (particularly those zoned RS1, RM1, RS2, RS3 and RS5) consist of larger lots (0.4 ha) and can be expected to eventually be redeveloped over time. For these residential areas, estimates were made across the catchment based on the type of residential zone and the likelihood that areas within the zone would experience redevelopment via “infill”.

Some Assumptions

Several assumptions apply to this analysis as follows:

- Existing older commercial developments are estimated to be redeveloped to a level that will increase the hard surface coverage from the existing to 20% more.
- Future multi-family and townhouse development sites are estimated to have a site coverage of 45%.
- Residential lands currently zoned RS1and RM1 could expect an increase of about 15% in total site coverage due to infill development within the next 15-20 years.
- Residential lands currently zoned RS2, RS3 and RS4 could expect an increase of about 10%.

Site Listing for Delta

Commercial Site No.	Existing Land Use	Future Land Use	Increase in Site Coverage
1	Commercial Zoned C1, under utilized (Scott Rd & 80th Ave)	More commercial/mixed use (Designated Mixed Use)	20%
2	Commercial Zoned C1, under utilized (Scott Rd & 80th Ave)	More commercial	20%
3 & 4	Commercial Zoned C1, under utilized (Scott Rd north & south of 72nd Ave)	More commercial/mixed use (Designated Mixed Use)	20%

Residential Site No.	Existing Land Use	Future Land Use	Estimated Site Coverage
1	Under developed (Scott Rd)	Townhouses (Medium Density Ground Oriented)	45%
2	Under developed (Scott Rd)	Townhouses (Medium Density Ground Oriented)	45%
3	Under developed (west of Scott Rd)	Townhouses (Medium Density Ground Oriented)	45%
4	Delsom Lands	Mixed use (Medium Density)	45%

APPENDIX E
BYLAWS

The following is a list of proposed by laws.

- By-laws could be used as an effective tool to regulate maximum impervious coverage and maintenance of rainwater and runoff control management features. The importance of keeping the impervious surfaces to a minimum is reflected in the Corporation of Delta's Bylaw 6349 Streamside Protection and Enhancement, Development Permit Area which requires a Development Permit for the creation of non-structural impervious or semi-impervious surfaces. The City of Vancouver has introduced a number of by-law amendments to limit impervious surfaces. As a result, the revised by-laws require 60% maximum impermeable materials site coverage on residential lands.
- Both the City and the Corporation have Waterways Protection Bylaws designed to prevent the fouling of any watercourse or sewer. Both municipalities should consider updating these bylaws to define what specifically constitutes "fouling" and potentially increase fines. These bylaws should also be harmonized with existing or proposed bylaws (*e.g.* Erosion and Sediment Control) to address requirements related to development, streamside setbacks, and drainage.
- Construction specifications should be developed to achieve the recommendations of the Cougar Creek/NEIC Integrated Watershed Management Plan.
- An administration protocol to manage design approval, construction inspection and monitoring of BMPs for new developments and re-developments is required for both municipalities. The Corporation is planning to update its Subdivision Bylaw to reflect these protocols.
- The City of Surrey currently has an Erosion and Sediment Control Bylaw that sets performance standards for the discharge of sediment to the storm sewer and drainage system. The Corporation of Delta should also consider enacting a similar bylaw. This would assist both in maintaining the conveyance capacity of the drainage system while at the same time protecting receiving fish habitat.
- Also floodplain regulations could be applied to new structures on existing or new lots through a number of administrative tools that include Official Community Plans, development permit areas, zoning bylaws, local building regulations, or floodplain bylaws. These measures have been enacted under the following pieces of legislation:
    - *Local Government Act* allows a local government to select from a number of options i) *(Section 910*) adopt a floodplain bylaw that designates an area as floodplain, specifies development levels and setback requirements in a designated area and enforces these conditions, ii) *(Section 919.1)* designate a development permit area under the Official Community Plan for the protection of development from hazardous conditions, iii) (*Section 903)* allows a local government to partition the floodplain into sections whereby zoning bylaws could be used to address flood hazard protection by controlling land-use, density, and location of buildings, and iv) (*Section 694)* allows local government to use building regulations to enforce flood proofing structural measures that would be controlled by the Building Inspector (Section 699 of the *Local Government Act*)
    - *Land Title Act* allows a local government to select from the following alternatives i) (*Section 86)* require an engineering report to certify that the land is safe for the use intended, at the time of subdivision for flood prone lands, ii) (*Section 219)* register a Restrictive Covenant to ensure flood protection measures are incorporated or to place restrictions on flood-prone property to ensure the property is safe for the use intended.
    - The Ministry of the Environment issued the *Flood Hazard Area Land Use Management Guidelines* in May 2004. The document outlines the regulatory mechanisms under the Local Government Act and the Land Title Act to regulate new development and enforce the inclusion of flood protection measures at the time of subdivision.

A list of existing and proposed By-Laws is presented in **Table E-1**.

Table E-1: Summary of Existing and Proposed By-Laws

By-Law	Delta	Surrey
Existing By-Laws		
Zoning	60% max impermeable area	60% max impermeable area
Waterways protection	Protect creeks and dykes, #1615, 1969	Protect creeks and dykes, # 2659, 1994
Streamside protection	Protect creeks, # 6349, 2005	
Tree-cutting	Delta and Burns Bog tree cutting and replacement	Tree cutting and replacement
Development standards	Including stormwater BMPs, # 5100, 2001	
Erosion and sediment control		#16138, 2006
Proposed By-Laws		
Stormwater management for new development and re-development	Yes	Yes
Streamside protection	-	Yes
Erosion/sediment control	Yes	-
Water quality	Yes	-
Flood plain	Yes	Yes
Miscellaneous		
Construction Specifications	Yes	Yes
Administration protocol	Yes	Yes

APPENDIX F
EXAMPLE OF PERFORMANCE AND EFFECTIVENESS MONITORING

Appendix F: Example of Performance and Effectiveness Monitoring

Parameter	Location	When Required	Frequency	Duration	Responsibility
Stormwater Management Facilities Monitoring - to determine whether the facility is meeting the design targets on flow, water quality and erosion control					
Rainfall	Suitable existing local rain gauge located within 5 km, if not install gauge in the vicinity of SWM facility	During and post-construction	Continuous	Until assumed; may also be adopted as a long-term rain gauge	Proponent until assumed; municipality if adopted as a long-term gauge
Pond water levels	SWM pond	Post-development	Continuous	2 years after completion of construction, or until pond operation confirmed	Proponent
Discharges	SWM pond inlet and outlet	Post-development	Continuous	2 years after construction, or until pond operation confirmed	Proponent
Water quality (TSS and TP)	Sample at SWM pond inlet and outlet	Post-development	Two events during runoff	2 years after completion, or until pond operation confirmed	Proponent
Temperature	At SWM pond outlet	Post-development	Continuous	Until assumed	Proponent
Stream Corridor Monitoring - to evaluate the effectiveness of the SWM facilities and to evaluate how a stream adjusts to new land use scenario.					
Discharge Temperature Water quality - turbidity and TSS Biophysical - Benthic Index of Biological Integrity (B-IBI)	Streamflow station to be established	Construction Post-development	Continuous	At an early stage to establish four seasons baseline conditions and continue long-term	Proponent for two years following substantial development in contributing drainage areas; Municipality there-after
Cross-section surveys Photo inventory Collection of substrate material samples	Sites determined to be at risk of erosion through detailed analysis at an early stage or where stream alteration or relocation has occurred	Construction Post-development	Annual	At an early stage to establish four seasons baseline conditions and continue long-term	Proponent for two years following substantial development in contributing drainage areas; Municipality there-after

Parameter	Location	When Required	Frequency	Duration	Responsibility
Natural Heritage/Open Space System - to assess the health of the natural heritage system					
Vegetation Habitat (patch size, shape, community type and connectivity)	Where established	Post-development	2 years after baseline and then 5 years later	Medium-term / potential long-term	Proponent for baseline and 2 years; Municipality at 5 years and periodic intervals
Engineered mitigation	Where established	On completion of implementation of mitigation measures	Once a year for 2 years and then 5 years later	Medium-term / potential long-term	Proponent or baseline and 2 years; Municipality at 5 years and periodic intervals
Restoration areas	Where established	On completion of restoration plan implementation	Spring and fall for 2 years and then 5 years later	Medium-term / potential long-term	Proponent for baseline and 2 years; Municipality at 5 years and periodic intervals

APPENDIX G

B –IBI CALCULATIONS

Spring 2007

Metric	C1-1		C1-2		C1-3		C1-SUM	
	value	B-IBI score	value	B-IBI score	value	B-IBI score	value	B-IBI score
Taxa Richness and Composition								
TOTAL number of taxa	5	1	5	1	4	1	6	1
number of mayfly *(Ephemeroptera)* taxa	0	1	0	1	0	1	0	1
number of stonefly *(Plecoptera)* taxa	0	1	0	1	0	1	0	1
number of caddisfly *(Trichoptera)* taxa	0	1	0	1	0	1	0	1
number of long-lived taxa	0	1	0	1	0	1	0	1
Pollution Tolerance								
number of intolerant taxa	1	3	1	3	1	3	1	3
% tolerant individuals (as whole number)[1]	98.58	1	98.97	1	99.51	1	99.07	1
Feeding Ecology								
% predator individuals (as whole number)	0.33	1	0.00	1	0.00	1	0.08	1
number of clinger taxa	0	1	0	1	0	1	0	1
Population Attributes								
% dominance (top 3 taxa) (as whole number)	98.34	1	98.56	1	99.39	1	98.84	1
Site B-IBI score (SUM of B-IBI scores for each riffle):		12		12		12		12

mean B-IBI score for all 3 riffles:	12
standard deviation:	0
pooled B-IBI:	12

Metric	CC2-1		CC2-2		CC2-3		CC2-SUM	
	value	B-IBI score	value	B-IBI score	value	B-IBI score	value	B-IBI score
Taxa Richness and Composition								
TOTAL number of taxa	5	1	8	1	5	1	8	1
number of mayfly *(Ephemeroptera)* taxa	1	1	1	1	1	1	1	1
number of stonefly *(Plecoptera)* taxa	0	1	0	1	0	1	0	1
number of caddisfly *(Trichoptera)* taxa	0	1	0	1	0	1	0	1
number of long-lived taxa	0	1	0	1	0	1	0	1
Pollution Tolerance								
number of intolerant taxa	1	3	2	5	1	3	2	5
% tolerant individuals (as whole number)[1]	88.51	1	94.44	1	85.19	1	91.42	1
Feeding Ecology								
% predator individuals (as whole number)	1.61	1	0.32	1	0.00	1	0.43	1
number of clinger taxa	1	1	1	1	1	1	1	1
Population Attributes								
% dominance (top 3 taxa) (as whole number)	85.16	1	94.4268	1	86.05	1	90.01	1
Site B-IBI score (SUM of B-IBI scores for each riffle):		12		14		12		14

mean B-IBI score for all 3 riffles:	13
standard deviation:	1.1547
pooled B-IBI:	14

[1] The calculation of % tolerance is based only on individuals with tolerance information available, not on all taxa

Spring 2007

Metric	CC3-1 value	CC3-1 B-IBI score	CC3-2 value	CC3-2 B-IBI score	CC3-3 value	CC3-3 B-IBI score	CC3-SUM value	CC3-SUM B-IBI score
Taxa Richness and Composition								
TOTAL number of taxa	4	1	8	1	5	1	8	1
number of mayfly *(Ephemeroptera)* taxa	1	1	1	1	1	1	1	1
number of stonefly *(Plecoptera)* taxa	0	1	0	1	0	1	0	1
number of caddisfly *(Trichoptera)* taxa	0	1	1	1	0	1	1	1
number of long-lived taxa	0	1	0	1	0	1	0	1
Pollution Tolerance								
number of intolerant taxa	1	3	2	5	1	3	2	5
% tolerant individuals (as whole number)[1]	53.22	1	91.73	1	93.30	1	82.05	1
Feeding Ecology								
% predator individuals (as whole number)	0.00	1	0.61	1	0.00	1	0.10	1
number of clinger taxa	1	1	2	1	1	1	2	1
Population Attributes								
% dominance (top 3 taxa) (as whole number)	82.89	1	87.88	1	90.51	1	82.99	1
Site B-IBI score (SUM of B-IBI scores for each riffle):		12		14		12		14

mean B-IBI score for all 3 riffles:	13
standard deviation:	1.1547
pooled B-IBI:	14

[1] The calculation of % tolerance is based only on individuals with tolerance information available, not on all taxa

APPENDIX H

ALTERNATIVE STORMWATER BEST MANAGEMENT PRACTICES

Stormwater Management Best Management Practices

BMP Alternatives	Applicability	Advantage	Disadvantage	Effectiveness
Source Control				
Disconnection of Roof Leaders	• Mostly for detached or semi-detached homes • Suitable outlet and soil conditions required • Requires cooperation of owners in existing homes • By-Law and/or public education required	• Decreased runoff quantity to receiving system • Increased infiltration • Runoff detainment • Potential for some water quality benefit	• Potential for home owner inconvenience (*e.g.,* ponding water, clogging of pond outlet/soakaway pit if implemented) • Difficult to implement in existing development or in poor soil conditions	• Effective in reducing peak flow and volume of runoff in storm and combined sewers • If combined with ponding or soakaway, it will impact homeowner's use of land
Disconnection of Foundation Drains	• Requires a potential outlet - often not available unless a clearwater sewer • Requires cooperation of owners in existing homes • Provide sump pump to discharge to surface	• Decreased runoff quantity to receiving system • Increased infiltration	• May require sump pump • Difficult to implement in existing developments • If enforced may cause unwanted discharge to sanitary sewer	• Effective in reducing peak flow and volume of runoff in storm and combined sewers • Sump pumps not effective if high water table exists
Catch Basin Restrictors/ Control Orifices	• Where temporary ponding will not create risk to safety	• Runoff detainment • Potential for limited sediment removal	• Potential for clogging inconvenience due to ponding water	• Effective if regularly maintained
Reduced Lot Grading	• New developments	• Decreased runoff quantity to receiving system • Increased infiltration and evapotranspiration • Runoff detainment • Some water quality benefit	• Potential for home owner inconvenience (*e.g.,* longer lot drainage time) • Vulnerable to alterations by home owner • Difficult to regulate	• Lack of monitoring data, little experience on efficiency of a subdivision scale • Could impact home owners use of the land
Rooftop Storage	• New commercial, industrial and institutional building flat roofs	• Runoff detainment	• Difficult to retrofit • Only suitable for flat industrial or commercial roofs	• Effective in controlling peak flows, but no volume reduction
Parking Lot Storage	• Mainly for new commercial, industrial or high rise residential development	• Decreased peak flow to receiving system	• More suitable for commercial and industrial areas • Represents potential hazard to motorists and pedestrians	• Effective in controlling peak flows, but no volume reduction

BMP Alternatives	Applicability	Advantage	Disadvantage	Effectiveness
Soakaway Pits	• Used in conjunction with other BMPs, such as roof leader or foundation drain discharge	• Runoff detainment • Flood control benefit • Water quality treatment • Increased infiltration	• Could interfere with sewage system leaching beds • Requires soils with minimum percolation rate of 15 mm/h • High maintenance requirement • Uncertain longevity	• Potential for clogging • More effective if used for relatively clean runoff, such as roof runoff
Porous Pavement	• New technology • Requires testing before applying	• Decreased runoff quantity to receiving system • Increased infiltration • Traffic noise reduction	• Potential for groundwater contamination • Potential for clogging	• Effectiveness not known • Effectiveness affected by type of maintenance to keep pores clean
Slope Stabilization and Erosion Control Measures	• Mainly construction sites	• Reduced maintenance of BMPs • Improved water quality		• Effective if properly operated and maintained
Conveyance Control				
Road Drainage, Curb and Gutter	• Built up areas where open ditches are not practical	• Safety to pedestrians • Protection from erosion at the edge of road • Weeping tiles can be connected to deep storm sewers • Generally preferred by public in urban areas because of level of service and aesthetics	• Limited quality treatment possibilities even when combined with oil/grit separators or sumps in catch basins • No recharge to groundwater • Ice and debris blockage at catchbasins • Risk to cyclists	• Only effective to convey runoff • No peak or volume control or quality control
Road drainage, Ditch and Culverts	• Where space available • Soils are suitable • Hydraulic losses at driveway crossings manageable	• Limited quantity control • Reduced risk of ponding on roads • Reduced risk to cyclists and motorists	• Lack of sewer requires sump pump discharges from weeping tiles • Aesthetically not attractive • Frequent blockage of driveway culverts resulting in overflow • Not suitable for lots with narrow frontage	• Only effective to convey runoff • No peak or volume control or quality control

BMP Alternatives	Applicability	Advantage	Disadvantage	Effectiveness
Grassed Swales	• To filter and detain stormwater • Used where no hazard to pedestrians and cyclists	• Potential for decreased runoff quantity to receiving system • Increased infiltration • Runoff detainment • Improved water quality • Generally preferred over ditches by the public	• Mosquito breeding ground • Require more land than conventional ditches • Contributing drainage area <2ha • Driveway connections by culverts	• Effective for stormwater treatment and infiltration if length is at least 60 m and a minimum channel slope is maintained
Channel/Outlet Protection	• Space permitting • Not in sensitive areas	• Decreased erosion • Improved water quality (*e.g.,* decreased sediment loading)	• Disruption of natural habitat	• Effective for erosion control
Pervious Pipe System	• Used for pre-treatment of road runoff • Requires soils with good infiltration potential and deep water table conditions • Combine with storage media	• Decreased runoff quantity to receiving system • Increased infiltration	• Requires porous soils • Potential for groundwater contamination • Potential for clogging • High cost of replacing existing sewer	• Little experience • Effective in reducing runoff and increasing infiltration • Expensive to maintain and repair
Pervious Catch Basin	• Used for pre-treatment of road runoff • Requires soils with good infiltration potential and deep water table conditions • Combine with storage media	• Decreased runoff quantity to receiving system • Increased infiltration	• Requires porous soils • Potential for groundwater contamination • Potential for clogging • Replacement filters are expensive	• Little experience • Effective in reducing runoff and increasing infiltration • Expensive to maintain and repair
End of Pipe Control				
Detention/ Retention Facilities (Dry, Wet and Extended Detention ponds)	• Where adequate space available • No adverse effects downstream	• Water quantity control • Improved water quality • Potential for downstream erosion control • Potential for spill control	• Potential for sediment re-suspension (dry ponds) • Potential for thermal warming (extended detention) • Potential for odour, algae, debris and/or mosquitoes (wet ponds) • Potential for outlet clogging • Not suitable/economical for small areas, wet ponds require more land area than dry ponds, although both are land consumptive	• Highly effective in reducing downstream flows, improving water quality and reducing erosion
Underground Storage	• No conflict with underground services	• Decreased runoff peak • Improved water quality	• Difficult to keep clean	• Effective in controlling peak flows

BMP Alternatives	Applicability	Advantage	Disadvantage	Effectiveness
Artificial Wetlands	• Requires adequate drainage area to provide runoff • Requires adequate space	• Runoff detainment • Potential for water quantity control • Improved water quality • Potential for downstream erosion control • Effective for spill treatment	• Potential for thermal warming • Potential for outlet clogging • Potential for mosquitoes • Not suitable/economical for small areas • May have plant sustainability problems where road salts are applied • Requires significant land area	• Highly effective in reducing downstream flows, improving water quality and reducing erosion
Infiltration Basins/Trenches	• Suitable soils • Suitable groundwater conditions	• Decreased runoff quantity to receiving system • Increased infiltration if allowed to recharge groundwater system • Improved water quality if collected and discharged	• Potential for clogging/compaction • Potential for groundwater mounding • Potential for groundwater contamination • Operations/maintenance problems reported • Pre-Treatment suggested	• Effective if implemented as one of a series in a treatment train
Filter/Buffer Strips	• Requires adequate space • Mainly for low intensity residential developments	• Potential for decreased runoff quantity to receiving system • Increased infiltration and evapotranspiration • Runoff detainment • Improved water quality • Erosion protection	• Potential for clogging	• Effective if implemented as one of a series in a treatment train
Sand Filters	• Mainly for low intensity residential developments	• Runoff detainment • Improved water quality	• Potential for clogging • Potential for unsightliness and odour • Operations/maintenance problems reported • May not be as cost-effective as other BMPs	• Effective if implemented as one of a series in a treatment train
Oil and Grit Separators	• For spill control • Mandatory for certain commercial sites • Where only limited water quality control is required	• Limited runoff detainment • Improved water quality • Spill control	• Can only control limited areas • Not suitable for quantity control • Not suitable for soluble pollutants	• Only effective for spill control or water quality control for low flows
Physical/Chemical treatment	• For effluents to very sensitive receiving systems	• Improved water quality • Spill control	• Not well tested for stormwater • Expensive	• Little experience, effective for water quality control