Attachment 1

THE CHINES

BACKYARD HABITAT ALIVE

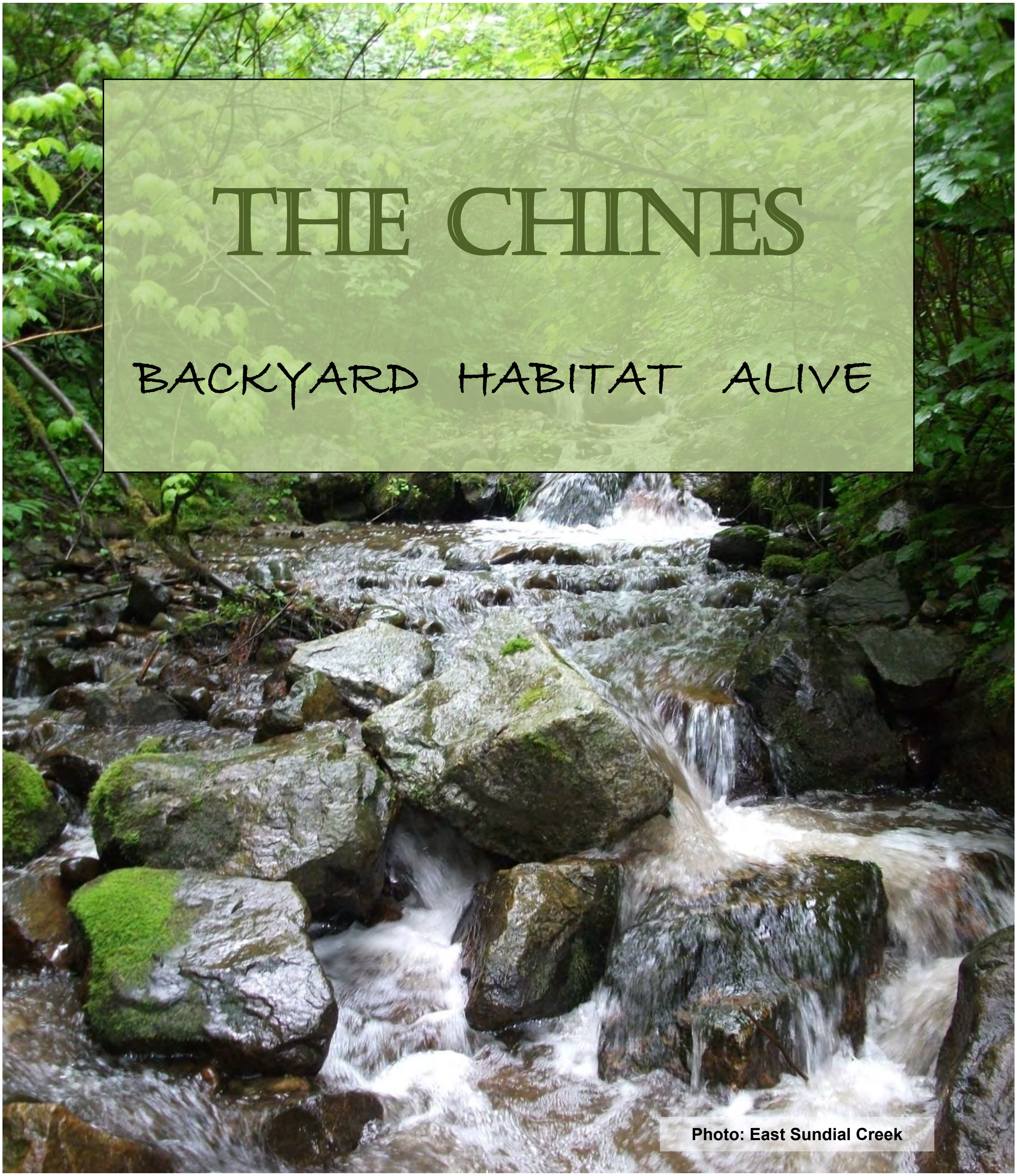

Photo: East Sundial Creek

Chines Integrated Stormwater Management Plan

Final Report

May 2016

metrovancouver · Coquitlam · Port Moody City of the Arts · Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

ASSOCIATED ENGINEERING

QUALITY MANAGEMENT SIGN-OFF

Signature

Date 30 MAY 2016

#04-16-048

Executive Summary

Metro Vancouver, in partnership with the City of Coquitlam and the City of Port Moody, engaged Associated Engineering to develop an Integrated Stormwater Management Plan (ISMP) for the Chines watersheds, which include the Port Moody-Coquitlam Drainage Area (managed by Metro Vancouver) and the Suter Brook and Pigeon Creek sub-watersheds, managed by the Cities. Metro Vancouver is only responsible for the main stems of the creeks and the major piping system.

ISMP Objectives

The objectives of the Chines ISMP are:

- Manage runoff to reduce erosion activity in the ravines.
- Implement measures to improve water quality.
- Enhance aquatic and terrestrial habitat, including identification of long term strategies for partial stream daylighting.
- Identify and recommend the use of green infrastructure to manage rainwater through volume and peak flow reduction and the improvement of water quality.
- Provide improvements in aesthetics/livability within the ISMP.
- Address any flooding risks.
- Address the increase in impervious surfaces and runoff associated with future development by promoting control of rainfall onsite to reduce the need for additional hard infrastructure.
- Develop a landslide risk analysis methodology and implementation of a landslide partial risk analysis.

Key Issues

The key issues are:

- The Chines ravine slopes are generally steep and slope stability is a concern.
- With the Evergreen Line planned to bisect the lower portion of the watershed, redevelopment of the City Centre area of Port Moody is anticipated.
- Flooding issues are limited and generally occur when debris blocks the intakes to the pipe system at the outlet of the ravines in Port Moody.

Recommendations and Costs

The recommended action items and cost estimates for the Chines watershed are summarized in Table ES-1.

Table ES-1
Summary of ISMP Recommendations

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
Source Control Standards and Implementation				
7.1	Enact and enforce the detention criteria discussed in Section 7.1. Potentially applicable BMPs are identified in Section 6.2, and should be selected as appropriate for each site.	< $50,000	Short	Coquitlam
7.1	The City of Port Moody should adopt equivalent standards or guidelines for rainwater management as discussed in Section 7.1.	< $50,000	Short	Port Moody
7.1	Develop and implement an education and outreach program to encourage implementation, retention and maintenance of source controls.	<$100,000	Short	Port Moody
Infrastructure Improvements				
7.2.1	Upgrade minor pipe systems in uplands.	$2,700,000	Long	City of Coquitlam
7.2.1	Upgrade minor and major pipe systems in lowlands.	$1,800,000 ($1,100,000 with optional daylighting of Clark Rd Tributary of S. Schoolhouse Creek)	Long	City of Port Moody
7.2.2	Upgrade deficient major trunk drainage pipes.	$250,000	Long	Metro Vancouver
7.2.3	Divert high flows if required to mitigate impacts to ravines.	$7,000,000 (order of magnitude)	Long	Metro Vancouver
7.4	Upgrade hydrometric monitoring stations (three stations) with direct flow measurement and real time telemetry.	$120,000 ($40,000/station)	5 years	Metro Vancouver

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
Environmental Enhancements				
7.3.1	Clear accumulated garbage and debris at culvert/pipe inlets.	< $50,000	Short	All
7.3.1	Clear accumulated urban refuse and other debris from the ravine corridors.	< $50,000	Short	All
7.3.1	Stabilize or remove erosion sites and fine sediment deposits that decrease or impact available habitat for juvenile salmonids and benthic invertebrates.	Varies with site	Short	All
7.3.1	Control or re-route runoff from heavy rainfall events that destabilize creeks resulting in loss of fish habitat.	Site dependant	Short	All
7.3.1	Develop plans for construction of pools and riffles in suitable fish accessible creek reaches to provide additional overwintering and rearing habitat.	$50,000	Short	All
7.3.1	Remove invasive plant infestations in interface areas between the ravines and residential development.	$200,000 (order of magnitude)	Short	All
7.3.1	Implement education efforts to discourage disposal of garden wastes or residential refuse into the ravines.	< $50,000	Short	All
7.3.1	Add spawning gravels to creeks.	< $50,000	Short	All
7.3.2	Lowland creek daylighting and restoration per outcome of feasibility study (see below).	Indeterminate, but significant depending on scope	Varies with opportunities , but should be a priority	Metro Vancouver/Port Moody
7.3.2	Limit further enclosure of open channel drainage components (ditches and swales). Provide compensating rainwater management features for lost	minor	Immediate	Both Cities

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
	hydrological function.			
Studies, Evaluations and Ongoing Efforts				
7.3.2	Conduct a feasibility study on daylighting lowland portions of Dallas Creek.	$50,000	Short	Metro Vancouver/Port Moody
7.3	Conduct a feasibility study to examine the replacement of the sediment basins at the Goulet intake.	$50,000	Short	Metro Vancouver
7.1	Conduct a groundwater monitoring study to determine suitable areas for infiltration.	$200,000 per city.	Short	Both Cities, Priority for Coquitlam
7.4	Develop and implement a monitoring and adaptive management process based on the recommendations of Section 7.4. Coordinate efforts of the Cities and Metro Vancouver.	Varies with selected level of effort.	Short - Ongoing	All
7.5	Ensure Operations and Maintenance activities and responsibilities for BMPs are identified and followed accordingly.	Varies	Short - Ongoing	All

Rainwater Management Criteria

The Chines watershed rainwater management criteria are summarized in the table box below:

> Rainwater source controls in the Chines watershed should be designed to limit the 2-year post-development peak flow to 50% of the 2-year pre-development peak flow.

It is recommended that the implementation of source controls in the Chines watershed be designed on a detention basis rather than infiltration basis until a groundwater monitoring study can identify safe areas for infiltration.

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1 Introduction

1.1 PROJECT OVERVIEW

Metro Vancouver, in partnership with the City of Coquitlam and the City of Port Moody, engaged Associated Engineering to develop an Integrated Stormwater Management Plan (ISMP) for the Chines watersheds, which include the Port Moody-Coquitlam Drainage Area (managed by Metro Vancouver) and the Suter Brook and Pigeon Creek sub-watersheds, managed entirely by the Cities. Within the Port Moody Coquitlam Drainage Area, Metro Vancouver is responsible for the main stems of the creeks and the major drainage trunks receiving creek flows below the escarpment, while the Cities are responsible for their respective local drainage system (pipes, ditches and swales) and overland flow paths such as along roads.

The ISMP project area consists of upland areas of largely residential development in Coquitlam, steep wooded ravines (the Chines) in Coquitlam and Port Moody, and residential, commercial and industrial development in the Port Moody lowlands. Within the Chines themselves, the watercourses are largely unaltered, remaining in a relatively natural state incorporating a mixed, mature deciduous and coniferous forest. However, within the upland/headwater and lowland areas, where there are substantial residential and industrial areas, the watercourses are now almost entirely piped and rerouted to centralized discharges to Burrard Inlet.

A master drainage plan was completed for the South Schoolhouse Creek Drainage System, Kyle Creek Drainage System, and Slaughterhouse/Dallas Creek Drainage System in 1998 by Dayton and Knight. In 1999, the three drainage areas were consolidated into the Port Moody Coquitlam Drainage Area for ease of administration. Additionally, a Stormwater Management Plan (SWMP) was completed on Suter Brook by Beesley Engineering and Pottinger Gaherty Environmental Consultants Ltd. in 1999. The SWMP discusses an overall strategy for disposal of post-development storm runoff from the Greystone-Suter Brook site.

1.2 WATERSHED OBJECTIVES

In a broad context, the objective of this ISMP is to outline a plan for the Chines watershed that meets the development objectives of the Cities of Port Moody and Coquitlam while addressing the specific needs of the watershed and preventing environmental degradation. A primary objective of most ISMPs is to balance flood protection with sustainable community planning. Environmentally, the bare minimum standard is to maintain existing watershed health and functionality, combined with no-net loss of aquatic habitat, though this is increasingly seen as insufficient for watersheds that are already significantly impacted.

The following are the key objectives for the Chines ISMP:

- Manage runoff to reduce erosion activity in the ravines.
- Implement measures to improve water quality.
- Enhance aquatic and terrestrial habitat, including identification of long term strategies for partial stream daylighting.

- Identify and recommend the use of green infrastructure to manage rainwater through volume and peak flow reduction and the improvement of water quality.
- Provide improvements in aesthetics/livability within the ISMP.
- Address any flooding risks.
- Address the increase in impervious surfaces and runoff associated with future development by promoting control of rainfall onsite to reduce the need for additional hard infrastructure.

In addition, the initial terms of reference for this ISMP included the development of a landslide risk analysis methodology and implementation of a landslide qualitative partial risk analysis. This last objective was pursued outside the framework of this ISMP with an initial study by Associated Engineering, “Qualitative Partial Risk Slope Analysis, Chines Escarpment and Corona Crescent Areas – Draft Report” (June 2013) with subsequent further assessment by others.

In consideration of the objectives presented above, the following vision statement was developed for the Chines ISMP:

The Chines: Backyard, Habitat, Alive

The Chines is a respected area valued for its unique ravines and creeks. Development occurs in harmony with wildlife and vegetation and supports a healthy, natural space for the community. An engaged and informed public care for this watershed with a sense of pride and ownership.

1.3 PROJECT PARTICIPANTS

This project is a joint effort between Metro Vancouver and the Cities of Port Moody and Coquitlam.

The Cities of Port Moody and Coquitlam co-chaired the steering committee for this ISMP and directed the technical development of the ISMP.

The consulting team is comprised of personnel from Associated Engineering and Summit Environmental. Key team members are:

• Michael MacLatchy	Project Manager
• Jenna Lee	Water Resources Engineer
• Andrew Wiens	Hydraulic Modelling Specialist
• Alexandra de Jong Westman	Terrestrial Wildlife Biologist
• Lyndsey Johnson	Aquatic Biologist
• Thibault Doix	Benthic Invertebrate Specialist
• Joe Alcock	Geoscientist

Metro Vancouver staff involved in this project include:

• Mark Wellman	Metro Vancouver Liquid Waste Services
• Greg Maximuk	Metro Vancouver Liquid Waste Services
• Shafiq Islam	Metro Vancouver Liquid Waste Services

City of Port Moody staff include:

• Kristi Garrod	Mapping & Engineering
• Neal Carley	Director of Engineering
• Mary de Paoli	Planning

City of Coquitlam staff include:

• Melony Burton	Infrastructure Management
• Henry Wong	Engineering and Public Works Department
• Dana Soong	Manager - Utilities
• Hagen Hohndorf	Environmental Services
• Margaret Birch	Environmental Services
• Wai-Sue Louie	Parks
• Shannon Wagner	Urban Forestry

Stewardship members include:

• Elaine Golds	Burke Mountain Naturalists
• Ian McArthur	Burke Mountain Naturalists

2 Watershed Overview

2.1 CLIMATE

In terms of general climate conditions, the Chines ISMP project area is located within the Coastal Western Hemlock biogeoclimatic zone, dry maritime subzone (CWHdm1) encompassing parts of the Cities of Port Moody and Coquitlam, and the Greater Vancouver Regional District (Metro Vancouver). The CWHdm1 occurs at low to middle elevations mostly west of the coastal mountains, along the entire British Columbia coast. The CWHdm1 occupies elevations from sea level to 900 m on windward slopes in the south and mid-coast (1050 m on leeward slopes), and to 300 m in the north. The CWHdm1 is, on average, the rainiest biogeoclimatic zone in British Columbia, experiencing cool summers and mild winters.

As is typical for the Greater Vancouver region, the warm, wet maritime climate of the Chines sees most of the annual rainfall occurring between October and April (Environment Canada 2011). Low rainfall over the summer often leads to surface soil moisture deficit conditions. The closest Atmospheric Environment Service (AES) climate stations are Port Moody Glenayre, just west of the study area, and Coquitlam Como Lake Ave to the south. The 1971 to 2000 climatic normals are provided in Table 2-1.

Table 2-1
Climatic Normals 1971-2000

Coquitlam Como Lake Ave.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Precip. (mm)	242.2	201.5	161.6	131.2	117.6	91.9	61.5	71.2	78.3	182	299.1	285.8	1924
Port Moody Glenayre	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Year**
Avg. Temp. °C	3	4.6	6.5	9	12.3	14.8	17.4	17.8	15	10.5	5.9	3.3	10
Rain (mm)	227	188	178.6	142.4	107.7	90.2	67.9	66.1	91.1	186.2	293.8	257.8	1896.9
Snow (cm)	22.6	11.7	2.8	0.2	0	0	0	0	0	0.2	3.2	17.8	58.4
Precip. (mm)	249.6	199.7	181.4	142.6	107.7	90.2	67.9	66.1	91.1	186.5	297	275.6	1955.3

Source: Environment Canada 2011: Climatic Normals 1971-2000.

The largest sustained precipitation events are associated with cyclonic winter frontal systems, with heavy rainfall over one to three days, at times associated with melt of a residual snowpack. Recent large precipitation events leading to high stream discharges and high soil moisture contents include:

- December 1966
- January 1968
- December 1972
- December 1979
- January 1984
- January 2005

Eisbacher and Clague (1981) also list significant storms linked to landslides events during the period 1905 to 1979.

To present, direct stream flow monitoring has not been undertaken on any of the subject watercourses. Metro Vancouver maintains three sites where water level monitoring is undertaken on a continuous basis, and recorded in data loggers. Flow data is calculated from recorded levels using ratings curves during post processing. The accuracy of the flow calculations is dependent on the rating curves for each site, which may vary over time. There is no real time reporting (telemetry) of stream flows at these sites. In addition, some individual stream discharge measurements have been completed by the streamkeeper groups.

2.2 AREA PHYSIOGRAPHY

The study watershed lies within the Fraser Lowland physiographic region (Holland 1976). The north-draining ravines are incised in a steep north-facing slope below a gently-sloped upland surface. The upland forms the headwaters area for the ravines and is in the northern portion of the City of Coquitlam. The main ravine sections and outlet areas are in the City of Port Moody. Surface elevations range from about 100 to140 m above sea level in the uplands at the stream headwaters, to about 10 to 30 m above sea level where the streams disgorge onto relic fans on the gentle slope to Burrard Inlet. The individual stream watershed boundaries are along the sharp ridges (Chines) between stream ravines. The ravine heads are generally steep and bowl shaped. The main stream ravines are deep, with steep slopes and V-shaped in cross section. The outlet areas range from narrow, V-shaped ravines with steep slopes to wide ravines with U-shaped cross sections. Some flat-floored areas, such as in Schoolhouse Creek and Dallas Creek, are found within the ravines. Terraces or more gently sloped areas are found on some ravine slopes near the base, which likely relate to impeded fluvial erosion of the underlying dense sediment.

2.3 STUDY AREA

The study watershed has five discharge points at Burrard Inlet. Thus, the watershed is divided into five drainage systems (or areas). The drainage systems and watercourses in the watershed are listed as listed below and shown in Figure 2-1.

South Schoolhouse Creek Drainage System (472 ha)

- Melrose Creek
- Unnamed/unmapped tributary of South Schholhouse Creek (This tributary arises in the hillside immediately south of Melrose through a yard on Charles Street.)
- Clark Road Tributary of South Schoolhouse Creek
- South Schoolhouse Creek*
- Noble Creek*

Kyle Creek Drainage System (211 ha)

- Ottley Creek*
- Axford Creek*
- Kyle Creek*
- Hatchley Creek*
- West Sundial Creek*
- East Sundial Creek*
- Goulet Creek*

Slaughterhouse/Dallas Creek Drainage System (193 ha)

- Williams Creek*
- Elginhouse Creek*
- Correl Brook*
- Dallas Creek*

Pigeon Creek Drainage System (41 ha)

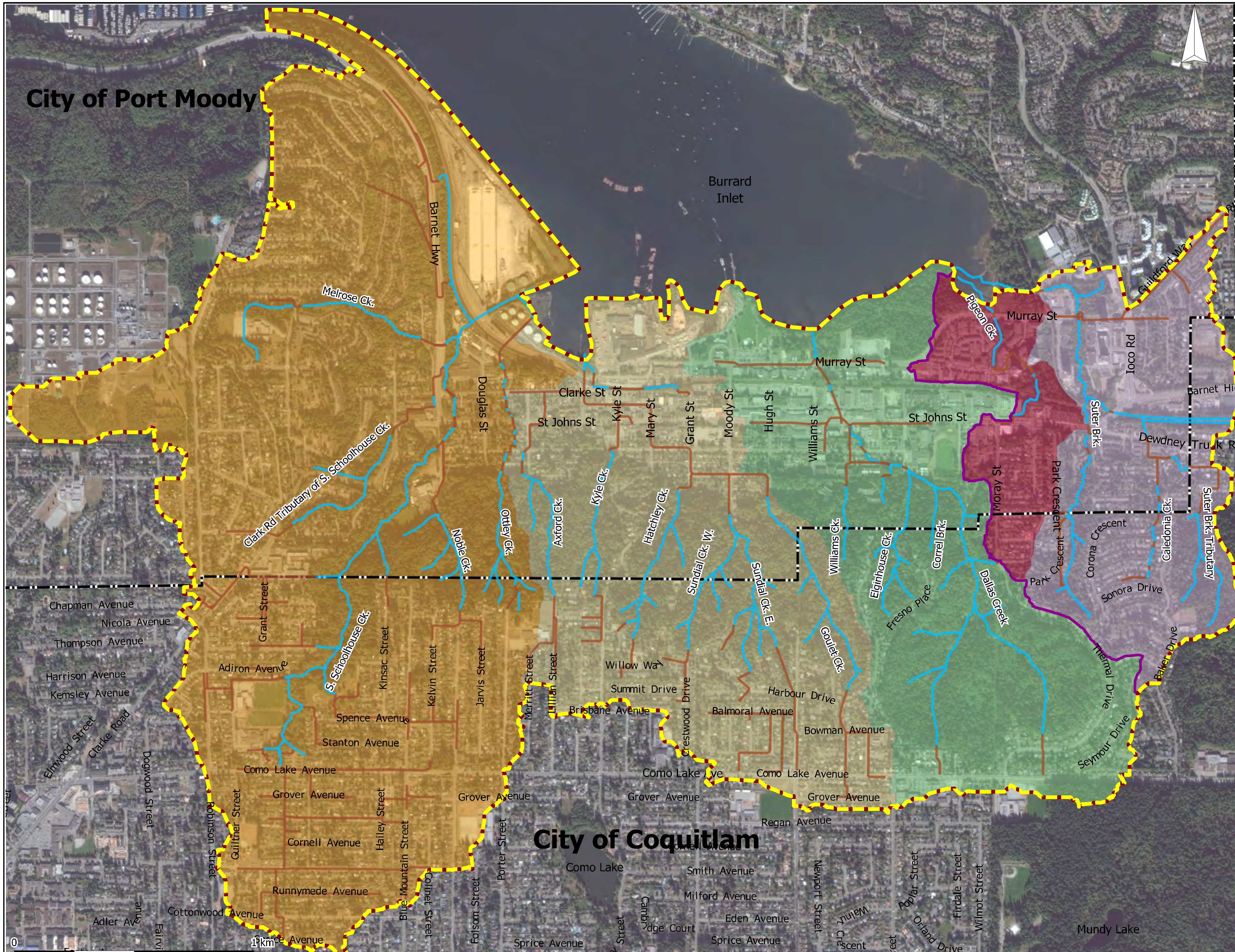
- Pigeon Creek

Suter Brook Drainage System (117 ha)

- Suter Brook
- Caledonia Creek
- Suter Brook Tributary

In total, these five drainage systems encompass 1034 ha. The main stems of the creek systems are managed downstream of the municipal boundary by Metro Vancouver, these are indicated in asterisk (*) above. Metro Vancouver undertakes the operation and maintenance of the regional major pipe systems in the South Schoolhouse Creek Drainage System, Kyle Creek Drainage System, and Slaughterhouse/Dallas Creek Drainage System that receive flow from the creek systems listed above. The regional major pipe system conveys creek flows through the City of Port Moody to their discharge points in Burrard Inlet.

While geographically a continuation of the Port Moody Coquitlam Drainage Area, the Suter Brook watershed, including the Pigeon Creek sub-watershed, is managed directly by the two Cities.



LEGEND

- South Schoolhouse Creek Drainage System
- Kyle Creek Drainage System
- Slaughterhouse/Dallas Creek Drainage System
- Pigeon Creek Drainage System
- Suter Brook Drainage System
- Pipe
- Watercourse
- Municipal Boundary
- Management Boundary
- Watershed Boundary

CHINES ISMP

Figure 2-1 Study Area

PROJECT NO:	**20112817**
SCALE:	**1:15,000**
DATE:	**September 2015**
DESIGNED BY:	**JL**
CHECKED BY:	**MM**

Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_JJ.map

3 Environmental Overview

An overview environmental assessment of the Chines ISMP study area was carried out by a multi-disciplinary team composed of a terrestrial ecologist and wildlife biologist, an aquatic biologist, and geoscientist. Benthic invertebrate sampling was completed by a sub-contracted specialist. Most field work occurred during early June 2011, with additional field visits taking place in late June and mid-September 2011.

3.1 TERRESTRIAL ASSESSMENT

Detailed discussion of the terrestrial assessment, including a review of field collected data as well as existing information is provided in Appendix A.

Invasive species found during the field assessment are indicated on Figure 3-1. We note that specific terrestrial assessment plots were completed at the points as indicated on the figure and some plots did not contain any invasive plants; however, this does not mean that the respective creek ravines in their entirety do not have invasive plant species.

3.1.1 Ecology Overview

Ecological Communities

Western hemlock (*Tsuga heterophylla*) is usually the most common species in the forest cover. In addition to western hemlock, red alder (*Alnus rubra*), broadleaf maple (*Acer macrophyllum*), black cottonwood (*Populous balsamifera tricocarpa*), beaked hazelnut (*Corylus cornuta*), western red cedar (*Thuja plicata*) and coastal Douglas fir (*Pseudostuga menzesii*) are also found within the forest communities in the study area.

At-Risk Vegetation Species

The creeks within this project area provide suitable habitat for a number of provincially and federally at-risk plant species. While no rare plants were found in the overview assessment, their presence in other riparian areas within close proximity indicates potential to occur within the Chines.

3.1.2 Wildlife and Habitat Assessment

Riparian habitats are typically more structurally complex and therefore are able to support a greater diversity of wildlife. The often hard edges between the riparian areas of the creeks within the Chines and residential development, detract from the overall continuity of habitats, limiting the resource availability for wildlife other than small mammals, birds, reptiles and amphibians.

Birds

Mature riparian forests such as those within the Chines offer habitats to a wide variety of bird species. Because these forests offer a mix of mature coniferous as well as deciduous trees, species from each habitat type are found. During the June and September assessments, forest generalist species detected via either visual or auditory observations included:

- spotted towhee (*Pipilo maculatus*),
- black-capped chickadee (*Poecile atricapillus*),
- dark-eyed junco (*Junco hyemalis*),
- ruby-crowned kinglet (*Regulus calendula*),
- American robin (*Turdus migratorius*),
- American crow (*Corvus brachrhynchos*) and
- songsparrow (*Melospiza melodia*).

In patches of deciduous forest with more shrubby understories, riparian oriented species such as the following were detected:

- Wilson's warbler (*Wilsonia pusilla*),
- winter wren (*Troglodytes hiemalis*),
- yellow warbler (*Dendroica petechia*)
- Swainson's thrush (*Catharus ustulatus*) (Sibley 2003).

Amphibians and Reptiles

Riparian habitats support an abundance of invertebrates and small mammals, a diverse prey base for amphibians and reptiles alike. The western garter snake (*Thamnophis elegans*) is common in riparian areas similar to those in the Chines. Pacific chorus frog (*Pseudacris regilla*) is another likely inhabitant of the riparian habitats within the Chines. Neither was specifically detected during our field assessments.

Mammals

Structural habitat diversity is increased by a diverse understory of shrubs, forbs and grasses, providing fruit and seeds for small mammals, which in turn are prey for larger mammal species. One of the more common small mammals in riparian areas such as these is the common shrew (*Sorex cinereus*). The small mammal populations in addition to berry-producing shrubs provide suitable food resources for larger mammals such as coyotes (*Canis latrans*) and black bears (*Ursus americanus*) which are frequently observed within the study area.

At-Risk Terrestrial Species

The following provincially- and federally-listed wildlife species are of interest to this ISMP.

- Northern Red-legged Frogs
- Pacific Water Shrew

Northern Red-legged Frogs

While no frogs were observed during the assessment, evaluation of the habitat potential indicates that northern red-legged frogs could occur within the Chines. None were detected during our field assessment, however they may potentially be present in the ravines areas of the Chines.

Pacific Water Shrew

The Pacific water shrew is a relatively large shrew occurring only in the lower Fraser Valley. This shrew is more strongly associated with riparian habitats than any other shrew or mouse within its range. Requiring large tracts of contiguous mature forests, an individual shrew will have a large home range paralleling the streams within the riparian areas. Unfortunately, the exact size of contiguous riparian habitat is currently unknown. Therefore, it cannot be determined if the fragmented riparian habitats within the Chines would be of sufficient size or not. However, stand age, leaf litter and amount of woody debris is suitable for this shrew.

3.1.3 Invasive Species Control

Currently, the most common invasives observed within the Chines are Japanese knotweed, false lamium and English ivy. To a lesser extent, morning glory (*Convolvulus arvensis*) and holly (*Ilex aquifolium*) are also spreading from a large number of backyards.

Recently, the BC Ministry of Agriculture and Lands (MAL) upgraded Japanese knotweed to provincially noxious and recognized it as a species to control under the BC Weed Control Act (MAL 2011). The Act states that any weed species identified must be controlled by the owner of the land on which it occurs.

Control of other invasive species is the responsibility of the owners of property on which they occur. Within, the ravines portions of the study area, this will largely be the respective Cities. Private property owners may be considered responsible where invasive species occurrence is the result of encroachment into natural areas from adjoining properties.

3.1.4 Forest Canopy Assessment

Associated Engineering undertook a high level assessment of the health of the tree canopy in the ravines and ridges between the uplands and lowlands. This assessment was intended to address concerns that there would be a concentrated die-off of the forest community over a short period of time, leading to public safety issues, and loss of habitat structure.

The objectives of the forestry canopy assessment were to:

1. Describe the current condition of the forest;
2. Identify areas that could pose a safety hazard to the public; and
3. Develop recommendations to help manage potential safety hazards.

The field work for the forest canopy assessment was completed on July 6 and 9, 2012. Visual observations were recorded at 35 locations across the Project Area. Each site was subjectively selected in areas representative of the surrounding forest type. Sites were visited across the edatope (i.e., upper slope, mid-slope and lower slope), with a greater emphasis placed on sites that interfaced with the public (e.g., trails and property boundaries). At each site, we assessed the forest structure and the potential risk to public safety.

All of the species identified above were prevalent throughout the Project Area. The 35 sites visited showed a diverse array of second growth forest types and it appeared that there was large scale disturbance approximately 100 years ago. These sites are indicated on Figure 3-2. The assessment area was separated into the following dominant forest types:

- Upper slope, coniferous forest with open deciduous patches;
- Mid-slope, coniferous forest with open deciduous patches;
- Riparian, deciduous forest; and
- Mixed forest bordering private property.

Upper Slope Forest

Forest types commonly observed on the upper slopes tended to be healthy, fairly dense, single layer canopy forests with a poor to moderately well-developed intermediate layer. These sites were typically leading in western hemlock with western red cedar, lesser components of deciduous species and isolated Douglas-fir trees. These areas also included small, open patches dominated by red alder and/or broadleaf maple. These forest types appeared to be young and healthy and appear to pose little risk to the public.

Mid-Slope Forest

Mid-slope forests were similar to those observed on the upper slopes; however, there were fewer Douglas-fir observations. These forest types also appeared to be young, healthy and posed little risk to the public.

Riparian Forest

The lower slope areas were divided into two forest types: forests occurring along the riparian areas within the ravines and forests occurring along the northern portion of the Project Area that interfaces with private property. Riparian forests within the ravines were mostly open grown and dominated by large deciduous trees (typically broadleaf maple) with a wide range of distributions of western hemlock and western red cedar in the intermediate canopy and understory. Because these stand types are approaching their climax condition, some will soon experience die-back and be replaced by western hemlock and western red cedar currently growing in the intermediate layer. Deciduous trees within ravines that have moderate to high public use should undergo a danger tree assessment and be monitored over time for potential risk to public safety. Deciduous trees in ravines with little public use pose little danger to the public.

Mixed Forest

The northern portion of the project that interfaces with private property is comprised of a range of coniferous (i.e., western hemlock with western red cedar) and deciduous leading forest types. Deciduous stand types are approaching their climax condition and will soon experience die-back and be replaced by species currently in the intermediate layer. The coniferous forests are relatively stable and, other than large wind events and disease outbreak, should experience little significant change in future for several decades.

However, the forests along the northern portion of the project area interfacing with private property should undergo a danger tree assessment and be monitored for risk to public safety. This is particularly true of the deciduous forest types located at Sites 11 to 14, where the forest is nearing its climax condition along the interface with private property.

3.2 AQUATIC ASSESSMENT

3.2.1 Aquatic Habitat Field Assessment

The aquatic assessment was conducted on June 1, 2, and 29, 2011 to assess the current aquatic habitat and to identify specific issues related to erosion, bank instability and barriers to fish movement. Inventory methods generally followed those established by the Resource Inventory Standards Committee (RISC) in the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (v. 2.0; RIC April 2001). Points of interest were geo-referenced in the field using GPS. Attributes of the open channel were characterized for specific stream reaches. Stream reaches were based on gradient breaks, shifts in substrate composition or other hydrological or morphological features, such as concentration points of erosion or channel barriers. Stream reaches were assessed on foot and detailed information was collected, including:

- Channel morphology
- Wetted width and depth, and bank width and depth
- Substrate composition
- Habitat values and problems
- Fish presence and barriers to fish movement
- Riparian characteristics
- Habitat enhancement opportunities
- Water quality

Seven creeks located within the Chines were assessed (travelling eastward):

- South Schoolhouse Creek
- Noble Creek
- Ottley Creek
- Hatchley Creek
- Sundial Creek (east and west branch)
- Goulet Creek

3.2.2 Benthic Invertebrate Field Assessment

Macro-invertebrates were collected on September 11 and 12, 2011 by Living Streams Environmental Services. Details of the sampling and analysis protocols are provided in Appendix A. Most of the creeks sampled for our study appeared to be in “fair condition”, with total B-IBI scores ranging from 28 to 32. However, both Sundial Creek east and west branches were considered to be in “poor condition” with scores of 24 and 22, respectively.

3.2.3 Surface Water Quality and Resources

Watercourses in urban and residential areas are often impacted by stormwater runoff and human activities which can degrade the quality of water. Given the amount of residential and urban activity within the watershed, water quality could be an issue without proper mitigation. Baseline *in situ* water quality data (temperature, dissolved oxygen, conductivity, pH, salinity and oxidation-reduction potential i.e. ORP) were collected at select locations on July 22, 2011 as shown in Figure 3-3. Generally, water quality results were within the range of the Ambient Water Quality Objectives for Burrard Inlet Coquitlam-Pitt River Area (Ministry of Environment, 1990) for pH (6.5-8.5) and dissolved oxygen (minimum 6.5 mg/L). Temperatures measured at water quality stations met the BC Ministry of Environment Environmental Protection Division Water Quality Guidelines for Temperature (2001) for streams with unknown fish distributions (mean weekly maximum temperature of 18ºC) and for rearing of cutthroat trout (7.0-16.0ºC), Coho salmon (9.0-16.0ºC) and chum salmon (12.0-14.0ºC).

3.2.4 Stream Classifications

Watercourses in Port Moody and Coquitlam are divided into four classifications which are based on fish presence, duration and source of water, and surrounding vegetation potential. Table 3-1 summarizes the stream classification system used by the City of Port Moody and Coquitlam.

Table 3-1
Watercourse Classification System

Classification/Colour Code	Description
Class A – Solid red	Watercourses inhabited by salmonids and/or rare or endangered fish species, or potentially inhabited by such fish with access enhancement (e.g. removal of culverts).
Class A (O) – Red dashed	Watercourses inhabited by salmonids and/or rare or endangered fish species, during the overwintering period, or potentially inhabited during the overwintering period, or potentially inhabited during the overwintering period with access enhancement.
Class B – Yellow	Watercourses that are a significant (as defined by MELP, 1999) source or potentially significant source of food and nutrients to downstream fish populations. These watersheds are characterized by no fish presence and no reasonable potential for fish presence through flow or access enhancement.
Class C – Green	Watercourses that provide an insignificant contribution of food or nutrients to downstream areas supporting or potentially supporting fish populations.

Within the Project Area, the major watercourses are classified as indicated on Figure 3-4. It should be noted the stream classifications are for open (i.e. non-piped) portions of the creeks.

3.2.5 Urban Drainage Channel Assessment

Several watercourses and drainage ditches exist in the watershed. These features potentially provide important hydrological functions in the watershed, such as conveying stormwater, regulating surface water flow rates, and allowing surface water to infiltrate the ground. Some of these ditches may also play important ecological roles in the watershed, as they improve water quality (e.g. filtering contaminants, reducing erosion, and facilitating ground infiltration), provide food and nutrients (i.e. leaf litter, organics, invertebrates) to downstream fish-bearing habitats, and provide habitat for fish and wildlife. Our team completed an inventory and assessment of roadside watercourses (i.e. drainage ditches) in developed areas of the watershed to evaluate the existing conditions, ecological functions, and habitat value of these watercourses.

A summary of this assessment is provided here, the complete letter report is contained within Appendix B.

METHODS

An inventory of the ditches in the watershed was completed on May 9 and 10, 2013. This was done by driving through developed areas of the watershed to locate known ditches on maps of the cities of Coquitlam and Port Moody, and by identifying any ditches in these zones that have not yet been mapped. A unique identifier was assigned to each inventoried ditch, and each ditch was geo-referenced and photographed.

Field assessments of the identified ditches were completed on June 27, 2013 and on February 7 and 11, 2014. These assessments consisted of characterizing the habitat and recording the measurements of each ditch. Habitat data were collected following steps noted in the document entitled, Reconnaissance (1:20,000) Fish and Fish Habitat Inventory Standards and Procedures, published by the B.C. Resource Inventory Standards Committee[1]. The following habitat data were collected:

- channel dimension (channel width, bankfull depth);
- surface water (wetted width, water depth);
- substrate composition;
- riparian vegetation composition;
- riparian vegetation canopy closure;
- observations of fish; and
- barriers to fish movement and connectivity to stormwater system or other watercourses.

As with the assessment of creeks and streams, the urban drainage channels were classified according to the system indicated in Table 3-1.

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[1] Resource Inventory Standards Committee (RISC). 2001. Reconnaissance (1:20,000) fish and fish habitat inventory: standards and procedures, Version 2.0. Prepared by B.C. Fisheries Information Services Branch for the Resource Inventory Committee. Available at: http://www.for.gov.bc.ca/hts/risc/pubs/aquatic/recon/recce2c.pdf

Non-fish bearing Permanent and *Non-permanent* watercourse classifications designated by the City of Coquitlam were grouped together as *Non-fish bearing*, or Class B (Yellow) watercourses because permanence of flows could not be accurately determined in these watercourses based on a single site visit, and for consistency with watercourse classification mapping undertaken earlier in this ISMP.

RESULTS

Eighty-two ditch locations in the Chines Watershed were inventoried and assessed. Eight sites that had been previously mapped as ditches are now filled/paved; no ditches were observed at these sites during the surveys. The conditions, habitat characteristics and assigned watercourse classification of each of the 82 inventoried ditch locations are briefly discussed below. Locations and classification of the 82 inventoried ditches are superimposed on Figure 3-4.

Class B (Yellow) Ditches

Eight of the 82 ditch locations assessed were designated Class B watercourses based on the habitat characteristics observed during the assessment. Class B watercourses are non-fish bearing but provide fish habitat and contribute potentially significant flows and/or food and nutrients to downstream fish populations.

Class C (Green) Ditches

Sixty-six of the 82 ditch locations assessed were designated Class C watercourses. Such watercourses are non-fish bearing, do not provide significant contributions of water, food and nutrients to downstream fish populations, and are not considered fish habitat. Class C ditches typically have shallow banks with grass growing throughout their bed and banks, and have no defined channel bed or substrate and no evidence of sustained flow. Cover by riparian vegetation is often limited or absent.

All 66 Class C ditches observed were frequently isolated or separated from fish habitat by long (>150 m) stormwater system connections. Six were flat, grassy roadside areas that had no defined ditch or channel banks.

While not providing functional fish habitat, these open channel drainage features will provide hydrologic benefits in slowing runoff, providing filtering action, and allowing for some infiltration of runoff. According, they should not be filled without providing an equivalent stormwater runoff control capacity by other means.

No Ditch Present

As noted, no ditches were observed at eight of the previously mapped ditch locations among the 82 ditch locations assessed. These sites had been previously mapped as ditches in the City of Coquitlam mapping files. At the time of the survey, most were paved with only catch basins or stormwater drains present.

Summary

Future developments in the Chines Watershed may involve work in or around the various urban drainage channels/ditches and other stormwater system components. Environmental protection and mitigation requirements and regulatory permitting will be requires as part of any future development plans.

The recommendations regarding environmental protection and mitigation, and regulatory permitting processes and requirements for each classification are as follows:

- Given that Class B watercourses are considered fish habitat, any future works with potential to affect the riparian or instream areas of these watercourses should be carefully considered and planned. Setback distances for development should be applied based on the provincial *Riparian Areas Regulation*[2] and municipal bylaw requirements for ditches. Under the new Fisheries Act, Fisheries and Oceans Canada (DFO) review is no longer required for non-fish bearing watercourses. Instead, the proponent is advised to follow DFO's "Measures to Avoid Harm". However, the Province, under the Fish Protection Act (Riparian Areas Regulation) and Water Act may still require habitat offsetting. In addition, the City of Coquitlam developed a Practice Statement in 2012 that specifies how the City intends to compensate for the enclosure of Class B ditches in Southwest Coquitlam.

- Class C watercourses are not considered fish habitat. As such, a DFO review would not be required for works within or adjacent to these watercourses. Implementation of best management practices for instream works, such as erosion control and working in the dry, should be applied to avoid impacts to downstream storm sewer connections, fish habitat, and fish-bearing areas.

- The hydrological benefits provided by each channel/ditch should be replaced with similar capacity if filling is proposed. A short list of possible equivalent drainage features may include, settling tanks or other treatment units, perforated pipes to allow infiltration, and detention storage systems.

3.2.6 Fish and Fish Habitat

The ravines remain in a relatively natural state and support a mixed, mature deciduous and coniferous forest. The overall salmonid productive capacity is rated moderate, based primarily on good rearing habitat, but a lack of adequate spawning gravels and presence of migration barriers. The lack of deep pools, riffles and refuge habitat (such as side channels or backwater pools) in some areas also limits overwintering and rearing habitat.

Fish species listed on the Ministry of Environment Habitat Wizard, the DFO Lower Fraser Valley Streams Strategic Review and in the Port Moody ESA Phase 2 Report (Robertson Environmental Services Ltd., 2000) for the Chines are listed in Table 3-2.

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[2] B.C. 2004. Riparian Areas Regulation. B.C. Reg. 376/2004. Available at: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/376_2004

Table 3-2
Fish Presence in the Chines

Watercourse	Fish Species Present
South Schoolhouse Creek	
Melrose Creek	Cutthroat trout (*O. clarkii*)
Clark Road Tributary of South Schoolhouse Creek	No fish present
South Schoolhouse Creek	Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), cutthroat trout, sculpin (*Cottus* sp.)[3]
Noble Creek	No fish present
Chines Creeks	
Ottley Creek	No fish present
Axford Creek	No fish present
Kyle Creek	No fish present
Hatchley Creek	No fish present
West Sundial Creek	No fish present
East Sundial Creek	No fish present
Goulet Creek	Cutthroat trout
Slaughterhouse Creek and Tributaries	
Williams Creek	No fish present
Elginhouse Creek	No fish present
Correl Brook	Cutthroat trout
Dallas Creek	Cutthroat trout
Suter Brook Creek	
Suter Brook	Cutthrout trout (O. clarkii), Coho salmon (Oncorhynchus kisutch), chum salmon (O. keta).
Pigeon Creek	Cutthrout trout (O. clarkii), Coho salmon (Oncorhynchus kisutch), chum salmon (O. keta).

[3] Ministry of Environment Habitat Wizard

During the field assessments, salmonids were observed in the upper portion of South Schoolhouse Creek (within Miller Park), as well as lower South Schoolhouse Creek.

The majority of lowland culverts and the piped system preclude fish access to areas below the ravines. Debris control structures (i.e., trash racks) are installed at most road crossings over creeks and may preclude fish access at lower flows due to organic and domestic debris clogging the structures. In the ravines, gradients are typically too steep for fish access and are steep enough to create a velocity barrier to fish migration (greater than 20%, based on the Forest Practices Code).

3.2.7 Common Watershed Productivity Constraints

Based on current conditions, there are a number of environmental constraints that limit the productivity of the terrestrial and aquatic environments within the Chines.

- Garbage and debris embedded in debris control structures at road crossings as well as within the riparian areas and upland areas which limit the seasonal movement of fish.
- Deposition of sand and domestic refuse from headwater areas and some lower areas (Dallas Creek, Correl Brook) contribute to downstream sedimentation and a decrease in available habitat for juvenile salmonids and benthic invertebrates.
- Pipes and culverted portions of the creeks preclude fish passage from the lowland areas into the upland areas.
- Heavy rainfall events may cause maximum water capacity within creeks which reduce fish habitat and nutrients. The lack of deep pools and riffles in some areas also limits overwintering and rearing habitat.
- Weed infestation from disposal of residential refuse and uncontrolled weeds on private properties is limiting the biodiversity and understory diversity in many of the forests.

3.3 HYDROGEOLOGICAL ASSESSMENT

An overview of the hydrogeological assessment carried out to support the development of the Chines ISMP is provided here. Detailed discussion is provided in Appendix C.

3.3.1 Field Assessments

Hydrogeological, surficial geological and physiographic assessments were conducted June 1 and 2, 29 and 30, and September 2 and 3, 2011. The field investigations included identification of surficial deposits, hand testing samples for grain size and moisture characteristics, recording evidence of groundwater seepage and high water tables, estimation of infiltration rates and vertical hydraulic conductivity, and review of areas of pervious soils and surficial deposits where stormwater infiltration may be possible.

Surficial deposit interpretation allowed the composition (grain size), distribution and thickness of surficial geological units to be determined. The depth to water table, and near-surface conditions (gleying/reduction, oxidation, mineral weathering) were also observed as possible. The field reviews were conducted generally within a few days of rainfall during a wet cool spring and summer, which aided locating groundwater seepage areas.

There are few places where the surficial geological units are exposed or accessible in the watershed north and south of the ravines as most is developed for residential, commercial and industrial purposes.

3.3.2 Surficial Geology and Stratigraphy

The generalized surficial geology and stratigraphy in the study area is indicated on Figure 3-5. Six main surficial geologic units are exposed or are present at depth in the study watershed:

- Modern deposits
- Salish Sediments, Stream Sediments
- Capilano Sediments
- Vashon Drift (Fraser Glaciation)
- Quadra Sand
- Cowichan Head Formation

The upland is comprised of at least three surficial deposit layers present as horizontal tabular bodies. Vashon Drift till and water-lain units are generally present at surface in the uplands. Near the heads of Schoolhouse and Kyle Creeks, horizontally laminated sand to pebbly sand deposits may represent Salish Sediments. In the ravines, the underlying Quadra Sand sediments are exposed by stream and slope erosion.

North of the ravines, Salish Sediments composed of sand are present but infrequently exposed.

3.3.3 Groundwater Resources and Hydrogeology

Chines Area Hydrogeology Overview

Based on our assessment, the following general hydrogeological conditions are understood to be present which would determine the feasibility of subsurface stormwater disposal:

- The upland surface is underlain by Vashon Drift and related sediments, with hydraulic conductivities likely in the order of 10^{-4} to 10^{-6} m/s (estimated from grain size). Slow northward and downward water movement through this layer generally occurs, supplying groundwater to the underlying silt, sand and gravel units of the Quadra Sand sediments.
- Portions of the uplands surface may be underlain by Salish Sediments, which would locally provide a higher surface infiltration rate and groundwater flow. However, the Salish Sediments are of limited extent and thickness and overlie generally low hydraulic conductivity Vashon Drift and Quadra Sand sediments.
- The Quadra Sand sediments underlying the ravines range from dense sands to dense clayey silts. Where the Quadra Sand sediments underlying the uplands (south of the ravines) have sand or

sand and gravel intervals, local groundwater flow would occur toward the ravine heads. The clayey silt intervals would form aquitards.

- The groundwater flow lines are predicted to converge toward the ravine heads in the Salish, Capilano, Vashon and Quadra Sediments, producing the largest subsurface flow at the ravine heads and less at the slopes and ridges in-between.
- The modern streams represent the approximate upper groundwater surface in the ravines, and that groundwater flow also occurs in the Quadra Sediments below the streams northward toward Burrard Inlet.

Any potential implementation of subsurface stormwater disposal in the uplands and lowlands will require detailed groundwater investigations as to the capacity to receive additional water volumes. A quantitative assessment of groundwater flow over several seasons would be required, using an array of piezometers above the ravines, and in the lowlands below the ravines, to determine:

- Direction and rate of near-surface and deep groundwater flow.
- The capacity of the surficial deposits to accommodate additional subsurface flow.
- Impacts to building foundations, roads and subsurface infrastructure from increased groundwater table elevations in the upland and lowland areas due to subsurface stormwater disposal.

A surface and subsurface water balance could be prepared to estimate the groundwater flux and the subsurface capacity available to receive stormwater from infiltration based source controls. As there are multiple aquifers and aquitards, and 13 stream ravines, a network of multi-level piezometer installations would be required to characterize the groundwater regime.

3.3.4 Future Slope and Drainage Condition Management

Certain areas such as the escarpment edge above Ottley, Axford and Kyle Creeks are clearly not preferable locations for stormwater disposal given the history of groundwater-influenced landslide events in these ravines. Due to the steep slopes, and the concentration of surface and near-surface groundwater, it is generally not advisable to construct infiltration facilities immediately above or within the steep ravines. Other locations such as the upper South Schoolhouse Creek watershed or the Dallas Creek watershed in the ravines may have some opportunity for stormwater storage or disposal but require a significantly better understanding of groundwater conditions.

Groundwater monitoring above apartments or condominium buildings would be justified in order to assess hydrogeological and stability conditions above these high population locations. Some existing groundwater monitoring above condominium buildings at the bottom of steeper slopes is already occurring in Port Moody. In addition, groundwater monitoring on the steep slopes above schools should be conducted.

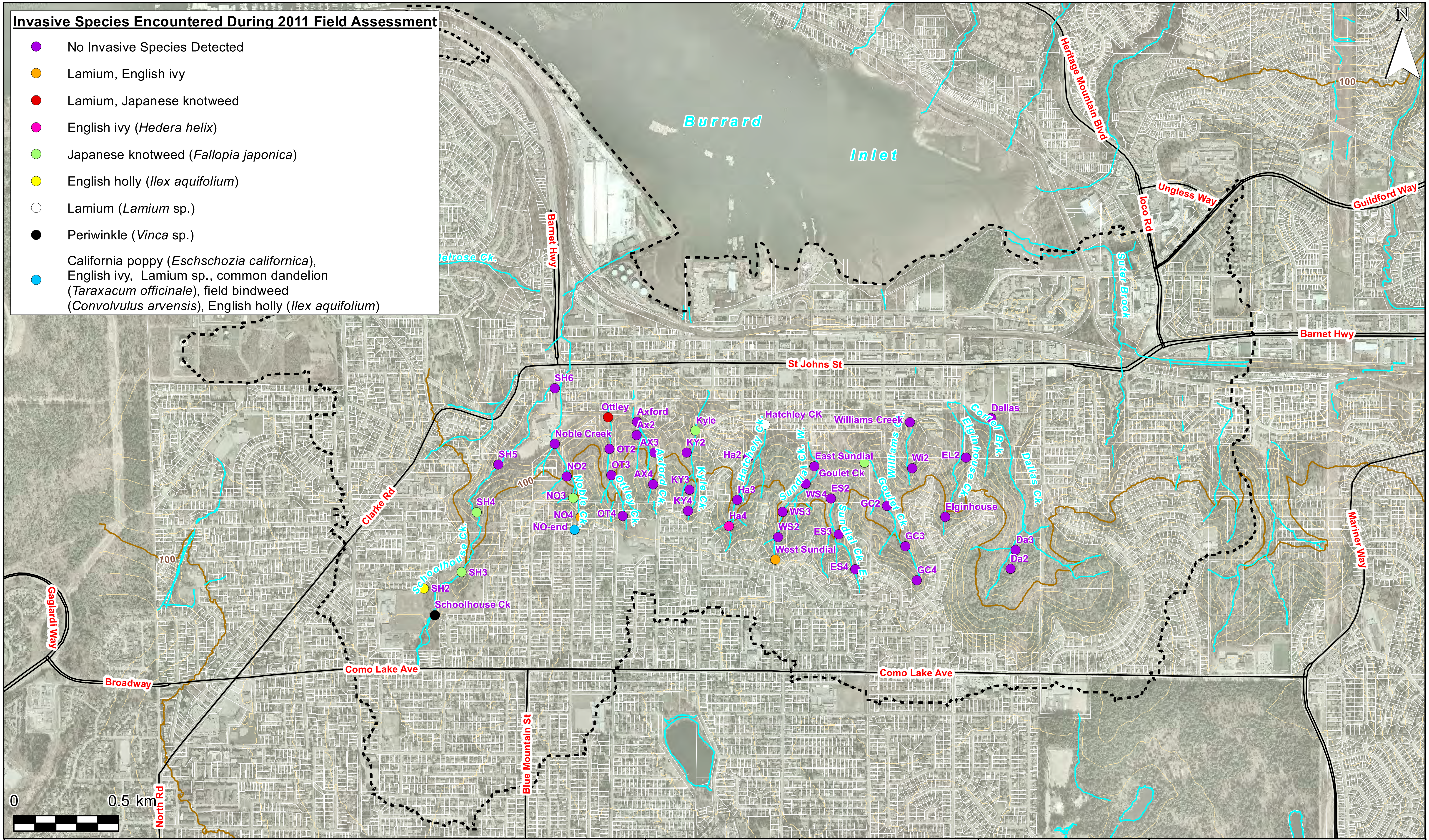
With installation of the groundwater monitoring wells, the subsurface geology can be logged and tested which will assist determination of soil properties and hydraulic conductivity.

If stormwater is directed to an infiltration installation, the stormwater collection area should be no larger than the natural runoff area which would have contributed to that point i.e. no combination of sub-drainages for infiltration installations. In addition, the stormwater should not arrive at a faster rate at the ravine heads than the natural near surface groundwater would have, to avoid conditions of perched water tables, and high soil pore water pressures that could destabilize slopes or cause emergent water and erosion. This implies the need for additional systems upstream of the infiltration facility to attenuate the stormwater flows. Further, the need for stormwater infiltration will be highest in November through March, when the natural groundwater levels are high and soils saturated.

It is unknown how the addition of stormwater drainage through subsurface infiltration facilities will affect groundwater seepage and stream flow. It may be advantageous to create a test facility to try some conversion of stormwater to subsurface flow above one ravine, with piezometers installed at shallow and deep depths, to determine the groundwater changes and the impacts to slope stability and stream flow below.

Estimated infiltration rates for the three main types of surficial material in the project area are:

- Vashon till: minimum 0.9 mm/hr and maximum 2.5 mm/hr
- Ravine colluvial soils: min 13 mm/hr and max 38 mm/hr
- Lowland Salish Sediments: min 13 mm/hr and max 38 mm/hr



Major Roads

Stream

Study Area Boundary

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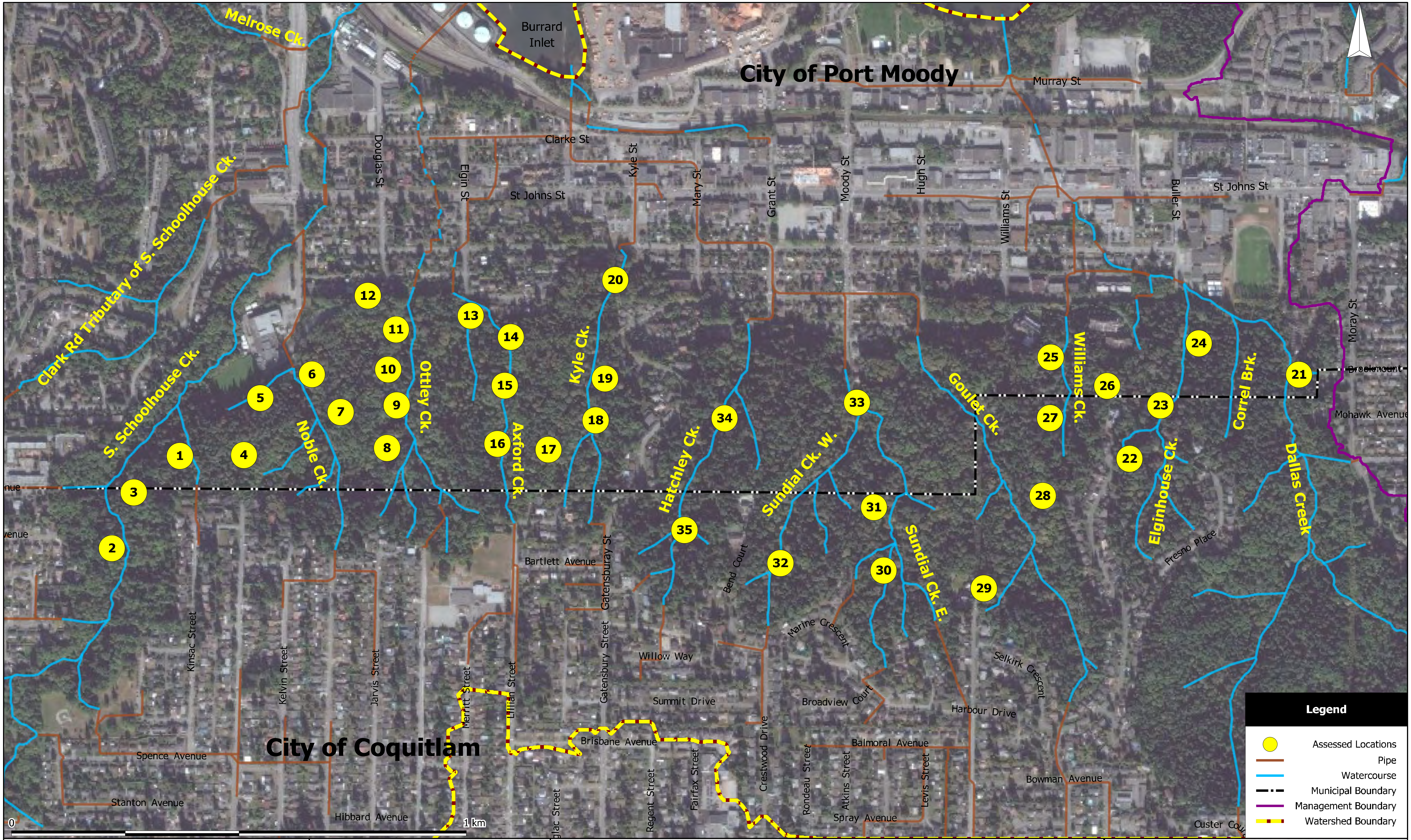
Port Moody City of the Arts

Coquitlam

PROJECT:	20112817
DATE:	January 2014
DRAWN BY:	DA

CHINES ISMP

Figure 3-1 Terrestrial Assessment



PROJECT NO:	**2011-2817**
SCALE:	**1:7,500**
DATE:	**January 2015**
DESIGNED BY:	**JL**
CHECKED BY:	**MM**

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Figure 3-2 Tree Canopy Assessment Sites

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Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure 3-2 Tree Canopy Assessment Sites

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Figure 3-3 Water Quality Sites

Sources: GEBCO, Survey, E OpenStre

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DATE: March 2015
DRAWN BY: DA
PROJECT: 20112817

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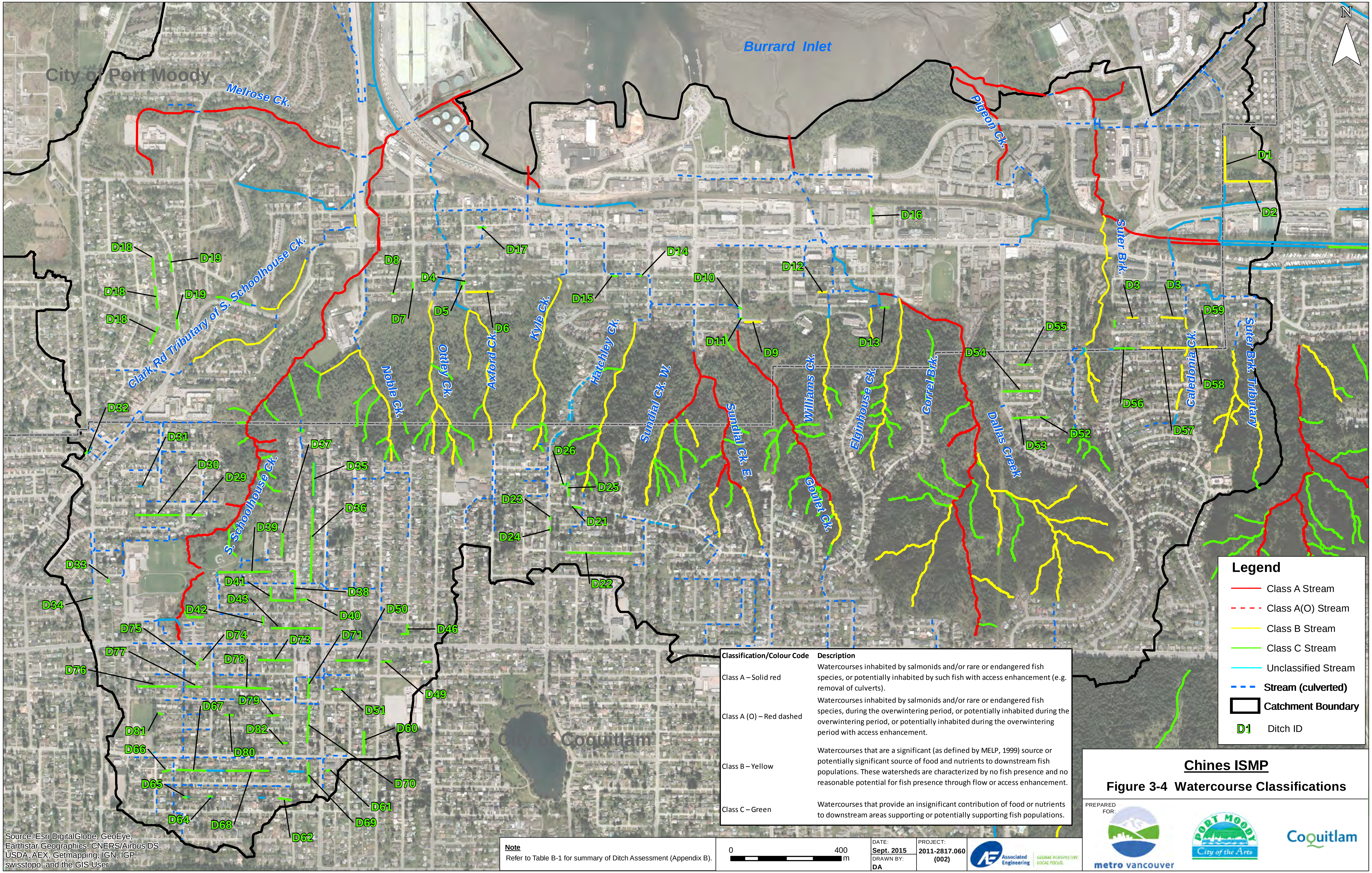

Classification/Colour Code	Description
Class A – Solid red	Watercourses inhabited by salmonids and/or rare or endangered fish species, or potentially inhabited by such fish with access enhancement (e.g. removal of culverts).
Class A (O) – Red dashed	Watercourses inhabited by salmonids and/or rare or endangered fish species, during the overwintering period, or potentially inhabited during the overwintering period, or potentially inhabited during the overwintering period with access enhancement.
Class B – Yellow	Watercourses that are a significant (as defined by MELP, 1999) source or potentially significant source of food and nutrients to downstream fish populations. These watersheds are characterized by no fish presence and no reasonable potential for fish presence through flow or access enhancement.
Class C – Green	Watercourses that provide an insignificant contribution of food or nutrients to downstream areas supporting or potentially supporting fish populations.

Note

Refer to Table B-1 for summary of Ditch Assessment (Appendix B).

DATE: Sept. 2015

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PROJECT: 2011-2817.060 (002)

Associated Engineering GLOBAL PERSPECTIVE. LOCAL FOCUS.

Chines ISMP

Figure 3-4 Watercourse Classifications

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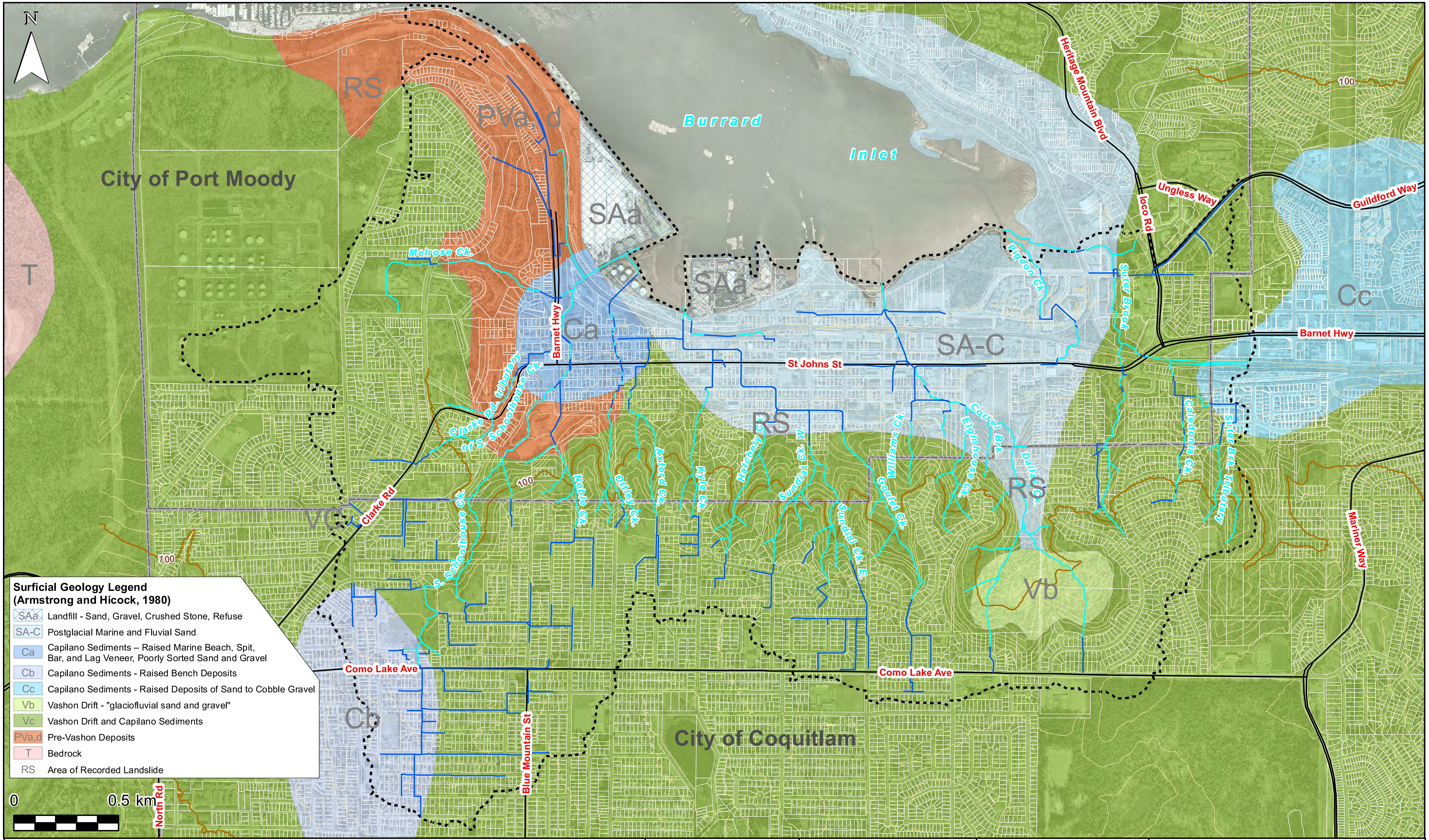

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Stream	Parcel Boundary (white)	Study Area Boundary
Culverted Stream	Major Road	Municipal Boundary

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Figure 3-5: Surficial Geology

4 Watershed Health

Further to the initial environmental assessments that are discussed in Section 3, we completed a watershed health assessment based on water quality, Benthic – Index Biotic Integrity (B-IBI), and riparian forest integrity (RFI).

4.1 STREAM CLASSIFICATIONS AND SETBACKS

Most of the remaining stream reaches in the Chines watershed provide significant food and nutrient value (i.e. Class B), as previously indicated in Figure 3-4. However, they are not considered fish-bearing due to barriers to fish passage in the lowland areas, primarily the piped drainage system. South Schoolhouse Creek, portions of Sundial Creek (both east and west) and Correl Brook are fish bearing (A or A(O)).

The importance of adequate setbacks for maintenance of watershed health, protection of fish habitat, wildlife corridors, access for maintenance, as well as for the protection of property is critical and those setbacks should be maintained. Encroachment into riparian areas leads to habitat degradation and loss of fish and wildlife habitat. The City of Coquitlam and City of Port Moody currently have streamside setbacks typically varying between 15 m and 30 m for fish-bearing streams. Under the Riparian Areas Regulation in Coquitlam, stream setbacks may vary from 10 m to 30 m from high water mark.

4.2 WATER QUALITY

The objective of the water quality sampling program was to obtain background data on the water quality of the Chines during dry-weather. Baseline, in situ water quality data (temperature, dissolved oxygen, conductivity, pH, salinity and oxidation-reduction potential, i.e. ORP) were collected from selected locations. Our sampling results generally indicated parameters conducive to the health and survival of salmonids, based on water quality objectives developed by the Ministry of Environment.

4.3 B-IBI

The presence of macro-invertebrate communities is an indicator of watershed health since organisms present within the cobble and gravel substrates are susceptible to and experience changes in the watershed, such as in the flow regime and in-stream habitat, and the presence of sediment and toxic substances. B-IBI is a rating system that reflects the measurement of benthic communities based on a 10-metrix index system. Values range from 10 (very poor) to 50 (excellent), although a maximum of 40 has been observed in pristine streams within Metro Vancouver (Kerr Wood Leidal 2005). The stream condition rating system used in Metro Vancouver is described in Table 4-1.

Table 4-1
Stream Condition Ratings Based on B-IBI Scores (EVS 2003)

10-metric B-IBI Score	Stream Condition Rating
45 to 50	Excellent
38 to 44	Good
28 to 36	Fair
18 to 26	Poor
10 to 16	Very poor

Results of the benthic survey indicated B-IBI scores mostly ranging from 28 and 32, representing a “fair” classification; however, both Sundial Creek east and west branches had B-IBI scores of 24 and 22, respectively, representing “poor” classification.

West Sundial is a very small creek system with a mainly sandy substrate where very diverse benthic communities cannot be expected. Conditions during the spring and the early summer of 2011, when the B-IBI sampling undertaken for this ISMP took place, were colder and wetter than normal, which likely suppressed the macro-invertebrates communities. Several taxa were represented by only one or two specimens, which can influence the total taxa richness, as well as the B-IBI scores.

4.4 RIPARIAN FOREST INTEGRITY ANALYSIS

The degree to which forest cover is maintained in proximity to watercourses has a significant impact on their health. The Metro Vancouver ISMP template employs Riparian Forest Integrity (RFI) as a key indicator for the health of a watershed. RFI is the percentage of forest cover remaining in a corridor extending 30 m to either side of a watercourse.

However, the RFI result can be skewed if a large percentage of the drainage paths in a watershed are piped, rather than remaining as open watercourses. Thus, extensive swathes of riparian corridor may be eliminated, but the RFI can appear high, indicating good watershed health, when only a small portion of watercourses remain unenclosed. This circumstance applies in the Chines study area where most former open watercourse reaches in the developed uplands and lowlands have been piped. To provide more realistic estimates of RFI to use in assessing watershed health, we extended the length of the stream corridors assuming that major pipes roughly correspond to former surface watercourses. These “phantom” riparian corridors are allocated a value of 0% retained forest cover. The result is a lower RFI that better reflects the reality of the study area. Figure 4-1 indicates the corridors along each watercourse, and the estimated extent of forest cover as interpreted from aerial photography. Notably, the resulting adjusted RFI values give indications of watershed health comparable to those indicated by B-IBI and EIA (refer to Figure 4-2).

Table 4-2 summarizes RFIs and EIAs for the major watercourses/watersheds in the Chines watershed.

Table 4-2
Existing Riparian Forest Integrity

Drainage System	RFI	TIA	EIA	Measured B-IBI	Predicted B-IBI**
South Schoolhouse Creek	38%	49%	43%	31	17
Kyle Creek	52%	39%	34%	26	24
Slaughterhouse/ Dallas Creek	72%	32%	28%	30*	24
Pigeon Creek	12%	53%	46%	30*	14
Suter Brook	41%	41%	41%	30*	17

* Based on the measured BIBI score for Goulet Creek which is the creek geographically closest to the Pigeon Creek and Suter Brook watershed.
** B-IBI = $0.0000058x^4 - 0.0009963x^3 + 0.0615x^2 - 1.8395x + 40$ where x is %TIA < 70% (B-BI = 10.0 for %TIA >= 70%)

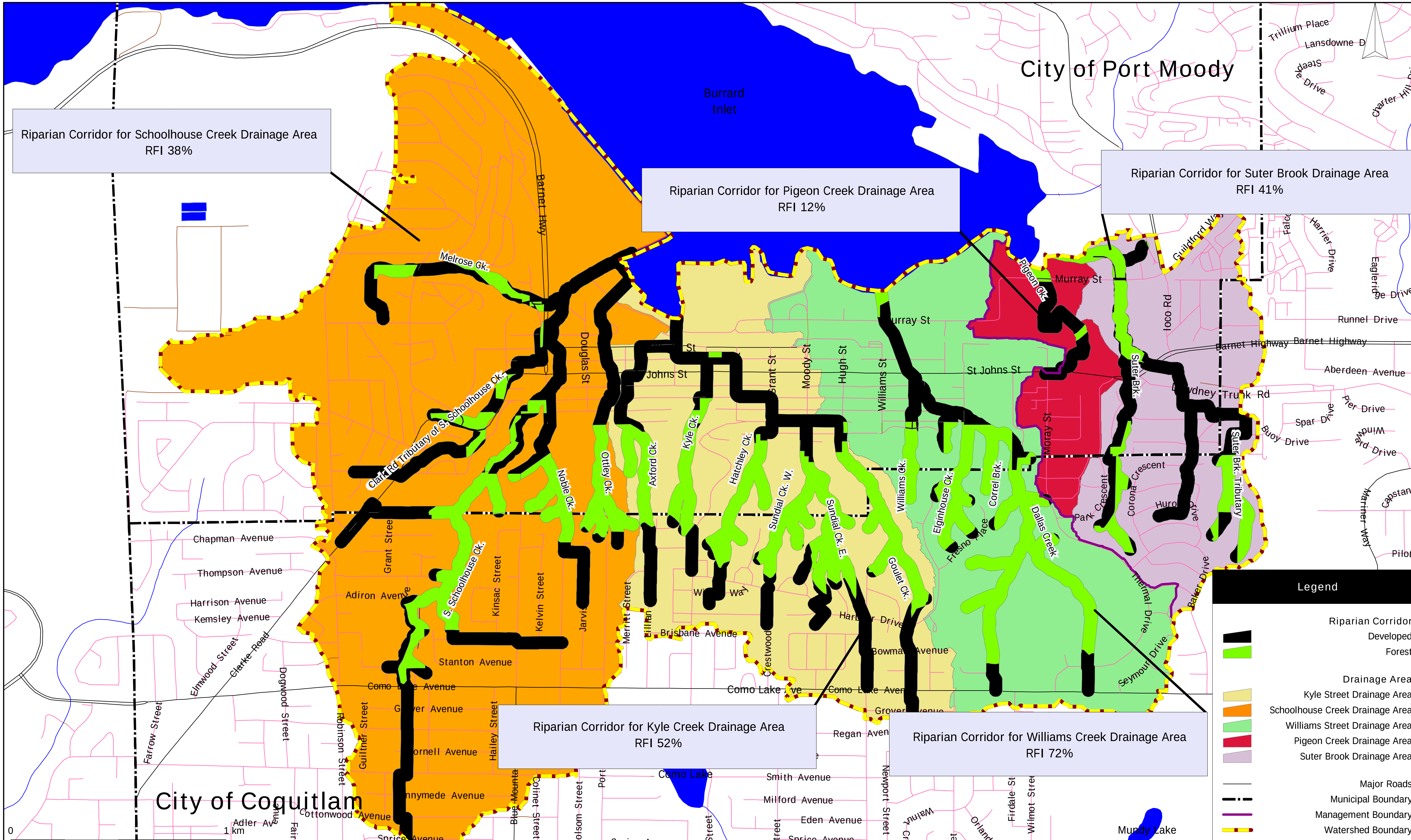
We note that the predicted B-IBIs reported in Table 4-2 are based on the RFI in the riparian corridors of remaining natural watercourse segments, and does not include the hypothetical former watercourse extents represented by pipe sections, discussed in the preceding paragraphs.

4.5 SUMMARY

We plotted the estimated health indices, as summarized in Table 4-2 above, on the GVRD Watershed Health Tracking System (Template for Integrated Stormwater Planning 2005) and presented as Figure 4-2. Currently, both the B-IBI and RFI ranking indicate that the individual watersheds in the study area have watershed health ranging from fair to poor.

In the future, if EIA increases in the upland areas as a result of redevelopment and the trend to larger homes and greater impervious surface coverage is unmitigated, then we expect that watershed health will further decline and the plotting positions will shift further to the right.

We note that the calculated B-IBI scores are lower than the measured B-IBI scores, which indicates that the watershed is currently performing better than expected, at least in regard to Benthic Invertebrates.



Time: 4:35:37 PM | Date: 2/3/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure 4-1 Riparian Corridor Integrity

PROJECT NO:	20112817
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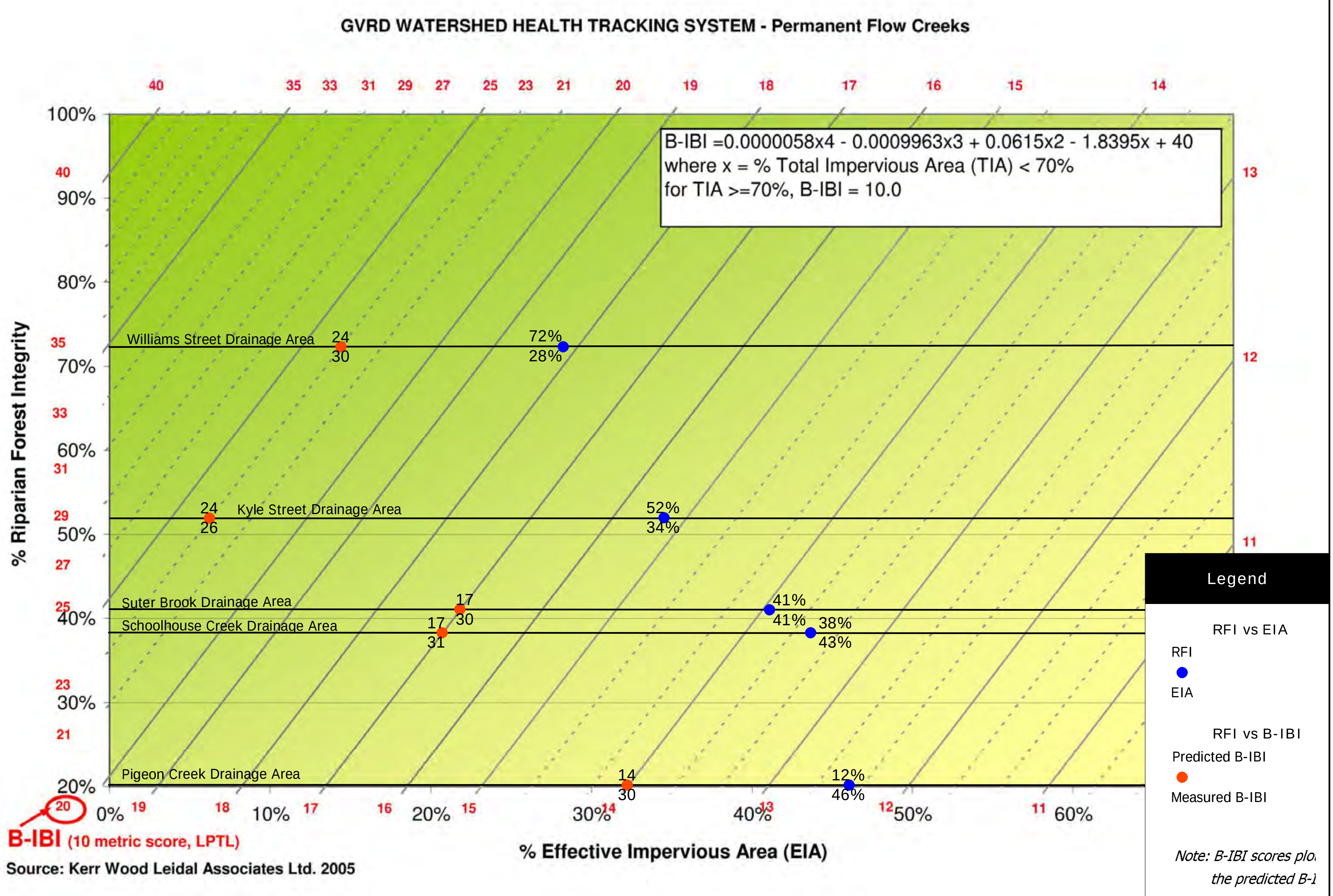
Figure 4-1 Riparian Corridor Integrity



Source: Kerr Wood Leidal Associates Ltd. 2005

PROJECT NO:	20112817
SCALE:	NTS
DATE:	January 2015
DESIGNED BY:	JL
CHECKED BY:	MM

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Figure 4-2 Estimated Existing Watershed Health

5 Watershed Evaluation

5.1 MODEL DEVELOPMENT

Associated Engineering developed a hydrologic and hydraulic stormwater model for the main drainage network in the study area in the PCSWMM software environment. Model data was assembled from a variety of sources including:

- Field inventory of drainage features collected on June 13, 2011 and June 14, 2011.
- GIS data of hydraulic structures from the City of Port Moody and the City of Coquitlam.
- Metro Vancouver LIDAR surface data for the ravines.
- Digital topographic data for the uplands and lowlands from the Cities of Coquitlam and Port Moody respectively.
- Current land-use and zoning mapping layers from both Cities.
- Future land-use and zoning mapping layers from both Cities.
- Record drawings of specific features as required.

Field data points and site photos are provided in Appendix D. Details of the model development are summarized in Appendix E.

We used GIS methodologies for rapid and accurate development of the hydrologic/hydraulic model. GIS routines facilitated the following tasks:

- Automated catchment delineation for each desired model node or critical point using a spatially based topographic analysis routine, applicable to establishing contributing catchment areas for culverts and other key points in a drainage network.
- Geometric model development and attribute generation for the overland flow network.

Current Land Use Conditions

Low density residential land uses comprise approximately 40% of the study area. A large portion of the lowland area is industrial, particularly the area bounded by Barnet Highway and Clarke Street. To the east of the industrial area, approximately 30 ha is green space adjacent to Burrard Inlet. Figure 5-1 illustrates the existing land use distribution.

Estimated total impervious area (TIA) and effective impervious area (EIA) for each existing land use type are summarized in Table 5-1.

Table 5-1
Estimated Existing TIA and EIA

	Existing Area (ha)		Total (ha)	TIA (%)	EIA (%)
	Coquitlam	Port Moody			
Commercial	3.6	61.7	65.3	70	60
Industrial	3.1	107.0	110.1	80	70
Institutional	25.6	23.5	49.1	55	45
Low Density Residential	270.5	160.3	430.9	45	40
Medium Density Residential	1.2	65.2	66.4	55	50
Parks and Open Space	8.7	49.1	57.8	5	5
Ravine	116.3	77.5	193.8	3	3
Municipal Roadways	24.2	36.4	60.5	90	70

Future Land Use Conditions

Significant redevelopment of the City Centre area of Port Moody is anticipated in the future, in part due to the Evergreen Line construction in the northern portion of the study area. As shown in Figure 5-2, the Evergreen Line will travel at ground level parallel to the Canadian Pacific Railway.

Figure 5-2
Evergreen Line Alignment

(Source: http://www.translink.ca/en/Plans-and-Projects/Rapid-Transit-Projects/Evergreen-Line.aspx)

The Official Community Plan also indicates a potential increase in residential density in the lowlands near the proposed Evergreen Line alignment. The future land use is illustrated in Figure 5-3. In addition to the explicit changes in land-use identified in both Cities' OCPs, redevelopment and renewal of the housing stock is expected to result in an overall increase in impervious area within residential areas. Construction of larger homes, addition of secondary "Laneway" homes and additional hard surface coverage are all factors contributing to the expected increase in impervious coverage.

Our estimates of the total impervious area (TIA) and effective impervious area (EIA) for each existing land use type under future conditions are summarized in Table 5-2.

Table 5-2
Assumed Future TIA and EIA

	Future Area (ha)		Total (ha)	TIA (%)	EIA (%)
	Coquitlam	Port Moody			
Commercial	0.4	59.4	59.9	70	60
Industrial	3.2	103.9	107.1	80	70
Institutional	25.0	24.6	49.6	55	45
Low Density Residential	274.1	151.4	425.5	75	70
Medium Density Residential	1.2	83.1	84.3	85	80
Parks and Open Space	8.7	46.9	55.6	5	5
Ravine	116.3	75.4	191.7	3	3
Municipal Roadways	24.1	35.7	59.9	90	70

Rainfall Data

Considering the number of record years and proximity of the rain gauge location, rainfall IDF data from the Metro Vancouver Gauge PT11 – Port Moody Pump Station was used for this ISMP.

5.2 EXISTING CONDITION MODEL RESULTS

We used the following criteria to identify deficient pipes, both of which must be met in order to consider a pipe deficient.

- The upstream manhole surcharges above the crown of the pipe for greater than 15 minutes.
- The hydraulic grade line (HGL) within the pipe is steeper than the pipe's physical grade.

Drainage Deficiencies

We investigated 10-year and 100-year return period event existing condition model results to locate capacity deficiencies in the drainage infrastructure. In both Port Moody and Coquitlam, storm infrastructure is designed with capacity for a 10-year return period flood event (10% probability of occurring in any given year) for the minor system. The major drainage system design standard is to have sufficient capacity for the more severe 100-year return period storm event (1% chance of occurring in any given year). For the Cities, the minor system includes underground storm infrastructure such as storm sewers, and the major system includes culverts on natural watercourses and overland flow and surface conveyance along roadways However, overland and surface conveyance was not included within the model analysis. Metro Vancouver's larger interceptor pipes, which receive and convey the creek flows emerging from the ravines, comprise the major system and intended to provide a level of service consistent with a 100-year return period storm event.

10-Year Service Level Deficiencies: The model results indicate that some of the minor system pipes are undersized for flows resulting from 10-year return period storm events. However, none of the manholes appear to surcharge to ground. See Figure 5-4 for deficient minor system pipes.

100-Year Service Level Deficiencies: Overall, the regional pipes (Metro Vancouver major system) in the lowlands have the capacity for conveyance of estimated 100-year return period flows, except for the South Schoolhouse Creek pipe system. See Figure 5-4 for deficient major system pipes.

5.3 ASSESSMENT OF FUTURE IMPACTS

Future development and redevelopment activities are expected to increase the global total percent imperviousness of the Chines study area from approximately 38% under existing conditions to approximately 53% under anticipated future conditions without mitigation. The majority of redevelopment is expected in the Port Moody lowlands. By implication, if no action is taken to address accompanying changes to the hydrologic regime, watershed health will degrade from current conditions.

Using the hydrologic and hydraulic model, we analyzed the existing and future conditions in the watershed. By comparing the results from the two conditions, we estimated the potential hydrological impacts on the watershed as a result of future development. Only a small number of additional pipes were indicated as deficient beyond those for current conditions and all are associated with current condition deficiencies. All deficient pipes, for both current and future conditions are shown on Figure 5-4.

To assess the potential impact of the future development on the watershed, we focused on flow conditions at 14 “indicator” locations. Overall, the peak flows, HGL, and runoff volumes increase in future conditions. The changes are relatively more pronounced in the Kyle Creek Drainage System and Slaughterhouse/Dallas Creek Drainage System than the rest of the drainage areas, as a result of future development conditions.

Climate Change

Climate change is anticipated to impact total rainfall volumes and peak rainfall intensity throughout the Lower Mainland, with increases of 20% or more over current conditions reported for the 100-year horizon. Over the long-term, this will result in greater portions of the drainage system having inadequate capacity for the relevant design storm events. This effect will be magnified if combined with the anticipated future increases in impervious cover in the study area.

However, the impact to some components of the drainage system is not necessarily proportional to the change in storm event magnitudes. Increased flows or runoff volumes may be throttled by limitations in catch basin, pipe and overland flow capacities in the upper reaches of the watersheds, with a delay in some flow volumes reaching the creeks and major pipe systems in the lowlands.

In addition, modelled increases in future flows due to redevelopment activities are likely to be conservative when applied on an overall watershed basis. Increases in impervious cover as assumed for the future condition analysis will only be reached over a long period of time, and likely only on a localized, rather than general basis. We note that the vast majority of the existing pipe system is operating at less than 80% of its actual capacity and has considerable ability to receive higher flows. However, there are vulnerable sections that will require focussed improvements and local issues with catch basins or inlets that may arise.

Modelled pipe sections that may be vulnerable to climate change driven flow increases, combined with assumed future development conditions are identified graphically on Figure 5-5. We do not identify specific upgrades for these pipe sections, given the uncertainty of the combined effects of future development and climate change.

5.3.1 Extended Period Simulation

We undertook an extended period simulation to assess the watershed response to future changes in hydrological conditions within the study area. The continuous simulation was performed using hourly rainfall data for 36 months from October 1st, 2008 to September 30th, 2011.

Tractive Force and Impulse

Tractive force and impulse represent the forces and total energy (respectively) that a stream exerts on its channel and bed and are the drivers for watercourse erosion. Tractive force is the force exerted by flowing water on the channel bottom and sides and is a product of the flow depth, cross-sectional area of flow, and the slope of the stream channel. Impulse is the summation of tractive force over a period of time and indicates the total energy expended on the stream channel over time. Generally, impulse is determined using only the tractive forces in excess of the critical force below which erosion will not occur.

We used the extended period simulation results to compute the maximum tractive force and the total in-stream impulse over the simulation period (October 1st, 2008 to September 30th, 2011) at the downstream end of each watercourse before it enters the piped system in the lowlands. Table 5-3 summarizes the channel slope, maximum tractive force, and impulse for each watercourse under both existing and unmitigated future conditions.

The results for stream impulse at these locations are graphically illustrated in Figure 5-6.

Table 5-3
Maximum Tractive Force and Impulse

ID	Watercourse	Maximum Tractive Force (N/m^2)			Impulse (kN.h/m)			Percentage Exceedance	
		Existing	Future	% Change	Existing	Future	% Change	Existing	Future
SH01	Melrose Creek	138	143	4	669	752	11	25%	26%
SH02	Clark Road Tributary of South Schoolhouse Creek	325	366	11	1121	1421	21	25%	28%
SH03	South Schoolhouse Creek	117	126	8	172	231	26	13%	15%
SH04	Noble Creek	275	305	10	576	736	22	28%	31%
SH05	Ottley Creek	141	147	4	256	289	11	21%	22%
KL01	Axford Creek	154	165	7	287	343	16	23%	25%
KL02	Kyle Creek	185	208	11	317	413	23	21%	24%
KL03	Hatchley Creek	205	227	10	317	709	55	23%	26%
KL04	Sundial Creek	315	342	8	1233	1545	20	27%	31%
KL05	Goulet Creek	266	287	7	2743	3083	11	46%	49%
WL01	Williams Creek	103	127	19	37	45	18	19%	20%
WL02	Elginhouse Creek	458	519	12	196	233	16	39%	43%
WL03	Correl Creek	195	221	12	56	69	19	21%	22%
WL04	Dallas Creek	131	148	11	37	45	19	17%	19%
PG01	Pigeon Creek	78	90	13	31	36	14	18%	19%
SB01	Suter Brook	422	445	5	146	175	16	33%	36%
SB02	Caledonia Creek	225	239	6	77	92	16	24%	26%
SB03	Suter Brook Tributary	204	206	1	43	46	5	18%	19%

5.4 CANDIDATE STORMWATER MANAGEMENT MEASURES

There are a range of source control measures and more general best management practices (BMPs) that can potentially be applied within the study watershed. Several of these source controls and BMP measures are already incorporated in the City of Coquitlam's Rainwater Management Guidelines. A combination of measures will be needed to effectively manage stormwater at the site, sub-watershed, and watershed levels. To effectively improve the hydrologic state of the watershed, stormwater management planning should be integrated into the planning, design, and construction phases of new development and redevelopment projects.

Source controls are defined as approaches to land development or redevelopment that work to manage rainwater at its source (prior to discharge from site). They are systems that manage rainwater by infiltrating, filtering, storing, evaporating, and detaining rainwater. BMPs encompass source controls as well as planning, design, and construction initiatives with the goal of managing stormwater to reduce the load placed on receiving watercourses and improve overall watershed health.

In the context of the Chines watershed, redevelopment offers the opportunity to improve the overall condition of the stream network and partially reverse past impacts. The measures identified in this section provide a means to improve the health of the watershed, as well as its amenities and sustainability, to varying degrees.

We considered the following BMPs for potential application in the Chines ISMP:

- Absorbent growing medium cover of 300 mm or more
- Bioswales
- Water Quality Devices
- Pervious Pavements/Paving in parking or lightly travelled lanes
- Green Roofs/Rooftop Detention
- Enhance Riparian Areas
- Limit On-Lot Effective Impervious Coverage
- Preserve Green Space
- Rain Gardens
- Reduced Effective Road Width
- Large Street Trees
- Under Road (Subgrade) Storage
- Underground Extended Detention Storage (tankage or porous subgrade storage)
- Peak Flow Diversion

Each of the above is discussed briefly below. Greater detail was provided in the Stage 3 report during development of this ISMP. Further information is also available in Metro Vancouver's Source Control Design Guidelines.

Absorbent Soil Cover

One of the simplest forms of source control in terms of concept and execution, the provision of a layer of uncompacted absorbent organic growing medium, has significant benefits in retaining rainwater on site, allowing for infiltration, evapotranspiration and gradual release to the drainage system. A minimum thickness of 300 mm is generally required for effectiveness, with a void ratio of 30%; this represents an ability to hold 90 mm of water. However, uncompacted wet soils can lead to property owner discontent with “soggy” lawns and alterations that reduce its effectiveness. Minimum absorbent soil cover is currently a key measure in the City of Coquitlam’s Rainwater Management Guidelines.

Bioswales

Bioswales are gently sloping natural drainage courses densely planted with a variety of native, water tolerant vegetation. They are intended to reduce peak flow velocities, promote infiltration, reduce runoff volumes, provide short term flow attenuation, and filter pollutants and sediment from runoff. Bioswales can be constructed adjacent to driveways and roads, located within or around parking lots, and integrated into development and redevelopment projects.

In soils with partial or low infiltration capabilities, like those in the study area, perforated drain pipes can be placed in the drain rock layer and connected to the storm sewer system or downstream stormwater management facility to prevent excessive ponding in the bioswale.

Water Quality Devices

Water quality devices are available from numerous vendors. The most common devices separate sediment and oils by settling or floatation and segregation from the water stream. Newer designs incorporate absorbent materials or are able to dose with chemical agents that promote coagulation and settling of fine particles.

In general, these devices are most effective when applied to areas that are concentrated pollution sources, such as parking lots, soil or sediment stockpiles, vehicle maintenance and some manufacturing activities. However, water quality devices can also be provided at outfalls (such as to the ravines) to provide treatment to the first flush response to rainfall and baseflows prior to entering the creek channels. These devices are useful in protecting other BMPs, such as infiltration systems and vegetated features, from excessive loadings that could degrade their performance.

Pervious Pavement

Pervious pavement promotes infiltration through surfaces that would otherwise be impervious. They may be applied to non-arterial roadways, driveways, emergency access ways, parking lots, and pedestrian and cycle pathways. Types of pervious pavement include, but are not limited to, porous concrete, porous asphalt (also termed open graded asphalt), brick, cobblestones, and porous structural pavers. Usually, the pavement structure consists of a pervious paving surface underlain by a uniformly graded coarse aggregate generally 0.30 m to 1.00 m thick, placed on a non-woven geotextile and a permeable subgrade. The layer of coarse aggregate provides temporary storage, the geotextile prevents the migration of fines, and the uncompacted soil promotes infiltration, if applicable.

Pervious pavement acts to reduce the peak flow rate and total volume of runoff from a site. In soils with low permeability, water can be collected in an under drain and conveyed to the receiving watercourse or stormwater conveyance system. Under these conditions, the pervious paving and subgrade acts as a distributed extended detention system. If applied extensively, these features can partially mimic the function of near surface water storage and movement in soils (i.e. interflow).

Green Roof / Rooftop Detention

Green roofs are level building roof areas that are either fully or partially covered with vegetation. Green roofs should consist of a variety of hardy native surface vegetation, a growing medium with a minimum thickness of 75 mm, and a drain rock reservoir with a perforated under drain to capture and direct water from the rooftop. Water proofing membranes and root barriers are required to protect the structure of the roof. Roof surfaces can also incorporate detention storage as an alternative to or in addition to a vegetated roof. Sizeable portions of large building roofs are generally occupied by HVAC equipment meaning that not all roof space will be available for use as a green roof.

Enhance Riparian Areas

Riparian areas are the natural vegetation along watercourses. Intact riparian corridors reduce erosion potential, filter sediment and pollutants from runoff, reduce peak flow rates and total volume of runoff, and act as a natural buffer between watercourses and development. In addition, riparian corridors provide fish and wildlife habitat.

The remaining reaches of creeks generally have reasonably intact riparian forest. However, if stream daylighting opportunities arise, the extent of riparian corridor can be increased. This would directly improve the health of the stream and watershed.

Multi-use paths and pedestrian bridges will encourage the public to use riparian zones for passive recreation. Educational signage can inform users of the sensitive ecosystems within riparian zones and foster a sense of environmental stewardship.

Furthermore, invasive plants in the riparian areas should be managed in order to prevent loss of trees and reduced overall canopy coverage.

Limit on Lot Impervious Coverage

The majority of the other stormwater management BMPs discussed in this report aim to reduce the negative hydrologic effects of runoff from increased impervious coverage. A similar benefit is achieved by limiting the percent impervious values of developed lands to directly reduce runoff.

Preserve Green Space

The uplands and lowlands are mostly developed; however, some green space in the form of urban parks, and playgrounds are present in these areas. When planning for park development and improvement, the total existing green space should be preserved and the overall impact of new facilities and other hard surface park improvements should be carefully evaluated.

Rain Gardens

Rain gardens are shallow landscaped depressions designed to capture and treat on-site surface runoff. Rain gardens can receive runoff from parking lots, roofs, and other impervious surfaces. Runoff is pooled on the surface and suspended solids and sediment are allowed to filter and settle. Water then interacts with vegetation for pollutant uptake and evapotranspiration. Finally rainwater filters through soil media for additional pollutant removal, storage, and infiltration, or is discharged through underdrains at a greatly reduced rate when compared to direct runoff.

Rain gardens should be designed to improve the aesthetics of their surroundings and are most appropriate for service areas less than approximately 5 hectares. Rain gardens are best suited for application to areas with slopes less than 2%, which encompasses most of the upland area and some portions of the lowlands. Rain gardens can be incorporated into site layout and landscaping requirements, including municipally controlled lands such as road rights-of-way.

Reduced Effective Road Width

Existing road rights-of-way within the Chines study area generally have a high proportion of impervious coverage, including the main travelled lanes, medians, shoulders, sidewalks and parking surfaces. Cumulatively, roadways account for approximately 60 hectares of impervious surface within the Chines watersheds. Reducing the area of paved surfaces within road rights-of-way, or providing other source control measures to reduce the overall EIA of roadways will benefit the overall health of the watershed. However, reducing the EIA of high volume arterials such as St. Johns Street or Como Lake Avenue is likely not feasible.

To improve rainwater management, and the aesthetics, of rights-of-way, the following actions can be implemented:

- Plant more trees in boulevards, and construct rain gardens in road bulges.
- Provide subgrade storage in porous aggregate or in constructed tankage.
- Provide peripheral bioswales receiving runoff via curb cuts or catch basin connections.
- Reduce paved surface width to the minimums required for traffic and parking.
- Construct parking lanes from pervious material.

Large Street Trees

Large trees can be planted within road boulevards or along roadsides as part of community streetscaping. Large trees effectively reduce peak flow rates, reduce total volumes, and enhance water quality during rainfall events by intercepting and storing rainfall in its leaves and branches, reducing soil moisture through transpiration, and improving the holding capacity of soils with their root systems. Tree canopies also reduce soil erosion by limiting the impact of rainfall on bare soil. Additional benefits of street trees include energy saving through shading and wind speed reduction, carbon dioxide reduction through cellular respiration, improved air quality through absorption, and improved community aesthetics.

Notably, in order to support the long term growth and health of large street trees, a significant growing medium volume is required, up to 30 m^3 depending on species and application. The total volume can be reduced if trees are located closely enough to share soil volumes. These soil volumes can be provided in underground chambers that receive runoff from paved surfaces.

By selecting the appropriate variety of large stature deciduous trees, the benefit of this BMP can be maximized. Allowance for irrigation during dry periods is essential to ensure tree survival.

Under Road (Subgrade) Storage

Road subgrades can be configured to provide storage volume for receiving road runoff by using a coarse open graded aggregate (e.g. railway ballast) with a void ratio of 30% or higher. These subgrade features can be combined with pervious paving features or can receive road runoff via catch basins. By providing throttled underdrains, the subgrade structure can act as an extended storage facility.

Alternatively, linear tank systems can provide similar functionality.

Underground Extended Detention Storage

Future development forms within the Chines watershed are expected to have high proportions of impervious cover and land consumption. As a result, large scale surface detention and treatment systems, such as ponds are wetlands, are not generally feasible. Instead, extended detention storage can be provided by underground systems. In commercial, industrial, and high density residential areas, detention storage can be provided as tanks located under parking or working areas and in urban residential areas within lawns or under driveways, preferably at the low point of each site. Runoff can enter tanks directly through catch basins and piped systems or after passing through other stormwater management source controls or BMPs.

Peak Flow Diversions

Peak flow diversions are a pipe conveyance approach to reduce the hydraulic stress placed on watercourses during significant flow events. Using a flow control structure (weirs, gates or orifices) a portion of the flood hydrograph is diverted to a high capacity pipe system and bypasses sensitive stream sections. At a downstream section, the diverted flow is returned to the creek or continues to an ultimate discharge location. Generally, a portion of high flows is retained in the creek system to maintain the natural flushing action that aides in renewing the stream sediments.

Peak flow diversions are a “hard” infrastructure approach that can be employed when green infrastructure strategies are not able to achieve required control of runoff or are not expected to be implemented over a reasonable time frame.

5.5 RELATIVE EVALUATION OF CANDIDATE SOURCE CONTROLS AND BMPS

We evaluated each candidate source control and BMP discussed above for its relative estimated degree of effort required for implementation and its probable effectiveness within each land use type. Accordingly, each BMP was categorized as being easy, moderate, or challenging to implement. The assigned implementation effort is based on general applicability to each land use type, aesthetics, capital and maintenance costs, feasibility of construction and maintenance, land consumption, and impacts to existing programs. Each BMP was also categorized as being low, medium, or highly effective for each land use type. Effectiveness was based on the ability of the selected management strategy to provide one or more of erosion and sedimentation control, peak flow rate attenuation, volume reduction, and water quality enhancement. Table 5-4 provides a summary evaluation of the candidate source controls and BMPs that may that were considered for the Chines ISMP.

Table 5-4
Relative Evaluation of Candidate Management Measures

BMPs and Source Controls	Management Strategy by Land Use (Implementation Difficulty / Effectiveness)				
	Commercial and Institutional	Industrial	Medium Density Residential	Parks and Open Space	Low Density Residential
Absorbent Soil Cover	Easy/ Medium	Easy/ Medium	Easy/ Medium	Easy/ Medium	Easy/ Medium
Bioswale	Moderate/ Medium	Moderate/ Medium	Easy/ Medium	Easy/ Medium	Easy/ Medium
Water Quality Devices	Easy/ Medium	Easy/ Medium	Moderate/ Low	Moderate/ Low	Moderate/ Low
Pervious Pavement	Moderate/ Medium	Moderate/ Low	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium
Green Roof / Rooftop Detention	Moderate/ Medium	Moderate/ Medium	Easy/ Medium	Easy/ High	Easy/ High
Enhance Riparian Areas	Challenging/ High	Challenging/ High	Challenging/ High	Challenging/ High	Challenging/ High
Limit Lot Impervious Coverage	Challenging/ High	Challenging/ High	Challenging/ High	Easy/ High	Challenging/ High
Preserve Existing Green Space	Easy/Medium	Easy/Medium	Easy/Medium	Easy/Medium	Easy/Medium
Rain Gardens	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium	Easy/ Medium	Moderate/ Medium
Reduce Effective Road Width	Challenging/ Medium	Challenging/ Medium	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium
Large Street Trees	Moderate/ High	Challenging/ High	Moderate/ High	Moderate/ High	Moderate/ High
Under Road (Subgrade) Storage	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium

BMPs and Source Controls	Management Strategy by Land Use (Implementation Difficulty / Effectiveness)				
	Commercial and Institutional	Industrial	Medium Density Residential	Parks and Open Space	Low Density Residential
Underground Extended Detention Storage	Moderate/ High	Moderate/ High	Moderate/ Medium	Moderate/ Low	Moderate/ Medium
Peak Flow Diversions	Moderate/ Medium	Moderate/ Medium	Moderate/ Medium	Moderate/ Low	Moderate/ Medium

5.5.1 Emergency Response Planning

Proper emergency response planning will minimize the negative environmental, economic, social, and health impacts associated with spills, flood conditions, and channel blockages. The objective of the plan is to develop trigger conditions whereby various levels of response action will be taken to prevent loss of life and minimize property damage. We have investigated the primary causes of past spills, floods, and channel blockages and identified monitoring and inspection strategies specific to the Chines watershed which can be incorporated into the Cities' existing Emergency Programs.

5.5.2 Spills

The purpose of an emergency spill response plan is to develop a strategy to allow for prompt and orderly responses to spills. The emergency spill response plan for the Chines watershed should satisfy the following objectives:

- Determine when and where a spill has occurred and alert emergency responders.
- Determine the extent and nature of the spill so that emergency responders can act appropriately.
- Report the spill to the appropriate governing authorities in a timely manner.
- Complete an investigation to determine the source of the spill.
- Compile investigation findings into a functional information database.

The first step to emergency response planning is hazard identification. We recommend that records of previous spills within the watershed be investigated to determine where spills have historically been found and which hazards have occurred most frequently and caused the most damage. Land use activities are highly correlated with the occurrence of spills. Locations of sources (gas stations, industries, etc.) should be plotted and the location of receiving drainage facilities identified. Locations for interception of spills can be identified for inclusion in response planning.

When a list of pollutants is compiled, the most effective monitoring methods can be selected and implemented or installed at the most appropriate location(s) within the watershed. Monitoring methods include investigations by environmental enforcement staff and installation of water quality devices that measure total suspended solids, pH, hydraulic conductivity, and other water quality indicators. Proper identification of hazards will enable emergency responders to respond to spills in real-time and take the most effective course of action.

If resources are available, reporting and investigation into the source of the spill should commence as soon as possible as the ability to track pollutants decreases with time. The water quality monitoring devices discussed above will provide investigators with a starting location from which to follow a pollutant upstream to its source and develop mapping of the pollutant's path.

The final step of the emergency spill response plan should be to develop a functional information database to store the findings and information gathered from each investigation. Adding a GIS component to this reporting and records keeping process will increase the effectiveness of the system. Spill location, date, time, pollutant type, affected areas, environmental and health related consequences, and probable sources can all be mapped together to provide an overall picture of historical spills within the watershed.

The emergency spill response plan should adhere to the BC Environmental Protection Act, the BC Emergency Program Act, and the BC Guidelines for Industry Emergency Response Plans.

Figure 5-7 illustrates the areas with heightened potential for pollution (spill) hazards.

5.5.3 Flood Conditions and Channel Blockages

The Chines watershed may experience flooding due to severe rainfall during major flood events. To reduce flood damage, we recommend that the Cities develop an emergency flooding response plan specific to the Chines watershed.

As stated in the Flood Planning and Response Guide for British Columbia, planning and response for floods can be divided into the following phases:

- Flood prevention and flood damage prevention
- Preparing a flood response plan
- Implementing the flood response plan
- Post flood management

The purpose of an emergency flood response plan is to reduce the negative impacts of erosion, debris blockages, and high water levels that are often associated with flood conditions. High water levels are often the result of blockages created by debris. Debris blockages in the Chines watershed is likely to be caused by fallen trees, accumulated sediment, mass wasted material, and other debris mobilized with erosion. Debris increases flooding potential when it obstructs or blocks flow through culverts, channels, bridge openings, and other drainage infrastructure.

Periodic inspection and maintenance of the drainage system is essential to mitigating the negative impacts of flooding caused by blockages. In addition to regular maintenance, critical components and sensitive locations within the watershed should be identified for surveillance during large storm events. We recommend that known problem areas and locations with severe flooding consequences be identified and that the emergency flood response plan outline guidelines for monitoring and removing debris from these areas during large rainfall events. We also recommend that a post flood management plan be created to help facilitate flood and damage reporting and help to expedite any required improvement works.

5.5.4 Provincial Emergency Program

The reporting of environmental incidents, including spills, is mandated by the provincial Spill Reporting Regulation. Larger spills, depending on their size, may be required to be reported to the Provincial Emergency Program (PEP). The Spill Reporting Regulation requires reporting of all significant spills to PEP at 1-800-663-3456. The type of materials likely to be spilled into watercourses and the amount of spill above which the PEP must be immediately advised include, but are not limited to:

- Fuels, engine oils and hydraulic oils: 100 litres;
- Petroleum oils and emulsions: 100 litres;
- Antifreeze: 5 litres; and
- Propane: 10 kilograms.

A report to the PEP must include, where applicable:

- The reporting person's name and telephone number;
- The name and telephone number of the person who caused the spill;
- The location and time of the spill;
- The type and quantity of the substance spilled;
- The cause and effect of the spill;
- Details of action taken or proposed;
- A description of the spill location and of the area surrounding the spill;
- The details of further action contemplated or required;
- The names of any agencies on the scene; and
- The names of other persons or agencies advised concerning the spill.

5.6 GENERAL TRAIL RECOMMENDATIONS

Currently, most trails within the study area are only intended to provide access to maintenance crews within the Chines and are maintained accordingly and are not intended or suitable for public access. The study area has an existing trail that runs from the north end of Blue Mountain Street to Port Moody Secondary School and an informal path that runs from Baron Place in Coquitlam to Port Moody, however, the conditions of these trails are unknown.

There is potential opportunity for public access trails to be developed to connect neighborhoods above and below the Chines, encouraging walking as a form of commuting into the commercial areas along St. Johns Street and associated bus routes. The desire to formalize and connect the network of trails in the Chines is identified in the City of Coquitlam Master Trail Plan (August 2013) and is an important long term goal requiring opportunity and partnership with the City of Port Moody and Metro Vancouver. Any trails built in Coquitlam should follow the Master Trail Plan and be built accordingly.

This section outlines recommendations for such activities in a general sense. Specific evaluation, planning and design will need to be undertaken to support development of any proposed public access trail. Further work required to develop a trail will include:

- Geotechnical/slope stability investigation.
- Environmental assessments along proposed trail alignments, including identification of and protection of riparian corridor and fish habitat in the proximity of proposed trail alignments.
- Parks/recreation planning co-ordination between the Cities.
- Community consultation.

General trail requirements include:

- Installing crushed gravel on trails, with drainage channels with diffuser rock to reduce erosion and pooling on trail surfaces and to reduce erosion due to trail use.
- Constructing boardwalks through skunk cabbage swamps and other permanently wet areas to encourage users to remain on the constructed trail.
- Removal of invasive and noxious weed species and plant with native shrubs and tree saplings.
- Constructing exclusion fencing through environmentally sensitive areas such as stream crossings and wetlands, as well as in areas of unstable terrain, to ensure people and pets remain on the trail.
- Installation of interpretive and educational signage highlighting the environmental values of the riparian corridors, including information on local ecological community types, frequently encountered plant and animal species, the importance of structural diversity of the forest floor to encourage no additional “trail blazing” or invasive species introduction, local highlights on geological history etc.
- Enforcement of dog control and waste removal through signage, with supporting monitoring and bylaw enforcement.
- Implementation of potential trail development in accordance with standards coordinated between the Cities of Port Moody and Coquitlam and Metro Vancouver.

Based on our overview assessment of the Chines and potential connectivity between parks and other green spaces, the greatest immediate potential for trail implementation is along South Schoolhouse Creek, beginning in Miller Park in the uplands. Miller Park is an actively used community park for recreational joggers, dog walkers and school children. Further, a South Schoolhouse Creek trail would terminate at Port Moody Secondary School and have the potential to further connect other green spaces and open areas in Port Moody.

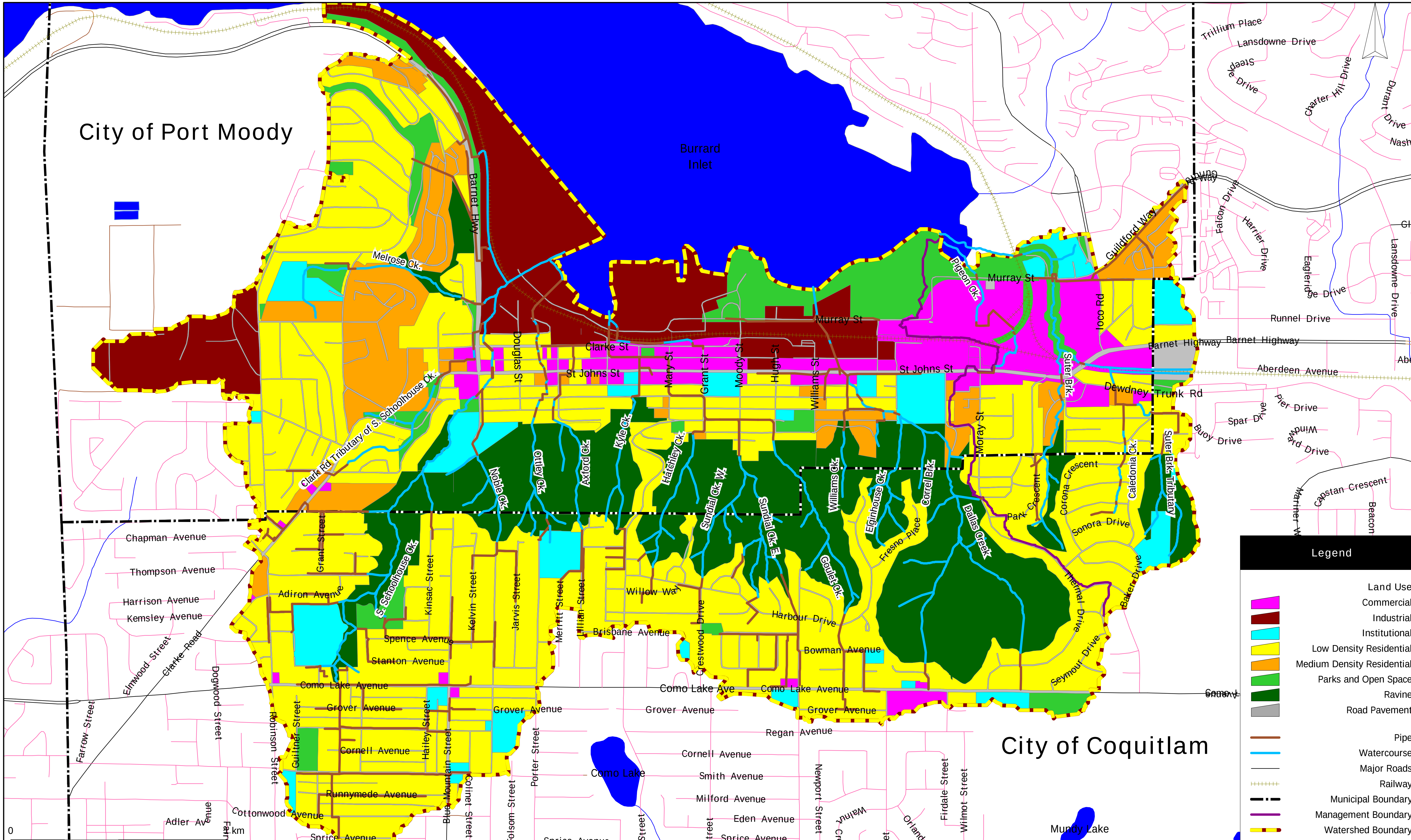

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Figure 5-1 Existing Land Use Designations

Time: 4:51:18 PM | Date: 2/3/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure 5-1 Existing Land Use Designations

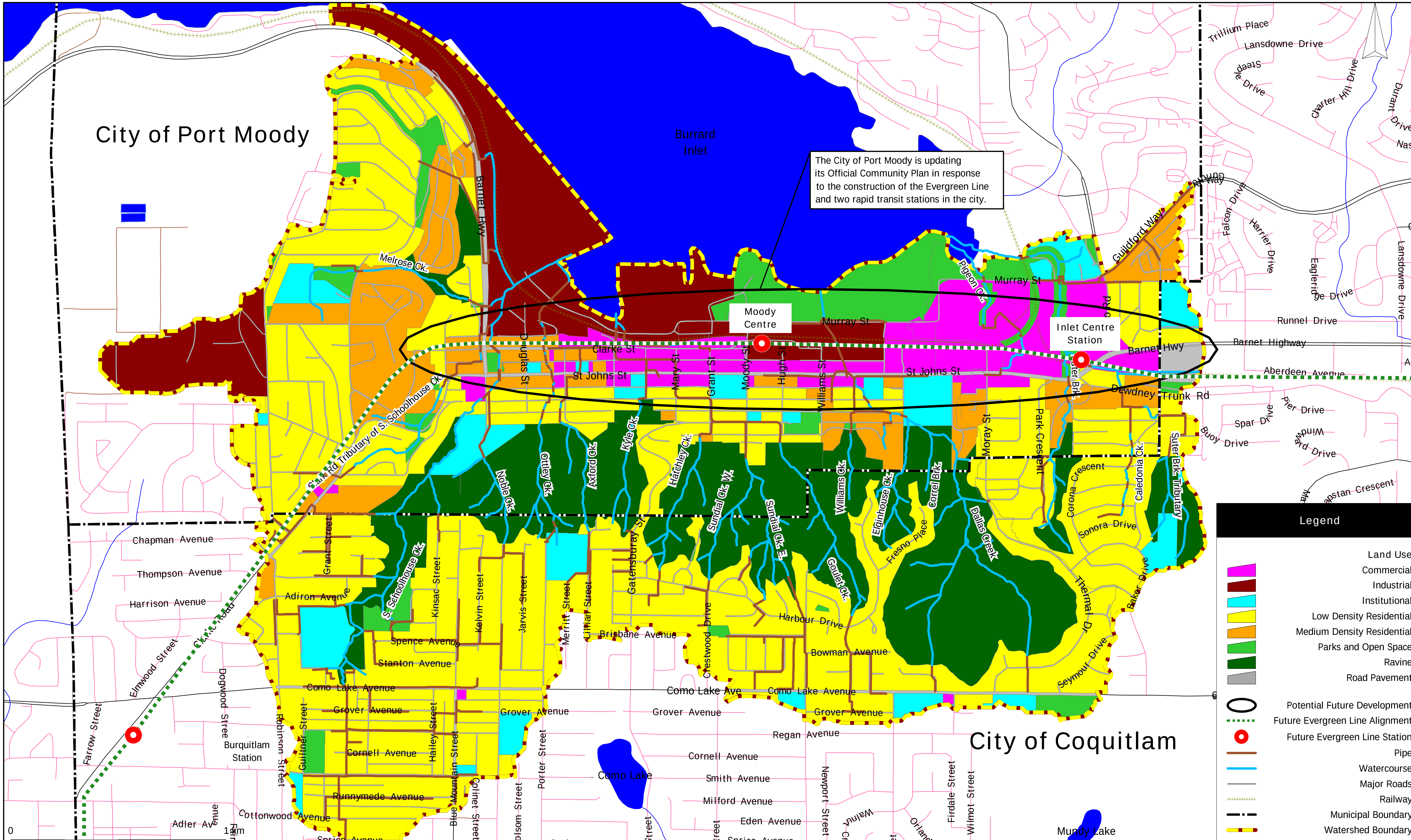

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Figure 5-3 Future Land Use Designations

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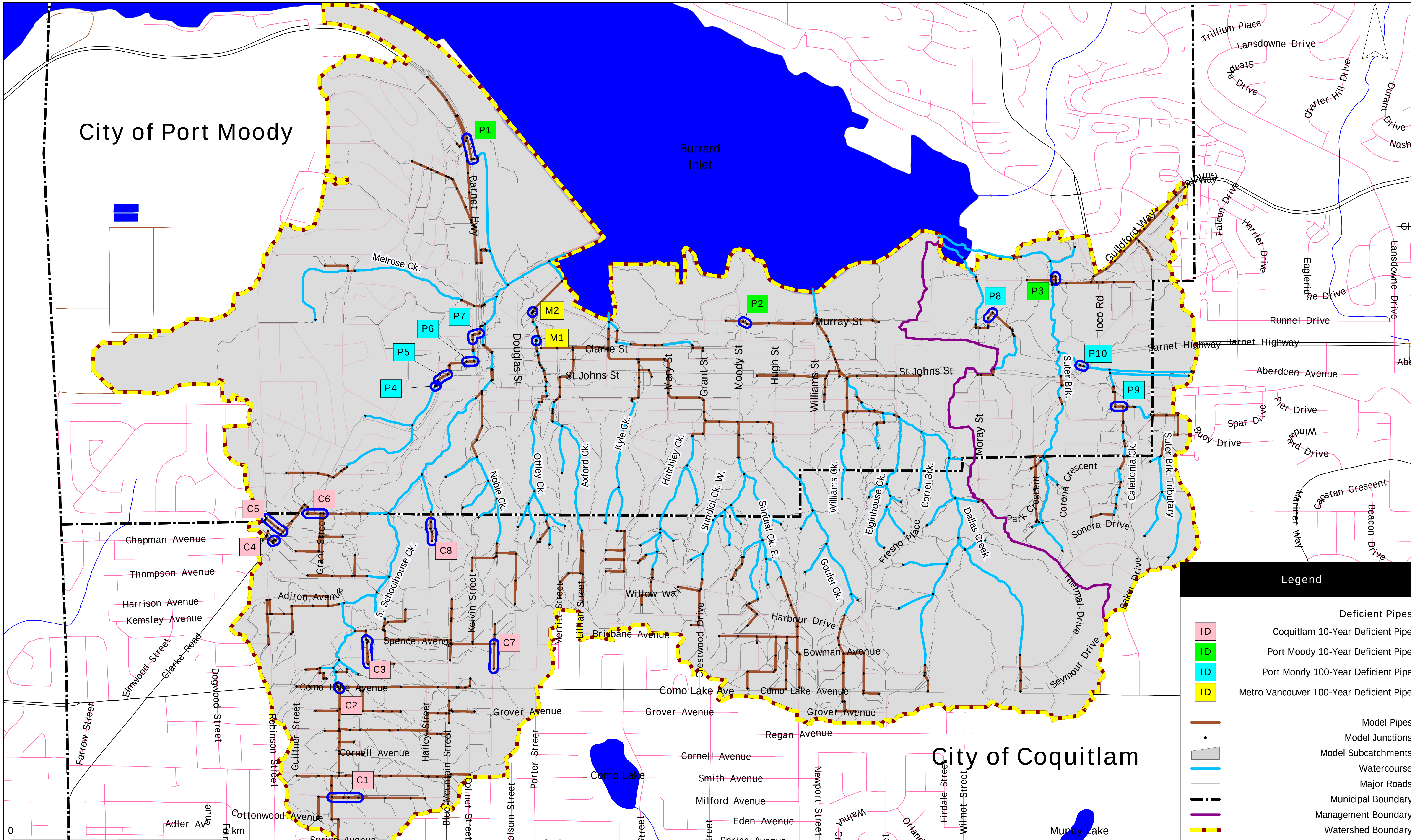

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Figure 5-4 Identified Deficient Pipes

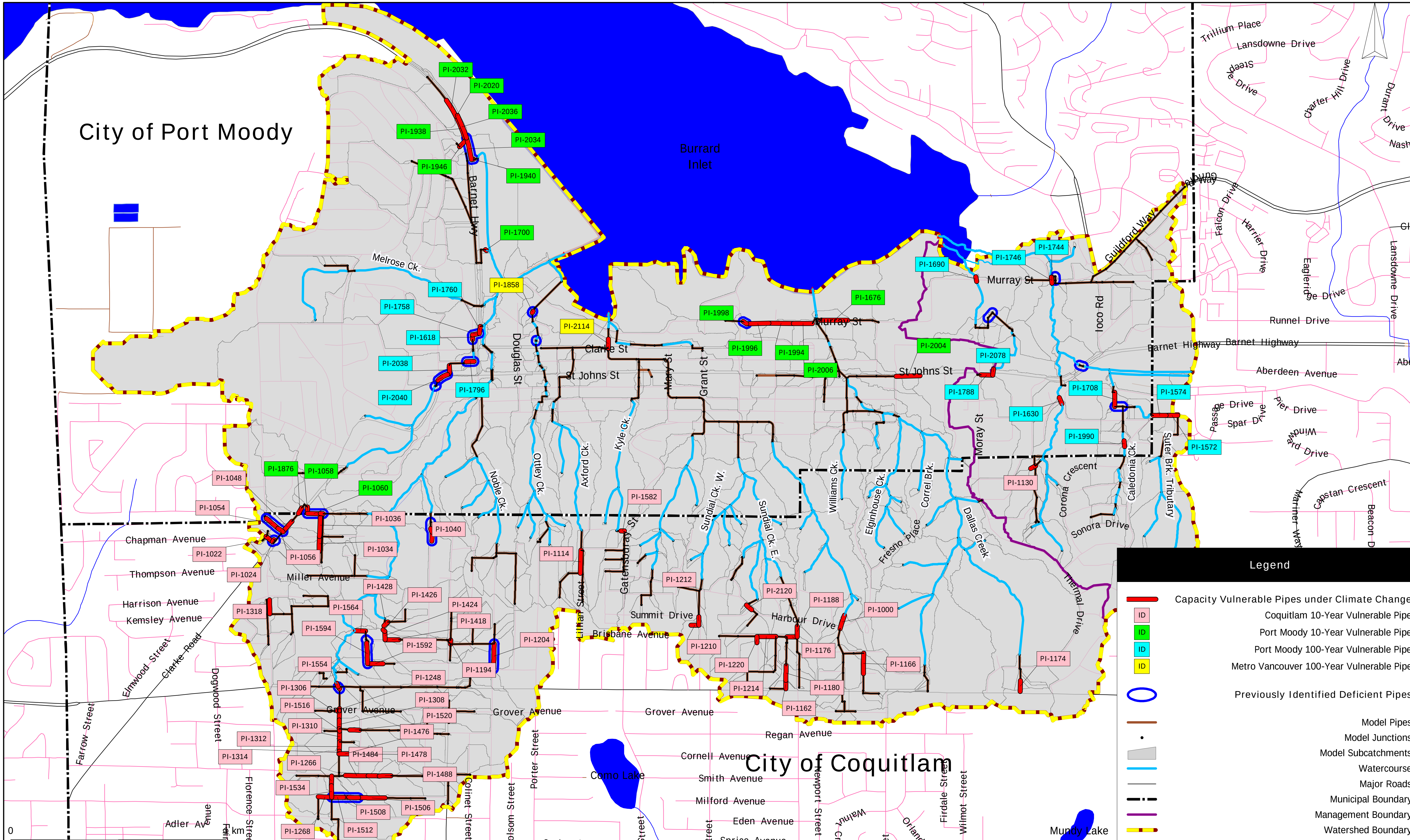

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Figure 5-5
Capacity Vulnerable Pipes under Climate Change

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Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure 5-5 Capacity Vulnerable Pipes under Climate Change

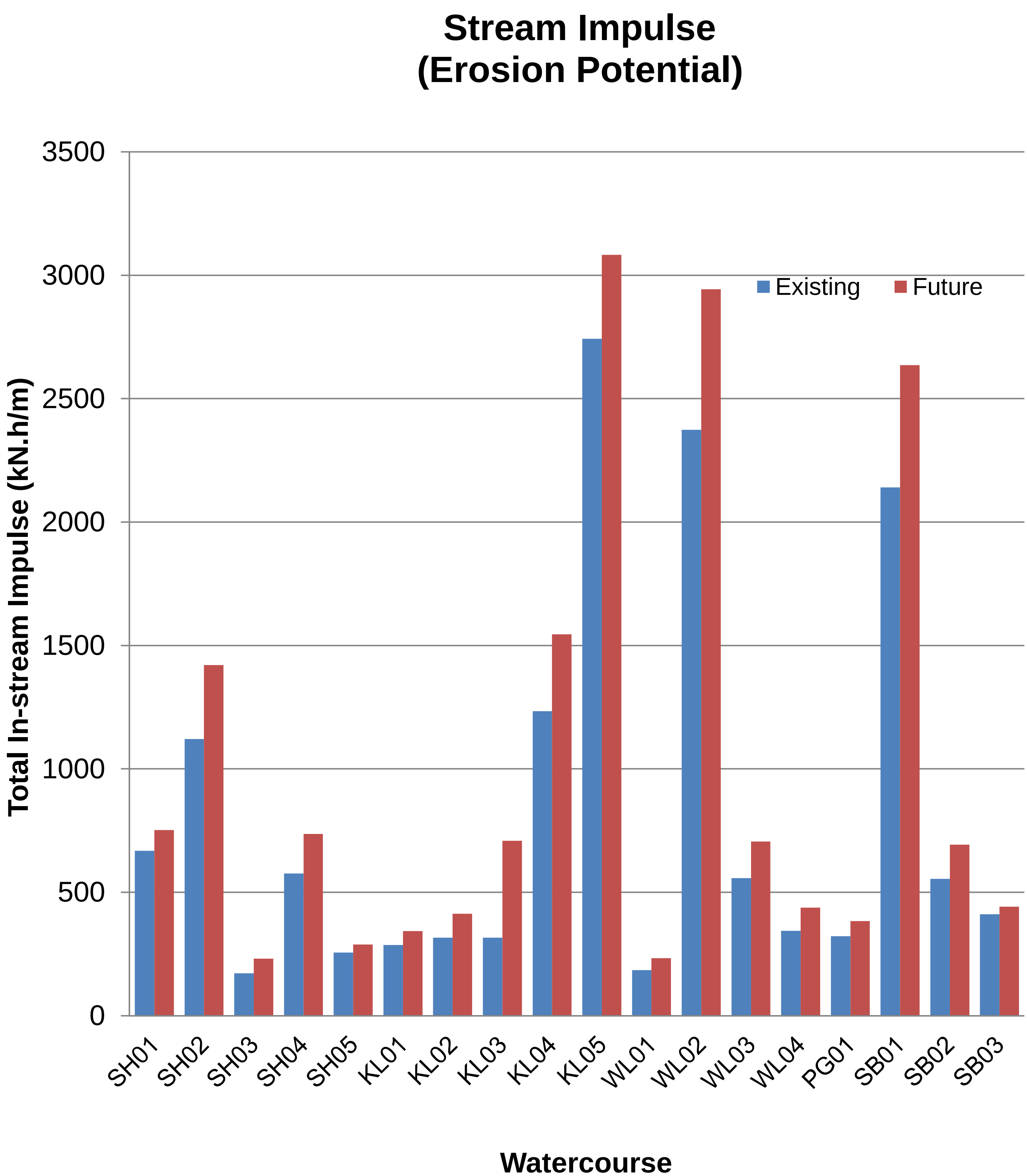

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Figure 5-6
Stream Impulse
(Erosion Potential)

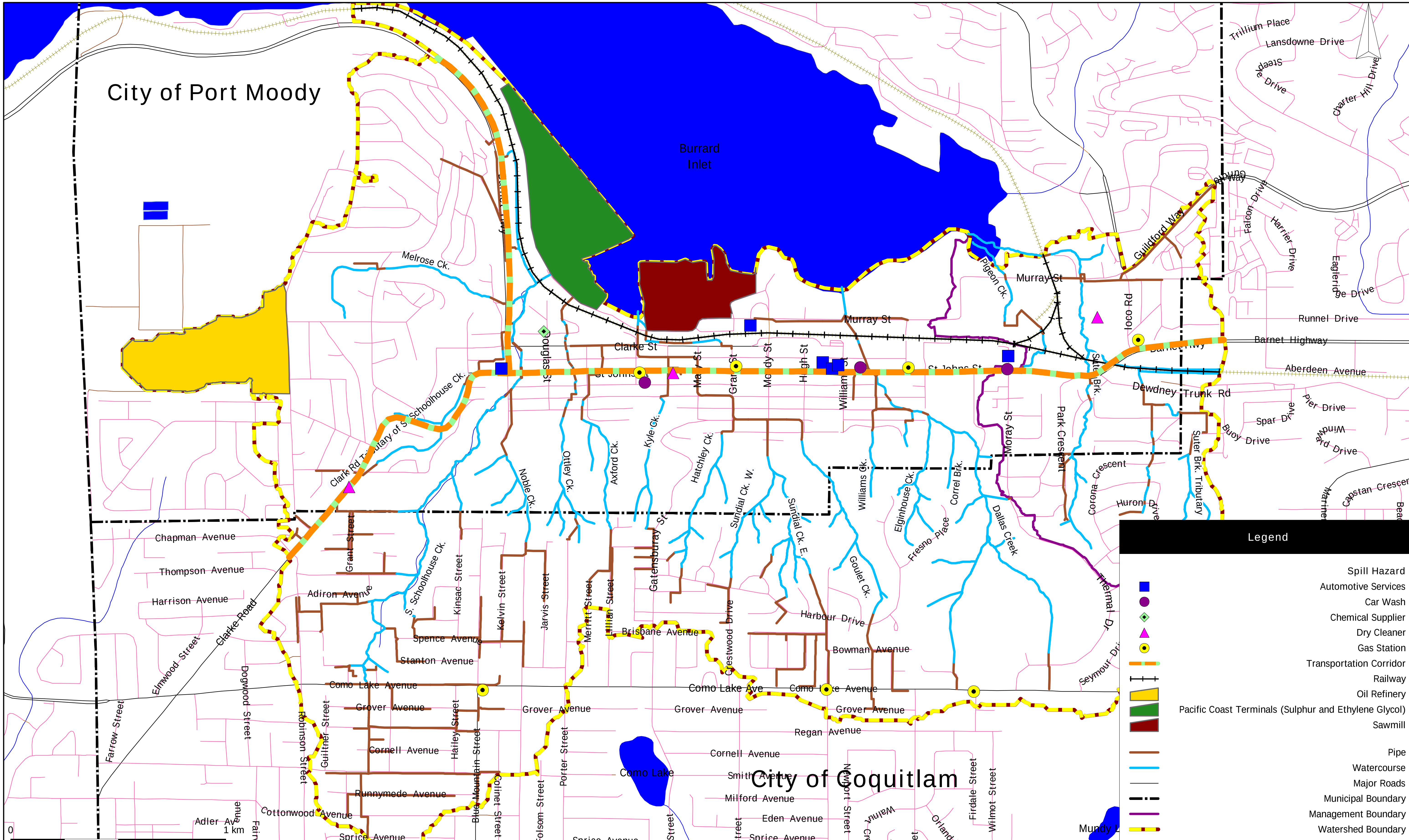

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Figure 5-7 Areas with Heightened Risk of Spills

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Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure 5-7 Areas with Heightened Risk of Spills

6 Management Strategies

6.1 INTRODUCTION

The uplands and lowlands of the Chines watershed are essentially fully developed, and as such most changes in the watershed will be related to redevelopment on existing lots. Redevelopment activities will include some increase in multi-family housing, often combined with ground level commercial premises. Older single family housing will be replaced with newer homes with larger impervious coverage, or secondary ("laneway") homes will be added onto current lot configurations.

Without the implementation of rainwater and stormwater management practices in the watershed, the expected increases in impervious coverage will have a direct consequence in terms of increased runoff volumes and peak flow rates. This will have an impact in a reduced level of service provided by the drainage systems, increased potential for instability within the ravine systems, and potential degradation of watershed health.

Accordingly, the present Chines ISMP identifies strategies to address the broad objectives of:

- Managing flows effectively to prevent major storm event flooding and erosion, and protect public safety.
- Protect and enhance stream and watershed health.

The required management strategies, drawn from the candidates identified in Section 5 are discussed in the following sections.

6.2 RAINWATER MANAGEMENT STRATEGIES

6.2.1 Rainfall Capture Target

The Metro Vancouver Stormwater Source Control Design Guidelines (2012), indicates a desired general rainfall capture target of 72% of the 2-year, 24-hour event. However, the upland portions of the study area are not conducive to the high levels of infiltration this implies, due to the expected low hydraulic conductivities of the surficial soils and concerns with slope stability due to seepage breakout at the top of banks of the various ravines. This rainfall capture target is likely not advisable for much of the study area, since rainfall capture is highly dependent on soil infiltration capacity for runoff volume reduction.

In the lowland portions of the Chines ISMP study area the soils are expected to have significantly greater infiltration capacity, with hydraulic conductivities of the order of 13 mm/h (1/2 inch/hour). However, infiltration of rainwater in the lowlands offers no benefit to the ravine system in terms of reducing erosion potential and control of runoff volumes and rates. Rainwater infiltration practices in the lowlands will benefit the receiving environment of Burrard Inlet from a water quality point of view.

In its Rainwater Management Guidelines, the City of Coquitlam has adopted a general rainfall capture target for developed watersheds of 50% of the 2-year, 24-hour storm event. The captured volume should be fully infiltrated or released at a controlled rate over the 24-hour period following the rainfall. In addition the maximum offsite release rate should limit the 2-year post development peak rate of runoff to 50% of the 2-year pre-development peak runoff. This target is appropriate for the conditions found in the Chines watershed, and should result in a significant improvement over the current performance of the watershed, as well as mitigating future impacts. Therefore, the rainfall capture target for the study area is:

> Rainwater source controls in the Chines watershed should be designed to limit the 2-year post-development peak flow to 50% of the 2-year pre-development peak flow.

6.2.2 Source Controls for Single Family Residential

Within the upland portions of the watersheds, a current typical single family residential lot is approximately 860 m^2. Based on the rainfall capture target previously defined, the total target capture volume for our assumed 860 m^2 lot is 32.5 m^3, once the lot is redeveloped.

Individually, or in aggregate, the following source controls are potentially capable of providing the required rainfall retention capacity to single family residential lots to achieve the rainfall capture target.

- *Infiltration Trench*
- *Pervious Paving with subgrade storage and subdrain*
- *Underground Detention Storage with throttled release*
- *Minimum 300 mm Absorbent Growing Medium*

Note: Refer to Metro Vancouver's Stormwater Source Control Design Guidelines (2012) for typical details.

We note that underground facilities, such as the infiltration trench or underground storage are problematic in terms of long term maintenance by individual property owners, and are subject to limitations in placement as a result of slope stability concerns. The simplest approach, providing 300 mm of absorbent growing medium, will have sufficient retention capacity for 50% of a MAR event but will require subdrains to allow release to the storm drainage system in a controlled manner.

6.2.3 Source Controls in Road Rights-of-Way

Several source controls measures can be applied within municipal road rights-of-way. These vary in applicability with the road classifications, where the wider rights-of-way associated with arterial roads allow for a greater range of options.

Viable options for arterial roads within the study area include:

- Tree and shrub planting in medians and boulevards.
- Minimum 300 mm growing median depth for lawn.
- Minimum 600 mm growing medium for shrubs and trees and minimum of 10 m^3 of soil per tree, where trees are part of the boulevard and median planting area.
- Hard engineered detention systems located under road structures (proprietary tankage products or porous sub-grade materials).

Each best management strategy is described in detail below.

Tree and Shrub Planting in Medians and Boulevards

We recommend that street trees and shrubs be placed within the vegetated medians and boulevards of arterial road rights-of-way. Tree spacing will be dependent on the presence of other shrub plantings, existing utilities, walking paths, and required sight lines. Larger trees and shrubs provide canopy interception and evapotranspiration to dissipate rainfall.

Minimum 600 mm Growing Medium in Boulevards

A minimum 600 mm growing medium depth has the ability to retain up to 180 mm of water depth on an ongoing basis (based on 40% void space). Road runoff can be routed to boulevards via conventional subsurface connections from catch basins, or can receive runoff directly from the road surface through curb cuts or side flow grates. Gradual release of accumulated water can be achieved with under drains. Additional water will be dissipated by evapotranspiration from vegetation on a varying basis.

These strategies may also be applied to local and collector roads, however, given the narrower rights-of-way these applications may be less extensive. Surface features such as boulevard planting and swales may need to be limited to only one side of local roads as median strips are less likely to be present.

6.2.4 Stormwater Management on Institutional/Commercial and Industrial (ICI) Properties

In the upland areas of the watershed, most large parcels of land are utilized for schools or other institutional purposes such as churches. One significant shopping centre is present at the southern edge of the study area at Linton Street and Como Lake Avenue. This shopping centre was recently (within the last 10 years) extensively renovated. Smaller commercial properties are scattered through the upland areas, primarily along Como Lake Avenue.

In the lowlands, significant commercial developments occupy the majority of the length of the St. Johns Street corridor and the area immediately to the north, including Clarke Road (on both sides of the railway). Significant recent residential and commercial developments are present in the lower reaches of the Suter Brook catchment area.

Larger properties offer the opportunity to implement source controls during redevelopment activities or (less frequently) as retrofits.

For commercial and institutional properties the following best management strategies are potentially feasible:

- Minimum 300 mm growing medium for lawn areas
- Minimum 600 mm growing medium for shrubs and trees; where trees are included in the landscape treatment, a minimum 10m^3 of soil per is required. Pervious paving in parking areas (except access for large trucks), walkways and pedestrian plazas.
- Subgrade detention storage or infiltration systems under parking areas and landscaping.
- Green roof / detention roof.
- Perimeter or localized bioswales or infiltration trenches (in the lowlands).
- Rain gardens.
- Water quality treatment units for parking lot runoff, as pre-treatment prior to other systems or discharge from site.
- Underground parking to reduce surface impervious coverage.

Stormwater Quality Improvements

Many of the source controls involving vegetation and/or organic soils will provide a significant measure of improvement in the quality of runoff from each site. However, there will be a need to address concentrated pollutant loads originating on commercial developments, large parking lots, specific “hot spot” activities such as industrial operations or service stations, or prior to stormwater outfalls to natural watercourses. In addition, underground detention storage and infiltration systems should be protected from sediment and hydrocarbon accumulations by pre-treatment in order to extend their service lives, and to minimize maintenance requirements and the risk of groundwater contamination.

Some land-use activities may require more intense management to prevent the excursion of pollutants from their respective sites. These activities may require specific engineered solutions and management practices, and should be identified, with the responsibility to address them resting with the property owner. The Cities should maintain an oversight, monitoring and enforcement capacity for such circumstances.

6.3 INFRASTRUCTURE BASED STRATEGIES

6.3.1 Pipe Network Capacity

Under future conditions (fully built out with increased impervious coverage), capacity improvements are required for the Chines watershed’s piped drainage network to prevent flooding and safely convey storm flows. We analyzed both minor and major drainage systems in the watershed and determined required pipe sizes to address capacity constraints.

Minor System Upgrades

The storm pipes in the uplands are intended to convey up to and including a 10-year return period flow event. Existing condition deficiencies were identified in Section 4. Required pipe upgrades for future conditions were previously indicated on Figure 5-4.

Major System Upgrades

The major event drainage pipes in the lowlands that receive stream flows from the respective creeks are designed to safely convey major flows up to and including a 100-year return period flow event. Some of these major trunks are indicated as being undersized for future conditions. Refer to Figure 5-4 for the locations of major pipe upgrades.

Climate Change

Specific upgrades to address increases in flows that may result from climate change driven increases in total rainfall volume and peak rainfall rates were not identified in this ISMP. However, pipes that are potentially vulnerable to capacity issues as a result of climate change, combined with future condition development conditions, were identified in Section 5.3.

6.3.2 Ravine Flow Management

High flows and associated erosion and instability in the ravines are a key concern of this ISMP. While the implementation of source controls over time may help to manage flow resulting from frequently occurring events, additional flow management may be required. Flows in the ravines can be managed by providing detention storage in the uplands, or by diverting a portion of flood hydrographs to the lowlands by a pipe system. These two approaches are discussed below.

Detention Storage

Currently, the upland portion of the study area is not provided with detention storage facilities. Detention storage would reduce the peak flows conveyed through the ravine systems and reduce the potential for erosion and instability in the ravines. As large expanses of land are not available to accommodate centralized stormwater detention facilities configured as ponds, we anticipate that detention storage facilities would be sited underground, under road rights of way and playing fields. Larger private developments, such as shopping centres or multi-family strata could be required to provide their own storage volumes on site, rather than in City facilities. However, this still limits the number of available sites and the total storage volume that could be provided.

Given the limitations on available sites, and the relative size of any detention system, a hybrid detention standard is proposed for the upland portions of the watershed. Under this proposed approach smaller storms (say less than a 2-year return period) under future conditions would be controlled to some percentage of the existing runoff condition rather than a hypothetical pre-development condition. The emphasis would be on providing extended duration detention for these smaller storms. Larger storms would receive relatively little attenuation in the detention systems. While not able to meet the usual pre-development standard, this approach could provide a significant improvement over current conditions in the watershed.

While respecting slope stability constraints, the most ideal locations for detention storage facilities in the uplands are at the downstream end of the collection system as near as possible to the top of the ravine system. The following locations were identified as being the only ones that might be feasible for larger centralized stormwater detention facilities:

- Mountain View Park (751 Smith Avenue, Coquitlam) 1.9 ha
- Miller Park (870 Oakview Street, Coquitlam) 3.0 ha
- Open field at Ecole Banting Middle School (820 Banting Street, Coquitlam) 3.9 ha
- Open field at Harbour View Elementary School (960 Lillian Street, Coquitlam) 1.7 ha
- Crestwood Park (907 Crestwood Drive, Coquitlam) 0.5 ha
- Open field at Baker Drive Elementary School (885 Baker Drive, Coquitlam) 0.5 ha

Due to the challenges associated with implementing detention storage facilities in the uplands, including identifying suitable sites, capital cost, community acceptance and coordination with other land uses (parks and schools), in consultation with the City of Coquitlam, we do not believe that detention storage is a reasonably feasible option. The application of detention storage to the upland areas is not considered further in this ISMP.

High Flow Diversions

As a potential strategy for addressing high peak flows in the ravine systems, we assessed the potential for diverting high flows to the lowlands through piped systems. The most immediately obvious alignments for peak flow diversions would be on the two roads which descend the escarpment between the upland and lowland portions of the study area; Gatensbury Road and Thermal Drive.

Given the prevailing topography, a diversion system based on Gatensbury Road could receive diverted peak flows and volumes from Kyle and Hatchley Creeks, and possibly from Axford, West Sundial and East Sundial Creeks. An interceptor pipe located along Harbour Avenue would receive flows from diversion structures located on the storm mains that discharge to the head of each ravine.

A diversion system along Thermal Drive/Moray Street could reduce high flows and total volumes conveyed in Dallas Creek and Suter Brook. Conveying high flows to a Thermal Drive diversion system would also require a top of bank interception pipe. However, the interception point is far into the upland area of both of these watersheds, and would service only a relatively small developed area. In addition, a diversion pipe along Thermal Drive is essentially located along a ridge line and would be unable to receive significant additional flows as it descends to the lowlands. Therefore, a diversion on Thermal Drive would have limited effectiveness.

In addition to Gatensbury Road and Thermal Drive, Harbour Drive could be considered for a high flow diversion alignment. Unlike Gatensbury Road and Thermal Drive, Harbour Drive is not continuous to the lowlands. The hill side below Harbour Drive (approximately a 200 m distance) remains relatively undisturbed, and pursuing this alignment will disturb the natural state of the hill slope. A diversion based on Harbour Drive could reduce peak flows and volumes conveyed in Dallas Creek and Goulet Creek. This will require lateral interception pipes at the top of banks or along roadways to divert flows.

All of these diversion concepts pose challenges in constructing the necessary pipes down the respective road alignments which would likely entail significant utility impacts, disruption to traffic and residents and the necessity to construct interception systems along the top of bank, through residential properties. Each diversion would need to tie-in to the trunk system within the lowlands. The proposed diversions should not bring major impacts to the major pipe network in the lowlands as the diversion system will only convey minor flows from the uplands (i.e. 10-year return period). However, the adequacy of the receiving system in the lowlands should be confirmed prior to proceeding with a diversion from the upland areas.

Conceivably, diversion pipes could service each creek individually by following an alignment parallel to the creek within the ravine. However, this would be extremely disruptive to each creek corridor, and would likely not be deemed acceptable by various stakeholder groups and regulatory agencies.

Effective implementation of source controls during redevelopment is a preferable strategy to that of constructing significant infrastructure in the form of peak flow diversions. However, diversions should be implemented if source control implementation over time is insufficient to control flows and protect the creek corridors in the ravines.

6.4 ENVIRONMENTAL ENHANCEMENT STRATEGIES

In Section 3, and Appendices A and B, we assessed general aquatic and terrestrial habitat conditions in the study areas. As part of that assessment, conditions limiting the productivity of the study area were identified along with the actions identified to address them. These actions should be incorporated into the overall management strategy for the ISMP and are reviewed below.

6.4.1 Invasive Species Management

An ongoing program to control, and minimize the presence of, intrusive plant species is required. As the majority of the green belts straddle the two municipalities, a simultaneous and coordinated program is required.

The most common invasive observed within the Chines study area is Japanese knotweed, false lamium and English ivy. Morning glory (*Convolvulus arvensis*) and holly (*Ilex aquifolium*) are also spreading from a large number of backyards into the green belt.

Japanese knotweed is particularly hard to eradicate, and prescribed treatment methods have been established. It is essential that they be followed in order to successfully control Japanese knotweed. Methods for controlling other invasive species are identified by the Ministry of Environment.

Once areas of invasives have been successfully treated, they should be replanted with native plants suitable for each site, such as red huckleberry, salmonberry, tall Oregon grape, salal (*Gaultheria shallon*) or snowberry (*Symphoricarpus alba*). It is highly recommended to plant with species that will spread rapidly to prevent the infestation of weeds into the newly restored areas. Detailed site-specific restoration plans for the infested sites should be developed in concert with control and eradication programs.

We note that the Cities of Coquitlam and Port Moody currently have Invasive Species Management Programs. We recommend the continued implementation of these programs, with coordination between the two Cities.

6.4.2 Common Watershed Productivity Constraints

Based on current conditions, there are a number of environmental constraints that limit the productivity of the terrestrial and aquatic environments within the Chines. Appropriate mitigation actions include:

- Remove garbage and debris collecting at debris control structures at roads as well as within the riparian areas and upland areas of the watersheds.
- Management or removal of sediment deposits and accumulation of domestic refuse from headwater areas and in some reaches in lowland areas (Dallas Creek, Correl Brook).
- Where possible, improve existing culverts to provide for fish passage and allow for greater fish access to open channel segments upstream of piped reaches.
- Implement stormwater management facilities to address regularly occurring channel movement during high flow events that may reduce the complexity of creek channels and reduce the available over-wintering and rearing habitat.
- Control invasive plants and weed infestation resulting from the disposal of residential green refuse and uncontrolled weeds on private properties.
- Provide residents with public education programs to help them understand their watershed and the importance of each private land owner's role to protect the watershed health.

6.4.3 Fish Habitat Compensation, Restoration and Enhancement

Within the Chines the majority of initial development and its related impacts to creeks and riparian areas have already taken place. The following management strategies should be implemented in order to retain and restore the integrity of creeks within the Chines, and protect against further impacts as a result of redevelopment:

- Maintain, enhance and protect existing stream corridors and riparian areas.
- Daylight appropriate stream reaches, if possible, to create additional fish habitat and improve fish passage.
- Remove debris from control structures in order to improve and allow for fish passage at low flow.
- Implement fencing and signage and/or native planting in riparian corridors to deter dumping of domestic refuse.
- Installation of refuge and/or side channels to improve fish rearing for overwintering or during heavy rainfall.
- Encourage involvement by stream keepers group for maintenance and monitoring within ravine areas and to restore and/or enhance the lower portions of the Chines.
- Undertake a more extensive water sampling program within the Chines in order to determine whether water quality is conducive to the health and survival of salmonids. Recommended analyses would include metals, coliforms, anion and hydrocarbons and would be collected during both low flows and high flows.

Specific locations for enhancement/restoration actions are included in Table 6-1 and indicated on Figure 6-1.

Table 6-1
Proposed Site Enhancements and Restoration

Proposed Enhancement/ Restoration Site	Watercourse	Specific Details	Responsible Party
ES-1	South Schoolhouse Creek	Remove debris from culverts and install trash racks (maintain regularly). Installation of a weir downstream of culverts to improve fish passage at low flows. Installation of fencing and signage and/or additional native plants along walking path to deter pedestrian traffic into riparian area. Construct pools and riffles in fish accessible creek reaches to provide additional overwintering and rearing habitat.	Metro Vancouver
ES-2	South Schoolhouse Creek	Install LWD/root wads/boulders to improve fish habitat and in-stream complexity upstream of the pedestrian bridge. Construct pools and riffles in fish accessible creek reaches to provide additional overwintering and rearing habitat.	Metro Vancouver
ES-3	South Schoolhouse Creek	Install LWD/root wads/boulders to improve fish habitat and in-stream complexity upstream of St. Johns, if possible (may be on private property). Install native plants within riparian corridor, is possible. Construct pools and riffles in fish accessible creek reaches to provide additional overwintering and rearing habitat.	Metro Vancouver
ES-4	Noble Creek	Removal of invasives and installation of restrictive covenant fencing and/or signage to deter dumping of domestic refuse.	Metro Vancouver
ES-5	Kyle Creek	Remove debris from culverts and install trash racks (maintain regularly), install fencing and/or signage and/or additional native plants Improve fish passage by installing a fish ladder near existing weir.	Metro Vancouver
ES-6	Hatchley Creek	Removal of invasives and installation of restrictive covenant fencing and/or signage to deter dumping of domestic refuse.	Metro Vancouver

Proposed Enhancement/ Restoration Site	Watercourse	Specific Details	Responsible Party
ES-7	Goulet Creek	Removal of fines from pool to create deeper fish habitat and install LWD/root wads/boulders within pool. Improve fish passage within weir structure. Construct pools and riffles in fish accessible creek reaches to provide additional overwintering and rearing habitat.	Metro Vancouver
ES-8	Slaughterhouse Creek	Remove debris from culverts and install trash racks (maintain regularly). Installation of fencing and signage and/or additional native plants along walking path to deter pedestrian traffic into riparian area. Install LWD/root wads/boulders to improve fish habitat in pool.	Metro Vancouver
ES-9	Elginhouse Creek	Removal of invasives and installation of restrictive covenant fencing and/or signage to deter dumping of domestic refuse.	Metro Vancouver
ES-10	Dallas Creek	Remove debris from culverts and install trash racks (maintain regularly) at Buller Street. Remove fines within channel downstream Buller Street to improve fish passage. Install LWD/root wads/boulders to improve fish habitat downstream of Buller Street.	Metro Vancouver
ES-11	Suter Brook, near Park Crescent in Brookside Park	Remove invasives and install restrictive covenant fencing and/or signage to deter dumping of domestic refuse.	Port Moody
ES-12	Suter Brook, west of Fraser Street	Install restrictive covenant fencing and/or signage to deter dumping of domestic refuse.	Port Moody
ES-13	Suter Brook, north of Barnet Highway	Install fish ladder and/or weir, remove rip rap and concrete within channel and install large boulders.	Port Moody
ES-14	Suter Brook, north of Capilano Road	Improve fish habitat by installing LWD/root wads/boulders.	Port Moody
ES-15	Suter Brook, north of Murray Road	Improve fish habitat by installing LWD/root wads/boulders.	Port Moody
ES-16	Pigeon Creek, north of West Klahanie Drive	Regular maintenance of channel (vegetation removal, as required) to ensure defined channel for fish passage.	Port Moody

Further to the proposal outlined in Table 6-1, we recommend developing an outreach program for private property riparian area management.

6.4.4 Lowland Creek Daylighting

We assessed the potential to daylight some of the currently enclosed lowland drainage network to recreate creek reaches as part of the environmental enhancement strategy. The major storm trunks convey the stream flows from the ravines and are required to have sufficient capacity for the major storm event (i.e. 100-year storm). The potential benefits of daylighting currently enclosed creeks are:

- Reduces impervious surfaces and reduces stormwater runoff;
- Expands aquatic habitat and provides for improved fish access to upstream reaches;
- Provides significant aesthetic benefits to the community;
- Improves water quality.

The following candidate creeks offer the potential to be daylighted in the lowlands, in whole or in part:

- South Schoolhouse Creek
- Dallas Creek

These creeks are considered candidates as they generally have the shortest and most direct runs to Burrard Inlet if daylighted, and potential alignments are available for the daylighted creeks. In some cases, portions of existing roads may need to be closed to provide a creek alignment and riparian corridor. Any creek daylighting likely represents a long term goal, tied to redevelopment opportunities in order to secure rights-of-way and funding.

In the early stages of the Chines ISMP development, Kyle Creek was considered as a candidate for daylighting in concert with re-development opportunities on the mill site near the estuary of Kyle Creek. However, the opportunities to daylight Kyle Creek have become limited as the culvert upstream of the estuary of Kyle Creek was recently extended for the Evergreen Skytrain Line. Therefore, opportunities to create spawning habitat have become even more limited.

Firstly, daylighting South Schoolhouse Creek provides significant ecological benefits to the Chines watershed as the creek holds great ecological values (i.e. fish bearing stream). The culverted sections of South Schoolhouse Creek include Albert Street, St. Johns Street, Clarke Street, and the railway near Pacific Coast Terminals. Daylighting a section of Clark Road Tributary of South Schoolhouse Creek upstream of Barnet Highway culvert crossing was considered for daylighting in the early stages of the ISMP. However, the opportunities of daylighting Clark Road Tributary have become limited due to configuring of new roads as part of the Evergreen Skytrain Line construction.

Secondly, Dallas Creek is a candidate for daylighting. The area upstream of Murray Street past St. Johns Street is proposed for higher density development, although the riparian corridor is narrow in currently open reaches. Dallas Creek flows through an area where high density development is currently proposed. This can create opportunities for developers to acquire sufficient land to daylight the stream. In addition, Dallas Creek has healthy headwaters and presently flows as an open channel through a number of private yards. Furthermore, it has been reported that chum salmon have attempted to spawn in the lower reaches of Dallas Creek.

We note that lowland creek daylighting presents challenges at the railway and major road crossings (e.g. St. Johns and Clarke Streets). Culverts will likely need to be retained at the railway, with simple bridges or arch culverts preferable for road crossings. Underground utilities may need to be re-routed to avoid conflicts and appropriate rights-of-way for the proposed channel alignments will need to be acquired.

Relatively few pipe upgrades were identified for the trunk drainage network in the lowlands, therefore the potential to reduce infrastructure replacement or upgrade costs is minimal. Where right-of-way purchase is required to achieve creek daylighting the overall cost will be high. Where property can be obtained through a redevelopment proposal, the cost of creek daylighting is significantly reduced, and could be partially financed through developer contributions.

We anticipate that Metro Vancouver would act as the lead agency for creek daylighting initiatives. A restored open channel watercourses would substitute for a portion of the trunk drainage system, and would be an extension of the existing creek main stems that are currently Metro Vancouver's responsibility.

Due to the variable scope and extent of potential daylighting projects it is not possible to identify a specific project cost or even a unit cost. In order to estimate the potential costs involved, specific feasibility studies would need to be pursued and preliminary designs developed.

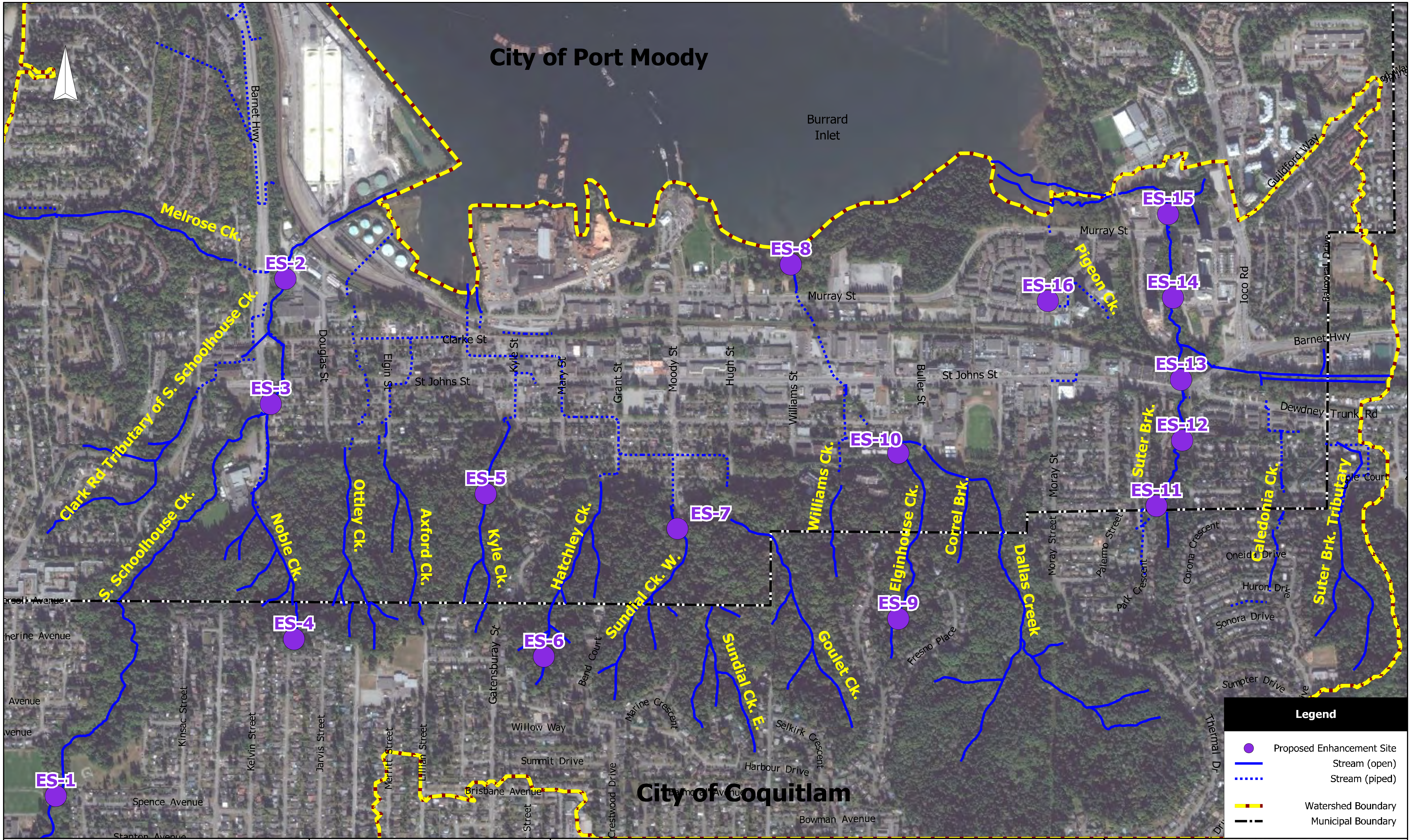

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Figure 6-1 Proposed Aquatic Enhancement Sites

7 ISMP Recommendations

In this section of the report, we present comprehensive recommendations to maintain or improve watershed health while allowing managed development to occur in the watershed. These recommendations include rainwater management measures, to manage runoff from frequent rainfall events at its sources, necessary and potential infrastructure upgrades, and environmental enhancements to strengthen the health of the watersheds and increase their value to the community.

An overview “Roadmap” of the recommendations of this ISMP is provided on Figure 7-1. Table 7-1, provides a snapshot summary of the recommendations, where a reasonable estimate is possible we indicate an order of magnitude cost for each, the time frame and lead jurisdiction. Each recommendation is discussed in addition detail in the indicated sections.

Table 7-1
Summary of ISMP Recommendations

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
Source Control Standards and Implementation				
7.1	Enact and enforce the detention criteria discussed in Section 7.1. Potentially applicable BMPs are identified in Section 6.2, and should be selected as appropriate for each site.	< $50,000	Short	Coquitlam
7.1	The City of Port Moody should adopt equivalent standards or guidelines for rainwater management as discussed in Section 7.1.	< $50,000	Short	Port Moody
7.1	Develop and implement an education and outreach program to encourage implementation, retention and maintenance of source controls.	<$100,000	Short	Port Moody
Infrastructure Improvements				
7.2.1	Upgrade minor pipe systems in uplands.	$2,700,000	Long	City of Coquitlam
7.2.1	Upgrade minor and major pipe systems in lowlands.	$1,800,000 ($1,100,000 with optional daylighting of Clark Rd Tributary of S.	Long	City of Port Moody

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
		Schoolhouse Creek)		
7.2.2	Upgrade deficient major trunk drainage pipes.	$250,000	Long	Metro Vancouver
7.2.3	Divert high flows if required to mitigate impacts to ravines.	$7,000,000 (order of magnitude)	Long	Metro Vancouver
7.4	Upgrade hydrometric monitoring stations (three stations) with direct flow measurement and real time telemetry.	$120,000 ($40,000/station)	5 years	Metro Vancouver
Environmental Enhancements				
7.3.1	Clear accumulated garbage and debris at culvert/pipe inlets.	< $50,000	Short	All
7.3.1	Clear accumulated urban refuse and other debris from the ravine corridors.	< $50,000	Short	All
7.3.1	Stabilize or remove erosion sites and fine sediment deposits that decrease or impact available habitat for juvenile salmonids and benthic invertebrates.	Varies with site	Short	All
7.3.1	Control or re-route runoff from heavy rainfall events that destabilize creeks resulting in loss of fish habitat.	Site dependant	Short	All
7.3.1	Develop plans for construction of pools and riffles in suitable fish accessible creek reaches to provide additional overwintering and rearing habitat.	$50,000	Short	All
7.3.1	Remove invasive plant infestations in interface areas between the ravines and residential development.	$200,000 (order of magnitude)	Short	All
7.3.1	Implement education efforts to discourage disposal of garden wastes or residential refuse into the ravines.	< $50,000	Short	All

Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
7.3.1	Add spawning gravels to creeks.	< $50,000	Short	All
7.3.2	Lowland creek daylighting and restoration per outcome of feasibility study (see below).	Indeterminate, but significant depending on scope	Varies with opportunities , but should be a priority	Metro Vancouver/Port Moody
Section	Actions	Cost	Timeline	Potential Lead Agency or Primary Responsibility
7.3.2	Limit further enclosure of open channel drainage components (ditches and swales). Provide compensating rainwater management features for lost hydrological function.	minor	Immediate	Both Cities
Studies, Evaluations and Ongoing Efforts				
7.3.2	Conduct a feasibility study on daylighting lowland portions of Dallas Creek.	$50,000	Short	Metro Vancouver/Port Moody
7.3	Conduct a feasibility study to examine the replacement of the sediment basins at the Goulet intake.	$50,000	Short	Metro Vancouver
7-1	Conduct a groundwater monitoring study to determine suitable areas for infiltration.	$200,000 per city.	Short	Both Cities, Priority for Coquitlam
7.4	Develop and implement a monitoring and adaptive management process based on the recommendations of Section 7.4. Coordinate efforts of the Cities and Metro Vancouver.	Varies with selected level of effort.	Short - Ongoing	All
7.5	Ensure Operations and Maintenance activities and responsibilities for BMPs are identified and followed accordingly.	Varies	Short - Ongoing	All

7.1 SOURCE CONTROL REQUIREMENTS

Given the lack of information pertaining to safe areas of infiltration in the study area, we recommend a groundwater monitoring study be completed prior to implementing infiltration measures in the study area.

Therefore, we recommend the implementation of source controls and/or other general best management practices in the Chines watershed on a detention basis as opposed to an infiltration basis. The rainfall capture target of the Chines watershed is as follows:

> Rainwater source controls in the Chines watershed should be designed to limit the 2-year post-development peak flow to 50% of the 2-year pre-development peak flow.

In many cases, a combination of source control measures or structural BMPs will be required to achieve the rainfall capture target. Various candidates were discussed in Section 6. These should be selected and implemented according to the particulars of each site. As a starting point, a minimum 300 mm of growing medium is required for lawn areas. For shrub beds and shrubs with trees, a minimum 600 mm of growing medium with a minimum 10 m^3 of soil per tree is required.

We recommend that the City of Port Moody adopt equivalent standards or guidelines for rainwater management. In Coquitlam, we recommend implementing the City's Rainwater Management Requirements and Guidelines (March 2009) in the Chines watershed with the capture target criteria identified above.

We recommend developing an outreach program to encourage implementation, retention and maintenance of source controls. In the outreach program it will be important to target individual property owners, neighborhood associations, and property developers. The programs should emphasize the importance of source controls in improving the health of natural watercourses. In particular it should be emphasized that source controls may allow for the postponement of, or will negate the need for, costly hard infrastructure projects such as pipe capacity increases or high flow diversions.

7.2 STORMWATER INFRASTRUCTURE

7.2.1 Recommended Minor System Upgrades

The storm pipes in the uplands are intended to provide a 10-year level of service. Existing and future condition deficiencies were identified in Section 5. All recommended pipe upgrades are indicated on Figure 7-1. Appendix F provides details of the required pipe diameters corresponding to the mapped locations.

The minor system upgrades are the responsibility of the respective Cities in which they are located.

7.2.2 Recommended Major System Upgrades

The major event drainage pipes in the lowlands that receive flows from the respective creeks are designed to safely convey major flows up to and including a 100-year return period flow event. Some of these major trunks are indicated as being undersized for future conditions. Refer to Figure 7-1 for the overview plan showing recommended upgrades for the major storm trunks.

The major system upgrades are the responsibility of Metro Vancouver.

7.2.3 High Flow Diversions

High flows and associated erosion and instability in the ravines are a key concern of this ISMP. High flow diversions are a contingency measure in the event that the implementation of source controls is insufficient to protect the ravine streams, and ongoing degradation or instability is noted during monitoring. Under those circumstances, high flow diversions are recommended to provide relief to the ravine systems and control erosion and damage. This option is only to be considered if implementation of onsite rainwater management does not achieve sufficient controls of high flows and total runoff volumes.

As required, potential diversion alignments include Gatensbury Road, Thermal Drive/Moray Street and Harbour Drive. Lateral interceptors will be required in the uplands to convey high flows to the diversion systems. Conceptual alignments for these diversion systems are indicated on Figure 7-1.

Effective implementation of source controls during redevelopment is a preferable strategy to that of constructing peak flow diversions. However, long-term climate change impacts will have a significant impact on rainfall, and may the determining factor as to whether high flow diversions become necessary.

7.3 ENVIRONMENTAL ENHANCEMENTS

7.3.1 Aquatic Habitat

Based on current conditions, there are a number of individual actions that can improve the productivity of the existing terrestrial and aquatic environments within the Chines. Specific enhancement locations are indicated on Figure 7-1. Enhancement actions include:

- Clear accumulated garbage and debris at culvert/pipe inlets.
- Clear accumulated urban refuse and other debris from the ravine corridors.
- Stabilize or remove erosion sites and fine sediment deposits that decrease or impact available habitat for juvenile salmonids and benthic invertebrates.
- Control or route runoff from heavy rainfall events that destabilize creeks resulting in loss of fish habitat.

- Construct pools and riffles in fish accessible creek reaches to provide additional overwintering and rearing habitat.
- Remove invasive and noxious weed infestations in interface areas between the ravines and residential development.
- Implement education efforts to discourage disposal of garden wastes or residential refuse into the ravines.

Open channel drainage features located in developed areas, were identified in Appendix B. Most of these drainage features are disconnected from fish habitat and from a fisheries point of view are Class C, as most are only grassed channels with little to no additional vegetation. However, they do provide some hydrological function by slowing flow, providing filtering action, and allowing for limited infiltration. Therefore, if enclosure of these channels is initiated, the equivalent hydrologic function should be provided by other means (e.g. perforated pipes or infiltration chambers, filtering and/or retention).

A small number of channels have characteristics that qualify them to be considered as Class B watercourses. If filling or alteration of these watercourses is desired, the proponent is advised to follow DFO's "Measures to Avoid Harm" and may be required to provide habitat offsetting under the Fish Protection Act and Water Act.

7.3.2 Lowland Creek Daylighting

Major redevelopment projects may allow some lowland creek sections which are currently enclosed to be restored as open channel with riparian corridor. Creek daylighting can be used to provide additional green space as well as forming part of the compensation for major projects.

We recommend that both Cities identify creek daylighting as a priority in their planning processes and encourage developers to consider incorporating these initiatives in development plans. Based on an overview of the current drainage system, potential alignments for restored channel, and integration with long term redevelopment opportunities, the following creeks appear to be the most promising candidates for daylighting and restoration:

- South Schoolhouse Creek
- Dallas Creek

These creeks are highlighted on Figure 7-1.

While the identified sections are located in the City of Port Moody, the City of Coquitlam should consider creek daylighting when opportunities arise. Metro Vancouver will likely be the lead agency in potential daylighting projects as the most likely candidate creeks in the Chines are managed by Metro Vancouver.

7.3.3 Terrestrial Habitat

The key recommendations related to Terrestrial Habitat are to:

- Maintain or enhance connectivity between existing areas of habitat, primarily ravine corridors and parklands.
- Improve existing habitat for small mammals and birds.

As a result of this assessment, we offer the following recommendations:

1. Complete forest typing of the deciduous forest that interfaces with the public, whether the proximity is close to private property or public trails. Include in this typing both an updated trail map and identify private property so that there is a clear understanding of the potential risk to the public.
2. Complete a danger tree assessment of the Project Area within approximately 75 m of private property and 75 m on either side of trails. Remove any trees that are deemed a danger to the public.
3. Monitor forest health in the areas that interface with the public to identify potentially hazardous trees. As part of this initiative, complete a danger tree assessment every 3 to 5 years to ensure public safety.

7.4 MONITORING AND ADAPTIVE MANAGEMENT

The long term success of the Chines ISMP in meeting the objectives of improving watershed health while supporting the Cities' land use objectives requires a process to monitor the performance of the watersheds, to identify issues and opportunities, and to modify or adapt the ISMP to address these issues as implementation progresses. The first requirement is an ongoing program that monitors key metrics that are most indicative of the state of the watersheds and how they are changing over time. Next is a process to assess challenges as they arise, and identify the required actions to ensure that the ISMP's objectives will still be met. Finally, implementation of those actions is required.

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

The Chines watersheds are hybrid systems, with piped urban areas, steeply sloped open channel reaches, and some low gradient reaches. Under the framework, these watersheds generally qualify for monitoring of water quality, hydrometric response and benthic invertebrate (B-IBI). However, each constituent watershed does not necessarily require monitoring of all three indicators. Benthic invertebrate monitoring should be prioritized on watercourses with fish presences, such as South Schoolhouse Creek and Suter Brook. Upgraded hydrometric monitoring is recommended for the three sites that Metro Vancouver currently operates. Water quality monitoring can be applied to any watercourses but it is more advantageous to provide it on the same creek as that on which the B-IBI and hydrometric monitoring is undertaken.

7.4.1 General Monitoring Recommendations

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

Accordingly, we recommend that hydrometric monitoring be carried out on a continuous basis on at least one of the major open channel reaches. To ensure data quality, a primary measurement device such as a weir or flume, with level sensor and data logger, is recommended. The advantage of a continuous monitor is the ability to record the response to large and infrequent events that may be missed with a periodic monitoring program.

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

We recommend that benthic invertebrate monitoring be carried out on an annual basis on one watercourse, with other watercourses monitored less frequently, but correlated to the annual record.

In addition to the three basic monitoring activities identified in Metro Vancouver's recent Monitoring and Adaptive Management Framework (September, 2014), we also recommend that the following be included in a monitoring program:

- % Forest Cover,
- % TIA,
- % EIA,
- % RFI,
- Fisheries Habitat Assessment
- Ravine Stability Assessment

All recommended monitoring parameters are presented in Table 7-2 below.

Table 7-2
Summary of Recommended Performance Indicators

Metric No.	Key Performance Indicator	Monitoring Strategy	Base (2010) Values	Maximum Frequency of Monitoring	Unit Cost
Land Use Metrics					
1	% Forest Cover	GIS analysis of aerial photographs	24.9%	12 years	$1,000
2	% TIA	GIS analysis of aerial photographs and existing zoning	37.1%	5 years	$2,000
3	% EIA	GIS analysis of aerial photographs and existing zoning; interpretation of degree of implementation of source controls	31.3%	5 years	$15,000
4	% RFI	GIS analysis of aerial photographs	48 %	5 years	$4,000
Flow Regime Metrics					
5	Number of Erosion Sites	Ravine Stability Assessment	See Section 7.4.3	5 years	$40,000
6	Base Flow, Mean Annual, and, Peak Flow Rates, Stream Power.	Analysis of flow rates at monitoring stations	See Section 7.4.3	Annually	$1,500
Environmental Metrics					
7	Benthic Invertebrates (B-IBI)	Sampling and B-IBI scores	Mean = 28	Bi-annually	$2,500
8	Fisheries Habitat Assessment	Fish Species Assessment	See Table 7-6	5 years	$10,000
9	Continuous Water Quality	Continuous water quality monitoring (1 site)	Varies	Annually	$20,000
10	Periodic Water Quality	Periodic water quality monitoring at additional sites to 9 above	Varies	5 years	$5,000/ cycle/site

Each key performance indicator is described in detail below with monitoring methods, measurement requirements, frequency and triggers for evaluation, and approximate costs.

7.4.2 Land Use Metrics

Metric 1 - Percent Forest Cover

Currently, approximately 257 hectares or 24.9% of the Chines watershed is covered by forest. The majority of forest cover is in the ravines and parks.

Tree cover will provide a measure of the health of the watershed. An increase in the percent tree cover will likely indicate that riparian zones and green areas are being maintained or expanded. A decrease in the percent tree cover will likely indicate that riparian zones and green space are being lost to development activity.

Timing / Triggers: Development of future ISMPs, passing of 5 years, or if development and/or redevelopment within the watershed equals or exceed 5% of the total study area.

Cost: Built in to the cost of an ISMP. $1,000 per assessment when completed separately.

Goal: Stable or Increased overall forest cover.

Metric 2 - Percent Total Impervious Area (TIA)

Percent total impervious area (TIA) is a measure of the proportion of the total area covered by impervious surfaces, and is the key indicator of the intensity of development and whether zoning requirements are being complied with. Table 7-3 summarizes the estimated current TIA distribution of the study area.

Table 7-3
Total Impervious Area

	Proportion of Study Area	Impervious Area Ratio	Weighted TIA
Commercial	6.3%	70%	4.4%
Industrial	10.6%	80%	8.5%
Institutional	4.8%	55%	2.6%
Low Density Residential	41.7%	45%	12.5%
Medium Density Residential	6.4%	55%	2.6%
Parks and Open Space, and Ravines	24.3%	5%	1.2%
Road Pavement	5.9%	90%	5.3%
Total	**100%**	**N/A**	**37.1%**

Timing / Triggers: Once every 4 years or after development or redevelopment of more than 5% of the study area.

Cost: $2,000 per investigation.

Goal: Minimize increases or mitigate to maintain or reduce EIA.

Metric 3 - Percent Effective Impervious Area (EIA)

In principle, the percentage of effective impervious area (EIA) provides a more precise measure of the imperviousness of an area that generates direct runoff than does the percent total impervious area. Effective impervious area accounts for nominally pervious open space that hydrologically functions like impervious surfaces and for impervious surfaces that do not directly contribute runoff to the storm drainage system and watercourses.

Using available information and interpretation of conditions in the study area, we estimate the overall effective impervious percentage as approximately 31.3%. Refer to Table 7-4 for a summary of the analysis.

Table 7-4
Effective Impervious Area

	Proportion of Study Area	Effective Impervious Area Ratio	Weighted EIA
Commercial	6.3%	60%	3.8%
Industrial	10.6%	70%	7.4%
Institutional	4.8%	45%	2.2%
Low Density Residential	41.7%	40%	10.4%
Medium Density Residential	6.4%	50%	2.2%
Parks and Open Space, and Ravines	24.3%	5%	1.2%
Road Pavement	5.9%	70%	4.1%
Total	**100%**	**N/A**	**31.3%**

Timing / Triggers: Once every 4 years or after development or redevelopment of more than 5% of the study area.

Cost: $15,000 per investigation.

Goal: Decrease or Stable EIA.

Metric 4 - Riparian Forest Integrity (RFI)

Riparian Forest Integrity is a measure of the proportion of intact forest cover within a hypothetical riparian corridor, generally 30 m to either side of the watercourse. RFI is a key factor used to characterized watershed health. Our estimates of RFI are summarized in the table below (Table 7-5).

Table 7-5
Summary of Riparian Forest Integrity

Drainage System	Theoretical Maximum Riparian Area (ha)	Actual Riparian Area (ha)	% RFI
South Schoolhouse Creek	68.4	26.1	38%
Kyle Creek	63.2	33.1	52%
Slaughterhouse/Dallas Creek	34.9	25.0	72%
Pigeon Creek	5.6	0.7	12%
Suter Brook	26.2	10.6	41%
Total	**198.3 ha**	**95.5 ha**	**48 %**

We included a “phantom” riparian corridor representing sections of major pipes that we assume roughly correspond to former surface watercourse, to estimate a theoretical riparian area that would exist before development in the Chines watershed. This value is compared to the riparian corridor that currently exists, and the ratio is calculated as the RFI.

Timing / Triggers: Once every 4 years or after development or redevelopment of more than 5% of the study area.

Cost: $4,000 per investigation.

Goal: Increase or Stable RFI.

7.4.3 Flow Regime Metrics

Metric 5 - Erosion Sites

Measurement: Locations and level of severity of erosion sites. Other information to be collected includes the following:

- Date of and conditions during survey,
- Photographs,
- Bank location,
- Channel dimensions,

- Risk probability and consequence,
- Description of stability issue(s),
- Approximate dimensions, and
- Cost to mitigate.

Timing / Triggers: Once every 5 years or immediately following a 5-year return period storm event.

Cost: $40,000 per investigation.

Goal: No increase at a minimum, but decrease in number and severity preferable.

Metric 6 – Flow Monitoring Upgrades and Continuous Hydrometric Monitoring

Metro Vancouver currently has three permanent flow monitoring stations within the watershed; South Schoolhouse Creek, Kyle Creek and Dallas Creek. However, these monitoring stations only measure water levels and the accuracy of the data is unknown as a QA/QC process for the data has not been established for these stations.

We recommend upgrading the flow monitoring stations to collect continuous data and implementing a QA/QC process to be undertaken regularly (i.e. monthly), possibly by an outside data management consultant. Data reporting and a QA/QC process can be established via a web-based mechanism and be reviewed and accessed by Metro Vancouver and others. A primary type device utilizing a weir or flume with a defined head-discharge relationship is preferred for flow measurement. Real time telemetry is essential to identify issues as they occur within the watersheds, including onset of major flow events and risks of debris blockages as indicated by unusual changes in flows.

Mean annual flow rates and volumes, minimum base flows, peak flow and total runoff response to storms, and stream power and impulse can all be calculated from continuous flow data. These flow metrics all provide an indication of the degree that the watersheds are impacted, and any trends in changing watershed hydrology.

Cost: $40,000 to upgrade each permanent station. $10,000 annually for maintenance, data QA/QC and analysis.

Goals: Mean annual flow/volumes – decrease
Minimum base flows – increase
Peak flows and runoff volumes – decrease
Stream power and impulse – decrease

7.4.4 Environmental Metrics

Metric 7 - Benthic Invertebrates (B-IBI)

Monitoring benthic invertebrates provides a biologically based performance measure of the health of a watershed as benthic invertebrates are susceptible flow regime and water quality impacts in a watershed.

The mean B-IBI scores at seven locations sampled on June 2011 was 28. Based on the stream conditions rating system used by Metro Vancouver, a B-IBI value of 28 relates to a stream condition rating of “Fair”.

We recommend that the benthic invertebrate sampling and analysis take place at the locations identified within the study area for future ongoing studies. Future B-IBI monitoring should consider the modified protocols in the Metro Vancouver Monitoring and Adaptive Management Framework (September 2014).

Timing / Triggers: Bi-annually if development and redevelopment within the watershed equals or exceeds 5% of the total study area. A reduced frequency to a maximum of every 6 years can be employed if no significant development or redevelopment activity occurs within the study area.

Cost: $8,750 per investigation, based on collection of 7 samples.

Goal: Increased scores and diversity.

Metric 8 - Fisheries Habitat Assessment

The table below (Table 7-6) summarizes the fish species recently identified as present in the Chines watersheds. The list is based on the British Columbia Ministry of Environment Habitat Wizard, and other sources.

Table 7-6
Fish Presence in the Chines

Watercourse	Fish Species Present
South Schoolhouse Creek Drainage System	
Melrose Creek	Cutthroat trout (*O. clarkii*)
Clark Road Tributary of South Schoolhouse Creek	No fish present
South Schoolhouse Creek	Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), cutthroat trout, sculpin (*Cottus* sp.)[4]
Noble Creek	No fish present
Kyle Creek Drainage System	
Ottley Creek	No fish present
Axford Creek	No fish present
Kyle Creek	No fish present
Hatchley Creek	No fish present

[4] Ministry of Environment Habitat Wizard

Watercourse	Fish Species Present
West Sundial Creek	Unknown (cutthroat trout possible)
East Sundial Creek	Unknown (cutthroat trout possible)
Goulet Creek	Cutthroat trout
Slaughterhouse/Dallas Creek Drainage System	
Williams Creek	No fish present
Elginhouse Creek	No fish present
Correl Brook	Cutthroat trout
Dallas Creek	Cutthroat trout
Suter Brook and Pigeon Creek Drainage Systems	
Suter Brook	Cutthrout trout (*O. clarkii*), Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*).
Pigeon Creek	Cutthrout trout (*O. clarkii*), Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*).

Stream reaches should be assessed on foot by a Qualified Environmental Professional (QEF) to collect information including:

- Channel morphology,
- Wetted width and depth,
- Bank full width and depth,
- Substrate composition,
- Habitat values,
- Fish presence,
- Barriers to fish passage, and
- Riparian characteristics.

Habitat characteristics should be evaluated and the habitat should be classified and compared to baseline conditions. Where there is degradation of habitat occurring, restoration projects, or mitigation of development influenced impacts, should be implemented to address habitat degradation.

Timing / Triggers: Once every 5 years or after development or redevelopment of more than 5% of the study area.

Cost: $10,000 per investigation.

Goals: Preservation or improvement of available fish habitat.

Metric 9 - Continuous Water Quality Monitoring

Continuous water quality monitoring will provide insight into the overall health of the watershed. We recommend continuous monitoring of the following parameters:

- Water temperature (°C)
- Conductivity
- Dissolved Oxygen
- pH
- TSS

One site should be selected for permanent and continuous monitoring. We believe that selecting the same watercourse as selected for flow monitoring would be advantageous to interpreting the significance of collected data.

Timing / Triggers: Continuous monitoring with periodic data collection, analysis and QA/QC.

Cost: $5,000 annually including equipment, installation, and downloading of information.

Goals: Stable or improved water quality for Fish.

Metric 10 - Periodic Water Quality Monitoring

In order to allow a wider range of water quality parameters to be monitored, an automatic sampler could be employed, allowing laboratory analysis of contaminants, including coliforms and PAHs. However, since the corresponding laboratory effort is relatively expensive, it should be possible to select specific samples, linked to key events such as first flush or base flow conditions, for analysis. We anticipate that the sampler would be set up for a period of time on a particular watercourse, until sufficient data is obtained.

We recommend that selected water quality indicators be sampled annually at 2 locations within the study area. This effort should provide a reasonable indication of the water quality within all of the watercourses in the Chines watershed. The preferred sites are in lowland reaches of South Schoolhouse Creek and Suter Brook on the basis of fish presence. We recommend sampling the following water quality parameters:

- Biological and chemical oxygen demand (mg/L),
- Fecal coliform bacteria (MPN/100mL),
- Total coliform bacteria (MPN/100mL),
- Metals: copper, zinc, aluminium, iron, and lead (ppm),
- Ammonia nitrogen (mg/L), and
- PAHs.

Sampling should follow the BC Field Sampling Manual for Continuous Monitoring and the Collection of Air / Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples prepared by the Water, Air, and

Climate Change branch of the Ministry of Environment, as well as the Freshwater Biological Sampling Manual prepared by the Resources Information Standards Committee, 1998 Edition.

Timing / Triggers: Maximum sampling interval of 5 years, with monitoring undertaken to collect dry-weather and wet-weather samples. The frequency of sampling should be increased if rapid changes in the watershed are occurring.

Cost: $10,000 per cycle.

Goals: Long term stability or improvement in water quality.

7.5 OPERATION AND MAINTENANCE

The proper operation and maintenance of best management strategies is necessary to ensure an acceptable level of performance from source controls. Notably, the source controls recommended for privately owned lots do not have significant maintenance requirements.

Table 7-7 below describes the required operation and maintenance associated with each recommended management strategy for future urban residential and industrial developments, and City owned right-of-ways. The operation and maintenance procedures will be the responsibility of individual land owners, and the Cities respectively.

Table 7-7
Operation and Maintenance Procedures

Strategy	Required Operation and Maintenance Procedures
Soil Requirements • Minimum 300 mm growing medium for lawn areas • Minimum 600 mm growing medium for shrub / tree beds • Minimum 10 m^3 of soil per tree	• Prevent compaction. • Remove accumulated sediment and debris.
Infiltration Trench	• Remove accumulated sediment and debris. • Prevent clogging of overflow pipe and/or drain.
Alternative Measure – Rain Garden	• Remove accumulated sediment and debris. • Prevent clogging of overflow pipe and/or under drain.
Alternative Measure – Pervious Pavement	• Prevent compaction and clogging. • Remove accumulated sediment and debris.
Alternative Measure – Green Roof/ Detention Roof	• Irrigate during dry periods. • Prevent compaction or disturbance of growing medium. • Remove weeds. • Prevent clogging of overflow pipe and/or under drain.

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Certification Page

The management strategies developed and recommended in this Chines (Port Moody Coquitlam Drainage Area) ISMP, once implemented, will provide an incremental improvement in the health of the Chines watershed while accommodating the expected increase in the intensity of development. The Chines watershed retains a significant, functioning aquatic and terrestrial ecosystem, so while impacted by development, the recommended actions are required to ensure these ecological and aesthetic values are maintained and enhanced in the future.

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Appendix A – Overview Environmental Assessment

The environmental assessment team consisted of a terrestrial ecologist and wildlife biologist, an aquatic biologist, and geoscientist. Benthic invertebrate sampling was completed by a specialist. Most field work occurred during early June 2011, with additional field visits taking place in late June and mid-September, 2011.

A.1 TERRESTRIAL ASSESSMENT

A.1.1 Field Assessment

The terrestrial ecological assessment was completed on June 1, 2, and 22, 2011 for the majority of the Chines watershed. An additional assessment was completed on September 19, 2011 within the Suter Brook watershed. The terrestrial ecological assessments included the quantification of ecosystems and ecological communities; as well as, habitat potential for various wildlife species and species at risk. The assessments focused on the riparian habitats along the creek corridors, noting habitat features (e.g. ponds, flooded fields, cavity nests), local ecology and plant communities, and areas for potential restoration (quality of existing habitats). Further, wildlife use through identification of movement corridors, scat or tracks within the riparian and directionality were all documented to better understand the level of ecosystem function. Figure A-1 illustrates the overview of the terrestrial assessment.

Figure A-1 also indicates the locations of invasive plant species encountered during the June 22, 2011 terrestrial assessment. It should be noted that specific terrestrial plots were completed at the points as indicated on the figure and some plots did not have any invasive plants encountered; however, this does not mean that the watersheds in their entirety do not have invasive plant species.

A.1.2 Ecology

Ecological Communities

Western hemlock (*Tsuga heterophylla*) is the most common species in this ecosystem. It regenerates freely under the canopy of mature stands on zonal sites and elsewhere if sufficient acid raw humus or decaying wood has accumulated on the forest floor. Characteristic floristic features of zonal ecosystems in the CWH are: the prominence of western hemlock, a sparse herb layer; and the predominance of several moss species, particularly step moss (*Hylocomium splenden*) and lanky moss (*Rhytidiadelphus loreus*) (Medinger and Pojar 1991).

Tree species include western hemlock, red alder (*Alnus rubra*), broadleaf maple (*Acer macrophyllum*), black cottonwood (*Populous balsamifera tricocarpa*), beaked hazelnut (*Corylus cornuta*), western red cedar (*Thuja plicata*) and coastal Douglas fir (*Pseudostuga menzesii*).

The riparian ecological communities associated with each stream are summarized below in Table A-1, with further detail provided in the following text.

Table A-1
Riparian Ecological Communities within the Study Area

Location	Stream Name	1° Ecological Community	2° Ecological Community	Comments
Noble Creek NO2 NO3 NO4 NO-end	Noble Creek	Coastal western hemlock – broadleaf maple – salmonberry – common horsetail/sword fern (*Tsuga heterophylla – Acer macrophyllum – Rubus spectabilis – Equisitem arvense/Polystichum munitum*)	Western red cedar – vine maple – Devil's club/salmonberry (*Thuja plicata – A. circinatum - Oplopanax horridus/R. spectabilis*)	False lamium (*Lamiastrum galeob*) and English ivy (*Hedera helix*) are prevalent in the understory
South Schoolhouse Creek SH2 SH3 SH4 SH5 SH6	South Schoolhouse Creek	Red alder – broadleaf maple - salmonberry – skunk cabbage (*Alnus rubra – A. macrophyllum – R. spectabilis - Lysichiton americanus*)	Western red cedar / coastal western hemlock – salmonberry – lady fern (*T. plicata/T. heterophylla – R. spectabilis - Athyrium felix-femina*)	Understory patches infested with Japanese knotweed, periwinkle (*Vinca major*) and false lamium
Ottley OT2 OT3 OT4	Ottley Creek	Western red cedar / coastal western hemlock – salmonberry – sword fern (*T. plicata – T. heterophylla – R. spectabilis – P. munitum*)	Red alder – coastal western hemlock – red elderberry – lady fern (*A. rubra – T. heterophylla - Sambucus racemosa – Acer felix-femina*)	False lamium and Japanese knotweed dominate the understory in large patches
Hatchley Creek Ha2 Ha3 Ha4	Hatchley Creek	Western red cedar / coastal western hemlock – salmonberry – Devil's club – skunk cabbage (*T. plicata/T. heterophylla – R. specabilis – Occidentis horridus – L. americanus*)	Red alder – salmonberry – Devil's club/skunk cabbage (*A. rubra – R. spectabilis – Occidentis horridus/L. americanus*)	Understory has patches of thick lamium and English ivy.
West Sundial WS2 WS3 WS4	West Sundial Creek	Coastal western hemlock – broadleaf maple – salmonberry/red elderberry – swordfern (*T. heterophylla – A. macrophyllum – R. spectabilisy/S. racemosa – P. munitum*)	Coastal western hemlock/red alder – salmonberry – Pacific bleeding heart/clasping twisted stalk (*T. heterophylla/A. rubra – R. spectabilis - Dicentra formosa/Streptopus amplexifolius*)	Dense patches of ivy and lamium where riparian and residential yards meet. Tree forts and residential refuse dumped in riparian.

Location	Stream Name	1° Ecological Community	2° Ecological Community	Comments
East Sundial ES2 ES3 ES4	East Sundial Creek	Red alder – coastal western hemlock – salmonberry/bracken fern (*A. rubra – T. heterophylla – R. spectabilis/Pteridium aquilinum*)		
Goulet Ck GC2 GC4	Goulet Creek	Coastal western hemlock – broadleaf maple – Oregon grape/sword fern – false Solomon's seal (*T. heterophylla – A. macrophyllum – Mahonia aquifolium - Maianthemum racemosum*)	Coastal western hemlock – salmonberry/red elderberry – bracken fern (*T. heterophylla – R. spectabilis/Sambucus racemosa – P. aquilinum*)	Japanese knotweed infestation.
Dallas Da2 Da3	Dallas Creek	Coastal western hemlock – vine maple – red huckleberry – sword fern (*T. heterophylla – A. circinatum – Vaccinium parvifolium – P. munitum*)	Coastal western hemlock – western red cedar – salmonberry – bracken fern (*T. heterophylla – T. plicata – R. spectabilis - P. aquilinum*)	False lamium dominating understory in forest adjacent to residential development.
Kyle KY2 KY3 KY4	Kyle Creek	Coastal western hemlock – vine maple/salmonberry – bracken fern (*T. heterophylla – A. circinatum/R. spectabilis – P. aquilinum*)		Japanese knotweed at north end, English ivy dense in understory near residential areas.
Williams Creek Wi2	Williams Creek	Coastal western hemlock – vine maple – salmonberry/red elderberry (*T. heterophylla – A. circinatum – R. spectabilis/S. racemosa*)	Red alder – broadleaf maple – salmonberry – bracken fern – mountain sweet cicely (*A. rubra – A. macrophyllum – R. spectabilis - P. aquilinum - Osmorhiza berteroi*)	
Axfod AX2 AX3 AX4	Axford Creek	Coastal western hemlock – salmonberry – bracken fern/skunk cabbage (*T. heterophylla – R. spectabilis – P. aquilinum/L. americanus*)	Coastal western hemlock/western red cedar – salmonberry – sword fern (*T. heterophylla/T. plicata – R. spectabilis – P. munitum*)	
EL2	Elginhouse Creek	Coastal western hemlock – red alder – deer fern/bracken fern (*T. heterophylla – A. rubra – Blechnum spicant/P. aquilinum*)	Coastal western hemlock – vine maple – salmonberry – common horsetail (*T. heterophylla – A. circinatum – R. spectabilis – Equisitem arvense*)	

At-Risk Species

The creeks within this project area provide suitable habitat for a number of provincially and federally at-risk plant species. While no rare plants were found in the overview assessment, their presence in other riparian areas within close proximity indicates potential to occur within the Chines. Table A-2 summarizes the at-risk plant species documented within 20 km of the Chines in similar habitats. Table A-3 provides the provincially-listed ecological communities with a complete list of all rare plants known within the CWHdm and within Metro Vancouver. Table A-4 provides the at-risk plant species potentially within the study area.

Table A-2
At-Risk Plant Species within 20 km of the Chines

Common Name	Scientific Name	SARA Status[5]	BC Status[6]	Habitat Requirements	Presence in Chines (Yes/No)
False pimpernel	*Lindernia dubia var. anagallidea*	-	Blue	Wet, sandy or muddy soils around wetlands and lakes	No
Streambank lupine	*Lindernia dubia var. anagallidea*	E (Nov 2002)	Red	Wandy, gravelly soil on river flood plains close to the coast	No
Ussurian water-milfoil	*Myriophyllum ussuriense*	-	Blue	Submerged or partly submerged in shallow waters along muddy lake margins, estuaries, and riverbanks	No
Dotted smartweed	*Persicaria punctata*	-	Blue	Wetlands and wet meadows	No
Small-flowered bitter-cress	*Cardamine parviflora var. arenicola*	-	Red	Dry sandy or rocky habitats	No
Pointed broom sedge	*Carex scoparia*	-	Blue	Moist to wet ditches, lakeshores, marshes and meadows	No
Three-flowered waterwort	*Elatine rubella*	-	Blue	Aquatic or semi-aquatic and grows in wet ditches, shallow ponds and on shorelines or mudflats	No

[5] The Species at Risk Act (SARA) protects species listed federally as at-risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Species are listed as Endangered, Threatened or Special Concern based on population numbers and degree of imminent threats to populations or ecosystems.

[6] Provincial designation where the Red listed includes any ecological community, and indigenous species and subspecies that is extirpated, endangered, or threatened in British Columbia. Extirpated elements no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered elements are facing imminent extirpation or extinction. Threatened elements are likely to become endangered if limiting factors are not reversed. The Blue list includes any ecological community, and indigenous species and subspecies considered to be of special concern (formerly vulnerable) in British Columbia. Elements are of special concern because of characteristics that make them particularly sensitive to human activities or natural events.

Table A-3
At-Risk Ecological Communities Potentially within the Study Area

Scientific Name	English Name	BC Status	Biogeoclimatic Units	Ecosystem Group
Leymus mollis ssp. mollis - Lathyrus japonicus	dune wildrye - beach pea	Red	CDFmm;CWHdm;CWHds1;CWHms2;CWHvh1;CWHvh2;CWHvm;CWHvm1;CWHwh1;CWHwm;CWHws1;CWHxm1;CWHxm2	Sparsely Vegetated, Herbaceous
Picea sitchensis / Rubus spectabilis Dry	Sitka spruce / salmonberry Dry	Red	CWHdm/08;CWHds1/08	Riparian, Forest
Populus balsamifera ssp. trichocarpa - Alnus rubra / Rubus spectabilis	black cottonwood - red alder / salmonberry	Blue	CWHdm/09;CWHds1/09;CWHds2/09;CWHmm1/09;CWHms1/08;CWHms2/08;CWHvm1/10;CWHwm/06;CWHws1/08;CWHws2/08;CWHxm1/09;CWHxm2/09	Riparian, Forest
Populus balsamifera ssp. trichocarpa / Salix sitchensis	black cottonwood / Sitka willow	Blue	CWHdm/10;CWHxm1/10;CWHxm2/10	Riparian, Forest
Pseudotsuga menziesii - Pinus contorta / Holodiscus discolor / Cladina spp.	Douglas-fir - lodgepole pine / oceanspray / reindeer lichens	Red	CWHdm/02	Woodland, Forest
Pseudotsuga menziesii / Polystichum munitum	Douglas-fir / sword fern	Red	CWHdm/04;CWHxm1/04;CWHxm2/04	Forest
Pseudotsuga menziesii - Tsuga heterophylla / Gaultheria shallon Dry Maritime	Douglas-fir - western hemlock / salal Dry Maritime	Blue	CWHdm/03;CWHxm1/03;CWHxm2/03	Forest
Thuja plicata / Carex obnupta	western red cedar / slough sedge	Blue	CWHdm/15;CWHxm1/15;CWHxm2/15	Wetland, Forest
Thuja plicata / Lonicera involucrata	western red cedar / black twinberry	Red	CWHdm/14;CWHxm1/14;CWHxm2/14	Forest
Thuja plicata - Picea sitchensis / Lysichiton americanus	western red cedar - Sitka spruce / skunk cabbage	Blue	CWHdm/12;CWHds1/12;CWHds2/12;CWHmm1/12;CWHms1/11;CWHms2/11;CWHvh1/13;CWHvh2/13;CWHvm1/14;CWHwh1/12;CWHwh2/06;CWHws1/11;CWHxm1/12;CWHxm2/12	Wetland, Forest
Thuja plicata / Polystichum munitum Dry Maritime	western red cedar / sword fern Dry Maritime	Blue	CWHdm/05	Forest

Scientific Name	English Name	BC Status	Biogeoclimatic Units	Ecosystem Group
Thuja plicata / Rubus spectabilis	western red cedar / salmonberry	Red	CWHdm/13;CWHxm1/13;CWHxm2/13	Forest, Riparian
Thuja plicata / Tiarella trifoliata Dry Maritime	western red cedar / three-leaved foamflower Dry Maritime	Blue	CWHdm/07	Forest
Tsuga heterophylla / Plagiothecium undulatum	western hemlock / flat-moss	Blue	CWHdm/01	Forest
Tsuga heterophylla - Thuja plicata / Blechnum spicant	western hemlock - western red cedar / deer fern	Red	CWHdm/06;CWHxm1/06;CWHxm2/06	Forest
Typha latifolia Marsh	common cattail Marsh	Blue	BGxh1/Wm05;BGxh2/Wm05;BGxw1/Wm05;CDFmm/Wm05;CWHdm/Wm05;CWHxm1/Wm05;CWHxm2/Wm05;IDFdk1/Wm05;IDFdk2/Wm05;IDFdk3/Wm05;IDFdk5/Wm05;IDFdm1/Wm05;IDFdm2/Wm05;IDFmw1/Wm05;IDFmw2/Wm05;IDFxh1/Wm05;IDFxh2/Wm05;IDFxk/Wm05;PPdh2/Wm05;PPxh1/Wm05;PPxh2/Wm05	Wetland, Herbaceous
Search Criteria: Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone, Ministry of Environment Region 2 (Lower Mainland), Chilliwack Forest District, Metro-Vancouver Regional District				

Table A-4
At-Risk Plant Species Potentially within the Study Area

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Alopecurus carolinianus	Carolina meadow-foxtail		Red	CDFmm;CWHdm;CWHds;IDFxh	Palustrine; Terrestrial
Alsia californica			Blue	CDF;CWH	
Amblystegium varium			Blue	CWHdm;SBSdw	
Anagallis minima	chaffweed		Blue	CDFmm;CWHxm	Estuarine; Palustrine; Terrestrial
Andreaea sinuosa			Red	CMA;CWHvm;MHmm;MHwh	Terrestrial
Bidens amplissima	Vancouver Island beggarticks	SC (Nov 2001)	Blue	CDFmm;CWHdm;CWHms;CWHxm	Palustrine
Brachythecium holzingeri			Blue	CDF;CMA;CWH;ESSF;ICH;IDF;IMA;MH;MS;SBS	
Brotherella roellii	Roell's brotherella	E (Nov 2010)	Red	CDF;CMA;CWH	
Bryum schleicheri			Blue	CMA;CWH;IMA;MH	
Callicladium haldanianum			Blue	CWH	
Callitriche heterophylla ssp. heterophylla	two-edged water-starwort		Blue	BAFAunp;CDFmm;CWHvm;CWHwh;CWHxm	Estuarine; Lacustrine; Palustrine
Caltha palustris var. radicans	yellow marsh-marigold		Blue	CDFmm;CWHvm;CWHwm;CWHws	Estuarine; Palustrine
Cardamine parviflora var. arenicola*	small-flowered bitter-cress		Red	CDFmm;CWHdm	Terrestrial
Carex interrupta	green-fruited sedge		Red	CDFmm;CWHdm;CWHxm	Lacustrine; Palustrine; Terrestrial
Carex scoparia*	pointed broom sedge		Blue	BWBSmw;CDFmm;CWHdm;CWHvh;CWHxm;ESSFdk;ICHdw;ICHwk;ICHxw;SBSvk	Lacustrine; Palustrine; Terrestrial
Carex vulpinoidea	fox sedge		Blue	BGxh;CWHdm;CWHxm;ICHmw;ICHxw;IDFmw;IDFxh	Lacustrine; Palustrine; Terrestrial
Claytonia washingtoniana	Washington springbeauty		Red	CDFmm;CWHdm;CWHxm;IDFww	Riverine; Terrestrial
Cuscuta campestris	field dodder		Blue	BGxh;CDFmm;CWHdm;CWHxm;IDFxh	Estuarine; Terrestrial

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Diphyscium foliosum			Blue	CWH	
Discelium nudum			Blue	CDF;CWH	
Drepanocladus aduncus			Blue	CDF;CWH;PP	
Elatine rubella*	three-flowered waterwort		Blue	BGxh;CDFmm;CWHdm;CWHxm;IDFxh	Estuarine; Lacustrine; Palustrine
Eleocharis parvula	small spike-rush		Blue	CDFmm;CWHvm;CWHwh;CWHxm	Estuarine; Lacustrine; Palustrine
Eleocharis rostellata	beaked spike-rush		Blue	CDFmm;CWHdm;CWHxm;ICHmw;IDFdm;IDFmw;MSdm;MSxk	Estuarine; Lacustrine; Palustrine; Riverine; Terrestrial
Elodea nuttallii	Nuttall's waterweed		Blue	BGxh;CWHdm;ICHdw;ICHmk;ICHxw	Estuarine; Lacustrine; Palustrine
Epilobium leptocarpum	small-fruited willowherb		Blue	BAFA;CMA;CWHdm;CWHds;CWHvm;CWHwh;CWHxm;ESSFmw;ESSFwc;ESSFwk;ESSFxv;ICHmc;ICHmw;ICHwk;IMA;MSdk;SBSwk;SWBmk	Palustrine; Riverine; Terrestrial
Epipterygium tozeri			Blue	CDF;CWH	
Fissidens pauperculus	poor pocket moss	E (May 2011)	Red	CWH	Riverine; Terrestrial
Fissidens ventricosus			Blue	CDF;CWH;ESSF	
Glyceria leptostachya	slender-spiked mannagrass		Blue	CDFmm;CWHdm;CWHwh;CWHxm	Estuarine; Lacustrine; Palustrine; Terrestrial
Helenium autumnale var. grandiflorum	mountain sneezeweed		Blue	BGxh;CDFmm;CWHdm;CWHxm;ICHmw;ICHxw;PPdh	Estuarine; Lacustrine; Palustrine; Terrestrial
Hygrohypnum alpinum			Blue	BAFA;CWH;ESSF;ICH;IDF;SWB	
Hypericum scouleri ssp. nortoniae	western St. John's-wort		Blue	CWHvh;CWHvm;CWHxm;ESSFdk;ESSFvc;ESSFwc;ESSFwcp;ESSFwm;ICHdw;ICHwk;IDFdm;IDFxh;PPdh	Lacustrine; Palustrine; Terrestrial
Isoetes nuttallii	Nuttall's quillwort		Blue	CDFmm;CWHxm	Palustrine; Riverine; Terrestrial
Juncus oxymeris	pointed rush		Blue	CDFmm;CWHdm;CWHxm	Estuarine; Palustrine; Terrestrial
Lilaea scilloides	flowering quillwort		Blue	CDFmm;CWHdm;CWHvm;CWHxm	Estuarine; Palustrine

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Lindernia dubia var. anagallidea*	false-pimpernel		Blue	BGxh;CWHdm;CWHxm;IDFxh	Estuarine; Lacustrine; Palustrine; Terrestrial
Lindernia dubia var. dubia	yellowseed false pimpernel		Red	CWHxm;PPxh	Lacustrine; Palustrine
Lupinus rivularis*	streambank lupine	E (Nov 2002)	Red	CDFmm;CWHdm;CWHxm	Riverine
Myriophyllum hippuroides	western water-milfoil		Blue	CWHdm	Lacustrine; Riverine
Myriophyllum pinnatum	green parrot's-feather		Red	CWHdm	Lacustrine; Riverine
Myriophyllum ussuriense*	Ussurian water-milfoil		Blue	CDFmm;CWHdm;CWHvh;ICHdw;IDFmw	Estuarine; Lacustrine; Palustrine; Riverine
Navarretia intertexta	needle-leaved navarretia		Red	CDFmm;CWHxm;ICHmk;IDFxh	Palustrine; Riverine; Terrestrial
Orthotrichum cupulatum			Blue	CDF;CWH;ESSF;IDF;PP	
Orthotrichum striatum			Blue	CDF;CMA;CWH;ICH;MH	
Persicaria punctate*	dotted smartweed		Blue	BGxh;CWHdm;CWHxm;PPxh	Palustrine
Physcomitrium immersum			Red	CDFmm;CWHxm	
Platyhypnidium riparioides			Blue	CDF;CWH;ESSF;ICH;MH	
Pleuropogon refractus	nodding semaphoregrass		Blue	CDFmm;CWHdm;CWHms;CWHvh;CWHvm;CWHxm;MHmm	Palustrine; Terrestrial
Pohlia cardotii			Red	CMA;CWH;IMA;MH	
Ptychomitrium gardneri			Blue	CDF;CWH;IDF	
Rubus nivalis	snow bramble		Blue	CDFmm;CWHdm;CWHmm;CWHvh;CWHvm;CWHxm;ICHmw;MHmm	Terrestrial
Rupertia physodes	California-tea		Blue	CDFmm;CWHmm;CWHxm;MHmm	Terrestrial
Sidalcea hendersonii	Henderson's checker-mallow		Blue	CDFmm;CWHxm	Estuarine; Palustrine
Sphagnum contortum			Blue	CWH;SBS	
Verbena hastata var. scabra	blue vervain		Red	BGxh;CWHdm;CWHxm;IDFxh	Palustrine; Terrestrial

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Wolffia borealis	northern water-meal		Red	CWHdm;CWHxm;ICHxw	Lacustrine; Palustrine; Riverine
Search Criteria: Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone, Ministry of Environment Region 2 (Lower Mainland), Chilliwack Forest District, Metro-Vancouver Regional District					
* Denotes occurrences within 20 km radius of Study Area.					

A.1.3 Wildlife and Habitat Assessment

Riparian habitats are typically more structurally complex and therefore are able to support a greater diversity of wildlife. The often hard edges between the riparian areas of the creeks within the Chines and residential development, detract from the overall continuity of habitats, limiting the resource availability for wildlife other than small mammals, birds, reptiles and amphibians.

Birds

Mature riparian forests such as those within the Chines offer habitats to a wide variety of bird species. Because these forests offer a mix of mature coniferous as well as deciduous trees, bird species requiring each habitat type are found. During the June and September assessments, species detected via either visual or auditory observations included spotted towhee (*Pipilo maculatus*), black-capped chickadee (*Poecile atricapillus*), dark-eyed junco (*Junco hyemalis*), ruby-crowned kinglet *(Regulus calendula*), American robin (*Turdus migratorius*), American crow (*Corvus brachrhynchos*) and songsparrow (*Melospiza melodia*). In patches of deciduous forest with established shrub understories, observed riparian species included Wilson's warbler (*Wilsonia pusilla*), winter wren (*Troglodytes hiemalis*), yellow warbler (*Dendroica petechia*) and Swainson's thrush (*Catharus ustulatus*) (Sibley 2003).

Amphibians and Reptiles

Riparian habitats support an abundance of invertebrates and small mammals, a diverse prey base for amphibians and reptiles alike. The western garter snake (*Thamnophis elegans*) is common in riparian areas. It eats soft-bodied invertebrates such as slugs, worms, snails, leeches, as well as tadpoles, frogs, other snakes, mice and freshwater and marine fish (Fisher et al. 2007). Pacific chorus frog (*Pseudacris regilla*) is another likely inhabitant of the riparian habitats within the Chines. These broad-niche generalists are one of the most wide-spread amphibian species in Canada. Needing slow-moving water where the stream gradient is low enough to allow pooling, these adaptable frogs will lay their eggs anywhere between February and July then hibernate under loose bark or leaf litter on the forest floor (Corkran and Thoms 2006).

Mammals

Structural habitat diversity is increased by a diverse understory of shrubs, forbs and grasses, providing fruit and seeds for small mammals, which in turn are prey for larger mammal species. One of the more common small mammals in riparian areas such as these is the common shrew (*Sorex cinereus*). While primarily insectivorous, the common shrew will predate on earthworms, spiders, millipedes and sometimes salamanders and young bird nestlings (Banfield 1974). This small mammal forages in runways along the ground, among the leaves and debris of the forest floor and may also forage in trees. If threatened, the common shrew will seek out escape cover such as dense herbaceous layer, decayed logs, or forest litter. The small mammal populations in addition to berry-producing shrubs provide suitable food resources for larger mammals such as coyotes (*Canis latrans*) and black bears (*Ursus americanus*).

Movement Corridors

Track and scat evidence show habitat use by coyote and black bear within Elginhouse and South Schoolhouse creeks. Coyotes are known to be one of the few mammals where populations have increased as human development has encroached on their habitats. Frequently preying on house cats and small dogs, coyotes are using the riparian habitats as movement corridors between residential developments and forested habitats. Black bears have adapted their diets to include household refuse, compost and domestic pets. In a riparian area of Elginhouse Creek, garbage cans from the neighbourhood were found overturned with bear claw marks on the lids, a result of the night-time activities of a mother bear and cubs in the neighbourhood (local resident pers. com.).

At-Risk Species

All provincially- and federally-listed wildlife species with the potential to occur within the Chines are provided in Table A-5. To better determine what species are present within the Chines without completing intensive species-specific searches, a search of known occurrences within a 20 km radius of the Chines was completed and summarized in Table A-6. Further, detailed accounts of the respective habitat requirements and comments on the likelihood of their occurrence within the Chines are provided.

Table A-5
At-Risk Wildlife Potentially within the Study Area

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Fish					
Acipenser medirostris*	Green Sturgeon	SC (May 1987)	Red	CDF;CWH	Estuarine; Marine; Riverine
Acipenser transmontanus pop. 4	White Sturgeon (Lower Fraser River population)	E (Nov 2003)	Red	CDF;CWH;IDF	Estuarine; Lacustrine; Marine; Riverine
Rhinichthys cataractae - Chehalis lineage	Nooksack Dace	E (Apr 2007)	Red	CWH	Riverine
Catostomus sp. 4	Salish Sucker	E (Nov 2002)	Red	CWH	Lacustrine; Riverine
Spirinchus sp. 1	Pygmy Longfin Smelt	DD (Nov 2004)	Red	CWH	Lacustrine
Thaleichthys pacificus	Eulachon	E/T (May 2011)	Blue	CWH	Estuarine; Marine; Riverine
Oncorhynchus clarkii clarkia*	Cutthroat Trout, clarkii subspecies		Blue	BWBS;CDF;CWH;ICH;SBS	Estuarine; Lacustrine; Marine; Riverine
Oncorhynchus kisutch*	Coho Salmon	E (May 2002)	Yellow	BAFA;BG;BWBS;CDF;CMA;CWH;ESSF;ICH;IDF;MH;MS;PP;SBPS;SBS;SWB	
Salvelinus confluentus	Bull Trout	SC (Jul 2011)	Blue	BG;BWBS;CWH;ESSF;ICH;IDF;MS;PP;SBPS;SBS;SWB	Lacustrine; Riverine
Salvelinus malma	Dolly Varden		Blue	BWBS;CDF;CWH;ESSF;ICH;MH;SBS	Estuarine; Lacustrine; Marine; Riverine
Amphibians					
Ascaphus truei	Pacific Tailed Frog	SC (May 2000)	Blue	CWH;ESSF;ICH;IDF;MS	
Anaxyrus boreas	Western Toad	SC (Nov 2002)	Blue	BG;BWBS;CDF;CWH;ESSF;ICH;IDF;PP;SBS;SWB	
Rana aurora*	Northern Red-legged Frog	SC (Nov 2004)	Blue	CDF;CWH;MH	
Rana pretiosa	Oregon Spotted Frog	E (May 2011)	Red	CWH	Lacustrine; Palustrine; Riverine

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Reptiles					
Chrysemys picta pop. 1*	Western Painted Turtle - Pacific Coast Population	E (Apr 2006)	Red	CDF;CWH;MH	Lacustrine; Palustrine; Riverine
Charina bottae	Northern Rubber Boa	SC (May 2003)	Yellow	BG;CWH;ICH;IDF;PP	
Birds					
Dendragapus fuliginosus	Sooty Grouse		Blue	CDF;CMA;CWH;MH	
Phalacrocorax auritus	Double-crested Cormorant	NAR (May 1978)	Blue	BWBS;CDF;CWH;ICH;IDF;PP;SBPS;SBS	Estuarine; Lacustrine; Marine; Palustrine; Riverine; Terrestrial
Ardea herodias fannini	Great Blue Heron, fannini subspecies	SC (Mar 2008)	Blue	CDF;CWH	Estuarine; Lacustrine; Palustrine; Riverine; Terrestrial
Botaurus lentiginosus	American Bittern		Blue	BG;BWBS;CDF;CWH;ICH;IDF;MS;PP;SBPS;SBS	Estuarine; Palustrine
Butorides virescens	Green Heron		Blue	BG;CDF;CWH;ICH;IDF;PP;SBS	Estuarine; Lacustrine; Palustrine; Riverine
Nycticorax nycticorax	Black-crowned Night-heron		Red	BG;CDF;CWH;ICH;IDF;PP	Estuarine; Lacustrine; Palustrine; Riverine; Terrestrial
Accipiter gentilis laingi	Northern Goshawk, laingi subspecies	T (Nov 2000)	Red	CDF;CWH;MH	Terrestrial
Falco peregrinus anatum	Peregrine Falcon, anatum subspecies	SC (Apr 2007)	Red	BG;BWBS;CDF;CWH;ESSF;ICH;IDF;MS;PP;SBS;SWB	Estuarine; Terrestrial
Hydroprogne caspia	Caspian Tern	NAR (May 1999)	Blue	BG;BWBS;CDF;CWH;ICH;IDF;PP;SBS	Estuarine; Lacustrine; Marine; Palustrine; Riverine; Terrestrial
Brachyramphus marmoratus	Marbled Murrelet	T (Nov 2000)	Blue	CDF;CWH;MH	Estuarine; Lacustrine; Marine; Terrestrial
Patagioenas fasciata	Band-tailed Pigeon	SC (Nov 2008)	Blue	CDF;CWH;ICH;IDF;MS;SBS	Palustrine; Terrestrial

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Tyto alba	Barn Owl	T (Nov 2010)	Blue	BG;BWBS;CDF;CWH;ICH;IDF;PP	Palustrine; Terrestrial
Asio flammeus	Short-eared Owl	SC (Mar 2008)	Blue	BG;BWBS;CDF;CWH;ICH;IDF;MS;PP;SBPS; SBS;SWB	Estuarine; Palustrine; Terrestrial
Megascops kennicottii kennicottii	Western Screech-Owl, kennicottii subspecies	SC (May 2002)	Blue	CDF;CWH;IDF	Palustrine; Terrestrial
Strix occidentalis	Spotted Owl	E (Mar 2008)	Red	CWH;ESSF;IDF;MH	Palustrine; Terrestrial
Chordeiles minor	Common Nighthawk	T (Apr 2007)	Yellow	BG;BWBS;CDF;CWH;ESSF;ICH;IDF;MH;MS; PP;SBPS;SBS;SWB	
Cypseloides niger	Black Swift	C (Jul 2011)	Yellow	BG;CDF;CWH;ESSF;ICH;IDF;MH;MS;PP;SBPS;SBS;SWB	
Contopus cooperi	Olive-sided Flycatcher	T (Nov 2007)	Blue	BWBS;CDF;CWH;ESSF;ICH;IDF;MH;MS;PP; SBPS;SBS;SWB	Palustrine; Terrestrial
Hirundo rustica	Barn Swallow	T (May 2011)	Blue	BAFA;BG;BWBS;CDF;CWH;ESSF;ICH;IDF;IMA;MH;MS;PP;SBPS;SBS;SWB	Estuarine; Lacustrine; Palustrine; Riverine; Terrestrial
Progne subis	Purple Martin		Blue	BWBS;CDF;CWH;ICH	Estuarine; Lacustrine; Palustrine; Terrestrial
Mammals					
Aplodontia rufa	Mountain Beaver	SC (Nov 2001)	No Status	CDF;CWH;ESSF;MH;MS	
Aplodontia rufa rufa	Mountain Beaver, rufa subspecies	SC (May 1999)	Blue	CDF;CWH;MH	Terrestrial
Myodes gapperi occidentalis	Southern Red-backed Vole, occidentalis subspecies		Red	CDF;CWH	Palustrine; Terrestrial
Lepus americanus washingtonii	Snowshoe Hare, washingtonii subspecies		Red	CDF;CWH	Palustrine; Terrestrial
Sorex bendirii*	Pacific Water Shrew	E (Apr 2006)	Red	CWH	Estuarine; Palustrine; Riverine; Terrestrial
Sorex rohweri	Olympic Shrew		Red	CDF;CWH	Terrestrial
Sorex trowbridgii	Trowbridge's Shrew		Blue	CDF;CWH	Palustrine; Terrestrial

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Corynorhinus townsendii	Townsend's Big-eared Bat		Blue	BG;CDF;CWH;ICH;IDF;PP	Palustrine; Subterranean; Terrestrial
Myotis keenii	Keen's Myotis	DD (Nov 2003)	Red	BWBS;CDF;CWH;MH	Palustrine; Terrestrial
Gulo gulo	Wolverine	SC (May 2003)	No Status	BAFA;BWBS;CMA;CWH;ESSF;ICH;IDF;IMA; MH;MS;SBPS;SBS;SWB	
Gulo gulo luscus	Wolverine, luscus subspecies	SC (May 2003)	Blue	BAFA;BWBS;CMA;CWH;ESSF;ICH;IDF;IMA; MH;MS;SBPS;SBS;SWB	Terrestrial
Mustela frenata altifrontalis	Long-tailed weasel, altifrontalis subspecies		Red	CDF;CWH;MH	
Ursus arctos	Grizzly Bear	SC (May 2002)	Blue	BAFA;BWBS;CMA;CWH;ESSF;ICH;IDF;IMA; MH;MS;SBPS;SBS;SWB	Palustrine; Riverine; Terrestrial
Invertebrates					
Argia emma	Emma's Dancer		Blue	CWH;IDF	Lacustrine; Riverine
Tanypteryx hageni	Black Petaltail		Blue	CWH	Palustrine
Octogomphus specularis	Grappletail		Red	CWH	Lacustrine; Riverine
Epitheca canis*	Beaverpond Baskettail		Blue	CWH	Lacustrine; Palustrine; Riverine
Pachydiplax longipennis*	Blue Dasher		Blue	CWH	Lacustrine; Riverine
Sympetrum vicinum*	Autumn Meadowhawk		Blue	CDF;CWH	Lacustrine; Riverine
Omus audouini	Audouin's Night-stalking Tiger Beetle	C (Jul 2011)	Red	CDF;CWH	Estuarine; Subterranean; Terrestrial
Epargyreus clarus	Silver-spotted Skipper		Blue	CDF;CWH;ESSF;ICH;IDF;MH;MS;PP	Terrestrial
Euphyes vestris	Dun Skipper	T (Nov 2000)	Blue	CDF;CMA;CWH;ESSF;IDF;IMA;MH;PP	Palustrine; Terrestrial
Callophrys eryphon sheltonensis	Western Pine Elfin, sheltonensis subspecies		Blue	CDF;CWH	Terrestrial
Callophrys johnsoni	Johnson's Hairstreak		Red	CDF;CMA;CWH	Terrestrial
Danaus plexippus	Monarch	SC (Apr 2010)	Blue	BG;CDF;CWH;ESSF;ICH;IDF;MS;PP	Palustrine; Terrestrial

Scientific Name	English Name	SARA Status	BC Status	Biogeoclimatic Units	Habitat Type
Speyeria zerene bremnerii	Zerene Fritillary, bremnerii subspecies		Red	CDF;CWH	Terrestrial
Sphaerium patella	Rocky Mountain Fingernailclam		Red	CWH;MH	Lacustrine; Riverine
Haliotis kamtschatkana	Northern Abalone	T (May 2000)	Red	CDF;CWH	Marine
Carychium occidentale	Western Thorn		Blue	CDF;CWH	Terrestrial
Prophysaon vanattae	Scarletback Taildropper		Blue	CDF;CWH;MH	Terrestrial
Zonitoides nitidus	Black Gloss		Blue	CDF;CWH;IDF;PP	Palustrine
Allogona townsendiana	Oregon Forestsnail	E (Nov 2002)	Red	CDF;CWH	Terrestrial
Cryptomastix devia	Puget Oregonian	XT (Nov 2002)	Red	CDF;CWH	Palustrine;Terrestrial
Monadenia fidelis	Pacific Sideband		Blue	CDF;CWH	Terrestrial
Search Criteria: Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone, Ministry of Environment Region 2 (Lower Mainland), Chilliwack Forest District, Metro-Vancouver Regional District.					
* Denotes occurrences within 20 km radius of Study Area.					

Table A-6
At-Risk Wildlife Species within 20 km of the Chines

Common Name	Scientific Name	SARA Status	BC Status	Habitat Requirements	Presence in Chines (Yes/No)
Fish					
White sturgeon (Lower Fraser River Population)	*Acipenser transmontanus*	E (Nov 2003)	Red	Large rivers with high velocities and turbulent, upwelling flows with exposed substrate, large boulders and rapids.	No
Cutthroat trout (*clarkii* subspecies)	*Oncorhynchus clarkii clarkii*	-	Blue	Requires small, low gradient coastal streams and estuarine habitats.	Yes
Coho salmon	*Oncorhynchus kisutch*	E (May 2002)	-	Spawning in forested coastal streams, in loose coarse gravel at heads of riffles.	Yes
Amphibians and Reptiles					
Northern red-legged frog	*Rana aurora*	SC (Nov 2004)	Blue	Permanent waters of stream pools, marshes, ponds and other quiet bodies of water in damp woods and meadows.	Yes
Western painted turtle (Pacific coast population)	*Chrysemys picta*	E (Apr 2006)	Red	Permanent lakes and ponds with mud bottoms for hibernation.	No
Mammals					
Pacific water shrew	*Sorex bendirii*	E (Apr 2006)	Red	Streams, creeks, and wetlands in mature coniferous and deciduous forests.	Yes
Invertebrates					
Beaverpond baskettail	*Epitheca canis*	-	Blue	Marshy lakeshores, bogs, beaver ponds, and sluggish streams.	No
Blue dasher	*Pachydiplax longipennis*	-	Blue	Ponds and lakes with abundant aquatic and riparian vegetation.	No
Autumn meadowhawk	*Sympetrum vicinum*	-	Blue	Ponds, slow streams and lakes with dense stands of emergent plants.	No

A.1.4 Forest Canopy Assessment

We completed a high level assessment of the health of the tree canopy in the ravines and ridges between the uplands and lowlands. This assessment was intended to address concerns that there would be a concentrated die-off of the forest community over a short period of time, leading to slope instability and loss of habitat structure.

The objectives of the forestry canopy assessment were to:

1. Describe the current condition of the forest;
2. Identify areas that could pose a safety hazard to the public; and
3. Develop recommendations to help manage potential safety hazards.

Methods

Hamish Robertson, RPF, and Amanda Miller, B.Tech. (Summit) completed the assessment within the Chines watershed on July 6 and 9, 2012. Visual observations were recorded at 35 locations across the Project Area. Refer to Table A-7 and Figure A-2. Each site was subjectively selected in areas representative of the surrounding forest type. Sites were visited across the edatope (i.e., upper slope, mid-slope and lower slope), with a greater emphasis placed on sites that interfaced with the public (e.g., trails and property boundaries). At each site, we assessed the forest structure and the potential risk to public safety. Visual assessment criteria included a description of:

- The co-dominant/dominant tree canopy layer including species composition (including live and dead trees [snags]) and forest structure;
- Intermediate tree canopy layer composition and cover; and
- Understory tree layer composition and cover (i.e., trees growing at ground level).

Table A-7
Forest Location Descriptions

Site	Drainage	Forest Description
1	South Schoolhouse Creek	The site is an open grown mix of second growth western hemlock, western red cedar and broadleaf maple with broadleaf maple snags in the surrounding area. The intermediate canopy layer is comprised of western hemlock and western red cedar. The adjacent stand appears to be healthy.
2	South Schoolhouse Creek	A highly mixed second growth forest comprising western hemlock, western red cedar, broadleaf maple and red alder. A well developed intermediate canopy layer with western hemlock, broadleaf maple and red alder. We recommend monitoring broadleaf maple snags which could fall across the trail, otherwise, the adjacent stand appears to be healthy.
3	South Schoolhouse Creek	This upper slope location shows a well developed, dense, western hemlock leading second growth single story canopy structure. Douglas-fir is present in the stand and a minor component of deciduous species in the surrounding area. The adjacent stand appears to be healthy.
4	Noble Creek	This upper slope location shows a well developed western hemlock leading second growth single story canopy structure with a minor red alder component. There is a small component of deciduous species in the surrounding area. The adjacent stand appears to be healthy.
5	Noble Creek	This area is a mature deciduous forest. Broadleaf maple and red alder comprise more than half the canopy, with some western hemlock. The understory is well established with western hemlock and western red cedar. We recommend monitoring the deciduous component for potential risk to public safety.
6	Noble Creek	This area is a mature broadleaf maple canopy with a well established western hemlock understory. We recommend monitoring the deciduous component for potential risk to public safety.
7	Noble Creek	This area is a mixed broadleaf maple and western hemlock canopy. A very well developed western hemlock understory that will eventually replace broadleaf maple in the canopy. The adjacent stand appears to be healthy.
8	Ottley Creek	This area is a western hemlock leading second growth forest on the mid-slope. Well developed western hemlock and western red cedar understory. Evidence of red alder and broadleaf maple formerly in the canopy. The adjacent stand appears to be healthy.
9	Ottley Creek	A well developed multi-story red alder and western hemlock canopy, with a smaller component of broadleaf maple and western red cedar. Well established understory of western hemlock and western red cedar. The adjacent stand appears to be healthy.

Site	Drainage	Forest Description
10	Ottley Creek	The canopy is a mature open grown red alder and broadleaf maple forest, with a minor component of western hemlock in the canopy. The understory is well developed in higher density areas, with western hemlock growing through in open areas. There is evidence of a few deciduous snags. We recommend monitoring the deciduous species health for potential risk to public safety.
11	Ottley Creek	The northern 200-300 m of the path is a near climax (i.e., mature) mixed red alder and broadleaf maple forest with a poorly developed understory. The forest appears healthy but the dominant canopy will likely begin to die off. This is a natural successional process for this stand type. We recommend a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for potential risk to public safety.
12	Ottley Creek	The forest is a near climax (i.e., mature) mixed red alder and broadleaf maple forest with more evidence of snags and blowdown than observed at site 11. Summit recommends a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for potential risk to public safety.
13	Axford Creek	This area is the continuation of the climax deciduous forest type that extends from sites 12. We recommend a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for potential risk to public safety.
14	Axford Creek	Along the creek and adjacent to the houses, the forest type is dominated by red alder with western red cedar and western hemlock. The understory is a well developed western hemlock and western red cedar. We recommend a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for risk to private property and public safety.
15	Axford Creek	The main canopy is dominated by mature red alder with some western hemlock. The adjacent forest appears healthy.
16	Axford Creek	The canopy is dominated by western hemlock, with some broadleaf maple in a complex stand structure with a well-developed understory. The adjacent forest appears to be healthy.
17	Kyle Creek	This area has a complex stand structure with western hemlock and red alder dominating the main canopy layer, with lesser components of broadleaf maple western red cedar. The understory is primarily western hemlock and western red cedar. Some snags are in the adjacent area, however, the adjacent forest to be appears healthy.
18	Kyle Creek	This overstory in this area is dominated by broadleaf maple and red alder with a well-developed understory. The adjacent forest appears to be healthy.
19	Kyle Creek	This area is a stable forest with a mix of western hemlock, red alder, broadleaf maple and the occasional Douglas-fir and snag in the main canopy. The understory is well developed. The adjacent forest appears to be healthy.

Site	Drainage	Forest Description
20	Kyle Creek	This site is located adjacent to private property. The forest in this area is somewhat open grown and highly mixed with western hemlock, western red cedar, red alder and broadleaf maple. One of the red alder appears as though it could soon fall on a coach house on the property. We suggest a danger tree assessment be completed on this site. Otherwise, the adjacent forest appears to be healthy.
21	Dallas Creek	This site is adjacent to the creek and surrounded by housing. The canopy on the east side of the creek is dominated by western hemlock, western red cedar. The west side of the creek is comprised of red alder and broadleaf maple, and there is some evidence of die-back. We recommend a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for risk to private property and public safety.
22	Elginhouse Creek	This site is located below the adjacent houses. The forest is open grown with several large broadleaf maple's dominating the canopy, with western hemlock and western red cedar. The area has a well established understory that is ready to succeed when broadleaf maple dies out. The adjacent forest appears to be healthy.
23	Elginhouse Creek	The forest is open grown, dominated by maple and red alder. The understory is well established and dominated by red alder and western hemlock. The adjacent forest appears to be healthy.
24	Elginhouse Creek	The forest in this area is multi-layer, open grown, and leading in western hemlock. There is a higher incidence of snags and downed coniferous species than observed in this assessment. This is likely the result of increased exposure in this area, but could be disease as well. We recommend a danger tree assessment be completed for trees posing a risk to public safety and that this area be monitored for risk to private property and public safety.
25	Williams Creek	This site is in an open grown riparian area situated between two developments. The forest is dominated by red alder and western hemlock with some broadleaf maple. Despite the proximity to the developments, this area poses a low public risk.
26	Williams Creek	This site is less than 100 m west of houses in a patch of immature red alder. The forest to the west is dominated by red alder, western hemlock and broadleaf maple, with a well established understory. This area poses a low public risk because trees should fall towards the gully and away from houses.
27	Williams Creek	This site is upslope of the riparian area in a large climax broadleaf maple area with a poorly established western hemlock and western red cedar understory. The adjacent forest appears to be healthy.
28	Goulet Creek	This site contains a mature open grown broadleaf maple forest with western hemlock. Western hemlock and red alder comprise the intermediate layer. There are some trees with broken tops adjacent to the site, though the site appears to be healthy and low risk.
29	Goulet Creek	This observation point was located in the power line extending north from the Poirier street cul de sac. There were no observed forest health risks.

Site	Drainage	Forest Description
30	East Sundial Creek	At the confluence of the 2 creeks, the forest is an open grown broadleaf maple stand, with lesser amounts of red alder, western hemlock and western red cedar. The intermediate canopy is a mix of western hemlock and western red cedar. The adjacent forest appears to be healthy.
31	East Sundial Creek	The forest is an open grown broadleaf maple stand, with lesser amounts of red alder, western hemlock and western red cedar. The canopy structure is complex with a mix of western hemlock and western red cedar. The adjacent forest appears to be healthy.
32	West Sundial Creek	The forest is an open grown broadleaf maple stand, with lesser amounts of red alder, western hemlock and western red cedar. The canopy structure is complex with a mix of western hemlock and western red cedar. The adjacent forest appears to be healthy.
33	West Sundial Creek	Terrain flattens out into an open-grown red alder forest that is in its climax stage. There is western hemlock in the intermediate and understory layers.
34	Hatchley Creek	The riparian area is a mixed, open grown, complex stand structure. The deciduous species appear to be dying out and western hemlock and western red cedar are expressing itself in the understory and intermediate layers. The adjacent forest appears to be healthy.
35	Hatchley Creek	This is an open grown, multi-storied stand structure. Mature Douglas-fir are abundant on both banks of the river. The intermediate layer is largely Douglas-fir, with broadleaf maple, western hemlock and western red cedar.

We also identified areas that in a climax (old growth) growing condition as trees in this growth stage are nearing the end of their life and could potentially pose a risk to the public.

Results and Discussion

Climax tree species in the CWHdm1 are typically western hemlock and western red cedar, with isolated Douglas-fir occurring in drier areas. Broadleaf maple and red alder are also prevalent throughout these forest types. The maximum age of western hemlock is typically over 400 years and western red cedar often reaches ages of 800 to 1,000 years[7]. Broadleaf maple grows to approximately 200 years and red alder is a relatively short-lived species with a maximum age of about 100 years[8]. Red alder is typically an early successional species, meaning, it tends to be the first species to occupy a site following disturbance (such as fire) and over time is out-competed by species such as western hemlock and western red cedar. Being shade intolerant, red alder tends to die soon after light resources are taken away.

[7]http://www.na.fs.fed.us/spfo/pubs/silvics_manual/volume_1
[8]http://www.na.fs.fed.us/spfo/pubs/silvics_manual/volume_2

All of the species identified above were prevalent throughout the Project Area. The 35 sites visited showed a diverse array of second growth forest types and it appeared that there was large scale disturbance approximately 100 years ago. The assessment area was separated into the following dominant forest types:

- Upper slope, coniferous forest with open deciduous patches;
- Mid-slope, coniferous forest with open deciduous patches;
- Riparian, deciduous forest; and
- Mixed forest bordering private property.

Forest types commonly observed on the upper slopes tended to be healthy, fairly dense, single layer canopy forests with a poor to moderately well-developed intermediate layer. These sites were typically leading in western hemlock with western red cedar, lesser tree canopy components of deciduous species and isolated Douglas-fir trees. These areas also included small, open patches dominated by red alder and/or broadleaf maple. These forest types appeared to be young and healthy and appear to pose little risk to the public.

Mid-slope forests were similar to those observed on the upper slopes; however, there were fewer Douglas-fir observations. These forest types also appeared to be young, healthy and posed little risk to the public.

The lower slope areas were divided into two forest types: forests occurring along the riparian areas within the ravines and forests occurring along the northern portion of the Project Area that interfaces with private property. Riparian forests within the ravines are typical of moist, water receiving sites in the CWHdm subzone. Most were open grown and dominated by large deciduous trees (typically broadleaf maple) with a wide range of distributions of western hemlock and western red cedar in the intermediate tree canopy and understory layers. Because these stand types are approaching their climax condition, some will experience die-back and be replaced by western hemlock and western red cedar currently growing in the intermediate layer. Deciduous trees within ravines that have moderate to high public use should undergo a danger tree assessment and be monitored over time for potential risk to public safety. Deciduous trees in ravines with little public use pose little danger to the public.

The northern portion of the Project Area that interfaces with private property is comprised of a range of coniferous (i.e., western hemlock with western red cedar) and deciduous leading forest types. Deciduous stand types are approaching their climax condition and will experience die-back and be replaced by species currently in the intermediate layer. The coniferous forests are relatively stable and, other than large wind events and disease outbreak, should experience little significant change for several decades. The forests along the northern portion of the Project Area interfacing with private property should undergo a danger tree assessment and be monitored for risk to public safety. This is particularly true of the deciduous forest types located at Sites 11 to 14, along the interface with private property, where the forest is nearing its climax condition.

Discussion

As a result of this assessment, we believe the following actions should be taken:

1. Complete forest typing of the deciduous forest that interfaces with the public, whether the proximity is close to private property or public trails. Include in this typing both an updated trail map and identify private property so that there is a clear understanding of the potential risk to the public.
2. Using a certified danger tree assessor, complete a danger tree assessment of the Project Area within approximately 75 m of private property and 75 m on either side of trails. Remove any trees that are deemed a danger to the public.
3. Monitor forest health in the areas that interface with the public to identify potentially hazardous trees. As part of this initiative, have a certified danger tree assessor complete a danger tree assessment every three to five years to ensure public safety.

References

Pojar, J., K. Klinka, D.A. Demarchi. 1991. Chapter 6: Coastal Western Hemlock Zone. In D. Meidinger and J. Pojar (Eds.), Ecosystems of British Columbia (pp. 95-124). Victoria: BC Ministry of Forests.

A.1.5 Terrestrial Ecological Restoration

Currently, the most common invasives observed within the Chines are Japanese knotweed, false lamium and English ivy. To a lesser extent, morning glory (*Convolvulus arvensis*) and holly (*Ilex aquifolium*) are also spreading from a large number of backyards.

The BC Ministry of Agriculture and Lands upgraded Japanese knotweed to provincially noxious and is now recognized as a species to control under the BC Weed Control Act (BCMA 2011). The Act states that any weed species identified must be controlled by the owner of the land on which it occurs. Several districts and municipalities throughout the Lower Mainland are employing a variety of control measures against knotweed, with varying degrees of success. It is recommended that stem-injection of glyphosate be applied to the patches of knotweed. Because knotweed spreads through rhizomes rather than through seed germination, foliar spraying and regular cutting does not kill the entire population. It merely suppresses individual plants temporarily. The BC guidelines for control of knotweed provides directions on how to administer the stem injection (SSISC 2010).

While not listed as noxious, English ivy is a highly aggressive invasive, outcompeting most native forbs and shrubs. Because of its extensive woody root system and ability to propagate from a single leaf, the removal of English ivy is most effective through hand-pulling methods. This method is normally repeated through several consecutive years. For example, the Lighthouse Park Preservation Society in West Vancouver has organized volunteer ivy pulls since 1998. This has successfully eliminated ivy from numerous areas within the park with no evidence of reintroduction. In addition to direct removal, is the necessary increase in public awareness and stewardship practices employed by individual land owners within the Chines.

False lamium is a frequent addition to potted plants and hanging baskets, and takes regularly to spreading into native ecosystems. Unfortunately, the success of broadcast spraying and stem injection is limited. The greatest success to removing this plant is painting glyphosate onto individual leaves (D. Beard pers. com. 2011). Because of the extent of infestation, using glyphosate in conjunction with hand-removal is recommended to minimize the time required to permanently remove this plant.

Morning glory and English holly are not as invasive as the other species mentioned here, and hand-removal is an effective method of control.

Once the patches of weeds are removed, replant with native plants suitable for each site, such as red huckleberry, salmonberry, tall Oregon grape, salal (*Gaultheria shallon*) or snowberry (*Symphoricarpus alba*). It is highly recommended to plant with species that will spread rapidly to prevent the infestation of weeds into the newly restored areas. Detailed site-specific restoration plans for the infested sites can be provided by request.

Suggested approaches to managing invasive plant species include repeated stem-injections with glyphosate for Japanese knotweed, hand pulling of ivy and periwinkle and direct application of glyphosate on lamium (conducted within the dry season).

A.2 AQUATIC ASSESSMENT

A.2.1 Aquatic Habitat Field Assessment

The aquatic assessment was conducted on June 1, 2, and 29, 2011 to assess the current aquatic habitat and to identify specific issues related to erosion, bank instability and barriers to fish movement. Inventory methods generally followed those established by the Resource Inventory Standards Committee (RISC) in the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (v. 2.0; RIC April 2001). Points of interest were geo-referenced in the field using GPS. Attributes of the open channel were characterized for specific stream reaches. Stream reaches were based on gradient breaks, shifts in substrate composition or other hydrological or morphological features, such as concentration points of erosion or channel barriers. Stream reaches were assessed on foot and detailed information was collected, including:

- Channel morphology
- Wetted width and depth, and bank width and depth
- Substrate composition
- Habitat values and problems
- Fish presence and barriers to fish movement
- Riparian characteristics
- Habitat enhancement opportunities
- Water quality

Seven creeks located within the Chines were assessed (travelling eastward):

- South Schoolhouse Creek
- Noble Creek
- Ottley Creek
- Hatchley Creek
- Sundial Creek (east and west branch)
- Goulet Creek

Within the Chines, the creek systems with associated tributaries are South Schoolhouse Creek, the “Chines” Creeks, Slaughterhouse Creek and Suter Brook Creeks, as described in Table A-8.

Table A-8
Summary of Watercourses within the Project Area

Creek System	Tributaries Within the System
South Schoolhouse Creek	Melrose Creek
	Clark Road Tributary of South Schoolhouse Creek
	South Schoolhouse Creek
	Noble Creek
Kyle Creek	Ottley Creek
	Axford Creek
	Kyle Creek
	Hatchley Creek
	West Sundial Creek
	East Sundial Creek
	Goulet Creek
Slaughterhouse Creek	Williams Creek
	Elginhouse Creek
	Correl Brook
	Dallas Creek
Suter Brook	Pigeon Creek
	Suter Brook

A.2.2 Surface Water Quality and Resources

Watercourses in urban and residential areas are often impacted by stormwater runoff and human activities which can degrade the quality of water. Given the amount of residential and urban activity within the watershed, water quality could be an issue without proper mitigation. Baseline *in situ* water quality data (temperature, dissolved oxygen, conductivity, pH, salinity and oxidation-reduction potential i.e. ORP) were collected at select locations on July 22, 2011; water quality sampling locations are shown on Figure A-3 and results are provided in Table A-9. Water quality results were within the range of the Ambient Water Quality Objectives for Burrard Inlet Coquitlam-Pitt River Area (Ministry of Environment, 1990) for pH (6.5-8.5) and dissolved oxygen (minimum 6.5 mg/L), with the exception of the pH of WQ1 which was slightly below the water quality objective. Temperatures measured at water quality stations met the BC Ministry of Environment Environmental Protection Division Water Quality Guidelines for Temperature (2001) for streams with unknown fish distributions (mean weekly maximum temperature of 18ºC) and for rearing of cutthroat trout (7.0-16.0ºC), Coho salmon (9.0-16.0ºC) and chum salmon (12.0-14.0ºC).

Table A-9
***In situ* Water Quality, July 22, 2011**

Location	Temperature (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	ORP (mV)
WQ-1	12.25	6.13	260	0.12	116.3	12.30	253.1
WQ-2	12.43	6.61	160	0.08	106.4	11.35	228.5
WQ-3	12.39	6.94	159	0.08	104.3	11.13	220.3
WQ-4	11.90	7.44	151	0.07	109.6	11.84	209.8
WQ-5	12.10	7.15	115	0.05	103.7	11.13	203.4
WQ-6	12.46	7.18	140	0.07	104.2	11.04	201.4
WQ-7	12.11	7.13	146	0.07	108.4	11.62	208.1
WQ-8	12.02	7.16	127	0.06	109.3	11.75	200.5
WQ-9	12.22	7.35	150	0.07	107.7	11.47	188.2
WQ-10	11.84	7.18	108	0.05	106.4	11.49	185.8
WQ-11	12.63	7.19	125	0.06	104.9	11.12	183.1
WQ-12	12.03	7.33	153	0.07	99.4	10.70	183.9
WQ-13	12.54	7.00	122	0.06	104.8	11.16	183.3
WQ-14	12.77	7.10	167	0.08	105.9	11.21	143.7
WQ-15	13.65	7.20	146	0.07	103.2	10.76	124.3
WQ-16	13.43	6.76	162	0.08	99.4	10.36	77.6
WQ-17	13.92	6.60	158	0.07	78.4	8.09	74.6
WQ-18	13.95	6.84	155	0.07	87.2	8.90	70.5
WQ-19	Suter Brook	13.68	7.30	223	124.4	12.88	109.0
WQ-20	Suter Brook	13.50	7.62	218	207.8	21.48	103.3
WQ-21	Suter Brook	13.72	7.67	226	140.7	4.60	143.2
WQ-22	Suter Brook	14.23	7.71	253	97.5	10.02	123.3
WQ-23	Suter Brook	16.76	7.56	391	58.9	5.74	126.9
WQ-24	Suter Brook	14.61	7.78	307	72.9	7.35	219.3
WQ-25	Pigeon Creek	13.31	7.73	172	178.5	18.65	110.8
WQ-26	Suter Brook	16.73	7.38	1168	55.5	5.54	141.1

ºC = degrees Celsius   µs/cm = microsiemens per centimetre   ppt = parts per thousand
mg/L = milligrams per litre   mV = millivolts

A.2.3 Stream Classifications

Watercourses in Port Moody and Coquitlam are divided into four classifications which are based on fish presence, duration and source of water, and surrounding vegetation potential. The classification system was developed by the City of Surrey, Envirowest Consultants Ltd. and MELP Region 2 (now MOE) Fisheries staff. Table A-10 summarizes the stream classification system used by the City of Port Moody and Coquitlam.

Table A-10
Watercourse Classification System

Classification/Colour Code	Description
Class A – Solid red	Watercourses inhabited by salmonids and/or rare or endangered fish species, or potentially inhabited by such fish with access enhancement (e.g. removal of culverts).
Class A (O) – Red dashed	Watercourses inhabited by salmonids and/or rare or endangered fish species, during the overwintering period, or potentially inhabited during the overwintering period, or potentially inhabited during the overwintering period with access enhancement.
Class B – Yellow	Watercourses that are a significant (as defined by MELP, 1999) source or potentially significant source of food and nutrients to downstream fish populations. These watersheds are characterized by no fish presence and no reasonable potential for fish presence through flow or access enhancement.
Class C – Green	Watercourses that provide an insignificant contribution of food or nutrients to downstream areas supporting or potentially supporting fish populations.

Within the Project Area, the major watercourses are classified as summarized below as shown in Table A-11 and Figure A-4. It should be noted the stream classifications are for the remaining open channel (i.e. non-piped) portions of the creeks. Pipes and culverted portions of the creeks may preclude fish passage from the lowland areas into the upland areas. Preliminary watercourse classifications are appropriate for watercourses within the Chines.

Table A-11
Stream Classifications for Chines Watershed

Watercourse	Classification
South Schoolhouse Creek Drainage System	
Clark Road Tributary of South Schoolhouse Creek	Class B (Yellow)
South Schoolhouse Creek	Class A (Red)
Noble Creek	Class B (Yellow)
Slaughterhouse/Dallas Creek Drainage System	
Williams Creek	Class B (Yellow)
Elginhouse Creek	Class B (Yellow)
Correl Brook	Class A (Red)
Dallas Creek	Class A (Red)
Watercourse	**Classification**
Suter Brook and Pigeon Creek Drainage Systems	
Suter Brook	Class A (Red) Class B (Yellow) at headwaters
Pigeon Creek	Class A (Red) Class B (Yellow) at headwaters

A.2.4 Fish and Fish Habitat

The ravines are in a very natural state and support a mixed, mature deciduous and coniferous forest. The overall salmonid productive capacity is rated moderate, based primarily on good rearing habitat, but a lack of adequate spawning gravels and presence of migration barriers. The lack of deep pools, riffles and refuge habitat (such as side channels or backwater pools) in some areas also limits overwintering and rearing habitat.

Fish species listed on the Ministry of Environment Habitat Wizard, the DFO Lower Fraser Valley Streams Strategic Review and in the Port Moody ESA Phase 2 Report (Robertson Environmental Services Ltd., 2000) for the Chines are listed in Table A-12. Fish presence information included in the Port Moody ESA Phase 2 Report was collected by reviewing applicable reports available from the City of Port Moody files, Coast River Environmental Services files, Port Moody Ecological Society library, Port Moody library, Mossom Creek Hatchery and the Ministry of Environment, Lands and Parks Region 2 (MELP, now the Ministry of Environment, MOE), as well as information provided from Port Moody, GVRD, MOE and DFO staff and stewardship groups.

Table A-12
Fish Presence in the Chines

Watercourse	Fish Species Present
South Schoolhouse Creek Drainage System	
Melrose Creek	Cutthroat trout (*O. clarkii*)
Clark Road Tributary of South Schoolhouse Creek	No fish present
South Schoolhouse Creek	Coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), cutthroat trout, sculpin (*Cottus* sp.)[9]
Noble Creek	No fish present
Kyle Creek Drainage System	
Ottley Creek	No fish present
Axford Creek	No fish present
Kyle Creek	No fish present
Hatchley Creek	No fish present
West Sundial Creek	Unknown (cutthroat trout possible)
East Sundial Creek	Unknown (cutthroat trout possible)
Watercourse	**Fish Species Present**
Goulet Creek	Cutthroat trout
Slaughterhouse/Dallas Creek Drainage System	
Williams Creek	No fish present
Elginhouse Creek	No fish present

[9] Ministry of Environment Habitat Wizard

Watercourse	Fish Species Present
Correl Brook	Cutthroat trout
Dallas Creek	Cutthroat trout
Pigeon Creek and Suter Brook Drainage Systems	
Suter Brook	Cutthrout trout (O. clarkii), Coho salmon (Oncorhynchus kisutch), chum salmon (O. keta).
Pigeon Creek	Cutthrout trout (O. clarkii), Coho salmon (Oncorhynchus kisutch), chum salmon (O. keta).

During the field assessments, salmonids were observed in the upper portion of South Schoolhouse Creek (within Miller Park), as well as lower South Schoolhouse Creek.

The majority of lowland culverts and the piped systempreclude fish access to areas below the ravines. Debris control structures (i.e., trash racks) are installed at most road crossings over creeks and may preclude fish access at lower flows due to organic and domestic debris clogging the structures. In the ravines, gradients are typically too steep for fish access and are steep enough to create a velocity barrier to fish migration (greater than 20%, based on the Forest Practices Code).

Benthic Invertebrates

Macro-invertebrates were collected following the CABIN protocol on September 11 and 12, 2011 by Living Streams Environmental Services. A 3-minute travelling 400 μm kicknet was used to collect the sample and the invertebrates were preserved in the field in 10% buffered formalin at a ratio of 1:3.

Each sampling site was located upstream of St. Johns Street and the culverted section leading to Burrard Inlet. Care was taken to avoid collecting samples in areas with potential creek bed disturbance (e.g. stormwater retention basin and trail crossing). Substrate and channel measurements were also taken *in situ*, such as water depth, wetted and bankfull width and hundred pebble count.

Taxonomic identification of the organisms was performed by a taxonomist certified by the Society for Freshwater Science (Formerly North American Benthological Society). Each organism was identified using a 3.5x – 45x dissecting microscope and/or 40x - 1600x compound microscope, as well as appropriate identification keys.

The taxonomic identification was performed to the lowest practical taxonomic level defined by the availability of keys for different groups (Plotnikoff and White, 1996).

Most of the creeks sampled for our study appeared to be in “fair condition”, with total B-IBI scores ranging from 28 to 32. However, both Sundial Creek east and west branches were considered to be in “poor condition” with scores of 24 and 22, respectively. The B-IBI scores are summarized in Table A-13.

Table A-13
B-IBI Scores for Streams in Chines

	South Schoolhouse Creek	Noble Creek	Ottley Creek	Hatchley Creek	Sundial West Branch	Sundial East Branch	Goulet Creek
Ephemeroptera richness	5	4	3	3	2	3	3
B-IBI Score	3	1	1	1	1	1	1
Plecoptera Richness	5	6	3	6	4	4	5
B-IBI Score	3	3	1	3	3	3	3
Trichoptera Richness	4	5	5	4	3	2	3
B-IBI Score	1	3	3	1	1	1	1
Total Taxa Richness	27	35	28	32	27	24	28
B-IBI Score	3	5	5	5	3	3	5
Long-lived Taxa Richness	4	5	3	4	4	3	5
B-IBI Score	3	5	3	3	3	3	5
Number of Intolerant Taxa	3	2	3	3	2	3	2
B-IBI Score	3	1	3	3	1	3	1
Clinger Taxa richness	9	13	9	10	8	4	9
B-IBI Score	3	3	3	3	1	1	3
Percent Tolerant Ind.	16.20%	0.00%	0%	0%	0.70%	0%	0.30%
B-IBI Score	5	5	5	5	5	5	5
Percent Dominant 3 Taxa	54.10%	55%	54.60%	60.80%	75.30%	64.30%	57.70%
B-IBI Score	5	5	5	3	3	3	5
Percent Predators Ind.	1.70%	5.9	3.60%	4.00%	1.30%	1.30%	2.80%
B-IBI Score	1	1	1	1	1	1	1
Total B-IBI Score	30	32	30	28	22	24	30
Stream Condition	Fair	Fair	Fair	Fair	Poor	Poor	Fair

Three B-IBI metrics showed particularly low values (=1) overall: Ephemeroptera and Trichoptera richness, as well as percentage of predator individuals. However, most of the metrics are lowered by relatively low pollution sensitive taxa richness, but the metrics indicative of organic pollution (i.e. percent dominant 3 taxa and percent tolerant individuals) show moderate to low signs of disturbance. The small size of the creeks sampled for this project can explain in part some of the low metric scores because of a low habitat complexity and wetted widths generally inferior to 1 m. It is worthy of note that the presence of long-lived taxa in every sample indicates that all the creeks have superficial or sub-surface flow year round.

Previous data available for South Schoolhouse Creek show comparable results to the 2011 study with mean B-IBI scores of 33.5 and 25 for 2006 and 2003, respectively below in Table A-14.

Table A-14
B-IBI Comparisons between Different Years on South Schoolhouse Creek

	2011	2006	2003
B-IBI	30	33.5*	25*
Stream Condition	Fair	Fair	Poor

*Mean values of four composite surber samples.
(Source of 2003 and 2006 data: Rain Coast Applied Ecology).

After taking a closer look at the detailed 2011 macro-invertebrate list, one can notice that eight taxa are only represented by a single individual. However, with such low abundances in certain taxa, B-IBI metrics show a potentially large variability.

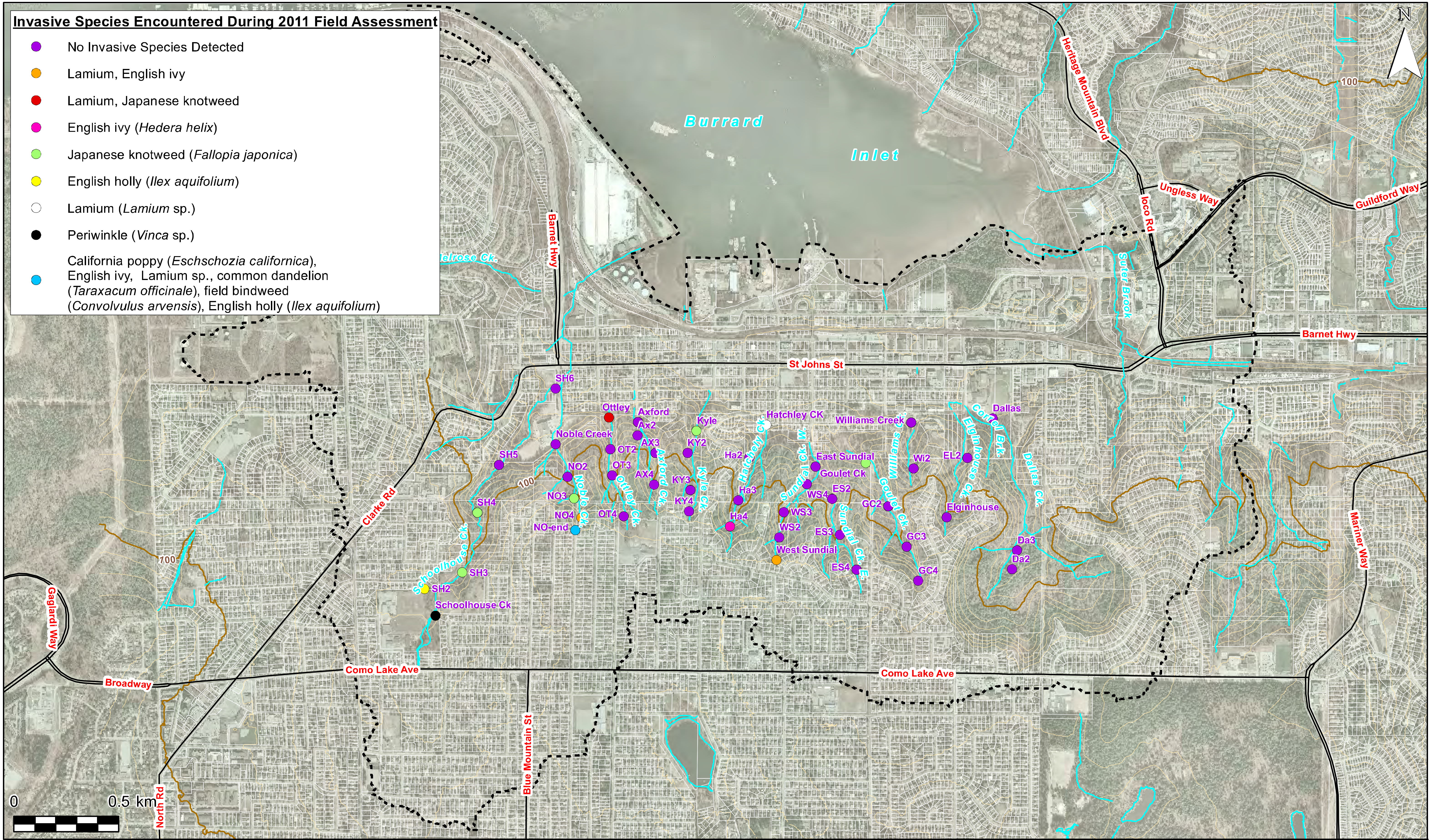
According to a 2006 report by Nick Page (Raincoast Applied Ecology) and Stephanie Strachan (Environment Canada), Surber and kicknet sampling and lab processing methods provide similar estimates of benthic invertebrate community structure. In addition, B-IBI and RCA-CABIN analysis methods also provide similar assessments of biological condition for streams in Greater Vancouver.

A.2.5 Common Watershed Productivity Constraints

Based on current conditions, there are a number of environmental constraints that limit the productivity of the terrestrial and aquatic environments within the Chines.

- Garbage and debris embedded in debris control structures at road crossings as well as, within the riparian areas and upland areas which limit the seasonal movement of fish.
- Deposition of sand and domestic refuse from headwater areas and some lower areas (Dallas Creek, Correl Brook) contribute to downstream sedimentation and a decrease in available habitat for juvenile salmonids and benthic invertebrates.
- Pipes and culverted portions of the creeks preclude fish passage from the lowland areas into the upland areas.
- Heavy rainfall events may cause maximum water capacity within creeks which reduce fish habitat and nutrients. The lack of deep pools and riffles in some areas also limits overwintering and rearing habitat.

Weed infestation from disposal of residential refuse and uncontrolled weeds on private properties is limiting the biodiversity and understory diversity in many of the forests.



Major Roads
Stream
Study Area Boundary

SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

metro vancouver

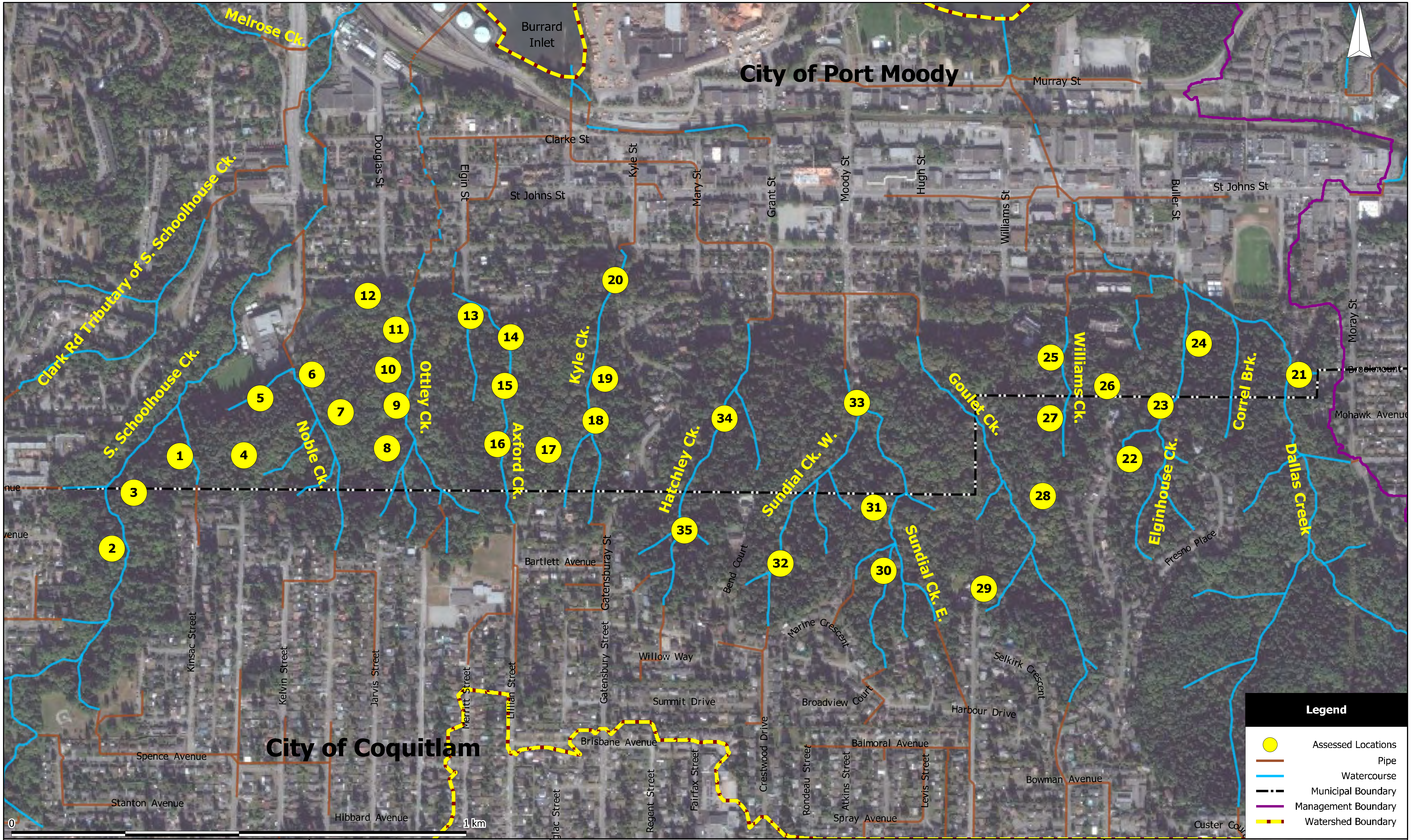
PORT MOODY City of the Arts

Coquitlam

PROJECT:	20112817
DATE:	January 2014
DRAWN BY:	DA

CHINES ISMP

Figure A-1 Terrestrial Assessment



PROJECT NO:	**2011-2817**
SCALE:	**1:7,500**
DATE:	**January 2015**
DESIGNED BY:	**JL**
CHECKED BY:	**MM**

Associated Engineering

PREPARED FOR: metro vancouver · Port Moody City of the Arts · Coquitlam

CHINES ISMP

Figure A-2 Tree Canopy Assessment Sites

Time: 2:03:52 PM | Date: 4/15/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure A-2 Tree Canopy Assessment Sites

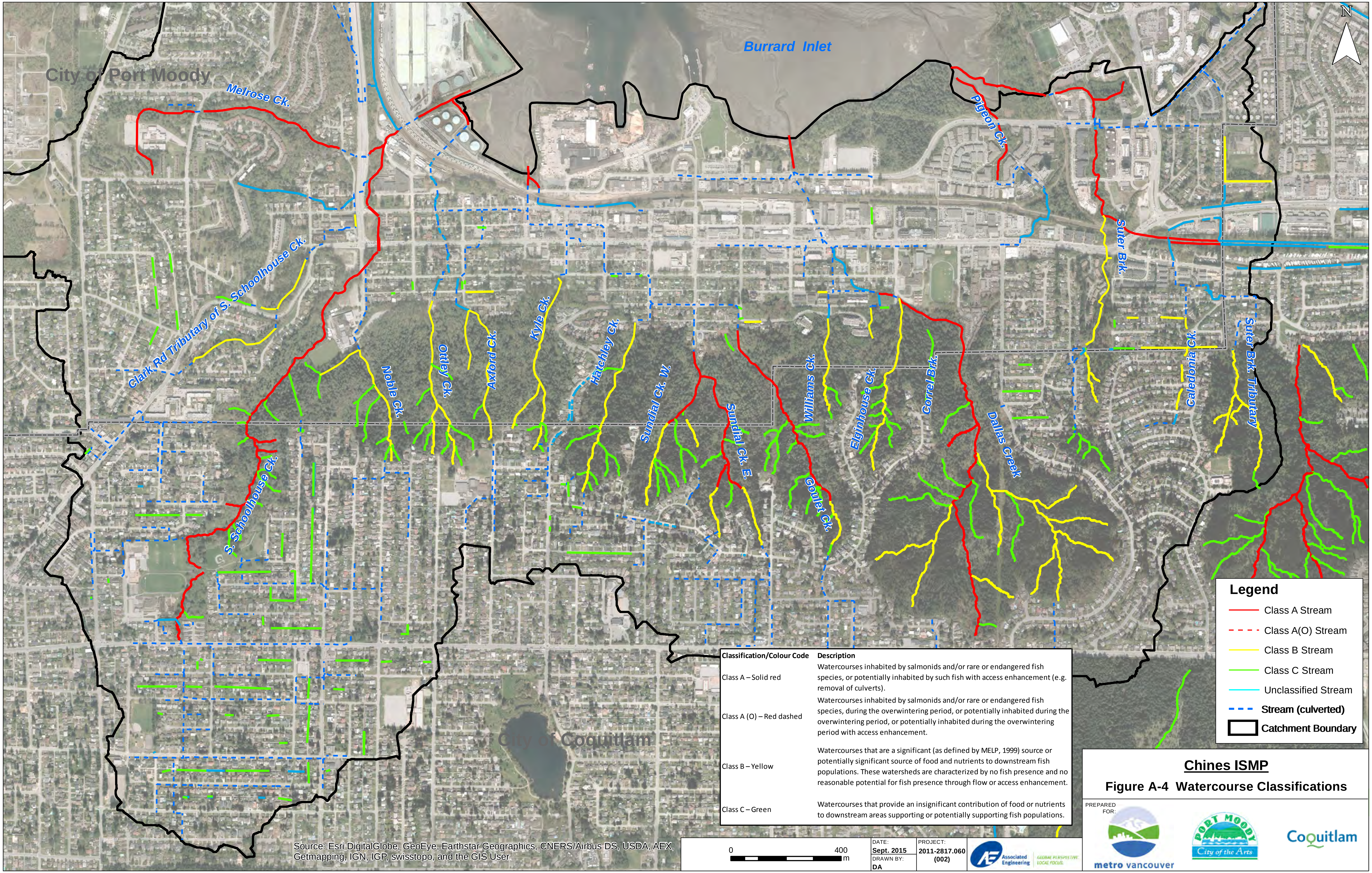
CHINES ISMP

Figure A-3 Water Quality Sites

DATE:	PROJECT:
March 2015	20112817
DRAWN BY: DA	

SUMMIT ENVIRONMENTAL CONSULTANTS INC.

PREPARED FOR: metro vancouver, Port Moody City of the Arts, Coquitlam



Classification/Colour Code	Description
Class A – Solid red	Watercourses inhabited by salmonids and/or rare or endangered fish species, or potentially inhabited by such fish with access enhancement (e.g. removal of culverts).
Class A (O) – Red dashed	Watercourses inhabited by salmonids and/or rare or endangered fish species, during the overwintering period, or potentially inhabited during the overwintering period, or potentially inhabited during the overwintering period with access enhancement.
Class B – Yellow	Watercourses that are a significant (as defined by MELP, 1999) source or potentially significant source of food and nutrients to downstream fish populations. These watersheds are characterized by no fish presence and no reasonable potential for fish presence through flow or access enhancement.
Class C – Green	Watercourses that provide an insignificant contribution of food or nutrients to downstream areas supporting or potentially supporting fish populations.

Chines ISMP

Figure A-4 Watercourse Classifications

Appendix B – Ditch Assessment

Associated Engineering has conducted an inventory and assessment of watercourses (i.e. ditches) for Metro Vancouver in the developed areas of the Chines Watershed in the City of Port Moody and the City of Coquitlam. A summary of the work completed and the results are presented in the following sections.

B.1 INTRODUCTION

Metro Vancouver is currently developing an Integrated Stormwater Management Plan (ISMP) for the Chines Watershed. Discussions regarding the Chines Watershed ISMP Project identified that several watercourses and drainage ditches exist in the watershed. These features carry out important hydrological functions in the watershed, such as conveying stormwater, regulating surface water flow rates, and allowing surface water to infiltrate the ground. The ditches also play important ecological roles in the watershed, as they improve water quality (e.g. filtering contaminants, reducing erosion, and facilitating ground infiltration), provide food and nutrients (i.e. leaf litter, organics, invertebrates) to downstream fish-bearing habitats, and provide habitat for fish and wildlife. Metro Vancouver retained Associated Engineering to complete an inventory and assessment of roadside watercourses (i.e. drainage ditches) in developed areas of the watershed to evaluate the existing conditions, ecological functions, and habitat value of these watercourses.

B.2 METHODS

An inventory of the ditches in the watershed was completed on May 9 and 10, 2013. This was done by driving through developed areas of the watershed to locate known ditches on maps of the cities of Coquitlam and Port Moody, and by identifying any ditches in these zones that have not yet been mapped. A unique identifier was assigned to each inventoried ditch, and each ditch was geo-referenced and photographed.

Field assessments of the identified ditches were completed on June 27, 2013 and on February 7 and 11, 2014. These assessments consisted of characterizing the habitat and recording the measurements of each ditch. Habitat data were collected following steps noted in the document entitled, Reconnaissance (1:20,000) Fish and Fish Habitat Inventory Standards and Procedures, published by the B.C. Resource Inventory Standards Committee[10]. The following habitat data were collected:

- channel dimension (channel width, bankfull depth);
- surface water (wetted width, water depth);
- substrate composition;
- riparian vegetation composition;
- riparian vegetation canopy closure;
- observations of fish; and
- barriers to fish movement and connectivity to stormwater system or other watercourses.

[10] Resource Inventory Standards Committee (RISC). 2001. Reconnaissance (1:20,000) fish and fish habitat inventory: standards and procedures, Version 2.0. Prepared by B.C. Fisheries Information Services Branch for the Resource Inventory Committee. Available at: http://www.for.gov.bc.ca/hts/risc/pubs/aquatic/recon/recce2c.pdf

All habitat measurements and observations were recorded in field notes. In addition to the photograph of each watercourse, any notable habitat features or barriers were also photographed.

Watercourse classifications have been developed for B.C.'s Lower Mainland to rate these watercourses based on fish presence, permanence of water flow, existing or potential riparian vegetation, and overall habitat value[11]. The City of Coquitlam watercourse mapping includes a classification system that specifies six designations[12]. Five watercourse classifications have been developed as part of the Chines Creek ISMP that are generally consistent with the City of Coquitlam classifications and other classification systems in the Lower Mainland. These classifications and their associated mapping colour codes are as follows, with the corresponding City of Coquitlam classifications in *italics*:

- **Class A (solid red)** - *Fish-bearing*: Watercourses that are inhabited by salmonids and/or rare or endangered fish species year round, or that have the potential to be inhabited year round by such with access enhancement;
- **Class A(O) (red dashed)** - *Fish-bearing (Potential)*: Watercourses that are inhabited by salmonids and/or rare or endangered fish species during the overwintering period, or that are potentially inhabited during the overwintering period with access enhancement;
- **Class B (yellow)** - *Non-fish-bearing (Permanent) and Non-fish-bearing (Non-permanent)*: Watercourses that are significant or potentially significant sources of food and nutrients to downstream fish populations;
- **Class C (green)** - *Non-fish habitat*: Watercourses that provide an insignificant contribution of food or nutrients to downstream areas that support or potentially support fish populations; and
- **Unclassified (blue)** - *Unclassified*.

Non-fish bearing Permanent and *Non-permanent* watercourse classifications designated by the City of Coquitlam were grouped together as *Non-fish bearing*, or Class B (Yellow) watercourses because permanence of flows could not be accurately determined in these watercourses based on a single site visit, and for consistency with previous watercourse classification mapping done as part of the Chines Watershed ISMP Project.

B.3 RESULTS

Eighty-two ditch locations in the Chines Watershed were inventoried and assessed. The conditions, habitat characteristics and assigned watercourse classification of each of the 82 inventoried ditch locations are provided in sections below and summarized in Table B-1. Eight sites that had been previously mapped as ditches are now paved; no ditches were observed at these sites during the surveys. These are described as

[11] Ministry of Environment, Lands, and Parks. 1998. Classification System for Lower Mainland Watercourses.

[12] City of Coquitlam. 2014. Q the map. Available at: http://www.coquitlam.ca/city-services/city-maps.aspx

“No ditch present. Stormwater drainage only” in Table B-1. Locations and classification of the 82 inventoried ditches are presented in Figure B-1.

B.3 RESULTS

Eighty-two ditch locations in the Chines Watershed were inventoried and assessed. The conditions, habitat characteristics and assigned watercourse classification of each of the 82 inventoried ditch locations are provided in sections below and summarized in Table B-1. Eight sites that had been previously mapped as ditches are now paved; no ditches were observed at these sites during the surveys. These are described as “No ditch present. Stormwater drainage only” in Table B-1. Locations and classification of the 82 inventoried ditches are presented in Figure B-1.

Table B-1: Summary of Ditch Assessment

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp)[4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D1	Balmoral Ave - east side, north of Palmer Ave	1.9	0.6	0.07	0.37	0.01	F/O	50G, 25S, 25T	30	B
D2	Palmer Ave - north side, east of Balmoral Dr	1.6	0.5	0.18	0.3	0.01	F/O	50G, 30S, 20T	20	B
D3	Alley west of Hope St and Viewmount Dr	1.2	0.4	0.17	0.35	0.01	O/F	30G, 45S, 25T	30	B
D4	Elgin St - east side, south of St. George	1.6	0.6	n/a	0.3	n/a	O/F	100G	0	C
D5	Elgin St - west side, south of St. George	1.55	0.3	n/a	0.35	n/a	F/O	80G, 10S, 10T	5	C
D6	Hope St - south side, east of Elgin St	1.25	0.65	0.35	0.4	0.03	F/O	50G, 40S, 10T	20	B
D7	Douglas St, south of St. George	1.8	0.45	n/a	0.55	n/a	O	70G, 30T	0	C
D8	Hope St, east of Douglas St	0.7	0.3	n/a	0.2	n/a	O	70G, 30S	0	C
D9	Jane St - north side, east of Hugh St	1.2	0.7	0.7	0.25	0.035	F/O	75G, 25S	0	B
D10	Hugh St - east side, north of Jane St	1.95	0.7	n/a	0.5	n/a	O	100G	0	C
D11	Hugh St - west side, north of Jane St	1.45	0.55	n/a	0.4	n/a	O	100G	5	C
D12	Hope St - south side	1.4	0.6	0.4	0.5	0.025	F/O	50G, 50S	20	B
D13	Henry St - north side, west of Buller St	1.6	0.8	n/a	0.3	n/a	O	50G, 25S, 25T	50	C

Notes:

1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd) [3]	Riparian Veg. (% comp) [4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB1	BOB2	Wetted	Bankfull	Water				
D14	St. George St - south side, west of Grant St	1.4	0.5	n/a	0.4	n/a	O	100G	0	C
D15	St. George St - south side, east of Mary St	2.1	0.5	n/a	0.35	n/a	O	100G	0	C
D16	Electronic Ave - east side, north of Spring St and St Johns	2.1	0.6	n/a	0.8	n/a	O	75G, 25S	10	C
D17	Spring St, east of Elgin St	1.3	0.4	n/a	0.4	n/a	O	100G	0	C
D18	Alley south of east end of Valley Dr north to Mt Royal	1.4	0.52	0.42	0.43	0.03	F/O	85G, 10S, 5T	0	C
D19	Tuxedo Dr north of Mt Royal to pathway	1.5	0.5	0.07	0.32	0.01	F/O	85G, 10S, 5T	10	C
D20	Harbour Dr, east of Crestwood Dr	0.88	0.22	0.07	0.2	0.01	F/O	95G, 5T	5	C
D21	Harbour Dr, east of Bayview Ct	1.5	0.4	n/a	0.18	n/a	O/F	100G	0	C
D22	Summit Dr, west of Crestwood Dr	1.7	0.3	n/a	0.2	n/a	O/F	95G, 5S	1	C
D23	Gatensbury, N of Willow St	1.5	0.4	n/a	0.25	n/a	O/F	100G	0	C
D24	Gatensbury, S of Willow St	1.7	0.4	n/a	0.3	n/a	O/F	95G, 5S	0	C
D25	Bayview Ct, north of Harbour St	1.2	0.2	0.01	0.2	0.01	O/F	100G	0	C
D26	Bayview Ct, east of Gatensbury	1.85	0.28	n/a	0.325	n/a	O/F	90G, 10T	10	C

Notes:
1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp) [4]	Riparian Canopy Cl. (%)[5]	Class [6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D27	Alley north of Miller Ave, east of Robinson St	No ditch present. Stormwater drainage only.								
D28	Alley east of Robinson St, south of Miller Avenue at corner	No ditch present. Stormwater drainage only.								
D29	North side of alley, south of Miller Ave	1.82	1.49	n/a	0.43	n/a	O	95G, 5S	0	C
D30	Alley south of Miller Ave, west of Adiron St	1.7	1.19	n/a	0.2	n/a	O/F	70G, 10S, 20T	50	C
D31	Alley west of Grant St, north of Miller Ave - north side	No defined drainage ditch or channel					n/a	n/a	n/a	C
D32	Northeast of end of Chapman Ct	No defined drainage ditch or channel					n/a	n/a	n/a	C
D33	Corner of first alley east of Robinson St, and south of Edgemont Ave	No defined drainage ditch or channel					n/a	n/a	n/a	C
D34	West side of first alley south of Marrison Ave, west of Robinson St at corner	1.09	0.79	n/a	0.25	n/a	O/F	90G, 10t	90	C
D35	Alley west of Blue mountain St, north of Miller Ave	0.81	0.51	n/a	0.18	n/a	O/F	70G, 20S, 10T	10	C
D36	Alley west of Blue mountain St, south of Miller Ave	1.07	0.64	n/a	0.14	n/a		93G, 5S, 2T	5	C

Notes:
1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp)[4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D37	Alley between Kinsac St and Oakview St	1.42	0.76	n/a	0.17	n/a	O/F	89G, 10S, 1T	10	C
D38	Alley between Spence Ave and Miller Park, west of Kinsac St	No defined drainage ditch or channel					n/a	n/a	n/a	C
D39	Alley between Spence Ave and Miller Park, west of Kinsac St	1.41	0.78	n/a	0.18	n/a	O	85G, 15T	15	C
D40	Alley between Spence Ave and Stanton Ave, west of Blue Mt. St	No defined drainage ditch or channel					n/a	n/a	n/a	C
D41	Alley between Spence Ave and Stanton Ave, west of Blue Mt. St	0.89	0.59	n/a	0.08	n/a	O/G	60G, 5S, 35T	30	C
D42	Alley south of Stanton Ave at corner	1	0.53	n/a	7.6	n/a	O	50G, 20S, 30T	40	C
D43	Alley between Stanton Ave and Como Lake Ave, west of Blue Mt. St	1.17	0.7	n/a	0.14	n/a	O/F	90G, 10T	15	C
D44	Alley west of Macintosh St at north end of Macintosh St	No ditch present. Stormwater drainage only.								
D45	1010 Spring Ave	No ditch present. Stormwater drainage only.								
D46	Alley east of Macintosh St, south of Hibbard Ave	0.99	0.6	n/a	0.15	n/a	O/G	80G, 15S, 5T	2	C
D47	1017 Hibbard Ave	No ditch present. Stormwater drainage only.								

Notes:

1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp)[4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D48	Porter St and alley south of Como Lake Ave	No ditch present. Stormwater drainage only.								
D49	Alley between Como Lake Ave and Grover Ave, east of Macintosh St	1.18	0.7	n/a	0.09	n/a	O/F	30G, 70T	60	C
D50	Alley between Como Lake Ave and Grover Ave, west of Macintosh St	1.43	1	n/a	0.21	n/a	O/F	70G, 30T	40	C
D51	Alley between Grover Ave and Regan Ave, east of Blue Mt. St	1.31	0.83	n/a	0.1	n/a	O/F	70G, 30T	30	C
D52	Alley between Pinecrest Ave and Park Ct, east of Moray St	0.3	0.19	n/a	0.2	n/a	O/F	95G, 5S	0	C
D53	Alley between Pinecrest and Park Ct, east of Moray St	1.19	0.64	n/a	0.23	n/a	O/F	95G, 5S	2	C
D54	Alley between Pinecrest Ave and Mohawk Ave, east of Moray St	1.5	0.63	n/a	0.1	n/a	O/F	85G, 5S, 10T	5	C
D55	Alley between Brookmount Ave and Mohawk Ave, east of Moray St	1.38	0.82	n/a	0.11	n/a	O/F	50G, 20S, 30T	25	C
D56	Alley between Viewmount Dr and Corona Ct, east of Brookside park	1.72	0.73	n/a	0.13	n/a	O/F	80G, 20T	15	C
D57	Alley between Viewmount Dr and Corona Ct, east of Brookside park	1.52	0.48	n/a	0.14	n/a	O/F	50G, 45S, 5T	30	B

Notes:

1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp) [4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D58	Alley between Viewmount Dr and Corona Ct, east of Brookside park	1.62	0.64	n/a	0.12	n/a	O	50G, 48S, 2T	25	B
D59	Alley between Viewmount Dr and Corona Ct, east of Brookside park	1.69	0.56	n/a	0.06	n/a	O	60G, 38S, 2T	10	C
D60	Alley between Colinet St and Macintosh St, north of Smith Ave	1.54	0.83	n/a	0.16	n/a	O/F	70G, 20S, 10T	20	C
D61	Alley south of Smith Ave, between Blue Mountain St and Colinet St	1.47	1.12	n/a	0.28	n/a	F/O	75G, 25T	10	C
D62	Alley between Runnymede Ave and Cottonwood Ave, west of Blue Mountain St	1.29	0.68	n/a	0.04	n/a	O	100G	0	C
D63	Alley between Runnymede Ave and Cottonwood Ave, west of Blue Mountain St	No ditch present. Stormwater drainage only.								
D64	Alley between Runnymede Ave and Cottonwood Ave, west of Blue Mountain St	1.38	0.6	0.37	0.12	0.02	F/G	50G, 10G, 40T	40	C
D65	Alley between Runnymede Ave and Cottonwood Ave, west of Blue Mountain St	0.86	0.44	n/a	0.07	n/a	O	85G, 10S, 5T	5	C

Notes:
1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp) [4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D66	Alley between Smith Ave and Runnymede Ave, east of Easterbrook St	1.88	1.26	n/a	0.31	n/a	O/F	90G, 10T	15	C
D67	Alley between Smith Ave and Runnymede Ave, east of Easterbrook St	1.72	1.03	n/a	0.16	n/a	O	75G, 10S, 15T	2	C
D68	Alley between Smith Ave./Runnymede Ave, east of Easterbrook St	1.22	0.84	n/a	0.16	n/a	O/F	50G, 35S, 15T	60	C
D69	Alley between Runnymede Ave and Smith Ave, west of Blue Mountain St	2	0.58	n/a	0.14	n/a	O	90G, 10T	10	C
D70	Alley between Blue Mountain St and Hailey St, south of Regan Ave	1.55	0.98	n/a	0.37	n/a	F/O	90G, 10T	5	C
D71	Alley between Blue Mountain St and Hailey St, north of Regan Ave	1.62	0.75	n/a	0.16	n/a	O/F	80G, 18S, 2T	20	C
D72	Parking lot entrance, south of Como Lake Ave, east of Blue Mountain St	No ditch present. Stormwater drainage only.								
D73	Alley between Como Lake Ave and Grover Ave, west of Hailey St	No defined drainage ditch or channel					n/a	n/a	n/a	C
D74	Alley between Como Lake Ave and Grover Ave, west of Townley St	1.57	0.22	n/a	0.08	n/a	O	60G, 40S	0	C
D75	Alley north of Grover Ave between Townley St and Guiltner St	1.39	0.4	n/a	0.1	n/a	O	60G, 40S	0	C

Notes:

1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

Ditch ID	Location	Avg. Width (m)			Avg. Depth (m)		Substrate (Dom/Subd)[3]	Riparian Veg. (% comp) [4]	Riparian Canopy Cl. (%)[5]	Class[6]
		TOB[1]	BOB[2]	Wetted	Bankfull	Water				
D76	Alley between Grover Ave and Regan Ave, east of Guiltner St	1.15	0.76	n/a	0.2	n/a	O/F	90G, 10T	2	C
D77	Alley between Grover Ave and Regan Ave, west of Townley St	1.25	0.35	n/a	0.06	n/a	O	90G, 10T	8	C
D78	Alley between Grover Ave and Regan Ave, east of Townley St	1.52	0.48	n/a	0.07	n/a	O	50G, 35S, 15T	20	C
D79	Alley between Regan Ave and Cornell Ave, west of Hailey St	1.2	0.5	n/a	0.09	n/a	F/O	50G, 30S, 20T	20	C
D80	Alley between Regan Ave and Cornell Ave, east of Townley St	1.75	0.54	n/a	0.14	n/a	F/O	90G, 8S, 2T	20	C
D81	Alley between Regan Ave and Cornell Ave, east of Mountain View Park	1.32	0.3	n/a	0.05	n/a	O	100G	0	C
D82	Alley between Cornell Ave and Smith Ave, west of Hailey St	1.68	0.88	n/a	0.16	n/a	O	95G, 3S, 2T	20	C

Notes:
1. Top of Bank
2. Bottom of Bank
3. Dominant / Subdominant: O – Organic, F – Fines, G – Gravels
4. Riparian Vegetation (% composition): G – Grass, S – Shrubs, T – Trees
5. Riparian Canopy Closure
6. Watercourse Classification

B.3.1 Class B (Yellow) Ditches

Eight of the 82 ditch locations assessed were designated Class B watercourses based on the habitat characteristics observed during the assessment. Class B watercourses are non-fish bearing but provide fish habitat and contribute potentially significant flows and/or food and nutrients to downstream fish populations. The habitat characteristics for individual ditches are summarized in Table B-1, and those for each Class B ditch are described below:

- **D1** is located on Palmer Avenue, east of Balmoral Drive. The bed and banks were covered with grasses, and all but a short section of the ditch (<25 m at the east end) had no defined channel bed or substrate. Minor amounts of fine substrate and water were present at the east end of the ditch, which drains to a culvert at the end of Palmer Avenue. A concrete culvert at the west end of the ditch (at Balmoral Drive) drains to the south. The riparian vegetation observed consisted of grasses, shrubs and trees along the bank that provided approximately 30% canopy closure. Very little water was present at the time of the survey, but the amount of riparian vegetation and leaf litter indicate potential for food and nutrient contribution during high flow events.

- **D2** is located on Balmoral Drive, north of Palmer Avenue. The bed and banks were covered with grasses, and the ditch had no defined channel bed or substrate. The bed was wetted and there were a few pools toward the south end of the ditch. Stormwater system connections consisted of a concrete culvert draining south at the south end of the ditch; no connections were identified at the north end. The riparian vegetation observed consisted of grasses, and a narrow band of shrubs and trees along the bank that provided approximately 20% canopy closure. Water was limited at the time of the survey, but the amount of riparian vegetation and leaf litter indicate potential for food and nutrient contribution during high flow events.

- **D3** is located along an alley west of Hope Street and Viewmount Street. The ditch is comprised of sections that drain to the east and west. The west portion of D3 is a short section with organic and fine substrate, and contained minor volumes of water (i.e. 1 cm depth, 0.3 wetted width) at the time of survey. A concrete pipe drains the ditch at the west end. The riparian area of the eastern portion of D3 was fragmented by sections of large retaining walls and was comprised of grass with interspersed shrubs and trees. The riparian area of the western portion of D3 consisted mainly of shrubs and trees that provided approximately 30% canopy closure. Water flows were limited at the time of the survey, but the amount of riparian vegetation and leaf litter indicate potential for food and nutrient contribution during high flow events.

- **D6** is located on Hope Street, east of Elgin Street. The substrate consisted of sand and fines, with organics. A low volume of water was in the channel (i.e. 3 cm depth, 0.4 m wetted width) at the time of the survey which was draining into a concrete culvert at the east end of D6 (i.e. the corner of Hope and Elgin Street). Based on existing watercourse mapping, it is likely that flows enter an adjacent, partially culverted watercourse to the west via pipes. The observed riparian vegetation consists of roadside grass, as well as shrubs and trees along the opposite bank that provided approximately 20% canopy closure. This watercourse was considered to be Class B based on its proximity to an adjacent watercourse, the presence of substrate and flows, and observed amount of riparian vegetation.

- **D9** is located east of Hugh Street, on the north side of Jane Street. This watercourse consists of two short (approximately 15 m) sections of open ditch that are separated by a section of pipe or culvert approximately 25 m long. There were small concrete culvert inlets and outlets (both approximately 20 cm diameter) at the east and west ends of the ditch. A small amount of water was in the ditch at the time of survey. The channel substrate consisted of fines with some organics, and was overgrown with grasses. The riparian vegetation consisted mainly of grass (75%), and the remainder was shrubs (25%) that provided limited canopy closure and overhanging cover. The amount of riparian vegetation, channel substrate, presence of flowing water, and proximity to a fish-bearing watercourse indicate potential for food and nutrient contributions to fish populations downstream.

- **D12** is a short ditch (approximately 30 m) located along the south side of Hope Street, east of Williams Street. The channel substrate consisted of fines with some organics, and was overgrown with buttercup and grass. A small amount of water was present at the time of the survey, and this flowed west and entered a concrete pipe (approximately 45 cm diameter) at the ditch's west end. The riparian vegetation consisted of equal amounts of grass and shrubs, and the canopy closure was approximately 20%. The amount of riparian vegetation, channel substrate, presence of flowing water, and proximity to an adjacent watercourse indicate potential to provide food and nutrients to fish populations downstream.

- **D57** is a drainage ditch located at the middle of the alley between Viewmount Drive and Corona Crescent, east of Brookside Park. The ditch is approximately 170 m long and drains west into a small storm drain that appears to drain to Caledonia Creek. The riparian vegetation consisted of approximately equal amounts of grass and shrubs, the latter providing 30% canopy closure. The ditch was dry at the time of the survey, but the amount of riparian vegetation and leaf litter present indicate potential for food and nutrient contribution to downstream fish-bearing habitats during high flow events.

- **D58** is located at the east end of the alley between Viewmount Drive and Corona Crescent, east of Brookside Park. This drainage ditch flows into the same storm drain as D57, which appears to drain into Caledonia Creek. The riparian vegetation consisted of equal amounts of grass and shrubs, the latter providing 25% canopy closure. The ditch was dry at the time of survey, but the amount of riparian vegetation and leaf litter present indicate potential for food and nutrient contribution to downstream fish-bearing habitats during high flow events.

B.3.2 Class C (Green) Ditches

Sixty-six of the 82 ditch locations assessed were designated Class C watercourses. Such watercourses are non-fish bearing, do not provide significant contributions of water, food and nutrients to downstream fish populations, and are not considered fish habitat. Class C ditches typically have shallow banks with grass growing throughout their bed and banks, and have no defined channel bed or substrate and no evidence of sustained flow. Cover by riparian vegetation is often limited or absent.

All 66 Class C ditches observed were frequently isolated or separated from fish habitat by long (>150 m) stormwater system connections. Six were flat, grassy roadside areas that had no defined ditch or channel banks. The habitat characteristics for the Class C ditches as observed during the field assessment are summarized in Table B-1.

B.3.3 No Ditch Present

As noted, no ditches were observed at eight of the previously mapped ditch locations among the 82 ditch locations assessed. These sites had been previously mapped as ditches in the City of Coquitlam mapping files. At the time of the survey, most were paved with only catch basins or stormwater drains present. These locations are noted as “No ditch present” in Table B-1.

B.4 SUMMARY AND RECOMMENDATIONS

Future developments in the Chines Watershed may involve work in or around the various watercourses, ditches and stormwater system components. Environmental protection and mitigation requirements and regulatory permitting will be a part of any future development plans.

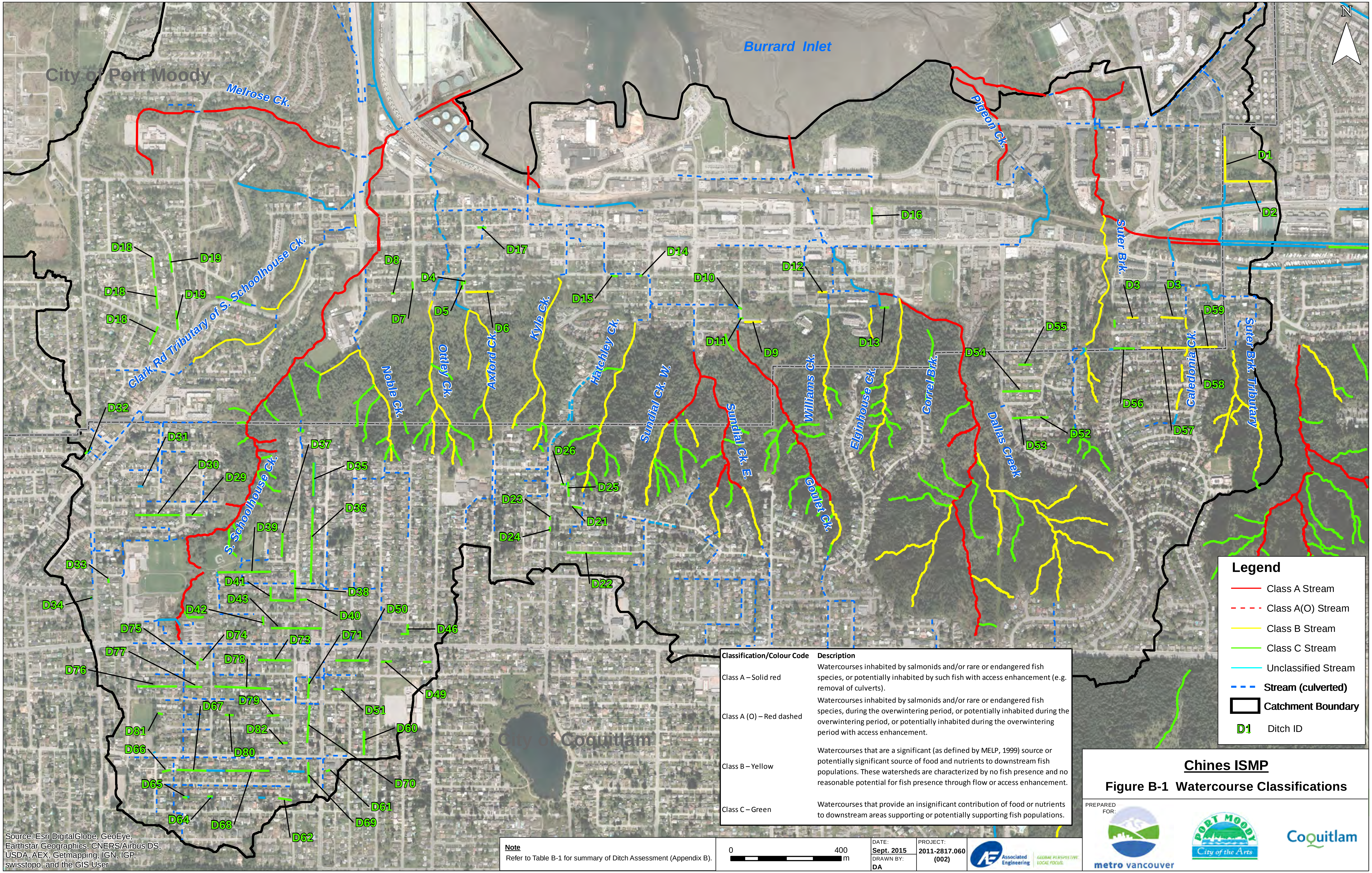
The ditch inventory and assessment completed by Summit and summarized in this report included an assessment of habitat characteristics and ecological values for each ditch. A watercourse classification was assigned to each ditch, indicating the overall habitat value and level of sensitivity for each ditch location. Eight Class B and 66 Class C watercourses were identified during the assessment.

The recommendations regarding environmental protection and mitigation, and regulatory permitting processes and requirements for each classification are as follows:

- Given that Class B watercourses are considered fish habitat, any future works with potential to affect the riparian or instream areas of these watercourses should be carefully considered and planned. Setback distances for development should be applied based on the provincial *Riparian Areas Regulation*[13] and municipal bylaw requirements for ditches. Under the new Fisheries Act, Fisheries and Oceans Canada (DFO) review is no longer required for non-fish bearing watercourses. Instead, the proponent is advised to follow DFO’s “Measures to Avoid Harm”. However, the Province, under the Fish Protection Act (Riparian Areas Regulation) and Water Act may still require habitat offsetting. In addition, the City of Coquitlam developed a Practice Statement in 2012 that specifies how the City intends to compensate for the enclosures of Class B ditches in Southwest Coquitlam.

[13] B.C. 2004. Riparian Areas Regulation. B.C. Reg. 376/2004. Available at: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/376_2004

- Class C watercourses are not considered fish habitat. As such, a DFO review would not be required for works within or adjacent to these watercourses. Implementation of best management practices for instream works, such as erosion control and working in the dry, should be applied to avoid impacts to downstream storm sewer connections, fish habitat, and fish-bearing areas.



Classification/Colour Code	Description
Class A – Solid red	Watercourses inhabited by salmonids and/or rare or endangered fish species, or potentially inhabited by such fish with access enhancement (e.g. removal of culverts).
Class A (O) – Red dashed	Watercourses inhabited by salmonids and/or rare or endangered fish species, during the overwintering period, or potentially inhabited during the overwintering period, or potentially inhabited during the overwintering period with access enhancement.
Class B – Yellow	Watercourses that are a significant (as defined by MELP, 1999) source or potentially significant source of food and nutrients to downstream fish populations. These watersheds are characterized by no fish presence and no reasonable potential for fish presence through flow or access enhancement.
Class C – Green	Watercourses that provide an insignificant contribution of food or nutrients to downstream areas supporting or potentially supporting fish populations.

Note
Refer to Table B-1 for summary of Ditch Assessment (Appendix B).

0 400 m

DATE: Sept. 2015
DRAWN BY: DA
PROJECT: 2011-2817.060 (002)

Associated Engineering — GLOBAL PERSPECTIVE. LOCAL FOCUS.

Chines ISMP

Figure B-1 Watercourse Classifications

PREPARED FOR: metro vancouver · Port Moody City of the Arts · Coquitlam

Appendix C – Hydrogeological Assessment

C.1 HYDROGEOLOGIST FIELD ASSESSMENTS

The hydrogeological, surficial geological and physiographic assessments were conducted June 1 and 2, 29 and 30, and September 2 and 3, 2011. In order to assess the hydrogeological conditions in the watershed, a preliminary field assessment was conducted. The groundwater conditions were studied by:

- Investigations at large and small surficial deposit exposures in the ravines.
- Observations of near-surface groundwater conditions from soil test pits and seepage patterns.

The lack overburden exposure is due to the small number of recent slope failures, stream gullying and other erosional events.

The field investigations included identification of surficial deposits, hand testing samples for grain size and moisture characteristics, recording evidence of groundwater seepage and high water tables, estimation of infiltration rates and vertical hydraulic conductivity, and review of areas of pervious soils and surficial deposits where stormwater infiltration may be possible. Hydrophilic vegetation and surface organic deposits indicative of near-surface groundwater flow were noted. Several temporary, small shovel test pits were completed in the ravine parks and ranged up to about 0.5 m depth.

Surficial deposit interpretation allowed the composition (grain size), distribution and thickness of surficial geological units to be determined. The depth to water table, and near-surface conditions (gleying/reduction, oxidation, mineral weathering) were also observed as possible. The field reviews were conducted generally within a few days of rainfall during a wet cool spring and summer, which aided locating groundwater seepage areas.

There are few places where the surficial geological units are exposed or accessible in the watershed north and south of the ravines as most is developed for residential, commercial and industrial purposes.

C.1.1 Surficial Geology and Stratigraphy

The surficial geology and stratigraphy in the western Metro Vancouver area has been compiled through interpreting exposures at many sites along eroding coastlines and river banks, in gravel pits and other excavations, and through boreholes (Armstrong and Hicock 1980; Armstrong 1984; Clague 1994). Figure C-1 illustrates the surficial geology. Six main surficial geologic units are exposed or are present at depth in the study watershed as shown in Table C-1.

Table C-1
Surficial Geologic Units

Unit Name	Depositional Environment	Approximate Time Period (years before present)
Modern deposits	Present day shore, stream and slope deposits.	10,000 – present
Salish Sediments, Stream Sediments	Marine shore, stream deposits	10,000 – 11,000 ybp
Capilano Sediments	Beach gravel and sand Glaciomarine stony silt to clay loam from glacier melt in ocean intertidal sand	11,000 - 13,000 ybp
Vashon Drift (Fraser Glaciation)	Lodgement till Waterlain tills Outwash sands and gravels	13,000 - 18,000 ybp
Quadra Sand	Fine to coarse sand, minor silt and gravel Interbedded silt, fine sand, minor peat	18,000 - 24,000 ybp
Cowichan Head Formation	Sand and silty sand Silt, clay, sand, peat beds	24,000 - >62,000 ybp

Reference: Armstrong and Hicock 1980
Armstrong 1984
Claque 1994

Armstrong and Hicock (1980) mapped the surficial geology at scale 1:50,000, based on decades of regional studies. Due to the complexity of the surficial geological units in the stream ravines and on the escarpment, the units were generalized for their map presentation. No recent detailed surficial geological mapping has since been completed which would assist the groundwater assessments. Hydrogeologic discussions will use the local surficial geology as determined through on-site identification and the previous geotechnical investigations.

The upland is comprised of at least 3 surficial deposit layers present as horizontal tabular bodies. Vashon Drift till and water-lain units are generally present at surface in the upland. Near the heads of Schoolhouse and Kyle Creeks, horizontally laminated sand to pebbly sand deposits may represent Salish Sediments deposited in nearshore environments during marine inundation. In the ravines, the underlying Quadra Sand sediments are exposed where cut through by stream and slope erosion. In some locations, these fine-grained deposits had iron and manganese deposited on fine fractures, indicating gleyed soil conditions from seasonal saturation.

North of the ravines, Salish Sediments composed of sand are present but infrequently exposed.

The ravine slopes are generally covered with a thick, low density juvenile forest soil formed in colluvial deposits of intermixed silt and sand. This forest soil has a relatively high permeability. Where previous erosion has occurred, or on the steeper slopes, only thin soils or duff layers are present on dense mineral subsoil. Some thin organic soils are present where wet conditions promoted plant growth and accumulation of organic debris.

In the study watershed, the overburden-bedrock interface is more than 100 m below surface and so has negligible effect on the surficial geological units or their hydrogeologic properties.

No agricultural soils mapping of the study watershed or nearby has been performed due to the low potential for agricultural development or production. Before land development, the soils on the upland and lowland were likely luvisols and brunisols formed beneath a mature coniferous forest in a wet maritime environment (Soil Classification Working Group 1998).

C.1.2 Groundwater Resources and Hydrogeology

Lower Mainland Hydrogeology

B. C. Ministry of Environment (2011) provided a hydrogeologic overview of the Fraser Lowland, which summarized earlier work by Halstead (1986). Halstead (1986) defines various “hydrostratigraphic units”, which are major glacial and post glacial overburden units with generally consistent hydrogeological properties.

Hydrostratigraphic Unit A is correlated with the Capilano Sediments, and includes marine and glaciomarine clay, stoney clay and silty clays, with varying stone content. This unit has a blocky structure and a buff colour when exposed, weathered and dry. Hydrostratigraphic Unit A is found at or near surface over the central part of the Lower Fraser Valley, and is generally less than 30 m thick. The unit may be capped by Salish Sediments which are littoral deposits from wave washing of earlier deposits.

Few specific groundwater studies of Hydrostratigraphic Unit A have been completed. There are no reported groundwater supply wells developed in it and no published groundwater studies. While the Salish Sediments generally form and extensive, permeable surface unit, Halstead did not separate it into a separate hydrostratigraphic unit. The Salish Sediments occur in a few places at surface in the study area and locally form an important unit for groundwater flow.

Hydrostratigraphic Unit B (glaciomarine stony clay) is found as the surface layer through much of the upland area of Coquitlam and can be correlated with Vashon Drift till and its waterlain subunits. Groundwater flow speeds are slow due to the grain size and compaction.
Hydrostratigraphic Units C (glaciofluvial deposits), D (glacial till) and F (bedrock) are generally not found at or near surface in the study area.

Hydrostratigraphic Unit E was deposited during the early part of the Fraser Glaciation, and consists mainly of marine, estuarine and fluvial deposits of fine sand, silt and clayey silts. This unit can be correlated with the Quadra Sand sediments. These deposits are generally present several metres below surface throughout the upland area and at surface in the ravines. Groundwater flow speeds are generally slow and the water has dissolved solids from the long residence time.

The B.C. Water Resources Atlas was queried as to the presence and nature of aquifers in the Chines study watershed (Ministry of Environment 2011). This aquifer information is highly generalized. Aquifers are rated as to vulnerability from surface contamination. A vulnerable surface aquifer is defined for the lowlands north of the ravines. The surface aquifer on the uplands south of the ravines is rated as being of moderate vulnerability. Bedrock aquifers below the lowlands and uplands are rated as having low demand.

Few groundwater wells are located in the immediate vicinity of the watershed. Several water supply wells are located on the lowlands northwest of the watershed, which have developed deep subsurface aquifers. No drinking water systems or community watersheds are present in the project area.

Chines Area

Based on some limited exposures, Halstead's (1988) descriptions, and borehole results, hydrostratigraphic units A (Vashon till) and E (Quadra Sand sediments) are interpreted to underlie much of the upland area. The finer-grained intervals form aquitards. The sandier intervals likely form aquifers with groundwater flow.

The hydrogeologic conditions encountered reflect the surficial deposit composition, layering and superposition, the presence of permeable and less permeable layers, post glacial erosion and weathering, and the flat to steep topography.

Groundwater seepage out of the Quadra Sand sediments commonly occurs in about the lower 3rd of ravine slopes, where organic-rich soils were found, hydrophilic plants are present (devil's club, horsetail, skunk cabbage), and some shallow surface ponds, wet areas or surface water tracks are present.

The near surface groundwater flow direction is strongly controlled by the topography, so the height of land to the south is likely also a surface aquifer divide, and the near surface groundwater flows slowly northwards. Slow groundwater flow is expected to occur beneath the low gradient upland surface.

Salish Sediments, which were not separately identified as a hydrostratigraphic unit by Halstead, were found on the lowland to the north, and in parts of the upland surface west of Kyle Creek. No seepage was noted from the pebbly sands and a trace amount of seepage occurred over some silty sands.

Most streams at the gully heads were constrained by stormwater structures (culverts, headwalls), fill materials, and dense vegetation; so the actual groundwater seepage zones feeding the creeks could not be observed. Most ravine streams gain water along their channels from small tributaries and groundwater seepage. It is interpreted that several groundwater outflow zones feed each stream.

Thurber (1988) reviewed the groundwater conditions in the study area as part of a stormwater modeling project (Dayton & Knight 1988). The groundwater conditions are complex due to the layered glacial and non-glacial sediments, with alternating aquitards (units which impede water movement) and aquifers (units which allow water movement). The ravine slopes expose non-glacial sediment units with perched water tables and multiple seepage zones where these units intersect the ground surface. Seepage at different levels may occur at different flow rates and timing, depending on the permeability and water table gradients in each geological unit, and seasonal inputs from rainfall.

Thurber (1988) interpreted that there is slow vertical recharge through the thick layer of glacial till capping the upland in the south part of the project area. No specific infiltration rates were measured or reported. The general groundwater outflow locations reported by Thurber (1988) are shown on Figure C-2.

Geotechnical investigations, including groundwater monitoring, by Golder Associates (1998, 1999) at the western side of South Schoolhouse Creek ravine near the upper edge indicated:

- Most sites in the ravine had no surface fill and had 5 to 31 m of native surface sediment.
- Considerable depths of fill (2 to 11 m) had been added at various times (1950s, 1960s) in some locations near roads and buildings.

Perched water tables were present in permeable units lying over dense, impermeable units.

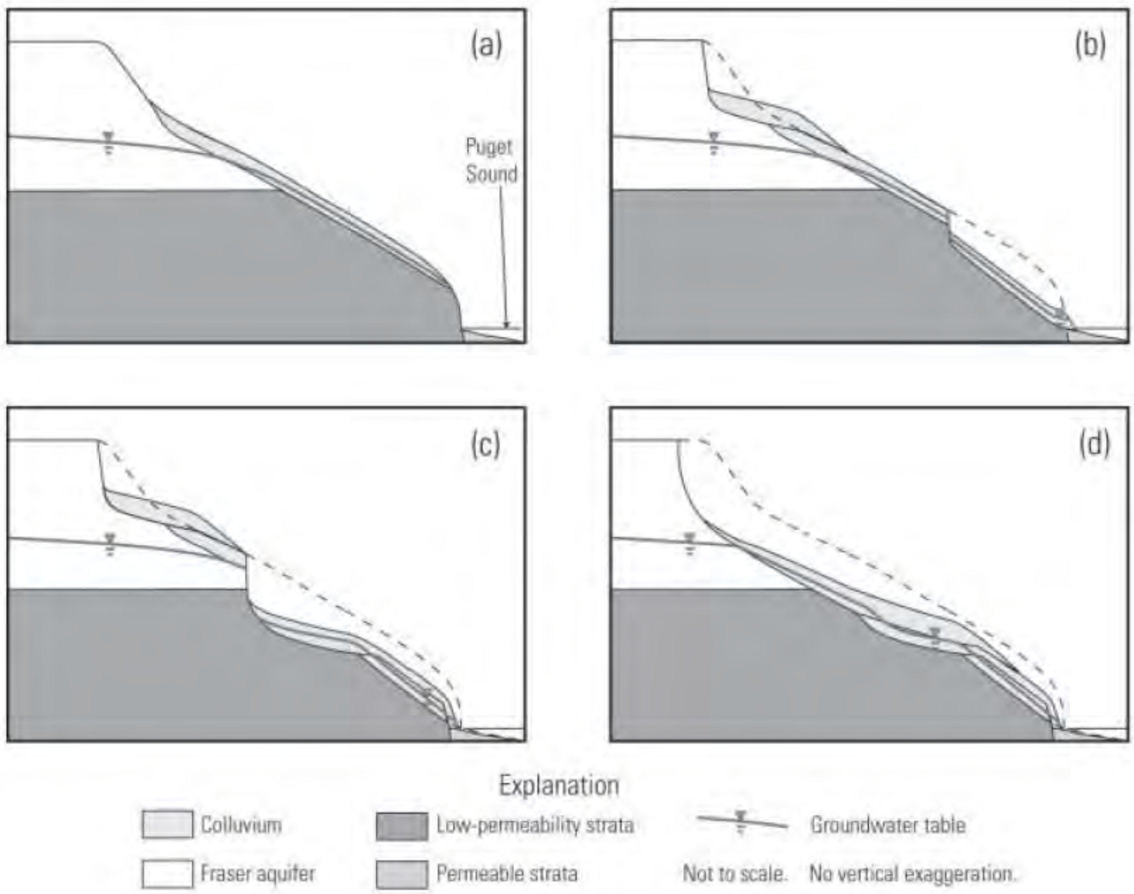
Water table elevation changes were measured over one year at several monitoring wells. In a deep well in Quadra Sand sediments, the seasonal water table ranged about 2 m/yr at about 18 m below ground surface.

In other more shallow monitoring wells, the water table varied about 0.7 m/yr in possible Quadra Sand sediments at 4 m below local ground surface, and 0.3 m in the same unit at about 14 m below surface. The water table variation is due to winter rains causing water table to rise, and summer dry conditions causing the water table to fall due to drainage.

Thurber (1983) mapped the Quadra Sand sediment exposed in erosion scarps below Canyon Court, near the head of East Sundial Creek. A large erosion scar about 20 m high and 40 m wide had been formed where the creek impinged on the steep slope below a stormwater outfall. The Quadra Sand was at least 15 m thick and composed of interlayered dense sand and dense silt units, with some gravelly sand intervals. Seepage occurred where sand overlay silt about 8 m below surface. Small scale seepage erosion occurred at several levels. The erosion scar has since been rehabilitated and revegetated.

The variable geological units, and the presence of ravines cut through horizontally layered units, produce a complex hydrogeological setting where individual assessment of groundwater flow direction and flow rates at each ravine and slope would be required to produce a groundwater flow direction map (See Figure C-3). The surface colluvial layer absorbs precipitation and also captures groundwater seepage and a significant quantity of interflow groundwater.

Figure C-3
Groundwater Outflow from Slopes and Resulting Failures



(Source: For the Seattle area, cross sections of various overburden units, with conceptual groundwater table elevations in units with low and high hydraulic conductivity, and surface colluvium. Slope failures in colluvium and underlying layers are depicted for various trigger mechanisms: (a) (b) slope toe erosion, (c) (d) retrogressive landsliding. Derived from, Schultz, W.H., Lidke, D.J. and Godt, J.W. 2008, Figure 2, Page 127.)

MacLeod Geotechnical (1996) completed a review of groundwater conditions at the Greystone Properties development site adjoining Suter Brook, between the CP Rail line and Murray Street. This site is in the lowland beside Burrard Inlet, and fill and silty sand to sandy silt sediment (likely Salish Sediments deposited in an offshore environment) are present at surface. A series of auger and rotary boreholes, some completed as monitoring wells, and some with piezometers, were completed over the site, to allow determination of the shallow and deep groundwater conditions.

An unconfined surface aquifer was present in the silty sands, and water table monitoring via piezometers indicated the water table had a yearly range of 0.6 to 1.2 m. Below the surface aquifer was a thick interval of clayey silt to silty clay (likely Quadra Sand sediments) which functioned as an aquiclude. It was interpreted that a confined subsurface aquifer was present in granular layers and lenses confined by a host till unit below the Quadra Sand sediments. It was considered that the confined aquifer was localized to the granular intervals and was supplied by deep groundwater flow starting in regional upland areas.

Groundwater outflow in the upland and ravine parts of the watershed was understood to contribute about 0.03 m^3/s to Suter Brook base flow during summer. Where Suter Brook crossed the development site, groundwater contributions to stream flow occurred in November to February, but not during summer, when the stream contributed water to the surface aquifer at a rate of about 0.01 m^3/s through infiltration into the stream bed.

The Macleaod Geotechnical report estimated that about 10 – 15% of rainfall infiltrated through the permeable surface soils to become near surface groundwater flow.

Geotechnical and groundwater investigations have recently been completed for the Evergreen rapid transit line which crosses Suter Brook just north of Barnett Highway (Ministry of Transportation and Infrastructure 2011). Testing included sonic continuous core, soil core drilling and mud rotary boreholes, piezometer installation and groundwater testing. The results indicated:

- Groundwater is found within a few metres of surface in the Port Moody lowlands.
- Groundwater is found within 3 to 4 m of ground surface in eastern Coquitlam.
- Water table elevations in the glacial and non-glacial deposits are variable, due to the steep topography, the grain size and permeability of the overburden layers.
- Perched water tables can be found above finer grained units and confined aquifers may produce artesian conditions.
- Confined aquifers, where the hydrostatic head is above local ground level, are found often near the bottom of steep slopes and in parts of the lowlands.

C.1.3 Viability of Subsurface Stormwater Disposal

Based on Summit's assessment, the following general hydrogeological conditions are understood to be present which would determine the feasibility of subsurface stormwater disposal (see Figure C-2):

- The upland surface is underlain by Vashon Drift and related sediments, which with their dense, cobbly, silty sand texture, have low hydraulic conductivity, likely in the order of 10^{-4} to 10^{-6} m/s (estimated from grain size). Slow northward and downward water movement through this layer generally occurs, supplying groundwater to the underlying silt, sand and gravel units of the Quadra Sand sediments.
- Portions of the uplands surface may be underlain by Salish Sediments, which would locally provide a higher surface infiltration rate and groundwater flow. However, the Salish Sediments are of limited extent and thickness and overlie generally low hydraulic conductivity Vashon Drift and Quadra Sand sediments.

- The Quadra Sand sediments underlying the ravines range from dense sands to dense clayey silts. Where the Quadra Sand sediments underlying the uplands (south of the ravines) have sand or sand and gravel intervals, local groundwater flow would occur toward the ravine heads. The clayey silt intervals would form aquitards.
- The groundwater flow lines are predicted to converge toward the ravine heads in the Salish, Capilano, Vashon and Quadra Sediments, producing the largest subsurface flow at the ravine heads and less at the slopes and ridges in-between.
- It is interpreted that the modern streams represent the approximate upper groundwater surface in the ravines, and that groundwater flow also occurs in the Quadra Sediments below the streams northward toward Burrard Inlet.

It is interpreted that the groundwater flow directions and rates have adjusted over time due to changes in the degree of exposure and the topography of the surficial units. After glacial retreat, it is inferred that northwards surface and subsurface water flow from the uplands converged at the ravine locations, and the ravines enlarged by headward stream erosion, slope failures and debris flows. The eroded sediment was transported by the streams towards Burrard Inlet and deposited as fans.

Before land development in the 20th century, it is interpreted that headward stream erosion and slope failures had diminished, as suggested by the large, old conifer stumps on the gully head slopes, indicative of old, more stable slopes. After logging and then land clearing and road building, surface runoff and subsurface groundwater flow towards the ravines would have temporarily increased, leading to further erosion and ravine enlargement. When the surface flow from roads, parking lots and roofs was directed into storm sewer pipes, the surface and groundwater flows to the ravine heads likely decreased. After urban development, the uplands surface would have more near-surface groundwater flow in summer, due to lawn and garden irrigation; however this is expected to be a small amount.

Stream flow is now transported by solid pipe to the ravine heads, with the exception of South Schoolhouse Creek. In many locations, stormwater flow is also conducted in flexible pipe from the upland to the ravine bases, where some downward channel erosion had occurred due to the larger and more rapid flows.

The uplands and lowlands will require detailed groundwater investigations as to the suitable amount of increase of near surface and deep groundwater flow with implementation of subsurface stormwater disposal. A quantitative assessment of groundwater flow over several seasons would be required, using an array of piezometers above the ravines, and in the lowlands below the ravines, to determine:

- Direction and rate of near-surface and deep groundwater flow.
- The capacity of the surficial deposits to accommodate additional subsurface flow.
- Impacts to building foundations, roads and subsurface infrastructure from increased groundwater table elevations in the upland and lowland areas due to subsurface stormwater disposal.

A surface and subsurface water balance should be prepared to estimate the groundwater flux and the subsurface capacity available for increased flows due to increased stormwater disposal.

C.2 HYDROGEOLOGICAL CONCLUSIONS AND RECOMMENDATIONS

This review of the hydrogeological conditions in the project area has provided a simple model of groundwater flow directions and quantities, based on the limited amount of existing information. The uplands above the ravines have surficial deposits of dense silty sand glacial till, and some littoral sand and gravel deposits. The top of the till deposit is weathered, and has somewhat higher hydraulic conductivity than below, but has slow lateral and vertical infiltration. The ravines are underlain by poorly drained, dense sandy to clayey silts from the pre-glacial time period. The ravine slopes have forest soil formed in colluvium where much near-surface water flow derived from precipitation and groundwater outflow occurs. The lowlands between the ravines and Burrard Inlet have Salish Sand and other deposits from nearshore and fan deposition. The infiltration rates may be higher but the groundwater table is likely near-to-surface in most areas. The land area above the ravines has full residential development. The streets are built with asphalt surfaces, concrete curbs and sidewalks, paved driveways, and roof gutters and downspouts which drain to the storm sewer system. Given the generally low surface infiltration rates, there may be limited opportunity for local stormwater drainage to subsurface unless zones with higher infiltration can be outlined.

A review of the groundwater conditions in the project area has indicated a lack of field measurements and observations, and a limited understanding of groundwater flow directions and flow rates. There are multiple aquifers and aquitards exposed in the ravines, which have previously had groundwater-induced slope failures.

There is a lack of groundwater field measurements and observations within the watershed where subsurface stormwater disposal is being considered. Some groundwater monitoring wells were present in middle South Schoolhouse Creek area in 1999. As there are multiple aquifers and aquitards, and 13 stream ravines, a network of multi-level piezometer installations would be required to characterize the groundwater regime.

C.2.1 Best Management Practices

A wide range of best management practices can be implemented to better manage stormwater and improve stream and slope conditions (Dayton & Knight et al. 1999, Washington State Department of Ecology 2005) including:

- Stormwater detention basins
- Infiltration basins and subsurface infiltration vaults or galleries
- Grassed channels and vegetated filter strips
- Porous pavement for streets and parking lots and other structural features.

One potential best management practice for reducing the volume and short response time of urban stormwater drainage is to direct roof, driveway, road and parking lot water into infiltration facilities such as roadside swales, rain gardens or infiltration galleries. The hydrogeologic conditions in the uppermost soils and surficial deposits, and the infiltration rates, will determine the opportunity for this subsurface stormwater to infiltrate. In the uplands and lowlands areas, stormwater detention facilities could potentially be constructed in existing parks and playing field areas.

The implementation of best management practices will likely occur over time, as some limited new development, and replacement and re-construction of older streets, parking lots, and stormwater infrastructure takes place. Most of the residential areas have already been constructed in the uplands area and so little new development can occur. In the lowlands, a change from older low to medium density industrial and commercial land use to high density residential and commercial along the proposed Evergreen Line will occur in the next decades, allowing the opportunity to convert older hard surface drainage to new development with possible surface detention and infiltration.

In order to assess the potential for using subsurface stormwater disposal, it will be necessary to locate quantify and locate areas with a high water table and higher groundwater flow. A network of piezometers may be installed along the upper ravine edges, in representative ravines, and below in the lowlands. Soil conditions, seasonal and long term groundwater table elevations, and flow directions will be necessary for locating and sizing the subsurface stormwater disposal infrastructure. Inclinometers could also be installed in some of the bore holes above the ravine crests for detection of slope movements.

Certain areas such as the escarpment edge above Ottley, Axford and Kyle Creeks are less preferable locations for stormwater disposal given the history of groundwater-influenced landslide events in these ravines. Other locations such as upper South Schoolhouse Creek or Dallas Creek watersheds in the ravines may have some opportunity for stormwater storage or disposal but require a better understanding of groundwater conditions.

Groundwater monitoring above apartment or condominium buildings would be justified in order to assess hydrogeological and stability conditions above these high population locations. Some existing groundwater monitoring above condominium buildings at the bottom of steeper slopes is already occurring in Port Moody. In addition, groundwater monitoring on the steep slopes above the elementary and high schools should be conducted.

With installation of the groundwater monitoring wells, the subsurface geology will be logged and tested which will assist determination of soil properties and hydraulic conductivity.

C.2.2 Future Slope and Drainage Condition Management

Future stormwater management may involve subsurface stormwater disposal along roads and in land parcels, where runoff would be added back to the near surface aquifers. If stormwater infiltration facilities were installed above the ravines, it is expected that concentrated stormwater flow would be changed to widespread sub-surface groundwater flow, draining to the ravine heads, and contributing seepage to the streams. The main flow paths would be where the surface till is most weathered and fractured, or where higher conductivity units (Salish Sediments) are present. The amount of subsurface water reaching the ravine heads and slopes would increase, likely leading to some ravine head erosion and increased slope failures at seepage sites.

If stormwater is directed to an infiltration installation, the stormwater collection area should be no larger than the natural runoff area which would have contributed to that point i.e. no combination of sub-drainages for infiltration installations.

The infiltrated stormwater should not arrive at a faster rate at the ravine heads than the natural near surface groundwater would have, to avoid conditions of perched water tables, high soil pore water pressures and other impacts which could destabilize slopes or cause emergent water and erosion. However, the need for stormwater infiltration will be highest in November through March, when the natural groundwater levels are high and soils saturated.

Due to the steep slopes, and the concentration of surface and near-surface groundwater, it is not recommended to construct infiltration facilities immediately above or within the steep ravines. However, the uppermost part of the South Schoolhouse Creek ravine may have the potential for some subsurface water disposal. The Dallas Creek ravine, with a large, gently-sloped headwater area, may also be suitable for some subsurface water disposal. However there is a generally high water table with seepage throughout the flatter area in the Dallas Creek headwater area, which may overload the local subsurface water balance. See Figure C-4 for landslides and erosion events.

It is unknown how the addition of stormwater drainage through subsurface infiltration facilities will affect groundwater seepage and stream flow. It may be advantageous to create a test facility to try some conversion of stormwater to subsurface flow above one ravine, with piezometers installed at shallow and deep depths, to determine the groundwater changes and the impacts to slope stability and stream flow below.

Infiltration rates have been estimated for the 3 main types of surficial material in the project area as follows:

- Colluvial soils over Quadra Sand sediments in the ravines
- Vashon Till and associated sediments on the upland
- Salish – Capilano sediments in the lowland

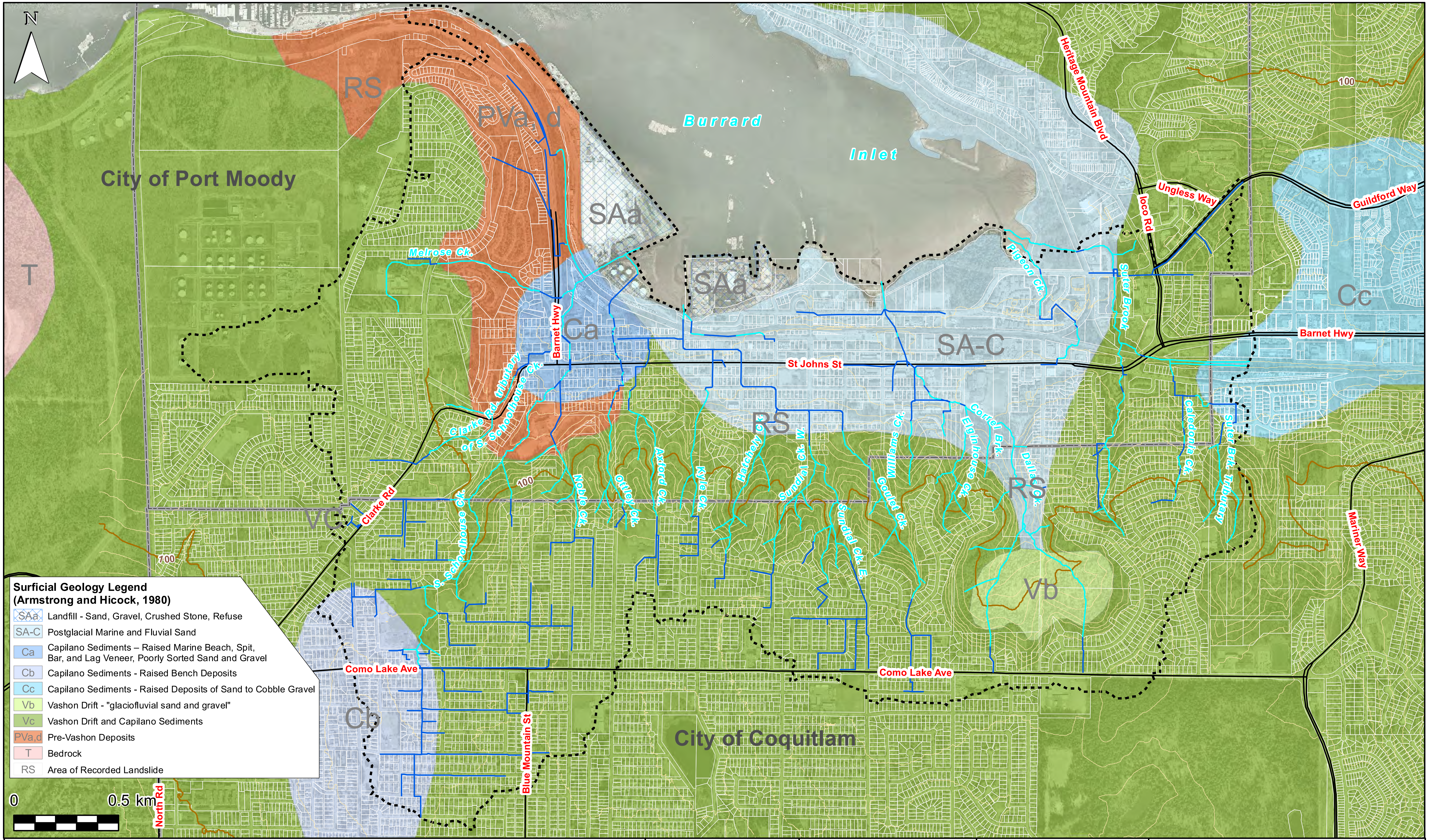
For the purposes of stormwater modelling, the values chosen were:

- Vashon till: minimum 0.9 mm/hr and maximum 2.5 mm/hr
- Ravine colluvial soils and lowland Salish Sediments: min 13 mm/hr and max 38 mm/hr

Local soil infiltration rates are summarized in Table C-2.

Table C-2
Summary of Local Soil Infiltration Rates

Location	Soil Type	Initial Infiltration Rate	Final Infiltration Rate
Kerr Wood Leidel (2006)			
East Clayton, east central Surrey	Till, Observed Values	0.9 mm/hr with interflow 1.6 mm/hr without interflow	N/A
	Clay, Observed Values	0.7 mm/hr	N/A
Literature Values Cited	Till	0.5 - 2.5 mm/hr	N/A
	Clay	0.2 - 2.5 mm/hr	N/A
Port Moody – Coquitlam			
Literature Values Cited	Colluvium Formed From Interglacial Silts, Sands, Gravels	36 - 360 mm/hr	N/A
Literature Values Cited	Vashon Till	0.5 - 2.5 mm/hr	N/A
Literature Values Cited	Salish and Capilano Sands	36 - 360 mm/hr	N/A



Stream — Culverted Stream — Parcel Boundary (white) — Major Road — Study Area Boundary — Municipal Boundary

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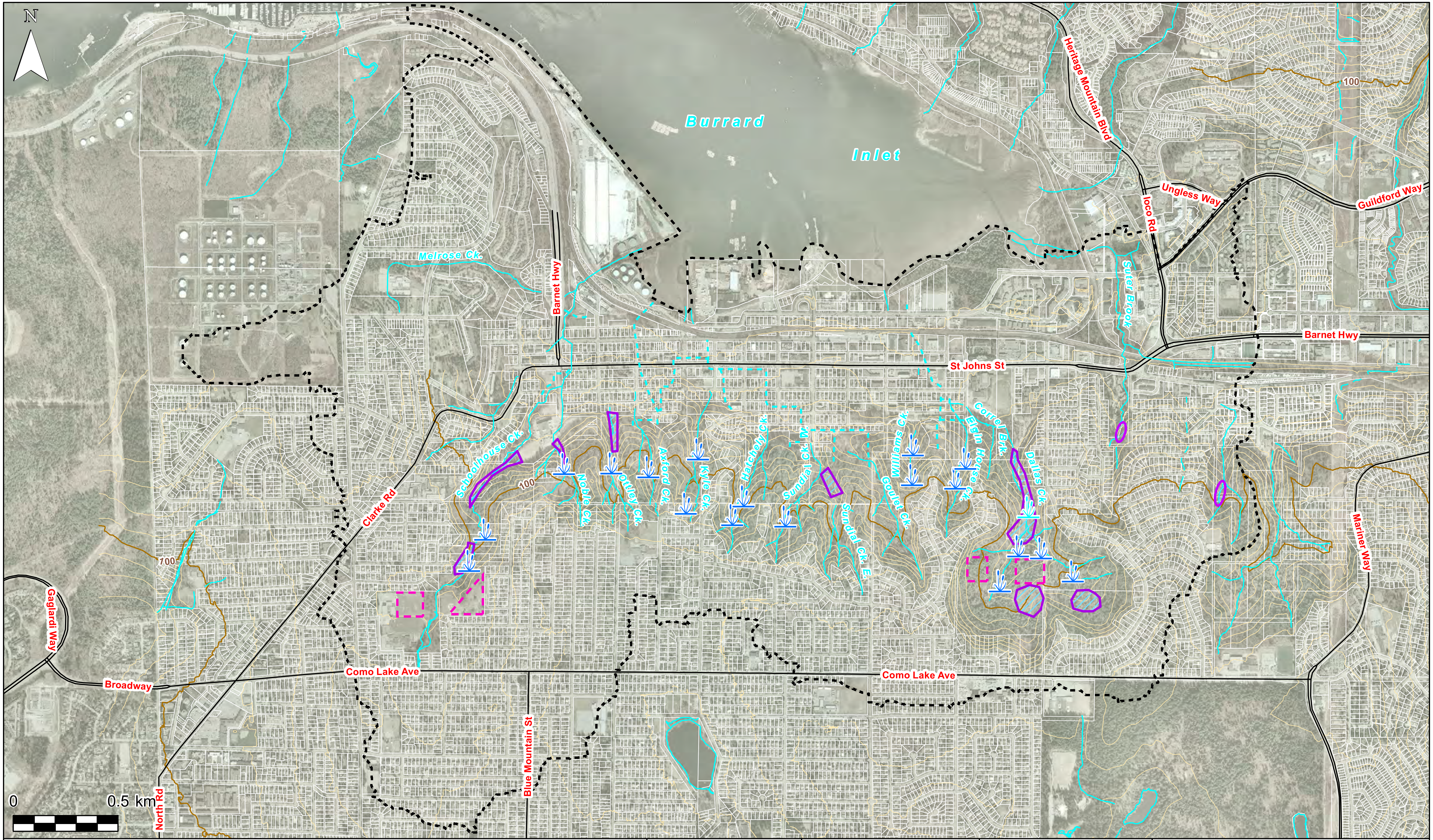
Figure C-1 Surficial Geology

Printing Date: 10/7/2011 2:08:27 PM
File: C:\mapping\projects\20112817010_Po_Mo\maps\Surficial Geology.mxd



Stream

Major Roads

Wet Areas (Thurber, 1983)

Study Area Boundary

Groundwater Discharge Area

Potential Stormwater Disposal Area

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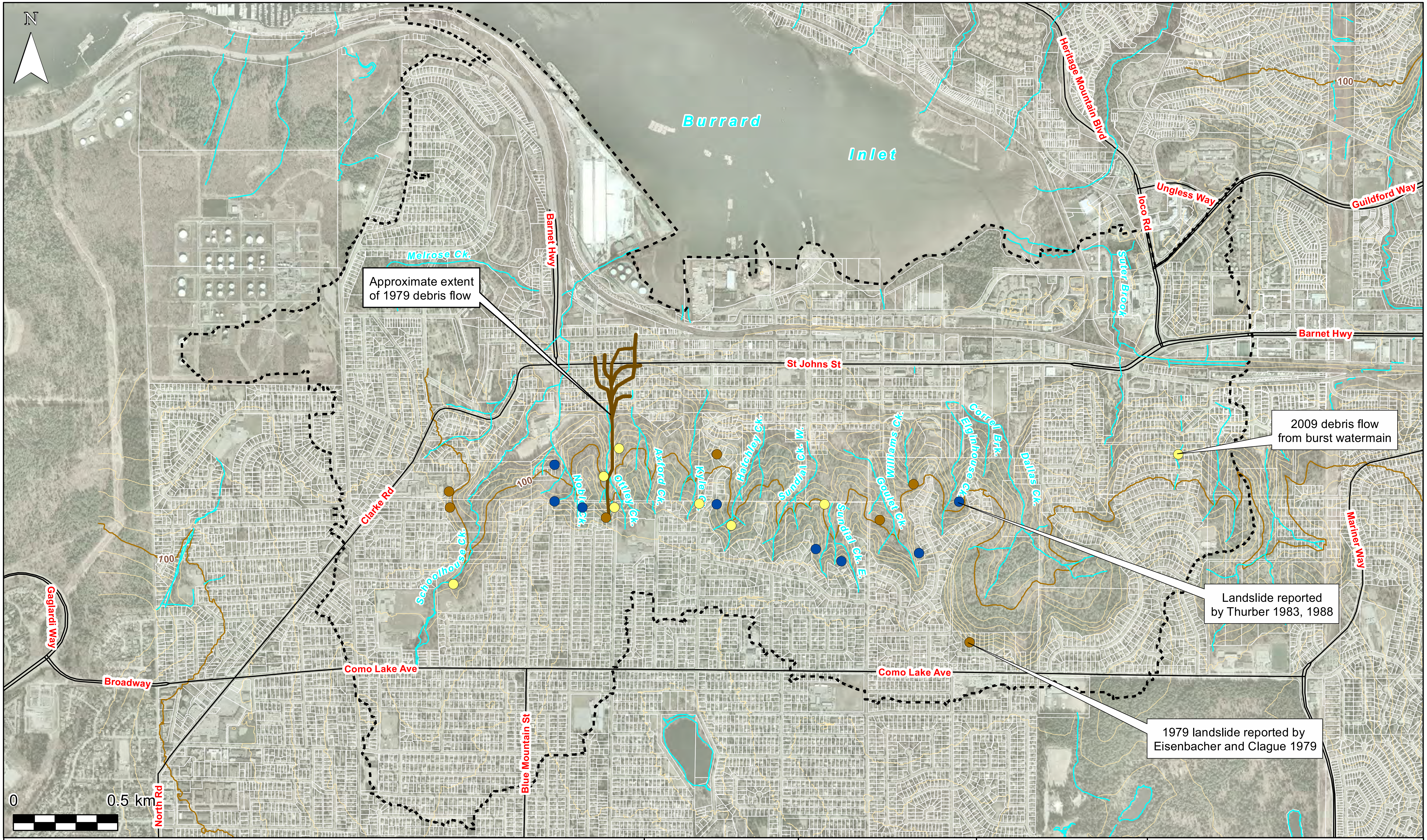
Figure C-2 Identified Groundwater Discharge Areas



Major Roads	December 1979, Reported by Eisbacher and Clague, 1980	
Stream	Various Years, Reported by Thurber 1983, 1980	
Study Area Boundary	Various Years, Summit and Other	

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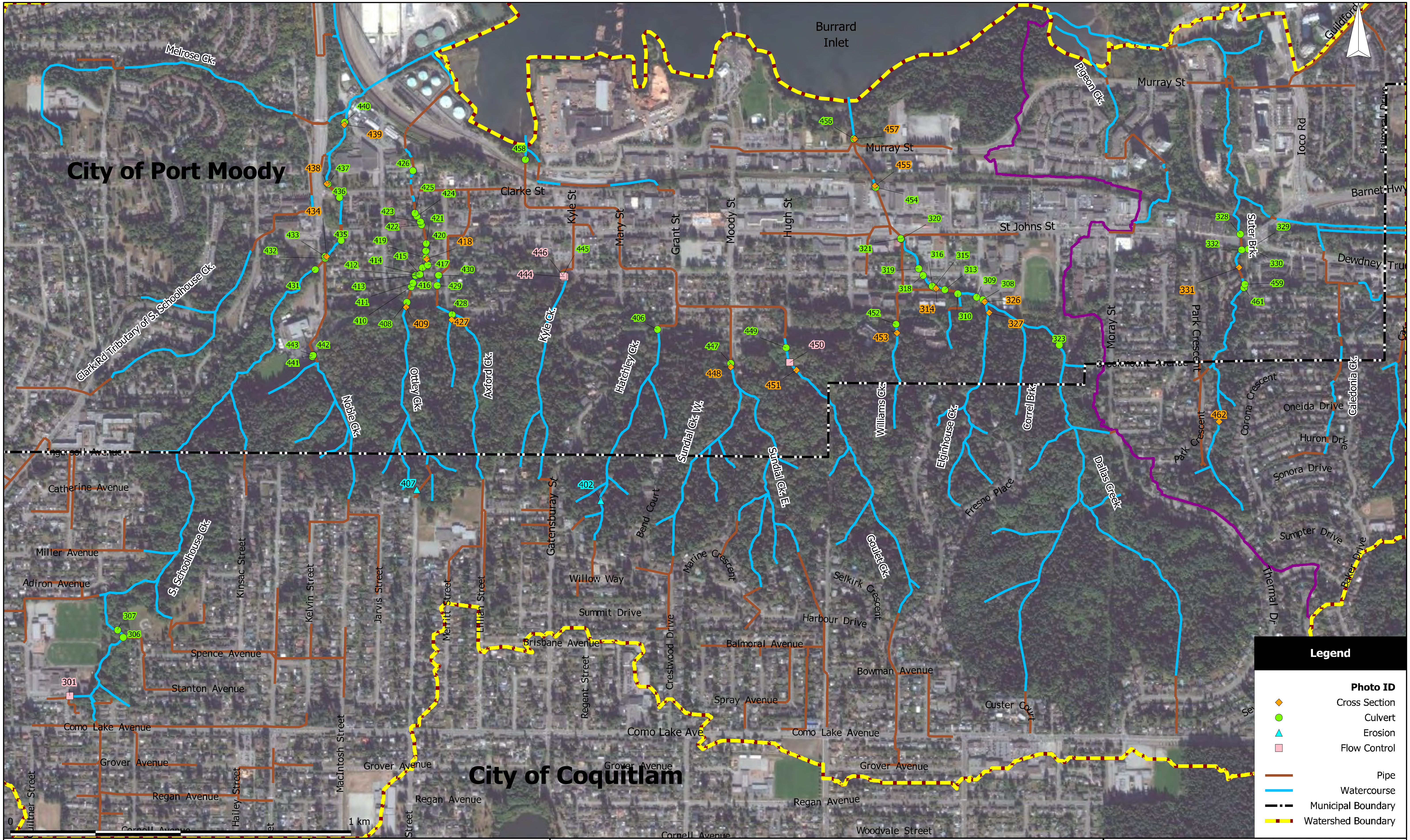
Figure C-4 Significant Landslide and Erosion Events

Appendix D – Hydraulic Field Reconnaissance

D.1 FIELD RECONNAISSANCE

Associated Engineering undertook a reconnaissance of the study area to collect field data on June 13, 2011 and June 14, 2011. We examined conditions and collected coordinates for channel cross sections, culvert inlets/outlets, erosion sites, and flow control structures. The data points are illustrated in Figure D-1. Site photos are provided on the Hydraulic Field Reconnaissance data sheets in this appendix.



Time: 1:55:04 PM | Date: 4/15/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_JL.mxd - Figure D-1 Hydraulic Field Reconnaissance

PROJECT NO:	20112817
SCALE:	1:10,000
DATE:	January 2015
DESIGNED BY:	JL
CHECKED BY:	MM

Associated Engineering

PREPARED FOR:

metro vancouver

PORT MOODY City of the Arts

Coquitlam

CHINES ISMP

Figure D-1 Hydraulic Field Reconnaissance

Survey Number:	1	Date:	June 13, 2011		
		Weather:	Cloudy		
Left Bank Height (m):	0.5	Right Bank Height (m):	0.5	Low Channel Width (m):	0.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130014.JPG

Photo ID:	314
GPS Height (m):	26.793
Northing:	5458053.688
Easting:	511497.657
Comment:	Dallas Creek cross section

Survey Number:	2	Date:	June 13, 2011
		Weather:	Sunny

Left Bank Height (m):	0.5	Right Bank Height (m):	0.5	Low Channel Width (m):	2.8
Left Bank Slope (H:V):	5:1	Right Bank Slope (H:V):	5:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130026.JPG

Photo ID:	326
GPS Height (m):	28.566
Northing:	5458014.665
Easting:	511640.274
Comment:	Dallas Creek cross section

Survey Number:	3		Date:	June 13, 2011	
			Weather:	Sunny	

Left Bank Height (m):	0.5	Right Bank Height (m):	0.5	Low Channel Width (m):	0.6
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

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Photo ID:	327
GPS Height (m):	21.294
Northing:	5457982.762
Easting:	511653.599
Comment:	Elginhouse Creek cross section

Survey Number:	4			Date:	June 14, 2011
				Weather:	Sunny
Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	5:1	Right Bank Slope (H:V):	5:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140009.JPG

Photo ID:	409
GPS Height (m):	44.365
Northing:	5457998.745
Easting:	509941.61
Comment:	Ottley Creek cross section

Survey Number:	5	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	0.5	Right Bank Height (m):	0.5	Low Channel Width (m):	0.7
Left Bank Slope (H:V):	1:1	Right Bank Slope (H:V):	1:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140018.JPG

Photo ID:	418
GPS Height (m):	30.451
Northing:	5458140.284
Easting:	510001.904
Comment:	Ottley Creek cross section

Survey Number:	6	Date:	June 14, 2011		
		Weather:	Sunny		
Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140027.JPG

Photo ID:	427
GPS Height (m):	47.729
Northing:	5457962.067
Easting:	510075.597
Comment:	Axford Creek cross section

Survey Number:	7			Date:	June 14, 2011
				Weather:	Sunny

Left Bank Height (m):	1	Right Bank Height (m):	1	Low Channel Width (m):	2.5
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140034.JPG

Photo ID:	434
GPS Height (m):	28.943
Northing:	5458147.562
Easting:	509708.312
Comment:	Schoolhouse Creek cross section

Survey Number:	8	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	3	Right Bank Height (m):	3	Low Channel Width (m):	5
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.5
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140038.JPG

Photo ID:	438
GPS Height (m):	16.97
Northing:	5458361.12
Easting:	509711.171
Comment:	Schoolhouse Creek cross section

Survey Number:	9	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140039.JPG

Photo ID:	439
GPS Height (m):	10.543
Northing:	5458538.796
Easting:	509760.335
Comment:	Schoolhouse Creek cross section

Survey Number:	10		Date:	June 14, 2011	
			Weather:	Sunny	

Left Bank Height (m):	2.5	Right Bank Height (m):	2.5	Low Channel Width (m):	3
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140048.JPG

Photo ID:	448
GPS Height (m):	39.776
Northing:	5457823.124
Easting:	510894.901
Comment:	Sundial Creek cross section

Survey Number:	11	Date:	June 14, 2011		
		Weather:	Sunny		
Left Bank Height (m):	1	Right Bank Height (m):	1	Low Channel Width (m):	3
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140051.JPG

Photo ID:	451
GPS Height (m):	46.371
Northing:	5457814.075
Easting:	511087.726
Comment:	Goulet Creek cross section

Survey Number:	12	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	0.3	Right Bank Height (m):	0.3	Low Channel Width (m):	0.3
Left Bank Slope (H:V):	8:1	Right Bank Slope (H:V):	8:1	Low Channel Depth (m):	0
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140053.JPG

Photo ID:	453
GPS Height (m):	29.332
Northing:	5457923.253
Easting:	511382.758
Comment:	Williams Creek cross section

Survey Number:	13	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	1	Right Bank Height (m):	1	Low Channel Width (m):	2.5
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140055.JPG

Photo ID:	455
GPS Height (m):	7.933
Northing:	5458354.753
Easting:	511318.258
Comment:	Dallas Creek cross section

Survey Number:	14	Date:	June 14, 2011
		Weather:	Sunny

Left Bank Height (m):	0.3	Right Bank Height (m):	0.3	Low Channel Width (m):	3.5
Left Bank Slope (H:V):	5:1	Right Bank Slope (H:V):	5:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.1	Right Bank Roughness:	0.1	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140057.JPG

Photo ID:	457
GPS Height (m):	4.951
Northing:	5458492.506
Easting:	511259.207
Comment:	Dallas Creek outfall channel cross section

Port Moody Coquitlam ISMP - Hydraulic Field Reconnaissance Photographs

Cross Section

Survey Number:	1	Date:	June 13, 2011
		Weather:	Sunny

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130031.JPG

Photo ID:	331
GPS Height (m):	27.891
Northing:	5458115.49
Easting:	512386.782
Comment:	Suter Brook cross section

Survey Number:	2			Date:	June 14, 2011
				Weather:	Sunny
Left Bank Height (m):	0.3	Right Bank Height (m):	0.3	Low Channel Width (m):	0.6
Left Bank Slope (H:V):	5:1	Right Bank Slope (H:V):	5:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140062.JPG

Photo ID:	462
GPS Height (m):	75.642
Northing:	5457662.874
Easting:	512328.276
Comment:	Suter Brook cross section

Survey Number:	15	Date:	June 13, 2011
		Weather	Rainy
Inlet or Outlet:	Inlet	Structure:	Projecting
Material:	CSP	Dia or Width (mm):	820
Risk Level:	High	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.1

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130006.JPG

Photo ID:	306
GPS Height (m):	117.746
Northing:	5457029.565
Easting:	509111.435
Comment:	Schoolhouse Creek twin culverts

Survey Number:	16	Date:	June 13, 2011
		Weather	Rainy
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CSP	Dia or Width (mm):	820
Risk Level:	High	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130007.JPG

Photo ID:	307
GPS Height (m):	114.667
Northing:	5457051.4375
Easting:	509095.28125
Comment:	Schoolhouse Creek twin culverts

Survey Number:	17	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CSP	Dia or Width (mm):	2400
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.5

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130008.JPG

Photo ID:	308
GPS Height (m):	25.816
Northing:	5458020.387
Easting:	511635.426
Comment:	Dallas Creek

Survey Number:	18	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CSP	Dia or Width (mm):	2400
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.5

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130009.JPG

Photo ID:	309
GPS Height (m):	36.461
Northing:	5458028.06
Easting:	511616.554
Comment:	Dallas Creek

Survey Number:	19	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	1830
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	3
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130010.JPG

Photo ID:	310
GPS Height (m):	17.91
Northing:	5458037.8125
Easting:	511561.21875
Comment:	Dallas Creek

Survey Number:	20	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CSP	Dia or Width (mm):	800
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130013.JPG

Photo ID:	313
GPS Height (m):	22.6
Northing:	5458049.919
Easting:	511523.204
Comment:	Dallas Creek

Survey Number:	21	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CSP	Dia or Width (mm):	1150
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Driveway	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	315
GPS Height (m):	19.481
Northing:	5458057.973
Easting:	511491.173
Comment:	Dallas Creek

Survey Number:	22	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CSP	Dia or Width (mm):	1150
Risk Level:	Medium	Road Crown Height (m):	1.5
Type:	Driveway	Sediment Depth (m):	0.5

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	316
GPS Height (m):	20.587
Northing:	5458060.227
Easting:	511486.063
Comment:	Dallas Creek

Survey Number:	23	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Inlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	850
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	318
GPS Height (m):	20.551
Northing:	5458091.938
Easting:	511459.409
Comment:	Dallas Creek

Survey Number:	24	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	850
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	319
GPS Height (m):	16.089
Northing:	5458111.877
Easting:	511446.55
Comment:	Dallas Creek

Survey Number:	25	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	1500
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.3

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	320
GPS Height (m):	17.235
Northing:	5458199.051
Easting:	511394.788
Comment:	Dallas Creek

Survey Number:	26	Date:	June 13, 2011
		Weather	Cloudy
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	300
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	321
GPS Height (m):	13.77
Northing:	5458199.892
Easting:	511393.814
Comment:	Storm sewer outlet

Survey Number:	27	Date:	June 13, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	680
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	323
GPS Height (m):	43.426
Northing:	5457887.907
Easting:	511859.172
Comment:	3x680dia

Survey Number:	28	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	800
Risk Level:	Low	Road Crown Height (m):	1.8
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.8	Right Bank Height (m):	1.8	Low Channel Width (m):	2.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	406
GPS Height (m):	37.819
Northing:	5457933.397
Easting:	510679.863
Comment:	Hatchley Creek intake with trash rack

Survey Number:	29	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	408
GPS Height (m):	44.207
Northing:	5458013.16
Easting:	509944.062
Comment:	Ottley Creek intake with overflow pipe

Survey Number:	30	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	480
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	410
GPS Height (m):	37.898
Northing:	5458058.365
Easting:	509957.12
Comment:	Ottley Creek

Survey Number:	31	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CSP	Dia or Width (mm):	610
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	411
GPS Height (m):	34.337
Northing:	5458069.404
Easting:	509961.927
Comment:	Ottley Creek

Survey Number:	32	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CSP	Dia or Width (mm):	610
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	412
GPS Height (m):	35.978
Northing:	5458092.042
Easting:	509968.222
Comment:	Ottley Creek

Survey Number:	33	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Porjecting
Material:	CSP	Dia or Width (mm):	620
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	413
GPS Height (m):	35.708
Northing:	5458091.497
Easting:	509970.066
Comment:	Ottley Creek

Survey Number:	34	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CSP	Dia or Width (mm):	620
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Driveway	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	414
GPS Height (m):	36.083
Northing:	5458094.534
Easting:	509979.936
Comment:	Ottley Creek

Survey Number:	35	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Mitered
Material:	CSP	Dia or Width (mm):	610
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	415
GPS Height (m):	37.828
Northing:	5458094.82
Easting:	509982.568
Comment:	Ottley Creek

Survey Number:	36	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	416
GPS Height (m):	34.72
Northing:	5458114.599
Easting:	509989.664
Comment:	Box culvert

Survey Number:	37	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	890
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	417
GPS Height (m):	33.694
Northing:	5458122.289
Easting:	510005.593
Comment:	Box culvert

Survey Number:	38	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	670
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	419
GPS Height (m):	31.341
Northing:	5458143.246
Easting:	509999.665
Comment:	Ottley Creek

Survey Number:	39	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	680
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	420
GPS Height (m):	35.561
Northing:	5458163.841
Easting:	509999.701
Comment:	Ottley Creek

Survey Number:	40	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	680
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	421
GPS Height (m):	29.347
Northing:	5458185.454
Easting:	510001.147
Comment:	Ottley Creek

Survey Number:	41	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	750
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	422
GPS Height (m):	28.508
Northing:	5458240.086
Easting:	509987.114
Comment:	Ottley Creek

Survey Number:	42	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	423
GPS Height (m):	27.464
Northing:	5458249.228
Easting:	509983.892
Comment:	Ottley Creek

Survey Number:	43	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Mitered
Material:	CONC	Dia or Width (mm):	500
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	424
GPS Height (m):	25.13
Northing:	5458265.694
Easting:	509973.534
Comment:	Ottley Creek

Survey Number:	44	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	700
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	425
GPS Height (m):	22.888
Northing:	5458274.654
Easting:	509967.817
Comment:	Ottley Creek

Survey Number:	45	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	426
GPS Height (m):	17.999
Northing:	5458399.234
Easting:	509961.966
Comment:	Ottley Creek

Survey Number:	46	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	800
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	428
GPS Height (m):	53.875
Northing:	5457977.109
Easting:	510076.953
Comment:	Axford Creek intake with trash rack

Survey Number:	47	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	HDPE	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	429
GPS Height (m):	34.713
Northing:	5458062.461
Easting:	510033.012
Comment:	Axford Creek

Survey Number:	48	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	1050
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	430
GPS Height (m):	36.165
Northing:	5458092.496
Easting:	510037.353
Comment:	Axford Creek

Survey Number:	49	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	1500
Risk Level:	Low	Road Crown Height (m):	4
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	4	Right Bank Height (m):	4	Low Channel Width (m):	2.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	431
GPS Height (m):	22.943
Northing:	5458109.111
Easting:	509675.221
Comment:	Schoolhouse Creek box culvert

Survey Number:	50	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	1500
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	432
GPS Height (m):	26.71
Northing:	5458142.361
Easting:	509704.222
Comment:	Schoolhouse and Nobel confluence

Survey Number:	51	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Mitered
Material:	CONC	Dia or Width (mm):	250
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Other	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	433
GPS Height (m):	24.95
Northing:	5458147.536
Easting:	509703.999
Comment:	Schoolhouse Creek

Survey Number:	52	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	1400
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	435
GPS Height (m):	24.306
Northing:	5458194.307
Easting:	509751.305
Comment:	Schoolhouse twin circular

Survey Number:	53	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	2320
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	436
GPS Height (m):	19.328
Northing:	5458320.422
Easting:	509746.253
Comment:	Schoolhouse box culvert

Survey Number:	54	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	437
GPS Height (m):	19.749
Northing:	5458360.302
Easting:	509712.314
Comment:	Schoolhouse 900dia and 2400x1500box

Survey Number:	55	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	440
GPS Height (m):	7.248
Northing:	5458542
Easting:	509761.748
Comment:	Schoolhouse circular

Survey Number:	56	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	441
GPS Height (m):	60.497
Northing:	5457853.406
Easting:	509666.849
Comment:	Noble Creek intake with trash rack

Survey Number:	57	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Mitered
Material:	CONC	Dia or Width (mm):	250
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	442
GPS Height (m):	61.495
Northing:	5457857.779
Easting:	509669.73
Comment:	Noble Creek ellipse pipe

Survey Number:	58	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Mitered
Material:	HDPE	Dia or Width (mm):	250
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	443
GPS Height (m):	62.231
Northing:	5457857.512
Easting:	509668.594
Comment:	Noble Creek

Survey Number:	59	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Mitered
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	2
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	2	Right Bank Height (m):	2	Low Channel Width (m):	1.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	445
GPS Height (m):	24.18
Northing:	5458093.359
Easting:	510403.077
Comment:	Kyle Creek intake with trash rack

Survey Number:	60	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	1.8
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.8	Right Bank Height (m):	1.8	Low Channel Width (m):	1.5
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140047.JPG

Photo ID:	447
GPS Height (m):	40.885
Northing:	5457833.693
Easting:	510894.458
Comment:	Sundials Creek intake with trash rack

Survey Number:	61	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	900
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140049.JPG

Photo ID:	449
GPS Height (m):	43.96
Northing:	5457879.753
Easting:	511057.258
Comment:	Goulet Creek intake with trash rack

Survey Number:	62	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	480
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140052.JPG

Photo ID:	452
GPS Height (m):	32.546
Northing:	5457948.753
Easting:	511380.009
Comment:	Williams Creek intake with trash rack

Survey Number:	63	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	800
Risk Level:	Low	Road Crown Height (m):	1.5
Type:	Building	Sediment Depth (m):	0.01

Left Bank Height (m):	1.5	Right Bank Height (m):	1.5	Low Channel Width (m):	1.2
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	454
GPS Height (m):	8.2915
Northing:	5458350.253
Easting:	511320.508
Comment:	Dallas Creek

Survey Number:	64	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	1500
Risk Level:	Low	Road Crown Height (m):	3.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	3.5	Right Bank Height (m):	3.5	Low Channel Width (m):	4
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140056.JPG

Photo ID:	456
GPS Height (m):	5.764
Northing:	5458492.921
Easting:	511255.997
Comment:	Outfall

Survey Number:	65	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CONC	Dia or Width (mm):	1500
Risk Level:	Low	Road Crown Height (m):	3.5
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	3.2	Right Bank Height (m):	3.2	Low Channel Width (m):	4
Left Bank Slope (H:V):	3:1	Right Bank Slope (H:V):	3:1	Low Channel Depth(m):	0.4
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140058.JPG

Photo ID:	458
GPS Height (m):	11.083
Northing:	5458431.749
Easting:	510292.026
Comment:	Outfall

Port Moody Coquitlam ISMP - Hydraulic Field Reconnaissance Photographs

Culvert

Survey Number:	3	Date:	June 13, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Projecting
Material:	CSP	Dia or Width (mm):	600
Risk Level:	High	Road Crown Height (m):	2.8
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	2.5	Right Bank Height (m):	2.5	Low Channel Width (m):	3
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth(m):	0.4
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130028.JPG

Photo ID:	328
GPS Height (m):	22.04
Northing:	5458213.249
Easting:	512390.401
Comment:	Suter Brook

Survey Number:	4	Date:	June 13, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	600
Risk Level:	Low	Road Crown Height (m):	2
Type:	Road	Sediment Depth (m):	0.2

Left Bank Height (m):	0.5	Right Bank Height (m):	0.5	Low Channel Width (m):	1.5
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130029.JPG

Photo ID:	329
GPS Height (m):	22.85
Northing:	5458169.124
Easting:	512414.276
Comment:	Suter Brook

Survey Number:	5	Date:	June 13, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Headwall
Material:	HDPE	Dia or Width (mm):	300
Risk Level:	Low	Road Crown Height (m):	1.3
Type:	Path	Sediment Depth (m):	0.1

Left Bank Height (m):	1.3	Right Bank Height (m):	1.3	Low Channel Width (m):	0.5
Left Bank Slope (H:V):	2:1	Right Bank Slope (H:V):	2:1	Low Channel Depth(m):	0.01
Left Bank Roughness:	0.04	Right Bank Roughness:	0.04	Channel Roughness:	0.04

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Photo ID:	330
GPS Height (m):	22.38
Northing:	5458167.124
Easting:	512429.401
Comment:	Suter Brook

Survey Number:	6	Date:	June 13, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Headwall
Material:	CONC	Dia or Width (mm):	1000
Risk Level:	N/A	Road Crown Height (m):	1.1
Type:	Road	Sediment Depth (m):	0.01

Left Bank Height (m):	0.7	Right Bank Height (m):	0.7	Low Channel Width (m):	0.6
Left Bank Slope (H:V):	4:1	Right Bank Slope (H:V):	4:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	332
GPS Height (m):	22.11
Northing:	5458166.999
Easting:	512394.401
Comment:	Suter Brook

Survey Number:	7	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Outlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	750
Risk Level:	N/A	Road Crown Height (m):	1.2
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.2	Right Bank Height (m):	1.2	Low Channel Width (m):	0.7
Left Bank Slope (H:V):	1:1	Right Bank Slope (H:V):	1:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	459
GPS Height (m):	35.33
Northing:	5458065.874
Easting:	512404.026
Comment:	Suter Brook

Survey Number:	8	Date:	June 14, 2011
		Weather	Sunny
Inlet or Outlet:	Inlet	Structure:	Conformed
Material:	CONC	Dia or Width (mm):	750
Risk Level:	N/A	Road Crown Height (m):	1.2
Type:	Path	Sediment Depth (m):	0.01

Left Bank Height (m):	1.2	Right Bank Height (m):	1.2	Low Channel Width (m):	0.7
Left Bank Slope (H:V):	1:1	Right Bank Slope (H:V):	1:1	Low Channel Depth(m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	461
GPS Height (m):	35.37
Northing:	5458055.746
Easting:	512401.401
Comment:	Suter Brook

Port Moody Coquitlam ISMP - Hydraulic Field Reconnaissance Photographs

Erosion

SurveyNumber:	66	Date:	June 14, 2011
		Weather	Sunny
Bank Location:	Left	Length (m):	5
Risk Level:	High	Height (m):	3.5
Stability:	Hatchley landslide		

Left Bank Height (m):	3.5	Right Bank Height (m):	3.5	Low Channel Width (m):	0.5
Left Bank Slope (H:V):	4:1	Right Bank Slope (H:V):	4:1	Low Channel Depth (m):	0.01
Left Bank Roughness:	0.035	Right Bank Roughness	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140002.JPG

Photo ID:	402
GPS Height (m):	106.583
Northing:	5457431.367
Easting:	510513.212
Comment:	Discovered in March, 2011 by Metro Vancouver field staff

SurveyNumber:	67	Date:	June 14, 2011
		Weather	Sunny
Bank Location:	Left	Length (m):	3
Risk Level:	High	Height (m):	2.5
Stability:	Landslide adjacent to Ottley		

Left Bank Height (m):	2.5	Right Bank Height (m):	2.5	Low Channel Width (m):	0.5
Left Bank Slope (H:V):	15:1	Right Bank Slope (H:V):	15:1	Low Channel Depth (m):	0.01
Left Bank Roughness:	0.035	Right Bank Roughness	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140007.JPG

Photo ID:	407
GPS Height (m):	152.175
Northing:	5457463.246
Easting:	509973.111
Comment:	Discovered in March, 2011 by Metro Vancouver field staff

Port Moody Coquitlam ISMP - Hydraulic Field Reconnaissance Photographs
Flow Control

Survey Number:	68	Date:	June 13. 2011
		Weather:	Rainy

Feature Description: 300mm high weir

Risk Level: Low

Left Bank Height (m):	2.5	Right Bank Height (m):	2.5	Low Channel Width (m):	3.5
Left Bank Slope (H:V):	4:1	Rigth Bank Slope (H:V):	4:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_13_2011\P6130001.JPG

Photo ID:	301
GPS Height (m):	122.035
Northing:	5456858.062
Easting:	508954.718
Comment:	Top of Hatchley Creek

Port Moody Coquitlam ISMP - Hydraulic Field Reconnaissance Photographs

Flow Control

Survey Number:	69	Date:	June 14. 2011		
		Weather:	Sunny		
Feature Description:	Weir 1100mm wide 540mm high				
Risk Level:	Low				
Left Bank Height (m):	1	Right Bank Height (m):	1	Low Channel Width (m):	3
Left Bank Slope (H:V):	4:1	Rigth Bank Slope (H:V):	4:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

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Photo ID:	444
GPS Height (m):	24.71
Northing:	5458087.835
Easting:	510407.336
Comment:	Kyle Creek

Survey Number:	70	Date:	June 14. 2011		
		Weather:	Sunny		
Feature Description:	High flow diversion				
Risk Level:	Low				
Left Bank Height (m):	2.5	Right Bank Height (m):	2.5	Low Channel Width (m):	2
Left Bank Slope (H:V):	3:1	Rigth Bank Slope (H:V):	3:1	Low Channel Depth (m):	0.2
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140046.JPG

Photo ID:	446
GPS Height (m):	24.725
Northing:	5458090.506
Easting:	510403.213
Comment:	Kyle Creek

Survey Number:	71	Date:	June 14. 2011		
		Weather:	Sunny		
Feature Description:	1180mm high; 250mm orfice 130mm above inv; 2x150mm orfice 470mm above inv				
Risk Level:	Low				
Left Bank Height (m):	2	Right Bank Height (m):	2	Low Channel Width (m):	6
Left Bank Slope (H:V):	4:1	Rigth Bank Slope (H:V):	4:1	Low Channel Depth (m):	0.1
Left Bank Roughness:	0.035	Right Bank Roughness:	0.035	Channel Roughness:	0.035

P:\20112817\00_ISMP\Engineering\01.08_Photos\June_14_2011\P6140050.JPG

Photo ID:	450
GPS Height (m):	25.975
Northing:	5457836.753
Easting:	511068.258
Comment:	Goulet Creek

Appendix E – Hydrologic and Hydraulic Modelling

E.1 DATA COLLECTION

We gathered GIS data for hydraulic structures from the City of Port Moody and the City of Coquitlam. Based on the data provided by the Cities and our field data, we compiled all data sets and completed our hydraulic inventory. For missing information, we acquired record drawings in order to address these data deficiencies.

The locations of the major system storm trunks are indicated in Figure E-1. Details are summarized in Table E-1.

Table E-1
Pipe Data Collection

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
Melrose Creek Major Storm Trunks						
mel01	Concrete	600	4.2	105.5	College Park Subdivision storm sewer	n/a
mel02	Concrete	600	7.3	26	College Park Subdivision storm sewer	n/a
mel03	Concrete	1200	6.3	31.7	Cecile Dr crossing culvert	n/a
mel04	Concrete	1500	12.4	64.7	View St crossing culvert	n/a
mel05	Concrete	900	5.9	35.4	Barnet Hwy crossing culvert	n/a
mel06	Concrete	900	5.8	36.5	Barnet Hwy crossing culvert	n/a
mel07	Concrete	900	6.9	13.6	Barnet Hwy crossing culvert	n/a
mel08	Concrete	900	7.4	13.3	Barnet Hwy crossing culvert	n/a
South Schoolhouse Creek Major Storm Trunks						
sch02	Concrete	1350	6.8	47.5	St. Johns St crossing twin culvert with concrete headwall and wingwalls at inlet; baffles	435
sch03	Concrete	1350	6.8	47.5	St. Johns St crossing twin culvert with concrete headwall and wingwalls at inlet; no baffles	435
sch04	Concrete	2400x1500	2.5	50.4	Clarke St crossing twin box culvert with concrete headwall and wingwalls at inlet and outlet; baffles	436 and 437
sch05	Concrete	900	2.6	50.8	Clarke St crossing twin circular culvert with concrete headwall and wingwalls at inlet and outlet; no baffles	436 and 437
sch06	Concrete	600	24.2	6.4	Storm inlet west of Clarke Rd	n/a
sch07	Concrete	750	4.9	26.6	Storm main west of Clarke Rd	n/a
sch08	CSP	750	8.5	52.6	Storm main built underneath Charles St and St Johns St	n/a
sch09	CSP	750	8	45.3	Storm main built in between St. Johns St and Spring St	n/a
sch10	CSP	750	5.1	73	Storm main built underneath Spring St	n/a
sch11	Unknown	900	9.5	14.2	Storm main built underneath Spring St	n/a
sch12	Concrete	750	2.8	35.9	Storm main built underneath Spring St	n/a
sch13	Concrete	750	0	1.6	Storm outlet north of Spring St	n/a
sch14	Concrete	1050	8.2	8.4	Storm main inlet south of Clarke St	n/a
sch15	Concrete	1050	5.2	45.5	Storm main built underneath View St	n/a
sch16	Concrete	1050	0.6	22.3	Storm main built underneath View St	n/a
sch17	Concrete	1050	0.6	33.1	Storm main across Barnet Hwy	n/a

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
sch18	Concrete	1050	0.6	32.5	Storm main built underneath Barnet Hwy	n/a
sch19	Concrete	1050	0	10.5	Storm main outlet east of Barnet Hwy	n/a
Nobel Creek Major Storm Trunks						
nob02	Concrete	600	7.9	70.1	Nobel Creek culvert east of Port Moody Senior Secondary School	n/a
nob03	Concrete	600	8	161.1	Culvert across Hope St and St. George St; confluences with South Schoolhouse Creek at outlet; outlet mitred	432 and 433
Ottley Creek Major Storm Trunks						
ott02	CSP	600	3.1	13.7	Culvert inlet south of St. George St with wingwalls made of concrete bricks but no headwall	413 and 414
ott03	Concrete	600	6.7	47.5	St. George St crossing culvert; inlet badly deformed; pipe bent at 90 degrees with a manhole; outlet has projecting wingwalls made of bricks and concrete slab on top	415, 416 and 417
ott04	Concrete	600	6.9	20.8	St. Andrews St crossing culvert with headwall and wingwalls at inlet and shallow headwall made of stones at outlet	419 and 420
ott05	Concrete	600	6.8	21.3	St. Johns St crossing culvert; inlet projecting; outlet connected to a manhole	421
ott06	Concrete	750	6.8	32.3	St. Johns St crossing culvert; inlet connected to manhole; outlet has headwall and discharges to concrete channel	422
ott07	Concrete	500	3.6	17	Culvert built under a walkway between Spring St and St. Johns St; concrete channel ties into inlet; outlet projecting	423 and 424
ott08	Concrete	600	6.2	33.9	Spring St crossing culvert with headwall and wingwalls made of stones at inlet	425
ott09	Concrete	600	3.8	33.1	Clarke St crossing culvert	n/a
ott10	Concrete	600	5.3	4.3	Culvert built under walkway between Vintner St and Clarke St	n/a
ott11	Concrete	350	4.9	38.9	Vintner St crossing culvert with projecting inlet	426
ott12	Concrete	600	3	41.8	Culvert south of CP Railway	n/a

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
ott13	CSP	450	3.4	6.8	Culvert south of CP Railway	n/a
ott14	CSP	600	2	15.6	Culvert south of CP Railway	n/a
ott15	Concrete	700	0.9	175.2	CN Rail crossing culvert	n/a
Axford Creek Major Storm Trunks						
axf02	Concrete	450	13.2	9.8	Culvert built underneath Hope St; inlet and outlet connected to manholes	n/a
axf03	PVC	450	6.2	8.2	Outlet culvert north of Hope St; inlet connected to manhole; outlet projecting with headwall; channel banks are riprapped at outlet	429
axf04	Concrete	450	5.1	15	St. George St crossing culvert with trash rack and riprapped side banks at inlet; outlet connected to manhole	430
axf05	Concrete	450	6.2	21.2	Elgin St crossing culvert	n/a
axf06	Concrete	525	6.7	43.5	Storm main east of Elgin St	n/a
axf07	Concrete	525	4.4	47.3	Storm main east of Elgin St	n/a
axf08	Concrete	600	1.5	45.8	Storm main south of St. Johns St	n/a
axf09	Unknown	600	11	82.6	Storm main across St. Johns St	n/a
axf10	Unknown	600	0.1	48.1	Storm main east of Elgin St between Spring St and Clarke St	n/a
axf11	Unknown	600	8.5	9.8	Storm main south of Clarke St	n/a
axf12	PVC	300	1	73.8	Storm main built underneath Clarke St	n/a
axf13	PVC	375	2.2	71.9	Storm main built underneath Clarke St	n/a
axf14	Concrete	600	3.8	88.8	Storm main built underneath Clarke St	n/a
axf15	Concrete	600	1.8	36.2	Storm main built underneath Clarke St	n/a
axf16	Concrete	600	3.9	16.5	Storm main built underneath Clarke St	n/a
axf17	Concrete	600	7.1	25.1	Storm main built underneath Queens St	n/a
Kyle Creek Major Storm Trunks						
kyl02	Concrete	900	7.2	8.7	Storm main built underneath St. George St	n/a
kyl03	Concrete	1050	2.7	31	Storm main built underneath Kyle St	n/a
kyl04	Concrete	1050	5.2	51.8	Storm main built underneath Kyle St	n/a
kyl05	Concrete	1050	6.1	41.5	Storm main built underneath Kyle St	n/a
kyl06	Concrete	1050	5.2	35.6	Storm main built underneath Kyle St	n/a

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
kyl07	Concrete	600	0	33.9	Storm main north of St. Johns St	n/a
kyl08	Concrete	600	1.3	44.5	Storm main built underneath Kyle St	n/a
kyl09	Concrete	1050	4.1	35.8	Storm main built underneath Kyle St	n/a
kyl10	Concrete	0	3.8	14.4	Storm main built underneath Kyle St	n/a
Hatchley Creek Major Storm Trunks						
hat02	Concrete	600	8.5	66.1	Strom main east of Grant St	n/a
Sundial Creek Major Storm Trunks						
sun02	Concrete	900	9	62.9	Storm main built underneath Moody St	n/a
Goulet Creek Major Storm Trunks						
gou02	Concrete	750	29	27	Storm main across Jane St	n/a
gou03	Concrete	750	5.1	67.6	Storm main built underneath Hugh St and Henry St	n/a
gou04	Concrete	1050	1.1	54	Storm main built underneath Henry St	n/a
gou05	Concrete	1200	0.5	93.7	Storm main built underneath Henry St	n/a
gou06	Concrete	1200	2.4	84.3	Storm main built underneath Henry St	n/a
gou07	Concrete	1200	2.5	66.7	Storm main built underneath Henry St	n/a
gou08	Concrete	1200	6.5	41.4	Storm main built underneath Grant St	n/a
gou09	Concrete	1200	5.3	55	Storm main built underneath Grant St	n/a
gou10	Concrete	1200	0	22.3	Storm main built underneath Grant St and St. George St	n/a
gou11	Concrete	1350	2.3	105.6	Storm main built underneath St. George St	n/a
gou12	Concrete	1350	2.9	52.4	Storm main built underneath St. George St	n/a
gou13	Concrete	1200	6.2	78.1	Storm main built underneath St. Mary St	n/a
gou14	Concrete	1350	2.7	90.9	Storm main built underneath St. Mary St	n/a
gou15	Concrete	1700	0.9	116.2	Storm main built underneath St. Spring St	n/a
gou16	Concrete	1700	0	10.2	Storm main built underneath St. Spring St	n/a
gou17	Concrete	1500	1.7	167.4	Storm main built underneath St. Spring St	n/a
gou18	Concrete	1500	11.8	7.2	Storm main built underneath St. Queens St	n/a
gou19	Concrete	1500	2	43	Storm main across Clarke St	n/a
gou20	Concrete	1500	2.2	47.8	Storm main across CP Railway	n/a
Williams Creek Major Storm Trunks						
wil02	Unknown	450	4.1	26	Storm main across Henry St	n/a
wil03	Unknown	600	7.1	70.5	Storm main across Hope St	n/a
wil04	Unknown	600	0.6	5.1	Hope St and Buller St	n/a

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
Dallas Creek (Slaughterhouse Creek) Major Storm Trunks						
dal02	CSP	0.9	2.3	26.6	Culvert north of Hope St with trash rack and slide gate at inlet; projecting outlet	310, 311, 312 and 313
dal03	Concrete	1	2.9	34.7	St George St crossing culvert with projecting inlet and outlet	318 and 319
dal04	Concrete	1.5	0.1	63.9	Storm inlet north of Hope St with trash rack	310, 311 and 312
dal05	Concrete	1.5	0.3	75.1	Storm main north of Hope St	n/a
dal06	Concrete	1.35	1.4	27.2	Storm main north of Hope St	n/a
dal07	Concrete	1.35	3.1	62.6	Storm main across St. George St	n/a
dal08	Concrete	1.35	2.5	86.1	Storm main north of St. George St	n/a
dal09	Concrete	1.5	3.5	49.3	St Johns St crossing culvert with headwall and wingwalls at inlet	320
dal10	Concrete	1.5	3.6	43	Storm main north of St. Johns St	n/a
dal11	Concrete	1.5	0	16.6	Storm main across Spring St	n/a
dal12	Concrete	1.5	2	60.9	Storm main north of Spring St with headwall at outlet	454
dal13	CSP	1.5	3.7	26.8	CP Rail crossing culvert	n/a
dal14	CSP	1.5	2	68.9	Culvert north of CP Rail	n/a
dal15	Concrete	1.5	3.8	28	Murray St crossing culvert; outfall to Burrard Inlet; projecting outlet	456
Suter Brook Major Storm Trunks						
sut01	CSP	900	4.5	31.1	Brookside Dr crossing culvert	n/a
sut02	Concrete	600	3.4	17.9	Culvert south of Barnet Hwy	329
sut03	Concrete	900	0.6	42.3	Barnet Hwy crossing culvert with headwall, wingwalls and trash rack at inlet; projecting outlet	332 and 328
sut04	Concrete	525	9.9	10.2	Storm inlet south of Cable Ct	n/a
sut05	Concrete	600	6.4	99.6	Storm main built underneath Cable Ct	n/a
sut06	Concrete	600	2.1	61.5	Storm main built underneath Cable Ct	n/a
sut07	Concrete	600	6.6	89.9	Storm main north of Cable Ct	n/a
sut08	Concrete	675	2.8	54.1	Storm main built underneath Channel Ct	n/a
sut09	Concrete	675	3	59	Storm main built underneath Channel Ct	n/a
sut10	Concrete	675	2.5	13.7	Storm outlet across Viewmount Dr	n/a

Culvert ID	Material Type	Diameter (mm)	Slope (%)	Length (m)	Comment	Photo Reference
sut11	PVC	900	11.6	4.2	Storm inlet north of Henry St	n/a
sut12	PVC	750	1.5	36	Storm main north of Henry St	n/a
sut13	Concrete	750	1.7	16.7	Storm main north of Henry St	n/a
sut14	Unknown	900	0.5	37.6	Storm main north of Henry St	n/a
sut15	Unknown	900	0.2	66.1	Storm main south of Dewdney Trunk	n/a
sut16	Unknown	900	0.5	9.8	Storm main south of Dewdney Trunk	n/a
sut17	Unknown	1050	0.2	25.7	Storm outlet across Dewdney Trunk Rd	n/a
sut18	Unknown	900	5.3	18.9	Barnet Hwy crossing culvert	n/a
Caledonia Major Storm Trunks						
cal01	Unknown	600	18.3	19.1	Huron Dr crossing culvert	n/a
cal02	Unknown	600	7.3	26.1	Oneid Dr crossing culvert	n/a
cal03	Unknown	600	26.3	60.4	Corona Crescent crossing culvert	n/a
cal04	Unknown	525	0	27.3	Viewmount Dr crossing culvert	n/a
cal05	Unknown	525	10.3	40.5	Storm inlet south of Henry St	n/a
cal06	Unknown	600	9	8.5	Storm main built underneath Henry St	n/a
cal07	Unknown	600	8.4	69.2	Storm main north of Henry St	n/a

E.2 BASE MODEL ASSEMBLY

E.2.1 Surface Build

Based on the LIDAR data provided by Metro Vancouver and contours from the Cities of Port Moody and Coquitlam, we developed a topographic surface with a grid resolution of 1 m x 1 m. LIDAR derived data was only available for the ravine areas. Contour data provided by the Cities was utilized for developed areas. Figure E-2 shows the complete surface for the study area.

The elevations vary in the range of 140 - 170 m in the residential areas of the uplands in the City of Coquitlam. Within the ravine area, the elevations range from 100 - 140 m at the stream headwaters in Coquitlam to 20 - 50 m at the intakes to the drainage pipe system at the outlet of the ravines with a general slope toward Burrard Inlet in Port Moody. The elevations in the lowlands in Port Moody vary in the range of 10-30 m.

E.2.2 Model Build

We used GIS methodologies for rapid and accurate development of the hydrologic/hydraulic model. We incorporated a number of advanced spatial analysis routines to aid the development of the model using the assembled data. The routines included consideration of attribute data, proximity of other features and topography. The routines facilitated the following tasks:

- Automated catchment delineation for each desired model node or critical point using a spatially based topographic analysis routine, applicable to establishing contributing catchment areas for culverts and other key points in a drainage network.
- Geometric model development and attribute generation for the overland flow network.

The assembled model includes 761 links which consist of culverts, storm pipes, and creek segments, 753 nodes, and 759 subcatchments.

Figure E-3 schematically illustrates the model build.

E.2.3 Land Use

Current Land Use

Low density residential land uses comprise approximately 40% of the study area. A large portion of the lowland area is industrial, particularly the area bounded by Barnet Highway and Clarke Street. To the east of the industrial area, approximately 30 ha is green space adjacent to the Burrard inlet.

The ravines located in the central part of the study area account for approximately 20% of the study area.

Figure E-4 illustrates the existing land use distribution.

Estimation of the total impervious area (TIA) and effective impervious area (EIA) for each existing land use type are summarized in Table E-2.

Table E-2
Assumed Existing TIA and EIA

	Existing Area (ha)		Total (ha)	TIA (%)	EIA (%)
	Coquitlam	Port Moody			
Commercial	3.6	61.7	65.3	70	60
Industrial	3.1	107.0	110.1	80	70
Institutional	25.6	23.5	49.1	55	45
Low Density Residential	270.5	160.3	430.9	45	40
Medium Density Residential	1.2	65.2	66.4	55	50
Parks and Open Space	8.7	49.1	57.8	5	5
Ravine	116.3	77.5	193.8	3	3
Road Pavement	24.2	36.4	60.5	90	70

Future Land Use

It is anticipated that the City Centre area of Port Moody will undergo significant redevelopment in the future as the Evergreen Line is built in the lower portion of the watershed. As shown in Figure E-5, the Evergreen Line will travel at ground level parallel to the Canadian Pacific Railway. However, major impacts or changes are not expected within the Coquitlam portion of the study area.

Figure E-5
Evergreen Line Alignment

(Source: http://www.translink.ca/en/Plans-and-Projects/Rapid-Transit-Projects/Evergreen-Line.aspx)

The Official Community Plan also indicates a potential increase in residential area density in the lowlands near the proposed Evergreen Line alignment. The future land use is illustrated in Figure E-6.

Our estimates of the total impervious area (TIA) and effective impervious area (EIA) for each existing land use type under future conditions are summarized in Table E-3.

Table E-3
Assumed Future TIA and EIA

	Future Area (ha)		Total (ha)	TIA (%)	EIA (%)
	Coquitlam	Port Moody			
Commercial	0.4	59.4	59.9	70	60
Industrial	3.2	103.9	107.1	80	70
Institutional	25.0	24.6	49.6	55	45
Low Density Residential	274.1	151.4	425.5	75	70
Medium Density Residential	1.2	83.1	84.3	85	80
Parks and Open Space	8.7	46.9	55.6	5	5
Ravine	116.3	75.4	191.7	3	3
Road Pavement	24.1	35.7	59.9	90	70

Hydrologic/Hydraulic Modelling Parameters

After delineating sub-catchments, we assigned parameters to each sub-catchment. The sub-catchment slope, minimum elevation, and maximum elevation for each sub-catchment were computed using GIS algorithms from the digital surface.

Table E-4 summarizes the parameters used in the model.

Table E-4
Hydrologic and Hydraulic Modelling Parameters

Horton Infiltration Parameters	
Maximum Infiltration Rate for Lowlands/Ravine/Uplands (mm/hr)	12.5/38/2.5
Minimum Infiltration Rate for Lowlands/Ravine/Uplands (mm/hr)	3/13/0.9
Decay Constant (hr^{-1})	4.5
Drying Time (days)	8.0
Manning's n for Impervious Surface	0.016
Manning's n for Pervious Surface	0.300
Depression Storage for Impervious Surface (mm)	0.5

Horton Infiltration Parameters	
Depression Storage for Pervious Surface – Urban Areas (mm)	5
Depression Storage for Pervious Surface – Ravine (mm)	20
Percent Zero Impervious (%)	0
Manning's Roughness	
Concrete	0.014
PVC	0.012
CSP	0.024
Wood	0.014
Natural Channel	0.035
Headloss Coefficient	
Entrance (Channel to Pipe)	0.9
Exit (Pipe to Channel)	0.2
Manhole Connection	0

Rainfall

We obtained and reviewed data for several rainfall gauges located near the study area. They are summarized in Table E-5.

Table E-5
Rainfall Gauges

Gauge ID	Description	Source	Period of IDF Curves	Number of Years
1106CL2	Port Moody	AES	1971-1998	28
BU35	Burnaby Mountain	Metro Vancouver	1993-2008	16
PT11	Port Moody Pump Station	Metro Vancouver	1959-1979, 1982-1983, 1994-2008	38
PT32	Rocky Point Park	Metro Vancouver	1994-2008	15
QT10	Coquitlam Maillardville	Metro Vancouver	1959-2008	50
QT77	Douglas College	Metro Vancouver	2001-2008	8

Figure E-7 illustrates the locations of the rainfall gauges located near the study area.

Considering the number of record years and proximity of the rain gauge location, data from the Metro Vancouver Gauge PT11 – Port Moody Pump Station was chosen as the preferred source of the IDF data for the study area. This rainfall gauge has an elevation of 4 m, and 38 years of data is available for the three (3) periods, 1959-1979, 1982-1983, and 1994-2008. Synthetic storms were generated for the two (2) frequencies (10-year and 100-year) and included storm durations ranging from 30 min to 24 hours. See Figure E-8 for the Port Moody Pump Station Rain Gauge (PT11).

Figure E-8
Rainfall IDF Curve for PT11 – Port Moody Pump Station

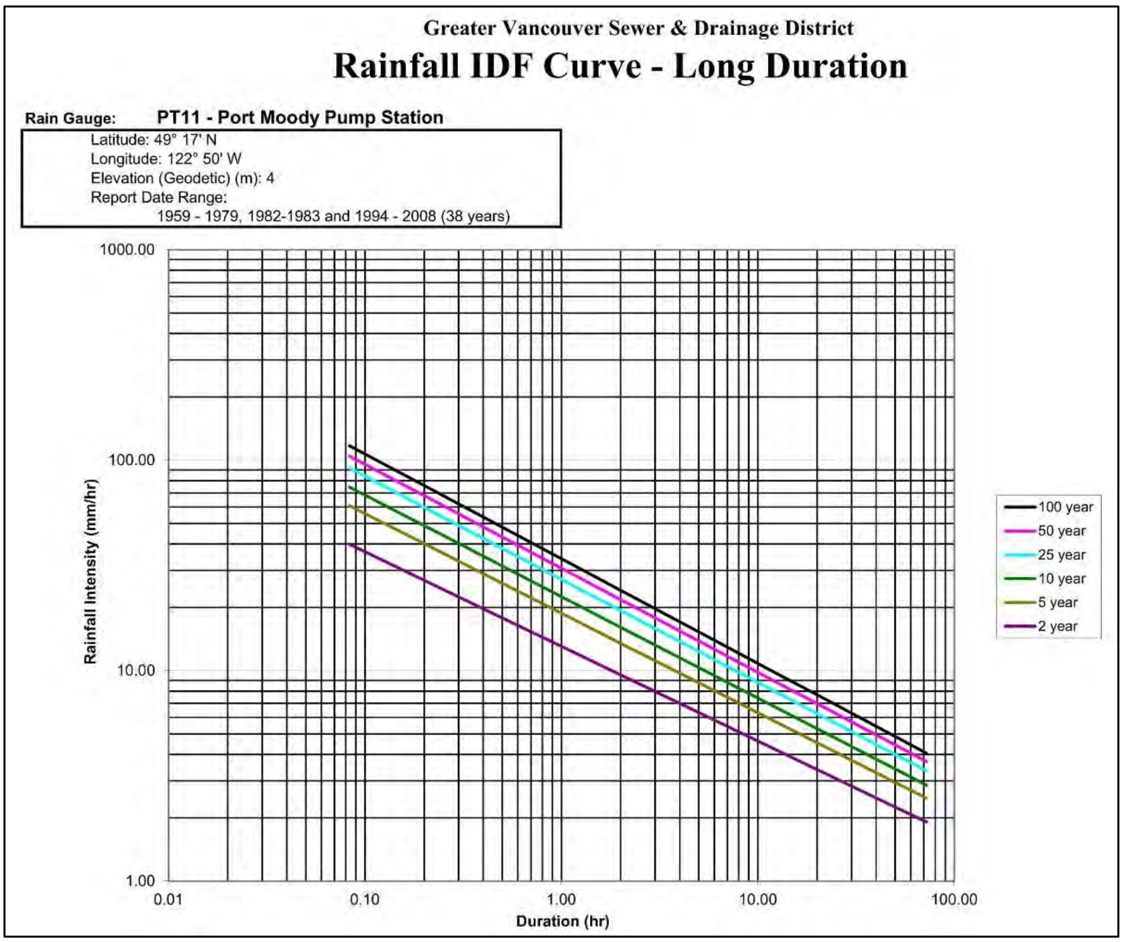


Table E-6 provides the Coefficient A and Exponent B values used to generate the all duration synthetic storms using the IDF equation (I=AT^B where I is rainfall intensity and T is storm duration).

Table E-6
Rainfall IDF Curve Data at Rain Gauge PT11

	10 year	100 year
Coefficient A	22.509	34.108
Exponent B	-0.482	-0.497

E.3 MODELLING RESULTS

E.3.1 Peak Flow and HGL Assessment

Using the hydrologic and hydraulic model, we analyzed the existing and future conditions in the watershed. By comparing the results from the two conditions, we were able to estimate the potential impacts on the watershed as a result of the future development.

To assess the potential impact of the future development on the watershed, we focused on flow conditions at 14 "indicator" locations. See Figure E-3.

The peak flows, HGLs and runoff volumes under existing and future conditions for 10-year and 100-year return period storm events for the 14 locations are summarized in Table E-7 and Table E-8.

Table E-7
Peak Flow and HGL Assessment for 10-year All Duration Storm Event

Discharge Location	10-year Peak Flow (m^3/s)			10-year HGL (m)			10-year Runoff Volume (m^3)		
	Existing	Future	% Change	Existing	Future	% Change	Existing	Future	% Change
South Schoolhouse Creek Drainage System									
SH01	3.27	3.49	6.4%	22.94	22.96	0.1%	55,685	58,346	4.6%
SH02	3.30	3.69	10.4%	39.11	39.11	0.0%	56,872	61,389	7.4%
SH03	4.86	5.28	8.0%	23.02	23.07	0.2%	99,765	110,838	10.0%
SH04	0.49	0.59	16.5%	47.43	47.47	0.1%	8,135	9,653	15.7%
SH05	0.36	0.39	7.2%	40.72	40.73	0.0%	5,801	6,220	6.7%
Kyle Creek Drainage System									
KL01	0.28	0.33	13.5%	38.59	38.61	0.1%	5,009	5,476	8.5%

Discharge Location	10-year Peak Flow (m^3/s)			10-year HGL (m)			10-year Runoff Volume (m^3)		
	Existing	Future	% Change	Existing	Future	% Change	Existing	Future	% Change
KL02	0.47	0.56	16.8%	17.99	18.02	0.2%	7,858	9,277	15.3%
KL03	0.57	0.68	16.5%	33.88	33.92	0.1%	9,296	11,059	15.9%
KL04	1.74	2.00	12.9%	38.79	38.85	0.2%	29,956	34,351	12.8%
KL05	1.03	1.20	14.6%	43.53	43.58	0.1%	16,594	19,594	15.3%
Slaughterhouse/Dallas Creek Drainage System									
WL01	0.11	0.16	34.8%	23.38	23.42	0.2%	1,804	2,783	35.2%
WL02	1.80	2.31	21.9%	21.59	22.17	2.6%	31,921	39,382	18.9%
WL03	1.71	2.13	19.6%	26.81	26.85	0.1%	30,334	36,338	16.5%
WL04	1.63	2.00	18.3%	38.51	38.54	0.1%	28,835	33,996	15.2%
Pigeon Creek Drainage System									
PG01	0.79	0.79	0.0%	10.54	10.54	0.0%	20,731	21,808	4.9%
Suter Brook Drainage System									
SB01	1.93	2.08	7.0%	19.82	20.06	1.2%	30,909	33,198	6.9%
SB02	0.73	0.77	5.7%	34.49	34.50	0.0%	11,704	12,665	7.6%
SB03	0.74	0.75	0.9%	47.08	47.08	0.0%	11,235	11,358	1.1%

Table E-8
Peak Flow and HGL Assessment for 100-year All Duration Storm Event

Discharge Location	100-year Peak Flow (m^3/s)			100-year HGL (m)			100-year Runoff Volume (m^3)		
	Existing	Future	% Change	Existing	Future	% Change	Existing	Future	% Change
South Schoolhouse Drainage System									
SH01	5.15	5.43	5.1%	23.07	23.09	0.1%	84,196	87,011	3.2%
SH02	5.14	5.62	8.5%	39.11	39.11	0.0%	85,970	90,753	5.3%
SH03	6.26	6.72	6.9%	23.18	23.23	0.2%	144,585	156,444	7.6%
SH04	0.78	0.92	14.6%	47.54	47.59	0.1%	12,356	14,327	13.8%
SH05	0.58	0.62	6.0%	40.79	40.80	0.0%	8,863	9,397	5.7%
Kyle Creek Drainage System									
KL01	0.39	0.40	3.5%	38.64	38.64	0.0%	7,466	7,908	5.6%
KL02	0.58	0.66	11.9%	18.03	18.05	0.1%	11,606	13,236	12.3%
KL03	0.90	1.05	14.9%	33.97	34.01	0.1%	14,150	16,451	14.0%
KL04	2.51	2.78	9.5%	38.95	39.01	0.2%	44,799	50,142	10.7%
KL05	1.54	1.78	13.5%	43.66	43.73	0.2%	24,945	28,807	13.4%
Slaughterhouse/Dallas Drainage System									
WL01	0.17	0.26	34.4%	23.42	23.46	0.2%	2,654	4,072	34.8%
WL02	2.78	3.52	21.0%	23.01	23.01	0.0%	48,214	58,400	17.4%
WL03	2.64	3.25	18.6%	26.89	26.93	0.1%	45,811	53,895	15.0%
WL04	2.52	3.04	17.2%	38.58	38.62	0.1%	43,609	50,473	13.6%
Pigeon Creek Drainage System									
PG01	0.86	0.86	0.0%	10.57	10.57	0.0%	29,287	30,449	3.8%
Suter Brook Drainage System									
SB01	2.61	2.71	3.9%	21.05	21.26	1.0%	47,310	49,705	4.8%
SB02	1.16	1.21	4.2%	35.14	35.64	1.4%	17,787	18,785	5.3%
SB03	1.17	1.18	0.6%	47.78	47.81	0.1%	17,481	17,609	0.7%

Overall, the peak flows, HGL, and runoff volumes increase in future conditions. The changes are relatively higher in the Kyle Creek Drainage System and Slaughterhouse/Dallas Creek Drainage System than the rest of the drainage areas, as a result of future development in Port Moody as highlighted in Figure E-6.

E.3.2 Deficiencies

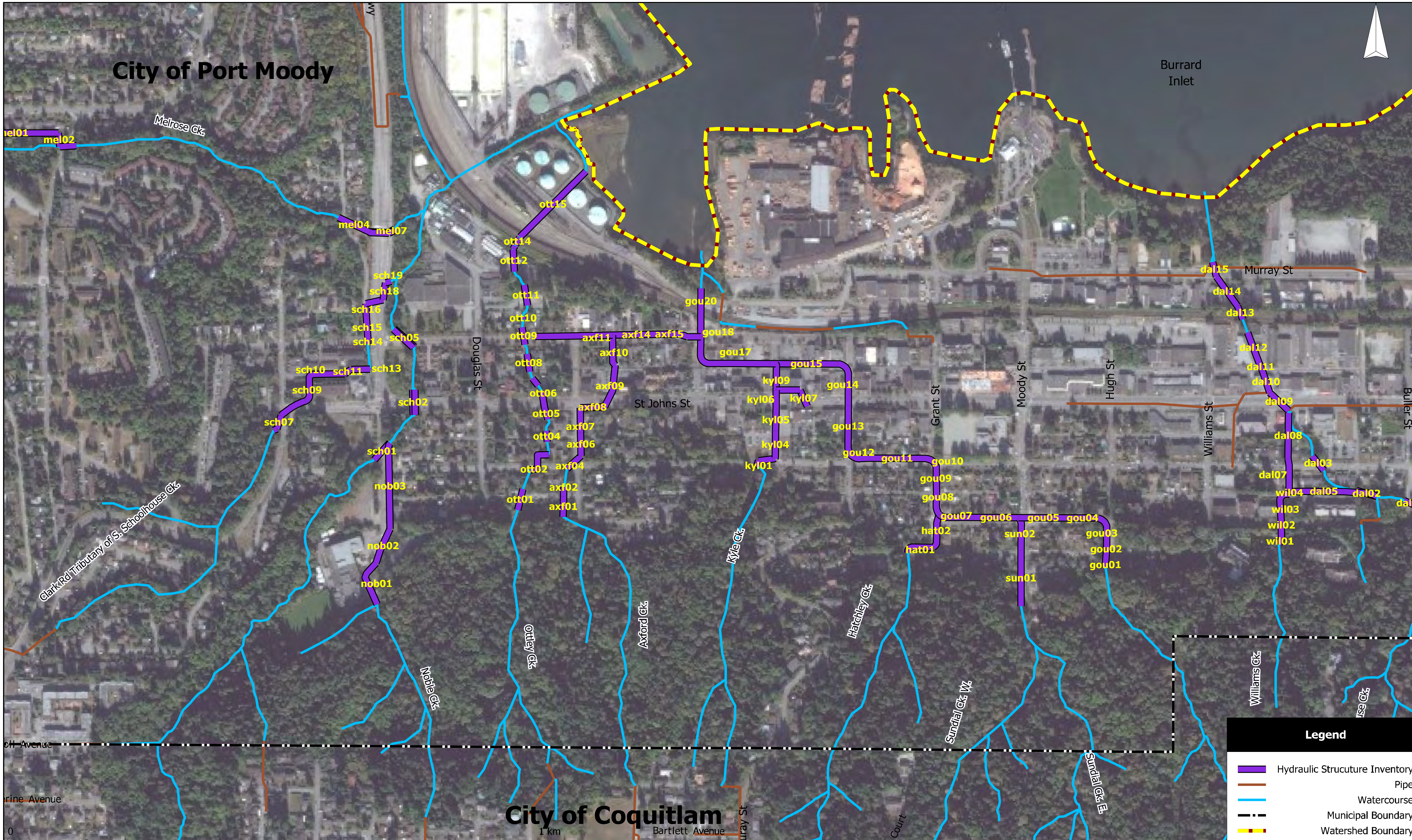
We investigated 10-year and 100-year existing condition model results to locate capacity deficiencies in the drainage infrastructure. In both Port Moody and Coquitlam, storm infrastructure is built to 10-year and 100-year storm events for minor and major systems, respectively. The minor system includes underground storm infrastructure such as storm sewers, and the major system includes culverts on natural watercourses and under roadways.

We compared the ground elevation and the HGL to determine the surcharge level and freeboard at each junction (i.e. manholes, catch basins, inlets, and outlets), and categorized into four different conditions: flooded, no freeboard, in the range of 0.1 m to 0.5 m freeboard, and greater than 0.5 m freeboard.

Similarly, we examined the flow capacity through each conduit (i.e. channels, culverts, and storm sewer) and categorized into five different conditions: flow greater than 100% of pipe capacity, flow between 90% and 100% of pipe capacity, flow between 75% and 90% of pipe capacity, flow between 50% and 75% of pipe capacity, and flow less than 50% of pipe capacity.

10-Year Event Deficiencies: The model results indicate that some of the pipes in the uplands are undersized for 10-year storm events. However, none of the manholes appear to surcharge above the ground. The pipes in the lowlands are generally under capacity for 10-year storm events. We note that most of these pipes are major regional trunks and the capacity of these pipes needs to be examined under 100-year storm event conditions. See Figure E-10 for the locations of deficiencies.

100-Year Event Deficiencies: The majority of storm sewer pipes in the uplands are surcharged as expected for 100-year storm events. Most of the manholes in the uplands are surcharged to the ground level. Overall, the regional pipes in the lowlands have the capacity to allow 100-year flows, except for the South Schoolhouse Creek pipe system. See Figure E-11 for the location of deficiencies.



PROJECT NO: 20112817
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DATE: January 2015
DESIGNED BY: JL
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Coquitlam

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Figure E-1
Major Trunk Drainage System in Port Moody

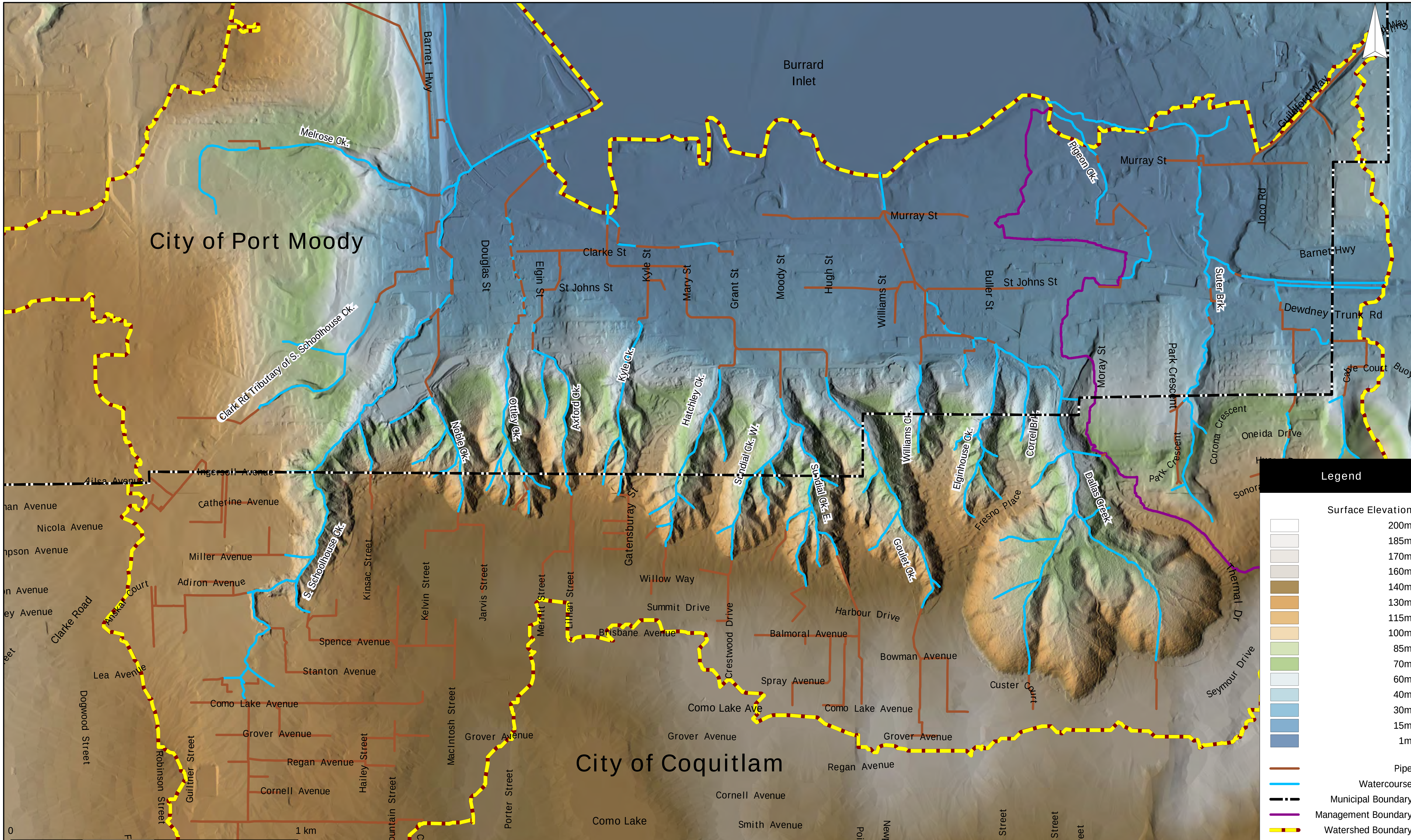

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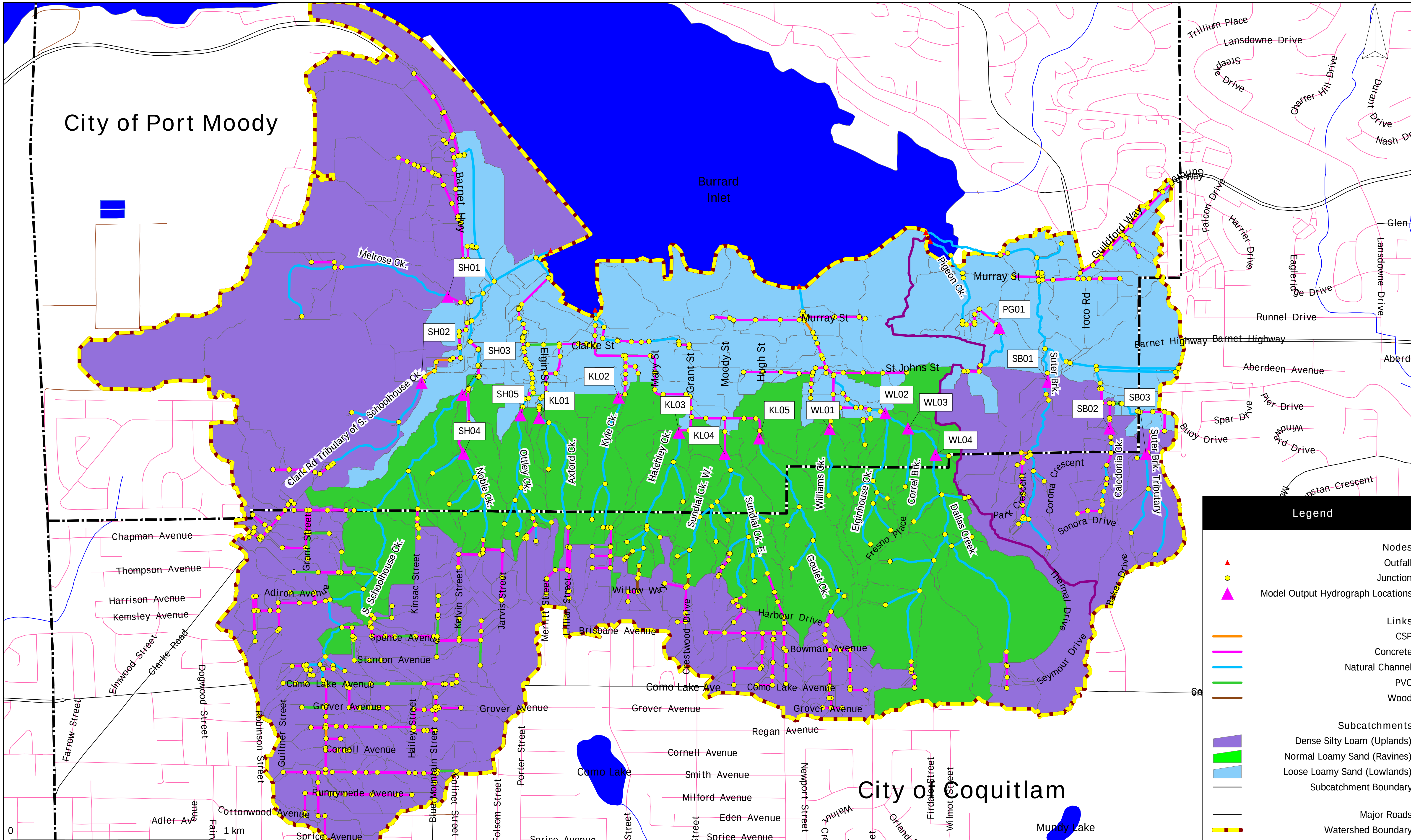
Figure E-2 Relief Map of Study Area

Time: 5:11:48 PM | Date: 2/3/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure E-2 Relief Map of Study Area



Time: 5:12:54 PM | Date: 2/3/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure E-3 Hydraulic Model Network

PROJECT NO:	20112817
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Figure E-3 Hydraulic Model Network

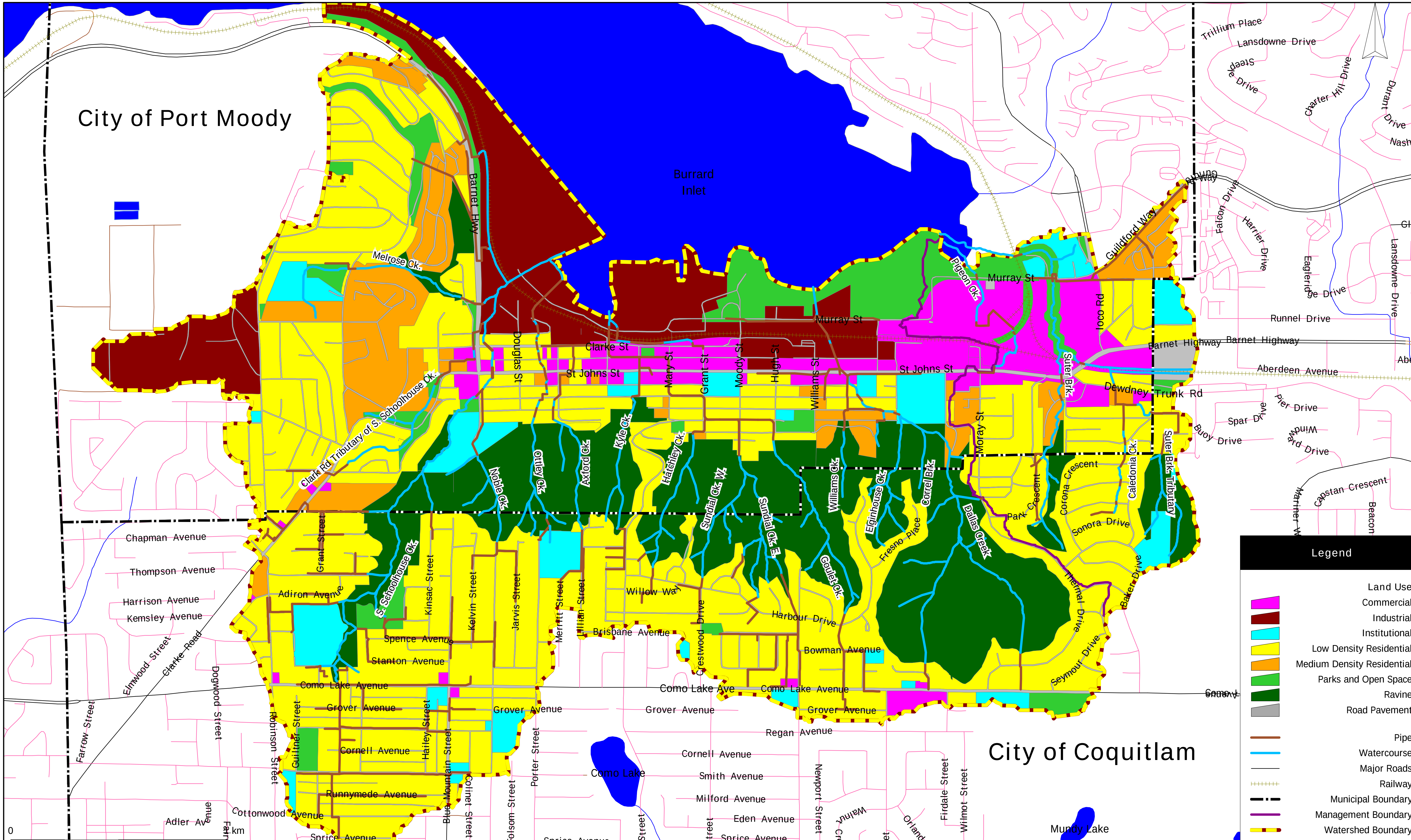

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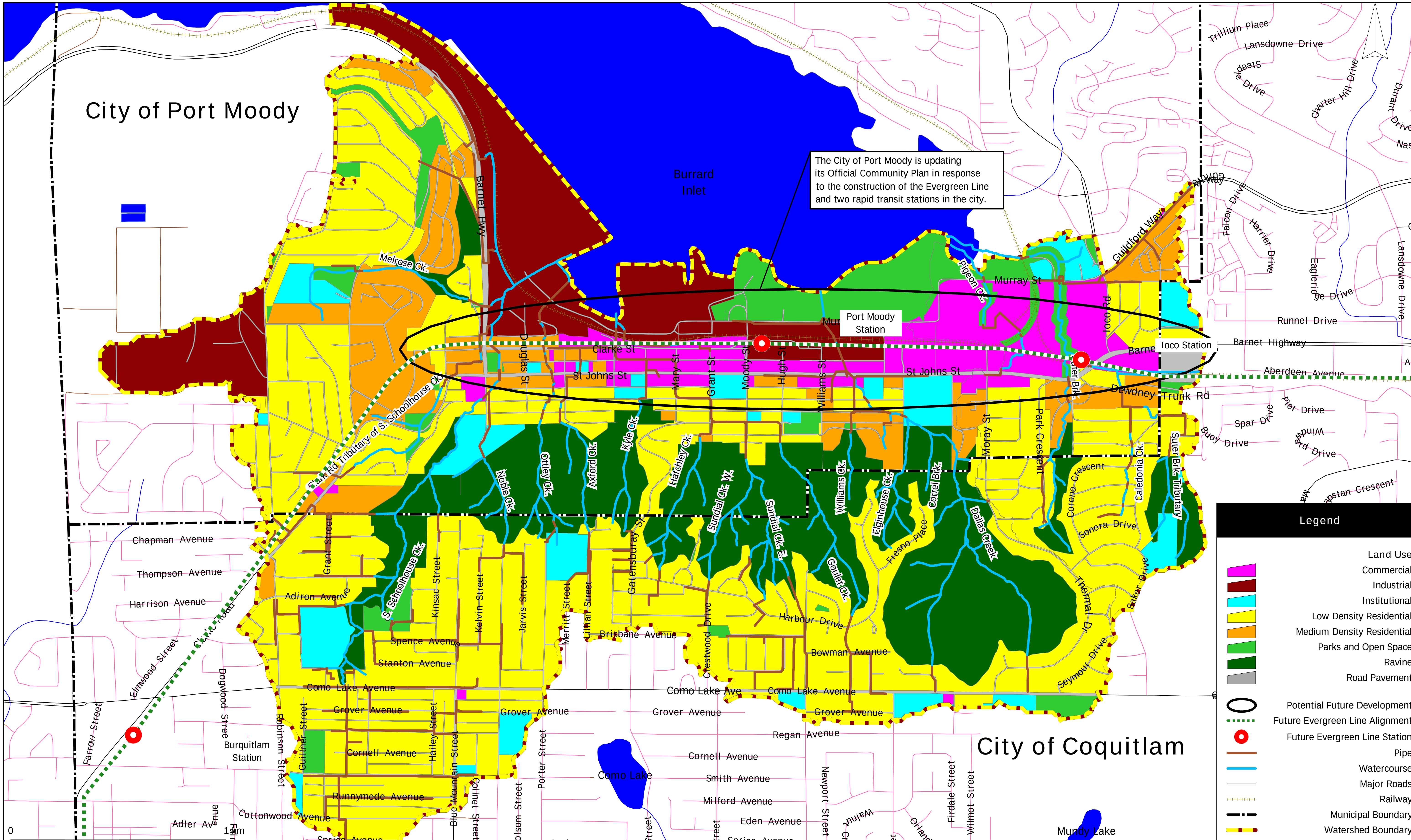
Figure E-4 Existing Land Use Designations



Time: 5:14:10 PM | Date: 2/3/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure E-6 Future Land Use Designations

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Figure E-6 Future Land Use Designations

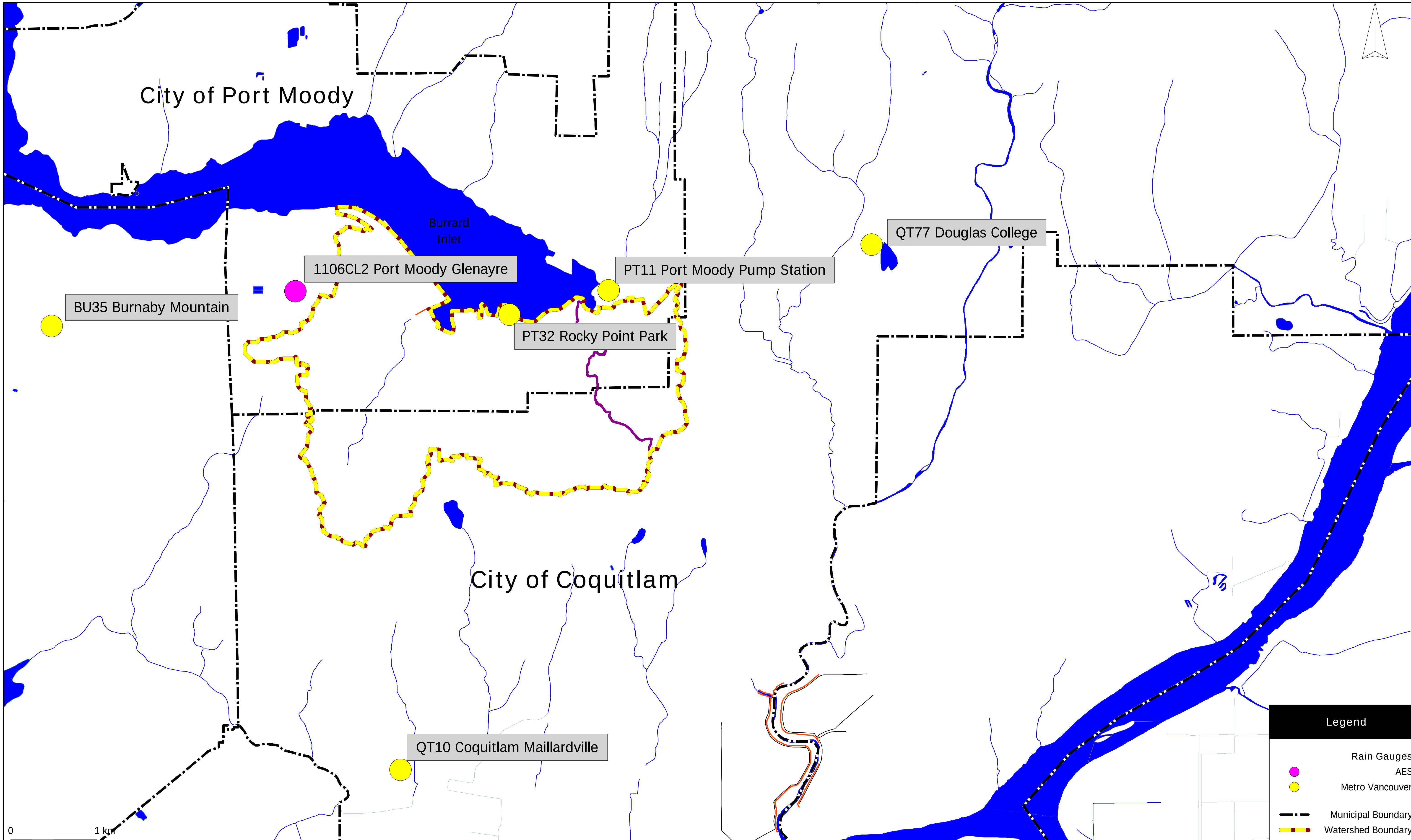

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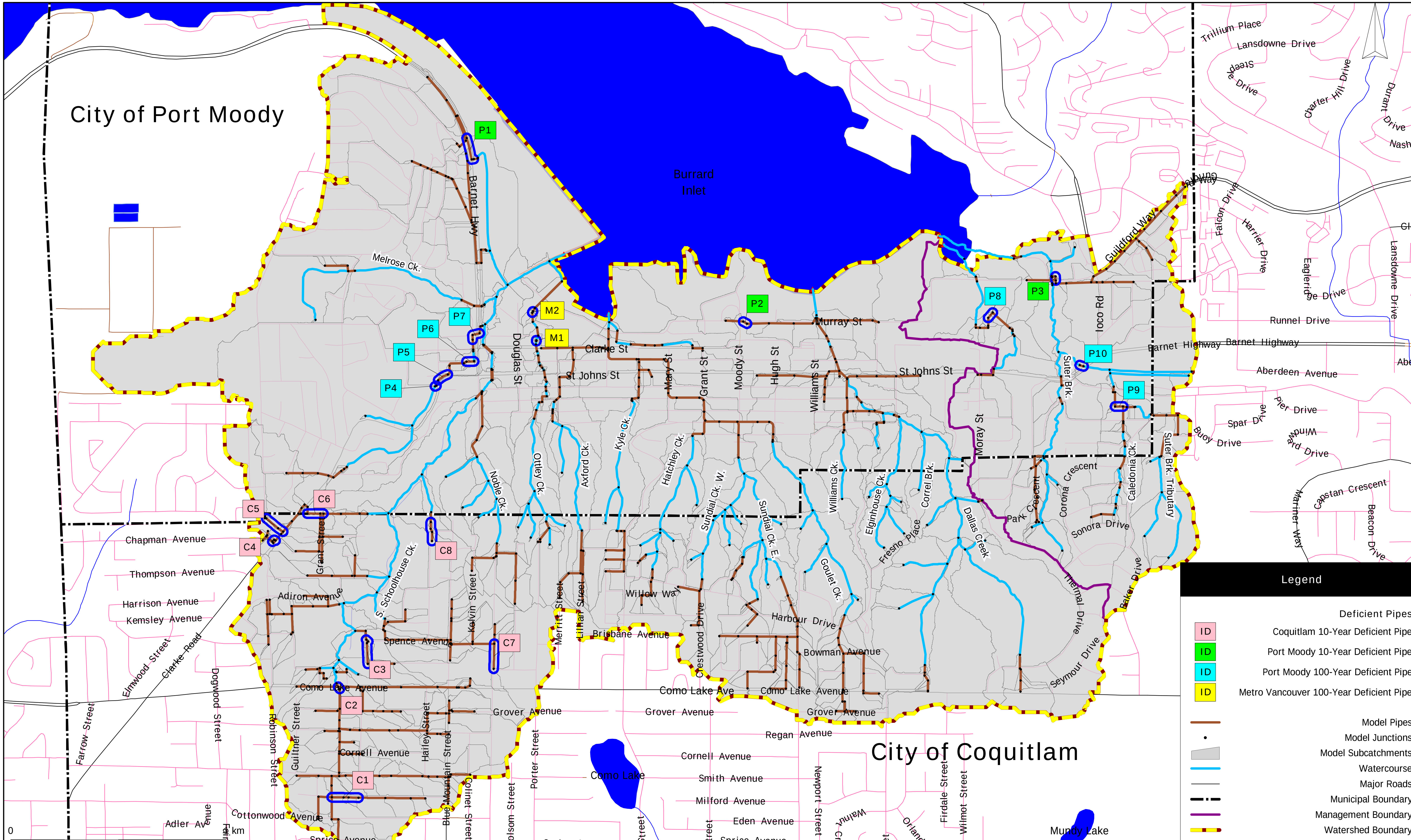
Figure E-7 Rainfall Gauge Locations



PROJECT NO:	20112817
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DATE:	January 2015
DESIGNED BY:	JL
CHECKED BY:	MM

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Figure E-9 Identified Deficient Pipes

Time: 5:28:25 PM | Date: 4/16/2015
Map File: P:\20112817\apps\GIS\map_FINAL_figures_20150121_jl.map - Figure E-10 Deficient Pipes

Appendix F – Details of Pipe Network Upgrades

F.1 REQUIRED PIPE UPGRADES

We summarize required pipe upgrades for the minor and major systems in Table F-1.
Note that all cost estimates are based on a high-level analysis and should be considered preliminary, subject to review with more detailed design. Cost estimates are in 2014 dollars and include engineering (10%) and contingencies (30%). Unit cost assumptions are provided in Table F-2.

Table F-1
Pipe Upgrades

ID*	Location	Existing Pipe Diameter (mm)	Required Pipe Diameter (mm)	Total Length (m)	Existing / Future Upgrade	Unit Cost	Existing Upgrade
C1	Runnymede Avenue	300	375	124	Existing	$4,050	$502,200
C2	Como Lake Avenue	1050	1200	12	Existing	$4,800	$57,600
C3	Norfolk Street	375	450	119	Future	$4,100	$487,900
C4	Clark Road	300	375	19	Future	$4,050	$76,950
C5	Glenayre Drive	300	375	100	Existing	$4,050	$405,000
C6	Ingersoll Avenue	450	525	74	Existing	$4,150	$307,100
C7	MacIntosh Street	300	375	116	Existing	$4,050	$469,800
C8	Kinsac Street	300, 375, 200	450	89	Existing	$4,100	$364,900
P1	Barnett Highway	450	525	113	Existing	$4,150	$468,950
P2	Murray Street	375	450	20	Existing	$4,100	$82,000
P3	Murray Street	1050	1200	18	Existing	$4,800	$86,400
P4	Clark Rd Tributary of S. Schoolhouse Creek	600	750	6	Existing	$4,400	$26,400
P5	Clark Rd Tributary of S. Schoolhouse Creek	750	900	53	Existing	$4,450	$235,850

P6	Clark Rd Tributary of S. Schoolhouse Creek	750	900	36	Existing	$4,450	$160,200
P7	Clark Rd Tributary of S. Schoolhouse Creek	1050	1200	55	Existing	$4,800	$264,000
P8	Pigeon Creek	900	1050	32	Existing	$4,500	$144,000
P9	Suter Brook Tributary	900	1050	38	Existing	$4,500	$171,000
P10	Suter Brook Tributary	900	1050	19	Existing	$4,500	$85,500
M1	Ottley Creek	600	675	4	Existing	Unit costs not applicable	$125,000
M2	Ottley Creek	450	525	7	Existing	Unit costs not applicable	$125,000
						City of Coquitlam Pipe Upgrade Total:	$2,671,450
						City of Port Moody Pipe Upgrade Total:	$1,724,300
						Metro Vancouver Pipe Total:	$250,000
						Total:	$4,645,750

Table F-2
Unit Cost Assumptions

Pipe Diameter (mm)	Unit Cost
300	$3,950
350	$4,000
375	$4,050
450	$4,100
525	$4,150
600	$4,250
675	$4,350
700	$4,350
750	$4,400
800	$4,400
900	$4,450
1000	$4,500
1050	$4,500
1200	$4,800