Final Report

Nelson Creek Integrated Watershed Management Plan

Submitted to

City of Coquitlam

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Prepared by

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Executive Summary

The Integrated Watershed Management Plan (IWMP) process is an approach that balances land development and environmental values. It strives to preserve watershed health as a whole, but also meet community needs and facilitate growth and development. The IWMP investigates issues related to the quality and quantity of rainwater runoff, flood protection, environmental protection of aquatic resources, wildlife and their habitats, land use, green ways, and recreation.

The Nelson Creek watershed in Coquitlam, British Columbia (BC) is approximately 250 hectare (ha) in area and is bounded by Blue Mountain Street to the west, King Edward Street to the east, Regan Avenue to the north, and the Fraser River to the south. This watershed is within the Southwest Coquitlam Area Plan and spans two Neighbourhood Plan Areas: the Austin Heights area to the north and the Maillardville area to the south. The main land uses are single-family residential in the upland area, and parkland, commercial, and industrial in the lowland area. The watershed is fairly well built out, with potential for development and redevelopment of the single-family lots into other housing choices (City of Coquitlam, 2010).

The Nelson Creek watershed contains a high level of urban development with land uses ranging from residential in the upper areas to commercial in the lower areas. The health of the watershed, as defined by the Greater Vancouver Sewerage and Drainage District (GVS&DD) classification system, is ranked poor, based on a 63 percent Total Impervious Area (TIA) and 16 percent Riparian Forest Integrity (RFI). The following main issues have been identified for the watershed:

- Stream channel erosion and sediment transport
- Poor water quality (i.e., for elevated fecal coliforms, nutrients, some metals)
- Limited conveyance capacity
- Alteration of fish and riparian habitat

The Nelson Creek IWMP is based on the following primary objectives:

- Short-term objectives:
  - Provide stream protection at critical erosion sites
- Medium-term objectives:
  - Improve stormwater conveyance capacity
  - Implement recommended flow and water quality monitoring and install water quality treatment units to enhance water quality
  - Peak flow control diverting runoff from upper watershed to lower watershed
  - Removal of fish barriers, restore in-stream habitat

- Long-term objective:
  - Restore overall watershed health through the implementation of integrated projects, including rainwater management, enhancing riparian vegetation, rehabilitating mouth of Nelson Creek and public education.

    Watershed management plans will be developed utilizing a “systems” approach to stormwater management that allows trade-offs in some areas for gains in others and a principle of “net environmental benefit” objective for fish habitat protection will be used. Watershed health will be determined based on the collective health of the aquatic and terrestrial systems within such as: hydrology, geomorphology, water quality, stream base flows, fish presence, spawning areas, riparian integrity, terrestrial habitat, and nutrient value. The recommended improvements are intended to provide a net improvement to fish habitat and fish productivity.

Recommendations

The recommendations below are suggested based on the findings of this study.

Sediment Erosion

- Manage high-risk erosion sites on a case-by-case basis
- Divert all runoff greater than the 5-year, 24-hour design storm (0.47 m^3/s, 8L/s/ha) out of the upper watershed (north of Austin Avenue) to the lower portion of Nelson Creek (south of Lougheed Highway)

Stormwater and Rainwater Management

- Adopt the proposed rainwater capture design target to control the first 34mm in a 24 hour period
- Implement the City’s Rainwater Management Guidelines

Water Quality

- Develop and implement a monitoring program
- Install water quality treatment units at proposed locations
- Assess and address coliform and nutrient sources (e.g., cross-connections between the sanitary and stormwater systems); this is especially important in upstream areas where the stream is buried and water quality is poorer
- Investigate for possible existence of cross-connections between sanitary and storm sewers that might explain the highly elevated fecal coliform levels (also elevated ammonia, phosphate, cadmium, and copper) in upper Nelson Creek reported in the water-quality study
- Investigate possible detergent pollutants entering the Nelson Creek periodically at the Alderson road culvert near or between its inlet and outfall

Conveyance Capacity Improvement

- Upsize pipes that result in flooding during a 10-year, 1-hour design storm
- Upsize pipes (within the commercial areas) that result in flooding during the 25-year, 1-hour design storm
- Upsize the major collector (between Foster Avenue and Charland Avenue) that results in flooding during a 100-year, 1-hour design storm
- Upsize in-stream culverts that result in flooding during the 100-year, 1-hour design storm

Riparian Enhancement Strategy

- Restore habitats infested with invasive species
- Establish fenced covenants through subdivision applications or redevelopment opportunities to protect riparian habitat
- Planting native shrubs and coniferous plus deciduous trees at moderate densities on private and public lands

Fish Habitat Enhancement Strategy

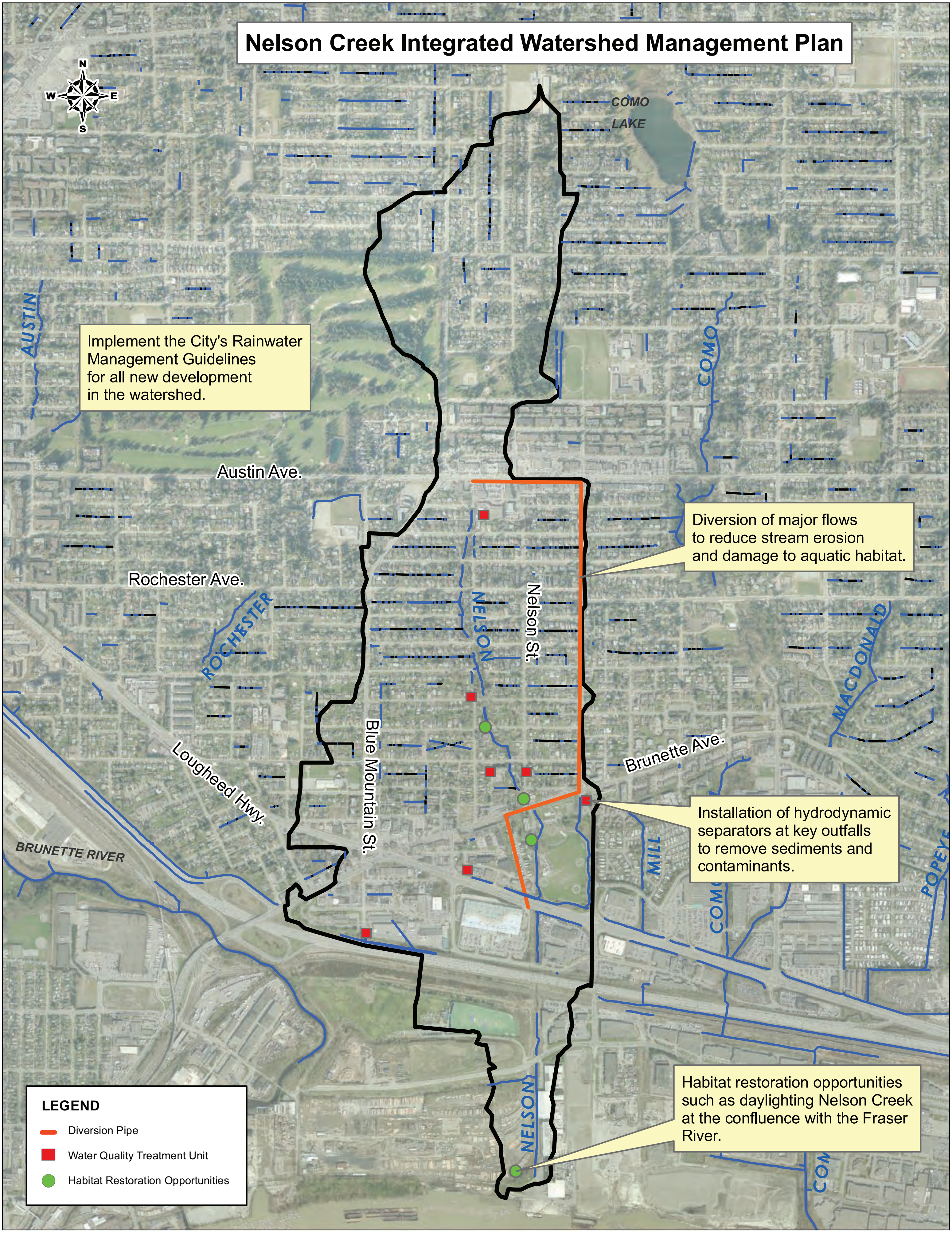
- Daylight Nelson Creek at the Fraser River confluence by creating a treed corridor to the west
- Remove permanent natural barriers and culverts with jumps

Ditch Management Compensation Strategy

- Enhancing riparian vegetation along Lougheed Highway Red classified ditches in Nelson Creek Watershed
- Protecting or providing habitat compensation for lane ditches (Yellow classified ditches) in Nelson Creek Watershed
- Enhancing riparian setbacks on Nelson Creek in Mackin Park
- Rehabilitating mouth of Nelson Creek (City-owned portion of Unit 1 of the proposed design)

Public Education

- Enhance City's website
- Install educational signs at sites that incorporate stormwater management alternatives
- Provide list of recommended native plant species for use in private property
- Encourage residents to implement landscaping techniques that help in rainwater management
- Explore the establishment of a Stream Stewardship Group



Nelson Creek Integrated Watershed Management Plan
N
W
E
S
COMO
LAKE
AUSTIN
COMO
Implement the City's Rainwater Management Guidelines for all new development in the watershed.
Austin Ave.
Diversion of major flows to reduce stream erosion and damage to aquatic habitat.
Rochester Ave.
ROCHESTER
NELSON
Nelson St.
MACDONALD
Brunette Ave.
Lougheed Hwy.
Blue Mountain St.
Installation of hydrodynamic separators at key outfalls to remove sediments and contaminants.
BRUNETTE RIVER
MILL
COMO
POPEYE
NELSON
Habitat restoration opportunities such as daylighting Nelson Creek at the confluence with the Fraser River.
COM
LEGEND
Diversion Pipe
Water Quality Treatment Unit
Habitat Restoration Opportunities

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Acronyms and Abbreviations

µm	Micrometer
B-IBI	Benthic Invertebrate Index of Biotic Integrity
BC	British Columbia
BCCDC	British Columbia Conservation Data Centre
BMP	Best Management Practice
cm	Centimetre
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWHdm	Coastal Western Hemlock Dry Maritime
DFO	Department of Fisheries and Oceans Canada
E. coli	*Escherichia coli*
EIA	Effective Impervious Area
ESA	Environmentally Strategic Areas
GPS	Global Positioning System
GVRD	Greater Vancouver Regional District; now Metro Vancouver
GVS&DD	Greater Vancouver Sewerage and Drainage District
HGL	Hydraulic Grade Line
hr	Hour
ID	Identification
ISMP	Integrated Stormwater Management Planning
IWMP	Integrated Watershed Management Plan
km	Kilometre
L/s/ha	Litre per second per hectare
m	Metre
MAF	Mean Annual Flow
MAR	Mean Annual Rainfall
mm	Millimetre
N/A	Not Applicable

NAD	North American Datum
PAH	Polycyclic Aromatic Hydrocarbon
pH	Measure of the acidity or basicity of a solution
QA/QC	Quality Assurance/Quality Control
RFI	Riparian Forest Integrity
SARA	*Species at Risk Act*
SC	Sub-catchment
SD	Standard Deviation
TIA	Total Impervious Area
TRIM	Terrain Resource Information Management
TSS	Total Suspended Solids

1. Introduction

In May 2008, the City of Coquitlam retained CH2M HILL to prepare an Integrated Watershed Management Plan (IWMP) for the Nelson Creek Watershed. The Nelson Creek basin is located in southwest Coquitlam. The basin drainage system collects stormwater runoff from an approximately 250 ha watershed. The basin consists of approximately 28 km of storm drain pipes, 2 km of Nelson Creek and approximately 3 km of other open drainage channels.

1.1 Project Scope

The main goal of this project is to develop an IWMP that will recommend and prioritize projects, programs, and policies to:

- Establish management objectives for the watershed
- Propose mitigation measures to mitigate development impacts
- Protect and, where possible, enhance existing aquatic and riparian habitat
- Maintain ecosystem integrity and support the viable development and redevelopment of lands within the watershed
- Develop cost-effective (life time cost) solutions for:
  - A prioritized set of recommended ecology projects and actions
  - A prioritized set of recommended capital improvement projects for stormwater and flood risk management
  - A strategy to achieve an optimum level of flood protection of the lowlands south of Brunette Avenue
  - A strategy for managing the accumulation of sediment in the lower reaches of Nelson Creek
- Describe the steps needed to implement the plan as well as plans for maintenance activities

1.2 Watershed Vision and Objective

The following statement represents a long-term vision for the Nelson Creek watershed. It is expressed in present tense to represent how it is hoped to be described in the future.

> *The Nelson Creek Watershed is recognized as a healthy ecosystem. The creek is valued as an asset and a resource, and it is surrounded by rich riparian habitat. Water quality and fish habitat are good, and there are salmon spawning all the way up to Mackin Park and resident trout throughout the stream. The vegetation and rainwater infiltration in the watershed moderates water flows and limits flooding. The community takes pride in the success of their joint efforts to restore watershed health.*

1.2.1 Watershed Objectives and Evaluation Criteria

Development on the Nelson Creek Watershed has been largely completed in the past few decades. The Austin Heights Neighbourhood Plan was adopted on April 4, 2011, and the Maillardville Neighbourhood Plan processes are currently underway.

Overall

- Strike a balance among social, environmental, and economic considerations;
- Reflect progressive planning and land management approaches, as well as Best Management Practices (BMPs);
- Protect the watershed without placing a burdensome cost on existing and future residents and property owners;
- Provide directions that will help to guide future planning and development.

Environment

- Improve fish access and in-stream habitat quality for fish, recognizing the direct connection to the Fraser River and the millions of salmon there;
- Protect and enhance the riparian habitat along the creek, particularly in Mackin Park;
- Restore the natural geomorphology and natural hydrology to the degree possible;
- Increase the cover of native vegetation throughout the watershed, particularly trees and shrubs;
- Protect habitat for red- and blue-listed fish, wildlife, and plant species; and maintain or enhance biodiversity;
- Reduce stream bank erosion and downstream sedimentation to levels approaching a more natural stream.

Water Quality and Quantity

- Prevent flood impacts on people, property, and the stream channel;
- Improve storm drainage system conveyance capacity;
- Strive to restore a more natural flow regime, increasing base flows in summer and reducing peak runoff rates and volumes;
- Protect and improve water quality; reduce levels of nutrients/fertilizers and coliforms.

Recreation and Aesthetics

- Retain and enhance the visual characteristics of the creek and the landscape characteristics of the watershed;
- Connect the Nelson Creek Corridor to the regional greenway along the Fraser River;
- Make the creek more visible and integrated with the community (e.g., habitat corridors, links with other trails, viewpoints).

Public Education and Stewardship

- Harness the efforts of passionate community members in stewardship and education;
- Work with property owners throughout the watershed to enhance watershed health through methods including:
  - Increase onsite infiltration on private and public property
  - Provide landscape treatment
  - Provide site design
  - Provide onsite spill control
- Work with property owners in the lower section of the creek to protect and enhance the creek, particularly when a redevelopment proposal is submitted.

Planning Process

- Integrate the IWMP with the land-use planning processes;
- Recognize budget limitations at the municipal and public levels;
- Provide for monitoring and evaluation, with adaptive management recommendations.

1.3 Stormwater Criteria

This section describes the stormwater criteria required to meet the goals of the Nelson Creek IWMP.

1.3.1 City of Coquitlam Standard Specifications

General Criteria

- The minor design storm shall be the 1:10 year storm, except the 1:25 year storm shall be used for high value commercial or industrial development
- The major system design storm shall be the 1:100 year and 1:200 year in floodplain hydraulic gradient line (HGL)

Source Control

- On site rainfall capture (runoff volume reduction) for 75 to 90 percent of the average annual rainfall volume for the region.
- Limit the post-development peak rate of runoff from the development site from the two-year design storm to 50 percent of the pre-development peak runoff flow from the two-year design storm.
- Full source control on housing choices, multi-family, commercial, and institutional, industrial land uses and roads. Minimum of 300 mm of absorbent topsoil on all pervious areas and grading hard surfaces to pervious areas.
- Minimum of 300 mm of absorbent topsoil on all pervious areas and grading hard surfaces to pervious areas on single family land uses.

1.3.2 Ministry of Water, Land and Air Protection Guidelines

Runoff Volume Target

An appropriate performance target for managing runoff volume is to limit total runoff volume to 10 percent (or less) of total rainfall volume. This means that 90 percent of rainfall volume must be returned to natural hydrologic pathways, through infiltration, evapotranspiration, or re-use on the development site.

Runoff Rate Target

The Mean Annual Flood (MAF) is defined as the channel-forming event; as the MAF increases with development, stream channels erode to expand their cross section, thereby degrading aquatic habitat. Therefore, an appropriate runoff rate target is to ensure that streamflow rates that correspond to the natural MAF occur no more than once per year, on average.

In order to achieve this target, stormwater systems should be designed to limit the frequency that the natural MAF is exceeded.

The MAF correlates roughly with the runoff from a Mean Annual Rainfall (MAR), which is defined as an event that is equal to the average of all the rainfall events in a year. Natural streamflow patterns can be approximated for the majority of rainfall conditions (all rainfall in an average year) by providing enough storage capacity to capture the runoff from a MAR, and releasing the stored runoff at a rate that mimics the rate of interflow in a naturally vegetated watershed.

1.3.3 Fisheries and Oceans Guidelines

The strategy for managing the complete spectrum of rainfall events is consistent with the Urban Stormwater Guidelines and Best Management Practices for protection of fish and fish habitat developed by Fisheries and Oceans Canada (DFO). These guidelines are based on the following priorities:

- Runoff Volume Reduction: Volume from the post development 6-month, 24-hour events (equivalent to the MAR) from impervious areas are not discharged and are infiltrated to the ground.
- Water Quality Improvement: Collect and treat the volume of the 24-hour precipitation event equalling 90 percent of the total rainfall from impervious areas.
- Runoff Rate Control: Restrict the post-development peak runoff flow rate to that of the pre-development peak runoff rate for the selected design return period.

1.4 Project Team

This report was prepared by Jackeline Luque from CH2M HILL, Mauricio Herrera (former CH2M HILL employee) from Hay and Company Consultants, Karen Munro from Stantec (formely Jacques Whitford AXYS), Catherine Berris from Catherine Berris Associates Inc.

1.5 Acknowledgements

CH2M HILL thanks all those who provided information and participated in the project. In particular, we thank Melony Burton, Dana Soong, Margaret Birch, Nadia Carvalho, Russell Nelson, and Wai-Sue Louis of the City of Coquitlam. In addition, the following individuals participated in the Advisory Committee Meetings:

- Murray Manson, Fisheries and Oceans Canada
- Pat Slaney, Resident

2. Overview of Nelson Creek Watershed

2.1 Nelson Creek Watershed

The Nelson Creek watershed in Coquitlam, BC, is approximately 250 ha in area and is bounded by Blue Mountain Street to the west, King Edward Street to the east, Regan Avenue to the north and the Fraser River to the south. This watershed is within the Southwest Coquitlam Area Plan and spans two Neighbourhood Plan Areas: the Austin Heights area to the north, and the Maillardville area to the south. The main land uses are single family residential in the upland area and parkland, commercial, and industrial in the lowland area. The watershed is fairly well built out, with some potential for development or redevelopment.

Nelson Creek (alias Sussex Creek; watershed code 100-021400) is a short (2.02-km-long) first order creek that flows south to its confluence with the Fraser River (Province of British Columbia, 2007). Nelson Creek is contained within the underground stormwater system upstream of Charland Avenue and mainly in open channels in downstream areas. Runoff from the storm sewer system discharges directly into the creek. Water levels in the lowest reach are influenced by those of the Fraser River. Four tributaries are identified, three small ditches in the lowlands and one larger tributary that flows along the east and south border of Mackin Park, entering Nelson Creek at the southwest corner of the park.

Watershed health assessments conducted by the GVRD (1999) provided predictions of change in impervious cover associated with population growth. The 62 percent TIA estimated in 1996 was predicted to increase to 72 percent TIA in 2036 under the growth strategies in place at that time. This increase would result in the current watershed health rating of poor remaining in place. The Integrated Stormwater Management Plan (ISMP) process was adopted by the GVRD and member municipalities to identify means by which growth could occur while maintaining or improving watershed health.

Although the level of development in the watershed indicates limited amounts of natural habitat, wildlife in the area may include small mammals (e.g., mice and voles), skunks, raccoons, coyotes, and a wide range of birds. Nesting by songbirds and transitory hunting, foraging, shelter, and migratory stopovers by other animals are anticipated uses of existing habitat.

2.2 Land Use Context

Traditionally, land use planning and watershed management planning have been conducted as completely separate processes by different teams of people. With increased awareness about the importance of watershed management in environmental stewardship, and information about how land uses and land development projects can incorporate stormwater and rainwater management practices, the Nelson Creek IWMP includes a land use planning component. Land use planning and watershed management planning must be integrated to achieve effective management of rainwater and environmental resources.

The land use planning component of the Nelson Creek IWMP involves the following primary components:

- Analysis of the existing and potential land uses within the watershed
- Consideration of rainwater control measures for subdivision and building permit applications
- Consultation with City staff and interest groups on potential onsite rainwater control measures
- Preparation of onsite rainwater control recommendations for inclusion in the Nelson Creek IWMP

2.2.1 Existing Land Use

The majority of the land within the watershed is developed as older one- and two-family residential lots. There are also two higher density commercial centres within the watershed. Austin Heights includes a small commercial street along Austin Avenue, with some medium density apartments to the north. Farther south, along Brunette Avenue, the Nelson Creek watershed includes the neighbourhood centre, and a portion of the service commercial land use of Maillardville. North and south of the Lougheed Highway, there is some service commercial and industrial land.

The major open spaces within the watershed are a portion of the Vancouver Golf Club and Blue Mountain Park just north of the Austin Heights neighbourhood centre and Mackin Park, which is just north of the Lougheed Highway. Figure 2-1 shows existing land use designations.

The relocation of the Nelson Creek tributary on the east side of Mackin Park was required for the widening of King Edward Street in 2010. This work provided an excellent opportunity for the removal of invasive species, extensive riparian planting with native shrubs, trees and herbaceous plants, and in-stream habitat complexing. About 230 m of channel was moved, an old culvert at the south end of the channel was removed, and an oil and grit separator was installed at the upstream end of the channel (see Figure 2-2).

FIGURE 2-1
Nelson Creek Existing Land Use

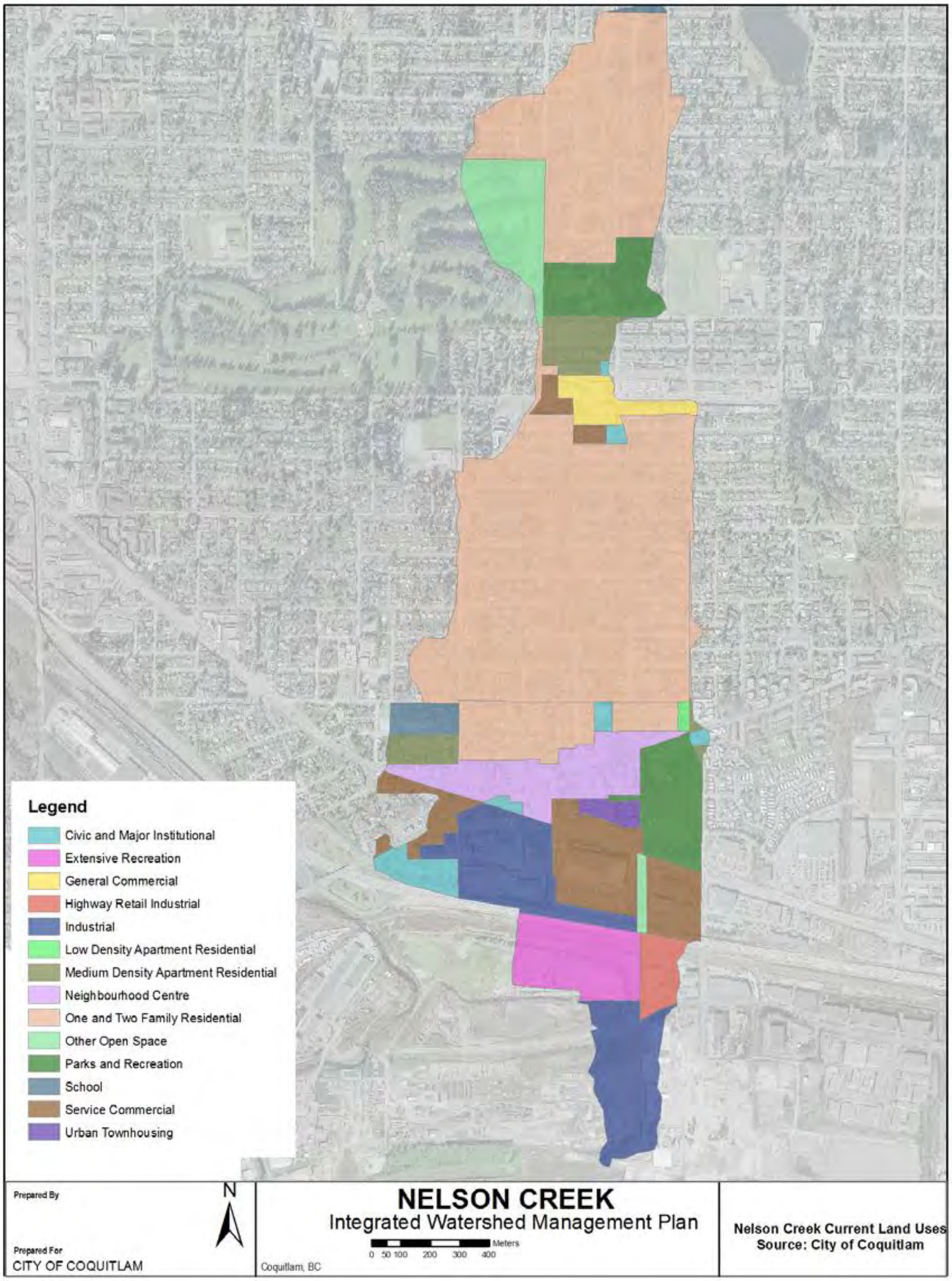


FIGURE 2-2
Mackin Park Enhancement Work

Nelson Tributary prior to realignment, with extensive invasive plant growth on the banks, summer 2010

Nelson Tributary during construction, summer and fall 2010

Nelson Tributary, summer 2011

2.2.2 Future Land Use

The Austin Heights Neighbourhood Plan was adopted on April 4, 2011, and the Maillardville Neighbourhood Plan processes are currently underway (see Figure 2-3: Nelson Creek Future Land Use Planning).

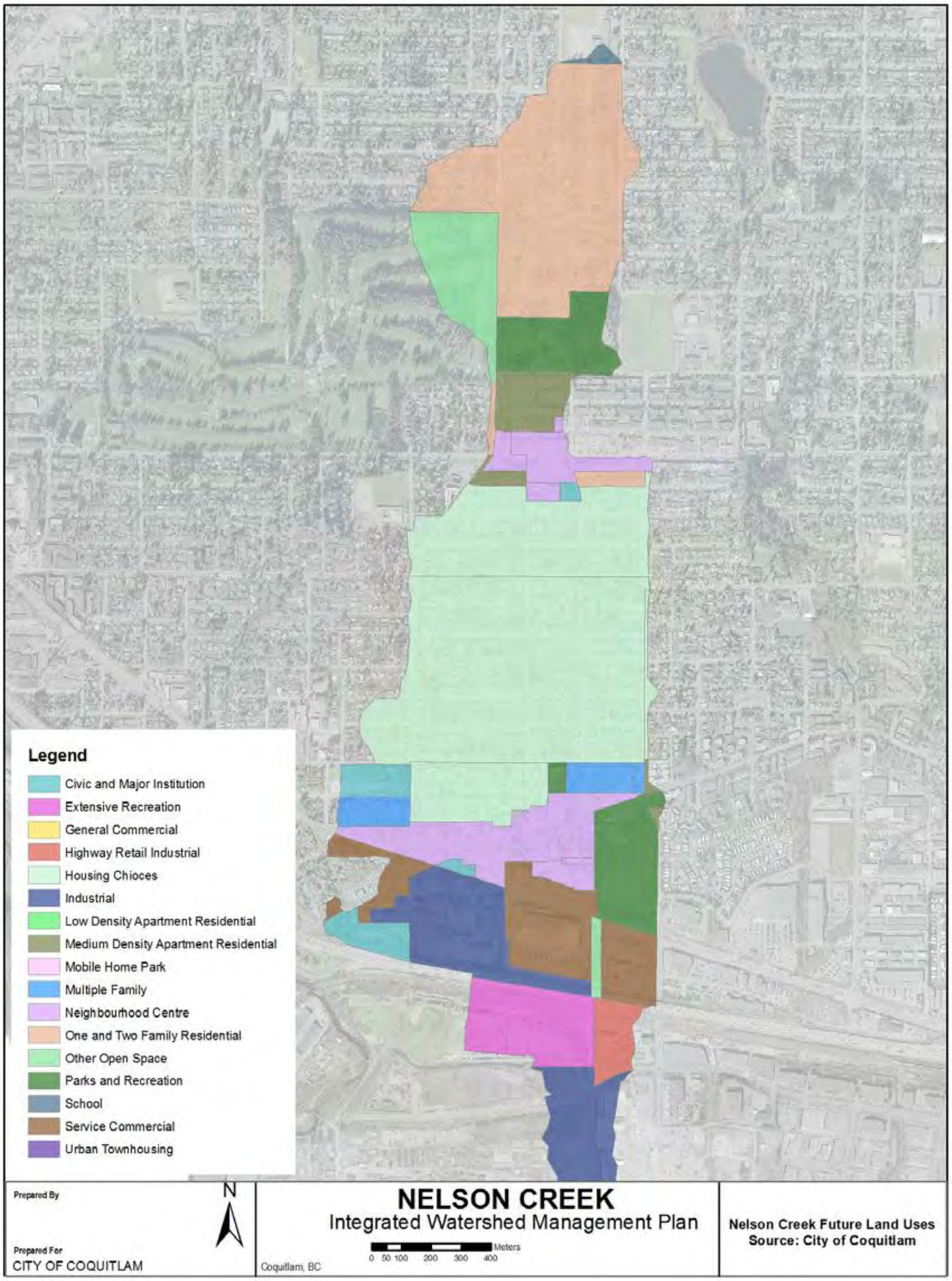
For Austin Heights, the key elements of the land use changes include:

- The transition of the neighbourhood commercial core to a high density mixed-use area
- The addition of new smaller areas of medium-density residential uses south of the commercial core to act as a buffer between the core and adjacent lower density residential areas
- An expansion of the existing Neighbourhood Attached Residential designation and the introduction of new small-scale, ground-orientated housing types in either attached or detached forms
- Maintaining and protecting the majority of the one-family residential area as an important part of the housing mix, while providing opportunities for secondary suites and home based businesses, where appropriate

For Maillardville, key land use changes include:

- The transition from one- and two-family residential to new small-scale, ground-orientated housing types in either attached or detached forms

FIGURE 2-3
Nelson Creek Future Land Use Planning



3. Watershed Reconnaissance

3.1 Aquatic Habitat

Information about fish and fish habitat quality in Nelson Creek was obtained from a review of available information (City records, FishWizard and Habitat Wizard websites, provincial websites, aerial photographs), field assessments conducted in August and November 2008 and fall 2010, and interviews with local residents and biologists (Slaney, 2008; Coulter-Boisvert, 2008). Additional information was incorporated from fish and fish habitat surveys conducted during reconstruction of the Nelson Tributary along the east side of Mackin Park in 2010 (required for widening of King Edward Avenue) and during the 2011 habitat monitoring program (Stantec 2012).

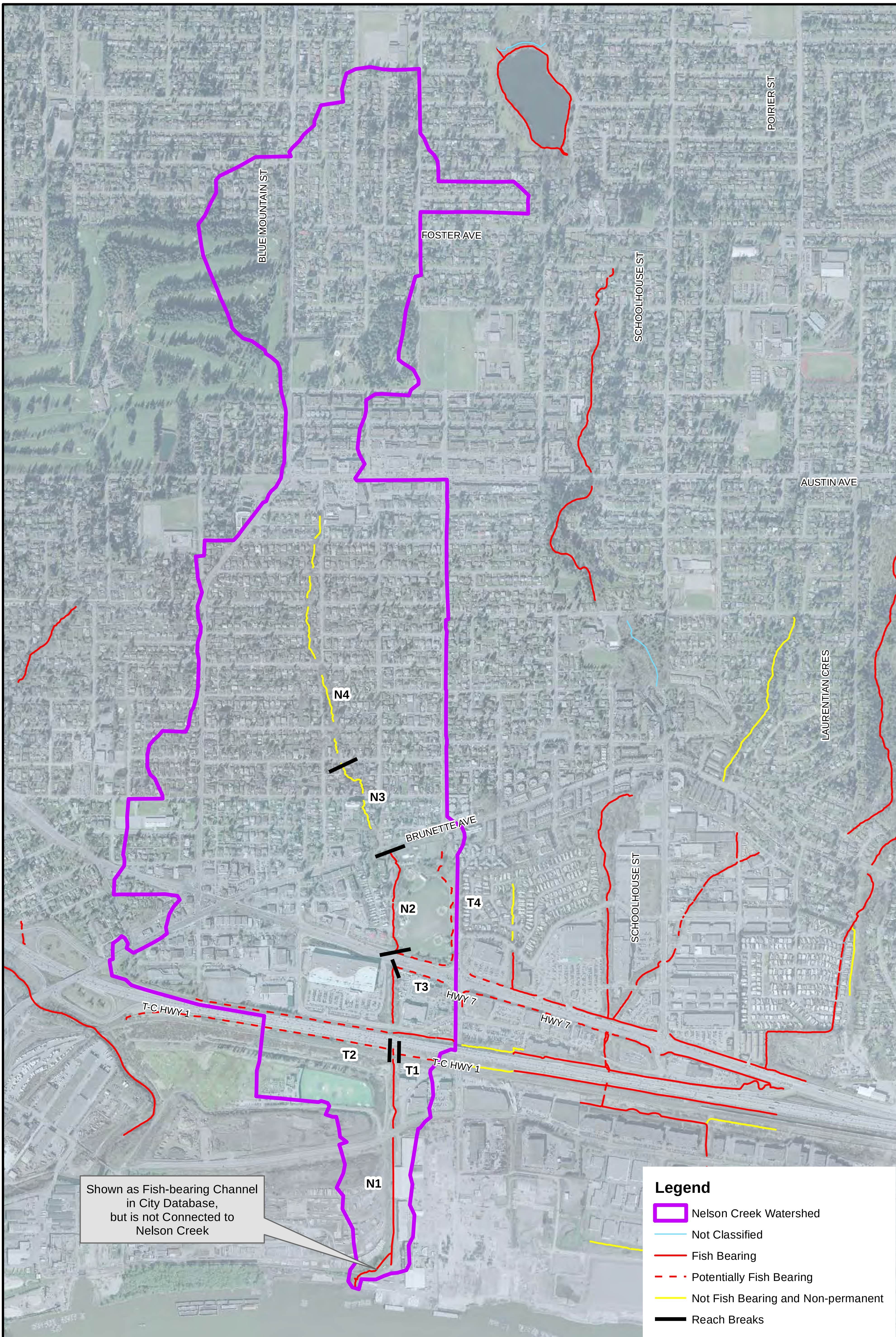
3.1.1 Stream Classification

Nelson Creek is shown in Figure 3-1, coded using the City system of watercourse classification, which uses the following classification system:

- Red – fish bearing
- Red dashed – potentially fish bearing
- Orange – not fish bearing and permanent
- Yellow – not fish bearing and non-permanent
- Green – not fish habitat
- Blue – unclassified

The red and red dashed designations are for permanent and ephemeral watercourses, respectively, than can support fish presence. The orange and yellow designations are for watercourses that do not contain fish but that provide food and nutrients to downstream fish habitat. The green designation is for watercourses such as ditches that do not contribute food and nutrients to downstream fish habitat. There are no blue-coded watercourses in the Nelson watershed.

Nelson Creek and its tributaries are considered fish bearing from the mouth to an impassable barrier at Brunette Avenue.



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Stantec
Prepared For
CITY OF COQUITLAM

N

NELSON CREEK
Integrated Watershed Management Plan

0 50 100 200 300 400 Meters

Coquitlam, BC

March, 2012

Figure: 3-1
Stream Classification and Reach Breaks for Nelson Creek

3.1.2 Fish Species

Fish presence has been confirmed from the mouth of Nelson Creek up to Brunette Avenue (Province of British Columbia, 2007). Documented species are listed in Table 3-1. The cutthroat trout listed in Table 3-1 is likely the subspecies, coastal cutthroat trout (*Onchorhynchus clarkii clarkii*), a blue-listed species provincially (British Columbia Conservation Data Centre, 2008), meaning it is an indigenous species of special concern.

TABLE 3-1
Fish Species Reported in Nelson Creek and Tributaries

Common Name	Latin Name
brassy minnow	*Hybognathus hankinsoni*
carp	*Cyprinus carpio*
coho salmon	*Onchorhynchus kisutch*
cutthroat trout	*O. clarkii*
anadromous cutthroat trout	*O. clarkii*
prickly sculpin	*Cottus asper*
sculpin	*Cottus* sp.
sucker	*Catostomus* sp.
threespine stickleback	*Gasterosteus aculeatus*

Source: Province of British Columbia (2007).

The presence of cutthroat trout in Nelson Creek was documented by Pat Slaney (resident and fisheries biologist; pers. comm.) in 2004. Using electro-fishing, abundant trout were captured in Mackin Park; however, no trout were captured upstream of Brunette Avenue to Austin Avenue. Slaney also reported that residents interviewed in 2002 commented that they had seen cutthroat trout in some areas upstream of Brunette Ave. prior to installation of road culverts.

Coho salmon have been reported in Nelson Creek historically, and fry were seen in December 2008 (Maurice Coulter-Boisvert, Fisheries and Oceans Canada, pers. comm.).

3.1.3 2008 Stream Assessment Methods

Habitat assessments were conducted on August 20, 2008, and November 18, 2008. Field 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 (RIC 2001). Nelson Creek was walked from near the mouth at the Fraser River to the upper end of the natural channel at Charland Avenue. Four tributaries (designated as T1, T2, T3, and T4) were also investigated.

There is limited access to Nelson Creek downstream of Highway 1, as the creek flows through industrial areas and there is considerable blackberry cover along the creek. Assessments in those areas were made at road crossings.

The following habitat characteristics were recorded on appropriate RIC cards:

- Fish migration obstructions (culverts, falls, in-stream debris, and structures)
- Fisheries sensitive zones (tributaries, side-channels, flood channels)
- Areas suitable for fish rearing, spawning and overwintering or that provide cover for species known or suspected to occur in a particular reach
- Width (bankfull and wetted)
- Depth (bankfull, residual pool)
- Stream stage
- Percentage cover (woody debris, boulder, cutbank, deep pool, over-stream vegetation, and in-stream vegetation)
- Bank shape and texture
- Turbidity
- Substrate (dominant and sub-dominant bed materials)
- Channel morphology, channel pattern, islands, bars, coupling, confinement
- Signs of disturbance, flood, erosion, or sediment deposition from construction areas
- Riparian vegetation community and crown closure

Reaches were defined as areas of consistent habitat characteristics, and reach breaks were established at tributary confluences, significant changes in gradient and barriers to fish passage. Reaches are described in Table 3-2 and shown in Figure 3-1.

3.1.4 Stream Features and Salmonid Habitat Summary

Stream features are summarized in Table 3-2. Photographs of various stream features are provided in **Appendix A**. The channel and headwater tributaries are buried in culverts upstream of Charland Avenue.

No barriers to salmon access have been identified at the Fraser River. Nelson Creek enters the Fraser River through a 110-m-long culverted channel under the Catalyst Paper property. There is a second, dry, channel to the west that is unconnected to Nelson Creek, but marked as a channel on City maps (this needs to be updated). A flood gate at United Boulevard is activated only under exceptionally high water in the Fraser River (spring freshet and higher than normal tide).

Overall salmonid productive capacity in Nelson Creek mainstem is rated as moderate, based primarily on:

- Moderate to good rearing habitat from the Fraser River up to Brunette Avenue, with overwintering and rearing habitat limited by the low amount of deep pools and riffles
- Good spawning habitat between the Lougheed Highway and Brunette Avenue

- Adequate dissolved oxygen measured upstream of Lougheed Highway
- Perched culverts presenting barriers to fish migration at Brunette Avenue, Alderson Avenue, Stewart Avenue, and Madore Avenue
- Average gradient <20 percent; but with short lengths of steep gradient (up to 30 percent) upstream of Brunette Avenue that create velocity barriers to fish migration (gradients > 20 percent are considered non fish-bearing; Forest Practices Code of BC, 1998)

Areas upstream of Brunette Avenue may provide short lengths of suitable habitat for cutthroat trout, although connection between these areas is limited to downstream movement, given the gradient and culvert barriers to upstream migration.

Overall salmonid productive capacity in Nelson Creek Tributary (T4) on the east side of Mackin Park is rated as moderate, based primarily on:

- Connectivity to fish bearing waters of Nelson Creek
- Patches of spawning habitat
- Variable channel cover (overhanging shrubs and tall grasses)
- High influence from park users and vehicle traffic
- Few deep pools to provide cover
- Channel and riparian habitat rehabilitation conducted in 2010, associated with movement of the channel to accommodate widening of King Edward Street

Overall salmonid productive capacity in the Nelson Creek Tributaries T1, T2, and T3 (ditches along the highways) is rated as moderate to poor, based primarily on:

- Connectivity to fish bearing waters of Nelson Creek
- Limited flow, few deep pools, absence of spawning gravels and limited cover
- Ditch morphology close to Lougheed Highway and Highway 1

TABLE 3-2
Fish Habitat by Reach

Reach	Gradient	Substrate	Physical Characteristics		Description	Habitat Features	Photos
Nelson Creek (N)							
N1 Mainstem downstream of Highway 1.	<1%	Fines (silty) with cobbles	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	2.5-5.0 m 2.5-4.75 m 1.0-1.5 m n/a None	Channelized straight ditch with low flow. In an industrial area. Nelson Creek enters the Fraser through a culvert under an industrial property. A floodgate at United Blvd. is activated only under exceptionally high flows in the Fraser River.	Substrate predominantly fines with some cobbles introduced from the rail bed crossing the creek. Tidally influenced. Tall overhanging grass with some overhanging shrubs, but few trees. No deep pools.	1, 2
N2 Mainstem between Lougheed Highway. and Brunette Ave.	<1%	Gravel and fines	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	1.8-3.5 m 1.7-3.1 m 0.17-0.2 m 0.15-0.17 m None	Riffle-pool channel flows adjacent to ball fields and road in Mackin Park. Channel is crossed by park driveways and pedestrian bridges. Fish were observed in three pools and a riffle.	Abundant gravels provide good spawning habitat. Riparian canopy is thicker; cover is still mainly from overhanging vegetation, with a few deep pools and boulders.	3-5
N3 Upstream of the barrier at Brunette and downstream of Quadling Ave.	10 to 18%	Gravels and cobbles	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	2.0 m 2.0 m not visible 0.5-0.6 m None	Channel flows through residential yards. One house is built over the creek on stilts. Channelized banks common, including vertical landscaped banks. Series of steps 55-65 cm high through this reach.	Riparian cover is mainly ornamental and landscaped vegetation and lawns. Some large boulders and pools provide cover; however, this reach is only accessible to resident fish, if present.	6-10
N4 Between Quadling Ave. and Charland Ave.	5 to 30%	Cobbles and Gravel	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	4.1-5.6 0.8-3.4 0.24-0.53 m 0.07-0.14 m Trace	Channel flows through ravine, away from residential yards; there is some evidence of erosion and debris in the ravine (steel drum, grocery carts, etc.); one structure is within 5 m of top of bank.	Channel incised in a ravine, with mature canopy. Step pool morphology with occasional deep pools. Boulders provide dominant cover. This reach is only accessible to resident fish, if present.	11-15

TABLE 3-2
Fish Habitat by Reach

Reach	Gradient	Substrate	Physical Characteristics		Description	Habitat Features	Photos
Nelson Tributaries (T)							
T1 Tributary south of Highway 1 flowing east to the mainstem	<1%	Fines (sand)	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	<1 m <1 m <0.5 m n/a none	Small stagnant ditch.	Channel is entirely covered by grasses. No riparian canopy present.	none
T2 Tributary south of Highway 1 flowing west to the mainstem	<1%	Fines (sand)	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	2.5 m 1.0 m 1.0 m n/a None	Deep linear rectangular channel. Downstream of train bridge, channel steepens and flow increases slightly.	Ditch morphology with an abundance of tall grasses and small overhanging vegetation. No trees present.	16
T3 Tributary south of Lougheed Highway flowing west to the mainstem	<1%	Fines (sand) with cobbles	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	4.0 m 2.0 m 1.0 m n/a none	Grassy ditch with stagnant water, receives backed up water from main channel.	Ditch morphology with tall grasses. Some blackberry overhanging channel but no riparian canopy. No spawning gravels present.	17
T4 Tributary at the east and south boundary of Mackin Park	<1%	Fines, gravels and cobble	Bankfull width Wetted width Bankfull depth Residual pool depth LWD	1.8-2.4 m 0.7-1 .5 m 0.12-0.19 m 0.09-0.16 m None	Linear channel with areas of artificial substrate and banks. Flows adjacent to playing fields and roads. Pedestrian bridges. Much of the flow is provided by a stormwater outfall at Brunette Ave. and King Edward Street. 2010 reconstruction resulted in more natural morphology.	In 2008, riparian canopy was limited to a few patches of mature trees. Cover consisted mainly of overhanging shrubs and tall grasses. Few deep pools, limited spawning gravels. In 2010, channel and riparian restoration including extensive planting, gravel placement, and habitat features (boulders, weirs, and artificial cutbanks).	18-20

3.1.5 Fish Presence

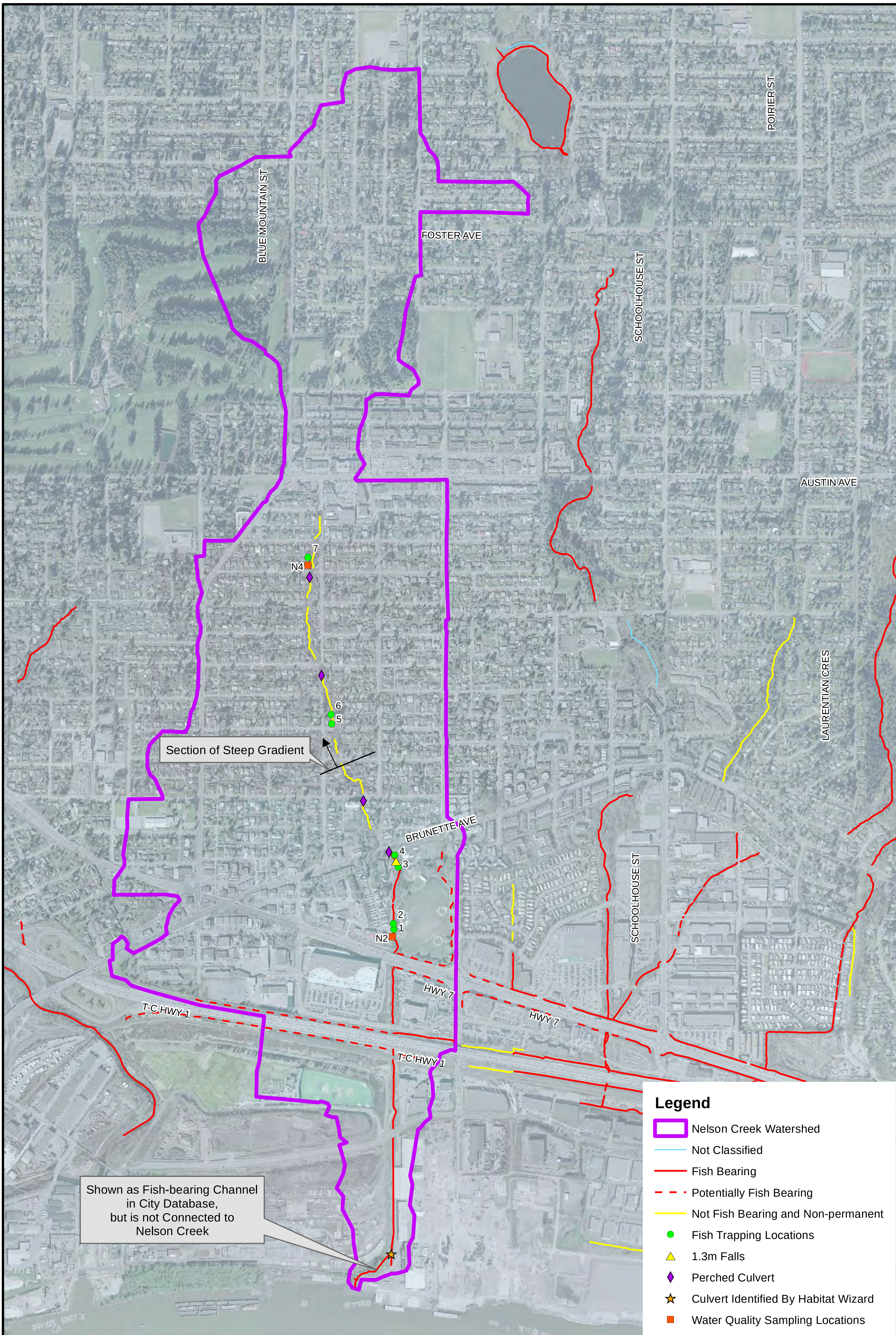
Sampling for fish presence was conducted on September 16 to 17, 2008, for the IWMP study, during seasonal low water. Seven baited minnow traps were set overnight for approximately 17 hours each. Two cutthroat trout and three threespine stickleback were found in the traps. Locations of traps are shown in Figure 3-2. A photograph of one cutthroat trout trapped in Nelson Creek is provided in **Appendix A,** Photo 21.

Results of the fry trapping are as follows:

- No fish were captured upstream of Brunette Avenue (two traps set between Delestre Avenue and Thomas Avenue, one trap set between Madore Avenue and Dansey Avenue; traps 5, 6, 7, and 8 in Reach N4)
- Two cutthroat trout were captured in Mackin Park between Lougheed Highway and Brunette Avenue (in Reach N2; one fish in each of traps 3 and 4); the fish were 127 and 165 mm in length
- Three threespine stickleback were captured in Mackin Park between Lougheed Highway and Brunette Avenue (in Reach N2; two fish in trap 1 and one fish in trap 2)

Fry salvage was conducted in Nelson Tributary on several dates between August 4 and 23, 2010, in preparation for channel reconstruction. Seining, electrofishing, and minnow trapping were used to capture fish. Nine cutthroat trout (45 to 92 mm in length) and 88 threespine stickleback were captured (20 to 46 mm) and released in Nelson Creek, away from the construction area.

Nelson Tributary and Nelson Creek in Mackin Park were monitored for fish populations in 2011, the first year of long-term monitoring of the reconstructed habitat in Nelson Tributary (Stantec 2012). Fish populations were assessed using minnow traps in defined reaches over three-day periods in April, July, September, and November. Cutthroat trout were abundant in Nelson Creek (54 in July, 26 in September, 6 in November; size range of 30 to 115 mm). Trout were recolonizing Nelson Tributary (0 to 2 fish per sampling period; 65 to 109 mm). Threespine stickleback were abundant in Nelson Tributary, less so in Nelson Creek.



Prepared By

CH2MHILL.

Stantec

Prepared For

CITY OF COQUITLAM

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NELSON CREEK

Integrated Watershed Management Plan

0 50 100 200 300 400 Meters

Coquitlam, BC

March, 2012

Figure: 3-2
Migration Barriers, Fish Sampling Locations and Water Quality Sites in Nelson Creek, 2008

3.1.6 Barriers to Fish Migration

Culverts and a 1.3-m high waterfall lacking a pool at its base at Brunette Avenue have been identified as barriers to fish migration (Province of British Columbia, 2007). Beavers occasionally build dams in the lower creek (north of United Boulevard), which may be periodic barriers to fish movement. Barriers to fish migration are summarized in Table 3-3 and shown in Figure 3-2. Barriers encountered during the survey include culverts, a waterfall, and sections of gradient >20 percent above Brunette Avenue.

TABLE 3-3
Barriers and Potential Barriers to Fish Migration

Location	Barrier	Photo
Near outlet to Fraser River	Culvert identified on Fish Wizard (Province of British Columbia, 2007) creates shallow fast moving water (this possible barrier was examined and found to be passable).	none
Downstream of Brunette Avenue	1.3 m high waterfall of boulders and concrete, with a 30 cm pool below (possible barrier).	4
Brunette Avenue culvert	Long culvert under Brunette Avenue. Perched 1.25 m above channel. Water falls onto boulders above a 20 cm deep pool (barrier).	5
Alderson Avenue culvert	>2.0 m perched culvert cascading over boulders at downstream end Alderson Avenue (barrier).	6
Upstream of Quadling Avenue	Step-pool morphology. Grade ranges from 5 to 30 percent.	none
Stewart Avenue culvert	2.0 m perched culvert (without significant pools for fish to use) at downstream end of Stewart Avenue (barrier).	13
Madore Avenue culvert	1.0 m perched culvert. Water collects in a 1.3 m deep pool, but directly below the outfall, the water is not deep as it splashes onto a shallow rock (barrier).	14

3.1.7 Water Quality

A water quality monitoring program is typically included in an IWMP to assess baseline conditions and as part of long-term monitoring. Water quality was assessed in 2008.

Water quality reflects activities on land and may be a concern in Nelson Creek, as it is for many urban watersheds. Physical parameters (temperature, conductivity, pH, dissolved oxygen, turbidity) and levels of bacteria, nutrients, and metals can provide evidence of degraded water quality due to human influences. The presence of bacteria such as coliforms indicates contamination with fecal material. Metals, pesticides, nitrate, ammonia and phosphate, can be transported to the stream via overland and stormwater runoff, and reflect vehicle use and commercial and residential practices. If unmitigated, future development will increase stormwater runoff and contaminant loads entering the creek.

Water quality was assessed at two sites in Nelson Creek (Figure 3-2) in 2008:

- Lower watershed (N2, in Reach N2) in Mackin Park by the southwest ball diamond
- Upper watershed (N4, in Reach N4) just upstream of Madore Avenue

Samples were collected on four dates in 2008: two during wet weather to reflect runoff (August 20 and October 13 [first flush of rainfall]) and two during dry weather to reflect base flow conditions (September 10 and 17). Dry weather samples were taken after at least 5 days without precipitation.

3.1.8 In Situ Water Quality

At each site, *in situ* water quality (temperature, conductivity, turbidity, pH, and dissolved oxygen [DO]) was recorded. Field meters included a Hanna pH meter, YSI 85 Multimeter (for temperature, conductivity, and dissolved oxygen), and a Lamott turbidity meter. Results are presented in Table 3-4. Water temperature ranged from 12.2 to 16.5°C, and was greatest on September 10, 2008. The two sites differed in temperature by less than 1°C. Conductivity provides a measure of ionic strength of the water and ranged from 43 to 250 µS/cm, tending to be higher at N2 than N4 during wet events and the reverse during dry events (likely reflecting dilution from runoff during wet events and differences in basic water composition between the sites during dry events). Turbidity was low (<10 NTU) at most sites, and was highest at N4 (10.5 NTU) during the first flush event. Values for pH ranged from 5.8 to 7.8, with low values likely related to accuracy of the field equipment. Dissolved oxygen levels ranged from 82 percent to 93 percent (8.0 to 10.0 mg/L). For salmonids, the optimum dissolved oxygen level is ≥ 90 percent and the minimum optimum dissolved concentration is ≥ 8 mg/L (Chilibeck *et al.* 1993). Temperature, pH, and dissolved oxygen were within the range expected for streams in the Lower Mainland; however, dissolved oxygen levels were on the low end and slightly below optimum levels.

TABLE 3-4
In Situ Water Quality, August 20 – October 13, 2008

Parameter	Date	Site	
		N2 (Lower Nelson)	**N4 (Upper Nelson)**
Weather	August 20	Intermittent rain	
	September 10	Dry for previous week	
	September 17	Dry for previous week	
	October 13	First flush of rain after a week of dry weather	
Temperature (°C)	August 20	15.9	15.8
	September 10	16.5	15.9
	September 17	14.2	15.1
	October 13	12.2	12.3
Specific Conductivity (µS/cm)	August 20	200*	168
	September 10	117	239
	September 17	205	250
	October 13	99	43
Turbidity (NTU)	August 20	0.6	1.0
	September 10	0.2	0.2
	September 17	1.1	0.8
	October 13	2.7	10.5

TABLE 3-4
In Situ Water Quality, August 20 – October 13, 2008

Parameter	Date	Site	
		N2 (Lower Nelson)	N4 (Upper Nelson)
pH (field)	August 20	7.0	7.2
	September 10	7.8	7.5
	September 17	7.5	7.3
	October 13	6.3	5.8
DO (%)	August 20	84	83
	September 10	87	82
	September 17	85	84
	October 13	82	93

Notes:

* Meter recorded only one significant figure for conductivity on Aug 20, at site N2

3.1.9 Analytical Water Quality

At each site, grab samples were collected for analysis of metals, nutrients, and coliforms. Results are summarized below and complete analytical reports are contained in **Appendix B**. A duplicate sample was collected at N2 on September 10. Trip blanks were included on each sampling trip. These quality assurance / quality control (QA/QC) samples indicated no sources of cross-contamination during sampling and good agreement of replicate samples.

Results were compared with Ministry of Environment (2006; Nagpal *et al.,* 2006) approved and working water quality guidelines for protection of aquatic life for chemical parameters, and with guidelines for recreation/primary contact for microbiological parameters (coliforms), as these are the most protective guidelines.

Total Suspended Solids

Total suspended solids (TSS) is a commonly used measure of sediment levels in stream water, and typically comes from runoff containing sand, silt, clay, and organic matter, for example from construction sites, erosion areas, and other exposed soils. High levels of TSS can damage the gills of salmonids, other fish, and aquatic invertebrates, and can degrade instream habitat when the material settles onto gravel and cobble substrates. Storm events have the potential to convey high sediment loads.

The TSS levels at the two sites were low (<3 mg/L) on the first three dates and high during the October 13 first flush event (4.0 mg/L at N2 and 15.3 mg/L at N4). The TSS levels on October 13 (Table 3-5) corresponded with turbidity values measured in the lab (0.4 to 17.4 NTU) and in the field (2.7 and 20.5 NTU, Table 3-5). TSS levels were below provincial guidelines in all samples (25 mg/L maximum induced TSS).

TABLE 3-5
Total Suspended Solids (TSS) in Nelson Creek, 2008

Parameter (mg/L)	Water Quality Guideline	Date	Site N2 (Lower Nelson)	Site N4 (Upper Nelson)
TSS	Maximum induced TSS of 25 mg/L when background is <250 mg/L	August 20	<3	<3
		September 10	<3	<3
		September 17	<3	<3
		October 13	4.0	15.3

Coliforms

Coliforms are a group of bacteria that live in soil, water, and the intestinal tracts of cold- and warm-blooded animals. Fecal coliforms, including *Escherichia coli (E. coli)*, are specific to mammals, including humans. The presence of *E. coli* and other fecal coliforms indicates contamination with fecal material. In a predominantly urban area, the most obvious sources of coliforms in stream water are dog feces and cross-connection with the sanitary system.

Coliform levels in Nelson Creek are presented in Table 3-6.

TABLE 3-6
Coliform Levels in Nelson Creek, 2008

Parameter (MPN/100 mL)	Water Quality Guideline[1]	Date	Site N2 (Lower Nelson)	Site N4 (Upper Nelson)
Total Coliforms	None	August 20	>2420	>2420
		September 10	>201	>201
		September 17	>2420	>2420
		October 13	51,700	141,000
E. coli	Geometric mean ≤ 77/100 mL	August 20	**308**	**2420**
		September 10	**>201**	**>201**
		September 17	**210**	**117**
		October 13	**1050**	**687**

Notes:

[1] BC water quality guidelines for recreation/primary contact (Min. Env. 2006)
MPN = Most Probable Number per 100 mL
BOLD numbers are higher than water quality guideline (mean value)

Levels of *E. coli* were compared with the BC water quality guideline for primary contact recreation and the identical guideline for irrigation of ready to eat crops (Ministry of Environment 2006). Since these guidelines are designed to assess mean values (five measurements in a 30-day period, triplicate samples), rather than the individual measurements collected for the IWMP program, comparisons to guidelines should be interpreted with caution. However, individual values for *E. coli* exceeded guidelines in all samples analyzed (Table 3-6).

Nutrients/Fertilizers

Nitrogen and phosphorus are essential elements for aquatic plants (algae); however, high levels of these compounds (e.g., from fertilizers, manure, detergents, or organic matter) can lead to high levels of algal growth and degradation of habitat for aquatic insects and fish. Both nitrogen and phosphorus concentrations were relatively high for an urban stream.

Nitrogen cycles through various forms (ammonia, nitrate, nitrite, and organic nitrogen) during uptake by and decomposition of algae and bacteria and by chemical processes (Wetzel, 2001). Nitrogen concentrations, shown in Table 3-7, were within BC water quality guidelines for protection of aquatic life (Ministry of Environment, 2006). Ammonia levels ranged from <0.005 to 0.097 mg N/L. Nitrate levels ranged from 0.39 to 2.20 mg N/L. Nitrite levels ranged from <0.0010 to 0.0153 mg N/L. There was no consistent trend in nitrogen levels between upstream and downstream sites.

TABLE 3-7
Nutrient Levels in Nelson Creek, 2008

			Site	
Parameter	**Water Quality Guideline Maximum**[1]	**Date**	**N2**[2] **(Lower Nelson)**	**N4 (Upper Nelson)**
Ammonia (mg N/L)	0.76 – 1.54 (based on temp & lab pH)	August 20	0.0383	0.0214
		September 10	0.0523	0.0078
		September 17	<0.0050	0.0067
		October 13	0.0310	0.0966
Nitrate (mg N/L)	32.7	August 20	0.836	1.78
		September 10	1.21	2.20
		September 17	1.11	1.50
		October 13	1.01	0.378
Nitrite (mg N/L)	0.24 (based on 6-8 mg/L chloride)	August 20	0.0024	0.0101
		September 10	0.0028	0.0015
		September 17	0.0033	<0.0010
		October 13	0.0130	0.0153
Phosphate, ortho (mg P/L)	N/A	August 20	0.0213	0.0316
		September 10	0.0263	0.0188
		September 17	0.0258	0.0345
		October 13	0.0359	0.0615

TABLE 3-7
Nutrient Levels in Nelson Creek, 2008

Parameter	Water Quality Guideline Maximum[1]	Date	Site	
			N2[2] (Lower Nelson)	N4 (Upper Nelson)
Phosphorus, diss. (mg P/L)	N/A	August 20	0.0263	0.0393
		September 10	0.0287	0.0235
		September 17	0.0266	0.0366
		October 13	0.0429	0.0706
Phosphorus, total (mg P/L)	N/A	August 20	0.0341	0.0442
		September 10	0.0363	0.0269
		September 17	0.0329	0.0385
		October 13	0.0695	0.150

Notes:

1. BC water quality guidelines for protection of aquatic life (Min. Env. 2006)
2. Mean of duplicates at N2, September 10

Phosphorus occurs in both organic and inorganic forms. Total phosphorus ranged from 0.0269 to 0.150 mg P/L (Table 3-7). Ortho phosphate (dissolved inorganic phosphorus) and total dissolved (organic and inorganic) phosphorus fractions were lower, ranging from 0.0188 to 0.0695 mg P/L. These results suggest the effects of urban and residential activities, given that ortho phosphate concentrations for unpolluted streams average approximately 0.01 mg P/L and can increase to 0.05 to 0.1 mg P/L in areas receiving additional inputs (Wetzel, 2001). Concentrations of most fractions analyzed decreased between the upstream and downstream site, suggesting high concentrations in the upper watershed are diluted with other sources of water downstream, and were higher in wet weather.

Metals

Metals such as zinc, molybdenum, copper, and cadmium are common components of street runoff and arise from vehicle use (e.g., wear and tear of brakes, tires), house materials (e.g., zinc strips and copper granules used to control moss and algal growth, copper plumbing pipes), lawn treatments (moss control), and other commercial, residential, and urban practices in the watershed.

Most parameters met the BC water quality guidelines, with the exception of cadmium, copper, and zinc. Highest contaminant levels were recorded in samples taken from N2 on October 13 during the first flush rain event (Table 3-8):

- Cadmium levels exceeded the guideline in six of eight samples and ranged from below detection to 0.000086 mg/L. Levels at N4 were fourteen-times higher than the provincial guideline of 0.000006 mg/L on October 13.

- Copper levels exceeded the guideline in three of eight samples, and ranged from 0.0017 to 0.0316 mg/L. Levels at N4 were ten-times higher than the provincial guideline of 0.0033 mg/L on October 13.
- Zinc levels exceeded guidelines in two of eight samples, and ranged from below detection to 0.0490 mg/L. Levels at N4 were 1.5-times higher than the provincial guideline of 0.033 mg/L on October 13.

TABLE 3-8
Instances in which Metal Concentrations Exceeded BC Water Quality Guidelines[1]

Parameter (mg/L)	Water Quality Guideline Maximum	Date	Site N2[2] (Lower Nelson)	Site N4 (Upper Nelson)
Cadmium[3]	0.000020/0.000021	August 20	0.000021	0.000046
	0.0000287	September 10	none	0.000040
	0.0000324	September 17	none	0.000037
	0.0000138/0.000006	October 13	0.000034	0.000086
Copper[4]	0.0075	August 20	none	0.0142
	0.0054/0.0033	October 13	0.0085	0.0316
Zinc[5]	0.033	October 13	0.0427	0.0490

Notes:

1 BC Approved and Working Guidelines for protection of aquatic life (Ministry of Environment, 2001; Nagpal *et al.*, 2001)
2 Mean of duplicates at N2, September 10
3 Guideline varies for cadmium depending on hardness [µg/L, total cadmium = 10 exp (0.86[log{hardness}]-3.2)]
4 Guideline varies for copper depending on hardness [µg/L, total copper = (0.094(hardness)+2)]
5 Guideline varies for zinc depending on hardness [µg/L, total zinc = 33 if hardness <90; µg/L total zinc = (33 + 0.75 x (hardness -90)]

3.1.10 Quality Assurance/Quality Control

Four travel blanks (one per trip) and one field duplicate were collected. Samples were preserved as required, kept in a cooler at 4°C and submitted to ALS Environmental laboratory (Vancouver, BC) within 24 hours of collection.

Sample quality (QA/QC) was high, as indicated by:

- Four travel blanks with no indication of sample contamination
- The field duplicate with close agreement (≤16 percent difference in concentrations of all parameters except total aluminum, which had a 32 percent difference)

Although field meters were calibrated prior to their use, there were some differences between field and lab measurements of conductivity, turbidity, and pH. In most cases, lab conductivity was similar or slightly higher than field conductivity and field turbidity tended to be lower than lab turbidity. Field measurements of pH were also lower than lab measurements (5.8 to 7.8 for field compared to 7.2 to 8.1 for lab measurements). Such differences are often noted, and can be attributed to differences in field and laboratory conditions and lower accuracy of field meters. As a result, the laboratory values for conductivity, turbidity, and pH are considered in site comparisons.

3.2 Terrestrial Habitat

This section describes wildlife habitat within the Nelson Creek watershed in terms of native undisturbed habitat and current developed conditions. Historical records of species of conservation concern are provided, along with descriptions of their preferred habitat in the watershed. Habitat suitability for focal species identified in Environmentally Strategic Areas (ESA) mapping conducted for the City of Coquitlam was also ground-truthed and updated during a field reconnaissance. Maintenance of wildlife corridors and protection of habitat for species of conservation concern (species listed under the federal *Species at Risk Act*, red or blue listed species), identified as important objectives of the IWMP, are discussed.

There are limited data and literature concerning wildlife and terrestrial habitat conditions in the Nelson Creek watershed, although information about riparian habitat obtained in the fish habitat surveys (Section 3.1) provides some information. Professional knowledge of the lower mainland natural landscape, a review of information available from the BC Conservation Data Centre [BCCDC], City of Coquitlam (policies, Draft Environmentally Sensitive Areas Management Strategy for the City of Coquitlam, Southwest Coquitlam Neighbourhood Plan, aerial photographs), and results of a site visit in October 2008 provide the basis for this section. The site visit was designed to document conditions in areas likely to have native vegetation and to locate rare or uncommon flora and fauna.

The City provides direction for land development through various policies, plans, and bylaws. The City also prepared an ESA Management Strategy (Jacques Whitford AXYS, 2006). The strategy was developed recognizing the joint role of the provincial and federal agencies, Metro Vancouver, the City, developers, private landowners, utilities, stewardship groups, and others in maintaining and protecting ESAs. It uses an integrated approach for management that considers ESA function, its value in a given watershed and the City as a whole, and the relative net benefits to be expected from implementing the recommended management strategies. While the City has not yet adopted the strategy, it does use the many maps identifying habitat suitability for focal animal species.

3.2.1 Vegetation and Wildlife in Nelson Creek Watershed

The Nelson Creek watershed is located within the Coastal Western Hemlock dry maritime (CWHdm) biogeoclimatic zone. The CWH zone is the rainiest zone in BC and typically has cool summers and mild winters (Meidinger and Pojar, 1991). Undisturbed mature upland forests are typically dominated by western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and Douglas fir (*Pseudotsuga menziesii*), with salal (*Gaultheria shallon*), red huckleberry (*Vaccinium parvifolium*), vine maple (*Acer circinatum*) and salmonberry (*Rubus spectabilis*) the dominant understory shrubs (Green and Klinka 1994). Devil's club (*Oplopanax horridus*) and Labrador tea (*Ledum groenlandicum*) are present in wetter locations within the CWHdm subzone.

There is little undisturbed, undeveloped habitat remaining in Nelson Creek watershed. The upland area is predominantly residential, and the lowland is commercial and, along the

Fraser River, industrial. Natural vegetation occurs mainly in the riparian area of Nelson Creek, with some mature forest found within parks. Riparian vegetation in the lowland area south of Lougheed Highway consists mainly of invasive plants, including reed canary grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus armeniacus,* and scotch broom (*Cytisus scoparius*), along with native hardhack (*Spiraea douglasii*) and stinging nettle (*Urtica dioica*). Mature coniferous and mixed forest occurs in the northern portion of Mackin Park, Blue Mountain Park and the golf course in the northwest corner of the watershed. Predominant tree species observed in the forested areas include Douglas fir, black cottonwood (*Populus balsamifera balsamifera*), western red cedar, bigleaf maple (*Acer macrophyllum*) and western hemlock. Predominant understory shrubs include hardhack, red-osier dogwood (*Cornus stolonifera*), reed canary grass, stinging nettle, willow (*Salix* sp.), beaked hazelnut (*Corylus cornuta*), common snowberry (*Symphoricarpos alba*), rose (*Rosa* sp.), sitka mountain ash (*Sorbus sitchensis*), vine maple, Indian plum (*Oemleria cerasiformis*), and thimbleberry (*Rubus parviflorus*).

Wildlife in the watershed are likely to include small mammals (e.g., mice and voles), skunks, raccoons, red fox, coyotes, and a wide range of birds. Nesting by songbirds and hunting, foraging, shelter, and migratory stopovers by other animals constitute the anticipated use of existing natural habitat. Given that much of the watershed has been developed, remaining patches of natural habitat are small and fragmented, limiting the watershed's ability to support mammals with large home ranges, such as black-tailed deer, while supporting the presence of tolerant species such as raccoon and coyote. The small areas of intact vegetation lead to a high proportion of edge habitat, which is typically inhabited by nest predators (e.g., crows and jays) or opportunistic species (e.g., starlings), further limiting the suitability of the area to native, more desirable songbird species (Paton, 1994; Flaspohler, 2001; Deng and Gao, 2005).

3.2.2 Species of Conservation Concern

Some plant and animal species, or their habitat, in the Nelson Creek watershed are of conservation concern, and are designated by BCCDC as either blue-listed (ecological communities, and indigenous species and subspecies of special concern in BC) or red-listed (ecological communities, and indigenous species and subspecies that are extirpated, endangered or threatened in BC). The federal *Species at Risk Act (SARA)* also has requirements for protection of certain species. Protection of these species, or their habitat, will be necessary during land development in the watershed.

The Province of BC will change its *Wildlife Act* in the future to include greater protection to species at risk. The *Wildlife Amendment Act*, 2004 received third reading and Royal Assent in May 2004 and changes will be brought into force through regulation. Changes that may affect land development include prohibitions respecting species at risk and specific legislation stating that no compensation is to be paid for reduced land values or damages/losses resulting from the new legislation. Upcoming changes in the *Wildlife Amendment Act* that may affect potentially developable lands are:

"6.1 (1) *A person must not do any of the following:*

(a) kill, harm, harass, capture or take a species individual of a species at risk, except as authorized by regulation or by a permit or agreement under this section;

(b) damage or destroy a species residence of a species at risk, except as authorized by regulation or by a permit or agreement under this section;"

Under the amendments, "*species residence*" is defined as:

"a place or area in, or a natural feature of, the habitat of the species at risk, or a class of such a place, area or natural feature that is habitually occupied or used as a dwelling place by one or more species individuals of the species at risk"

To track the status of species at risk, the BCCDC maintains a database of rare vertebrates for each Forest District in BC. Species or populations at high risk of extinction or extirpation are placed on the red list, and are candidates for formal Endangered Species status. Species or subspecies considered to be of Special Concern are placed on the blue list. The yellow list includes all remaining wildlife species. Yellow-listed species are not considered "at risk." However, the BCCDC maintains a "watch list" of yellow-listed taxa that have a small range or low abundance in the province, have shown provincial declines, or are susceptible to perceived long-term threats.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is the federal equivalent of the BCCDC. COSEWIC is a committee of experts that assesses and designates wild species that are in some danger of disappearing from Canada. COSEWIC ratings for species are defined as follows:

Extinct – A species that no longer exists.

Extirpated – A species that no longer exists in the wild in Canada, but occurs elsewhere (for example, in captivity or in the wild in the United States).

Endangered – A species facing imminent extirpation or extinction.

Threatened – A species likely to become endangered if limiting factors are not reversed.

Special Concern – A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.

Not at Risk – A species that has been evaluated and found to be not at risk.

Data Deficient – A species for which there is insufficient scientific information to support status designation.

A COSEWIC designation of Extirpated, Endangered, Threatened, or Special Concern makes a species potentially eligible for listing on Schedule 1 of *SARA,* which then provides special protection for these species and their critical habitats, and requires development of management plans for these species. Schedule 1 of *SARA* has grown from 233 plant and animal species in 2002, at the time of royal assent, by an additional 195 species.

A search of databases for the CWHdm biogeoclimatic zone in the Chilliwack Forest District yielded 40 plant, 6 mammal, 14 bird, 2 reptile, and 4 amphibian species, as well as 11 ecological communities at risk, whose distribution includes the Nelson Creek watershed. These are listed in Appendix C, Table C1, along with habitat and distribution information.

In addition, two red-listed and seven blue-listed species of invertebrates (not protected under the *Wildlife Act*) were reported and may be present in the Nelson Creek watershed (Appendix C, Table C2).

There are 17 rare element occurrences within 5 km of the watershed: 3 invertebrate, 1 mammal, and 13 plant species. These are listed in Table 3-9 along with the location and year they were last observed. Of these species, only false pimpernel has been observed within the watershed. It has been reported from the old Terra Nova Dump site (extirpated when the driving range and waste recycling facilities were built around 1991) and on the bank of the Fraser River at Fraser Mills (last observed in 1989).

TABLE 3-9
Rare Species Occurrences within 5 km of the Nelson Creek Watershed

Scientific Name	Common Name	Provincial Status	Location	Year Last Observed
Epitheca canis	Beaverpond Baskettail	Blue	Colony Farm	1996
Pachydiplax longipennis	Blue Dasher	Blue	Burnaby Lake	1996
Sympetrum vicinum	Autumn Meadowhawk	Blue	Mundy Park Como Lake	1974 1974
Sorex bendirii	Pacific Water Shrew	Red[1]	East side of Mundy Lake	2000
Lindernia dubia var. *anagallidea*	false-pimpernel	Blue	Burnaby Lake	1999
			Fraser Mills – Fraser River shore	1989
			Fraser Mills (Old Terra Nova Dump) – no longer there	1991
			Sapperton Island	1994
			Fraser Surrey Docks	1989
Epilobium leptocarpum	small-fruited willowherb	Blue	Rail Yard – E. of North Rd.	1991
Lupinus rivularis	streambank lupine	Red[1]	Coquitlam R. at Lougheed Fraser Surrey Docks	1993 2004
Salix sessilifolia	soft-leaved willow	Blue	Near Essondale Fraser Surrey Docks	1988 1989
Cardamine parviflora var. *arenicola*	small-flowered bitter-cress	Red	Mary Hill	1991
Polygonum punctatum	dotted smartweed	Blue	Mary Hill Road	1994
Elodea nuttallii	Nuttall's waterweed	Blue	Colony Farm	1996
Myriophyllum ussuriense	Ussurian water-milfoil	Blue	Coquitlam R. near Port Mann	1987
Wolffia borealis	northern water-meal	Red	Colony Farm	1996
Carex scoparia	pointed broom sedge	Blue	E. bank Fraser R. at Patullo	1991
Elatine rubella	three-flowered waterwort	Blue	Fraser R. at Patullo Bridge	1989
Callitriche heterophylla ssp. *heterophylla*	two-edged water-starwort	Blue	Fraser Surrey Docks	1989
Juncus oxymeris	pointed rush	Blue	Annacis Island	1989

NOTE:
[1] also listed under SARA Schedule 1 as E status

3.2.3 Field Assessments

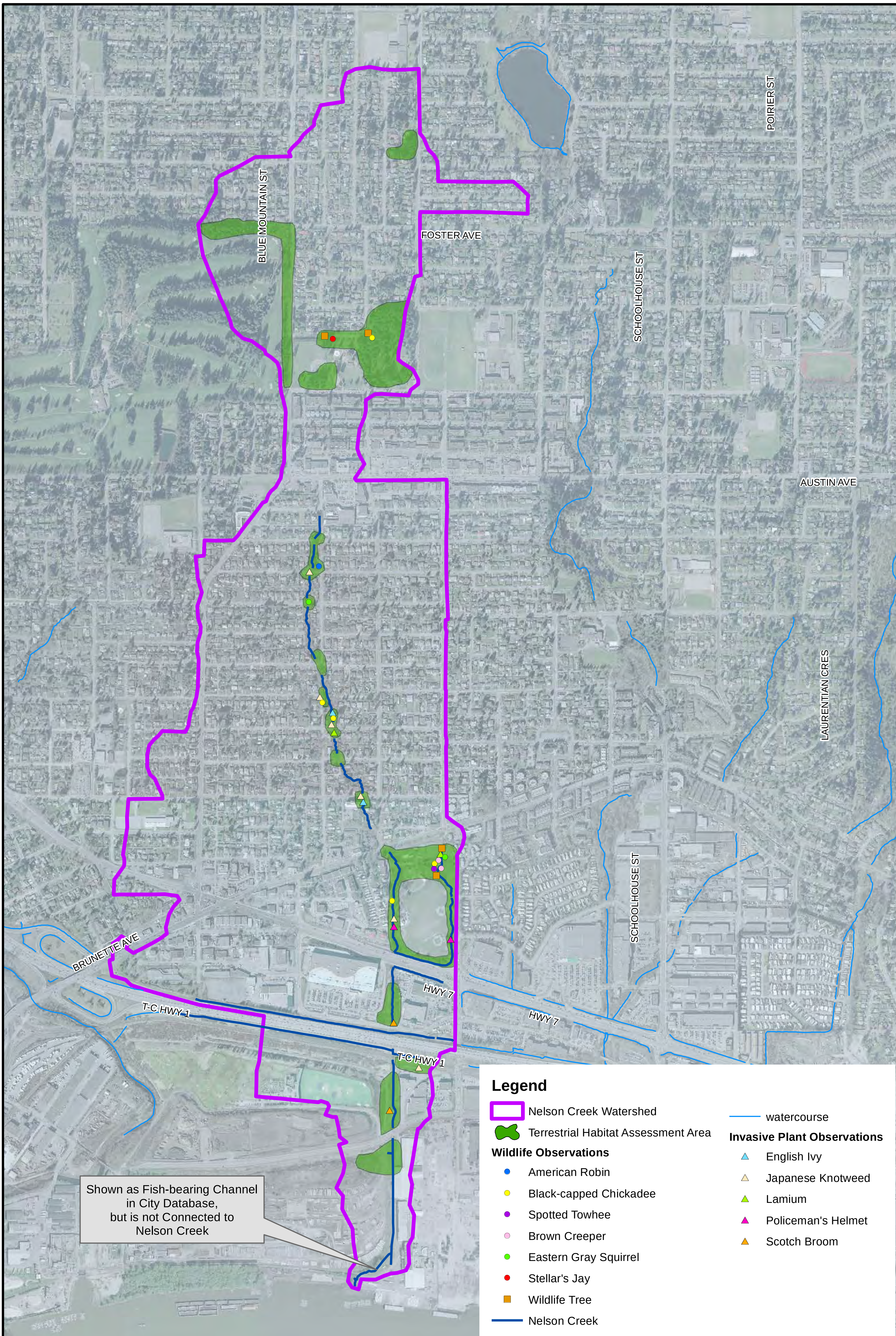
Wildlife habitat was assessed during a site visit on October 30, 2008 to areas with natural habitat. This included the riparian area of Nelson Creek, Mackin and Blue Mountain Parks, and land bordering the golf course (Figure 3-3). Riparian habitat south of Highway 1 was also assessed. The upland area is predominantly residential and the lowland area is commercial/industrial use.

The riparian and park areas provide suitable habitat for songbirds and small mammals, although, due to their lack of connectivity, these areas likely do not provide habitat for mammals with large home ranges, such as deer. More tolerant mammals, such as raccoon and coyote, may be present.

Wildlife species observed during the site visit include European starling (*Sturnus vulgaris*), killdeer (*Charadrius vociferus*), an unidentified sparrow, brown creeper (*Certhia americana*), black-capped chickadee (*Poecile atricapillus*), spotted towhee (*Pipilo maculatus*), American robin (*Turdus migratorius*), Stellar's jay (*Cyanocitta stelleri*), northwestern crow (*Corvus caurinus*), and Eastern gray squirrel (*Sciurus carolinensis*).

No rare plant species or ecosystems were observed during the field survey; however, invasive species were observed throughout the watershed, predominantly in riparian areas. Himalayan blackberry and Japanese knotweed were the main invasive species, but policeman's helmet (*Impatiens glandulifera*), scotch broom (*Cytisus scoparius*), English ivy (*Hedera helix*), and Lamium (*Lamium* spp., *Lamiastrum galeobdolon*) were also observed. Figure 3-3 shows the locations where wildlife and invasive plants were observed.

Habitat suitability for the focal wildlife species identified in the ESA Management Strategy for the City of Coquitlam was also assessed during the field assessment. Information is summarized in Table 3-10 for modelled and observed habitat suitability. Field observations confirmed many of the modelled habitat suitability ratings provided in the ESA maps, and identified new areas of suitable habitat for some of the focal species (Cooper's Hawk, Brown Creeper, Hairy Woodpecker). The likelihood of suitable habitat for coastal tailed frog, Johnson's hairstreak, and Great Blue Heron was reduced based on field observations.



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CH2MHILL.
Stantec
Prepared For
CITY OF COQUITLAM

NELSON CREEK
Integrated Watershed Management Plan

Coquitlam, BC
March, 2012

Figure: 3-3
Terrestrial Habitat Assessment Area & Observations 2008

TABLE 3-10
Habitat Suitability of Focal Wildlife Species

Common Name	Scientific Name	Habitat Requirements	Habitat Suitability Defined in ESA	Observed Suitability
Cooper's Hawk	*Accipiter cooperii*	Coniferous forests, riparian woodlands, Garry oak stands, and tracts of aspen, birches and alder (Campbell *et al.* 1990a)	None previously identified in Nelson Cr. Watershed	New – may be low-moderate habitat in Blue Mtn. Park and golf course
Barn Owl	*Tyto alba*	Agricultural fields, grasslands and other open areas for hunting (Campbell *et al.* 1990a)	Some low and moderate habitat	Confirmed
Red-legged Frog	*Rana aurora*	Breed in cool ponds or lake margins, slow-moving streams, marshes, bogs or swamps at least 50 cm deep. During non-breeding, found along streams or in moist habitat in the summer. Can be found in forests far from open water in moist conditions (COSEWIC 2002a)	Low – High habitat previously identified	Confirmed, may also be found in non-riparian habitat during winter
Coastal Tailed Frog	*Ascaphus truei*	Cold, fast moving mountain streams, with year-round flow and stable substrates, such as boulders and cobbles (Cannings et al 1999).	Low suitability in Nelson Creek, including lowland habitat	Unlikely due to poor water quality
Johnson's Hairstreak	*Callophrys johnsoni*	Lower elevation mature and old conifer forests along the coast. Larvae feed on dwarf mistletoe only found in western hemlock in BC (MWLAP 2004).	Moderate habitat in Blue Mtn. Park and border of golf course	Unlikely as western hemlocks are rare at both locations
Douglas' Squirrel	*Tamiasciurus douglasii*	Coniferous forests (NatureServe 2008)	High suitability habitat identified in watershed	Confirmed, also habitat within golf course
Brown Creeper	*Certhia americana*	Mature coniferous and mixed wood forests. Forages on trunks of medium- and large-sized trees with rough bark, especially conifers such as Douglas-fir, western redcedar and western hemlock (Campbell et al 1997)	None	New – brown creepers observed in Mackin Park
Hairy Woodpecker	*Picoides villosus*	Mature forest types, mixedwood forests for nesting (Campbell *et al.* 1990a)	None	New – low suitability habitat in Blue Mtn. Park, golf course
Warbling Vireo	*Vireo gilvus*	Deciduous or mixed wood forests near river valleys, estuaries or wetlands. Seldom found in pure coniferous stands (Campbell *et al.* 1997)	Border of golf course (High)	Confirmed
Spotted Towhee	*Pipilo maculatus*	Open, coniferous forests with a substantial shrub understorey (Campbell *et al.* 2001)	High habitat throughout the watershed	Confirmed – observed in Macken Park
Great Blue Heron	*Ardea herodias fannini*	Breed in forested locations close to wetland feeding areas. Forage in marine and freshwater habitats (lakeshores, marshes, ponds, wetlands, slow-moving portions of the Fraser River (Gebauer and Moul 2001)	Moderate nesting habitat, high-moderate foraging habitat throughout watershed	No moderate nesting habitat identified south of Lougheed Hwy, except at edge of River

Habitat suitability details include:

- Cooper's Hawk habitat was not identified in ESA modelling; however, some low to moderate quality habitat in Blue Mountain Park and at the golf course was identified in the field, in areas of mature coniferous forest, albeit smaller than the 4 ha minimum area defined in the model.
- Barn Owl habitat (some low and moderate forage habitat) was identified in the ESA for lowland riparian areas of the watershed. Habitat quality was confirmed in the field, and additional habitat identified (nearby large coniferous trees, for example at the north end of Mackin Park, which may provide daytime roosting).
- Red-legged frog habitat (low to high quality) was identified entirely in riparian areas in the ESA modeling. The field observation suggests red-legged frogs may also be found in upland areas of the watershed, away from water, especially in winter.
- Coastal tailed frog habitat (low quality) was identified in ESA modelling for Nelson Creek, including the lowlands. While suitable physical conditions may occur in Nelson Creek upstream of Mackin Park, gradient of the lowlands is not suitable and the high proportion of stormwater suggests that water quality is not sufficient to support Coastal tailed frog populations.
- Johnson's Hairstreak habitat (moderate quality) was identified in both Blue Mountain Park and the golf course in the ESA. Field observations suggest low habitat quality, given the rare occurrences of western hemlock and hence dwarf mistletoe, on which the larvae feed.
- Douglas' squirrel habitat quality was rated high for any mature coniferous forest. Field survey identified two additional high quality areas: forested strips within the golf course and an area adjacent to Ikea (the latter is not mature coniferous forest and the chance of finding Douglas' squirrel here would be very low).
- Although no Brown Creeper habitat was identified in habitat suitability modelling for the watershed, brown creepers were observed in Mackin Park. Suitable habitat is also present in Blue Mountain Park and the golf course.
- No Hairy Woodpecker habitat was identified using the model; however, Blue Mountain Park and the golf course may provide trees suitable for nesting.
- The only Warbling Vireo habitat identified in the ESA modelling was the border of the golf course and this was confirmed during the site visit.
- Spotted Towhee habitat (high quality) was identified throughout the watershed using the habitat suitability model. This was confirmed during the site visit and Spotted Towhees were observed in Mackin Park.
- Great Blue Heron habitat (moderate to high quality foraging and nesting habitat) was identified throughout the watershed using modelling. Although modelling identified moderate nesting habitat south of the Lougheed Highway, it is unlikely that herons would nest in this area, due to lack of mature trees.

3.3 Physical Assessment

3.3.1 Physical Environment

Physical characteristics of the watershed influence Nelson Creek, and are important considerations in integrated watershed management planning. In undisturbed watersheds, infiltration of rainfall into the ground is governed by surface area and the permeability of the underlying soils. In urban watersheds, the amount of impervious cover (paving) also influences infiltration, through removal of trees and native vegetation, an increase in impermeable area and reduction in, or removal of, porous topsoils. One of the consequences of altered hydrologic regime associated with urban development is increased peak flows during rain events and decreased base flows during dry weather. These hydrologic changes can lead to increased erosion of stream banks and deposition of sediment in downstream areas, in turn leading to increased flood potential, maintenance issues for the City or hazards for landowners. These processes also affect the ability of a stream to support fish and other aquatic life.

Information about the hydrogeological, channel geomorphological and geotechnical stability aspects of watershed function are provided in Appendices D through F and summarized below. Based on these reports, it does not appear that erosion and sedimentation processes alone would lead to flooding and municipal maintenance issues. Other sources, such as conveyance capacity of tributaries and ditches along the main roads may contribute to the historic flooding in this area.

3.3.2 Hydrogeology

Groundwater, climate, and surficial soils of the Nelson Creek watershed are described in Appendix D. The hydrogeology report is based on a review of available reports and a site visit in November 2008 to identify areas of seepage and springs, confirm surficial soils in the watershed and survey for areas with potential for infiltration.

The moist maritime climate and relatively high precipitation rate contribute to seasonally high groundwater levels, which can lead to drainage problems in some areas. Surficial geology maps indicate that soils are mainly comprised of Vashon Drift (glacial soils) and Capilano Sediments (raised marine, deltaic, and stream deposits). This is confirmed in well logs conducted in similar areas of the City and in the field survey, which indicate that upland soils generally consist of medium to coarse sands and sand gravels, underlain by silty clay loam. Hydraulic conductivity (a useful measure of a soil's ability to transmit water) is considered low (approximately 10^{-6} m/s) for the majority of soils in the watershed. There are two sand-gravel aquifers in the watershed (one in the uplands and the other in the lowlands, not used for drinking water), which may discharge directly to the Fraser River rather than Nelson Creek.

The hydrogeologic system of the Nelson Creek watershed is comprised of a shallow groundwater flow system in the near surface coarser-grained soils (sand and gravel), with perched groundwater within 2 m of the surface. This flow system is most likely driven by infiltration of rainwater (recharge) in the upland regions. Groundwater discharge provides base flows for Nelson Creek, and is expected to occur in mid and lower areas of the main channel and its tributaries and in low-lying areas (e.g., adjacent to the Fraser River). This was confirmed in the field survey, which identified seepage and springs along Nelson Creek and ponding south of Brunette Avenue.

Major changes to the hydrological and hydrogeological function of the Nelson Creek area attributed to urbanization include altered flow regimes, decreased infiltration, lowered water tables, and reduced baseflows (particularly notable during the summer dry period).

3.3.3 Channel Geomorphology

Channel geomorphology characteristics are described in Appendix E. An increase in peak flow magnitude may result in higher rates of erosion along stream banks, with more sediment deposited in the stream, possibly leading to a greater risk of flooding. In Nelson Creek, channel characteristics were assessed during a site visit in November 2008 when stream flows were low, which allowed examination of potential erosion areas in the stream.

Most of the sediment supplied to the creek is a mix of fine- and coarse-grained material that appears to be eroded from the lower stream banks, mainly at the outer bends of the creek. Erosion processes on steep exposed banks (rain dislodging sediment, runoff erosion or gravity failure) contribute a much lesser amount of sediment. Sediment from upper portions of the upland area moves downstream during high flow events and appears to be stored within the upland channel (seen as deposits of coarse-grained sediment) and in the Mackin Park area. These deposits could be mobilized during extreme high flow events and result in debris blockages at culverts or deposition in the lowlands. There were few observations of excessive sediment build up (aggradation) or potential debris blockage in the uplands area. Fine-grained deposits would move out of the upland area quickly due to the relatively steep gradients and high stream flows, and into the lowlands and Fraser River.

In the lowland area, flow is slow and influenced by tidal effects in the Fraser River and streambed material consists of coarse sand to silty material. The field survey identified few sediment sources along the creek and no observable instances of significant sedimentation below Lougheed Highway, although, these may be masked by the thick vegetation growth. There were no significant instances of creek aggradation or large bar deposits in the lower sections of Nelson Creek. However, with continued deposition of coarse-grained material in Nelson Creek near Mackin Park, there is potential for decreased channel flow capacity and increased flood risk during high flows.

3.3.4 Geotechnical Stability of Erosion Areas

Erosion areas develop and change over time as a result of altered hydrologic regimes and channel structure. Increased erosion can lead to maintenance issues for the City or hazards for landowners. An assessment of erosion areas on Nelson Creek conducted in 2005 (Associated Engineering, 2006) included a geotechnical assessment by Jacques Whitford AXYS (now Stantec). In November 2008, for the IWMP, Stantec re-inspected six high priority erosion sites that were identified in 2005. The 2008 inspection was done to determine changes in the extent of erosion over the last three years, assess whether recommended remedial works have been completed, and comment on the likelihood of these sites developing stability concerns. The full report, provided in Appendix F, describes slope characteristics, observed soil conditions and changes between the 2005 and 2008 site visits. A brief summary is provided in Table 3-11.

The priority erosion sites were in the upper watershed on private property, and were attributable to homeowner modifications along the bank (discharge pipes, retaining walls, deck foundations at the creek) and altered hydrologic regime associated with urban development. Situations included localized bank failures and slope instability due to drainage pipes discharging onto the slope and/or high stream flows, one location where the stream is undermining a concrete retaining wall that forms a stream bank, and one location where a deck extending to the stream had lost footings.

In most cases, there was no noticeable change or only a small change observed between 2005 and 2008. Remedial works and periodic inspections had been recommended for all these sites in 2005, as the bank failures are considered likely to increase in size eventually. The only repairs conducted to date were at the residence where the deck footings were being lost, as well as the two bank failures between Thomas Avenue and Delestre Avenue.

While there has been no or small change over a 3-year period, the recommendations for ongoing inspections and remediation work remain valid. The timing of extreme weather and streamflow events is not predictable, and the consequence is loss of bank habitat at residences and introduction of additional sediment in downstream areas, with implications for fish habitat and municipal maintenance schedules for flood control.

Subsequently, the City reported that at Sites No. 17 and 18 (Nelson Creek at Thomas Avenue), work was done in fall 2009 to repair the toe of the slope. At that time, instability on the upper east slope was identified and then stabilized.

TABLE 3-11
Summary of Conditions at Six High Priority Erosion Sites Along Nelson Creek

Location[1]	Summary of Conditions
Site No. 3 (20 m north of Dansey Avenue)	A localized failure of the west creek bank above the stream at location 20 m north of Dansey Avenue, identified in 2005, has resulted in undermining of the foundation of a garden shed on the adjacent property to the west. The bank failure appeared to result directly from water flow out of a drainpipe on the property. If unmitigated, the erosion is likely to continue, which will further undermine the garden shed. Similar conditions were observed in 2005 and 2008, as no remedial work had been done.
Site No. 4 (between Dansey Avenue and Madore Avenue)	Minor slope instability between Dansey Avenue and Madore Avenue, identified in 2005, will gradually destabilize the slope. Given the presence of a house approximately 3 m from the top of the slope, annual inspection and eventual remedial work was recommended in 2005. By 2008, the stream bank appears to have de-stabilized further, with additional erosion on the face of the slope, likely due to high water flows within Nelson Creek. No remedial work had been conducted.
Sites No. 17 and 18 (between Thomas Avenue and Delestre Avenue)	Two bank failures between Thomas Avenue and Delestre Avenue were identified in 2005: a small failure area on the west bank (Site No. 17) and a larger (approximately 15 m wide) failure area on the east bank (Site No. 18). Both failure zones lacked any significant vegetation, and there was evidence of groundwater seepage and a perched water table, suggesting relatively recent bank failure. The initial cause of the failure is likely erosion caused by Nelson Creek, compounded by water from a drainpipe on the east bank. The steep banks (56 to 63 degree slope) are likely to continue to be unstable until a more stable slope evolves. Similar conditions were noted in 2008, and none of the recommended remedial works had been completed. The City reported that the sites were repaired in fall 2009.

TABLE 3-11
Summary of Conditions at Six High Priority Erosion Sites Along Nelson Creek

Location[1]	Summary of Conditions
Site No. 19 (between Thomas Avenue and Delestre Avenue)	Undermining of a retaining wall forming the west bank of Nelson Creek between Thomas Avenue and Delestre Avenue was identified in 2005. The 3 m high concrete wall had a noticeable lean toward the creek, with horizontal and vertical cracks, and the wall foundations was undermined by stream flow by up to 300 mm. The north section of the wall had already failed, leaving concrete rubble in the creek. There were no changes in retaining wall structure noted in 2008, although increased vegetation growth around the wall and creek bank may be contributing temporary stability. Given that the wall is likely to fail eventually, recommendations were made for ongoing inspection and eventual remediation.
Site No. 25 (north of James Avenue)	A deck extending to the eastern edge of the creek at a location north of James Avenue was identified as missing a column and footing in 2005 and showing undermining at an adjacent column. There was also a series of sinkholes at the top of the bank, resulting from loss of soil as the finer grained soils are being “piped” through the larger boulders due to water flow from the creek. By 2008, the homeowner had repaired the deck foundations and covered the slope with poly sheeting. There does not appear to be any significant erosion or movement of the boulders along the creek bank.

Note:

[1] Site locations shown on a map in the Geotechnical Conditions memo (Appendix F)

3.4 Ditch Assessment

An assessment of 30 ditches, most of them within lanes, was undertaken in 2010 as part of the IWMP. The objectives of this work were to investigate conditions and classify lane ditches according to the City’s watercourse classification system, consider stormwater management implications of ditch removal, and update the City’s watercourse classification map. The study also was done to provide regulatory context for alteration of ditches (any *Fisheries Act* or City of Coquitlam permitting implications) and make recommendations for ditch management and any habitat compensation requirements associated with ditch removal or alteration.

Ditches in the watershed provide some benefits to stream health as well as stormwater management, through infiltration into the soil (improving stream flows and water quality) and transport of food and nutrients (leaf litter, invertebrates) to downstream fish habitat. Removing the ditches during redevelopment has the potential to impair some of these functions. While infiltration and water quality can be maintained by installing infiltration trenches along the lanes, this would not address the loss of food and nutrient supply. The ditch assessment focused on habitat and food and nutrient supply considerations.

Details of the study are contained in Appendix G. The findings are summarized here.

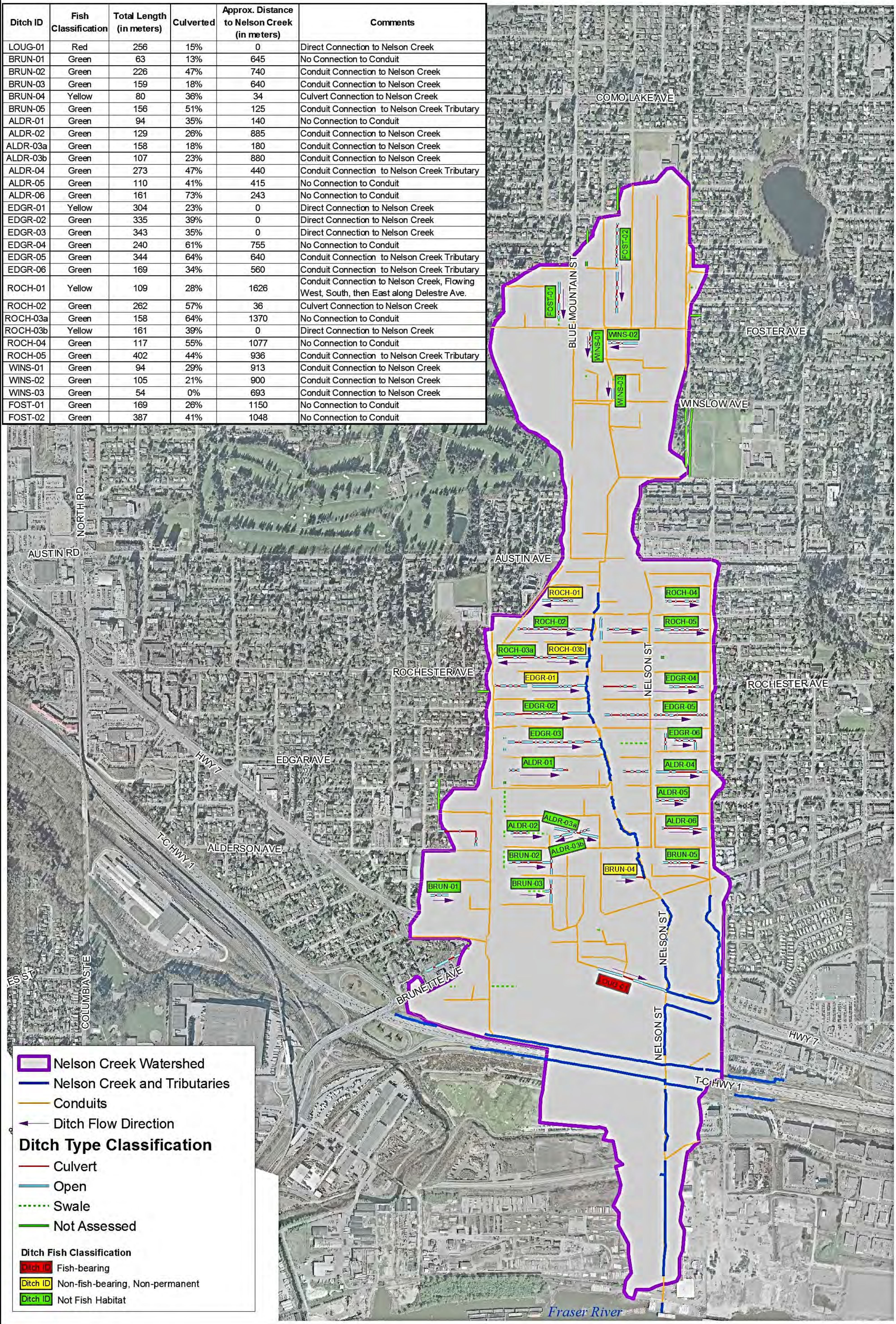
The 30 ditches were classified using the categories defined by the City: one ditch was classified Red (fish-bearing), four ditches were Yellow (not fish-bearing and not permanent), and 25 ditches were Green (not fish habitat); see Figure 3-4.

The lanes are currently paved, but with an open ditch along one side. There are culverts for driveways, some longer stretches in stormwater conduits, and small amounts of vegetative cover (mostly non-native trees and shrubs, 0 to 30 percent canopy cover). Most of the ditches contain grass, which is mowed periodically.

The ditches that contribute recognizable food and nutrient supply are the Red-classified ditch and stretches of the Yellow-classified ditches close to Nelson Creek. Locations of the Red and Yellow-classified ditches are as follows:

- The Red-classified ditch is along the Lougheed Highway and is directly connected to Nelson Creek
- The two Yellow-classified ditches in the lane behind Rochester Avenue are in the Austin Heights Neighbourhood Plan area
- The two Yellow-classified ditches in the lanes behind Edgar Avenue and Brunette Avenue are in the Maillardville neighbourhood

Ditch ID	Fish Classification	Total Length (in meters)	Culverted	Approx. Distance to Nelson Creek (in meters)	Comments
LOUG-01	Red	256	15%	0	Direct Connection to Nelson Creek
BRUN-01	Green	63	13%	645	No Connection to Conduit
BRUN-02	Green	226	47%	740	Conduit Connection to Nelson Creek
BRUN-03	Green	159	18%	640	Conduit Connection to Nelson Creek
BRUN-04	Yellow	80	36%	34	Culvert Connection to Nelson Creek
BRUN-05	Green	156	51%	125	Conduit Connection to Nelson Creek Tributary
ALDR-01	Green	94	35%	140	No Connection to Conduit
ALDR-02	Green	129	26%	885	Conduit Connection to Nelson Creek
ALDR-03a	Green	158	18%	180	Conduit Connection to Nelson Creek
ALDR-03b	Green	107	23%	880	Conduit Connection to Nelson Creek
ALDR-04	Green	273	47%	440	Conduit Connection to Nelson Creek Tributary
ALDR-05	Green	110	41%	415	No Connection to Conduit
ALDR-06	Green	161	73%	243	No Connection to Conduit
EDGR-01	Yellow	304	23%	0	Direct Connection to Nelson Creek
EDGR-02	Green	335	39%	0	Direct Connection to Nelson Creek
EDGR-03	Green	343	35%	0	Direct Connection to Nelson Creek
EDGR-04	Green	240	61%	755	No Connection to Conduit
EDGR-05	Green	344	64%	640	Conduit Connection to Nelson Creek Tributary
EDGR-06	Green	169	34%	560	Conduit Connection to Nelson Creek Tributary
ROCH-01	Yellow	109	28%	1626	Conduit Connection to Nelson Creek, Flowing West, South, then East along Delestre Ave.
ROCH-02	Green	262	57%	36	Culvert Connection to Nelson Creek
ROCH-03a	Green	158	64%	1370	No Connection to Conduit
ROCH-03b	Yellow	161	39%	0	Direct Connection to Nelson Creek
ROCH-04	Green	117	55%	1077	No Connection to Conduit
ROCH-05	Green	402	44%	936	Conduit Connection to Nelson Creek Tributary
WINS-01	Green	94	29%	913	Conduit Connection to Nelson Creek
WINS-02	Green	105	21%	900	Conduit Connection to Nelson Creek
WINS-03	Green	54	0%	693	Conduit Connection to Nelson Creek
FOST-01	Green	169	26%	1150	No Connection to Conduit
FOST-02	Green	387	41%	1048	No Connection to Conduit



Prepared By

CH2MHILL Stantec

Prepared For

CITY OF COQUITLAM

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Coquitlam, BC

NELSON CREEK

Integrated Watershed Management Plan

0 100 200 400 Meters

Figure 3-4
Ditch Classification

3.5 Summary

Nelson Creek and its tributaries provide habitat accessible to fish downstream of Brunette Avenue. The channel is steeper above Brunette Avenue, with culvert and velocity barriers upstream to Charland Avenue, and the headwaters are buried upstream of Charland Avenue. Cutthroat trout, coho salmon, and smaller species (e.g., brassy minnow, sculpin, threespine stickleback) have been reported historically, with only cutthroat trout and threespine stickleback documented since 2004. Although there is no barrier restricting salmon access from the Fraser River, there have been few sightings of coho, the most recent being coho fry in December 2008.

The main area of fish habitat is below Brunette Avenue in the mainstem and a tributary that border Mackin Park. Habitat in that area is considered to have moderate productive capacity, with rearing and spawning habitat, but limited overwintering habitat (deep pools). Riparian vegetation was improved along the tributary in 2010 when the channel was moved to accommodate widening of King Edward St. Upstream of Brunette Avenue, there is potential for cutthroat trout, but it is isolated by the migration barriers.

Water, sampled on two dry and two rainy days at sites in the upper and lower watershed, indicated some concerns with water quality, particularly during rain events. Concentrations tended to be higher at the upper site, just below where the creek daylights, than at the downstream site. Temperature and dissolved oxygen were near sub-optimal levels for salmonids during warm weather. Fecal coliform levels were elevated, suggesting potential cross-connections between the sanitary sewer and stormwater systems. Nutrient levels (ammonia, nitrate, and phosphorus) were elevated, also suggesting sewer cross-connections and perhaps fertilizer inputs. Metal levels (cadmium, copper and zinc) were above BC water quality guidelines for protection of aquatic life during rain events, with cadmium levels also higher than guidelines during dry periods; these metals are common in road runoff.

Terrestrial areas provide little undisturbed natural habitat for wildlife, given the extent of residential, commercial and industrial development. Natural vegetation occurs mainly in riparian areas of Nelson Creek and in forested areas of parks. Below the Lougheed Highway, invasive plants dominate the riparian vegetation. Remaining patches of natural habitat are too small and fragmented to support mammals with large home ranges, such as black-tailed deer, but are able to support the presence of tolerant species such as small mammals (e.g., mice and voles), skunks, raccoons, red fox, coyotes, and a wide range of bird species. The small natural areas lead to a high proportion of edge habitat, typically inhabited by nest predators (e.g., crows and jays) or opportunists (e.g., starlings), further limiting suitability for native, more desirable songbird species. During the field surveys, no rare plant species or ecosystems were observed; however, areas suitable for focal wildlife species identified in the City's ESA Management Strategy were assessed and in many instances confirmed.

Groundwater discharge provides base flows for Nelson Creek. There is a shallow groundwater system in the near surface soils, most likely driven by infiltration of rainwater (recharge) in the upland regions, which discharges mainly in mid and lower areas of Nelson Creek and its tributaries. Major changes to groundwater function are attributed to urbanization (altered flow regimes, decreased infiltration, lowered water tables and reduced baseflows, particularly during summer).

Channel geomorphology was assessed, given that increased peak flows may result in higher rates of erosion along stream banks, more sediment deposited in the stream, and possibly a greater risk of flooding. The majority of sediment supplied to the creek appeared to be eroded from the lower stream banks, with little material coming from erosion on steep exposed banks. Sediment transported from the upper watershed during high flow events appeared to be stored within the upland channel and in Mackin Park. There were no significant instances of creek aggradation or large bar deposits in the lower sections of Nelson Creek. However, with continued deposition of coarse-grained material in Nelson Creek near Mackin Park, there is potential for decreased channel flow capacity and increased flood risk during high flows.

Geotechnical stability of previously identified erosion areas was assessed, given that increased erosion can lead to maintenance issues for the City or hazards for landowners. In November 2008, six high priority erosion sites identified in 2005 (localized bank failures and slope instability, all on private property) were inspected. In most cases, there was little or no noticeable change between 2005 and 2008. By 2008, remedial works had been conducted at one location and in 2009, two more sites were remediated.

Ditches in the watersheds were classified using the City watercourse classification. These ditches, mostly in lanes and along the highways, contribute water, leaf litter and invertebrates to downstream fish habitat and are helpful in managing stream flows and water quality. Because removing the ditches during redevelopment has the potential to impair some of these functions, ditch habitat was assessed to evaluate habitat implications of removing them. Of the 30 ditches, one was classified Red (fish-bearing), four were Yellow (not fish-bearing and not permanent), and 25 were Green (not fish habitat). Habitat quality in most of the ditches is marginal (paved lanes with an open ditch on one side, high proportion of culverts and conduits, small amounts of non-native vegetative cover, including mown grass in the ditches).

4. Hydrologic and Hydraulic Model

This section describes the hydrologic and hydraulic model developed for the Nelson Creek watershed. Additional sub-sections were included to summarize the input data used to build the model, and to describe the steps that were completed to build and calibrate the model.

4.1 Input Data Summary

4.1.1 Topographic Survey

Two separate surveys were completed as described below:

1. A topographical survey of the main stem of Nelson Creek from Brunette Avenue to near the discharge point to the Fraser River, including the tributary that runs south and east of Mackin Park, the highway ditch that runs along the north side of Lougheed Highway, and the highway ditch that runs along the north side of Highway 1; and
2. An alignment survey of the main stem of Nelson Creek, upstream of Brunette Highway to Charland Avenue.

From the two surveys, the following items were obtained:

a) Stream cross sections

b) Longitudinal profile

c) Key elevations and dimensions of the main structures, primarily culvert crossings

d) Field observations, such as water surface elevations at the time surveys were conducted, and location of erosion sites among other site conditions recorded

Table 4-1 summarizes the main culvert crossings in Nelson Creek including the surveyed upstream and downstream invert elevations, culvert length, and cross section shape and dimensions. The table also includes the ID of the link used in the model to represent each crossing. The full survey report is included in Appendix H.

TABLE 4-1
Nelson Creek Culvert Crossing Inventory

Crossing Description	Crossing Type	Dimensions (m)	Length (m)	US/DS Inverts*(m)	Model Link ID
Barge Loading Area (Discharge to Fraser River)	Concrete Box Culvert	3.5 x 2.5 m	(approx.) 100 m	-0.33/ (approx.) -0.5 m	BargeTunn
Tracks Upstream of Barge Loading Area	Wooden Culvert	2.8 x 2 m	19 m	0.33/0.29 m	WoodChamb
United Blvd (includes baffle for flood control at downstream end)	Twin Concrete Box Culvert	2.4 x 1.6 m	28 m	0.78/0.071 – 0.69/0.71 m	UnitBlv1 – UnitBlv2
Highway 1	Corrugated Metal Pipe	3.2 x 2.2 m	47 m	1.5/1.54 m	Hw1-Clv
Woolbridge	Twin Corrugated Steel Pipe	2.8 x 1.6 m	31 m	1.29/0.84 – 1.13/0.86 m	WBr1 –WBr2
Lougheed Highway	Twin Corrugated Metal Pipe	3.2 x 1.9 m	42 m	1.52/1.02 – 1.85/1.07 m	LougHw1 – LougHw2
Driveway to Mackin Park parking lot	Box Culvert	1.83 x 0.91 m	8 m	4.11/4.15 m	CulvtBox1
Driveway to Mackin Park parking lot	Concrete Pipe	1.5 m	13 m	10.32/9.85 m	Culv2
Brunette Avenue	Concrete Pipe	1.2 m	28 m	15.42/14.86 m	BrunHw
Marmont St. (Middle Section of Culvert that goes through Brunette Highway)	Concrete Pipe	0.9 m	38 m	18.47/15.71 m	STPI06794
Nelson Creek (starts crossing that goes through Brunette Highway)	Concrete Pipe	1.5 m	41 m	20.58/18.47 m	STPI06788
Alderson Avenue	Concrete Pipe	1.35 m	22 m	35.04/32.51 m	Alderson
Quadling Avenue	Corrugated Steel Pipe	0.96 m	30 m	50.77/47.7 m	Quadling

TABLE 4-1
Nelson Creek Culvert Crossing Inventory

Crossing Description	Crossing Type	Dimensions (m)	Length (m)	US/DS Inverts*(m)	Model Link ID
Delestre Avenue	Concrete Pipe	0.93 m	48 m	57.35/54.32 m	Delestre
Stewart Avenue	Concrete Pipe	1.1 m	49.5 m	80.21/76.1 m	Stewart
Rochester Avenue	Concrete Pipe	0.93 m	12 m	97.58/96.28 m	Rochester
Madore Avenue	Concrete Pipe	0.93 m	28 m	105.56/103.88 m	Madore
Dansey Avenue	Concrete Pipe	0.9 m	17 m	114.02/112.85 m	Dansey
Charland Avenue (Starts day lighted creek)	Concrete Pipe	0.9 m	26 m	121.51/120.52 m	Charland

Notes: * US: Upstream, DS: Downstream

4.1.2 Nelson Creek Watershed Geodatabase (Source: City of Coquitlam)

The geodatabase provided by the City of Coquitlam in ESRI ArcGIS format included the following information:

- Storm drainage network, including: network topology, conduit dimensions, manhole location, invert elevations of manhole and upstream and downstream end of pipes, and conduit material
- Land use: included polygons depicting the various land uses within the watershed and vicinity
- Soils: included polygons depicting the various soil types within the watershed and vicinity
- Watercourses: Shows general alignment of watercourses within the watershed
- Topography: included contour lines every 0.5 m and spot elevations

4.1.3 Flow Gauge at Brunette Ave. (Pressure Transducer)

To measure stream flows in Nelson Creek, a temporary pressure transducer, equipped with a datalogger, was installed at the downstream end of the Brunette Avenue culvert crossing (See Figure 4-1). Data from the transducer was recorded from the installation date on July 11, 2008, until the removal date on January 15, 2009. The sampling frequency was set to 5 minutes and data was downloaded periodically onsite. To improve the accuracy of low flow measurements during the summer period, a weir was built-in the culvert from the onset of the monitoring period until October 16, 2008, when it was removed. Although sediment build-up at the upstream side of the weir, after rainy periods, invalidated a portion of the transducer readings, valuable data was recovered from the low flow period. These episodes were properly recorded and reported in the Field Maintenance Record shown in Appendix I. Using the transducer readings, flows were calculated using the monitored water depth, and the weir and culvert geometry.

FIGURE 4-1
Nelson Creek Flow Monitoring Location

4.1.4 Rain Gauge Installation (Leisure & Parks)

A temporary tipping bucket rain gauge was installed on the roof of the Leisure & Parks Building of the City of Coquitlam at 640 Poirier Street. The sampling frequency was set to 5 minutes, and data was collected concurrently with the flow monitoring at Brunette Avenue. The rain gauge was removed on January 15, 2009.

4.1.5 Monitoring Data

Figure 4-2 shows the flow and rainfall monitored data, including the 24-hour cumulative rainfall. During the monitoring period the rain-gauge measured a total precipitation of 936.5 mm, a maximum instantaneous rainfall intensity of 24 mm/hr (October 4, 2008), and a maximum 24-hr cumulative rainfall of 63.75 mm (January 7, 2009). The latter is close to the 67.2 mm equivalent to the 2-year 24-hr rainfall event as shown in the IDF curve for the Maillardville Station (City of Coquitlam, 2003).

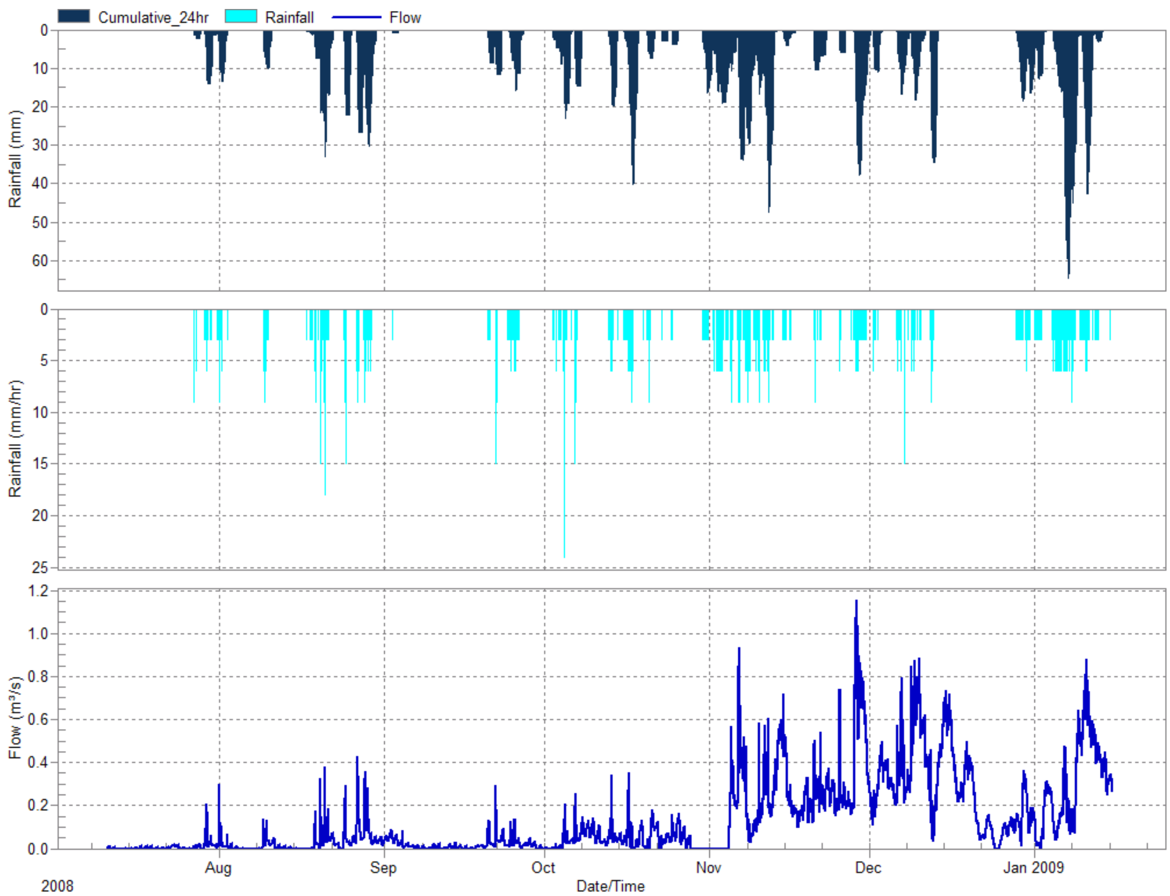
The flow response of the watershed shows two distinctive regimes, summer and winter. The main flow characteristics summarized in Table 4-2. Flow parameters such as baseflows, mean flows, and peak flows are significantly higher during the winter period.

TABLE 4-2
Flow Monitoring Summary

Flow Characteristic	Summer	Winter
Baseflow (m³/s)	0.008	0.2
Baseflow (L/s/ha)*	0.067	1.65
Mean flow (m³/s)	0.03	0.29
Maximum flow (m³/s)	0.43	1.15

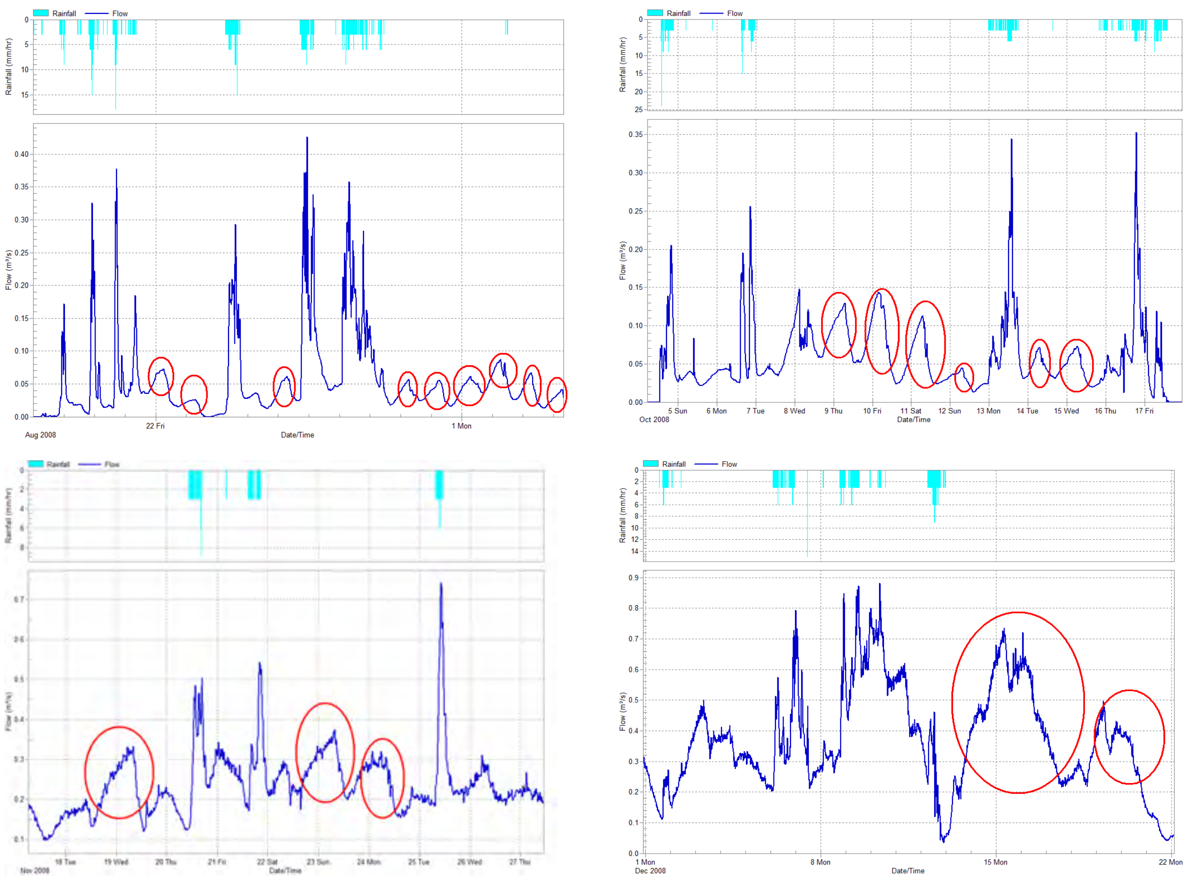
*Using upstream tributary area of 120 ha.

FIGURE 4-2
Flow and Precipitation Monitored Data. Nelson Creek IWMP



An interesting behaviour was observed in the flow monitoring data characterized by the presence of flow 'pulses'. Such pulses were observed during inter-event (i.e., between storm events) periods, in both summer and winter data. Because the operational condition of the equipment was repeatedly checked in the field (see Appendix I), and because the pulses were consistently observed throughout the monitoring period, monitoring errors were ruled out as a plausible explanation. Figure 4-3 shows the pulses circled in red for various periods. The pulses do not seem to be related to fast rainfall-runoff processes, but rather to late aquifer discharges. During the summer the peak pulse values were around 0.025 m³/s, while during the winter the maximum peak pulse was 0.73 m^3/s. These pulses acquire significance during the winter period because, if a precipitation event coincides with the occurrence of the pulse, the resulting stream peak flows from the rainfall-runoff process can be magnified. The implications of these pulses in the process of model calibration are discussed further in the text.

FIGURE 4-3
Hydrograph Close-ups Showing Groundwater Flow 'Pulses'



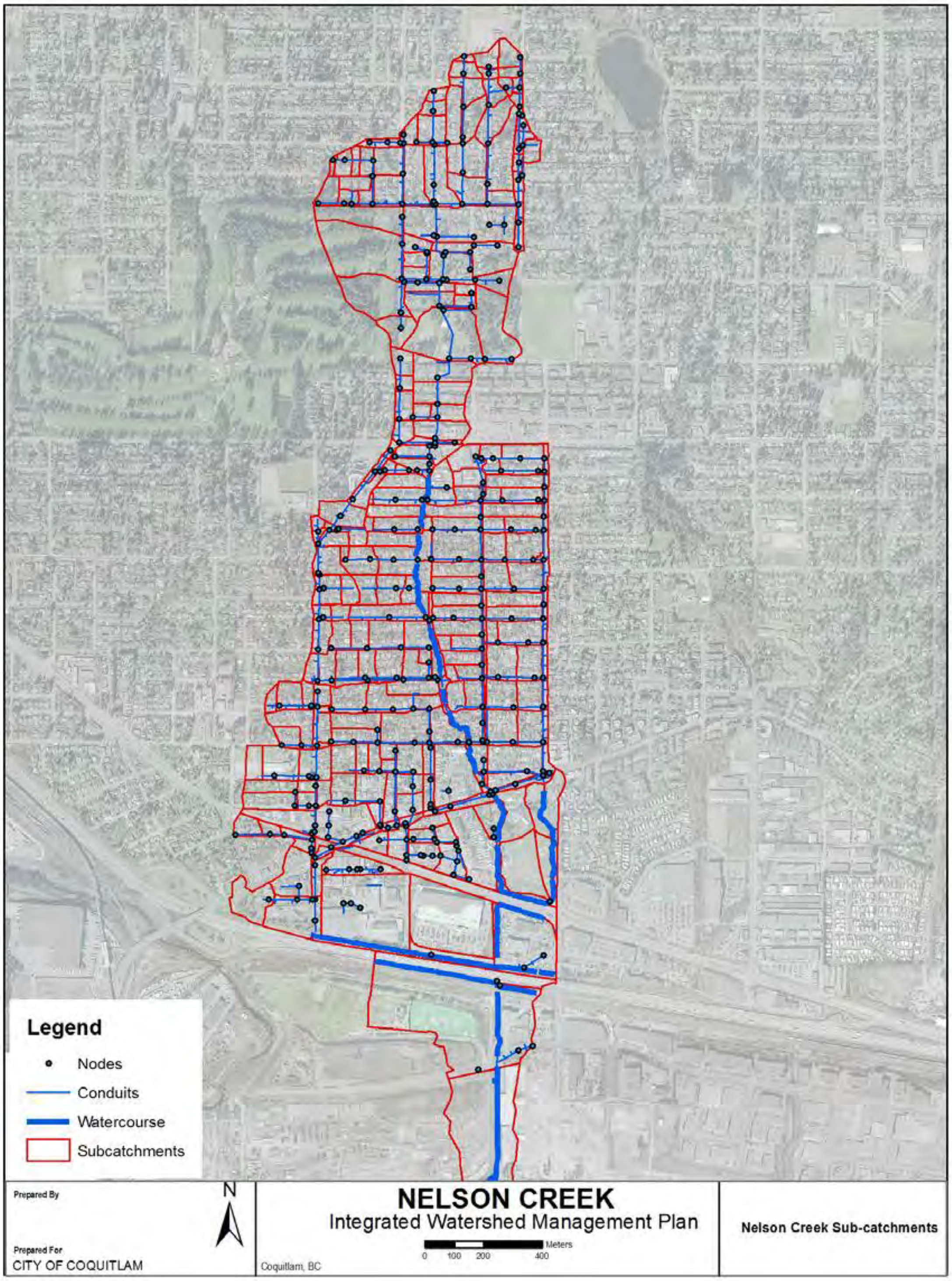
4.2 Model Assembly

4.2.1 Hydrology

Sub-catchment Delineation

Sub-catchment boundaries were delineated at the manhole level, taking into consideration terrain elevations, location of catchbasins, and drainage patterns. The sub-catchments are shown in Figure 4-4. Each sub-catchment was assigned an outlet node or manhole. Hydrologic parameters were computed and assigned to each sub-catchment as subsequently described in the text. Rainfall from the Leisure & Parks temporary rain gauge was uniformly applied to all model sub-catchments.

FIGURE 4-4
Nelson Creek Sub-catchments and Drainage Network



Imperviousness

The percentage of imperviousness of each sub-catchment was determined by intersecting the existing land use coverage described in Section 2 with the delineated sub-catchments in ArcGIS to calculate the area weighted average value. Table 4-3 shows the impervious percentage assigned to each catchment.

TABLE 4-3
Nelson Creek Watershed % of Imperviousness per Land Use (Existing Conditions)

Land Use Description	% of Imperviousness
Low Density Apartment Residential	45
Civic and Major Institutional	30
School	30
Medium Density Apartment Residential	65
Urban Town housing	80
One and Two Family Residential	65
General Commercial	85
Neighbourhood Centre	90
Service Commercial	85
Industrial	85
Highway Retail Industrial	85
Parks and Recreation	15
Other Open Space	15
Extensive Recreation	15

Surface Roughness and Depression Storage

Table 4-4 shows the parameters were used for pervious and impervious areas in the model.

TABLE 4-4
Surface Roughness and Depression Storage

	Impervious Areas	Pervious Areas
Manning's "n"	0.014	0.035
Depression Storage	0.5	1

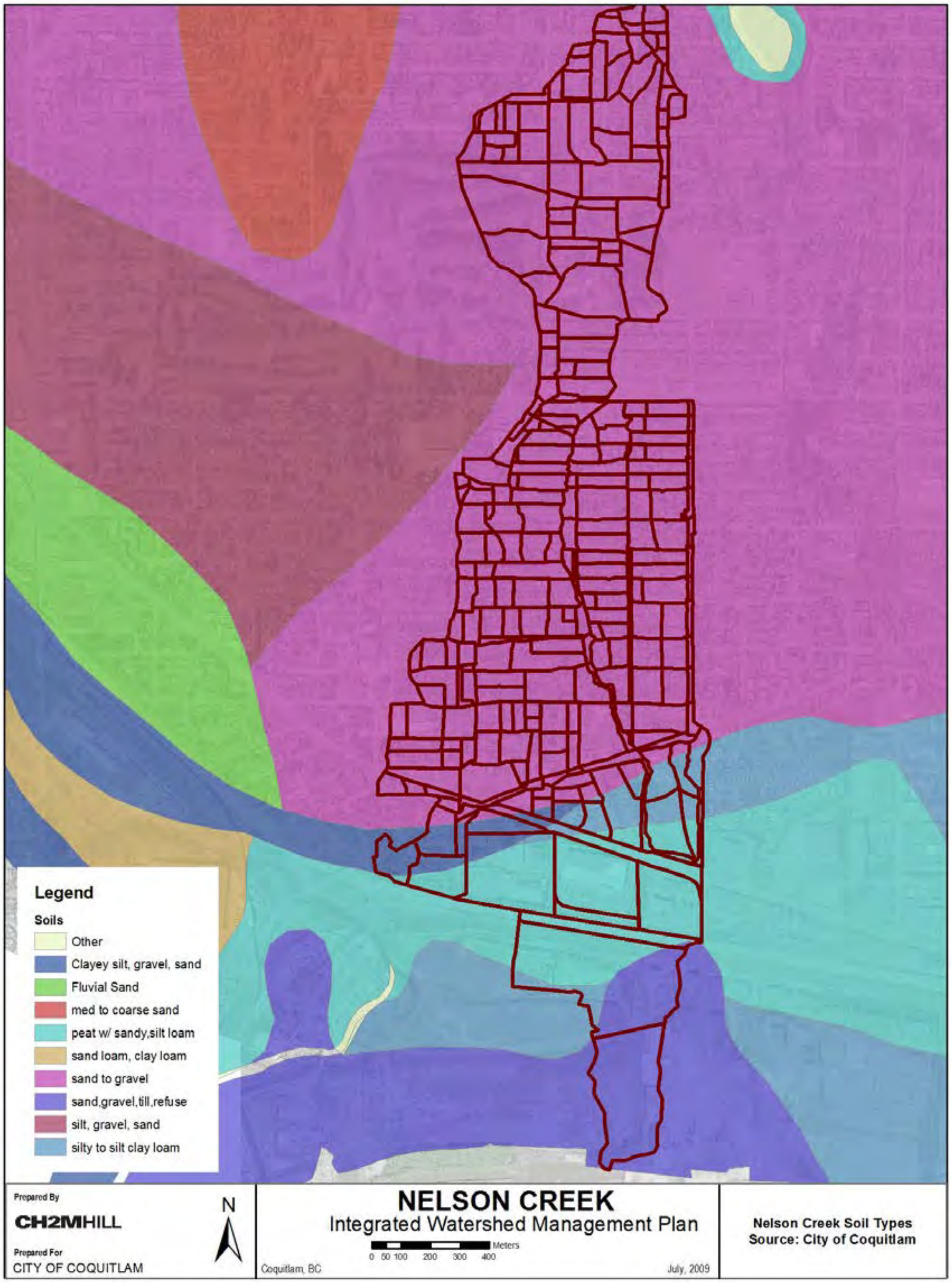
Infiltration Parameters

To calculate the infiltration parameters, the digital BC Soils Data map was intersected with sub-catchments to assign the respective soil texture (Figure 4-5). While the soil data does not provide direct information on the infiltration parameters of the various soils, the classifications do provide sufficient information for initial estimates of infiltration parameters. Initial soil infiltration parameters adopted in the model are provided in Table 4-5.

TABLE 4-5
Soil Infiltration Parameters

Soil Texture Classification	Average Capillary Suction (mm) 1	Saturated Hydraulic Conductivity (mm/hr) 1	Initial Moisture Deficit (Moist Soil) (Va/Vv) 1
Sand to Gravel	49.5	235.6	0.404
Silty to Silt Clay Loam	61.3	59.8	0.382
Clayey Silt Gravel Sand	110.1	21.8	0.358
Peat Sandy Silt Loam	88.9	13.2	0.346
Sand Gravel Till Refuse	166.8	6.8	0.368

FIGURE 4-5
Nelson Creek Watershed and Vicinity Soil Types



Groundwater Parameters

To represent baseflow behaviour, the groundwater routine was activated in the model. Table 4-6 shows the global parameters assigned to all the sub-catchments.

TABLE 4-6
Groundwater Soil Parameters

Parameter Name	Parameter Value
Upper Zone Depth, m	0.5
Lower Zone Depth, m	9.75
Field Capacity	0.32
Wilting Point	0.187
Groundwater Flow Coefficient	0.5
Groundwater Flow Exponent	1.5
Max Depth of Significant Lower Zone Transpiration, m	1
Fraction of Max. ET assigned to upper	1

4.2.2 Hydraulics

Drainage Network

The drainage network was compiled and processed from the GIS geodatabase provided by the City of Coquitlam. The network used in the model is shown in Figure 4-4. Conduit cross sections, dimensions, upstream and downstream elevations; manhole inverts, and ground elevations were determined primarily from the geodatabase provided by the City and complemented with other sources, including contour lines, survey data, and as-built drawings, where available.

Head Losses

Inlet and Outlet Losses

Inlet and outlet losses were included in the model for conveyance elements. Generally, losses were assigned to represent losses at manholes, and at culvert inlet and outlets. Losses were set on an individual element basis and shown in Table 4-7.

TABLE 4-7
Standard Losses for Conveyance Elements

Conduit	Loss Coefficient
Storm drain manhole	0.2
Inlet manhole	1.5
Culvert inlet	0.9
Culvert outlet	0.2

Friction Head Losses

Values for roughness were set using established or previously-reported values. Table 4-8 shows standard roughness values used in the model for different conduit types.

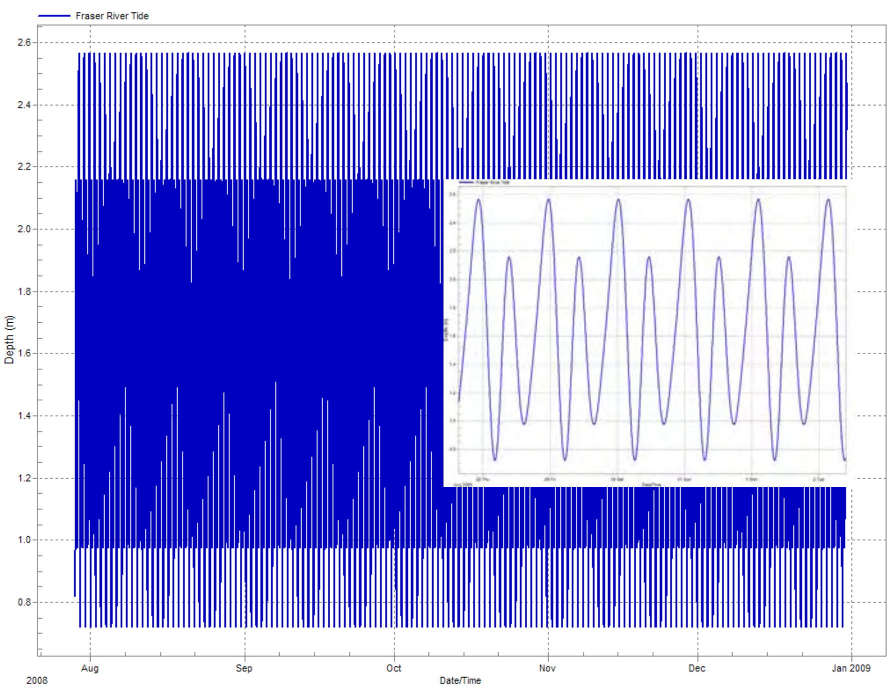
TABLE 4-8
Standard Roughness Values

Element	Manning's Roughness
Natural Channel	0.035
Concrete Pipe	0.014
Concrete Box	0.018
Corrugated Steel Pipe	0.027

Boundary Conditions

A tidal boundary condition was set at the outfall node in the model. Typical summer tidal conditions were used in the XPSWMM model (Figure 4-6) based on the tide data from the Port Mann Pumping Station in the Fraser River (Station code: 08MH126, extracted from http://scitech.pyr.ec.gc.ca/).

FIGURE 4-6
Fraser River Tidal Condition Used in the Model



4.3 Model Calibration

Calibration is the process of adjusting selected model parameters until a reasonable agreement is found between observed and computed values for a defined watershed response function (for example, water depth, flow, and so on). Typically, hydrologic parameters such as infiltration rates, and groundwater flow associated parameters are selected for calibration, although some hydraulic parameters such as the roughness may also be included in the calibration process.

The Nelson Creek watershed model was calibrated considering three objective functions:

a) Peak Flows,

b) Mean Flows, and

c) Total Flow.

From Figure 4-7 to Figure 4-11 the calibration results are shown for various storm events, and a summary of the goodness of fit for each calibration event is shown from Table 4-9 to Table 4-14. During the first storm events monitored in the summer, when baseflows are negligible, the model represents very well the runoff generation, as shown in Figure 4-7. As more events occurred during August, the model represents reasonably well the overall hydrograph, including peak flow, time to peak, and rising limb; however, the models over-estimates the recession limb, computing larger than observed baseflows (Figure 4-8 and Figure 4-9). However, after a relatively dry period in September, the model produced a closer agreement with the observed flows, as shown in Figure 4-10. Interestingly, during the winter season, the model underestimates the baseflows as depicted in Figure 4-11 for the November 6, 2008, storm event. It is noted that the flow pattern is similar between the observed and computed. It is also, noted, how by artificially adding a constant baseflow to the computed flows on this particular winter event, the calibration agreement is noticeably improved. The November 6, 2008, storm event occurred concurrently with one of the ‘Flow Pulses’ described above the monitoring data section. These pulses are not well represented by the model since they seem to be related to late aquifer discharge processes. However, in general, it is considered that the model is appropriately calibrated for the purpose of this project.

4.3.1 Calibration Results

FIGURE 4-7
Summer Calibration Event. July 29, 2008 to July 31, 2008

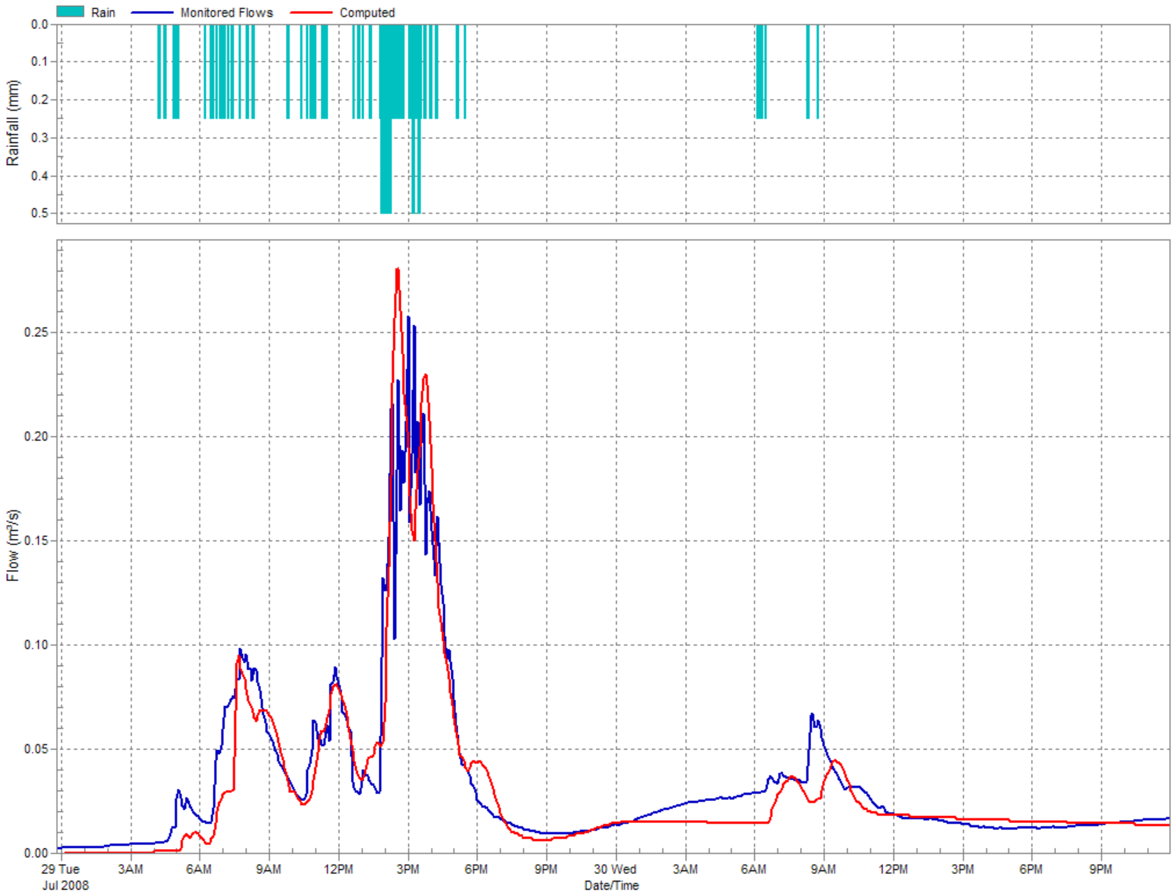


TABLE 4-9
Summary – Summer Calibration Event. July 29, 2008 to July 31, 2008

	Observed Flow	Computed (XPSWMM)	Error
Maximum Flow(m³/s)	0.281	0.258	9%
Mean Flow(m³/s)	0.030	0.033	-7%
Total Flow(m³)	5,272	5,724	-8%

FIGURE 4-8
Summer Calibration Event. August 24, 2008 to August 25, 2008

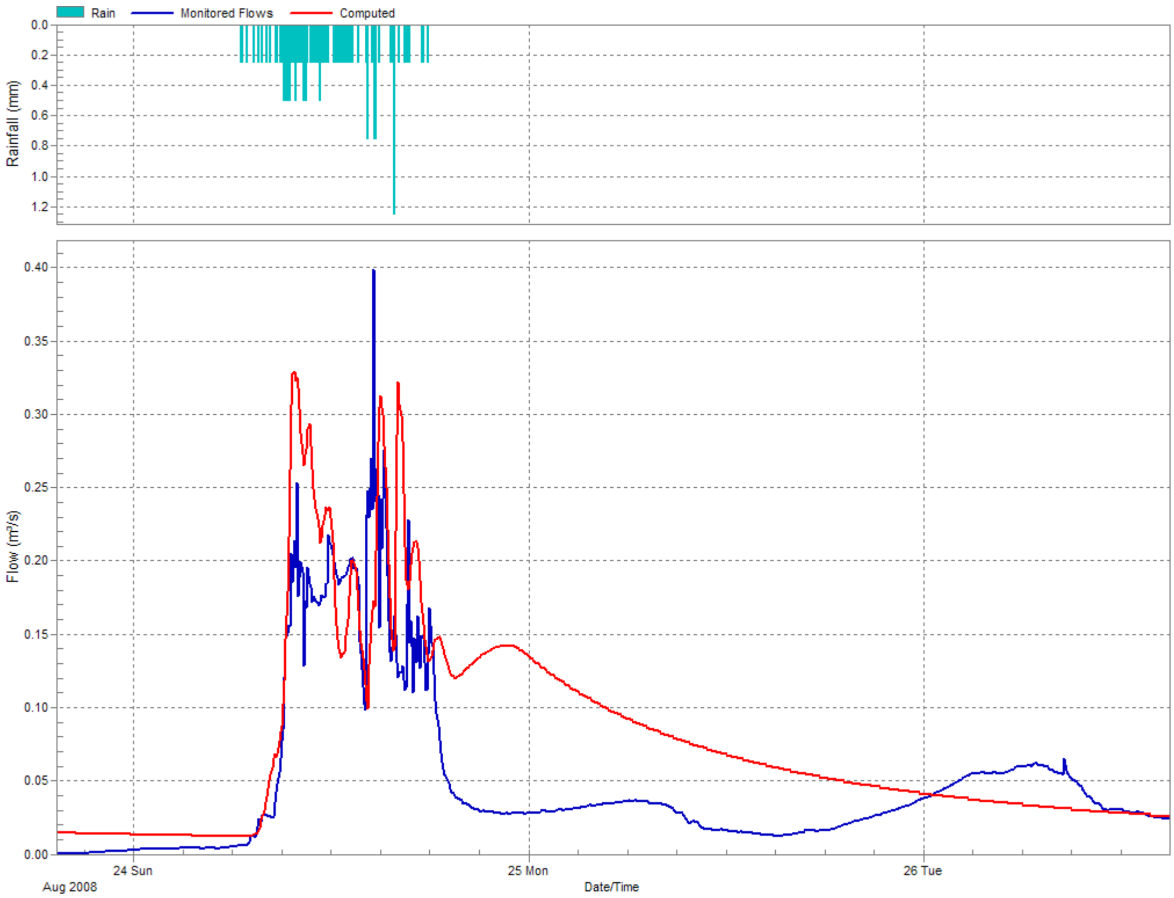


TABLE 4-10
Summary – Summer Calibration Event. August 24, 2008 to August 25, 2008

	Observed Flow	Computed (XPSWMM)	Error
Maximum Flow(m³/s)	0.329	0.399	-18%
Mean Flow(m³/s)	0.077	0.047	62%
Total Flow(m³)	18,710	11,530	62%

FIGURE 4-9
Summer Calibration Event. August 26, 2008 to August 27, 2008

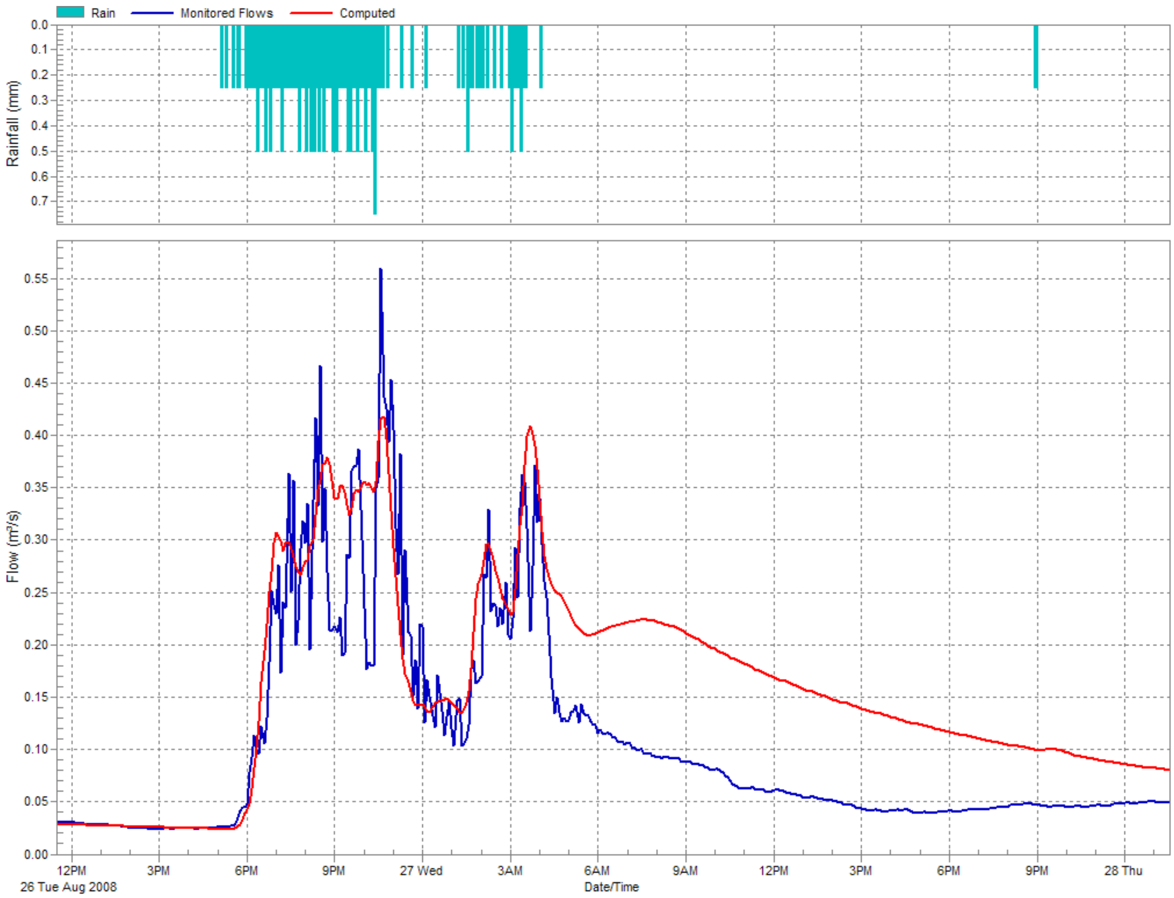


TABLE 4-11
Summary – Summer Calibration Event. August 26, 2008 to August 27, 2008

	Observed Flow	Computed (XPSWMM)	Error
Maximum Flow(m³/s)	0.42	0.56	-25%
Mean Flow(m³/s)	0.15	0.11	50%
Total Flow(m³)	21,790	14,530	50%

FIGURE 4-10
Summer Calibration Event. October 13, 2008

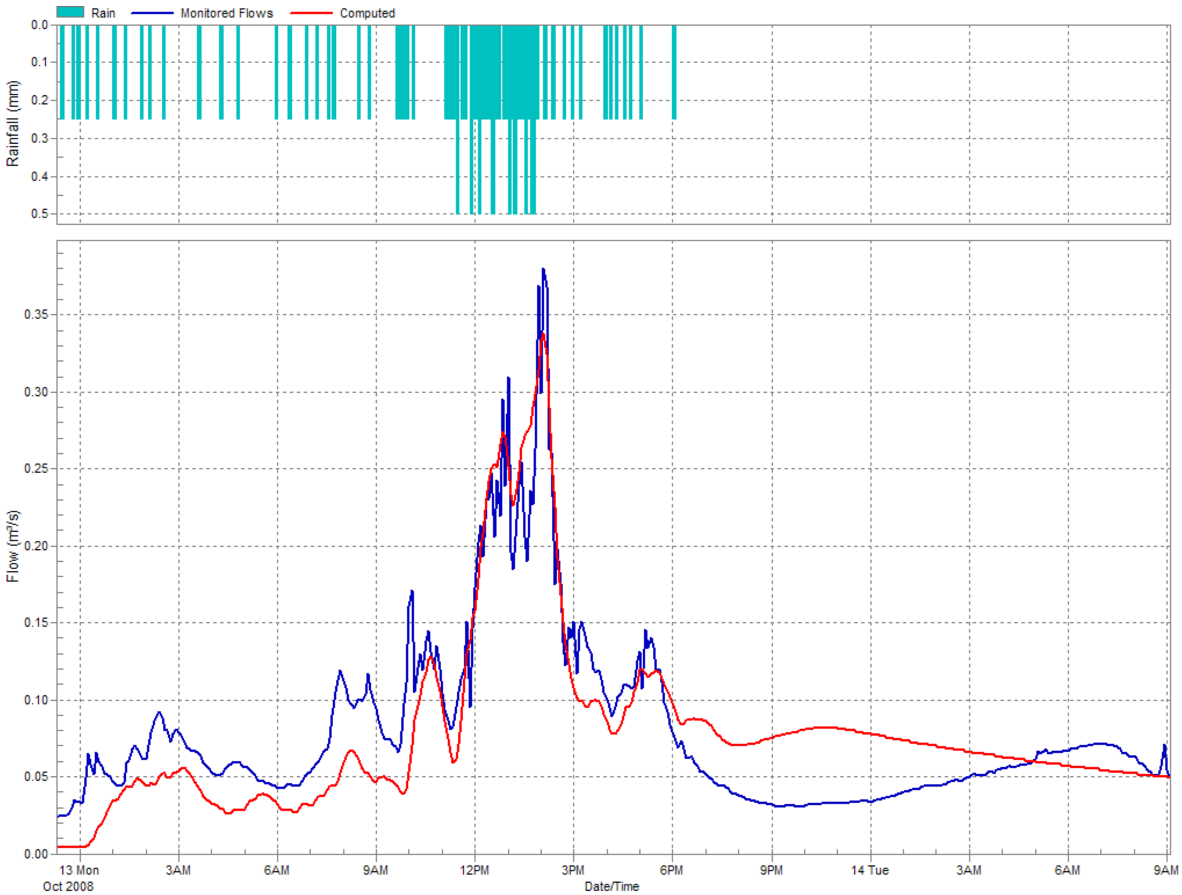


TABLE 4-12
Summary – Summer Calibration Event. October 13, 2008

	Observed Flow	Computed (XPSWMM)	Error
Maximum Flow(m³/s)	0.338	0.38	-11%
Mean Flow(m³/s)	0.078	0.080	-2%
Total Flow(m³)	9,550	9,746	-2%

FIGURE 4-11
Winter Calibration Event. November 6, 2008

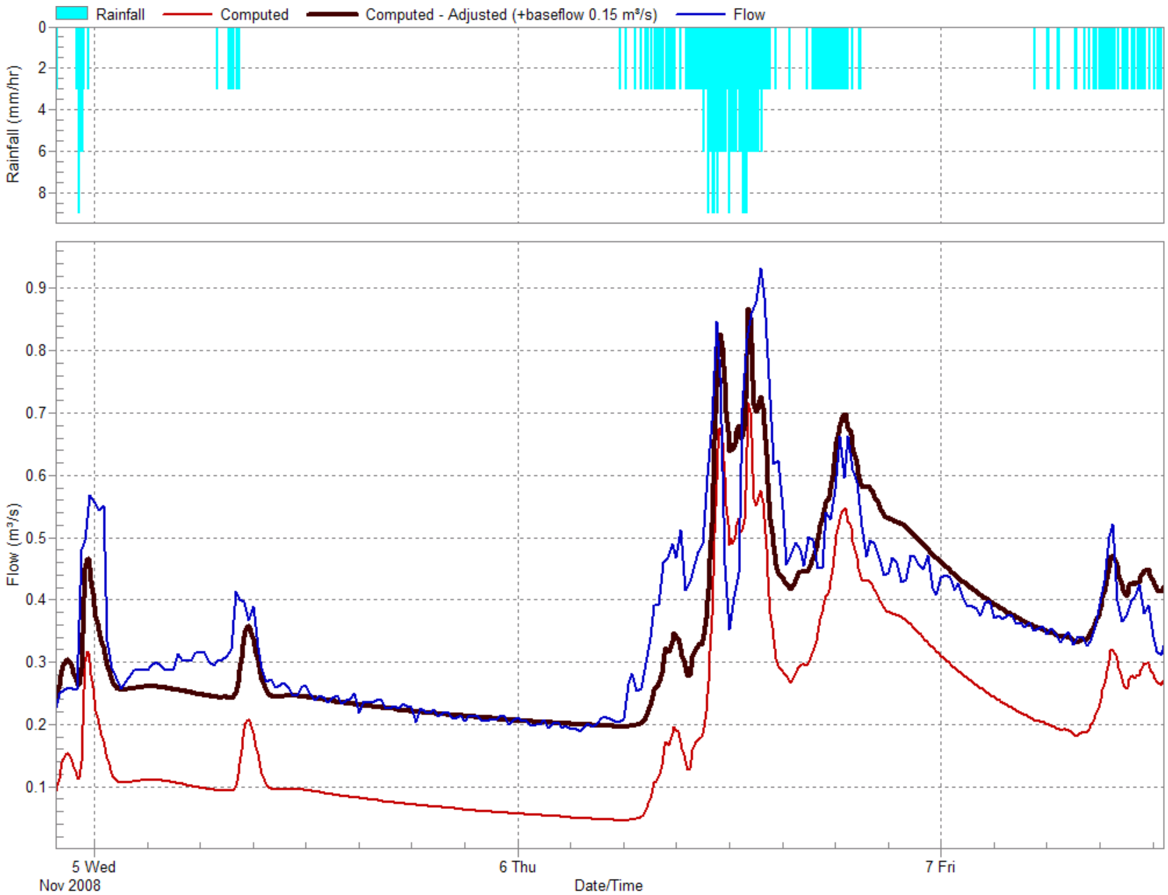


TABLE 4-13
Summary - Winter Calibration Event. November 6, 2008

	Observed Flow	Computed (XPSWMM)	Error
Maximum Flow(m³/s)	0.932	0.717	-23%
Mean Flow(m³/s)	0.357	0.194	-46%
Total Flow(m³)	80,800	43,850	-46%

TABLE 4-14
Adjusted Calibration Summary - Winter Calibration Event. November 6, 2008

	Observed Flow	Computed – Adjusted	Error
Maximum Flow(m³/s)	0.932	0.867	-7%
Mean Flow(m³/s)	0.357	0.344	-4%
Total Flow(m³)	80,800	77,760	-4%

5. Assessment of Drainage System

The hydraulic performance of the Nelson Creek watershed was assessed for existing and future conditions.

The calibrated model was used to simulate existing conditions. The future conditions model is the result of updating the calibrated model to reflect future land use changes including the additional imperviousness resulting from the re-development of the established one- and two-family residential lots into small-scale housing choices (see Figure 2-3: Nelson Creek Future Land Use Planning).

The City's Planning and Developing Department is currently evaluating different alternatives of small-scale housing choices; however, the triplex was selected for modelling purposes. Figure 5-1 shows the site plan layout for the triplex, and Table 5-1 shows the percent of imperviousness for each land use type. The housing choices result in an approximately 15 to 20 percent increase in lot imperviousness.

FIGURE 5-1
Small-Scale Housing Choice (Triplex)

TABLE 5-1
Nelson Creek Watershed % of Imperviousness per Land Use

Land Use Description	% of Imperviousness	
	Existing Conditions	Future Conditions
Low Density Apartment Residential	45	N/A
Civic and Major Institutional	30	30
School	30	30
Medium Density Apartment Residential	65	65
Urban Town housing	80	80
One- and Two-Family Residential	65	65
Housing choices	N/A	80
General Commercial	85	N/A
Neighbourhood Centre	90	90
Service Commercial	85	85
Industrial	85	85
Highway Retail Industrial	85	85
Parks and Recreation	15	15
Other Open Space	15	15
Extensive Recreation	15	15

The models were run using various design storm events to evaluate the hydraulic performance of the storm drainage system and assess culvert performance. In addition, the flooding issues in the lower reaches of the watershed are discussed in a separate section.

5.1 Storm Drainage System Assessment

The procedure to assess the drainage system for the Nelson Creek watershed was:

1. Run the models with four sets of design storms. Each set corresponds to one storm duration, including: 24-hour, 12-hour, 6-hour, and 1-hour; and each duration includes four return frequencies, including: 100-year, 25-year, 10-year, and 2-year. The total volume for each of the design storms is summarized in Table 5-2.

2. Extract the results from the model output file and map the relationship [d/D] using a color coded mapping, where d is the maximum depth of water, and D is the maximum depth of the conduit, or the diameter in the case of circular pipes. The colour green was used to denote pipes with 0<[d/D]<0.8, orange for pipes with 0.8<[d/D]<1, and red for pipes with [d/D]>1.

3. Determine critical duration scenario for the 10-year return frequency from the colour coded map.

4. Determine critical duration scenario for the 25-year return frequency from the colour coded map.
5. Summarize the conveyance capacity of the critical duration based on the following criteria provided by the City:
   - If the HGL rose 1 m or more above the crown of the pipe, the structure was considered "flooded."
   - If the HGL rose above the crown of the pipe but below the "flooded" mark, the structure was considered surcharged.
   - If the HGL did not rise above the crown of the pipe, the structure was considered "sufficient conveyance."

TABLE 5-2
Summary of Design Storm Volumes

	Total Rain Volume (mm)			
	Return Frequency			
Storm Duration	**100-year**	**25-year**	**10-year**	**2-year**
24-h	121	104	91	67
12-h	87	74	65	46
6-h	63	53	46	31
1-h	27	22	19	12

Source: "Stormwater Management Policy and Design Manual" (July, 2003). City of Coquitlam

The results of the hydraulic evaluation for the 10-year, 1-hour storm are presented in the map shown on Figure 5-2 and Figure 5-3 for existing and future conditions, respectively. The hydraulic evaluations for the remaining design storms are shown in Appendix J.

It is observed that the critical condition is produced by the 1-hour design storm for both the 10-year and 25-year return frequencies. The least severe scenario corresponds to the 2-year, 24-hour storm event. It is noted that, consistently for all scenarios, the storm drainage system along Marmont Street, between Brunette Avenue and Madore Avenue, shows to be deficient.

The conveyance capacity criteria was evaluated at the upstream and downstream ends of the pipes and categorized based on the least desirable condition. Results are summarized in Table 5-3.

TABLE 5-3
Summary of Conveyance Capacity Limitation

	Flooding			Surcharge		
Scenario	**No. Pipes**	**Linear Feet**	**Percent**	**No. Pipes**	**Linear Feet**	**Percent**
Existing 10-yr, 1-hr	28	2,104	8.5	62	3,278	13.3
Existing 25-yr, 1-hr	54	3,953	16.0	90	5,397	22.0
Future 10-yr, 1-hr	38	2,877	12.5	64	3,324	14.4
Future 25-yr, 1-hr	66	4,874	21.1	94	5,569	24.1

The hydraulic model predicts that for future conditions, about 30 percent of the Nelson Creek stormwater system is experiencing capacity limitations during the 10-year, 1-hour storm event, and almost 50 percent of the stormwater system is experiencing conveyance limitations during the 25-year, 1-hour design storm.

In the 10-year, 1-hour design storm, 13 percent of the pipes flood and 15 percent surcharge. In the 25-year, 1-hour design storm, 21 percent of the pipes flood and 24 percent surcharge. The details of the pipes with flooding and surcharged conditions are summarized in Appendix J.

FIGURE 5-2
Nelson Creek Hydraulic Performance – 10-year, 1-hour Storm – Existing Conditions

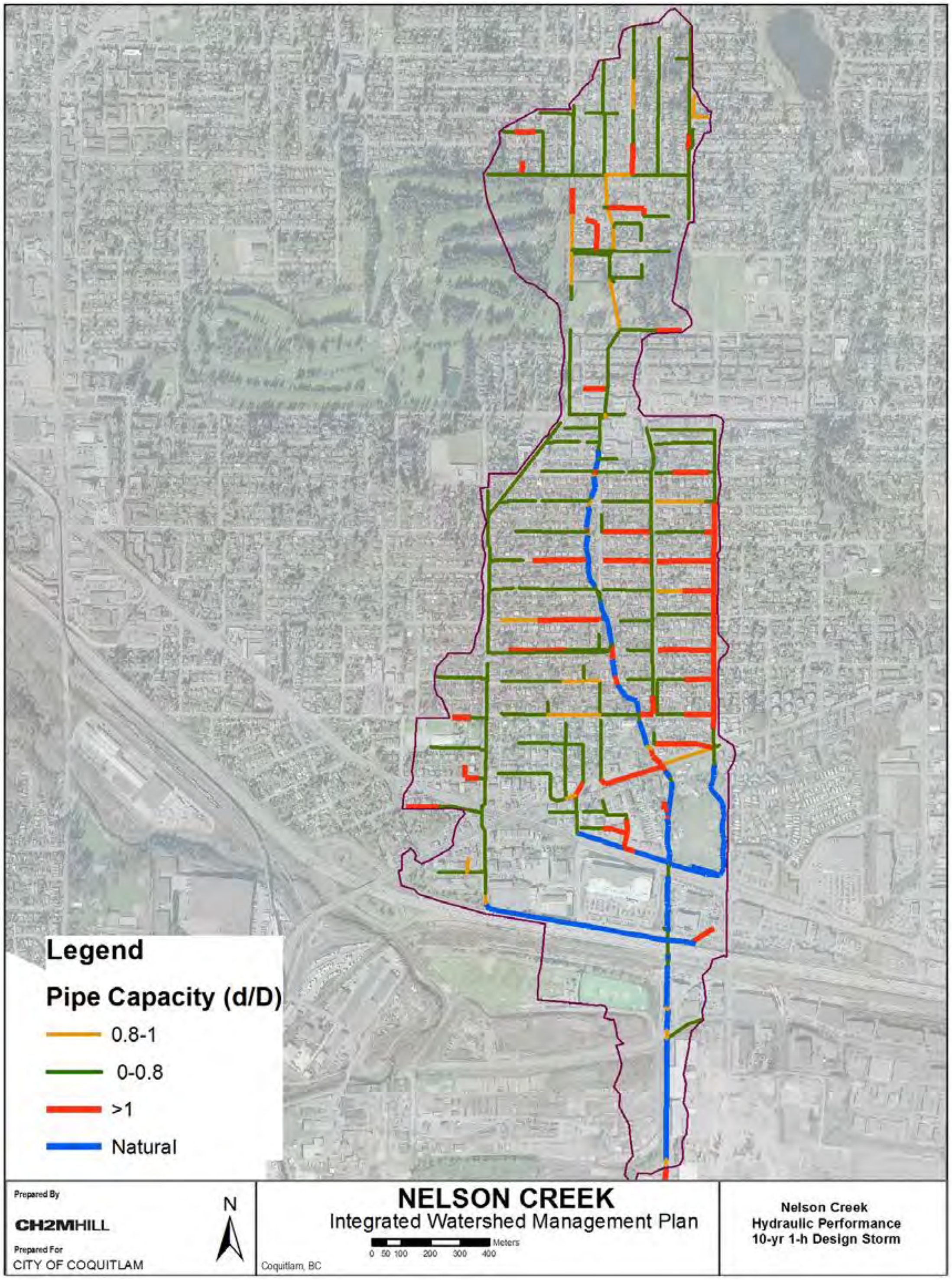
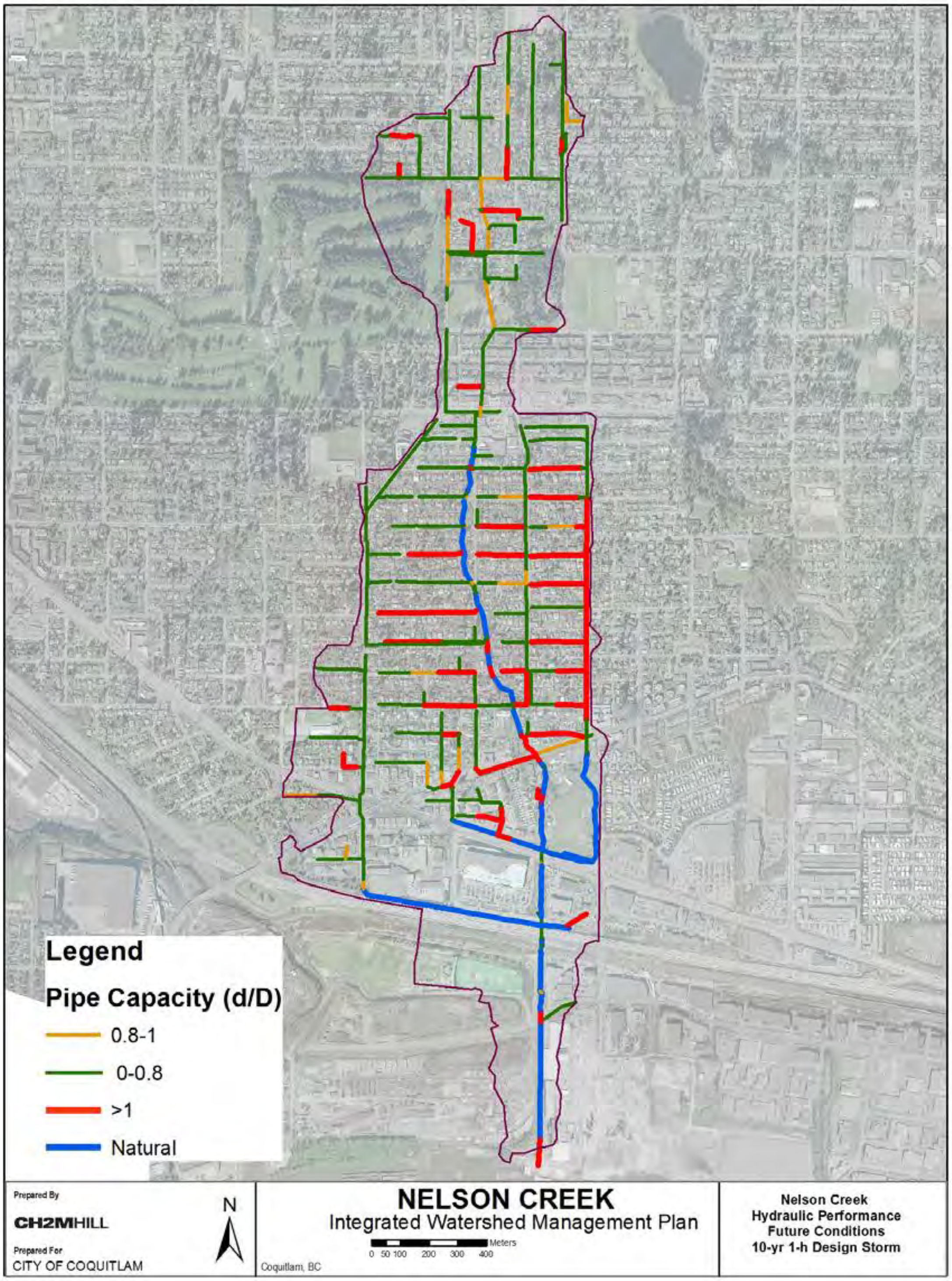


FIGURE 5-3
Nelson Creek Hydraulic Performance – 10-year, 1-hour Storm – Future Conditions



5.2 Culvert Hydraulic Capacity Assessment

Culverts located on Nelson Creek and under roadways were assessed for the 100-year, 1-hour design storm event; results are shown in Table 5-4 and Table 5-5 for existing and future conditions scenario, respectively. Some of the culverts in the lower watershed are affected by the tidal influence of the Fraser River and may show surcharge during high tides. This is a recurrent process, typical of tidally influenced drainage systems, but for regular tide conditions it is not a major concern. A discussion is presented in a separate section regarding flooding issues in the lower watershed.

TABLE 5-4
Culvert Assessment for Existing Conditions (100-year, 1-hour Storm)

Reach	Model Link	Max. Flow (m^3/s)	Max. Velocity (m/s)	Max. WSEL Upstream (m)	Max. WSEL Downstream (m)	Condition
Charland-Dansey	Charland	3.49	5.49	122.78	121.34	Surcharge
Dansey-Madore	Dansey	3.71	5.93	116.39	113.48	Flooding
Madore-Rochester	Madore	3.78	6.00	108.01	104.56	Flooding
Rochester-Walls	Rochester	3.72	6.01	99.71	96.83	Flooding
Walls-Stewart	Stewart	3.83	6.11	80.88	76.60	Sufficient Conveyance
Thomas-Delestre	Delestre	4.75	7.29	61.97	55.22	Flooding
Delestre-Quadling	Quadling	3.83	5.21	54.25	48.66	Flooding
Quadling-Alderson	Alderson	5.33	5.85	35.90	33.03	Sufficient Conveyance
Alderson-Brunette	STPI06788	5.35	3.09	22.52	21.84	Surcharge
Alderson-Brunette	STPI06794	3.77	5.86	21.15	17.31	Flooding
Alderson-Brunette	BrunHw	3.91	3.41	16.59	15.69	Surcharge
Mackin1	Culv2.1	3.91	3.41	11.29	10.43	Sufficient Conveyance
Mackin2	CulvtBox1.	3.80	2.31	5.34	4.91	Surcharge
Brunette-Lougheed	LougHw1	2.48	1.26	2.99	2.98	Surcharge
Brunette-Lougheed	Loughw2	3.23	1.19	2.99	2.98	Surcharge
Woolbridge	WBr1	2.80	0.63	2.89	2.86	Surcharge
Woolbridge	WBr2	2.97	0.63	2.89	2.86	Surcharge
Lougheed-Hw#1	Hw1-Clv	6.61	1.57	2.86	2.57	Sufficient Conveyance
Hw#1-United	UnitBlv1	5.39	1.54	2.57	2.57	Surcharge
Hw#1-United	UnitBlv2	2.44	0.73	2.57	2.57	Surcharge
Tracks US of Barge Loading Area	Woodchamb	6.74	1.93	2.57	2.57	Surcharge
Barge Loading Area	BargeTunn	7.02	1.13	2.57	2.57	Surcharge

WSEL: Water Surface Elevation

TABLE 5-5
Culvert Assessment for Future Conditions (100-year, 1-hour Storm)

Reach	Model Link	Max. Flow (m^3/s)	Max. Velocity (m/s)	Max. WSEL Upstream (m)	Max. WSEL Downstream (m)	Condition
Charland-Dansey	Charland	3.50	5.50	122.79	121.35	Surcharge
Dansey-Madore	Dansey	3.73	5.96	116.41	113.48	Flooding
Madore-Rochester	Madore	3.81	6.04	108.06	104.56	Flooding
Rochester-Walls	Rochester	3.73	6.03	99.73	96.83	Flooding
Walls-Stewart	Stewart	3.85	6.12	80.88	76.60	Sufficient Conveyance
Thomas-Delestre	Delestre	5.07	7.75	62.87	55.22	Flooding
Delestre-Quadling	Quadling	3.85	5.23	54.29	48.66	Flooding
Quadling-Alderson	Alderson	5.36	5.85	35.90	33.03	Sufficient Conveyance
Alderson-Brunette	STPI06788	5.38	3.10	22.54	21.86	Surcharge
Alderson-Brunette	STPI06794	3.79	6.04	21.20	17.33	Flooding
Alderson-Brunette	BrunHw	3.93	3.44	16.60	15.69	Surcharge
Mackin1	Culv2.1	3.93	3.41	11.29	10.43	Sufficient Conveyance
Mackin2	CulvtBox1.	3.80	2.32	5.34	4.91	Surcharge
Brunette-Lougheed	LougHw1	3.07	1.29	3.09	3.08	Surcharge
Brunette-Lougheed	Loughw2	3.73	1.18	3.09	3.08	Surcharge
Woolbridge	WBr1	3.33	0.77	2.99	2.96	Surcharge
Woolbridge	WBr2	3.43	0.72	2.99	2.96	Surcharge
Lougheed-Hw#1	Hw1-Clv	7.90	1.75	2.96	2.57	Sufficient Conveyance
Hw#1-United	UnitBlv1	6.51	1.71	2.57	2.57	Surcharge
Hw#1-United	UnitBlv2	3.26	0.90	2.57	2.57	Surcharge
Tracks US of Barge Loading Area	Woodchamb	7.93	2.09	2.57	2.57	Surcharge

WSEL: Water Surface Elevation

Approximately 30 percent of the in-stream culverts flood and 55 percent surcharge during a 100-year, 1-hour design storm event.

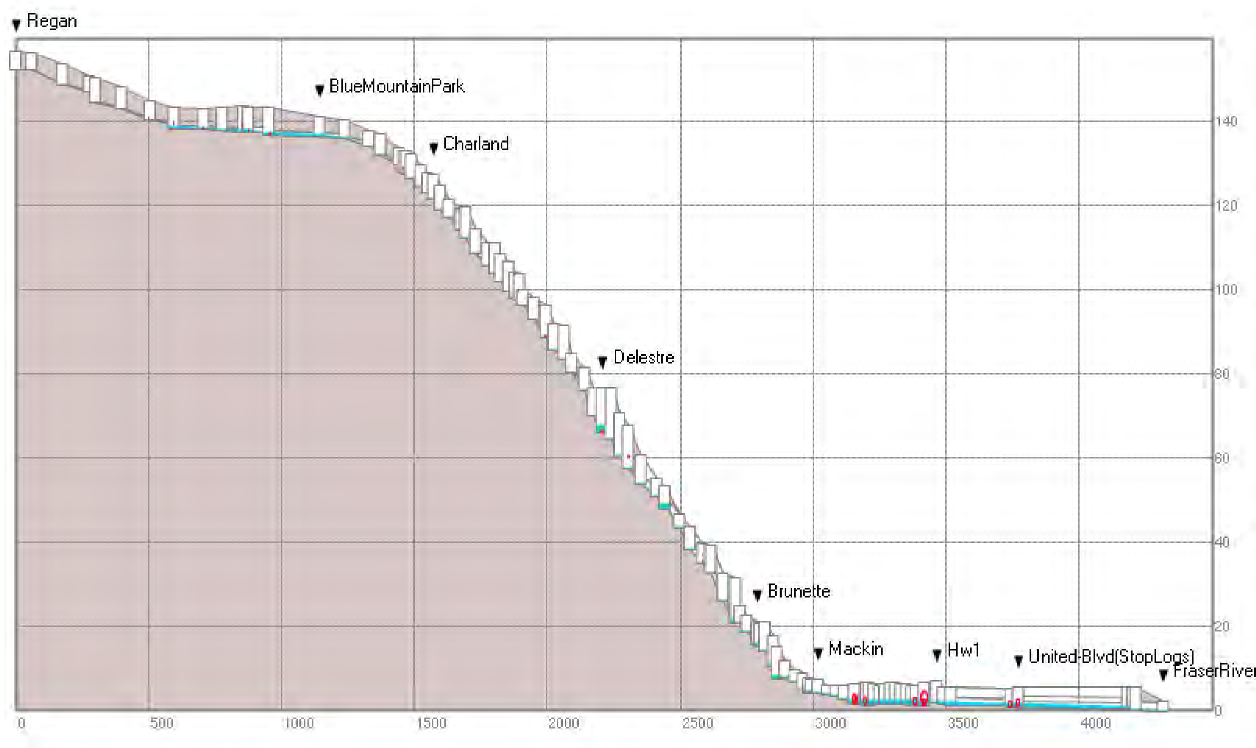
Culverts that constrict and accelerate flow should be equipped with energy dissipaters at the downstream end to reduce erosion as per City’s design guidelines.

6. Flooding Assessment of the Lower Nelson Creek

The lower Nelson Creek, south of Lougheed Highway, is a low-lying area that may be subject to flooding under unusually high Fraser River levels (Figure 6-1 shows a vertical profile of Nelson Creek). The City of Coquitlam is well aware of this condition, and it is prepared with a flood management strategy to deal with such events. High water elevations above 3 m would trigger the City of Coquitlam's Flood Response Plan which is posted on their website (www.coquitlam.ca), and it is also shown in Appendix K.

When a high water condition is expected, the stop logs at the United Blvd. crossing are shut down. If needed, temporary pump stations can be installed to evacuate upstream water. Furthermore, the City is prepared to install sandbags and other temporary dams to prevent the high water from migrating further upstream of United Blvd. However, the 200-year flood condition (4 m water surface elevation) for the Fraser River can potentially create flooding in certain areas, and evacuation might be needed. The City continually monitors the water level conditions, to assess the course of action.

FIGURE 6-1
Nelson Creek Vertical Profile



7. Emergency Response to Spills and Channel Blockages

The water quality studies conducted for the Nelson Creek IWMP focused on ambient water quality for wet and dry periods during base flows in late summer. The studies did not address effects of spills on conditions in Nelson Creek. Environmentally hazardous spills can occur by accident, through negligence or ignorance, or intentionally from diverse actions, such as: a) washing cleaning supplies, paint, or engine oil down a storm drain; b) draining a hot tub onto a road; c) washing cement water (very high pH) from a cement truck onto the road, into the storm drain; d) illegal dumping hazardous materials; and e) poor sediment and erosion control measures at a construction site. Any of these activities can discharge toxic contaminants into the stream via the storm drain system. Although spills can be common in urban areas, they are short-lived and not always documented. Benthic invertebrate community monitoring often provides evidence for such stresses.

The City's procedures for responding to spills are outlined in its Operations Policy and Procedure Manual (2008). The City typically records and responds to spills based on reports from the public about odour, colour, turbidity, or fish kills. Since there are few fish (mainly in Mackin Park), there may not be visible fish kills, and since much of the creek flows through a ravine (upstream) or industrial/commercial areas (downstream of Lougheed Highway and Highway 1), there may be relatively little foot traffic to provide reports on creek conditions.

The City responds to a spill report through a defined procedure, which includes sending staff to investigate, calling the fire department if it is deemed that dangerous materials could be involved, containing and cleanup up the spill, and, in some cases, tracing the spill. Spills on land are blocked from entering the catch basins and watercourses. In the event of substantial spills, additional support is provided by other agencies, the Provincial Emergency Program, Environment Canada, and private contractors. It is recommended that the City expand education and stewardship programs through the IWMP for Nelson Creek and City-wide to raise awareness about what constitutes a spill, how to prevent one, and how to report one. It would also help to have a well-publicized reporting telephone number (during the day and after-hours) on the City website.

The City has an Engineering and Public Works Storm Response Plan (2008) to mitigate hazards and property damage during extreme wet weather (including: culvert blockages, floods, and landslides). The Response Plan includes quarterly review of critical inspection points, additional review prior to onset of extreme wet weather, and inspections and actions during the storm event.

Culverts can be blocked by large, woody debris or sediment within or upstream of it. Many flooding events in lower Nelson Creek (below Lougheed Highway) are related to high rainfall combined with high winter tides, which are associated with small culvert size, although there is also potential for sediment transport to reduce culvert capacity. The Channel Geomorphology assessment (Appendix E) discussed movement of sediment through Nelson Creek and identified some areas of coarse sediment accumulation in the uplands and Mackin Park, and no apparent evidence of substantial sediment accumulation in the lowlands (downstream of Lougheed Highway). The lack of observed sediment accumulation in the lower creek may have been masked by the thick vegetation growth that occurs on both banks and overbank areas. It is also possible that a substantial portion of sediment (likely coarser fractions) is deposited above Lougheed Highway, perhaps at the identified areas near Mackin Park. The report noted that, with continued deposition of this material, decreased channel flow capacity would result in increased flood risk during high flows; as a result, it is recommended that the City inspect the Mackin Park area and downstream culverts periodically (e.g., prior to fall rains) to assess whether culvert and channel capacities have been reduced by sediment/debris accumulations.

8. Watershed Health

Metro Vancouver's (formerly the GVRD) ISMP template provides guidance on preparing watershed health assessments using two physical characteristics: impervious area and percent riparian integrity (Kerr Wood Leidal, 2002 and 2005). Watershed health is then rated and compared to biological assessments obtained from assessments of benthic invertebrate communities (EVS, 2003).

8.1 Total and Effective Impervious Area

Impervious areas (e.g., roads, buildings, parking areas, patios) reduce the amount of surface available for natural infiltration of precipitation. Increases in impervious area result in changes to stream hydrology (higher high flows, lower base flows), which have been correlated to reduced ability of streams to support salmonids and other species.

Impervious area is one of two key factors used in the Metro Vancouver ISMP template to characterize watershed health. The impervious area provides an estimate of the paved and hard surface areas in the watershed and is measured as either TIA or EIA. The TIA calculation is based on the assumption that paved and hard surface areas do not provide any infiltration. EIA accounts for only the impervious area directly connected to a storm drain, and it recognizes the use of BMPs to encourage infiltration.

Percent TIA was assessed for several watersheds by Metro Vancouver using 1996 data and predictions for 2036 to forecast change associated with population growth using the strategies in place at that time. The Metro Vancouver percent TIA assessment for Nelson Creek was 62 for 1996 and 72 for 2036 (GVRD, 1999), as shown in Table 8-1.

TABLE 8-1
Riparian Forest Integrity and Total Impervious Area Calculations for Nelson Creek and its Tributaries

	Metro Vancouver Assessment		
Watershed Health Indicator	**1996**	**2036 (Prediction)**	**2009 Assessment**
Percent RFI	N/A	N/A	16
Percent TIA	62	72	63

Note:

Percent RFI = Percent Riparian Forest Integrity
Percent TIA = Percent Total Impervious Area, estimated to be equivalent to Effective Impervious Area for Nelson Creek Watershed
N/A = Not available

CH2M HILL reassessed the percent TIA for current conditions in Nelson Creek, based on 2008 zoning and land use data, and obtained an estimate of 63 percent, similar to the 1996 calculation of 62. The reassessment was done by dividing the watershed into sub-catchments (SCs). The percent imperviousness of each SC was determined by intersecting the land-use coverage information with the delineated SCs in ArcGIS to calculate the area weighted average value. Then, the overall percent TIA was calculated as the sum of the individual SC area times imperviousness calculations, divided by total watershed area. Values were obtained by multiplying the total amount of land in six land-use categories by estimates of impervious cover associated with each use, using the following assumptions for TIA:

- Open spaces, parks, and other recreational areas are 15 percent impervious
- Schools and civic/major institutional areas are 30 percent impervious
- Low-density Apartment Residential Areas are 45 percent impervious
- Medium-density Apartment Residential areas are 65 percent impervious
- Urban town houses and one- and two-family residential areas are 80 percent impervious
- Commercial and industrial lands are 85 percent impervious

For the Nelson Creek Watershed, EIA and TIA are considered to be equivalent, due to the type and age of development and infrastructure, as it is assumed that all impervious areas connect to storm drains.

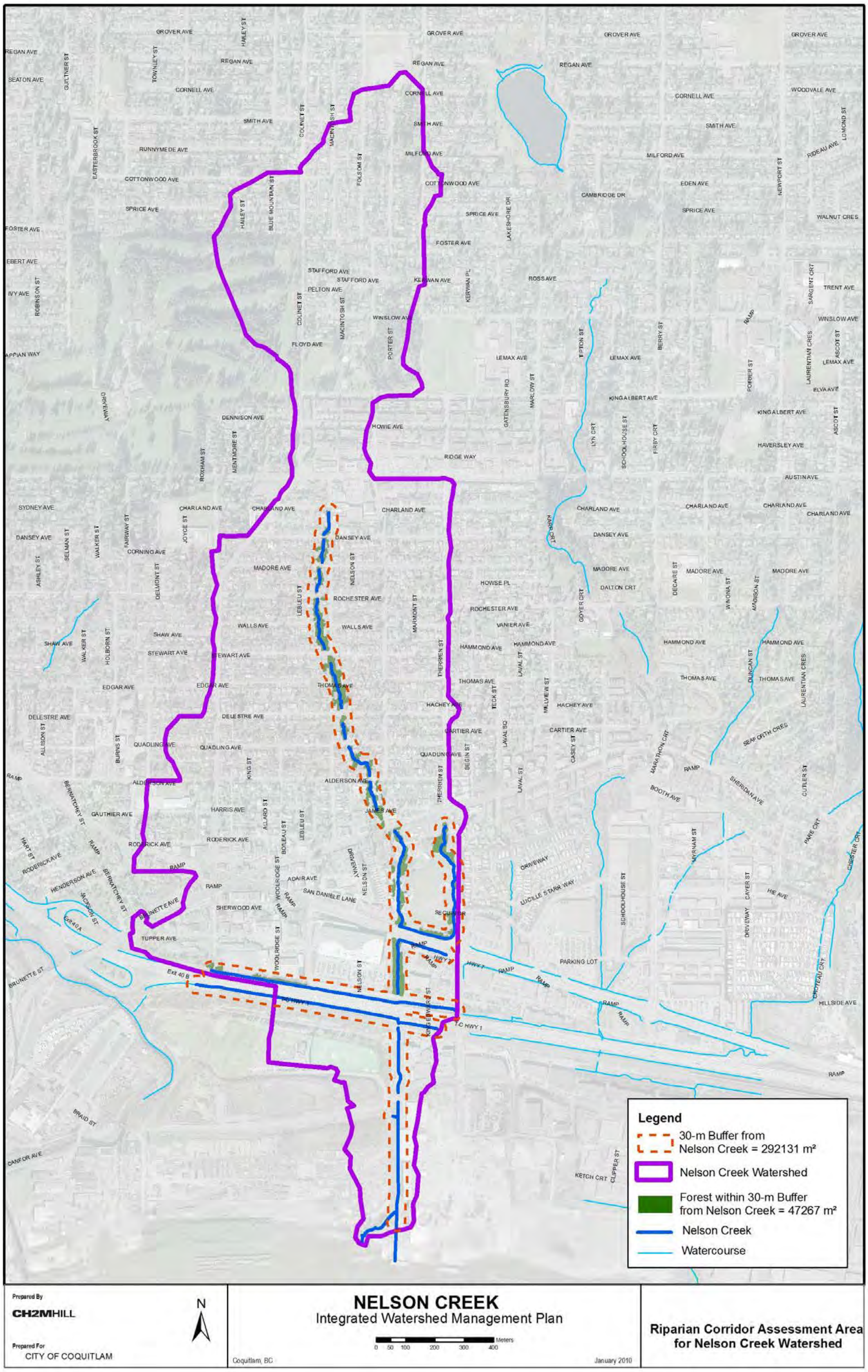
8.2 Riparian Forest Integrity

RFI is the second of two key factors used in the Metro Vancouver ISMP template to characterize watershed health. Natural riparian forest vegetation provides many ecological benefits to stream and watershed health, including: shade, nutrients, bank stability, stable soils that promote infiltration and purification of water, and habitat for many species of birds and wildlife. Property development within the riparian corridor is regulated through the provincial *Fish Protection Act* (Riparian Area Regulations) and/or municipal bylaws and BMPs.

RFI is calculated as the proportion of intact forest cover within the entire riparian corridor and includes culverts and other developed areas (assessed as "zero" percent forest cover). The riparian integrity assessment describes the proportion of riparian corridor (habitat within 30 m of each bank of the stream) that contains natural forest habitat. The riparian assessment corridor is a 30-m buffer on either side of the stream (total width of 60 m). The riparian corridors for Nelson Creek and its tributaries were delineated in Arc GIS, based on available Terrain Resource Information Management (TRIM) data and orthophotos taken in 2006. Buffers were measured from the stream centreline, given that top-of-bank data are not available. In creeks where top-of-bank data are available, the riparian corridor width would be 60 m plus the bankfull width.

The Nelson Creek riparian assessment corridor extends from its confluence with the Fraser River upstream for approximately 2 km to the stormwater outfall near Charland Avenue and also extends along all tributaries and mapped watercourses (ditches) along Highway 1 and the Lougheed Highway. Figure 8-1 shows the riparian corridor used for the assessment.

FIGURE 8-1
Riparian Corridor Assessment Area for Nelson Creek Watershed



The total riparian assessment area is 292,100 m^2, and the total intact riparian area is 47,300 m^2. This results in an estimate of 16 percent RFI, as shown in Table 8-1. There was no comparable estimate of RFI in 1996 (GVRD, 1999). Most of the riparian vegetation occurs along the main channel between Charland Avenue, where the creek daylights, and Highway 1; much of this corridor is private property, although there is also municipal land in Mackin Park. The assessment area also includes 100,300 m^2 of land along the highways (2,300 m^2 of which has riparian forest) and 47,700 m^2 along the main channel south of the highways. If the RFI assessment is done omitting the areas associated with highway watercourses, the percent RFI would increase to 23.

There are a number of causes for low riparian vegetation along Nelson Creek, including:

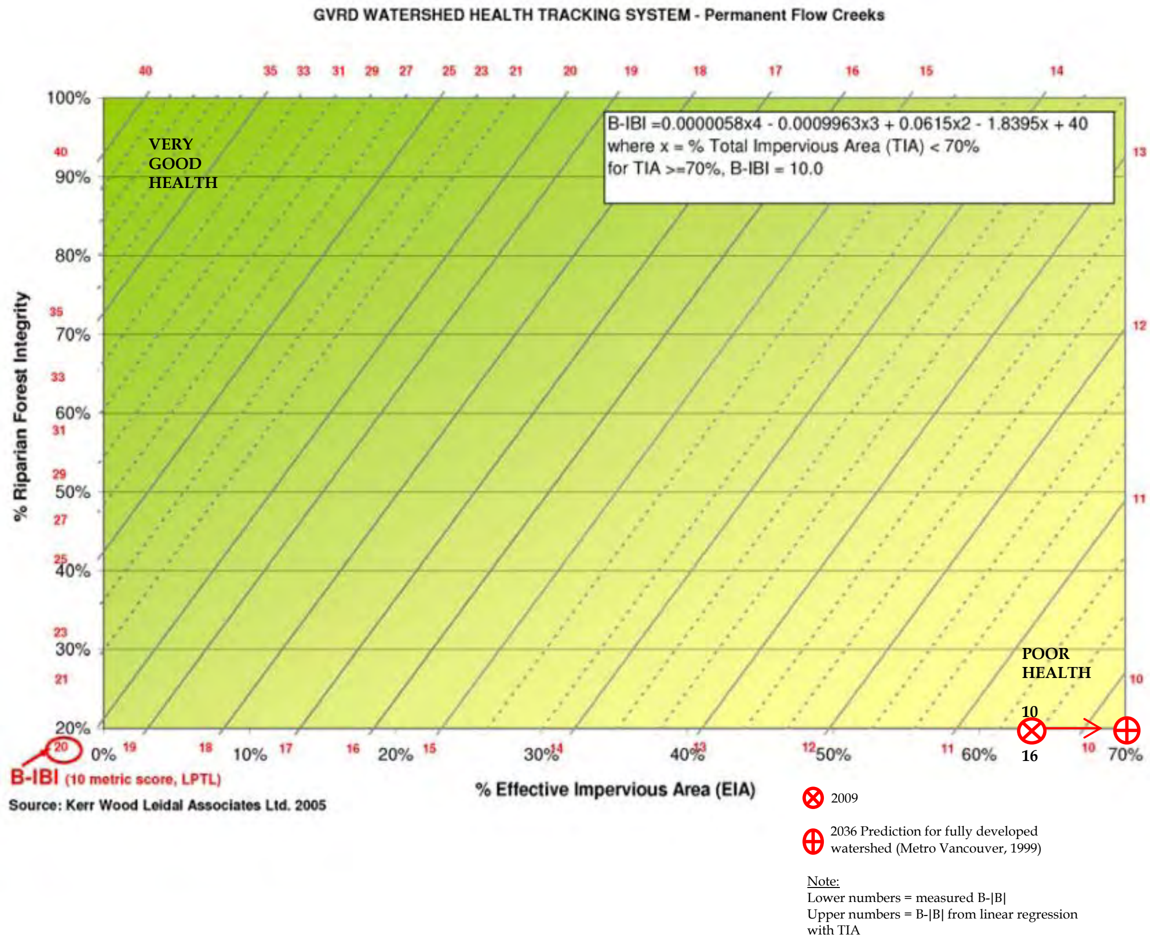
- Loss along the main channel due to urban encroachment on residential land and in Mackin Park
- Lack of vegetation along the watercourses (ditches) beside Highway 1 and the Lougheed Highway due to highway maintenance procedures
- Extensive growth of invasive Himalayan blackberry in the lowland industrial areas along the main channel south of Highway 1

8.3 Watershed Health Assessment

The preliminary watershed health assessment was prepared using TIA and RFI, and follows the Watershed Health Tracking System described in the revised ISMP template (Kerr Wood Leidal, 2005), which was modified from the originally proposed Watershed Classification System. TIA (or EIA) and RFI are considered key physical performance indicators that correlate strongly with watershed health. Values shown in Table 8-1 for existing conditions were overlain on the template chart shown in Figure 8-2.

Nelson Creek is ranked in the lower end of the chart ("poor" health) based on 63 percent TIA and 16 percent RFI under current conditions. These values are expected to move further into the "poor" area as TIA increases with future development, although efforts to increase infiltration of stormwater through use of BMPs and development criteria (as described in Section 9.4 and Appendix M) will offset the increased TIA and create EIA. The percent RFI may decrease over time, given that the provincial Riparian Areas Regulation and City riparian areas policy (Bylaw 3746) allow for stream setbacks ranging from 5 to 30 m, depending on stream classification and assessment approach. This could result in further loss of forest within the 30-m assessment boundary, which would also contribute to a decline in watershed health.

FIGURE 8-2
Nelson Creek Watershed Health Assessment



8.4 Benthic Invertebrate Community

Results of benthic invertebrate community monitoring are used to augment the preliminary watershed health assessment, as recommended by the ISMP template (Kerr Wood Leidal, 2002) and Metro Vancouver Benthic Invertebrate Index of Biotic Integrity (B-IBI) guide (EVS, 2003). Benthic surveys provide a biologically based performance measure of the effectiveness of watershed planning and implementation processes because these organisms experience the ambient conditions and stressors of the watershed (e.g., changes in flow regime and instream habitat and inputs of sediment and toxic substances through storm drains).

The B-IBI values incorporate a variety of environmental and benthic community characteristics (taxon richness and composition, pollution tolerance vs. sensitivity, feeding ecology, population structure) and have been shown to correlate well with TIA and RFI (Kerr Wood Leidal, 2005). Values range from 10 (very poor) to 50 (excellent), although a maximum of 40 has been observed for pristine streams within Metro Vancouver (Kerr Wood Leidal, 2005).

Samples were collected in four locations within Nelson Creek (three in Mackin Park and one upstream of Brunette Avenue) on September 16, 2008, by Rainforest Applied Ecology (see

Appendix L for sampling locations). Sampling methods followed the protocol described in Metro Vancouver's Benthic Macroinvertebrate B-IBI Guide (EVS, 2003). Each sample consisted of three subsamples collected from riffle habitat with a 500-µm mesh Surber sampler. Cobble and large gravel substrates within the sampling area were gently brushed to dislodge surface organisms. Underlying sediment was then disturbed for 2 minutes to a depth of 10 cm using a trowel. All organic detritus, inorganic sediment, and benthic organisms were transferred to plastic jars, fixed in a 10-percent formalin solution, and transferred to an 80-percent ethanol solution for long-term storage and shipping.

B-IBI scores and other results of the 2008 Nelson Creek benthic invertebrate sampling program are listed in Table 8-2. Scores from each site in the survey area were the same (16). Scores of 10 to 16 are considered "very poor," and scores of 18 to 26 are considered "poor" according to the B-IBI system, and indicative of moderate to notable urbanization (EVS, 2003). This result for benthic communities correlates with the prediction of watershed health based on percent RFI and percent TIA.

TABLE 8-2
Results of 2008 Nelson Creek Benthic Invertebrate Sampling Program

Characteristic	C1	C2	C3	C4	Mean and Standard Deviation
B-IBI score	16	16	16	16	16 (SD = 0)
Stream Condition Rating	Very Poor	Very Poor	Very Poor	Very Poor	Very Poor
Taxon Richness	11	12	15	15	13 (SD = 2.1)
EPT Taxon Richness	3	4	6	5	4.5 (SD = 1.3)
Total organisms	**2174**	**1173**	**528**	**1481**	**1339**

Note:

1. SD = standard deviation
Source: Raincoast Applied Ecology, 2009

Five taxa accounted for over 92 percent of the organisms in the samples: the mayfly *Baetis tricaudatus* (37 percent), oligochaete worms (26 percent), amphipod *Crangonyx* (12 percent), midges (Chironomidae) (11 percent), and blackflies (*Simulium spp.*) (5 percent). This community is similar to many urbanized streams in Metro Vancouver, including Como Creek to the east and Byrne Creek in Burnaby to the west (Raincoast Applied Ecology, 2009), and includes some organisms that provide food for fish (e.g., mayflies and midges).

The B-IBI of 16 in Nelson Creek is marginally higher than in Como Creek in Coquitlam (long-term B-IBI mean = 12.6), Byrne Creek in Burnaby (B-IBI mean in 2008 = 14.6), and Still Creek in Vancouver (long-term B-IBI mean = 11.9), all of which are highly urbanized.

The B-IBI value can also be calculated as a regression with TIA, using the formula shown in Figure 8-2. A value of 10 for the B-IBI is calculated using this formula, lower than actually measured in the field sampling program, but in the same range (very poor).

9. Develop and Evaluate Concept Alternatives

9.1 Key Watershed Issues

The following main issues have been identified for the watershed:

- Stream channel erosion and sediment transport
- Poor water quality (i.e., for elevated fecal coliforms, nutrients, some metals)
- Limited conveyance capacity
- Alteration of stream and riparian habitat

This section presents a group of integrated strategies to address watershed management issues.

9.2 Water Balance Approach

9.2.1 Changes to the Hydrology

Major changes to the hydrological function of the Nelson Creek area have been attributed to urbanization of the watershed. At this time, there are no data available for long-term quantitative hydrological assessments of the impacts of urbanization. However, symptomatic assessments of hydrologic functions that have changed in the watershed are associated with land use changes. Specific changes included increased surface runoff, flow alteration, and contaminant concentrations.

Approximately 63 percent of the watershed area is impervious and this is expected to increase to 67 percent based on the land use changes in the Austin Heights and Maillardville neighbourhood plans. Failure to manage stormwater resulting from land use changes will cause additional erosion and water pollution issues in the watershed.

9.2.2 Components of the Integrated Strategy

Achieving long-term restoration of the Nelson Creek Watershed requires a retrofit strategy to restore the water balance of the watershed and thereby reduce erosion issues. The key elements of a retrofit strategy are:

- Flow Volume: Reduce runoff volume to prevent erosion and support base flows
- Flow Rate: Slow down the rate of runoff to prevent erosion and flooding

9.3 Stream Geomorphology Rehabilitation Strategy

9.3.1 Fish Barriers

Nelson Creek has been highly altered by road culverts, channelization, and, above Charland Avenue, burying of the channel. The gradient upstream of Brunette Avenue ranges mainly from 10 to 30 percent, with some areas of 5 percent. Areas of steep gradients provide natural barriers to upstream fish migration, so replacing perched and otherwise impassable culverts (i.e., at Brunette, Alderson, Stewart, Madore, and Quadling Avenues) are a low priority.

Enhancement Opportunities

In 2010, habitat in the Nelson Tributary on the east side of Mackin Park was rehabilitated when the channel was moved to accommodate widening of King Edward Street. The work involved addition of spawning gravel, instream structures (boulders, weirs, artificial cutbanks), and riparian vegetation, which provides valuable fish habitat off the main channel.

Some opportunities for restoring instream habitat include:

- Improving access and habitat for salmon at the confluence with the Fraser River. Nelson Creek currently enters the Fraser through a 150-m-long culvert under a pier that smells strongly of creosote. The stream could be re-routed into the treed corridor to the west of this culvert. There is no evidence of a historic channel in the treed area, but a channel could be excavated and stabilized to provide a naturalized entrance to Nelson Creek, resting habitat for adult and juvenile salmon in the Fraser, and local improvements to water quality.
- Improving the quality of riparian vegetation throughout the watershed (on private and public land).

9.3.2 Erosion Issues

Watercourse erosion is a natural process. It occurs whenever the streamvelocity exceeds a threshold that causes sediment and bed load transport. However, the increase in surface runoff associated with development in the Nelson Creek watershed has dramatically increased erosion in Nelson Creek.

The level of development, and resulting increase in surface runoff, means that a greater proportion of every rainfall event contributes to stream flow in downstream watercourses, which results in greater total flow volume and peak flows.

Short-Term Erosion Control

- Based on a 2008 re-visit to the priority erosion sites identified in 2005, in most cases there was no noticeable change
- While the change was small over a 3-year period, the recommendations for ongoing inspections and remediation work at these sites (Associated Engineering, 2006) remain valid. Repairs have been made at three of six high priority sites.

Long-Term Erosion Control

The proactive approach to erosion control is to eliminate the causes:

- Reduce total volume—eliminate the surface runoff from small, frequently-occurring rainfall events
- Reduce peak flow rates—reduce the rate of runoff from large rainfall events

These become the key objectives of integrated stormwater solutions: 1) retain the small events at the source (onsite rainwater management on all new developments and re-development); and, 2) detain or divert the flow from larger events.

9.4 Rainwater Management Strategy

The high level of land development in the Nelson Creek Watershed has reduced the infiltration capacity volume compared to pre-development conditions and has altered the overall hydrologic processes in the watershed, such as: canopy interception, surface detention, and evapotranspiration.

There is limited space available for runoff detention facilities. The opportunities for managing rainwater during development will be primarily through use of management strategies for infill and redevelopment to higher densities, particularly in the neighbourhood centres.

This section outlines a strategy to take advantage of available opportunities and proposes a design target for future rainwater management – rainwater capture at source.

Rainwater capture at source includes development standards and practices that reduce the impact of land development on the natural environment. The basic principles are to minimize impervious surfaces and to maximize infiltration through hydraulic "disconnects," lengthening water flow paths, dispersing runoff, and providing water storage. This leads to conservation of natural features by reducing the harmful effects of high peak flows and by retaining summer baseflows in creeks. Rainwater capture at source strives to approximate natural storage and infiltration functions to the degree possible.

Rainwater capture at source provides the following benefits:

- Improved hydrological function by capturing runoff from frequently-occurring, small rainfall events, allowing infiltration and a greater chance of retaining summer baseflows in creeks
- Reduction of pollutants loadings reaching watercourses by routing contaminated water through soils and vegetation
- Reduction of erosion of creek banks and resulting negative impacts on riparian and fish habitat by capturing and directing runoff to appropriate locations

9.4.1 Rainfall Target Runoff Control

Targets are important in order to provide consistency in designs across the watershed and also to provide the City with an evaluation metric to assess compliance for development applications. Typically, targets are presented for rainfall capture volume that needs to be controlled, as well as a maximum allowable release rate. Various tiers can be presented, according to the issues that need to be addressed, in the case of developed watersheds, or the issues that need to be prevented, in the case of an undeveloped watershed.

A rainwater management strategy, with tiers of targets, will help address the water quality, stream erosion, fish habitat, storm sewer capacity, and lowland flooding issues identified for the Nelson Creek Watershed. Each tier is designed to address one or more of the identified issues. For instance, water quality issues associated with build-up and wash-off processes are strongly linked to the more frequent, small, rain events that account for most of the yearly precipitation volume. A tier that focuses on control of these small, frequent events will address the water quality issues. Larger events, such as a 2-year rain event, are considered to be responsible for erosion and sedimentation problems. A tier designed to address these events will benefit downstream erosion control. Furthermore, much larger events, responsible for flooding problems, can be addressed through a separate tier. Using a tiered approach allows a more compartmentalized solution to be achieved, one that is able to restore the hydrologic regime to a condition that enables economic development to be harmonized with the receiving ecosystem.

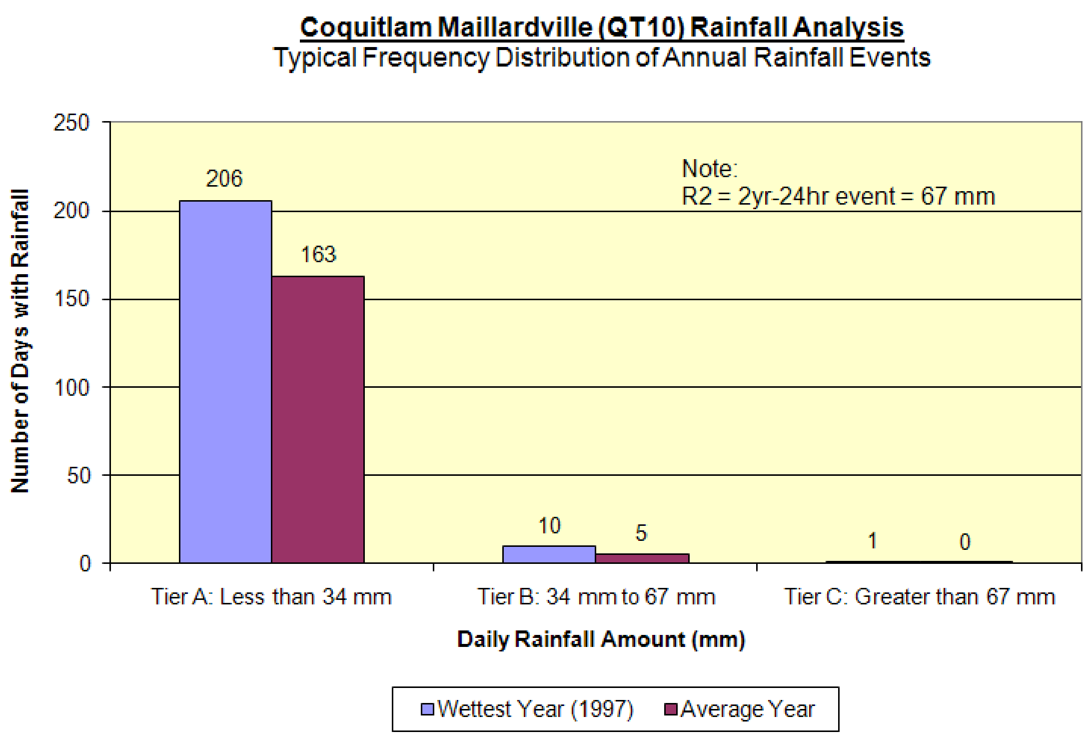
Runoff Volume Target

The design target for rainwater capture at source was defined as half of the 2-year, 24-hour storm event. For the Nelson Creek Watershed, the 2-year storm is 67 mm/day. As such, ***the design target for volume control using onsite rainwater controls in the Nelson Creek Watershed is set as 34 mm in 24 hours***. This is equivalent to providing control for approximately 95 percent of the rainfall events in a year.

Figure 9-1 shows a frequency analysis of rainfall data from the Coquitlam Maillardville station. This figure separates the annual rainfall events into three categories:

- Tier A events: The small rainfall events that are less than half the size of a 2-year storm volume event (equivalent to MAR)
- Tier B events: The larger rainfall events that are greater than half the size of a 2-year storm but do not exceed the 2-year event
- Tier C events: The largest events exceeding the 2-year storm that may occur in a given year

FIGURE 9-1
Frequency Analysis of Rainfall Data from Coquitlam Maillardville Station



The conventional detention–based approach to stormwater management focuses only on managing extreme storms. The water balance approach extends the management focus to include the small frequent events (Tier A).

The rate and volume targets for the Nelson Creek Watershed can be summarized as follows:

Onsite rainwater controls in the Nelson Creek Watershed should be designed to control the first 34 mm in a 24-hour period.

The maximum release rate from the development site should limit the 2-year post-development peak rate of runoff to 50 percent of the 2-year pre-development peak runoff flow.

9.4.2 Rainwater Capture at the Source

Given the previously identified need to control runoff volume, erosion, and water pollution attributed to an increase in impervious area, the use of rainwater management options will be implemented where redevelopment occurs through subdivision and building permit applications.

In the Nelson Creek Watershed, the following are the primary opportunities for implementation of onsite rainwater controls:

- Upgrading, infill, or redevelopment in existing single-family and multi-family neighbourhoods
- The new neighbourhood centres in Maillardville and Austin Heights, both of which will be developed to similar high-densities
- The redeveloped roads in Maillardville and Austin Heights; these are different from standard City roads due to the urban treatment
- New large-format retail development anticipated in the Lougheed Highway/ Schoolhouse Road area

Perhaps the greatest land development change expected in this watershed is the potential for the redevelopment of large, single family lots to add up to four additional units through the Housing Choices option. This change marks a substantial increase in impervious area. Without mitigation, such changes would increase runoff volume, erosion, and water pollution in a watershed already suffering heavily from these impacts.

Hydrologic modelling was undertaken to evaluate the potential effectiveness and feasibility of implemented rainwater control options to capture and store the rainwater volume for a multi-family and single family lot redevelopment. Details of the modelling assessment can be found in Appendix M.

There are a number of onsite rainwater control alternatives available to developers. For instance, they can use infiltration trenches, storage tanks, absorbent landscape, and rain gardens, amongst others, or a combination of alternatives. The modelling showed that it is possible for single family lots redeveloping to Housing Choices to achieve the rainwater targets through a combination of these onsite controls.

Table 9-1 summarizes the onsite source control that can be implemented for each type of development and details are described below:

TABLE 9-1
Rainwater Management Guidelines

Land Use	Proposed Rainwater Source Control Measure
All single-family lots	• A minimum of 300 mm of topsoil in landscaped areas • Hard surfaces graded to landscaped areas • Encourage the use of permeable paving material and rain barrels
Multi-family, commercial, institutional, industrial, housing choices	• All of the above • Onsite infiltration/retention trench, underground storage tank, green roofs, or alternative measures designed to control to 100 percent of the stormwater volume reduction targets in applicable IWMPs
City roadways in urban residential areas	• A minimum of 300 mm of growing medium in landscaped areas • Permeable pavement on parking lanes, rain gardens and infiltration trenches in medians and boulevards

Existing Neighbourhoods

The opportunities and requirements in existing single-family and multi-family neighbourhoods are addressed in Coquitlam's rainwater management guidelines (City of Coquitlam, 2007). The potential onsite rainwater controls include:

- Provide infiltration facilities (e.g., rain gardens, subsurface channels or infiltration chambers, bioswales in parking lots)
- Implement rainwater capture and reuse for irrigation (e.g., rain barrels, cisterns)
- Minimize impervious surfaces (e.g., narrower roads, driveways, and sidewalks; decks instead of patios; permeable, porous paving; underground parking instead of impervious surface parking)
- Provide road-side drainage swales or infiltration trenches instead of storm sewers (these can be underground instead of being visible)
- Disconnect impervious surfaces (e.g., sidewalks and roof leaders drain to pervious landscape and infiltration areas, not storm sewers)
- Provide absorbent landscaping (e.g., 300 mm minimum depth growing medium in all landscape areas including grass, deeper growing medium for shrubs and trees, good-quality growing medium (sufficient organic content and good permeability); increased planting areas; increased surface roughness through grading or planting; increased flow path; sheet flow over landscaped areas; flattened swales; and preservation of existing vegetation)

quality growing medium (sufficient organic content and good permeability); increased planting areas; increased surface roughness through grading or planting; increased flow path; sheet flow over landscaped areas; flattened swales; and preservation of existing vegetation)

Neighbourhood Centre Development

For the Austin Heights Neighbourhood Plan, a Commercial Core Preliminary Preferred Concept has been prepared (HB Lanarc, 2009). For Maillardville, a New Development Concept was prepared and approved by Council (City of Coquitlam, 2010). The City confirmed that the Maillardville plan is intended to have a similar density to the Austin Heights plan. Since building heights and configuration were not available for the Maillardville plan, two different blocks of the Austin Heights plan were graphically modelled in three-dimensions (3D), as shown in Figures 9-2 and 9-3, respectively, in order to illustrate the following proposed onsite rainwater controls:

- **Absorbent Landscape in Courtyards** – Since most of these developments extend to the lot line on all sides, the primary opportunity for absorbent landscape is within the courtyards that are over parking garages, so these landscapes are essentially "green roofs." The growing medium should preferably be a minimum of 300 mm deep on average for optimum rainwater absorption, and the surface should be level with the adjacent paving (not raised planters) to enable capture of drainage from adjacent hard surfaces. The absorbent landscape is assumed to cover 75 percent of the courtyard areas. Paved surfaces in courtyards typically consist of pavers set above the surface. These function like impermeable areas because the water flows quickly down to the membrane and into the storm system. There may be opportunities to place drainage material beneath the pavers to reduce the rate of the flow; weight is a consideration so growing medium may need to be deeper over support columns and shallower in between.
- **Green Roofs** – Some of the tops of the buildings can be developed as green roofs, excluding areas needed for mechanical equipment and access. The growing medium should preferably be a minimum depth of 200 mm for extensive green roofs (not accessible other than to workers). For intensive (accessible) green roofs, the guidelines are the same as for absorbent landscape in courtyards. The green roofs are assumed to cover 50 percent of the roof area.
- **Terrace Roofs** – Terracing of the buildings allows for some planting areas on the terraces, most likely along the outer edges. The growing medium should preferably be a minimum of 300 mm deep, and level with the adjacent surface if possible. The green roofs are assumed to cover 25 percent of the terrace area.
- **Absorbent Landscape at Grade** – Where the facades of the buildings are residential rather than commercial, there may be limited opportunities to provide absorbent at-grade landscape, minimize impervious surfaces, or provide infiltration facilities. There will not likely be enough space at grade for swales or significant infiltration facilities due to the buildings occupying almost all of the lots.
- **Green Walls** – Green walls can absorb runoff and delay peak flows. They consist of a vertical structure that holds growing medium into which plants are placed (see

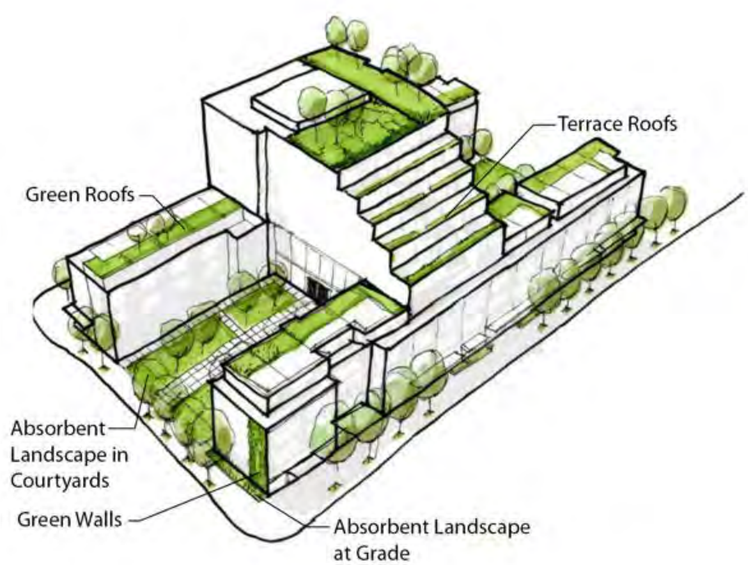
Figure 9-4). Green walls are relatively expensive to build and maintain; however, they have high aesthetic value and can be used as a marketing tool.

- **Storage Tanks** – Storage tanks, likely in or below the parking garages, can be used to store rainwater captured from the roofs, for reuse as irrigation and/or for toilet flushing. Overflows are provided for times when the tanks are full.

FIGURE 9-2
Onsite Rainwater Controls – Scenario 1

Absorbent Landscape in Courtyard
(Source: Peter Harrison)

FIGURE 9-3
Onsite Rainwater Controls – Scenario 2



Terrace Roofs
(Source: NNECAPA)

 374208/WBG012010221725VBC

FIGURE 9-4
Onsite Rainwater Controls – Green Wall

(Source: Flickr.Whisker)

Large-format Retail

The City anticipates some new, large-format retail development in the Lougheed Highway/ Schoolhouse Road area. This presents an opportunity to incorporate the rainwater management methods, as follows (see Figure 9-5):

- **Green Roofs** – Some of the tops of the building(s) can be developed as green roofs, excluding areas needed for mechanical equipment and access. It is unlikely that the growing medium could be more than 75 mm deep in this application due to the large spans below, lack of maintenance, and economical type of construction. Extensive green roofs with shallow growing medium like this cannot absorb all of the target rainfall event, but they have been shown to delay peak flows. The green roofs are assumed to cover 80 percent of the roof area, which may be optimistic.
- **Rain Gardens** – There are opportunities for rain gardens in the wider boulevards near the parking lot. Curbs will need openings into the rain gardens, which should have a minimum 450 mm depth of good quality growing medium over a minimum 300 mm depth of drain rock, with an overflow pipe to the storm sewer system.
- **Bioswales** – These are buried infiltration trenches with vegetation (grass, or low shrubs or herbaceous plants) on the surface. They are similar to rain gardens, but they also can convey water. In the example in Figure 9-5, bioswales are shown between every alternate double-loaded row of parking. Curbs will need openings into the bioswales,

which should have a minimum 300 mm depth of good quality growing medium over a minimum 600 mm depth of drain rock, with a perforated pipe within the trench and an overflow connection to the storm sewer system.

- **Absorbent Landscape at Grade** – There may be opportunities for absorbent at-grade landscape, to minimize impervious surfaces, or to provide infiltration facilities around the perimeter of the site.

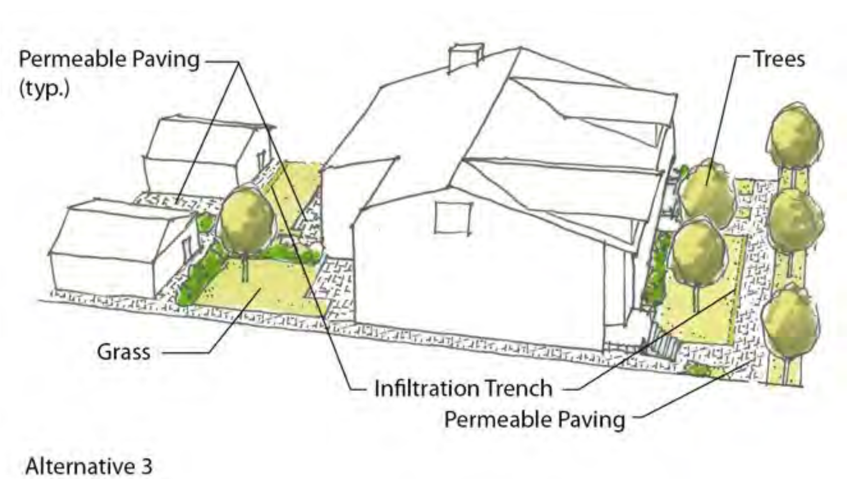
FIGURE 9-5
Large-format Retail Onsite Rainwater Controls

Green Roof
(Source: Jeff McNeil)

Housing Choices

The single family lots will re-develop to duplex and triplex lots. Using conventional construction methods and material will result in an increase of impervious surface, hence, additional runoff which goes to the storm system. Figure 9-6 is an example of how rainwater management can be implemented to mitigate impacts of re-development and capture the target of 34 mm of rainfall in 24 hour period.

FIGURE 9-6
Housing Choices Onsite Rainwater Controls

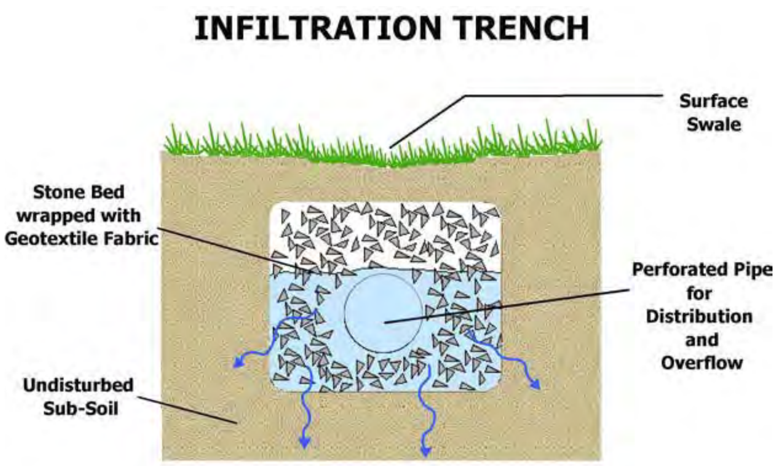


Permeable Paving
(Source: djprybyl [Kathryn])

The roads within the housing choices area also have opportunities to improve infiltration (see Figure 9-7). The primary opportunities include:

- **Absorbent Landscape** – This would likely be grass boulevards over a minimum depth of 300 mm growing medium.
- **Swale and Infiltration Trench** – This would involve a buried infiltration trench under a grass swale. Perforated pipe may be included within the trench with outlets to the storm system.
- **Trees** – Trees planted in the boulevards with a minimum depth of 450 mm growing medium will help to manage rainwater. The volume of growing medium per tree should follow best management practices in relation to the ultimate tree size (see Figure 9-8).

FIGURE 9-7
Roads in Housing Choices Area Onsite Rainwater Controls



Roadside Infiltration

FIGURE 9-8
Soil Volume Required for Trees (Urban, 2002)

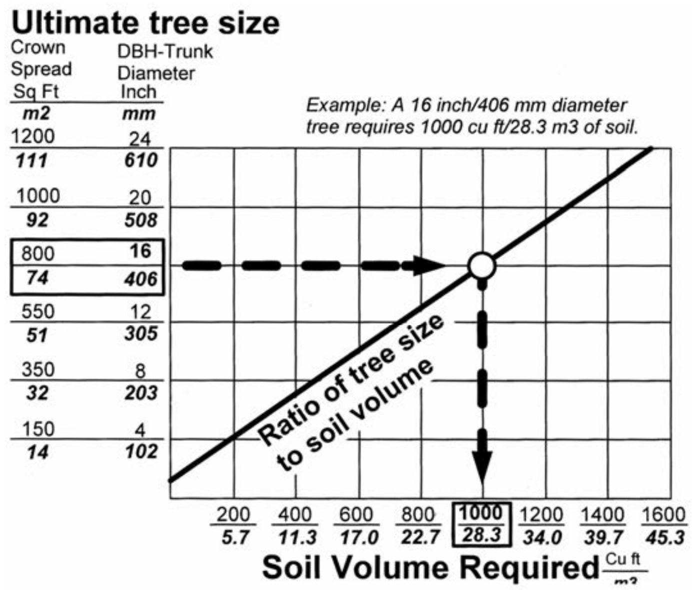


Figure 1 Soil volume and ultimate tree size relationships

(Source: James Urban)

Neighbourhood Centre Roads

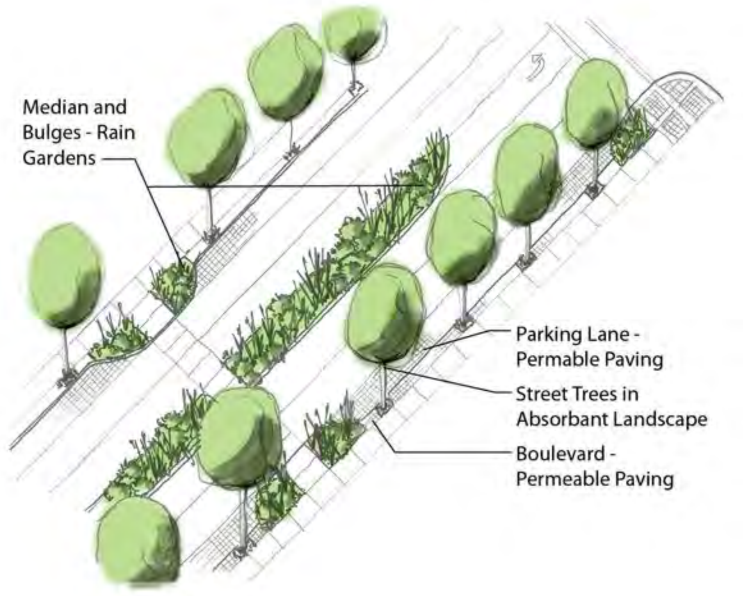
The proposed roads in Austin Heights and Maillardville are very urban, consisting of wide pedestrian-oriented sidewalks, one driving lane and one parking lane on each side of the road, and left-turn lanes alternating with a centre median. Bulges are located in line with the parking lanes at corners and at cross-walks.

Figure 9-9 shows the following opportunities for rainwater management:

- **Permeable Paving** – This can be used in the parking lanes and along the boulevards. Permeable paving is placed over a reservoir base course, minimum depth 300 mm, to ensure that rainfall landing on surface paving is stored underground and allowed to soak into underlying soils. In the boulevards, a continuous permeable trench can be used under the permeable paving to help support the growth of the street trees. Structural soil (a blend of load-bearing, angular stone and growing medium) a minimum of 600-mm deep should be used in this trench between planting pits and under the road and/or the sidewalk sufficient to support tree growth.
- **Absorbent Landscape** – Absorbent landscape (e.g., ground cover, or low shrubs or herbaceous plants) over a minimum 600 mm depth of growing medium can be planted adjacent to trees. These areas are only 1 by 2 m in dimension in the example due to the urban context. Absorbent landscape areas should be as large as possible, and can likely be larger in residential and lower density areas.
- **Rain Gardens** – There are opportunities for rain gardens in the medians and bulges (see description in Large-format Retail). Curbs will need openings into the rain gardens.

There is no space available for roadside swales in these urban areas.

FIGURE 9-9
Austin Road Onsite Rainwater Controls



Rain Garden

9.4.3 Design Recommendations

Stormwater and rainwater issues need to be addressed in a manner that is consistent with the City's *Stormwater and Rainwater Management Policy and Design Manual (City of Coquitlam, 2007)* and *Rainwater Management-Source Control (City of Coquitlam, 2009)*. Furthermore, the following items should be considered for development applications within the Nelson Creek watershed:

- The design of the onsite detention and infiltration facilities should be based on the size of the TIA of the development lot. TIAs are defined as fully impervious areas with direct hydraulic connection to the storm drainage system of the site; fully impervious areas include building roofs and impermeable pavements. Fully pervious areas are those with a permeable soil structure that is capable of absorbing the rainfall of a 5-year return period without surface runoff.
- Storage facilities should be designed to capture the design rainfall (for example, 340 m^3/ha EIA).
- Soil investigations need to confirm that sufficient permeable soil body is located around the facility to ensure dispersal of infiltrated water.
- An overflow structure should be provided to convey rainwater to the City's storm drainage system when the amount originating from the site exceeds the capacity of the onsite.
- Lot overflows should be fully received by the City's storm drainage system without exceeding its conveyance capacity up to the 10-year storm event. This should include storm drain flows from areas upstream of the development lot.
- Source controls are not designed to replace drainage infrastructure used for minor and major runoff flows. They must also be designed with adequate overflows to pass extreme events.

9.5 Detention or Diversion Strategy

Development or re-development in the Nelson Creek Watershed will lead to changes in the hydrologic regime, if it is not mitigated. Peak flows will increase as results of an increase in impervious area. Larger and more frequent peak flows will increase the rate of erosion at the sites already identified within the watershed.

Two stormwater routing alternatives were identified and considered to reduce runoff volume and peak flows. Alternative 1 consists of two community storage units, sized to capture and control the 2-year, 24-hour event. Alternative 2 employs a diversion scheme to direct the runoff from larger storm events out of the upper watershed into the lower watershed, south of Lougheed Highway.

These alternatives can be adapted to employ onsite rainwater management to capture and control the small frequent events (Tier A events).

Use of onsite source controls would not affect sizing of a diversion pipe, as this is determined by the size of the major storm events, but could reduce the required size of the community storage units.

9.5.1 Alternative 1 – Community Storage

Providing community storage facilities for SCs of the Nelson Creek can help improve water quality in the watershed and reduce peak runoff rates (i.e., provide rainfall capture), which reduces the risk of downstream flooding by:

- Reducing downstream peak flows
- Partially controlling erosion and reducing downstream bedload deposition

The City of Coquitlam provided CH2M HILL with the location of proposed sites for active park land acquisition. These sites are potentially suitable for community storage; however, it is questionable whether the benefits of providing community storage at these locations would justify the cost.

Figure 9-10 shows the two sites and tributary areas based on the existing stormwater layout. Table 9-2 summarizes the available area for the two sites, the total tributary area, percent imperviousness, and storage volume that would be needed to detain the runoff resulting from a 2-year, 24-hour event (Tier B events). It is not possible to capture storms higher than the Tier B due to site constraints.

If the storage target was selected based on a single rainfall event, then the release rate would be subtracted from the 2-year, 24-hour inflow to reduce the storage volume. However, evaluation of continuous rainfall patterns shows that the large rainfall event often follows extended wet periods, and therefore, it is likely that a portion of the storage capacity will be used up when another rainfall event occurs. Retaining the larger storage criteria (i.e., excluding the release rate) builds redundancy into the storage function to account for this.

TABLE 9-2
Storage Volume Required

Site ID	Available Area (ha)	Tributary Area (ha)	Percent Impervious	Storage Volume (m^3)	Minimum Depth of Community Storage (m)	Construction Cost ($ million)
A	0.60	63.62	52	29,820	5	15
B	1.20	15.7	80	8,347	0.7	5

Evaluation of Community Storage Sites

Site A

A storage facility at this site will be able to control the runoff from all storm events up to and including the 2-year, 24-hour event (Tier B). Events larger than the 2-year return period would be routed to the creek via overflows in the community storage.

This storage facility will control the runoff from the area north of Charland Avenue, which is equivalent to about 30 percent of the Nelson Creek watershed. It will also assist with partial erosion control because it is located upstream of the eroded section of Nelson Creek.

As an indication of the effectiveness of the proposed alternative, we plotted the hydrograph of a natural watercourse for the 2-year, 24-hour event (See Figure 9-11). Note that peak flow for the post-development conditions with community storage is equal to 50 percent of the peak flow for pre-development conditions. The maximum assumed velocity threshold for the natural water course is 1.5 m/s (source: Stormwater and Rainwater Management Policy and Design Manual, City of Coquitlam).

Even though community storage units can limit peak runoff flows during storms, they tend to release moderate flow rates for sustained periods after the storm until the community storage is empty as shown in Figure 9-11.

Figure 9-12 shows that for the 100-year, 24-hour event; the peak flow is not reduced. This is associated with the overflow routed to the creek due to limited capacity of storage A.

Because re-development north of Charland Avenue is limited to certain areas of the Austin Heights Neighbourhood, the community storage sizing would not be significantly reduced by application of onsite source controls.

However, onsite source controls would be needed, as well as the community storage, to try to replicate the hydrological characteristics of the watershed. Significant summer baseflow augmentation would not be provided consistently by community storage.

Site B

A storage facility at this site will be able to control the runoff from all storm events up to and including the 2-year, 24-hour event (Tier B). Events larger than the 2-year return period would be routed to the creek via overflows in the community storage.

This storage facility will control the runoff from about 7 percent of the watershed area. Similarly to Site A, this community storage unit would reduce peak flows and assist with partial erosion control in Nelson Creek. Retrofitting this area with onsite source control would likely reduce the size of the community storage.

FIGURE 9-10
Alternative 1 – Community Storage

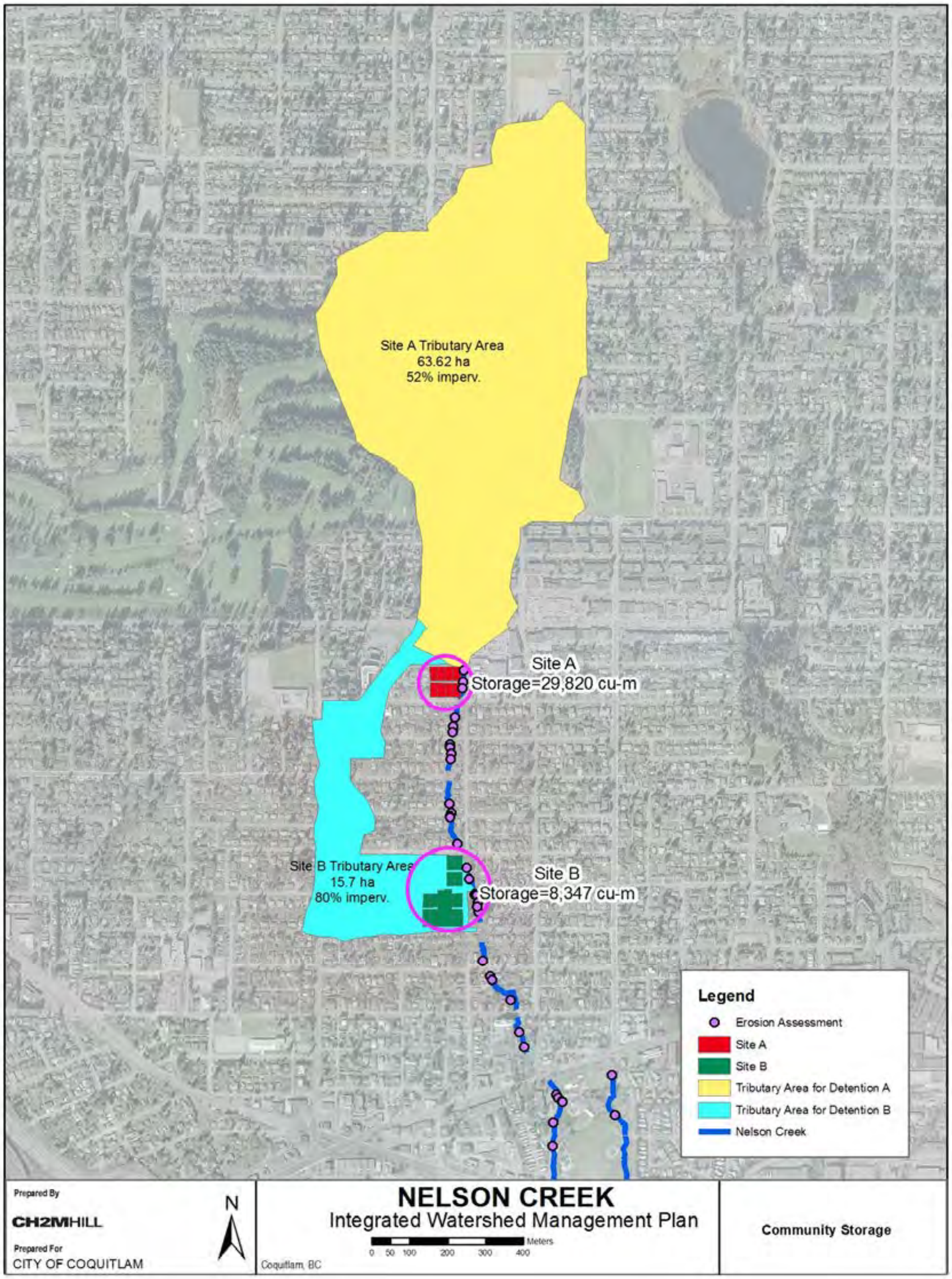
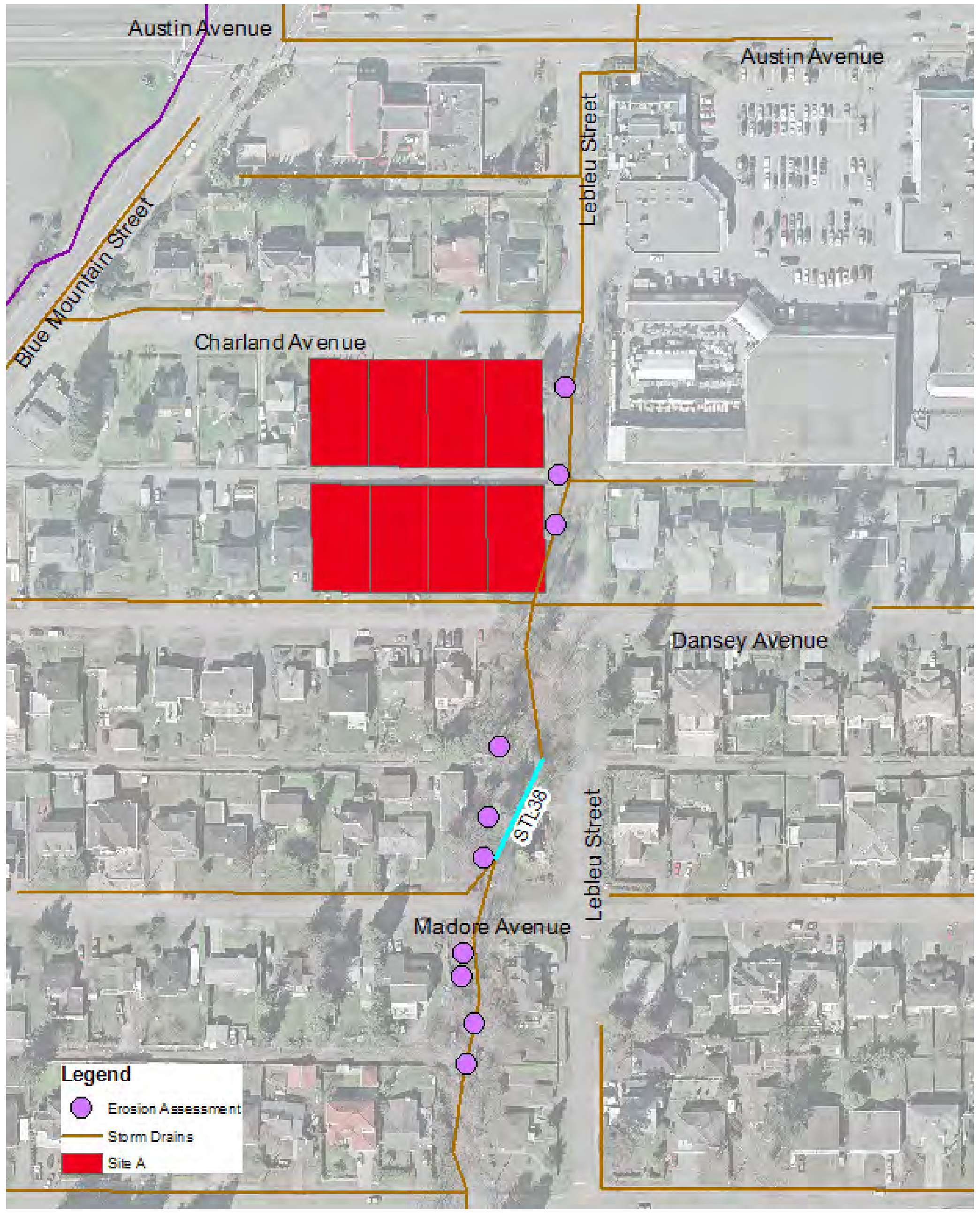
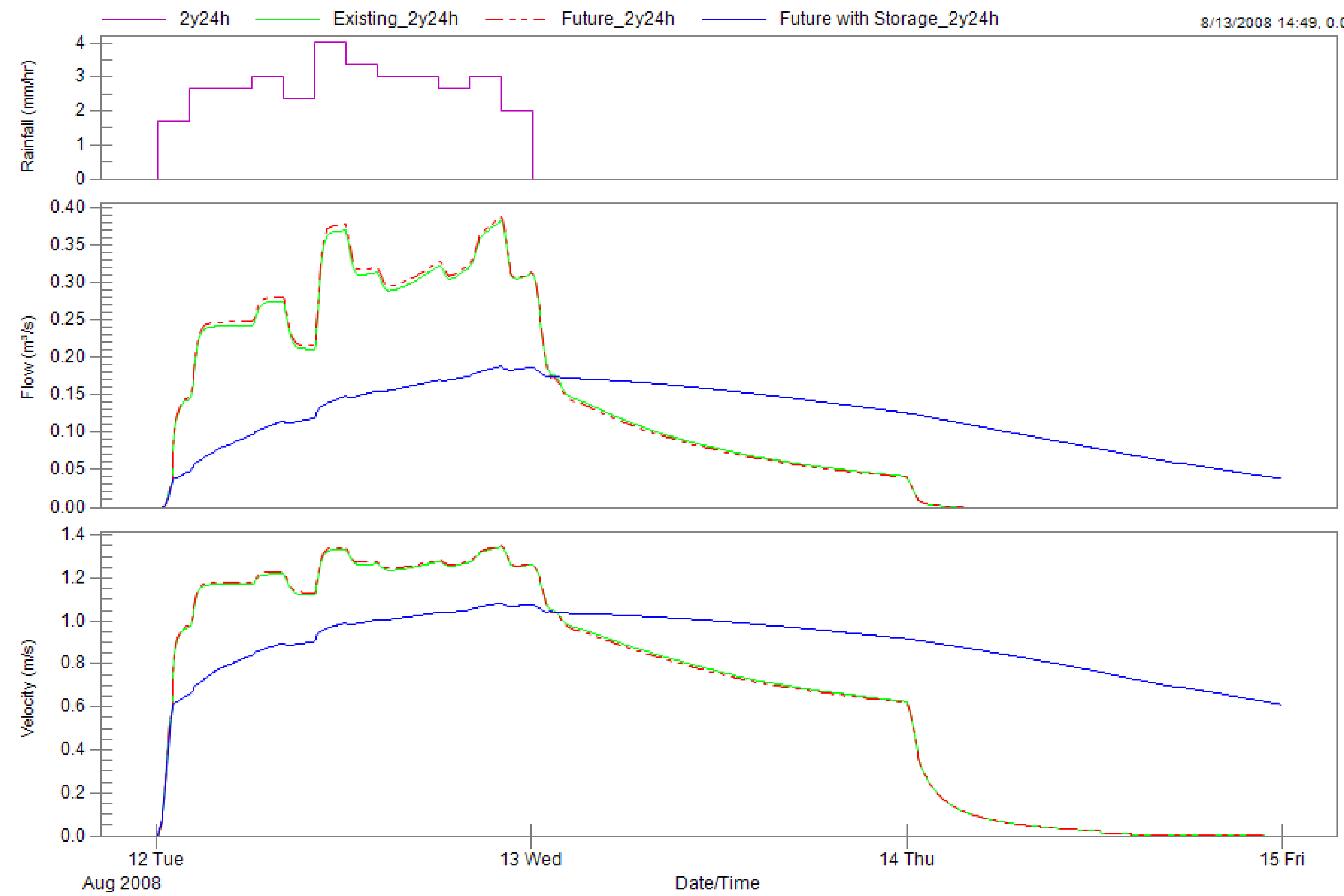


FIGURE 9-11
Peak Flow and Velocity (Link GID STL38) – 2-year, 24-hour for Alternative 1





Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	67	67	67
Maximum Flow (m^3/s)	0.38	0.39	0.19
Maximum Velocity (m/s)	1.35	1.35	1.08

FIGURE 9-12
Peak Flow and Velocity (Link GID STL38) – 100-year 24-hour for Alternative 1

Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	120	120	120
Maximum Flow (m^3/s)	0.82	0.83	0.83
Maximum Velocity (m/s)	1.60	1.60	1.60

9.5.2 Alternative 2 – Diversion Pipe

This alternative would employ a diversion scheme to direct runoff from the larger storms out of the upper watershed (north of Austin Avenue). Effectively, all runoff greater than the 5-year, 24-hour design storm (0.47 m^3/s, 8L/s/ha) is diverted to the lower portion of Nelson Creek (south of Lougheed Highway). The diversion pipe is sized for the critical event (post-development 100-year, 1-hour).

Figure 9-13 shows the proposed alignment based on the following considerations:

- Take advantage of the planned replacement of pipes along Marmont Street with larger pipes to improve conveyance capacity (as reported in Section 7)
- Avoid impact to the recent road widening of King Edward Street
- Avoid impact to the existing spawning areas immediately upstream of Lougheed Highway

The diversion will start on Austin Avenue, run south on Marmont Street to Brunette Avenue, then west to Nelson Street, and south to a discharge location immediately downstream of Lougheed Highway. The cost for this diversion pipe is approximately $8 million.

This alternative provides partial erosion control because it carries major flows around the eroded section of Nelson Creek. Figures 9-14 and 9-15 show how the peak flow and velocity are reduced in the upper watershed for the 100-year, 24-hour and 100-year, 1-hour storm events, respectively.

For the lower watershed, Figure 9-16 shows there is a slight increase in peak flows during the 100-year, 24-hour event. Figure 9-17 shows an increase in peak flow during the 100-year, 1-hour event; however, this is not considered detrimental to the creek (velocity is below 1.5 m/s).

Flow monitoring is recommended to validate the flows to be diverted.

A modification to improve water quality is installation of a hydrodynamic vortex separator upstream of the diversion, to control particulate matter and hydrocarbons.

FIGURE 9-13
Alternative 2- Diversion Pipe

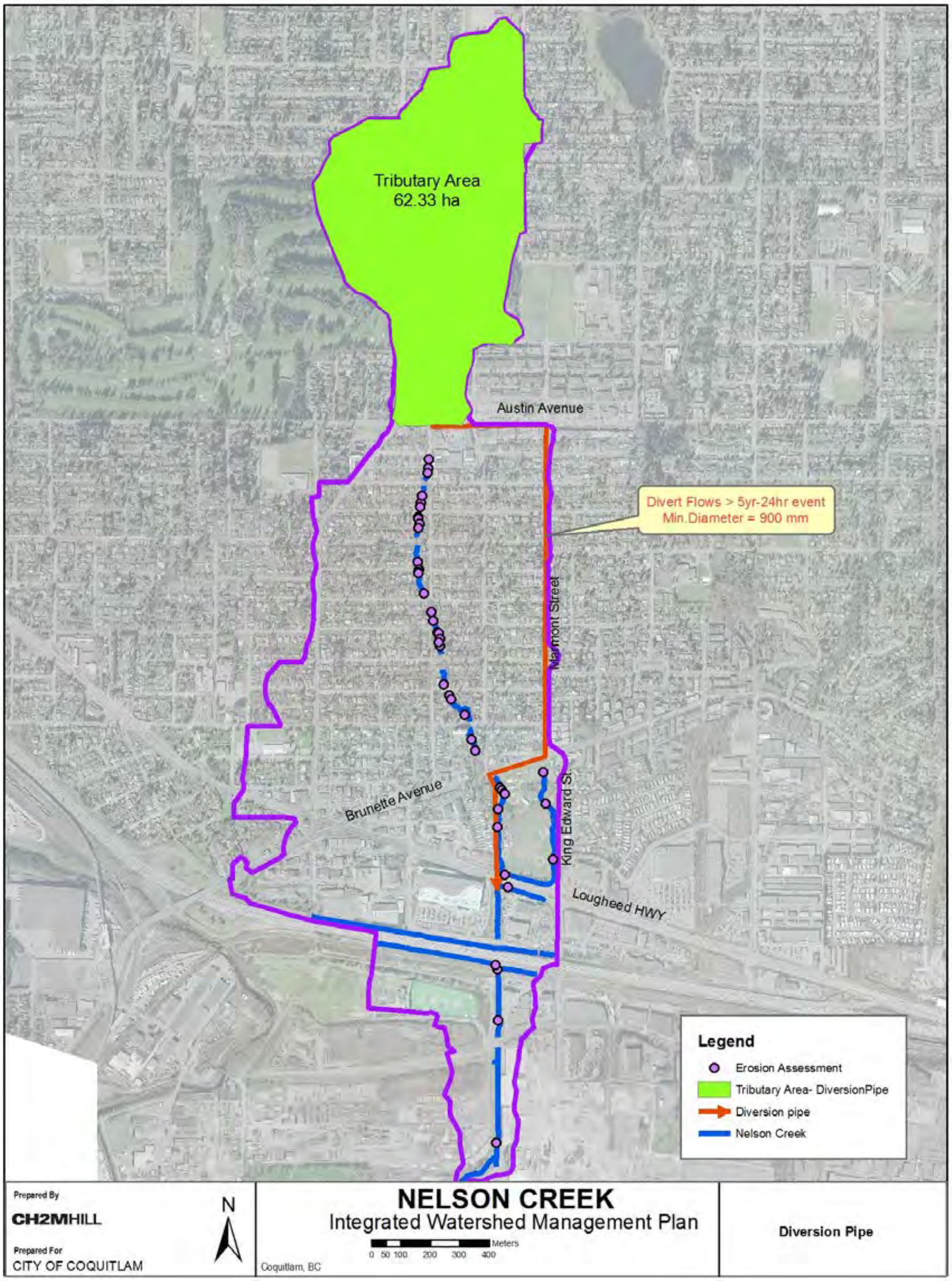
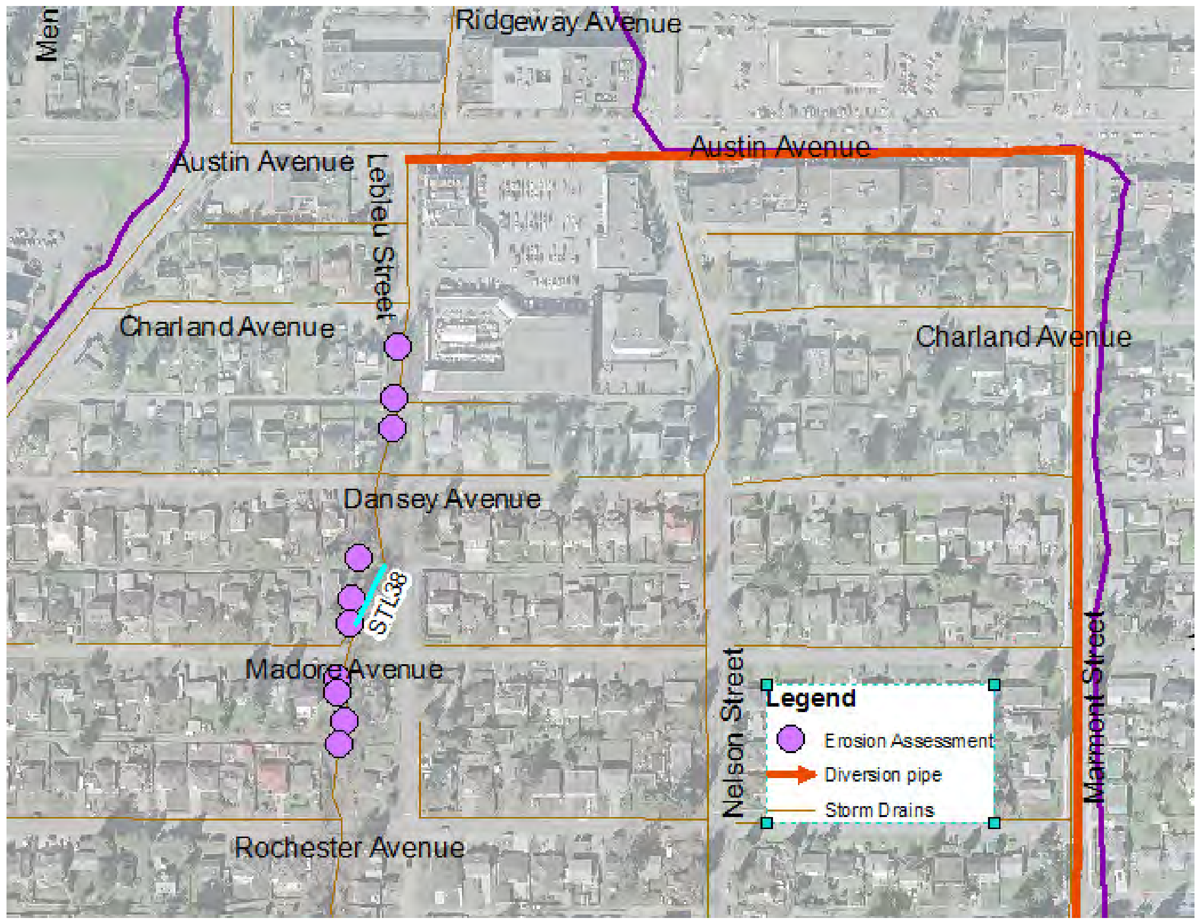
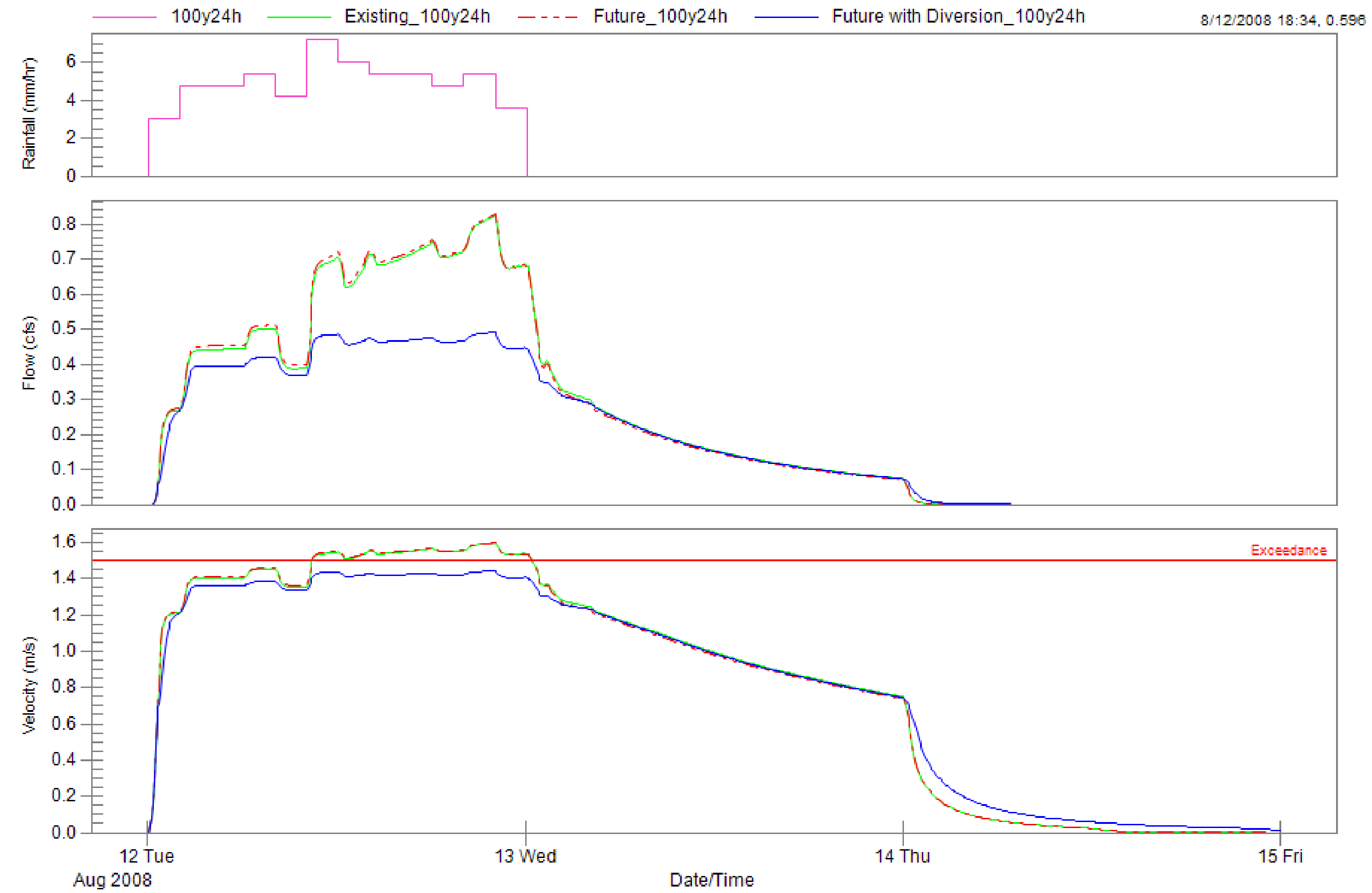


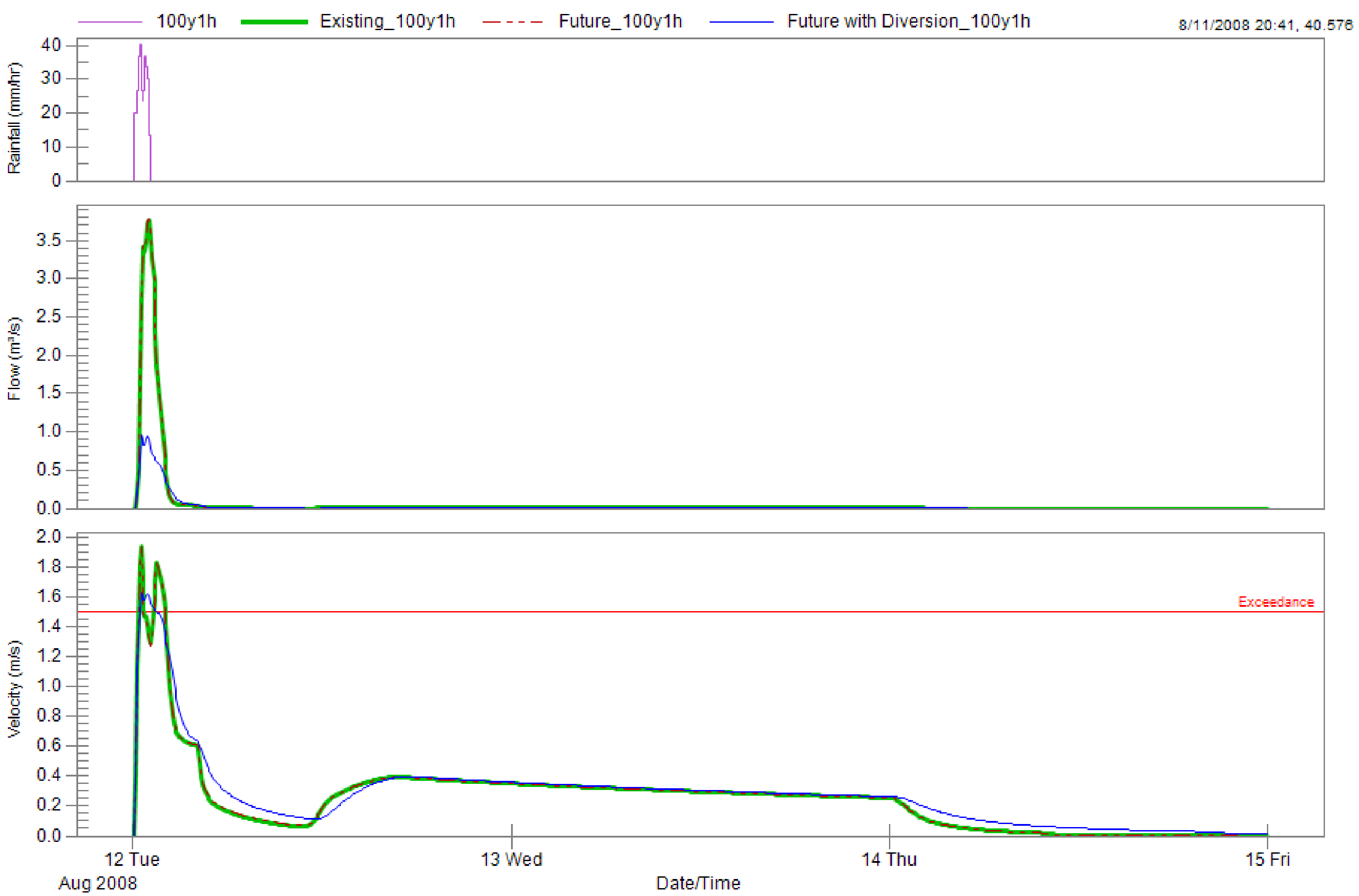
FIGURE 9-14
Peak Flow and Velocity (Link GID STL38) – 100-year, 24-hour Storm Event for Alternative 2, upper watershed





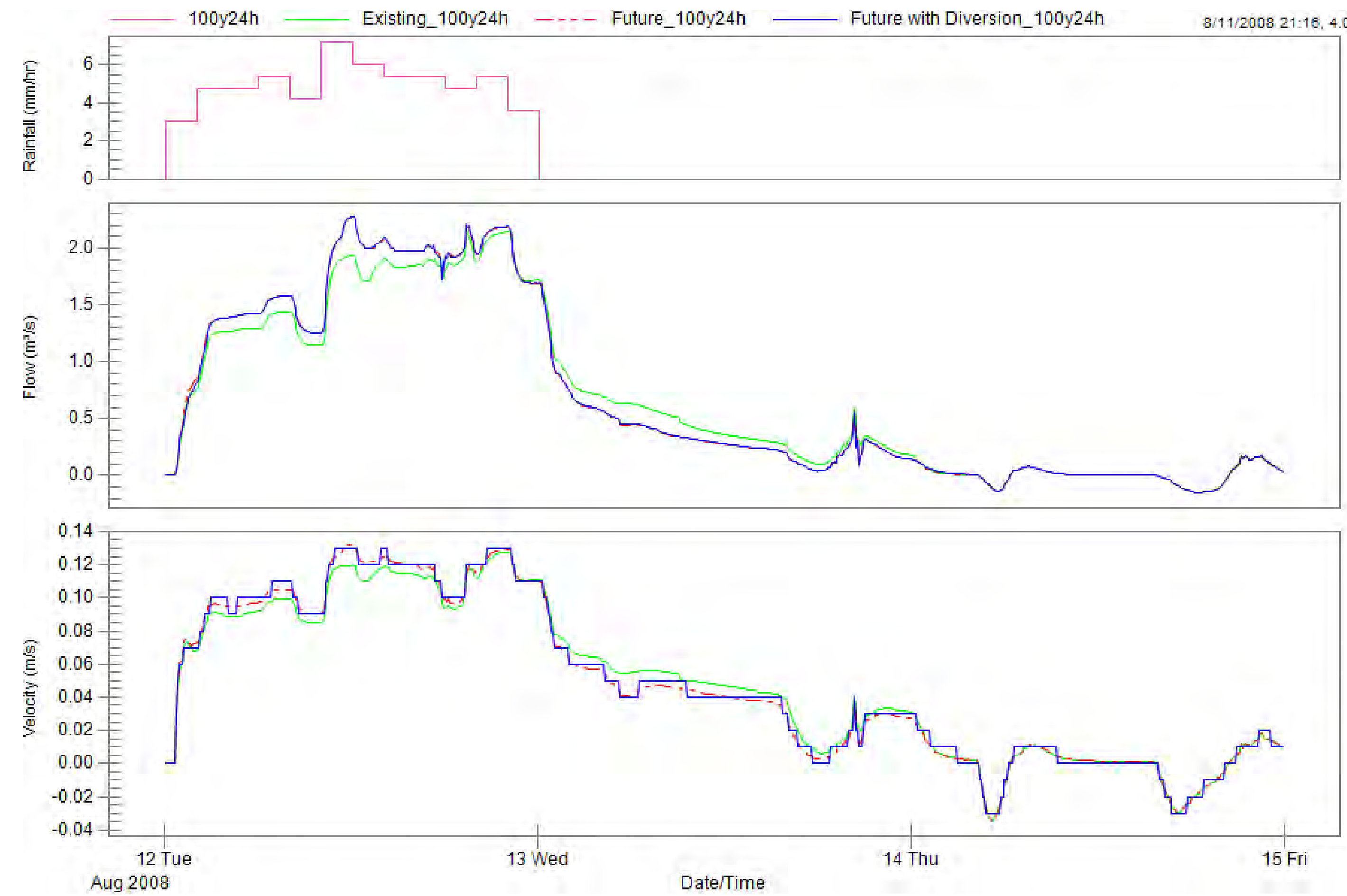
Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	120	120	120
Maximum Flow (m^3/s)	0.82	0.83	0.49
Maximum Velocity (m/s)	1.60	1.60	1.44

FIGURE 9-15
Peak Flow and Velocity (Link GID STL38) – 100-year, 1-hour Storm Event for Alternative 2, upper watershed



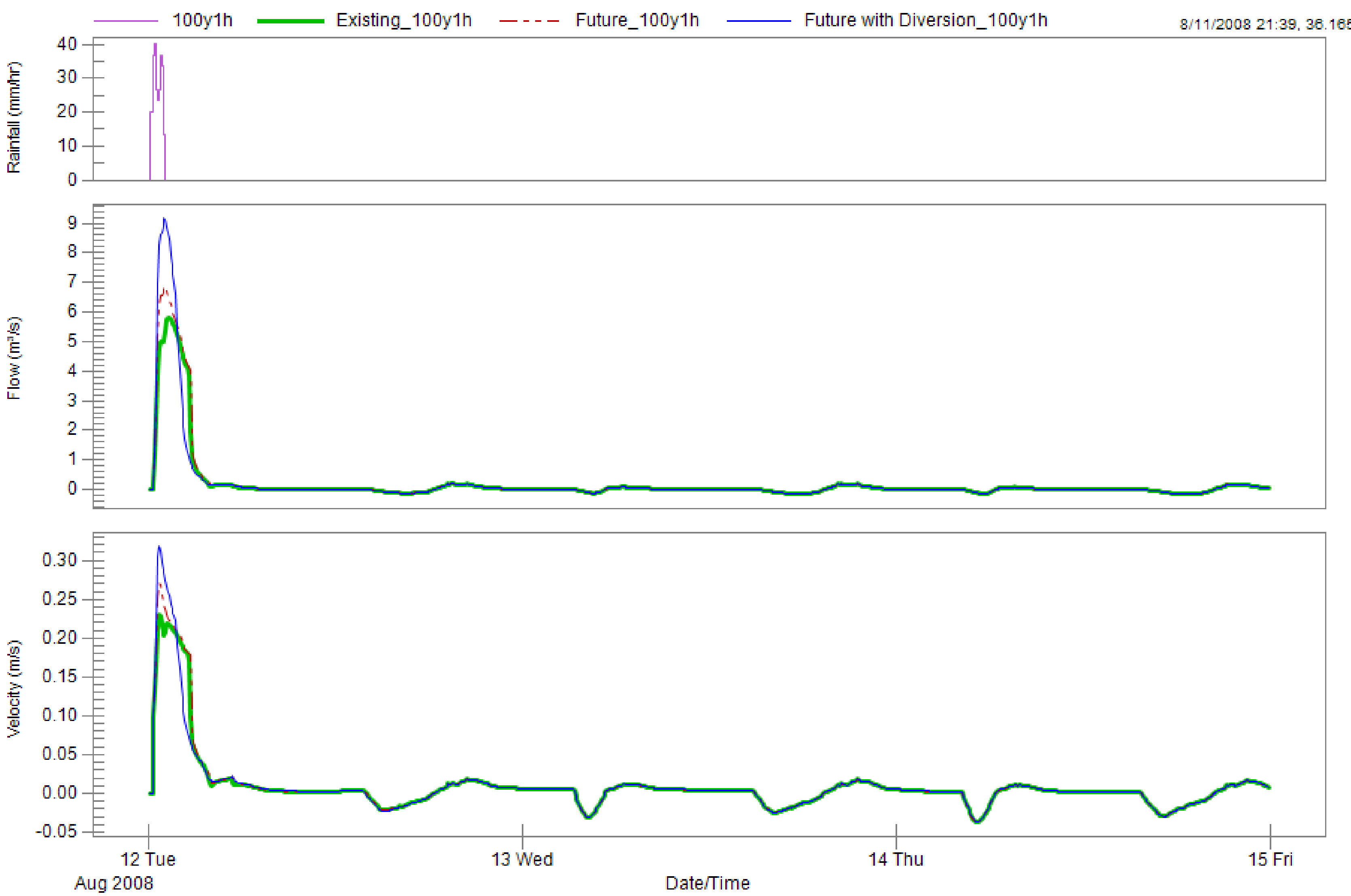
Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	27	27	27
Maximum Flow (m^3/s)	3.76	3.78	0.96
Maximum Velocity (m/s)	1.94	1.94	1.63

FIGURE 9-16
Peak Flow and Velocity (Link GID STL49) – 100-year, 24-hour Storm Event for Alternative 2, lower watershed



Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	120	120	120
Maximum Flow (m^3/s)	2.16	2.28	2.28
Maximum Velocity (m/s)	0.12	0.13	0.13

FIGURE 9-17
Peak Flow and Velocity (Link GID STL49) – 100-year, 1-hour Storm Event for Alternative 2, lower watershed



Description	Existing Conditions	Future Conditions	Future Conditions with Storage A
Total Rainfall (mm)	27	27	27
Maximum Flow (m^3/s)	5.81	6.86	9.19
Maximum Velocity (m/s)	0.23	0.27	0.32

9.6 Water Quality Strategy

Water quality was assessed at two sites in Nelson Creek on two dates during dry weather and two dates during wet weather (see Figure 3-2):

- Upper watershed just upstream of Madore Avenue
- Lower watershed in Mackin Park by the southwest ball diamond

Physical water quality parameters (temperature, specific conductivity, turbidity, pH, and dissolved oxygen) were measured. During summer, temperature and dissolved oxygen levels were at almost at the suboptimal level for salmonids (high temperature, low dissolved oxygen). Turbidity was low (<10 NTU) at most sites, but the maximum value (10.5 NTU) was measured in upper Nelson Creek during a first flush rain event. The analytical results reported elevated values for fecal coliform, nutrients, and some metals at both monitoring sites, with cadmium consistently higher than water quality guidelines and copper and zinc higher than guidelines during rain events.

The first priority for restoration of Nelson Creek is improvement of water quality, given the current conditions, steep gradient upstream of Brunette Avenue, presence of spawning and rearing habitat downstream of Brunette Avenue, and low numbers of fish (cutthroat trout, stickleback) currently documented in the stream. Once ambient water quality is improved, efforts can then shift to improving fish habitat in accessible areas of the creek.

Stormwater quality can be improved by removing contaminants wherever feasible and reducing the amount of runoff from the lots and roads by increasing the capacity of the land to absorb rain before it reaches the stormwater system and streets.

Examples of strategies to improve water quality include the following:

- Assess and address coliform and nutrient sources (e.g., cross-connections between the sanitary and stormwater systems); this is especially important in upstream areas where the stream is buried and water quality is poorer
- Assess whether the wood waste (hogfuel) and creosote fill under playing fields at Mackin Park are having an effect on water quality by seeping into groundwater and then into the stream
- Investigate periodic and repeated water quality concerns (for example, reports of detergent pollutants entering Nelson Creek at the Alderson road culvert)
- Install oil-grit separators at key locations with heavy traffic(Section 9.6.2)
- Improving vegetative cover in riparian areas to moderate water temperature and provide local improvements to water quality from runoff adjacent to the creek.

9.6.1 Flow and Water Quality Monitoring

An ongoing water quality monitoring program at the sites in Mackin Park and upstream of Madore Avenue established for the IWMP is recommended to track total runoff and status of water quality as these improvements are made. This should include monitoring at the two established sites four times in a year (twice during dry and twice during wet conditions.

Parameters to be measured include in situ measurements (temperature, conductivity, pH, dissolved oxygen, turbidity) and laboratory analyses (coliforms and *E. coli*, TSS, turbidity, nitrate, ammonia, nitrate, total phosphorus, total dissolved phosphorus, ortho-phosphate, hardness, total metals). QA/QC measures (travel blanks, duplicate samples) should be included.

The benthic invertebrate monitoring program will also be useful in tracking improvements in watershed health, and should be conducted in late summer (late August or early September), following the B-IBI approach described in Section 8. The long-term monitoring required for the Nelson Tributary restoration work already includes a benthic monitoring program three times between 2011 and 2016 in the mainstem and tributary. Results from that program can be used to track conditions in Nelson Creek.

The water quality and benthic invertebrate programs should be done on a 2- to 5-year cycle (depending on how quickly the above-mentioned strategies are implemented and on how quickly redevelopment in the watershed occurs).

9.6.2 Stormceptors

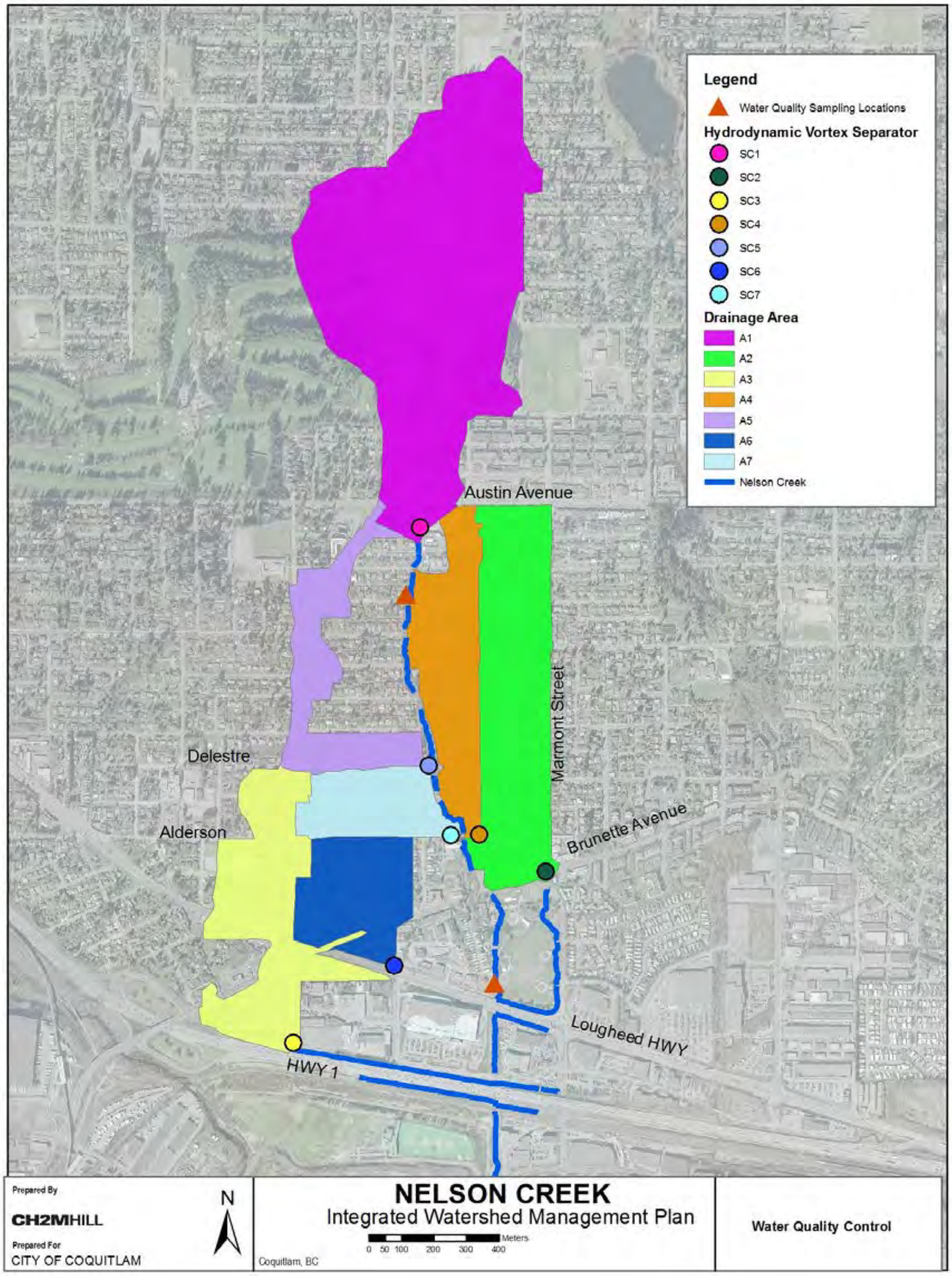
Hydrodynamic vortex separators are considered to be another feasible alternative for water quality control. Figure 9-18 shows a proposed location based on drainage area, high traffic, and outfalls that discharge into Nelson Creek. Table 9-3 details the impervious drainage areas captured, the location, and the priority based on poor water quality conditions identified.

TABLE 9-3
Proposed Hydrodynamic Vortex Separator

Stormceptor ID	Manhole ID	Location Description	Impervious Drainage Area, ha	Priority
SC1	STMH03650	Charland Ave. & Lebleu St.	32.96	1
SC2*	STMH06701	Brunette Ave. & Marmont St.	20.26	1
SC3	STOU06427	HWY-1 & Blue Mountain St.	14.14	2
SC4	STMH06838	Alderson Ave. & Nelson St.	12.30	1
SC5	STMH03428	Delestre Ave. & Lebleu St.	9.92	2
SC6	STMH06810	HWY-7 & Woolridge St.	9.75	2
SC7	STMH06743	East of Alderson Ave. & Lebleu St.	7.16	2

* Stormceptors have been installed in King Edward Street at Brunette Avenue and at Lougheed Highway as part of the King Edward Street widening project

FIGURE 9-18
Water Quality Monitoring and Stormceptors



9.7 Hydraulic Capacity Enhancement Strategy

9.7.1 Conveyance Capacity Improvement

The City has provided the following guidelines to improve the conveyance capacity of the major and minor storm drainage system:

- Upsize pipes that result in flooding during a 10-year, 1-hour design storm
- Upsize pipes (within the commercial areas) that result in flooding during the 25-year, 1-hour design storm
- Upsize the major collector (between Foster Avenue and Charland Avenue) if these pipes result in flooding during a 100-year, 1-hour design storm
- Upsize in-stream culverts that result in flooding during the 100-year, 1-hour design storm

Table 9-4 summarizes the pipes that need to be upsized either to reduce flooding or to avoid a potentially dangerous situation where a larger pipe is placed upstream of a smaller pipe. Appendix N shows the sewer network and highlights the location of the pipes listed in Table 9-4.

It is important to note that the analyses are based on flow capacity only and do not include pipe condition and age. It was also assumed that there is no constriction downstream of the sewers identified in Table 9-4 that would result in less than the peak flows in each section of these pipes.

TABLE 9-4
Summary of Pipes to be Replaced

Conduit ID	Design Criteria	Length(m)	Existing Diameter (mm)	Peak Flow for Design Criteria (m^3/s)	Required Diameter (mm)	Replacement required under existing conditions
10	100-yr, 1-hr	14.39	900	3.59	1,050	Yes
Dansey	100-yr, 1-hr	16.89	900	3.73	1,050	Yes
Delestre	100-yr, 1-hr	48.58	900	5.07	1,050	Yes
Madore	100-yr, 1-hr	27.71	900	3.81	1,050	Yes
Quadling	100-yr, 1-hr	30.36	960	3.85	1,200	Yes
Rochester	100-yr, 1-hr	12.58	900	3.73	1,050	Yes
STOI06788	100-yr, 1-hr	26.36	1,500	5.38	1,650	Yes
STPI06794	100-yr, 1-hr	38.75	900	3.79	1,050	Yes
STPI08931	100-yr, 1-hr	90.53	600	0.95	750	Yes
STPI08641	100-yr, 1-hr	111.28	1,066	1.73	1,350	Yes
Link2603	100-yr, 1-hr	69.50	1,066	2.16	1,350	Yes
Link2604	100-yr, 1-hr	80.87	1,066	2.18	1,650	Yes
Link2605	100-yr, 1-hr	18.19	1,066	2.62	1,650	Yes
STPI08947	100-yr, 1-hr	76.76	1,200	2.59	1,650	Yes
STPI08946	100-yr, 1-hr	190.38	1,200	2.58	1,650	Yes
Charland	100-yr, 1-hr	26.39	900	3.50	1,650	Yes
Link2609	100-yr, 1-hr	93.69	1,200	2.77	1,650	Yes
Link2611	100-yr, 1-hr	71.07	900	3.06	1,650	Yes
STPI04071	100-yr, 1-hr	16.85	900	3.16	1,650	Yes
STPI04263	100-yr, 1-hr	21.17	900	3.49	1,650	Yes

TABLE 9-4
Summary of Pipes to be Replaced

Conduit ID	Design Criteria	Length(m)	Existing Diameter (mm)	Peak Flow for Design Criteria (m^3/s)	Required Diameter (mm)	Replacement required under existing conditions
STPI04264	100-yr, 1-hr	25.80	900	3.45	1,650	Yes
STPI04265	100-yr, 1-hr	35.81	900	3.36	1,650	Yes
STPI04266	100-yr, 1-hr	17.90	900	3.36	1,650	Yes
STPI04267	100-yr, 1-hr	10.75	900	3.36	1,650	Yes
STPI08638	100-yr, 1-hr	43.97	900	3.00	1,650	Yes
STPI08639	100-yr, 1-hr	91.44	900	2.89	1,650	Yes
5	25-yr, 1-hr	90.22	600	0.00	750	Yes
Link903	25-yr, 1-hr	16.00	700	0.00	750	Yes
STPI06428	25-yr, 1-hr	119.50	250	0.10	300	No
STPI06429	25-yr, 1-hr	80.35	250	0.16	300	No
STPI06567	25-yr, 1-hr	47.00	200	0.06	300	Yes
STPI06568	25-yr, 1-hr	46.00	200	0.05	300	Yes
STPI06760	25-yr, 1-hr	147.40	200	0.03	300	Yes
STPI06761	25-yr, 1-hr	57.37	250	0.14	300	Yes
STPI06777	25-yr, 1-hr	10.36	200	0.14	600	Yes
STPI06778	25-yr, 1-hr	137.76	600	0.24	675	Yes
STPI06779	25-yr, 1-hr	55.47	200	0.05	450	Yes
Link769	10-yr, 1-hr	20.84	1,000	0.11	1,050	Yes
STPI01767	10-yr, 1-hr	92.13	200	0.04	250	No
STPI01768	10-yr, 1-hr	105.93	250	0.08	300	No

TABLE 9-4
Summary of Pipes to be Replaced

Conduit ID	Design Criteria	Length(m)	Existing Diameter (mm)	Peak Flow for Design Criteria (m^3/s)	Required Diameter (mm)	Replacement required under existing conditions
STPI01800	10-yr, 1-hr	114.95	200	0.04	250	No
STPI01806	10-yr, 1-hr	115.59	300	0.07	375	No
STPI03401	10-yr, 1-hr	94.73	250	0.03	250	Yes
STPI03402	10-yr, 1-hr	74.56	250	0.13	300	Yes
STPI03411	10-yr, 1-hr	89.80	200	0.03	250	Yes
STPI03412	10-yr, 1-hr	76.79	200	0.08	250	Yes
STPI03483	10-yr, 1-hr	88.90	200	0.00	250	No
STPI03484	10-yr, 1-hr	100.80	200	0.06	250	Yes
STPI03489	10-yr, 1-hr	37.56	200	0.01	250	No
STPI03490	10-yr, 1-hr	123.15	200	0.07	250	No
STPI03491	10-yr, 1-hr	30.35	250	0.07	300	Yes
STPI03604	10-yr, 1-hr	107.35	200	0.06	250	Yes
STPI03608	10-yr, 1-hr	95.16	200	0.05	250	Yes
STPI03609	10-yr, 1-hr	100.10	200	0.06	250	Yes
STPI03819	10-yr, 1-hr	95.10	300	0.12	375	Yes
STPI04056	10-yr, 1-hr	44.90	250	0.09	300	No
STPI04057	10-yr, 1-hr	19.54	250	0.11	300	No
1734	10-yr, 1-hr	99.62	200	0.10	250	Yes
1722	10-yr, 1-hr	52.64	200	0.11	250	Yes
1720	10-yr, 1-hr	48.19	200	0.13	250	Yes

TABLE 9-4
Summary of Pipes to be Replaced

Conduit ID	Design Criteria	Length(m)	Existing Diameter (mm)	Peak Flow for Design Criteria (m^3/s)	Required Diameter (mm)	Replacement required under existing conditions
1662	10-yr, 1-hr	103.42	250	0.06	300	Yes
1711	10-yr, 1-hr	80.99	200	0.12	250	Yes
1705	10-yr, 1-hr	119.86	600	0.34	675	Yes
1692	10-yr, 1-hr	99.20	200	0.10	675	Yes
1679	10-yr, 1-hr	119.88	200	0.10	675	Yes
1661	10-yr, 1-hr	53.04	200	0.12	675	Yes

9.8 Riparian Enhancement Strategy

Problem Identification

The riparian area of Nelson Creek has been highly altered by adjacent land uses, as indicated by the 16 percent RFI (Section 8-2), and growth of invasive plant species, such as Himalayan blackberry. In the lowland area, the mainstem, tributaries and highway ditches have little or no tree canopy. Trees provide important benefits for stormwater management, shade, and nutrients for the stream, as well as habitat for wildlife.

Enhancement Opportunities

Recommendations for riparian area rehabilitation include:

- Restore habitats with extensive growth of invasive species, replacing with native species of trees and shrubs
- Establish fenced covenants through subdivision applications or redevelopment opportunities to protect riparian habitat
- Plant native shrubs and trees (mix of coniferous and deciduous species at moderate densities on private and public lands

The recommended riparian habitat enhancements for publicly-owned lands are consistent with the goals of the City's Invasive Plant Management Strategy. Currently, these restorations activities are undertaken annually on a priority basis.

9.9 Terrestrial Restoration and Enhancement Strategy

9.9.1 General Habitat and Migration Corridor Considerations

Corridors connecting habitat fragments play an important role in maintaining wildlife populations because they facilitate local and regional movement of animals. In a fragmented landscape, as occurs in the Nelson Creek Watershed and surrounding area, corridors are especially important to ensure that various wildlife species can move between seasonally important breeding, over-wintering and other habitats (Beier, 1998) and to maintain genetic variability in the populations (Saxena *et al.,* 1997). Many animal species indigenous to the Coastal Western Hemlock biogeoclimatic zone require connectivity between suitable habitat patches within their ranges. The Nelson Creek Watershed is a matrix of mainly residential land use, with commercial and industrial use in the lowland area, and some natural habitat, connected mainly through riparian habitat. As a result, wildlife using the area are restricted to using creeks and small areas of forested habitat.

Due to the amount of development that has taken place in the watershed, there is minimal corridor remaining and minimal opportunity for corridor use by wildlife. Previous studies (Jacques Whitford-AXYS, 2006) identified the golf course, a portion of which is within the Nelson Creek watershed, as a corridor. A corridor along the Fraser River was also identified, connecting to Highway 1 through the golf course on the old landfill site. The river will facilitate some migration, limited to the lowland area of the watershed.

Fragmentation of the watershed due to transportation corridors and development greatly restricts wildlife movement, particularly between the lowland and the upland habitats.

9.9.2 Watershed Opportunities and Constraints

Recommendations for restoration of terrestrial habitat away from Nelson Creek include:

- Rehabilitating habitats with extensive growth of invasive species, as discussed for riparian areas
- Planting native shrubs, conifers, and deciduous trees at moderate densities on private and public land to improve stormwater management naturally (via interception of rain by leaves and roots)
- Establishing a park and natural area network within the context of existing planning
- Ensuring that land-use zoning reflects natural area covenants
- Consulting the provincial Draft Environmental Management Practices for Urban and Rural Land Development (Polster and Cullington, 2004) prior to development, which provides BMPs for protection of habitat for nesting raptors, amphibians, and reptiles. These include:
  - For raptor nests, a buffer of undisturbed natural vegetation for a distance of 1.5 tree lengths (Demarchi and Bentley, 2005)
  - For amphibians (including red-legged frogs) and reptiles, a buffer of undisturbed native vegetation around key habitat areas, suitable movement corridors between important seasonal habitat, and siting of roads away from the areas to minimize road kill (Ovaska et al., 2004)

The major constraint to restoration opportunities is that many areas are on private property, so landowner cooperation will be required for access and restoration of suitable areas. Because most of the land is privately held, establishment of natural covenants or parks would require significant land purchases by the City or private land donations for green space preservation. As discussed in Section 3.2.1, the small size of natural habitat patches is a limiting factor for mammals with large home ranges.

9.10 Ditch Management Strategy

There are two circumstances in which ditch habitat may be altered. The first is through the actions of an individual property owner (e.g., installation of a culvert to accommodate a driveway), which would be addressed through the regular City permitting process. The second is through larger scale redevelopment associated with implementation of the Neighbourhood Plans, where an entire lane would be widened or paved and stormwater infrastructure is installed in place of a ditch. The second circumstance requires a review of the ditch assessment results to assess loss of instream and riparian habitat and, for Red and Yellow-classified ditches, compensation for lost habitat. The results of the ditch assessment are summarized in Table 9-5 along with management recommendations for each ditch classification. Loss of riparian and instream habitat associated with removal of the ditches was estimated.

TABLE 9-5
Summary of Ditch Assessment for Nelson Creek Watershed

Ditch Classification	Assessment Results	Management Recommendations
Red	• One ditch, along the Lougheed Highway • Provides fish habitat, directly connected to Nelson Creek, and provides food and nutrients directly into Nelson Creek • Likely to provide wildlife values given the amount of ground cover and vegetation canopy	• Alterations should be reviewed by DFO • Mitigation measures or habitat compensation will be required
Yellow	• Four lane ditches • Not fish bearing, flows are non-permanent but provide food and nutrients to downstream fish habitat • Alterations will require additional consideration depending on the location and extent of alteration • Total instream habitat is 350 m^2 • Total riparian habitat (2 m strip beside the ditches) is 942 m^2	• Alterations related to a single lot (e.g., culverting to accommodate a driveway) to be dealt with through regular City permitting channels. Mitigation may consist of replacing any trees or shrubs removed with native species, preferably in a nearby area • Alterations related to the City replacing the ditch with stormwater infrastructure will require compensation for instream and riparian habitat losses to replace the lost food and nutrient supply to Nelson Creek
Green	• 25 lane ditches • Not fish bearing, non-permanent, do not provide food and nutrients to downstream fish habitat	• Alterations will not require mitigation or review by DFO

Options for habitat compensation have been identified and are described in Table 9-6. Typically, DFO requires a 2:1 ratio of compensation area to loss area. The options range from small scale planting close to the affected lanes to larger scale restoration projects that would provide significant habitat benefits.

TABLE 9-6
Habitat Compensation Opportunities in Nelson Watershed for Ditch Replacement

Option	Instream Area (m^2)	Riparian Area (m^2)	Preliminary Cost Estimate
Enhancing riparian vegetation along Red and Yellow classified ditches in Nelson Watershed	none	180 m^2	$2,200 to $3,200
Enhancing riparian setbacks on Nelson Creek in Mackin Park	none	535 m^2	$6,400 to $9,600
Rehabilitating mouth of Nelson Creek (City-owned portion of Unit 1 of the proposed design)	560 m^2	Nominal	$149,100

9.11 Public Education

Public education programs are important to provide residents with a greater understanding of their watershed and how practices on private land affect watershed health. Some recommendations for public education are:

- Enhance the City's website with information about the watershed and about stormwater and rainwater management
- Install educational signs at sites that incorporate BMPs
- Explore the establishment of a Stream Stewardship Group
- Encourage retention of as much native vegetation as possible on private property and removal of exotic and invasive species
- Provide a list of recommended native plant species for use on private property
- Encourage protection and enhancement of native vegetation in riparian areas and removal (and avoidance) of hard surfaces, structures, and grass in riparian areas
- Encourage use of landscaping techniques that help in rainwater management
- Encourage appropriate pick-up and disposal of animal (dog) feces, providing information on home composters for dog waste

9.12 Summary

Table 9-7 shows a summary of the various projects described in this section including project type, the main issues associated with the project, potential solutions, and location.

TABLE 9-7
Summary Projects

Project Classification	Issues	Potential Solutions/Recommendations	Potential Location
Watershed Health Tracking		• Review TIA / EIA and RFI • Conduct benthic invertebrate sampling	
Stormwater Management	• Erosion	• Manage high-risk erosion sites on a case-by-case basis (short-term) and monitor	• Along the creek
	• Peak flow and runoff	• Reduce peak flow and runoff volume by: – Source control where development and re-development is considered – Detention facilities – Diversion pipe	• Re-development Locations • Proposed land for active park land acquisition • North of Austin Avenue
Hydraulic Capacity	• Limited conveyance capacity	• Upsize the pipes that result in flooding	• Various locations (Appendix N)
Water Quality	• Evidence of poor water quality	• Develop a monitoring program (water quality and flow) • Investigate possible cross connections with the sanitary sewer system • Implement source controls • Use hydrodynamic vortex separator • Remove steel drum on bank • Commission study of groundwater quality to assess condition associated with current development level • Investigate specific pollution and spill reports	• Mackin Park and upstream of Madore Avenue • Upper Nelson Creek • Re-development locations • Various (Figure 9-18) • Upstream of Delestre Avenue • Alderson road culvert
Fish Habitat	• Habitat altered by road culverts, channelization	• Daylight Nelson Creek at the Fraser River confluence by creating a treed corridor to the west of existing channel	• Fraser River

TABLE 9-7
Summary Projects

Project Classification	Issues	Potential Solutions/Recommendations	Potential Location
		• Remove permanent natural barriers and replace impassable culverts	• Various locations upstream of Brunette Avenue, as the opportunity arises during replacement programs
Riparian Habitat	• Major intrusions of invasive plants	• Riparian zone fence • Encourage planting of native species • Encourage retention of as much native vegetation as possible on private property and removal of exotic and invasive species	• Along the creek
Ditch Replacement	• Alteration of ditch habitat	Habitat compensation alternatives include: • Enhancing riparian vegetation along Red and Yellow classified ditches in Nelson Creek Watershed • Enhancing riparian setbacks on Nelson Creek in Mackin Park • Rehabilitating mouth of Nelson Creek (City-owned portion of Unit 1 of the proposed design)	 • Various • Mackin Park • Mouth of Nelson Creek
Public Education		• Enhance City's website • Install educational signs at sites that incorporate stormwater management alternatives • Provide list of recommended native plant species for use in private property • Encourage residents to implement landscaping techniques that help in rainwater management • Explore the establishment of a Stream Stewardship Group	

10. Implementation Strategy

The purpose of this section is to outline the implementation plan for the management actions selected for the Nelson Creek Watershed.

10.1 Summary of the Nelson Creek IWMP

The Nelson Creek IWMP is based on the following primary objectives:

- Short-term objectives:
  - Provide stream protection at critical erosion sites
- Medium-term objectives:
  - Implement recommended flow, water quality, and study programs to support long-term management actions intended to restore watershed health
- Long-term objective:
  - Restore overall watershed health through the implementation of integrated projects, including rainwater management, stream enhancements, riparian habitat enhancement

10.2 Implementation Actions for the Nelson Creek IWMP

Table 10-1 summarizes the specific actions that are required to implement the short-term, medium-term, and long-term management strategies required to improve overall watershed health. The table provides information for each action, including:

- Timeframe for implementation
- Action items
- Summary of recommended actions
- Cost estimate

In addition, Appendix O present the Class C cost estimates.

TABLE 10-1
Implementation Actions for Nelson Creek Watershed

Timeframe	Action Items	Summary of Recommended Actions	Cost Estimate
Short-term			
Stream Channel Erosion			
0 – 2 years	Manage high-risk erosion	Manage high-risk erosion sites on a case-by-case basis	N/A
	Total – Short-term (Class C Cost Estimate)		**N/A**

TABLE 10-1
Implementation Actions for Nelson Creek Watershed

Timeframe	Action Items	Summary of Recommended Actions	Cost Estimate
Medium-term			
Water Quality			
0 – 5 years	Enhance water quality	Implement a flow and water quality monitoring program every 2 to 5 years	$16,000[1]
		Install hydrodynamic vortex separator	$200,000
		Investigate possible sanitary sewer cross connections and possible detergent pollutants	NA
Peakflow Control			
0 – 5 years	Divert flows higher than 5-year, 24-hour design storm	Design supported with monitoring data	$5,000,000
Fish Habitat			
0 – 5 years	Remove fish barriers	Remove permanent natural barriers and replace impassable culverts	NA
	Total – Medium-term (Class C Cost Estimate)		**>$5,216,000**
Long-term			
Continuously ongoing	Stream erosion surveillance program	Implement a surveillance program to monitor conditions at identified stream erosion sites and identify where action is needed	NA
Continuously ongoing	Public Education	Programs for residents to provide them with a greater understanding of their watershed, how practices on private land affect watershed health and how to enhance it	NA
2 – 10 years	Riparian habitat enhancement	Undertake riparian planting, install riparian zone fencing, and remove invasive species	NA
0 – 50 year	Improve hydraulic capacity	Upsize the pipes and culverts that surcharge and result in flooding	$3,000,000
0 – 50 years	Rainwater source control	Apply to any new development and redevelopment activities that take place	NA
0 – 50 years	Compensate for ditch replacement	Enhance riparian vegetation along Red and Yellow classified ditches in Nelson Watershed	$2,200-3,200
0 – 50 years	Compensate for ditch replacement	Enhance riparian setbacks on Nelson Creek in Mackin Park	$6,400-9,600
0 – 50 years	Compensate for ditch replacement	Rehabilitate mouth of Nelson Creek (City-owned portion of Unit 1 of the proposed design)	$149,100
	Total – Long-term (Class C Cost Estimate)		**>$3,162,000**
TOTAL			**>$8,378,000**

[1] One water quality program (4 trips in a year) and benthic invertebrate monitoring program (1 trip in a year)

11. Conclusion and Recommendations

Based on the information presented in the previous sections we have made the following conclusions.

11.1 Reconnaissance

11.1.1 Land Use Component

- The majority of the land within the watershed is developed as older one- and two-family residential lots. There are also two higher density commercial centres within the watershed
- The Austin Heights Neighbourhood Plan was adopted on April 4, 2011, and the key elements of the land use changes include:
  - The transition of the neighbourhood commercial core to a high density mixed-use area
  - The addition of new smaller areas of medium-density residential uses south of the commercial core to act as a buffer between the core and adjacent lower density residential areas
  - An expansion of the existing Neighbourhood Attached Residential designation and the introduction of new small-scale, ground-orientated housing types in either attached or detached forms
  - Maintaining and protecting the majority of the one-family residential area as an important part of the housing mix, while providing opportunities for secondary suites and home based businesses, where appropriate
- The Maillardville Neighbourhood Plan processes are currently underway; key land use changes include:
  - The transition of one and two family residential to new small-scale, ground-orientated housing types in either attached or detached forms

11.1.2 Aquatic Habitat

Stream Classification

Nelson Creek is classified as Class A (inhabited by salmonids year-round or potentially inhabited year-round) from the mouth up to Brunette Avenue, and as Class B (significant food/nutrient value, no fish present) from Brunette Avenue up to Charland Avenue Nelson Creek Tributary T4 in Mackin Park is also Class A.

Fish Species

The following species have been documented from the mouth of Nelson Creek up to Brunette Avenue:

a) Brassy minnow
b) Carp
c) Coho salmon
d) Cutthroat trout
e) Anadromous cutthroat trout
f) Prickly sculpin
g) Sculpin
h) Sucker
i) Threespine stickleback

Stream Features and Salmonid Habitat Summary

- Overall salmonid productive capacity in Nelson Creek mainstem is rated as moderate
- Overall salmonid productive capacity in Nelson Creek Tributary T4 (at the east and south boundary of Mackin Park) is rated as moderate
- Overall salmonid productive capacity in the Nelson Creek Tributaries T1 (south of Highway 1 flowing east to the mainstem), T2 (tributary south of Highway 1 flowing west to the mainstem), and T3 (tributary south of Lougheed Highway flowing west to the mainstem) is rated as moderate to poor

Fish Presence

- Cutthroat trout and sticklebacks have been documented in Nelson Creek since 2008.

Barriers to Fish Migration

Barriers to fish migration were identified in Nelson Creek, including:

1. Four culverts (Brunette Avenue, Alderson Avenue, Steward Avenue, and Madore Avenue)
2. One waterfall near Quadling Avenue
3. Sections of steep gradient (up to 30 percent) upstream of Quadling Avenue

In Situ Water Quality

- Physical water quality parameters (temperature, specific conductivity, turbidity, pH, and dissolved oxygen) were measured at two locations, one in the upper and the second in the lower Nelson Creek on four dates (two dry weather, two wet weather)
- Temperature, pH, and dissolved oxygen were within the range expected for streams in the Lower Mainland; however, temperature and dissolved oxygen levels were almost in the suboptimal range for salmonids
- Turbidity was low (<3 NTU) at most sites, but a value of 10.5 NTU was measured in the upper Nelson Creek during a first flush event

Analytical Water Quality

- TSS were below provincial guidelines (25 mg/L maximum induced TSS)
- Individual values for *E. coli* exceeded guidelines in all samples analyzed
- All nitrogen compounds were within BC water quality guidelines for protection of aquatic life (Ministry of Environment, 2006); however, levels were relatively high for an urban stream
- Levels of ortho phosphate (dissolved inorganic phosphate) and total dissolved (organic and inorganic) fractions were elevated and indicated the effects of urban and residential activities
- Cadmium, copper, and zinc did not meet the BC water quality guidelines, and had the highest concentrations during rain events
- Coliform, nitrogen, and phosphorus levels are suggestive of cross-connections with the sanitary sewer system

11.1.3 Terrestrial Habitat

Vegetation and Wildlife

- There is little undisturbed, undeveloped habitat in Nelson Creek watershed
- The main areas of natural vegetation occur in the riparian area of Nelson Creek, with some mature forest found within parks
- Wildlife in the watershed is likely to include small mammals (e.g., mice and voles), skunks, racoons, red fox, coyotes, and a wide range of birds
- Remaining patches of natural habitat are small and fragmented, limiting the watershed's ability to support mammals with large home ranges, such as the black-tailed deer

Species of Conservation Concern

- There are 17 rare elements occurrences within 5 km of the watershed: 3 invertebrate, 1 mammal, and 13 plant species. Of these species, only false-pimpernel has been observed within the watershed

Field Assessments

- The riparian and park areas in Nelson Creek provide suitable habitat for songbirds and small mammals
- Wildlife species observed during the site visit include European starling (*Sturnus vulgaris*), killdeer (*Charadrius vociferous*), unidentified sparrow, brown creeper (*Certhia Americana*), black-capped chickadee (*Poecile atricapillus*), spotted towhee (*Pipilo maculates*), American robin (*Turdus migratorious*), Stellar's jay (*Cyanocitta stelleri*), northwestern crow (*Corvus caurinus*), and eastern gray squirrel (*Sciurus carolinensis*)
- No rare plant species or ecosystems were observed during the field survey; however, invasive species were observed throughout the watershed, predominantly in riparian areas

- Field observations confirmed many of the modelled habitat suitability ratings provided in the ESA maps, and identified new areas of suitable habitat for some of the focal species considered in the ESAs (Cooper's hawk, brown creeper, hairy woodpecker)

General Habitat and Migration Corridor Considerations

- Due to the amount of development that has taken place in the watershed, there is minimal corridor remaining and minimal opportunity for corridor use by wildlife
- Two corridors have been identified: a portion of the golf course and a corridor along the Fraser River, connecting to Highway 1 through the golf course on the old landfill site
- The Fraser River facilitates some migration, limited to the lowland area of the watershed
- Transportation corridors and development greatly restrict wildlife movement

Watershed Opportunities and Constraints

- The major constraint to enhancement opportunities is that many areas are on private property
- Establishment of natural covenants or parks would require significant land purchases by the City or private land donations
- The provincial Draft Environmental Management Practices for Urban and Rural Land Development (Polster and Cullington, 2004) should be consulted prior to development

11.1.4 Physical Environment

Hydrogeology

- Soils are mainly comprised of Vashon Drift (glacial soils) and Capilano Sediments (raised marine, deltaic, and stream deposits)
- Hydraulic conductivity is considered low, approximately 10^{-6} m/s, for the majority of soils in the watershed
- The hydrogeologic system is comprised of a shallow groundwater flow system in the near surface coarser-grained soils (sand and gravel), with perched groundwater within 2 m of the surface
- Groundwater discharges are expected to occur in mid and lower areas of the main channel and its tributaries and in low lying areas

Channel Morphology

- Most of the sediment supplied to the creek is a mix of fine- and coarse-grained material that appears to be eroded from the lower stream banks, mainly at the outer bends of the creek
- There were few observations of excessive sediment build up (aggradation) or potential debris blockage in the upland area

- The field survey identified few sediment sources along the creek and no observable instances of significant sedimentation below Lougheed Highway, although, these may be masked by the thick vegetation growth

Geotechnical Stability of Erosion Areas

- Based on a re-visit in 2008 of the priority erosion sites identified in 2005, in most cases, there was no noticeable change
- While there has been no or small change over a 3-year period, the recommendations for ongoing inspections and remediation work (Associated Engineering, 2006) remain valid

Ditch Assessment

- The 30 lane ditches within the Nelson Creek watershed were classified into three of the six categories defined by the City: one ditch was classified Red (fish-bearing), four ditches were Yellow (not fish-bearing and not permanent), and 25 ditches were Green (not fish habitat)

11.1.5 Hydrologic and Hydraulic Modelling

Input Data Summary

- Two independent topographical surveys were completed, covering Nelson Creek from the discharge point to the Fraser River, to Charland Avenue, including the tributary that runs east and south of Mackin Park, and the tributaries along Lougheed Highway and Highway 1
- Flows were measured in Nelson Creek at Brunette Avenue using a pressure transducer from July 11, 2008 to January 15, 2009
- Rainfall was measured during the same period using a temporary rain gauge installed on the roof of the Leisure & Parks building at 640 Poirier Street

Model Calibration

- An XPSWMM model was successfully built and calibrated for the Nelson Creek Watershed

Model Assembly

- The existing conditions model was developed based on the calibrated model
- The calibrated model was updated with future land use changes to simulate future conditions

11.1.6 Assessment of the Existing Drainage System

Storm Drainage System Assessment

- The critical hydraulic condition of the Nelson Creek drainage system was identified to be caused by the 1-hour design storms
- For all considered design storms, the drainage system along Marmont Street between Brunette Avenue and Madore Avenue shows to have conveyance capacity issues

Culvert Hydraulic Capacity Assessment

- The results of the hydraulic modelling indicate that the culverts in the Nelson Creek watershed do not surcharge for all the simulated storm events, except for the 1-hour design storms
- Flooding conditions are reported for Dansey, Madore, Rochester, Delestre, Quadling, and Brunette. Of particular concern are the culvert crossings at Quadling, which show maximum water surface elevations exceeding the top of bank elevation
- Approximately 30 percent of the in-stream culverts flood and 55 percent surcharge during a 100-year, 1-hour design storm event

11.1.7 Flooding Assessment of the Lower Nelson Creek

- The lower Nelson Creek, south of Lougheed Highway, is a low-lying area that may be subject to flooding under unusually high Fraser River levels
- The City of Coquitlam is well aware of this condition, and it is prepared with a flood management strategy to deal with such events

11.1.8 Emergency response to Spills and Channel Blockage

- The City's procedures for responding to spills are outlined in its Operations Policy and Procedure Manual (2008)
- Spills on land are blocked from entering the catch basins and watercourses. In the event of substantial spills, additional support is provided by other agencies, the Provincial Emergency Program, Environment Canada, and private contractors
- The City has an Engineering and Public Works Storm Response Plan (2008) to mitigate hazards and property damage during extreme wet weather (including: culvert blockages, floods, and landslides)

11.1.9 Watershed Health

- Nelson Creek is ranked in the lower end of the chart ("poor" health) based on 63 percent TIA and 16 percent RFI under current conditions
- B-IBI scores from each site in the survey area were the same (16). Scores of 10 to 16 are considered "very poor," consistent with the TIA and RFI assessments

11.2 Management Alternatives

11.2.1 Sediment Erosion

- Long-term plan to reduce total volume and peak flow rate
- Routing alternatives to reduce runoff volume and peak flows include community storage units and a diversion pipe
- Total cost for two community storage units to control the runoff from all storm events up to and including the 2-year, 24-hour event would be approximately $ 20 million

- Diversion scheme to direct the runoff from the larger storms out of the upper watershed (north of Austin Avenue). All runoff greater than the 5-year, 24-hour design storm (0.47 m^3/s, 8L/s/ha) is diverted to the lower portion of Nelson Creek (south of Lougheed Highway)
- The diversion will start on Austin Avenue, then run south on Marmont Street up to Brunette Avenue. At Brunette, the diversion will run west until it reaches Nelson Street, where it will run south until it discharges immediately downstream of Lougheed Highway. The cost for this diversion pipe would be approximately $8 million

11.2.2 Rainwater Management

- Rainwater controls in the Nelson Creek watershed should be designed to capture and hold the first 34 mm in a 24-hour period
- The captured volume should be fully infiltrated or released at a control rate during the next 24-hour period
- The maximum release rate from the development site should limit the 2 year post-development peak rate of runoff to 50% of the 2 year pre-development peak runoff
- In the Nelson Creek Watershed, opportunities for implementation of onsite rainwater controls include: upgrading, infill, or redevelopment in existing single-family, multi-family neighbourhoods, redeveloped roads, new large-format retail and neighbourhood centres

11.2.3 Water Quality Strategy

- Rainwater controls (i.e., infiltration trench, rain garden, green roof)
- Hydrodynamic vortex separators as a feasible alternative for water quality control
- Maintain ongoing water-quality monitoring
- Investigate possible cross connections of sanitary and storm sewer systems

11.2.4 Conveyance Capacity Improvement

- Upsize pipes that result in predictions of flooding

11.2.5 Ditch Management

- Alteration to existing ditches, associated to individual property owner (e.g., installation of a culvert to accommodate a driveway) would be addressed through the regular City permitting process
- Habitat compensation options have been identified for large scale redevelopment associated with implementation of the Neighbourhood Plans, where an entire lane would be widened or paved and stormwater infrastructure is installed in place of a ditch

11.3 Recommendations

11.3.1 Sediment Erosion

- Manage high-risk erosion sites on a case-by-case basis
- Divert all runoff greater than the 5-year, 24-hour design storm (0.47 m^3/s, 8L/s/ha) out of the upper watershed (north of Austin Avenue) to the lower portion of Nelson Creek (south of Lougheed Highway)

11.3.2 Stormwater and Rainwater Management

- Adopt the proposed rainwater capture design target to control the first 34mm in a 24 hour period
- Implement the City's Rainwater Management Guidelines

11.3.3 Water Quality

- Develop and implement a monitoring program
- Install water quality treatment units at proposed locations
- Assess and address coliform and nutrient sources (e.g., cross-connections between the sanitary and stormwater systems); this is especially important in upstream areas where the stream is buried and water quality is poorer
- Investigate for possible existence of cross-connections between sanitary and storm sewers that might explain the highly elevated fecal coliform levels (also elevated ammonia, phosphate, cadmium, and copper) in upper Nelson Creek reported in the water-quality study
- Investigate possible detergent pollutants entering the Nelson Creek periodically at the Alderson road culvert near or between its inlet and outfall

11.3.4 Conveyance Capacity Improvement

- Upsize pipes that result in flooding during a 10-year, 1-hour design storm
- Upsize pipes (within the commercial areas) that result in flooding during the 25-year, 1-hour design storm
- Upsize the major collector (between Foster Avenue and Charland Avenue) if these pipes result in flooding during a 100-year, 1-hour design storm
- Upsize in-stream culverts that result in flooding during the 100-year, 1-hour design storm

11.3.5 Riparian Enhancement Strategy

- Restore habitat in areas with extensive growth of invasive species
- Establish fenced covenants through subdivision applications or redevelopment opportunities to protect riparian habitat

- Plant native shrubs and coniferous plus deciduous trees at moderate densities on private and public lands

11.3.6 Fish Habitat Enhancement Strategy

- Daylight Nelson Creek at the Fraser River confluence by creating a treed corridor and channel to the west of the existing alignment
- Remove permanent natural barriers and impassible culverts

11.3.7 Ditch Management Compensation Strategy

- Enhancing riparian vegetation along Lougheed Highway Red classified ditches in Nelson Creek Watershed
- Protecting or providing habitat compensation for lane ditches (Yellow classified ditches) in Nelson Creek Watershed
- Enhance riparian setbacks on Nelson Creek in Mackin Park
- Rehabilitate the mouth of Nelson Creek (City-owned portion of Unit 1 of the proposed design)

11.3.8 Public Education

- Enhance City's website
- Install educational signs at sites that incorporate stormwater management alternatives
- Provide list of recommended native plant species for use in private property
- Encourage residents to implement landscaping techniques that help in rainwater management
- Explore the establishment of a Stream Stewardship Group

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