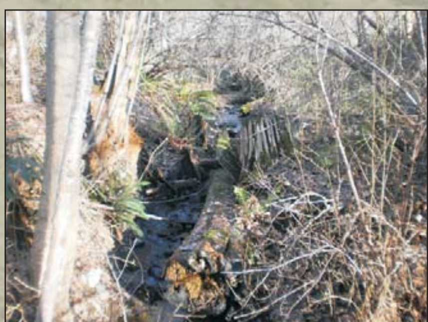
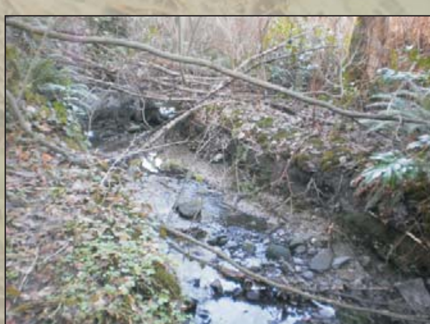
CITY OF SURREY

Lower Bear Creek Park Integrated Stormwater Management Plan





Submitted By:

PARSONS

May 2015
EB3752

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Integrated Stormwater Management Plan

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Contents

1. Introduction

British Columbia's municipalities have a mandate to manage drainage and stormwater systems. Conventional stormwater systems are designed to protect properties from flooding after rainfall events by collecting and safely conveying water downstream. However, as the science of stormwater management evolves, it is becoming increasingly clear that traditional stormwater practices are contributing to waterway degradation and the decline of fish populations. To counter these impacts, Metro Vancouver's municipalities have committed to developing Integrated Stormwater Management Plans (ISMPs) for each of their urban watersheds by 2014. Surrey continues to be a leader in stormwater management and the Lower Bear Creek ISMP is one of 25 watersheds for which Surrey is completing ISMPs.

Before the 1970s, comprehensive urban drainage planning was not completely considered in urban development in Surrey. By the early 1970s, however, drainage had become an issue in the suburban areas and the agricultural lowlands that often were the outlet for stormwater runoff. Water resource management is a longstanding City priority and the City has recently used tools such as Master Drainage Plans (MDPs) Liquid Waste Management Plans, and now ISMPs. Currently in its fifth decade of continuous implementation experience, the City continues to evolve and adapt a watershed-based approach that incorporates lessons learned in getting green infrastructure right.

The Lower Bear Creek ISMP Study Area (**Figure 1.1**) is currently a suburban / agricultural area, containing extensive medium-high density residential areas, as well as agricultural lands which are currently developed as golf courses in the lower reaches of the ISMP drainages. The study area ends at Surrey Lake, just downstream of the 152nd Street Bridge. Much of the study area has been "built-out" for many years with increasing modernization of developments. High development densities result in greater impervious surface cover, which is characteristically accompanied by an increase in peak flow volumes and velocities as well as a decrease in water quality.

The ISMP applies the principles of integrated stormwater management planning to provide the City with guidance in two areas for Lower Bear Creek:

1. **Directing Future Growth:** Providing technical and planning directions for future development and land-use changes to reduce or offset negative impacts of these developments; and
2. **Identifying Improvement Opportunities:** Identifying potential projects that could improve the watershed health that could be implemented in the short and long term.

The study was delivered in four phases with each phase addressing a central question:

Phase 1 – Existing Conditions: "*What do we have?*"
Phase 2 – Visioning: "*What do we want?*
Phase 3 – Implementation: "*How do we put it into action?*"
Phase 4 – Targets and Monitoring: "*How do we stay on target?*"

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Lower Bear Creek Integrated Stormwater Management Plan

Figure 1.1 STUDY AREA

1.1 Report Structure

An ISMP must be accessible to a number of end users including engineers, planners, developers and the public. Therefore it is not being presented like a typical engineering report. The focus of an engineering report is to describe an engineering process, while the focus of this ISMP is to provide direction and insight to the reader. The main body of the report is developed to efficiently provide the reader with the important information needed to understand in implement the recommendations.

Table 1.1: Report Structure and Delivery

	Report Section	Description
1	Introduction	Provides an overview of the location and scope of the study and introduces the reader to the structure of the document
2	Plan Summary	Summarizes the recommendations of the ISMP. This is the equivalent of an executive summary for those readers not requiring a greater level of detail.
3	ISMP Principles	Provides an overview of the main principles of integrated stormwater management planning.
4	Watershed Existing Conditions	Documents the existing conditions of the watershed including current land use, creek habitat, erosion, current stormwater management infrastructure and green spaces.
5	Vision	Outlines how the watershed should be developed in the future.
6	Analysis and Recommendations	Provides the background and technical information used to developing the recommendations.
7	Monitoring	Outlines how to track the watershed health and effectiveness of the implementation of the ISMP.

2. Plan Summary

This section of the report summarizes the specific plan items for the Lower Bear Creek ISMP. The details of why and how those plan items were developed are found in Section 6 of this report.

The recommendations for an ISMP are ultimately dictated by the physical and community setting of the watershed. In watersheds where large-scale development is planned the ISMP must provide guidance on how land development should take place. In watersheds where flooding is an issue the ISMP must provide recommendations on flood protection and management measures required to ensure that Surrey is safeguarding public and private infrastructure. In watersheds where groundwater is used for drinking water the ISMP must address how stormwater measures can protect groundwater quality. In the same way, the ISMP for Lower Bear Creek has been created to provide recommendations that address the issues of Bear Creek specifically.

Lower Bear Creek is not a watershed defined by urgent problems. There are no major flooding issues noted. Erosion in general is not posing a hazard to public or private infrastructure. Watercourses are generally set within riparian areas and the watercourse health is good given the state of development in the watershed. There is no major land development expected to occur in the watershed. Therefore the recommendations of this ISMP are opportunity driven, and are as follows:

Recommendation 1: Prepare for densification within the Lower Bear Creek catchment by requiring development to mitigate the impacts of stormwater runoff by meeting performance requirements.

1. No net increase in volume of runoff from pre-development conditions.
2. Remove 80% of total suspended solids from stormwater.

This is in addition to stormwater management requirements outlined in the existing City of Surrey guidelines.

See section 6.1.1 for more details.

Recommendation 2: Implementation of a long-term program that will move towards requiring single residential lots to implement BMPs on site at time of redevelopment. BMPs would be similar to larger-scale densification projects – no net increase in runoff and removal of 80% of total suspended solids.

This long-term program should be developed with involvement of City of Surrey staff from all affected departments. It would be implemented through the building permit process rather than the planning process.

See section 6.1.2 for more details.

Recommendation 3: Within existing wildlife corridors remove barriers or allow for improved movement when the area is impacted by new construction or infrastructural renewal. Avoid creation of new barriers to wildlife movement.

See section 6.1.3 for more details.

Recommendation 4: Identify and secure new wildlife corridors along Price and Enver Creeks if re-development begins to occur in the area.

See section 6.1.3 for more details.

Recommendation 5: Develop new roads and road rehabilitation design guidelines to include a minimum of 25% reduction in total flows using green infrastructure. Stormwater quality BMPs would be required to limit total suspended solids to 20% of pre-development state.

See section 6.2.1 for more details.

Recommendation 6: Approach golf course owners to include improvement of Riparian Corridors in their long range plans. Assist in developing a plan that encourages natural vegetation planting and maintenance along the creek, planting of trees to enhance shading, and facilitates environmentally friendly maintenance procedures in these areas.

See section 6.2.2 for more details.

Recommendation 7: Initiate a site-specific design to review and restore the riparian areas and headwall at 76A Ave near 138 St. The estimated cost of the project is $25,000.

See section 6.2.2 for more details.

Recommendation 8: A site specific d near Hunt Brook headwater storm outfall to combine storm outfalls and create a small pond or wetland. The estimated cost for the project is $45,000.

See section 6.2.2 for more details.

Recommendation 9: Replace culvert at existing trail at 78 Ave between 145A St. and 146 St. with bridge or fish baffled culvert to improve fish passage upstream. The estimated cost for the project is $40,000.

See section 6.2.2 for more details.

Recommendation 10: A pilot project to retrofit two existing dry ponds to provide better water quality treatment and erosion control. If successful this pilot project could be expanded into a retrofit program to target existing dry ponds that could be providing more stormwater benefits:

- Retrofit the existing dry pond at 144 Street and 92 Avenue (Pond 3) in the headwaters of Enver Creek to construct an enhanced swale and sediment forebay. The estimated construction cost of this pilot project would be $50,000.
- Retrofit the existing dry pond at 146 Street and 85A Avenue (Pond 1) as a wet pond / wetland project. The estimated construction cost of this pilot project would be $125,000.

See section 6.2.3 for more details.

Recommendation 11: Consider large stormwater detention facilities for existing communities as a long-term possibility to be tied to future redevelopment.

See section 6.2.4 for more details.

Recommendation 12: The high flow diversions suggested by the 1998 Master Drainage Plan are not required.

See section 6.2.4 for more details.

Recommendation 13: Culvert replacement should be based on operating experience and specific issues at particular locations. Culvert size should be maintained or upgraded with similar sized culverts. If flows increase in the future due to climate change then additional overflow conveyance can be installed above the existing culverts.

See section 6.2.5 for more details.

Recommendation 14: Create a layer on COSMOS that highlights existing stormwater BMPs installed in Surrey. Provide information on the projects and encourage people to visit.

See section 6.3.1 for more details.

3. ISMP Principles

Stormwater Planning: A Guidebook for British Columbia (May 2002) and the *Metro Vancouver Template for Integrated Stormwater Management Planning* (December 2005) provides a framework for effective stormwater management throughout the Province. It establishes the framework for rainfall capture and a design approach based on performance targets. In 2007 the Inter-Governmental Partnership and the Green Infrastructure Partnership collaborated to produce *Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia*. Now that practitioners are comfortable with the concepts of 'rainfall capture' and 'source control', local governments and developers are turning their attention to achievable outcomes and results that have net environmental benefits for the watersheds. Together, these two publications bring some of the key ideas behind rainwater management into the local BC context.

The following four fundamental principles from these publications will guide the analyses, discussion and implementation of this ISMP:

- Account for the full spectrum of rainfall events;
- Use performance targets;
- Allow for adaptive management as our knowledge and understanding of the watershed increases; and
- Integrate the ISMP with the City's planning documents.

3.1 Full Spectrum of Rainfall

The understanding in integrated stormwater planning is that, within the rainfall spectrum, light rainfall events account for the majority of the annual rainfall. This understanding of the rainfall spectrum is fundamental in framing discussions about integrated stormwater management solutions. It creates a language of stormwater / rainwater management that is used to deal with each type of event within the spectrum. **Table 3.1** shows the different management objectives for each type of rainfall event.

Table 3.1: Rainfall Management Objectives

Rainfall Type	Range	Design Objective	Description
Light	< 30 mm	Rainfall Capture	Keep rain on site by means of 'rainfall capture' measures such as rain gardens and infiltration features
Heavy	30 – 60 mm	Runoff Control	Delay overflow runoff by means of detention storage ponds which provide 'runoff control'
Extreme	> 60 mm	Flood Mitigation	Reduce flooding by providing sufficient hydraulic capacity to 'contain and convey'

3.2 Performance Targets

Performance targets are required to move from integrated stormwater planning to implementation. They provide the necessary direction with flexibility for designers to adapt solutions in the future. Performance targets can be applied at either the site level or the watershed level and they provide local government staff and developers with practical guidance for development.

For a performance target to be implemented and effective, it must be quantifiable. It must summarize the complexity of the rainfall-runoff requirements into a single number that is simple to understand. Performance targets based on runoff volume fulfill these criteria. For example, a performance target for a residential lot in a new development may be to increase rainfall capture so that a 25 mm rainfall event will result in no site runoff.

3.3 Adaptive Management

Adaptive management is an iterative decision making process that is used in uncertain circumstances. In the context of integrated stormwater management, the aim of adaptive management is to reduce uncertainty and risk over time by monitoring the outcomes of decisions and adapting accordingly. Adaptive management acknowledges that we do not have all the answers for every watershed. Instead, we can apply Best Management Practices (BMPs) based on available science, and then monitor the impacts. A monitoring plan is developed to track key indicators within the watershed. As we observe the effectiveness of each BMP, the overall approach can be adapted to modify or reject various practices. That is why an ISMP is not a rigid document but rather has flexibility built in and is revisited as our knowledge of the watershed grows.

3.4 Integration with Planning Documents

An ISMP is a planning document based on a scientific study of an area consisting of one or more watersheds. ISMPs are most appropriately linked to a municipality’s key planning documents such as the Official Community Plan (OCP) and Neighbourhood Concept Plans (NCPs). The OCP describes the fundamental philosophy and principles behind the policies for future growth in the community. The NCPs reflect this philosophy in greater detail for individual neighbourhoods. Correspondingly, the ISMP describes the policies and principles behind the protection of natural creeks, wetlands, and other features dependent on rainfall and the natural hydrologic cycle, as well as aquatic and terrestrial ecosystems of value to the community.

The analyses and details presented in the ISMP must be consistent with the objectives outlined in other planning and policy documents. The concept is that there are linkages in both directions between engineering and planning documents that highlight the “living” nature of these documents and the ongoing need to update them. Significantly, the Sustainability Charter is shown as the overarching document governing all planning in the City and the OCP already provides some direction for the watershed.

4. Watershed Existing Conditions

Bear Creek watershed is one of the largest urban watersheds in Surrey and Bear Creek is the largest single tributary to the Serpentine River. The Serpentine River drainage basin is approximately 144 km^2 almost entirely within the City of Surrey. A small portion of the upper catchments are in the Township of Langley and the Corporation of Delta. The Serpentine River is fed by three main tributaries: Latimer Creek, Bear Creek and Highland Creek. **Figure 4.1** shows the study area location and the watershed context within the overall Serpentine River.

The Bear Creek Watershed itself has been divided up into three watersheds by the City for the purpose of implementing ISMPs. Quibble and Cruikshank / Grenville are both upstream catchments to the Lower Bear Creek watershed. The Lower Bear Creek ISMP will cover the lower 50% of the Bear Creek watershed. Within Lower Bear Creek, the main stem of Bear Creek runs from the Northwest to the south east. There are a number of tributaries to the main stem. **Figure 4.2** shows these streams and their sub-catchments. The lowland agricultural area and Surrey Lake were not included in the study area and may be part of a future study by the City of Surrey. For the purpose of this ISMP the study area ends at the crossing of 152nd Street.

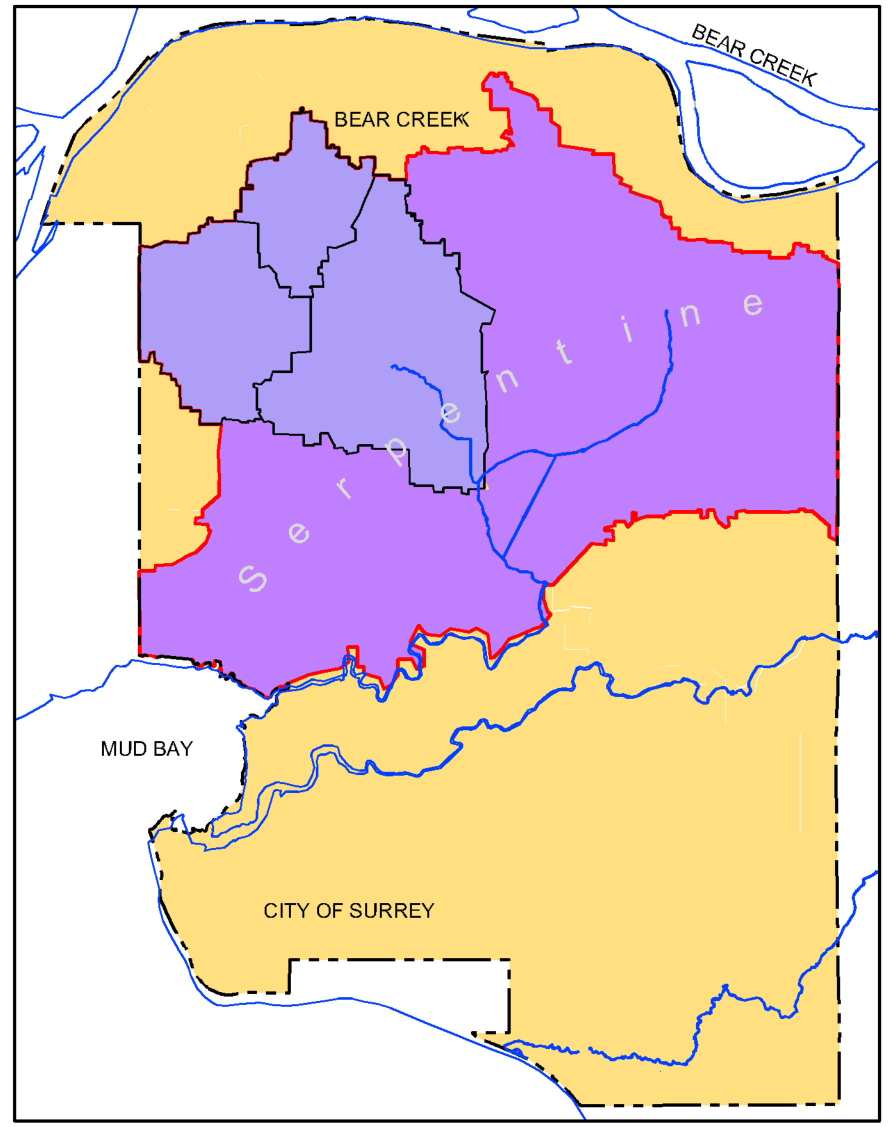
It is important to note that while the study is focused on a defined area, the nature of an ISMP is that it is watershed based, and therefore an awareness of the areas above and below the study area is required. The recommendations of the study will however focus on the study area.

This section of the report documents the existing conditions of the study area including the following:

- **Section 4.1:** A review of background documentation;
- **Section 4.2:** An overview of past, present and future land use conditions;
- **Section 4.3:** A discussion of the significant watershed features;
- **Section 4.4:** An overview of the hydrology within the watershed; and
- **Section 4.5:** A summary of the environmental conditions.

Study Area Context
Figure 4.1

SURREY VICINITY MAP



SERPENTINE SYSTEM

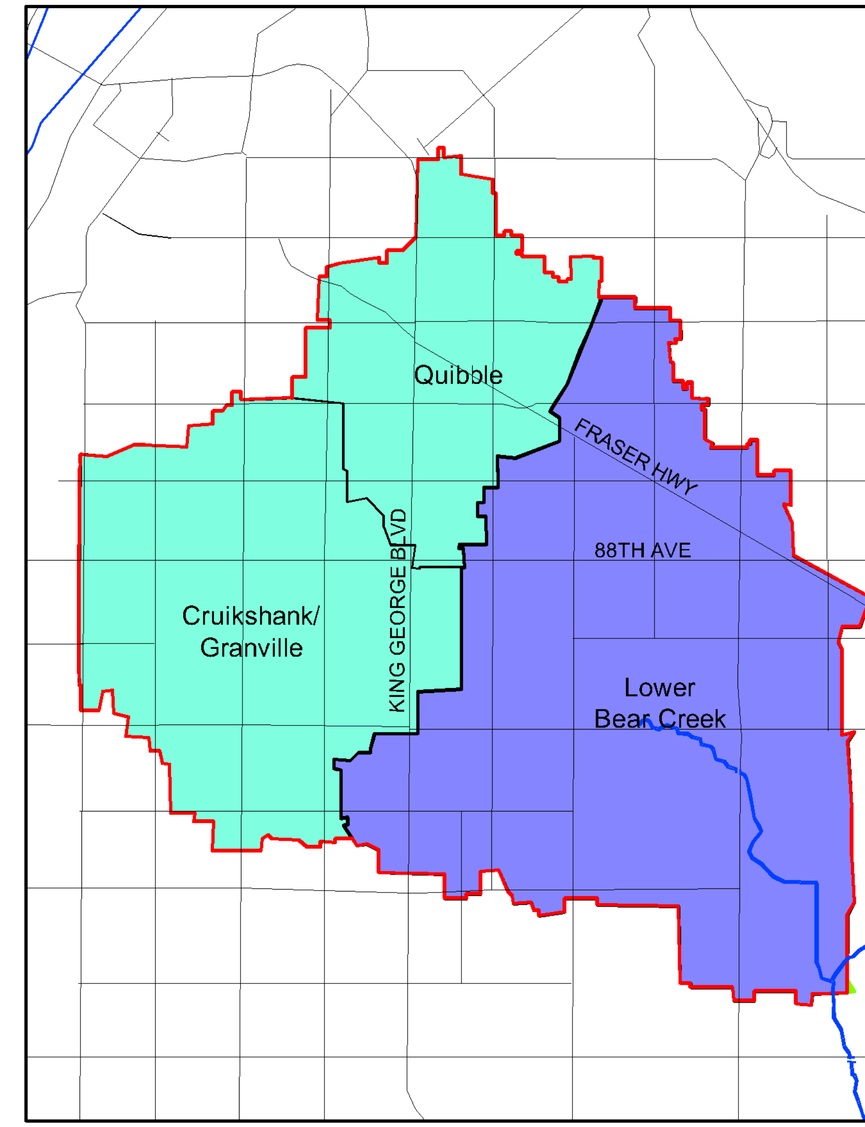


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Figure 4.2-A
Sub-Catchments

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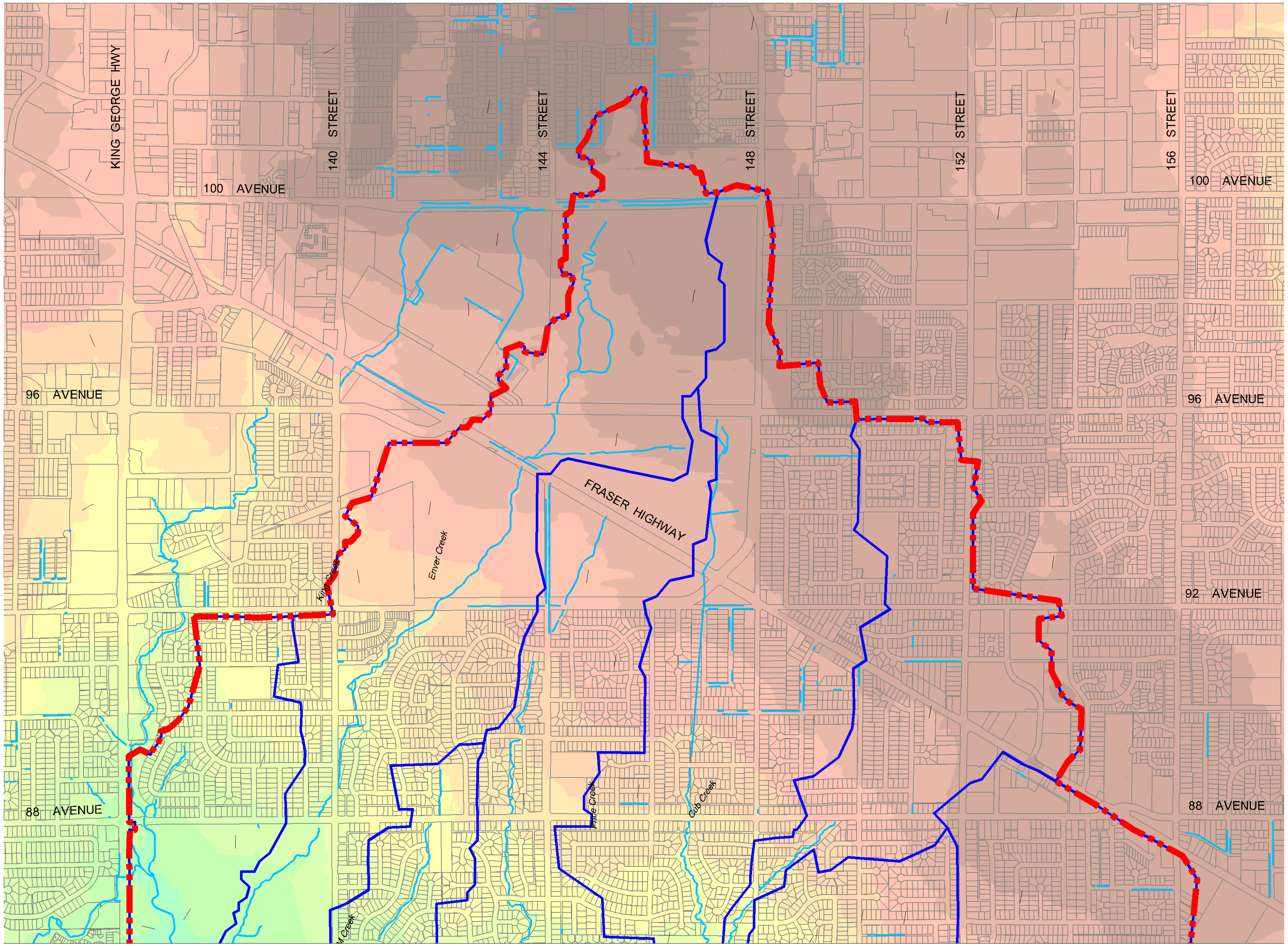

FOR CONTINUATION SEE FIGURE B

LEGEND:

- Study Boundary
- Watershed Sub-Boundary
- Streams

Elevation Range (Metres)

-1 to 7.5	37.5 to 45	75 to 82.5
7.5 to 15	45 to 52.5	82.5 to 90
15 to 22.5	52.5 to 60	90 to 97.5
22.5 to 30	60 to 67.5	97.5 to 105
30. to 37.5	67.5 to 75	105 to 112

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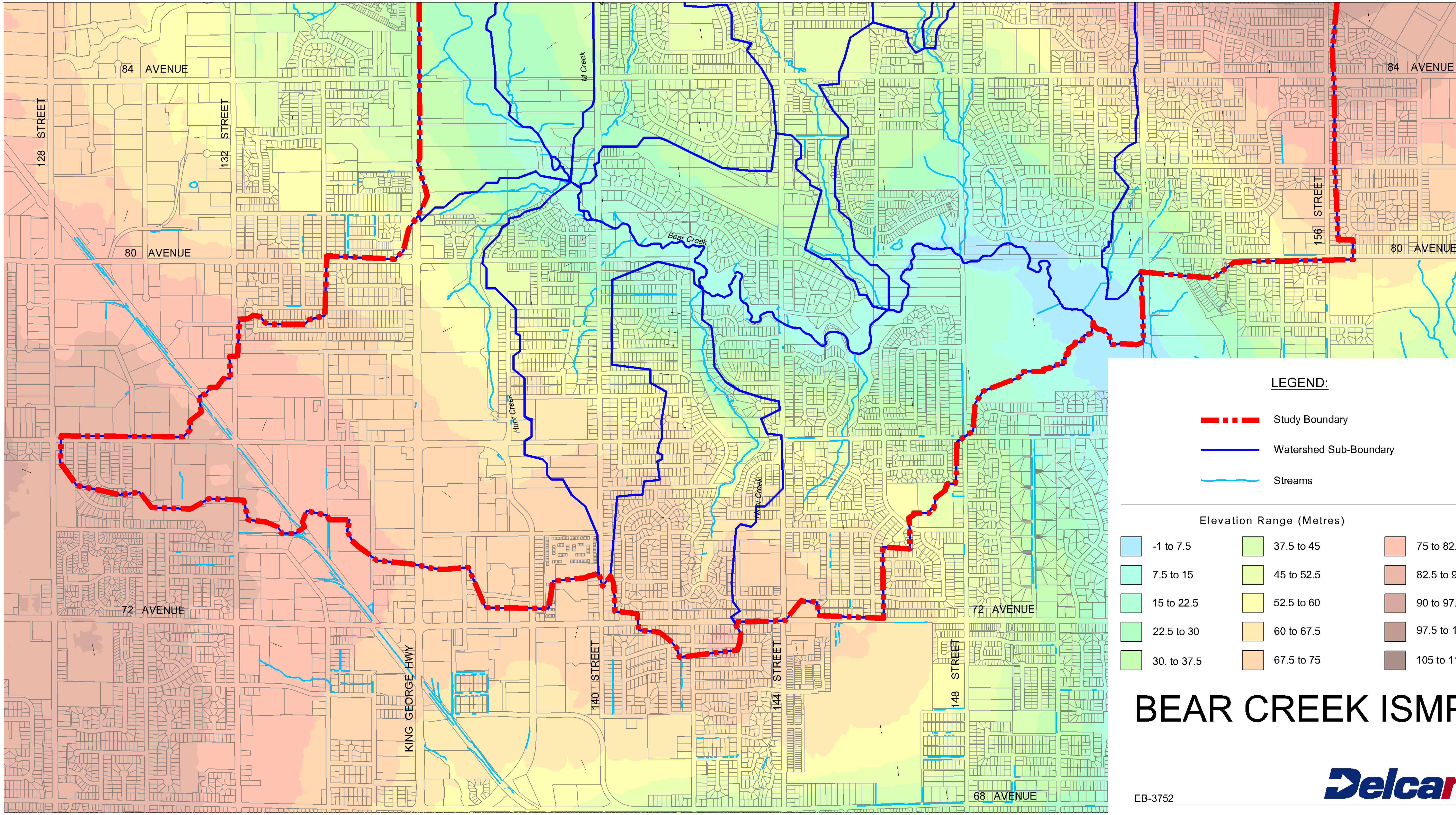
Figure 4.2-B
Sub-Catchments

FOR CONTINUATION SEE FIGURE A



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4.1 Background Reports

A number of background reports are available for the study area. These documents, listed in the reference at the end of this document, were reviewed to determine relevant information for this ISMP. Key reports that have contributed to the content of this ISMP are discussed below.

4.1.1 Bear Creek Master Drainage Plan (1997-1999)

Much of the engineering study on stormwater management occurred during the late 1990s through the Master Drainage Plan (MDP) study. This study delivered a number of reports and addressed several relevant issues. The study area included all of Bear Creek, including the Quibble and Cruikshank-Grenville watersheds.

The stated purpose of the study was to provide the City with a strategy to resolve potential conflicts between protecting private property, allowing economic land use and sustaining the natural value of stream corridors. The study occurred during the early years of Integrated Stormwater Management Planning.

A number of recommendations were made for high-flow diversions. These were designed to protect reaches of creeks by diverting high flows around the creeks. Seven of these were recommended in the Lower Bear Creek area including one major trunk running from King George Highway to 148th Street. To date none of these have been built, and are not included in the 10 Year Servicing Plan. They would be expensive, and the MDP does not present a strong cost-benefit case for making the improvements. During the implementation plan section of this ISMP, high flow diversions and detention ponds have been investigated and their cost-benefit evaluation will determine if they should be carried forward.

A number of new storm detention ponds were also proposed for the study area. These recommendations have also not been implemented, as none of the ten ponds recommended in the MDP study have been constructed or remain in the 10 Year Servicing Plan.

The MDP culminated in an extensive series of recommendations for culvert upgrades, storm diversions and stormwater ponds. Some of the investigation performed during the MDP will prove valuable in the preparation of the ISMP, although many of the recommendations ultimately proved to be difficult to justify against competing municipal projects the recommendation are discussed in Section 6 of this report.

4.1.2 Impact of Urbanization on Groundwater Recharge and Watercourse Base Flows

This hydrogeological analysis by Piteau Associates was completed within the Master Drainage Plan project, and involved collation and interpretation of available data in sufficient detail to develop a conceptual model of groundwater flow systems in the Bear Creek watershed. The report provides insight into groundwater recharge and base flow relationships. There was a finding that groundwater recharge in the area was generally low due to low permeable underlying soils and that 80% of rainfall eventually becomes runoff. The report also found no evidence of declining base flows due to urbanization within the period of record for the data available (1960 to 1985). This is contrary to what is generally expected in urban watershed and suggests that the streams naturally have a lower influence from groundwater and are more highly influenced by surface water or interflow (near surface water).

4.1.3 Ravine Stability Assessments (2009, 2007, 2005)

The City of Surrey completes a ravine stability assessment every two years where all ravines in the City are inspected and all erosion zones are documented and classified. Any sites that have significant erosion are further examined by a Professional Engineer, and remedial actions recommended by the Engineer are undertaken. The City's latest report was for the year 2009. It identified over 200 sites within the study area, but most were deemed low risk. The state of erosion within the study area is discussed in further sections of this report.

4.1.4 Bear Creek Erosion Study Project # 4898-712

In April 1998 the City of Surrey enlisted Dillon Consulting Limited in association with Esse Nova Consultants Inc. to conduct a detailed assessment of the Bear Creek Channel within the vicinity of the City's Bear Creek Park located near King George Highway and 88 Ave. This study was initiated in direct response to reported bank and channel instabilities identified in this area by both the earlier 1996 Bear Creek Watershed Master Drainage Plan Study (MDP), and by field inspections conducted by City of Surrey personnel. Importantly these reports had identified potentially serious threats to the City's sanitary sewer alignment located in the vicinity of the Bear Creek Channel. The report recommended erosion protection works for high, medium and low risk areas. It also recommended ongoing monitoring of this reach of the creek and the area continues to be a potential concern for the City of Surrey.

4.1.5 Bear Creek Trunk Stability Review

This report, completed in 2008, followed up on the issue discussed in the document above. Associated Engineering investigated 60 potential erosion sites along the same reach of Bear Creek, seven in the vicinity of the sanitary sewer. Ultimately, none of the sites were deemed high risk. The report recommended some rip-rap protection and ongoing monitoring.

4.1.6 Sustainability Charter

The City of Surrey has developed a Sustainability Charter, which is an overarching policy document to guide the City's approach to socio-cultural, environmental, and economic sustainability. It is a living document that will establish high-level principles to direct all future initiatives. Future planning and engineering documents will be required to consider the Sustainability Charter, which contains goals regarding transportation, employment, lands, community services, environmental protection and land development. Most relevant to the ISMP are the goals that could impact creeks and drainage systems. Some of the rainwater / stormwater-specific goals that influence the ISMP are listed below:

- Protect the integrity of the City's ALR and industrial land base for food production, employment and agri-business services that support the local economy. Work with these sectors to find ways to enhance the productivity of ALR lands in Surrey;
- Respect natural areas and minimize the impacts of economic activities on the environment;
- Promote environmentally friendly businesses and "green" building practices;

- *Terrestrial Habitat and Life:* Create a balance between the needs of Surrey's human population and the protection of terrestrial ecosystems;
- *Water Quality / Aquatic Habitat and Life:* Protect Surrey's groundwater and aquatic ecosystems for current and future generations; and
- *The Built Environment:* Establish a built environment that is balanced with the City's role as a good steward of the environment:
  - Minimize the impacts of development on the natural environment;
  - Promote the use of native species and reduce the impact of invasive species;
  - Promote permeable surfaces where possible in new developments;
  - Incorporate opportunities for natural areas and urban wildlife; and
  - Protect unique and valuable land forms and habitats.

The Sustainability Charter reinforces some of the principles of integrated stormwater management. This helps add weight to the ISMP's recommendations as City Council has already indicated that sustainable stormwater and riparian management is important.

4.1.7 Sustainability Charter – Progress Report

In May of 2011, the City of Surrey completed an update to City Council on the progress made on the goals outlined in the Sustainability Charter. It is worth noting that stormwater was not mentioned in the summary report to Council. However, it was mentioned in the body of the report that the City has introduced standards for absorbent top soil cover on private yards in new development and rainwater infiltration systems in city boulevards.

4.1.8 Official Community Plan

The OCP is a statement of objectives and policies to guide City planning decisions, on land use and development in Surrey in order to achieve orderly growth for complete sustainable communities with sensitivity to the environment. Taking a comprehensive and long-term perspective, the plan provides guidance for the:

- Physical structure of the City of Surrey;
- Land use management;
- Industrial, commercial and residential growth;
- Transportation systems;
- Community development;
- Provision of City services and amenities;
- Agricultural land use;
- Environmental protection; and
- Enhanced social well-being.

The OCP was adopted by City Council under By-Law No. 12900 and is reviewed on an annual basis with major reviews taking place every 10 years. It establishes general land use designations, policies to guide development and includes a map illustrating land use designations for each parcel of land in the City. For each designation, the plan also documents allowable zoning categories and maximum allowable density to guide the preparation and implementation of secondary plans such as Local Area Plans and NCPs.

The OCP contains several policies that relate to the ISMP. Of particular relevance are those policies that impact stormwater management and riparian protection. These policy statements express the City's desire to manage stormwater and fish habitat in an environmentally sustainable way. The ISMP must incorporate these principles in order to stay aligned with the City's priorities.

4.1.9 10 Year Servicing Plan

The objective of the 10-Year Servicing Plan is to establish a program of municipal engineering infrastructure works and services that are required to meet the needs identified under the Official Community Plan and Neighbourhood Concept Plans approved by Council. The Servicing Plan identifies the costs to provide transportation, drainage, water, and sanitary sewer services for both the existing population and the projected growth in population for 2012 to 2021.

The 10-Year Servicing plan contains recommendations from past ISMPs and the next update will consider new recommendations from recently completed ISMPs.

Stormwater and Environmental Works

There are currently no major storm network construction or improvement projects planned within the Lower Bear Creek study area. There are seven erosion related works proposed in the plan, stemming from the Ravine Stability Assessments. There is one short term project near 7867 - 144 St that is expected to be implemented within the next 1-3 years. The remaining projects are medium or long term.

Related Transportation Projects

There are three proposed road widening projects that may present an opportunity for the ISMP. They are listed in the 10-Year Servicing Plan, and are shown in the below table.

Table 4.1: Transportation Projects in the 10-Year Plan

Surrey ID#	Type	Location	Priority	Estimated Cost ($)
11830	Arterial Widening	140 St: 88 Ave - 92 Ave	Short Term (1 - 3 Yrs)	8 ,000,000
12147	Collector Widening	76 Ave: 148 St - 152 St	Short Term (1 - 3 Yrs)	969,000
2804	Arterial Widening	92 Ave: 140 St - 144 St	Long Term (7 - 10 Yrs)	4 ,522,000

Understanding of these projects and awareness of their proposed timing allows for coordination of ISMP recommendations before and during construction.

4.2 Land Use

A critical component of any ISMP is to understand how past, present and future land use impact hydrology. Current OCP land use is shown on **Figure 4.3**.

4.2.1 Past and Present

The current land use of the study area is predominantly urban residential. A very large portion of the area is public land in the forms of rights-of-way (ROWs) and parks. There is some lower density suburban residential land along the Bear Creek alignment. There is some industrial land in the upper portion of the Hunt Creek catchment and a large portion of the upstream Cruikshank-Grenville ISMP area is also industrial. There is some denser residential land used, primarily along King George Boulevard. The golf course in the south-east of the study area is zoned for agricultural land use. Within the private lot ownership, the breakdown of zoning is presented in the table below and shown in **Table 4.2**.

Table 4.2: Breakdown of Land Ownership and Land Use

Ownership	Area (ha)	Area (%)
Private	1016.9	59%
ROW	310.7	18%
Parks and City Land	387.5	23%

Category	Percentage
Urban Residential	63%
Suburban Residential	20%
Multi-Unit Residential	4%
Industrial	6%
Commercial	3%
Agriculture (Golf Course)	4%

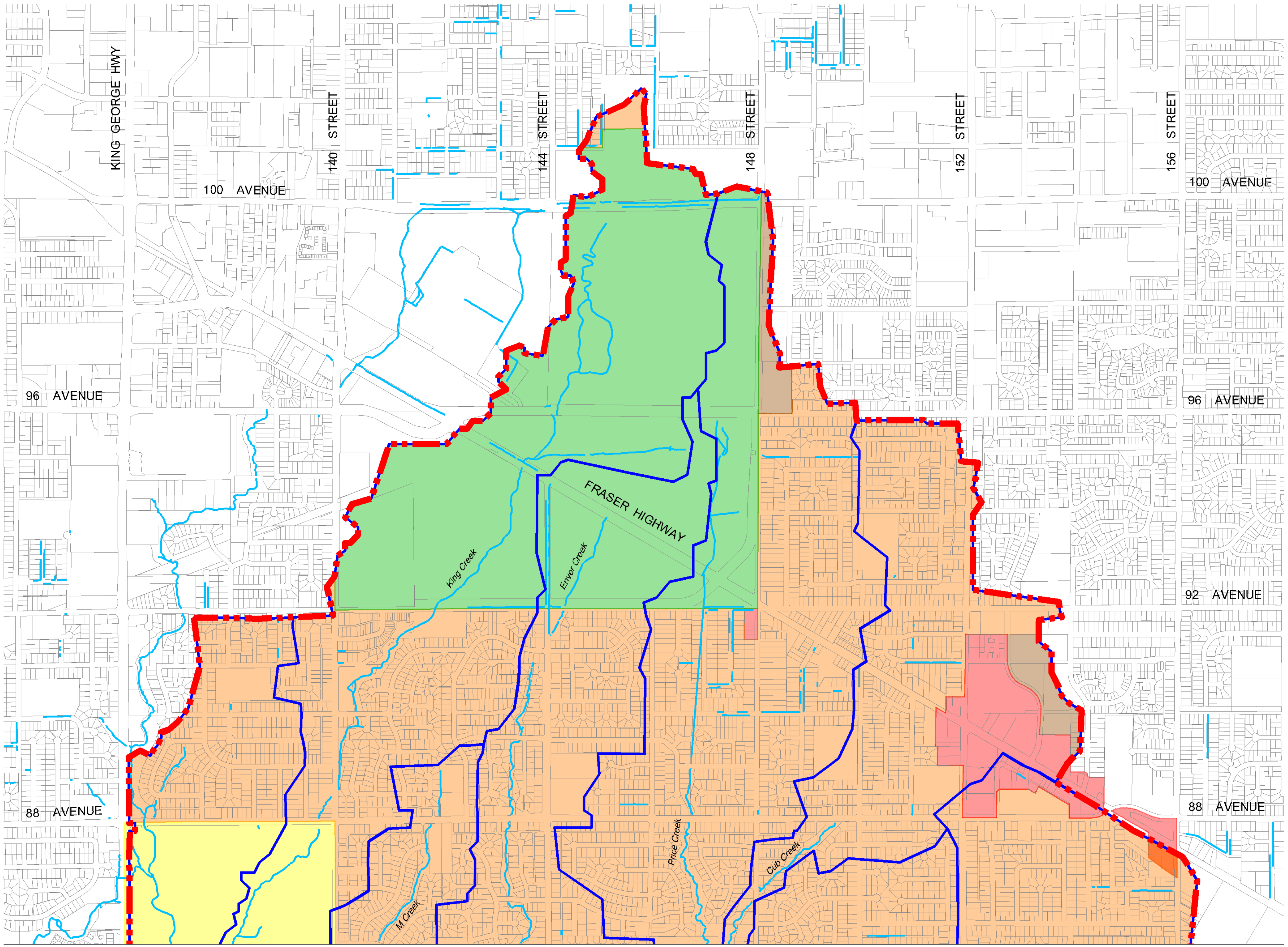
There are 9500 private lots in the study area. Almost all of these lots have been created over the last 50 years. In the 1950s, development was focused in two areas; north of the study area, along Fraser Highway and to the south-west in the community of Newton. In the 1960s, relatively few lots were created, and then in the 1970, 80s and 90s the development spread from the north and the south toward the main stem of Bear Creek (**Figure 4.4**).

Table 4.3: Age of Lots

Age of Development	Percentage of Lots Created
Before 1950	1%
1950	14%
1960	1%
1970	23%
1980	28%
1990	20%
2000 to present	13%

This development pattern is roughly consistent with developing the headwaters of Bear Creek tributaries first. In the 1970s, City of Surrey drainage engineers first started completing Master Drainage Plans. This resulted in a stormwater ponds being a requirement of new development. Timelines of the residential development and the thinking in stormwater management practices is apparent by viewing where the ponds have been installed. Most of the ponds are installed partially down the tributary catchments with relatively few ponds in the upper headwaters.

Figure 4.3-A
Official Community Plan



FOR CONTINUATION SEE FIGURE B

LEGEND:

- Agricultural
- Commercial
- Conservation
- Industrial
- Multiple Residential
- Suburban
- Town Centre
- Urban
- Study Boundary
- Watershed Sub-Boundary
- Streams

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Figure 4.3-B
Official Community Plan

FOR CONTINUATION SEE FIGURE A

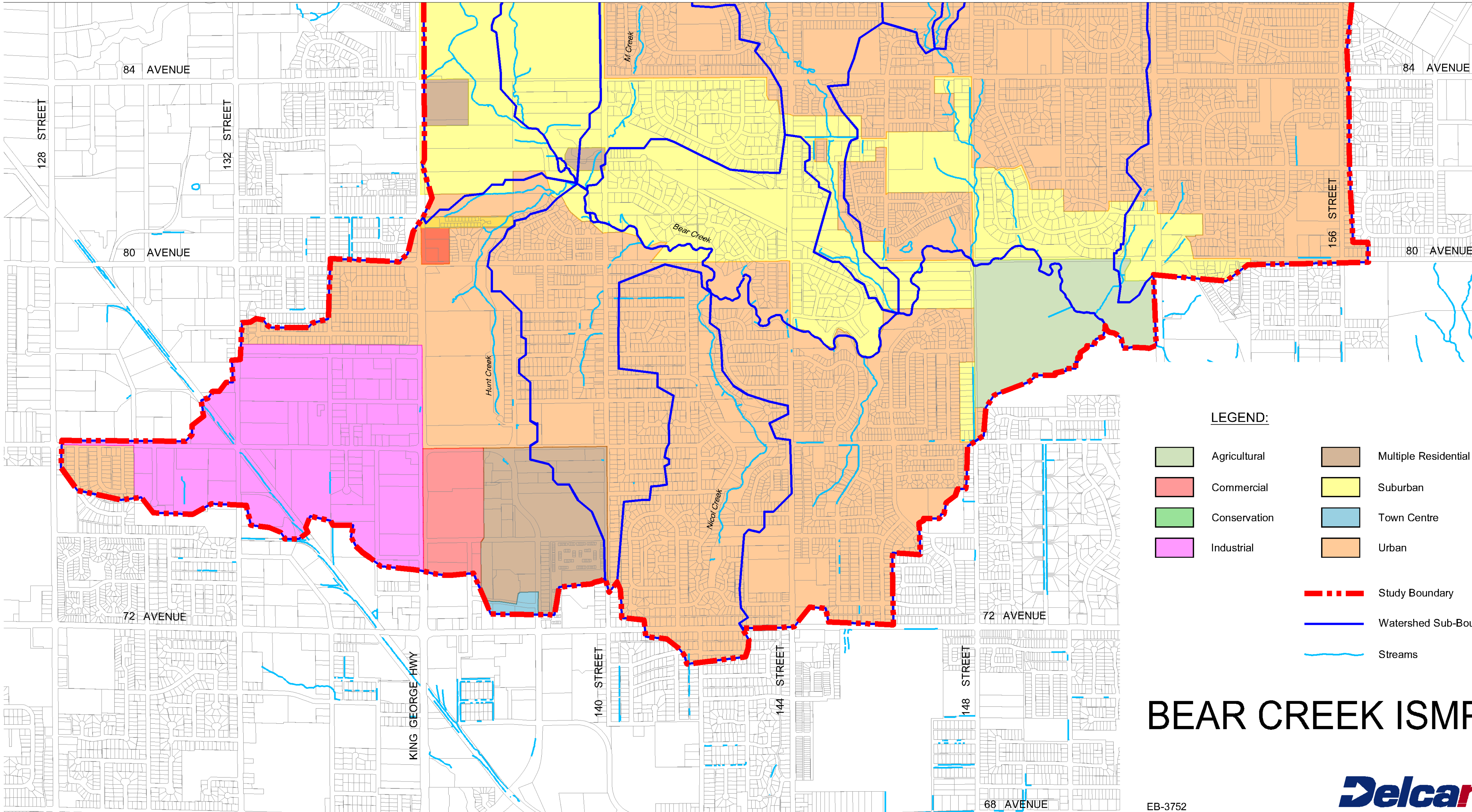

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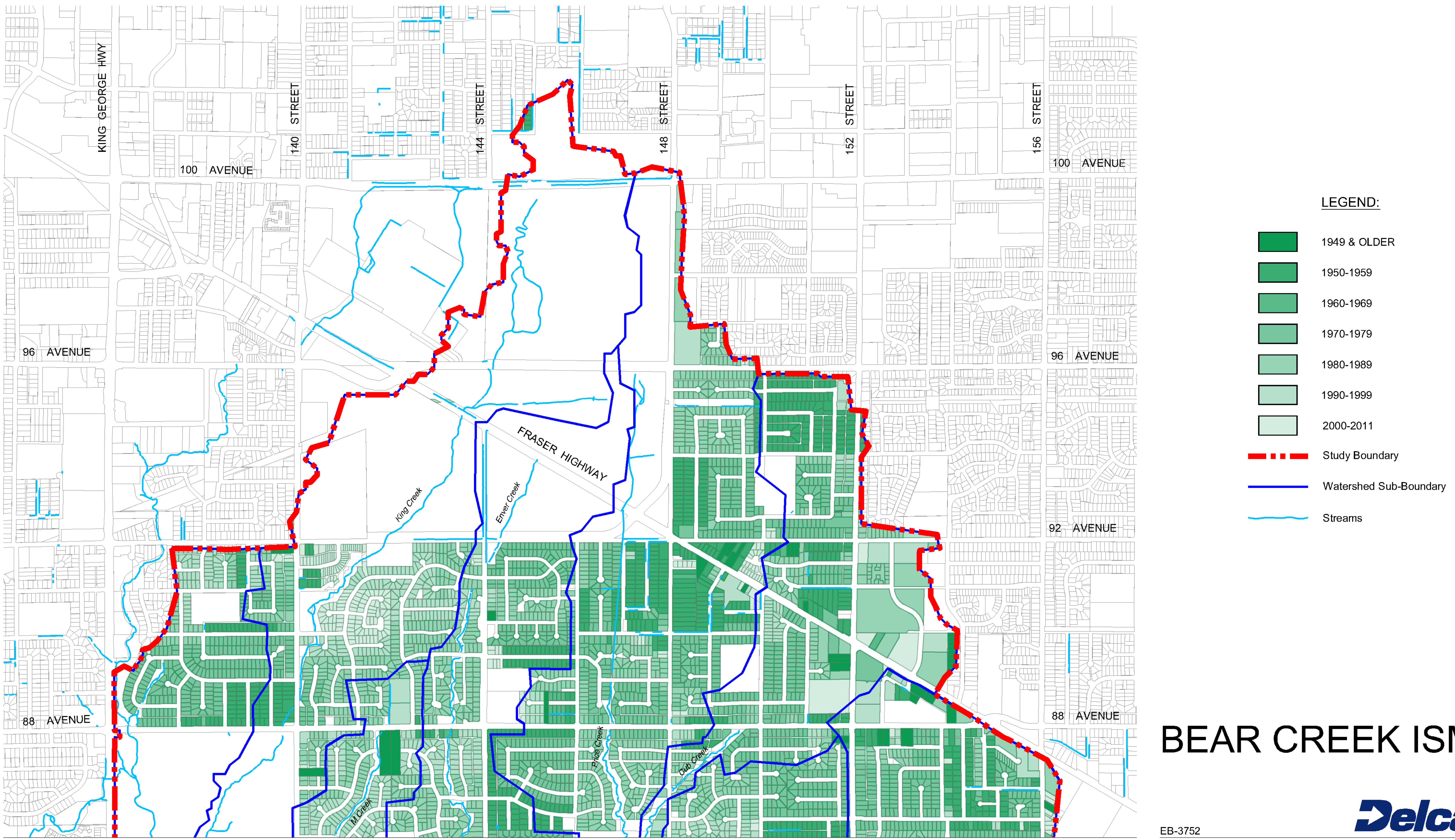
Figure 4.4-A
Age of Development



FOR CONTINUATION SEE FIGURE XX

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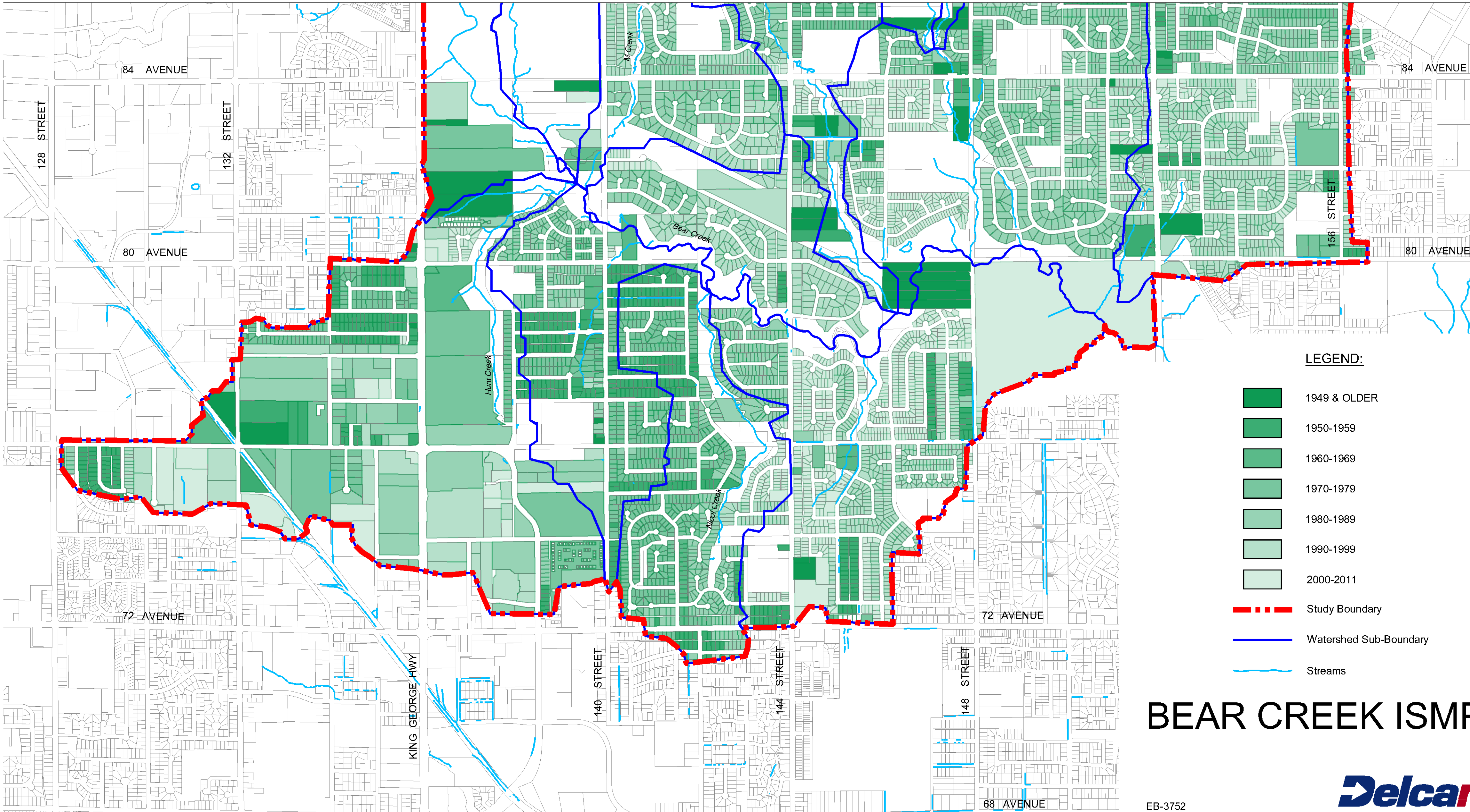
Figure 4.4-B
Age of Development

FOR CONTINUATION SEE FIGURE XX



LEGEND:

- 1949 & OLDER
- 1950-1959
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-2011
- Study Boundary
- Watershed Sub-Boundary
- Streams

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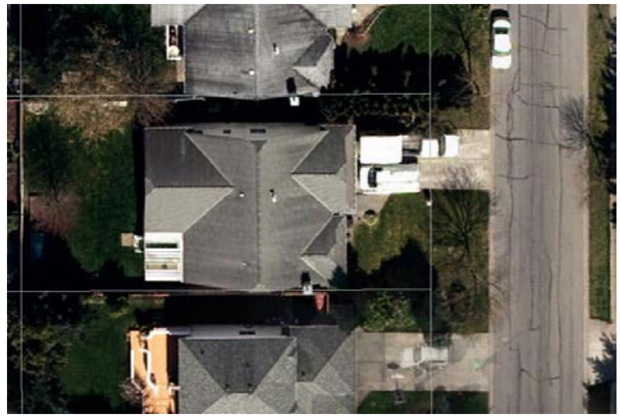
Although more than 50% of the lots were created since 1980, only 32% of the entire residential area within the study area is contained within the catchment areas of these existing offline stormwater ponds. The remaining lots either drain uncontrolled to the creeks or have on-lot stormwater controls. Given that on-site stormwater low impact development measures are a relatively new practice, it is anticipated that most lots are uncontrolled. Pond coverage is discussed more in subsequent sections of this report.

The age of development is also very important for understanding the overall impervious area within the watershed. The series of photos below illustrate how development practices have changed over the course of development of the Bear Creek study area. As can been seen, the development from 1950 to the 1970s was relatively constant. A lot size of 750 square metres would have a house covering about 120 square meters (15-20% lot coverage) and 75 square metres covered by driveway. In the 1980s, the lot size remained the same but the house coverage roughly doubled to 275 m^2 (30-40% lot coverage). In the last 15-20 years, the trend in development is to reduce lots size and maximize building size. In the areas of Bear Creek that were developed in the 1990s, lots were 370 m^2 and houses were 175 m^2.

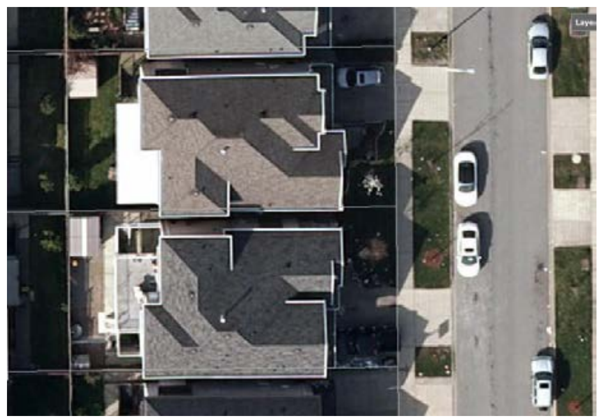
1950s – Typical House and Lot

1970s – Typical House and Lot

1980s – Typical House and Lot



1990s and 2000s – Typical House and Lot



4.2.2 Future Land Use Changes

An important part of the development of an ISMP is to understand how existing planning documents govern land development and planned infrastructure upgrades. An ISMP must have a two-way link with the City's relevant planning documents, meaning that the existing planning documents provide input into the ISMP and the ISMP provides recommendations for revisions to the existing planning documents and for the preparation of new planning documents.

There are no Neighbourhood Concept Plans (NCPs) active in the study area. The East Newton North Neighbourhood Concept Plan covers a portion of the study area, but development has been almost completed. The 2011 OCP update indicated that only 185 units remained from the 2500 unit allocated in the NCP.

Future development could likely take the form of densification of existing lots from smaller homes to larger homes. 60% of residential development occurred during a time period where lot coverage ranged from 30% to 40% or higher. The current zoning bylaw allows maximum lot coverage of 40% for typical residential lots, so single lot reconstruction is not expected to be a major factor for the more recently developed subdivisions. However, 40% of area was developed prior to 1980, so some of these lots many be redeveloped to have higher lot coverage.

The study area has over 800 lots that are designated suburban and developed to a low density. This represents about 15% of the watershed area. While some of these parcels will not likely be redeveloped because of lot constraints, some of those parcels may see applications to convert to higher density land use such as single family urban or strata development. Although each lot will be examined separately, it is possible that many of these applications could be supported by the City to be in line with densification trends of urban development that are common within Surrey and throughout the Lower Mainland.

Future densification along major transportation corridors of King George Highway and Fraser Highway, and possibly 152nd Street is expected, as the City works toward meeting density targets for transit service. This will likely include the conversion of single family residential lots to multi-unit residential lots.

4.3 Watershed Features Overview

ISMPs are generally prepared and implemented on a watershed or sub-watershed basis. As shown previously in **Figure 4.2**, the Lower Bear Creek ISMP study area can be broken into a number of sub-catchments that feed into tributaries to the main stem of Bear Creek. The following is a brief overview of the characteristics of some of the important tributaries and major features within Lower Bear Creek.

King Creek - King Creek is one of the longest tributaries to Lower Bear Creek. The catchment is 236 hectares in area and is long and narrow. A large portion of its headwaters are in forested lands of the Green-Timbers Heritage Society Urban Forest, and the lower portion of the creek is within Bear Creek Park. The King Creek catchment is 64% park land. The 36% privately-owned lots are entirely residential and predominantly single family residential. 80% of the development occurred since 1980.

King Creek itself remains open though most of its 6000 metre length. There are five stormwater ponds identified within the catchment of King Creek servicing about 20% of the catchment. There are signs of erosion but no major erosion issues were noted by the Ravine Stability Report or during our visits.

Photo: King Creek at 90th Avenue within riparian corridor.

Photo: King Creek at 90th Avenue showing some signs of debris and erosion. Extensive blackberry also noted.

Enver Creek - Like King Creek, Enver Creek has the upper portion of its catchment in the Green-Timbers Heritage Society Urban Forest, and its park area accounts for 34% of the long narrow catchment. It remains open for almost its entire length of 3000 metres. Within the catchment, residential urban development governs, with 60% of the development taking place in the 1970s and 1980s. Only 13% of the Enver Creek tributary area is contained within a pond catchment of one of the six stormwater ponds.

South of 84th Avenue, Enver Creek becomes more entrenched in a valley which is about 10 to 15 metres deep at its deepest points. While the upper portion of the catchment extends into Green-Timbers Forest, the Class 'A' watercourse designation does not extend to that length. The photos on the following page show the watercourse alignment just upstream of 144th Street.

Photo: Headwaters of Enver Creek. Creek passes through the pond.

Photo: Enver Creek at 86A Avenue within Riparian Corridor

Price Creek and Cub Creek – The Price Creek and Cub Creek catchments cover 450 hectares of the northeast part of the study area. The catchments are entirely urban with riparian area green space around the creeks. The upper portions of Cub and Price Creek have been enclosed, and they both outlet approximately at 88th Avenue. The channels are both contained within a well-defined valley and converge just north of 84th Avenue. Over 90% of the development in the upper catchment took place before 1990. The lower portion of the catchment (south of 84th Avenue) was developed in the 1980s and 90s. There are six of stormwater ponds in the southern portion of the catchment.

Photo: Cub Creek near 148th Street.

Photo: Cub Creek prior to convergence with Price Creek, some signs of erosion.

M Creek – M Creek is between the King Creek and Enver Creek catchment. It is shorter then these two creeks at just over 1 km in length. The urban residential catchment for M Creek was developed 60% in the 1980s, and 40% in the 1990s. There are five stormwater ponds in the catchment including a large pond in the BC Hydro right-of-way at 140th Street.

Photo: M. Creek Near 88th Ave

Photo: M. Creek near 84th Ave. Signs of erosion

Hunt Creek – Although not as long as some of the creeks discussed above, Hunt Creek is significant because its catchment contains the only industrial lands within the study area. Hunt Creek likely used to have a longer open channel, but has been enclosed in favour of a storm sewer system to service the impervious area. The storm system outlets in a number of places along the creek and area of erosion were visible.

Photo: Hunt Creek outlet near 80th Ave

Photo: Erosion in Hunt Creek

Main Stem Bear Creek – The lower portion of Bear Creek is a significant watercourse within Surrey. It is almost entirely contained within a large riparian corridor. Along a section upstream and downstream of 152nd Street the creek runs through two golf courses. The road crossings of Bear Creek are all bridges and generally span top-of-bank to top-of bank. For the most part, Bear Creek is not confined within a narrow valley but instead meanders through a wider floodplain.

Photo: Bear Creek Erosion at 144th Street

Photo: Bear Creek Erosion at 148th Street.

Green Timbers Urban Forest – The Green Timbers Urban Forest is located in the northern portion of the catchment which also contains the headwaters for King Creek and Enver Creek. It consists mainly of trees planted from seedlings in the first attempt at reforestation in British Columbia. It sits on a 2.5 km^2 of forest astride the Fraser Highway.

Green Timbers Urban Forest offers wetlands, lakes, grassland meadows and nature trails, all nestled within a second growth forest. Green Timbers is known as the birthplace of reforestation in British Columbia. As early as 1860, people tried to designate the area for parkland. Now administered by the Surrey Parks and Recreation Commission, Green Timbers is open for the enjoyment and education of all people. It is a mix of remnant woodland and natural re-growth displaying 60-year-old specimens of vine maple, broadleaf maple, western red cedar, hemlock, Douglas fir and grand fir.

Photo: Small lake within Green Timbers

Photo: Second growth forest within Green Timbers

The Green Timbers Forest has been identified in the 2002 Surrey Ecosystem Management Study (EMS) as a key Terrestrial Hub within the ecosystem network of the City of Surrey. The Green Timbers Forest is one of the five largest Hubs in size within the City, and one of the five highest value Hubs in terms of ecological significance.

Bear Creek Park – Bear Creek Park is another significant green space within the study area. The park contains playing fields, the Surrey Arts Centre, walking trail, and a botanical garden. It is also the location of the convergence of Quibble Creek, Cruikshank-Grenville Creek and King Creek. The park also contains a large parking area which could present an opportunity for improving the runoff from the site.

Photo: Bear Creek within Bear Creek Park

Photo: Parking Lot in Bear Creek Park

4.4 Hydrology

The Lower Bear Creek study area is one in which the City of Surrey has no reported notable drainage or infrastructure problems. This is likely a combination of the extensive length of open channel drainage that has been preserved and the relatively young age of the urban development and associated infrastructure.

The majority of the catchment is developed to typical urban stormwater standards. Storm sewers are designed to collect and convey the smaller storms and discharge them into creeks. Larger storms typically exceed the capacity of the underground infrastructure and flow overland to reach the creeks. Once within the creek, stormwater is conveyed through bridges and culverts along its natural route.

4.4.1 Surface Water Modeling

In general stormwater modeling is a tool used to identify and confirm problem areas, as well as, a platform on which to test possible solutions. It can be used to understand how land use changes have in the past, and might in the future, affect the watershed hydrology. Because there have been no reported infrastructure problems, the focus of the modeling in Lower Bear Creek has been on assessing the changes in hydrology that have taken place since urban development. The model developed could also be used as a component in developing a larger model for the Serpentine River. Further details of the stormwater modeling can be found in **Appendix A**.

An important input to discuss is the effective impervious area for a catchment. More so than any other parameter, the effective impervious area drives changes in a stormwater runoff regime. Impervious surfaces are areas that have been covered by any material that impedes the infiltration of water into the soil. Areas of land covered by pavement or buildings are impervious to rain water. Concrete, asphalt, rooftops and even severely compacted areas of soil are also considered impervious. For the modeling in each sub-catchment the percentage of impervious area was determined using a weighted area calculation. The overall catchment impervious area is calculated using the same method. The assumed impervious areas per lot type were based on sample air photo analysis and age of lots to choose representative lot coverage for each land use type. **Table 4.4** shows the breakdown.

Overall, the impervious area of the watershed is estimated at 41%. This is an important indicator for overall health of the watershed. Although it can differ with factors such as soil type, slope, etc, studies of other watersheds have found that significant impairment to streams often occurs when more than 10% of the land within a watershed is covered with impervious surfaces. When these levels exceed 25%, most watersheds experience more severe ecosystem and water quality impairment. Because of the relatively impervious soil in this area of Surrey, these numbers may be higher for the Bear Creek watershed that would be expected given the relative good health (compared to other urban streams) of many reaches of Lower Bear Creek. The generally ample riparian setbacks are assumed to play a role.

Table 4.4 Overall Watershed Imperviousness

Land Use	Area (ha)	Area (%)	Percent Impervious
Industrial	68	4%	95%
Multiple Residential	49	3%	90%
Commercial	35	2%	90%
Right-of-way	295	17%	80%
Urban Residential	746	43%	38%
Suburban Residential	111	6%	15%
Parks	368	21%	5%
Agriculture	47	3%	5%
Total Area	1720		
	Weighted Average		**41%**

Lot Age	% lots	% Impervious
Old	1%	20%
1950	14%	20%
1960	1%	20%
1970	23%	20%
1980	28%	45%
1990	20%	50%
2000	13%	60%
Weighted Average:		**38%**

For the purpose of modeling, the watershed was divided into 58 catchments. The upper catchments from Quibble and Cruikshank-Grenville were also included in the model. When/if better data becomes available from other studies in the Bear Creek watershed, the model can be updated, but for the purposes of this study the current level of accuracy is sufficient. Each of these catchments was modeled for its current land use. All catchments were also modeled for a pre-development scenario (less than 5% impervious) to allow us to see what an unaltered flow regime would be. A summary of some of the maximum flow rates is shown below in the **Table 4.5**.

Table 4.5 Watershed Flows – Pre-Development vs. Existing

Location	Flow (m^3/s)			
	5 year		100 year	
	Pre	Existing	Pre	Existing
Bear Creek @ 152nd	6.41	47.52	65.64	100.79
King Creek	0.32	1.71	4.33	5.25
Enver Creek	0.55	4.55	5.58	13.47
Cub/Prince Creek	0.88	11.53	8.87	18.88
Hunt Creek	0.93	13.32	8.84	21.18
Nichol Creek	0.65	7.16	6.27	11.38

The changes between pre-development and existing are much more pronounced in the smaller, 5 year event than in the 100 year event. This is because large events are not as heavily impacted by impervious areas. In those large events the ground becomes saturated and even pervious ground surfaces generate significant runoff.

4.4.2 Continuous Stormwater Modeling

Current thinking on stormwater management is that designs should mimic nature, not only for major events but also for smaller more frequent rainfall events. Continuous simulation recognizes that the majority of annual rainfall volume falls in frequent small events. As can be seen **Figure 4.5** more than 80% of the rainfall is 30 mm or less. Therefore, managing the smaller events will have a benefit to the downstream watercourse by reducing the potential for minor but frequent erosion.

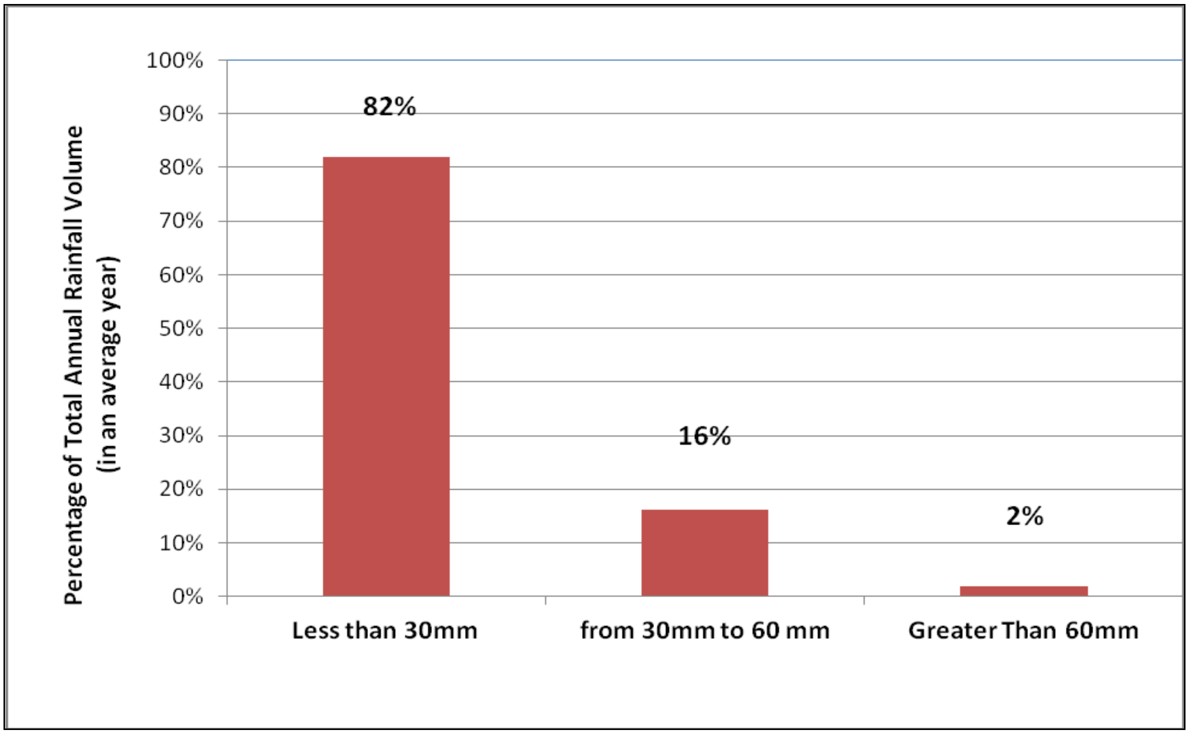


Figure 4.5: Rainfall Distribution for the Surrey Municipal Hall Rainfall Gauge

The Water Balance Model has been integrated with QUALHYMO in order to provide a “runoff-based tool” for source control evaluation and stream health assessment. The “runoff-based approach” holds the key to assessing environmental impacts in watercourses and the effectiveness of mitigation techniques. The Water Balance Model enables an understanding of the past and the ability to compare it to many possible future scenarios. This tool, combined with the continuous simulation capability of XPSWMM can give a good picture to how the overall water balance in Bear Creek is being affected by past development.

The graph in **Figure 4.6** shows the flow exceedence curve for a sample urban area in upper Enver Creek where storm flows run through an existing stormwater pond. The pond at 146th St. and 85A Ave. appears to be designed to mitigate high flow events but would not impact smaller storms. For **Figure 4.6** the vertical scale is logarithmic. It shows us what we would expect for the change in flow regime: There are fewer hours of smaller flows (i.e. loss of baseflow) and an increase in higher flows.

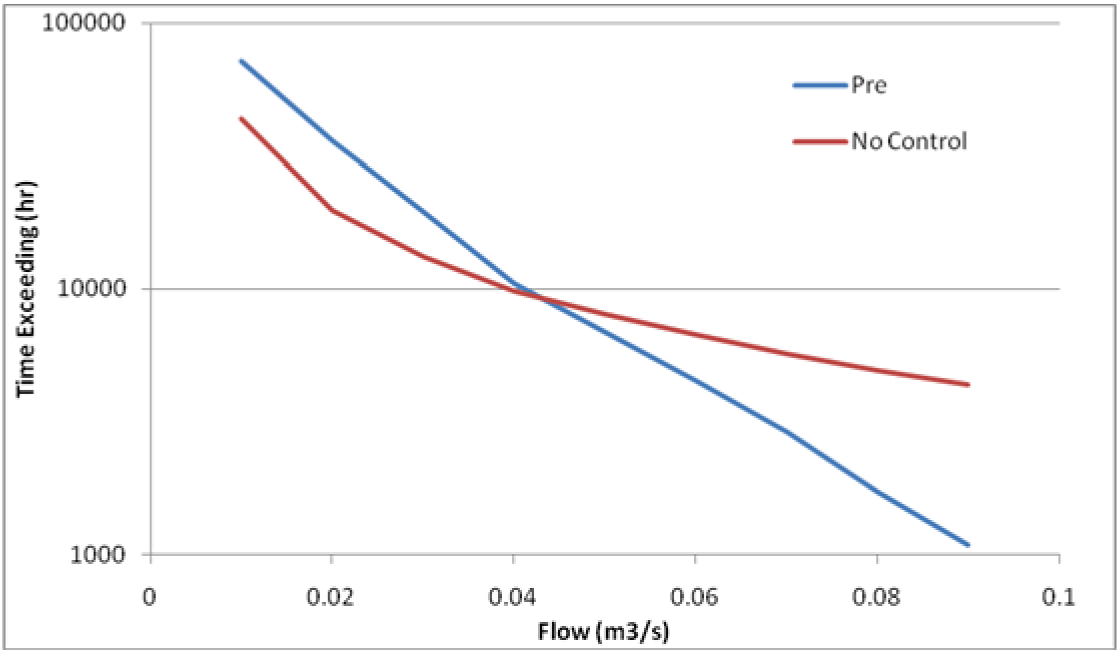


Figure 4.6 – Flow Exceedence Curve for a typical pre-development (Pre) and urban with no stormwater BMPs (No Control)

Current thinking in pond design would be to move the current situation back towards the pre-development scenario. This would require modification/adjustment the outlet configuration to retain excess flows but not too much of the smaller storms. This situation would be similar across the watershed. It would also apply where stormwater management designs have been completed because those designs focus on reducing post-development peak flows, not water balance.

4.4.3 Soils and Groundwater

Virtually the entire Bear Creek watershed, with the exception of the lowland area in the southwest corner and some stream corridors, is underlain by low permeability marine silts and clay to stony silt and clay deposits. This layer is between 20 and 40 metres thick. The soil map for the study area is attached as **Figure 4.7**.

Much of the baseflow for the creeks appears to be transmitted through the top 0.5 to 1.5 metres of soil. This flow path is called 'interflow.' Interflow is often the dominant drainage path in prolonged glaciated landscapes of British Columbia. Even undeveloped sites that are found on till and bedrock rarely show overland flow because of interflow pathways. Interflow has been traced flowing at velocities that are 1/200th as fast as channel flows on a similar gradient. This slow flow has a beneficial effect in prolonging flows from rainfall to streams.

Unlike deeper aquifer fed groundwater, interflow water is often rich in dissolved organic carbon and other nutrients. It is this flow that feeds the small streams throughout the study area. Such streams provide important salmonid food supply and rearing habitat. In some cases, they may even support fish spawning.

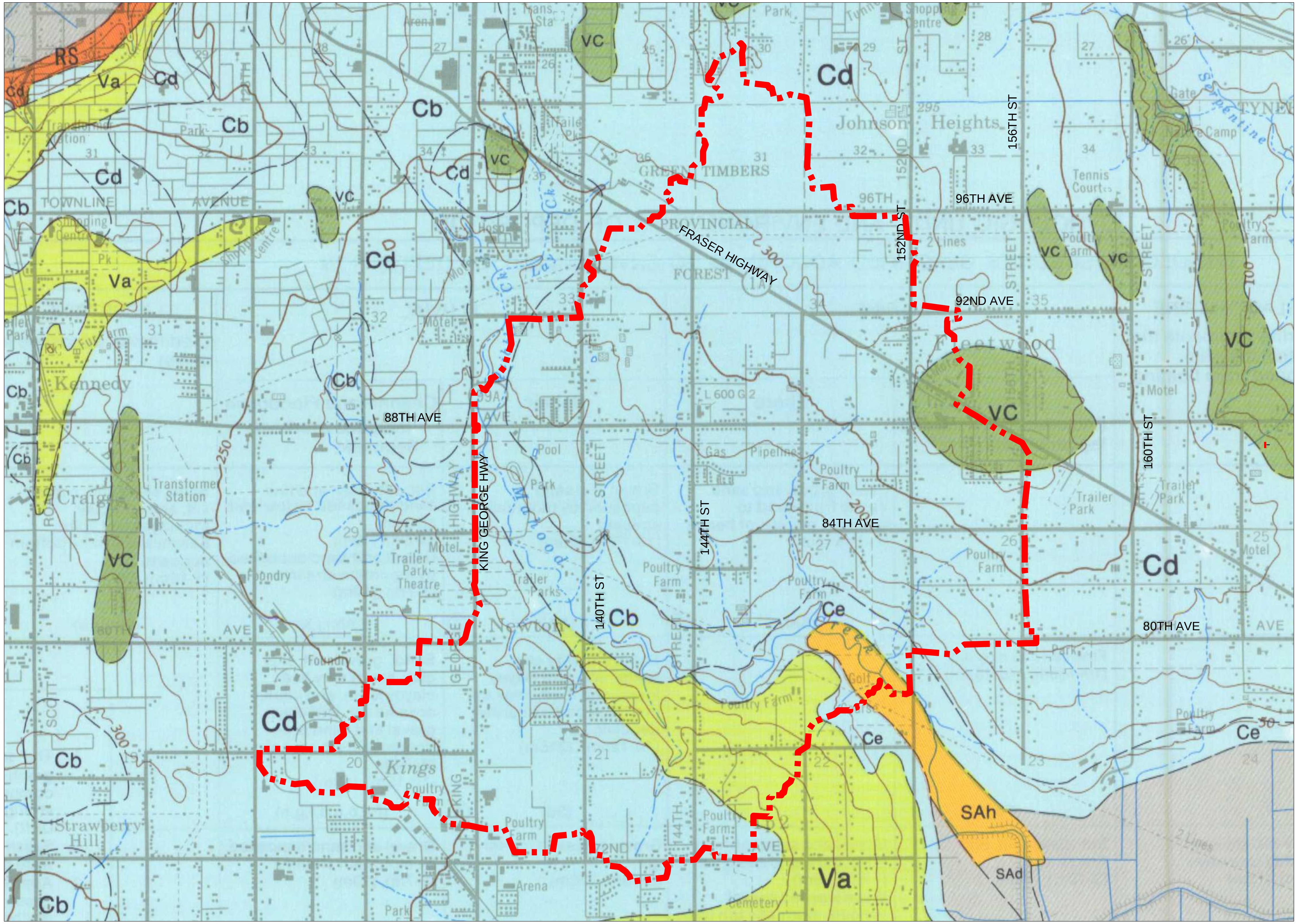
Present patterns of land development often work to eliminate interflow. Utility trenches, basements, discontinuous and highly compacted soils all work together to deprive small streams of baseflow. In this watershed the role of interflow and its ability to absorb and slowly discharge precipitation could have as much of an impact to stream health as overall watershed imperviousness.

In 1998, Piteau Associates assessed the impact of urbanization on groundwater recharge and watercourse baseflow for Bear Creek. The study looked at soil conditions, groundwater monitoring and stream gauges. Some key findings were:

- Due to the low permeability of the underlying sediments, deep groundwater recharge is generally low, such that 80% of the annual precipitation becomes runoff either directly or through interflow;
- There is minimal evidence of a declining trend in the long term baseflow data available for Bear Creek in the period of records available;
- The abundance of winter rainfall guarantees that the shallow groundwater table, or interflow layer, will be fully recharged at the end of the winter wet weather period; and
- Since there is a correlation between summer rainfall and baseflow response, it appears that the "time since last precipitation" has a much larger impact on summer base flows than the winter recharge period.
- Providing recharge capability within 600m wide corridors parallel to creeks should have a beneficial effect on base flows because of the short flow paths. Recharge from outside of the corridor would be too far away from the creek to provide beneficial summer baseflow augmentation.

From an ISMP perspective, the final point is possibly the most important. It underscores the need for implementation of appropriate BMPs within "groundwater corridors" to augment base flows outside the winter recharge period. This will be discussed more in the following sections of this report, particularly when discussing stream setbacks.

Figure 4.7
Soil Map



LEGEND

Study Area

Ca–e: Capilano Sediments
Ca, raised marine beach, spit, bar. And lag veneer, poorly sorted sand to gravel (except in bar deposits) normally less than 1 m thick but up to 8m thick, mantling older sediments and containing fossil marine shell casts up to 175 m above sea level;

Cb, raised beach medium to coarse sand 1 to 5m thick containing fissile marine shell casts;

Cc: raised deltaic and channel fill medium sand to cobble gravel up to 15 m thick deposited by proglacial streams and commonly underlain by silty clay loam;

Cd: marine and glaciomarine stony (including till–like deposits) to stoneless silt loam to clay loam with minor sand and silt normally less than 3m thick but to 30 m thick, containing marine shells. These deposits thicken from west to east.

Ce: mainly marine silt loam to clay loam with minor sand, silt, and stony galcio–marine material (see Cd, up to 60+m thick. In many of the upland areas sediments mapped as Cc and Cd are mantled by a thin veneer (less than 1m) of Ca.

VC: Vashon Drift and Capilano Sediments

Glacial drift including: lodgement and minor flow till, lenses and interbeds of sub–stratified glaciofluvial sand to gravel, and lenses and interbeds of glacio–lacustrine laminated stony silt; up to 25 m thick but in most places less than 8 m thick (correlates with Va, b); overlain by glaciomarine and marine deposits similar to Cd normally less than 3 m but in places up to10m thick. Marine derived lag gravel normally less than 1 m thick containing marine shell casts has been found mantling till and glaciomarine deposits up to 175 m above sea level; above 175 m till is mantled by boulder gravel that may be in part ablation till, in part colluviums, and in part marine shore in origin.

Va,b: Vashon Drift

Till, glaciofluvial, glaciolacustrine, and ice–contact deposits.

Va, lodgement till (with sandy loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt;

Vb, glaciofluvial sandy gravel and gravelly sand and ice–contact deposits.

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4.4.4 Erosion

Erosion is a natural process that can be divided into three stages: erosion, transportation and deposition. Erosion plays an important role in the transformation of the landscape by moving soil, in the form of sediment. Sediment is eroded from the landscape, transported by river systems, and eventually deposited downstream. For example, the Fraser River carries an average of 20 million tonnes of sediment a year into the marine environment. Bear Creek would deposit sediments in some of the reaches of Lower Bear Creek, the Serpentine River and Mud Bay.

Natural, or geologic, erosion takes place slowly, over centuries or millennia. Erosion that occurs as a result of human activity may take place much faster. The greater the discharge, or rate of flow, the higher the capacity for sediment transport. When there is not enough energy to transport the sediment, it comes to rest. Sinks, or depositional areas, can be visible as newly deposited material on a flood plain or as bars and islands in a channel.

Erosion, both natural and human induced, has the potential to cause problems to development or infrastructure near the creek. The City of Surrey monitors all their river and creek systems for such erosion every two years with the Ravine Stability Assessment. The Ravine Stability Assessment is an extensive field study that looks for:

- Erosion;
- Bank Instability;
- Exposed Pipe;
- Failing or Damaged Headwalls;
- Damaged or Plugged Culvert;
- Debris Accumulation; and
- Damaged Erosion Protection Works.

A relative risk designation is assigned to each site:

- *High Risk:* likely or immediate risk (within 1 year) to public safety, or damage to structures or infrastructure;
- *Medium Risk:* no anticipated risk to structures and no significant risk to public safety, but increasing risk may develop over time (beyond 1 year). May involve some impact to yard area, but no immediate risk to structures; and
- *Low Risk:* minimal risk of impact to private property or public safety in the near or foreseeable future.

For the Lower Bear Creek Study Areas there were 199 erosion sites based on the 2009 Ravine Stability Assessment. These sites and the ratings they received are shown on **Figure 4.8**. 158, or 80%, of the sites were deemed to be Low Risk Sites. There were 40 Medium Risk sites and one High Risk site. The High Risk site was on Hunt Brook where down-cutting erosion of the river has exposed a sanitary sewer previously buried under the stream.

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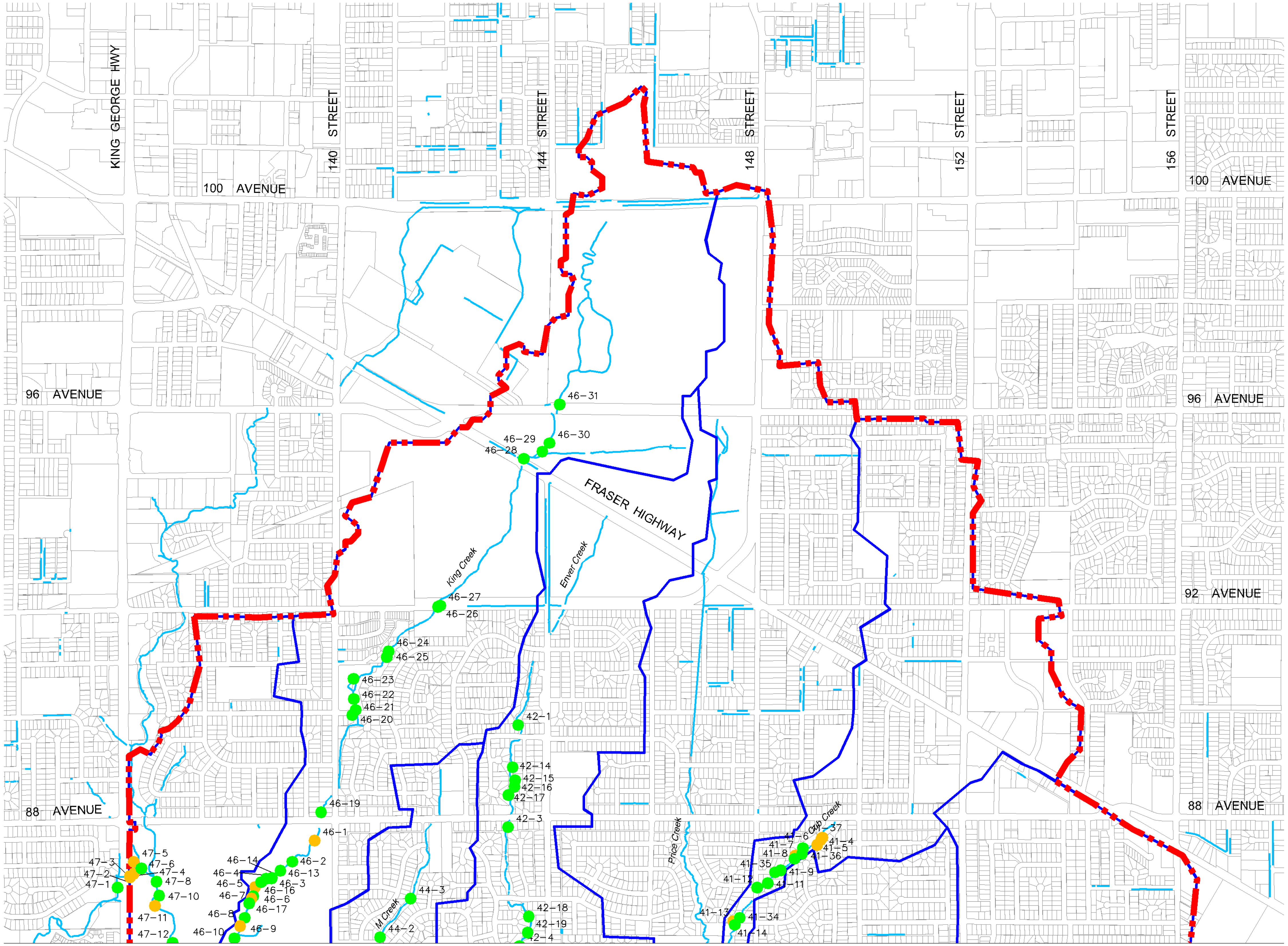
Figure 4.8-A
Erosion Sites



FOR CONTINUATION SEE FIGURE B

LEGEND:

- Low
- Medium
- High
- Study Boundary
- Watershed Sub-Boundary
- Streams

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Figure 4.8-B
Erosion Sites

FOR CONTINUATION SEE FIGURE A

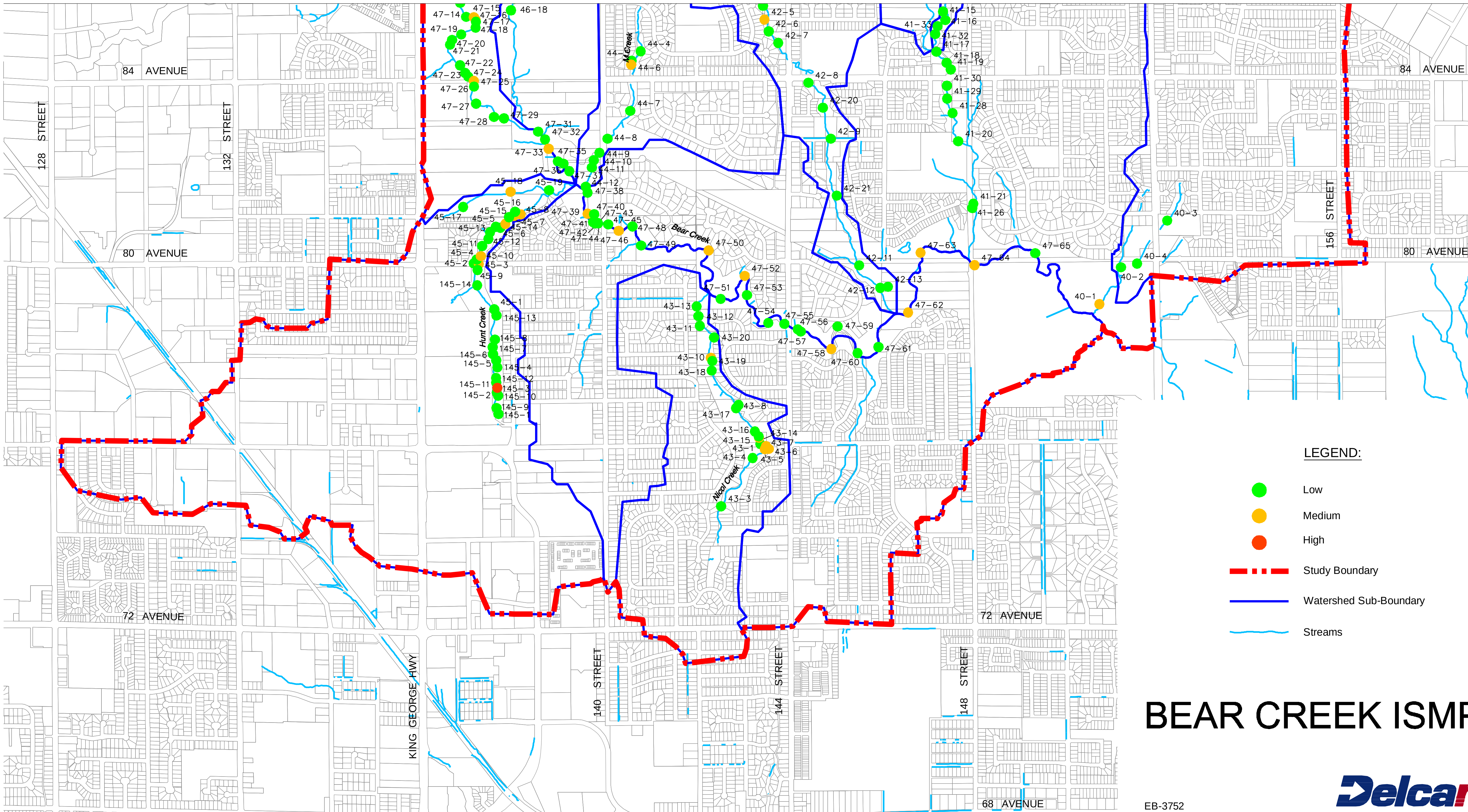

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Photo: Exposed pipe in Hunt Brook. The location was given a high erosion risk because of the potential for the pipe to be damaged during a high flow event.

In April 1998 the City of Surrey enlisted Dillon Consulting Limited to conduct a detailed assessment of the Bear Creek Channel within the vicinity of the City's Bear Creek Park located near King George Highway and 88 Ave. This study was initiated in direct response to reported bank and channel instabilities identified in this area by both the earlier 1996 Bear Creek Watershed Master Drainage Plan Study (MDP), and by field inspections conducted by City of Surrey personnel. Importantly these reports had identified potentially serious threats to the City's sanitary sewer alignment located in the vicinity of the Bear Creek Channel. Dillon recommended erosion protection works for high, medium and low risk areas. They also recommended ongoing monitoring of this reach of the creek. In the 2009 ravine stability reports there has been no mention of high risk erosion sites for this reach. However, ongoing monitoring of the area, particularly related to the sanitary sewer was recommended. In 2008 Associated Engineering found that medium to low risk erosion and recommended some repair work and ongoing monitoring at this location.

However, erosion with the potential to cause property damage is not the only effect of erosion to cause concern. Accelerated erosion rates also have an impact on fish habitat and stream health. Field verification observations have revealed numerous locations in the upper tributaries and headwaters where scour and erosion from excessive flow velocities in stormwater discharges has a negative impact on the habitat values in the Bear Creek watershed.

Given the built-out suburban land use in the headwaters and upper tributaries of Bear Creek, and probable increased densification of urban land uses over time, source controls (e.g. future green roofs, infiltration landscapes) as well as increased detention facilities in the headwaters, over time will improve the overall environmental quality in the watershed by reducing erosion and scour. Excessive high volume, short duration stormwater discharges from extensive impervious areas, much of which are pollution-generating (i.e. roads, parking lots, commercial sites), produce a broad range of detrimental environmental impacts that can be improved through implementation of ISMP recommendations.

Generally, impacts of excessive scour and erosion from stormwater discharges in stream receiving environments include:

- scour and often distant re-deposition of substrates, and invertebrate populations inhabiting those substrates,
- progressive exposure of fine-textured soils (e.g. clay chutes) and down-cutting (erosion) of the stream channel, coincident bank instability or channel meandering-induced bank failures,
- increased frequency and duration of high turbidity (i.e. suspended sediments),
- loss of in-stream habitat complexity and niche habitat for aquatic populations,
- increased downstream sediment deposition and flooding in lower gradient reaches, and
- an overall decline in the productivity and aquatic health of the stream.

Best Management Practices such as preservation and restoration of riparian forests, onsite infiltration, bio-filtration, stormwater detention facilities, source controls for commercial oil / water separators and catch basins, and other innovative stormwater management techniques are options to reversing the degradation of water quality and nutrient production and the loss of existing aquatic and riparian habitats in the Lower Bear Creek watershed.

The greatest potential for fish and aquatic habitat improvements through mitigation of scour and erosion is in the upper, highly developed headwaters where most of the Phoenix Environmental field verification observations were located. Stormwater management improvements to headwaters will in turn reduce flood flow volume, frequency and duration, which will improve habitat quality and water quality in the lower reaches.

4.4.5 Pond Coverage

Stormwater ponds have played an important role in drainage design and stormwater management since the 1970s. The development of the uplands created more impervious areas and collected stormwater into storm sewers. The changes lead to more runoff and higher peak flows, increasing flooding downstream, particularly in the lowland, predominantly agricultural areas. The City reacted by constructing stormwater ponds as part of new developments. These ponds were designed to retain peak flows during large storms and release the water over a longer period of time.

There are 42 municipal stormwater ponds or storage chambers in the study area. As noted earlier, only 32% of the entire watershed area currently drains through offline detention ponds. **Figure 4.9** shows the coverage of the ponds. The earliest ponds were constructed in 1978 and the majority of the ponds were constructed in the 1980s and 1990s (see table).

Table: 4.6: Age of Pond Construction

Decade	Number of Ponds	Percentage
1970s	2	5%
1980s	23	55%
1990s	13	31%
2000s	4	10%
Total	42	100%

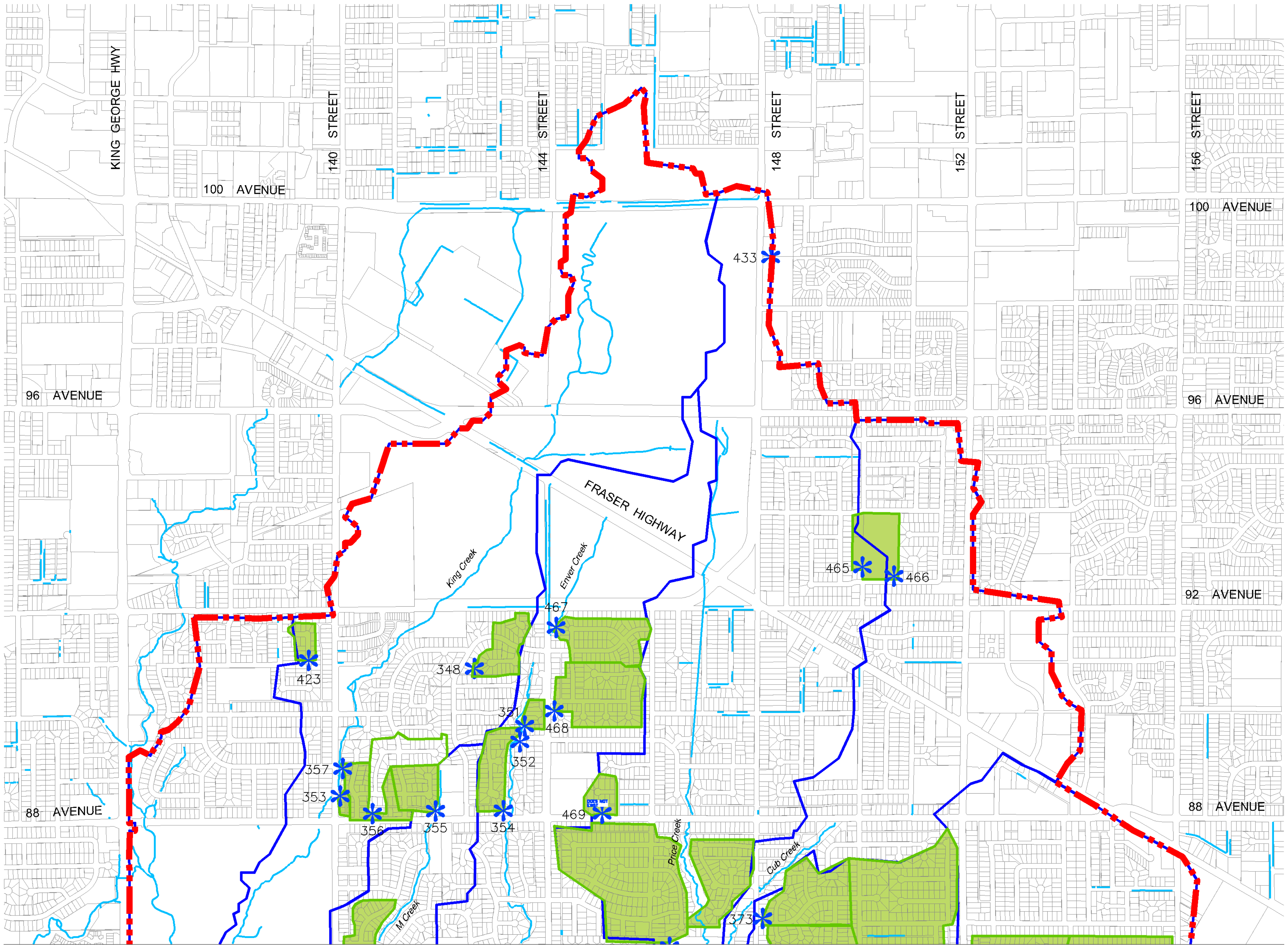
The objective of ponds constructed during that time period was to target large infrequent storms with the goal of reducing the potential for downstream flooding. The ponds are predominantly dry ponds placed just prior to storm sewer discharge locations in a creek. The ponds may double as park spaces and are low flat areas where water would only pond in large stormwater events. Some examples are shown below.

Photo: Pond at 92nd Avenue and 144th Street

Photo: Pond 145 Street and 79nd Avenue

Photo: Pond at 156th Street and 82A Avenue.

Figure 4.9-A
Pond Catchment



LEGEND:

465 Pond ID

Pond Catchment

Study Boundary

Watershed Sub-Boundary

Streams

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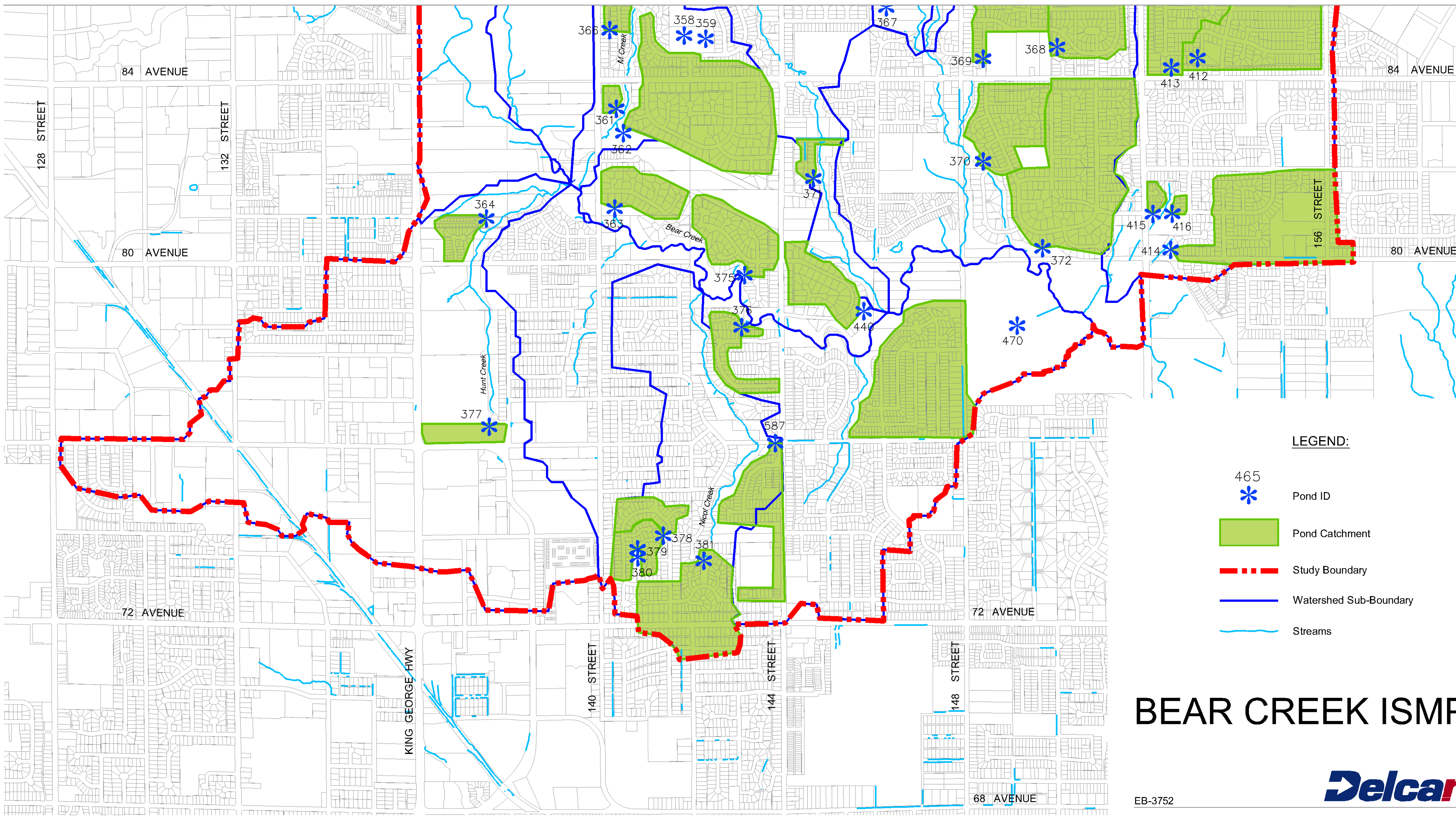
Figure 4.9-B
Pond Catchment

FOR CONTINUATION SEE FIGURE A



BEAR CREEK ISMP

EB-3752

4.5 Environment Conditions

Phoenix Environmental Services Ltd., in collaboration with Bianchini Biological Services and Sartori Environmental Services Inc., has conducted an environmental assessment of the Lower Bear Creek study area. A summary of the key findings are presented below and a more detailed environmental assessment can be found attached in **Appendix B**.

The study area displays fragmented forest and varied riparian conditions due to development densities in upstream reaches, and to agricultural activities in lower reaches. Portions of meadow habitat, providing moderate habitat resources and corridors for terrestrial wildlife, were observed in some areas due to historic disturbance by a BC Hydro transmission right-of-way and other unopened road rights-of-way.

Agricultural areas within the Lower Bear sub-catchment display reduced riparian conditions due to anthropogenic channelizing of lower reaches of Bear Creek, and clearing / tilling for agricultural purposes closer to the Serpentine River confluence. Furthermore, decreased in-stream complexity was observed in these areas due to man-made channeling for irrigation and flood control for agricultural purposes.

The majority of the Lower Bear Creek study area has been developed with single family housing. Disturbances within the study area appear to have resulted in effects on Bear Creek and its tributaries typical of urban streams. These effects include:

- Increases in storm flows (i.e. elevated peak flows, increased water level fluctuations);
- Altered benthic macroinvertebrate communities with elevated presence of pollution-tolerant species;
- Fragmented and discontinuous vegetation and ecological communities;
- Fragmented terrestrial wildlife habitats, with remaining natural channel areas serving as wildlife corridors between habitat fragments; and
- Decreased function of natural succession processes including forest renewal, creek substrate recruitment, watercourse channel movement through floodplain, etc.

As much of the study area is currently developed, and long reaches of Bear Creek and its higher value tributaries remain within natural channel alignments, especially in the north and south tributary sub-catchments, there remains a relatively high level of ecological function within an urban setting. In light of this, it is concluded that a multi-faceted approach to ecological management be incorporated in future development planning including:

- Conservation of remaining riparian areas and connected terrestrial habitat fragments (e.g. Green-Timbers Forest, Bear Creek Park, and Bear Lake Park), especially in the north and south tributary sub-catchments;
- Enhancement of straightened channels in current agricultural areas within the Lower Bear sub-catchment, and installation of engineered compensatory channels with revegetated riparian areas, improved in-stream and flow path complexity, where opportunities exist;
- Improvement of wildlife passage utilizing the Bear Creek and tributary watercourse corridors in concert with infrastructure upgrade works as they occur; and

- Removal of current fish and wildlife barriers at road crossings and replacement of passable crossings.

4.5.1 Vegetation and Ecological Communities

No Species at Risk (SARA) listed vegetation species were observed during the field program. Due to survey timing (late fall) many herbaceous species could not be identified. The site may provide habitat for at least six provincially listed species including the Blue-listed pointed broom sedge, Vancouver Island beggarticks, streambank lupine, dotted smartweed, false-pimpernel and slender-spiked mannagrass.

British Columbia Conservation Data Centre (BCCDC) records for the six species occur within five kilometres of the study area. These species may occur along the floodplain and banks of Bear Creek. No Best Management Practices (BMPs) currently exist for these species.

Four Blue-listed ecological communities of the CWHdm are known to occur within Green Timbers Urban Forest area. In addition, the Blue-listed Common Cattail Marsh ecological community is also expected to occur upstream of Green Timbers Lake. No Terrestrial & Predictive Ecosystem mapping is available for the remainder of the study area. All tributaries of Bear Creek appeared to be dominated by the Red-listed Western Redcedar – Foamflower (Site Series 07) ecological community. All forested units of the Biogeoclimatic Zone (CWHxm1 Coastal Western Hemlock, Eastern Very Dry Maritime) are listed by the BCCDC and all forested sites within the study area are highly likely to be either Red or Blue-listed ecological communities.

Invasive vegetation species such as Himalayan blackberry, Japanese knotweed, Scotch broom and English ivy were regularly encountered along interfaces of forested and disturbed or developed sites. Removal of these invasive plant species at strategic sites would benefit many native wildlife and vegetation species.

4.5.2 Wildlife Assessment

No provincially listed wildlife species were detected during the field program. Signs of coyote, beaver, river otter, raccoon, grey squirrel, woodpecker and passerines were detected within the study area. One Red-tailed Hawk was foraging within the project area and a pair of adult Bald Eagles was observed near the Bald Eagle nest tree at Surrey Lake Park. Most of the treed portions within the study area provide potential breeding / roosting habitat for raptors, passerines, woodpeckers and a number of bat species.

Mammals

Moderate to high rated habitat for the SARA listed Pacific water shrew and provincially listed Trowbridge's shrew occurred within the riparian zones of all watercourses within the study area. One BCCDC record for Pacific water shrew is located within 5 km of the ISMP area.

Birds

Bald Eagle and Red-tailed Hawks were observed within the study area. In addition, two Bald Eagle nests were observed within the Bear Creek and Surrey Lake parks. The forested blocks provide suitable breeding and roosting habitat for many raptor species such as Cooper's Hawk and owls, as well as songbirds and woodpeckers.

Amphibians

Rearing habitat for the SARA listed red-legged frog was detected within the riparian zones of the study area. Potential breeding habitat occurs in the beaver ponds and backwater channels along Bear Creek. These ponds and wetland complexes occurs along Bear Creek, near the confluences of Enver, Price and Bear Creeks. The wetland complex upstream of Green Timbers Lake and the wetlands associated with Surrey Lake also provide potential breeding habitat for this species. These wetlands and ponds also benefit other amphibian species as well as other wildlife.

Invertebrates

The forested block northeast of Surrey Lake provides potential habitat for the Oregon forest snail. Pacific sideband habitat was found within the riparian zones of all creeks and forested portions of Green Timbers Urban Forest, Bear Creek Park and Surrey Lake Park. There are no BCCDC records for these two snail species within 5 km of the study area.

4.5.3 Wildlife Corridors

Moderately used wildlife corridors were observed within the riparian zones of all watercourses and within the BC Hydro 500 kV ROW during the field survey. Installing open bottom culverts and bridges suitable for wildlife passage at all road crossings bisecting forested areas and creeks within the study area would improve habitat connectivity for all wildlife, including listed species such as red-legged frog, Pacific water shrew and Trowbridge's shrew. This habitat enhancement would also provide a secure wildlife corridor for all wildlife species. Improved passage for wildlife would also reduce roadkill. The addition of riparian of vegetation and increasing the riparian buffer along Bear Creek as it bisects the Guildford and Coyote Creek golf courses would greatly improve security habitat for many wildlife species and improve wildlife values along this important wildlife corridor.

4.5.4 Water Quality

There have been two major water quality data collection programs in the Bear Creek system over the past decade. The first was done around the construction of Surrey Lake and the second is part of the Boundary Bay Assessment & Monitoring Program.

Surrey Lake Monitoring: From January 2001 to July 2004 the City of Surrey collected water quality data above and below Surrey Lake, which was constructed in 2001. This water quality monitoring was a requirement of DFO authorization to construct the pond. This monitoring involved collection of:

- Specific conductivity readings;
- Dissolved oxygen measurements (in mg/L and percent saturation);
- pH measurements;
- Temperature measurements.

The purpose of the study was to show if Surrey Lake was having an effect on Bear Creek, it so included water quality measures in the lake and in nearby locations Bear Creek. In general, water quality in Bear Creek was found to be suitable for salmonid use on a year-round basis.

One important water quality indicator is temperature. **Figure 4.10,** taken from Jacques Whitford's 2004 report, shows the temperature over the study period and the limits for rearing as well as the lethal temperature for salmonids.

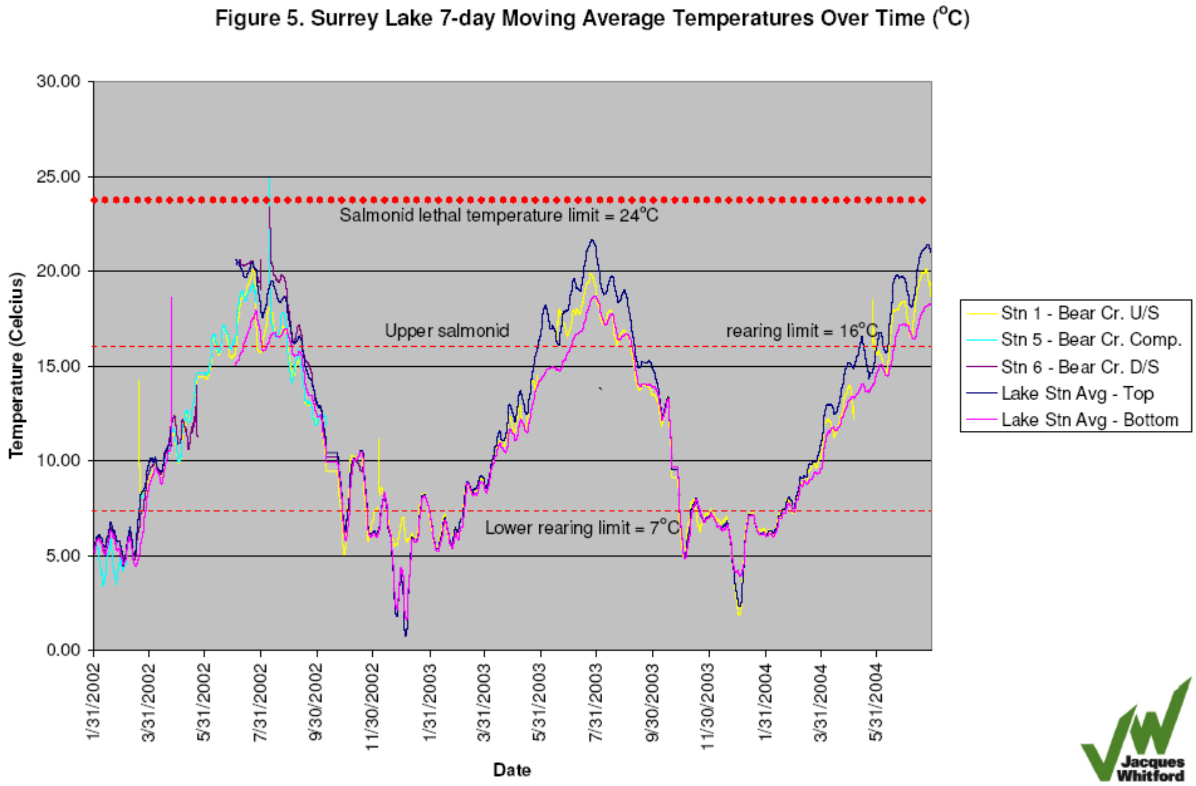


Figure 4.10: Temperature in Lower Bear Creek and Surrey Lake.

The data shows that the conditions in Surrey Lake are suitable to support a variety of fish. Temperature ranges in Bear Creek upstream of the lake during summer months do not reach temperatures that would cause mortalities to salmon or trout.

Dissolved oxygen and pH data were variable. While there were some periods where the lower water quality objectives for these two parameters were not met, the general trends observed over the monitoring program indicate that the lake meets the British Columbia and Canadian Council of Ministry of the Environment (CCME) water quality objectives on an annual basis. This conclusion is supported by the results of fish sampling that was conducted in June and September 2004.

Boundary Bay Assessment & Monitoring Program (BBAMP): Water sampling was undertaken by the Boundary Bay assessment and monitoring program partners during 2010. Samples were collected during the dry-weather period from July to August, while wet-weather samples were collected during the late October through early December period. The testing included pH, conductivity, salinity, temperature, dissolved oxygen, turbidity, fecal coliforms, e. coli, enterococci, nitrite, ammonia, organic nitrogen, total nitrogen, total phosphorus, dissolved orthophosphate, and metals. Dissolved oxygen concentrations measured during the dry weather period exceeded the guideline for an instantaneous measurement is (a minimum of 5 mg/L) on three occasions in Bear Creek indicating a potential concern.

The water quality index (WQI) is a tool that was developed in British Columbia in the mid-1990's and was applied to the BBAMP data. It is used to provide the public with information on water quality in an easy-to-understand format. The rankings from the WQI are described as follows:

> Excellent (95–100) indicates that water quality measurements never or very rarely exceed water quality guidelines. Aquatic life is not threatened or impaired.
>
> Good (80–94) indicates that measurements rarely exceed water quality guidelines and, usually, by a narrow margin. Aquatic life is protected with only a minor degree of threat or impairment.
>
> Fair (65–79) indicates that measurements sometimes exceed water quality guidelines and, possibly, by a wide margin. Aquatic life is protected, but at times may be threatened or impaired.
>
> Marginal (45–64) indicates that measurements often exceed water quality guidelines by a considerable margin. Aquatic life frequently may be threatened or impaired.
>
> Poor (0–44) indicates the measurements usually exceed water quality guidelines by a considerable margin. Aquatic life is threatened, impaired or even lost.

The two testing sites in Bear Creek returned values as shown in **Table 4.7** below.

Table 4.7: Water Quality Index (BBAMP, 2010)

Testing Location	Year	Rating
Bear Creek at 152nd St.	2010	42.2 Poor
Bear Creek at 68th Ave.	2010	65.0 Fair

BC Hydro PCB Issue: BC Hydro has a documented problem with polychlorinated biphenyls (PCBs) entering the upper reaches of Mahood Creek which flows into the Lower Bear Creek study area near King George Highway. A 2010 water quality monitoring report for BC Hydro found that the PCBs move downstream through the entire Bear Creek system, although results downstream show smaller concentrations than near the BC Hydro Site (**Figure 4.11**). While BC Hydro is managing this site contamination issue, the issue is noted for this ISMP.

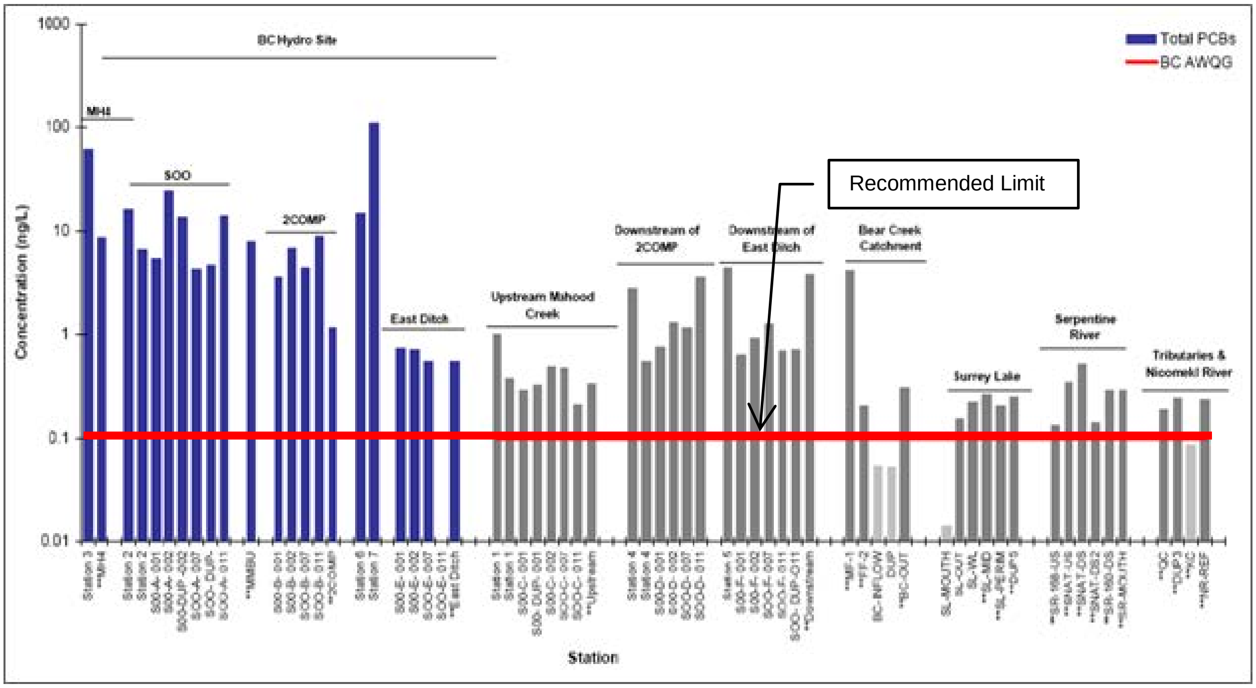


Figure 4.11: Total PCBs concentration in stormwater at testing sites in logarithmic scale (Azimuth 2009)

5. Vision

The vision defines the ISMP's general direction and is intended to reflect the City's long term objectives for the study area. This section of the report states the Vision for Lower Bear Creek and outlines some of the goals for achieving it. The section also briefly summarizes the key inputs into the Vision including contact with stakeholders and guidance from policy documents.

The Vision must be in line with other objectives and documents followed by the City. This ISMP has a two-way link with the City's relevant planning documents, meaning that the existing planning documents provide input into the ISMP, and the ISMP provides recommendations for revisions to the existing planning documents and for the preparation of new planning documents.

5.1 City of Surrey Sustainability Charter

The City of Surrey has developed a Sustainability Charter, which is an overarching policy document to guide the City's approach to socio-cultural, environmental, and economic sustainability. Future planning and engineering documents will be required to consider the Sustainability Charter, which contains goals regarding transportation, employment, lands, community services, environmental protection and land development. It is fundamental to the establishment of the Vision for Bear Creek since it is the highest level of environmental guidance within the City.

Most relevant to ISMPs are those goals that could impact creeks and drainage systems. Some of the rainwater/stormwater-specific goals that were considered are:

- Respect natural areas;
- Create a balance between the needs of Surrey's human population and the protection of terrestrial ecosystems; and
- Protect Surrey's groundwater and aquatic ecosystems.

The Sustainability Charter reinforces some of the principles of integrated stormwater management that are considered in the Vision.

5.2 City of Surrey OCP

The City of Surrey's Official Community Plan (OCP) is a fundamental document in outlining the objectives and policies that guide City planning decisions. The OCP has policies for to every aspect of City governance and responsibilities. In linking to the Lower Bear Creek ISMP there are a few categories of policies that are important: *Manage Growth for Compact Communities, Protect Agriculture and Agricultural Areas*, and *Protect Natural Areas*.

The first category, *Manage Growth for Compact Communities*, is indirectly linked to stormwater management. The policies within promote increased urban density as a City of Surrey value. This could impact stormwater management in the Bear Creek area if increased density is not also coupled with attention to stormwater management.

The second category, *Protect Agriculture and Agricultural Areas*, is also indirectly linked to Bear Creek, which flows into the agricultural areas of the Nicomekl and Serpentine River lowlands. With the City of Surrey's goal to protect agricultural areas it will be important to consider how runoff water, both quantity and quality, from Bear Creek watershed impacts the agricultural area. The Vision should reflect this important link.

The third category, *Protect Natural Areas,* includes policies that more directly speak to stormwater management and environmental protection. These include:

- Identify and endeavour to protect Fisheries Sensitive Zones as defined in conjunction with the Department of Fisheries and Oceans, the Ministry of the Environment, Lands and Parks, and the City
- The City recognizes the intrinsic value of wildlife, bird and fish habitat to the quality of life for the citizens of Surrey. Through the development process the City will strive to balance habitat losses with habitat replacement and/or compensation.
- Conserve, enhance and promote wildlife corridors connecting parks, open spaces, and other large wildlife habitat areas, thereby increasing the variety.

These three policy statements outline the City's desire to minimize impacts that could potentially be caused by other activities (such as land development). The Bear Creek ISMP must consider how it can be implemented in Bear Creek.

Two other stated policies that will need consideration in the Vision for Lower Bear Creek are:

- Provide street trees and landscaping in medians and boulevards to reduce heat absorption by road surfaces and buildings, and increase opportunity for the natural absorption of storm water.
- Locate detention ponds a safe distance away from play areas for children or school grounds.

These are important to document here as they could impact how the Vision is implemented.

5.3 Parallel Planning Processes

Where applicable, ISMPs should always be linked with other planning initiatives. This will help ensure the consistency of plans across disciplines and take advantage of shared goals for easier implementation.

5.3.1 City of Surrey Planning Charrette

In January of 2012 the City of Surrey engaged in a Design Charrette. A Design Charrette is an intensive, hands-on workshop that brings together people from different disciplines and backgrounds to explore design options for a particular area or site. This Charrette was examining the future of the neighbourhood roughly defined by 92nd Avenue to the north, 72nd Avenue to the south, King George Blvd to the west and 152nd Street to the east. This neighbourhood covers much of the study area of the Lower Bear Creek ISMP. The purpose of the Charrette was to generate ideas and discussion on how the area could change with respect to economy, transportation, education and community. We were asked to attend the closing presentation of the Charrette where the participants presented some of the ideas that were generated over the three day period. .

Many ideas were discussed and it is unknown how many of the ideas will eventually be recommended for implementation. Those in the presentation that were of relevant to the Bear Creek ISMP were:

- The Charrette is laying the groundwork for eventual densification of the area. Because the City of Surrey currently has unrealized development potential in NCP areas in other locations in Surrey, the densification of this neighbourhood is not a short term priority. However, in the future, it would be prudent to consider that eventual re-development to a denser land-use will be an issue in the watershed.
- Densification is expected in the short term along transportation corridors of Fraser Highway and King George Highway. This densification will be linked to improved rapid transit projects along these corridors. This is already occurring at Fraser Highway and 152^{nd}. When the transit projects occur, it will be important to provide further detail on how stormwater management should be incorporated.
- There was also discussion about allowing density bonusing in some areas in order to encourage return of residential properties to green space. The idea is that if properties adjacent to a riparian corridor can be converted to green space then the whole community can benefit from having the street face the green space. This could be done by allowing properties on the non-green space side of the street to redevelop to a denser land use in exchange for converting the green space side lot to park. Subsequent discussion with City of Surrey staff saw limited short term potential for this to be implemented in the study area. However, if at some point in the future this idea gains some momentum it would have positive implications for management of riparian and wildlife corridors.
- The discussion of pedestrian friendly green streets was also prevalent in the Charrette. The ideas were that when transportation corridors are improved, potentially linked with transit upgrades, those corridors should be friendly to multiple modes of transportation and be inviting to greener transportation such as walking and cycling. Green streets would also need to be green in terms of stormwater management.

5.4 Bear Creek Vision

This Vision was developed by reviewing the existing conditions in the study area and in discussion with City of Surrey staff. The proposed Vision statement was developed in consideration of the City of Surrey's Sustainability Charter and OCP and uses language consistent with those documents.

Lower Bear Creek ISMP Vision
To protect the study area's natural aquatic and terrestrial ecosystems in an integrated manner that accommodates growth and development and to take advantage of opportunities to enhance or improve the environment.

As with the Sustainability Charter, below the Vision there must be goals to support the vision. The goals below in most cases echo the policies stated in the City of Surrey OCP.

Lower Bear Creek ISMP Goals
A. Reduce flood impacts on the stream channel and strive to restore a more natural flow regime.
B. Reduce stream erosion and downstream sedimentation to levels approaching a more natural system.
C. Return stream base flows towards their natural pre-development levels
D. Improve or increase habitat, including riparian areas and wildlife corridors.
E. Improve water quality of stormwater run-off.

5.5 Vision Implementation Strategy

The Vision and Goals outline the direction for the watershed and the next step is to determine how to get there. The details of the implementation plan are in subsequent sections of this report but a part of the Vision is to discuss the framework within which the Vision and Goals will be implemented. The City of Surrey has the ability to influence stormwater management in three fundamental ways:

1. As a regulator and approval authority;
2. As a land owner and infrastructure manager; and
3. As an educator and through the promotion of ideas.

During discussions at the charrette and with City of Surrey staff it was stressed that the ISMP should both work within the context of current implementation mechanisms and recommend changes where appropriate. Therefore implementation items related to the City's ability as a regulator should be linked with current regulatory tools, and where current tools are insufficient to meet the goals, recommendations on potential changes to the tools can be made.

6. Analysis and Recommendations

Section 3 (Plan Summary) of the report outlined the specific plan recommendations. This section of the report provides further detail and supporting for the plan recommendations.

Municipal governments such as Surrey play a large role in our daily lives. They provide and maintain the community's basic essential services (water, sewer, garbage, etc.). They also own and maintain libraries, parks, and recreational facilities. When it comes to shaping the land use in the community, municipalities play a key role through policies and land-use planning. They can determine what gets built and how, as well as the area's density. They can also serve as a messenger for information that empowers people and companies to take positive action themselves. The ISMP recommended items have been roughly categorized into the three roles the City of Surrey can play:

1. **Regulator and approval authority** – the City has the power to influence the activities of developers and private land owners through the Municipal Act which allows the City to control land form. Typically this influence can be applied at time of application for land use changes or building changes. This role is fundamental in the application of integrated stormwater management principles because managing water where it falls is key and therefore controlling land form plays a large role.
2. **Land owner and infrastructure manager** – the City owns a significant portion of land within the catchment (40% is park and road rights-of-way). This makes the City the single most influential land owner in the catchment. This is a huge opportunity for the City to provide good examples of how managing stormwater is an important City priority.
3. **Educator and through the promotion of ideas** – the City has made a commitment to make the principles of social, environmental and economic sustainability as the foundation of all decisions. As part of this commitment, Surrey can promote the principles of integrated stormwater management through education and awareness programs, and by practices that highlight how human activities are linked to stream health.

6.1 Regulator and approval authority role

The City of Surrey is one of the fastest growing municipalities in BC. As a result, it has developed a comprehensive set of policies, bylaws and operating practices that guide development to shape that growth. The recommendations of this ISMP are focused on working within the City of Surrey's current framework defined by the OCP, bylaws and the applicable legislation. Where appropriate, changes in bylaws or planning documents would aid in the managing of stormwater in Bear Creek or throughout Surrey.

6.1.1 Land Development – Densification

The vast majority of the Bear Creek Watershed has already been developed. With existing development the stormwater infrastructure is in place, and areas for new stormwater detention are limited. Therefore it will be important to target land use densification and re-development as an opportunity where some changes in stormwater management can be made.

Eventual densification is expected along the transportation corridors within the Bear Creek. This potentially includes Fraser Highway and King George Boulevard and arterial roads such as 72nd Avenue, 88th Avenue and 144th Street. In discussions with the City of Surrey planning staff they indicated that Fraser Highway densification was already occurring near 152nd Street. Along King George Boulevard the densification is not expected to occur in the next few years but possibly in the future. The densification along arterial roads is expected to be minor, in the form of allowing changes like laneway homes or secondary suites. These changes are expected to be 15 or 20 years in the future as currently pressure for widespread densification is not felt in the area with development opportunities still widely available in other locations in Surrey.

However, while the impact of densification in the short term is small, it is important to begin to develop a framework for dealing with these developments from a stormwater management perspective. This approach may not be widely applicable in Bear Creek but in other ISMP areas it will be important to address this land use change.

Recommendation 1: Prepare for densification within the Lower Bear Creek catchment by requiring development to mitigate the impacts of stormwater runoff by meeting performance requirements.

3. No net increase in volume of runoff from pre-development conditions.
4. Remove 80% of total suspended solids from stormwater.

This is in addition to stormwater management requirements outlined in the existing City of Surrey guidelines.

Land developers involved in densification will have the resources and expertise to meet these requirements to current state-of-practice. This could be achieved using a tool such as www.waterbalance.ca or by using other engineering tools.

6.1.2 Land Development - Single Residential Lot Re-development

About 40% of the residential lots within Lower Bear Creek watershed were created before 1980. These lots in particular can be expected to be prime targets for re-development as they typically do not maximize the building footprint that is currently allowed. The long term impact of such a change, should all properties eventually redevelop to a higher density, would be to add almost 10% to the overall impervious area of the catchment. This could be the most significant impact on rainfall runoff in the catchment, as it is roughly equivalent to Bear Creek Park in area.

Implementing on-lot BMPs could reduce the impact to the overall system over time. Below is an example of how on-lot BMPs could be applied. A representative lot was taken and aerial photos of the old and new houses are shown. The areas were measured for each scenario. **Figure 6.1** below illustrates the differences between these two conditions.

Prior to redevelopment:

Surface	Area (m^2)
Roof	195
Paved	59
Landscape	521

Percent Impervious: 33%

After redevelopment with no BMPs:

Surface	Area (m^2)
Roof	356
Paved	129
Landscape	290

Percent Impervious: 63%

Figure 6.1: Typical Single Family Home Rebuild

The values for this example were then used to create a single-lot model within the www.waterbalance.ca model. The model was used to compare a number of scenarios (**Table 6.1**).

Table 6.1 – Single Lot Redevelopment Water Balance Scenarios

#	Name	Characteristics
1	Natural	This scenario represents the lot prior to any urbanization. The land was assumed to be free of impervious area. The scenario is an important point for comparison as it represents the ideal runoff pattern.
2	Existing	The house prior to redevelopment as shown in the figure and table above.
3	Proposed – No BMPs	The new larger house as shown in **Figure 6.1** above.

4	Proposed – 300 mm topsoil	This scenario models the proposed larger house with absorbent topsoil applied to a depth of 300 mm.
5	Proposed – Pervious Pavement	This scenario models the proposed larger house with all paved surfaces being pervious pavement.
6	Proposed – rain garden	This scenario models the proposed larger house with the roof area being directed to a large rain garden.
7	Proposed All BMPs	Application of all of the above BMPs.

Figure 6.2 below shows the water balance volume for each scenario.

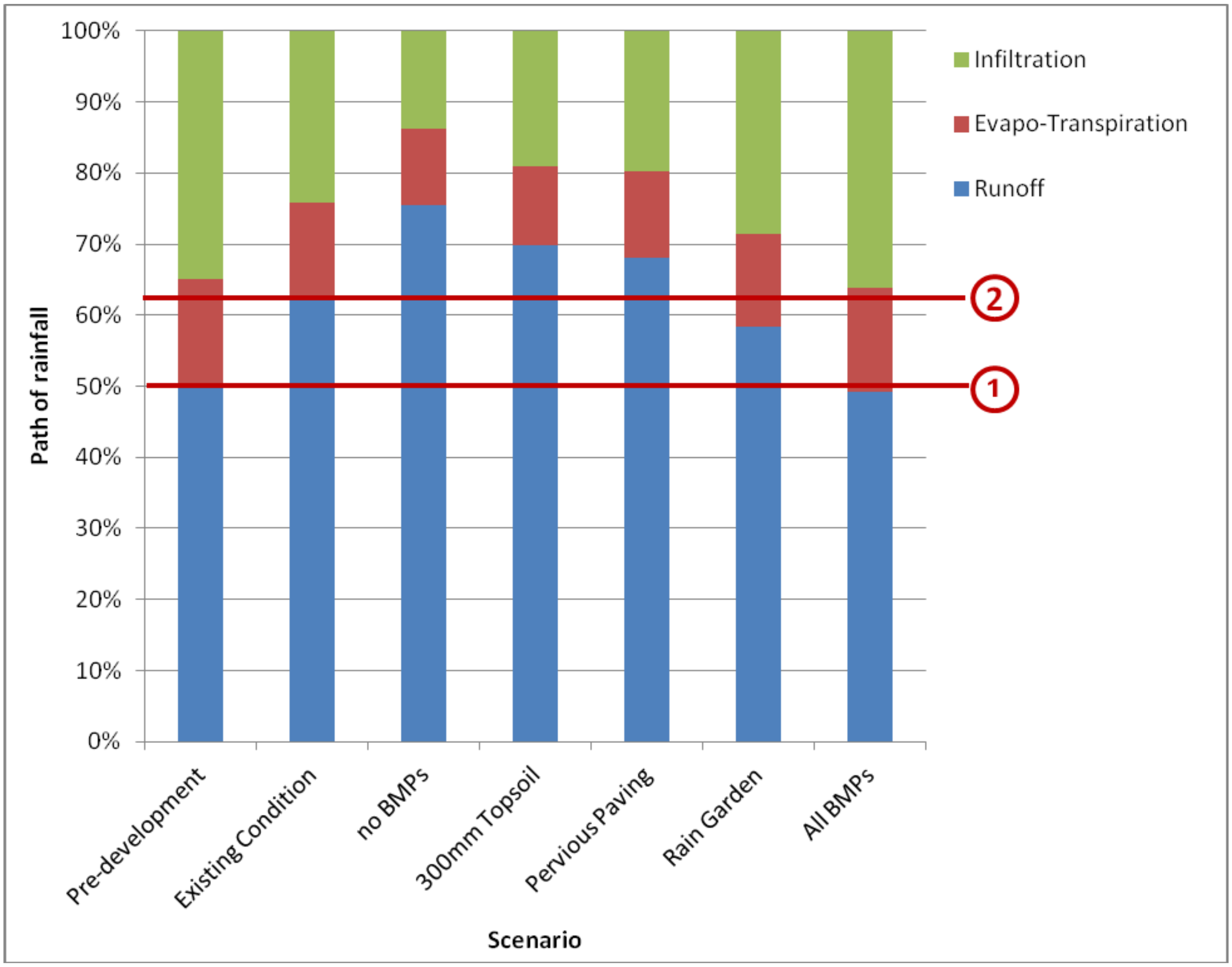


Figure 6.2: Water Balance Scenario Results

The first scenario on the left defines the runoff regime prior to development (i.e. if the lot did not have any pavement or house on it). This is the optimal runoff scenario for protection of downstream watercourses because it is the natural condition. During this condition only 50% of the water falling on the site runs off.

Line #1 on the chart shows that target level for the remaining scenarios. This is an optimal target that would be reached in an ideal scenario.

The second scenario is that of the small house before redevelopment. During this scenario 62% of the water runs off. Line #2 shows the target for a 'hold the line' approach. Although this target will not restore natural flow conditions, scenarios that meet it will at least not be making the situation worse.

The third scenario, the new larger home, has 75% of the water running off the site. This is what would happen in a normal scenario without BMPs. This is the scenario which if applied to all lots could eventually increase the impervious area of the Bear Creek catchment by 10%.

The remaining scenarios show how the application of BMPs can reduce the runoff volume and meet the optimal and 'hold the line' target. The results show that as BMPs are applied, they can have a positive impact. When all BMPs are applied the runoff meets the optimal target of a pre-urban development condition.

The implementation of on-lot BMPs at the single lot level is challenging for a number of reasons:

a. Single lot redevelopment only goes through a building permit process, no planning process is required.

b. To require those involved in single lot residential re-development to hire a professional to design a stormwater BMP system(s) would generate more cost to home owners.

c. The success of BMPs in reducing stormwater runoff is highly dependent on the quality of construction. Presently the contracting community is not widely implementing these measures, particularly not at the single lot level.

d. The success of BMPs is also tied to regular and correct maintenance of those BMPs which can be difficult to achieve if individual home owners are not aware of how to keep the BMPs operating efficiently.

The implementation of residential lot BMPs will need to be a long term goal achieved through participation of the public and the City. The undertaking of this recommendation should not be confined to the Lower Bear Creek ISMP scale. It should be a City-wide program.

Recommendation 2: Implementation of a long-term program that will move towards requiring single residential lots to implement BMPs on site at time of redevelopment. BMPs would be similar to larger-scale densification projects – no net increase in runoff and removal of 80% of total suspended solids.

This long-term program should be developed with involvement of City of Surrey staff from all affected departments. It would be implemented through the building permit process rather than the planning process.

The first stage of implementation is to form a working committee to develop an overall lot-level BMP program. This committee should consist of City of Surrey staff but could be facilitated by an outside expert. This committee would develop the policy and next steps for implementing BMPs at the site level. Stages would include:

a. The first stage would be education of City staff and interested public on implementing BMPs. This would include providing written and staff resources to the public and contractors on how to implement BMPs. This could begin with easy to implement BMPs like absorbent topsoil and soak-away pits for roof drainage.

b. Then a voluntary / pilot program on implementing BMPs would need to be created. At this time the City would also want to promote demonstration projects so that home owners and contractors could see the benefits of BMPs in action.

c. And finally, once the institutional framework and public knowledge are at an acceptable level some form of mandatory BMPs program can begin. The City would need to develop prescriptive requirements to be implemented through the building permit process.

6.1.3 Watercourse Setbacks and Wildlife Corridors

The City of Surrey has completed its Ecosystem Management Study (EMS). This study identifies important green infrastructure within the City. Surrey's Green Infrastructure Network is composed of hubs and potential corridors. Hubs are larger areas of contiguous natural landscape that support ecological processes. Potential corridors delineate connections between hubs that are critical to the long-term function of the overall network. Corridors allow for animal movement and seed dispersal between hubs. Corridors often incorporate sites and these inter-connections further complement network success. **Figure 6.3** from the EMS report shows some of the desired habitat corridors to connect existing hubs within the study area.

The recommendation from the EMS is to protect or restore effective aquatic and/or wildlife corridors that link hubs together, so that species are able to disperse and intermix for genetic diversity and population security. To do this in Lower Bear Creek the City should to protect and enhance existing corridors. There are four main wildlife corridors in the Study area. The King Creek and Hydro ROW corridor are continuous while the Enver Creek and Price Creek corridors are interrupted by urban development.

Barriers to species movement such as road crossings should be minimized in the wildlife corridors. Where roads or other barriers are being constructed or rebuilt, provision for ease of passage of the fish or wildlife species that the corridor serves should be provided.

Recommendation 3: Within existing wildlife corridors remove barriers or allow for improved movement when the area is impacted by new construction or infrastructural renewal. Avoid creation of new barriers to wildlife movement.

In cases where potential corridors have been highlighted but no corridor exists, it is difficult to create corridors without property acquisition. In some cases it may be defensible to provide some site densification incentives to developers in exchange for intensive restoration efforts on an impaired corridor. However, given that the City has no immediate plans for densification in the area it is not anticipated that these opportunities would arise in Lower Bear Creek.

Recommendation 4: Identify and secure new wildlife corridors along Price and Enver Creeks if re-development begins to occur in the area.

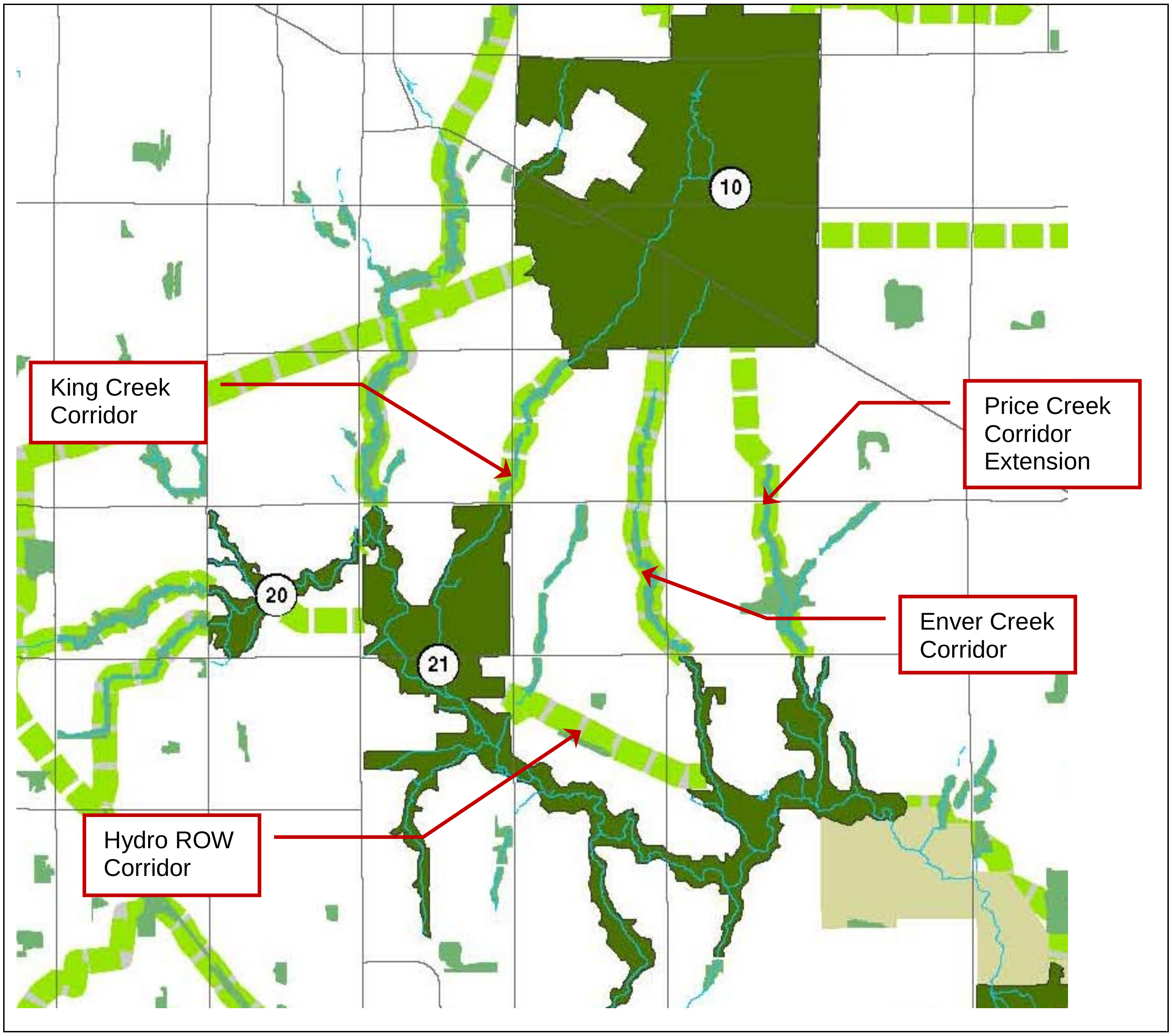


Figure 6.3: Potential Habitat Corridors and Hubs (Source: EMS, April 2011)

6.2 Land owner and infrastructure manager role

6.2.1 Transportation Projects

There are many roads in the study area, with 18% of the land being road right-of-way. That land, if developed without consideration for stormwater management, will lead to stormwater problems in terms of quality and quantity. Contaminants from vehicles and from activities associated with road and highway construction and maintenance are washed from roads and roadsides when it rains or snow melts. And consequently many pollutants are delivered to streams, lakes and rivers, including pathogens, nutrients, sediment, and heavy metals.

By retaining rainfall from small storms, the implementation of green infrastructure and Best Management Practices (BMPs) reduces stormwater discharge volumes which translate into reduced combined sewer overflows and lower pollutant loads. Additionally, green infrastructure and BMPs treat stormwater that is not retained. Integrated stormwater management is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible and it must be applied to roadway development as well.

Green infrastructure and BMPs can be used instead of, or in addition to, more traditional stormwater controls.

There are some new road projects on the horizon within the Bear Creek watershed including general infrastructure replacement and rehabilitation projects which will create an opportunity to implement good stormwater practices when constructing new or upgrading old road networks. The following section considers various green technologies that could enhance the water quality and quantity regime within the Bear Creek study area.

Green Roads vs. Conventional Roads

Conventional roads usually consist of an impervious surface such as asphalt and concrete that sheds rainfall and associated surface pollutants forcing the water to run off paved surfaces directly into nearby storm drains and then into streams and lakes. However, by implementing green infrastructure technologies such as grassed or vegetated filter strips, grass swales and pervious paving, enhancement of stormwater quality and control quantity can be achieved.

Water Quality Enhancement

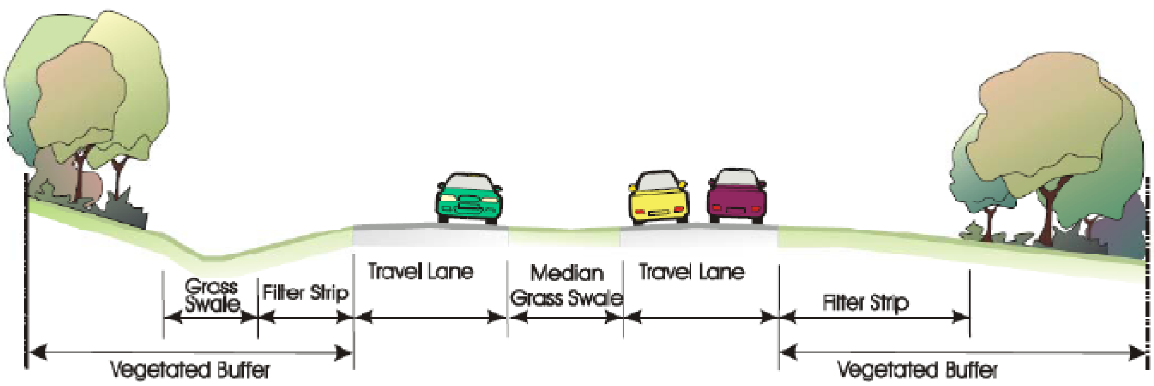
A few quality enhancement options exist:

Grass swales are a vegetated, open-channel designed specifically to filter and attenuate stormwater runoff. There are various different types of swales such as enhanced grass swales, dry swales and wet swales with varying pollutant removal rates.

Grassed filter strips are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Filter strips can provide a relatively high pollutant removal rate with proper design and maintenance. Filter strips are well suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and other pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer or as pre-treatment to another stormwater treatment practice such as grass swales.

Many stormwater BMP manuals recommend the use of filter strips as a secondary device to complement the function of grass swales. The application of the filter strip/grass swale combination is depicted in **Figure 6.4**. In this application, the filter strip is used as pre-treatment to reduce pollutant loading prior to entering a grass swale.

Figure 6.4: Combination of a grass filter strip and a grass swale



Filter strips and swales can perform well as a first-flush BMP because they capture and treat the early part of the storm runoff which is generally the highest in stormwater contaminants. Since grass vegetation is generally part of a landscaped area, grass filter strips and swales are relatively easy to incorporate into many BMP strategies.

Water Quantity Control

There are various green infrastructure technologies that can help control water quantity by reducing runoff generated by the impervious road and by further increasing infiltration and evapotranspiration rates. A water balance model was developed for this ISMP using the on-line software available at www.waterbalance.ca. The model can be used to compare a number of scenarios. These were applied to an example residential roadway to show the potential impact. The scenarios were created as outlined in **Table 6.2**.

In order to compare the effectiveness of each scenario in terms of runoff, evapotranspiration and infiltration, the same road area was applied throughout the water balance model. The results are included in **Figure 6.5**, which present the path of rainfall as a percentage.

#	Name	Characteristics
1	Conventional Road	Comprises of an impervious surface such as asphalt and concrete that sheds rainfall and associated surface pollutants forcing the water to run directly into nearby storm drains and then into streams and lakes.
2	Filter Strip (1m wide)	1m wide filter strip treating runoff generated from the adjacent road.
3	Filter Strip (2m wide)	2m wide filter strip treating runoff generated from the adjacent road.
4	Grass Swale	Grassed open channel treating runoff generated from the adjacent road without an underdrain.
5	Grass Swale & Filter Strip (1m wide)	Combines scenario #2 and #4.
6	Grass Swale & Filter Strip (2m wide)	Combines scenario #3 and #4.
7	Pervious Paving	Type of hard surfacing that allows rainfall to percolate to an underlying reservoir base where rainfall is either infiltrated to underlying soils or removed by a subsurface drain. The scenario assumed that the entire modelled impervious road network was replaced with pervious paving and would infiltrate to the underlying soil (silty loam).

Table 6.2 – Green Road Infrastructure Water Balance Scenarios

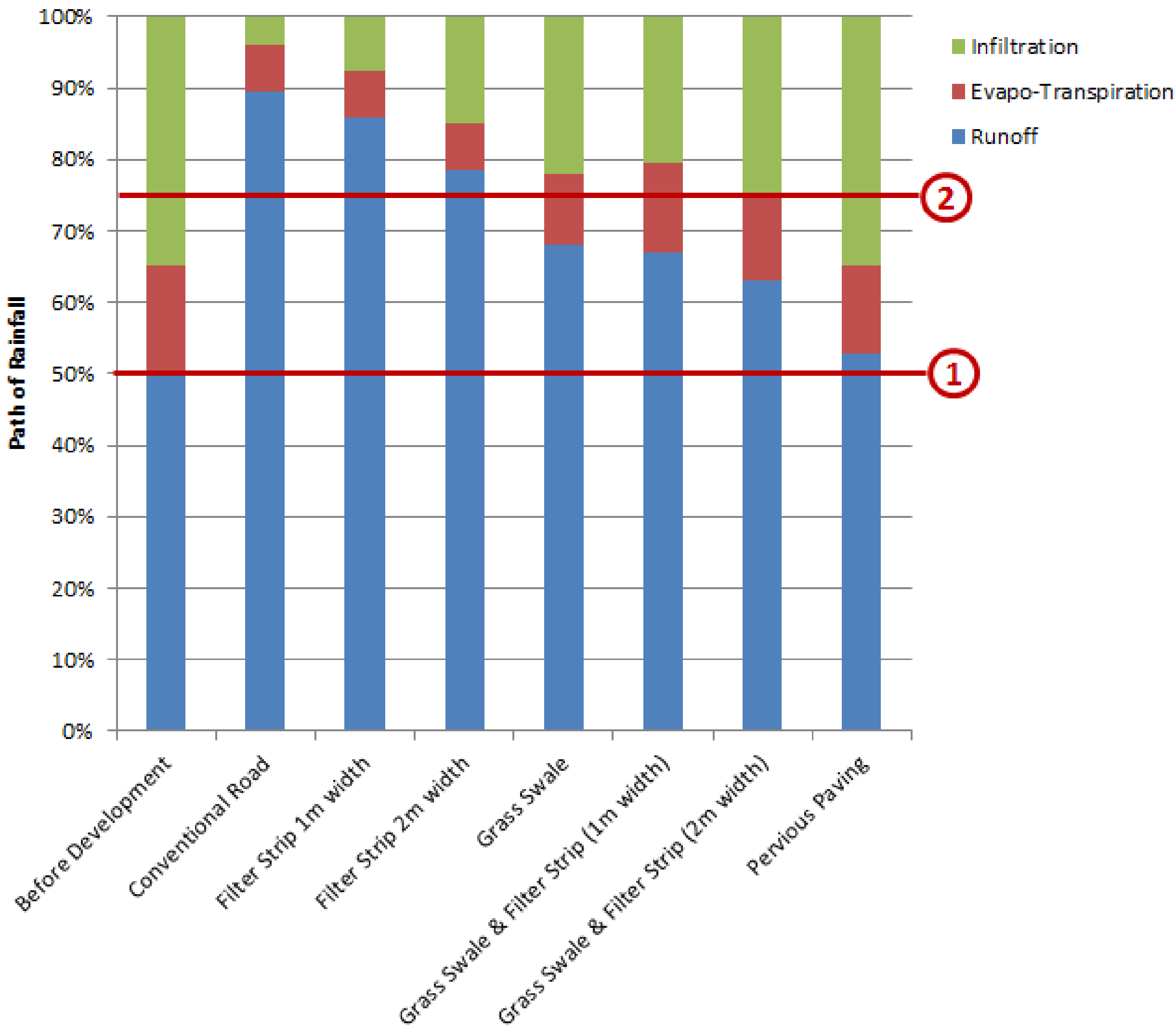


Figure 6.5 – Results from Water Balance Scenarios

Because of the high impervious area of roadways, it is difficult within a right of way to provide enough source controls to meet the ideal target of a predevelopment water balance (Line #1). However, within residential roadways with a typical 20 metre ROW, it is reasonable to expect a target of 75% runoff to be met (Line #2).

Recommendation 5: Develop new roads and road rehabilitation design guidelines to include a minimum of 25% reduction in total flows using green infrastructure. Stormwater quality BMPs would be required to limit total suspended solids to 20% of pre-development state.

6.2.2 Environmental Enhancement Opportunities

As much of the study area is currently developed, and long reaches of Bear Creek and its higher value tributaries remain within natural channel alignments, especially in the north and south tributary sub-catchments, there remains a relatively high level of ecological function within an urban setting. Therefore it is important to protect and enhance the natural environment though policy and land development but also to identify specific opportunities to enhance the natural environment through projects.

Enhance Lower Bear Creek Habitat Through Golf Courses

1250 metres of Lower Bear Creek run though the Guildford Golf and Country Club and the Coyote Creek Golf and Country Club. In these areas, although the land use adjacent to the creek is not urban, there is still opportunity for improvement. Currently the land is maintained as lawn right up to the top of bank. By maintaining a more natural riparian area the creek habitat would be improved which would increase not only the habitat in this area but the overall productivity of the linked system.

Figure 6.6 shows a typical Bear Creek Channel through a golf course. The light red line shows the current setback from the edge of water, about 5 metres. The second red line shows what providing an additional 5 metres would look like. While a setback of this size would have an impact on golf course operations it likely could be achieved without requiring reconstruction or reconfiguration of the tees and greens.

Figure 6.6: Example of increasing natural stream buffer.

Recommendation 6: Approach golf course owners to include improvement of Riparian Corridors in their long range plans. Assist in developing a plan that encourages natural vegetation planting and maintenance along the creek, planting of trees to enhance shading, and facilitates environmentally friendly maintenance procedures in these areas.

Making changes to the golf courses would require a relationship between the City and the golf course operators. Natural and environmentally productive lands can be a positive attribute for a golf course. It should be possible for the City and the operators to explore those improvements that would benefit both the golf course and the environment.

Stream Enhancement Opportunities

During the field work performed in Stage 1, a number of specific projects were identified as having a potential benefit. The list below is not exhaustive, but provides a sample of projects that could be undertaken. The location of these projects is shown in **Figures 6.7, 6.8 and 6.9**.

Site H1: Hunt Creek/Hunt Brook Complex:

Location: Hunt Creek headwater storm outfall near 76A Ave. Upper end of Class "A" classification.

Figure 6.7: H1 - Project Location

Elevated peak flow velocities/volumes have resulted in down-cutting and loss of suitable substrates at the outfall, and unstable channel conditions. Approx. 300mm angular riprap has been placed unsorted in an outfall pool, but displays low success in erosion protection. The site presents a habitat enhancement opportunity. Increase channel roughness and complexity through strategic boulder and coarse woody debris installation. Improve downstream substrate recruitment and fluvial process through installation of mixed, clean round gravels and coarse sand.

Recommendation 7: Initiate a site-specific design to review and restore the riparian areas and headwall at 76A Ave near 138 St.

The estimated cost of the project is $25,000

Site H2: Hunt Creek / Hunt Brook Complex:

Location: Hunt Brook headwater storm outfall.

Manicured yard space areas utilized by joined trailer parks at 13560 – 80 Ave and 7850 King George Hwy extend beyond property boundaries and into potential riparian areas of Hunt Brook. Three headwater stormwater outfalls contribute flow to Hunt Brook in this area, which could be consolidated to the lawn area, and tied into a latency pond or wetland attenuating headwater storm flows, improving riparian vegetation conditions, and providing improved food and nutrient input to Hunt Brook.

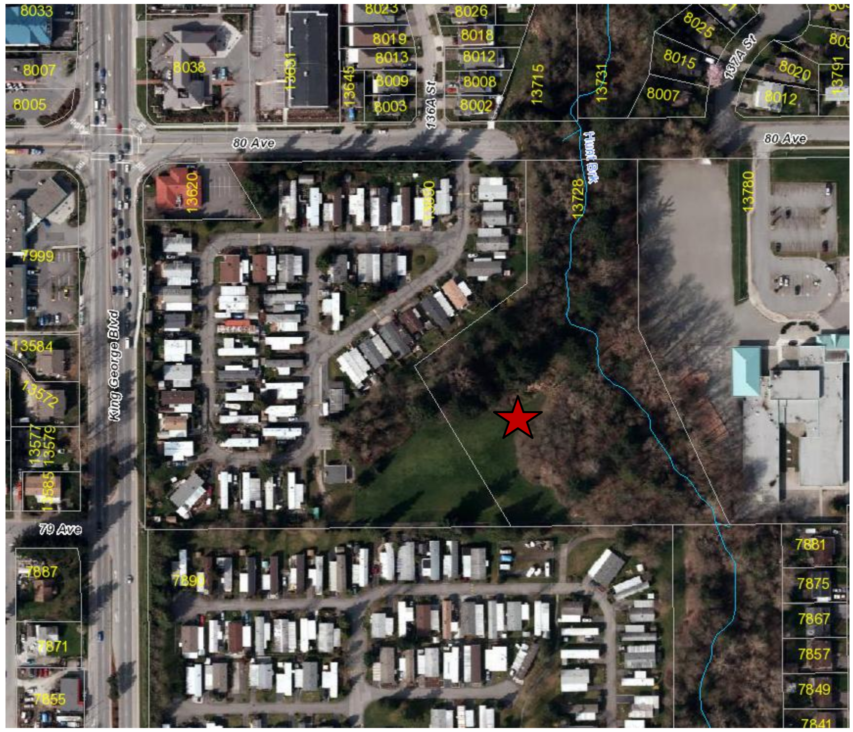


Figure 6.8: H2 - Project Location

Recommendation 8: A site specific d near Hunt Brook headwater storm outfall to combine storm outfalls and create a small pond or wetland.

The estimated cost for the project is $45,000.

Site H3: Burke Creek:

Location: Burke Creek on alignment of 78th Avenue.

An existing trail between 145A St. and 146th St. at 78th Ave uses a concrete pipe to cross Burke Creek. This culvert crossing serves as a barrier to fish passage upstream of 78th Ave. Replacement of this culvert with a bridge crossing and restructuring of the channel would improve fish access to suitable habitat upstream of the 78th Ave trail, to at least 76th Ave.

Figure 6.9: H3 - Culvert Location

Recommendation 9: Replace culvert at existing trail at 78 Ave between 145A St. and 146 St. with bridge or fish baffled culvert to improve fish passage upstream.

The estimated cost for the project is $40,000.

6.2.3 Pond Retrofits

Existing ponds service an area of over 30% of the watershed which, given that 25% of the watershed is park and agriculture, means that the pond service area is almost 50% of the urban land. The pond sites within the study area represent an opportunity for enhancing stormwater runoff in both quantity and quality. The properties are already owned by the City and designated for stormwater use. Most of the ponds were constructed before the theory of stormwater design evolved and therefore the ponds might be missing to improve stormwater management. There is a new emphasis on:

- Controlling smaller storms;
- Enhancing infiltration; and
- Improving water quality.

The ponds with the larger catchment areas have the potential to make a larger impact on the runoff to the creeks. The pond sites with the larger property areas available have a greater potential for expansion which provides more options. Ponds in the headwaters of the tributary creeks have greater potential to impact the health of the streams as their impacts will be more noticeable when the overall catchment contributing to the stream is still small. Older ponds also represent more chance for improvement as the advancement in thinking is likely to be greater.

The greatest potential for fish and aquatic habitat improvement through mitigation of scour and erosion is in the upper, highly developed headwaters where most of the field verification observations have been located. Headwater stormwater management improvements will in turn reduce erosive flow volume, frequency and duration, which will improve habitat quality and water quality in the lower reaches.

Improving Stormwater Quality Treatment

Contaminants that are commonly detected in urban runoff which may adversely affect receiving waters include suspended solids (SS), oxygen demanding substances (BOD and COD), toxic metals and trace elements, organic contaminants, nutrients and pathogenic bacteria. Other constituents which may affect the characteristics of the pollutants in urban runoff are (but not limited to) sodium, chloride, calcium, magnesium, potassium, alkalinity, hardness, pH, salinity and temperature.

Stormwater treatment programs have traditionally attempted to treat all pollutants in one way. However, with the technology that is available today, targeting specific pollutants is possible. Water treatment performance goals may differ as some receiving water bodies may need enhanced treatment of a specific pollutant such as salmon streams or eutrophying lakes. **Table 6.3** below illustrates treatment level related to water body type.

Table 6.3: Treatment Level Related to Water Body Type (Milton, Stormwater Treatment, 2002)

Water Body	Performance Goals
Eutrophying Lakes	80% TSS + 50% total phosphorus
Salmon Streams	80% TSS + 50% total zinc
Special Wetlands	80% TSS + 50% total phosphorus NO3, pH and alkalinity control
Remainder	80% TSS

Table 6.4 below is an excerpt from B.C. Ministry of Environment's 1992 document Urban Runoff Quality Control Guidelines for the Province of British Columbia, which illustrates the various constituents of general urban and highway runoff. This table includes limits for protection of aquatic life.

Table 6.4: Constituents of General Urban and Highway Runoff (ref: MOE, 1992).

Constituents	Mean General Urban Runoff	Mean Highway Runoff	Limits for Protection of Aquatic Life
Suspended Solids (mg/l)	150	220	10 if background d100 mg/l 10% of background if background is >100mg/l
Lead (ug/l)	140	550	34
Copper (ug/l)	34	43	6.7
Zinc (ug/l)	160	380	30
Oil and Grease (mg/l)	7.8	30	No data reported
Total Hydrocarbons (mg/l)	3.7	No data reported	No data reported
Total Nitrogen (mg/L-N)	1.5	2.72	No data reported
Phosphorus (mg/l)	0.33	0.59	0.005-0.015 (for lakes with salmonids as the predominant fish species.
Alkalinity (mg/l)	38.2	No data reported	Recommend >20
pH*	6.2-8.7	6.6-8.0	6.5-9.0

Note that pH is given as a range and not a mean

There are 25 dry ponds in the Bear Creek watershed. Although dry ponds are suitable for large detention volumes and can control peak flows, their main disadvantage is their poor water quality treatment and sediment removal performance. This could be enhanced by retrofitting existing dry ponds to enhance water quality. The options include:

- Converting the dry pond to a wet pond or wetland;
- Constructing water quality swales through the dry pond; or
- Installing structural oil-grit separators.

These above options could be partially implemented as part of an overall treatment-train approach.

Wet Pond

Metro Vancouver's Best Management Practices Guide for Stormwater lists the benefit and constraints of wet ponds. The benefits and constraints of wet ponds are as shown in **Table 6.5** below.

Table 6.5 – Typical Benefits and Constraints of Stormwater Ponds

Benefit	Constraints
• Can provide effective flood control, stream bank erosion control, removal of particulate and soluble contaminants, and limited groundwater recharge (depends on soil conditions); • One of the most aesthetically pleasing structural BMPs – can increase property value; • Can include other uses – recreation, fish and wildlife habitat or wetland; • Wet ponds accomplish removal of soluble contaminants such as nutrients (important if receiving waters are sensitive to nutrient inputs); • Wet ponds are most cost effective in larger catchments; and • Provides some infiltration unless lined.	• Wet ponds are more expensive than extended detention dry basins • Temperature increase is a concern on cold water streams; • Inadequate maintenance can lead to problems with floating debris and scum, algae, odours, and insects; • Safety concerns associated with side slopes; and • Loss of the area as dry land recreation such as playing fields.

Water Quality Swales

Water quality swales are a type of BMP that could be implemented within pond sites. There are a number of variations on these designs that could be tailored to a specific site - enhanced grass swales, dry swales, and wet swales. These could be introduced as part of a treatment train to enhance the effectiveness of the existing dry ponds.

Enhanced grass swales are vegetated open channels that convey, treat and attenuate stormwater runoff, as depicted in **Figure 6.10**. Unlike typical grass swales with V-shaped bottoms, enhanced grass swales include flat bottoms and vegetation which decreases the velocity of the water, allowing for sedimentation, filtration through the root zone and soil, evapotranspiration and infiltration into the underlying soil. Check dams could also be added to enhanced grass swales to further reduce the velocity and enhance infiltration. Enhanced grass swales are well suited for conveying and treating runoff from roadways because they are a linear practice and they are easily incorporated into roads right-of-way.

Dry swales are open channels that are designed to convey, treat and attenuate stormwater runoff as depicted in **Figure 6.11**. They are similar to enhanced grass swales but they incorporate an engineered soil bed, such as a filter bed or growing media, and an optional perforated pipe underdrain or a bio-retention cell configured as a linear open channel. Check dams could also be added to further reduce velocity and enhance infiltration. Overall, dry swales provide better water balance and water quality benefits than enhanced grass swales due to their engineered soil media and increased storage capacity. One of their greatest benefits is that dry swales decrease thermal impacts on a receiving watercourse.

Wet swales could be considered as an alternative design where soils are not permeable or where there are low lying areas with a high water table as depicted in **Figure 6.12**. Wet swales combine elements of a dry swale, and a wetland system, which is why they are typically wider than dry swales ranging from 4 m to 6 m. Check dams are used to create shallow impoundments where wetland vegetation can be planted. A primary disadvantage of wet swales is that, similar to wet ponds and wetlands, prolonged standing water creates additional concerns due to mosquito breeding.

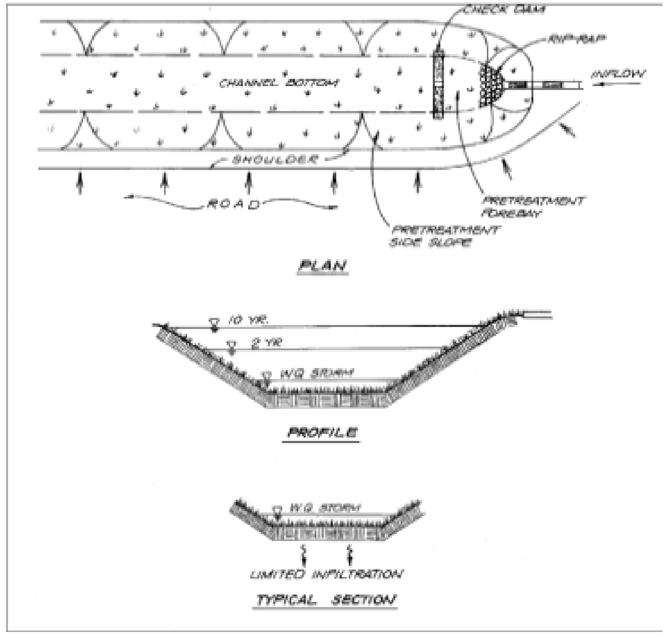


Figure 6.10: Enhanced Grass Swale

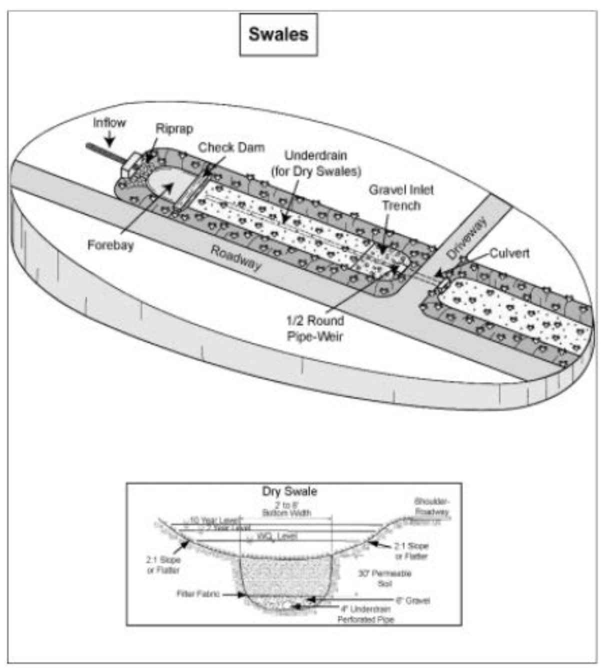


Figure 6.11: Dry Swale

PARSONS

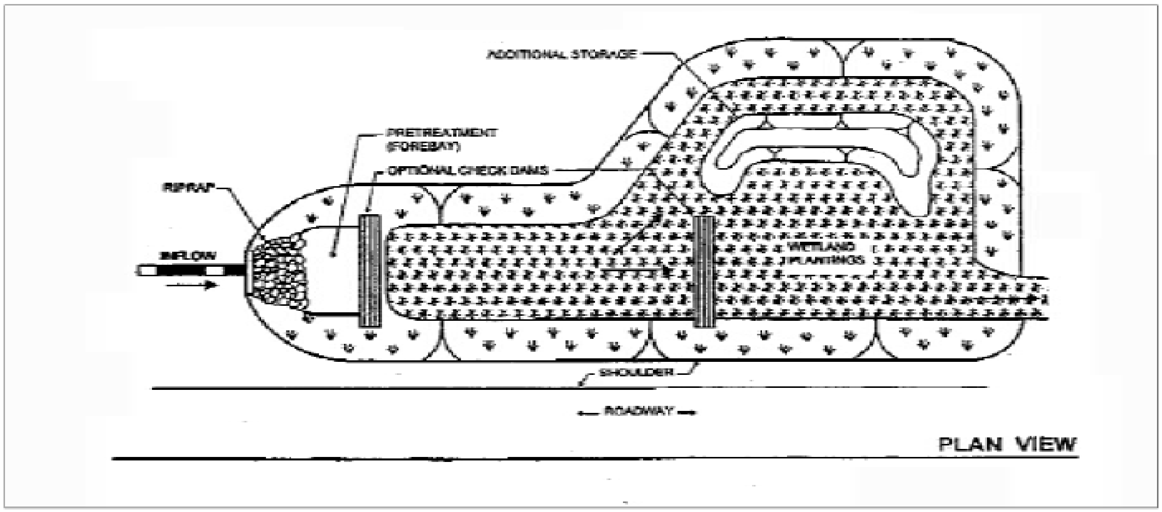


Figure 6.12: Wet Swale

These retrofits have varying degrees of pollutant removal rates as illustrated in the **Table 6.6**. However, it is important to note that their effectiveness is highly dependent on their design and maintenance.

Table 6.6: Typical Estimated Pollutant Removal Rates

BMP	Mean Pollutant Removal Rate				
	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Total Zinc	Total Copper
	%	%	%	%	%
Enhanced Grass Swale	76	55	50	60	60
Dry Swale	80	20	60	75	70
Wet Swale	74	28	40	-	-

Oil Grit Separators

Oil/grit separators are a conventional device used to trap and retain oil and/or sediment in detention chambers that are located below ground. Separators are often used to control spills and as a pre-treatment device for end-of-pipe controls as part of a multi-component approach to water quality control. As with water quality inlets, oil and water separators are used to enhance water quality only and not for peak flow attenuation or ground water recharge. The following removal efficiencies were obtained from the Ministry of Environment website.

- oil and grease: 50% to 80%
- sediment: 20% to 40%
- chemical and biochemical oxygen demand: <10%
- total phosphorous: < 10%
- total nitrogen: < 10%
- heavy metals: < 10%

There are many limitations to using oil/grit separators. For instance, high flows include the potential re-suspension of sediments and flushing of trapped oil and grease during heavier storms. Odours may be a problem during summer due to degradation of organic matter under anaerobic conditions in the permanent pool. Water quality inlets require frequent (several times per year) removal of sediments, trash and trapped oil and should be cleaned before the onset of the dry season, after spills of polluting substances and when inspection shows oil accumulation greater than 25 mm, sediment accumulation greater than 150 mm, or as recommended by the manufacturer.

Furthermore, oil-grit separators provide marginal water quality improvement compared to other treatment BMPs and should only be considered as a pre-treatment step to protect downstream conveyance and BMP facilities (such as ponds and infiltration basins) from trash, coarse sediments and excessive concentrations of oil and grease.

Improving Erosion Control

Urbanization and uncontrolled runoff cause increasing erosive forces within a watercourse which lead to erosion and degradation of aquatic habitat. Although channels are able to tolerate some increases in water, the threshold varies depending on their physical characteristics such as distribution of riparian vegetation and soil properties. It has been found that at levels of watershed imperviousness above 10%, stream channels become unstable and begin eroding. The Bear Creek system and its tributaries all show signs of increased erosion rate.

In order to mitigate erosion within the channel of the receiving watercourse, smaller storm events could be controlled within the pond site to pre-development flow rates. Ponds could be retrofitted with an orifice to control the discharge for smaller rainfall events into the receiving watercourse. Essentially this means the ponds will be utilized more often. Although this does not preclude dry-pond type land uses (recreation field), it would likely limit this use as the ponds would often be wet and different vegetation and safety requirements would be required.

Pond Analysis

There are 25 dry ponds in the study area and 60% of them were constructed prior to 1990. Three ponds listed in the table below were selected for a more detailed analysis of their overall performance and potential for improvement.

Pond 1

GIS ID#: 10004293671

Location: 146 Street and 85A Avenue

Sub-Watershed: Price Creek

Pond 2

GIS ID#: 1000429381

Location: 142 Street and 73A Avenue

Sub-Watershed: Nichol Creek

Pond 3

GIS ID#: 1000429467

Location: 144 Street and 92 Avenue

Sub-Watershed: Enver Creek

The analysis considered existing pond infrastructure, catchment conditions and outlet controls. The details of this analysis are contained in **Appendix A**. The goal was to determine potential changes that could be made to the pond sites that should result in better management of stormwater.

The ponds were modeled for typical design events of 2 and 5 year. Smaller return period storms were also ran to better see how the pond was impacting smaller frequent events. Overall rainfall distribution in the Lower Mainland is many rainy days with small amounts of rain. **Table 6.7** shows the breakdown of the last 15 years of rainfall data in the City of Surrey. Importantly, of the volume of rain falling, only 4% of the rain comes in large events.

Table 6.7 – Rainfall Distribution in Surrey

Rainfall Amount	% of days	% of Total Rain
0 - 5 mm	53%	11%
5 - 10 mm	18%	16%
10-20 mm	18%	30%
20-30 mm	6%	19%
30-60 mm	4%	21%
60 mm +	0.4%	4%

Of all the rainy days 53% are 5mm or less. Only 0.4% of the rainy days had 60mm or greater rainfall, which is roughly consistent with a 2 year event. Therefore older stormwater ponds are likely ignoring 95% of the rain that falls on the City of Surrey.

The modeling of the three existing ponds confirmed that while they do provide some peak flow control for 2 year events and larger they do not provide any attenuation for smaller more frequent events. Therefore they provide very little in the way of erosion control and water quality improvements.

Pond 1:

This pond area is currently a passive recreation field. There are a number of options for the area. This ISMP briefly looked at Wetland, Wet Pond and Water Quality Swale options but it is important to note that any potential final solution would need to involve a more site specific review and stakeholder consultation.

Option 1 – Wet Pond: The area could be partially converted to a wet pond or wetland type development in order to improve water quality and erosion control (through better water balance). A wet pond / wetland system, complete with a forebay, could improve water quality. The outlet of the pond would contain a smaller orifice restriction that would give more flexibility in reducing erosion by controlling small flow events. If the pond was sized to control flows up to a 20mm storm event then a 2400m^3 volume could be accommodated within the 'wet area' shown below. Storms greater than 20mm would then bypass the as is the case today until the 2 year storm which would use the dry pond area in the same way as present condition.

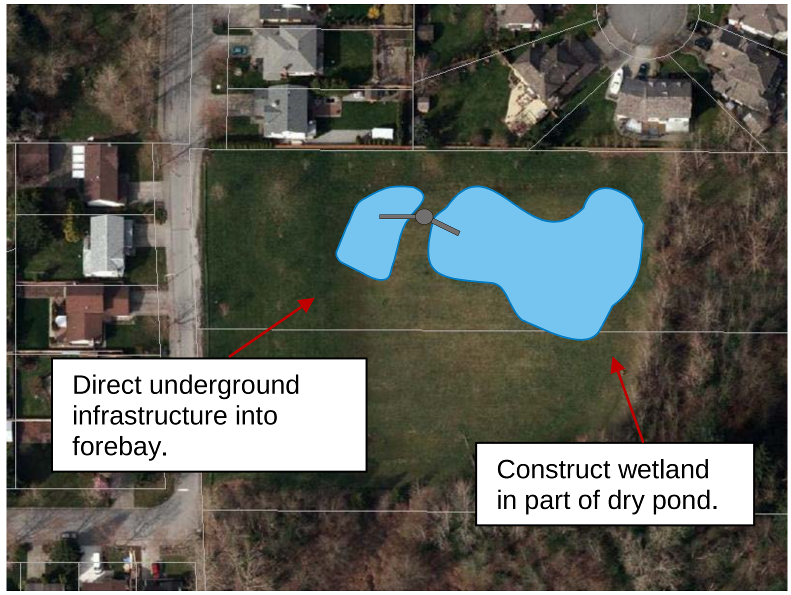


Figure 6.13 – Pond 1 with a Wet Pond/Wetland Added

Option 2 – Water Quality Swale: Alternatively, with less impact to the property, a water quality swale could be constructed. Presently the underground infrastructure directs all small flows directly to the creek. Small flows and the first flush of large flow events have the potential to contribute the most stormwater pollutants to the watercourse.

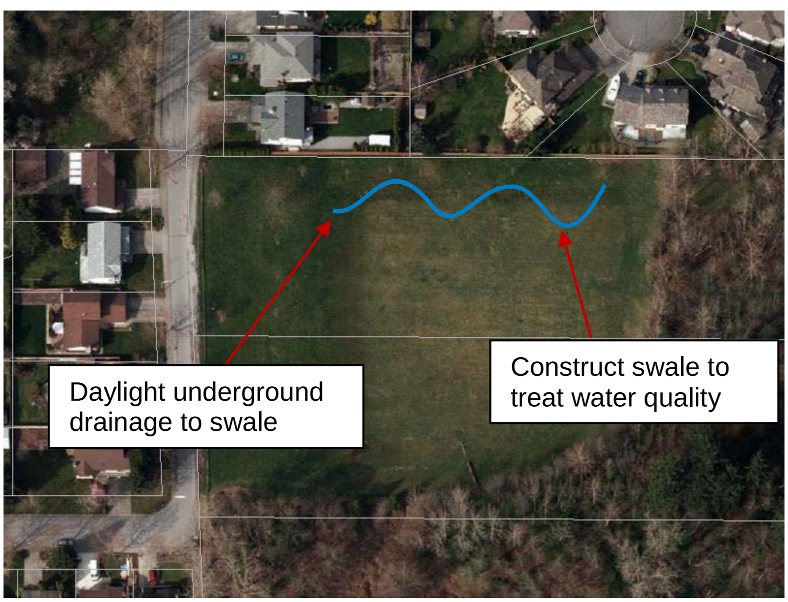


Figure 6.14 – Pond 1 with a Water Quality Swale Added

Pond 2:

This existing pond area is also a passive recreation field.

Wet Pond: Similar to Pond 1, the area could be partially converted to a wet pond or wetland type development in order to improve water quality and erosion control (through better water balance). A wet pond/wetland system, complete with a forebay, could improve water quality. The outlet of the pond would contain a smaller orifice restriction that would and give more flexibility in reducing erosion by controlling small flow events. If the pond was sized to control flows up to a 20mm storm event then a 1400 m^3 volume could be accommodated within the 'wet area' shown below (excluding the forebay area). Storms greater than 20mm would then bypass, as is the case today, until the 2 year storm which would use the dry pond area in the same way as the present condition.

Figure 6.15 – Pond 2 with Wetland/Wet Pond Added

Pond 3:

A watercourse currently runs within the existing pond area. Although, there are a number of options for the area a water quality swale is deemed the most feasible option in order to maintain the integrity of this existing watercourse. In order to enhance water quality, this existing watercourse could be re-aligned to increase its length as illustrated in the below figure and check dams could be added to slow the flow. During higher rainfall events this watercourse will be susceptible to flooding and therefore the existing dry pond area will be inundated with stormwater.

Figure 6.16 – Pond 3 with swale added

Recommendation 10: A pilot project to retrofit two existing dry ponds to provide better water quality treatment and erosion control. If successful this pilot project could be expanded into a retrofit program to target existing dry ponds that could be providing more stormwater benefits:

- Retrofit the existing dry pond at 144 Street and 92 Avenue (Pond 3) in the headwaters of Enver Creek to construct an enhanced swale and sediment forebay. The estimated construction cost of this pilot project would be $50,000.
- Retrofit the existing dry pond at 146 Street and 85A Avenue (Pond 1) as a wet pond / wetland project. The estimated construction cost of this pilot project would be $125,000.

Implementing this program would depend a lot on Surrey Staff and stakeholders to buy-in to the project. The conversion of lands that people may use for recreation needs to consider which objective for the site best meets the community needs.

6.2.4 Commentary on MDP Recommendations - Detention Ponds

The 1998 Master Drainage Plan (MDP), recommended a long term program of constructing stormwater detention facilities to partially restore natural hydrology. The plan covered diversions in the entire Bear Creek watershed including the Lower Bear Creek area and the Quibble and Cruikshank/Grenville ISMP areas. Within the Lower Bear Creek area nine detention sites were proposed as shown in **Figure 6.17** with an open square. **Table 6.8** shows the approximate storage volumes the MDP recommended these ponds to provide.

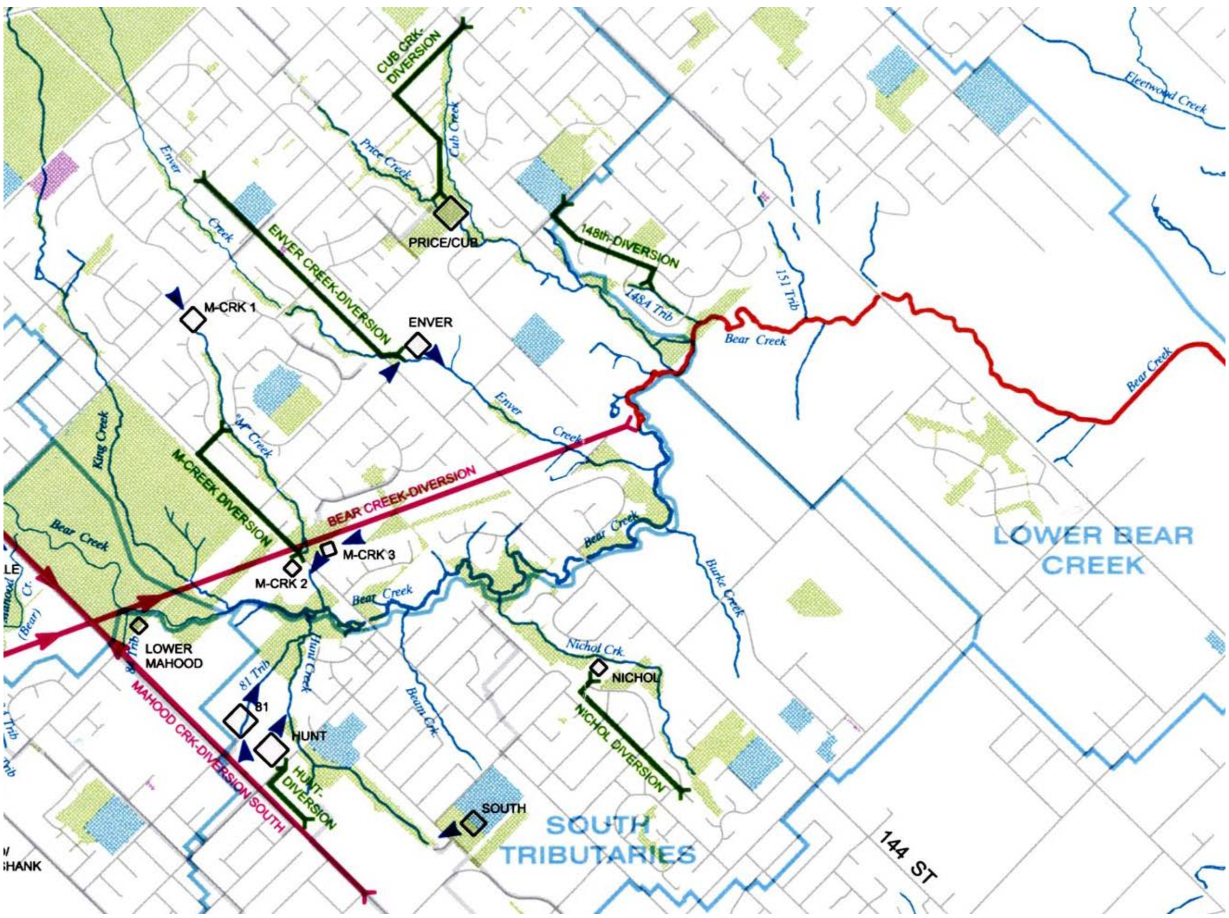


Figure 6.17 – MDP Proposed Detention Pond (adapted from KWL-CH2M, 1998)

Table 6.8 – MDP proposed detention ponds

MDP Functional Planning area	Proposed Facilities	Volume (m^3)	Cost
North Tributaries	1. Price/Cub 2. Enver 3. M Creek 1 4. M Creek 2 5. M Creek 3	123,590	$18,538,500
South Tributaries	1. 81st 2. Hunt 3. South 4. Nichol	81,420	$12,213,000

These detention volumes were designed to meet current City of Surrey design criteria for current developments that are underserviced stormwater detention. They were only approximately sized and located with the intention that they would be designed in more detail as part of site-specific studies.

As discussed earlier, there are portions of Lower Bear Creek that have developed to an urban land use without including stormwater detention. These tend to be in the neighbourhoods that were constructed during a time when stormwater was managed by draining water to creeks without consideration for increased flow. These new ponds would undoubtedly improve stormwater runoff in Lower Bear Creek and its tributaries. Design with water quality measures and consideration for the full spectrum of rainfall could allow these regional detention facilities to serve multiple stormwater objectives. However, these benefits are not without costs.

The estimate cost for all Bear Creek detention in 1998 was $152 million which would be about $222 million in 2012 dollars. Given that in 2011 the capital construction budget for drainage was $8.9 million it would be 25 years of construction if 100% of the budget was spent in the Bear Creek watershed. These costs do not include property costs. The cost to install ponds after development has taken place would fall entirely to the tax base because that development can no longer be called upon to pay for the ponds.

These ponds would assist enhancing the fish habitat of the immediate tributary streams a point of discharge but no major flood risk has been identified in these tributaries so the benefit is primarily environmental. Historically there has been some flooding in the agricultural lowlands which has been attributed to upland urban development and these proposed detention ponds would provide incremental improvement. However, the City is handling this through flood protection and conveyance improvements. Currently an expenditure of this magnitude is too large to justify unless there is a more pressing need or a shift in priorities to support major expenditures on habitat protection.

Recommendation 11: Consider large stormwater detention facilities for existing communities as a long-term possibility to be tied to future redevelopment.

6.2.5 Commentary on MDP Recommendations - High Flow Diversions

The 1998 Master Drainage Plan, recommended a long term program of constructing high flow stormwater diversions. These diversions would serve to reduce flows in the upper portions of the tributaries of Bear Creek. The high flows would be conveyed downstream while low flows and base flows would still discharge into the creek. The potential benefit would be the protection of upstream reaches, much of which is spawning area for fish. Also, if there is an erosion hazard in the upstream reach, the potential for high erosion flows is reduced. The downside of high flow diversion systems is they only benefit one short reach of watercourse and could increase a flooding and erosion problem downstream.

High flow diversions are good where an erosion hazard has been identified in a short reach of watercourse. The diversion can help mitigate future erosion. In the Lower Bear Creek, while erosion effects are visible throughout there were no high hazard erosion areas noted in the last Ravine Stability Report.

Recommendation 12: Diversion pipes identified in the MDP are not required.

6.2.6 Commentary on MDP Recommendations – Culvert Improvements

The 1998 Master Drainage Plan, recommended a number of culvert upgrades for undersized culverts along Lower Bear Creek and its tributaries. This was because these culverts are not sized to meet current City of Surrey design standards. Larger culverts could convey more flows during large and infrequent storms but may also have the downside of reducing the artificial detention of water behind these culverts.

Although unintended this detention may be assisting the reduction of flooding and erosion downstream. Upsizing of existing small culverts should be based on existing problems and risks associated with individual culverts. Based on discussions with City operations staff, the system appears to be working with no overtopping or roads being observed during major rainfall events.

Recommendation 13: Culvert replacement should be based on operating experience and specific issues at particular locations. Culvert size should be maintained or upgraded with similar sized culverts. If flows increase in the future due to climate change then additional overflow conveyance can be installed above the existing culverts.

6.3 Educator and through the promotion of ideas role

The City of Surrey has made a commitment to place the principles of social, environmental and economic sustainability as the foundation of all decisions. As part of this commitment, Surrey can promote the principles integrated stormwater management through education and awareness programs and practices that highlight how human activities are linked to stream health.

6.3.1 Demonstration Projects

There are a growing number of resources available on stormwater BMPs. There are also an increasing number of projects being implemented in the City of Surrey and surrounding areas. One of the best education tools, particularly to those who doubt the value of stormwater BMPs, is to see examples of these practices in action.

The City of Surrey website already provides links to general resources on stormwater BMPs. However, adding information about complete projects and their location would allow developers, contractors and designers to find out more information. The City of Surrey online GIS system (COSMOS) could be developed to include a map of BMPs similar to the "Green Projects Map" developed by the Credit Valley Conservation Authority in Ontario (http://www.creditvalleyca.ca/low-impact-development/).

Recommendation 14: Create a layer on COSMOS that highlights existing stormwater BMPs installed in Surrey. Provide information on the projects and encourage people to visit.

6.4 Implementation Priorities

The following ***Table 6.4.1*** presents suggested implementation priorities for the 14 previously discussed recommendations.

Table 6.4.1: Prioritization of Recommendations

Priority	Recommendation
1	**Recommendation 1:** For areas of densification require no net increase in volume of runoff from pre-development conditions and removal of 80% of total suspended solids from stormwater, tied to planning approvals.
2	**Recommendation 2:** For single residential no net increase in volume of runoff from pre-development conditions and removal of 80% of total suspended solids from stormwater, tied to building permit.
3	**Recommendation 5:** New roads and rehabilitation to provide 25% reduction in total flows and limit total suspended solids to 20% of pre-development state.
4	**Recommendation 3:** Within existing wildlife corridors remove barriers or allow for improved movement.
5	**Recommendation 4:** Identify and secure new wildlife corridors along Price and Enver Creeks.
6	**Recommendation 11:** Consider large stormwater detention facilities for existing communities as a long-term possibility to be tied to future redevelopment.
7	**Recommendation 7:** Review and restore the riparian areas and headwall at 76A Ave near 138 St.
8	**Recommendation 8:** A site specific d near Hunt Brook headwater storm outfall to combine storm outfalls and create a small pond or wetland.
9	**Recommendation 9:** Replace culvert at existing trail at 78 Ave between 145A St and 146 St with bridge or fish baffled culvert to improve fish passage upstream.
10	**Recommendation 10:** Pilot project to retrofit two existing dry ponds: • 144 Street and 92 Avenue (Pond 3) in the headwaters of Enver Creek to construct an enhanced swale and sediment forebay. • 146 Street and 85A Avenue (Pond 1) as a wet pond / wetland project.
11	**Recommendation 13:** Culvert replacement based on operating experience and specific issues. Culvert size maintained as now. Additional overflow conveyance can be installed above the existing culverts if flows increase due to climate change.
12	**Recommendation 12:** Diversion pipes identified in the MDP are not required.
13	**Recommendation 14:** Create COSMOS layer to highlight existing stormwater BMPs for public education.
14	**Recommendation 6:** Encourage golf course owners to provide riparian protection.

7. Monitoring

Monitoring helps us understand the watershed and identify future opportunities. Information gathered from monitoring allows for long-term strategies to be tracked and adapted as the plan moves forward. The City of Surrey is already engaged in a number of different monitoring activities in Bear Creek, most notably:

- Benthic Monitoring of four locations, two in Bear Creek, one in King Creek and one in Enver Creek
- Water Quality monitoring near Surrey Lake as part of the Boundary Bay Assessment & Monitoring Program (BBAMP)
- Erosion monitoring every two years as part of the Ravine Stability Assessment Program
- Flow monitoring of Bear Creek at 144th Street and 152nd Street

Overall the monitoring required in Bear Creek is covered by existing monitoring programs. The only recommendation for increased monitoring is to add scope to the erosion monitoring program.

7.2 Stream Erosion Monitoring

The City of Surrey monitors erosion in the Bear Creek watershed through the Ravine Stability Assessment Program. This provides an excellent tool to observe the effects of erosion over time, with respect to vegetation and apparent stability of various locations with a focus on protection of public and private property. Two limitations of the program are:

- It does not provide a quantifiable measurement which can be compared from site to site.
- It does not evaluate erosion from a stream habitat perspective. Erosion can be a significant factor in degrading fish habitat and still not register as a 'hazard' to be classified in the Ravine Stability Program.

As stormwater best management practices are introduced, a monitoring program that can quantify erosion will help determine which practices are most effective. This information is valuable to move creeks towards their pre-development flow levels.

A variety of additional methods are available to monitor erosion along streams in the Bear Creek watershed. Some may be done in conjunction with the City's current Ravine Stability Assessment Program:

- **Channel Cross-Section Survey** – Monitoring cross sections of creeks provides a simple means of quantifying channel erosion and providing details of its stability. Through successive surveys, channels can be easily monitored to measure the extent of erosion or deposition at a given site. A survey program would require a long-term commitment and it may be possible to combine with the City's current Ravine Stability Assessment Program, which would reduce costs. The combination of survey data and photo monitoring would provide excellent tools to assess the health of creeks.

- **Water Quality Monitoring** – Water quality sampling can provide a quantifiable and simple means of erosion over time by directly measuring what is often the most important item of concern. The sampling program can be increased to provide detailed assessments of specific creeks, and monitor the effectiveness of potential sediment control projects. Water quality monitoring can be labour intensive and can become expensive depending on the size of the program. A program which monitors key downstream locations may be a viable option.
- **Aerial Photography** – Comparison of aerial photographs over time provides a simple tool to assess the relative erosive impacts along creeks. Costs for aerial photography can be high and may only be feasible for wider creeks with less vegetative cover.

The major obstacle in additional erosion monitoring is likely to be funding. With that in mind, cross-section surveys would provide the best value of the three options listed above. Survey could be done at the same time as the Ravine Stability Assessment and provide a quantifiable measurement of erosion over time.

8. References

Title	Date	Author
2002 Ravine Stability Assessment	2002	Urban Systems
2005 Ravine Stability Assessment Update	Mar-06	Associated Engineering
2009 Ravine Stability Assessment	2009	Web Engineering

Bear Creek MDP - Integrated Framework for Master Drainage Planning and Stakeholder Involvement	Mar-97	CH2M - KWL
Bear Creek MDP - Fish Habitat Assessment and Implications for Management Strategies	Jan-98	CH2M - KWL
Bear Creek MDP - Impact of Urbanization on Groundwater Recharge and Watercourse Base Flows	Apr-98	CH2M - KWL
Bear Creek MDP - Watercourse Investigation Program and Drainage Facility Assessment	Sep-98	CH2M - KWL
Bear Creek Erosion Study Project	Dec-98	Dillon
Bear Creek MDP - Summary Report on Stormwater Management and Master Plan for Drainage System Upgrading	Feb-99	CH2M - KWL
Bear Creek MDP - Executive Summary for an Integrated Stormwater Management Strategy and Master Drainage Plan for Bear Creek Watershed	May-99	CH2M - KWL
Bear Creek - Cruikshank and Grenville Stormwater Servicing Functional/Feasibility Plan and Appendix A	Feb-02	EarthTech
Quibble Creek Functional/Feasibility Plan	Nov-01	EarthTech
Bear Creek Trunk Stability Review	Nov-08	Associated Engineering
Serpentine-Nicomekl Lowland Flood Control Project - Integrated Functional Plan for Flood Protection and Environmental Enhancement in Lower Bear Creek	Aug-98	CH2M - KWL
Surrey City Centre - General Land Use Plan Update - Utility Servicing	Sep-10	AECOM

Environmental Impact Assessment N.E. Newton Pocket Land Development Study	Jun-96	IRC Integrated Resource Consultants
Salmon Habitat Restoration Program "SHaRP"	10-Dec-96	Dillon
Environmentally Sensitive Areas	undated	City of Surrey
Metrics Report - Enver Creek	2000-2008	
A Literature Review of Benthic Invertebrate Usage of the Hyporeic Zone and Implications for Culvert Designs	Feb-95	ECL Envirowest

Benthic-Invertebrate Sampling Program 2003 – 2005 Summary Report	Jan-07	Dillon
2006 Invertebrate Sampling Program	2006	Dillon
2009 Benthic Invertebrate Sampling Program	2010	Raincoast Applied Ecology
Surrey Lake Water Quality Monitoring Report	17-Dec-04	Jacques Whitford
The Serpentine River Watershed Salmonid Resource Studies 1984-85	Jun-85	Tynehead Zoological Park
Bio-Inventory and Habitat Enhancement Assessment of Quibble Creek	21-Mar-95	R.U. Kistritz Consultants
Bio-Inventory and Identification of Habitat Enhancement Opportunities in King Creek	May-96	ECL Envirowest
Boundary Bay Assessment & Monitoring Program - 2010 Sediment Monitoring Report	Mar-11	Tri-Star Environmental Consulting For Metro Vancouver
Boundary Bay Assessment & Monitoring Program - 2010 Water Column Monitoring Report	Mar-11	Tri-Star Environmental Consulting For Metro Vancouver
Ecosystem Management Study (EMS)	Apr-11	HB Lanarc
Review of Boundary Bay Monitoring – 2010 Final Assessment Report	Mar-11	Metro Vancouver- LWMP Environmental Management

Appendix A
Modeling

Appendix A – Modeling

1. INTRODUCTION

The ISMP involves the creation of a hydrologic and hydraulic model. The model is developed to serve a number of purposes:

- Give an estimate on pre-development flows to provide targets when implementing and assessing the effectives of runoff control measures;
- Compare the present day situation with future development scenarios; and
- Provide input to a future lowland model of the Serpentine River.

The model doesn't include details of the existing piped system as it's intended to provide an overview of the watershed with the effects of development on the creek flows.

1.1 Study Area

The study area bridges the three Surrey communities of Whalley, Newton and Fleetwood. The entire Bear Creek watershed is the largest watershed within the City of Surrey at almost 40 km², with the lower portion in this study area representing about half of the overall area. The study area includes the main stem of Bear Creek as well as a number of smaller tributaries. The major catchments upstream of the study area are Quibble Creek Catchment and Cruikshank/Grenville Catchment which will be studied under separate ISMPs. Understanding the links between the upstream catchments and the study area will be an important consideration throughout the ISMP. There are an estimated 18 km of open channels in the Lower Bear Creek study area, almost double that of the contributing Cruikshank/Grenville and Quibble catchments which have a similar catchment area.

2. MODEL SET-UP

XPSWMM was used to model the Bear Creek catchment under existing, pre-developed, and post-development conditions. Peak flows were modeled for 2-year, 5-year, and 100-year storm events. The following information was used to build the model:

- Catchment and sub-catchment boundaries were determined based on provided topographic data and a review and existing storm sewers. The sub-catchments, as imported into XPSWMM are shown in **Figure A-1**. The catchments are based on the existing conditions;
- Hydrological parameters for each parameter were inputted including catchment area, percent impervious area, catchment slope and catchment width;
- Creek data for 31 sections of creek throughout the watershed. Data included lengths, roughness coefficients, slopes and cross section information imported from contour data; and
- Rainfall data was used based on the 2004 City of Surrey Design Criteria Manual. Design storms for 1, 2, 6, 12 and 24 hours were provided at the Kwantlen Park gauge. All five durations of storm events were run to determine peak flows of the 2-year, 5-year and 100-year return period events.

2.1 Catchment Data

The Bear Creek catchment was delineated into 61 sub-catchments (**Figure A-1).** Slopes, widths and areas were based on the topography and dimensions of the sub-catchments. The same sub-catchment dimensions and topographic characteristics were used for the existing, pre-development and post-development conditions. The percent impervious was altered for each condition based on land use. The catchment data is included in **Table A-1** below. The four catchments highlighted red have had the peak flows calculated and summarized in subsequent section. These locations are also included in **Figure 1**.

Table A-1: Key Hydrologic Data

Name	Sub-catchment	Slope (%)	Width (m)	Area (ha)	Pre-develop Impervious (%)	Existing Impervious (%)	Post-develop Impervious (%)
QU072	1	5.45	1266	47.7	5	70	72.6
QU072	2	3.70	2520	123.4	5	65	67.8
QU073	1	3.52	1920	55.6	5	30	34.2
QU073	2	4.31	1810	38.6	5	40	46.9
QU075	1	4.33	1060	29.4	5	30	38.6
QU075	2	3.98	2700	180.0	5	70	75.3
QU079	1	4.12	1700	101.3	5	60	65.1
QU090	1	4.48	1200	45.9	5	64.4	64.4
QU090	2	4.46	1350	50.9	5	40	64.6
KG078	1	2.69	2480	71.6	5	65	65
KG078	2	3.36	900	13.8	5	65	65
KG081	1	2.49	2200	110.1	5	65	65.3
KG081	2	2.50	3000	72.7	5	65	65
KG087	1	5.93	620	4.9	5	67.3	67.3
KG087	2	2.51	3000	71.1	5	78.7	78.7
KG088	1	2.55	1692	56.7	5	87.3	87.3
KG088	2	1.65	1096	39.9	5	65	70.3
KG092	1	8.84	310	2.6	5	40	65
KG092	2	4.04	700	16.8	5	60	74.6
KG098	1	3.05	3540	141.8	5	88.1	88.1
KG098	2	3.95	1444	13.7	5	80	87
KG098	3	3.99	1556	31.0	5	87.6	75
KG101	1	2.40	1320	16.6	5	83	88
KG112	1	2.42	2300	31.1	5	5	83.4
KG112	2	2.71	500	3.8	5	5	90
KG112	3	1.95	2810	77.6	5	5	78.4
KG116	1	2.19	2026	40.9	5	5	75.7
KG116	2	2.00	2100	48.5	5	5	72.1
KingGeorge							
MA091	1	4.48	1210	28.2	5	40	5
MA091	2	2.80	3400	64.6	5	79.5	5
MA109	1	6.85	840	14.0	5	5	58.9
MA109	2	2.91	2806	63.9	5	5	71.4
MA119	1	4.71	1420	38.6	5	5	54.3
MA119	2	4.42	1700	60.2	5	5	60
MA124	1	5.68	1250	93.7	5	50	59
MA124	2	4.99	1400	36.2	5	65	65
MA124	3	7.88	2300	70.5	5	60	65

MA128	1	7.15	500	25.3	5	60	60
MA128	2	4.52	1760	43.9	5	65	65
MA148	1	2.62	1800	81.1	5	10	24.5
MA153	1	3.61	2210	105.3	5	30	43.7
BearCr	1	7.15	500	25.0	5	5	5
MH119	1	4.18	1880	64.5	5	62.4	62.4
MH119	2	5.19	900	18.8	5	54.2	54.2
MH119	3	2.87	4720	206.2	5	78.1	78.1
LA077	1	2.32	3800	106.8	5	69.3	69.3
LA077	2	2.86	3310	164.9	5	60	57.1
LA102	1	5.25	2340	41.0	5	50	63.8
LA102	2	3.87	300	120.4	5	65.6	65.6
LA102	3	6.42	1300	44.9	5	40	48.7
LA102	4	4.83	1840	63.0	5	49.5	49.5
LA106	1	5.55	1860	36.5	5	64.5	64.5
LA123	1	6.05	1880	16.0	5	63.8	68.3
LA123	2	9.27	312	5.1	5	30	37.7
LA133	1	8.02	980	8.4	5	30	58.1
LA133	2	6.84	620	41.3	5	60.6	60.5
LA82	1	3.86	4600	127.9	5	45	83
LA82	2	7.45	615	43.9	5	30	62.4
LAKE	1	6.29	1710	5.7	5	20	54.5

2.1.1 Imperviousness

The characteristic that provides the major difference between the existing, pre-development and post-development flows is the imperviousness of the sub-catchments. As shown in the above table, pre-development conditions assume a 5% impervious ground cover. The impervious percentage of the existing condition sub-catchments are calculated by land use. Each property is assigned an impervious percentage value based on its land use type and a weighted average is calculated for the total catchment.

Overall, the impervious area of the watershed is estimated at 41% as shown in **Table A-2.**

Table A-2 Overall Watershed Imperviousness

Land Use	Area (ha)	Area (%)	Percent Impervious
Industrial	68	4%	95%
Multiple Residential	49	3%	90%
Commercial	35	2%	90%
Right-of-way	295	17%	80%
Urban Residential	746	43%	38%
Suburban Residential	111	6%	15%
Parks	368	21%	5%
Agriculture	47	3%	5%
Total Area	1720		
		Weighted Average	**41%**

Lot Age	% lots	% Impervious
Old	1%	20%
1950	14%	20%
1960	1%	20%
1970	23%	20%
1980	28%	45%
1990	20%	50%
2000	13%	60%
Weighted Average:		**38%**

This is an important indicator for overall health of the watershed. Although it can differ with factors such as soil type, slope, etc, studies of other watersheds have found that significant impairment to streams often occurs when more than 10% of the land within a watershed is covered with impervious surfaces. When these levels exceed 25%, most watersheds experience more severe ecosystem and water quality impairment. Because of the relatively impervious soil in this area of Surrey, these numbers may be higher for the Bear Creek watershed that would be expected given the relative good health (compared to other urban streams) of many reaches of Lower Bear Creek. The generally ample riparian setbacks are assumed to play a role.

By altering the imperviousness of a catchment, parameters such as time of concentration and soil abstraction are recalculated within the model and don't require further deliberation.

2.2 Hydraulic Data

For this model the 19 km open channel network was modeled. In general, smaller creeks flowed either north or south towards Bear Creek which flows, in general, west to east. The average grade of all creeks and streams was 1.5%. **Table A-3** below summarizes channel data inputted.

Table A-3: Stream Network

Channel Name	from Node	To Node	US Invert Elevation (m)	DS Invert Elevation (m)	Slope (%)	Length (m)
B075	QU073	QU075	78.00	63.26	3.41	432
B076	QU075	QU072	63.26	49.99	1.48	896
B079	QU072	QU079	49.99	34.79	1.58	965
B085	QU079	QU085	34.79	26.82	1.99	400
B086	KG081	KG078	56.37	54.95	0.36	394
B087	KG078	KG087	54.95	42.00	2.60	499
B_Quibble	QU085	QU090	26.82	26.82	0.00	124
B090	KG092	KingG	37.68	26.82	1.36	800
B_KingG	KingG	QU090	27.00	26.82	0.19	94
B091	QU090	MA091	26.82	23.03	0.59	644
B092	KG087	KG092	42.00	37.68	1.61	268
B097	KG098	KG092	40.27	37.68	1.61	161
B098	KG101	KG098	73.25	40.27	2.02	1635
B101	KG088	KG101	90.00	73.25	1.78	939
B106	LA077	LA106	35.76	17.47	3.42	535
B110	MA091	MA109	23.03	20.20	0.70	405
B112	KG116	KG112	72.49	63.68	2.59	340
B114	MA109	MA119	20.20	18.82	0.63	220
B115	LA106	LA133	17.47	5.47	2.16	556
B119	MA119	MH119	18.82	16.87	0.49	396
B124	MH119	MA124	16.87	12.35	0.42	1071
B125	LA133	LA123	5.45	4.55	0.31	290
B127	LA123	LA102	4.55	3.00	0.23	665
B_BearCr	BearCr	MA128	10.42	8.49	0.37	529
B128	MA124	BearCr	12.35	10.42	0.37	529
B133	LA82	LA133	6.90	5.45	0.24	617
B134	MA128	LA82	8.49	6.90	0.55	287
B152	MA153	MA119	39.00	18.82	1.68	1200
B153	MA148	MA153	83.62	39.00	2.39	1868
B222	KG112	KG098	63.68	40.27	2.59	904
B_Lake	LA102	LAKE	3.00	2.00	0.35	287

2.2.1 Channel Geometry

The channel geometry was based on a combination of GIS data, as-built information and field visits. A unique cross-section was imported in XPSWMM for each of the 31 stream sections. The sections were chosen to be representative of the overall stream and, where possible, represented average dimensions for the channel. Model results did not show overtopping at any of the sections.

The below **Figure A-2** is shown as a sample section after it has been imported into XPSWMM.

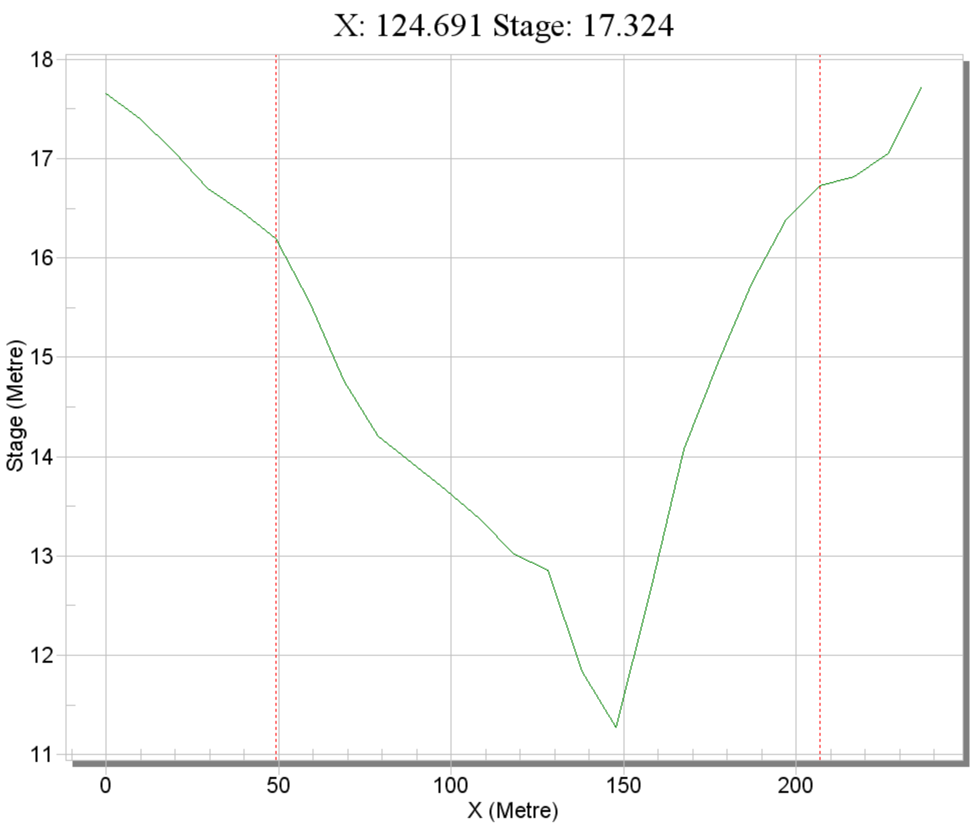


Figure A-3 - Cross Section: B_Bear Creek

3. MODEL RUN RESULTS

The model was created with three scenarios, Pre-development, Existing and Post-development conditions. Rainfalls from three separate return periods were inputted, 2-year, 5-year and 100-year, for 1, 2, 6, 12 and 24 hour duration storms. In total, 15 separate rainfall events were used on three scenarios. Maximum flows at the four locations labeled in Figure A-1 are shown in the below **Table A-4, A-5, A-6,** and **A-7**. The results of peak flows show the following:

- Pre development flows for smaller rainfall events (2 year) are over ten times smaller than existing and post-development flows, while larger events (100 year) are roughly half. This indicates that in existing conditions, there will be significantly more minor events that could potentially cause erosion to the creeks than in pre-development conditions;
- If development (i.e. densification) continues are is currently scheduled, post-development peak flows will be a little more than 10% higher than the existing peak flows.

Table A-4: Results at Quibble Creek

Name	Scenario	Storm	Max Flow (cms)
1. Quibble	Pre-Development	2yr-2hr	0.70
1. Quibble	Pre-Development	5yr-1hr	0.91
1. Quibble	Pre-Development	100yr-12hr	8.68
1. Quibble	Existing	2yr-2hr	9.18
1. Quibble	Existing	5yr-1hr	11.73
1. Quibble	Existing	100yr-1hr	20.82
1. Quibble	Post-Development	2yr-2hr	9.85
1. Quibble	Post-Development	5yr-1hr	12.68
1. Quibble	Post-Development	100yr-1hr	22.83

Table A-5: Results at King George

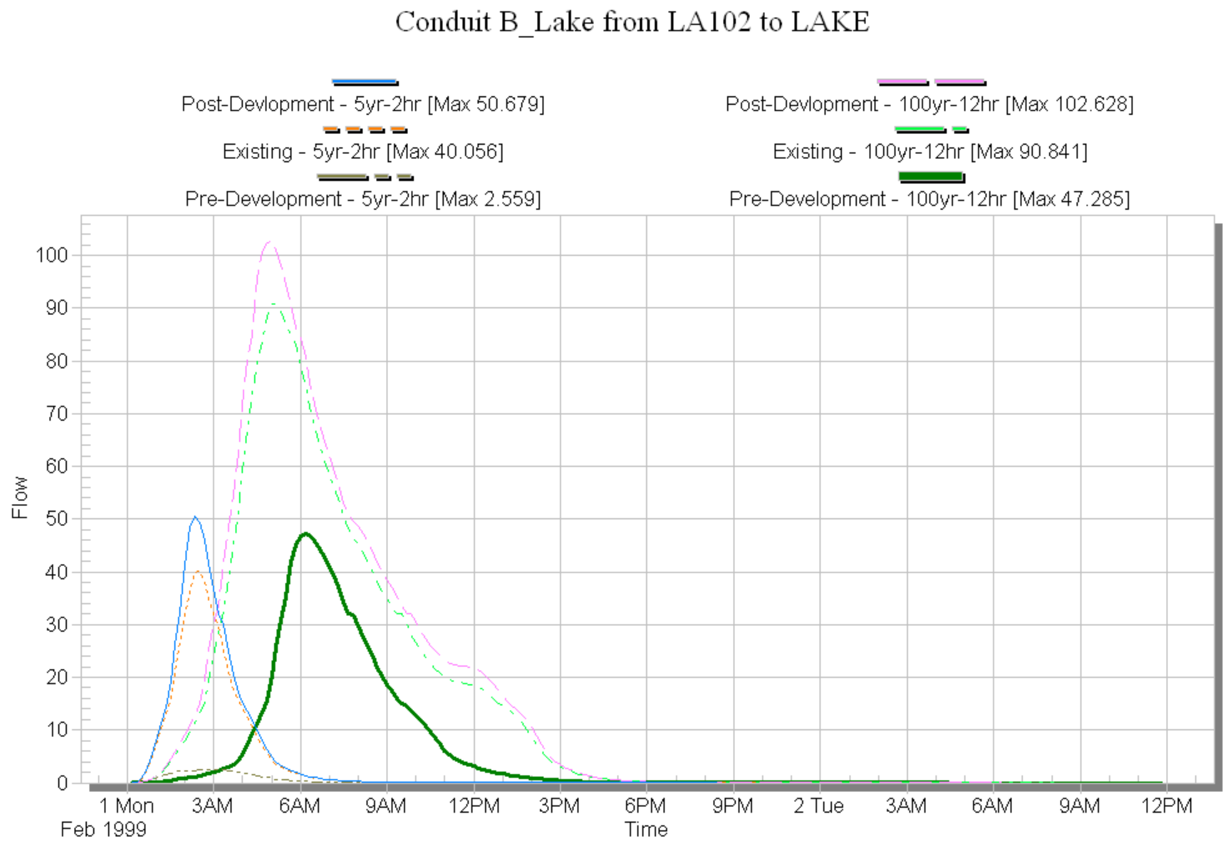
Name	Scenario	Storm	Max Flow (cms)
2. KingG	Pre-Development	2yr-2hr	1.23
2. KingG	Pre-Development	5yr-12hr	1.31
2. KingG	Pre-Development	100yr-12hr	14.13
2. KingG	Existing	2yr-2hr	14.78
2. KingG	Existing	5yr-1hr	20.37
2. KingG	Existing	100yr-1hr	35.67
2. KingG	Post-Development	2yr-2hr	19.60
2. KingG	Post-Development	5yr-1hr	27.07
2. KingG	Post-Development	100yr-1hr	47.08

Table A-5: Results at Bear Creek at 148th

Name	Scenario	Storm	Max Flow (cms)
3. BearCr	Pre-Development	2yr-12hr	2.57
3. BearCr	Pre-Development	5yr-12hr	3.17
3. BearCr	Pre-Development	100yr-12hr	37.52
3. BearCr	Existing	2yr-2hr	28.89
3. BearCr	Existing	5yr-2hr	36.88
3. BearCr	Existing	100yr-12hr	69.57
3. BearCr	Post-Development	2yr-12hr	36.48
3. BearCr	Post-Development	5yr-2hr	46.22
3. BearCr	Post-Development	100yr-2hr	80.85

Table A-5: Results at Bear Creek at Surrey Lake

Name	Scenario	Storm	Max Flow (cms)
4. Lake	Pre-Development	2yr-12hr	3.12
4. Lake	Pre-Development	5yr-12hr	4.02
4. Lake	Pre-Development	100yr-12hr	47.29
4. Lake	Existing	2yr-12hr	38.59
4. Lake	Existing	5yr-12hr	47.03
4. Lake	Existing	100yr-12hr	90.84
4. Lake	Post-Development	2yr-2hr	37.61
4. Lake	Post-Development	5yr-12hr	56.76
4. Lake	Post-Development	100yr-12hr	102.63


Conduit B_Lake from LA102 to LAKE
Post-Devlopment - 5yr-2hr [Max 50.679]
Existing - 5yr-2hr [Max 40.056]
Pre-Development - 5yr-2hr [Max 2.559]
Post-Devlopment - 100yr-12hr [Max 102.628]
Existing - 100yr-12hr [Max 90.841]
Pre-Development - 100yr-12hr [Max 47.285]
Flow
100
90
80
70
60
50
40
30
20
10
0
1 Mon
Feb 1999
3AM
6AM
9AM
12PM
3PM
6PM
9PM
2 Tue
3AM
6AM
9AM
12PM
Time

4. EXISTING POND ANALYSIS

There are 25 dry ponds in the study area. These sites may not be utilized to their full potential. Three ponds have been selected for a more detailed analysis of their overall performance and potential for improvement. Their ID numbers, which were obtained from the City of Surrey's online mapping system COSMOS are as follows:

- Pond 1000429367
- Pond 1000429381
- Pond 1000429467

This analysis looks at existing pond infrastructure, catchment conditions and outlet controls. The goal is to determine potential changes that could be made to the pond sites that should result in better management of stormwater.

4.1 Existing Conditions Modelling Results

4.1.1 Rainfall IDF Data

The City of Surrey Design Criteria Manual includes Bear Creek in the Surrey Kwantlen Park rainfall boundary. Therefore, Kwantlen Park IDF curve was used in this analysis and various return periods were run. Smaller return period storms were also ran to better see how the pond was impacting smaller frequent events.

4.1.2 Pre-Development Flow Conditions

Today much of the Bear Creek watershed is developed, but historically the area consisted of forest followed by development agricultural/rural land. A high level analysis using XPSWMM was carried out in order to determine the pre-development flows of service area for Ponds 367, 381 and 467 to determine what a more natural flow rate would have been before urban development. A CN value of 74 was used and an imperviousness of 5% was assumed to take into account roads and the odd farm house and barn.

4.1.3 Pond 367

As-built drawings for Pond 367 are available from COSMOS. The drawings depict a dry pond located in the Price Creek (146 Street and 85A Avenue) sub-catchment. **Table A-8** summarizes the existing design conditions and characteristics of Pond 367.

Table A-8: Design Conditions for Pond 367

Pond Area	7,500 m^2
Property Area	11,000 m^2
Live Storage	2,900 m^3
Permanent Pool	0 m^3
Service Area	237,000 m^2
Inlet Pipe Diameter	600 mm
Outlet Pipe Diameter	450 mm
Engineering Company	Aplin and Martin
Year Constructed	1984

Modelling Results

Existing conditions were modelled in order to determine how Pond 367 is currently operating. Based on a CN value of 83, **Table A-9** illustrates the maximum flow rates based on the Surrey Kwantlen Park IDF curve.

Table A-9: Pre-Development Flow Rates and Maximum Flows into Pond 367

	Peak Flows (m^3/s)		
Rainfall Events	**Pre Development**	**Post Development**	**% change**
5mm	0.000	0.000	0 %
10mm	0.000	0.000	0 %
20mm	0.000	0.049	
30mm	0.001	0.163	16200 %
1 year	0.000	0.191	
2 year	0.126	0.582	362 %
5 year	0.268	0.938	250 %
10 year	0.377	1.200	218 %
25 year	0.534	1.583	196 %
50 year	0.655	1.868	185 %
100 year	0.784	2.163	176 %

Results confirmed that capacity of the 600 mm diameter inlet pipe with a 1.1% slope is 0.644 m3/s and the capacity of the 450 mm diameter outlet pipe with a 1.64% slope is 0.365 m3/s. Based on the above table, Pond 367 is designed to accommodate the 1-year rainfall event.

4.1.4 Pond 381

An as-built drawing (number SS-52-515) for Pond 381 has been obtained from COSMOS. The drawings depict a dry pond located in the Nichol Creek (142 Street and 73A Avenue) sub-catchment. **Table A-10** summarizes the existing design conditions and characteristics of Pond 381.

Table A-10: Design Conditions for Pond 381

Pond Area	2,500 m^2
Property Area	4,500 m^2
Live Storage	1,650 m^3
Permanent Pool	0 m^3
Service Area	144,000 m^2
Inlet Pipe Diameter	600 mm
Outlet Pipe Diameter	375 mm
Engineering Company	McElhanney
Year Constructed	1982

Modelling Results

Existing conditions were modelled in order to determine how Pond 381 is currently operating. Based on a CN value of 83, Table A-11 illustrates the maximum flow rates based on the Surrey Kwantlen Park IDF curve.

Table A-11: Pre-Development Flow Rates and Maximum Flows into Pond 381

	Peak Flows (m^3/s)		
Rainfall Events	**Pre Development**	**Post Development**	**% change**
5mm	0.000	0.000	0 %
10mm	0.000	0.000	0 %
20mm	0.000	0.030	
30mm	0.000	0.099	
1 year	0.000	0.116	
2 year	0.076	0.353	365 %
5 year	0.163	0.570	250 %
10 year	0.229	0.729	218 %
25 year	0.325	0.962	196 %
50 year	0.398	1.135	185 %
100 year	0.477	1.314	176 %

Results confirmed that capacity of the 600 mm diameter inlet pipe with a 0.62% slope is 0.483 m3/s and the capacity of the 375 mm diameter outlet pipe with a 0.55% slope is 0.130 m3/s. Based on the above table, Pond 381 is designed to accommodate the 1-year rainfall event.

4.1.5 Pond 467

The as-built drawings (numbers SS-33-574 and SS-33-538) for Pond 467 have been obtained from COSMOS. The drawings depict a dry pond located in the Enver Creek (144 Street and 92A Avenue) sub-catchment. **Table A-12** summarizes the existing design conditions and characteristics of Pond 467.

Table A-12: Design Conditions for Pond 467

Pond Area	2,200 m^2
Property Area	4,300 m^2
Live Storage	1,853 m^3
Permanent Pool	0 m^3
Service Area	76,000 m^2
Inlet Pipe Diameter	900 mm
Outlet Pipe Diameter	675 mm
Engineering Company	Triffo Engineering
Year Constructed	1990

Modelling Results

Existing conditions were modelled in order to determine how Pond 467 is currently operating. Based on a CN value of 81, **Table A-13** illustrates the maximum flow rates based on the Surrey Kwantlen Park IDF curve.

Table A: Pre-development Flow Rates and Maximum Flows into Pond 467

	Peak Flows (m^3/s)		
Rainfall Events	**Pre Development**	**Post Development**	**% change**
5mm	0.000	0.000	0 %
10mm	0.000	0.000	0 %
20mm	0.000	0.015	
30mm	0.000	0.049	
1 year	0.000	0.057	
2 year	0.040	0.179	348 %
5 year	0.086	0.290	237 %
10 year	0.121	0.369	205 %
25 year	0.171	0.489	186 %
50 year	0.210	0.579	176 %
100 year	0.252	0.671	166 %

Results confirmed that capacity of the 900 mm diameter inlet pipe with a 2.43% slope is 2.82 m3/s and the capacity of the 675 mm diameter outlet pipe with a 0.25% slope is 0.420 m3/s. Based on the above table, Pond 381 is designed to accommodate the 10-year rainfall event.

Appendix B
Environmental Assessment Report

ENVIRONMENTAL ASSESSMENT REPORT

Bear Creek Integrated Stormwater Management Plan (ISMP)
STAGE 1

Project: 4811-707

Surrey, B.C.

Prepared for:

Delcan and City of Surrey

Prepared by:

PHOENIX ENVIRONMENTAL SERVICES LTD.

December, 2011

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EXECUTIVE SUMMARY

Phoenix Environmental Services Ltd., in collaboration with Bianchini Biological Services (BBS) and Sartori Environmental Services Inc., have conducted an environmental assessment of the West Bear Creek Integrated Stormwater Management Plan (Bear Creek ISMP) Study Area (Figure 1) to support the integration of environmental features and environmental mitigation and enhancement measures into the land use planning and engineering components of the Bear Creek ISMP.

Bear Creek and its tributaries and associated aquatic and riparian habitats have been assessed with respect to watercourse classifications (i.e. fish-bearing is Class A), channel stability, habitat complexity and quality and indicators of aquatic ecosystem health (i.e. benthic macroinvertebrate data). This Environmental Assessment has confirmed the existing watercourse classification mapping for the Bear Creek ISMP is accurate, where field verifications have been conducted.

Key issues associated with the stream habitat assessment conducted for this Environmental Assessment are:

- excessive scour and erosion from existing stormwater discharges, especially in the upper reaches of the Bear Creek watershed;
- stream habitat degradation from loss of riparian habitat, stormwater erosion and pollution;
- terrestrial habitat fragmentation and loss or reduction of wildlife movement corridors
- continued conservation, protection and enhancement of key ecologically significant areas (e.g. Green Timbers Forest, Bear Creek Park, Surrey Lake Park, Bear Creek and tributaries riparian habitats)

The Environmental Assessment includes recommendations for addressing these issues and several site-specific recommendations for fish and aquatic habitat enhancement works.

Bianchini Biological Services (BBS) conducted an overview wildlife and vegetation assessment for the Bear Creek ISMP project (see Appendix 2 for the BBS report). The assessment focused on federally and provincially listed terrestrial wildlife and vegetation species and potential wildlife corridors that may be affected by any future works related to the West Bear Creek ISMP.

All riparian areas (creeks, lakes, ponds and wetlands), forested blocks, meadows and undeveloped right-of-ways (ROW) encountered were assessed during the field program. These areas were part of potential wildlife corridors and habitats that may be used by at least 15 federally or provincially listed terrestrial wildlife and vegetation species. The riparian habitats, forested blocks and BC Hydro 500 kilovolt (kV) ROW were identified as having high wildlife values within the study area and provided moderate to high rated habitat for a number of federally listed wildlife species including Pacific water shrew (Sorex benderii) and red-legged

frog (Rana aurora) and Western Screech-owl (Megascops kennicottii kennicottii). These riparian areas and forested stands also provided important nesting habitat for other wildlife including raptors such as Bald Eagle (Haliaeetus leucocephalus), Red-tailed Hawk (Buteo jamaicensis) and Cooper's Hawk (Accipiter cooperii). Wildlife sign encountered during the field program included coyote (Canis lantrans) beaver (Castor canadensis), river otter (Lontra canadensis) and raccoon (Procyon lotor). The lakes and ponds and associated terrestrial habitats provided important habitat for many waterfowl, songbird and amphibian species. The northeastern forested block of Surrey Lake Park provided potential habitat for the federally and provincially listed Oregon forestsnail (Allogona townsendiana) while the riparian zones of all creeks provided moderate to high rated habitat for the provincially listed Trowbridge's shrew (Sorex trowbridgii) and Pacific sideband snail (Monadenia fidelis).

The BC Hydro 500 kV ROW, Bear Creek and its tributaries provided important wildlife corridors for many listed wildlife species including red-legged frog and Pacific water shrew as well other wildlife. Bear Creek and the BC Hydro 500 kV ROW have also been reported to be occasionally used by large mammals such as black bear (Ursus americanus) and Columbia black-tailed deer (Odocoileus hemionus columbianus). The replacement of culverts with bridges or open-bottom culverts would improve wildlife passage and reduce wildlife mortality due to impacts with vehicles.

No SARA listed vegetation species were detected during the field program. Due to survey timing (late fall) many herbaceous species could not be identified. The site may provide habitat for at least six provincially listed species including the Blue-listed pointed broom sedge (Carex scoparia), Vancouver Island beggarticks (Bidens amplissima), streambank lupine (Lupinus rivularis), dotted smartweed (Persicaria punctata), false-pimpernel (Lindernia dubia anagallidea) and slender-spiked mannagrass (Glyceria leptostachya).

Past studies have identified at least four listed ecological communities occurring within Green Timbers Urban Forest and it is anticipated that most forested sites within the West Bear Creek study area would also be identified as either Red or Blue-listed ecological communities listed by the British Columbia Conservation Data Centre (BCCDC).

Key environmentally significant areas within the Bear Creek ISMP include:

- Green Timbers Forest
- Lowland floodplain lands along the lower reaches of Bear Creek
- B.C. Hydro Right-of-Way Wildlife Corridor
- All ravines and riparian areas adjacent to Bear Creek and its tributaries

The Bear Creek ISMP can help conserve environmentally sensitive areas in the ISMP area by adopting conservation protection and enhancement measures into the land use planning component of the ISMP, by improving rainwater management within the Bear Creek watershed, providing enhancement of existing habitat such as recommendations presented in this

Environmental Assessment, and by similar contributions to improved ecological health within the Bear Creek watershed (e.g. pollution reduction, reduced erosion).

1. INTRODUCTION

Phoenix Environmental Services Ltd. (Phoenix) has been retained by Delcan to provide the environmental assessment components for Stage 1 of the Bear Creek Integrated Stormwater Management Plan (ISMP); which Delcan has been retained to prepare for the City of Surrey Engineering Department. The following outlines the environmental assessment objectives, methodologies, observations, and conclusions.

1.1 Stage 1 ISMP Environmental Objectives

From the Terms of Reference issued by the City for Stage 1 of the Bear Creek ISMP, it is clear that the ISMP is to incorporate significant environmental inventory and assessment to support engineering and land use planning and design. The City is interested in a holistic approach, whereby environmentally friendly designs as well as protection and restoration of natural features would be an integral component, and would be related back to the City's Sustainability Charter.

The objectives of Phoenix's contributions to Stage 1 of the ISMP have been:

- to provide an inventory and assessment of the key environmental features (watercourses, fisheries resources, riparian, and forest areas, wildlife, and Species at Risk);
- to identify and recommend priorities for conservation areas, setbacks, and habitat restoration opportunities;
- to provide recommendations for green infrastructure and incorporation of sustainability principles into land use planning for the Study Area;
- to contribute to development of the watershed vision with Delcan, the City of Surrey staff, DFO, and other stakeholders;
- to contribute to development of design criteria that will help achieve the long-term watershed goals of protecting and enhancing watercourses ad aquatic life as well as preventing pollution and maintaining water quality;
- to contribute to and participate in the public consultation process for the Study;
- to contribute to the establishment of a monitoring and assessment strategy for long-term assessment of watershed health; and
- to contribute to the Integrated Stormwater Management Plan Report and maps.

Figure 1. Bear Creek ISMP study area in relation to the City of Surrey (CoS 2011)

1.2 Methodology

The scope of work by Phoenix for Stage 1 of the ISMP has included use of existing research and reports, as well as field verification where necessary, to conduct an inventory and assessment of the wildlife and aquatic habitats within the ISMP Study Area.

The methodology for this Stage 1 ISMP Environmental Assessment has entailed:

- Verification of classification for key watercourses and assessment of current health conditions of selected watercourses, including associated terrestrial habitats such as ravines, riparian areas, and wetlands.
- Identification of significant terrestrial habitats including trees and forests, old fields, and wildlife corridors.
- Identification of sensitive environmental areas and areas of concern such as deteriorated watercourses (e.g. scour and erosion), potential sources of negative impacts to water quality, and degraded wildlife habitats.

2. WATERCOURSES

The watercourses within the Study Area have been separated into three sub catchments as identified in the Bear Creek Master Plan (Figure 2), and the Bear Creek ISMP request for proposals (RFP). The three identified sub catchments are:

- South Bear Creek Tributaries
- North Bear Creek Tributaries
- Lower Bear Creek

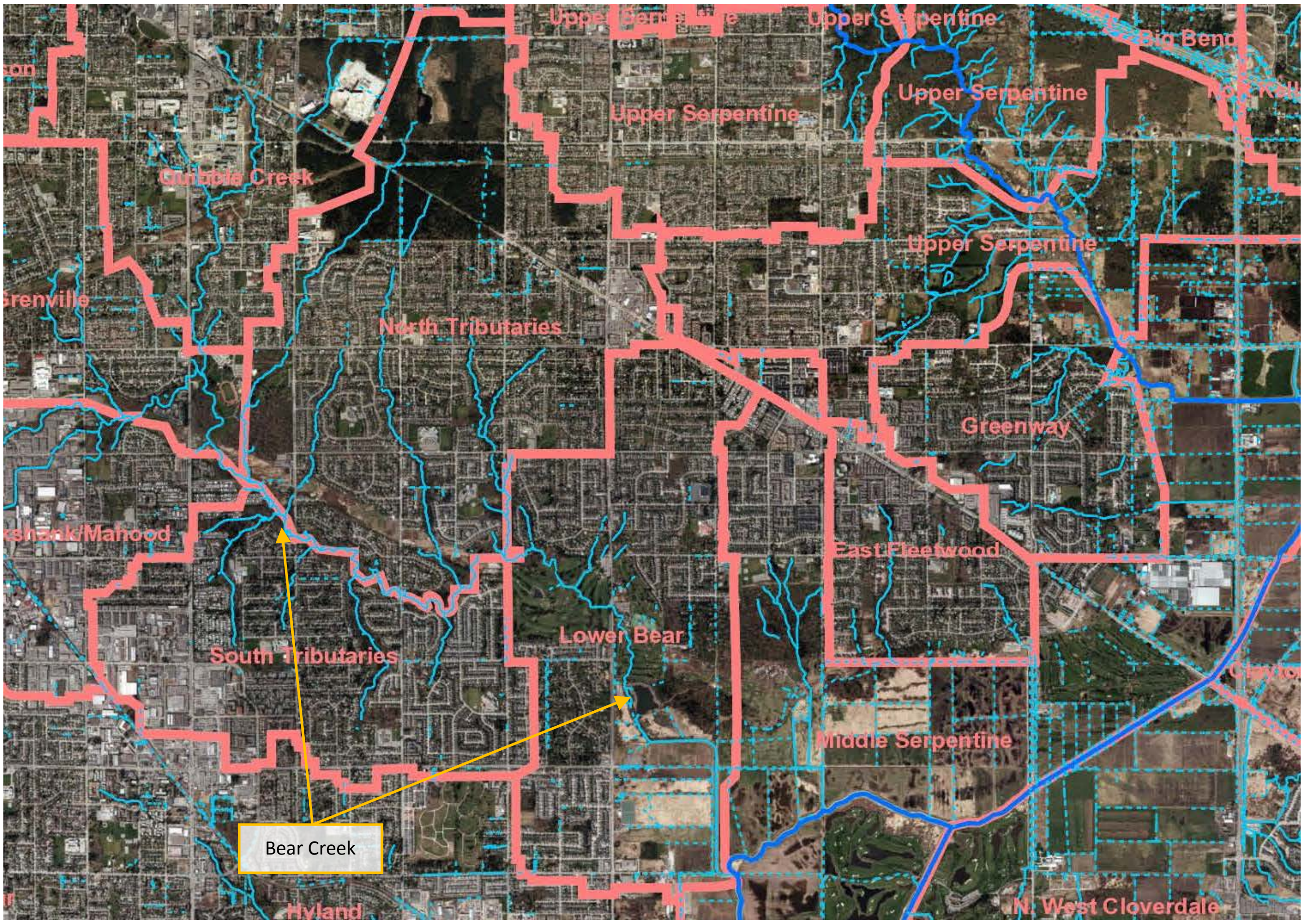

Figure 2: Project Area sub-catchments (*Source*: City of Surrey COSMOS).

2.1 North Tributaries

The North Tributaries sub-catchment includes numerous high quality north-south draining tributaries to the Bear Creek main channel following their historic flow paths (*i.e.* not anthropogenically-straightened), as well as a host of lower value tributary ditches and artificial drainage paths. Rough sub-catchment boundaries include 80 Ave. to the south, 100 Ave. to the north, 152 St. to the east, and 140 St. to the west.

The north tributaries sub-catchment is largely residentially-developed, except in northern areas within the Green-Timbers Heritage Society Urban Forest (an Environmentally Sensitive Area for forested wildlife habitat). Key watercourses within the north tributaries sub catchment include:

- King Creek
- “M” Creek
- Enver Creek
- Price Creek
- Cub Creek.

2.2 South Tributaries

The south tributaries sub-catchment includes numerous high quality south-north draining tributaries to the Bear Creek main channel following their historic flow paths (*i.e.* not anthropogenically-straightened), as well as numerous of lower value tributary ditches and artificial drainage paths. Rough sub-catchment boundaries include 72 Ave. to the south, 80 Ave. to the north, 145 St. to the east, and 132 St. to the west.

The south tributaries sub-catchment is largely residentially-developed. Key watercourses within the north tributaries sub catchment include:

- Hunt Creek (incl. Hunt Brook)
- Beam Creek
- Nichol Creek
- Burke Creek

2.3 Lower Bear Creek

The lower Bear Creek sub-catchment largely includes lower reaches of Bear Creek within agriculture-primary areas, the Guildford Golf and Country Club, and the BC Hydro transmission line right-of-way. In this area, Bear Creek flows northwest-southeast within low-gradient portions of natural channel before entering a network of anthropogenically-straightened agricultural canals/ditches and confluencing with the Serpentine River at 68 Ave. between 152 and 160 Street. Northern and southwestern portions of this catchment display dense residential development; however, areas in close proximity to Bear Creek are largely agricultural.

2.4 WATERCOURSE CLASSIFICATIONS

The City of Surrey has classified streams within the Study Area according to their ability to support fish populations. Streams in Surrey are classified into the following categories:

Class A – watercourses support fish populations year round or have the potential to support fish populations year round if migration barriers are removed

Class A(O) – watercourses support fish populations generally only during the winter months; often roadside ditches that have very low flows and warm temperatures in the summer

Class B – do not support fish populations, but provide food and nutrients to downstream fish habitats and often are supported year-round by groundwater

Class C – do not support fish populations and generally only convey flows associated with rainfall events; often roadside ditches in headwater areas

Based on the background data, airphoto interpretation, and limited ground-truthing, it is apparent that streams in the watershed have been classified correctly, as shown on the City of Surrey GIS mapping (COSMOS). Field verification consisted primarily of locating reach breaks between Class A and Class B designations to observe fish barriers or flow restrictions for inconsistencies with classifications. No fish sampling was done, but fish were observed at some locations during the field reconnaissance. No inconsistencies with current City of Surrey classifications were observed over the course of field verification.

Field verification findings, including habitat improvement opportunities, are discussed further in the following sections.

2.4.1 South Bear Creek Tributaries

Ten inspections sites were identified as priority field-verification areas in the South Bear Creek Tributaries Sub-catchment through aerial photography interpretation and Surrey GIS information review. Appendix I spatially presents field verification sites and outlines assessment results by location and watercourse.

Upon inspection of all south tributary watercourses and the Bear Creek main channel, no reclassification of watercourses as listed on the City of Surrey GIS is proposed.

Habitat enhancement opportunities were observed in the Hunt Creek/Hunt Brook complex and, Burke Creek. Observed South Tributary enhancement opportunities are summarized below (see (Figure 3 - Figure 4):

2.4.1.1 Hunt Creek/Hunt Brook Complex

1.

a) At Site #1 (Appendix I): Reduce down-cutting from elevated peak storm flow velocities and volumes at the 76A head water storm outfall to Hunt Creek through

installation of boulders and coarse woody debris, increasing channel roughness and complexity.
b) At Site #1 (Appendix I): Improve downstream fluvial process and clean substrate recruitment through installation of clean, round gravels and coarse sand substrates at 76A outfall discussed above.

2. At Sites #3 – #5 (Appendix I): Manicured yard space areas utilized by joined trailer parks at 13560 – 80 Ave., and 7850 King George Hwy. extend beyond property boundaries and into potential riparian areas of Hunt Brook. Further, three headwater stormwater outfalls contribute flow to Hunt Brook in this area. All three outfalls could be consolidated to the lawn area, and could be tied into a latency pond or wetland, attenuating headwater storm flows, improving riparian vegetation conditions, and providing improved food and nutrient input to Hunt Brook.

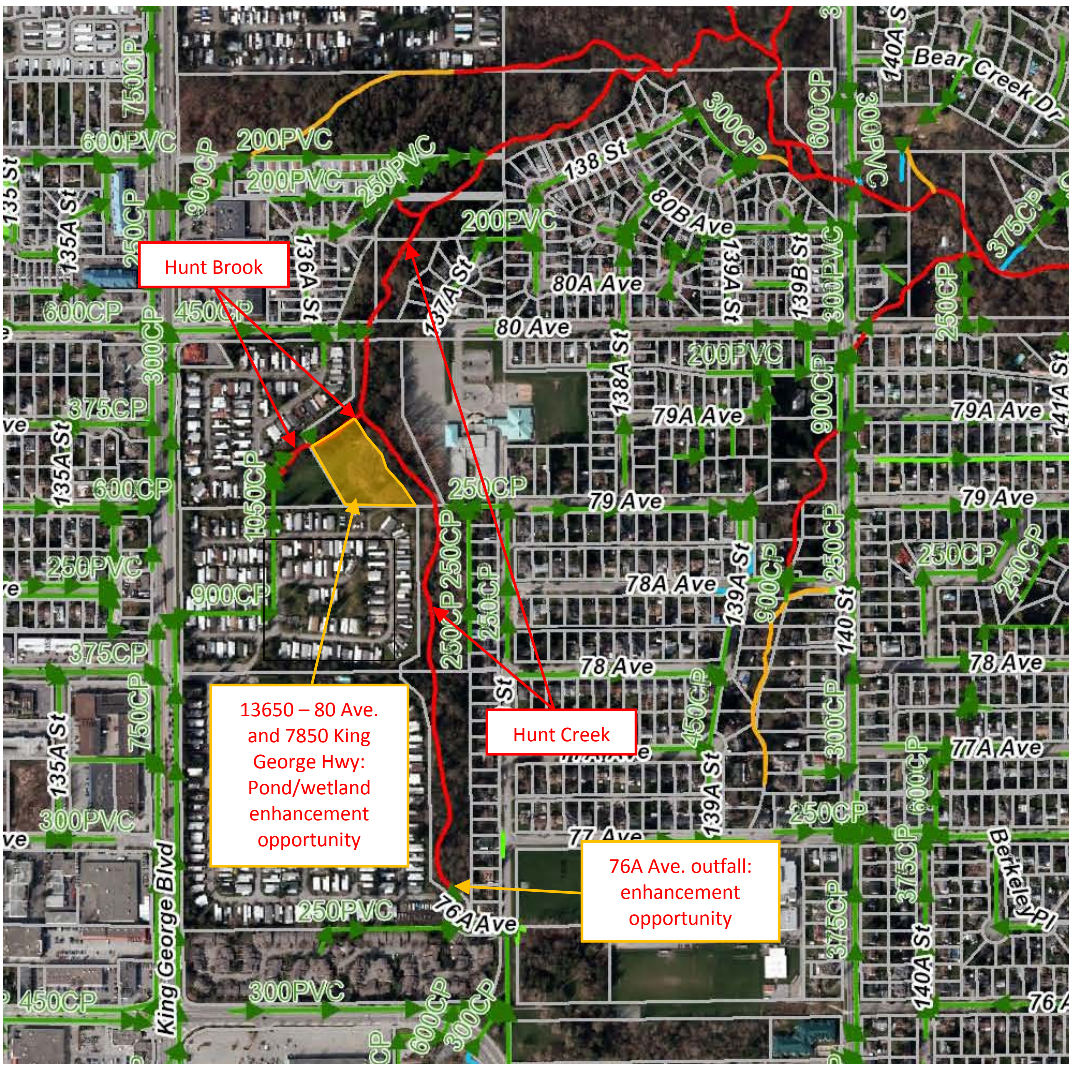

Figure 3: Observed habitat enhancement opportunities, Hunt Creek/Hunt Brook Complex (nts, *Source*: City of Surrey GIS).

2.4.1.2 Burke Creek

3. At Site #9 (Appendix I): An existing trail between 145A St. and 146 St. at 78 Ave. utilizes a concrete pipe to cross Burke Creek. This culvert crossing serves as a barrier to fish passage, and is the root cause of the Class "B" classification reach break in Burke Creek reaches upstream of 78 Ave. Replacement of this culvert with a bridge crossing and channel restructuring would allow fish access to suitable habitat upstream of the 78 Ave. trail to at least 76 Ave.

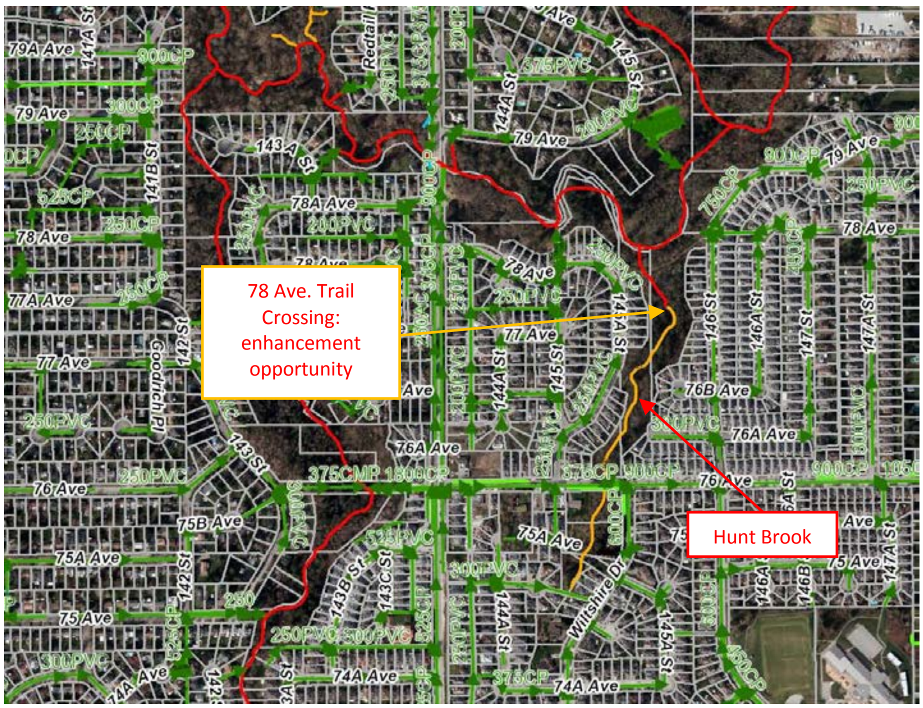

Figure 4: Observed habitat enhancement opportunity, Burke Creek (nts, *Source*: City of Surrey GIS).

2.4.2 North Bear Creek Tributaries

Six field inspection sites were identified as priority field-verification areas in the North Bear Creek Tributaries Sub-catchment through aerial photography interpretation and Surrey GIS information review. Appendix I spatially presents field verification sites and outlines assessment results by location and watercourse.

Upon inspection of all north tributary watercourses and the Bear Creek main channel, no reclassification of watercourses as listed on the City of Surrey GIS is proposed.

One habitat enhancement opportunity was observed in the upper Enver Creek, and is discussed below (see):

2.4.2.1 Upper Enver Creek

4. At Site #16 (Appendix I): Install an elevated outlet or weir at outlet of the existing stormwater detention pond between 92 Ave 144 St. (9184 - 144 St.) to hold a minimum water level (e.g. 200 – 300 mm) at all times, allowing for function as a wetland as well as a latency pond, as originally intended. Ample freeboard was observed during the field reconnaissance, based on the pond dry pond side slope vegetation and outlet pipe size. Replace periodically-mowed grass riparian areas with native shrub and tree transplants. Recommended enhancements should provide improved food and nutrient production to fish bearing waters downstream and improve local terrestrial wildlife habitat.

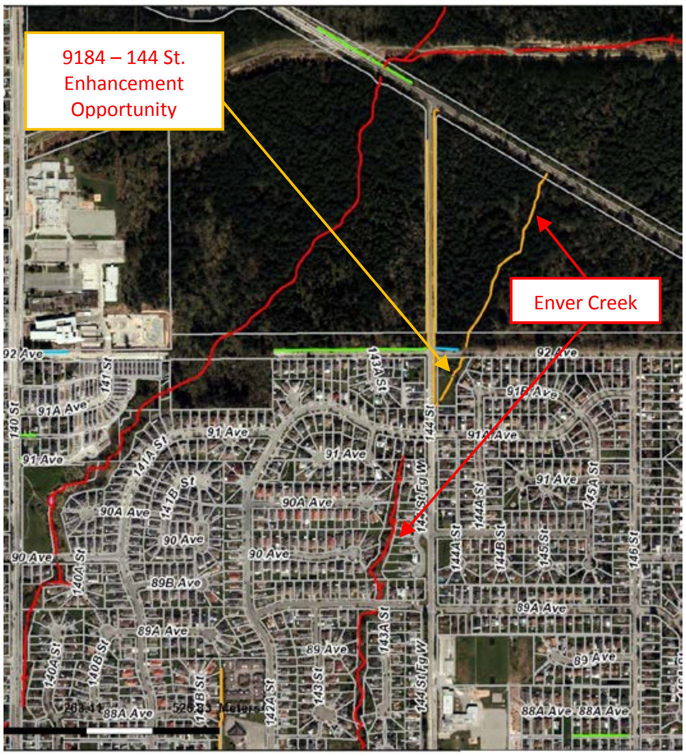

Figure 5: Observed habitat enhancement opportunity, Enver Creek (nts, Source: City of Surrey GIS).

2.4.3 Lower Bear Creek

As previously discussed, the Lower Bear Creek sub-catchment has been considerably altered through agricultural processes and golf course development. Lower reaches of Bear Creek have been historically anthropogenically-straightened for the purposes of agricultural irrigation and flood control.

No priority field-verification sites were identified from aerial photography interpretation and review of previous information. These low gradient reaches of Bear Creek have large channels wherein very large flow events during storms or prolonged rainfall periods are conveyed within realigned channels and zero-setback flood control dykes.

The greatest potential for fish and aquatic habitat improvements through mitigation of scour and erosion is in the upper, highly developed headwaters where most of the Phoenix field verification observations have been located. Headwaters stormwater management improvements will in turn reduce flood flow volume, frequency and duration, which will improve habitat quality and water quality in the lower reaches.

As the majority of lower Bear Creek is contained within private agricultural, and/or commercial properties (golf courses) as well, no opportunities for immediate habitat enhancement were observed (Appendix I).

2.5 Benthic Macroinvertebrate Community Indicators of Aquatic Health

The City of Surrey has commissioned routine benthic invertebrate community monitoring in numerous watercourses throughout the city since 1999. All data and reports made available by the City of Surrey were reviewed in attempt to draw general conclusions on aquatic health within Bear Creek reaches within the study area and its tributaries. Upon review of available metrics data for the Study Area, it was deemed that analysis of resultant Benthic Index of Biotic Integrity (B-IBI) information provided the clearest indication of aquatic ecosystem health.

2.5.1 Benthic Index of Biotic Integrity (B-IBI)

B-IBI is a recognized standard method for determining the health of the aquatic ecosystem of a stream using analysis of the benthic macroinvertebrate population composition. The B-IBI is most useful in comparing streams with different watershed conditions or to track changes over time. Ten metrics are used, each with a possible score of 1, 3, or 5 for a combined possible total of 50 points. For each sampling date, the mean B-IBI of three replicates is reported.

Three monitoring stations relevant to this report have been established within or near the study area by the City of Surrey to monitor the composition of the benthic macroinvertebrates. They are:

- *BEAR1* - located within the Bear Creek mainstem approximately 50m upstream of the confluence of Quibble Creek, in the northwest corner of Bear Creek Park. This sampling site is not within the study area, but is deemed relevant due to its close proximity and because it is the only current station within the Bear Creek mainstem.

- *K1* – located within the east branch of Kings Creek, approximately 20m south of 88 Ave.

- *ENV1* – located within the mainstem of Enver Creek, approximately 40m south of 84 Ave.

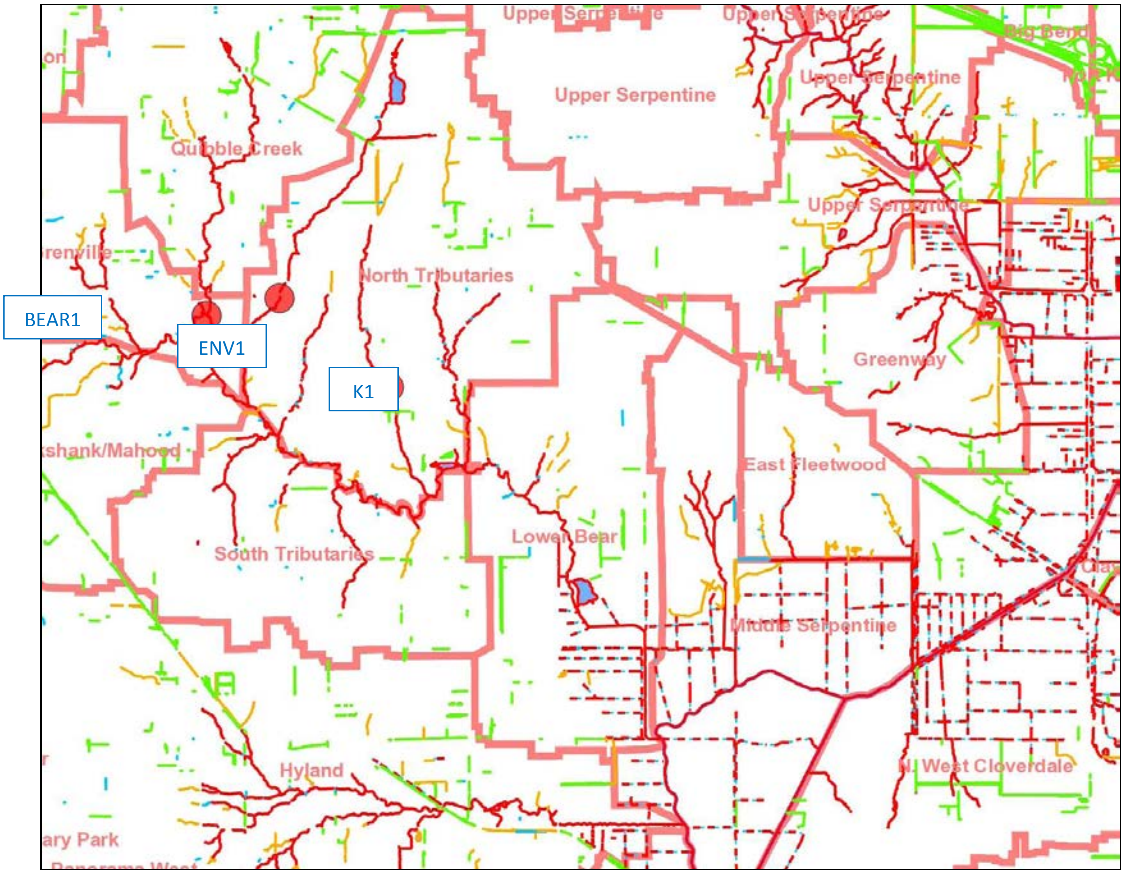

Figure 6: Approximate benthic community monitoring sites (*Source:* City of Surrey Cosmos).

Data from the ENV1 station was provided to Phoenix Environmental comprising sampling results from 2000 to 2009. The BEAR1 and K1 sites were added to the City of Surrey benthic invertebrate sampling program in 2009, and data for these two sites is therefore only available for one year. At each sampling station, three benthic macroinvertebrate sample replicates were seasonally-collected roughly twice per year (spring and fall).

Upon review of available data, it is apparent that Enver Creek has displayed consistently low B-IBI values since the commencement of monitoring in 2000. Further to this, Bear and King Creeks displayed similar values for the 2009 monitoring year, especially in spring, where all three monitoring stations displayed identical mean B-IBI values (14, Figure 7).

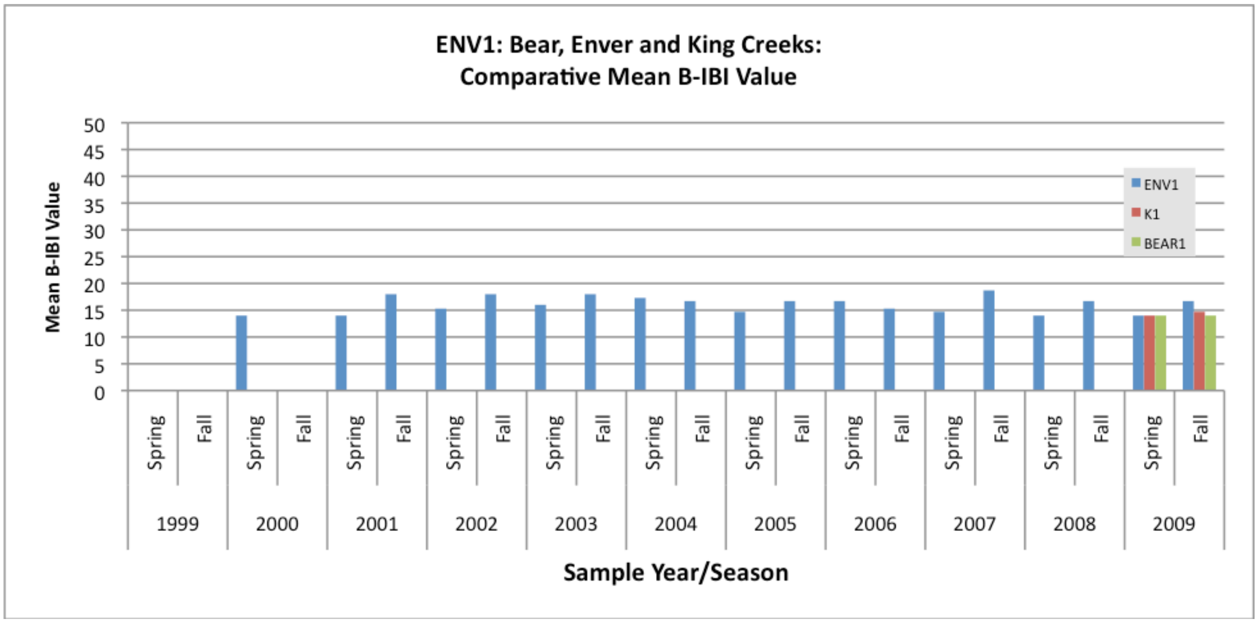

Figure 7: Observed mean B-IBI at Enver, King, and Bear Creek benthic macroinvertebrate monitoring stations, 1999 - 2009

2.5.2 Aquatic Ecosystem Health

Though available data is limited, the range of the entire mean B-IBI results (*n*=23) lies within "poor" (18 – 26) and "very poor" (10 -16) ranges, as defined for other large scale comparative B-IBI studies in a similar geophysical settings (Morely, 2000, adopted in Henderson, et al., Unknown).

From topical review of benthic macroinvertebrate data, it appears benthic communities in Bear Creek and its tributaries display symptoms of poor water quality and general anthropogenic pollution including (adopted from Morely, 2000):

- Depressed taxa richness,
- Dominance by a few pollution-tolerant species,
- Low presence and/or absence of longer living, pollution-intolerant species,
- Low relative abundance of predators.

3. TERRESTRIAL HABITATS AND VEGETATION

Terrestrial habitat and vegetation assessment for this report was conducted by Bianchini Biological Services (BBS). The following sections are excerpts from the BBS report attached in Appendix II.

The study area falls within the Georgia Depression Ecoprovince, Lower Mainland Ecoregion, Fraser Lowland Ecosection. The study area was mainly situated in the Very Dry Maritime Coastal Western Hemlock (CWHxm1) Biogeoclimatic (BGC) subzone and the Green Timbers Urban Forest area occurring within the Dry Maritime Coastal Western Hemlock (CWHdm) BGC subzone.

3.1 VEGETATION OVERVIEW

Three vegetation types were identified within the study area:

1. Riparian Vegetation Type
2. Forested Blocks Vegetation Type
3. Right-of-ways and Meadows Vegetation Type

Representative photographs of each of the vegetation types are in Appendix II; Attachment 2. A list of observed vegetation within the vegetation types is included in Appendix II; Attachment 3.

The three vegetation types identified within the subject area are described below.

3.1.1 Riparian Areas

The Riparian Vegetation Type occurred along all creeks and included the wetlands and ponds along Bear Creek and the vegetation along the peripheries of Green Timbers Lake and Surrey Lake (Appendix II; Attachment 2). The largest riparian zone occurred along the banks of Bear Creek which originated along the western boundary of the study area and flowed eastward to the Serpentine River. This upland areas surrounding this riparian habitat were typically developed to the top-of-bank (TOB). Many slow-moving backwater channels were observed along the Bear Creek floodplain. The vegetation composition along Bear Creek varied with typical floodplain species including Sitka spruce (*Picea sitchensis*), black cottonwood (Populus balsamifera), western redcedar (Thuja plicata) and red alder (Alnus rubra) (Appendix II; Attachment 2; Photograph 1). The shrub layer was mainly dominated by salmonberry (Rubus spectabilis) with patches of Himalayan blackberry, red-osier dogwood (*Cornus stolonifera*) and red elderberry (Sambucus racemosa). Sword fern (Polystichum munitum) dominated the herb layer with common horsetail (*Equisetum arvense*) and skunk cabbage (*Lysichiton americanus*) occurring in wet depressions. The portions of Bear Creek within the Guildford and Coyote Creek golf courses were developed to near the creek edge with minimal riparian habitat (Appendix II; Attachment 2; Photograph 2). Downstream of the golf courses Bear Creek becomes channelized as it approaches the agricultural areas near the Serpentine River and the banks become dyked with reed canarygrass (*Phalaris arundinacea*) and Himalayan blackberry the predominate vegetation species (Attachment 2; Photograph 3). A beaver pond was also encountered along Bear Creek, within the BC Hydro 500 kV ROW, with red alder and hardhack (*Spiraea douglasii*) dominating the periphery (Appendix II; Attachment 1; Figure 2: Attachment 2; Photograph 4).

The tributaries along the north side of Bear Creek flowed southward and the southern tributaries flowed northward. These tributaries were typically moderate to steep sloped (25-70%) ravines. As with the Bear Creek floodplain development occurred to the TOB along most portions of these riparian habitats (Attachment 1; Figure 2). Within the ravines the habitats were relatively intact and were dominated by mixed mature stands of western red-cedar, western hemlock (Tsuga heterophylla) and black cottonwood with occasional Douglas-fir (Pseudotsuga menziezii) and bigleaf maple (Acer macrophyllum). The shrub cover varied from sparse (5%) in some areas to very dense (90%) with salmonberry dominating most sites. Invasive plants such as Himalayan blackberry were often encountered. The herb cover also varied from sparse to dense (5 - 70%) with sword fern typically dominating most sites (Appendix II; Attachment 2; Photograph 5).

The periphery of Green Timbers Lake and Surrey Lake were mainly vegetated with salmonberry, hardhack, red osier dogwood, young red alders and reed canarygrass. Common cattails (*Typha latifolia*) and small-flowered bulrushes (*Scirpus microcarpus*) were observed within both waterbodies (Appendix II; Attachment 2; Photographs 6 and 7). Common cattail dominated wetlands were also associated with both lakes with a small (~40 m X 70 m), rehabilitated wetland occurring north of Green Timbers Lake and a larger (~115 m X 275 m) wetland occurring south of Surrey Lake (Appendix II; Attachment 2; Photographs 8 and 9). In addition to these ponds and wetlands a stormwater detention pond, west of Enver Creek Secondary School (14505-84 Avenue), was well vegetated with young red alder trees and red-osier dogwood shrubs along its periphery. Common cattails were observed within this waterbody (Appendix II; Attachment 2; Photograph 10).

3.1.2 Forested Blocks

The Forested Blocks Vegetation Type was associated mainly with Green Timbers Urban Forest, Bear Creek Park and Surrey Lake Park. Green Timbers Urban Park was conifer dominated with western redcedar, Douglas-fir and western hemlock commonly encountered and with occasional grand fir (Abies grandis). Patches of deciduous trees were also observed including red alder, bigleaf maple and paper birch (Betula papyrifera). The understorey was composed generally of sparse to moderate (5 - 50%) cover of shrubs including salmonberry, vine maple (Acer circinatum) and red huckleberry (*Vaccinium parvifolium*). Sword fern typically dominated the herb layer (Appendix II; Attachment 2; Photograph 11).

The forested portions of Bear Creek Park were dominated by mature black cottonwood and red alder with occasional western redcedar, western hemlock, Douglas-fir and bigleaf maple. The moderate to dense (25 - 80%) shrub layer was dominated by salmonberry. Sword fern was commonly encountered in the sparse (2 - 10%) herb layer (Appendix II; Attachment 2; Photograph 12).

The topography of Surrey Lake Park mainly influenced stand composition. Sitka spruce, western redcedar and black cottonwood dominated the lowland areas east of the lake. The sloped portion situated northeast of the lake was dominated by bigleaf maple with occasional red alder and paper birch. The moderate to dense (25 - 80%) shrub layer was dominated by salmonberry. Sword fern was commonly encountered in the sparse to moderate (2 - 40%) herb layer (Appendix II; Attachment 2; Photograph 13).

3.1.3 Rights-of-Way and Meadows

The Rights-of-way and Meadows Vegetation Type was situated mainly along Bear Creek with a smaller ROW bisecting Green Timbers Urban Forest. Meadow habitat was generally associated with the areas northeast of Green Timbers Lake and areas surrounding the wetland south of Surrey Lake. This vegetation type also included the agricultural fields south of Surrey Lake Park.

The two BC Hydro ROWs were cleared of trees and were dominated by shrub stage red alder, salmonberry, Himalayan blackberry and hardhack. Large patches of reed canarygrass were dominate within the BC Hydro 500 kV ROW along Bear Creek (Appendix II; Attachment 2; Photograph 14).

The meadow habitats of Green Timbers Urban Forest and Surrey Lake Park were dominated by reed canarygrass as well as other gramanoid species.

The agricultural fields south of Surrey Lake Park were a combination of cultivated and fallow fields (Appendix II; Attachment 2; Photograph 15).

3.2 WILDLIFE TREES

A wildlife tree is any standing dead or living tree with special features that provides present or future critical habitats for the maintenance or enhancement of wildlife. There are nine classifications of coniferous and six classes of deciduous wildlife trees in various successions from live and healthy with no decay, to stumps and debris (Fenger et al. 2006). All of these wildlife tree stages provide important habitat, and are known to support more than 90 animal species in British Columbia, including cavity nesting birds and mammals (Backhouse 1993). Some of the uses include nesting, feeding, territoriality (i.e. bear mark trees, bird singing sites, etc.), roosting, shelter, and overwintering (Backhouse 1993).

There are nine decay classes of coniferous trees and six decay classes of deciduous trees within British Columbia (Fenger et al. 2006). Most of the trees observed in the study area were identified as Class 1 wildlife trees. Class 1 wildlife trees are described as live healthy trees with no decay. Class 2 to 9 wildlife trees were also identified within the study area. Most of the decayed trees were situated within the riparian areas of all watercourses. A figure with a description of each of the decay classes can be found in Appendix II; Attachment 6.

Due to survey timing (late fall) no active nests were observed within the study area during the field program. Nest cavities (likely from this breeding season) were detected in many of the wildlife trees observed. A number of old cavities were also observed in many of the wildlife trees encountered. Pileated Woodpecker (*Dryocopus pileatus*) foraging sign was observed on many of the wildlife trees. One Hairy Woodpecker (*Picoides villosus*) was observed within the forested block of Surrey Lake Park during the field assessment. These trees also provided habitat for many bird and mammal species including songbirds, squirrels and bats.

A Red-tailed Hawk was observed foraging within the study area during the field survey. Two Bald Eagle nests were also observed within the study area (Appendix II; Attachment 1; Figure

2). One previously known nest (WiTs 2011 and CoS 2011) was observed within Surrey Lake Park and an undocumented nest was observed within Bear Creek Park (Appendix II; Attachment 2; Photographs 16 and 17). A historical record (2001) for a Great Blue Heron nest occurred southeast of the intersection of 152nd Street and 72nd Avenue (WiTs 2011). No Great Blue Heron nests were observed at this location during the field investigation.

3.3 Coarse Woody Debris

CWD is typically described as woody debris greater than 0.3 m in diameter. CWD provides critical foraging, nesting, and cover components in the forested ecosystem for small mammals, amphibians, reptiles and invertebrates (Anonymous 1991). Many insectivorous small mammals, birds, and black bears feed on insects found in decomposing woody material. CWD provides a safe, moist environment in which species such as salamanders and shrews can forage and seek shelter.

Good CWD cover (5-15%) was recorded within most of the riparian habitats within the study area. CWD cover within the forested blocks varied from sparse to moderate (1-5%). No CWD was observed within the ROWs and meadows.

4. WILDLIFE INVENTORY AND HABITAT

Wildlife inventory and habitat assessment for this report was conducted by Bianchini Biological Services (BBS). The following sections are excerpts from the BBS report attached in Appendix II. BBS undertook the field work for this assessment on November 16, 17 and 22, 2011. The study area was assessed for occurrences of species listed under the federal Species at Risk Act (SARA), Committee on the Status of Endangered Wildlife in Canada (COSEWIC), provincial Wildlife Act, provincially Red and Blue-listed species and for general wildlife and vegetation species as well as raptor/heron nests and current wildlife use.

Prior to the field assessment, a literature search was conducted covering the West Bear Creek study area of Surrey, including BCCDC searches, Wildlife Tree Stewardship Program (WiTS) and local knowledge. Past reports of the study area including the City of Surrey Ecosystem Management Study (HB Lanarc and Raincoast 2011), Environmentally Sensitive Areas (ESA) database (Abs et al. 1990), Green Timbers Urban Forest Recreation and Access Management Plan (Coulthard and Cox 2002) and the Environmental Impact Assessment N.E. Newton Pocket Land Development Study (IRC 1996) were also reviewed. The BCCDC website was searched for all species listed under SARA, COSEWIC, Provincial Identified Wildlife and the Provincial Wildlife Act that are suspected to occur within habitats identified within the study area. In addition, species listed as Red and Blue-listed by the BCCDC but not specifically covered under legislation were also included. BCCDC data within 5 km of the study area were also reviewed. Aerial photographs of the study area were examined and all potential habitats and wildlife corridors were stratified.

The riparian habitats, forested blocks, meadows and ROWs within the study area were assessed for wildlife and vegetation values during the field survey. Transects were walked throughout the identified habitats. Due to survey timing (late fall) only readily identifiable vegetation species within each site were identified and recorded. In addition, the presence of coarse woody debris

(CWD), wildlife trees, dens, burrows and other habitat features were also recorded. All wildlife trees were classified according to methodologies identified by Backhouse (1993) and Fenger et al. (2006).

Pacific water shrew habitat was assessed following methodologies described by Craig and Vennesland 2008. Potential raptor/heron nest trees were scanned visually with binoculars. All wildlife and wildlife sign encountered was recorded.

4.1 Federally and Provincially Listed Species of Concern

Fifteen Federally and/or Provincially listed species may occur within the Bear Creek ISMP study area. These species are listed in Table 1.

Table 1: Federally and/or Provincially-listed species that occur or may occur in the study area (SARA 2010; BCCDC 20101).

Species	Federal/Provincial Status		Legislation			Site Occurrence
Common/Scientific Name	**COSEWIC/SARA Status**	**BCCDC Status***	**SARA**	**Provincial Identified Wildlife**	**Provincial Wildlife Act**	**Expected Onsite Habitat Use**
Vegetation:						
Pointed Broom Sedge (*Carex scoparia*)	-	Blue	-	-	-	**Suitable -** The moist to wet ditches, lakeshores, marshes and meadows of the study area provided potential habitat for this species.
Vancouver Island Beggarticks (*Bidens amplissima*)	Special Concern (November 2001)	Blue	**Y**	-	-	**Suitable** - The moist to wet ditches, streambanks and pond edges, particularly along the Bear Creek floodplain area provided potential habitat for this species.
Streambank Lupine (*Lupinus rivularis*)	Endangered (November 2002)	Red	**Y**	-	-	**Suitable** – The wet to moist meadows and banks along the Bear Creek floodplain provided potential habitat for this species.
Dotted Smartweed (*Persicaria punctata*)	-	Blue	-	-	-	**Suitable -** Swamps and wet meadows, particularly along the Bear Creek floodplain provided potential habitat for this species.
False-pimpernel (*Lindernia dubia anagallidea*)	-	Blue	-	-	-	**Suitable –** The banks of Bear Creek provided potential habitat for this species.
Slender-spiked Mannagrass (*Glyceria leptostachya*)	-	Blue	-	-	-	**Suitable** – The ditches and wetlands along Bear Creek provided potential habitat for this species.
Vertebrates: Amphibians						
Red-legged Frog *(Rana aurora*)	Special Concern (November 2004)	Blue	**Y**	**Y**	**Y**	**Suitable** –Breeding habitat (ponds) occurred within Green Timbers Urban Forest, Surrey Lake Park, Enver Creek stormwater detention pond and along Bear Creek. Rearing habitat occurred along most riparian areas and forested blocks.

Table 1 (concluded):

Species	Federal/Provincial Status		Legislation			Site Occurrence
Common/Scientific Name	**COSEWIC/SARA Status**	**BCCDC Status***	**SARA**	**Provincial Identified Wildlife**	**Provincial Wildlife Act**	**Expected Onsite Habitat Use**
Vertebrates: Birds						
Barn Owl (*Tyto alba*)	Threatened (November 2010)	Blue	**Y**		**Y**	**Suitable** – The BC Hydro 500 kV ROW provided suitable foraging habitat and barn-like structures associated with the ROW provided suitable nest sites.
Western Screech-owl (*Megascops kennicottii kennicottii*)	Special Concern (May 2002)	Blue	**Y**	**Y**	**Y**	**Suitable** – The riparian habitat of all watercourses provided moderate to high rated nesting and roosting habitat.
Green Heron (*Butorides virescens*)	-	Blue	**-**	-	**Y**	**Suitable** – Potential breeding habitat occurred in the trees surrounding Green Timbers Lake and Surrey Lake.
Great Blue Heron (*Ardea herodias fannini*)	Special Concern (April 2008)	Blue	**Y**	**Y**	**Y**	**Suitable** – Potential nests sites occurred in many of the mature trees within the study area. A historical WiTs nest record occurred southeast of the 152nd Street and 72nd Avenue intersection.
Vertebrates: Mammals						
Pacific Water Shrew (*Sorex bendirii*)	Endangered (April 2006)	Red	**Y**	**Y**	**Y**	**Suitable –** Moderate to high rated habitats were detected along all creeks within the study area.
Trowbridge's Shrew (*Sorex trowbridgii*)	-	Blue	**-**	-	**Y**	**Suitable** – Moderate to high rated habitats were detected along all creeks within the study area.
Invertebrates:						
Oregon Forestsnail *(Allogona townsendiana)*	Endangered (November 2002)	Red	**Y**	-	-	**Suitable** – Potential habitat occurred in the northeastern forested block of Surrey Lake Park.
Pacific Sideband *(Monadenia fidelis)*	-	Blue	-	-	-	**Suitable** – Moderate rated habitat occurred within the riparian and forested block of the study area.

*Red= Extirpated, Endangered or Threatened *Blue= Special Concern

4.2 Potential Vegetation Species and Ecological Communities with Special Federal/Provincial Status that May Occur in the Study Area

Due to survey timing (late fall) the presence of many herbaceous vegetation species could not be confirmed during the field survey. The following are descriptions for federally and/or provincially listed species that may occur within the study area and have been recorded south of the Fraser River in similar habitats within 5 km West Bear Creek study site.

4.2.1 Pointed Broom Sedge

This provincially Blue-listed species occurs in moist to wet sites in the lowland and montane subzones of British Columbia. It is considered rare in southern British Columbia and the lower Fraser Valley (Douglas et al. 2002).

One BCCDC record for this species occurred within 5 km of the study area along the Fraser River, near the Patullo Bridge (Attachment 1; Figure 3). The plants were situated in wet ground (BCCDC 2011[1]). The banks of Bear Creek provided potential habitat for this Blue-listed species.

4.2.2 Vancouver Island Beggarticks

The Vancouver Island beggarticks is listed under Schedule 1 (part 4) of SARA. Except for a single historical location on a research station in Brandon, Manitoba, the entire global range of the species occurs in the Pacific Northwest of North America. In Canada, it has been found in the Lower Fraser Valley and on Southern Vancouver Island, with one additional record on the mainland coast of British Columbia just north of Vancouver Island. The Vancouver Island beggarticks is a wetland species found occasionally in successional wetlands, but is generally limited to a very narrow band of habitat around pond, lake and stream margins, areas where annual and seasonal water level fluctuations are prevalent. It tends to occur in sites where waterfowl are common and shows a distinct preference for silty alluvial soils (EC 2011[1]).

One BCCDC record for this species occurred within 5 km of the study area (Appendix II; Attachment 1; Figure 3). This habitat for this record was described as moist ditch bank near railroad tracks near the Surrey Fraser Docks (BCCDC 2011[1]). The ditches, lakes, ponds, wetlands and portions of Bear Creek within the study area may provide habitat for this Blue-listed species.

4.2.3 Streambank Lupine

The streambank lupine is listed under Schedule 1 (part 4) of SARA. It is only found along the Pacific Coast of North America, from southwestern British Columbia to northwestern California. There are six known populations in the southwestern corner of British Columbia with five in the lower Fraser Valley and one is on Vancouver Island. The populations of these six sites ranged from 1 to 100 plants (EC 2011[2]).

One BCCDC record for this species occurred within 5 km of the study area (Attachment 1; Figure 3). This record is associated with three sites near Surrey Fraser Docks. These sites were situated beside railway tracks and/or roadsides (BCCDC 2011[1]). Portions of Bear Creek within the study area may provide habitat for this Blue-listed species.

4.2.4 Dotted Smartweed

This provincially Blue-listed species occurs in swamps and wet meadows in the lowland and steppe subzones of southern British Columbia and is considered rare in southwestern British Columbia including the lower Fraser Valley (Douglas et al. 2002).

Dotted smartweed was not observed during the field survey. One BCCDC record for this species occurred within 5 km of the study area and was associated with wet, sandy soil; abundant over a small area near the Scott Road SkyTrain Station (Appendix II; Attachment 1; Figure 3). The ditches and portions of Bear Creek within the study area provided potential habitat for this Blue-listed species.

4.2.5 False-pimpernel

The Provincially Blue-listed false-pimpernel occurs on wet, sandy or muddy banks and shores in the drier lowland and steppe subzones of the Bunch Grass (BG), CWH and Interior Douglas-fir (IDF) biogeoclimatic zones within B.C. It is considered rare in south-central B.C. and the lower Fraser Valley. Disjunct populations also occur east to Ontario and south to New Hampshire, New York, South Carolina, Florida, Missouri, Texas, Utah, Arizona, California, Mexico and South America (Douglas et al. 2002).

One BCCDC record for this species occurred within 5 km of the study area along the Fraser River, near the Fraser Surrey Docks (Appendix II; Attachment 1; Figure 3). The plants were situated in mud along the tidal foreshore (BCCDC 2011[1]). The banks of Bear Creek provided potential habitat for this Blue-listed species.

4.2.6 Slender-spiked Mannagrass

Slender-spiked mannagrass usually occurs in brackish tidal marshes, swamps, lakeshores, streamsides and wet meadows in the lowland subzones of the Coastal Douglas-fir (CDF) BGC zone and CWH. It is considered rare in coastal British Columbia (Douglas et al. 2002).

Slender-spiked mannagrass was not observed during the field survey. One BCCDC record for this species occurred within 5 km of the study area near 104 Ave and 176 Street (Attachment 1; Figure 3). The record is of one large plant growing in shallow ditch, in moist dredged sand, near railway tracks (BCCDC 2011[1]). The ditches and portions of Bear Creek within the study area provided potential habitat for this Blue-listed species.

4.3 Ecological Communities

The BCCDC defines listed ecological communities as natural plant communities and plant associations. These communities and associations include a wide range of known ecosystems with their environmental site requirements such as soil moisture and nutrients, climate, physiographic features and energy cycles. These sites are generally old growth stands that are usually 500 m^2 or greater. These ecosystems are often the remnants of the natural ecosystems that once occupied a much larger area. Typically, mature and old growth upland ecological communities are of concern to the BCCDC. In addition, all listed riparian, wetland and estuarine communities at any growth stage are also of concern to the BCCDC (K.A. McIntosh pers. comm.). The listed ecological communities are classified using methodologies and nomenclature developed by Green and Klinka (1994).

The forested portions within the study area were second to third growth stands. Of the 15 forested ecological communities identified within the CWHdm, 14 have been identified as either Red or Blue-listed by the BCCDC. In addition, one non-forested site has also been listed. Of the 15 forested ecological communities identified within the CWHxm1, all 15 have been identified as either Red or Blue-listed by the BCCDC. In addition, 8 non-forested ecological communities have also been listed.

The forested blocks within the Green Timbers Urban Forest were restricted to the CWHdm. During a Terrestrial Ecosystem Mapping (TEM) program conducted by Diamond Head Consulting Ltd. (Coulthard, M. and T. Cox 2002) Blue-listed ecological communities were identified by within this portion of the study area and included the Western Hemlock – Flat Moss (Site Series 01), Western Redcedar Sword Fern (Site Series 05), Western Redcedar – Foamflower (Site Series 07) and the Western Redcedar/Sitka Spruce – Skunk Cabbage (Site Series 12). The cattail marsh, upstream of Green Timbers Lake, likely is classified as the Blue-listed Common Cattail Marsh (Site Series Wm 05).

The remainder of the study area fell within the CWHxm1 BGC subzone. No TEM information for the area was available. Based on data collected during the field program the tributaries of Bear Creek were dominated by the Red-listed Western Redcedar – Foamflower (Site Series 07). The stormwater detention pond, west of Enver Creek Secondary School, is likely the Blue-listed Common Cattail Marsh (Site Series Wm 05).

Although no TEM data is available for Bear Creek, Bear Creek Park and Surrey Lake Park, all forested units within the CWHxm1 are listed by the BCCDC and such many of these units, particularly the floodplain and fluctuating water table units will occur within these areas.

Invasive vegetation species were encountered at many of the habitats and ecological communities observed within the study area and included species such as Himalayan blackberry, Japanese knotweed, scotch broom and English ivy. These invasive plant species were regularly encountered along interfaces of forested and disturbed or developed sites.

4.4 General Wildlife Observations

Wildlife sign and activity was recorded throughout the study area. Songbirds were observed flying and feeding in vegetation throughout the site. Suitable nesting habitat for raptors such as Bald Eagle, Red-tailed Hawk, Cooper's Hawk and owls were observed in most forested areas. Sign of coyote, raccoon, beaver and river otter were detected within the study area (Figure 8). A pair of Bald Eagles was also observed within Surrey Lake Park. All animal species detected are listed in Appendix II; Attachment 4.

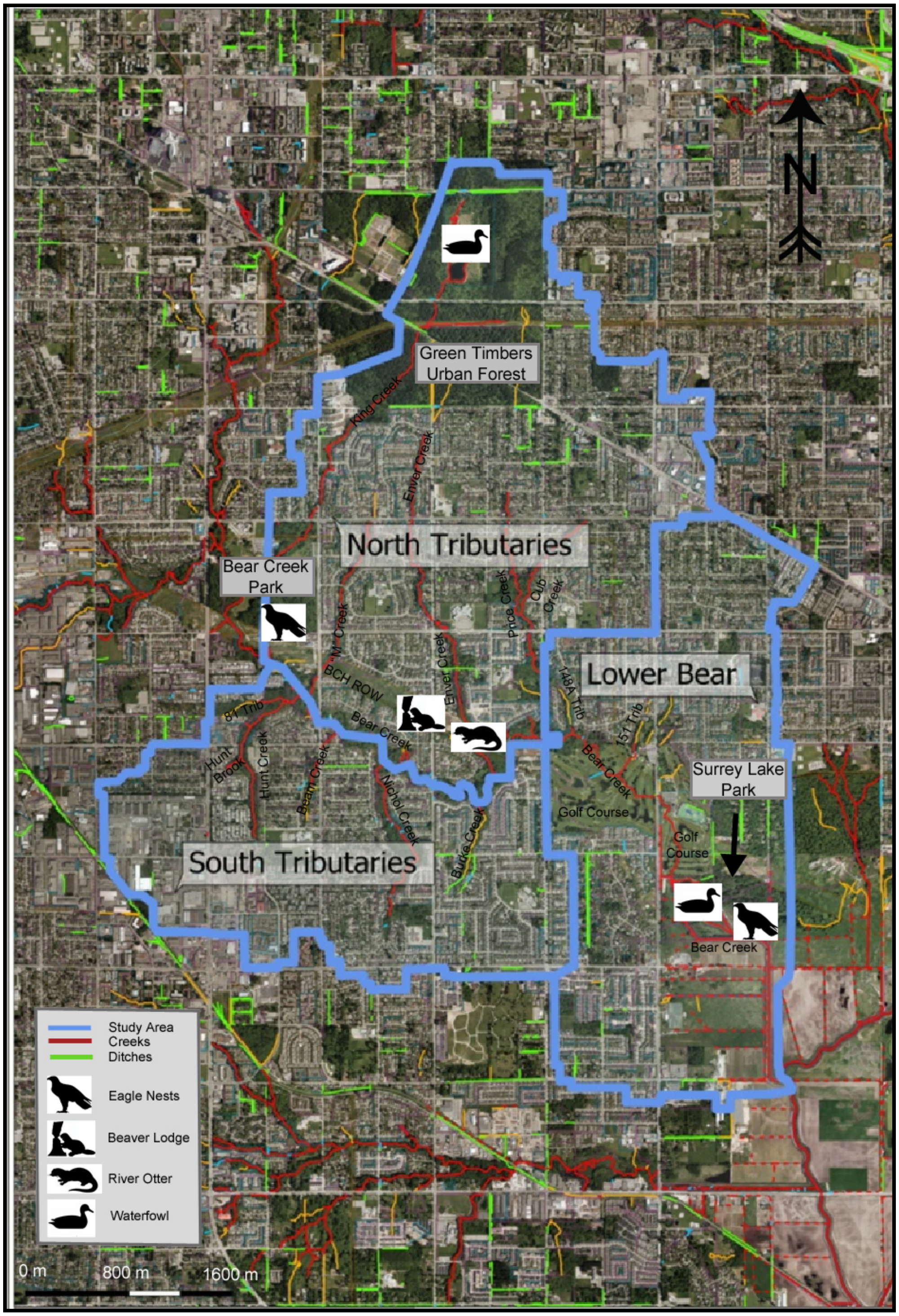

Figure 8: Significant wildlife observations during November 2011 field program

4.5 Wildlife Habitat Assessment

Habitats were assessed for the nine wildlife species listed in Table 1, deemed to be of particular concern. The following are the results of the habitat assessment for each of the nine species.

4.5.1 Red-legged Frog

In addition to being listed on Schedule 1 (Part 4) of SARA, the red-legged frog is also listed on the provincial Blue List (BCCDC 2011[1]). Red-legged frogs in BC are found in moist forests and in forested wetlands (Corkran and Thoms 1996). Adults will often wander far from standing water to forage on small insects or forest invertebrates (Nussbaum et al. 1983 in Ovaska and Sopuck 2004). Generally, they breed in cool, shaded temporary ponds where they attach their eggs to submerged woody debris or vegetation (Corkran and Thoms 1996). Critical habitats for the red-legged frog would include all temporary and permanent breeding ponds. CWD would also be considered a critical habitat element for cover and foraging.

No red-legged frogs were detected during the late fall field survey. Red-legged frogs are generally not active in the late fall and winter which limits their detection. The ponds and wetland complexes that occurred along Bear Creek, near the confluences of Enver, Price and Beam Creeks provided suitable breeding habitat for red-legged frog. The wetland complex upstream of Green Timbers Lake and the wetlands associated with Surrey Lake also provided potential breeding habitat for this species. The forested blocks and creeks provided suitable rearing habitat for red-legged frog and many other amphibian species. On BCCDC record occurred within Green Timbers Urban Forest (Appendix II; Attachment 1; Figure 3).

4.5.2 Barn Owl

The Barn Owl is listed in Schedule 1 of SARA and has been Blue-listed by the Province of British Columbia (BCCDC 2011[1]). This species is considered an uncommon resident throughout the Fraser Lowlands to Hope. Barn Owls are solitary nesters who prefer agricultural areas. Nests are usually situated in man-made structures including barns and old buildings (Campbell et. al, 1990).

Although this species was not detected during the survey, the fallow portions of the BC Hydro 500kV ROW within the study area provided foraging opportunities for this species. In addition, barn-like structures along the ROW may provide nesting opportunities for this owl species.

4.5.3 Western Screech Owl

In addition to being listed on Schedule 1 (Special Concern) of SARA, the *kennicottii* subspecies of the Western Screech-owl is also listed on the provincial Blue List (BCCDC 2011[1]). Along the coast the Western Screech-owl seems to be mostly found in either coniferous or mixed (deciduous or coniferous) forests, particularly near riparian areas. This owl prefers open forest for foraging and requires cavities in old, large trees for nesting and roosting. During the daytime it roosts in either coniferous or deciduous trees (COSEWIC 2002).

Although this species was not detected during the field surveys the forested riparian zones of all creeks within the study area provided potential breeding and roosting habitat for this owl species.

4.5.4 Great Blue Heron

In addition to being listed on Schedule 3 (Part 4) of SARA the Great Blue Heron *fannini* subspecies is also listed on the Provincial Blue List (BCCDC 2010). In British Columbia, Great Blue Heron populations have been decreasing, resulting in the listing of this species (MELP 1998). Population decreases are believed to be the result of human disturbance (EC 2011[3]). Great Blue Herons nest in a wide variety of tree species. Foraging habitat does not appear to be limiting factor for this subspecies as not all available habitat is used by herons each year (Campbell et al. 1990). Critical nesting habitat includes both an established colony and a suite of alternative sites to retreat to should disturbance occur.

No Great Blue Heron nests were detected during the field survey. A historical nest record (2001) occurred southeast of the intersection of 72nd Avenue and 152nd Street (WiTs 2011). The mature trees within the study area, particularly along Bear Creek, provided potential nesting habitat for this subspecies.

4.5.5 Green Heron

The Green Heron is listed on the Provincial Blue List (BCCDC 2011[1]). In British Columbia, the small population size and the risk of habitat loss to urbanization has resulted in the listing of this species (Harper *et al*. 1994). Green Herons use a variety of habitats, including sloughs, rivers, lakes, ponds, reservoirs, estuaries and beaches in British Columbia. Important habitat components for Green Herons include: slow-moving or shallow water for foraging and nearby dense trees or tall shrubs for nesting (Fraser 1996).

No green heron nests were detected during the field survey. Records for this species do occur within Green Timbers Urban Forest (Coulthard and Cox 2002). The trees adjacent to Green Timbers Lake and Surrey Lake provided potential nesting habitat for this species.

4.5.6 Pacific Water Shrew

Pacific water shrews are usually associated with riparian areas (Nagorsen 1996; Craig 2003). Past studies have reported that the majority of water shrews were captured within 25 m of streams, however in moist forests, Pacific water shrews can be found up to 1 km from water (Pattie 1973 in Craig 2003). The home range of the Pacific water shrew is suspected to be 400 m along a waterbody (Craig 2003).

In British Columbia, capture sites appear to be primarily associated with coniferous or deciduous forest with capture sites located very close to water. Habitat components usually found at Pacific water shrew sites include the presence of red alder, bigleaf maple, western hemlock or western redcedar that border streams and skunk cabbage marshes (Nagorsen 1996). In addition, Pacific water shrews have also been captured in more open habitat, with dense marsh vegetation. These include reed canarygrass vegetated roadside ditches and water bodies within highway medians (C. Schmidt, pers. comm.). CWD also seems to be an important habitat component. The presence of moist habitat appears to be more important than forest age (Craig 2003).

No Pacific water shrews were detected during the field survey. One BCCDC records for this species occurred within 5 km of the study area (Appendix II; Attachment 1; Figure 3). Records occur for this species occurred along the Fraser Heights area of Surrey. All creeks, ponds and wetlands within the study area provided moderate to high rated habitat for this species.

4.5.7 Trowbridge's Shrew

The Trowbridge's shrew is Blue-listed by the Province of British Columbia (BCCDC 2010[1]). Trowbridge's shrew use both riparian and non-riparian forest (Zuleta and Galindo-Leal 1994). In non riparian forests, the Trowbridge's shrew has shown a preference for areas with a high moisture regime (Nagorsen 1996).

Critical habitat elements for this species include rich soils and abundant decaying CWD and leaf litter on the forest floor (Nagorsen 1996). Ground litter, woody debris and shrub cover provides a secure environment for tunnelling and nesting.

All riparian habitats that provided moderate to high rated habitat for Pacific water shrew also provided moderate to high rated habitat for Trowbridge's shrew based on the presence of preferred vegetation and habitat features.

4.5.8 Oregon Forestsnail

The Oregon forestsnail has been listed as endangered by SARA (Schedule 1; Part 2) and is on the provincial Red List. The Oregon forestsnail is found in the western part of Oregon and Washington states, north into extreme southwestern British Columbia. Provincial records are mainly from Chilliwack and Fraser River valleys from near Hope to Mission (Forsyth 2004). Two additional locations are from Langley and southern Vancouver Island, and are considered outside the core region (EC 2011[4]).

The Oregon forestsnail occupies older mixed wood and deciduous lowland forests, typically dominated by bigleaf maple with an understory of stinging nettle (*Urtica dioica*). This species appears to require sites that include some CWD, heavy leaf litter, and both living and dying vegetation (EC 2010[4]). It is suspected that these conditions aid in preventing the loss of moisture and extreme fluctuations in temperature that are thought to be particularly detrimental to hibernating snails (EC 2010[4]).

No Oregon forestsnails or their shells were detected within the study area. Oregon forestsnails are typically dormant in the late fall and winter which limits their detection. Bigleaf maple stands were observed in the northeast forested block within Surrey Lake Park. Due to survey timing the detection of stinging nettle was limited.

4.5.9 Pacific Sideband

The Pacific sideband snail is Blue-listed by the Province of British Columbia (BCCDC 2010). This large snail species is found from Alaska to California; west of the Coast and Cascade Mountains. Pacific sidebands live in deciduous, coniferous or mixed forests as well as in open forests and grassy areas (Forsyth 2004).

No Pacific sideband snails were detected within the study area. Pacific sideband snails are typically dormant in the late fall and winter which limits their detection. The riparian areas and forested blocks within the study area provided potential habitat for Pacific sideband snail (Appendix II, Attachment 1; Figure 2).

4.6 WILDLIFE CORRIDORS

Moderately used wildlife trails, attributed to coyotes, were detected within the study area. Coyote sign was particularly abundant along the BC Hydro 500 kV ROW along Bear Creek and within Surrey Lake Park. Grey squirrels (*Sciurus carolinensis*) were observed throughout the study area. Sign of beaver and river otter were observed along Bear Creek. Evidence of use by raccoon was also observed. These animals appeared to travel mainly along the watercourses and riparian areas. In addition to coyotes, beaver, river otter and raccoon, these corridors have also be used by species such as Columbia black-tailed deer and black bear as well as many species of small mammals, birds, amphibians and reptiles.

5. SENSITIVE ENVIRONMENTAL AREAS

5.1 SURREY ECOSYSTEM MANAGEMENT STUDY

The Green Timbers Forest has been identified in the 2002 Surrey Ecosystem Management Study (EMS) as a key Terrestrial Hub within the ecosystem network of the City of Surrey. The Green Timbers Forest is one of the 5 largest hubs in size within the City, and one of the 5 highest value Hubs in terms of ecological significance. The lowlands along the lower reaches of Bear Creek have also been identified as ecologically significant habitat. The Hydro Right-of-Way has been identified in the Surrey EMS as a key wildlife corridor. Refer to Figure 9 for a copy of the Map from the Surrey EMS showing the ecological significance of mapped Terrestrial Hubs.

This Environmental Assessment has confirmed the same findings as the Surrey EMS. Namely, that the key environmentally sensitive areas within the Bear Creek ISMP are:

- Green Timbers Forest
- Lowland floodplain lands along the lower reaches of Bear Creek
- B.C. Hydro Right-of-Way Wildlife Corridor
- All ravines and riparian areas adjacent to Bear Creek and its tributaries.

The Bear Creek ISMP can help implement the objectives of the Surrey EMS and conserve environmentally sensitive areas in the ISMP area by adopting conservation protection and enhancement measures into the land use planning component of the ISMP, by improving rainwater management within the Bear Creek watershed, providing enhancement of existing habitat such as recommendations presented in this Environmental Assessment, and by similar contributions to improved ecological health within the Bear Creek watershed (e.g. pollution reduction, reduced erosion).

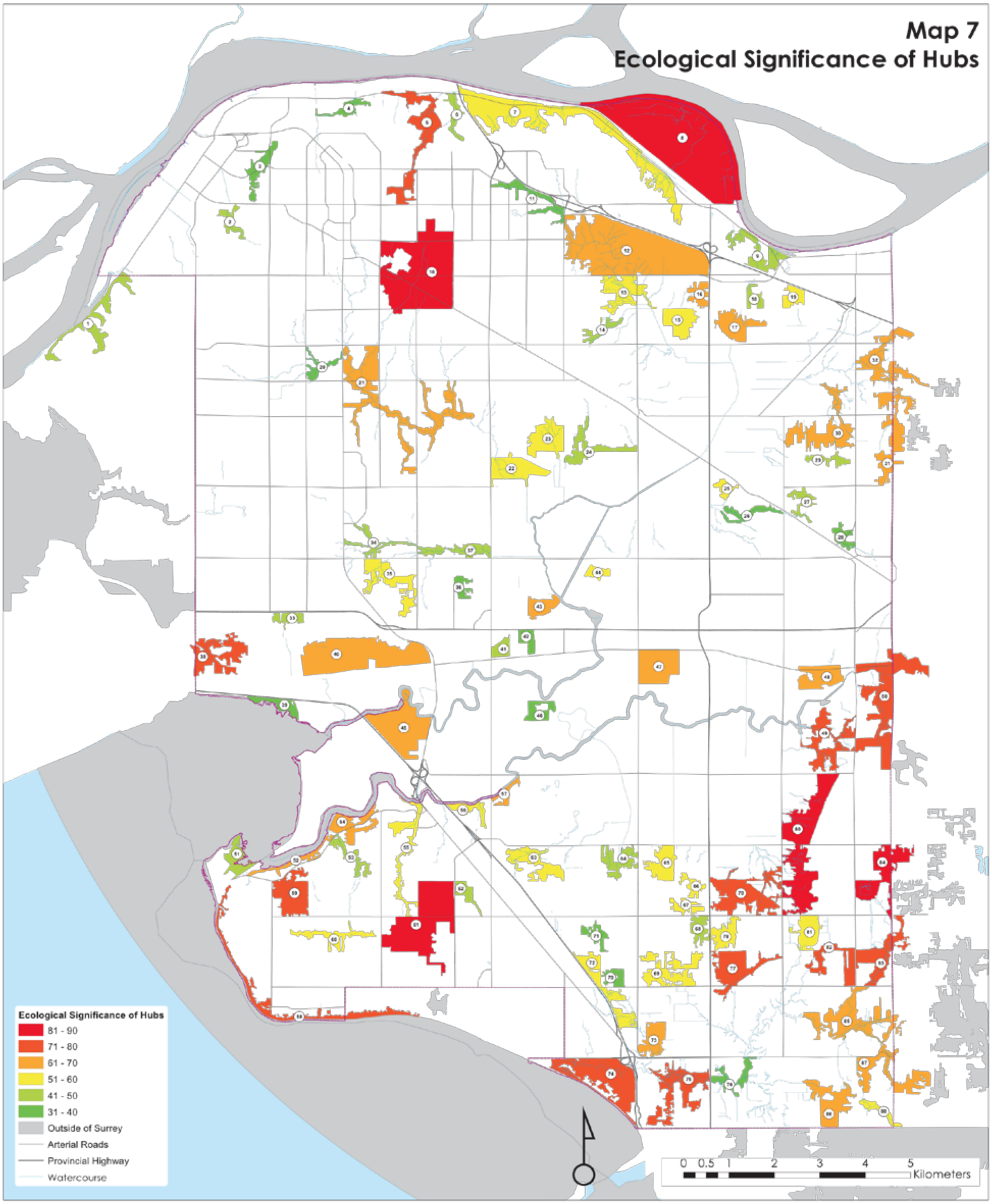

Figure 9: Ecologically Significant Hubs, Surrey EMS, 2002

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Key Areas of Concern

The Study Area is currently medium-high density residential in land use character with large agricultural land areas in the valley bottom and floodplain reaches of Bear Creek and the Serpentine River. Increasing development densities in the up-gradient slopes and plateaus within the largely suburban watershed of Bear Creek will result in greater pollution-generating impervious surface areas, which is usually accompanied by an increase in peak flow volumes and velocities as well as decreases in water quality. Unless, mitigated through the Bear Creek ISMP. Increased urban density is probable, so the ISMP has to address existing, long-standing stormwater problems, but those associated with urban densification in a fast growing urban center.

6.1.1 Scour and Erosion

Field verification observations revealed numerous locations in the upper tributaries and headwaters were scour and erosion from excessive flow velocities in stormwater discharges has and continues to have a deleterious impact on the habitat values in the Bear Creek watershed. Given the built-out suburban land use in the headwaters and upper tributaries of Bear Creek, and probable densification to urban land uses over time, source controls (e.g. future green roofs, infiltration landscapes) as well as increased detention facilities in the headwaters over time will improve the overall environmental quality in the watershed by reducing erosion and scour.

Excessive high volume, short duration stormwater discharges from extensive impervious services areas, much of which are pollution-generating impervious surface areas (i.e. roads, parking lots, commercial sites), produce a broad range of detrimental environmental impacts that can be rectified through an ISMP and its implementation. Generally, impacts of excessive scour and erosion from stormwater discharges in stream receiving environments include scour and often distant re-deposition of substrates, and invertebrate populations inhabiting those substrates, and progressively exposing fine-textured soils (e.g. clay chutes) and down-cutting (erosion) the stream channel, coincident bank instability or channel meandering-induced bank failures, increased frequency and duration of high turbidity (i.e. suspended sediments), loss of instream habitat complexity and niche habitat for aquatic populations, increased downstream sediment deposition and flooding in lower gradient reaches, and overall decline in the producitivity and aquatic health of the stream.

Best management practices such as preservation and restoration of riparian forests, onsite infiltration, biofiltration, stormwater detention facilities, source controls for commercial oil/water separators and catch basins, and other innovative stormwater management facilities are essential to reversing the degradation of water quality and nutrient production and loss of the existing aquatic and riparian habitats in the Bear Creek watershed.

Specific to the Study Area, there are a few areas of particular concern that will be most affected by improvements to the hydrologic regime through this ISMP.

6.1.2 Stream Habitat Degradation and Terrestrial Habitat Fragmentation

The Study Area has exhibited varied environmental conditions in the three identified sub-catchments, and currently has fragmented forest and varied riparian conditions due to “built-out suburban development densities in upstream reaches, and agricultural land uses in the lower reaches. Portions of meadow habitat, providing moderate habitat resources and corridors for terrestrial wildlife, were observed in some areas due to historic disturbance of a BC Hydro transmission right of way, as well as other unopened road rights-of-way, without subsequent development.

Agricultural areas within the Lower Bear sub-catchment display reduced riparian conditions due to anthropogenic channelizing of lower reaches of Bear Creek, and clearing/tilling for agricultural processes closer to the Serpentine River confluence. Further, decrease instream complexity was observed in these areas due to anthropogenic channeling for irrigation and flood control for agricultural purposes.

The majority of the Bear Creek Study Area has been developed with single family housing with corner commercial to date. Anthropogenic disturbances within the Study Area appear to have resulted in effects on Bear Creek and its tributaries typical of urban streams. These effects include:

- Decreased stability in stream flows (i.e. elevated peak flows, increased water level fluctuations), erosion/bank failure, and flooding;
- Altered benthic macroinvertebrate communities with elevated presence of pollution-tolerant species;
- Reduced rearing and spawning habitat for fish populations through loss and scour/redeposition of coarse textured substrates (e.g. spawning gravels);
- Fragmented and discontinuous vegetation and ecological communities;
- Fragmented and isolated terrestrial wildlife habitats, with remaining natural channel areas serving as wildlife corridors between habitat fragments; and
- Decreased function of natural succession processes including forest renewal, creek substrate recruitment, watercourse channel meandering through floodplain, and similar degradation in environmental quality.

As much of the Study Area is currently developed, and long reaches of Bear Creek and its higher value tributaries remain within natural channel alignments, especially in the north and south tributary sub-catchments, there remains a relatively high level of ecological function within an urban setting.

In light of this, it is concluded that a multi-faceted approach to ecological management be put forth for future development and infrastructure upgrade planning within the catchment including:

- Specified stream enhancements described in this report (section 2.4 of this report).

- Conservation of remaining riparian areas and connected terrestrial habitat fragments (*e.g.* Green Timbers forest, Bear Creek Park, and Bear Lake Park), especially in the North and South Tributary sub-catchments.

- Potential enhancement of ditched drainage channels in current agricultural areas within the Lower Bear sub-catchment, by enabling channel sinuosity in wider buffer strip with enhanced and diversified streamside restoration planting, and improved instream and flowpath complexity, using possible tax credit incentives, as part of the flood-reduction plan foragricultural lands.

- Improving wildlife passage utilizing the Bear Creek and tributary watercourse corridors in concert with infrastructure upgrade works as they occur.

- Removal of current fish and wildlife barriers at road crossings and replacement of passable crossings where possible.

- Replacing culverted crossings bisecting forested blocks and watercourses with bridges or open-bottom culverts to improve passage for wildlife and maintain connectivity to forested areas within the study area. Open-bottom culverts and bridges will also reduce wildlife fatalities on roads due to impacts with vehicle traffic.

- Conducting a survey for Oregon forestsnails within the bigleaf maple dominated stand of Surrey Lake Park during the appropriate season (late March – late June). If any Oregon forestsnails are detected then develop an Oregon forestsnail management plan and incorporate the plan as part of the parks overall management plan.

6.1.3 Vegetation and Ecological Communities

No SARA listed vegetation species were detected during the field program. Due to survey timing (late fall) many herbaceous species could not be identified. The site may provide habitat for at least six provincially listed species including the Blue-listed pointed broom sedge, Vancouver Island beggarticks, streambank lupine, dotted smartweed, false-pimpernel and slender-spiked mannagrass.

BCCDC records for the six species occur within 5 km of the study area. These species may occur along the floodplain and banks of Bear Creek. No Best Management Practices (BMPs) currently exist for these three species.

Four Blue-listed ecological communities of the CWHdm are known to occur within Green Timbers Urban Forest area. In addition, the Blue-listed Common Cattail Marsh ecological community is also expected to occur upstream of Green Timbers Lake. No TEM mapping is available for the remainder of the study area. All tributaries of Bear Creek appeared to be dominated by the Red-listed Western Redcedar – Foamflower (Site Series 07) ecological community. All forested units of the CWHxm1 are listed by the BCCDC and all forested sites within the study area are highly likely to be either Red or Blue-listed ecological communities.

Invasive vegetation species such as Himalayan blackberry, Japanese knotweed, scotch broom and English ivy were regularly encountered along interfaces of forested and disturbed or developed sites. Removal of these invasive plant species at strategic sites would benefit many native wildlife and vegetation species.

6.2 WATERCOURSE CLASSIFICATIONS

This Environmental Assessment has confirmed the existing watercourse classification mapping for the Bear Creek ISMP is accurate, where field verifications have been conducted. Most of the field verification sites have been in the upper headwater tributaries of Bear Creek, due to the key environmental issue of excessive scour and erosion of stream habitats from existing stormwater discharges. However, much of the Bear Creek ISMP study area has been extensively studied by previous broad-based and site-specific habitat assessments.

It remains possible that site-specific watercourse re-classification requests may arise in conjunction with future re-development proposals in the Bear Creek ISMP area.

6.3 WILDLIFE ASSESSMENT

No provincially listed wildlife species were detected during the field program. Sign of coyote, beaver, river otter, raccoon, grey squirrel, woodpecker and passerines were detected within the study area. One Red-tailed Hawk was foraging within the project area and a pair of adult Bald Eagles was observed near the Bald Eagle nest tree at Surrey Lake Park. Most of the treed portions within the study area provided potential breeding/roosting habitat for raptors, passerines, woodpeckers and a number of bat species.

6.3.1 Mammals

Moderate to high rated habitat for the SARA listed Pacific water shrew and provincially listed Trowbridge's shrew occurred within the riparian zones of all watercourses within the study area. One BCCDC record for Pacific water shrew occurred within 5 km of the study area.

6.3.2 Birds

Bald Eagle and Red-tailed Hawks were observed within the study area. In addition, two Bald Eagle nests were observed within the Bear Creek and Surrey Lake parks. The forested blocks provided suitable breeding and roosting habitat for many raptor species such as Cooper's Hawk and owls as well as songbirds and woodpeckers.

6.3.3 Amphibians

Rearing habitat for the SARA listed red-legged frog was detected within the riparian zones of the study area. Potential breeding habitat occurred in the beaver ponds and backwater channels along Bear Creek. These ponds and wetland complexes occurred along Bear Creek, near the confluences of Enver, Price and Bear Creeks. The wetland complex upstream of Green Timbers Lake and the wetlands associated with Surrey Lake also provided potential breeding habitat for this species. These wetlands and ponds also benefit other amphibian species as well as other wildlife.

6.3.4 Invertebrates

The forested block northeast of Surrey Lake provided potential habitat for the Oregon forestsnail. Pacific sideband habitat was found within the riparian zones of all creeks and forested portions of Green Timbers Urban Forest, Bear Creek Park and Surrey Lake Park. No BCCDC records for these two snail species occurred within 5 km of the study area.

6.3.5 Wildlife Corridors

Moderately used wildlife corridors were observed within the riparian zones of all watercourses and within the BC Hydro 500 kV ROW during the field survey. Installing open bottom culverts and bridges suitable for wildlife passage at all road crossings bisecting forested areas and creeks within the study area would improve habitat connectivity for all wildlife, including listed species such as red-legged frog, Pacific water shrew and Trowbridge's shrew. This habitat enhancement would also provide a secure wildlife corridor for all wildlife species. Improved passage for wildlife would also reduce wildlife mortalities due to impacts with vehicles. The addition of riparian of vegetation and increasing the riparian buffer along Bear Creek as it bisects the Guildford and Coyote Creek golf courses would greatly improve security habitat for many wildlife species and improve wildlife values along this important wildlife corridor. However, it is acknowledged that substantially wider setbacks are less achievable than increasing the overhanging and shade-casting riparian vegetation density and diversity within existing riparian corridors at these golf courses.

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APPENDICES

APPENDIX I: FISH HABITAT CLASSIFICATION MAPS, FIELD VERIFICATION RESULTS, SITE PHOTOS AND HABITAT IMPROVEMENT OPPORTUNITIES

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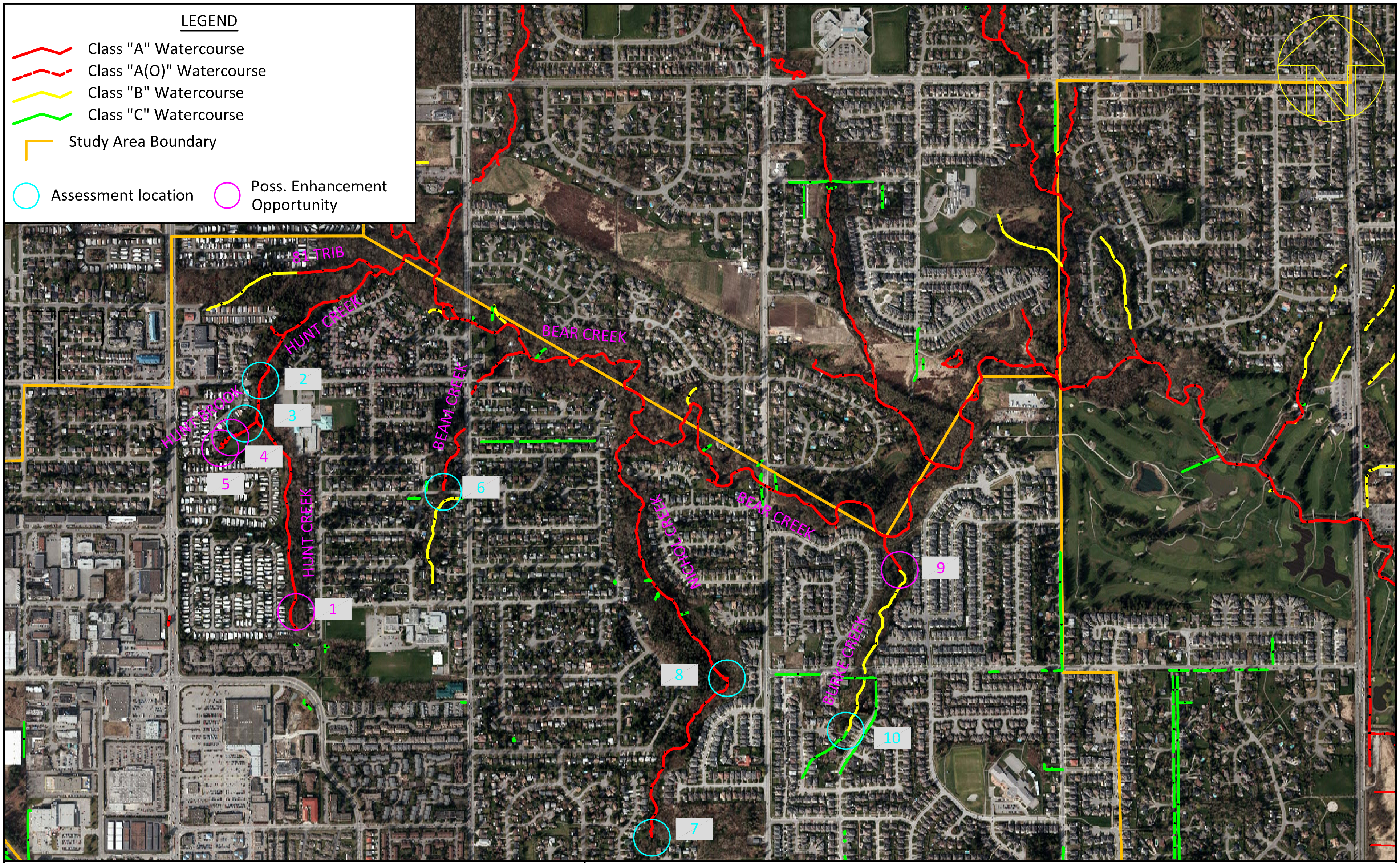
APPENDIX II: CITY OF SURREY WEST BEAR CREEK ISMP WILDLIFE AND VEGETATION ASSESSMENT

(Bianchini Biological Services, 2011)



Enhancement Opportunities

Site 1, Hunt Creek:
Stormwater outfall near 76A Ave. has downcut channel and angular riprap has been introduced. Little substrate complexity remains. Introduce suitably-sized gravel and sand at outfall to allow downstream recruitment. Downstream deposition may provide improved spawning areas and increase invertebrate productivity. Addition of coarse woody debris may also improve complexity, cover as well as scour protection.

Site 4, Hunt Brook:
Stormwater outfall fromtrailer park off of 80 Ave. Channel conditions appear stable good quality substrates. Low storey riparian vegetation is dominated by invasive vegetation (blackberry/ivy), while upper riparian comprises large conifers and deciduous. Low storey riparian could be improved through invasive vegetation removal and revegetation with native stock (deciduous trees) .

Site 5, Hunt Brook:
Small tributary storm oufall to Hunt Brook originating in 80 Ave. trailer park. channel lined with rip rap, and flows adjacent to mowed park space, leaving a narrow riparian zone on right bank. Right bank riparian areas could be revegetated with native stock to improve shading, food/nutrient input, and diversity.

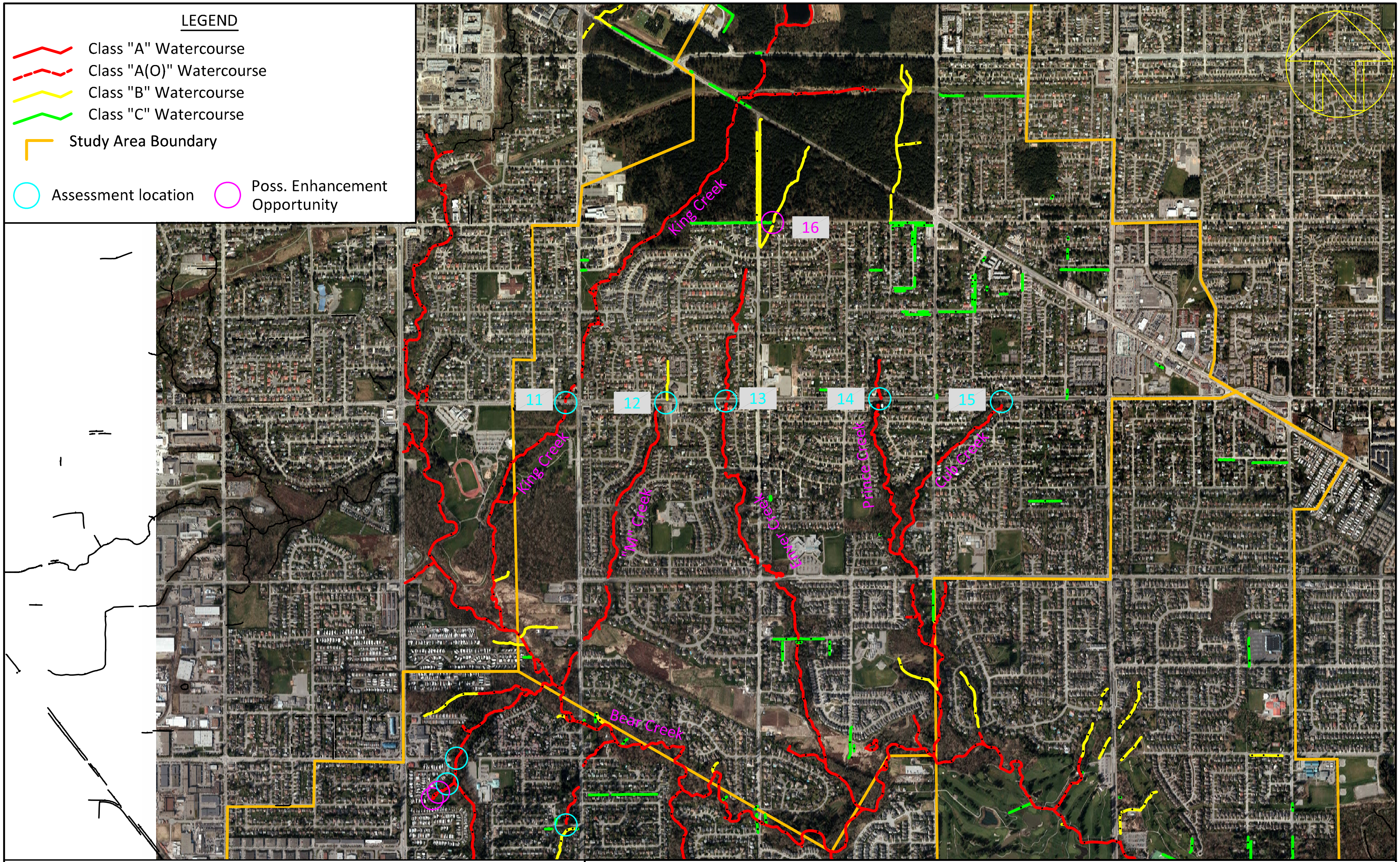
Site 9, Burke Creek:
Approx. 10m round concrete culvert acts as a fish barrier causing the observed Burke Creek reach break from Class "A" to Class "B", approx. 30m upstream from Bear Creek conluence. Culvert replacement with a bridge crossing or baffle installation could provide upstream fish access. Channel areas upstream of the barrier are suitable for fish utilization. Culvert replacement with passable structure could result in re-classification of upstream areas to Class "A"

South Bear Creek Tributaries: Fish Classification and Enhancement Opportunities

Bear Creek Stage 1 ISMP
City of Surrey

PHOENIX
ENVIRONMENTAL SERVICES LTD.
103 - 1600 West 6th Av. Vancouver V6J 1R3
tel. 604.689.3888   fax. 604.689.3880

DATE: 12/20/2011 | DRAWN BY: CM | SCALE: 1: 15 000



Enhancement Opportunities

Site 16, Enver Creek Detention Pond, 92nd Ave:

Site comprises a periodically-dry detention pond with small flowpath down centreline. Pond is not fish accessible. No effective riparian vegetation was observed. The pond area is dominated by mowed grass and aquatic macrophytes in interior areas. The pond could be designed to maintain approx. 200 - 300mm of water at all times through the installation of a raised outlet at 92nd Ave., or a weir. Increased waterlevels would allow the pond to function as a wetland, and increase primary food and nutrient production to fish accessible reaches immediately downstream.

North Bear Creek Tributaries: Fish Classification and Enhancement Opportunities

Bear Creek Stage 1 ISMP
City of Surrey

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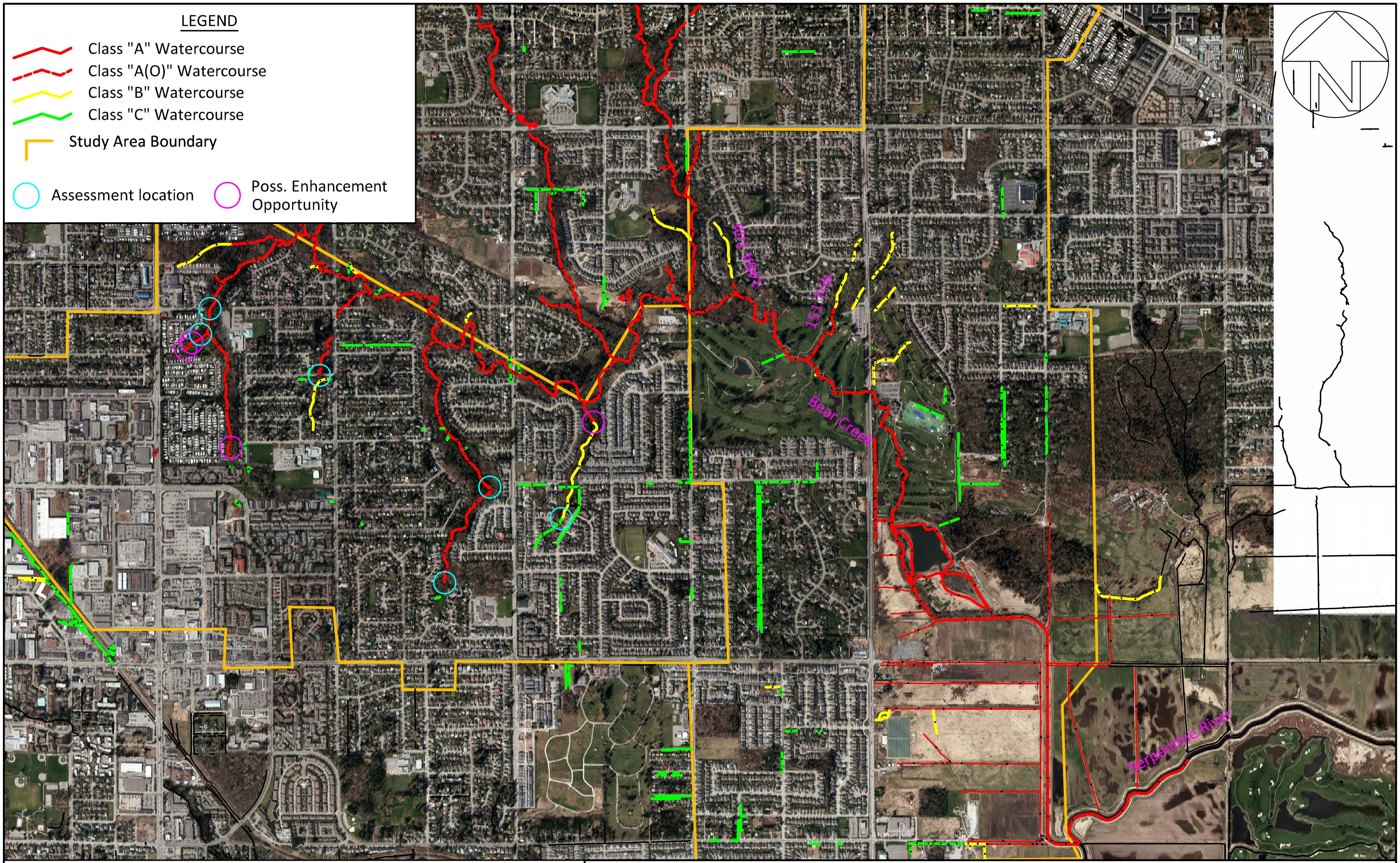
DATE: 12/20/2011	DRAWN BY: CM	SCALE: 1: 25 000



Enhancement Opportunities

None Identified

Lower Bear Creek: Fish Classification and Enhancement Opportunities

Bear Creek Stage 1 ISMP
City of Surrey

PHOENIX
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DATE: 12/20/2011 | DRAWN BY: CM | SCALE: 1: 25 000

Sub-Catcment	Watercourse	Site #	Photos	Assessed Feature(s)	Assessment Results	Conclusion
South Tributaries	Hunt Creek/Hunt Brook	1	1 & 2	Hunt Creek headwater storm outfall near 76A Ave. Upper end of Class "A" classification.	Elevated peak flow velocities/volumes have resulted in downcutting and loss of suitable substrates at outfall, and unstable channel conditions. Approx. 300mm angular riprap has been placed unsorted in outfall pool, but displays low success in erosion protection. Hunt Creek classification as Class "A" confirmed in this area.	Site presents a habitat enhancement opportunity. Increase channel roughness and complexity through strategic boulder and coarse woody debris installation. Improve downstream substrate recruitment and fluvial process through installation of mixed, clean round gravels and coarse sand.
		2	3 & 4	Hunt Creek headwater 300mm storm outfall near west end of 80 Ave. Downstream of Hunt Brook Confluence.	Assessed feature comprises a small stormwater outfall that discharges at the bottom of a ravine, and confluences with Hunt Creek via an approx. 20m x 1.2m rip rap open channel. Water quality from the storm outfall was visibly turbid with a grey colour. Hunt Creek classification as Class "A" in this area confirmed.	The assessed open rip rap channel may be utilized as off channel refuge during elevated Hunt Creek flows. Upstream storm system should be inspected for sanitary system cross-connection. No significant habitat improvement opportunities were observed.
		3	5 & 6	Hunt Brook headwater 300mm storm outfall originating from a trailer park at 7850 King George Hwy.	Assessed feature comprises a piped outfall that discharges to a short (aprox. 20m x 1.5m) open rip rap channel to Hunt Brook. Riparian vegetation remains largely intact, with nominal presence of invasive blackberry and laurel. No downcutting or scour observed at outfall.	No perceived enhancement opportunities observed. Hunt Brook classification as Class "A" in this area confirmed.
		4	7 & 8	Large Hunt Brook headwater storm outfall (1050mm originating from trailer park at 13560 80 Ave.	Assessed feature comprises a large piped outfall that discharges to an approx. 120m open rip rap channel to Hunt Brook within ravine areas south of 80 Ave. Hunt Brook Classfication as Class "A" in this area confirmed.	Riparian areas at outfall and tribuatary open channel is dominated by invasive understorey (blackberry and ivy). Upper storey vegetation comprises native mixed coniferous and deciduous trees. Removal of invasive vegetation and underplanting with appropriate native stock presents a habitat enhancement opportunity in this area. Manicured lawn areas utilized by trailer park at 13560 80 Ave. extend beyond property boundaries to riparian covenant (13728 80 Ave.). Site 3 - 5 storm outfalls could be combined and released to Hunt Brook through a stormwater latency wetland/pond complex constructed in this area in concert with revegetation works discussed above.
		5	9	Small unmapped Hunt Brook headwater storm outfall originating from a trailer park at 7850 King George Hwy. Flows in open channel south-north along trailer park yard space and discharges at site 4.	Open channel areas are adjacent to manicured lawn areas within 7850 King George trailer park, that extend beyond property boundaries.	Habitat improvement potential exists with replanting of lawn areas at 7850 King George that extend beyond property boundaries, and installation of a storm latency wetland as discussed above for Site 3 – 5 outfalls.
	Beam Creek	6	10 & 11	78A Culvert Crossing of Beam Creek. Crossing is high in catchment, no flow observed upstream. Nominal downstream flow.	This culvert lies at the reach break between Class "A" and Class "B" habitat in Beam Creek as identified in City of Surrey GIS. Fish access to upstream areas at this location is dictated by stream flow, not passibility of culvert. Fish usability of upstream areas is low and unlikely. Classification as Class "A" -"B" reach break confirmed.	No enhancement opportunity observed.
	Nichol Creek	7	12 & 13	Existing detention pond outfall to upstream terminus of Nichol Creek near the end of 73A Avenue. Detention pond was dry upon inspectoin	Nichol Creek channel appears a stable with no signs of erosion up to terminus. Adjacent riparian areas have been impacted by residential development (limited widths), but remain intact and well-vegetated. Classification of Nichol Creek as Class "A" at this location is confirmed.	No enhancement opportunity observed.
		8	None	Nichol Creek at undeveloped 76 Ave right of way.	Nichol Creek channel appears a stable with no signs of erosion at this location. Riparian areas remain intact with little disturbance. Classification of Nichol Creek as Class "A" at this location is confirmed.	No enhancement opportunity observed.
	Burke Creek	9	14 & 15	Burke Creek at pedestrian trail culvert crossing. 78 Ave trail between 145A and 146 St. Reach break between Class "A" and Class "B" reaches as per Surrey GIS mapping.	Culvert appears impassable to fish, and prevents access to usable reaches upstream of trail crossing up to at least 76 Ave, and potentially above. Reach break confirmed at trail crossing, however Surrey GIS data should be updated to move the reach break to the crossing location. The reach break appears slightly inacurate by air photo interpretation.	Replace culvert crossing with bridge structure or baffled culvert and restore fish access to upstream areas.
		10	None	Upstream terminuns of Burke Creek near Wiltshire Dr., between 76 and 74A Ave.	Instream conditions are stable with an intact riparian zone. Instream habitat likely usable to fish, at least seasonally, but is currently inaccessible. Classification of Burke Creek as Class "B" at this location confirmed with present conditions.	No enhancement opportunity observed at this location. Fish access could be provided with enhancement opportunities discussed for site #9.
North Tributaries	King Creek	11	None	King Creek culvert crossing - 88 Ave.	Instream conditions are stable with an intact riparian zone.No barrier to fish passage observed. Classification of King Creek as Class "A" at this location confirmed .	No enhancement opportunity observed.
	"M" Creek	12	16 & 17	"M" Creek culvert crossing - 88 Ave. Culvert is impassable to fish and serves as reach break between Class "A" and Class "B" habitat.	Channel conditions downstream of 88 Ave. appear stable with no visible erosion. Fish usage of "M" Creek likely to culvert, however fish passage of culvert is not possible. Limited flow was observed at this location, as it is high in the catchment.	There is limited usable channel upstream of the 88 Ave crossing that could be opened to seasonal fish use with passable crossing installation, however gained accessibility would be seasonal only, and crossing replacement would likely be cost-probibitive. No significan enhancement opportunities observed.
	Enver Creek	13	None	Enver Creek culvert crossing at 88 Ave. Watercourse is located under a home at this location, and could not be assessed.	N/A	The crossing at this location extends below a private residence at this location. No ehnancement opportunities observed.
		16	18 & 19	East Class "B" tributary to Enver Creek, between 92 Ave and Fraser Hwy.	Watercourse is inaccessible to fish at this location due to a downstream barrier. The site comprises a detention pond with a small channel down the centreline. Vegetation comprises periodically-mowed grass, with some aquatic macrophytes (Typha) along centreline. Class "B" classification confirmed in this area.	No effective riparian vegetation was observed in the area, and the pond was dry upon inspection. The pond could be designed to maintain a minimum water level (e.g. 200 - 300mm) throught he installation of a raised outlet or weir control at the the 92 Ave. crossing. Through native stock installation or natural recruitment the pond could be improved to function as a wetland while maintaining stormflow latency and provide improved food and nutrient production for downstream fish habitat as well as improved wildlife habitat.
	Prince Creek	14	None	Prince Creek culvert crossing at 88 Ave.	Instream conditions are stable with an intact riparian zone.No barrier to fish passage observed. Classification of Prince Creek as Class "A" at this location confirmed .	No enhancement opportunity observed.
	Cub Creek	15	None	Upstream Cub Creek terminus at 88 Ave. stormwater oufall	Instream consitions area stable with an intact riparian zone. No downcutting or erosion was observed at stormwater outfall. Ripaian zone is intact and dominated by deciduous forest with salmonberry understorey. Classification as Class "A" is confirmed in this location.	No enhancment opportunity observed.
Lower Bear				**No Field Verification Required.**		

Location: Site 1

Photo 1. Minor erosion downstream of outfall near 76A Ave.

Photo 2. Outfall near 76A Ave. with recently placed rip rap.

Location: Site 2

Photo 3. Hunt Creek headwaters, storm outfall.

Photo 4. Hunt Creek headwaters, storm outfall channel.

Location: Site 3

Photo 5. Hunt Brook headwaters, 300mm storm outfall originating near trailer park at 7850 King George.

Photo 6. Hunt Brook headwaters looking downstream.

Location: Site 4

Photo 7. Hunt Brook headwaters originating from at large 1050mm culvert.

Photo 8. Hunt Brook channel & riparian conditions.

Location: Site 5

Photo 9. Small unmapped storm outfall originating from trailer park.

Location: Site 6

Photo 10. Beam Creek riparian area condition.

Photo 11. Beam Creek looking downstream from 78A Ave culvert outfall.

Location: Site 7


Photo 12. Nichol Creek headwaters at detention pond outfall.


Photo 13. Nichol Creek habitat conditions looking upstream near detention pond outfall.

Location: Site 9


Photo 14. Burke Creek downstream of pedestrian trail culvert.


Photo 15. Burke Creek looking upstream of pedestrian trail crossing.

Location: Site 12


Photo 16. "M" Creek culvert at upstream end of 88th Ave.


Photo 17. "M" Creek downstream conditions of 88th Ave culvert.

Location: Site 16

Photo 18. Enver Creek tributary with potential enhance wetland location.

Photo 19. Enver Creek tributary culvert discharge near 92nd Ave.